Rf: Wi-Fi_Text
Dt: 09-Jan-2003

# The Spirit of Wi-Fi

**where it came from**
**where it is today**
**and where it is going**

**by**

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**Wi-Fi pioneer of the first hour**

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# 0. Preface

This book is about Wi-Fi, and where it all of a sudden came from. At least that is the way it looks: that it all of a sudden came up, despite the fact that it existed in the market already in its earlier forms since 1990. But it went by unnoticed until the email culture started to bloom, notebooks came up, and many of the telecom service providers started to launch the concept of wireless mobile Internet.

This book is also about the differences between the telecom industry and the PC industry, about their backgrounds, and about the thorough misunderstandings they both had about the other's market over the last three decades. Because of these misunderstandings billions of dollars (euros) have been wasted over the last few years on acquisitions and divestitures and finally on something that was called 3G. Actually quite a lot of these investments are still on the balance sheets of wireless telecom companies and will have to be written off, sooner or later…

This book should be for generalists, not for specialists. About many of the subjects in this book the Internet can provide thorough information, neatly structured. This is a book that runs you through the subjects and events inside out, as I personally have worked them through, and as I have enjoyed them. I have tried to keep the technical content to a minimum, and at the conceptual level, to make this book accessible to a larger audience, that wants to understand the general concepts of new technology development and marketing through the example of wireless LANs.

This book should also provide insight on the wireless Internet, and what can be reasonably expected. However, one warning, if history teaches something about technology, then it is that the ways of technology are unpredictable, and even improbable in foresight – although usually easy explainable in hindsight. Wasn't the early notion about computers, that the whole world would only need a few? Didn't the success of the Internet not take us by totally surprise, and weren't cellular phones not an unprecedented success in marketing, changing some consumer fundamentals within the time frame of just a few years. So, a humble warning is in place: the world will look differently in ten years, and we just don't know.

This book is not about taking the market in a few heroic swipes, this book is about stamina, endurance and staying power. I think my management had given up on me at least five times in the last ten years, believing that this whole notion of wireless LAN would go nowhere. Well, they were almost right… But as we all know: almost right is completely wrong at the same time.

This book can be read from front to back, from back to front, or being zapped through from anywhere in the middle. The last way is the way that I read this type of books my self anyhow, so I understand and will not take it as an insult!

Let me thank my bosses over the years to give me the opportunity for giving me the freedom to get on this exciting venture. Let me also thank my colleagues in NCR, AT&T, Lucent Technologies and Agere Systems for having lived through this with me, the bad times and the good times. I would not know how I could have lived this through without you all. Only, if I would start to write down any names here, the coming ten pages would be filled, and I still would get complaints about having left out people, so let me not do this, but realize, that I have written this book with you in mind!

I probably should also thank our competitors – this is probably a more difficult one. But already in our early marketing efforts it became very clear that it is very difficult, if not impossible to build up a market without competition. Competitors create a reality check for customers, as well as provide a credibility mark for a market.

Let me foremost thank the customers, who in particular in the early years of the development were patient with us, to get the product right, to get the price right and to get the business model right enabling the real breakthrough in the market. In that last respect I want to thank Apple Computers, who despite their questionable supplier tactics helped to create this wireless market.

Maarssen
The Netherlands
Fall 2002

# 1. Introduction

The period 1990 – 2000 will probably go into history as the decade where the industry transitioned from computing into networking. It was clearly the decade that the Internet came to fruition, it showed the rapid growth of "networking" companies like Microsoft, Cisco and Intel, and it became the decade of the explosion of the cellular phone industry. It was also the decade in which wireless LANs were born and Wi-Fi (Wireless Fidelity) got launched. Looking back it is my conviction, that in the future wireless LANs in combination with Internet will be recognized as the real breakthrough of the 90-ties.
To quote Bill Gates, Microsoft on this: "After we woke up and realized that all the dotcom-mania was just smoke and mirrors, we will look back at the late 90-ties and realize that wireless LANs at least were a real innovation from that period!".

The wireless LAN development that I was responsible for during a period of about 15 years, started in 1987(!) in NCR Corporation, a computer company that still exists and focuses on applications for the Retail markets (cash registers, Point-of-Sales terminals for department stores, mass merchandisers, etc.) and the Financial markets (financial transaction terminals, check readers for banks and financial institutions). After NCR was acquired by AT&T in 1991, the wireless LAN developments continued and moved internally from NCR to the Network Systems Division in AT&T, which turned into Lucent Technologies, the luster networking products company, when AT&T split up in three companies in 1997. The other two were AT&T (the telephone service organization as we know it today) and NCR (computers

– again). So, this time we were not part of NCR anymore, we became part of Lucent Technologies. Lucent Technologies itself split up in three companies in 2000: Lucent Technologies, targeting communication technology and products for service providers, Avaya Communications targeting networking for enterprise and businesses and Agere Systems, a semiconductor company. That the wireless LAN organization became part of the last one was not because of any specific strategy, it more or less just happened, and considering the success that came from it, it was probably the right choice, although that was not know at the time.

Throughout these 15 years higher management in these companies actually did not very well know what to do with wireless LANs, with my organization or for that sake, with specifically with me personally. There was a notion that what we were trying to accomplish made sense, but for the rest it seemed that it was something that was difficult to relate to – I admit, hard to understand when many people today enjoy their Wi-Fi connections and who can hardly imagine how life was without it. Throughout all these years, I saw it as a larger part of my job to ensure that these changes were as shielded off as much as possible from the rest my organization, so they could keep working the subject at hand. Only the logo on the business card changed, and that was it! Being able to keep the team in-tact over this decade of pioneering was probably the key accomplishment, wondering where we would have been today with and in Wi-Fi without it.

The wireless LAN division ended up as part of Agere Systems, and it grew into a very profitable $380M business in 2001. In October 2001 and after many discussions I split the total business into a semiconductor business unit (developing chipsets), and in an infra-structure end-product business unit (developing products: ORiNOCO), a split in about two equal parts. In 2002 Agere Systems divested from the infra-structure business unit and had it acquired by Proxim Corporation, and the semiconductor business unit has been integrated with other Agere Systems business units: at this time wireless LANs had become sound and solid mainstream chipset

business and companies no longer could be vertically integrated from core technology chipsets to branded end-products.

I have been personally involved since 1988 in driving the wireless LAN market and product development over the years in NCR and its successors, and as I was in the lucky circumstance, that I have kept all my business notes over this long period. Originally thanks to Time/system!, a comprehensive paper organizer system and method, and later replaced with keeping notes on my computer notebook – which I was used to carry with me all the time, thanks to "Wireless"!
I thought that writing a book about this "real innovation" of the late 90-ties might be fun and entertaining, but also useful from a variety of angles: what is it to develop a new and innovative technology and bring it to market, and what does it mean to do this as part of a large corporation – which is probably not that different compared to doing this as a start-up.

Making a new market is one of the most intriguing things in business. Although a lot is known about it, I think that nobody fully comprehends this. Sometimes it succeeds, sometimes it completely flops, and it is forgotten quickly: for instance the pen tablet computers of the mid 90-ties or a wireless data networking system like Metricom's Ricochet in early 2000. Making sure new technologies get adopted is in particular in technology business a key item, as this business thrives on new ideas and innovations, and failures can be very expensive. Over the years I have learnt a lot about the concepts to make sure that new technology proceeds and many of them make a lot of sense, are relevant and need to be applied. But in reality, as far as I can see, there is no golden bullet, some ideas just catch on and other ideas just don't. The common theme is: usefulness and convenience at a reasonable price, but this is not more than a necessity, as not all good ideas against a reasonable price make it in the market. In retrospect usually a lot can be explained, while for the future, again little can be predicted…. Still I believe over time, we will get better at it, as reading through my

notes, I am appalled and amused at the same time about the mistakes that I made, and that I think would improve the chances of success a next time around.

However, of all the new business start-ups that I have seen, there is one common denominator: an idea, hard work, persistence, risk-taking and a never-give-up attitude: resilience and the will to survive and succeed are the key words. This was in particular the case as starting this new wireless market as part of a large corporation created a whole extra set of challenges. I remember a discussion with Bob Holder, a Senior Vice President in AT&T: "I know that we are not very friendly for internal start-ups." The reality was, that "very unfriendly" would have been the better formulation. What I learned was that despite people in large corporations may work hard and can be persistent, large corporations themselves have a preference for quick, instantaneous success – just like start-ups…. They are continuously looking for the next $100 or $1B opportunity, without any appreciation for the $1M and the $10M phase one has to go through to get it right.

What makes it worse is that large companies are also very particular about the technologies they want to embrace, and the way they serve their markets. The marketing of a new technology is can be just not in line with the existing company model, and therefore it can create major havoc, I have seen this several times in particular where new products need to be fit in sales and distribution models. Our wireless LAN technology did not really fit NCR Computers, because NCR was not really a networking company. It just did not really fit AT&T, with Bell Labs used to lots of innovation, but not to risk taking. It also did not really fit Lucent Technologies: Lucent was dial-tone networking and no data-networking. And finally, even when wireless LANs had developed to a $1B market, it only partially fitted Agere Systems (the semi-conductor part of the business), and therefore they spun half of the business off to Proxim in 2002 (the products and systems part).

In the mean time we had gone through a lot of agonizing questions about “how to get it right”, something that even lead to a serious attempt to take the business private via a Management Buy-Out early 1996. Unfortunately the Lucent Technologies management at that time did not want to “cooperate”, and the business stayed part of Lucent, which was a great disappointment for the wireless LAN Management Team at that time. The feeling with Lucent’s management was that there was “something” there, but they were never sure what.
The same Lucent management tried to sell this business to companies as 3Com, Intel and Cisco in 1998 and 1999, however unsuccessfully. Still at time, in particular these three companies, who pride themselves in data networking leadership, had not really seen “the light”, and were still fully underestimating the potential of what had to become the Wi-Fi technology.

Nevertheless while all these distracting and sometimes disturbing events took place, it was an exciting period, and I cannot describe the satisfaction when in 1999 we saw our revenue growing from $30M the year before to over $70M. This was nine years(!) after the first product release at Networld in Dallas in 1990. This was clearly just the start, as we saw the revenue further growing to $210M in 2000, and despite the big bust happening in the telecom industry, we continued growing to $380M in 2001, with an estimated market share of 40 to 50%. This was the ultimate proof that the concept had been right from the early days on, but it also showed how big of a challenge it was to get the product right and the market ready.

# 2. The Roots of Wi-Fi: Wireless LANs

This chapter falls into three pieces. There is in the first place the product and application background of wireless LANs or to start with: more specifically Local Area Networking (LAN's). There is also a business background that as far as I can see is still not fully evaluated and understood. It is about the war between the PC industry and the telecom industry, with "data networking" as the battle field. Interestingly enough, quite recently the Consumer Electronics industry is pulled into this battle as well, and they will probably give this battle a complete new direction.
Let me then close it off with a description of the breakthrough of the key applications that were necessary to make this technology come to fruition: without any applications, "what you can do with", hardware is pretty much a futile effort.

## 2.1 The product and application background: networking

To understand what wireless LANs are, it is probably good to understand what LANs are in general. To loosely define it: LANs or Local Area Networks are the way a set of computers are connected together in a company or business. By connecting these computers together, it allows these computers to communicate with each other, for instance for sending and receiving email, for "chatting", and/or for sharing files. Another reason for networking is to be able to share

common and usually more expensive resources like printers, mass storage devices, or plainly something like a connection to the Internet.

These LANs were more or less the natural successor in the 1980-ties of the (mini)computer networks. Up to the later 1980-ties “computer networks” existed out of a large (mini)computer in the computer room, connected with a set of computer screens, the so called “dumb” terminals, and the (mini)computer in the computer room itself did all the work. In the 1980-ties we saw the dumb terminals being replaced by “smart” terminals, in essence Personal Computers, on which you could run local applications like word-processing (WordStar) or spreadsheets (VisiCalc). These smart terminals usually could operate as “dumb” terminals at the same time for the application that ran on the (mini)computer. This was the start of the migration to the network as we know it today. The reality of today is that to a large extent the central (mini)computers are replaced with “servers”, in essence these are usually multiple large Personal Computers. The reality is also that the “dumb” terminal mode does not exist anymore on the Personal Computer: all the PC computing now has become PC network computing.
Interestingly, a PC can operate, when it is “on-line”, on the network, or “off-line”, when it is stand-alone and off the network. After a PC was “off-line”, away from the network and gets connected to the network again, it needs to “synchronize” with the other computers and servers that are on the network. This means to make sure that all the functions that were suspended during off-line mode are caught up on-line.

To initially connect or to “network” PCs, these computers require a plug-in card, also called a Network Interface Card (NIC). A NIC had a connector, and a (special) cable was required to connect computers to other computers, usually via central boxes (Ethernet Hubs). In the very early networking days there were two types of cards, and two systems were popular and actually the de-facto standard: ARCNet and Omninet. However, the industry recognized the need for formal

standardization, and the industry body, that took ownership for this effort was the IEEE (Institute of Electrical and Electronics Engineers). Interestingly the IEEE is a standardization body with a policy, that is based on a mixture of democratic majority and consensus, so it took quite a while and compromise coalition forming before these de-facto standards were replaced with three formal industry standards: Ethernet (IEEE 802.3), Token Bus (IEEE 802.4) and Token Ring (IEEE 802.5). Of these three the Token Bus standard already quickly "died" in the early 1990-ties, and by the day of today also Token Ring is almost completely abandoned in favor of Ethernet, maybe with the exception of some small areas. This IEEE organization is important to mention, as they would play a crucial role in the definition if a wireless LAN standard.

At the same time when networking came up, there was another clear trend to be recognized. Computers became smaller in plain physical size very quickly. When I studied at the Twente University in Enschede, The Netherlands the computer room was incredibly large, housing a sizable DEC-1020 mainframe. The reason that this room was so large, was the expectation that computers in the future would be even larger, and the idea was to avoid space problems in the future…. Well the reality of today is that the current computer room is about one tenth of its original size.

This trend of computer size reduction continued during the 90-ties and PCs became so small that portable and/or mobile computing became popular. Originally nicknamed "luggables", because of their high weight, these small computers started a clear direction where a Personal Computer, became really a "personal computer", that is a computer that is not bound to a desk, but in the contrary, is very personal to someone, wherever s/he goes. I believe that today about half of the Personal Computer market is represented by laptops, notebooks and/or any other form of mobile and therefore true personal computing.

Well, interestingly, these two trends: (1) computers being networked via a LAN, and (2) computers becoming mobile, that is becoming truly personal, in themselves are with each other in conflict. The cable required for networking as such destroys mobility. This conflict was clearly recognized in the late 1980-ties in our facility, where we did all kind of interesting networking "stuff" in NCR, but where we also were looking for a new product and market opportunity. We decided to explore the opportunity of a wireless LAN, a Network Interface Card with a radio transceiver and antenna at the end, instead of a cable transceiver and connector, as we felt that the two converging trends could converge with wireless networking. It is fair to say though that in these days the market of portable computers was not very well developed, and as a consequence original marketing ideas focused more on cable replacement than on mobility.
Initially we called the concept Radio-LAN and actually it was a "radio NIC", a radio Network Interface Card, with an antenna connected to it that could be slid into a computer, and provided a radio based networking connection.

Originally this idea was completely ridiculed as "completely impossible". It would be: way too slow, way too sensitive for interference causing data to be garbled, far too risky from a security perspective, and just too expensive. Darrell Clark, Vice President of NCR Corporation put it at that time: "Companies have money, they can pay for wiring." By the way, to put some time perspective on this: this was in the time, that electronic mail was only sporadically used by some US West Coast companies, and definitely not by NCR as an East Coast company. This was also the time, that NCR's popular (mini)computer, the Tower series, was one of their main cash producing product lines.
But to the credit of NCR Corporation, the President and CEO at that time, Chuck Exley, who later managed to sell NCR to AT&T, showed to be the most visionary leader of the Executive Team in NCR, and not only supported the program, but was also quite active in the company political field to have the development program continue. It is also good to mention that Wiek Schellings, my General

Manager at that time, also really believed in this program, and gave me the freedom to really work it out and bring the product to market.

Although the vision of wireless LANs was clearly around networking for mobile computing, the positioning during the early years of the first products was around replacing the network cable with radio waves. The original theme was for wireless LANs in the early 1990-ties was: “cut the cable” and the market positioning was around “ease of installation”, “ease of relocation” and “reducing total cost of ownership for the network”. There were a variety of reasons for that “cut the cable” market positioning. One of NCR Corporation’s key markets was cash registers and Point-of-Sales terminals. Installing these terminals was quite an expensive effort, not so much because of the power cables, but because of the specialty network cables. Also these network cables were quite error prune, or sensitive to damage. Although it took quite some time, but in the years after, we have seen a significant shift retailers from wired to wireless terminals, and still as of today NCR is selling wireless LANs as a cable replacement for their terminal installations, as do their competitors in this field: IBM, Symbol Technologies, Intermec, LXE and Teklogix. These were niche markets that stayed niche markets for a long time, even when the product was considerably reduced in size. The consequence of this was that the marketing campaign “cut the cable” became a problem, as it was too hostile to the cable and networking industry, which made a lot of money on wiring and wiring products. We had to show to be complementary.

This original wireless LAN NIC was only the first phase of what is included in the concept of wireless LANs today. Today wireless LANs are more the equivalent on a company facility scale for computers of what cellular phones are on a more global scale.

Already early in the 1990-ties, we started to work on size and power reduction to make a wireless LAN card fit the size and power requirements of a notebook

computer, our original goal. We also realized, that we had to work on a system, that would support "seamless roaming" through a larger office building, where the radio network takes fully care of the connectivity on every location in that building.

To that end the concept of Access Points was developed. Actually Access Points would become for the wireless LAN industry the equivalent of cellular base stations for the cellular phone industry, and a pretty sizable building can be completely covered (lit up) with a reasonable number of Access Points: one Access Point covers on one floor of a building about the size of 5,000 square feet (500 square meters). Access Points can be connected together (networked again!) with Ethernet, and software in the notebook computer, as well as in the Access Points take care of a seamless and not noticeable for the end-user hand-off, once one is getting out of range of one Access Point, and getting in range of another Access Point.

## 2.2 The business background: convergence of telecom and computers?

This war actually started in the 70-ties with a first fence-off between AT&T and IBM.

AT&T, before spinning out Lucent Technologies, was clearly the worldwide representative of everything that was telecommunication. It was a service provider, in providing telephone services to millions, it owned a large part of the world's telecom infra-structure, it developed all communication switching products itself, it was a very prominent player in the telephone switching industry for enterprises, and on top: it owned Bell Labs, the renowned research arm, that seemed to be able to generate an unlimited stream of new technologies. Actually AT&T was synonym to telecommunications.

In the same way IBM was computing and computers. If there was any company, that had managed to leverage the change over of manual administration to electronic administration, it was IBM. They actually covered the world of computing from mainframe down to the smaller machines as were available at that time: the hardware, the Operating System, the programming software and compilers, the application software, etc. The slogan in the IT-world was: “Nobody in IT will ever be fired over having selected IBM instead of one of its competitors.” IBM was the safe choice. In NCR we feared IBM very much.

Actually an interesting side step to mention here is the fact that IBM always had to deal with competition. On its main turf, large computers, companies like Control Data and Sperry were challengers, in the lower end it was originally DEC (later Digital), at the PC side it was Apple, and several others, at the Operating System side it was Microsoft. IBM was an incredible strong company. Even in the 1980-ties, I remember the statement that was made in NCR: IBM is growing every year the size of a complete NCR…. And as NCR employees we looked at each other in amazement, because we thought NCR was pretty big, and growing ourselves at all in NCR was one of our bigger challenges.

The first battle in the 1970-ties started was started with the realization, that telephone switching technology could be computerized, and that a telephone call in essence could be digitized and run over a computer. This lead to the decision that AT&T decided to go into “computing” and that IBM decided to go into “switching”. AT&T started its Computer Systems Division, and IBM bought Rolm, a switching division from Siemens AG. Apparently Siemens had already decided not to compete any longer with AT&T. Anyhow, ten years later, and making up the bill, it was bleeding red ink all around: IBM was no success in switching and divested from Rolm and AT&T was no success in computing and was looking for ways to get out, and to land its customer base without losing

credibility. The result was the acquisition and the divestiture of NCR in the course of the 1990-ties.

Still today, it looks quite logical to combine the two: voice networking and data networking. AT&T proceeded in this period quite well in making their switches based on computer technology: the digital switches made us all say goodbye to the rotary phones. Still owning and developing these computing capabilities did not make AT&T a computer company.
IBM in the other hand became a big networking company. Actually in the early 1990-ties with Token Ring, IBM was the largest network vendor in the market, at least for enterprise networking. But apparently there was a big gap between enterprise computer networking and telephone networking. Apparently the step from enterprise networking to public networking, the technology that AT&T owned was too large, and IBM never made it here.

The underlying reason of the fact that these “convergence” efforts as they were called, never came to fruition was the fact that voice networking and data networking were too different. In the first place from a marketing perspective: the company decision makers for telephones were different people, usually a real estate department in the company, responsible for buildings, gas, water and electricity. The decision makers for computers were usually made in the IT department, overworked and in catch-up mode continuously. Even despite the fact that this changed in the late 1980-ties, and usually the IT department took also control over the PBX and telephone equipment, this still did not create enough synergy to expect the supply of both from one single vendor.
Probably even more important than the different decision makers at the customer side, were the very deep product differences between telephones and computer. The way the computer industry was built was so different compared to the telephone industry. Phones in essence are “dumb” and “cheap” and all the “brains” of a telephone system are in PBX or in the switch. But at the same time

the trend in computing was to move away from dumb terminals and move into smart PCs, as mentioned before. This created a situation where in essence there was a large divergence going on in the industry. Interestingly the current trend in the cellular phone industry is to make cellular phones “smart”, but later about that more.

There were other tries. A serious “run” by the telecommunications industry on the general enterprise and home networking was with ISDN (Integrated Services Digital Networking). Interestingly also originally ISDN was developed in the 1970-ties. ISDN would bring integrated voice and data networking at a speed of 128 Kbit per second. Originally when this standard was established, this sounded attractively fast, as “dumb” terminals were connected to mainframes at much lower speeds.

Unfortunately for ISDN these were also the years that the first rumblings could be heard about the privatization of the telecom industry and already at that time the different telecom companies started to jockey for positions. And if it were not the telephone companies them selves, than it were their loyal suppliers, an AT&T (equipment division) in the USA, or a Siemens in Germany who started to dream up proprietary ISDN implementations. The consequence was that the roll-out of ISDN standard definition got seriously delayed, and that per country different variations started to be implemented. The real momentum started only in the late 1980-ties and early 1990-ties, but at that moment the idea of ISDN was already made technologically obsolete by much faster data networking technologies like Token Ring and Ethernet, that were coming from the computing world. On top of this the PC companies were not really very enthusiastic about ISDN, because of its different variations around the globe, which made them looking at alternatives, because if computer companies need one thing to proceed with the adoption of something new, then it is “one worldwide standard”. Despite this serious efforts have been made to create products that bring “ISDN to the desktop”, they all never succeeded.

ISDN had another major drawback, going to the roots of the lack of understanding of the difference in architecture between voice networks and data networks. ISDN is switched based technology that means that for building a connection between to two points; in essence a sort of physical connection is built up. Token Ring and Ethernet however are packet based, which means, that only a packet is transmitted from one address to another address: only a temporary (virtual) connection is built up. This last method is significantly cheaper and more effective for data, where again "quality" is secondary to speed. This made ISDN already a losing proposition for the longer term, and were Token Ring and even more so Ethernet developed to next levels of speed, ISDN dropped out of the market even before it had reached a reasonable penetration.

Somewhat anecdotal, but one just very practical and amazing example of how different telephones and computers are and that is usually overlooked, can be found by comparing the numeric keypads. A telephone starts with the "1" in the top left corner and works it way right and down. Not so with the computer (or even the pocket calculator) numeric keypad: there the "1" is to be found in the bottom left corner, from where it works it way right and up. This all has logical and historical reasons: telephones just follow the normal Western world script style, but computes came from the original mechanical calculators, where the location of the numbers is ergonomically optimized for number usage: in accounting the lower digits are used more often than the higher ones. Therefore these higher numbers are more remote. But this history aside, as this ergonomic reasoning does not apply to the majority of mankind, however it causes me and almost everyone else to have always to look at a numeric keypad to make sure to enter the right (phone) numbers. I would not be surprised, that it may be also the source of many errors in numeric key entries today. At one time I have even been seriously thinking of changing the numeric pad of my telephone to be the same as my calculator, by switching and re-soldering the wires in the telephone, and I

would really appreciate a phone with a computer based numeric key pad. I think the best solution for this confusion would be that both computer vendors as well as telephone equipment vendors create the opportunity to select either way: computing or telephone pads on their piece of equipment.

On top of all of this, the real underlying factor is the difference in technology, or actually in the quality of the technology. With this I do not want to say, that the quality of data networking is low, but the reality is that the quality and reliability of switched voice networking is just a few factors higher.

Voice technology needs to be synchronous. Many of us probably remember the lack of "quality" that manifested itself in the delays in turn-around time that initially plagued transatlantic calling. Giving a response to a question of someone at the other side of the Atlantic quite regularly interfered and collided with an extra explanation of the question, and when both parties realized the contention, both parties would be quiet, and then to make things really awkward, both parties would start talking at the same time again, causing again a communication contention.

The underlying architecture and focus of research and development in the telephone industry is to make the communication experience instantaneously present: "To be able to hear the subtleties in someone's voice." This is meant when the voice technology is characterized by very high quality instantaneously synchronous, and two-way (so you can interrupt each other!) networking. But interestingly enough it actually does not need a lot of bandwidth. The reality of today is that the bandwidth of a voice call is 64 Kbit per second or less, it can be even as little as 16 Kbit per second.

The computer technology however does not look at networking this way at all. For computer technology bandwidth is very important. Ethernet was offering 10 Mbit per second early in the 1990-ties, however with relatively low quality in respect of timeliness, or synchronization. A few hundred milliseconds earlier or later did not really matter, as long as the data packet would came over correctly,

or could be requested to be retransmitted in case it was garbled. This in essence is “low quality” compared to voice, but more than good enough quality required for data. So data networking needs “fat” pipes, the bigger the better, the faster the better, and the timeliness was more or less a “don’t-care”.

So, this explains why also the technologies could not merge, even until the day of today. A compromise between “the high timeliness” (quality of service) of the voice networking and “the bigger the better” of the data networking would indeed “compromise” either of them. Or the “quality” is too low to have a real intuitive voice communication, or it is too slow for a real larger data communication, say, a transfer of a large file. Or if it would be able to do both, it would be too expensive altogether.

The industry has tried to merge these needs. Was ISDN already written off as a failure quickly, the development of ATM (Asynchronous Transfer Mode) technology was a typical example of trying to reach this compromise, and therefore it became too expensive. By the day of today there is quite some ATM technology implemented, including its many variants. However, the goal of ATM to reach the desk turned out to be a non-starter, as another example of a too expensive compromise.

Anyhow, in the 1990-ties, both IBM’s and AT&T’s endeavors on each other’s turf unraveled. IBM had never had any real success or made any real money with Rolm, so they could divest themselves relatively easily. AT&T was in a more difficult shape. They had made progress with their computer division, and won quite a lot of customers, their technology base, as well as the AT&T brand name and reputation had taken care of this. Unfortunately they were literally losing money on any computer sold. For them to get out of the computer business was not as simple as closing it down, as it would negatively impact their reputation.

By this time AT&T had already come under serious competitive pressure in the different areas they did business in, not in the least from MCI (now WorldCom) in

their core service business. So Bob Allen, the CEO of AT&T at that time, came up with a smart way to resolve this. Instead of retrenching and divesting like IBM did, he chose for "fleeing forward", and acquired an experienced computer company: NCR, I believe for $6B, in these days a pretty large number. His strategy originally was to have NCR take over and run AT&T Computer Systems under the name of AT&T GIS (Global Information Solutions). However, the reality was that AT&T started to run NCR, which made the original AT&T problem only worse: the integrated company started to lose even more money than AT&T Computer Division did on its own. This all ended up in a situation, that AT&T later in the 1990-ties divested itself now from its computer division, and put NCR back on the market – only now for an amount of less than $1B and considerable lower amount than $6B that it had originally paid.

