



Overview

Timing and Synchronization in Next-Generation Networks

Introduction

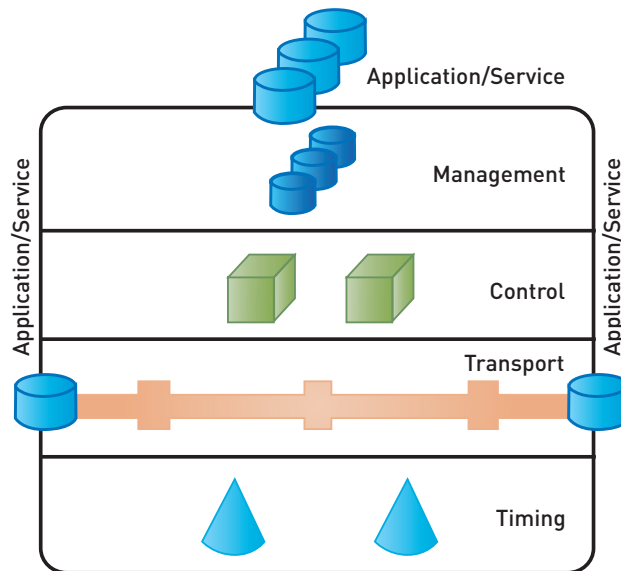
In traditional circuit switched or Time Division Multiplex (TDM) networks, frequency synchronization is required for alignment of transport equipment. In the each node of the network, synchronization is distributed from a synchronization system to all the network elements, and through out the network from node to node with TDM frame alignment of PDH or SONET/SDH. In addition to synchronization of transport and switching equipment, synchronization is also needed by service endpoints such as PBXs (Private Branch Exchanges) and IADs (Integrated Access Devices). These endpoints require a service clock to ensure the alignment of the originating and terminating service endpoints for proper service operation.

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The foundation of the Next Generation Network (NGN) is a packet-based transport. The network transition from TDM to packet technologies started many years ago and gradually the deployment of packet equipment is migrating to the access networks. It is expected that some parts of the network will continue to use TDM elements for the next 5 to 10 years until they reaching end-of-life. Thus, the network today is hybrid with a mix of circuit and packet technologies, particularly in the access and metro layers.

The NGN is also evolving from a service perspective where more efficient ways of providing existing TDM services are being explored by leveraging packet technologies such as circuit emulation. As well as new services such as voice over IP (VoIP) or IP-Television (IPTV) have become feasible over a packet-based infrastructure.



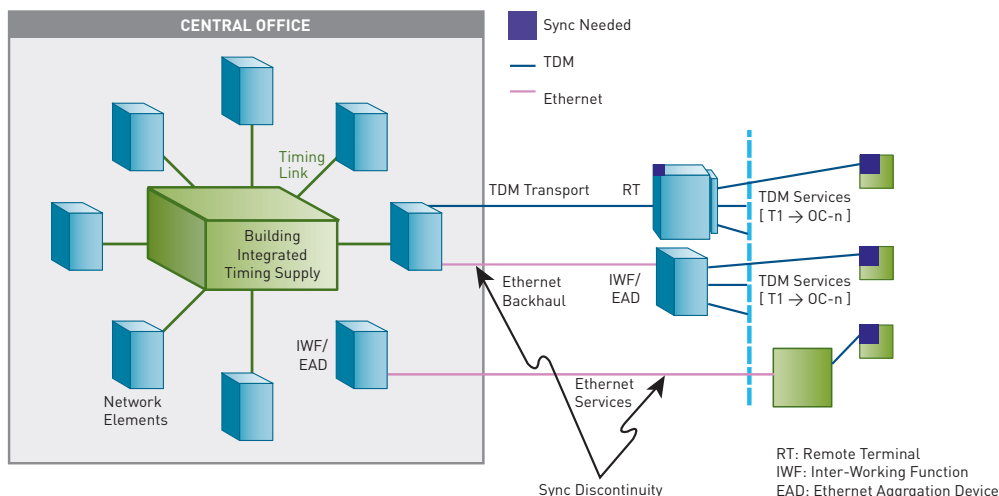
Traditional View of Timing

This transition and evolution of the network has two main implications for synchronization. First, the network infrastructure still requires synchronization for service continuity. And second, additional timing requirements are emerging due to new services now deployed over packet networks. Hence, the need for synchronization of the network is not diminishing but actually transcending and transmuting into new requirements and new technologies serve the NGN.

