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SERVICE REQUIREMENTS

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टाइम सिनक्रोनाईजेसन आई पी नेटवर्क मे

Time Synchronisation in IP Network

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FOREWORD

Telecommunication Engineering Centre(TEC) functions under Department of Telecommunications (DOT), Government of India. Its activities include:

- Issue of Generic Requirements (GR), Interface Requirements (IR), Service Requirements (SR), Essential Requirements (ER) and Standards for Telecom Products and Services
- Field evaluation of products and Systems
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- Support to DOT on technology issues
- Testing & Certification of Telecom products

For the purpose of testing, four Regional Telecom Engineering Centres (RTECs) have been established which are located at New Delhi, Bangalore, Mumbai, and Kolkata.

ABSTRACT

This SR specifies the Service Requirements of time synchronisation in Packet Networks deployed in Indian Telecom Network.

CONTENTS

HISTORY SHEET

S. No.	Name of the document and Number	Issue	Remarks
1.	Time Synchronization in IP networks	01	First version
2.	Time Synchronization in IP networks	02	Second version

REFERENCES

S.NO.	Title	Document number
	I : ITU Recommendations	
1.	ITU-T G.811, ITU-T G.812, ITU-T G.813	
2	G.8261, G.8262, G.8264	
3.	G.8272/Y.1367	
4.	G.8272.1/Y.1367.1	
5.	G.8273.2/Y.1368.2	
	II : IETF Recommendations	
1.	RFC 1305,	
2.	RFC 3971	
3.	RFC 4330,	
4.	RFC 5905	
5.	RFC 5908	
	III : IEEE Recommendations	
1.	IEEE 1588	
2.	IEEE 802.3	

CHAPTER-1

1.0 INTRODUCTION

1.1 In view of the availability of a limited number of public IP addresses, many telecom/ Licensed service providers (LSP) are allocating dynamic private IP addresses to their customers. Using Network Address Translation (NAT) techniques a single public IP address is shared between multiple customers. It has been found that at any given point of time, despite date and time stamps, service providers are unable to pinpoint the exact subscriber /user.

By design, IP networks are very robust and not supposed to fail. But the original design was not meant to make a carrier class IP network like TDM/SDH networks. Because of this approach the time and timing information travelling in an IP network was not considered to be a critical requirement. In IP networks traffic can move from source to destination via multiple routes. If there a route failure, the network is not affected and traffic can still reach the destination via alternate routes. However, in this process, the traffic packets travel across multiple paths travelling through different routers, switches, hubs, gateways etc. The time kept by the different intermediaries may not be in sync. Timing differences can also cause the problem of different time stamps on server and log files on different systems. This causes handover failures in Mobile networks, frame loss during video transmission or loss of voice quality like slips etc. This complicates the process of network forensics when it is required to trace a call or an IP session end to end between two customers at any instant of time. This issue is often faced by the security agencies leading to incorrect results when they try to resolve the IP addresses to actual subscribers.

1.2 Tracing requirement to be complied by the licensed service providers

1.2.1 The licensed service providers have been given licenses to operate data services as per the Indian Telegraph Act. As per the relevant clauses of their license conditions clauses, the licensees have to abide by the following: -

1.2.1.1 The clause 38.2 of Unified License is reproduced as follows:- “The licensee is obliged to provide, without any delay, all the tracing facilities to trace nuisance, obnoxious or malicious calls, messages or communications transported through his equipment and network, to the agencies of Government of India as authorised from time to time, when such information is required for investigations or detection of crimes and in the interest of national security. Any damages arising on the account of Licensee’s failure in this regard shall be payable by Licensee.”

1.2.1.2 Each licensed service provider(LSP) must maintain a log of all users connected and the service they are using (mail, telnet, http etc.). The LSPs must also log every outward login or telnet through their computers. Type of logins, where the identity of the logged-in user is not known, should not be permitted.

1.2.2 In view of the above, it is important for the LSPs to ensure that proper mechanisms are in place to uniquely identify the users at any point of time. However, it is observed that security agencies are having difficulties in identification of subscribers at any given point of time according to the information provided by the service providers.

1.2.3 In this regard, it is indicated that one essential requirement is that all service providers implement a uniform IST time zone time synchronization as part of the solution to address the problem of traceability of users. This service requirement document mainly examines this aspect and addresses the possible solutions needed to be implemented by the service providers.

1.3 Network Synchronization

Packet Transport Networks and Packet based Mobile Radio systems require high accuracy timing synchronization mainly for the transport of voice and video information. If this is not implemented, it may lead to poor quality of service being provided to the customers. Hence Network Synchronization also is an important aspect of Synchronization in telecom Networks.

2.0 DESCRIPTION

2.1 Purpose of Network Time Synchronization:

The goal of network time synchronization is to help ensure that all embedded system clocks in servers and networking equipment use accurate time. Time on these devices is kept by either Software interrupt based clocks or hardware clocks. Both types of clocks depend on a local oscillator present in the device. Since the quality of the local oscillator varies from device to device, local oscillators usually run slow or fast. When a device is left alone the time of the device will become either slow or fast after some time. As a result various network elements will show different time over a period of days/months. During synchronization, the time of the device is adjusted back to the correct time by comparing with a standard reference time (like UTC in our case). Correct time across the network is required to ensure that event capturing is correct and the events can be correlated across different network elements.

2.1.1 Requirement of Time Synchronization in Packet Networks:

Packet switching was originally introduced to handle asynchronous data. The ongoing evolution in telecommunications increases the likelihood of hybrid packet/circuit environments for voice and voice band data services. These environments combine packet technologies (e.g., ATM, IP, Ethernet) with traditional TDM systems. Typically, a TDM circuit service provider will maintain a timing distribution network, providing synchronization traceable to a primary reference clock (i.e., clock compliance with [ITU-T G.811]). Real-time applications have relatively tight timing requirements concerning delay and delay variation, which is generally resolved in the higher layers of the communication protocol. Other applications rely on the timing support provided by one or more of the lower layers (e.g., physical layer).

The transport of TDM signals through packet networks require that the signals at the output of the packet network comply with TDM timing requirements, this is crucial to enable interworking with TDM equipment. However, this is generally not extended to synchronization of time.

2.1.2 **Components of Time Synchronization:** The Time Synchronization comprises of three elements namely Frequency, Phase and Time of Day [TOD]

2.1.2.1 **Frequency:** Frequency is required for applications that need to recover periodic phenomena (e.g. bit streams), transmit with spectral compatibility, accurately measure time durations (differences), periodicities, distances (using the constant speed of light) and perform actions at a constant rate. Typical applications would be synchronous (TDM) networking – bit recovery, delivery of frequency to lock RF of GSM base-stations, calibration and metrology, FDD/FDMA applications. The common method of achieving frequency accuracy are through use of frequency references like crystal oscillators, atomic clocks, use of GPS clocks, use of synchronous networks like PDH, SDH, SyncE or use of Time distribution protocols.

2.1.2.2 **Phase:** Phase sync is defined as "Maximum absolute deviation in frame start timing between any pair of cells on the same frequency that have overlapping coverage areas". Phase is needed for applications that need to perform an action just in time, transmit in bursts w/o interfering with others, tightly coordinate execution with multiple neighbours or triangulate to find location. Typical applications would be TDD, PON, TDMA applications, optimization of networking resources/paths, GPS etc. Sources like SyncE are used for Phase Synchronization.

2.1.2.3 **Time of Day [TOD]:** TOD is needed for applications that need to precisely schedule events, timestamp events or prove an event took place before/after another event. Typical applications would be delivery of time to set clocks, coordination of Roaming between base stations etc. Protocols like NTP and PTP are used for sending the TOD information.

2.1.2.4 The synchronization accuracy requirements for various mobile technologies is given in the table below:

Mobile Standard	G.8261.1 network limits for traffic interface (G.823)	Frequency sync for the air Interface	Phase Sync	Standards
2G - GSM	16ppb	±0.05ppm	No requirements	3GPP TS25.104 (FDD) and TS25.105 (TDD)
3G - UMTS/WCDMA Wide area BS Medium Range BS Local Area BS Home BS	16ppb	 ±0.05ppm ±0.1ppm ±0.1ppm ±0.25ppm		
3G Femtocells	N/A	±0.25ppm		
LTE (FDD) Wide Area BS Home BS	 16ppb N/A	 ±0.05ppm ±0.25ppm		
LTE (FDD) Local Area & Medium Range BS	16ppb	±0.1ppm	No requirements (but see hetnets for LTE-Advanced)	3GPP TS36.104
LTE (TDD) Wide Area BS	16ppb	±0.05ppm	• 3usec - small cell (<3km radius) • 10usec – large cell (>3km radius)	3GPP TS36.133 & TS36.922
LTE (TDD) Home BS	N/A	±0.25ppm	• 3usec – small cell (< 500m radius) • 1.33 + Tpropagation μs, for large cell (> 500m radius), Tpropagation: propagation delay between the Home BS and the cell selected as the network listening synchronization source	

Table-1: Frequency and phase accuracy requirements of the Air Interface for different mobile technologies and the backhaul network

2.2 Time Synchronization Protocols:

Common time synchronization protocols widely used in IP networks are the Windows W32 Time Service (using the Simple Network Time Protocol - SNTP), Network Time Protocol (NTP), Precision Time Protocol (PTP) and Synchronous Ethernet (SyncE). Brief description of W32 Time Service, NTP, PTP and SyncE are given below.