It is important to capture this decade long misunderstanding between the computer and the telecom world to understand how separate the voice and the data industry already were in the wired world, and the billions of dollars that were lost because of this. In the wireless world this separation would be even sharper, but even less understood, costing companies therefore tens of billions of dollars, as we will see later.

## 2.3 The application background: computers and communications

Computers were originally designed for as the word says: "computing", and there are still a small number of computers today designed specifically for doing real computing. However, although most computers today still can run some computing applications – popularly called "spreadsheets" – most of the computers nowadays are developed for communications and entertainment: whether for doing email, chatting, and writing documents – the communication and therefore

the networking are essentials. If the telecom world would have invented the computer, it would have been surely called the “communicator”.
During the 1990-ties I remember that we have thought and discussed many times: “What is the “killer” application for wireless LAN.” Its equivalent in the telecom world was clearly the cordless phone. A computer was clearly a piece of office equipment, why wouldn’t people want a cordless computer in the office. This was the original thought behind wireless LAN’s, and to be honest it did not go very far. Interesting in itself was that the cordless phone had become very popular in the consumer market, but it had never made it from the home into the office. This was in itself a signal, and even in the 1990-ties cordless phones for the office, based on the DECT standard never really got great acceptance.
Well, maybe that is too harsh, there were some wireless DECT PBX phone installations and wireless LAN sales in the original years, but in reality, it did not make even a little dent in the ever growing numbers of Ethernet and Token Ring networking volumes.

Then the killer application showed up, the Internet, or maybe specifically the use of email. Not that anybody realized that this was the killer application initially: email existed already since the early and mid 1980-ties on mini computers, largely on internal corporate networks. But this communication application, that was going to transform the computer into a communicator, sneaked in, slowly but surely, and everyone who had started using this, realized that there would be no way back. Technology makes it ways along many unexpected roads.
Internet and wireless LANs are not directly connected, but the usage of Internet and email fiercely increased the need for networked computers and for networking in general. The Internet stimulated the usage of notebook computers, and with that the need for wireless LANs to support the networking of notebook computers.

Email in itself is an interesting thing that I have spent some serious time thinking of in terms of what it meant. Before the "email society", there were in large two means of indirect communication: the memo (the "letter" for the romanticists) and the phone. The memo was very indirect, and had a delay of usually one or a few days. How did the memo improve our quality of communication! No rash "reply-all's", but a really thorough and well thought through form of exchanging viewpoints.
If there was something urgent, you picked up the phone, and had a (interrupting) conversation, much more expensive, but compared to travel and a face to face meeting it saved a lot of time. Between the two concepts slow and quality, quick and expensive, I think nobody developing a computer would have thought about a very popular application that would generate a new form of communication in between these two extremes – fast and inexpensive, though still indirect. Actually I would like to categorize "chatting" over the Internet in the same category, but maybe as a simple form of email: if you see someone getting on-line, just dropping a few notes – without being as interrupting as a telephone.

In this respect I went through some "traumatic" experience that until mid 1986 I had been working for a MAI Basic/Four out of Tustin, California. MAI Basic/Four was a mini-computer development and manufacturing company and they had implemented a company wide email system, even to the point that it pushed every employee white and blue collar to have an account, and to have access to a terminal to read and write email, which was a challenge for the factory workers, but it happened. When I moved on and joined NCR, another mini computer company, email was an unknown concept for them. So I was forced to "unlearn" email, and having to write memos again. It cannot be described how difficult and painful this was, as I was used to the instantaneous delivery, and usually hourly response, which the memo system did not show. My desperation even grew beyond that when the Vice President of the Division, Darrell Clark asked for ideas – he had some budget left for the year that he needed to spend. I

pleaded that implementing an email system would be an excellent investment, but apparently I was not convincing enough, he dismissed the idea and it took NCR another three years before they adopted email.

The 1990-ties showed a few technology applications that together paved the way for the wireless LAN industry at the end of that decade. These applications were: computers becoming small and mobile, computers getting networked, and finally email and the Internet becoming pervasive applications. As I will show below, these development created the environment for wireless LANs to break through, although it still required a catalytic event to make it really happen: Steve Jobs from Apple Computer, a person known of his technology views starting to promote wireless LANs. More about this will follow later.

Getting back to email, some other interesting observation needs to be shared here. The buzzword in the industry in the mid 1990-ties was “the paperless office”. However, in this period, things did not look like going that way at all. In the contrary: it looked as if computers created more paper than less. We all remembered the piles of computer paper output, that we had to study trough, with on each page usually maximally one bit (literally) of interesting information. So it looked as if the computer generated more paper, and the paperless office seemed a hoax.

In retrospect, I think it was a transition phase. Indeed this was the time that the printing and copying business boomed, but in the late 1990-ties, at least the technology leading edge companies saw a turning point. With the usage of notebooks, the print-outs became less necessary: why make a print-out if you carry the electronic version around anyhow? Also the email flooding makes it virtually impossible to sustain a paper print-out life. Simultaneously with the reduction in print-outs the reduction of photocopies became very clear. I think that in 2002 we made only a fraction of the number paper copies compared to 1992.

Going through this phase lead to hilarious situations, actually appalling…. This is in 1998, my Lucent Technologies Vice President who was clearly from the previous generation ("dial tone country and memo land"). She visited our office, and yes, she was very nice, but email was a bridge too far. Also she cleaerly thought: "typing was for secretaries" and managers need to manage. So, while visiting our facility she had her secretary printing out her emails, and faxing them over to our facility, where my assistant sorted them and handed them to her. She then marked up with pen the faxed and printed emails and gave them back to my assistant, who then faxed them back to her own secretary, who took the comments, typed them as replies on the emails. The hilarious part was, that at a certain moment I had written an email to her, while she was visiting, and I got a reply this way the same afternoon – my assistant had already given me the marked up faxed printed version – after she had faxed it back, so about an hour later the email version came in….

The sad part was that this was already 1998, and that she was not the exception in Lucent. The conclusion can be that for new technologies not only the technological requirements should be satisfied, but also the social context need to be upgraded appropriately. In the example above "keyboard fear" was a clear roadblock to using a computer or even a notebook computer to create some efficiency.

In the following chapters I will describe the how wireless LANs moved through the 1990-ties from the early idea phase and into real product, and from its initial niche markets in retail and via education into the "mass" volume where it is today: at this moment I estimate the number of wireless NIC cards being shipped at about 1 million per month. These shipments include standalone cards (PCI or PCMCIA-bus) sold through distribution to end-users, as well as integrated cards (mini-PCI) sold via the computer industry.

# 3. The original idea (1987 – 1991)

Few people realize that Wi-Fi goes back to the late 1980-ties, and that the technology really developed in the heart of the computer world. That it was also having quite a rough time getting accepted in the industry. Everything around what is Wi-Fi today needed to be invented: from spectrum to standardization, from implementation to customer acceptance.

## 3.1 The radio legislation in the US

It most likely will be impossible to trace back, who was the first person that created the idea of wireless LANs. I think the original concept was with some thoughts of the FCC (the Federal Communications Commission) in the USA to enable some frequencies for data communications in the 915 MHz, the 2.4 GHz and 5.8 GHz, probably for warehouse data collection terminals. This was in the mid 1980-ties. These three bands existed already for so-called ISM usage, where the three letters stand for Industrial, Scientific and Medical. Examples of applications that have been and are running in this band are microwave ovens, garage door openers, and cordless telephones(!). Another example of how this band was used was with popular retail security system from a company called Sensormatic (now part of Tyco Corporation), that was running in the 915 MHz. Considering that retail was considered as one of the target markets it is probably

not surprising that there was immediately a serious interference concern. Fortunately Sensormatic and we at NCR could quickly sort out how to use the 915 MHz spectrum (actually ranging fro 902 MHz to 928 MHz), so mutual interference was avoided.
In the late 1990-ties also Bluetooth started to use the ISM band, in the 2.4 GHz this time, causing interference, so about this later more.

These bands were called “unlicenced”, as one did not require a license to have radio equipment using this band, as long as certain restrictions were met. The usage of these bands was restricted to only using a low transmission power (less than 1 Watt), and in secondary status. This last requirement meant that the primary user of the band (amateur radio) could request to stop transmission in case they received harmful interference from a secondary user – something that I have not run into during my 15 year work in the ISM band. However this and the fact that the band was “unlicensed” also meaning “free for all” had many major companies and service providers concerned in the early days, which limited the acceptance of the technology.

Still, from a marketing side, this “unlicenced” turned out to be a major concern. The typical customer question was: “What happens if I have set-up and invested into a wireless LAN configuration, and a radio amateur asks me to close down my system?” Usually the answer was quite unsatisfactory for the customer. The assurances were usually not good enough, and the customer was left with FUD (the standard marketing term for Fear, Uncertainty and Doubt). Promises like, we will immediately replace your wireless LAN with Ethernet usually did not help: “Why go through all the hassle of wireless in the first place?”
In our development we have been always targeting low power transmission and high receiver sensitivity, or in better marketing terms: we had focused on “being very good and sensitive listeners, so our cards do not have to shout so loudly, or

have to transmit a lot of power". But at this stage in the selling cycle this story was not more than an interesting fact.
This uncertainty could only over the long term be worked away with enough success stories, and hoping that harmful interference of a primary user would not take place.

This all did not mean that the FCC with their regulation had already any particular product idea in sight or even a clear idea how such a product would have such a broad benefit, or that it even would work. As happens more often in this type of situations, product ideas start to pop-up in more than one place in the world. Besides on our location of NCR in Nieuwegein, Utrecht in The Netherlands, there were at least four other places in the late 80-ties work that work was going on in wireless LANs, probably all driven by the thought, that cordless phones would have lead to an equivalent of cordless computers.
By the way, interestingly, but maybe with exception of the UK, this "cordless" term never caught on, although that term probably would have described much better what we were doing than terms like "wireless" or "Radio". It therefore should not be surprising, that we usually required quite some time to explain, what we were really trying to achieve. We called our project initially Radio-LAN, until we choose the product name WaveLAN in an internal contest, that provided the two winning employees, Martin Jansen and Ton Wormgoor and their spouses a free dinner. They both had proposed this name.

## 3.2 Pioneers

Of the companies and locations where initially wireless LAN ideas were developed, the Motorola location of Schaumburg, IL in the USA was probably one of the more important ones. If there was any company known about radio

technology, it was Motorola. Tom Freeburg and his team had worked out and mastered an incredible difficult technology, and what later turned out to be too expensive as well. Interestingly it was not based in any of the ISM bands, but it was based on an 18 GHz radio frequency, and was using all kind of sophisticated algorithms to work properly. The second important one was relatively close by in Toronto, Canada, where a start-up called Telesystems tried an approach that was fairly common to ones tried in other locations, including us in NCR. The Telesystems approach based on the so-called ISM band in the 915 MHz lead to a product called Arlan. On the "West Coast", in Spokane, Washington, there was a company called "RLAN" (probably for Radio-LAN), and then on the East Coast there were two companies LAWN and O'Neill Communications. These companies also used 915 MHz ISM technology, and tried some products in the market, but all dropped out, sooner or later. I think at this time also Proxim existed, but they were focusing at that time on wireless meter reading. Also on the West Coast in San Jose with Symbol Technologies some original efforts were taking place in the late 1980-ties.
This was more or less the initial competitive "playing field".

Looking back of what is left today of these initial efforts: of the large companies Motorola dropped out already quickly (in late 1992 or early 1993). Their 18 GHz product line, named Altair, turned out to be based on a way too complicated technology architecture, although it had a higher speed: 3-4 Mb/s was advertised. Overall the product turned out to be way too expensive. Most likely every product sold, was sold at a loss.
NCR survived following a long path via AT&T and Lucent Technologies into Agere Systems, where it split into a chip division and a into an infra-structure product division, that merged with Proxim. Proxim itself has lived through the years, facing good times an bad times, but had survived, and merged in the year 2002 both with Western Multiplex and the infrastructure products division "ORiNOCO" that Agere divested itself from in that year.

Telesystems developed a very interesting history. It was originally acquired by Telxon in the mid 90-ties, to allow Telxon to compete with Symbol Technologies, who by that time had built up their internal radio knowledge, and effectively competed with Telxon in the wireless data-collection market. But later in the 1990-ties both Symbol Technologies and Telxon came to the conclusion that wireless technology needed to be independently competitive in the market. Both companies had unsuccessfully tried to compete in the OEM market, by selling their radio technology to third parties, but neither of them had made real progress. Therefore they tried to divest their wireless LAN divisions. Telxon was successful in initially putting Aironet in the market as a separate division in 1997 and completely independent in 1999. Symbol even per the day of today (mid 2002) still owns their own wireless LAN division, probably simultaneously an asset for the key knowledge it provides to their business, as well as a liability as with the relatively low volumes in their retail market segments, they are probably struggling to meet effective price points. In early 2000 Aironet was taken off the market, as it was acquired by Cisco, and considering, that they started as a start-up in the late 80-ties can be considered as a great success story, in particular considering the future opportunities that Wi-Fi has in store.

## 3.3 Product definition

But let's not get ahead of ourselves here, as in the early 1990-ties the plans were big, but the challenges were probably even bigger. In NCR we had the typical problems that a new start-up has finding itself within the boundaries of a larger organization.

In the first place the definition of the product in the context of NCR was a big problem, and even some fundamental technology choices had to be ironed out. My division happened to be part of the NCR Financial Systems Division.

Unfortunately wireless LANs had not so much affinity with ATMs, check readers and sorters, and this sort of equipment. NCR had two other important divisions here: RSD, the Retail Systems Division and PCD, the PC Division. The Retail Systems Division was the most interested in wireless LANs, despite the fact that they did not have a handheld or data collection product line like Symbol Technologies had. Their main interest was the ease of installation and relocation of cash registers or POS's (Point of Sale terminals) for department stores like JC Penney's and SEARS, or mass merchandisers like Wal-Mart. The PC Division was not really interested. In the early 1990-ties the PC industry was already as extremely competitive and as fragmented as it is today. A relative small player like NCR could not afford to spend the time and bandwidth to bring wireless networking into the market. Despite the fact that we many times approached this division, they were not really interested in even trying. Also in their view the price of the product was prohibitive. After many efforts it would take until 1999 before the PC industry started to embrace wireless LAN technology.

In these early years in NCR the relationship between the Financial Systems Division, where we were part of and the Retail Systems Division, where the first applications would be possible, did not develop very well. It was the usual "turf battle stuff" between divisions in a large company, that started in some difference in understanding of the technology and than moved out from the factual phase into the emotional phase. The battle field in itself was not that interesting, it was around what protocol to be used: Token Bus (RSD's preference) versus the use of CSMA/CA (do not worry about what it means, but it was the name for our preference – Carrier Sense Multiple Access with Collision Avoidance). This difference in opinion was uncertainty about the actual performance of either protocol in real circumstances, and the lack of facts to really support either view. But it blew so out of proportions, that RSD decided to go their own path, and subcontracted their development to a company called SSS at that time, later changing it name to Omnipoint.

But this was not the only product decision that needed to be made. At this moment the PC market was quite diverse in terms of hardware interfaces ("busses") and software interfaces ("network operating systems"). But also local area networks were just starting to become common place, while discussions were still going on whether "client-server" computing would be viable at all (compared to a "dumb" terminal based architecture). Looking back this maybe weird, but the reality is that still at time IT departments were struggling with the somewhat renegade concept of the PCs in general and probably rightly so. The management, maintenance and support costs of client-server based systems quickly showed to be significant, off-setting the gains made, because of the lower costs of the equipment.

In this environment the PC market was still quite fragmented and the choices needed to be made were far from obvious at that time. Our original choices were AT(8-bit) for the bus and Novell Netware as operating system, probably the right ones at the moment of selection. However, very quickly we were forced to support AT(16-bit) and Microchannel, the new hardware interface bus that was defined by IBM, and that had some limited success for some time. At the operating system level our initial choice with quickly challenged when Microsoft started their attempts to get into the network operating system market with "LAN Manager".

But there was also another layer of difficult architectural choices to be made. Should for instance a radio based network be built on a LAN architecture as was standardized by IEEE, or should it only be a transmitter and receiver connected to an Ethernet card itself. Or would it be better to base it on ISDN, or even just on DECT (the Digital European Cordless Standard).

The DECT standard just had come up trying to harmonize the many proprietary cordless phone technologies that were in use around the globe, and in NCR we have seriously looked at using this. It would have had a lot of advantages, at least

by taking away for instance the FUD about interference. In the end we rejected this as a solution for reasons of throughput. Combining all the available DECT voice channels would give us a product running at 1 Mbit per second, but at that moment not allowing any voice conversation. This was when we were looking at 3 channels, each of them running at 2 Mb/s (Megabit per second).
Interestingly Olivetti, at that time one of the larger IT equipment conglomerates located in Italy, and also one of the key promoters of DECT, went all the way in implementing a product that implemented wireless LAN's running over DECT. Andrew Budd was the great inspirer of this project, and he was also involved in a variety of European standardization activities around this. The product however, just like the Motorola Altair product, showed to be very expensive, and probably was not in the market for longer than a year.

And than last but not least there were these "other" technologies: implementing a LAN with infra-red technology or via transmitting signals over the power cables. Both technologies had several "runs" at the market with the implementation of real products, none of them being really successful. But that is all hindsight. At the time that we made the choices that we made the total picture was showing many options.

During the first years of the development the number of people, that worked on wireless LANs slowly grew to around 40 or 50 people in 1991. They were a mix of radio and digital hardware development engineers, manufacturing and test system development engineers and software and system test engineers. Actually it was always amazing to see how many software engineers were required for what looks as a hardware product.
The target of the cost for the initial product was around $300. Actually we made this target pretty well, however, only after a year of manufacturing. The initial products costed probably around $600 for the initial low volumes. However, this

was still significantly lower than Motorola's Altair product that we estimated to be over $1,000.

## 3.4 Early marketing

After the separation with the Retail division we continued on our own path. We continued our development based on the CSMA/CA protocol, and this decision showed to be a right one. This protocol was later also adopted with many changes and upgrades, as the core of the 802.11 MAC protocol as we know it today. Retail's subcontracted development with SSS turned into a large failure: there was a large discrepancy between what Retail thought, that SSS could offer, and what they in reality did. This meant that in the years after, Retail retraced their steps and followed our approach by using our products, although some special adaptations were required.

Actually, this temporary separation turned out to be a blessing in disguise, as it helped us to focus the development on something concrete, and start translating the wireless ideas into a tangible product. Our interest from the beginning had already been more in the horizontal market, the wireless notebook computer, than a vertical segment like retail.

So, we started with a lot of "horizontal" market research. I remember that we hired a bureau to do focus groups, where we watched from behind a glass window to a group of about 10 (IT-) employees, discussing the wireless LAN concept. We did three of these focus groups in the US: in New York, Chicago and Los Angeles, and we learned about what people liked and disliked in general. The outcome was generally positive, although the reactions varied. I think these sessions were useful, as they were also followed up with a quantitative study, where about 150 companies were interviewed via the telephone. In a third phase I

personally had in-depth follow-up interviews with about 10 of these 150 companies, and so we got a picture how a wireless LAN product should look like from a user perspective.

The general opinion was, that wiring in general was difficult, and quite expensive – significantly more than one would expect at first sight. The actual numbers ranged from a $200 to $1,500 per "drop", per connection. Not too many buildings at that time had a structured wiring plan in place. Another problem was the expertise required for installing and maintaining a cabled network. In particular relocations were a "royal pain", as I remember one of the participants contributing. It was clear that notebooks had not really entered the market, or the minds of people, and so we slowly moved from the original concept of mobility, to the concept of "cutting the cable", and defining lower cost of installation and relocation as the key selling feature. We had to get back on the "mobility" track later.

The product launch was a major excitement around Networld in September 1990 in Dallas, however, it also got us in major trouble, because despite the fact that we had working prototypes at the show, the productizing, radio certification and the manufacturing start-up turned significantly longer than expected. Radio products are clearly a different "breed" than the digital products that we were used to at time. In December 1990, we started to ship products in very limited quantities, but the general product release took until May 1991. The main reasons for the delay were around product stability, in particular getting the Novell drivers passing certification, as well as the availability of the product diagnostics.

## 3.5 Early sales efforts

At the true sales side we came into some challenging situations as well, separately from the fact that we initially had only a limited number of products available for pilots. Customers in general tried to understand the technology, and were fascinated about its capabilities, but the benefits were seen as too marginal and the price as too high, so relatively few customers really started buying and implementing it. Also the price that the product was launched at was probably too high at $1,390 per card, including the Novell Netware driver, as Novell Netware the reigning NOS (Network Operating System) of that time. In these days an ARCNet card was selling at $300, and Ethernet card at $495, and a Token Ring Card at $645.
Already quickly we decided to lower the price to $995. This was a step forward, but in reality the number of products we sold stayed relatively low.

Also the question was initially, how do we sell the product? NCR's background was clearly in the "direct sales" environment: selling mini-computer systems to large accounts in horizontal and vertical markets. That was not directly the sales environment that was appropriate for something as small as a wireless LAN card. The product was offered to many retail customers, to many financial customers and to several governmental agencies. We did a lot of trials and testing with JC Penney's, with SEARS, and out of the early days we could mention some success with for instance Chemical Bank in Raleigh, NC or with Revenue Canada. Actually, Revenue Canada was out first large order, it was for about 1,000 cards, quite a phenomenal size order at that time.

These days however NCR was also trying to move into the indirect distribution channel, and worked with distributors, system integrators and value added resellers. We did do some initial business with companies like Computerland, Softsel, Ingram, and with Micro/D, where the last two have merged into one company (Ingram Micro), still selling ORiNOCO, the successor of WaveLAN today.

This was indeed a more appropriate distribution environment, however, selling a wireless LAN card in these early days was a too complex sale, and despite many efforts we undertook on training and providing sales material, this turned out to be only with limited success.

Interestingly NCR also had an OEM sales force that was related to their semiconductor division, selling chips. They had the relationships with many of the computer companies and networking companies these days. With their help we make direct calls on quite a lot of them.

Several of them were quite interested: IBM, Apple, Compaq, Toshiba and Digital to mention specifically. But unfortunately it stayed just with that. What I learned there for the first time: there is quite some herd mentality amongst the PC vendors, and few are taking the step into something new, unless everybody else does as well. This is quite amusing, as many of them claim to be innovative and provide thought leadership. Clearly wireless LANs at this stage was a bridge too far.

The only exception I have to make is for Apple. Unfortunately Apple was already working with Motorola, but interestingly not with their Altair product line. They were trying to do something with a technology called FHSS (Frequency Hopping Spread Spectrum). Our product was using DSSS (Direct Sequence Spread Spectrum), and for one or another reason Apple had an “internal hang-up” on DSSS, and had declared that FHSS should be the technology of choice, because of its perceived better interference resistance.

This was the first skirmish of a technology battle that raged through the mid 1990-ties, the war between DSSS and FHSS that delayed the uniform standardization and actually caused the market to stall for several years. Looking back the FCC had done something very useful by allowing data communication in the ISM bands. However, by also allowing two radio technologies in the band, they had also put in there a poison pill, that the industry failed to cope with for a period of at least five years.

We did not only approach PC companies with our technology, but also networking companies. 3Com was not interested: come back when there is an IEEE standard. Xircom, a networking company that a few years ago was completely taken over by Intel, seemed not to be really interested, except the year after…, when they had launched their own internal development program.
We had a success with Puredata, at that time a successful Ethernet card supplier that is still around as a communication company. It was a very questionable result, because once they were signed up, the first customer they went after was Revenue Canada, trying "to steal" them away from the direct sales channel, where we had an earlier reported win. This was our first exposure to what is known in distribution channel management as a "channel conflict". It was an enlightening experience, but not necessarily a very pleasant one.

What really struck us unexpectedly in the first year was the needs for outdoor point to point connections, actually more than half(!) of the leads coming in were for "outdoor", despite the fact that the product was completely designed for indoor networking, in an office, in a store, in a warehouse or in a factory. But what customers really liked to use the product for was to connect the building on the other side of the street, or further down town. Fortunately our design was modular, and the omni-directional antenna that was specifically designed for indoor, could be easily replaced with a directional antenna, and if necessary to include "antenna boosters", whether still meeting FCC requirements or not….
Several VARs, Persoft and Hiperlink are two to mention here did a lot of pioneering work and started businesses based on this long range value proposition, and achieved amazing results. Anecdotal stories talked about 50 Miles ranges in Kansas, to connect buildings.
Most of the initial customer enthusiasm clearly came from this type of application, as it was not only significantly cheaper than leasing a T1 line with it

monthly recurring costs, it was also under own control, and actually quickly installed.

## 3.6 Security

Another big marketing problem was (and still is today) the security of wireless networks: eaves dropping and/or breaking-in. Also this added seriously to the FUD factor that I mentioned before. Radio waves go everywhere – even when the range is rather limited, and there is no way to avoid, that networking radio waves can be picked up outside of a building, for instance from the parking lot allowing unauthorized people to listen in. At the same time, and from the same parking lot, radio signals can be transmitted into the building and into the data network that is used.

Now in general this was not as easy as it looked like. There were and are all kind of levels of security built in, ranging from physical security to network security, from what radio technology was used at what frequency to password protection on network access. But as with all security measures: given enough time and money they can be broken.

Initially we had identified a good solution for this: we provided as an option in WaveLAN a DES (Data Encryption Security) encryption chip. DES was a publicly known and described algorithm, and it looked like a reasonable choice. Unfortunately it created a whole set of complications that we only became painfully aware of later, when our legal department was informed, that the implementation and distribution of this algorithm was controlled by the government via the NSA (National Security Agency).

In the course of 1990 and 1991 I have been told to come several times to Washington to the NSA and The Hague in The Netherlands, to the Dutch

equivalent of the NSA (NBVB, the Netherlands Bureau for Connection Security) to explain, what we are doing with DES, as well as with Spread Spectrum, the special radio technology that we used for the first out product, and that was approved by the FCC for the 915 MHz band. Both technologies were considered under control of the NSA, and under regulation for export. Well, actually the problems with Spread Spectrum were quickly resolved. We were using Direct Sequence Spread Spectrum with a low spreading code 11 bits per chip, so this was OK. I never got a real explanation why this was OK, probably they realized that Spread Spectrum with such a low spreading code was very easy to unscramble.
Much more difficulties we ran into with DES itself, the data encryption methodology that we used. It almost seemed that we run into a big panic with the authorities here, and the reasons why this was were very confusing. In the first place the DES algorithm itself was fully published and available in any standard cryptography text book so what was not new. Secondly, we implemented DES on a separate chip, while this chip was developed by a Dutch chip development company in The Netherlands, and manufactured in a foundry in France. So, at a certain moment I even wondered why the NSA would even have jurisdiction over this. But actually they exercised their power as an American institution over the American firm (NCR), that we were part of, and showed to be very strict and nervous about this. This was actually when I learned the expression “red tape”…. It was also the NSA, who involved in The Netherlands the NBVB.

Anyhow, the bottom line was, that we were allowed to ship this DES security feature with our product on the following conditions: it was free distribution in the United States and Canada, and it was a controlled export to only financial institutions (mainly banks) in other countries in the world, as long as these countries were not blacklisted (like Libya, North Korea or out South Yemen). The DES-chip also had to be on a socket on the board, it was not allowed to be soldered on it directly. This last requirement was a very strange one. If the chip is soldered on the board, it is much more difficult to take it off, and to do mean

things with the chips, than when it is soldered on the board: removing a chip from a board by de-soldering it can easily lead to its destruction or at least reduction of it life time. So, let's make it easy and put it in a socket….

This controlled export forced us to implement a thorough administration including up to the end-user of the product. For non-financial customers in the non-US market we found a work-around. We developed a simpler security algorithm ourselves, based on DES, but with some reduced complexities. This algorithm had to be disclosed to the NSA for screening and approval, and after that we got it implemented, again by a Dutch chip development company, and manufactured in France…. For marketing reasons we called the chip AES (Advanced Encryption Security) and we shipped it over several years. This all came to an end, when the IEEE came up with an encryption standard as part of the wireless LAN standard this was called WEP (Wiring Equivalent Protection), that was the moment that we de-released both DES and AES.

