GTI
Technical Specification of 5G RedCap Lightweight Universal Modules

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Support members	Sercomm
Editor	Lei Cao(CMCC), Songhe Lu(CMCC), Tianming Jiang(CMCC), Hang Ruan(CMCC), Xin Li(CMCC), Kangwei Zheng(CMCC), Xianda Zhang(QUECTEL), Qingchun Gao (QUECTEL), Wei Pan(QUECTEL), Sunzhi Liu(Fibcom), Zhiping Yang(Fibcom), Dingwei Lu(SIMCom), Changshun Tan(SIMCom), Gongda Fan (MEDIATEK),Jianwei Zhang (MEDIATEK), Birui LI(MEDIATEK), Wentao Zhang(QUALCOMM) , Hong Qiu (QUALCOMM) , Siyun Yang(QUALCOMM) , Wei Guan(QUALCOMM) , Sicong

	Zhao(UNISOC) , Zhiqiang Yun (UNISOC) , Jiancheng Hu(UNISOC) , Weicheng Li(ASR), Jian Xu(ASR), Xin Liu(bluewave), Yuanchun Tan(bluewave), Kun Yang(TD Tech), Wen Qin(TD Tech), Shengmiao Kong(TD Tech), Qian Wang(TD Tech), Guanyi Wang(TD Tech), Jing Ding(Hongdian),Tao Zhang(gt+), Shibin Tang(Four Faith)
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1 Abbreviations

Abbreviation	Explanation
BWP	Bandwidth part
CAG	Closed Access Group
CD-SSB	Cell-Defining SSB
DRX	Discontinuous Reception
eDRX	Extended DRX
IFRI	IntraFreqReselectionRedCap
MIB	Master Information Block
NCD-SSB	Non Cell-Defining SSB
NSSAI	Network Slice Selection Assistance Information
PRACH	Physical Random Access Channel
RACH	Random Access Channel
RedCap	Reduced Capability
RRC	Radio Resource Control
RRM	Radio Resource Management
SIB	System Information Block
TDD	Time Division Duplex
URLLC	Ultra-Reliable Low Latency Communication
UE	User Experience
VoNR	Voice over NR

2 Introduction

2.1 Development of 5G Mobile Network

China Mobile has built the world's largest 5G mobile network. As of May 2023, China Mobile has deployed over 1.62 million 5G base stations and is actively enhancing its capabilities in utilizing RedCap technology.

2.2 Development of 5G Terminals, Chips & Modules

In the realm of chip products, the development and research of 5G terminal chips have progressed through three stages since 2017: prototype terminals, baseband chips and SoC chips. The chip process has evolved from 10 nm to 6 nm, and currently to 3 nm. Since September 2019, major chip manufacturers, such as HiSilicon, MediaTek, Qualcomm, Samsung and Unisoc, have not only released commercial 5G SoC chips but also conducted comprehensive testing to verify their chip performance. In 2021, chips compliant with the 3GPP R16 standard, such as Snapdragon 8 Gen 1 and MediaTek Dimensity 9000, were successively released for commercial use and underwent the necessary tests for new features introduced in the 3GPP R16 standard, including MDT, carrier aggregation enhancement, and terminal power-saving. Currently, multiple chip manufacturers are actively planning and developing 5G chip products as per the 3GPP R17 standard, with commercial release expected in the second half of 2023. New features introduced in the 3GPP R17 standard, such as Redcap, are currently undergoing technical verification.

In the realm of module products, multiple models have achieved compliance with the 3GPP R15 standard. Currently, over 30 module models are available commercially at prices ranging from 400 yuan to 500 yuan, in M.2 or LGA packages, and in different sizes, such as 30 mm × 52 mm, 41 mm × 44 mm, and 52 mm × 52 mm.

2.3 Status Quo of RedCap Standardization

The 3GPP R17 standard, which was frozen in June 2023, defines the types of RedCap terminals to ensure the low complexity, cost-effectiveness, small form factor, and lower power consumption of terminal devices used in medium-speed and low-speed IoT (Internet of Things) applications, such as industrial wireless sensors, videos & monitors, and wearable devices. Building upon the 3GPP R17 standard, the upcoming R18 standard will focus on further research and development to reduce terminal costs, improve terminal power-saving capabilities, evaluate and enhance the positioning performance of RedCap terminals, and foster the development of the RedCap ecosystem.

