WHITE PAPER

5G RedCap: RF Implications for IoT Devices

Introduction

The global transition to 5G is in full swing, with more than 1 billion connections expected by 2023. To date, 5G has primarily been used for smartphones and fixed wireless access (FWA) applications. While those are critical use cases, the potential applications for 5G are much broader – and over the next few years, 5G will expand in scope to cover many more applications and device types.

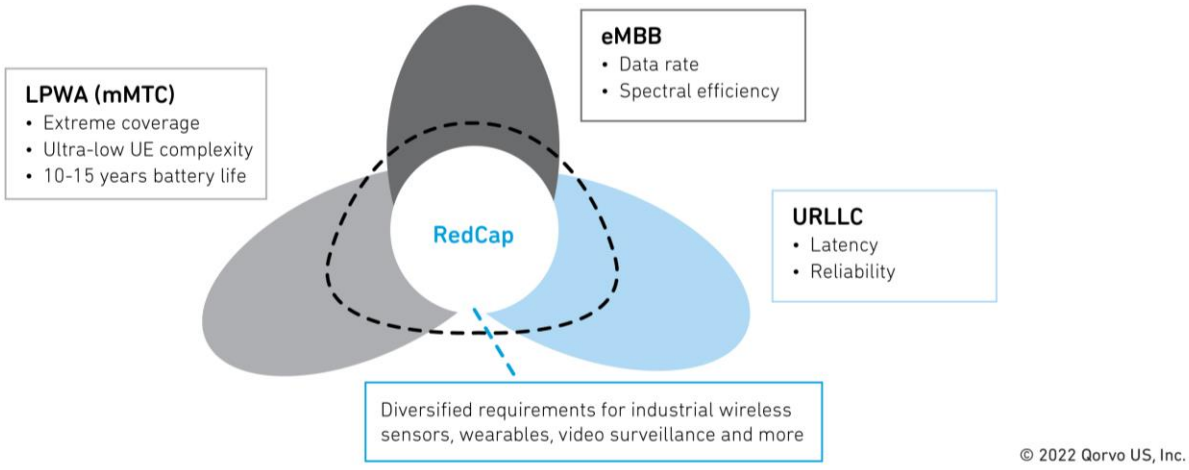
5G Reduced Capability (RedCap) is a key step in this evolution. It's the first 5G standard designed for the vast and growing Internet of Things (IoT) landscape. RedCap aims to meet the requirements of IoT devices that need smaller, less complex, lower-cost RF solutions with better battery life than existing 5G offerings. The first set of RedCap specifications were defined in 3GPP Release 17 and finalized in mid-2022, with chipsets and end-user products expected to become available over the next 1-2 years. These specifications focus on three application areas: wearables, industrial wireless sensors and video surveillance.

This white paper dives into RedCap specifications, IoT application requirements, development timelines and the RF implications for IoT device manufacturers and wireless carriers.

Why is RedCap Needed?

5G ultimately will support an enormous range of new and existing use cases. These use cases are typically divided into three broad categories or pillars. Each pillar has a different set of requirements, as shown in Figure 1. RedCap will support a subset of applications with low to moderate RF requirements across the base of all three pillars.

Figure 1. RedCap fits into the 5G landscape.



Advantages for IoT Device Makers

For manufacturers of IoT devices, RedCap provides the advantages of 5G but with lower RF complexity and cost than currently available 5G solutions. Key benefits include higher speeds than the existing low-power wide area (LPWA) IoT network standards LTE-M and NB-IoT. Additionally, manufacturers are likely to be able to choose from a variety of 5G RedCap services tailored to the needs of specific IoT applications, offering different data rates, latency and levels of availability.

Advantages for Carriers

RedCap will help carriers transition from non-standalone 5G networks (which require them to maintain 4G links for device connectivity) to standalone (SA) 5G networks. SA networks offer carriers huge advantages in cost and efficiency. SA networks also create new revenue-generating opportunities; carriers can take advantage of 5G's dynamic network slicing capability to create customized services for different applications and connect millions of new devices.