2.2.1 Windows W32 Time Service:

2.2.1.1 The W32Time service uses the Simple Network Time Protocol (SNTP) in Microsoft Windows 2000. SNTP is based on RFC-4330. The W32Time service uses the Network Time Protocol (NTP) in Microsoft Windows Server 2003, in Windows Server 2003 R2, in Windows Server 2008, and in Windows Server 2008 R2. W32 may not be used as the clock source.

2.2.2 Network Time Protocol (NTP)

2.2.2.1 NTP is based on RFC-1305 (NTPv3.0) and RFC-5905 (NTPv4.0).

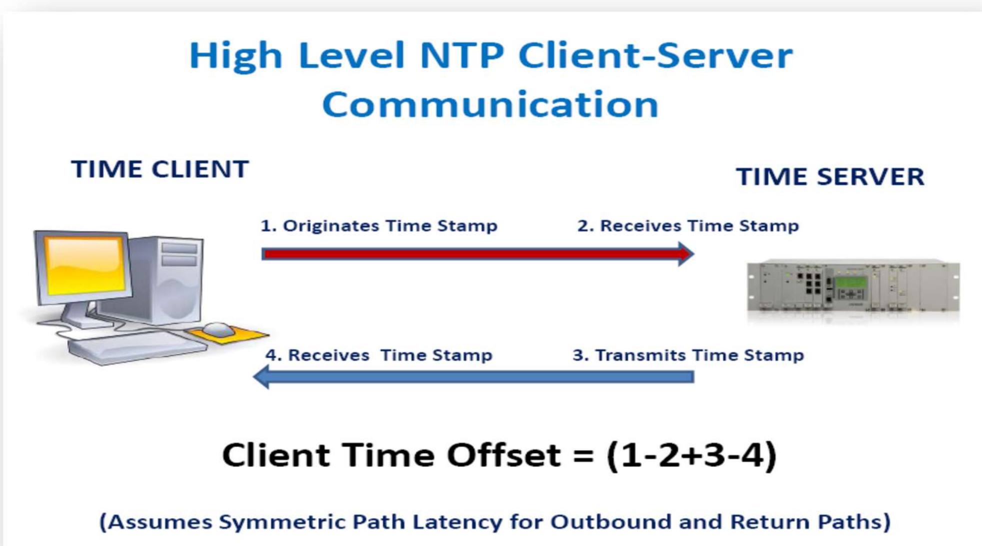
2.2.2.2 NTP (RFC 1305 for NTP version 3.0) synchronizes servers and network devices using a reliable time source, such as a dedicated network time server that references the global positioning system (GPS). NTP uses Coordinated Universal Time (UTC), which can be easily accessed through the GPS satellite system or from synchronized atomic clocks. Because UTC is the same worldwide, networks synchronized to UTC avoid interoperability problems with other networks. This synchronization is particularly important when administrators are troubleshooting their network and need to compare log files from various networks using their time stamps.

2.2.2.3 NTP in a network uses the UDP (User datagram Protocol) on port 123. In order to effectively operate over the variable path lengths of packet-switched networks, NTP estimates three key variables in the relationship between a client and a timeserver *(i) network delay*, *(ii) dispersion of time, which is a measure of maximum clock error between two hosts*, *and (iii) clock offset*, *which is the amount of correction that shall be applied to the system clock in order to synchronize it with UTC (Coordinated Universal*

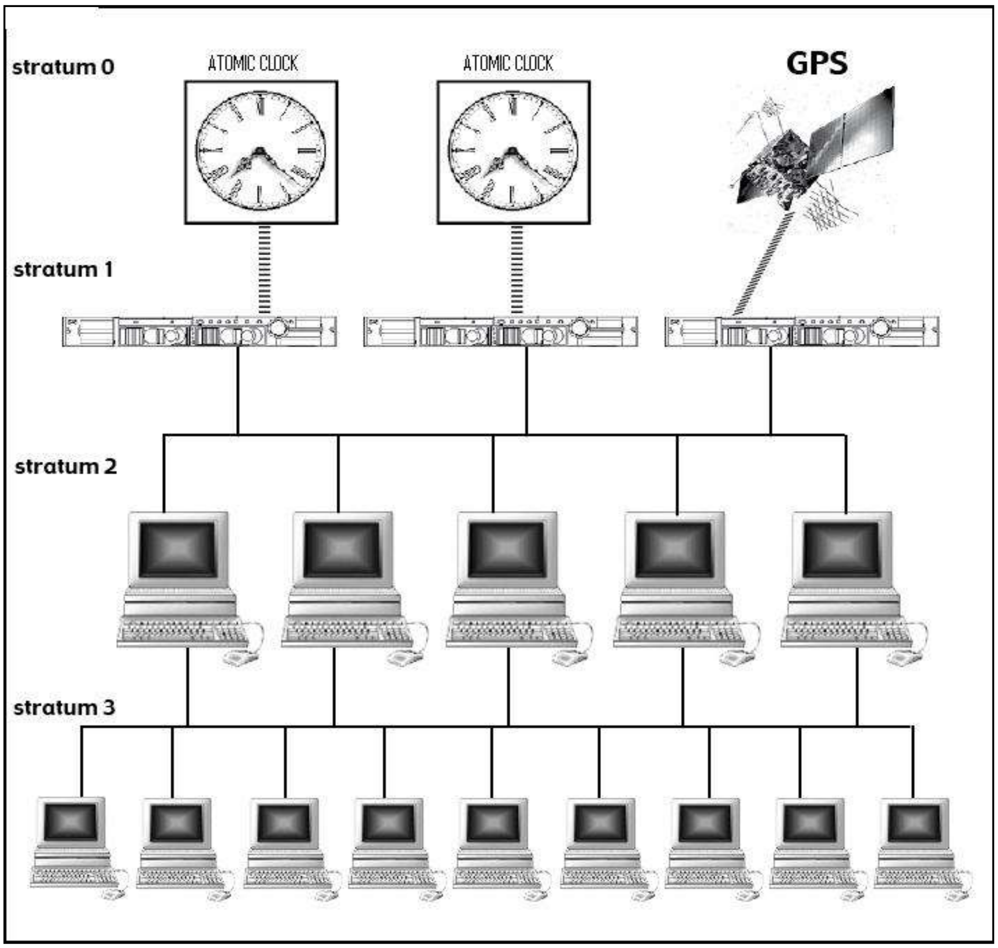
Time). NTP applies the estimates of these three variables to a system clock in order to synchronize it with UTC. The NTP (network time protocol) mechanism will gradually synchronize the system time over the network. The goal is twofold (i) maintaining the absolute time as close to UTC as possible and (ii) synchronizing the system time of all machines within a network.

2.2.2.4 The latest version of NTP, version 4(NTPv4), can maintain time to within 10-20ms on a WAN using traditional software-interrupt based solutions and can achieve accuracies of < 2ms or better on a LANs under ideal conditions. However, on a WAN, the limits cannot be guaranteed because of the uncertain delays caused by intermediate switches and routers in network paths.

2.2.2.5 NTP protocol operates in both the client/server mode as well as broadcast mode. The client/server mode is more preferable because it minimizes NTP network traffic, especially on a WAN. As shown in Figure below, with NTP a client-initiated packet is time-stamped by both the client and the time server. The client computes its time offset from these time stamps and adjusts its clock accordingly. NTP is widely supported by different operating systems and network devices.



2.2.2.6 NTP time distribution uses a stratum hierarchy (figure below). With the authoritative time source (atomic clock or GPS) defined as stratum-0 NTP servers and clients down the line operate in strata 1, 2, 3, and so on and link their clocks to the primary time source. Because accuracy declines a little in each successive stratum, servers and clients access multiple sources over diverse network paths, providing redundancy and greater reliability.



2.2.2.7 NTP uses more than one server, and automatically measures and dynamically chooses the best one based on the observed behaviour of each available server. If a server goes down, another one is selected without user intervention.

2.2.2.8 NTP contacts the servers only as frequently as needed, between once a minute to about once in 17 minutes (as the polling interval in NTP varies from 64 seconds to 1024 seconds), so that the clock will stay as close as possible to UTC between corrections.

2.2.2.9 NTP pools servers located nearer, and not ones that are far away.

2.2.2.10 Once NTP is running, the time is not stepped, but is adjusted smoothly.

2.2.2.11 NTP tries to keep the maximum frequency drift within +/-500ppm or about +/- 0.5 seconds between two polls which are 1024 seconds apart. However, if the difference between NTP client and NTP server is more than this value, NTP protocol will fail and manual intervention is required.

2.2.2.12 It is possible to use own time sources with NTP, such as a GPS receiver, and it will then work independently.

2.2.2.13 NTP allows checking on its performance like automated NTP monitoring.

2.2.2.14 NTP cannot account for network delays due to No. of Router hops to reach the NTP server, Network congestion, outage, routing changes etc. Time accuracy has not been defined.

2.2.2.15 The NTP protocol has been designed to keep a jitter of 1ms or less on the network.

2.2.3 Precision Time Protocol (PTP)

2.2.3.1 *PTP Standards*: IEEE 1588 defines the Precision Time Protocol (PTP) which enables precise synchronization of clocks via packet networks. IEEE 1588 provides high precision. Synchronization and data transfer use the same standard network.