With the completion of the 3GPP R17 standard for RedCap, CCSA has initiated the development of industry standards for key RedCap technologies. In June 2022, TC5WG9#120 meeting approved the implementation of industry standards for 5G RedCap terminal devices (Phase I). Subsequently, the TC5WG9#123 meeting approved the implementation of industry standards for general-purpose 5G RedCap modules (Phase I). These milestones laid a solid foundation for widespread application of RedCap technology.

2.4 RedCap Use Cases

■ Video & Monitor Devices

With the implementation of "Safe Cities" program and the advancement of smart society initiatives, there is an increasing demand for video and monitor devices in the market. In certain areas where wired network connections are challenging or impractical, the need for robust wireless network capabilities for video data transmission becomes crucial. Additionally, industry policies are driving the adoption of 5G technology in the security sector. The "14th Five-Year" Development Plan of China's Security Industry explicitly emphasizes the accelerated implementation and widespread application of wireless communication technologies, including 5G, within China's security industry.

Based on the data in Table 1-1, videos and monitors prioritize system capacity over individual user network speed, latency and reliability. While the requirements for single-user performance

may not be significant, the ability to support multiple users concurrently is becoming crucial for optimal performance.

Table 2-1 Video Data Transferred Under Different Network Conditions

Resolution	FPS	Data Rate (Mbps) (H.265)	Latency (ms)	Reliability
720P	25	1.82	< 500	99–99.9 %
1080P	25	4.11	< 500	99–99.9 %
2K	25/30	8.76	< 500	99–99.9 %
4K	25/30	19.71	< 500	99–99.9 %

5G RedCap is capable of effectively supporting various video and monitor use cases, utilizing the 100M bandwidth of 5G network to ensure ample system capacity for video data transmission, while also contributing to terminal cost reduction.

■ Smart Electric Power

Electric power industry is a key sector for integrating the "5G-plus Industrial Internet" mode, as outlined by the MIIT (Ministry of Industry and Information Technology of the People's Republic of China). The electric power communication network plays a crucial role in supporting the development of smart electric power grid, ensuring the safety, punctuality, timeliness, accuracy, and reliability of different electric power-related processes, including generation, transmission, substation operation, distribution, and utilization. In particular, electricity distribution requires low latency and highly reliable networks for tasks such as differential protection, remote distribution automation, precise load controls, and distribution integrated monitoring. Furthermore, to ensure the safety of electricity generation as well as the confidentiality of information, it is crucial to isolate the electric power generation control areas and the information management areas to prevent any potential information leakage. However, the existing 4G networks and electric power private networks are unable to meet the high requirements set by electric power procedures in terms of isolation and security.

Table 2-2 Requirements for Smart Electric Power

Procedure	Latency (ms)	Data Rate	Reliability	Time Distribution	Isolation	Average Connection

Distribution PMU	≤ 50	≥ 2 Mbps	99.99 %	1 μs	Physical isolation	X per km^2 X ≤ 10
Distribution differential protection	≤ 80	≥ 2.5 Mbps		< 10 μs	Physically separate power generation control areas from information management areas; logically segment internal areas	X × 10 per km^2 X ≤ 10
Three remote distribution automation	≤ 100	Remote signaling, telemetry ≥ 1kbps Remote control ≥ 100kbps		/	Physically separate power generation control areas from information management areas; logically segment internal areas	X × 10 per km^2 X ≤ 10
Smart distribution room	≤ 200 (data collection procedure) ≤ 50 (control procedure)	20–100 Mbps	99.90%	/	Physically separate power generation control areas from information management areas; logically segment internal areas	5-10 per km^2 1-5 working concurrently

5G RedCap leverages the excellent technical features of 5G network, such as low latency, high reliability, network slicing to effectively meet the specific requirements of electric power

industry while reducing terminal costs.

■ Smart Manufacturing

With the advancement of the national strategy "Made in China 2025", the manufacturing industry is undergoing a significant shift towards informationization, digitalization, and smart manufacturing. The industrial digital transformation necessitates increasing network connectivity, cost-effective terminals, and reduced power consumption.

