



5G Networks Require Quality of Service

by Jun Jie Low
Field Marketing Engineer
Field Test Solutions

Stuart Whitehead
Senior Product Marketing
Field Test Solutions

A large background image showing a city skyline at sunset. The sky is filled with orange and yellow clouds. Several vertical blue light beams emanate from the bottom of the image, passing through the city and extending upwards. The text "5G technology" is overlaid in the center of the image.

5G technology



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Background

For the first time ever, multiple standards organizations now require 5G mobile networks to deliver traffic-based **Quality of Service (QoS)**, and QoS is key to operators recovering the large costs of 5G upgrades, because data traffic is the most profitable part of their business. The 5G QoS requirements are based on delivering network services, such as **URLLC** (Ultra Reliable and Low Latency Communications), and **CoMP** (Coordinated Multi-Point), both of which require **very low latency** and **very accurate timing** at the Radio Unit (RU) and User Equipment (UE).

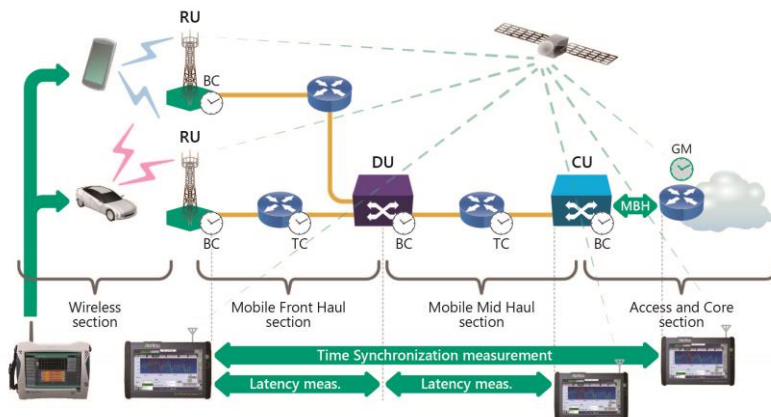


Figure 1 UE, DU, CU and Core Network Sections

5G Service Types

URLLC

- Commonly used for machine-to-machine communications and also called cMTC (critical Machine Type Communications), this service has the most stringent latency and up-time requirements. Many real-world applications are yet to be defined for this service type, but include automated factories, and self-driving vehicles communicating with roadside infrastructure.

CoMP

- This service is used to achieve maximum throughput at the UE, and minimum data loss at handover between RUs. The TDD (Time Division Duplex) air interface between RUs demands very accurate timing to prevent frame loss and delay at the UE.

Technology Introduction

Usually, traffic from the CO (Central Office) to RU is transported using various Ethernet technologies. The Core section could use Ethernet over OTN (Optical Transport Network), while the Access section to the Distributed Unit (DU) uses Ethernet—often MPLS (Multi-Protocol Label Switching)—and from the DU to RU uses either Radio over Ethernet (RoE) or eCPRI^{*1} (CPRI over Ethernet). The RF section from the RU to the UE uses Quadrature Phase Shift Keying (QPSK) over Radio Frequency (RF).

Different standards cover the different network sections, but all must deliver traffic with very low latency and ensure the network delivers very accurate timing to all network elements.

^{*1} The eCPRI specification is available at CPRI.info

Low Latency Network Requirements

Table 1 Network Latency Requirements – Combined from 3GPP and IEEE 1914 Standards

10 ms	Network from CO or often Cloud storage location (Data Center) to CU
100 μ s	Mobile transport network from Central Unit (CU) to RU
400 μ s	Mobile radio network from RU to UE (500 μ s from CU to UE)

Due to the very high latency specification (10 ms) back to the Core section, many URLLC applications require servers to be located either at or close to the CU. This MEC (Multi-access Edge Computing) enables operators to meet the required QoS for these URLLC applications.

- ***Measuring and confirming that the network complies with the required one-way latency is essential to ensuring network QoS.***

Network Timing Requirements

Using PTP (Precision Time Protocol) over Ethernet to supply timing information to clocks in each network section allows very accurate synchronization. Synchronizing the GM (Grand Master) clock to all the BCs (Boundary Clocks) at RU sites supports correct CoMP operation. A timing difference between any two NR (New Radio) signals is defined as the TAE (Time Alignment Error).

