White Paper

Addressing 5G Sync Plane Issues

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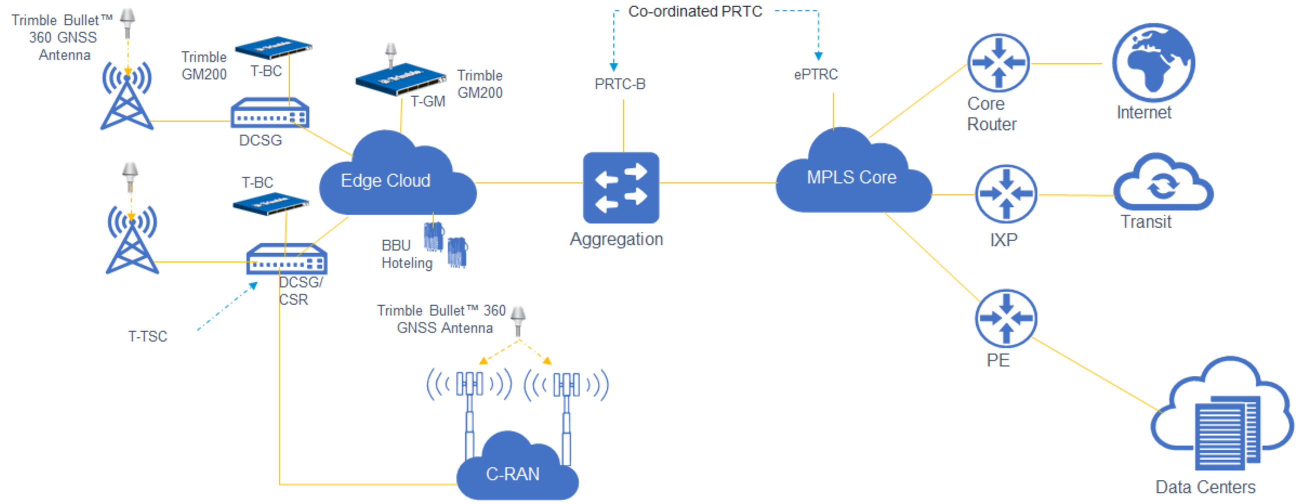


As the fronthaul networks are upgraded to support higher bandwidth for LTE Advanced technologies and 5G, MNOs (Mobile Network Operators) are face with unparalleled challenges to comply with stringent requirements for the synchronization or sync plane across the network. We are witnessing paradigm shift in traditional telecom networks that rendering the transport networks in two distinct parts: RAN (Radio Access Network) and Packet core. However, this process of disaggregation of otherwise tightly coupled transport system into two functionally distinct elements is not easy. It requires decoupling of tightly integrated network functions into bite size pieces for processing, improve bandwidth to deliver enhanced human experience and facilitate advanced application services. This transformation in technologies and the implementations thereof requires that timing information distributed in a precisely frequency and phase-aligned networks for advanced applications to function. The problem is that 5G requires precision time distribution due to TDD spectrums and time critical applications. In traditional 4G, time synchronization requirements are not as stringent as 5G and thus reliance on GPS and GNSS is good enough. However, a sync loss in 5G TDD deployment such as CBRS could be disastrous. Similarly, all other time critical applications such as V2X and IIOT etc. would suffer catastrophic failure. This implies that 5G network need careful sync plane design, one that cope with GNSS/GPS sync loss and capable of providing high precision time distribution across the network from a PRC (Primary Reference Clock) or Primary Reference Time Clock (PRTC).

Method of Timing Distribution

The job of a PRTC is to continually sync with Universal Coordinated Time (UTC) and distribute it across the networks. It may use a combination of GPS/GNSS, Atomic Clock or Cesium Clock and timing distribution mechanisms to achieve this. There are several mechanisms to carry timing information throughout the networks that includes SyncE, BITS (Building Integrated Timing Supply), IRIG (Inter Range Instrumentation Group) time code type B (IRIG-B) and 1PPS (1 Pulse per Second). All these technologies are dedicated timing signals requiring a physical connection specifically for timing. One exception is that SyncE can coexist in a physical connection of a packetize network; in other words, same port of an ethernet switch can implement SyncE and transport packets for shared physical link.

