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White paper

Optical Fiber in 5G: Why It’s Important and How to Test It

Fiber's Important – and Expanding – Role in 5G

5G is impacting every element of the network – core, transport, and radio access network (RAN). It will also change the fiber optic technology that serves as the backbone connecting it all. Service providers, data center management, and technicians responsible for the deployment, installation, and maintenance of these networks need a new generation of validation solutions. These instruments combine testing capabilities to meet 5G standards and performance metrics, and are efficient, easy to use, and versatile enough to address maintenance of existing 4G infrastructure.

The importance of fiber will continue to grow in mobile fronthaul, as expanding 5G use cases require greater network speed. To accommodate this evolution, Next Generation Fronthaul Interface (NGFI) and Fiber to the Antenna (FTTA) will be used so the mobile fronthaul can accommodate 5G latency, bandwidth and transmission speed requirements.

Figure 1 shows the flexibility of the RAN architecture created by NGFI. There is versatility, with multiple RU, DU, and CU deployment combinations. The NGFI network has two classifications. NGFI-I, commonly known as MFH (Mobile Fronthaul), is between the RU and DU and NGFI-II, known as MMH (Mobile Midhaul), is between the DU and CU.

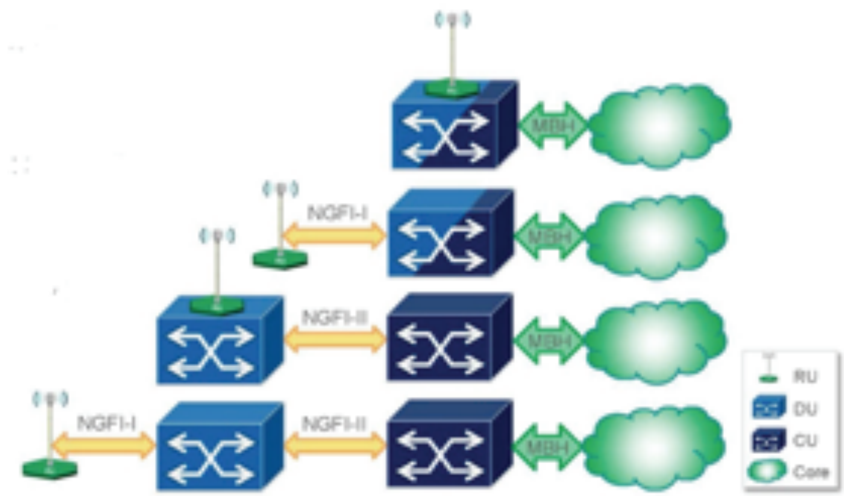


Figure 1: *Flexible RAN architecture*

Wireline network infrastructure needs to be fiber-based to satisfy the specific requirements of emerging 5G use cases such as augmented reality (AR), massive machine type communication, and autonomous vehicles. The network must be ultra-flexible to support the specific requirements of enhanced Mobile Broadband (eMBB), with its 5 Gbps – 20 Gbps high speed and capacity; massive Machine Type Communications (mMTC) and its never-before-realized connections (106 devices/km2); and Ultra Reliable Low Latency Communications (URLLC) that will require 500 μs one-way latency.

Ensuring 5G Network Latency

Network latency is a banner specification in 5G and is essential for many mission critical use cases. Latency times of the all 5G network elements, including mobile fronthaul, must be precisely managed. For eMBB, the threshold for user plane latency is 4 ms for uplink (UL) and downlink (DL). In URLLC, 3GPP requires 500 μs latency in DL and UL.

3GPP defines the 500 μs one-way latency as, “from the radio protocol layer 2/3 SDU ingress point to the radio protocol layer 2/3 SDU egress point via the radio interface in both uplink and downlink directions.” In other words, there must be less than 500 μs one-way latency between the UE and servers to meet 3GPP standards. In addition, IEEE 1914.1 specifies less than 50 μs one-way latency between the DU and the RU and 100 μs one-way latency between the CU and the DU.

