

# Tellabs® 8600 Managed Edge System — Synchronization for Packet Networks

Synchronization is critical for many applications. Tellabs® 8600 Managed Edge System switches provide excellent timing capabilities in order to assure the accurate timing services that enable utilization of cost-efficient packet networks for applications that require strict synchronization.

## Overview

Packet network is a cost-efficient transport solution for many applications. Ethernet and IP/MPLS networks are widely deployed for providing various data services, but today these technologies are also used for applications where synchronization is essential. UMTS networks and TDM transport over packet networks are the two most obvious examples.

ITU-T and ANSI have specified the requirements for synchronization. The synchronization requirements for UMTS networks are specified by 3GPP. These specifications include requirements for clock accuracy, hold over capabilities and for jitter and wander tolerance.

Synchronization methods in TDM networks are well understood and implemented. The Primary Reference Clock (G.811) is typically distributed through the network with the line signals to which network elements are synchronized.

Since packet networks are initially designed for asynchronous services the timing features and capabilities of typical packet switch are insufficient for timing critical applications. Metro Ethernet networks are widely implemented since they provide cost effective packet transport. Service providers like to use Metro Ethernet for wide range of applications, even for services that require accurate timing.

## Synchronization in TDM networks

PDH and SDH/SONET transmission technologies require that all of the network elements be synchronized with each other. In PDH 64kbit/s cross connection (1/0) equipment TDM frames are phase-aligned in order to implement the synchronous cross-connection. The frequency offset between interfaces due to synchronization failure is accommodated in the elastic buffer and results in frame slips. The frame slips cause loss or corruption of the data. In SDH and SONET transmission technologies, frequency difference causes pointer operations that are unwanted since they produce additional jitter to the signal.

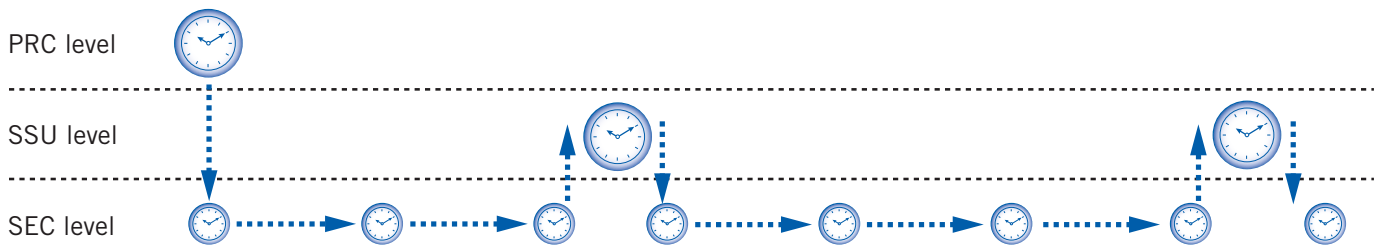
The timing requirements for TDM networks are specified in ITUT, ETSI and ANSI documents. Clause 8 in G.803 describes the distribution of timing reference in an SDH network. ANSI T1.TR.81 specifies synchronization network architecture for the SONET hierarchy. ITU-T specifies jitter and wander requirements are in G.823 (E1), G.824 (T1) and G.825 (SDH). ANSI specifies jitter and wander at network and equipment interfaces in T1.105.03.

There are four quality levels for clocks in SDH:

- Primary Reference Clock G.811
- SSU Slave clock (transit node) G.812
- SSU Slave clock (local node) G.812
- SDH network element clock (SEC) G.813

In SONET, there are four Stratum levels.

Tellabs 8600 system supports SEC (G.813) and Stratum 3.



General representation of SDH synchronization network

TDM networks require network-wide synchronization scheme in order to provide quality signal with low frame slip rate. This chapter describes SDH network synchronization but in SONET hierarchy the timing distribution is essentially the same even though a different reference frequency (1.544MHz vs. 2.048MHz) is used.

In SDH networks, timing is typically distributed according to a masterslave synchronization method. Master-slave principle uses a hierarchy of clocks where each clock is synchronized with reference to a higher level clock. SDH core networks are usually timed from redundant Primary Reference Clock (PRC, G.811) using a carefully planned hierarchical synchronization network.