Apart from dedicated timing signals, there are other packet base solutions for timing distribution as well, e.g., NTP (Network Transport Protocol) and PTP (Precision Time Protocol). Both protocols require no specific connection for timing and best suited for packetized networks. While NTP is a common time distribution protocol for computer networks and in existence for nearly three decades, PTP (IEEE 1588) is relatively new. It is defined by IEEE 1588 specification in 2002. Since its inception, PTP has gained increase attention due to the possibility of achieving sub nanosecond accuracy when used in conjunction with PRTC for primary clock source and SyncE to distribute Timing information.

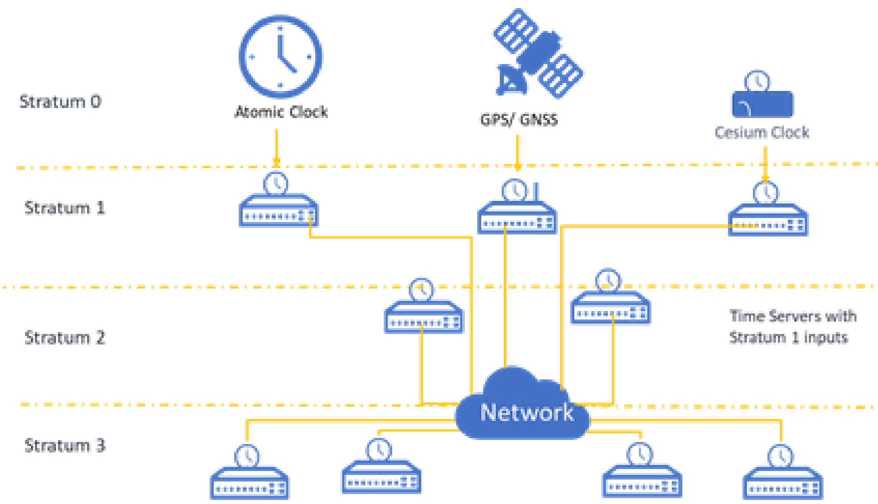
The following table shows different methods of timing distribution and relative timing accuracy for each. A point to note here is that both NTP and PTP supports TOD, phase and frequency synchronization making them ideal for today's packetized networks. However, NTP is less suitable for applications and network where sub nano seconds to microsecond accuracy is needed e.g. 5G TDD deployments such as CBRS, mmWave etc.

Table 1. Methods of Timing Distribution.

Method of Timing Distribution	Time of Day (TOD)	Phase	Frequency	Accuracy	Topology
PTP (IEEE1588)	Yes	Yes	Yes	Sub ns to 100 µs [note]	LAN/WAN
NTP	Yes	Yes	Yes	100 µs to ms	LAN/WAN
SyncE	No	No	Yes	Sub ns [note]	LAN
IRIG-B	Yes	Yes	Yes	10 µs to sub ms	Point to Point
PPS	No	Yes	Yes	< 100 ns	Point to Point
BITS	No	No	Yes	< 100 ns	Point to Point

Note: *A network with SyncE (Synchronous Ethernet) and PTP together can achieve sub nanosecond accuracy as evident in white rabbit experiment by CERN.*

All time distribution methods should adhere to respective standards e.g. ANSI, Telcordia and ITU-T requirements for PRC (Primary Clock Source) or PRS (Primary Clock source) and time synchronization mechanisms. In a typical deployment, Stratum 1 level clock is considered as PRC/ PRS for the network. A Stratum 1 is part of clock hierarchy level defined by ANSI for which Stratum 0 is atomic clock that provides input to Stratum 1. Where atomic clock inputs are not available, the PRC/PRS may take input from GPS/GNSS or Cesium Clock and a combination thereof as required. At Stratum 2 level, time servers generally get time reference from Stratum 1. The sync plane design should consider respective ANSI and ITU-T standards together for optimal outcomes. It is also useful to define a sync plane that is backward compatible. The figure below shows a relative map between ANSI clock hierarchy and ITU-T recommendations for frequency plane and time/phase plane (e.g. ITU-T PTP profile).