Timing in TDM Services

With the increasing need for bandwidth, circuit-based infrastructure faces limits in scalability in terms of operational cost and maintenance, therefore carriers are moving to replace circuit-based transport with packet-based (Ethernet) transport to realize cost and operational efficiencies and also to meet increasing bandwidth demands from customers at reasonable price points. In addition, these technologies are bringing a new level of flexibility and dynamic configuration to the network that enables service providers to offer more tiered and time-based or on-demand services.

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Discontinuity in delivery of synchronization to service endpoints

Circuit Emulation Services (CES) are the primary driver for provision synchronization in packet networks. CES refers to the emulation of TDM services such as Nx64 kbit/s, T1/E1, T3/E3 over a packet transport. Until recently, CES for T-n/E-n circuits were being delivered natively or over Asynchronous Transfer Mode (ATM) transport using constant bit rate (CBR) and permanent virtual circuits (PVCs). With the network expansion and gradual replacement of TDM/ATM technologies with Ethernet, a new CES is emerging where the TDM emulation is provided over Ethernet transport in metro and access networks in order to take advantage of a lower cost and higher flexibility of the packet infrastructure.

TDM service requires that the clock in the transmitting and receiving ends of a T1/E1 circuit must be properly synchronized (ITU Rec.823/824), this principle has been incorporated in ATM, as well as in new switching technologies such as Multi-protocol Label Switching (ITU-Y.1413) where different synchronization methods are defined for CES. These methods require a network reference clock as well as network distribution mechanism.

Similarly, CES over packet networks require synchronization methods where a network reference and clock distribution mechanisms are needed to support TDM services (ITU Rec.8261). In some cases, Ethernet transport is used as backhaul from a remote terminal that is aggregating TDM circuits. In other cases, Ethernet transport may extend its reach to the customer premise such as a building or a wireless base station.

Wireless backhaul is a main driver for CES where timing requirements for wireless base stations have two key aspects:

- A service clock required for the transport of the TDM circuits that are terminated at the base station.
- Wireless base stations also require radio frequency synchronization for the purpose of RF alignment and mobile call hand-offs.
- GSM and UMTS base stations have relied on loop timing over T1/E1 circuits to obtain frequency. However, conversion to Ethernet transport creates a discontinuity in the timing distribution, which must be addressed for proper base station operations.

In the world of CES, network time distribution mechanisms are needed in lieu of loop timing to ensure service continuity and operation.

Timing in NGN Services

New forms of timing requirements are emerging for IP services and Ethernet transport, where timing is a critical enabler for the implementation and assurance of Quality of Service (QoS) in NGN. Some of these requirements are discussed below.

Performance Measurement

Although packet transport was designed for data traffic with a store and forward mechanism, many real-time services, that are extremely sensitive to delay and packet loss, are now being deployed over packet networks creating the need for an extensive real-time network monitoring to prevent jitter, and minimize packet loss and congestion.

The dynamic monitoring of packet networks has created the need for traceable time references throughout the network. Since all measurements have the basic principle of comparing data collected to a reference, traceability of the time reference is fundamental for measurement accuracy, consistency and reliability. Lack of traceability in performance measurements can lead into misdiagnoses, delayed response, and ultimately failures and outages. All these incidents have a direct impact on service disruption representing revenue loss and customer dissatisfaction.

One of the advantages of proper timing in IP/Ethernet based infrastructure is the ability to provide granular services, dynamic bandwidth management, QoS, and service level agreement (SLA) assurance. The need of timing references applies to service providers as well as customers for the proper initiation and monitoring of these SLAs. Therefore, from a network performance and measurement perspective as well as service configuration perspective, traceable time is key to service delivery.

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Timing is a critical enabler for the implementation and assurance of Quality of Service (QoS) in NGN.

Billing

Accuracy in billing is an important factor in customer satisfaction. Accurate billing has become a service differentiator in dynamically configurable services. Many carriers now offer complete billing accuracy to their customers and the use of precise time references is a key element to achieve billing accuracy.

For example, in VoIP services the Call Detail Records (CDRs) are time stamped since they provide details about call origination, destination, and duration. As calls travel across various networks, gateways, and servers, CDRs are updated to contain information from each segment of the call. In order for all CDRs to be consistent, it is necessary that all gateways and servers be properly time synchronized. Therefore, billing accuracy is dependent on the accuracy of the time stamps, especially for real-time services and dynamic bandwidth allocation. Time synchronization is particularly important when CDR data is shared between carriers, where resolution of billing discrepancies requires either costly mediation or revenue write-off.