Even till the day of today, I do not understand the deeper meaning behind all of this. What I know is that also Microsoft ran into similar problems, when they wanted to freely ship DES encryption as part of a security feature in one of their earlier versions of the Windows Operating System.

Actually just a few years ago the restrictions on DES have been largely lifted, however, when that happened this has already become a mute point for us, because of the implementation of the IEEE WEP algorithm: RSA instead of DES.

## 3.7 Health risks

The last FUD factor to be mentioned here was the health risk. These concerns came and went quite regularly, almost with a predictable repetition of once every other year. And all understandably, as our society is seeing a growing number of

manmade radio emissions, in particular of the last decades. The real problem is also that there has been no research that really proves that radio waves are not dangerous. The usual situation is the other way around research has not been able to show that radio waves are dangerous. This last statement is clearly not enough to be true assurance for customers.

What helped, was being able to show, that usually only one computer was transmitting at one time, and that the radiation of our product (around 100 mW) was significantly lower than the radiation transmitted for the early generations of cell phones (around 2-3 Watt), and also that the cell phone was kept very close to one's head, but that the antenna of a wireless LAN card was usually some distance away. This all was a helpful explanation just up till the moment that in the US there was a case of someone who got a brain tumor, and started to sue the cellular phone company as well as the cellular phone equipment provider.

This event lead a whole set of initial customers to start raising questions again, and at this moment in particular the concept of "accumulated" radiation became a key word: what about the effects when one had multiple, for instance ten wireless LAN cards in a small area, what would be the impact? It got even to the point where customers were asking for a guarantee or a health certificate, something that was not possible for us to provide. I think we definitely lost sales in these days. It was going to take years to get the public to a level of comfort about the radio waves at the low power levels that are used in the cellular phone industry as well as in the wireless LAN industry. In the course of the years additional scientific information has been collected, none of it being able to show that there are negative effects from radio waves on the public health at the power levels that we were using.

## 3.8 Developing new technology in a large organization

Actually it was somewhat strange that NCR developed this new technology internally. This was clearly the old way that larger corporations had internal "advance development" organizations that tried to come up with ideas and then tried to translate this into profitable business. The more "modern" way was looking at companies who had launched something in the market, and had received a positive business response. Actually later in the 1990-ties this difference in approach was very clear between Cisco and Lucent Technologies: Cisco grew through acquisitions of "proven" companies and technologies, Lucent Technologies originally tried the same through developing technologies in Bell Labs, and bringing them to market. From the position where both companies are in today, it maybe clear, which of the two ways is the preferable one – although this maybe a too quick conclusion: besides their internal development Lucent also acquired companies, with Ascend probably as the largest example.
Looking back the Bell Labs model truly produced Nobel prize winners and internally we had jokes about this, as it seems that this was clearly creating PR value, but not necessary any revenue. The efficiency of a model where many small start-ups try new ideas and technologies is unmatched. Many of these start-ups die quickly if the idea does not have enough commercial merit. The few that survive are proven in the market, and may have a high price tag, however, this price tag maybe lower than maintaining an advance development organization. Although in the late 90-ties there was also a frenzy of buying start-up companies, before the commercial viability was shown – just to make sure that the competition did not acquire this company before you. As a consequence of this in these days the price of these companies was driven up considerably.

Wireless LANs were an internal NCR development, initiated by NCR's Corporate Advance Development in Dayton, Ohio, and championed by Gary Spencer and Don Johnson. Don actually retired from his efforts in wireless LANs only in the year 2000, until that time working on standards and legislation. So he can be qualified as one of the true wireless LAN pioneers of the very early days.

The Corporate Advance Development organization in NCR was not solely focused on maintaining their own momentum. Part of their model was to fund Advance Development programs in the different Business Units. The Business Unit in the Netherlands had a set of skills that seemed to match the original ideas of what would be necessary to successfully develop wireless LANs: a blend of knowledge in three areas: analogue radio, digital and software. Plus the team had a few really brilliant experienced engineers, who later have been recognized as key developers of the standard. In this respect I want to mention Albert Claessen for overall system knowledge, Bruce Tuch for radio technology and Willem Diepstraten for in particular protocol development.

But good experienced engineers were not the only reason of success. Wireless LANs were embraced by the top of NCR: Chuck Exley and Tom Tang were both believers of the potential power of the technology, so despite the politics, that developed around the subject, an its breakthrough being postponed for years, they continued to function as corporate sponsors, which is a requirement, otherwise "persistence" at the bottom of an organization will be to no avail. Being far remote from the headquarters, even being located outside of the US turned into a positive thing here as well. Usually the "out of sight, out of mind" expression is used in a negative context, but in our case it definitely was a positive.
Still my experience with "headquarters" in general is, that their involvement has a tendency to create more problems, than that were resolved. The general "help" from headquarters can be very distracting, is usually remote from customers and has a tendency to include personal "hobby horses". The best advice I got from headquarters was: do not listen to us, but listen to the customer – but go and tell this to your boss from headquarters!

## 3.9 Summarizing the first period (1987 – 1991)

Looking back on the first years of wireless LANs, the period 1987 – 1991, it was a true pioneering time, and somewhat of a business and marketing disaster. The issues we faced were manifold.

The product technically worked fine, but was in essence just a single card. The product line needed serious review to become a true system supporting a true mobile indoor environment. But that was the far out strategic problem we had. Short term we had to deal with serious marketing issues: the technology had serious market acceptance problems: security, interference and health created tremendous FUD. On top of that we had pricing problems: the premium for wireless was recognized, but was not $500, so the $995 price was too high, but we had to ask for this to make some margin on the product. At the same time our manufacturing was not sorted out, as for political reasons we were forced to use expensive internal NCR manufacturing. Our distribution channels were in arms, because of channel conflict, did not really understand the product, or were just ignoring it, because a wireless sale was too complicated. It goes without saying that we did not make any money in these years either.

But on the positive side there were a few good things to say. We had proven the basics of a completely new technology, we had started the standardization – about this later more –, we got first customer experience, including an understanding what applications we could support, plus we had a clear concept and architecture for the product, which afterwards looked like having walked through a large minefield of wrong decisions, compare the traps that Motorola and Olivetti fell into.

We also had become absolutely convinced that with wireless LAN, we were up to something of which we were convinced of, that the number of applications would outrun our imagination, as soon as we could find “the tornado”. We were convinced that if we got it right, then the applications would generate the volume that would reduce the price of the card. Via this lower price new applications

would be enabled further growing the volume and further reducing the price. The big question these days was: how to get this momentum started.

Last but not least by the end of 1991 we had built a team that was very committed to make the product line work. Actually everyone who would form the key technical team, the key marketing team and the Management Team of the later 90-ties was working on and committed to the WaveLAN product line at this time. Maybe that was the biggest asset out of this first pioneering phase. We got the idea, that there was something big that we were on. We had a tiger by the tail, but the tiger was sleeping. Our Martin Bradley, our General Manager these days formulated it this way: “Bringing new technologies to market takes time, and whatever time your estimate it will take, it will take longer.”

# 4 The system and the world market (1991 – 1994)

It was clear at the end of 1991 that wireless LAN was an interesting concept, but that it also had some significant flaws that needed work. Also the economic situation had turned into a harsher climate these days, and rationalization of all activities was required. At the end of 1991 it was clear that the days of "the idea" were over, and that persistence needed to set in.

These were also the days that AT&T Computer Systems came into trouble so much, that AT&T decided to solve the problem by buying NCR, and merging their organization Computer Systems together with NCR in an effort to gracefully exit their own computer business and bringing their customers into the home of NCR. However, because of the economic downturn NCR was not that healthy either, and NCR management used the merge of the organizations as an opportunity for a complete internal "clean-up". Wireless LANs did not really come into focus, because we were still that small at that time. Otherwise I am sure the story would have ended here.

## 4.1 An incomplete product

In the course of 1991 it became clear that the technology was very interesting to everybody, but that the WaveLAN product was incomplete compared to the notion that people had about this.

At the technical side WaveLAN was a wireless LAN card making the cable unnecessary to go to the central computer or server in the computer room. However, the computer room in many cases was too far away, even on another floor. We developed many ideas how to overcome this distance problem: repeaters, leaky cable, passive antenna amplifiers. However, none of them showed to be really feasible with the exception of the concept of the base station, that we internally baptized “Access Point”. Later we translated the name of the access point into “WavePOINT” for our WaveLAN product line, a name that came from Tino Scholman, one of our Product Managers and that we all really liked. It said what it did: it provided a point of wireless access to the network.

But immediately with the concept of access points, we realized that we needed to have multiple access points to cover larger buildings, plus the capability of roaming (also called hand-off) between these access points. Walking around with a notebook through a building should keep you connected, getting out of range of one access point and coming within range of another should not interrupt the communication session. Actually, the user should not even realize when one reaches the end of a cell, the range of an access point, or even where the access points were located.

This concept that was easily described, and had it parallels in the cellular phone world, so therefore it was relatively easily adopted. However, the implementation turned out to be completely different compared to the cellular phone world, and for good reasons. At that moment however, we had no clue that the migration from a wireless LAN card to a wireless LAN system was an effort of the same size and magnitude as to develop the original wireless LAN card. To be frank, nobody in the industry had an idea of the magnitude, it was completely new territory. But I remember we started the effort with an enthusiasm, as if the whole concept of wireless LANs was just invented yesterday.

Coming back on my earlier description about the difference between the telecom world and the computer world, here we ran into another interesting difference between the two. A cellular phone is a very smart piece of equipment, however, in the networking sense it is “pretty” stupid: when having a telephone conversation, the decision to hand-off from one base station to another base station is taken by the base station. This base station is in close contacts with its “neighbors” to make sure this happens “seamless”. The amount of software technology this requires is quite complex, in particular to maintain the right voice quality in such a system.

In the data world this concept, where access points (base stations) keep track of the “terminals”, and the signal quality of the communication with these terminals, would be unnecessarily complex. Data requires integrity. Quality in the sense of timeliness is not of significant importance. Therefore the decision making to disassociate from one access point and reconnect through another access point takes place in the terminal. A PC or a notebook is powerful enough to keep track of the available access points, as well as being able to make the right decision of when to switch and to what access point. Actually this is a relatively simple process: each access points sends out regularly a beacon, and the PC keeps track of the beacons. If the quality (integrity) of the current connection is not good enough, it looks in the table for a better one. Has it found such an access point, then it creates a “connection” with that access point, telling the previous access point to ignore whatever (weak) signals it still may receive.

The implementation of this concept was relatively easy, the real challenge as usually in these systems is size. In principle one PC roaming from one access point to another access point worked fine. But the real need was to have a robust protocol that would allow 10,000 students roaming over a campus with a 1,000 access points, as we would quickly learn, when we closed an agreement with the Carnegie Mellon Institute in Pittsburgh, Pennsylvania. Testing such a system required us working with other companies, as it was virtually impossible for a small organization as ours to size up a testing program to such an enormous scale.

## 4.2 The market outside of the US

Beside the lack of roaming more limitations had shown up in the WaveLAN product: the product could not sell in Europe and Japan. It was clearly targeted on the wireless LAN market in the US, as it used the 915 MHz band, a band that was only approved in the United States for this type of unlicenced data communication usage. Europe had reserved this band space for one of its versions of its cellular system (GSM), so after some quick inventory, it was clear, that there was "no way", that we could even think about exporting this to many other countries outside the US. But for computer companies it was very clear, that wireless networking products have only any level of viability, when they can be sold and shipped to all parts of the world.

There was an alternative, a frequency band that was available both in Europe and in the US in the 2.4 GHz for again ISM applications. But there were many complications to overcome. People may wonder, what took us all so long. Well, contrary to the US, but in Europe the 2.4 GHz ISM band was excluded from the usage for (data) communication. Actually the most important application in the 2.4 GHz ISM band was to use it for "microwave" ovens. I did not know either, but as we found out later, the common microwaves in our kitchens, but also in restaurants "run" at 2.4 GHz. Despite this fact, that would cause us serious grief later, we energetically start to move to pave the way for wireless LAN applications in the 2.4 GHz.

My vague notion was that we needed a "lobbyist", someone who could work the authorities and find the ways through which we could establish WaveLAN in Europe on a similar concept basis as in the US. We found our lobbyist through a conference that he presided over: Doug Postlethwaite, maybe with a difficult name to spell, but with the absolute right skills to get the job going. We hired him

on a retainer basis and developed a plan to approach the opportunity along two lines – one line was the direct approach: asking for approval, the second line was indirect by publishing a set of articles on the concept of wireless Ethernet, creating the image of how it had established itself in the United States, including positive quotes from companies that had started to use the WaveLAN product there. Then clearly we used these articles to further support the direct approach that proved that this technology needed to find its way into Europe.
When this all started to work NCR Japan picked up on these efforts and started to replicate them in Japan. Although these activities were somewhat later, the reality was that a somewhat frontal worldwide attack took place in 1992 and 1993 on using the 2.4 GHz for data communication applications.

Although at this moment some other companies were in the market, in particular Proxim and Aironet (now Cisco), I am not aware that they developed serious efforts themselves to develop the market outside the US, but this could have been the case. Asking them probably leads to a positive answer: success has many fathers. And a success it became, first in the UK, Australia, Norway, Sweden, Japan, The Netherlands, and Germany. Slowly but surely the worldwide acceptance started to roll in, even before any official product was available.
Not that the situation in Europe or the rest of the world was as trivial as it was in the US. What is called today conveniently the “2.4 GHz” turned out to be a patchwork of different rules and regulations in different countries. For instance the allocated band in the US was from 2400 to 2473.5 MHz, in Australia it was from 2400 to 2450 MHz, in Japan it was from 2474 to 2500 MHz, and in Europe different countries had different rules. So there was France that allowed the usage of the 2.4 GHz only in about 70 of its largest cities, as the France army was using the band for military purposes as well. Italy even brought the bureaucracy a step further: although the 2.4 GHz band was license free, when it was used for data communication a license fee was required to the government.

Today the bands are pretty much harmonized across the world, and so are the products. But in the original 2.4 GHz product definitions we had several “flavors” for the different countries and regions in the world, with different software tuning the radio to the required channels in the band.

Interestingly enough in efforts to open up the 2.4 GHz band in Europe we got a lot of hostile opposition, if not plain sabotage from Olivetti. I still vividly remember the negative and defensive contributions to the discussion from Andrew Budd, Director in Oliver. Olivetti’s development was based on DECT and they clearly understood that ISM based wireless LANs would mean the end of DECT based product, their vested interest. In retrospect, the early license fee required in Italy could have had something to do with this opposition. However, when Olivetti withdrew from the market, the license fee requirement for the 2.4 GHz very quickly disappeared as well.

Our initial strategy by the way was to continue with the 915 MHz products in the US, and the 2.4 GHz would be marketed in the international markets. The reason was very simple: 915 MHz product had a better range than the 2.4 GHz, and also penetrated walls better. This is just based on the laws of nature: the higher the frequency the quicker the wave dampening, and therefore these limitations. The advantage of the 2.4 GHz was clearly the availability of more channels: three instead of only one channel in the 915 MHz.
Internally in the company there were forces, that stated that striving for one product worldwide (2.4 GHz) would be preferable, but as the percentage of travelling wireless LAN users was still very minimal, the business case for selling 2.4 GHz in the United Stated did not seem very compelling. On top of that the cost of a 2.4 GHz product is higher than a 915 MHz product, while the functionality is comparable, so, it would be difficult, if not impossible to ask a higher price, and therefore this would shrink our margins. But this is where all the logic ended.

Other companies who had no product in the 915 MHz started to market products in the 2.4 GHz, and with the story of more channels they gave the market the impression that 2.4 GHz was faster than 915 MHz, which was largely fake, and would only be visible with intensive usage. So instead of balking over a move from 915 MHz to 2.4 GHz, the market started to ask for 2.4 GHz product instead. The range reduction was taken, and probably not really noticed because of the relatively low market penetration of 915 MHz products, and the illusion of higher speed with overriding everything. So in essence we avoided an expensive marketing campaign to create this migration from 915 MHz to 2.4 GHz and in 1994 the shipments of 915 GHz had dwindled.

But in 1991 and 1992 the prospect for being able to reach any profitable business case were pretty dim. This was the time when the cost of an 2.4 GHz radio product was estimated to be higher than $350, when the business case most likely needed a cost of product below the $250, or maybe even below the $200. This meant that we immediately started with product cost reduction activities via integration of many circuits into larger single chips. But this was still early, and for the years to come cost of product was going to be a major issue.

## 4.3 Incompleteness at the marketing side

Also at the marketing side the WaveLAN product was incomplete. The pricing was a major issue, our margins were horrible, usually below the 10%, where at least 30% was required. And on top of that, the outlook was not really positive either, as going to the 2.4 GHz, which was clearly required, would only drive up the cost, higher frequency components for higher frequency products are just more expensive.

At the same time a lot of the customer feedback indicated that price was seen as a major obstacle. There were also clear signals about the price elasticity: a price reduction always immediately showed an increase in volume. These volumes initially were quite low. Usually the deals we closed were around 10 to 20 cards, say around $10K order deals. Sometimes opportunities came up for 1,000 WaveLAN cards. These deals got a very high level of attention, but usually, if they came through the quantity had been lowered significantly by that time to usually in the area of 200 cards or about.

The customers that we engaged with for these large deals were typically the larger US companies. I remember American Airlines that we tried to close a deal with for a pre-configured travel agency computer system. The main reason for American was that about 40% of the travel agencies that started had stopped with one year, and wiring a travel agency was usually a big write-off.

Based on NCR's market positioning we did a lot of work with retail customers like JC Penney's, Littlewoods, Younkers, House of Frazier, Victoria Secrets, Stop 'n Shop, Wal-Mart. The results were mixed at best. Probably the most successful we were with JC Penney's, where we "had" three of their department stores with on average six Access Points and eighty Point of Sale terminals. The good news was that the system not only was working, but also was fail proof to support larger installations.

I remember being pretty proud of this result. I went to one of the stores and paid over a wireless LAN, taking some impertinent views behind the terminal, making the sales assistant somewhat unsure about my intentions, which I shyly decided not to share, what would be the point?

More successful we were initially with banks, another market segment that NCR was quite strongly represented in. During the early years we worked with many smaller banks as well like: Chemical Bank and HighPoint Bank. The main interesting feature was called replicated branch. The central staging of a bank branch computer system could be done centrally and tested. Then overnight the

total system with trucked to the branch and installed before the next day the employees would come in. No disruption, and up and running instantaneously. Wherever we could sell this benefit it was a success. But in general banks turned out to be very concerned about security, despite the fact that we supported DES encryption.

Interestingly enough we also were quite successful in Mexico. Still by the day of today I am not sure why that was. Probably the presence of the NCR sales force played a positive role; probably the publicity around NAFTA gave the Mexico sales positive support. It stopped immediately when Mexico fell into a financial crisis in 1995. At that time we had been quite successful with larger sales to companies like Bancomext, Operadora Vips, and Bancaser.

Another application that started to be defined was the PoC (Point of Care) application. It was amazing to see how little computing data collection was done in healthcare, and how a central database would help. We worked with large companies targeting PoC solutions like IBAX and Baxter, but progress was really slow.

We had a lot of thought about the successes in Mexico, and why the US was such a more difficult market. One concrete thought was the fact that networking cabling in the US was a quite established and profitable business: wireless was more or less a threat to this business. In Mexico the networking, and therefore the cabling installation market, was significantly less developed, creating a much more open mind for newer technologies. Anyhow, after 1995 this all had become a mute point: the Mexican market was gone.

One of the markets that we seem to have developed quite some traction was in the healthcare market, in particular reaching into hospitals. Despite the fact that there was serious concern about 2.4 GHz radios interfering with other medical equipment, the reality was, that hospitals were quite behind in automation. In particular the data collection part was rather primitive: hand-written notes at the

bedside, instead of collected by a central hospital database, so retrievable from wherever in the hospital the patient would be. But even in the hospital world good applications were missing to be very conducive to wireless LANs. Hospitals were very much based on mainframe machines, so, where we were trying to move hospitals from wired to wireless networking, they still had to make the first steps into networking. Interestingly enough, the successes that we achieved over time created quite some excitement, but not necessarily enough follow-up.

Besides direct sales, that is NCR's sales teams directly selling to the large retail and financials customers, we have worked hard on developing a so-called indirect distribution channel, a network of distributors and Value Added Resellers (VARs) who function as an intermediate between the product brand and the end customers. This was in the middle of the days, that all the large computer companies were looking for ways to reduce their expenses, in particular in the sales area.

One particular tool that we used in the indirect distribution channel was the so-called sales kit. This was the time to pack two WaveLAN cards and an Access Point combined with a Novell network operating system in one package to sell this as a "Network in a Box". This was supposed to make the installation very easy, but in reality, these were still the days that networking was not yet to any level of maturity to support these types of effort. Actually these were still very much the days, that Microsoft LanManager and Novell Netware, the market leader at that moment, were in a bitter battle for the leadership in this market. No surprise that the simplification in the networking only came when this battle was decided.

## 4.4 Reaching into the wired world

In this respect these were also the days that there was another big industry battle going on: the fight between Token Ring (IEEE 802.5) and Ethernet (IEEE 802.3). Token Ring was a deterministic protocol running at 4 Mb/s; Ethernet was a stochastic protocol running at 10 Mb/s. Initially one could wonder why 10 Mb/s was not an easy winner over the 4 Mb/s. But this simply laid in the fact that a stochastic 10 Mb's may suffer throughput degradation quickly with many computers connected: in practice the 10 Mb/s was significantly lower. But the other reason might simply be that Token Ring had the stamp of approval of IBM. There was very much a fight going on between IBM and the rest of the computer industry. The IEEE committee with their somewhat democratic procedures did not want to "just adopt" IBM's proposals for wired networking, while IBM did not want their proposals go by without standardization. The compromise was that IEEE created a separate standardization committee for IBM outside of IEEE 802.3, and this became IEEE 802.5. This is all important, because in the wireless standardization (IEEE 802.11) something similar was going to happen.

Initially IBM could sell Token Ring well against the higher speed of Ethernet. The reason was that they could convince the customer base, that IBM's Token Ring protocol was more efficient than Ethernet. And the choice for IBM was the safe choice, wasn't it?

This fight went on for almost a decade, mainly because IBM was so strong in the industry, that many computer companies were forced to develop Token Ring solutions as well. They needed to be able to interface with other IBM Token Ring based solutions. Where IBM had the volume, they could produce these cards with a profit, while most other companies lost money on this.

In the second part of the decade this battle was decisively won by "the rest of the computer industry". The main reason was that the cabling of Ethernet significantly improved. Ethernet originally required coax cabling, but later on it also support shielded twisted pair, and again alter unshielded twisted pair. At about the same time when Token Ring technology moved from 4 Mb/s to 16 Mb/s, Ethernet moved from 10 Mb/s to 100 Mb/s. That last fact really did it.

Ethernet had already been consistently less expensive than Token Ring, when it was also easier to install and lower in cost, the war was over, and also IBM slowly but surely had to accept Ethernet in their portfolio.

This battle in the wired world had impact on the development of the wireless market for two reasons. In the first place, the drive for higher speeds made it more difficult to get wireless accepted. When we started with wireless, and we found ways to get to 2 Mb/s through the air, the market was largely dominated by Omninet (1 Mb/s) and ARCNet (2 Mb/s). But when we came with our wireless product WaveLAN to the market at 2 Mb/s, the market's mind had already moved to Token Ring (4 Mb/s) and Ethernet (10 Mb/s), indicating that "networking marketing" was going to be a speed game. Actually, I have to say here "networking marketing", as the applications that were using the network had to deal with the real speed, that usually was significantly lower, sometimes even between 50 and 80% lower!

The most striking example these days was the Xircom Ethernet port adaptor. This was a very strong product, as it allowed computers to relatively easy get on the network by connecting this port adaptor to the Centronics port of the computer, creating the illusion of a 10 Mb/s network connection, where a centronics port had a maximum throughput of 700 Kb/s. In my discussions with Durk Gates, the CEO of Xircom these days he carefully circumvented ("xircomvented" we called it) to have to answer the question about speed: a great example for me about brilliant marketing or shrewd customer deception, but it worked, and Xircom was a quite successful marketing company until the days that they were taken over by Intel.

So the wired market moving up in speed was one thing that made it more difficult to get lower speed wireless products accepted in the market. The other complication it created was the integration between wireless and wired networks via the described access points. To integrate in a wired environment, we had to bridge back to both Ethernet networks (IEEE 802.3) as well as to Token Ring networks (IEEE 802.5). Both technologies are very different, and therefore the

bridge products required were very different as well, just increasing the amount of work for developing, and reducing the chance to turn to profitability quicker. The integration with Ethernet was the easier part. The main reason was that the protocol used for WaveLAN, our wireless product, was quite comparable with Ethernet. WavePOINT, our access point therefore also was a wireless Ethernet bridge. For our Token Ring bridging we created a relationship with a company called Persoft, based in Madison, Wisconsin. They provided our Token Ring bridge solution for as long as Token Ring was around….

But overall the integration into existing wired environments was painful and time consuming, and the fact that there was a split in the wired world had a complicating factor for the emerging wireless world.

## 4.5 OEM marketing

Another way to get a product out of the sold is via so-called OEM-programs. The idea of OEM-ing a product is to sell the product under the brand name of some one else, who did not made the investment to develop a technology. “OEM-ing” is very common in the PC industry, even to the point that most PC companies today are more “integrators” than technology developing companies. In this respect it is interesting to mention that Steve Jobs, the CEO of Apple Computers, has as the view on the computer market, that there are only two computer companies: Apple and Wintel – where Wintel stands for a combination of Windows of Microsoft and Intel. In his opinion all other PC vendors are just “distributors” of Microsoft’s and Intel’s technology: or OEMs, as the term that is often used here.

Under NCR and AT&T we had developed wireless LAN technology, but getting this technology into the market was not very easy under these brand names, as the real names in the networking industry these days were IBM, 3Com and DEC. Therefore we developed the strategy to try to sell our products under other brand

names. We unsuccessfully approached IBM and 3Com. IBM or had no clue about how to use this technology, or they were doing something themselves, deep down in some one of their own divisions, and considering their size, this actually both could be true. 3Com had an explicit strategy to only support standards and not to bother anything new that was not standard. Wireless LANs these days was far away from a standard, and therefore were chosen to be ignored by 3Com. Not so Digital Equipment Corporation. For one or another reason wireless had caught the attention of Ken Olsen, the CEO of DEC, and someone who was very interested in technology. Via his lieutenants we were contacted for cooperation and this over the years into the day of today this turned into a success that brought real products into the market. Actually, DEC became a serious competitor to AT&T, and we had some very serious channel conflicts over the years, as a consequence of this OEM strategy.

But these companies were not the only ones we approached. Virtually every company in the IT industry was at least approached, from Europe to Japan and to the US. Nokia, Sony, Samsung, Toshiba, Dell, Siemens, etc: of virtually every company I still have the notes of the referrals of whom we contacted. It was just amazing to see how little interest and response there was. Usually, if a company responded with sending someone to the IEEE 802.11 meeting, this was already big progress!

I need to mention something special on Dell and Toshiba.

After Apple Computer in 1999 did a major launch with wireless, I received an email in my inbox that happened to have in its tail an original discussion generating email from Michael Dell, who furiously expressed himself about the fact that Apple had beat them. Going through my notes, I found out that I personally had called Michael Dell in 1992 to propose cooperation, but even more interesting, in 1993 Dell had tested some wireless LAN products internally. As they stated, they had been playing with it, but they were not convinced that there was a real market for this type of technology. Probably and rightfully so, the price

in these days was a major stumbling block, however, also in that period I think there might have been good premium applications that would have justified the investment.

We also were in very close contact over the years with Toshiba. Actually Toshiba and NCR have initially been working closely together on developing some portions of the MAC protocol. Toshiba has been a firm believer in wireless connectivity since the early 1990-ties. However, they were also very aggressive in the price points that they wanted to achieve, maybe just too unrealistic. That probably drove them into the arms of Bluetooth in the later 1990-ties as well, but in this period they were eyeing wireless LANs, trying to integrate this in both their computer as well as notebook portfolio.