2.2.3.2 In telecommunication networks service quality depends on accurate synchronization. Such networks are traditionally circuit switched and allow the distribution of clock signals over the physical layer. While the networks migrate more and more to packet switching, many traditional circuit switched services continue to exist. An important telecommunication application is wireless networks. In cellular networks, the handover capability requires precise synchronization of all base transceiver stations. Time critical applications like VoIP IPTV etc require precise timing information. In Digital TV broadcast systems, multiple transmitters operating at the same frequency need to be synchronized (in terms of both time and frequency)

2.2.3.3 IEEE 1588 was developed with the following goals:

(i) Accuracy to at least microsecond and preferably nanosecond levels. Minimal network, computing and hardware resource requirements so that it can be applied to low-end as well as high-end devices.

(ii) Applicable with minimal or no administration to systems defined by a single subnet.

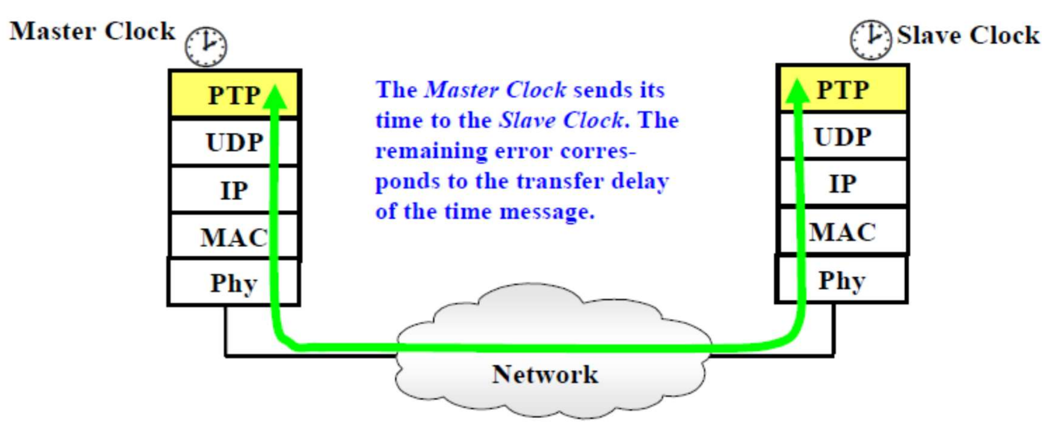
(iii) Applicable to common and inexpensive data networks including but not limited to Ethernet.

(iv) Applicable to heterogeneous systems where clocks of different capabilities and qualities can synchronize to each other.

2.2.3.4 The standard now in force is IEEE 1588 version 2 approved in March 2008.

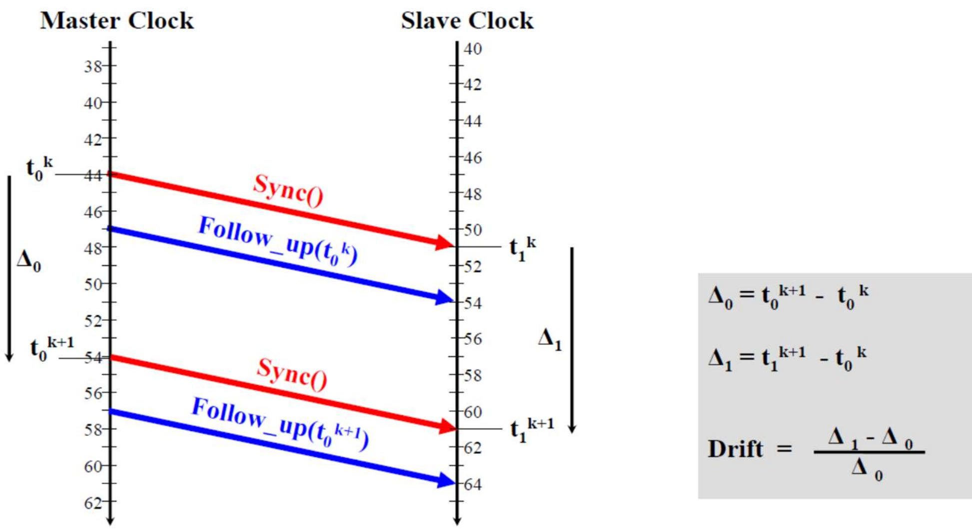
2.2.3.5 PTP uses UDP as its transport protocol (although other transport protocols are possible). The well-known UDP ports for PTP traffic are 319 (Event Message) and 320 (General Message).

2.2.3.6 The PTP synchronization mechanism is based on a master/slave protocol. PTP instances exchange messages in order to determine the offset between master and slave clocks but also the message transit delay through the network. This is explained in the figure below.

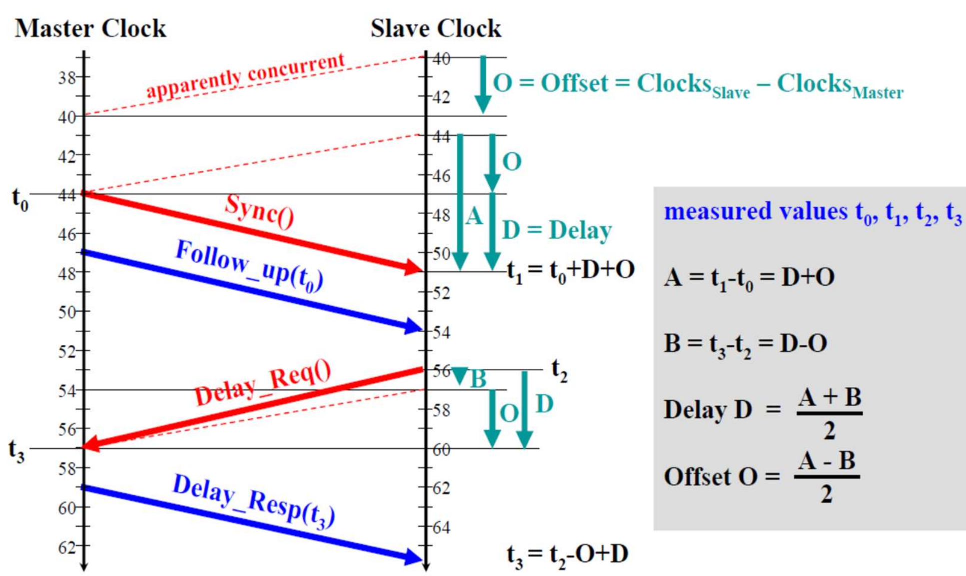


PTP Precision Time Protocol (Application Layer)
UDP User Datagram Protocol (Transport Layer)
IP Internet Protocol (Network Layer)
MAC Media Access Control
Phy Physical Layer

Two procedures take place in parallel: The first task, called synchronization, is responsible to run the slave clock at the same speed as the master. This is achieved by sending a continuous flow of Sync messages from master to slave. It is given in the figure below.



The second task determines the slave's offset from the master, i.e. the difference of time of day between master and slave. This is achieved by measuring the two-way delay (round trip time). This is explained in the figure below.

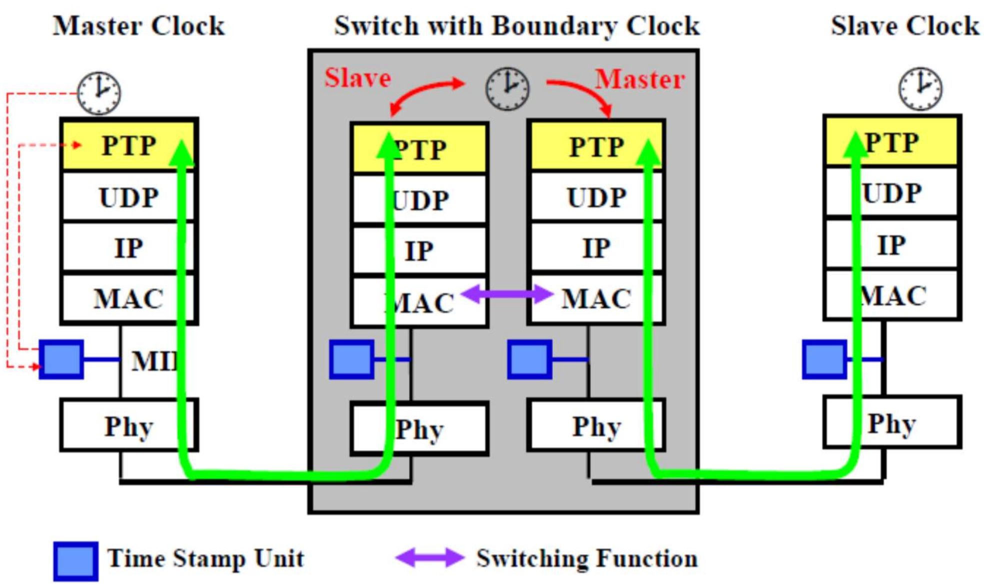


2.2.3.7 **PTP Grand Master Clock:** The PTP Grandmaster clocks are referenced to Stratum-0/1 clocks and/or GPS clocks so that they are very stable and accurate. For the generic requirements for the PTP Grandmaster clock, the TEC GR No. TEC/GR/TX/PTP-002/01/MAR-12 shall be referred.