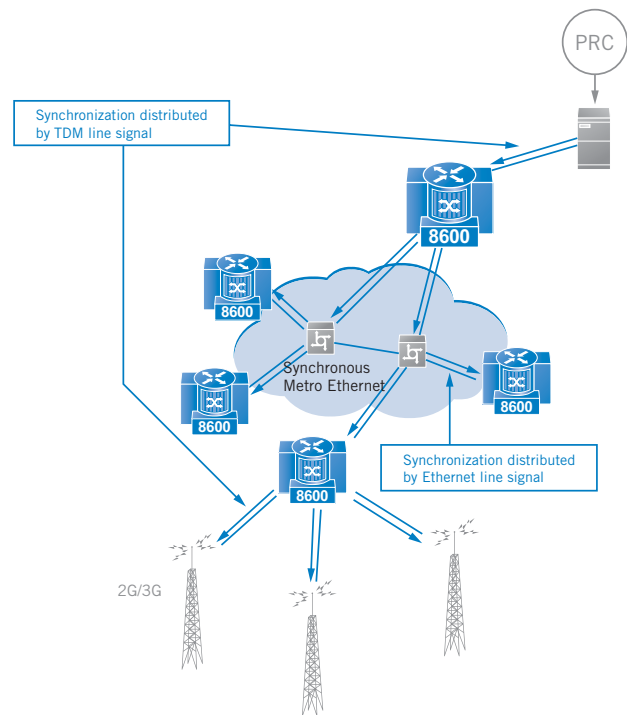
The timing reference can be derived from the line signal or from dedicated synchronization input. In the event of failure in a link that is used for timing reference, the element should select another link, or clock input, as a reference input. As soon as there are multiple references available the element must employ some selection algorithm. Synchronization Status Messages (SSMs) are used to provide information on the quality of the clock source. By using SSM information and the configured list of clocks that can be accepted as a reference, the element is able to select the new reference input. Tellabs 8600 system provides support for SSM and a fallback list for the clock references.

If such reference redundancy is not available, which may be the case lower in the network, the element will move to holdover state when the primary reference fails. Holdover means that the element is capable of keeping the timing it learned before the reference was cut. The standards specify how accurately and for how long the element needs to be able to perform without a reference signal. Tellabs 8600 system supports SEC and Stratum-3-level hold over performance.

In summary, Tellabs 8600 system switches provide complete, “TDM like” synchronization functionality with multiple-reference-clock provisioning, automatic clock selection, holdover and clock downstream forwarding.

## Synchronization in packet networks

The synchronization requirements for TDM have to be fulfilled also when a packet network is used to transport TDM signals. There are also other services, such as 3G backhauling, that require stringent synchronization. Reference timing signal can be distributed by using a synchronous physical layer, via dedicated clock ports or through packet-based methods. All of these methods can be used in planning network/service synchronization. For instance, one can use adaptive timing over the legacy asynchronous Ethernet network, and in new parts of the network Synchronous Ethernet can be utilized to convey the timing reference.



Timing reference distribution with synchronous Ethernet network

### Synchronous Ethernet

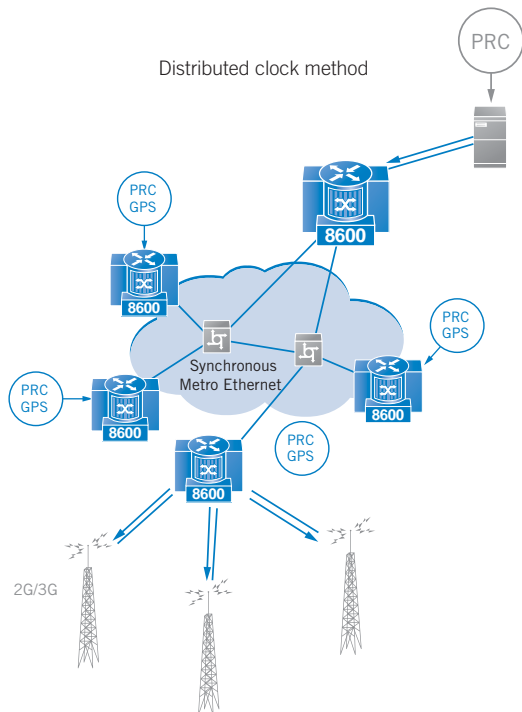
Tellabs 8600 system can distribute the synchronization similarly to TDM devices by using line signal as a reference timing signal and synchronize the element clock to that. The synchronization can be distributed via TDM interfaces or via Ethernet interfaces. This method is well-known and currently used in TDM networks thus Synchronous Ethernet can be considered as an extension to current sync distribution. Synchronous Ethernet is recommended approach for frequency synchronization since the accuracy that is achieved is not dependent on the traffic load in the network. In other words the accuracy is guaranteed during the business hours and in the night.