I still pleasantly remember my first true "notebook" computer, being the famous Toshiba one, with the half screen. I have been using it for several years, and despite this was the early 90-ties, personally I got already very committed to notebook computing. Actually, since 1996 I got rid of my desktop PC altogether, and "run" on a wireless notebook only – but that should be no big deal, understanding the natural marriage between notebooks and wireless networking.

In retrospect in these days we have learned a lot about the channel marketing and distribution channels via our OEM strategy. But with new technology, one is very much in the situation best described as: damned if you do, damned if you don't. Doing it created a lot of channel conflict, where the AT&T WaveLAN product line, and later the Lucent Technologies product line competed with DEC, or later its successors Cabletron and Enterasys. But not doing it would reduce the number of distribution channels to market as only the channels owned under the own brand, and they maybe too limited, as in our case.

DEC (now Enterasys) was one of our more successful brands under which we were able to have our technology reach the market; others were Puredata, Solectek and NEC. Interestingly enough: these companies (with exception of Puredata) are still the companies today that are better positioned in this market

than others, which leads to the conclusion, that even in the case of not owning the technology, an OEM strategy might be useful for quick learning and building market share.

## 4.6 Getting the product right

We did a tremendous amount of analyses to understand what we could do to become more successful. The key word at that time was the ToC (Total Cost of Ownership) calculation, showing the total cost of a network system during its life time, including the cost of cabling and re-cabling, to show the cost benefits of a wireless system. In general I have to admit though that these calculations were not always that convincing in the eyes of the customer. The weak point usually was, that an investment in WaveLAN meant a higher investment upfront, and although companies in those years may not have been as "cash conscious" as many companies are today, this upfront investment was still was a difficult point in the total proposition. The real successful wireless LAN applications were the applications, that were focusing on mobility, more than the ones that were about getting "rid of the cable". But the technology was only marginally supporting mobile applications: usually the product was too bulky, and it still used quite a lot of power from the device's battery that it was loaded on. Nevertheless we were already trying hard to really get mobility features integrated in the development of the product.

We continued to look at Apple as a target customer and distribution channel. We worked this through a company, called Digital Ocean, a start-up group out of Lenexa, Kansas, and very enthusiastic about wireless LANs. Their focus was clearly the Apple market, and they had a lot of knowledge about the Apple technology to integrate this with wireless. Apple was pioneering these days with a

new concept, the PDA (Personal Digital Assistant), the predecessor of the palmtop. It was really a predecessor, as it was clunky and heavy, and overall not successful compared to the expectations, although I have seen quite a lot of enthusiastic users, who were really satisfied. Digital Ocean worked on in general wireless LAN connectivity between Apple computers, and they also developed a sleeve for the PDA that functioned as housing for a wireless LAN card. Unfortunately when this product was available, it did no create the excitement that we had hoped for, even not inside Apple that in these days was going through some very difficult times to even just stay afloat. Many visits and selling efforts, but all clearly ahead of its time, it never broke through.
Actually, when Apple later cancelled the PDA product program, it killed at the same time Digital Ocean as a company. The company had been relying too much on Apple, and did not survive their market share decline. In the mean time Digital Ocean together has been doing a lot of development work on the MAC protocol that would lead to interesting future standardization efforts.

These years we also worked together closely with Teledyne and Raytheon as well: it was the early days of GaAs (Gallium Arsenic). The idea was to build a first integrated radio chip. In these days CMOS was not suitable yet to generate the high speed, high frequency radio signals, that are required. The program with Teledyne and Raytheon ran into severe complications. Initially the chip did not work, and revisions were required, but with the revision we also saw the cost of the chip going up very severely, as there were serious manufacturing problems. For every good chip produced, there were at least two failures as well, so the cost of the chip, originally targeted below $20 turned out to be over $50, and could not compete with a so-called “discrete design”. This turned out to be one of those cases were a design with traditional components: resistors, capacitors and inductors was just significantly more cost effective, although, larger in size.

But there were more technical complications to understand the slow progress. Developing networking products these days was still a quite cumbersome effort for product developers. There were many networking "flavors", requiring many different software drivers: Novell and Microsoft were battling, together with a group of smaller network technology providers like Banyan and others. Each provider had its own peculiarities, as well as different versions requiring start-ups like us who wanted to compete to try to interface with and through each of them. It looked as if every customer required a version that we just did not support…. Software driver development was the key to be successful, and fortunately our team had a few smart guys to help us through these days. Unfortunately the whole problem was exacerbated by the introduction of a new hardware interface by IBM, and some of their fellow PC companies. This interface was called the Microchannel bus, competing as a successor of the AT bus with EISA. So, all the software varieties existed for each hardware bus version creating a serious challenge in determining what to develop first and how many resources needed to be spent on what. Getting the product right seemed to become an impossible challenge, purely by the number of permutations that existed.

## 4.7 Outdoor products

I think it happens to a lot of product developers at least a few times. After having done all the marketing and product management home work, and launching the product, the customers who really start buying the product are using it in a way as you never thought off. Even worse: they use the product in a way that the product was not intended to use for. Especially hurting for engineers is the situation that they could have developed the product much better, had they known that usage…. So was the case with WaveLAN. In the first years over 50% of the usage was for so-called "outdoor" usage: connecting the networks of two or multiple buildings

together into a single network, by using the wireless LANs. These wireless LAN connections create “network bridges” between the buildings.

There were plenty of reasons why the usage of wireless LAN cards to resolve these building interconnectivity problems were manifold. In the first place it was simple and easy to install. The alternative was a so-called T1-line (or E1-line in Europe), that needed to be leased from a telecom operator. Such a lease with a monthly rate was expensive plus the multiplexing equipment that was required for such a connection was not simple either. Amazingly, several VAR’s (Value Added Resellers) found out to add special (and low cost) directional antenna’s to the WaveLAN cards, and then surprisingly being able to cross distances easily extending the 3 to 5 Miles range, 5 to 10 Km. There are even situations know, where the distance would go up to 50 Miles, say 75 Km. That was unheard of, as the product was developed to produce a robust link in-house, with its multiple reflections, because of the internal walls and furniture or equipment in offices or in buildings in general. I believe that at a certain stage in 1992, more than 80% of our sales of wireless LAN products, these products were used for outdoor connections, unintended by the developers of the product.

The situation even got out of hand, when some VAR’s found ways to add “power amplifiers” to the product between the card and the antenna, boosting the output power significantly above the maximum of 1 Watt that was allowed in the 2.4 GHz. We had a lot of internal debates about this: this was clearly illegal, but was it our responsibility? Should we bring this situation back under control, but how could we? What was the long term consequence: would it pollute the ether, so it would cause interference with legal products?

Fortunately the FCC realized that this was getting out of hands, and came to help by prescribing a special antenna connector in a special format, and a closed distribution, so that selling was only allowed to those companies, who had signed for the legal use of this connector, that is: for compliance with the regulations for the 2.4 GHz.

In the mean time, while this all was happening, the "outdoor" market was flourishing, and despite the fact that the product was not developed for this application, the results were amazing. In the mean time, more specialized products have been developed for the outdoor market, not even compliant with the standards, but interestingly enough, that is not necessary. The Wi-Fi standard is a voluntary standard, compliant with the transmission rules of the 2.4 GHz. This means that products as long as they are compliant with these rules will be allowed in the 2.4 GHz band.

In general the need for standardizing the technology in an "outdoor" point to (multi) point connection is significantly less compared to the "indoor" situation, where different PC brands and different infra-structures need to talk together.

## 4.8 Related technologies creating opportunities and confusion

When wireless LANs were struggling to get into the market, also wireless Wide Area Networks came up, also with struggling business models, but nevertheless trying hard. In the first place there was Ardis that started as an internal network for Motorola and IBM support technicians. Ardis was privatized and to reach economy of scaled supposed to win a much larger customer base. One of the ways that Ardis tried to achieve this was to get more companies to develop modems, and so also we were invited to develop a modem for Ardis. Unfortunately we could not accept up the invitation, as we plainly did not have the resource base to support such a development. Our focus was very much "cordless" networking, where Ardis was pursuing more the concept of "cellular networking".

Another company that really made waves these years was McCaw. Actually McCaw had seamed together a wireless network and was about to be acquired by AT&T, when it launched its CDPD initiative. CDPD was going to be what

cellular companies are trying today with GPRS. Also here we were invited for a program to develop a wireless modem. Actually, this was during the times that we were already part of AT&T, and our interest in this program was very high, we actually did some development on this, but we were unable to complete the business case with then McCaw in a satisfactory matter, so the program was dropped.
Looking at the day of today, the wide area wireless technology that pretty well survived is Mobitex. In its different formats, and with the help of some big operators, it managed to pull-in enough subscribers to stay in business, and has a presence across the globe. It still remains a proprietary solution, Ericsson based and therefore is mainly used for closed applications – compared too the open applications.

This period was also the period of the "tablet hype". There had been several breakthroughs in screen technology, ruggedness, reduced scratch sensitivity. This had lead to a new trend in the computer industry: keyboard-less. A computer became a "tablet", and writing on it was possible with a pen. Apple was pioneering this with their PDA (Personal Digital Assistant), Fujitsu, Grid, NCR Computers, new start-ups like EO or Momenta, etc. These companies were all clearly immediately the target of the wireless LAN companies willing to "help" to further improve the tablet business case as a mobile device. Unfortunately the tablet technology overall was not really accepted in the market, probably because in particular the handwriting technology was difficult to master, and relatively slow in execution. The product opportunity fizzled, and only re-emerged later as part of the palmtop technology –and then with great success.

In this period also another interesting event took place. In 1992 Bill Gates and Steve Balmer visited NCR Computers, in Dayton Ohio. They got a presentation about NCR's product portfolio, NCR was working these days on a tablet computer, and they worked closely together with Microsoft on the Operating

System software. They also received a presentation on wireless LAN's, and I understood, that he was quite intrigued by it, although there was never any follow-up from Microsoft's side, despite our hard trying – but probably not hard enough! It took until 1999 until Microsoft thought the standard had developed well enough, that they started to embrace this for their own network, later touting that the Microsoft's Redmond campus was the largest wireless network in the world. Not sure whether this was true or not, but for Microsoft this was all very new at that moment.

These years there was also additional confusion because of new spectrum that became available in the US. The confusion between Direct Sequence (DSSS) and Frequency Hopping (FHSS) was exacerbated with a wireless LAN data communication proposal for the 1.9 GHz, the so-called PCS band that is used today for the US version of GSM, the cellular telephone network. For new vendors, new spectrum is always seen as a new opportunity. For companies like us, with vested interests in existing bands, new bands could easily mean a threat, annihilating or at least reducing investments that we had done so far. The amount of energy sapped away by these proposals in industry committees, with consultants and with the press is always very concerning. Looking back, and realizing that nothing came out of this 1.9 GHz PCS band proposal, creates also the awareness how much time sometimes gets lost with nothing….
This was also the period that the first interest was raised on 5 GHz as the successor of the 2.4 GHz. This was as early is in 1993, and it started in Europe, where in particular the 5.2 GHz was proposed for harmonization on a worldwide scale. This 5.2 GHz is now known as the "lower part" of the 5 GHz band that has been standardized via IEEE 802.11a.

More threats to the business were coming up these years, and not only from outside. NCR by now was acquired by AT&T, and AT&T Consumer Electronics started eying the 2.4 GHz band for a new generation of digital cordless phone.

Research had shown that this band was very appropriate, only that there was some wireless LAN activity in the band, and therefore the design requirement was such, that the engineers must make sure to blast "WaveLAN" out of the band, when the ether is required for the cordless phone. It was clear, that with this type of colleagues, you do not need any competitors….

We had a lot of discussion going forward and backward on this, but "AT&T" (I have this between brackets, as we were AT&T ourselves…) took the position, that if they did not take on this opportunity, then somebody else would, so, therefore a discussion leading to a win-win situation and even the opportunity to co-market wireless voice and wireless data was rejected.

Fortunately for us, this program came in trouble, as the AT&T development team was not able to make a low cost radio, at least not low cost enough to effectively compete with lower cost alternatives, and the program was cancelled.

It was a good warning sign for us though, as still by the day of today, the 2.4 GHz band (the band that is used by Wi-Fi) is not "protected", which is a major difference in comparison with for instance a cellular phone band. It means that still other applications can be developed that in essence interfere with a Wi-Fi radio. Fortunately interference is usually a reciprocal activity, and in all the cases I have seen until today, new applications are interested in peaceful coexistence with Wi-Fi, also because Wi-Fi nowadays has become pretty widespread.

## 4.9 Summarizing the second period (1991 – 1994)

Was the first product development phase (1987 – 1991) somewhat of a disaster, at the end of the second phase (1991 – 1994) our situation was not much better. In essence we had "doubled our bets", but there were no real profits in sight. After the first period we had a wireless LAN card, after the second period we had a wireless LAN system, so we could bridge into a wired environment, and we could

roam through a building while staying connected. After the first period we had a US only product, after the second period we had a worldwide product, or at least as worldwide as we could expect. So, this all was clear and encouraging progress in these areas.

But the cost was still too high and the speed (2 Mb/s) was falling behind in comparison with the wired market: the overall market acceptance for wireless LANs was still very low. Also there were serious market concerns raised about the lack of standardization. The major players in the market at this time were Proxim, Aironet and now: AT&T, plus a whole array of smaller companies like Breezecom, WaveAccess, Xircom (Netwave) etc. and all these companies had different products and were using different technologies. Publicly these companies were telling the customer base, why they were the best, and what was wrong with the technology of the competitor. But the consequence of this all was that customer did not trust anybody: “data was precious, and waves were weird”, so wait and see was the consequence for everybody.

Also, none of the companies had a clear marketing muscle or the supporting financials to really launch a marketing campaign, although several companies tried with some advertisement.

Closing of the second period it was clear: we needed standards, we needed higher speeds, and we needed lower cost, which meant: more integration, so the size of the products would become smaller, and therefore also suitable for mobile products like notebooks.

By this time we all had read Regis McKenna’s “Crossing the Chasm”, a marketing book that described that in high tech market there is a gap (“chasm”) between the adoption of a new technology between the “early adopters” and the “mainstream users”. We had by now won quite a few early adopters, but main stream seemed to be far away. We were also reading Geoffrey Moore’s “Inside the Tornado”, but despite all the hard work, the market seemed to be extremely quiet: enthusiasm all around, but the real sales were rather limited.

It was clear: more work to do, and keeping the faith. The fundamentals of what we understood the market was were there: mobility and networking both were profiling themselves more emphatically, but wireless as the solution of the two together was still to be waited for. Could we wait long enough?

# 5 The initial standardization (1995 – 1998)

Part of strategy in NCR and later in AT&T and Lucent Technologies was that the process of standardization was wholeheartedly supported, as the belief was that creating a standard would be critical to the acceptance of wireless LANs in the market. The whole process of coming to standardization however took quite long, because there were many different interests from many different companies. But at the same time, the result has been a very thorough versatile and feature rich standard, that probably will be with us for the coming decades. I know, it is extremely dangerous to make future statements in the world of technology, but I am quite convinced that the IEEE 802.11 standard is also a standard that is a solid basis for future extensions and newer capabilities.

## 5.1 The early days of IEEE 802.11

Already very early in the days that we started with wireless LANs we were clear that this concept would only fly when we were able to get a standard established, like the Ethernet standard for the wired LAN world. Ethernet was established as a standard in IEEE 802.3 and in the mid 90-ties had established itself. This had clearly not gone uncontested as initially there were two competing standards: IEEE 802.4, also called Token Bus, and IEEE 802.5, also called Token Ring.

Each networking standard had so its advantages, and coming with that its supporters, had created initially a lot of confusion in the industry.
The original ideas for a wireless LAN standard found a home in the IEEE 802.4 standardization committee, in a working group called IEEE 8024L. But it already became clear quickly, that creating a wireless standard under IEEE 802.4 would not give an appropriate result.
In this respect it is important to understand what is standardized in an IEEE committee. Actually, a standard exists out of two parts: a physical layer (also call PHY) and a media access control layer (also call MAC). Although this may sound somewhat technical, actually it is pretty straight forward: the physical layer describes how a computer connects physically to a LAN, what sort of cable to be used, the number of wires in the cable, what level of power of power over the cable, the measures of the connector, in short, everything that has to do with the physics. In the case of wireless the physics also has to do with the band to be used, the frequencies in the band (the channels) and the type of transmission (how to put the data bits on "radio"). The MAC describes how a computer connects logically to a LAN. Compare two ships on the ocean within each other's sight communicating with each other before the time radios existed: the PHY defined the flags that were required for the communication and the MAC defined how each flag had to be used and what the meaning of the flag was. The MAC is also called the "protocol", for these reasons.

The MAC and the PHY are quite dependent on each other, and it became already clear very quickly, that the IEEE 802.4 Token Bus MAC was not suitable for wireless technology. The Token Bus protocol works with a "token" that is sent around from station to station, and only the station that has the "token" is allowed to "say something", while other stations have to be quiet to avoid the communication get disturbed and messages get garbled up. The advantage of "wired" compared to "wireless" communication is that wired electrical signals over a wire are more robust, so less susceptible to noise or interference compared

to wireless radio signals. In both the Token Ring and the Token Bus protocol the risk is always that the token gets lost. These protocols have capabilities to recover from such a loss, but these recovery procedures take time, which manifest itself as a slowdown in the communication. In a radio environment the risk of losing a token is even bigger, because of the susceptibility of radio signals for noise, and therefore the conclusion was that a token passing protocol was not the right way to go.

Some serious thoughts have been given to use the Ethernet IEEE 802.3 protocol, also called CSMA/CD (Carrier Sense Multiple Access with Collision Detect). This protocol is quite ingenious and interesting, as it does not predetermine who is allowed to "speak", or "who has the token", actually there is no token at all. The Ethernet protocol simply works as follows: if a computer wants to send a data packet, it just "throws it on the cable". At the same time when doing this, it is listening whether not another computer is doing the same at the same time. If that is the case, it is assumed that a collision has taken place and that both messages have garbled up each other. So therefore both computers will decide to send their packet again. To avoid that they decide to send the packet again at the same time, each computer waits a random time, called the "back-off time". These (very short) random times are usually so different, that in a second go around this is not happening again. Quite some thinking work has been gone into this, an although it may not look that efficient, actually Ethernet has turned out to be a very efficient and cheap protocol, and it is one of the main communication protocols in place today in the data communication industry.

However, for the radio world, this "collision detect" mechanism of the Ethernet protocol had a serious drawback. Contrary to electrical lines, radios have usually quite some trouble in receiving while transmitting (or: "listening" while "talking"). Already in the early phases an efficient variant of CSMA/CD had been thought of: CSMA/CA, where CA stands for "Collision Avoidance". The variant here is that before starting to transmit, the radio listens whether someone else is transmitting. If so, it waits a random time (like in Ethernet), and then the whole

procedure repeats itself. Only if the channel is clear the transmission starts. Actually this type of a protocol is somewhat more efficient than Ethernet, as the chance for collision has been considerably reduced, and therefore the time lost on recoveries. However, the extra complexity had a cost penalty that made the initial products more expensive. Nowadays these features are largely fully integrated in chipsets.

The conclusion of all of this technical groundwork was that the standardization of wireless could not efficiently take place in one of the existing wireline standardization committees, and therefore a separate standardization committee was created. The number assigned was 802.11, and that was the beginning.
The interest in IEEE 802.11 has been quite high from the beginning, but it was largely driven by relatively small companies like NCR, Aironet, Intermec, Symbol, Xircom and also Proxim. Other companies stepped by on a very regular basis: IBM, Apple, Motorola, but their interest seemed to be spotty and monitoring. Also the regular changes in participants from these companies did not help the progress, as usually in the early days many private agendas were pursued.

## 5.2 The original IEEE 802.11 MAC standard

Although today the IEEE 802.11 standards are known as IEEE 802.11b and IEEE 802.11a, the original standard was plainly known as IEEE 802.11. This was a 1 and 2 Mb/s standard in the 2.4 GHz ISM band and the basis for the IEEE 802.11b standard.

The MAC protocol came largely together from cooperation between NCR (AT&T at that time), Symbol Technologies and Xirom. NCR was the computer company that my organization was part of, Symbol Technologies was a company that was

and still is largely known as a data collection terminal company with specific strengths in infra-red bar-code reading. Symbol's contribution was specifically on the needs for power management. Also the need for "range" was made very articulate: bar code scanners need to be held under pallets, and seemingly out of reach of everything. Xircom was known in the market with their "pocket LAN" adaptors, allowing computers to be connected to a network via a printer port, a nice innovation that gave them quite some deeper insight in the intricacies of networks. In 1999 Xircom has been acquired by Intel. Working together these three companies made a proposal that became the foundation of the MAC for all what is known as Wi-Fi today. The amount of effort that went into this MAC was quite extensive, although the basis was quite straightforward and comparable to the IEEE 802.3 Ethernet standard. However, because of the nature of wireless and with the need for fulfilling the promise of true mobility, there were quite specific extensions put into this MAC protocol.

In the first place there was the need for "roaming", or as this is called in the telecom world: for "hand-off". But actually "hand-off" is a term that clearly makes this action a base station responsibility. In the IEEE 802.11 MAC protocol however, this is a computer (also called: terminal) initiated action. Although the implementations may differ with the different product providers, the essence is a process of association. A computer listens on all channels to find what access points it can connect with. Then it selects the best one: both the access point and the channel. When one is walking around with the laptop the quality of this connection may degrade. At that moment it checks again, and if there is a clear other base station and channel through which to connect to the network, the switch is made. In technical terms: the computer disassociates from the access point it was connected with, and it reconnects with the new access point. The access points, as real bridges between the wireline and wireless network, are told that the computer has moved to another access point, and they update their network topology tables for make sure that the reverse traffic, the data packets from the network to the computer, is going to the right place as well. To make this

work more efficient, there is also a “protocol” between the two access points, as they are both on the wired network and they confirm with each other the re-routing of the traffic.

A second important feature that was thoroughly investigated and included in the protocol, were capabilities for power management. Here was clearly the hand of Symbol Technologies as handheld provider recognizable: “life time” of data collection terminals, that is the time that the battery stayed up is very essential: preferable one full day. So, how to avoid that stand-by for radio communication drains the battery unnecessarily quickly. In this respect it was important to recognize that a computer or more specifically a handheld computer may only really “communicate”: 11 Mb/s (Megabits per second). To put this in perspective: 11 Mb/s effectively translates into 500 Kilobytes per second, while the effective data transmission probably is in the order of magnitude of 500 Kilobytes per hour. The Wi-Fi protocol contains a lot of special power management features, including requiring the access point to wait and store data packets, as long as the terminal unit is “asleep”, allowing the terminal to wake-up once in a while, give a signal to the access point and check for anything waiting, and then quickly go back to sleep. This allowed for creating a radio unit that effectively used very little battery power. However, this all should not be confused with the fact that when the battery used by the radio for transmitting or receiving, there is still quite some power required, usually in the area of 1 to 1.5 W. By the day of today this is still a problem for the batteries of palmtop computers: palmtop usually cannot deliver this power simultaneously with keeping its processor alive.

A last feature included in the standard was a feature that improved the reliability of the communication, but that turned out to be in general not necessary. Actually it was quite heavily promoted from Xircom’s side and it is called RTS/CTS (stands for Request to Send, Clear to Send). It makes sure that a computer or a terminal is not sending any information without first having received approval to do so. Although this feature initially had become quite redundant, it currently may find a revival in relation to recent work in relation to a newer addition, called

Quality of Service, a feature that is necessary to enable solid voice communication over wireless LANs.

Other features that got special attention were the “ad-hoc” networks and the repeater function. The “ad-hoc” networks allowed two or more PCs to get together and to spontaneously set-up a network, without anyone controlling the network. This is like calling between two cell phones without the mediation of and/or a subscription with a telephone company. Think about it: two cell phones can probably hear each other within each other’s reach of 2 to 3 Km (1 to 2 Miles). Technically therefore there is no reason to have a telephone company “in between”, other than the current generation of cell phones needing the infra-structure to set up the conversation.

The repeater function is a function that allows each access point that is connected to the wireline network to have satellite access points that can function as a go-between a PC and the wireline access point. This feature helps to extend the reach of a single access point without the need for extra wiring.

The MAC proposal that came together from AT&T, Symbol Technologies and Xircom was not the only one. Actually before the real voting took place I believe, there were 5 or 6 proposal going around.

One of the other proposals around and important to mention was a proposal from a group around IBM. This proposal was based on quite a different architecture, and actually reminded many people of old Ethernet versus Token Ring controversy. Just like with Token Ring, there was also in the wireless MAC proposal from IBM a central mechanism that would control the network. It was called the PCF proposal, where PCF (Point Control Function) was the mechanism that controlled the wireless network: controlling who in the network was allowed to send at what moment in time. One of the reasons that this proposal did not make it, was the fact that it did not support “ad-hoc” networks, and also that the structure of the protocol was as such that this would not be easy to add either.

Contrary to the wired situation before were IBM proposal in IEEE 802.3 was rejected and lead to the start of a separate standardization committee, this time IBM took its loss. The reasons can only be guessed: uncertainty about the viability of the wireless LAN market, a reduced interest in networking in general, as their market leadership had been significantly reduced or the fact, that IBM was going through a difficult period overall, not unlikely it was a mix of all of this.

## 5.3 The standardization process in IEEE 802.11

In this respect it maybe interesting to describe some of the processes in IEEE, as agreeing on standards in a highly politicized body is usually a quite cumbersome process, in particular when engineers have to play politics, something that is not necessarily a natural strength. For true engineers something is right or it is wrong, and if it is not clearly right or wrong, than it is a problem that needs to be resolved, so it can lead to a clearly right or wrong. The real political world contains a lot of nuances and ambiguities and managing engineers in a process that leads to something useful is not that easy to comprehend for true engineers. Well, not so in IEEE. Probably based on the rich IEEE experience that many of the IEEE members have, the politics in IEEE, in particular around the days of voting is incredible. Lobbying, coalitions, everything that one is used to in normal politics is happening here.

In this respect I need to mention Vic Hayes, who was part of our organization and who has been chairing the IEEE 802.11 committee for a decade. Although he was an employee of NCR, AT&T, Lucent and Agere, over the years he has been able to build up a reputation that put him clearly above the parties leading the standardization committee through the mazes of politics to a set of standards, that

turned out to be very robust and useful, and also laid a solid foundation for future generations of higher speed wireless LANs.

The summary of the process of coming to a standard is as follows. Once the higher order in IEEE has approved a PAR (Project Authorization Request) the subcommittee, in this case the IEEE 802.11 goes to work and holds week long meetings, about every other six weeks. First there is a period when proposals can be issued, usually covering about three to five months. These proposals are discussed in a few subsequent meetings and judged on their merits: completeness compared to the original PAR and implementability into real products. When the time is ripe, that is, the proposals have been discussed enough, and also there has been given enough thought to mix and match proposals, there is a voting round.
This voting is interesting, as the rule is “one person, one vote”, contrary for instance ETSI (European Telecommunications Standards Institute) where in essence the rule is one company, one vote. Actually voting is also depending on the sort of membership and big companies that can afford high membership contributions can get “heavier” votes than lower contributing members. Not so in IEEE, which has as an advantage that small companies have a chance to really contribute, but as an disadvantage that these small companies can also stall progress…. The consequence is that large companies are pushed to send over large contingents of people to participate in the meeting, and are also force to be seriously compromise oriented. But just being a member and participate in the meeting is not enough, participation in the meeting for a few times on a row is required to build up and solidify these voting rights, while these voting rights also quickly evaporate when missing too many meetings.
About the voting procedure itself can be voted, but the bigger ones that I have been exposed work as follows. There is a set of voting rounds, in which in each voting round the proposal with the least votes drops off. So when there are six proposals, there are five voting rounds. It goes without saying that despite this may sounds a solid procedure, the reality is, that it leads to incredible politics:

who gets the vote that in the previous round went to the losing proposition. The reality is that there are big swings in the number of votes per proposal: despite the rule, that everyone needs to vote for the best proposal, quite often voting is done to make sure that the proposals of certain companies do not proceed to the next round.