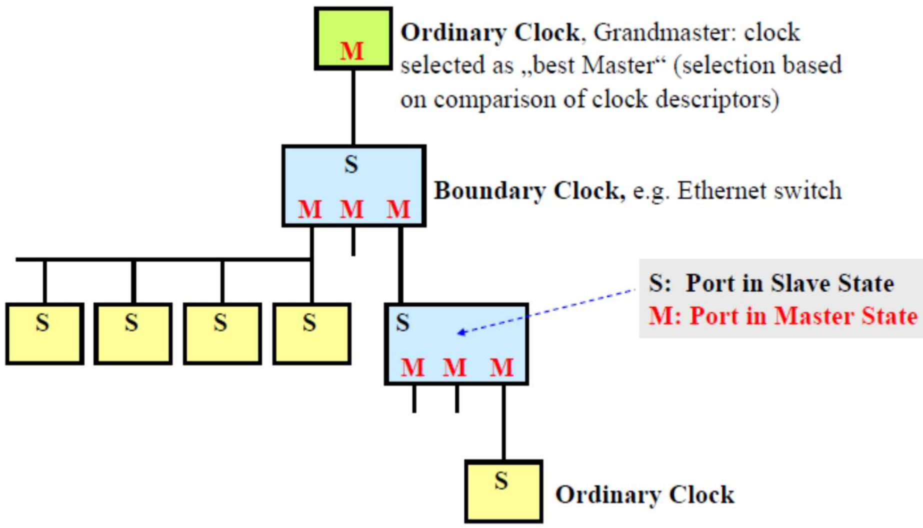
2.2.3.8 PTP Slave Clock: The end equipment like Base Stations etc have the PTP Slave clock which is used to synchronize the internal oscillators. For the generic requirements for the PTP slave clock, the TEC GR No. TEC/GR/TX/PTP-003/01/MAR-12 shall be referred.

2.2.3.9 PTP defines four different clock objects namely Ordinary clock, Boundary clock, End-to-end transparent clock and Peer-to-peer transparent clock.

a. PTP uses IEEE-1588-aware bridges, known as Boundary Clocks (BC). A BC is a bridge equipped with a PTP clock synchronized by the master over one of its ports. Over the other ports, the BC synchronizes slave clocks attached to it.

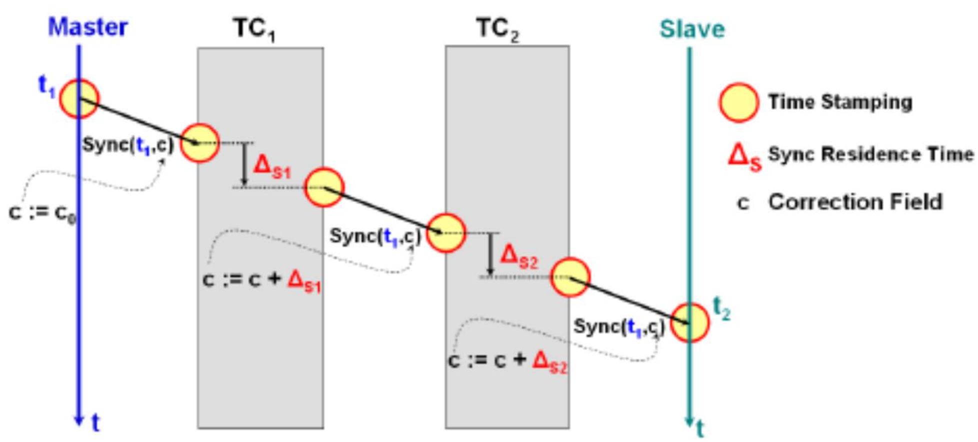


b. Synchronization Hierarchy: The physical layout of a machine determines the topology of an automation network, which is in many cases a daisy chain. Such a configuration represents a synchronization hierarchy as given in figure below which is established automatically by the so called Best Master Clock (BMC) algorithm. This algorithm takes clock quality and priority settings into account and guarantees that the best available master, the Grandmaster, is the root of the synchronization tree.

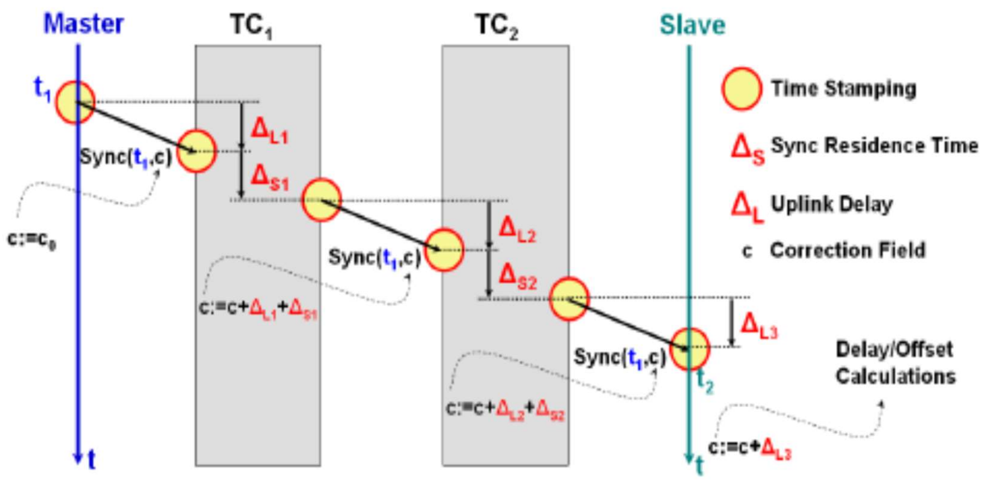


c. Transparent Clocks: When such a topology is built up with Boundary Clocks (BCs), the result is a chain of control loops which is susceptible to error accumulation. Hence PTPv2 has proposed the new clock type TC. This is an Ethernet bridge which is capable to measure the residence time of PTP event messages, i.e. the time the message has spent in the bridge during transit. Because the residence time is the difference of two timestamps, the TC does not need to be synchronized.

d. The end-to-end TCs, slave measures the delay to the master with an end-to-end delay request / delay response message exchange



e. The peer-to-peer (p2p) TCs measure the link delay to all neighboring clocks with Pdelay_Req / Pdelay_Resp / Pdelay_Follow_Up messages. When a Sync traverses a p2p TC, not only the residence time is added to the correction field but also the uplink delay, i.e. the delay of the link over which the Sync has been received. The Peer to Peer is not used in Telecom network. Inputs required.



2.2.3.10 *Features of PTPv2*: The main features PTPv2 are as follows:

(i) Transparent Clock (TC) and Profiles: TC's are used to prevent error accumulation due to synchronization hierarchy using BC's.

(ii) Short Sync Message and higher Message Rates: Telco applications require a high Sync rate of up to 128 messages per second. A shorter Sync message saves considerable bandwidth.

(iii) Mappings: This describes how PTP messages are mapped to a specific network technology. In v1 there is only one mapping specified: PTP over UDP/IPv4 over IEEE 802.3. The v2 specification adds mappings for PTP over UDP/IPv6 and for pure IEEE 802.3 operation without UDP/IP. PTP messages are identified in this case by a special Ether type rather than by a port number.

(iv) Timestamp Representation: Timestamps are taken whenever a PTP event message (i.e. a PTP message which has a measurement purpose) is sent or received by a clock. Timestamp resolution is 1 ns in v1 and 2-16 ns (i.e. 15 femto seconds) in v2. This enhanced resolution paves the way to sub-nanosecond precision.

(v) Unicast Operation: Multicast is the default addressing mode of PTP. Telecom networks may consist of a huge number of slaves and do not always support multicast. Unicast operation has been specified for this purpose.

(vi) Extension Mechanisms: A type, length, value (TLV) construct is used to give PTP messages specific or additional functions.

(vii) PTP for CE & DVB: TDM circuits over Packet [Circuit Emulation Technologies], Digital Video Broadcast [DVB] over IP etc services which are time sensitive and requires high clock accuracies. DVB requires frequency stability of the order of 1µsec.

(viii) PTP is a hardware based implementation thereby improving the accuracy and reducing the delays.

2.2.4 Synchronous Ethernet (SyncE)

2.2.4.1 SyncE Standards: The timing and synchronization aspects of Packet Networks are defined in G.8261. G.8262 defines the timing characteristics of a synchronization slave clock.

2.2.4.2 SyncE Overview: A reference timing signal traceable to a PRC is injected into the Ethernet switch using an external clock port. This signal is extracted and processed via a synchronization function before injecting timing onto the Ethernet bit stream. The synchronization function provides filtering and may require holdover. The clock supporting synchronous Ethernet networks is called EEC, synchronous Ethernet equipment clock.