Table 2 Network Timing Requirements

1.1 μ s	Absolute maximum TE (Time Error) between any RU and GM
3 μ s	Maximum TAE between any two RUs (UE can hand over between)

The RU-to-UE connection uses TDD. To ensure that the UE maintains the maximum possible bandwidth as it moves between two RUs, both RUs must have exactly the same timing back to the GM clock.

- ***Measuring and confirming that the network complies with the required network timing is essential to ensuring network QoS.***

Air Interface Latency Requirement

Similar to the stringent required latency for wired segments, the air interface between the RU and UE has its own requirements. Network latency is especially important for CU handover, because poor timing and synchronization between RUs causes handover problems.

3GPP has long-defined goals about how each technology must perform in terms of data rates and latency; 5G brings massive increases in data rates, but demands a tenfold decrease in latency.

Table 3 Interface Rate and Latency Requirements

2G	≤100 kbps throughput per UE (GPRS (General Packet Radio Service)) with delays exceeding 500 ms
3G	~10 Mbps throughput per UE (HSDPA (High Speed Downlink Packet Access)) with delays around 100 ms
4G	≤300 Mbps throughput per UE (1 Gbps with LTE-A (Long Term Evolution-Advanced)) with delays of tens of ms
5G	≤1 Gbps throughput per UE with 1-ms round-trip delay time

The benefits of achieving these data rates and latency are significant as summarized below:

- Maximized efficiency
 - o Minimizes required guard frequencies/times to maximize spectral efficiency
 - o More efficient utilization of bandwidth-boosting technologies, such as Carrier Aggregation (CA) and Multiple Input Multiple Output (MIMO)/CoMP
- Optimized user experience
 - o Smooth handover
 - o Reduced user application delay
 - o More accurate Location Based Services (LBS)

Although CUs have historically obtained their timing from the RU via the RAN (Radio Access Network), since this procedure is reversed by modern 4G LTE-Advanced and 5G networks, the RAN becomes a key factor influencing network timing. 5G NR gNodeB (Next Generation NodeB) can use either a local timing source or Global Navigation Satellite System (GNSS) etc. in conjunction with and backing- up the timing from the GM via the CU and RAN.

Different gNodeB and Massive MIMO Types

Massive MIMO is a key advantage of 5G networks where 100 or more antenna elements offer various benefits. However, it is difficult physically to introduce antennas with 100 or more elements into traditional RUs, because connecting 100+ RF cables between each antenna element and RF TRx unit is impractical and increases RF loss. A more effective solution is to use an AAS (Active Antenna System) integrating antennas, RF Tx, and RU (Tx and Rx chains) in one unit. Commonly, the DU and RU are either integrated or at the same location to satisfy the tight AAS timing restrictions.

Massive MIMO is a technique where a base station (BTS) with more antennas forms localized beams targeting each UE.

The basic concept is an array of low-gain and low-directivity antenna elements with careful management of the phase relationship between signals at each element. The composite signal from all elements supports a higher gain as well as directional beams controlled by electronic phase shifters. Combining this concept with the MIMO concept using baseband processing to exploit multiple spatial paths between sets of antenna elements allows simultaneous transmission of multiple data channels with MIMO spatial coding to separate data channels to different UEs according to spatial location and unique channel propagation characteristics for each Tx–Rx combination.

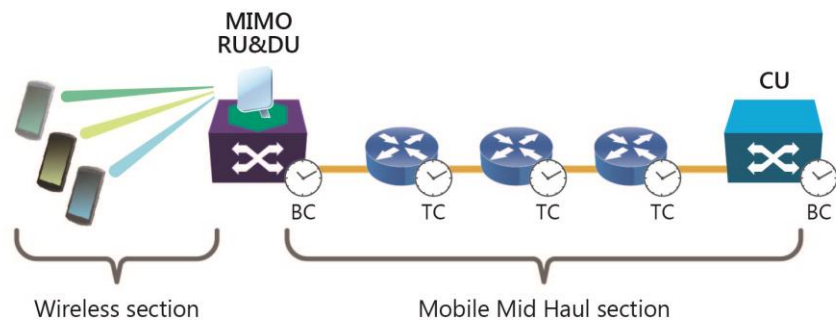


Figure 2 Massive MIMO with Combined RU and DU Connected to CU

Investigation of higher frequency bands (24 to 86 GHz) with shorter wavelengths for 5G supports use of large arrays in smaller form factors while still maintaining the correct proportions in relation to wavelength (correct separation of antenna and correct antenna patch size), making arrays with tens or hundreds of antenna elements practical.