RedCap Applications

The initial RedCap specifications defined in 3GPP Release 17 target three use cases: wearables, industrial wireless sensors and surveillance video. These use cases have differing requirements in terms of wireless data rate, latency, availability, size and battery life, as shown in Table 1.

Table 1. RedCap use cases targeted in 3GPP Release 17.

Use case	Example devices	Data rate	Latency	Availability and reliability	Battery life	Size
Wearables	Smartwatches, VR headsets, health monitors	5-50 Mbps DL, 2-5 Mbps UL (peak rate up to 150 Mbps DL/50 Mbps UL)	N/A	N/A	At least a few days, up to 1-2 weeks	Compact
Industrial wireless sensors	Motion, pressure, temperature, humidity sensors, many new and existing applications (e.g. autonomous wireless forklifts)	2 Mbps	<100 ms	99.99%	At least a few years	N/A
Video surveillance	Smart cities, factories, agriculture	2-4 Mbps for basic applications, 7.5-25 Mbps for high-end applications	<500 ms	99%-99.9%	N/A	N/A

RF Challenges and Solutions

To meet the needs of IoT devices, RedCap RF solutions must offer reduced size, improved battery life and lower cost than earlier 5G solutions. To meet those goals, RedCap requires much less RF complexity compared to the 5G RF solutions in smartphones. These reductions in complexity are feasible because RedCap devices – unlike smartphones – do not need extremely high data rates.

Table 2 summarizes key differences in RF requirements between RedCap devices and 5G smartphones.

Table 2. RF requirements for RedCap devices vs 5G smartphones.

	Frequency Range 1 (<7 GHz)		Frequency Range 2 (mmWave)	
	Smartphone	RedCap Device	Smartphone	RedCap Device
Maximum bandwidth	100 MHz	20 MHz	200 MHz	100 MHz
Maximum number of antennas	2 or 4 depending on frequency band	1 or 2 depending on frequency band	2	1
Maximum number of MIMO layers/Rx chains	2 or 4 depending on frequency band	1 or 2 depending on frequency band	2	1
EN-DC support	Required	Not required	Required	Not required
Maximum downlink modulation	256 QAM	64 QAM	64 QAM	64 QAM
Duplex operation	Full-duplex FDD or TDD	Half-duplex FDD or TDD	TDD	TDD
Maximum transmit power	Power class 2 (26 dBm) or power class 3 (23 dBm)	Power class 3 (23 dBm)	Power class 3	Power class 7

Here's how the differences between RedCap and 5G smartphone RF solutions help to reduce power consumption, size and cost:

- **Narrower bandwidth.** RedCap devices are only required to support 20 MHz maximum bandwidth in 5G frequency range 1 (Bands < 6 GHz), compared to 100 MHz for smartphones. This reduces power consumption and extends battery life.
- **Fewer frequency bands.** While premium 5G smartphones may have 50+ bands to support global use, RedCap devices will support fewer bands – resulting in lower cost and smaller size. Even high-end wearables such as premium smartwatches may have a regional subset of bands, plus a few for international roaming. Simpler IoT devices may need just a few bands, especially if they're designed for use in a single location.
- **Standalone 5G networks only.** RedCap devices won't be required to support non-standalone networks, so they won't need to have two simultaneously active Tx chains in order to provide dual 4G/5G connectivity (EN-DC). This greatly reduces the RF complexity, solution size and power consumption.
- **No 2G/3G support.** RedCap devices don't need to support legacy 2G/3G networks, so they won't need 2G/3G PAs, which can consume a considerable amount of power.
- **No carrier aggregation (CA).** RedCap devices are only required to use one frequency band at a time, unlike 5G smartphones which use CA to achieve higher data rates by communicating on multiple bands simultaneously. Therefore, RedCap solutions won't need the complex filters required to support CA. That helps to reduce insertion loss, complexity and cost. Lower insertion loss translates into lower power consumption and extended battery life.
- **Fewer antennas and Rx chains.** RedCap devices have much lower MIMO requirements than 5G smartphones. While smartphones must support 4x4 downlink MIMO in most bands – requiring four cellular antennas and four independent Rx chains – RedCap devices will need to support only one or two cellular antennas and Rx paths, depending on the band. This reduces current consumption, solution size and cost. It also makes it easier for manufacturers to design highly compact wearables and other IoT devices.
- **Half-duplex communications in FDD bands.** RedCap introduces the option for half-duplex instead of full-duplex operation in FDD bands. As a result, some RedCap applications, such as inventory/asset trackers,

may not need the duplexers that are required to support full-duplex operation. Those applications may instead be able to use simpler filters and switches, reducing cost and insertion loss.