The proposal that ultimately wins is the proposal that the IEEE committee continues to work with, that is to say, this is the proposal that with collective effort will be further in detail worked out and improved upon, until 75% of the voters are in favor. Actually the goal as a true engineering organization is to reach 100%, with the assumption that there is only one right solution to the problem. Fortunately also the reality has set in that 100% maybe too idealistic, as there sometimes can be stubborn renegade members, who are absolutely convinced that something in the proposal is absolutely necessary, or absolutely redundant. Also sometimes companies have an interest to make sure that no agreement is reached about a new standard, for instance if they dominate the market with a closed de-facto standard, or when they want to stop a new standard to make an older standard redundant.

Another rule in IEEE that also really helps to move the process of standardization forward, while making the proposed standard technically solid is that one cannot vote against a proposal unless one clearly defines the reasons. From a technical perspective an engineer will not quickly approve something unless he is reasonably convinced that it is engineering sound, while when he disapproves something he is challenged at the same time to come up with a proposal for solution.

The process of standardization in IEEE has been heavily criticized, because it is relatively slow, and because it favors small companies, or maybe: it does not favor big companies (that is at least what these big companies say). But all in all it maybe at the same time a solid and a fair process, as solid and fair as these processes can be.

## 5.4 The original IEEE 802.11 PHY standard

Well the good news was the common agreement on the MAC. But this was not the way it was going to be with the PHY. The definition of the physical layer, in essence the radio, turned out to have two major different larger groups that had a very strong preferences either for DSSS (Direct Sequence Spread Spectrum) or for FHSS (Frequency Hopping Spread Spectrum). Neither of the two groups wanted to give in, and neither of the groups would be able to reach the 75%. Actually the FCC had given the ISM band to the industry for helping to further grow the economy; however, this gift contained a poison pill that created a discord in the development community. Each side defended its preference with fervor, but the arguments were never conclusive. As happens more often in the technology world, the discussion quickly moves from an objective debate to a subjective positioning where people assume that what is best for them is the best for everyone. This was also the case here.

The main difference between the two technologies was in essence the way to look at speed. FHSS was defined in the standard as 1, 1.5, 2, 2.5, 3, 3.5, 4 and 4.5 Mb/s, but in essence it was only truly working at a speed of 1 Mb/s.

DSSS was defined at 1 Mb/s and 2 Mb/s, and also worked at both speeds: 2 Mb/s at somewhat closer range, 1 Mb/s at longer ranges. From a first look this would favor DSSS over FHSS; however, DSSS was only in general available on 3 channels. For FHSS the number of channels for frequency hopping was higher, although because of the statistical nature of the technology it is difficult to state how many effective channels are actually available. It is fair to say that for the end user experience there were at least 10 to 15 channels available. Therefore, the total capacity of a Frequency Hopping system is higher. So, this would lead

already quickly to customers, who got completely confused in a discussion about raw data speed and system capacity.

The problem really was that the two systems DSSS and FHSS did not talk to each other, or even worse, they actually interfered with each other. In the MAC protocol the safeguards were nicely built in to reduce the number of lost data packets, in the way it was described before. However, this did not work "across radio technology", that is from DSSS and FHSS and vice versa. So, actually, with both DSSS and FHSS systems "in the air", the data loss during transmission could become quite significant.

It goes without saying that furious debates in the IEEE have been held for one party to convince the other part or vice versa. There were also quite some serious efforts to harmonize the two technologies, that is, to avoid that transmissions from one technology would be harmful for the other. But these were not successful. The IEEE 802.11 committee ended up clearly with a: "let the market decide" type of cop-out, and the market decided: it waited just a few years longer with accepting this wireless technology, and let the companies struggle for another few years with marginal revenues. This also pushed the telecom community into the direction of further ignoring this technology. If IEEE would have been stronger and more unanimous these years, wireless LAN would have been put more clearly and forcefully on the map, I wonder whether the UMTS could have really taken off, at least in the minds of the marketers and advertising people.

Also the failure of IEEE at this stage probably caused people to re-look at alternatives, and this was also probably when the thinking about a Bluetooth, as a low cost LAN solution started to form.

## 5.5 The Intellectual Property ownership in standards

Leading edge technology is always about IP (Intellectual Property) and getting into IP business gets always very tricky, very contentious, and with so many lawyers usually very complicated at the same time. Standardization is trying to balance between on one hand making something open and for the better of everybody, while at the same time companies want to have “fair compensation for their investments in research and development”, to coin a legal phrase here.

Different companies have different IP strategies depending on the type of business they are in. Usually small companies can be very narrow minded and single focused around one single patent. Their goal in life is than usually to make sure that large companies pay them of with relatively little amounts, usually a few $M’s or less.

Larger companies are less single patent focused and usually build larger patent portfolios and use these portfolios in the first place in a defensive way to avoid being put out of business, and secondarily, depending on the strength of their patent portfolio they try to close large deals with other large companies, so-called “cross license agreements”. These deals usually end up in weighing each other’s total applicable patent portfolio, and then striking a deal. If there is a significant weight difference between the two patent portfolios, the company with the lighter portfolio has to pay the other company an extra amount that then usually can run into the $100M’s. These large deals usually include a lot of negotiations plus large sets of lawyers.

To make things even more complicated some patents are only worth something if a standard is adopted. If a certain technology is rejected as a standard, then underlying patents may render useless at the same time.

The way the IEEE is trying to handle this all is to assure that all companies that participate on the standardization of a technology would make their IP available in a “fair, reasonable and non-discriminatory” way. This is also a legal phrase and it means that the IEEE expects that all the members who are contributing to a standard also work to make sure that their IP policy supports this effort. Practically it means that (the legal department of) each participating company

writes a letter to the IEEE make this fair, reasonable and non-discriminatory statement. Interestingly though: nowhere has been described what this exactly means in for instance a $-amount. This is fully left to the individual companies to sort out amongst themselves, or even involves legal action for a judge to determine.

In Lucent Technologies we got ourselves into an interesting dilemma. Lucent Technologies, the owners of Bell Labs, has one of the strongest patent portfolios in the world. Their strong and explicit preference was and is to close one-on-one cross license agreements with other companies, and to never make a generic statement like “fair, reasonable and non-discriminatory”, because in the eye of the IP lawyers that could only backfire in negotiations with other companies and it could also jeopardize their position in other standardization bodies. In the way Lucent Technologies was and is organized, and in the way its legal structure is built: all the IP is automatically owned by the IP department. Although this department always has to be very careful not to interfere with the immediate business of the business unit entity that had developed the IP, the position was always very clear. Just when the standard was about to finish the Lucent Technologies IP department was starting to wake up and realize what was happening in that small entity that was doing “something on wireless data”. We clearly ran in this situation in a serious contention that required a significant number of multi-level meetings.
Ultimately we – the business unit – won the discussion after a fight and stand-off that took several weeks. I think the IP department realized that the patents may no have been a lot of value without the standard – as they were very standard related. They also assumed that wireless LAN business would be small and insignificant compared to the total picture. Therefore also the Lucent Technologies IP lawyers wrote and signed a “fair, reasonable and non-discriminatory” letter. But overall I do not know whether Lucent as a company realized the significance of what was

happening. The rules in the computer and data world were clearly differently written compared to the rules in the voice phone and cellular world.

## 5.6 The forming of IEEE 802.11a and IEEE 802.11b

As soon as the first IEEE 802.11 “double standard” was completed many companies started to work on higher speeds. It became clear quickly that this original first 2 Mb/s standard despite all the good intentions and all the hard work was going to be a failure in the market. To a large extent this was due to the fact that this standard actually was a double standard, but also that the speed was perceived as too low. On top of that the standard did not add much to what existed already in products on the market. The critical issues at the end of the previous period still existed: need for standardization, the need for higher speeds and for lower cost products.

But there are things to mention on the positive side. Despite the PHY was ambiguous at this stage, the MAC turned out to be a unanimous success. It showed to work really robustly and although the following years small corrections and extensions have been made, it stood and stands for years to come. Probably it was over-engineered for what was required at this stage, probably it contained features that were only useful in small market segments, nevertheless, it will go into history as a monumental piece of work, but only after still many people will have used it, whether being aware of it or not.
Together the MAC and PHY definition that make the IEEE 802.11 are all assembled into a very large and neat document of 528 pages and is downloadable from the Internet.

At the end of 1997, early 1998 it was clear to everybody in the IEEE 802.11, that higher speeds was now the first thing that needed to be pursued. The MAC seemed to be robust enough to handle higher speeds, the challenge was the PHY. In the 2.4 GHz the PHY was divided between DSSS and FHSS, and then there were the unused capabilities in the 5 GHz. But there was another pressure as well. Europe regulatory bodies one had never been very much in favor of the 2.4 GHz and the ETSI had developed a standard in the 5 GHz band, called HIPERLAN/1. This standard was over 20 Mb/s, but generally seen as too difficult to efficiently implement. The response of the IEEE was double sided. The target was set to develop a high speed 10+ Mb/s standard in the 2.4 GHz and a very high speed 50+ Mb/s standard in the 5 GHz. Actually from an administrative perspective the proposal for the 5 GHz preceded the high speed proposal of the 2.4 GHz. That is how the more complex and later to be implemented ".11a" designator came out ahead of the simpler ".11b" that conquered the market. But the IEEE had managed to do it again: after the confusion of a double standard in IEEE 802.11, there was now confusion between the IEEE 802.11a and IEEE 802.11b.
Actually my organization here was part of the problem as well, as we were quite influential in both standards. Being an American organization with strong historical ties into the IEEE, but at the same time being located in Europe and having started the wireless LAN efforts in ETSI, we were pushed equally hard to participate on both standardizations simultaneously.

So actually we had two teams working in Lucent Technologies in The Netherlands simultaneously and side by side – and sometimes competing. One team was working on the high speed 2.4 GHz in the IEEE and the other team on 5 GHz in the IEEE and in ETSI.
The IEEE quickly realized and confirmed the decision to only change the PHY, and keep the MAC the same for the 2.4 GHz and the 5 GHz. At the same time the transmission methods in the 2.4 GHz and the 5 GHz more or less had to be different. The 2.4 GHz ISM band requirements put extra constraints around the

way signals could be transmitted, and these constraints were not required in the 5 GHz. Therefore dropping these constraints would allow for lower cost and simpler product in the 5 GHz compared to the 2.4 GHz.
Both the critical phase for IEEE 802.11a and 802.11b was in the spring of 1998.

The least contentious was the IEEE 802.11a. There were two serious main proposals, one from Naftali Chayat from Breezecom (currently Alvarion) and one from Lucent Technologies and NTT, based on OFDM (Orthogonal Frequency Division Modulation) technology. The voting was won by the Lucent Technologies and NTT combination, so actually IEEE 802.11a, with its 54 Mb/s transmission technology in the 5 GHz is an older agreed standard than IEEE 802.11b.

Actually the accepted proposal was very close to the proposal that Lucent Technologies had made in the ETSI. The acceptance by the IEEE of the OFDM technology inspired the ETSI to follow the same route for HIPERLAN/2, as was proposed by Lucent Technology. This explains why the radio technologies of IEEE 802.11a and HIPERLAN/2 are almost similar.

The voting for the IEEE 802.11b radio (PHY) was very contentious, and almost a fighting war on the brink of tearing the IEEE 802.11 committee apart. The main contenders were Jim Zyren and his team from Harris (nowadays Intersil) and Lucent Technologies, and then there was an outsider proposal from Microlor, John Cafarella, a start-up company with very good radio knowledge. Actually Microlor was largely supported by Clarion, who had serious plans at that time to go into the wireless LAN. When these three companies were left the Lucent Technologies proposal was voted out, and the final voting round between Harris and Microlor started. What happened then is hard to describe, and challenged the democratic rules in IEEE. In the voting Microlor came out with 52 votes, Harris came out with 51 votes, and there was one vote abstaining. According to one set

of rules, Microlor had won the vote, but this was immediately contested, as Microlor did not have a majority: 52 of 104 votes is not “more than 50%”. A violent discussion started to unfold about the interpretation of the outcome of the vote with many real and emotional arguments floating around. Then Jeff Abramowitz, who was the 3Com Product Manager for wireless LANs at that time (he currently works for Broadcom, still on wireless LANs) stood up, and moved a motion in which he contested the whole voting procedure. His statement was that according to the rules of IEEE, an IEEE member engineer should vote for the best technical proposal, and according to his assessment, despite the fact that the voting was “closed”, the reality of the voting was that the individual members had voted along party lines, that is, along the lines of the companies they worked. This was of course true to a high extent, but he phrased his motion in a way, that the Harris proposal should be declared the winner, as the voting for Microlor was not based on technical reasons, but coming from the anti-Harris camp. It was very clear at this moment to everybody, that 3Com was a Harris supporter.
So in essence 3Com asked the IEEE meeting presidency to reject the minimal majority vote for Microlor, and to declare Harris the winner. The chaos this proposal created was incredible, and the whole meeting went down in flames. I think there must have passed a motion to adjourn the meeting, but in all the chaos there I do not really remember anymore.

There was of course some truth to the statement of 3Com that most of the Lucent Technologies supporters had decided to side with Microlor, to avoid that Harris, and their supporters would have an unfair advantage in the market, by having the IEEE sanction their proposal of which the development was already pretty fair underway! At the same time, I think that John Cafarella from Microlor had one of the more miserable days of his life. I do not think that he had expected to come that far with his proposal, but when he saw the outcome of the vote, he had rally expected that he had won. Actually, I think he had won, but the majority of people did not want him to win…. If the voting would have been 52 against 51, with

nobody abstaining, I am not sure that there would have been any room for discussion. I know that John Cafarella has escalated it to the higher ranks in the IEEE committee, but actually when he started to get some traction there, he was already being overtaken by the facts.

Already in the same week as the IEEE meeting took place both Lucent and Harris sat together, realizing that they quickly needed to compromise and come up with "something". Actually it was to a large extent Jim Zyren from Harris and Richard van Nee from Lucent who figured out a new radio transmission scheme, different from anything that had been proposed so far. It was called CCK (Complementary Code Keying). Actually I think it largely came from Richard, although I do not want to do short to anybody else who was involved as there were surely more people involved. The advantage of this proposal was that it did not give any real advantage to any player, in particular not to Harris and Lucent, and therefore acceptable to both and to the larger part of the IEEE members. This meant that six weeks later in the next IEEE meeting when this new proposal was brought forward jointly by Lucent and Harris, that most of the membership had already decided to want to forget the outcome of the vote of the previous meeting….

This is how the IEEE 802.11b was born, a heavy birth and initially not particularly a beautiful baby. But as happens more time in history, this baby was destined to make a difference for wireless LANs, for 3G (UMTS) and for the whole telecommunication industry

As far as John Cafarella goes, he came out smiling after all, as his company Microlor was acquired about two years later by Proxim. And when Proxim started to sue half of the wireless LAN industry this was partially based on the patents that Proxim had acquired via this acquisition.

## 5.7 European standardization: HIPERLAN/1 and HIPERLAN/2

Interestingly enough also Europe had started under the umbrella of the ETSI (European Telecommunications Standards Institute) to look at wireless LANs. The European regulatory was never really enthusiastic of the 2.4 GHz band for wireless LAN, as this was an unlicensed band for ISM (Industry, Scientific and Medical) applications. Therefore in Europe the 5 GHz band was set aside, specifically for wireless LAN communication, and the ETSI was requested for standardization of the MAC and the PHY.

Originally my organization was quite enthusiastic about this opportunity, as we saw this as the possible next generation higher speed product. Just like Vic Hayes in the IEEE, also our organization delivered the chairman for the HIPERLAN/1 committee, and the work for this effort started quickly. Our goal was to keep IEEE and ETSI aligned for simplification, and also because we saw in the future that notebooks would be traveling all over the world. Pushing the burden on the end-user to tell the computer in what country he or she is did not seem very feasible to us. Unfortunately the HIPERLAN/1 committee fell into the hands of some people and companies with interesting ideas however these idea turned out to be very difficult to implement. The concept that was brought forward was the concept of an “access point –less” MAC protocol that is a protocol that in essence could work without direct intervention of access points. Messages (data packets) would just hop from one computer to another computer until it had found the computer it needed to reach, or an access point “to go on the wire”. In technical terms it would mean that every computer in essence would be a bridge. The big supporter of this solution was Apple Computer, who at that time had a big office in Paris and the research department in this office had taken HIPERLAN/1 as a primary target. The idea is pretty neat, and probably could be made workable, but at the same time it would run into major complications. Very special attention would be required to make the ease of use good enough, but also the security concerns were very high. It would be necessary to avoid the interception of

messages or the injection of messages as if they were coming from someone else. That would not be very easy to implement. On top of this all there were concerns about the performance: if your PC or notebook happened to be in a “central” spot, it could become quite busy with receiving and forwarding other PC’s messages, not only slowing your PC down, but also eating into the battery power. Probably features could be developed to reduce the “cooperation” to the wireless networking, but that would at the same time defeat the purpose.

Actually I do not know of anyone who seriously implemented HIPERLAN/1. I know that Proxim and Intel have looked at this seriously for some time. In general there was also quite some skepticism about how well this all would work, even independent from all the concerns that came with it. Would a completely open and fluid concept of radio terminals be able to maintain robust network connections? And what would be the impact on the overall performance?
On top of this the industry was very skeptical about the 5 GHz as a good frequency for wireless LANs. Attractive was the higher speed, and maybe the somewhat cleaner spectrum. However, the with the frequency going up from 2.4 GHz to 5 GHz, which is more than a doubling, the range goes down by about factor four, the coverage of say an access point would go down by at least a factor ten, which meant that it would require at least ten times as many access points to cover an comparable area in the 2.4 GHz, given everything else is kept the same. Later on there have been methods developed to mitigate this problem, but with the state of the market in and around 1998 this was not yet in sight. Also, the scope of HIPERLAN/1 was clearly Europe, with maybe access in the US, which did not help to make this attractive either.

Actually this was all about the MAC protocol. The radio of HIPERLAN/1 was quite straightforward. It run in the 5 GHz, and this was not an ISM-band frequency like the 2.4 GHz that required all special constraints around the allowed type of radio transmission. Practically speaking: it did not require spreading that

is: the need for using DSSS or FHSS, as discussed before, and it could be a high speed, narrow band radio. So the actual result was a raw data speed of over 20 Mb/s, actually 23.5 Mb/s under ideal circumstances. Let me put it this way: if not anything else, the work for the HIPERLAN/1 standard was clearly pointing into the direction that higher speeds in the future would be pursued. But during the completion phase of HIPERLAN/1 standard, there was already an awareness building that this had been an interesting artificial exercise, and a remarkable trial, but in essence that it was a total waste, as the IEEE was already starting to develop a 5 GHz standard with even higher speed.

The ETSI response to this was to start aligning themselves more with the IEEE. Jan Kruys of the Lucent organization started to head the ETSI committee, and he was very close with Vic Hayes, also from the Lucent organization who was heading IEEE. ETSI made somewhat clean ship, and renamed the working group that was working these standards fro RES-10 to BRAN (Broadband Radio Access Networks). Actually they want to cover not only wireless LANs but also the area of wireless local loop.

In the wireless LAN work group Apple was gone as things were not going very well for Apple in general at this moment. Initially our idea was to align ETSI as close as (politically) possible to the IEEE. This was very successful for the radio part, as the 5 GHz ETSI-RES radio is very similar to the IEEE 802.11a radio: same transmission methodology (OFDM) and same channelization, that is the way that the band is split in multiple channels over which the transmission takes place. But for the MAC there were clearly other power to be in Europe. The flaws of the HIPERLAN/1 MAC were clearly accepted, but there was also quite some criticism on the IEEE 802.11 MAC. For instance the way Quality of Service was absent in the IEEE 802.11 MAC was considered as serious negative. Quality of Service is the feature to enable a protocol to transmit time sensitive information like voice and video. This was a feature that is not original part of the (wireless) LAN required feature list, but was getting more attention as companies are

starting to use the Internet, and therefore the LAN for telephone calling. Beside the lack of Quality of Service there were also items like power control and frequency selection that the European regulators wanted to see implemented in a certain way.

As usual amongst engineers, the thinking was that the best ways to fix this all was to develop a new MAC, again from ground up. Quite some lobbying and voting took place and after all an IBM proposal was accepted as the basis. This proposal was in essence a newer version of the proposal that had lost the voting in the IEEE a few years earlier. Again a lot of work was done to define this new MAC, and the result again was a nice standard. Some companies started to implement it, in particular the larger European telecom product providers initially were very much in favor: Ericsson, Nokia and Philips in particular. In Lucent we made the assessment bout the acceptance of the IEEE 802.11a in Europe, and we came to the conclusion, that most likely IEEE 802.11a would be enough in compliance with the European radio regulations to be acceptable. Therefore we decided not to waste any time on this. We turned out to be right: slowly but surely everyone turned away from HIPERLAN/2 again, just as with HIPERLAN/1, and per the day of today I think no company is working on any HIPERLAN/2 based product development. In particular the decision in IEEE to add functionality to the MAC that addressed the needs of the European regulators and also to start to work on Quality of Service finished the need for anyone to seriously invest in the HIPERLAN/2 based product development.

Despite the huge success of the European legislation with GSM to standardize voice communication, all the European efforts and investments to play a role in the standardization of the data communication turned out to be a big waste of money and time. Where top down “guidance” in the wireless voice communications had worked, it was not working in the much more dynamic and versatile world of the data communication, where IEEE and the computer industry turned out to be the winners.

## 5.8 What about IEEE 802.11g

It is interesting to watch where a competitive world all leads to. But for standardization it does not necessarily mean that the best solution is found the quickest.

The industry had settled with two standards, one for today (IEEE 802.11b) and one for the future (IEEE 802.11a), and as discussed, the future standard was already there before the one of today. Most of the industry has run for implementing products in the 2.4 GHz following the IEEE 802.11b standard, while putting investments in the 5 GHz following the IEEE 802.11 on the backburner. One exception, Atheros was a company that developed technology solely focusing on IEEE 802.11a – having the future seemed to them to be the best bet. And in a way, Rich Redelfs, their CEO has it right: IEEE 802.11a will arrive. The only question is really: when. The computer industry however is not planning to wait until all the regulatory issues have been sorted out, and they placed their bets on IEEE 802.11b, making this to a real success.

This is causing a real problem for the IEEE 802.11a standard, as customers want to have a migration: an enterprise that has installed IEEE 802.11b with 2.4 GHz base stations (access points) everywhere, does not like it to go to IEEE 802.11a, which in essence means a complete reinstall of the base stations. The extra complication is the footprint. Because the indoor radio characteristics of the 5 GHz are quite different compared to the 2.4 GHz a switch from IEEE 802.11b to IEEE 802.11a is not very attractive. Some companies are trying to compensate for this by providing base stations that support both standards as an interim solution, but this is not more than a stopgap, as it does not take away the concerns about worldwide legislation for the PC industry or the difference in footprint.

The conclusion was that the industry needed so-called a/b-combo cards. These were radios that support both the IEEE 802.11a and IEEE 802.11b, and can be compared very much with dual band (or triple band) GSM phones. The user is ignorant about the infra-structure capabilities, but the radio card in the computer tries and find the best way to connect to the internet, whether it is via IEEE 802.11b in the 2.4 GHz, or via IEEE 802.11a in the 5 GHz. The problem only is, that such an a/b combo card uses a quite significant amount of power, and therefore would drain the battery of the notebook very quickly. Still the computer industry would not be very interested in an a/b combo card to include in a notebook PC, as this would still not be a worldwide shippable product.

In the mean time the pressure was mounting on the industry to come up with higher speed solutions than the 11 Mb/s of the IEEE 802.11b. This lead to a conclusion to try to get the 54 Mb/s OFDM technology approved in the 2.4 GHz. This was in the past something unheard of, as the requirement for the 2.4 GHz had always been that only Spread Spectrum technologies would be allowed. However, in particular the FCC in the US had created a serious problem for itself: they had never narrowly described what Spread Spectrum was: they had never described clear rules to measure minimum spreading of a radio signal against. The risk that the FCC started to run was to be sued for inconsistent ruling, and their behavior became extremely cautious. In Europe the situation was somewhat simpler. OFDM in Europe would be allowed as long as the signal strength over time would stay below a certain value.

In the year 2001 a meeting has been arranged between the IEEE and the FCC to understand the necessary conditions under which the FCC would allow higher speeds in the 2.4 GHz ISM band, read: would allow dropping the spreading requirement without getting into trouble based on older rules. The outcome of this meeting was a quiet statement of the FCC that they would approve a radio technology that was created by the IEEE. This was the way that the IEEE 802.11g standardization committee was born: it would create a higher speed wireless LAN

standard for the 2.4 GHz, compliant with a more lenient interpretation of the FCC rules in the US, and compliant with the rules in Europe.

The choice for the PHY of the IEEE 802.11g was in favor of using the 5 GHz technology, called OFDM, and get is scaled down to the 2.4 GHz. This way there was an interesting migration path created between the two other standards as IEEE 802.11g is using the same band as the IEEE 802.11b, but it uses the transmission technology of IEEE 802.11a. The advantage is clear. While it still may take a few more years before IEEE 802.11a worldwide legislation is established, with the IEEE 802.11g standard higher speed products can already be rolled out at a lower cost, and with no legal restrictions anywhere in the world. The expectation therefore is that companies and the computer industry will start rolling out IEEE 802.11g products soon, and a few years later the so called a/g combo cards will find its way to the market.

By the way, this scenario is heavily contested by some companies who's interest in IEEE 802.11g is very low. In their scenario they prefer a/b combo cards going into the market quickly, and then moving to a/g combo cards later. Although this is a potential scenario, its feasibility really depends on the market leaders of IEEE 802.11b products: Intersil and Agere Systems. If they have 802.11g chipsets, reference designs and products available in time the route definitely will be from .11b to .11g and to .11a/g later. If the .11g development programs are slowed down too much, and the interested companies find a way to make .11a/b combo cards attractive for a large enough market, the route will be from .11b to .11a/b and to .11a/g probably later.

The market jury is out and will decide in the coming 12 months.

## 5.9 Bluetooth

While in the wireless LAN world we were all working very hard to get the technology of wireless LAN's endorsed in the industry, in 1998 we all got suddenly surprised about the Bluetooth announcement. The core technology for Bluetooth was developed by Ericsson in The Netherlands, interesting as also significant parts of the core technology of Wi-Fi (both IEEE 802.11a and IEEE 802.11b) were developed in The Netherlands as well. But Ericsson rightfully realized that it would be very difficult to set a de-facto standard for this technology, so they started together with several companies a standardization committee, a SIG (Special Interest Group) as it was called to get this technology standardized. Interestingly enough besides Nokia and Motorola they enticed Toshiba, Intel and IBM into this effort, in a serious attempt to cross the boundaries between the telecom world and the computer world. Actually the crossing of the borders between telecom and computers was a real breakthrough, considering how both industries had moved on separately from each other over the years.

The original idea of Bluetooth was a low cost wireless connectivity device, that would connect phones with computers, or get phones and computers connected with peripherals, like headset, printers, PDA's and so forth, and actually that was and is a very practical idea. Comparing it with Wi-Fi, the Bluetooth technology characterized itself with short range, up to 10m (30 feet) and low speed, under 1 Mb/s. For comparison Wi-Fi covers up to 100m (300 feet) and 11 Mb/s. But the claim to fame of Bluetooth was that it was advertised as extremely low cost. The target of $5 was mentioned already in early Bluetooth press releases. But also besides the technology differences, there were differences at the business side. Looking at the wireless LAN world, actually IEEE 802.11 does the standardization, WECA (the Wireless Ethernet Compatibility Alliance) puts the infra-structure in place to certify interoperability under the Wi-Fi logo, and does the marketing of Wi-Fi as the global wireless LAN standard. So, IEEE 802.11 does the wireless LAN technology, WECA does the wireless LAN "business".

This historical split does not exist in the Bluetooth world, where both technology and business are covered in the SIG.

This integration may look like an advantage; however, in practice it has shown to be a big disadvantage. The marketing promotion of Bluetooth really moved ahead, much faster than the technology could keep it, and created a big promotion disaster. In the Spring of 2000 in CeBIT, the goal was to have more than 100 Bluetooth devices working together, but it failed miserably, forcing the standardization to retreat. Also the $5 price target, of which it never became clear whether this was the price of the device for the end customer, or whether this was the price of the chipset that goes into the device. When in 2001 the first products came on the market, the actual prices seen are over $150, or beyond, significantly exceeding the price of Wi-Fi products, another blow on the credibility of Bluetooth.