There are two antenna categories for AAS systems:

- Hybrid AAS RU with both conducted and radiated interfaces
- Over-The-Air (OTA) AAS RU with only radiated interface

Four main types of RU conducted and radiated reference points are summarized below based on 3GPP TS 38.104 documents.

Table 4 Four Main RU Types as per 3GPP TS 38.104

RU Type/Requirement Set	Requirement Type	RU Test Description Reference Points
1-C	Conducted	RU operating at Frequency Range 1 (FR1) with all requirements defined at individual antenna connectors
1-H	Conducted and Radiated	RU operating at FR1 with requirements defined at Transceiver Array Boundary (TAB) and OTA requirements defined at Radiated Interface Boundary (RIB)
1-O	Radiated	RU operating at FR1 with OTA requirements defined only at RIB
2-O	Radiated	RU operating at FR2 with OTA requirements defined only at RIB

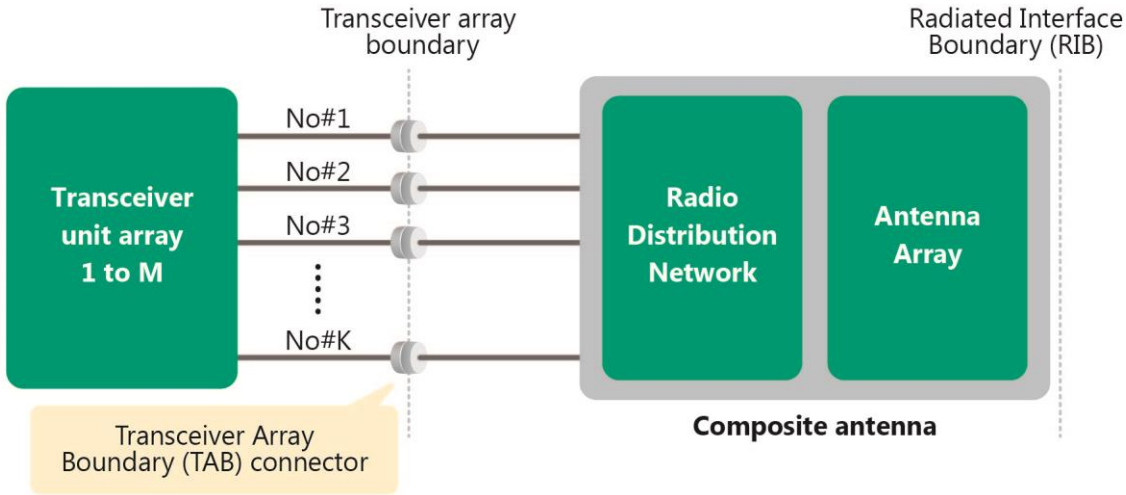


Figure 3 Example of 1-H RU Type and Reference Points

TAE requires testing to confirm the exact timing between two RUs. Many standards define the required TAE with most referencing 3GPP, which also defines required test points based on the RU type as described in Table 4. The TAE requirements per RU type are outlined in Table 5.

Table 5 TAE Requirements Between Any Two RUs as per 3GPP TS 38.104

	1-C/1-H ^{*1} /1-O ^{*2}	2-O ^{*2}
TAE shall not be exceeded for MIMO or TX diversity transmissions at each carrier frequency.	65 ns	65 ns
TAE shall not be exceeded for intra-band contiguous carrier aggregation with or without MIMO or TX diversity.	260 ns	130 ns
TAE shall not be exceeded for intra-band non-contiguous carrier aggregation with or without MIMO or TX diversity.	3 μ s	260 ns
TAE shall not be exceeded for inter-band carrier aggregation, with or without MIMO or TX diversity.	3 μ s	3 μ s

*1 Conducted and Radiated connections, physical or OTA measurements

*2 Radiated connection, OTA measurements only

The timing difference between two RUs must be tested when the distances between the UE and RUs are different. The timing difference must be within 3 μ s, which is the required TAE between each site.