ANSI	ITU-T Frequency Plane Profile	ITU-T PTP Profile
PRS	PRC (G.811/G811.1)	PRTC/ T-GM with PRTC (G.8272)
BITS	SSU (G.812)	T-GM (PTP Grandmaster)
SMC	SEC	T-BC (Boundary Clock)

Figure 1. Clock Hierarchy levels for timing source

This relative map as presented in figure above is not an exact representation rather an attempt to broaden the understanding of clock hierarchy levels for timing source and distribution. Such understanding will help readership to implement the concept in network synchronization design. For a given network synchronization deployments, e.g. fronthaul, ITU-T recommendations should be understood in two distinct planes: frequency and time/phase. In the frequency plane, a set of ITU-T recommendations defines characteristics of the clock and timing distribution: G.811 & G.811.1 defines PRC and enhanced PRC (ePRC) respectively.

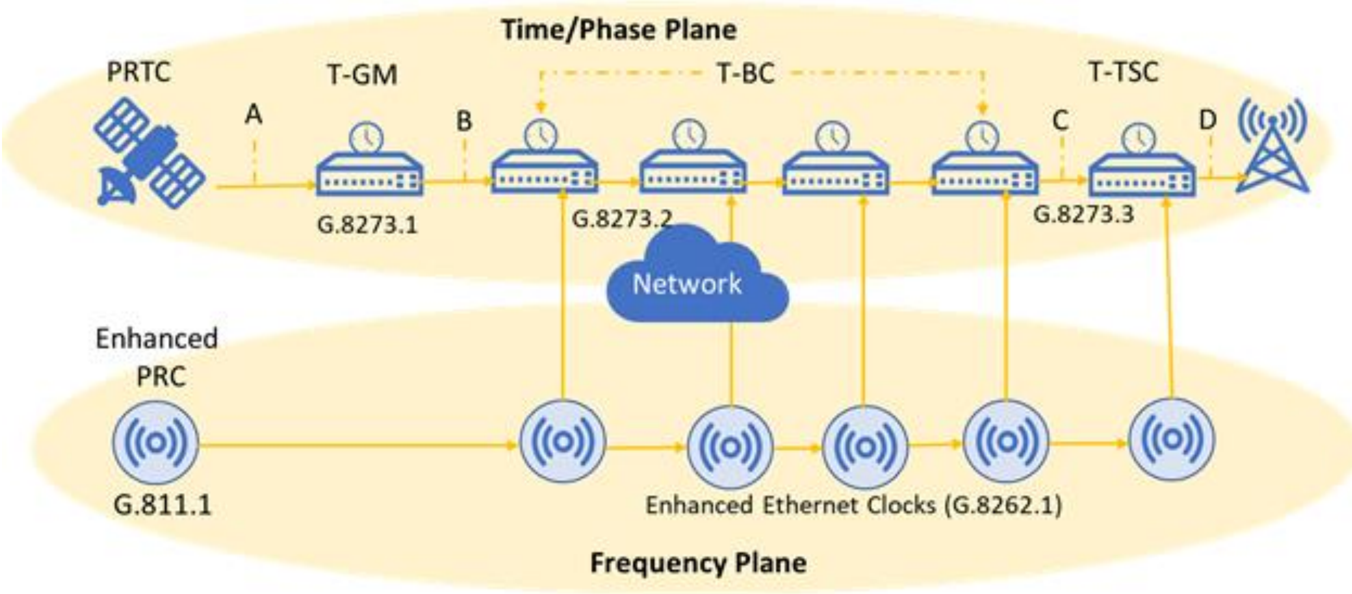


Figure 2. Timing Distribution and applicable ITU-T standards in frequency and time/phase plane.

SyncE (Synchronous Ethernet) is a good example of frequency plane timing distribution. Similarly, PTP (a protocol set defined by IEEE1588) timing distribution can be better understood by applying time/phase plane characteristics and requirements set forth in ITU-T recommendations G.8271 & G.8272 etc. as depicted in the diagram above. Please note, frequency and time/phase sync planes can be managed and routed independently.

5G Splits and Sync Plane

Implementation of timing distribution is generally done in both frequency and time/phase planes due to underlying network requirements. Hence, understanding of the concept is important for 5G sync plane design as such network must be frequency and phased aligned. 5G as defined in 3GPP standards distinctly divides the network concept into two elements: RAN (Radio Access Network) and Packet Core. An obvious indication that packet network will be pervasive in 5G deployments. Even in the deployment of 4G, it is discernable that packetization and penetration of ethernet in fronthaul is increasingly becoming a reality. Packetization and Ethernet technologies are fundamental conduit for flexible network configuration, virtualization and improved services.

