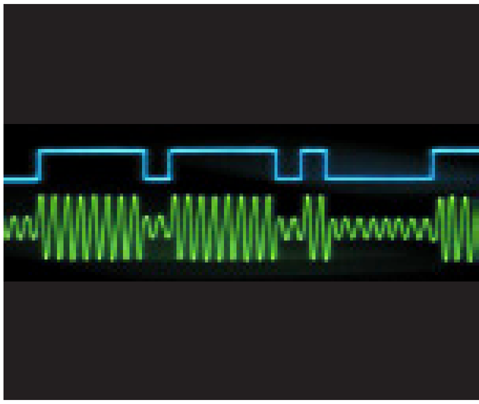
Building a Unified Synchronization Platform for IP Wireless Backhaul



WHITE PAPER

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Demystifying Packet Timing and the Case for a Coherent Network Timing System

EXECUTIVE SUMMARY

The proliferation of IP networks in mobile backhaul has resulted in base stations being isolated from traditional TDM synchronization references.

Making sense of, and differentiating short term fixes from long term solutions can be challenging with the diversity of messaging in the market.

Industry authorities know that standards-based solutions are key, and that while Adaptive Clock Recovery enabled the rapid deployment of circuit emulation, it remains proprietary. IEEE 1588 and SyncE are recognized as the long term solutions...but the economic viability of a timing platform is not predicated on just technology. The advantages of a unified synchronization platform outweigh mixed and disparate embedded systems.

Ultimately, an independent synchronization platform, built on standards-based solutions removes deployment risk and saves money.

WHERE ARE WE AND HOW DID WE GET HERE?

While the wireless industry searched for the killer 3G application, consumers quietly learned the value of mobile broadband. Supported by generous data plans, smart handsets and wireless modems, the demand for mobile broadband grew exponentially and became the new business opportunity for service providers.

But that opportunity came at a cost, with data utilization growth surpassing revenue increases.

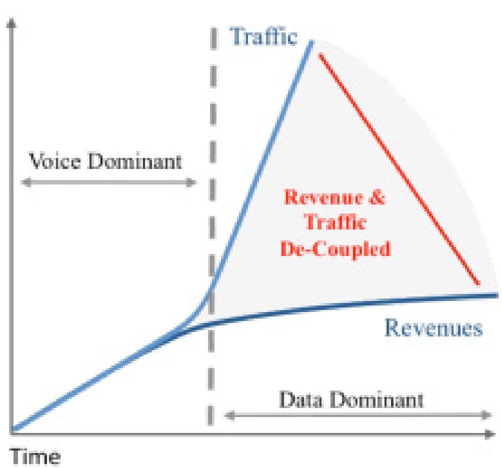

FIG 1. Revenue/traffic relationship

What is ACR, IEEE 1588, PTP and SyncE? How are they relevant to me?

Symmetricom explains Timing over Packet Networks and the benefits of a unified, standards-based, synchronization platform.

Coupled to that, the backhaul (often referred to as the Radio Access Networks) does not have the transport capacity needed for the data tonnage.

With the largest part of the operating cost being attributed to the Radio Access Network, the linear relationship between bandwidth and cost for channelized E1/T1 circuits was of concern, particularly where these services are leased. Mobile operators needed to transport more data between the base station and the Radio Controller for less money, and TDM was not a long term solution. The inevitable choice was IP/Carrier Ethernet. See Figure 1.

IP/Ethernet meets the investment drivers...increased bandwidth and reduced cost. And IP does not need synchronization to transport data. Surely this solves the problem?

As we drive for "more performance at lower cost", we innovate, and sometimes our innovation is predicated on secondary, enabling technologies. This is especially true for IP transport platforms in communication networks. It is true that network synchronization is not required to transport data through packet networks. By the same token, packet networks do not transport synchronization naturally as was the case for SONET and SDH. The nodes within a packet network are therefore asynchronous and there is no traceability to a stable frequency (and time) reference.

But services are dependent on timing, and wireless base stations need a stable frequency reference to support mobility. These requirements are outlined in Table 1.