When a UE moves between two RUs at different distances, a large timing difference between RUs may cause the UE handover to fail.

Measurement of timing synchronization across wired networks between the RU and GM is completed by evaluating the PTP; these Ethernet frames carry control and clock synchronization across the network. Full details of wired latency, timing, and different frame structures are discussed in our [1914.3 \(RoE\) eCPRI Transport](#) White Paper.

Full compliance with the 3GPP TS 38.104 version 15, ITU G.82xx, and IEEE 1914.x standards requires air-interface and wired tests consisting of many essential measurements. Table 6 summarizes the standards-based measurements related to latency, timing, and accuracy.

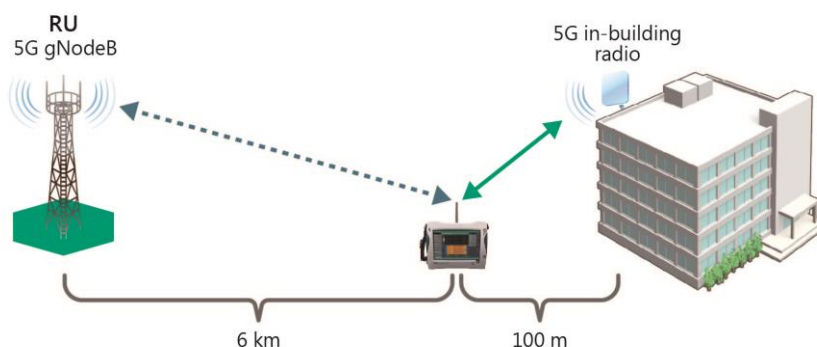


Figure 4 UE Handover at Different RF Distance

Table 6 Timing and Latency Measurement Requirements

Air Interface Tests and Accuracy	Wired Interface Tests and Accuracy
Conducted and Radiated Test <ul style="list-style-type: none"> - Time Offset - Frequency Error: $\pm 2.0 \times 10^{-8}$ Hz, typ. - Modulation Quality Error Vector Magnitude (EVM): 2.0%, typ. 	Latency <ul style="list-style-type: none"> - High Accuracy 100 ns Timing <ul style="list-style-type: none"> - High Accuracy <5 ns - 1PPS - Max TE - cTE - dTE Packet TE <ul style="list-style-type: none"> - max TE1 and max TE4 - cTE1 and cTE4 - max Terr and Terr

Conclusions

5G networks bring many new technologies and challenges to wired and wireless networks. Confirming end-to-end QoS is the key to help operators recoup large investments in 5G infrastructure. This is possible only by confirming that the network meets the required standards across both the wired and wireless sections.

References

3GPP TS 38.104 v15

- https://www.3gpp.org/ftp/Specs/archive/38_series/38.104/

eCPRI MFH CPRI over Ethernet

- <http://www.cpri.info/spec.html>

Explain Radio Requirement Set for 5G NR (1-C, 1-H, 1-O, 2-O BS Types)

- <http://www.techplayon.com/explain-radio-requirement-set-5g-nr-1-c-1-h-1-o-2-o-bs-types/>