In the mean time another serious mistake was made in the Bluetooth positioning. Despite the fact that the Bluetooth technology tried to address low cost, low speed, short range peripheral interconnect, the Bluetooth marketers positioned the technology as going to replace LAN data connectivity: which is high speed, longer range connectivity between computers, the area that was covered by IEEE 802.11. Apparently the cooperation in the Bluetooth SIG between the telecom world (Ericsson, Nokia and Motorola) and the computer world (3Com, Intel and Toshiba) was not that well organized that this could be avoided. Actually Bluetooth created an attitude of planning to “kill” IEEE 802.11 and Wi-Fi. This was probably fueled by another fact as well: both Bluetooth and Wi-Fi are using the same 2.4 GHz radio band. But both technologies are somewhat different in how they use the frequency band: Bluetooth is using FHSS (Frequency Hopping Spread Spectrum) technology; Wi-Fi is using DSSS (Direct Sequence Spread Spectrum) technology. Therefore these two technologies interfere with each other, to a certain level. This interference leads to reduction of quality in the Bluetooth link, creating drops, noticed as “cracks” in the communication. It also leads to

some reduction in the range of the Wi-Fi link and/or of a reduction in speed, because of the loss of packets, that then need to be retransmitted.

Between 1998 and 2001 serious initial efforts have been undertaken to "harmonize" Wi-Fi and Bluetooth, to avoid interference. In particular several tests have been done between Ericsson and Agere Systems to understand the level of interference, and to build models for protocol adaptations that would reduce or eliminate this. Also several other companies have seriously addressed this with special features in software, but even per today, there is no fundamental solution for this interference. Initially the efforts to resolve this were effectively frustrated by the Bluetooth SIG with in their minds to "kill" Wi-Fi altogether. Probably also Bluetooth turned out to have enough internal compatibility problems of their own to be able to pay too much attention on this aspect.

In the 802.11/Wi-Fi world there has always been a clear recognition of the fact that a low cost, low speed, short range wireless solution would be feasible, and potentially an attractive market opportunity. Serious frustration about the fact that the Bluetooth community had no interest in working out the interference problems pushed IEEE 802.11 to create a new group called IEEE 802.15. This group's charter was to define a standard for a low cost, high speed, short range peripheral interconnect, actually, a high-speed successor for Bluetooth. As part of the 802.15 charter coexistence with IEEE 802.11 is explicitly defined. Because many companies nowadays have representation in both Bluetooth and in IEEE 802.11 and 802.15, the attitude towards harmonization has improved significantly.

Bluetooth itself is also recovering from its initial marketing problems. It has realized that there is a difference between peripheral interconnect and LAN connectivity, and it has decided to focus on its core mission, a low cost wireless peripheral interconnect, realizing that LAN connectivity requires so many additions to the Bluetooth, that it would end up with something like Wi-Fi is already today.

The main problem of Bluetooth was the interoperability, and the levels of freedom in Bluetooth 1.0 were too high to force this interoperability to happen. So, part of the refocusing effort of Bluetooth was to clean up and tighten up the efforts and come out with the Bluetooth 1.1, although general interoperability is still a long way to go. This has to do with the fact that Bluetooth not only tries to standardize the interface, but also tries to standardize the application used over the interface, in Bluetooth term called "the profile". One of the profiles of Bluetooth for instance is the "wireless headset" application, connecting a headset (ear piece and microphone) wirelessly to a cellular phone. The ultimate goal is to have "any" headset of "any" vendor, working with "any" cellular phone. To be frank, I am quite skeptical about this goal. Not so much because it would technically not be feasible, but much more because of the fact that currently the industry players probably are more interested to make sure that once you have bought a phone, that you buy the same brand headset.

Nevertheless, Bluetooth is clearly on a path of recovery, and the expectation is that with the growing popularity of the wireless headset application the volume will increase so much, that the price will come down enough to trigger many other applications, in particular the interconnect between phones and computers. Currently the computer industry is already getting more seriously interested after the initial high price failures from Toshiba and IBM. The prices have come down and at the same time the integration of a Bluetooth radio and a Wi-Fi radio, into one device for the 2. 4GHz has come within reach. This is important as it will create a seamless connection between the computer and the phone. This enables to computer to connect to the Internet via Wi-Fi directly in the so-called hotspot, as well as on other places via GPRS over the cellular phone.

## 5.10 Summarizing the third period (1995 – 1998)

The third period wireless LANs industry almost went under. They were walked over by the hype around the cellular phone industry. The cellular phone industry did not understand LANs, and was starting to make the same mistake as their wired predecessors has made with ISDN, assuming that data was just a variation of voice. The companies that worked the wireless LAN field were struggling to keep the head above water. Although I think most of the companies were marginally profitable the large expected growth was just not there. Every year the forecast moved out another year.

Many executives were expecting that wireless data was going to be "something", but the companies that could make a difference did not trust the unlicensed ISM band, and actually they did not trust an Ethernet like protocol either.

The telecom industry represented by Lucent Technologies, Ericsson, Nortel, Nokia, Alcatel, Motorola and Siemens were riding their magnificent growth numbers, and were already looking for the "next thing". Fiber was the area where the investments went, and 3G (UMTS in Europe) was the mantra for the next revenue spurt. Wireless LANs was too flaky, to uncertain, and to PC centric, which means, maybe interesting for the enterprise market, but not sexy enough for the consumer market.

The computer industry was too wrapped up in driving for cost reductions. Actually compared to the telecom industry the model in the computer industry is completely different. The computer industry is so cost reduction biased that a lot of innovations have taken place in the logistics and distribution. I think there are few industries, maybe with exception of the car industry, which have so much focused on cost reductions. Innovation has clearly suffered and the PC of today hardly differs from the PC five years ago. The only innovators in the computer industry maybe are Intel and Microsoft, and I think they are currently focusing more – and probably rightly so – on improving security, reliability and cleaning up "the bugs of the past" than that we see real new innovation coming. Still the breakthrough for the wireless LAN industry came via the computer industry, from another true innovator in this field: Apple.

# 6 The breakthrough (1999 – 2000)

In retrospect, in the second part of 1998 higher management in Lucent Technologies was getting really fed up with wireless LANs. At this stage it was really being looked at as the eternal promise, never coming through. Slowly but surely resources were sucked into a new promising concept called Wireless Local Loop. Wireless LANs seemed to be going to be abandoned forever. However, as happens more often: when everything seems to be lost the resolution is there. So was also the case here. The real market launch of wireless LANs took out of the vertical solution space took place this year, and changed our world forever.

## 6.1 Wireless Local Loop

The name of the game in Wireless Local Loop is the price or better the cost of the so-called CPE, the Customer Premise Equipment, or simply stated the unit that goes on the house and that wirelessly connects to the central based station of the neighborhood. The whole idea of this was quite simple: it is very expensive to dig up the street to get the access to every house to run a telephone wire, doing this wireless would save a lot of money. Unfortunately, the problem turned out to be, that also the CPE units needed to be installed at the outside of a house, and carefully pointed to the central base station. The consequence was that the price per connection, the price per house, just shot up, to a level too high to compete

with wire. But we were not that far in the late 80-ties, when many companies invested highly in WLL, and so did Lucent Technologies.

For WLL systems, there were in essence two target markets. In the first place the low-end market, where the immediate need to satisfy was the need for plain telephone: the new telephone markets in the so-called third world. The second market was the high end market, where in essence the need was for services, in particular DSL, that could not be run over traditional wire, for instance because it was too old, and noise sensitive.

Our target was to make a simple CPE unit in the 3.4 GHz that would cost less than $120. Our core expertise was low cost radio development and manufacturing, so we started the work in the course of 1998, and all through this time we made very significant progress. The challenge of such a product was not only to meet the cost targets, but also to comply with a very stringent temperature spec: the product should be usable in cold, below freezing point temperatures, as well as under hot direct sunshine exposure circumstance, under ultimate dry, or under ultimate humid conditions. From a technical perspective we were able to make such product, I think a major achievement. But when the product was ready, late 1999, it had become clear that that the market was not buying the product. Actually most of the telecom companies had started to freeze their investments in WLL, as a pre-cursor of what doom and gloom was going to come over the telecom industry.

At this moment the WLL industry has largely come to a stand-still. With the exception of a few courageous efforts, this market is dead. But it is important to realize that Wi-Fi may have the capabilities to revive this market. The main reason is that Wi-Fi could bring down the cost of the CPE unit significantly, or could combine the CPE unit with other functionality, like the DSL-box and or the Wi-Fi residential gateway functionality. Also Wi-Fi itself or its potential

successor in IEEE 802.16 may come to help here. But it goes without saying that the telecom industry itself first should overcome its doom and gloom.

## 6.2 The Apple Story

In the years 1998 and 1999 all the hard work to create understanding and acceptance for the technology all of a sudden came to fruition. Although I believe it is not necessary the situation for all technology breakthroughs, but in many cases, and specifically in the case of Wi-Fi wireless LAN, there was a clear set of events that really put this technology on the map – even when at that time the name of Wi-Fi did not existed.

We tried hard with many computer industry critical companies. I remember to have personally called with AST Computers in their hay days. I remember that I personally called to Michael Dell in the summer of 1994so in the mid 90-ties, and spoke with his secretary, and that I got a call back from a European sales guy, who had no clue where I was talking about. Spoke with many people in IBM. Spoke with Toshiba, with Mr. Nishida already in the early 90-ties. Actually, he had the right vision, but we were not ready or at the right cost level, that he considered as necessary to have this technology breaking through.

Last but not least we had spoken several times with Apple Computer. If there is one person who caused the wireless LAN world to happen, it was Steve Jobs, the at that time interim CEO (he called himself the i-CEO) of Apple Computer Inc., when he decided to select wireless LAN as a differentiating feature for the iBook launch in 1999. Credit to him and his organization for being at the center point, and I think Apple has greatly benefited from this as well. Actually, still at the day of today, Apple has a leadership position in the PC industry on wireless LANs, although now other companies like Dell, Sony, IBM and Toshiba are catching up very rapidly, both in internal knowledge as well as in “attach rate”, the number

that defines the percentage of (notebook) computers that have a wireless connection when shipping.
So, all praise to Apple, but not for having done anything to develop the technology. I think Apple's quality was, to "be there" when the technology and standardization had reached the level that economic viability was around the corner. That was the moment when they struck: so the praise is about timing, remembering us all on "timing is everything".

In the years before we had already targeted Apple to sell wireless to, however, to no success. Apple earlier had their own thoughts about wireless, and was in particular more in favor of FHSS, the Frequency Hopping technology, as they kept erroneously thinking, that this technology had better interference resistance than DS, the Direct Sequence. Apple had a whole history with wireless going back to the beginning of the decade, where they were secretly trying to develop this technology, inside and outside the standardization bodies. In the US they seemed to have had activities with Motorola, and with Plessey, a UK company. They also have had several passes with a Bay-area start-up company called Photonics, using infra-red technology instead of radio. Interestingly Dick Allen, who lead this company Photonics spent many years in Apple and was the Frequency Hopping supporter, who changed his mind in 1998 and helped Apple to create this wireless LAN leadership position.

Apple was the first PC vendor who launched wireless causing their competitors, and in particular Dell to take swift action. But it took all the PC vendors about a year to also include wireless LANs after Apple did. Actually Apple gave us quite a lot of heat for this at that time, as they thought we were not aggressive enough with other PC vendors to further popularize the technology. In reality, also the implementation with Apple had taken more than one and a half year from the basic decision to implement to the moment of launching, a fact that they tended to conveniently forget.

The whole interaction with Apple was an experience in itself, and quite characteristic for any dealing with this company, because comparing notes with other vendors, who tried to sell technology to Apple, there were a lot of similarities. First of all, there can be a lot of selling to Apple, they clearly have a mindset and schedule of their own, which leads to no movement at their side until the moment they make a positive decision, at that moment a supplier cannot move fast enough.

In the Apple situation, early in 1998 Apple contacted us to express their interest in wireless LANs. Actually this was Steve Jobs directly through one of his lieutenants. I have to admit, initially after unsuccessfully selling to them for eight years, there was some level of skepticism about this call from Apple. In particular the way the interest was communicated: “Steve Jobs wants to have a meeting with Rich McGinn about wireless LANs”. Rich McGinn was the CEO of Lucent Technologies that our organization was part of that time, and Rich’s exposure to wireless LANs had been virtually zero. Actually I believe Lucent Technologies at that time was about ten times as large as Apple ($30B versus $3B), telecom operators were the key customers, large switching and cellular base station deals were the core business, and someone asking for access to Rich McGinn for a deal far below $100M was somewhat odd. I remember that Rich McGinn’s staff was trying to keep Apple away from him, so we had to fluff up the wireless LAN potential, threw in some other technologies on the agenda (DSL), and we managed to get Rich McGinn interested. Steve Jobs own persistence probably helped as well, as he kept his people calling on everyone in the Lucent Technologies chain of command. Actually, I believe, that for Rich McGinn only the DSL acceptance in the computer community was an interesting subject, and not so much the wireless LAN sales to be expected the coming quarter (nothing) or maybe the year after ($5M).

The meeting date was set (20-Apr-1998), and a pre-meeting was scheduled in the restaurant the Peppermill opposite to the Apple headquarters in Cupertino. I still remember this meeting quite clearly – a small Divisional manager did understandably not have that frequently contacts with Rich McGinn. He came in together with John Dickson, the head of the semi-conductor division; actually, if there was any Division in Lucent doing business with Apple, it was this division.
As known Rich always took immediately the initiative by firing of the questions: "How much are we going to sell", "Explain me what it is: wireless LANs", and "Why is Apple interested". A preview of the presentation we were planning to give to Steve Jobs, and then a "Let's go". Actually Rich McGinn quite impressed me in the way he was able to use the right words at the right moment in the meeting, as if he believed in the wireless LAN business already for years, and had been personally pushing the technology, which he just learned about.

The meeting in the Apple board room in Cupertino was very peculiar, actually interesting. Lucent had drummed up probably ten of its brass, and Apple had done the same. Cordialities were exchanged, business cards, the usual nice stuff, but – for whoever wants to do business with Apple: this is only the first meeting. All other meetings with them afterwards are a little more challenging so to say. The meeting started at 2:00 PM, both companies either at one side of the table. Lucent was sitting there with suits and ties; Apple was showing up in Californian style. No Steve Jobs, so the atmosphere is actually a little awkward: Steve has been delayed.
Lucent wants to talk and present, Apple is waiting for the king. Then the king comes in, Californian style too, walks over to Lucent ties and shakes hands with everyone, need no introduction, and I was thinking "who is this guy?" as a European I had not really been exposed to too many Steve Jobs pictures, and in Europe corporate people do not present themselves in the media as movie stars either. Anyhow, but celebrities do not need and introduction. Steve Jobs sits down, and starts talking: wireless LANs are the greatest thing on earth, this is

what Apple wants, for about ten minutes straight. I believe that Rich tried a few comments, no traction. Then Steve Jobs: “Are there any questions?” I remember that I tried to prepare a few slides: key winners, market positioning, product offering, value creation, etc. Presenting with Steve Jobs actually is quite easy: you put up the slide, and he will do the talking, not necessary related to the slide. Then he asks for the next slide. Rich McGinn chiming in a few words, interested in DSL, he thinks 1999 will be the big year for DSL: “Will Apple be ready?” Read: “Will Apple PC’s have DSL?” Steve Jobs: “Probably not next year, maybe the year after, depends on whether there is one standard worldwide…” Turning the conversation back to wireless LANs: need the radio card for $50, wants to sell at $99.

Then Steve apologizes, he has to leave – stands up, says “Hi!” and goes. Room is quiet.

This was clearly the extreme of the “Telecom World” meeting the “PC World”, although, yes, Apple is somewhat of an extreme sort of a company itself. For Steve Jobs the job was done. But for us the work started in a way we had not seen before, and it was going to be very intense as our cost at that moment was probably above $100. We had the chipset in development, that probably would lead to a cost of a little above $50, but not clear how much.

In the months later we went through several rounds of product definition. Apple wanted a special interface. Actually, it took quite some time before the real negotiations started, as both Apple Computers and Agere Systems tried to figure out what the total system proposition should be, in particular what access points (base stations) needed to be added, which all confused the total picture significantly. Initially Apple wanted three different Access Points to be added: a high-end one, a medium one and a low-end one. But later in project they defined their own access point, and dropped ours. Originally the plan was to launch in the spring of 1999, but both Apple and ourselves we slipped into the later part of the summer of that year.

During this period I learned a negotiation technique, that it interesting to share. The technique is that you ask your supplier to take a loss on one product, and make it up with a higher margin on the other. Then after agreement, you decide that the product that makes the higher margin, actually is giving the supplier an "unfair" windfall, so at an appropriate time the negotiations are opened again on that specific product, while the lower margin product is conveniently forgotten. In projects that run over longer time there seems to be always the opportunity "to muddy up the water" for instance by changing the requirements, or threatening to drop the whole business altogether, or the most effective way: threaten to take away other business in the future. I think Apple has the most sophisticated supply line process: bullying elevated to a level of art – or we were just plain stupid. But key of the process is, to have different discussions with different layers in the organization. And really, Lucent was not so sophisticated at that time, and also not that interested in wireless LANs: getting DSL going was more important.
Fortunately we had never agreed to take a loss on the radio card product, the negotiation agreement was cost plus 5%, where we agreed on doing joint negotiations with suppliers. When the product indeed launched for $99 the industry was shocked. Actually we were accused of "buying" the market, and that we were losing money on every card. But we were not. The mechanism we used was, to "forward" price the product, so the volume would go up substantially, the cost would go down quickly, and the market share gained would bring in the margin. That is the theory – well, it worked in practice, and it worked very well as would turn out the years after.

Another very confusing element was the fact that the agreement we closed with Apple was on the first IEEE 802.11 standard product, 2 Mb/s. Our thoughts were that we would lower price the 2 Mb/s products anyhow, and be able to make better margins on the 11 Mb/s. During 1999 the 11 Mb/s standard solidified, and so it became clear to that the goal needed to be to break in the next IEEE 802.11b

product, the next generation 11 Mb/s. When these negotiations were going on the real question was, when is the next generation standard going to hit, and will we be ready for this? What actually happened, with some stretching and delaying, Apple went straight for the next generation standard. We tried to negotiate a better price for this newer standard, as we felt that the market would bear that. This was clearly not in Apple's interest. Actually, wireless LAN's were not in Apple's interest as such: their goal was selling more PC's. So we were given the choice: continuing with the program and deliver 11 Mb/s (IEEE 802.11b) for the price of 2 Mb/s (IEEE 802.11), or see the whole program cancelled. We decided to give in, something that looked like the wrong decision at that time, but has contributed to the very quick commoditizing of the wireless LAN business.

There was another real negotiation trick that was played in what was going on. The first round of agreement was based on every Apple notebook to have a wireless LAN card, this was called EUI (a Wireless LAN connection as Every Unit Item for all Apple notebook PC's). This would guarantee to us the required volumes to create a profit, and that would be attractive enough to take a low margin on ("make it up in volume"). This was agreed in December 1998, and was the justification for taking the business at a cost plus 5% level.

Well, in March 1999, the program all of a sudden had changed in the understanding of Apple. All the notebook PC's would "be able" to carry a wireless LAN card, that is to say, all notebook PC's would have a radio card bay, and an antenna integrated in the back of the screen. But the deal to sell one radio for every notebook sold was off, and we saw the volume dwindling to about one twentieth of what the deal originally was based on…. I remember we have seriously considered canceling the program at this stage. For one or another reason however, we had tried so long to break in into the PC industry, and I believed, that once this breakthrough was established, this wireless LAN market could become real big. Apparently Apple understood this all too well, and saw an opportunity to exploit it.

This trick was not the last negotiation trick. Another trick was around a very important feature of the Access Point, called roaming. It allows users to roam around buildings covered by multiple access points and be continuously connected while the connection switches from access point to access point. In Lucent Technologies we were working on a family of access products differentiated in power to support different numbers of users, ranging from the home user access points without roaming to very large access points supporting many (hundreds of users). The agreement was that the original Apple Airport would work only in a home environment and had no roaming, as the roaming capabilities were a higher end feature for which Apple would buy and resell a Lucent Technologies product. This was all fine and agreed, even put in contract, until the moment that the roll-out would start. Apple had thought about the concept again, and preferred to get the roaming feature in their Airport base station, so they could sell it to schools as well. But what about the higher end product that would be bought and resold? Clearly, Apple had changed their mind. Generally spoken one could think, great, more endorsement. However, in business there is such a thing as required price to make a decent margin. Adding a critical feature to a product that sells for a rock bottom price in a home market to allow it to be sold in a higher end market like a school or enterprise is asking for a market to erode quicker than one can afford to build it up. The simple possibility is always to say “no” to a customer, and explain that you cannot afford it to give this feature away for free, as it erodes the price in other market segments. So, you learn again the hard way that bullying suppliers really exist as your CEO gets a call that he may lose business in a different, unrelated business unit, if he does not still provide this feature for free. Apple won this battle as well, despite earlier agreements.

From a theoretical business perspective the conclusion might be that there are also disadvantages to be part of a larger organization, as it exposes you to potential

attacks on your business through colleague businesses. But that was the theory, because the practice was that the price in the access point market now started to erode much quicker than necessary. Apple's comment: "If we had not forced you to take the price down, someone else would have." My reply was: "Only not yet!", but I do not think anyone heard…! It was another good lesson in supply management tactics though!

## 6.3 Others PC vendors following

Despite Dell's furious reaction on Apple's announcement it still took about a year to change this into real sales of products. Dell had assigned a tiger team and was trying to find the quickest way to resolve. The problem in Del is though that they always try to balance between quick and quality, and where quick was required here, the team really started to focus on quality: what is the best we can get in the industry, and how are we going to integrate this. Dell, just like the other PC manufacturers has a major disadvantage compared to Apple that the Operating System of the computer is coming from Microsoft Windows. So where Apple and Lucent and Agere could resolve software and Operating System interface problems straightaway, in Dell's case, they had to forward Agere straight into Microsoft. Microsoft themselves had gone a little fed up with all the interface problems they were exposed to, to they had developed a new procedure pushing the testing and responsibility away from themselves by defining a certification called WHQL (Windows Hardware Quality Labs). This word, pronounced as "wickel" has probably kept awake more software programmers than anything else…. It is a stamp of certification that is required to avoid the Windows program to state at start-up, that you have uncertified software running on your machine, your computer or notebook. Well, this really did it for the PC-industry, who want to reduce the number of telephone support calls as much as possible. Therefore

everyone delivering peripheral products to a PC vendor, like a wireless LAN NIC card in our case needed to make sure that the WHQL stamp of approval has been obtained.

Unfortunately for us, there were some requirements in the Windows certification program that could not be met with wireless LANs, in particular in the area of immediate “being alive” messages. So this required us starting to engage with Microsoft to explain the concept of wireless LAN, and the needs that this technology puts on operating systems. To be fair: it was also for us to learn about making rock solid drivers that kept on working under all circumstances. So initially we had to close some compromises with Microsoft to obtain some waivers to expedite our going into the market, while after that sharpening up the WHQL tests and the wireless LAN drivers to meet the required quality levels. This seems to be easily described, the reality was somewhat more gruesome, as until this time Apple was feasting in the market with their wireless LAN solution.

Almost in parallel with Dell we were approached by Toshiba, Compaq, HP and IBM to provide also wireless LAN solutions for them. So in the summer of 2000 one could see many announcements from many of the PC vendors with their wireless LAN solutions: wireless Ethernet had arrived. Not that everybody was immediately convinced: issues around security, reliability kept on hovering around. But the price had come in below $100, so the investment risk had become relatively low.

As Agere Systems we had almost what was called a clean sweep of the wireless LAN market for PCs, an amazing result after the initial efforts with Apple. The interesting experience with the PC vendors though is that they really are trying to claim exclusivity with a supplier. Not that this is in writing, or necessarily even spoken, but PC companies are running on so small margins, that in essence they have pushed out all the technical work into their supplier base. The technical part of a PC company has very much become a management shell, where suppliers are managed to deliver their technology, and where the technologist in the PC

company are trained to ask questions, and make right judgment calls in their supply base. The technical support requirement on a supplier therefore has become incredibly large, so large that it becomes a strain on every organization to support multiple companies at the same time – which I suspect is part of the supply line management strategy: all the time that you support Dell, cannot be put in IBM or Toshiba – so, keep on asking!

It was clear that with the success of Wi-Fi many companies rushed into this market. All of a sudden Wi-Fi had become hot.

## 6.4 Networking companies catching on

During the years there had been only one networking company really engaged with Wi-Fi. This company was DEC. Actually DEC (Digital Equipment Corporation, or later Digital), in the late days of Ken Olsen, their famous CEO, has been personally engaged with wireless LANs. DEC has never invested in radio technology, but they had focused on the Access Point side of the business. They have launched their Access Point, RoamAbout, in 1994 that had been developed in cooperation with AT&T, and later with Lucent. This DEC Access Point still exists, but it has gone through several transitions as well. These transitions had not so much to do with wireless as well as much more with the woes that DEC was going through as a computer company. When DEC Computers was sold to Compaq, DEC Networking was already sold to Cabletron, and when Cabletron reengineered itself, the enterprise networking, including wireless ended up with a company called Enterasys, still selling the RoamAbout product line and its successors today. Enterasys therefore is one of the longer existing companies in the wireless field.

Another networking company that was interested in wireless and that really looked at wireless long and hard was 3Com. I remember already contacts very early on, but 3Com was so convinced about Ethernet, that their position initially was: wait until the standard is there, and then we will take over the market, based on our name and reputation. Strangely enough, the outcome of everything that 3Com tried for a long time was not good enough to their own standards, or they were just not capable of what wireless meant as part of their total portfolio. They had worked extensively with Lucent to integrate Lucent's wireless portfolio, even to the point of acquiring the wireless LAN division from Lucent. Then they worked with Intersil and with Symbol initially without a lot of marketing success, despite the coolness of their product with the click-out antenna, an idea that revealed their click-out V.90 modem (the one from US Robotics). Probably a role played the woes that they went through as a company, and the repercussions that had on their wireless product development. Today, 3Com is in the wireless LAN business with their OfficeConnect product portfolio.

So what was Cisco up to? They had been a power house in enterprise networking and they could have definitely leaded the way. Actually they did, but in the typical Cisco style, and without any vision. Although the details will never be public, Cisco was pushed into wireless by Microsoft. The sequence of events has been that after the launch of AirPort, the wireless LAN product of Apple, Microsoft got really interested. Their relationship with Lucent and later with Agere was very open and constructive, and Microsoft got excited about wireless LAN, even to the point that they wanted to get the campus in Redmond completely covered by wireless Access Points. The IT department in Microsoft is probably the most challenging place to work in the world, as most of their "customers" know more about IT than they know themselves about it…. Anyhow, they were told to go wireless and they approached amongst others Cisco, Aironet, 3Com and Lucent Technologies (the part that was on the verge of becoming Avaya Communication) to quote for the contract. I do not know for what contract

we have worked harder, and have flown in more people to sell our capabilities. However, only success counts…. and the success was for Aironet. This was probably one of the most painful moments in my career, as we had excellent relationships and capabilities in Microsoft, but apparently not good enough to win over their IT department.

There was more to it. Already during the final bidding phase the rumors went around that Cisco was going to acquire Aironet, as appalled as they were for not having anything to offer. Apparently this linkage was already in place when the deal was given to Aironet. It seems that Microsoft more or less has forced Cisco to go into the wireless LAN business, and up to the day of today, this has been quite a success for them, as "Aironet" today one of the most successful wireless LAN offerings.

Another big success of Cisco was the way they won Boeing as an account. Boeing was interested in unwiring their facilities and they were out with a very large contract that almost went to Lucent. The IT department had gone out and evaluated all the products on the market and clearly favored the Lucent product. Then as rumors say, Michael Chambers, the CEO of Cisco went in to the top IT guy in Boeing, and explained to the Boeing IT department, that it probably made more sense to buy Cisco wireless LAN product, as their whole network was already Cisco. These were not even rumors; this was the inside track of the participants of the evaluation committee, who had tried to make an objective evaluation of the functions and capabilities of each product. Chambers seemed to have promised that everything that was not provided by the Cisco Aironet product would be resolved in another six months, and there went another big deal for us. Already in my early days in business I had been taught to ask myself the soothing question: "what is fair about a 600-pound gorilla?" and have tried to avoid them since, sometimes with less success, as was the case here….