In 5G deployments, RAN can be deployed in many split options and that is for good reasons: first, it allows easier decoupling of hardware and software. Secondly, network functions can be virtualized and processed in COTS (Common Off The Shelf) servers. These process of decoupling and virtualization significantly reduces CAPEX and OPEX and at the same time removes constraints of vendor locked systems. The concept of decoupling is not new, in fact cloud providers and data centers are benefiting from the implementation of this concept of "disaggregation" or “open networking”. For simplification, decoupling, disaggregation, open networking and whitebox terms are synonymous. For example, the concept of decoupling as in whitebox is implemented through DCSG (Disaggregated Cell Site Gateway), a project of TIP (Telecom Infrastructure Project) to provide telecom service providers a choice of vendor neutral networking solutions. The DCSG aims to replace CSR (Cell Site Router), a vendor locked product that help aggregate cell sites. It is an "open networking" initiative that takes into the benefit of decoupling and vendor neutral approach to help telecom service provider reducing their CAPEX and OPEX for fronthaul aggregation. Similarly, OpenRAN is a project of TIP that aims to decouple basestations or Base Band Unit (BBU). The BBU provides RF (Radio Frequency) processing services to cell towers. While DCSG provides whitebox solutions to replace CSR, OpenRAN initiative create standards for decoupling hardware and software for radio access networks. Both these projects help tremendously in 5G split options deployments.

5G specification allows fronthaul to be created in 8 different split options. Depending upon split options and fronthaul connectivity technologies, time sync requirements slightly differs. For example, for CPRI connectivity PTP is ideal whereas ROE (Radio over Ethernet) implementation requires both PTP and TSN are implemented in different segments of the network. The diagram below depicts four common split options for 5G deployments: option 1 (upgraded 4G), option 2 (5G standalone), Option 7 (dual connectivity) and Option 8 (vRAN/ORAN). For the sake of sync plane discussion, other options such option 3, option 4, option 5 and option 6 are not presented here.