ITU-T G.8262 describes the method for distributing timing via Ethernet line signal. G.823/G.824 jitter and wander specifications are met. The Tellabs 8600 system solution supports synchronous optical GE interfaces. The support for the electrical 10/100/1000 Base-T interfaces will be added in future releases.

Tellabs 8600 system supports SSM messages in its Synchronous Ethernet implementation. Standardization of SSM support for Ethernet interfaces is ongoing, and when the standard is available, Tellabs 8600 system SSM support is adjusted accordingly.

**Distributed clock**

This method means that there is a clock available that can be connected to the router's synchronization input at both ends of the TDM pseudowire. The clock can be from GPS or from SDH network element. This is simple method but has a problem in the availability of such a clock. When packet-based networks become more common the SDH/SONET is not necessary available especially in access part of the network. The cost of this solution may come high if GPS devices are required in all the sites.



**Adaptive timing**

Tellabs 8600 system supports adaptive clock recovery scheme where the service clock of the TDM attachment circuit is derived from the arrival rate of the TDM emulation packets.

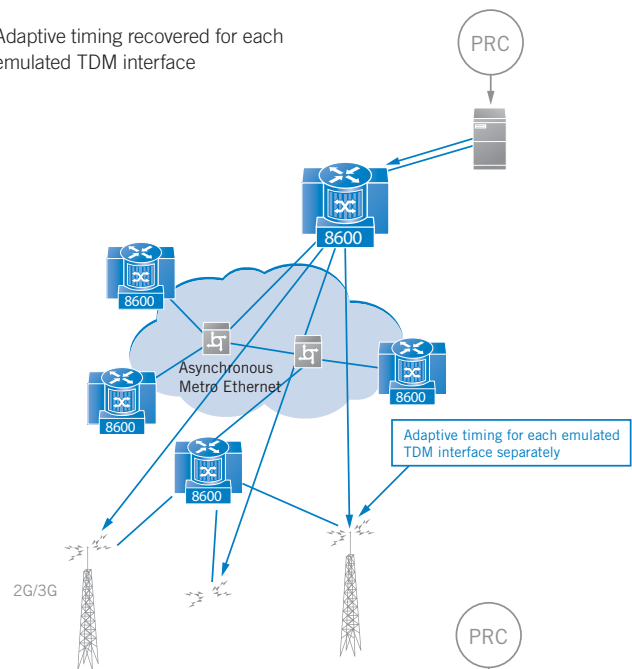
Both SAToP and CESoPSN pseudowires support adaptive timing. In Tellabs 8600 system any pseudowire with adaptive timing can be used as a synchronization source for any other interface on the same interface module. In Tellabs 8605 system any interface can be synchronized based on any TDM PW. This enables the Tellabs 8600 system to synchronize ATM interfaces based on emulated TDM circuit. Note that ATM PW itself does not carry network synchronization. As an alternative method, the node synchronization can be used to synchronize ATM interfaces instead of TDM PW; this is configurable per E1/T1 interface.

When TDM is emulated over packet switched network, TDM data packets are transmitted to the destination at the constant rate.