IEEE 1914.1 Standard for Packet-based Fronthaul Transport Networks

- https://standards.ieee.org/project/1914_1.html

Acronyms

3GPP	3 rd Generation Partnership Project	LBS	Location Based Services
5G	5 th Generation	LTE-A	Long Term Evolution-Advance
AAS	Active Antenna System	MEC	Mobile Edge Computing
BC	Boundary Clock	MIMO	Multiple Input Multiple Output
CA	Carrier Aggregation	NR	New Radio
CPRI	Common Public Radio Interface	OTA	Over The Air
cMTC	critical Machine Type Communications	PTP	Precision Time Protocol
CO	Central Office	QoS	Quality of Service
CoMP	Coordinated Multi Point	OTA	Over-The-Air
cTE	constant Time Error	OTN	Optical Transport Network
CU	Central Unit	QPSK	Quadrature Phase Shift Keying
dTE	dynamic Time Error	RAN	Radio Access Network
DU	Distributed Unit	RF	Radio Frequency
EIRP	Effective Isotropic Radiated Power	RIB	Radiated Interface Boundary
EVM	Error Vector Magnitude	RoE	Radio over Ethernet
FR1	Frequency range 1 (450 to 6000 MHz)	RU	Radio Unit
FR2	Frequency range 2 (24,250 to 52,600 MHz)	TAB	Transceiver Array Boundary
GM	Grand Master	TAE	Time Alignment Error
gNobeB	Next Generation NodeB	Terr	Time error
GNSS	Global Navigation Satellite System	TDD	Time Division Duplex
GPRS	General Packet Radio Service	TE	Time Error
HSDPA	High Speed Downlink Packet Access	UE	User Equipment
IEEE	Institute of Electrical and Electronic Engineers	URLLC	Ultra Reliable and Low Latency Communications

Anritsu references

Anritsu is currently working with many operators globally, leading the way in field-testing the first 5G networks as they are deployed worldwide.

Anritsu's success stories in industry

- <https://www.anritsu.com/en-au/test-measurement/news/news-releases/2019/2019-01-29-au-06> (Network Master Pro)
- <https://www.anritsu.com/en-au/test-measurement/news/news-releases/2019/2019-05-21-au-27> (Field Master Pro)

Further details on 5G for field testing can be found at the following Anritsu websites.

- <https://www.anritsu.com/test-measurement/solutions/mt1000a-05/index>
- <https://www.anritsu.com/test-measurement/technologies/5g-everything-connected/5g-mobile-network-testing-im>

Application notes for 5G OTA (Over The Air) and coverage testing

- <https://www.anritsu.com/test-measurement/support/downloads/application-notes/dwl19682> (OTA testing)
- <https://www.anritsu.com/test-measurement/support/downloads/application-notes/dwl19611> (Coverage testing, sign-in may be required)

White Papers and application notes for transport timing testing

- <https://www.anritsu-apsr-response.com/acton/fs/blocks/showLandingPage/a/19504/p/p-0129/t/page/fm/0?model=MT1000A&cta=WP> (RoE and eCPRI technical standard review)
- <https://www.anritsu.com/test-measurement/support/downloads/application-notes/dwl19352> (Testing RoE and eCPRI)
- <https://www.anritsu.com/test-measurement/support/downloads/application-notes/dwl19575> (Testing O-RAN)

For more details on the Anritsu [Network Master Pro](#) (for transport and optical network testing) or [Field Master Pro](#) (for RF testing), visit these product pages.

- <https://www.anritsu.com/test-measurement/products/mt1000a> (Network Master Pro)
- <https://www.anritsu.com/test-measurement/products/ms2090a> (Field Master Pro)

Product brochures and datasheets

- <https://www.anritsu.com/en-au/test-measurement/support/downloads/brochures-datasheets-and-catalogs/dwl010587> (Network Master Pro - brochure)
- <https://www.anritsu.com/en-au/test-measurement/support/downloads/brochures-datasheets-and-catalogs/dwl010570> (Network Master Pro - Datasheet)
- <https://www.anritsu.com/test-measurement/support/downloads/brochures-datasheets-and-catalogs/dwl19569> (Field Master Pro)

• United States

Anritsu Americas Sales Company

450 Century Parkway, Suite 190, Allen,
TX 75013 U.S.A.
Phone: +1-800-Anritsu (1-800-267-4878)

• Canada

Anritsu Electronics Ltd.

700 Silver Seven Road, Suite 120, Kanata,
Ontario K2V 1C3, Canada
Phone: +1-613-591-2003
Fax: +1-613-591-1006

• Brazil

Anritsu Elettronica Ltda.

Praça Amadeu Amaral, 27 - 1 Andar
01327-010 - Bela Vista - Sao Paulo - SP
Brazil
Phone: +55-11-3283-2511
Fax: +55-11-3288-6940

• Mexico

Anritsu Company, S.A. de C.V.