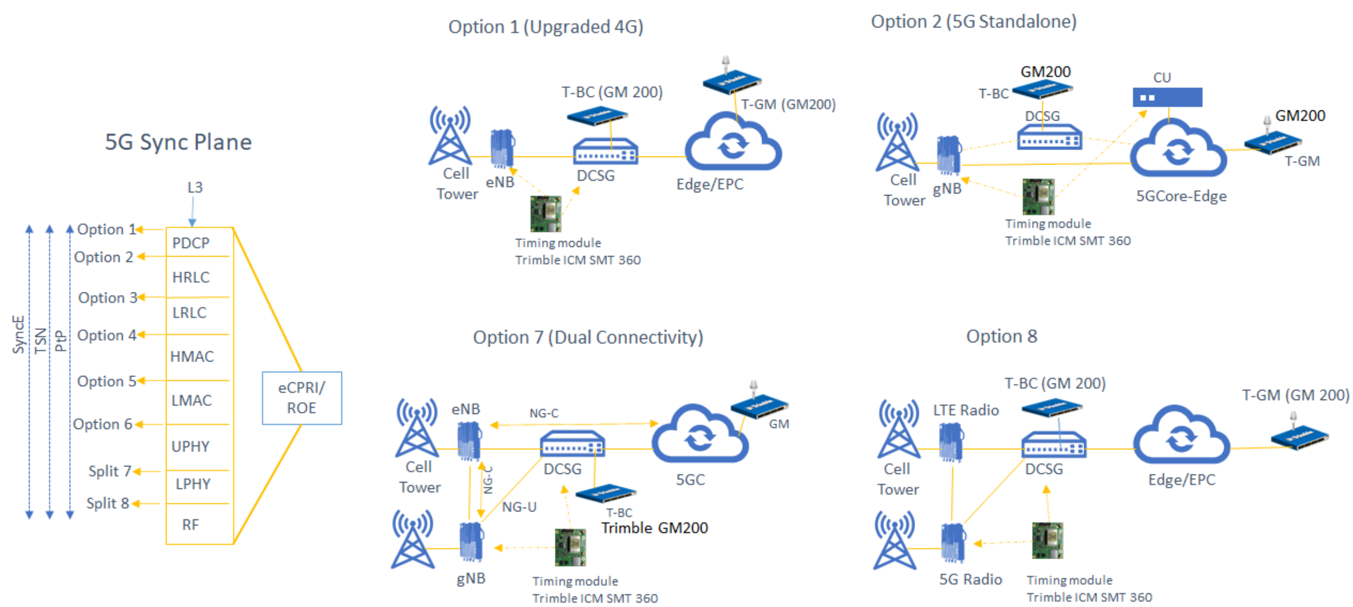


Figure 3. 5G splits and Sync Plane requirement.

One of the major considerations for time sync plane design is time error budget and ITU-T did a great job specifying requirement for complex sync plane design. The ITU-T G.8271.1/Y.1366.1 specifies time error budget or tolerance for fronthaul network which must be adhered while implementing timing distribution. A group of eNB, gNB or RU can form a sync cluster within a basestation cooperating cluster for which Time Error budget should be <260ns. The overall network budget should be <1.5µs (1.1 µs preferred).

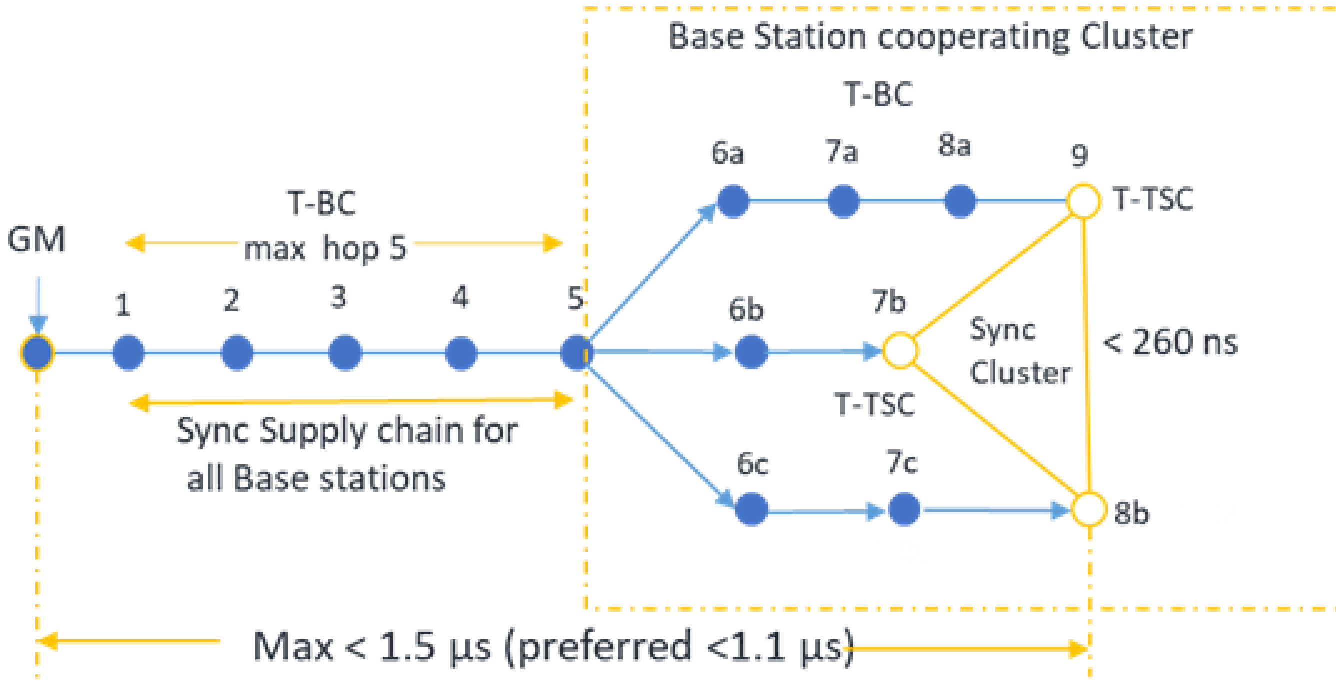


Figure 4. Time Error Tolerance consideration for 5G mobile transport (Ref: ITU-T G.8271.1/Y.1366.1).

