MIGRATING TDM SERVICES TO PACKET NETWORKS

ENSURING RELIABLE AND EFFICIENT TRANSPORT WITH THE ALCATEL-LUCENT 9500 MICROWAVE PACKET RADIO

APPLICATION NOTE

ABSTRACT

As bandwidth-hungry IP services become more common, it is essential to provide IP network scalability that protects investments and makes the network ready for the future. In modern microwave systems scalability is managed at the network level instead of on a link-by-link basis as is the case for older microwave systems. The change of paradigm starts with site aggregation. The site aggregation device must have a low-delay, non-blocking, packet-based switching fabric with service-awareness to provide deterministic quality of service (QoS) to high-priority traffic in the microwave environment. The site aggregation device must also support legacy TDM services that are still deployed in many networks.

The Circuit Emulation Services over Ethernet (CESoETH) standard has become the mechanism to transport TDM services over packet networks. However, making CESoETH work over an end-to-end packet network requires algorithms and technologies that go beyond the CESoETH standard.

This paper describes the Alcatel-Lucent 9500 Microwave Packet Radio (MPR) technological innovations that ensure efficient and reliable transport of CESoETH over packet networks.

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INTRODUCTION

Energy, transportation, and public safety mission-critical networks plus carriers' mobile backhaul and fixed networks worldwide have moved or are planning to move to all-IP packet networks. However, in many of these networks TDM services need to be supported for the foreseeable future.

The CESoETH standard has been designed to support the transport of legacy TDM services over a converged, efficient, all-IP packet network. Successful deployment of CESoETH, however, requires the introduction of technologies that control packet delay variation (PDV), latency, traffic prioritization, and TDM circuit performance.

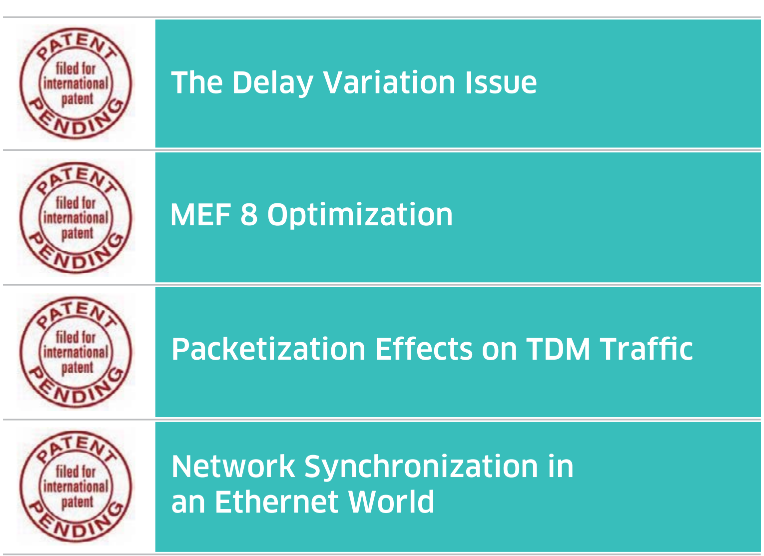
The Alcatel-Lucent 9500 Microwave Packet Radio (MPR) delivers the technologies required to support CESoETH while also enabling an efficient evolution to an all-IP packet network. This level of support enables a seamless migration to future IP technologies and allows network operators to evolve to packet networks on their own schedule and within achievable budgets.

ALCATEL-LUCENT 9500 MPR CESoETH TECHNOLOGIES

Designed with packet technology as its foundation, the Alcatel-Lucent 9500 MPR maximizes scalability and facilitates legacy-to-packet transformation over a converged packet network.

During the initial design phase of the 9500 MPR, Alcatel-Lucent was keenly aware of potential issues associated with CESoETH pseudo-wire technology and various vendors' failure to suitably address important issues such as PDV, latency, TDM circuit performance, prioritization, and synchronization. Consequently, Alcatel-Lucent went beyond the stringent standards developed by the Metro Ethernet Forum (MEF 8, Implementation Agreement for the Emulation of PDH Circuits over Metro Ethernet Networks)[5] and developed patent-pending technologies for packet-based microwave transmission (see Figure 1).