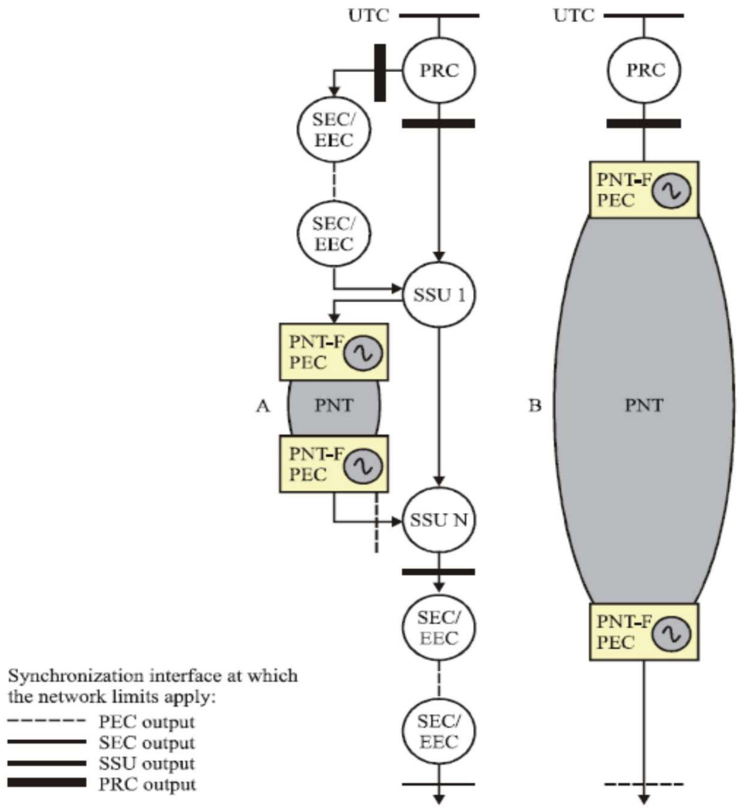
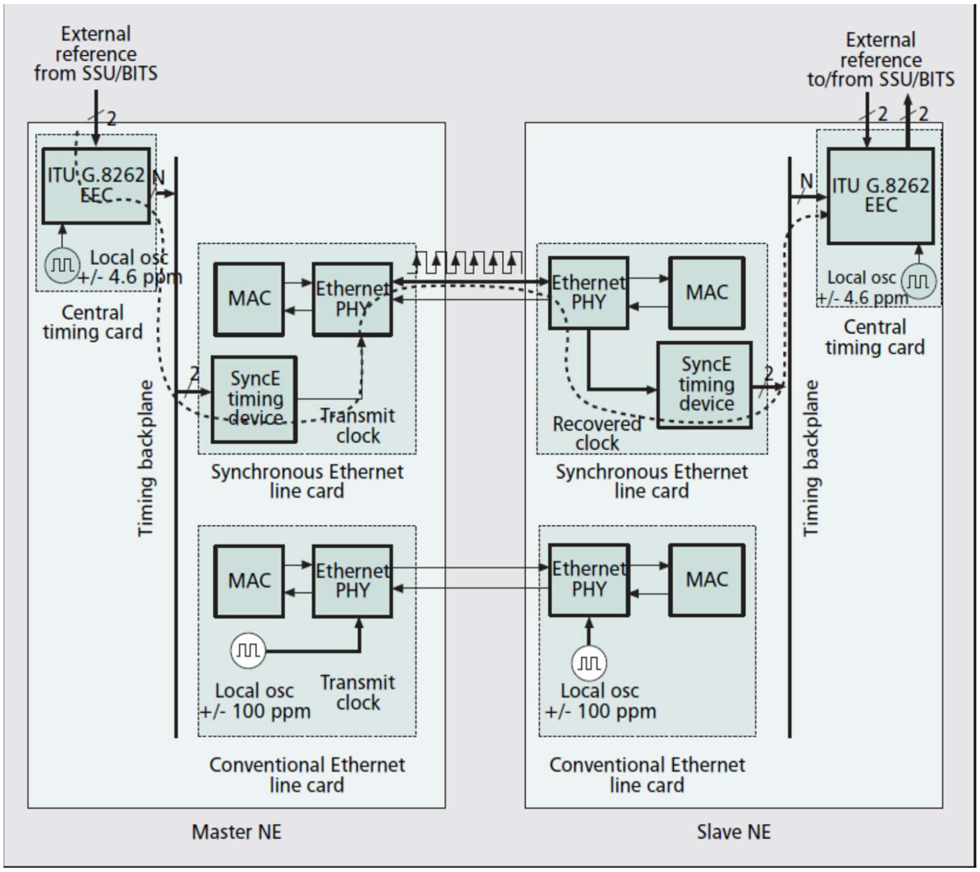


Figure: Evolution of traditional TDM and Packet based network into a pure Packet based Network.

2.2.4.3 **SyncE Network Element Architecture:** Figure below is a diagram of two network elements connected via an Ethernet interface. There are two types of line cards i.e. Synchronous Ethernet capable line cards and conventional Ethernet line cards. Synchronous Ethernet line cards can interface to a timing backplane to source and terminate timing. Both card types are interchangeable from the perspective of the data transport capabilities.



The Master NE takes external input timing references coming from the network clock (SSU or BITS) interface are per ITU- T G.703 (e.g., 2048 kHz synchronization interface). The external input timing reference might be Synchronous Ethernet based also. These references are then used as input to the ITU G.8262 EEC clock, typically located on the central timing card of the NE. The figure also shows a free-running input crystal operating at ±4.6 ppm, as specified in ITU G.8262 (Or G.813 option 1 and G.812 clock type IV). The G.8261/G.8262, specifies the level of jitter and wander at the input and output of the clock, as well as the specification under short-term and long-term transients such as loss of timing reference or link failure. It is also responsible for timing reference selection and switching. The EEC output timing reference is then distributed via the NE backplane to reach the Ethernet line cards.

The output of the timing device serves as the TX clock reference into the transceiver, replacing the free-running crystals with ±100 ppm accuracy in the conventional line card. The reference is then used to synchronize the physical line coding (e.g., 4B/5B for FE, 8B/10B for GE) of the interface toward the Slave NE.

At the Slave NE, the clock is recovered within the transceiver Synchronous Ethernet line card. The recovered output clock is then fed into a timing device for functions such as jitter attenuation and transceiver frequency conversion to backplane frequency. The clock is then sent through the backplane to reach the Slave's central timing card. This timing reference then becomes a reference to the EEC. EEC can accept line and external references, as well as the input of a ±4.6 ppm local oscillator. The EEC can also provide timing outputs in the form of 2048 kHz synchronization interface to external SSU/BITS network elements (typically Stratum-2 NE).

The Slave NE then becomes the Master NE for the next downstream NE, and synchronization is transported on a node-to-node basis, where each node participates in recovery and distribution. It is by this process that synchronization traceable to a primary reference source can be recovered and distributed within each NE.

Synchronization distribution would be through multiple paths, and provide redundancy through multiple central timing cards and line cards. The EEC as defined in ITU G.8262 was specified to inter- work with SONET/SDH, and by doing so, Synchronous Ethernet can inherit most of the SONET/SDH synchronization design principles.

2.2.4.4 Features of SyncE:

(i) SyncE is similar to SDH/PDH synchronization of derivation of the synchronization clock to be referred from the physical interface.

(ii) It uses differential or adaptive methods for Packet transfer delay and delay variations which can occur due to Routing changes, Congestion etc.

(iii) Traditional Ethernet output frequency variation is of the order of ±100ppm whereas for Synchronous Ethernet, the output frequency variation is of the order of ±4.6ppm.

(iv) Various interface specifications like Jitter, Wander, Noise tolerance are defined in G.8262.

(v) List of Ethernet Interfaces capable of supporting SyncE also is defined in G.8262. This is mainly depending upon the type of coding used in the output interface like 4B/5B, 8B/10B etc

(vi) In addition to the distribution of physical signals, a simple communication protocol is needed between NEs. This protocol is specified in ITU G.8264 as the ESMC. ESMC is used to transmit, from NE to NE, the clock quality level value. The ESMC will typically be implemented outside the MAC and PHY, similar to other Ethernet OAM protocols.

2.2.5 Primary Reference Time clocks (PRTC)

2.2.5.1 The recommendation ITU-T G.8272/Y.1367 specifies the requirements for primary reference time clocks (PRTCs) suitable for time, phase and frequency synchronization in packet networks. It defines the error allowed at the time output of the PRTC. A typical PRTC provides the reference signal for time, phase and frequency synchronization for other clocks within a network or section of a network. In particular, the PRTC can also provide the reference signal to the telecom grand master (T-GM) within the network nodes where the PRTC is located. The PRTC provides a reference time signal traceable to a recognized time standard (e.g., coordinated universal time (UTC)). UTC can be obtained from a UTC time laboratory registered at Bureau International des Poids et Mesures (BIPM) (e.g., a national UTC time lab) or, most commonly, from a global navigation satellite system (GNSS).

2.2.5.2 The noise generation of a PRTC is characterized by two main aspects:

– the constant time error (time offset) at its output compared to the applicable primary time standard (e.g., UTC);

– the amount of phase error (wander and jitter) produced at its output.

2.2.5.3 Under normal, locked operating conditions, the time output of the PRTC, or the combined PRTC and T-GM function, should be accurate to within 100 ns or better when verified against of the applicable primary time standard (e.g., UTC). For the PRTC this value includes all the noise components, i.e., the constant time error (time offset) and the phase error (wander and jitter) of the

PRTC.

2.2.6 enhanced Primary Reference Time clocks (ePRTC)

2.2.6.1 Recommendation ITU-T G.8272.1/Y.1367.1 specifies the requirements for enhanced primary reference time clocks (ePRTCs) suitable for time and phase synchronization in packet networks. It defines the error allowed at the time output of the ePRTC. The enhanced PRTC provides a reference time signal traceable to a recognized time standard (e.g. UTC) and also a frequency reference. Compared to the PRTC as defined in [ITU-T G.8272], the ePRTC is subject to more stringent output performance requirements and includes a frequency input directly from an autonomous primary reference clock. An enhanced PRTC provides the reference signal for time, phase, and frequency synchronization for clocks within a network or section of a network. In particular, the ePRTC can also provide the reference signal to the telecom grand master (T-GM) within the network node where the ePRTC is located.