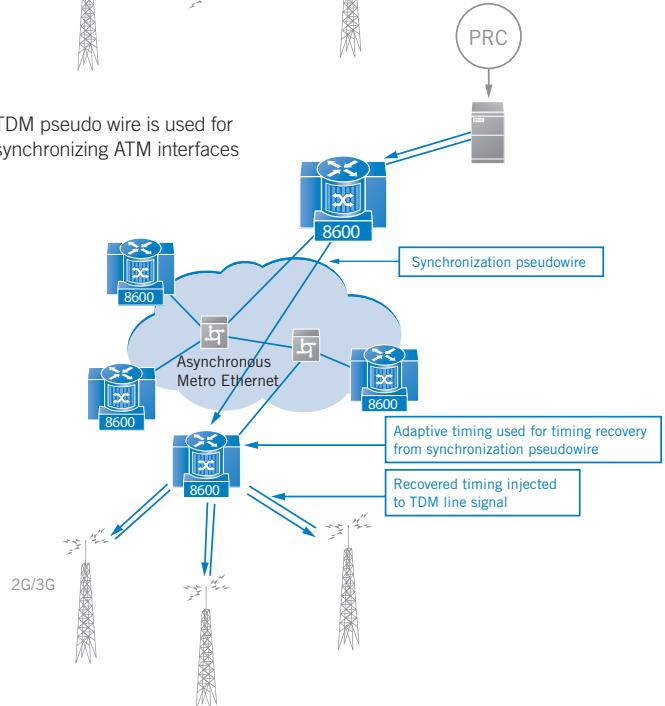
However, due to characteristics of the PSN the packets may arrive to the destination with alternating rate. The algorithm used for adaptive timing at receiver recovers the frequency of the transmitter from the received packet rate. Different types of algorithms can be used for recovering the clock. Adaptive timing algorithms perform well in QoS aware Metro Ethernet environment, since high priority traffic is less likely to be queued long at the egress ports in the network. The timing can also be recovered in DSL access environment depending on the network characteristics.

Adaptive timing recovery scheme can be use to provide the timing that is fully compliant with the G.823/G.824 jitter and wander specifications.

Adaptive timing recovered for each emulated TDM interface



TDM pseudo wire is used for synchronizing ATM interfaces



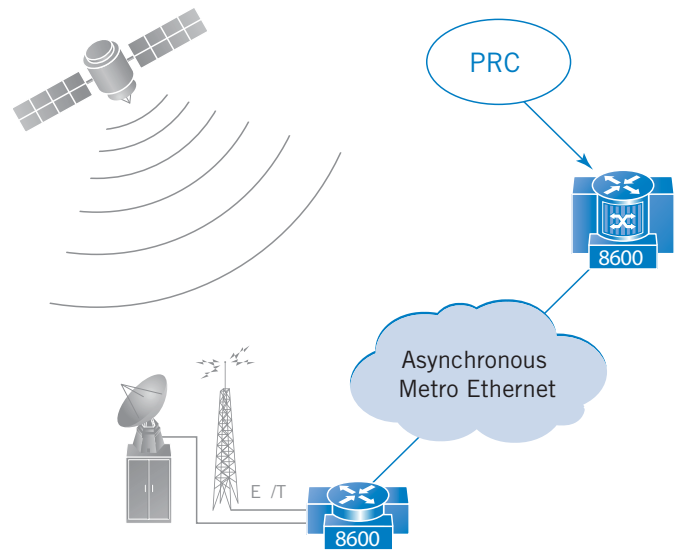
**IEEE 1588 Precision Time Protocol (PTP)**

IEEE 1588 was originally designed for testing and automation in order to achieve sub-microsecond clock accuracy in local area networks. PTP builds hierarchical tree where a grand master clock is selected and slave clocks synchronize with the master clock. There are various reasons that the original IEEE 1588 specification is not suitable for telecoms application: assumptions concerning symmetrical network delay, shortcomings in redundancy support, requirement for multicast and boundary clocks, too long messages and too long a sync interval. The standardization for telecoms version is ongoing and Tellabs plans to support this synchronization method after the protocol is specified and accepted by the industry. Under certain circumstances, some network elements require time of day time synchronization, and here IEEE 1588v2 is the only valid alternative to GPS. Typical networks requiring both frequency and phase alignment are CDMA networks in North America.

The accuracy for frequency synchronization that can be achieved depends on network environment and how IEEE1588 PTP is used. PTP specifies different type of devices: ordinary clocks, boundary clocks, end-to-end transparent clocks, peer-to-peer transparent clocks, and management nodes. Tellabs sees that in many network the first step is to use only ordinary clocks (master and slave) and no boundary or transparent clock that are specified in the standard. This is because current metro Ethernet networks do not have the support for IEEE1588. In this scenario the accuracy is same as what can be achieved by adaptive timing algorithms that were described in previous chapter. If IEEE1588 Boundary and/or transparent clock support becomes common in switches and routers then better accuracy is achievable.