To suppress latency times between the mobile fronthaul 5G antenna and core/metro network, it is important to minimize the latency of the overall network, as well as network equipment as much as possible. The best way to verify the equipment meets specification is to conduct measurements using two optical testers at each end of the fiber cable. This configuration (figure 2) allows for accurate measurements of one-way delay between two distant separate points.

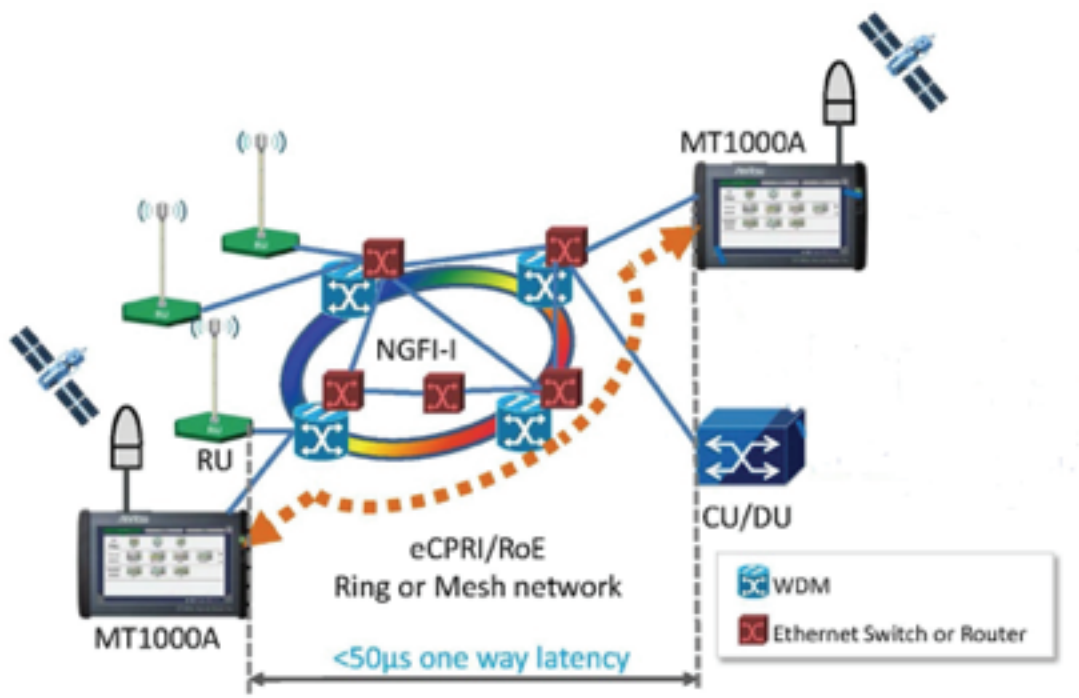


Figure 2: *Latency test configuration.*

Transport Testing

4G LTE systems use Common Public Radio Interface (CPRI)-compliant interface equipment to convert the mobile fronthaul wireless signal to optical signals. 5G transmission speeds, are multitudes of 10x faster than LTE.

With extremely high time accuracy required at the RU and many RUs unable to have a direct Global Navigation Satellite System (GNSS) connection, 5G networks must often carry the network timing over Ethernet frames. The speed difference, plus the integration of Ethernet timing has introduced eCPRI and Radio over Ethernet (RoE) into the new generation of networks.

A key difference between CPRI and eCPRI, or RoE, is that the former is a serial-based technology while the latter are packetized interfaces. So, eCPRI and RoE are the payload of Ethernet frames, taking advantage of the existing ubiquitous Ethernet networks. eCPRI and RoE can split the baseband functions, so some functionality can be transferred to the remote radio unit (RRU) or RU, which frees bandwidth within the fiber.

RoE is specified in IEEE 1914.3 to detail the encapsulation and mapping of radio protocols for transport over Ethernet frames. It supports mapping, digitized radio data, CPRI, I/Q data and control channel frames across a routed Ethernet network. Using Ethernet as the transport layer with IEEE 1914.3 or eCPRI as the payload results in fronthaul networks having higher link capacity and greater transfer efficiency while maintaining required network latency guarantees.