2.2.6.2 Under normal, locked operating conditions, the time output of the ePRTC should be accurate to within 30 ns or better when verified against the applicable primary time standard (e.g., UTC). For the ePRTC this value includes all the noise components, i.e., the constant time error (time offset) and the phase error (wander and jitter) of the ePRTC.

2.2.7 Timing for Boundary clocks and slave clocks

2.2.7.1 Recommendation ITU-T G.8273.2/Y.1368.2 specifies minimum requirements for time and phase for Telecom Boundary Clocks and Telecom Time Slave clock used in synchronization network equipment that operates in the network architecture as defined in Recommendations ITU-T G.8271, G.8271.1, G.8275 and G.8275.1. It supports time and/or phase synchronization distribution for packet based networks. This Recommendation allows for proper network operation for phase/time synchronization distribution when a network equipment embedding a Telecom Boundary Clock (T-BC) and Telecom Time Slave Clocks (T-TSC) is timed from another T-BC or a T-GM.

2.2.8 Ethernet Equipment Clock

2.2.8.1 ITU-T Recommendation G.8262 defines requirements for clock accuracy, noise transfer, holdover performance, noise tolerance, and noise generation. It defines two options for clocks for Synchronous Ethernet; these clocks are called Synchronous Ethernet equipment slave clocks (EECs). The first option, referred to as EEC-Option 1, applies to Synchronous Ethernet equipment designed to interwork with networks optimized for the 2048 kb/s hierarchy. Requirements for this option are based on those found in G.813 Option 1 used in SDH networks. The second option, referred to as EEC-Option 2, applies to Synchronous Ethernet equipment designed to interwork with networks optimized for the 1544 kb/s hierarchy. Requirements for this option are compatible with the requirements for Stratum 3 clocks deployed in SONET network elements.

3.0 FUNCTIONAL REQUIREMENTS

3.1 Synchronization Timing Source

3.1.1 The NTP protocol has been designed to keep a jitter of 1ms or less on the network. All equipment/operating systems cannot meet this requirement. Therefore, only dedicated NTP servers shall be used. The NTP servers shall meet the TEC specification No. - TEC/GR/IT/NTS-001/02 FEB-19

3.1.2 Public NTP servers shall not be used by service providers. They shall have their own dedicated Stratum-1 or Stratum-2 NTP servers. In case service providers opt to use stratum-2 NTP servers, these shall be synchronized only to Stratum-1 NTP servers in each Service Area.

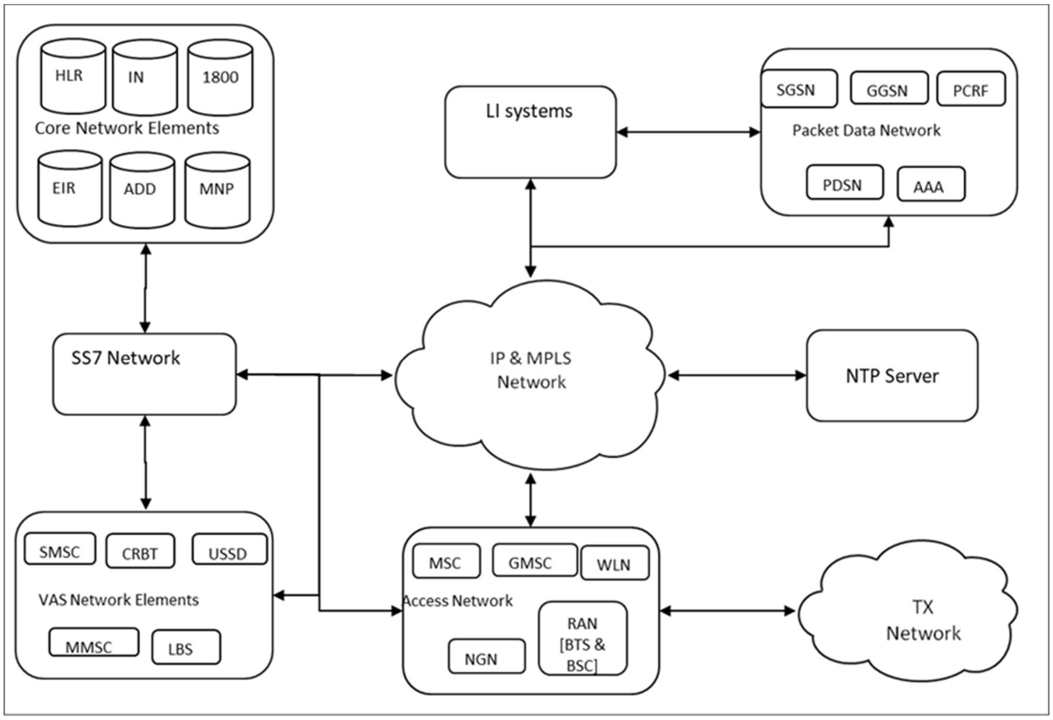
3.1.3 The Timing servers shall be configured to work only in a client-server mode to minimize network traffic. Further, it shall be ensured that UDP port 123 is open in the firewall of both Timing server and Timing client for communication.

3.1.4 Timing servers shall be isolated from Public internet.

3.1.5 All the Timing servers deployed in the network shall be as close to the clients as possible to minimize the uncertainty in network delay. Therefore, one Stratum-1 Timing server needs to be deployed in each Service Area (in case of a network within India). All clients shall necessarily operate at stratum-2/3 connecting to the nearest stratum-1/2 Timing server to ensure minimum drift from UTC. Higher strata may be used provided the client time deviation from UTC is within limits as mentioned in Table-2.

3.2 Implementation of NTP

The NTP protocol is the preferred protocol on the WAN because it can work over larger distances. The typical network architecture shown below is similar to the networks of most of the service providers providing data services along with the other services. The network of service providers providing only Internet services is a subset of the above architecture. The implementation by service providers varies in time sources, types and locations of the NTP servers used for synchronization and the capabilities of the devices used in the network to remain synchronized.



3.2.1 *Conditions to be met for implementation of NTP in the service provider networks:*

3.2.1.1 The various logs maintained by service providers have a time resolution of 1 second. Therefore, service providers shall achieve time accuracy within UTC+/-0.5 second in the network. The following steps shall be taken by service providers to ensure that network servers are synchronized using the NTP protocol within the time band UTC+/- 0.5 second.

3.2.1.2 The requirement for the network servers is the Time of the Day [TOD] information. The Network Servers like CDR generation, Billing etc which are sensitive to time shall be synchronized using NTP.

3.2.1.3 NTP uses the UDP protocol on port number 123 (both source and destination). This port shall be opened in the firewall of the device if not done, otherwise the device will not be able to communicate with the NTP server.

3.2.1.4 All windows based machines shall be installed with proper NTP software fully complying with the IETF RFCs. All critical servers shall be synchronized using NTP. NTP server software shall be installed in all client computer/device on the network.

3.2.1.5 All the firmware shall be upgraded to allow soft configuration of NTP server addresses.

3.2.1.6 Firmware upgradation /replacement shall be done for those networking devices having NTP related software errors.

3.2.1.7 The firewall/packet filter shall not block incoming NTP packets.

3.2.1.8 At least one Stratum-1 NTP server shall be available per Service Area. All the Stratum-2 clients in the Service Area shall use this as the Primary NTP Server and NTP Server in the neighbouring Service Area as the secondary NTP Server.

3.2.1.9 All the NTP clients shall operate either on stratum-2 or stratum-3 level. There shall be no more than +/-0.1 second deviation from UTC for clients at stratum-2 and +/-0.2 second from UTC for clients at stratum-3 (to meet the limits specified in clause 4.4 & 4.5 of TEC specification No. TEC/GR/SW/NTS – S01/01/ FEB. 2011). Additional stratum-1 or stratum-2 NTP servers shall be installed in the network to bring the Servers closer to clients and meet the above specified limits.

3.2.1.10 All the CDR/record/log/billing information generating network elements shall be identified for NTP time synchronization. All such network elements (clients) shall synchronize their time with only the closest stratum-1 NTP servers having their own authoritative time source.

3.2.1.11 All the network elements which cannot support NTP and require manual time setting shall be immediately identified. Action shall be taken for upgrading them with the required hardware /software. If upgradation is not possible then they shall be replaced.