**Global Positioning System (GPS) Timing**

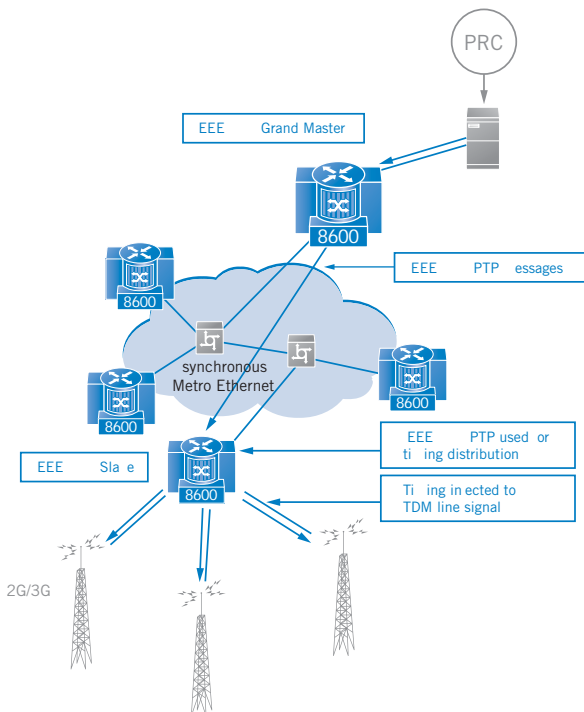
CDMA Networks, like those deployed in North America, require highly accurate and synchronized timing. Virtually all CDMA deployments utilize a GPS receiver to meet this timing and synchronization need. These GPS devices are typically deployed with the ability to provide an external timing reference for devices other than the base station itself. This timing reference can be used as a low cost means to provide a highly accurate source for a cell site aggregator/router device, such as the Tellabs® 8605 Access Switch. The Tellabs 8605 switch is able to accept frequencies from the CDMA BTS's GPS including 5, 10, 15 or 20 MHz frequencies.



This GPS alternative to Adaptive Timing and the IEEE 1588 implementations alleviate the need for QoS guarantees to assure the high priority based timing packets get proper treatment in the backhaul network. This approach then uses the GPS to provide node timing, which can then be used to synchronize the customer or backhaul facing interfaces.

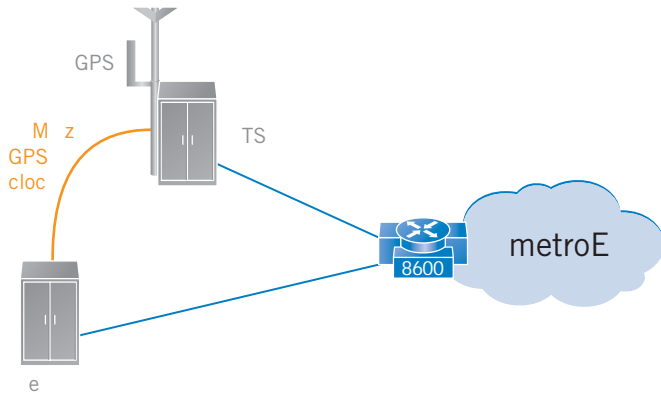
**Example: CDMA and LTE Timing Sharing**

CDMA2000 networks require synchronous air interface across all base stations. GPS is proven to be the best source of timing and equipped in each cell site. On the other hand, air interface of LTE is asynchronous among base stations. It does not require the timing as stringent as CDMA2000 systems. When LTE is overlaid with CDMA2000 and share the same cell sites, there can be two different 8600 scenarios to share the timing system.