Smart manufacturing encompasses various use cases, including smart logistics, manufacturing monitoring, and smart unmanned inspection.

Smart logistics primarily focuses on assembly line logistics and smart warehousing. Assembly line logistics involves timely and precise distribution of materials along assembly lines, from upstream to downstream workstations, as well as from workstations to buffer warehouses and from centralized warehouses to assembly line warehouses. Smart warehousing enables the automation and smartization of logistics terminal control, as well as the storage, movement, and sorting of inbound commodities. This is achieved through the use of devices such as inner-factory AGVs (Automated Guided Vehicles) and robotic arms. In the context of smart logistics, it is crucial to have low network latency and high network reliability during material distribution at fixed locations and scheduled times, as well as remote control operations.

Manufacturing monitoring ensures the safety and management of manufacturing operations by implementing extensive smart monitoring and management systems in industrial zones, factory areas, or workshops through the use of multiple sensors, cameras and data monitoring terminals that capture the data on the surroundings, employee activities, and device performance. The collected data is transmitted to the manufacturing monitoring system for precise recognition of manufacturing activities, customized alarms, real-time monitoring of manufacturing areas, prompt identification of abnormal statuses. Effective manufacturing monitoring requires not only low network latency and high network reliability for safety management and real-time

alarms, but also high uplink data rate for transferring video data to the monitoring system.

Unmanned smart inspection involves conducting tests, inspections, data recording, and remote alarm verification using inspection robots instead of human labor. It relies on capturing on-site videos, voices, and snapshots to gather data. Unmanned smart inspection has specific requirements for low network latency and high uplink data rate to ensure smooth the remote control and efficient transfer of video data.

Table 2-3 Network Requirements for Smart Manufacturing

Use Case	Data Rate (Mbps)	Latency (ms)	Reliability
Smart logistics	1	< 50	99.9%
Manufacturing monitoring	Uplink 2–10	< 50	99 %
Unmanned smart inspection	Uplink 10–20	< 50	99 %

Featuring low network latency, high reliability and fast data rate, 5G RedCap terminals are suitable for various applications, such as smart logistics, manufacturing monitoring, and unmanned smart inspection etc. These terminals reduce terminal cost and power consumption in these use cases.

■ Petroleum Exploration

Energy safety is of paramount strategic importance for the country's economic development, overall prosperity, improved living standard, and long-term social stability.

Petroleum exploration primarily relies on the geophysical method known as "seismic exploration", which involves recording and analyzing seismic waves with node seismographs to estimate the storage capacity of crude oil and natural gas. At present, oil & gas cable technology is widely utilized in the majority of petroleum exploration devices in the international market. However, this technology is not only monopolized by overseas companies but also exhibits several limitations, such as the requirement for cable connections in all seismographs, significant manpower consumption, limitations in uncommon terrains, and difficulties in troubleshooting

problems. To facilitate the seismic data collection in the process of petroleum exploration, there is a growing demand for efficient cableless seismograph data collection systems. However, these systems face limitations in transferring massive real-time data and lack adequate measures to control construction quality. Consequently, there is an urgent need for more advanced communication technologies featuring massive connections, high data transfer rates, and cost-effectiveness in seismic data collection systems.

Table 2-4 Network Requirements for Petroleum Exploration

Use Case	Data Rate	Connection
Seismic data collection node	Uplink 24 kbps per node	320 per km^2 (target coverage: 100–128 km^2)

With the required data rate for seismic data collection nodes, 5G RedCap ensures cableless and extensive real-time collection of seismic data through multiple nodes, thereby decreasing construction issues and lowering deployment costs.

3 Communication Capability Requirements

With the widespread adoption of 5G system, the 3GPP R17 standard has introduced RedCap technology to meet the requirements of medium-level IoT applications, such as industrial wireless sensors, videos & monitors, and wearable devices, etc. The main objective of RedCap technology is to minimize terminal device complexity, size, costs and power consumption, resulting in cost-effective solutions with extended terminal life.