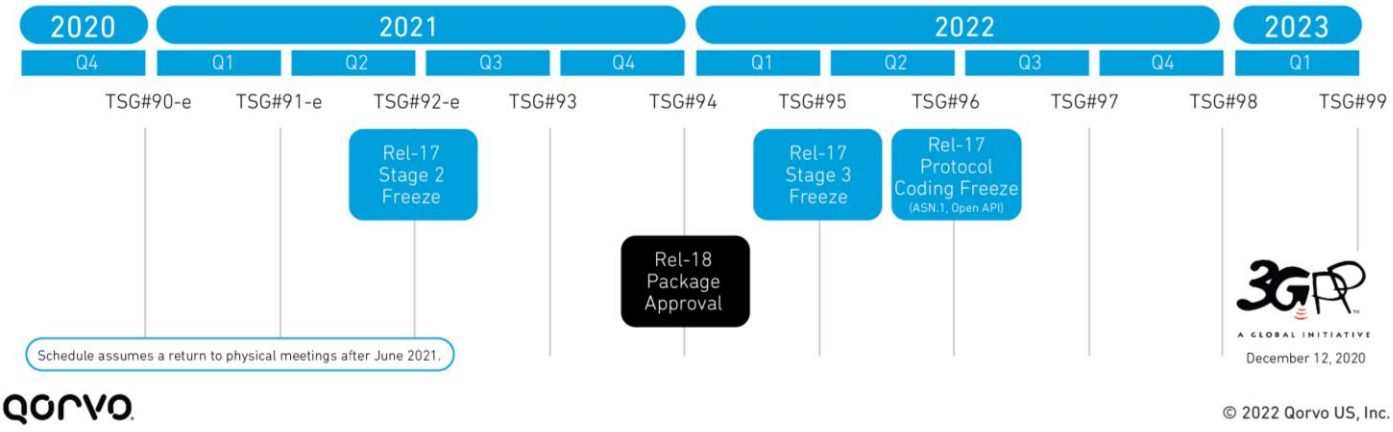
- **Lower transmit power requirements.** The maximum power output requirement for RedCap devices is generally lower than for smartphones. This reduces power consumption and extends battery life.
- **Integration**. The level of integration in RedCap RF solutions will vary depending on the application. For some wearables, size is extremely important – so premium smartwatches will likely include highly integrated solutions. For other applications, such as surveillance cameras, size is less important and therefore less-integrated solutions may be used to reduce cost.

RedCap Timeline

The initial RedCap specifications were finalized in mid-2022 in 3GPP Release 17 — but that's just the first step for this standard. Chipsets and RF solutions typically arrive about a year after a standard is finalized, and end products using those solutions appear after about 2 years (i.e. in 2024). By that time, many carriers will have transitioned to the standalone 5G networks that are necessary to support RedCap devices.

Meanwhile, 3GPP is continuing to enhance the RedCap standard and is in the process of defining new features to be included in Release 18. 3GPP is also studying ways to further reduce RF complexity and cost and extend battery life. Specific features under consideration include:

- **Positioning.** Improvements in narrowband (NB) positioning for RedCap applications.
- **Lower speeds** to bring RedCap functionality down to the level of LPWA networks, with a potential reduction in bandwidth to 5 MHz.
- **Sidelink** – direct communication with other 5G devices. For example, a smartwatch could communicate directly with a phone or headset, instead of communicating via a 5G base station. This reduces latency and power consumption.



Conclusion

RedCap is an important addition to the cellular network options available to IoT device manufacturers. The promise of RedCap is that IoT manufacturers will have access to RF solutions that are smaller, less expensive and use less current than currently available 5G solutions. This will enable manufacturers to build compact IoT devices that support 5G networks, offer extended battery life and deliver higher data rates than devices using older IoT network standards.