NGN Application	Business/Operational Need for Timing
Circuit Emulation Services	Essential for delivering Circuit Emulation
IPTV	Essential for Video Service Delivery, basic requirement for Customer Retention
QoS Assurance, Network Monitoring, Performance Measurement	Network Uptime, Alarms, Diagnostics, Event Correlation
Ethernet Services	Essential for SLA Management, Billing
Business VoIP, VoIP Centrex Services	SLAs, VoIP service integrity/availability, Performance Monitoring, Prevention of DoS Attacks/Theft of Service
Wireless/Mobility Backhaul Services	Call Hand-off and RF alignment

Troubleshooting and Maintenance

Accurate timing plays an important role in enabling network administrators to identify and analyze failures and outages. When problems arise, accurate server and router log files enable administrators to quickly locate and troubleshoot root-cause problems.

In order to set the time and order of events, each log file entry must have an accurate time stamp. Given that server logs are the compilation of data from a variety of hosts, it is imperative that time stamps on the data events from different sources be traceable and consistent. The lack of traceability and consistency makes event ordering and analysis almost impossible to process. Troubleshooting an outage takes a long period of time, extending service downtime and the possibility of recurring incidents.

Network synchronization provides precise time stamping, enabling network operators to quickly identify problems, correlate events, and effectively solve the source of the problem, leading to improved performance and availability.

Real-time Services

Real-time interactive services such as IPTV, online gaming and video conferencing also require timing. In the case of IPTV, IP transport of video and the interactive nature of IPTV are creating new requirements for timing. Video is much more latency and loss intolerant than VoIP or data services. Network jitter and latency affects a video viewer's experience far more significantly as artifacts, pixellation, blurring, or

audio distortion are very noticeable events. Timing requirements for IPTV are rapidly being identified as carriers move from field trials to large-scale deployments. ATIS IPTV Interoperability Forum has recently published timing and frequency synchronization requirements for IPTV (Ref ATIS 0800001, ATIS0800002)

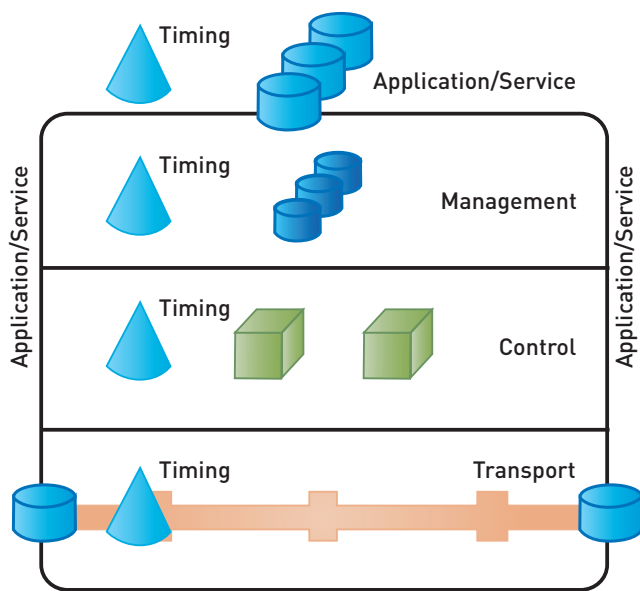
Triple play services are driving the need for timing into the access network and residential customer premise. As home networks become more pervasive, there are new needs for timing at the residential gateway that in many cases will need to be provided by a network clock distributed by an access element such as an IP-DSLAM or GPON. Several standards bodies, such as the IEEE Residential Ethernet Study group, are looking at these requirements and standards are currently being defined.

Triple play services are driving the need for timing into the access network and residential customer premise.

Traditional Synchronization

Every network element in a digital communications network has a clock subsystem (often just called the "clock"), typically containing a crystal or rubidium atomic standard oscillator. This oscillator is used, in conjunction with other circuitry, to generate various frequency signals (i.e., clock waveforms or reference timing signals) used to clock circuits throughout the system. The objective of network synchronization is to ensure that all the clocks in a network are operating at the same rate or frequency, minimizing time errors and avoiding service disruptions.