There was another reason why this move of Cisco into wireless LANs was so important, and the reason was IBM. Although IBM had grown into the largest network provider of the industry in the late 80-ties and early 90-ties, their betting on and promotion of the Token Ring technology had slowly but surely pushed them out of the game, leaving the field to 3Com and Cisco. Looking backward this could create some interesting thinking about IBM's moves to contest their loss in IEEE 802.3 and their move to IEEE 802.5. IBM's strategy at that time came from a perspective of controlling the market through owning the standard. But the world had changed, also for IBM, and the free forces that promoted Ethernet and TCP/IP (Internet) pushed out IBM's Token Ring and SNA (Systems Network Architecture) altogether – admitting that I probably should make a sub note about SNA, of which the targets were far beyond the goals of TCP/IP.
For all practical and financial purposes, during the mid and later 90-ties IBM has slowly resolved all its owned networking technologies capabilities in favor of Cisco, and therefore also their wireless activities have been minimal, although they have tried several times to carve out their own niche.

A few words here about Proxim are in place here. As mentioned before Proxim always has tried to do something just different. Their claim to fame in 1999 was HomeRF, and they had managed to line-up several larger companies behind the idea: Intel, Siemens and Motorola are probably the most important ones to mention. But they saw their plans go up in smoke when we closed the deal with Apple that really pushed down the cost of IEEE based products taking so drastically that it took away the key benefit of HomeRF. Actually only Siemens today is pioneering some HomeRF as successor of DECT, both Motorola and Intel have abandoned the idea. Dave King, the CEO of Proxim has admitted that the launch with Apple was the real blow to for HomeRF, and he moved on with Proxim to start to embrace IEEE 802.11, first with the acquisition of Farallon, and later, but then it is already 2002, with the acquisition of ORiNOCO out of Agere Systems.

## 6.5 WECA

The wireless LAN community had always looked with a certain level of envy to the Bluetooth world. Bluetooth was already a household name years before a first product hit the streets. The opposite was the case with IEEE 802.11. This was a very solid technical standard, but not recognized outside of the wireless LAN in-crowd. This was generally realized as an industry wide problem and that needed resolution. Simultaneously there was another problem not really addressed yet: the IEEE has formulated a set of standards (IEEE 802.11 and its flavors), but there was not a uniquely defined and accepted way of standard compliance, This could practically lead to a situation that two companies both could claim IEEE 802.11 standard compliance, while products from these two companies would not work with each other, and where the two companies easily could started to blame each other for this lack of interoperability.

This situation forced the leading wireless LAN companies to sit together, amongst them Harris Semiconductor (now Intersil), Lucent Technologies Semiconductor (now Agere Systems), 3Com, Aironet (now Cisco), Symbol Technologies and Nokia. The last name maybe a surprise, but Nokia over the last few years had started to test the water of IEEE 802.11. Partly driven by the idea that wireless LAN technology may become a factor for their terminal (cellular telephone) business Nokia had started to develop technology that would lead to the first smart phone later. A smart phone is loosely defined as a cellular telephone combined with a PDA that supported a personal management system (contact list and agenda).

The constitution of this group was quite remarkable. It existed out of Intersil, with four of their customer plus Agere Systems. Still Agere Systems had a real need to

participate. They were already part of WLANA (pronounced as “walana”, the Wireless LAN Association), however, WLANA had become more or less a frontier promotion institute for Proxim, and Proxim’s OEM customers. All efforts to make WLANA at least a neutral body in this respect had turned out to be in vain. So for Agere Systems partnering up with Intersil was the right thing at that time, and it has worked out positively. WECA (today it is called “The Wi-Fi Alliance”) organized itself quickly and also made a smart move by not allowing a complete and per person democracy, as was and is the case with IEEE itself. Governed by a small board, the WECA was quickly out to establish an interoperability testing procedure and seal of compliance via a tested logo, the logo Wi-Fi (standing for Wireless Fidelity). Mentioning people here will do short to people not mentioned, but anyhow I think full credit needs to go to Angela Champness (then Agere Systems, now Proxim), Jim Zyren (Intersil), Phil Belanger (then Cisco, now Vivato) and Greg Innes (Symbol Technologies). They knew what was required to get done, and how to get it done, and although IEEE-like politics was around the corner, they established with credibility the Wi-Fi logo, to the point that the technology today is widely known under that logo, and the IEEE 802.11b statement is disappearing.

In this respect it is interesting to mention that Jim Brewington, who was Sr. Vice President in Lucent Technologies, and my boss over the period 1995 through 1999. Before the technology had broken through he had already complained about IEEE 802.11. In his mind GSM, TDMA, CDMA, GPRS, UMTS and 3G were much easier for the general public to grasp than IEEE 802.11, and he personally gave me an action item “to fix this”. Well, he got what he wished for and probably even something with more marketing appeal than that he could think of. I have heard statements, that he now is an enthusiastic Wi-Fi supporter, which is somewhat of a change compared to his position in 1999…

# 7 The hay days and beyond (2001 – 2002)

The end of the year 2000 it started to happen: the burst of the bubble of the IT industry. Actually this happened in two ways: the Internet bubble burst with the dotcoms going bankrupt very quickly and with that the telecom bubble burst as well: the need for capacity reach its saturation point. It became clear that also the "new economy" had to reckon with the harsh laws of the old economy and the simple fact that the goal of business is to make money – and not to just spend it. But while in the year 2001 the real crisis developed itself to its full extend, it was at the same time the thriving year for the wireless LANs, and the peak years of all companies who had survived the pioneering times of the wireless LAN.

## 7.1 Managing growth

After the successes with Apple and the other PC-vendors, as well as the progress of the wireless LAN industry we came to deal with a complete new set of problems. The whole organization was set on pioneering and establishing new markets. Now the broader market had accepted wireless LANs the name of the game became: flawless execution. This turned out to be a major challenge and an exciting opportunity at the same time. All of sudden volume became the key item in manufacturing, flexibility and lead time reduction, inventory management, optimizing test capabilities. Agere Systems had for about a decade worked with USI (Universal Scientific Inc.) as Taiwanese manufacturing organization. Interestingly enough this organization has been helping us through the early

manufacturing start-up, invested in manufacturing like we did in R&D and became in these years the largest Wi-Fi radio card manufacturer in the world. Development working closely together with manufacturing engineering and with test engineering, as well as with the manufacturing organization itself made very significant progress. Compared to the first radios in 1990 the progress was even more astounding. In those years each wireless LAN card "radio" had about 15 test and calibration components: little screws some of the components of the design that helped the product to work properly. Nowadays wireless LAN cards are fully software tested, and have no hardware calibration points anymore. Also the first products had over 300 components, gone down under 30 components today, and with the progress in the further integration, the goal of less than 10 is close in sight. This was all the effect of growing from 100 wireless LAN cards a week in 1991 to 100,000 wireless LAN cards in 2001.

Managing this growth was a challenge; however managing what was called "customization" was even more of a challenge. Despite the fact that all PCs look the same, and despite the fact that they all run Windows, there is a desperate drive in each PC company for differentiation, for just looking and feeling a little different than everybody else, looking for just another step more in the software integration, for just complying with another test in the complicated and somewhat archaic PC architecture. PC companies have become masters in technology supply line management. They are demanding not only to reduce their own cost – shifting all work from themselves to their supplier, but also to reduce the time that any supplier can work on resolving differentiation issues for any of their competitors. At the same time the tremendous competition amongst PC vendors is replicated amongst the PC supplier base, where the margins are even more under pressure, because of that.

This was also the time that the PC industry – together with was trying to go through a major quality improvement. I think a very good initiative, and it forces

the industry to do what they had to do anyhow: making sure that product meet customer objectives.

One of the mechanisms for this was the WHQL (Windows Hardware Quality Labs, and pronounced as “wickel”) certification, an abbreviation that still brings up with some software engineers the nightmares of long and lonely nights, where they were debugging and testing many times without any visible progress, if not worse: ending the night with more test failures than the night started. Every piece of hardware that gets added to a PC interfaces with this PC via a piece of software called a driver. So called “WHQL-ing” the driver certified that the driver had gone through a set of tests that made sure that the driver met the requirements set by WHQL. Although Microsoft seems to be pretty independent in setting the requirements for these tests, the reality is that the rest of the industry understands that contesting these requirements is not the right way to approach the general notion of quality improvements. Probably rightly so: when a PC or a notebook hangs, we tend to blame Microsoft for this, although there is a serious likelihood that the problem is caused by the peripherals of the PC and their interaction with the Operating System. At the same time it is interesting to see that this is called Windows Hardware Qualification Labs, and one would wonder: what about a Window Software Qualification Labs. This is maybe in the works, or would it cause too many problems because then Windows would have to go through this Qualification itself as well? However, considering all the long hours that go in working compliance with these tests the hope is that the quality of PCs will go up significantly.

## 7.2 New markets: Residential Gateways

Over the years our vision for wireless LANs had been very PC focused on how to connect mobile PCs to the enterprise network. However, through Apple it had

already become clear that there was a home market as well, as the Apple Airport product had been focusing on the home users (and the education market) in the first place. So, this helped us to completely rethink our marketing strategy that lead to redefining the product line that was still called WaveLAN. The new concept was around Internet connectivity everywhere and we looked at Internet as a river of information that flows through our society and where everybody can tap into at any moment. So we came up with a new name for the product line called "ORiNOCO", as this was an interesting sounding name for a river. It was a river in Venezuela that according through old stores had on its banks the city of El Dorado, where everything was of gold…
ORiNOCO stood for wireless connectivity to the Internet, not only as a LAN in the office, but also as wireless DSL or wireless cable at home, or as a wireless "modem" in hotels or other hotspots. We started working these new markets, the home market and the hotspot market, with mixed successes.

The home market was very interesting however we learned a few lessons quickly. In the first place the home market needs a product that needs another class of ease of installation and use than we were used to in the enterprise market. As the wireless to the home provider we seemed to get the first brunt of this. But actually in the enterprise environment the IT department knew how to install wireless to the existing LAN, and was used to the tools that Microsoft offered. In the home environment no LAN existed and no IT department either, and as is generally known: the Microsoft environment is not as simple as the closed Apple environment. So the first launch of the product in the home market lead to a flurry of support calls, and made us realize that there was still a lot of work to do, including closing the loop with Microsoft, who now fortunately knew how to spell wireless as well. This was a great help and in Windows 2000 and XP nowadays are good support tools to make installation a lot easier. At the same time this market now has completely commoditized as well, and the home market has become a major target for Taiwanese and Chinese low cost product providers. At

the same time the companies that are used in delivering cable set top boxes or DSL modems to the end users are working now diligently to include wireless in their offerings as well. It will be just a matter of time and "cordless" Internet will be as common as cordless telephone is already for decades.

## 7.3 New opportunities: hot-spots

An even more challenging new proposition was the hot spot market. The idea for this had already floating around since 1997. It did not as such require so much special wireless technology: it was an interesting application of existing technology. Unfortunately many trials have been done so far, all without success so far. The issue is not so much the technology or the products as well as how to build a profitable business case.

Many existing service providers have made trials, and we have participated in several ourselves as well. Unfortunately this is another example of a chicken and egg problem. When there are enough computers with Wi-Fi cards then it will hit a threshold where the business case of hotspot Internet access will become attractive.

In the mean time on the path of hotspot trials there are many failures so far. The most prominent in visibility is maybe Mobilstar. Mobilstar got great press with the announcement together with Starbucks, where the Starbucks in the US would server Internet combined with coffee. Unfortunately the deal was struck in such a way that the investments for Mobilstar were not justified by the revenue it created and as a consequence the company went under. However, this deal and this announcement had sparked the interest to a next level. The efforts of Mobilstar have not been totally wasted either, as Voicestream, a US cellular provider acquired the assets out of the bankruptcy, and being acquired themselves by T-

Mobile it looks that the hotspot market has taken off. T-Mobil, a German cellular provider is active in Europe, as is British Telecom.

The good news is that the number of PCs with a Wi-Fi card is growing steadily, at the end of 2002 with about one million units a month, and growing. So, it will be a matter of time. At this moment there are about 20 companies offering hot-spot services, reminding of the times of the early cellular days. Worldwide I estimate the number of hot-spot service providers at least at 250, maybe even ranging to 500. According to market research the actual number of hotspot has grown in 2002 from 2,000 to 10,000, a clearly booming market. The big challenge unfortunately is still to make money in it.

Interestingly enough the companies that did not want to have anything to do in the late 90-ties with Wi-Fi, including Lucent Technologies and Ericsson are now exploring this business seriously. Their biggest challenge is how to make this seamlessly work with their CDMA and GPRS offerings. From a business perspective a combined customer offering that includes wireless WAN and wireless LAN seems to be the way to make the original idea of hot spots effective that is: enabling hot spot service providers to make money.

## 7.4 Social consequences

One of the reasons it is clear that the Wi-Fi market has now really arrived is the fact that articles in the paper start debating the social consequences of instant and immediate networking.

The consequence of wireless networking is that the Internet gets pervasive, that is, it is present with almost all activities that we are doing. A few examples can be given here.

With the arrival of notebooks and wireless LAN connectivity in universities a professor in a classroom all of a sudden has competition for the attention span of the student. In a recent interview a professor complained that as soon as he has to look up something, a rattle of keyboard clicks tells him that his audience has moved on to other subjects: chatting, email, or even watching a movie. Stories are going around of lecturers furiously sabotaging Access Points to make sure that no one could access the internet. In some cases students have been asked not to make notes on their computers, but on paper…. A more realistic professor took all this more sporty, and realized he had a challenge to make his lectures really entertaining to make sure he captivated his audience, his conclusion was that this internet competition had forced him to improve his presentation style.
Similar things happen nowadays at conferences where boring presenters are immediately penalized by finding out that his audience has left for “cyberspace”.

In enterprises that are completely wireless notebook enabled something similar is happening. Meetings are running the risk that most of the attendants have drifted away into their stacks of emails, which is usually not a good sign for the quality of the meeting. In several companies conductive codes are agreed on to not do email during the meetings. Interestingly however, the consequence also is that meeting attendants are demanding more to the point meetings plus the requirement that the agenda items should be relevant for them. Still this is clearly a downside of the continuous connectivity. In the past being early for a meeting allowed people to network and get some latest and often relevant information. Nowadays being early for a meeting you find everyone hidden behind the screen, which clearly creates a barrier for communication. It is clear that we need to get more used to our new wireless notebook play toy, and that we have to accommodate the related strengths and the weaknesses into a new working style.

Fortunately at home we have already passed that station. The television has already been a dominating force in many families for a few decades, and people

have to learn to live with it and found out ways to preserve some non-television life. The complaints of the past that an ever increasing amount of time was lost on watching television is gone, maybe because people are watching less television nowadays, because the increased amount of advertising. Maybe also the Internet has become a serious competitor for the television, and therefore people won't really notice if television time is replaced with Internet time.

It still goes without saying though that life is changing. Getting hot spot access to the Internet in the Chiang Kai-shek airport in Taipei, and seeing an instant message "Hi dad!" from my daughter in The Netherlands over the chat while she is in the middle of attending a lecture at the university, is a signal of a different era, where continuous connectivity is paramount. This is largely because of the nature of the Internet itself, but Wi-Fi has clearly become an essential enabler.

## 7.5 Over the top: trouble looming

By the beginning of 2001 we had reached in Agere Systems our top as Wi-Fi provider of the world. The market had grown to about one billion US dollars, and it was probably the only segment in the high tech market that showed active growth signs this years. In Agere and our distribution channel we owned about 50% of this market. The technology had now become well accepted with the computer industry leading the way. The entrance in the home market and in the hot-spot market and after that finding the next step into consumer electronics was within reach.

In Agere Systems however with our success we had created our own conflict. We had become chip supplier (of wireless LAN chipsets), a product manufacturer (via our subcontracted manufacturing house USI in Taiwan), as well as product brand

supplier (with the ORiNOCO product line). However, as a chip supplier we were selling chips to companies that competed with our own brand, creating continuously priority conflicts: external customers always took the impression that they were served later than ORiNOCO themselves. Our relationship with a subcontractor manufacturer made it also very difficult for us to work with the group of Taiwanese ODMs (Off-shore Development and Manufacturers).

This last item may need some explanation: the way the PC industry has been set up is very particular. Despite the fact that the PC market looks like being dominated by companies like Toshiba, Dell, HP/Compaq, IBM, NEC, Sony and others, the reality is that almost all these PCs are developed and manufactured by a limited group of Taiwanese companies, called ODMs. The PC companies themselves are in essence companies who manage the supply and distribution chain with in a lot of cases a deep knowledge of the technology, but contrary to what an outsider would think, just as they don't manufacture, they don't develop products either: that is what the ODMs are doing for them. Most of these ODM companies (Ambit, Compal, Alphatop, Gemtek, etc.) are quite unknown to the general public, as they have not invested in marketing beyond selling their expertise to the PC and also to the networking companies. Working with USI, a manufacturing house, excluded us from general access to the Taiwanese ODMs.

## 7.6 The solution

At the end of 2001 it became clear to us that sooner or later the hay days would be over, whether we liked it or not. Although 2001 was still an excellent year in number of growth and profitability the competitive pressure was starting to really kick in. A trend started that every quarter(!) the prices came down with 10%. This had already started in 1999, but continued with a steady pace into 2000 and 2001. Up to a certain level the margin decline could be compensated with cost

reductions, but it became clear that the competitive pressure was going to ask for a reformulation of the business. This was also because of another reason: with Wi-Fi becoming fully accepted the next step was to integrate Wi-Fi as a technology with other technologies, like Bluetooth and Gigabit Ethernet, with for the longer term the need to integrate Wi-Fi into the general computer I/O chip (input/output chip), also call the Southbridge. Something needed to happen with the business to avoid that the market would move on and leave us out.

The year 2002 became the year of the "unraveling", something that needed to be managed very carefully.
In the first place already at the end of 2001 the organization was carefully split in a chip division and in a product division. The chip division was going to focus on developing and selling chips, just like many of their competitors as they started to show up left and right now: Intersil, Broadcom, Infineon, AMD and others. The product division was becoming a customer of the chip division and was focusing on selling the ORiNOCO brand and the infra-structure products: Access Points, Residential Gateways and Outdoor Routers. As third activity the USI was going to transform themselves from a manufacturing subcontractor into an ODM and going to make the necessary investments to do so.

The first phase is completed, the chip division of what was the famous WaveLAN product, has now been integrated with Agere Systems' micro electronics division for client products, further building the technology into new chipsets, and also selling the wireless LAN chipset technology to other chipset providers who lack the wireless technology, but who have the capability of combining the wireless technology with other I/O technology. At the same time there is a space wide open in the consumer area. The wireless technology in the home is largely limited to cordless phones, and many of us have to go through the trouble of wiring stereo equipment, computers and other home gear.

Also the second phase is completed per the mid of 2002: the ORiNOCO business unit in Agere Systems was acquired by Proxim, who had been their biggest enemy in the last decade. This was a friendly take over for $65M, although Angela Champness, the General Manager of the ORiNOCO remarked ironically: “If you cannot beat them, buy them!” to Dave King, who had been Proxim’s CEO for a long time. Currently Angela Champness is Senior Vice President of Proxim’s LAN Division.

The last phase with USI is going on in full progress and will be completed quite successfully. USI is migrating from being a subcontractor manufacturer into becoming an ODM, with special expertise in wireless LANs. Although the market share of USI may have gone down somewhat, they are still the largest wireless LAN card producer in the world.

# 8 The Future of Networking

To be able to talk about the future of Networking, or more specifically the future of Wireless Networking, it is important to better understand the situation the communication industry is in today. This future in general is solid and bright: as communication is a key human requirement and the basic need cannot be satisfied other then with more bandwidth and more gadgets, and despite the current softness of the market, there will be a steady need for more bandwidth. But as usually, to get "there", will take just take a little longer, than everyone expects. Plus the problem is that "there" is only known and understood after arrival. Until that time "there" is usually quite foggy.

But trying to look through the fog, and to understand this communication future a little better, it is important to understand the key drivers today.

## 8.1 The telecom networking industry today

Currently the telecom world is in a state of turmoil. Actually it is in a sort of death struggle, as the way it was in the late 1990-ties, it will never be again.

This is the way I see, what has happened over the last decade. The telecom industry was a slow growing industry, a few percents per year, steady and predictable. They were rooted in a monopoly type culture, not only AT&T in the USA, but in most countries worldwide. Telecom companies were actual or pseudo

state driven companies, slowly moving, and only somewhat exposed to the dynamics of competition. Then both in the United States (initially by the surge of the Internet) and in Europe (initially by the surge of the cellular phone industry) some unsettling events happened, that created first a frenzy, and after that an aftermath, that we still have to overcome. These events were different in the US and in Europe, but they started to feed on each other.

The frenzy in the United States was based on the very rapid growth of the usage of the Internet. It was a frenzy, because the Internet business model was totally flawed for the telecom companies. They saw their traffic increasing, but not in a way that paralleled their increase in revenue and cost. Quickly the Internet Service Providers had figured out how to enable local calling for providing nation wide access, and local calling in the US was virtually free of charge. The Internet Service Providers themselves also had a major flaw in their business model. They did not make their primary revenue stream come from the service they provided (Internet access): customers got Internet access from a service provider for almost free. Instead the Service Providers thrived on advertizing money as the primary revenue source. And on the back of this, many product services on the Internet started to make its money primary from advertizing, and not from the service they provided. This created the well known “dotcom mania”, the “Internet bubble” or the “new economy illusion”, which in essence was living of the belief, that advertizing would pay for everything.
But this bubble burst, as over time people were looking for true service, and not for advertizing. And with the bursting of the bubble we got the punishment for our collective greed: also in the Internet economy stock prices will grow only in line with value created.

In Europe the Internet frenzy always stayed within proportions compared to the United States. The main reason was the fact, that local calls were always charged. This meant that there was a natural limitation on the usage of the Internet, as

many parents found out the hard way, when they got the telephone bills for the Internet usage by their kids….! I had to personally put my children on "an Internet diet", after being hit by a few astronomical phone bills. And by the way, this was not because they spent their time collecting useful information for their study or education (at least that was the parents' interpretation). Their time spent was on chat programs and other Internet games that ate connection time from early in the evening until in the early morning hours. Internet addiction showed to be a fact, although at the same time, as far as I can see it was quite benign disease as at least all our children grew over it….

However, despite the, compared to the US, more measured growth of the Internet industry in Europe, the telecom industry in Europe had its own frenzy and hype and it became victim of a comparable form of collective greed as in the US. This greed, however did come not from the capitalistic stock market, but, with some big irony, it was collectively "organized" by the mostly socialistic European governments. In the mid 90-ties the cellular phone market had become very successful, more successful, than anyone had expected, and because of a worldwide cellular phone standard (GSM) really made almost everywhere in the world. Almost everywhere, as there were a few large exceptions, like the Korea, Japan and the United States, who really struggled a few years longer to get to a reasonable uniform coverage.

This success made the European governments organize two activities: one was privatizing (parts of) their cellular phone companies, which actually was already planned for or started, the other one was selling to these phone companies more spectrum for future cellular phone service. Both activities targeted many multiples of billions of dollars to go into the European states finances, and helped to create further European integration with the final introduction of the Euro in 2002.
The strong belief in Europe was, that UMTS (Universal Mobile Telephony System, now also called 3G for 3$^{rd}$ Generation Mobile Phone System), probably

best described as a combination of a cellular phone plus wireless Internet access, in essence again a combination of voice and data, would be the next “gold-rush”. The need for more spectrum was very clear to everybody. The phone companies had worked with their network infra-structure suppliers (like Lucent, Nortel, Ericsson, Nokia, Alcatel and Motorola), and they unfortunately had completely missed the point about the difference in voice networking and data networking and how difficult the convergence of the two is already since the days that AT&T and IBM tried and failed miserably. UMTS was the name for the solid belief that in the future all, or at least significant portions of the Internet access would take place wirelessly by using the same technology as was used for cellular phones.

I cannot describe, who everyone in the data networking world, including myself, were very skeptical about the viability of UMTS, and we have given multiple presentations at even so many conferences to show the flaws of this route and its alternatives. And it was not only the lack of success of convergence of voice and data in the past that could have predicted the overestimation and overvaluing of UMTS. Another reason was clearly the speed of the network. UMTS was defined as 2 Mbit per second under ideal circumstances: while stationary and close to a base station. Wired data networking is already moving from 100 Mbit per second to 1 Gbit per second, DSL wired networking is over 5 Mbit per second, wireless networking via Wi-Fi technology is moving from 11 Mbit per second to 54 Mbit per second and beyond. So what would be the basis for expecting a lot from 2 Mbit per second UMTS connection in 2005 anyway?

But the most convincing reason for the lack of viability of UMTS was the fact that a cell phone is not a computer. A cell phone, with it roots in the “dumb” terminal industry was built, for providing high quality voice, including being able to have a low weight, small size and long battery life: for long talk times and long stand-by times. Supporting certain data applications, like messaging, is fine, but “true data” requires a serious more powerful processor, even beyond the level of the PDA’s

today. And more powerful processors require heavier batteries. And while at it: a bigger screen and a larger keypad would come handy as well. Before we know, we have redesigned a laptop computer…. But a laptop computer has already has wireless connection, significantly faster than UMTS is going to provide….

Summarizing, the technology needs brought in via data networking requirements are in serious conflict with the original requirements for a cell phone: weight, size and battery life. A full fledged UMTS cell phone would be a compromise resembling the compromise that the industry in the past tried to make for voice and data networking, and that never succeeded: most likely it will be to clunky for a phone, and too primitive as a computer.

And the television commercial showing video on a cell phone is somewhere in the middle between a joke and seriously misleading. Unfortunately the makers of it did not even realize that this is not going to happen for a long time. The ones who paid for the advertisement probably could have known, so they did not have to write off the $B's of their UMTS spectrum investments.

Summarizing what has happened: the European governments "gave away" spectrum for free in the ISM bands (2.4 and 5 GHz) to be used for "license free" data communications, and at the same time, they sold spectrum for billions of dollars to the telephone companies for licensed data communication. Also, as shown many times, telephone companies did not understand data communication well enough, and had not learned from the mistakes in the past to try to integrate voice and data, so they bought the spectrum, to find out that it is pretty worthless with the pace the technology is developing.

The UMTS frenzy fed on the Internet industry and the belief that voice and data would converge quickly and easily in the wireless world. This drove the price up, that the wireless Service Providers wanted to pay to the European governments for buying so called UMTS spectrum. Large bidding exercises have been set-up in the UK, Germany, The Netherlands and many other European countries. The total

sum of money that has been spent on new UMTS spectrum by the European cellular phone companies beats the staggering amount of $120B.
However, in the aftermath slowly the awareness is setting in, that this money is probably all to be written off, and some telephone companies already started doing this, like Telefonica in Spain. Unfortunately, the financing of these transactions and therefore the writing off of this involves a lot of banks and financials institutions, and the consequence is not necessary already fully understood and absorbed by them.
The reality of today is, that even after a few years that the UMTS spectrum was sold, very little or none of this is being used, and most likely will not be used for anything else, than where GSM and GPRS is being used for today.

It maybe good to make some further comments about GPRS (GSM Packet Radio Service), or better the data networking capability of GSM. Actually the technological capability is pretty good, theoretical capable of supporting around 100 Kbit per second. Comparing this with the 56 Kbit per second modem speed of a wired telephone line, it actually is so good, that many of today's low end mobile data communication applications, mainly sending and receiving of messages and/or email, can already be supported.
Another good thing of GPRS is the fact, that it can be implemented in the base station of the cellular phone networks via relative simple upgrades, making it relatively inexpensive. This in the contrary with the UMTS network infra-structure that needs to be implemented from scratch: not only the equipment is totally different, it also scales differently, with other words, not the same cell size per radio station. This all means only more "bubble" trouble for UMTS. As the speed of GPRS is pretty good for the low end data applications required, and the cost to bring up the infra-structure is relatively affordable for the service providers.