Mobility Standard	Frequency	Time/Phase
CDMA2000	50 ppb	Range: <3μs to <10μs
GSM	50 ppb	
WCDMA	50 ppb	
TD-SCDMA	50 ppb	3μs inter-cell phase Δ
LTE (FDD)	50 ppb	
LTE (TDD)	50 ppb	*3μs inter-cell phase Δ
LTE MBMS	50 ppb	*5μs inter-cell phase Δ
Backhaul	16 ppb	

* Exact specifications pending

TABLE 1. Mobility Air Interface Stability Needs

From the table, it is apparent that the air interface stability should be 50 ppb irrespective of the mobile protocols or technology generation. It is the air interface stability that allows the user equipment (typically the cell phone) to hand-off call between cell towers without interruption, and it is, therefore, central to the Quality of Service.

You may ask what does this have to do with the IP backhaul? The answer lies in the origin of the base station's frequency reference. Base stations traditionally sourced their reference from the E1/T1 links (assuming they meet the synchronization masks defined by the ITU-T G.823 or Telcordia GR.253). When the TDM circuits are replaced with Ethernet/IP, the frequency source is lost, and the timing chain is broken. Healing these timing chains is one of the design challenges for backhaul planners.

Rebuilding the Synchronization Chains

While the transport vendors built packet network elements, the timing community worked on methods to deliver Timing Over Packet cost effectively. The obvious goals were to keep it simple, cost effective, and predictable. Simple suggests using the network to deliver time and frequency (at the physical layer or in-band). There were many resultant methods to distribute precise time and frequency through the network, but those of interest to us are Adaptive Clock Recovery (ACR), Synchronous Ethernet (SyncE) and IEEE 1588 (also referred to as PTP v2). Although not a packet technology, the use of GPS is also considered.

Adaptive Clock Recovery (ACR)

Simplistically, ACR is the recovery of a frequency (not time) from the traffic bits without concern for the packet content. Stable oscillators and averaging algorithms correct for Packet Delay Variation to the extent possible. While not losing sight of the enabling role ACR had on early CES/PWE, there is no standard for ACR, and the performance is specific to the vendor implementation and local oscillator.

Setting aside the cost of the source oscillator, and the performance of some ACR implementations with high packet jitter, ACR remains proprietary. Service providers will accept these solutions for a while, but will ultimately demand interoperability, driving vendors to standards-based solutions and limiting the usefulness of ACR. Traditional ACR vendors are already evolving to IEEE 1588.

> **Deployment of any interim solution such as ACR or NTPv3 (is) NOT contemplated in the VF (Vodafone) Group Strategy**[1]

Global Positioning System (GPS)

Technology advances and the widespread adoption of GPS have resulted in cost reductions, allowing timing GPS receivers to be deployed without the cost penalties of former versions. GPS is a high performance solution, providing time, frequency and location information independently of the network.

One obstacle is service availability due to weak signals in metropolitan and indoor installations. The second concern is that GPS is not autonomous, and international operators prefer not to be dependent on GPS at many thousands of locations. Finally, antenna deployment costs in urban environments can be an insurmountable obstacle.

Synchronous Ethernet

Synchronous Ethernet is a schema that preserves physical layer synchronization over Ethernet, without compromising the asynchronous switching functions. Based on the IEEE 802.3 standard for Ethernet, it is synchronous at layer one, with the higher layers being asynchronous. There is therefore no difference between a Synchronous and Asynchronous switch in the way the data is managed and switched. The difference is only at the clock layer.

Asynchronous switches receive data at the incoming line rate, and in adherence to IEEE 802.3, transmit data using a free-running clock of 100 ppb (poor stability in synchronization terms, but suitable for the switching function). Refer to Figure 2.

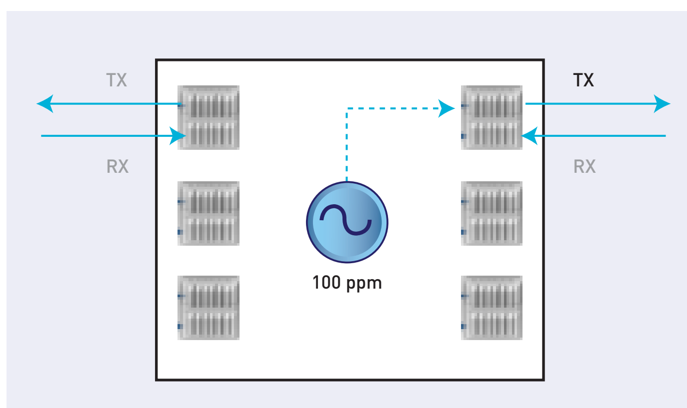

FIG 2. Asynchronous switch

1 Achieving reliable backhaul and network synchronization - The case for All IP solutions, Max Gasparroni - VF Group, Paulino Correa - VF Portugal, Next Generation Networks 2009.