This guidance though helpful, operators must consider time error budget specific to their deployment scenarios considering requirements of ITU-T G.8271.1. For example, despite ITU-T specifying max hop count 5 nodes between GM to basestation cooperating cluster, a Tier 1 decided to deploy maximum of two nodes from T-GM (Grand Master Clock) to T-TSC (Transparent Clock). The operators may choose to use ITU- Rec 8275.1 for the edge and ITU- Rec 8275.2 for the core in their 5G option 7 sync plane design. Here, coordinated PRTC sync plane was implemented using ITU-T recommendation G.8275.2.

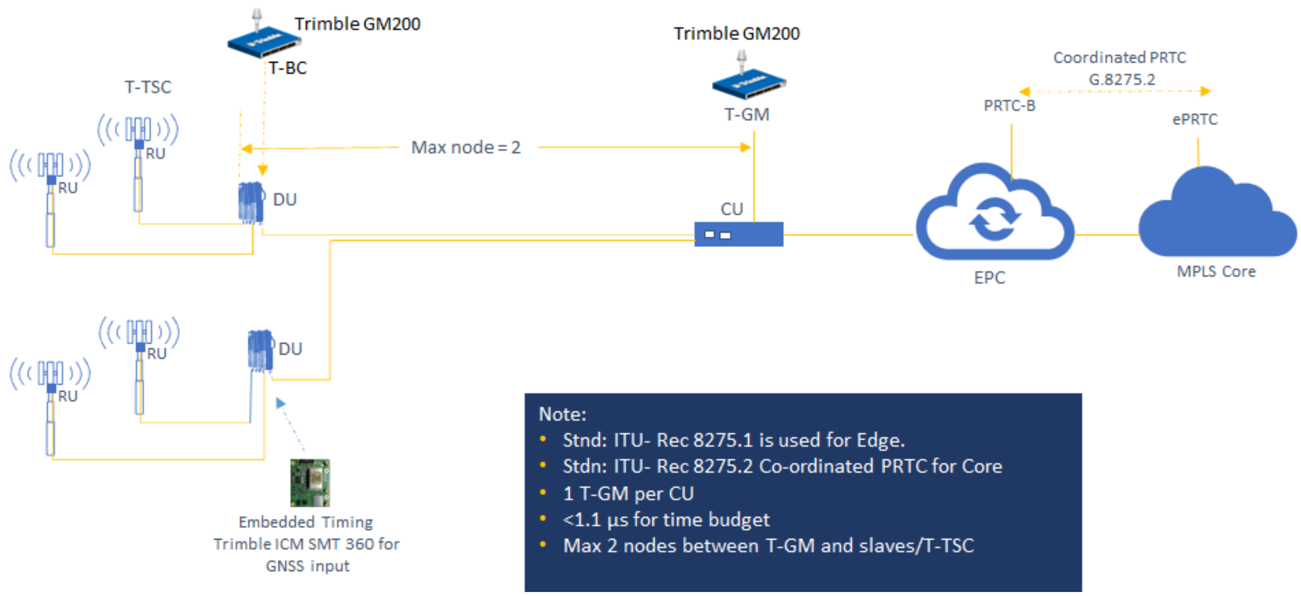


Figure 5. An example of Tier 1 5G option 7 sync plane deployment.

In this scenario, multiple RUs (Radio Units) are connected to DU (Distribution Unit) and DUs are directly connected to CU (Central Unit). The PTP grand master is connected to CU while DU implemented boundary clock. On the backend, PRTC-B and ePRTC coordinated synchronization is used for effective fault tolerance in case of a sync path failure. This deployment is a good example of how operator may choose to decide sync plane design based on their own time error budget calculation.

Similarly, deployments for 5G option 8 may requires specific consideration on sync plane since sync cluster span over different segment of network. Here, sync cluster may include vRU (virtual Radio Unit) and other VNF (Virtual Network Function) related to RAN functions. 5G option allows separation of the RF and PHY layers thus splitting sync cluster and extending it over to COTS server as VNF (please refer figure 6).