Underpinned by RedCap technology, which prioritizes cost-effectiveness and low power consumption, general-purpose 5G RedCap modules have seamlessly integrated key technologies necessary for industrial applications.

3.1 Mode Requirement

General-purpose 5G RedCap modules should support at least 5G (SA) network mode. Currently, it is recommended to support 4G. Once the 5G RedCap network coverage matches that of 4G, either 5G or 4G can be selected.

3.2 Frequency Band Requirement

The inclusion of various features, such as multiple modes, frequencies, and voices, in RedCap terminals may contribute to increased terminal costs. Therefore, it is recommended to estimate the costs as per different use cases and industries.

3.3 Antenna Capability

The modules should support 1T2R (1 transmitter and 2 receivers) for effective communication.

3.4 AP/MCU Requirements

R17 stage, the module's CPU clock speed should not be below 1GHz. Additionally, to ensure the seamless operation of communication protocols and the operating system, the module should have a minimum RAM + Flash ROM configuration of 128 MB + 128 MB.

3.5 RedCap Technology Requirements

3.5.1 Basic Capability Requirements

For the FR1 system, it should support a maximum system bandwidth of 20MHz. The DL/UL channel modulation scheme should support at least 64QAM. To reduce the RedCap UE buffer requirements, the PDCP SN and RLC-AM SN length should be adjusted from 18 bits to 12 bits.

3.5.2 BWP Requirements

In the initial BWP and business-specific BWP configuration, independent BWP should be supported.

- Initial Downlink BWP

The network can configure an independent initial downlink BWP for Redcap terminals in system messages, and the bandwidth of this BWP should not exceed 20MHz.

When the independent initial downlink BWP configured by the network includes CD-SSB and the entire CORESET#0, Redcap terminals in idle or non-active states should support receiving SIB and monitoring paging in this independent initial downlink BWP.

When the independent initial downlink BWP configured by the network does not include CD-SSB and CORESET#0, Redcap terminals in idle or non-active states should support receiving SIB and monitoring paging messages on CORESET#0.

- Initial Uplink BWP

When the frequency domain position of the network on the NR carrier is the flexible configuration of the RedCap terminal to flexibly configure the independent uplink initial BWP, Redcap terminals should support random access on the independent initial uplink BWP and support the configuration of PUCCH-ResourceCommon-Redcap-R17 to realize the independent Common Pucch resource configuration of the RedCap terminal.

- Business-specific BWP

The modules should support the ability to configure dedicated BWP for uplink and downlink, and support the configuration of NCD-SSB for downlink dedicated BWP. Should support RLM and serving cell measurements based on NCD-SSB in RRC_CONNECTED state. Should support the ability to configure multiple BWP.

3.5.3 Access Control and Terminal Identification

In terms of access control, the network indicates in the SIB1 system information of the 5G cell whether RedCap terminals are allowed to select or reselect to the same frequency cell when the cell is in a barred state, through the IFRI (IntraFreqReselectionRedCap) field. When the SIB1 does not carry this field, it means that the cell does not allow RedCap terminals to access. RedCap terminals should choose to stay in 5G cells that support RedCap by receiving and correctly parsing the IFRI field to determine whether the current cell allows RedCap cell selection or reselection. At the same time, the base station should inform RedCap terminals whether they meet the access conditions through the cell barred indication information in the MIB, and the terminals should support the ability to correctly parse the cell barred indication information in the MIB.

In terms of terminal identification, RedCap terminals should be able to report their RedCap capability to the network equipment through MSG1 (PRACH occasion, PRACH Preamble), MSG3 (LCID), and UE Capability Information messages.

3.5.4 Residency and Mobility Management

Redcap terminals in idle and non-active states should support the ability to reside in and perform cell selection and reselection between RedCap-supported cells. Redcap terminals in connected state should have the ability to switch between RedCap-supported cells according to network configuration.

3.5.5 Redcap Power Saving

RedCap is designed around reducing power consumption and mainly includes the RRM measurement relaxation mechanism and the extended discontinuous reception (eDRX) power optimization feature.

- RRM measurement relaxation

In idle and inactive states, the network can configure the trigger conditions for RRM measurement relaxation through system messages. When the Redcap terminal meets the trigger conditions, it relaxes the RRM measurement for neighboring cells in order to save terminal power.