SyncE switches by contrast use a more accurate 4.6ppb oscillator disciplined to the RX (incoming) line rate. There is a Sync relationship between the RX and TX, with the incoming clock being propagated. Refer to Figure 3.

By adding an external sync port to the SyncE switch, a Stratum 1 reference can be introduced to, and distributed through a packet network independently of the traffic.

Clearly cascading synchronous and asynchronous switches will interrupt the originating (and accurate) sync flow, making SyncE an end to-end frequency delivery method. This means that cascaded synchronous and asynchronous switches will not deliver the source frequency through the network. The 100ppb reference will be substituted in the asynchronous switch, breaking the sync chain. Refer to Figure 4.

In summary, SyncE has the advantage of being a layer one frequency distribution method, but requires end-end support. Interoperability among vendor solutions will be important, but SyncE adoption will ultimately be governed by the ease with which the installed asynchronous switches can be upgraded.

IEEE 1588-2008 (PTP)

The IEEE 1588-2008 protocol (also called Precision Time Protocol or PTP) is a standardized method to distribute accurate time and frequency over IP networks. The basis of operation is that packets carry timestamp information between a master (server) and slave (client), and the slaves use the timestamps to synchronize to the master. Bidirectional flows eliminate the round trip delay to enhance the accuracy. Frequency can in turn be recovered from the disciplined time-of-day clock.

The timing and management messages are transported in-band with the mainstream traffic, eliminating the need for a dedicated timing plane.

IEEE 1588 was initially developed for industrial automation over Local Area Networks, but a second version, tailored for constrained telecommunication environments was published in 2008. The subsequent ITU-T G.8264.1[2] telecom profile simplified the diversity of configurable parameters needed to support WAN's, significantly improving the protocol's interoperability.

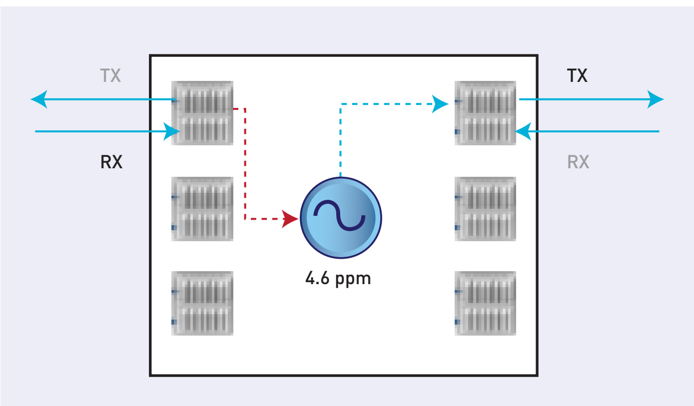

FIG 3. SyncE switch (Line Timing)