With 5G featuring high speeds and large capacity, maintaining mobile fronthaul transmission quality requires communications and latency tests measuring either eCPRI or RoE frame bit errors and latency with high accuracy. RoE and eCPRI are based on standard routable Ethernet frames to ensure network connectivity requires testing the end-to-end connection using the 1914.3 (RoE) or eCPRI framed header. Figure 3A/3B provides visuals of RoE and eCPRI frame formats.

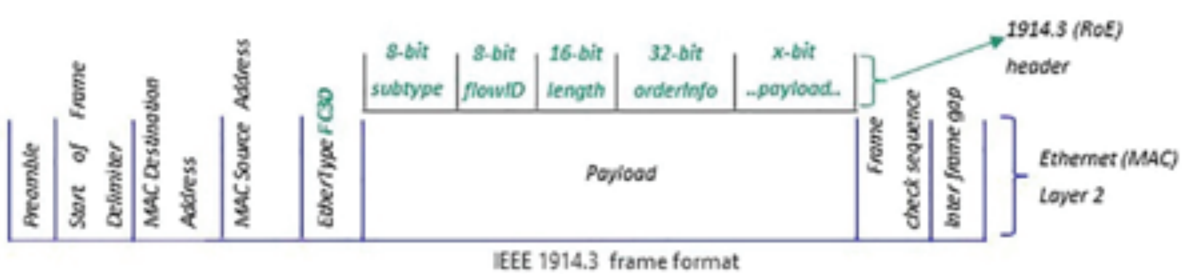


Figure 3A: *IEEE 1914.3 frame format*

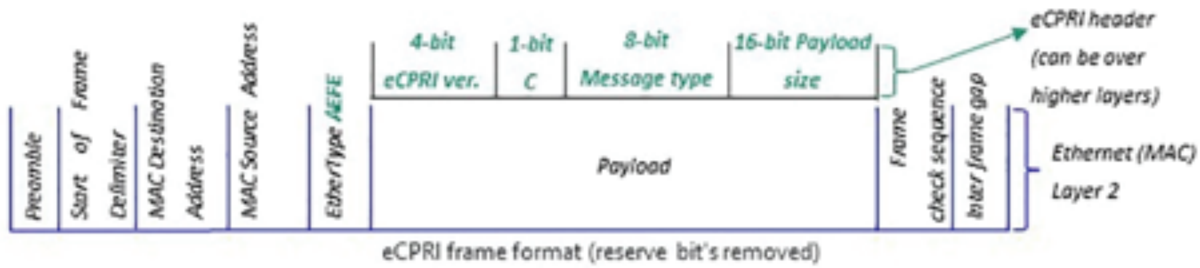


Figure 3B: *eCPRI frame format*

Since NGFI-I and NGFI-II can be routed across multiple network connections each with multiple traffic streams from different end points, confirming end-to-end connectivity with a very low BER (Bit Error Rate) ensures the network connection stability, which is essential. Table 2 shows other transport tests that need to be conducted.

Mobile xHaul Test Requirements

eCPRI/RoE throughput and latency up to 25 Gbps	Optical fiber and network element performance verification
G.8275.1/.2 network timing error verification	Network timing performance verification
Optical physical layer performance	Confirming optical fiber, connectors, and bulked loss performance

For time and cost efficiencies, both eCPRI and RoE measurements should be made with a single instrument. Some test instruments have a dual-port 25G eCPRI/RoE function to optimize testing by offering efficient signal generation and analysis plus high-precision one-way latency measurement of transport networks. This ability provides support for implementing URLLC.

Time Synchronization Measurements

To achieve the faster data speeds and higher bandwidth associated with 5G, millimeter wave (mmWave) bands are utilized. From a network deployment perspective, it means that there will be many small base stations because the high radio-wave frequency (24.25 GHz to 52.6 GHz for 5G New Radio and up to 100 GHz eventually) only propagates over short distances.

One option to synchronize all these base stations is to use GNSS receivers. This will add costs, however, as antenna facilities will need to be installed. It will also be difficult to find open sky locations, and there is a continual risk of jamming and physical damage.