Blvd Miguel de Cervantes Saavedra #169 Piso 1, Col. Granada
Mexico, Ciudad de Mexico, 11520, MEXICO
Phone: +52-55-4169-7104

• United Kingdom

Anritsu EMEA Ltd.

200 Capability Green, Luton, Bedfordshire, LU1 3LU, U.K.
Phone: +44-1582-433200
Fax: +44-1582-731303

• France

Anritsu S.A.

12 avenue du Québec, Bâtiment Iris 1- Silic 612,
91140 VILLEBON SUR YVETTE, France
Phone: +33-1-60-92-15-50
Fax: +33-1-64-46-10-65

• Germany

Anritsu GmbH

Nemetschek Haus, Konrad-Zuse-Platz 1
81829 München, Germany
Phone: +49-89-442308-0
Fax: +49-89-442308-55

• Italy

Anritsu S.r.l.

Via Elio Vittorini 129, 00144 Roma, Italy
Phone: +39-6-509-9711
Fax: +39-6-502-2425

• Sweden

Anritsu AB

Isafjordsgatan 32C, 164 40 KISTA, Sweden
Phone: +46-8-534-707-00

• Finland

Anritsu AB

Teknobulevardi 3-5, FI-01530 VANTAA, Finland
Phone: +358-20-741-8100
Fax: +358-20-741-8111

• Denmark

Anritsu A/S

Torveporten 2, 2500 Valby, Denmark
Phone: +45-7211-2200
Fax: +45-7211-2210

• Russia

Anritsu EMEA Ltd.

Representation Office in Russia

Tverskaya str. 16/2, bld. 1, 7th floor.
Moscow, 125009, Russia
Phone: +7-495-363-1694
Fax: +7-495-935-8962

• Spain

Anritsu EMEA Ltd.

Representation Office in Spain

Edificio Cuzco IV, Po. de la Castellana, 141, Pta. 5
28046, Madrid, Spain
Phone: +34-915-726-761
Fax: +34-915-726-621

• United Arab Emirates

Anritsu EMEA Ltd.

Dubai Liaison Office

902, Aurora Tower,
P O Box: 500311 - Dubai Internet City
Dubai, United Arab Emirates
Phone: +971-4-3758479
Fax: +971-4-4249036

• India

Anritsu India Private Limited

6th Floor, Indigube ETA, No.38/4, Adjacent to EMC2,
Doddanekundi, Outer Ring Road, Bengaluru - 560048, India
Phone: +91-80-6728-1300
Fax: +91-80-6728-1301

• Singapore

Anritsu Pte. Ltd.

11 Chang Charn Road, #04-01, Shriro House
Singapore 159640
Phone: +65-6282-2400
Fax: +65-6282-2533

• P.R. China (Shanghai)

Anritsu (China) Co., Ltd.

Room 2701-2705, Tower A,
New Caohejing International Business Center
No. 391 Gui Ping Road Shanghai, 200233, P.R. China
Phone: +86-21-6237-0898
Fax: +86-21-6237-0899

• P.R. China (Hong Kong)

Anritsu Company Ltd.

Unit 1006-7, 10/F., Greenfield Tower, Concordia Plaza,
No. 1 Science Museum Road, Tsim Sha Tsui East,
Kowloon, Hong Kong, P.R. China
Phone: +852-2301-4980
Fax: +852-2301-3545

• Japan

Anritsu Corporation

8-5, Tamura-cho, Atsugi-shi, Kanagawa, 243-0016 Japan
Phone: +81-46-296-6509
Fax: +81-46-225-8352

• Korea

Anritsu Corporation, Ltd.

5FL, 235 Pangyoeyeok-ro, Bundang-gu, Seongnam-si,
Gyeonggi-do, 13494 Korea
Phone: +82-31-696-7750
Fax: +82-31-696-7751

• Australia

Anritsu Pty. Ltd.

Unit 20, 21-35 Ricketts Road,
Mount Waverley, Victoria 3149, Australia
Phone: +61-3-9558-8177
Fax: +61-3-9558-8255

• Taiwan

Anritsu Company Inc.

7F, No. 316, Sec. 1, NeiHu Rd., Taipei 114, Taiwan
Phone: +886-2-8751-1816
Fax: +886-2-8751-1817