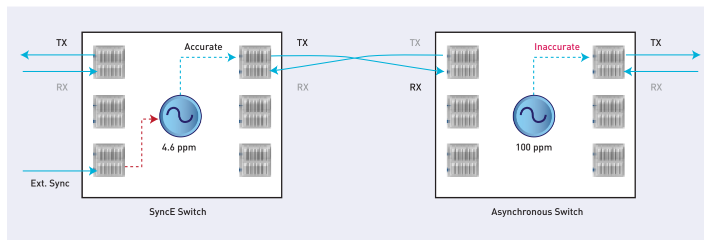

FIG 4. Broken synchronization chain

2 ITU-T G.8264.1 is pending final approval at the time of publishing this white paper.

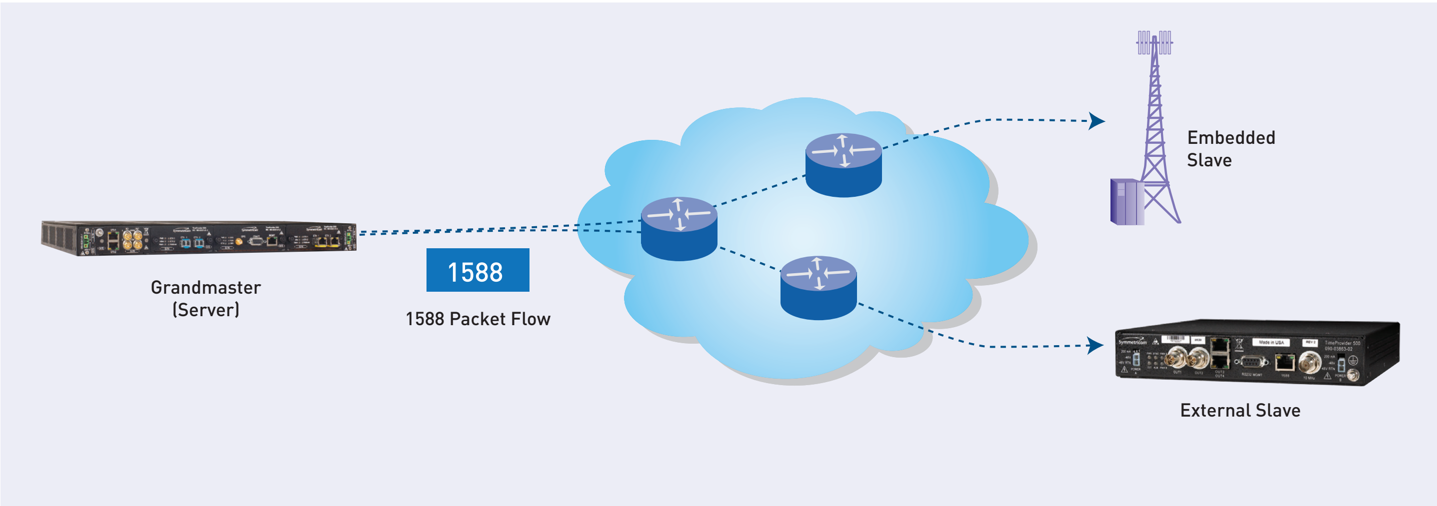

FIG 5. IEEE 1588 architecture

What makes IEEE 1588 very attractive is the microsecond accuracy (and associated 1PPB frequency stability) that can be realized over managed Ethernet. This allows PTP platforms to support a wider range of applications than any other solution, addressing for example both the FDD and TDD modes of LTE.

Being packet based, IEEE 1588 is sensitive to the network behavior and the accuracy depends on the clock recovery algorithm and the packet jitter (also called Packet Delay Variation or PDV). The primary contributors to packet jitter are bandwidth utilization and number of serial "store and forward" buffer elements, also called number of hops. In general, meeting the frequency requirement is moderately easy, but phase synchronization is more sensitive and requires added network engineering. Fortunately, the protocol designers foresaw this, and included on-path support in the specification On-path support consists of Transparent and Boundary clocks that reduce the packet jitter, improving performance over long hop counts.

IEEE 1588-2008 (PTP) & SyncE In Perspective

How are IEEE 1588 (PTP) and SyncE similar? How are they different? And what does this mean to you?

Both SyncE and IEEE 1588 are standards-based methods to transport frequency (and time for PTP) through the network to heal the broken synchronization chains. Where they differ is in the implementation.

Table 2 summarizes the key differences, but in essence, SyncE is a conscious decision to add the feature to every switch between the source and the destination. Cascaded synchronous and asynchronous switches will not transport synchronization (even though they can route data).

1588 is largely independent of the transport elements; largely because PTP clients may be embedded in network elements, but is not a pre-requisite. This allows PTP networks to be built independently over diverse transport systems.

Attribute	IEEE 1588	SyncE
Capability	Frequency, Phase, Time	Frequency
Layer	Ethernet/UDP	Physical
Distribution	In-band 1588 Packets	Physical layer
Schema	Point to multi-point	Point to point
Transport Media	Native Ethernet, xDSL, Microwave	Native Ethernet
Interoperability	Standards based. grandmaster & slave	Standards based SyncE switches only
Sensitivity	Packet Jitter / Bandwidth utilization	Asynchronous switches
Standards	IEEE 1588, ITU G.8264	ITU G.8261/3/5

TABLE 2. IEEE 1588 / SyncE comparison

The majority of Carrier Ethernet vendors continue to develop new products with consideration to multi-vendor interoperability.[3]

PUTTING IT TOGETHER, A SYSTEMS VIEW

While the two standards-based methods for delivering synchronization are IEEE 1588 and SyncE, there are many proprietary methods embedded into next generation elements. ACR, for example, can be found in access routers, wireless base stations, and microwave radios. We know that this was implemented out of necessity, but what should your synchronization platform look like going forward?