The consensus is to distribute timing via the RAN using Precise Timing Protocol (PTP) as defined by IEEE. PTP is utilized for synchronization of frequency and phase. A grand master, which is the root timing reference that all other clocks synchronize directly to, distributes timing to all cell sites via the Ethernet packet network. Every cell site has its own path and synchronization quality must be confirmed for each. PTP can also serve as a backup of GNSS failure, and is often referred to as “assisted PTS” (Partial Timing Support).

PTP is defined in the IEEE 1588v2 standard and the technology is an effective means to carry the clock across the 5G Ethernet network. Recommendation G.8275.1 is for full timing support (FTS). A PTP network with a G.8275.1 profile is the best for accurate synchronization. All nodes are PTP aware and it is specifically designed for PTP so it is well managed. Unfortunately, it is not always feasible because building out a new network may not fit in the budget and certain elements of the network may be leased and/or unmanageable.

For these reasons, another profile – G.8275.2 – has been specified for partial timing support (PTS). It allows operators to utilize existing networks to carry a clock where the boundary clock and SyncE are not required. It is more economical than building a new network. In this configuration, not all nodes are aware of PTP and there is additional design on existing IP network. Figure 3 outlines the different configurations for FTS and PTS.

G.8275.1 Full-timing Support (FTS)

G.8275.2 Partial-timing Support (PTS)

Proper timing synchronization is necessary to allow multiple base stations to communicate with a single UE without interference. One technique to assist in this area is the Coordinated Multiple Point transmission and reception (CoMP). It is field proven, as it is used in LTE-Advanced to increase the average cell throughput and cell edge user throughput in the UL and DL.

CoMP requires accurate base station timing to achieve the highest download ability. A 5G network must have 3 μs or better accurate time synchronization between nearby cells to meet 5G specifications. If synchronization falls out of specification, phase misalignment will occur. The result is collisions between UE and base station, which will introduce interference.

Maintaining synchronization quality will help ensure that the network meets the stringent 5G latency requirements. An unmanaged packet network will cause large latency variations and asymmetry, introducing poor time synchronization performance. Latency variation can be caused by network congestion, poor switching and routing, policing and shaping. Asymmetry may be due to rate mismatch within a path. To minimize asymmetry and variation, testing should be completed when turning up the network before it goes live.

Another factor influencing phase synchronization is the length of the GNSS antenna cable. A 100m cable causes approximately 500 ns misalignment between the antenna and PTP timestamping point. The grand master compensates for this error factor via a special setting to ensure proper timing.

When it comes to testing, time synchronization using PTP demands strict evaluation of the entire network to maintain time differences within the permissible range. Test instruments must measure the element threshold based upon the PTP G.8275.2 and G.8275.1 profiles. If they fail to meet these standards, performance issues, including dropped calls, lower data throughput and outages, will eventually occur.

Many of these problems will not directly point to poor synchronization, which makes troubleshooting long, expensive, and frustrating. Therefore, field technicians need a PPT-aware test set that can connect to the different clocking elements to determine the nodes that are causing slips and fails.

Benefits of PON Integration

As noted, 5G fronthaul networks will utilize many smaller base stations (RRH) and baseband units (BBUs) compared to 4G LTE. Passive Optical Network (PON) technology is an efficient technique to connect the many RRHs with one BBU. PONs are a point to multi-point architecture using passive splitters to serve more end devices in the mid haul CU to DU. Sharing an optical fiber by using a PON helps cut costs in comparison to other methods, making it the technology of choice in most network designs.

PONs utilize xWDM technology, which presents a set of challenges. Because DWDM channels are so close, their transmitters require precise temperature control to maintain wavelength stability and operate properly. Wavelength filters must pass the correct wavelength while blocking others.

For PON verification, the instrument of choice is an OTDR. It is used to measure optical fiber transmission losses as well as distances to and locations of fiber faults. To do so accurately, however, the instrument must have high precision to analyze a PON optical splitter with up to 128 branches, as well as an easy-to-use Pass/Fail function to evaluate the optical splitter status quickly and efficiently.