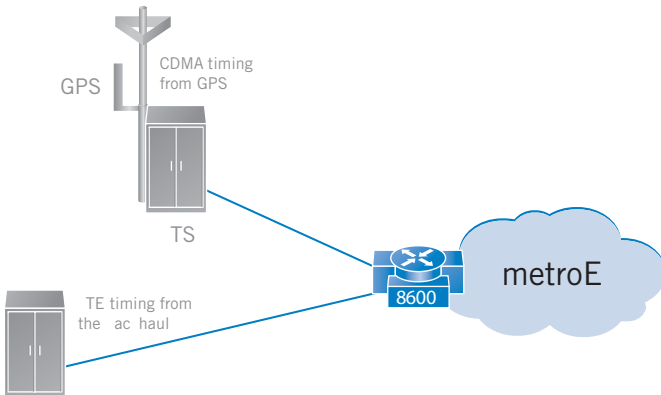
IEEE 1588 Precision Time Protocol is used for timing distribution

Scenario A: both CDMA2000 and LTE share the same GPS. LTE eNB can receive its timing either from CDMA2000 BTS 10MHz clock output or directly from the GPS receiver.



Scenario A: CDMA2000 BTS and LTE eNB share the same GPS

Scenario B: keep CDMA2000 and LTE timing independent. CDMA2000 continues receiving timing signal from GPS while LTE uses timing from the backhaul, which offers flexible implementation options.



Scenario B: CDMA2000 BTS and LTE eNB have independent Timing

Both scenarios have pros and cons. Scenario A uses the GPS already in the cell site. The implementation is simpler and independent from the backhaul. However, both CDMA BTS and LTE eNB would be out of service, should the GPS receiver in the cell site fail. Scenario B is more flexible for LTE implementation. It decouples the two base stations from network timing point of view, offers better overall availability of the mobile network, i.e. the failure of backhaul-based timing will not bring down the GPS-based timing and vice versa. However, the backhaul-based timing may require a tighter SLA on the metroE service provider in terms of the delay jitter specification of its Ethernet backhaul network.

### Conclusion

All the methods explained in this paper have their own pros and cons. The service provider has to do careful synchronization planning for distributing the timing to all places where it is needed. These methods are tools for distributing the timing. The service provider can use all or a subset of these methods, not only one, for synchronization distribution. The table that follows summarized the advantages and disadvantages of these methods.

Tellabs 8600 system provides synchronization features that enable synchronization distribution with a costeffective Metropolitan Area Network. The Tellabs 8600 system can synchronize itself and distribute the synchronization via line signals. If no timing signal is available, packet-based methods can be used.

Term	Explanation	Explanation
PRC	Primary Reference Clock	
SSU	Synchronization Supply Unit	
SSM	Synchronization Status Messages	
PTP	Precision Time Protocol	
SEC	SDH network element clock	
GPS	Global Positioning System	
UMTS	Universal Mobile Telecommunications System	

Synchronisation distribution method	Pro	Con
Distributed clock	Most accurate	Cost
Line synchronization	Accurate and simple. Accuracy is not depended on the traffic load in the network. Standard available.	Can not be used with legacy Metro Ethernet networks that do not support line sync.
Adaptive timing based on Pseudo Wire	Can be used over packet networks without requiring additional support from other elements.  Can support multiple synchronization domains	The accuracy depends on network traffic load.
IEEE 1588	More accurate than adaptive timing, if the intermediate switches supports boundary or transparent clocks.  Provides synchronization of time of day.	Complicated. High accuracy not achievable if used with legacy Metro Ethernet networks that do not support boundary or transparent clocks.  The accuracy depends on network traffic load.  Standardization for telecom applications still ongoing.

**North America**

Tellabs  
1415 West Diehl Road  
Naperville, IL 60563  
U.S.A.  
+1 630 798 8800  
Fax: +1 630 798 2000

**Asia Pacific**

Tellabs  
3 Anson Road  
#14-01 Springleaf Tower  
Singapore 079909  
Republic of Singapore  
+65 6215 6411  
Fax: +65 6215 6422

**Europe, Middle East & Africa**

Tellabs  
Abbey Place  
24-28 Easton Street  
High Wycombe, Bucks  
HP11 1NT  
United Kingdom  
+44 871 574 7000  
Fax: +44 871 574 7151

**Latin America & Caribbean**

Tellabs  
Rua James Joule No. 92  
EDIFÍCIO PLAZA I  
São Paulo – SP  
04576-080  
Brasil  
+55 11 3572 6200  
Fax: +55 11 3572 6225

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