To answer this, let's reflect on the attributes of a typical TDM platform…

- Based on more than one technology (e.g. hybrid GPS and Cesium primary reference clocks),
- Based on ITU-T and ETSI / Telcordia standards for vendor inter-operability and reliability,
- External to the transport elements (core and access),
- Includes an element manager for monitoring and remote management,
- Distributed synchronization elements, but work as one unified system.

Why did we build coherent synchronization systems before? Why should we continue using unified systems in the future? In short, to save money and improve performance.

While low price embedded solutions may be financially enticing, a single coherent system costs less than disparate schemes that were purchased on a project by project basis. And that is just the capital component. Consider for a moment the increased operational expenses associated with different systems from multiple vendors in a central office. After all, how many GPS rooftop antennae do the operations teams want to support? It will not take long for the cost benefits of a unified synchronization system over project based alternatives to become overwhelming.

We all agree that saving money is important, but so too is the resilience of the network. Given the influence synchronization has on the network Key Performance Indicators, investing in a resilient and high performance system is a natural choice. One pair of redundant atomic clocks for example provides extended holdover to all the network elements in an office. Higher availability and enhanced performance can be bought for less when you only need to buy once.

But those are not the only concerns to planners and finance. When investing in network infrastructure, the extent to which a solution addresses the future requirements is a crucial consideration. And never more so than today. It did not take long for GigE links to be increased to 10G, and 40G is not far away. This rapid progression of technologies would result in three different sync systems in a very short time, but one independent Sync platform is future proof, and will grow with the network. The planning and engineering associated with integrating disparate synchronization platforms is complex…but not so for a unified and future-proof system.

Finally, multiservice platforms allow service providers to converge their wireless, wireline, IP and transport networks to fewer vendors and associated device types. This means that solutions must be standards-based to ensure interoperability, and this is especially true for synchronization. A unified standards-based timing system assures performance, enables management and facilitates the deployment of all next generation equipment and services.

Table 3 provides further insight into the benefits of the unified synchronization solution.

Synchronization Delivery Consideration	Embedded/ Proprietary Soln.	Self-Managed Solution
Scalable and Cost Effective	Not typically	√
Interoperable with multiple vendors	No	√
Simplified Planning & Engineering	Not typically	√
Sync Quality to support service delivery	Unknown	√
Independent of transport & services platforms	No	√
Works with all generations of equipment	No	√
PRC/UTC Traceability	Unknown	√
Standards based	Unknown	√
Clock Hardware Redundancy Protection	Not typically	√
Network Redundancy Protection	Unknown	√
Holdover Protection (Atomic grade clocks)	Not typically	√
End-to-End Management/Visibility	No	√
Ability to correlate alarms through the network	Unknown	√

TABLE 3. Benefits of Unified Synchronization Platform

3 Carrier Ethernet World Congress 2009, Multi-Vendor Interoperability Event White Paper, Carsten Rossenhövel

When all is said and done, the network must be managed, resulting in enhanced synchronization availability, and shorter down-time, leading to a better quality of service.

From the NOC perspective, this it is difficult when the embedded multi-vendor synchronization alarms systems are not integrated. This is exacerbated when the traditional Sync platforms are managed independently of the embedded systems.

A unified management platform will provide access to all legacy and packet synchronization elements without network security breaches (bonding of network segments and VPN's), and without the need for an overlay data communication network. Refer to Figure 6.