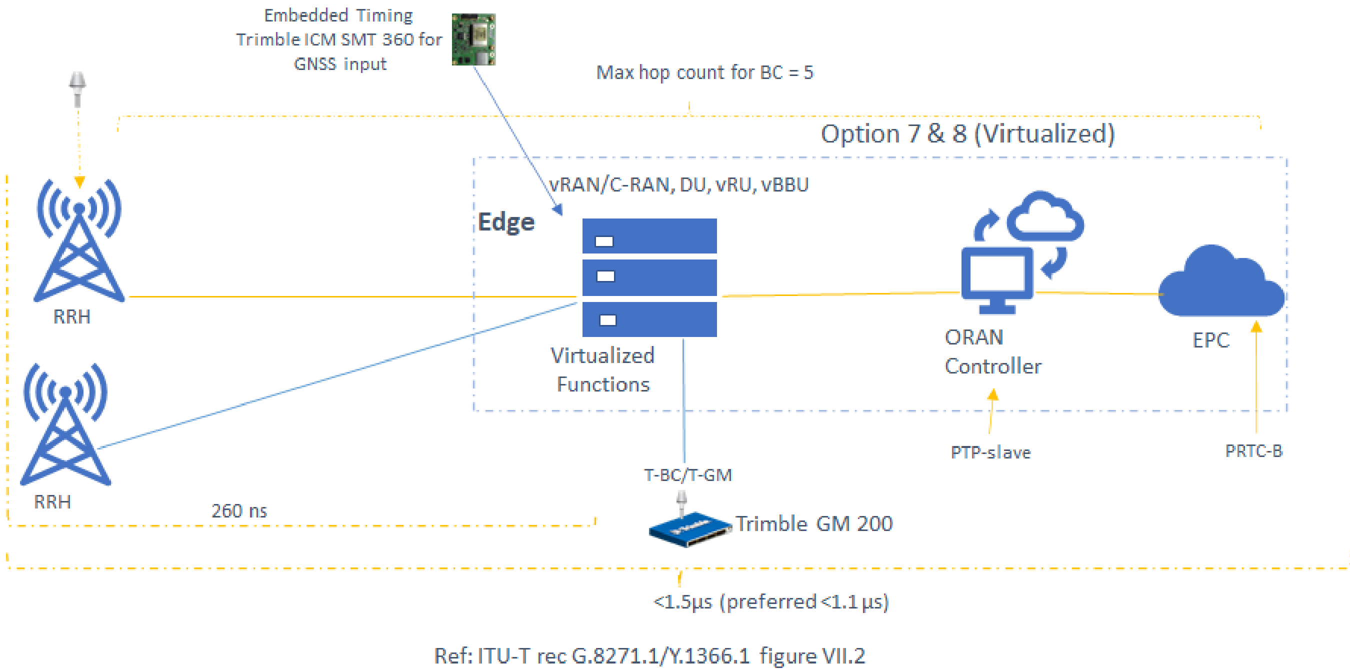


Figure 6. Typical Sync plane for ORAN deployment.

Option 8 poses great challenge for estimation of sync cluster time error budget and how such deployment manages overall network time error tolerance. Figure above depicts a typical deployment in which vRU and vBBU etc. implemented in COTS server for which orchestration and management is done through ORAN controller. For such deployments, COTS server should include HW assisted PTP and embedded GNSS timing input in case a T-GM (PTP Grand Master) is not in each rack. In ideal setup, each rack should deploy a T-GM with GNSS input. Given the price point of T-GM for 16 to 32 clients, putting T-GM at each rack is viable. Trimble provides cost effective GPS/GNSS antenna and PTP grand master that would be useful in such sync plane design.

Summary

ITU-T recommendations for Time error tolerance should be de facto in 5G sync plane design whether in fronthaul or CBRS deployment. Placing a T-GM after one or two T-BC hop away is a great way to design 5G with ample room for time error budget. Given that the price of T-GM in lower client counts is much cheaper, deploying T-GM at CU after one or two hops is a viable and cost effective option. This type of design provides improved time error tolerance for fronthaul. If you are considering 5G sync plane design, please visit http://www.trimble.com/timing for product and solutions offered by Trimble.

Trimble offers an extremely cost-effective T-GM, Antenna and GNSS timing modules for edge making the design of fronthaul sync plane much easier.

For more Information contact Step Global: sales@stepglobal.com