In connected state, the network can configure the RRM measurement relaxation conditions through RRC reconfiguration messages. When the Redcap terminal meets the trigger conditions, it reports the information to the network through User Auxiliary Information (UAI), and the network decides to configure appropriate measurement parameters to relax the measurement in the connected state, such as reducing the measurement of neighboring cell frequencies and extending the measurement period.

- eDRX

In idle mode, the periodic wake-up and paging of the terminal are the main factors affecting power consumption. In order to further reduce terminal power consumption for applications that are not sensitive to delay, RedCap introduces the eDRX power saving feature, which extends the terminal's listening and paging period, allowing the terminal to enter sleep mode when not listening for paging.

For modules in RRC_IDLE state, the maximum eDRX period is extended to 10485.76 seconds, and for modules in RRC_INACTIVE state, the maximum eDRX period is extended to 10.24 seconds. Using a longer eDRX period can increase the terminal's sleep duration and reduce the terminal's standby current.

3.5.6 RF Indicators

The modules should meet the corresponding frequency band requirements in 3GPP 38.101-1 and 38.101-4.

3.5.7 Transmit Power

Should support PC3 capability and it is recommended to support PC2 capability.

3.6 Voice Characteristics

For scenarios requiring voice/video capabilities, should support VoNR/ViNR. If supporting 4G, should also support VoLTE to meet user requirements.

3.7 URLLC/IIoT Requirements

3.7.1 Low-rate MCS/CQI Tables

For high reliability scenarios, It is recommended to support NR system's low-rate MCS table (MCS index Table 3) and support NR system's low-rate CQI table (4-bit CQI Table 3).

3.7.2 Repetition Transmission (PUSCH/PDSCH repetition)

It is recommended to support slot-level repetition transmission for PUSCH and PDSCH, with a maximum repetition count of 8 times, and each transmission can use a different redundancy version.

3.7.3 Configured Grant Configuration

It is recommended to support the activation of a single configured grant configuration for the same BWP, including type 1 or type 2 configurations.

It is recommended to support the activation of multiple configured grant configurations for the same BWP, including type 1 or type 2 configurations.

3.8 SIB9 Timing Requirement

5G high-precision timing is one of the key technologies for 5G industry applications. The 5G lightweight universal module should support the correct parsing and utilization of broadcast timing information carried by SIB9. If the module needs to output timing information to the backend, it should ensure that the output timing accuracy meets the requirements of the backend.

3.9 Ethernet Header Compression Requirement

The module is recommended to support Ethernet header compression and decompression for user plane data at the PDCP protocol layer (R16 feature).

3.10 NPN/CAG Requirements

The modules should support the integration of NPN services with public networks through dedicated DNN and network slicing provided by the network.

Should support CAG capability to control the access of terminals to the integrated NPN network with public networks.

Should support reporting of CAG supported capability indication in UE MM Core Network Capability.

Should support reading CAG ID information from cell broadcast and allow access to 5G network if permitted by CAG.

The modules should support configuration, update, and storage of CAG information list.

3.11 5G LAN Requirements

The modules should support session functions and procedures based on Layer 3 IP type and Layer 2 Ethernet type.

3.12 Secondary Authentication and Authorization Requirements

The modules should support algorithms and process frameworks for secondary authentication based on PAP/CHAP and EAP.

The modules should support a two-way secondary authentication process (including reauthentication and revocation) based on PAP/CHAP and EAP algorithms during PDU session establishment phase, and control the establishment of PDU session for external data networks based on authentication results.

3.13 Power Saving Enhancement Requirements

The modules should support R15/R16/R17 other related power saving technologies, including: C-DRX in RRC_CONNECTED state (R15), connection state wake-up signal (R16), SkipULTxDynamic (R16), RRC link release request (R16), terminal power saving auxiliary information reporting (R16, including RRC state transition, downlink MIMO layers), early indication and paging groups (R17), PDCCH monitoring skipping (R17), search space set switching (R17).