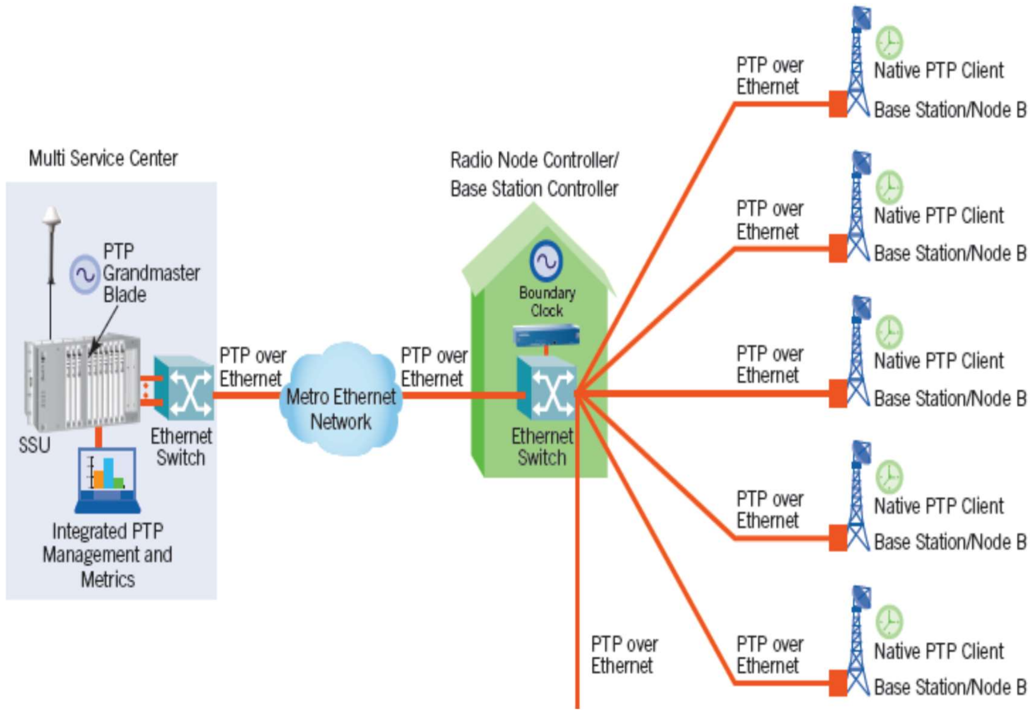
3.2.1.12 It may be also ensured that in case any of their customers are using NAT servers, the Service Providers shall ensure that such NAT servers are synchronized using NTP Server at Stratum-1 positively.

3.2.1.13 NTP protocol may not work automatically and manual intervention is required if the maximum difference between client and NTP server exceeds +/-43 seconds per day. Therefore, periodic checks preferably on a daily basis of various network elements are required to control the time drift.

3.3 *Implementation* of PTP:

3.3.1 All GSM and UMTS base stations must be frequency synchronized within the limits as per Table-1 to support handover as mobiles transition from one base station to another. Failure to meet the synchronization requirement as per Table-1 will result in dropped calls. Base stations have traditionally met this requirement by locking their internal oscillators to a recovered clock from the T1/E1 TDM backhaul connection. When the backhaul transitions to Ethernet, the base station becomes isolated from its traditional network sync feed. IEEE 1588 PTP shall be used by base stations to be synchronized under such situations.

3.3.2 An example of an architecture using PTP for mobile backhaul service is given in the figure below. In the Mobile backhaul network, the PTP Grandmaster is located along with the MSC who receives the clock information from GPS or a G.811 PRC. PTP client/slave clock will be running in the Base stations or a cell site switch/router (CSS/CSR). This requires that the transport / backhaul equipments shall have either PTP support or shall tunnel the PTP packets.

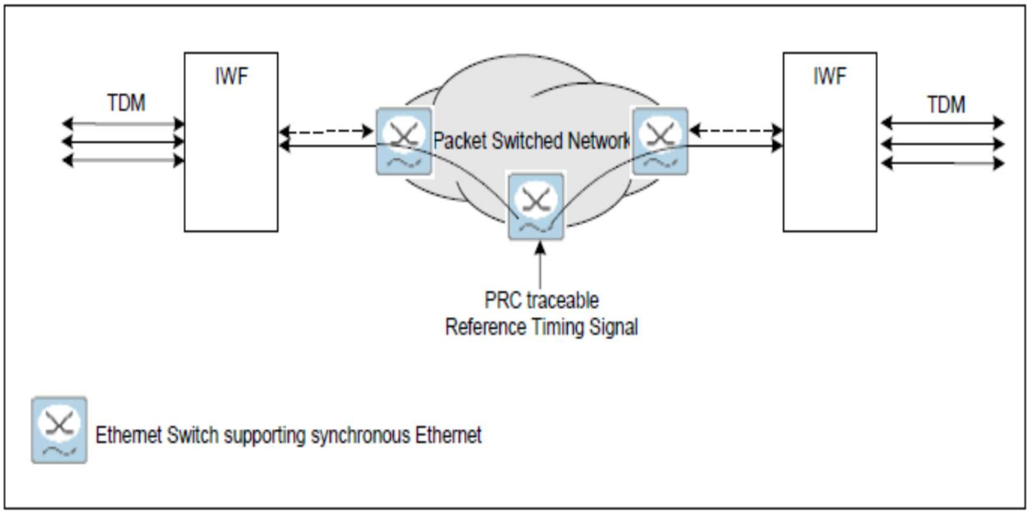


3.3.3 The base stations or CSR/CSS shall incorporate a PTP slave device to recover timing packets used to discipline the base station's internal oscillators to meet the requirement as per Table-1. PTP slaves in the base stations shall rely on access to a carrier-class PTP grandmaster clock deployed in the mobile switching centre (MSC).

3.3.4 PTP grandmaster functionality shall be deployed at the MSC or RNC or Other location. This may be integrated into existing MSC synchronization platforms (i.e. BITS — building integrated timing supplies, and SSU — synchronization supply units) or, a new compact PTP Grandmaster device.

3.4 Implementation of SyncE:

3.4.1 Network Architecture of timing distribution for transport of TDM signals over Packet Switched Networks is indicated in figure below.



3.4.2 Synchronous Ethernet shall be applied to both existing networks (when the existing Ethernet devices support SyncE) and new network. Synchronous Ethernet deployment is not required ubiquitously over an entire network, but only where frequency distribution is needed. In the green field case it is expected that new Synchronous Ethernet equipment will be the desirable approach; however, in existing networks, it may be possible to simply replace asynchronous line cards with new synchronous line cards to provide this capability. But this is dependent on the architecture of the existing equipment.

3.4.3 Additionally, a simple communication protocol ESMC specified in ITU G.8264 is needed between NEs. ESMC is used to transmit, from NE to NE, the clock quality level value.

3.4.4 The deployment of synchronization networks utilizing Layer-1 Synchronous Ethernet shall distribute frequency that is not subject to packet delay variation. Due to the characteristics of the clocks, in general, existing network planning and engineering rules can be employed, greatly simplifying the integration of Synchronous Ethernet technology into the SONET/SDH synchronization network.

3.4.5 However, as networks evolve, operators may be dealing with a mix of Ethernet equipment that may or may not provide Synchronous Ethernet capabilities. Operators may ensure that Ethernet links on equipment with appropriate Synchronous Ethernet functionality are selected as timing links. This extra step contrasts the SDH/SONET case, where all NEs by definition are capable of being integrated into the synchronization network

3.5 Time Synchronization Requirements:

3.5.1 Synchronization of Network Servers: The various logs maintained by service providers have a time resolution of 1 second. Therefore, service providers shall achieve time accuracy within UTC+/-0.5 second in the network with appropriate network engineering. The following steps will have to be taken by service providers to ensure that network elements are able to properly synchronize using the NTP protocol within the time band UTC+/- 0.5 second.

3.5.1.1 The requirement for the network servers is the Time of the Day [TOD] information. The Network Servers like CDR generation, Billing etc which are sensitive to time shall be synchronized using NTP.

3.5.1.2 All windows based machines (and also machines which are using some variant of the NTP protocol) shall be installed with proper NTP software fully complying with the IETF RFCs as per clause 2.2.2.1 of this document.

3.5.1.3 All critical servers shall be synchronized using NTP.

3.5.1.4 All the CDR/record/log/billing information generating network elements shall be identified for NTP time synchronization. All such network elements (clients) shall synchronize their times with only the closest stratum-1 NTP servers having their own authoritative time source.

3.5.1.5 All the network elements which cannot support NTP and require manual time setting shall be identified and action shall be taken for upgrading them with the required hardware /software.

3.5.1.6 It may be also ensured that in case any of their customers are using NAT servers, the Service Providers shall ensure that such NAT servers are synchronized for time using NTP.

3.5.1.7 NTP protocol may not work automatically and manual intervention is required if the maximum difference between client and NTP server exceeds +/-43 seconds per day. Therefore, periodic checks preferably on a daily basis, of various network elements, are required to ensure that time drift is controlled within limits.

3.5.1.8 Network devices shall be inspected for any hardcoded NTP server addresses. If such is the case then device vendors shall be approached for upgrading the firmware to allow use of any NTP server. Thereafter the device shall be configured to use only the NTP servers of the service provider.

3.5.2 <u>Synchronization of Mobile Networks:</u>

3.5.2.1 PTP shall be used for precision synchronization for mobile networks etc. to eliminate network & equipment jitter.

3.5.2.2 The Mobile Radio networks require precision time synchronization of the order as per Table-1. The synchronization requirement in such cases is both Frequency and Time of the Day [TOD]. Most of the Radio backhaul networks used by the Service Providers are TDM based. Hence the TDM provides this accuracy of frequency synchronization.

3.5.2.3 Service Providers using Packet based backbone networks for 3G/LTE networks shall resort to PTP based synchronization.

3.5.3 <u>Synchronization of Packet Transport Networks:</u>

3.5.3.1 SyncE is used by Packet Transport Networks [PTN] like carrier Ethernet or MPLS Transport networks where the Frequency is critical.

3.5.3.2 Whenever a network is transporting Voice or Video which are both time and delay sensitive, synchronization becomes more critical. Currently most of the service providers are transporting the Voice and Video traffic through their TDM networks like SDH systems. These systems have the capability of transporting the frequency information. Moreover, these networks use an SSU [Synchronous supply Unit] based architecture for deriving the timing information.