The real killer for UMTS is now becoming the combination of GPRS with Wi-Fi in a public environment. This was not the planned concept of the late 90-ties, but if we have learned anything from history, this combination has all the ingredients to cost effectively deliver voice and "true" data at appropriate speeds and quality. It keeps voice and the needs of its "quality" where it belongs, including cellular telephone weight, and battery life. It also provides mobile computers what it needs, high speed, "low quality" and cost effective access to the Internet.

## 8.2 The consumer networking industry today

Somewhat similar to the battle between "telecommunications" and "computing", there are also two other industry battles going on, who both target the consumer: one battle between "computers" and "consumer electronics", and one between "telephone networking" and "cable networking". Actually these battles are being fought on two battle fields close to the consumer, one battle is the battle field to provide access to our homes (is it going to be DSL or "Cable"?), the other battle field is in our homes, our living rooms and our study rooms (is it going to be the "television", radio, etc… or the computer?). Let me explain this a little further, starting with the last one.

Also between televisions (and let me include radios, or consumer electronics in general for a completer picture) and computers, there is already some older "convergence" history, as both industries made efforts to crawl into each other's "territory".

The computer industry tried to enter the consumer space with the so-called multi-media PC. The idea was that a desktop computer can easily be converted into a radio, television, CD-player, movie theater encyclopedia, all at the same time. And indeed looking at a desktop PC nowadays with sound blasters (integrated

stereo speakers), CD-RW (readable and writable CD players), high speed Internet connection and a television card we can listen to the radio and to music and "watch" television on a desktop machine, while roaming the Internet all at the same time, even to the point, where you would wonder whether there is still space for consumer electronics.

At the same time, the television industry has been looking at data already for a longer time: one of the services on (at least European) television is something that is called "teletext". This allows the television viewer to find with the remote control "written" background information on the programs that are being watched, the important sport and news items, weather, stocks, etc. It also makes programming of the VCR easier, as recording a movie can be based on clicking on its teletext announcement. Actually, in a crude format it reminds of an early "one-way" Internet. So this was a first step of the consumer industry into the world of data in the early 80-ties – at least from an application level, and a quite useful one. I actually still use teletext almost daily for the different applications mentioned above. Interestingly it is much quicker also than via Internet.

To quote Steve Jobs, Apple's CEO when he claimed: "Watching television is switching off your brain, while with a computer what you want to do is to switch your brain on." He was trying to point to the fundamental difference between computers and televisions, at least at that time – this quote is from 1998…. Today I am not sure anymore. There are many areas where the difference between the televisions and PCs start to blur.

An example of this is providing news. About a few years ago I switched my paper Wall Street Journal subscription for an electronic (Internet) subscription. The reason for this switch was pretty flawed: I wanted to read the paper at 6 AM, and the delivery service had moved from 6 AM to 7 AM. Until that time I had always preferred "the smell of freshly printed paper" – and actually I still do today.

However, I did not want to move reading the paper to later in the morning, so I cancelled the paper subscription and saved myself some money going electronic. Let me be frank – now used to the electronic version, I do not think I want to go back to a paper version at all anymore. Stronger, in many of the Internet news services today, for instance the BBC Online News Service provides "television clips" alongside with the written news articles.

Nowadays on modern television one can split the screen in half television and half teletext. Would it be nice to be able to split it in half television and the other half being a browser, so one can watch the news and simultaneous check items being mentioned in the news, or watching a sport game, while at the same moment following the scores of some other games?

These are just a few examples. But there are many more and also more obvious ones: downloading music or movies on the computer and playing them, even on the television screen, if required, or the more recent Philips' Internet based radio and "CD player". Actually, the claim is that there are already more than 1,000 (digital) Internet radio stations.

One may debate whether reading a paper or watching a movie is something that you need to brains to be switched-on or switched off for. But the reality is, that the borders between the usage of a television (as representative for the consumer electronic industry) and the computer are blurring quickly. This has definitely consequences for the home networking as such. Currently the consumer electronics industry does not have a true home networking standard. Actually the consumer electronics does not really think "wireless" either. This is in contrast with the PC networking industry, that already established itself a solid place for in-house networking (Ethernet) and in-house wireless networking (Wi-Fi), although the network implementation is mainly between a computer and so-called "Residential Gateway", a box that connects to the wide area network.

There is a very significant difference between the consumer electronics industry and the telephone equipment industry however. The consumer electronics market has been over the years very competitive, and therefore, I do not think that the PC industry will just walk in and walk over. Still, the rate with which the consumer electronics industry is embracing the computer industry seems to be relatively slow, and the explanation could be that the consumer electronics is much more focused on design, cost reductions and large scale innovations, like recently the DVD-players or digital televisions. From the view of the consumer electronics the computer industry is probably too small, and to erratically driven by innovations. At the same time in the consumer electronics a lot of thinking is going on about networking. This is in particular driven now with the arrival of plasma displays: they make it possible to have a television screen hanging flat on the wall, and connected via a wire to the television tuner.

The residential gateway market has developed itself quickly out of the wireless LAN industry, and is coming at it from two angles. The first angle is basing this gateway on an enterprise Access Point, and adding a wide area connection (modem) to this, and it can be just plain telephone, know as (V.90), DSL or a cable modem connection. The other angle is from the set top box provider angle, where a Wi-Fi wireless LAN connection is integrated in the set top box (for cable) or the DSL box, in addition to or actually replacing the Ethernet connection.

In this light it probably good to spend some words on the cable television industry, and their position in the consumer space, as they have leveraged this to start successfully providing Internet services to the consumer. This clearly has created a marketing battle with the telecom companies, where the consumer has two options: an Internet connection coming from a telephone company with a DSL (Digital Subscriber Line, from the DSL Forum) connection, or from a cable company with a Cable connection (using the DOCSIS standard: Data Over Cable Service Interface Specification from CableLabs).

There was more to this war though, as both the telephone companies and the Cable companies are trying to conquer the homes with “a box”, a DSL box or a cable modem box, and then use this box, as a “beach head”, where over time more services can be added to, and in particular the cable industry has never made it a big secret that their target is to deliver voice telephone services as well…. And the opposing view clearly is to have the telecom DSL providers distributing television…. Well, this last one is not insight, but also how feasible the first one is going to be maybe questionable – as indicated earlier: voice “quality” is something that is from a different magnitude than that it could be offered over a “cable” network, for the same reasons as voice over the Internet has clear quality limitations.

Also, both technologies, providing Internet via a DSL box or via a cable modem box have turned out to be very expensive propositions for the service providers, and the actual consequence of this is, that the growth of the Internet by using these high speed access technologies is seriously falling behind expectations. Actually what is happening at this moment is that this industry is resetting itself to find sustainable price points for the boxes as well as the Internet access services to create a sustainable business model. Another point to mention her is that the roll out of DSL infrastructure proved to be much more expensive than expected and has taken much more time, because of all kind of quality and distance problems with the physical cabling.

One of the questions going around in the industry is: “who is going to win: DSL or cable?” Actually both technologies are a good step forward compared to the slow speed access of the past, but neither of them have a real advantage over the other. The cable industry has some advantage of an “instant” connection, but it is a shared connection at the same time, potentially suffering serious throughput degradation. The advantage of a DSL connection is a cleaner high performance switched connection that at least is made to look as an instant connection. Another

element is that the telecom service providers in general have a better relationship with the end customer, but they have to spend some serious money to provide a DSL line to the end user. The cable provider has a less direct relationship with the end customer, but probably a somewhat lower investment to make to connect an end-user.

Still it is unclear where the balance will swing. Not unlikely a newer technology will start to threaten both, interestingly a technology coming from the computer world, call ETTH: Ethernet To The Home. With this technology that should reach into 100 Mb/s to the home it carries a lot of promises. The IEEE has already a standardization working group in place working on the definition of this.

At the same time the IEEE is also working on the wireless equivalent for this ethernet to the home, called BWA (Broadband Wireless Access). This is currently under definition by IEEE 802.16.

Summarizing: the networking industry getting into the home is a big battle between the different sorts of technologies that could provide this. Cable, telephone DSL, and in the future ETTH or its wireless equivalent are the real contenders here.

But also looking in the home we are starting to create a serious wiring mesh ("mess"). There is a box from which the cables are run that distribute the television (and radio) signals through the house. These cables run parallel to the telephone cables that also go through the house, supporting the telephones in the different rooms. And sure, if you want to run a wired ethernet network through your house to connect together all the different PCs of all the family members, then it requires another set of cables running from room to room…. Each PC of each family member needs to be connected to the Internet as well clearly. Not even to mention if there is a burglary alarm system in the house, requiring another set of cables to the different motion detectors in the different rooms….

It is clear that home networking is a major opportunity for wireless networking, however, also here is the question: how is such network going to look like, and will it be integrated, or will it stay separated?

## 8.3 POTS versus VoIP

There are more industry battles going on, that are important to understand to total picture. The two more that I want to mention are POTS (or ISDN) versus VoIP. The other one is between the cell phone and the palmtop.

POTS stands for Plain Old Telephone System and is probably what most of us are still using today for their landline phones at home. In the 70-ties POTS was upgraded from analogue to digital, or from pulse dialing to tone dialing. This upgrade to digital was the step necessary to implement ISDN, however, the adoption of this technology took just so long, that before it has really taken over completely, it is already been replaced by ADSL today. By the way, sometimes on vacation in some out of range area, I have the pleasure to run into a real old tone dialing telephone system, a pleasure of nostalgia – but at the same a nuisance, because it is impossible to check your voicemail with such a system. This migration as described over the years will probably not see a real next generation. What is generally known as Internet Telephony, but what in technology terms is called VoIP (Voice over the Internet Protocol) is planning to disrupt this gradual flow of technology development. Although this promise has already been made quite some time ago, it is my expectation that slowly but surely this technology will break through, despite all the skepticism.

However, there are clear reasons why the technology development is taking "longer", but there are also clear reasons why this technology unavoidably will

break through. The reason for the delays, are the lack of user friendliness of IP telephoning, the quality of the connection and the lack of migration capabilities from POTS to VoIP. These shortcomings limit the volumes of IP-phones, so actually making an IP-phone too expensive, reducing the interest of companies to invest in this technology. So far the bad news, but in the mean time the volumes of IP-phones are slowly but surely growing to several hundred thousands per year. The reason for this growth is that there are very strong underlying economic factors that keep on pushing this technology forward to the point, that the current shortcomings will have been designed out of the system, after which this technology will break through. These underlying economic factors are in the first place the fact that an Internet call in essence is for free, once one has an Internet connection. Furthermore, the cabling for Internet telephony is much simpler than for POTS telephony, in essence in an office where today there are separate outlets for voice and data, in the future these outlets will be fully interchangeable. This will reduce the installation cost, it will make management easier, and on top of that: Internet calls and voicemails can be easier managed and routed with and via computers, than today in their separate domains.

Slowly but surely the roadblocks are moved out of the way. One serious roadblock was the fact that a phone needs power, and that this power is usually provided over the POTS (or ISDN) telephone line. Well, since about a year the concept of PE (Powered Ethernet) is making its entry into the industry. The battle for the standardization is not yet fully resolved: Cisco is trying to force the industry into their “standard”, while IEEE 802.3af is trying to set general public standard. But in the mean time products are shipping, which allow IP-phone to plug into Powered Ethernet ports, just like a normal phone, not needing its own power.

Places where IP-phones are in use today are in multinational companies that have their own Intranet domain within the Internet. Good high speed connections make the quality of telephone connections quite acceptable, and against a fraction of the cost of an external call. Internet telephony will slowly but surely take a position in

enterprises, and from there on make its way into the broader consumer market, at least for these consumers with an Internet connection.

Why is this POTS versus VoIP battle important for the wireless industry? Actually the reason is that not unlikely the wireless will help VoIP gain ground in the enterprise and from there into the worldwide telephone market. Some more background is required here. The current standard for cordless phones as indicated earlier is DECT (Digital Enhanced Cordless Telecommunications). Although the penetration of DECT technology in the enterprise is limited, the technology is mature and has come down in cost very significantly. It actually has even become more success in the consumer and residential market. But DECT as a technology is isolated, because it is not integrated in the IP world. The big advantage of wireless VoIP, or to be more precise, of Wi-Fi based VoIP is that is can seamlessly use the existing Wi-Fi infra-structure, as all the roaming protocols provided by DECT are integrated in Wi-Fi as well. But Wi-Fi based VoIP will bring DECT a step further: a Wi-Fi based DECT phone can also work, while visiting other Wi-Fi environments, for instance Wi-Fi hot-spots. Actually this creates an interesting proposition: a cordless phone that can be used in the office, that then also can be used as a phone in Wi-Fi hot-spots, as well as at home. But interestingly this phone has another implicit feature that has been touted by the telecom industry for almost a decade, but that has never found a way for easy implementation: this phone has automatic follow-me capabilities. Actually it is a Wi-Fi cell phone that can be used in all the Wi-Fi hotspots.

The next question then will clearly be: will this Wi-Fi phone also a serious competitor for the cell phone? Actually, I do not think so, but I expect the arrival of cell phones with Wi-Fi capabilities that can make calls of the Internet if in the hotspot, or at least in a Wi-Fi enabled area. Then also the next step is quite critical, being able to move in and out of a hotspot, and have the GPRS network taking over the call from the Wi-Fi network, and vice versa, when moving into the

network. This is actually how I see the future for the cell phone industry: the cell phone industry will have to further consolidate and accept Wi-Fi as a complementary opportunity for voice as well: it may be clear that also for the cellular service industry there is a future, but that future is by embracing the Internet. As a stand alone solution it will over time eradicate itself.

Interestingly enough there is another trend that needs watching: the coming of the smart phone. Already since the initial "palm" computers, there is the notion that a palmtop computer and a cell phone are pretty close, actually are overlapping. So the cell phone industry has been looking for a while to see what it takes to make a cell phone into a palmtop, while on the other hand the palmtop industry has been looking at what it takes to add telephone capabilities to a palmtop. Of the first category Nokia is the real pioneering company, although as with much new concepts, acceptance takes a while. The main roadblock for such a piece of equipment is the usability. Shorter battery life for the cell phone, because it is used as a palmtop, is a serious drawback. Bigger batteries would be he solution, but have as a drawback that the cell phone becomes larger and heavier, and not really a nice experience to keep at your ear… So, here the wireless headset, using Bluetooth, comes into the picture, where the smart phone is a palmtop computer, but has a wireless connection to a headset. If only the price of the Bluetooth headset would come down, and the battery life of this headset would be reasonable this solutions comes "in sight" for broader acceptance.

## 8.4 The Future of Networking

Well, having explored the different territories or battle fields, let's see whether we can make some future predictions about where the networking industry is going to be and what the role of Wi-Fi is going to be. The interesting part of predicting the

future is that one can be sure that the reality will be different, whatever the prediction was. Maybe therefore it might be better to discuss some scenarios, to get a better chance of success.

The enterprise is more or less the place where Wi-Fi started in the mid 1990-ties. Over the years the technology has improved and reduced in cost significantly, allowing it to go from its original data collection niches and into main stream computing. Some PC notebook models already have Wi-Fi as a standard feature. Just is commodity as Ethernet is today as commoditized will Wi-Fi be tomorrow. This means: further integration of Wi-Fi technology into the core processing of the PC, a subject that Intel is already working on for a few years, although not yet very successful up till now. From there on and with the further cost reductions, clear expansions can be expected into other types of computing: in desktop computing, really cutting the cable as the original marketing campaign in 1990 was promised.

The more interesting part will be the future of Wi-Fi itself, as this may become a more interesting subject. Just as with Ethernet, the future in Wi-Fi will be in the future higher speeds. Ethernet followed a clean path of 10 Mbit per second to 100 Mbit per second, and from there to 1 Gbit per second. Unfortunately Wi-Fi is using some more exotic stepping stones. The first IEEE 802.11 standard was 2 Mb per second, the next standard (IEEE 802.11b) was 11 Mbit per second, and the next standards (IEEE 802.11g and .11a) run 54 Mbit per second, while work is going on beyond the 100 Mbit per second (108 Mb/s is one of the stepping stones to be looked at).
Important here is the backward compatibility of all these standards, something that is worked into the standard definitions. This is in particular important in an enterprise environment, where one will not be very willing to completely re-implement the wireless infra-structure (Access Points), when a newer and higher speed standard will become available.

At the infra-structure side in the enterprise still a major trajectory is to be followed and completed. This has everything to do with the fact that both Ethernet infra-structure (switches and hubs) as well as wireless infra-structure have completely independent trajectories. An Ethernet switch does not specifically expect and Access Point on one of its connectors, and the same with the Ethernet port of an Access Point, not expecting a switch. More interestingly even: an Access Point is a fully functioning networking bridge that is running on full blown PC hardware, in essence an Access Point is a PC itself.
In particular in a larger facility with for instance a configuration of twenty access points all are hanging on a few Ethernet switches or even on just one Ethernet switch, one can think about considerable cost reductions, concentrating key functionality of the Access Points into the switches, and reducing the functionality and the cost of the Access Point to a bare minimum. The size of a complete access point can be as small as a matchbox, and should be directly pluggable on to the Ethernet connector of hub or of the standard cabling system. At the same time the price could be reduced to significantly below $50 per Access Point. One step further would be to find a convenient way back to hub, for instance through a wireless backhaul including solar cells for power….

Also the functionality can be further improved. In particular in larger facilities quite some radio planning work is required today. Together with the further integration of the functionality auto configuration capabilities are required. These configuration capabilities include the channel settings as well as the power output, managing the range of each access point. With the fact that Access Points can also hear each other, these Access Points can balance the traffic, that they need to support and with that further optimize the total configuration and response time of the total system.
This will require significant development work, not only on the access points themselves, but also in the interface definition between Access Points and

Ethernet switches, where most likely the necessary standardization work needs to be done.

The coming years we will see that GSM migrates to GPRS and gets combined with Wi-Fi for short range data services. This is not so much news, as well that in my opinion there is currently no role for UMTS, as the UMTS business case does not makes sense. Even after writing off the investment for the license, the investment of the infra-structure will be too high.

My expectation is that the business person will have four "gadgets" in the near future: a computer notebook with Wi-Fi and Bluetooth, a palmtop with Bluetooth and a cell phone with GPRS and Bluetooth, plus including a wireless headset with Bluetooth.
My computer notebook will connect directly to the Internet via Wi-Fi over a high-speed connection, or indirectly via GPRS with Bluetooth to my cell phone, for a low speed connection. My palmtop will connect via Bluetooth to my cellular phone or to my notebook computer for Internet access.
From a hardware perspective this is all pretty straightforward, from a software perspective however much more a challenge: how does my address list (or my agenda) on each of the devices stay synchronized, and how to avoid that integrity is compromised? For whoever has thought about this synchronization problem – this is far from trivial, in particular if an address card is updated on both two devices before synchronization has taken place. The better solution clearly is, to avoid duplication, and to make sure that there is only one card stored altogether, but that is not necessary trivial either.
This synchronization problem will even grow one dimension more complicated if there is a desk-top PC at home, as well as a desktop PC in the office. Keeping track of what is where will become more complicated, and actually end up in the notebook computer becoming the dominant business tool altogether, despite the fact that it is about twice as expense compared to desktop – a difference that is

expected to continue in the future. But if there is a synchronization requirement between these PC's the connection between these computers will be dominated by Wi-Fi wireless technology.

The immediate question that comes forward is whether the number of four devices can be reduced. One combination could be to integrate the cellular phone and the palmtop. There have been already many efforts going into this direction, actually coming from both directions: adding palmtop functionality, in particular short email, agenda, contacts and calculator capabilities to the phone or adding phone capability to a palmtop. One of the roadblocks has been the battery life and the weight of this device, but assuming that a Bluetooth headset will become more or less the standard, this will be a feasible solution from a weight perspective: one at least does not have to keep all this weight to the ear all the time. Still the battery life and the weight will be somewhat of a challenge, both for the Bluetooth headset, as well as for the combined cell phone palmtop, but I expect that this will be solution that will be quite accepted in the market place. However, in shear number units I think the simple cell phone as well as the simple palmtop will beat this combined unit for quite some time.

Let's in the mean time not forget the watch. Is a watch a jewel, like an [armband] or is it a functional device that could and should be synchronized with your notebook computer, preferably with wireless? I think there is maybe room for both approaches, although to get something useful out of a watch will require a sophisticated user interface to be friendly.

But now being at the subject, what about combining the notebook computer, the cell phone and the palmtop into one device altogether? I think that this would be a feasible solution, however, the weight and the battery life of the laptop to carry this around is not very attractive. Still, if the price of a GPRS radio has come down enough, that the PC industry is interested in integrating this, it seems to be a

logical solution. The Bluetooth headset talks directly via Bluetooth to the notebook in the briefcase. It would be interesting if the notebook could be even in sleep mode as well.

## 8.5 Wireless Networking all over

This journey of Wi-Fi may have started in the late 1980-ties, and was off for a slow start, as many technical and market barriers had to be conquered. In reality it has so far been just a small start of what is expected to come in the future years. The coming years will show a significant growth of the usage of the Internet, and much more equipment to be connected on the Internet. Also the expectation is that in the future more "non-computer" equipment, actually peripherals or devices, will be connected to the Internet, about this later more. Actually the expectation is that the number of devices connected to the Internet will rapidly completely outnumber the number of computers.

To avoid cabling to become a major limitation of this growth the need for wireless technology will become even more critical. Actually, as wireless technology in itself will just follow the lines of faster products that are becoming very small in size, that will use less power and of which the price will continue to drop to a bare minimum. What is really going to be interesting is the growth in the usage of the Internet, with more management and control type applications, and therefore creating the pull through for wireless technology as a key enabler for those applications. In this respect both GPRS and Wi-Fi will play a role, and these applications will have an awareness of a slow connection (GPRS) or a fast connection (Wi-Fi). This knowledge will take care that in case of the slow link only the most necessary information will be transferred, and a "full synchronization" will take place when the fast link is available.

The consequence of wireless in a business environment will be a permanent connection of every employee to the network, both for voice and for data independent, whether this employee is an inside or an outside worker. Paperless will become the norm, electronic forms the standard way of operating and immediate access to key information necessary to execute the job will be come vital – even more than it is already today. Actually it is going to take a few more years, before the application space in the business environment has caught up with the technical capabilities of anytime, anywhere (wireless) access to the company's resources. In that respect it is interesting to mention, that I completely disagree with anyone saying that last decade spending on automation was completely wasted. Sure, there was waste, but comparing the ways we ourselves operated in the late 80-ties compared to the recent years is showing a key acceleration in accuracy, timeliness and in general being "on-top".

At the same time I do not want to deny that with every two steps forward, there possible was also sometimes a step back. In this light I vividly remember the complaints about the hundred plus emails that daily filled my inbox in the office. At the same time a complaint about this is not new, as also from the 1980-ties I remember the (paper) inbox piling up. I think it is a "law" that work always will pile up to the level that someone is barely able to handle, independent from what period of time that one lives in. But this does not take away the fact, that today more work can be done more efficiently with less people, which is a form of creating wealth, while at the same time an opportunity to do more.

But more than in the business environment I am excited about the "progress" that can be made in the consumer environment, which is an attractive environment for the Wi-Fi business development, as because of its volumes it is a key opportunity. But also here we will have to wait until the applications are developed to support new Internet consumer applications, or maybe even more: the time it will take for

new “behaviors” to establish themselves in consumer environments. In this respect it is interesting to see where consumer spending is going, where the major consumer “annoyances” are, and how efficient improvements can be made.

Energy management in a household will become more important, as energy for the decades to come will continue to be a scarce resource, and the reduction in energy usage will also reduce environmental pollution. Despite our energy bills are sizable, energy management in our homes is limited, if not, absent. Usually we have little idea what equipment is using what energy, and although probably 20% of our household equipment is using 80% of the energy, I wonder whether many people know what the 20% consists of.

But probably even more than usage, the control and management of energy, in particular the forecasting of usage is creating waste of energy: inventory of available energy have the tendency to “age” if not used quickly. So major energy saving can be achieved by more awareness and better prediction. For both wireless and Internet connectivity will be the key, which requires that every piece of relevant electronic gear will have a energy control “chip” and a radio “chip”, where a computer with the necessary software will operate as the control board. This is coupled to an application that helps to predict the energy usage, and one can even imagine that a correctly predicting user gets his energy at a lower rate, than when this mechanism is absent.

A directly related application can be the (preventive) maintenance of electronic equipment, although I must say, that I would be somewhat more skeptical about such an application, as quality of products is improving so much, that at this maybe not a justifiable implementation, although including a car or the house’s heating and air conditioning installation probably can be controlled and preventively managed more than is the case today.

Another application may be the inventory management of goods in the house. All goods today have a UPC (Universal Product Code), identified with a barcode. Despite the dropped prices for barcode scanner, I do not yet know about any private use of these codes for home inventory management and reordering. Keeping a manual shopping list is still the preferred way.
At the same time, ordering of the weekly home shopping and delivery over the Internet is growing in popularity. This "application" could be the basis of an extension into management, and then coupled with retail organizations it could be connected to their forecasting systems. That both wireless and the Internet play a role, as one of the prerequisites for this would be another "computer in the kitchen". I know people who are using this already, also to get new recipes from the Internet.

Other applications in the home environment are starting to develop in the area of medical control and support. These applications today are usually not wireless, and do not run via the Internet, but directly via the computer into a hospital system. This requires more individual and expensive application development than necessary compared to a more standard Internet related application development. When homes are "wireless enabled" the automatic positive consequence is also a standard infra-structure can be assumed that is not bound to a specific room in the house or requires cabling. When this way the infra-structure is simplified it will be easier to check and control patients without having to have them in a hospital, another way to reduce the cost of our healthcare systems.

I think that the number of applications in the household will grow quickly, once the infra-structure is in place. Regulating room temperatures, home security, Internet radio and television, the sky is the limit once the basic conditions of a solid and standard infra-structure are established. But these examples are not even mentioning the role that wireless Internet, and the easy access to it, can play for home entertainment in general, or on the back of it, for home based education –

from the philosophy that learning and playing are synonym. But the bottom line is the fact that home networking has just started, and will create many new horizons.

## 8.6 An additional but different viewpoint: telematics

It is always fun to sometimes run into a different viewpoint, and try to think where this would lead us. This different viewpoint is based on the notion that one is usually not further away from his car than say 1,000 feet. Living in down-town Utrecht in The Netherlands, where parking is a higher art, this maybe not completely true, but in general it is amazing how true this is.

So the different viewpoint comes from thinking about the car as the center of the data networking. This is already required in itself, as the car in the world of telematics is already a complete info and communication center. Understanding that my notebook computer is already a personal extension, likely my car is as well. What about a configuration in which my car has a GPRS connection as well as Wi-Fi connection to the outside world, and my notebook has a Wi-Fi connection to my car?

# 9 Epilogue

Going through the history of Wi-Fi it is always interesting to think back about the critical moments and what could have gone differently: “what-if”. Is history filled with lost opportunities or is it a miracle that we “made” it after all? Sometimes there is that oblique answer: “future will tell”, but I am afraid that this will not be the case. Very quickly Wi-Fi will be gone up in the mainstream of communication technologies and protocols like Ethernet, DSL, USB, V.92 and the likes.

Critical moments in the industry were clearly getting the 802.11b standard agreed on, as at moment the standardization committee was very close to “going up in smoke”, and if that would have been the case, most likely the industry had taken another route, probably via an extension of Bluetooth.

Another critical juncture was the acceptance of the technology at least by one PC vendor (Apple) creating a beachhead from where the market has built. At the same time the question is how much of a blessing in disguise this was: the price was pushed down so heavily that commoditizing happened so fast, that relatively few companies have enjoyed a sustainable growth; but this maybe not something to look for in the world of Information Technology development anyhow.

A critical juncture for us personally was when Lucent Technologies decided that wireless data was going to be GPRS and UMTS (3G), and that Wi-Fi would never find acceptance in the market. Many things could have happened to us, the most logical that all the WaveLAN would have stopped right then and there. Probably the industry would have proceeded without us without a hitch, although if a well known company that is market leader in a new technology decides to abandon ship, that would definitely give the market a serious blow.

The conclusion might very well be that one can compare the world of Information Technology with shooting stars. A new idea sublimated into a product looking for a market, suddenly starting to shine like a star and then find itself absorbed by its environment before even one realizes.

Let’s go for the next idea!