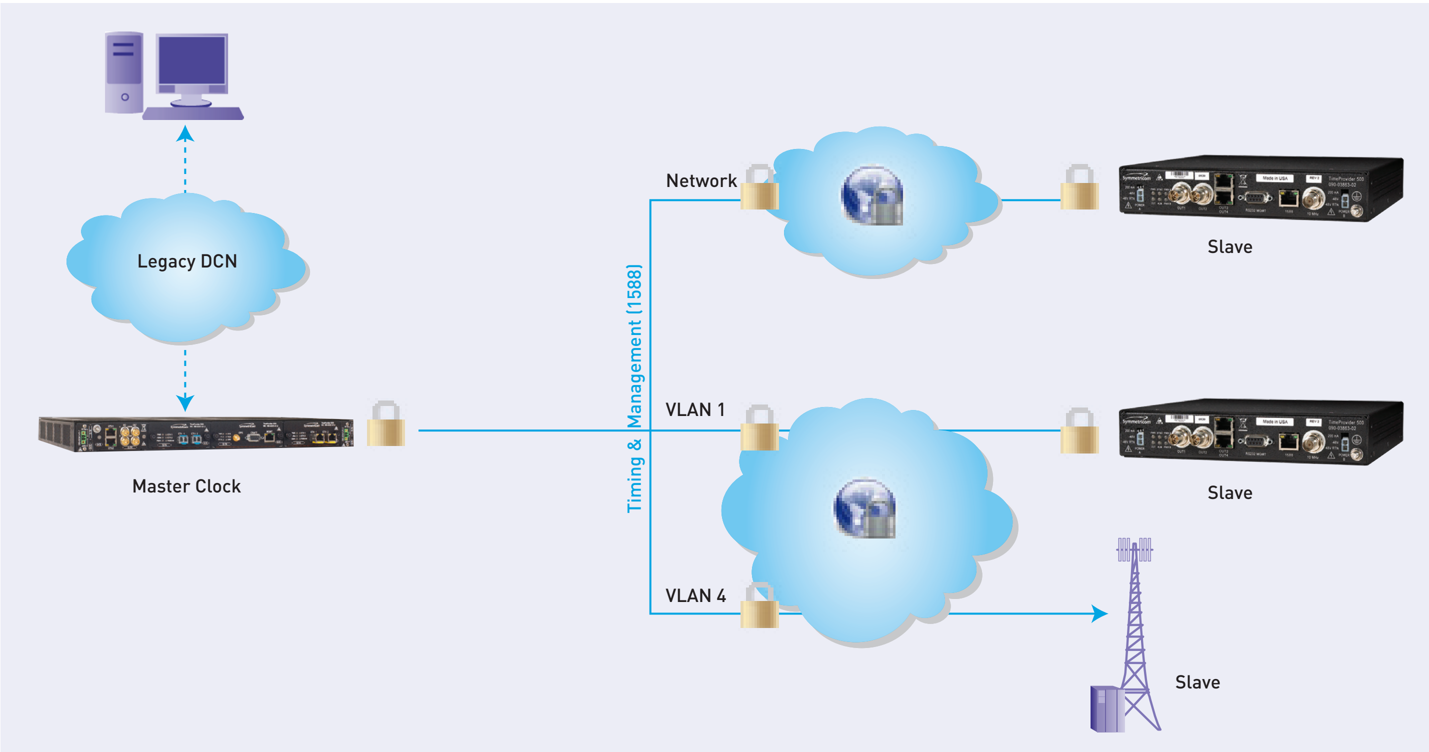

FIG 6. Sync management architecture

CONCLUSION

The telecommunication industry has endorsed the ITU-T's standardization of two time and frequency transport methods through packet network. These are Synchronous Ethernet (for frequency), and IEEE 1588-2008 (for time and frequency) and apply to the European and North American markets. Vendor interoperability mitigates deployment risks in today's fast paced roll-outs, supporting standardization efforts. Adaptive Clock Recovery and other proprietary methods were enablers of early deployments, but are ultimately not standards based and do not support vendor interoperability.

Looking beyond just the technology choices, a unified synchronization platform provides many financial, operational and performance benefits. This requires a conscious decision to avoid synchronization that is embedded into network elements, no matter how alluring the initial cost.

A unified synchronization platform, built on standards-based solutions removes NGN deployment risk, saves money and improves the your customer's quality of experience.

To find out more about next generation synchronization, contact your local Symmetricom representative, or e-mail us at expertadvice@symmetricom.com

ACR .... Adaptive Clock Recovery
BTS........ Base Station Transceiver
CES........ Circuit Emulation Service
DSL........ Digital Subscriber Line
ETSI .... European Telecommunications Standards Institute
FDD .... Frequency Division Duplex
GigE....... Gigabit Ethernet
GPS .... Global Positioning System
IEEE....... Institute of Electrical and Electronic Engineers
ITU-T ..... International Telecommunication Union
LTE .... Long Term Evolution
NGN ...... Next Generation Network
PDV........ Packet delay Variation (synonymous with Packet Jitter)
PTP........ Precision Time Protocol
PWE....... Pseudo-Wire Emulation
SDH .... Synchronous Digital Hierarchy
SONET... Synchronous Optical Networking
SyncE .... Synchronous Ethernet
TDD .... Time Division Duplex
TDM....... Time Division Multiplex
UDP....... User Datagram Protocol
UTC........ Universal Coordinated Time

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