3.5.3.3 But these traditional TDM based transport networks are being replaced by

Packet Transport Networks [PTN] like MPLS and Carrier Ethernet networks which are Multi Service Carrier platforms like Voice, Video and Data. But when these networks are carrying the Voice and Video traffic, transport of timing information becomes critical.

3.5.3.4 SyncE is the method used for transport of timing information in such case where SyncE has the capability to transport frequency synchronization.

3.5.3.5 Service Providers using Packet transport network (PTN) for carrying voice/video shall synchronize the transport infrastructure also. The synchronization of the PTN shall either be done either through TDM based synchronization or using SyncE for those interfaces used for the transport of the Synchronization information.

3.5.4 Summary of the Requirement: The requirement of Time Synchronization for the Network Elements, Protocol, Timing accuracy and application is summarized below.

Type of Server/Network to be synchronized	Protocol to be used	Timing Accuracy Achievable	Remarks / Recommendations
Network Servers, CDR/record/log/ billing information generating network elements	NTP v4.0	10-20ms	• Server logs shall achieve a time accuracy of UTC+/- 0.5 second
Mobile Networks	PTP	As per Table-1	• Shall be used for Frequency & ToD Synchronization • PTP is required when backhaul is only Ethernet.
Applications / Services in Packet Transport Networks	SyncE	PRC traceable, hold over accuracy of ±4.6ppm	• Shall be used for High Accuracy Frequency Synchronization • Required only when voice and video is transported.

Table-2: Summary of the Requirements

3.6 Synchronization Timing Source Service solution

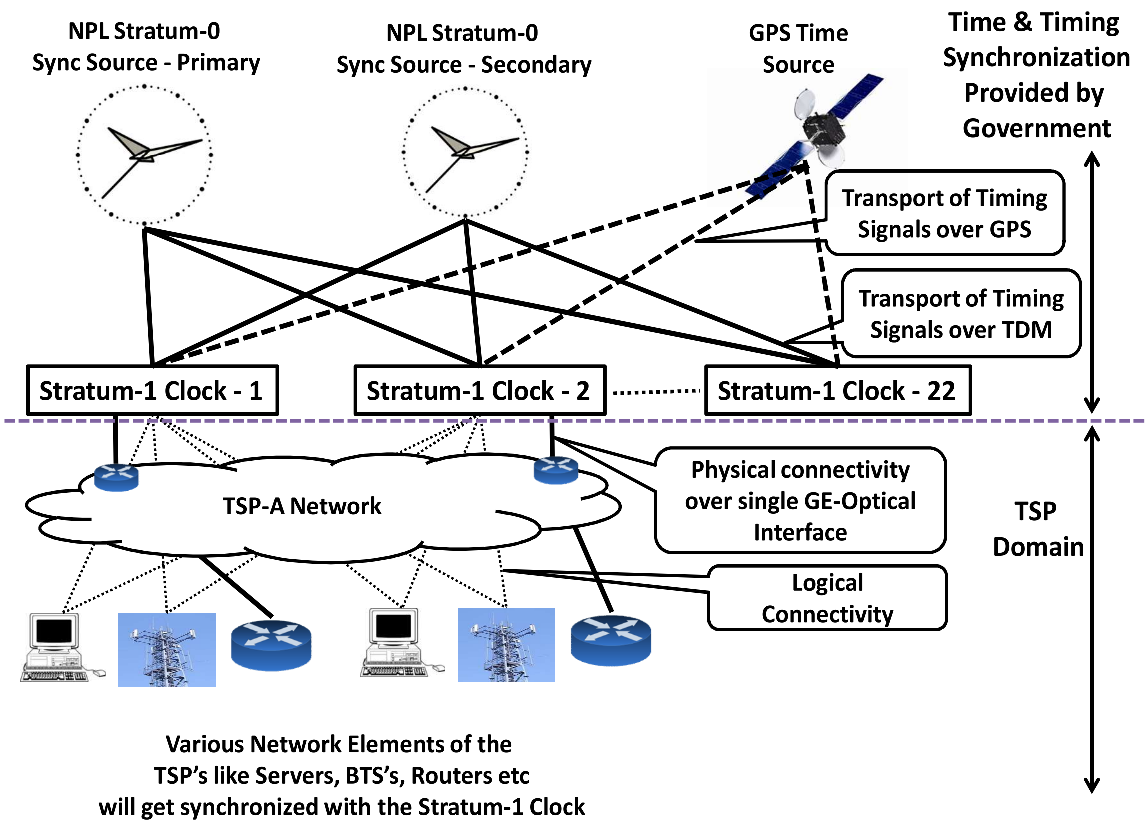
3.6.1 Service providers shall not rely on public Timing Source on the Internet. They shall use dedicated Stratum-1 servers directly connected to GPS or atomic clocks as per the directions of DoT.

3.6.2 The Timing servers shall be configured to work only in a client-server mode to minimize network traffic. Further, it shall be ensured that UDP port 123 is open in the firewall of both Timing server and Timing client for communication.

3.6.3 Timing servers shall be isolated from public Internet.

3.6.4 All the Timing servers deployed in the network shall be as close to the clients as possible to minimize the uncertainty in network delay. Therefore, one Stratum-1 Timing server shall be deployed in each Service Area (in case of a network within India). All clients shall necessarily operate at stratum-2/3 connecting to the nearest stratum-1/2 Timing server to ensure minimum drift from UTC. Higher strata may be used provided the client time deviation from UTC is within limits.

3.7 Proposed common time and timing reference solution using distributed architecture:



3.7.1 The proposed solution provides time & timing synchronization as per NTP, PTP and SyncE standards.

3.7.2 The objective of this solution is to provide the complete frequency, phase and TOD synchronization requirements for all the Network elements and servers from common reference source i.e. the Stratum-0 Timing system maintained by CSIR-National Physical Laboratory (CSIR-NPL) the official timekeeper of the country and GPS.

3.7.3 This Stratum-0 reference clock will be re-distributed in all the Service Area using the proposed solution.

3.7.4 The proposed solution seeks to minimize the network delay by bringing the stratum-1 time references as close to the network elements as possible.

3.7.5 To facilitate this, Stratum-1 server is required at every Service Area Level.

3.7.6 Stratum-1 Servers shall derive the timing information from the Stratum-0 Servers with CSIR-NPL over TDM links. Each Stratum-1 Server will have connectivity to the Primary and Secondary Stratum-0 Servers.

3.7.7 Stratum-1 Servers shall also have a GPS receiver. The GPS receiver shall receive synchronous timing information from GPS atomic clocks which acts as a time reference.

3.7.8 The priorities shall be set in the system for the selection of the clock source. The Stratum-1 Server has suitable built in algorithms to check the accuracy of the incoming clock and in case of any deviations beyond 1pps, it automatically switches over to the next priority clock.

3.7.9 Stratum-1 Servers shall have internal Rubidium atomic clock to act as the standby in case all the references fail.

3.7.10 In the downlink direction, the Physical connectivity with the TSP network will be over GE Optical Synchronous links.

3.7.11 A TSP network covering one or more service areas shall have Physical connectivity at each State HQ as shown in the figure.

3.7.12 The end devices use the Clock source from the Home Service Area as the Primary reference and another Service Area as secondary, etc in the order of Priority.

3.7.13 The Physical connectivity over the GE optical interface to the TSP Router provides the SyncE clock to the TSP network with an accuracy as per G.8261 and G.8262 standards. This method is similar to the clock synchronization in SDH networks.

3.7.14 The Physical connectivity also provides NTP and PTP protocol support for the logical time distribution to the end devices.

3.7.15 The TSP or his customers shall configure their Servers and computers to use these NTP clock sources as Primary, Secondary, tertiary etc. in the order of Priority. The Server URL as well as the IP address will be published for use by the TSP and their clients.

3.7.16 In case of PTP configurations, the TSP has two options. In the first option, the TSP may configure their base stations which act as PTP slave to use the Stratum-1 clock as the PTP Grandmaster. In the second case where the TSP has already deployed the PTP Grandmaster in the MSC equipments, the MSC shall in-turn use the Stratum-1 clock as the Primary/Secondary clocks and will function as a Boundary clock.

3.7.17 *The modality of installation of the Stratum-0/1 Servers at Central Location / Service Area HQ and the Valid Primary references to be used for Synchronization of the Stratum-0 Servers shall be notified by the DoT separately.*

GLOSSARY

BC:	Boundary Clock
BITS:	Building integrated timing supplies
CBR:	Constant Bit Rate
CES:	Circuit Emulation Services
CSS:	Cell Site Switch
CSR:	Cell Site Router
EEC:	Synchronous Ethernet equipment clock
ESMC:	Ethernet Synchronous Messaging Channel
GPS:	Global Positioning System
ISP:	Internet Service Provider
IST:	India Standard Time
LSP:	Licensed Service Provider
MPLS:	Multi-Protocol Label Switching
MSC:	Mobile Switching Center
NAT:	Network Address Translation
NE:	Network Element
NTP:	Network Time Protocol
PRC:	Primary Reference Clock
PSN:	Packet Switched Network
PTP:	Precision Time Protocol
SDH:	Synchronous Digital Hierarchy
SNTP:	Simple Network Time Protocol
SSU:	Synchronization supply units
SyncE:	Synchronous Ethernet
TDM:	Time Division Multiplexing
TC:	Transparent Clock
TOD:	Time of Day
TSP:	Telecom Service Provider
UTC:	Coordinated Universal Time