Overall Optical Line Verification

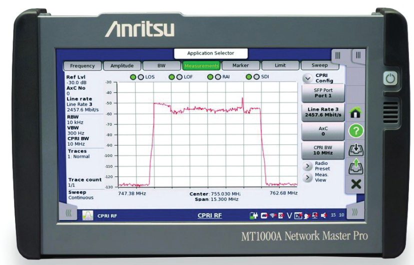
Optical fiber is in the core, metro, and mobile fronthaul and backhaul of 5G networks. Therefore, detection and measurement of fiber breaks at trunk-cable during installation and maintenance, including the access drop cable, are required. An OTDR must have sufficient performance to detect events, such as loss and reflections, with high accuracy to test fibers ranging from a few meters to 200+ km in length.

Selecting Proper Test Solutions

When selecting test solutions to verify fiber in a 5G network the evaluation must go beyond the instrument category itself. Optical transport testers and OTDRs are used in most applications but they must meet specific performance capabilities based on technologies and use cases. Another important but sometimes overlooked aspect is ease-of-use, as it allows technicians of any experience level to conduct the necessary tests on a network.

Transport Testing – 5G will increase aggregate data transmitted and received to a tower by 10X compared to 4G. For this reason, field transport testers need to measure high data rates up to 100 Gbps to support this added bandwidth capability.

PTP – For commissioning, optical transport testers must emulate the PTP slave clock. The Anritsu Network Master Pro MT1000A supports both G.8275.1 and G.8275.2 and conducts real-time monitoring of the PTP protocol status and log. The MT1000A also directly synchronizes with GNSS and compares observed time information in the PTP packet to conduct time error measurements.



Network Master™ Pro **MT1000A**

***Latency* –** To ensure 5G networks are in compliance with industry standards when it comes to latency, test instruments should provide QoS analysis with up to 16 streams. The Anritsu MT1000A supports this capability, and can conduct simple Pass/Fail judgement tests for general SLA parameters during network commissioning. Highly accurate one-way latency testing is achieved by leveraging the GNSS.

PON – For deployment of large-capacity 5G mobile network infrastructure, an OTDR must perform PON analysis. The ACCESS Master MT9085 series has functions for detecting and measuring PON optical splitters used in mobile fronthaul as well as for measuring events, such as fiber loss and reflections, in 5G mobile networks with high accuracy. Measurement results are clearly displayed on an 8-inch wide touch screen because of a unique detection algorithm.

Access Master™ **MT9085**

Specifications are subject to change without notice.

• United States
Anritsu Company
450 Century Pkwy, Suite 109,
Allen, TX, 75013 U.S.A.
Toll Free: 1-800-267-4878
Phone: +1-972-644-1777
Fax: +1-972-671-1877

• 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 Electrônica 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.
Av. Ejército Nacional No. 579 Piso 9, Col. Granada
11520 México, D.F., México
Phone: +52-55-1101-2370
Fax: +52-55-5254-3147

• United Kingdom
Anritsu EMEA Ltd.
200 Capability Green, Luton, Bedfordshire LU1 3LU, U.K.
Phone: +44-1582-433280
Fax: +44-1582-731303

• France
Anritsu S.A.
12 avenue du Québec, Batiment 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: +39-06-509-9711
Fax: +39-06-502-2425

• Sweden
Anritsu AB
Kistagången 20B, 164 40 KISTA, Sweden
Phone: +46-8-534-707-00
Fax: +46-8-534-707-30

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

• Denmark
Anritsu A/S
Kay Fiskers Plads 9, 2300 Copenhagen S, 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
P O Box 500413 - Dubai Internet City
Al Thuraya Building, Tower 1, Suite 701, 7th floor
Dubai, United Arab Emirates
Phone: +971-4-3670352
Fax: +971-4-3688460

• India
Anritsu India Pvt Ltd.
2nd & 3rd Floor, #837/1, Binnamangla 1st Stage,
Indiranagar, 100ft Road, Bangalore - 560038, India
Phone: +91-80-4058-1300
Fax: +91-80-4058-1301

• 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.
27th Floor, Tower A,
New Caohejing International Business Center
No. 391 Gui Ping Road Shanghai, Xu Hui Di District,
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: +81-46-225-8359

• Korea
Anritsu Corporation, Ltd.
5FL, 235 Pangyoyeok-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