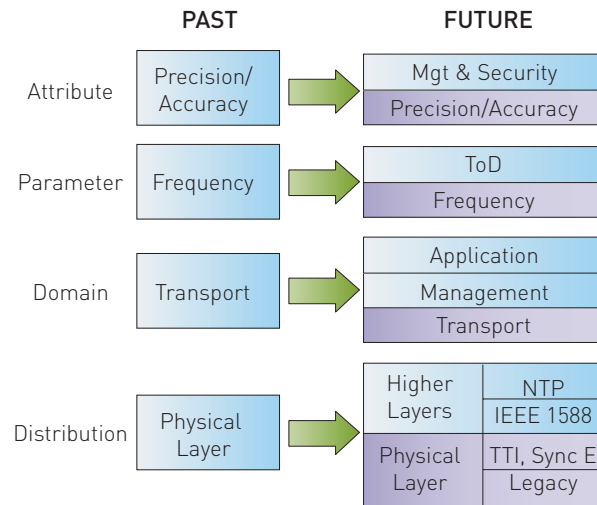
The clocks in the network elements need to be disciplined by an external reference, provided by a stand-alone synchronization source defined as Building Integrated Timing Supply (BITS) according to Telcordia GR-1244-CORE or Synchronization Supply Unit (SSU) according to ITU G.812, which are responsible to distribute synchronization (time and frequency) from a primary reference source (PRS) or primary reference clock (PRC) to all the network elements in the site, also referred to as intra-synchronization as well as to all the different nodes of the network, also referred to as inter-synchronization.



Timing in Next-Generation Networks

The characteristics of network synchronization have been governed by Telcordia standards GR-2830-CORE for PRS and GR-378-CORE for BITS, and ITU standards G.811 for PRC and G.812 for SSU.

Timing and Synchronization plays a critical role in next-generation networks.



Evolution of Timing

Timing and Synchronization Evolution

Synchronization was directly associated with the transport domain in TDM networks and indirectly with services. In NGN, timing and frequency are evolving to more comprehensive set of requirements for transport infrastructure, management and services or applications. The synchronization infrastructure for NGN will need to meet legacy TDM needs as well as new timing requirements that are being defined as carriers deploy new services.

Parameters

While frequency transfer is used in TDM networks to achieve synchronization, both time and frequency are required in NGN and must be distributed over packet transport.

Timing in TDM networks were not so critical to network operation and service delivery and were usually self administered by network elements. Network wide timing synchronization is a new requirement driven by performance measurement, service assurance and real-time services in NGN. These timing requirements unlike before are far more pervasive and stringent in NGN.

Timing Distribution

In PDH and SONET/SDH inter-office synchronization distribution was done through frame alignment from one telecom office to another or to remote terminals or to customer premise equipment. However, this is no longer possible with asynchronous Ethernet transport. New synchronization distribution methodologies such as IEEE 1588 Precision Time Protocol, and Synchronous Ethernet (ITU G.8261) are being developed to restore inter-office synchronization distribution.

With respect to performance management and real-time services where timing requirements are based on Network Timing Protocols (NTP) standardized by the IETF, requirements for more scalable, reliable and precise NTP are also being employed. Since both frequency and time are required in NGN, new intra-office synchronization distribution technologies such as the Universal Timing Interface (ITU J.211) are under consideration in standards bodies.

Packet based protocols such as Precision Time Protocol (IEEE 1588) and NTP are subject to much higher latency and jitter that is a characteristic of packet networks. Due to the non-deterministic nature of packet transport, timing and synchronization techniques have to be implemented in such a way that the implementation addresses network latency and jitter requirements. This can be achieved by constraining the number of network hops over which a primary reference source is distributed and also with traffic engineering in order to minimize packet delay variation. In addition performance improvement mechanisms based on servo control technologies and algorithms are being developed which will enable these protocols to meet stringent requirements, such as the CES requirements, such as defined in G.823/824.

Manageability

As network operators enable their networks to be fully manageable remotely, it becomes imperative that timing systems also support two-way intelligent time and frequency transfer mechanisms so that timing at the receiving equipment can be managed. Synchronization equipment that is already deployed in telecom offices does not have the capability to monitor synchronization of the network element clock. The PRS/PRC and the BITS/SSU equipment can only ensure the performance of the timing source and this currently deployed equipment cannot detect the loss of synchronization or failure in the receiving equipment. Therefore, sophisticated monitoring, management and measurement features are a necessity in the next generation of synchronization and timing equipment.

Security

Furthermore, packet networks are vulnerable to malicious attacks and threats to network integrity and security. Many of the network disruption tactics involve disruption of system clocks in the network path. The existing practices for the timing administration in network elements are not very secure or actively managed. The timing distribution in NGN must be from a trusted source and distributed in a protected transport infrastructure, preventing malicious intrusions that may result in service outages.

Conclusion

Timing and Synchronization plays a critical role in next-generation networks for the support of legacy services as well as for emerging services. Precise frequency and timing and their effective distribution will continue to be a cornerstone of highly available networks. Consistent and reliable timing will be essential for quality assurance, network performance, service availability and seamless interoperability across the diverse universe of network elements, service infrastructure and customer premise equipment.

As the network evolves, timing and synchronization technologies are also evolving to address new requirements.



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