3.14 Industry Slice Requirements

The modules should support SST as the URLLC slice type;

The modules should support DNN in URSP rules, and support local configuration of multiple DNNs;

Recommended to support traffic descriptors in URSP rules such as APPID, IP3 tuple, FQDN, and Non-IP types;

Should support receiving, storing, and updating information from NSSAIs (including Configured NSSAI/Allowed NSSAI/Rejected NSSAI) based on the network side;

The modules should support carrying the identification of network slices (S-NSSAI) in RRC and NAS signaling messages and passing it to the network;

Should support selecting the corresponding NSSAI and sending it to the network based on NSSAI inclusion mode indications;

The modules should support the ability to carry multiple (number of slices of the same type greater than or equal to 2) network slice identifications simultaneously.

3.15 4/5G Interoperability

The modules should support mobility management between 4G and 5G, including reselection/redirection/handover.

4 Hardware Package Requirements

4.1 LCC+LGA/LGA Package

The overall size of LCC+LGA/LGA package shall not be greater than (32±0.15) mm * (29±0.15) mm, and the thickness shall be within (2.4±0.2) mm. The modules adopt Type 3229, which confers the advantage of being compatible with CAT4 modules in terms of dimensions and interfaces.

For evolution of Redcap capability to 3GPP Release 18 and to replace CAT1 modules, the overall size of LCC+LGA/LGA package shall not be greater than (20±0.15) mm * (22±0.15) mm, and the thickness shall be within (2.2±0.2) mm.

4.2 Mini PCIe Package

The overall size of mini PCIe package shall not be greater than (30±0.15) mm * (51±0.15) mm, and the thickness shall be within (3.6 ± 0.2) mm single-sided and within (4.9 ± 0.20) mm double-sided.

4.3 M.2 Package

The overall size of M.2 package shall not be greater than (30±0.15) mm * (52±0.15) mm, and the thickness shall be within (2.3 ± 0.08) mm single-sided and within (3.6 ± 0.08) mm double-sided. In terms of dimensions and interfaces, the package confers the advantage of being compatible with eMBB modules in Type 3052.

To match the requirements of miniaturization and for evolution of RedCap capability to 3GPP Release 18, the overall size of M.2 package shall not be greater than (30±0.15) mm * (42±0.15) mm, and the thickness shall be within (2.3±0.08) mm single-sided and within (3.6±0.08) mm double-sided.

5 Electrical Interfaces Requirements

5.1 SIM Interface

The modules shall support ID-1 (U)SIM , and may support OTA functionality.

5.2 UART Interface

The UART interface shall contain at least 2-wire configurations, and supports at least 1 line of high-speed UART with a rate of no less than 4 Mbps.

5.3 USB Interface

The USB interface capability shall be USB 2.0 or above.

5.4 WLAN Interface

In scenarios where WLAN is required for data transmission, the modules shall support to expand capabilities to at least wifi5 via external interfaces (such as SDIO).

5.5 RGMII&SGMII Interface

The RGMII&SGMII interface works as a gigabit media independent interface to connect to the Ethernet.

If Ethernet port connection is supported, for modules with LGA or LCC+LGA package, at least one of the RGMII and SGMII interfaces shall be supported – that is, either RGMII or SGMII interface shall be selected.

5.6 I2C Interface

For modules with LGA or LCC+LGA package, I2C interface of 2 lines shall be supported; for modules with M.2 or mini PCIe package, I2C interface of 1 line shall be supported.

5.7 I2S/PCM Interface

I2S/PCM interface of at least 1 line shall be supported for connecting with audio codec.

5.8SDIO Interface

For modules with LGA or LCC+LGA package, SDIO interface is used to connect with SD card or eMMC storage chip, and 4-bit or 8-bit SDIO interface can be supported.

6 Summary

With the continuous enrichment and expansion of video surveillance, power, industrial fields, XR, vehicle networking and other business areas, the application of RedCap capability modules will be more and more extensive. At the same time, in the ongoing standardization of R18, RedCap evolution of new features is still being studied. China Mobile will continue to pay attention to and analyze new features and technologies that help improve the end-to-end performance of the 5G technology industry and optimize network deployment, and consider introducing them in a timely manner, so as to continuously promote the evolution of 5G wireless technology and the improvement of user experience, and strive for the integration of 5G into thousands of industries.