Figure 1. Alcatel-Lucent 9500 MPR patents-pending technologies



Data awareness

Data awareness in a microwave system is pivotal when applying the innovations previously described. With data awareness, algorithms and techniques can be applied to packet traffic carrying TDM circuits to uniquely manage latency, jitter/wander[1], and bit error rate (BER) performance and to maximize throughput. These algorithms and techniques for over-the-air microwave transmission are divided into three major groups:

- PDV control
- Bandwidth optimization
- BER improvement

PDV control

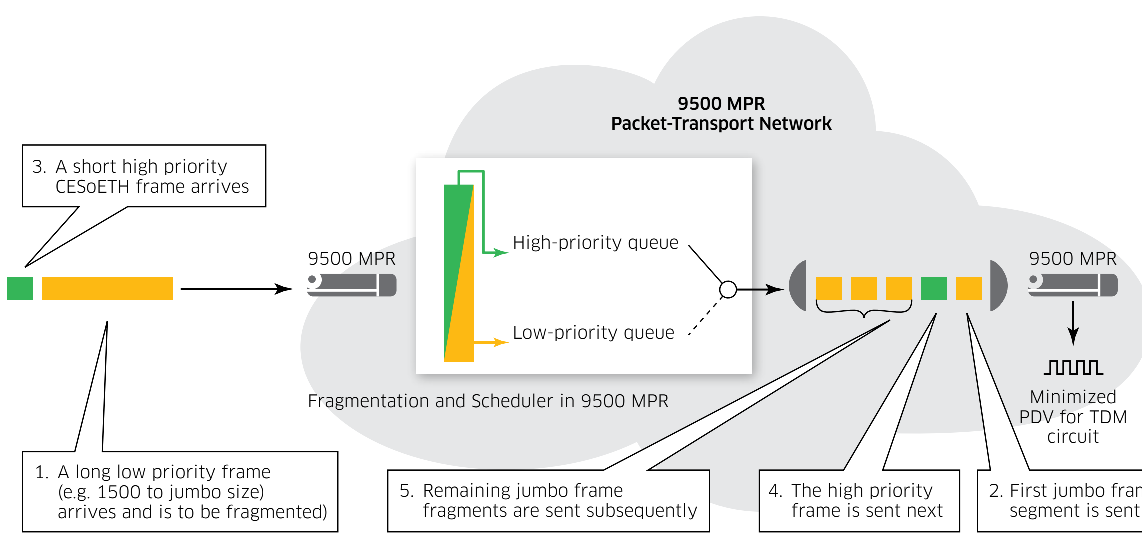
PDV control is addressed by the Delay Variation Issue patent.

Indiscriminately mixing frames of different length over a microwave link introduces high PDV, which degrades the quality of real-time TDM services. When a CESoETH frame arrives just one instant after a long best-effort frame, despite its high priority classification, it is blocked by the best-effort frame which has just started transmission. This phenomenon is known as head-of-line (HOL) blocking. This incurs high PDV in a microwave link.

The 9500 MPR controls and bounds PDV with a patented fragmentation and interleaving technique that fragments longer frames before placing them in queues. This technique controls delay variations caused by longer Ethernet frames. In addition to providing PDV control, this algorithm also reduces latency.

Figure 2 provides a high level illustration of the algorithm.

Figure 2. Alcatel-Lucent 9500 MPR PDV, wander and latency control



1 Wander is jitter under 10 Hz.; jitter is also commonly known as packet delay variation (PDV).

The essence of the fragmentation and interleaving technique is described below:

1. A long low-priority frames arrive, they are fragmented into multiple shorter fragments, and subsequently placed in the appropriate lower priority queue.
2. If there are no higher priority frames the first low-priority fragment starts the transmission process.
3. If a subsequent high-priority frame carrying CESoETH traffic arrives, it is placed in a high-priority queue to wait for transmission. Since CESoETH frames are engineered to be short, no fragmentation is required for these higher priority frames.
4. When the transmission of the first low-priority fragment has finished, the transmitter serves the high-priority CESoETH frames, interleaving them with the low-priority fragments.
5. After the high-priority frames are served, the transmitter switches back to service the low-priority frame fragments.

CESoEtH encapsulation and end-to-end latency calculation

The 9500 MPR supports low-latency DS1/E1 CESoETH encapsulation options to address the most latency-sensitive TDM service deployments (for example, teleprotection circuits commonly used in power utilities). These encapsulation options leverage the 9500 MPR QoS flexibility to tune CESoEth frame size and related buffer depths to ensure the lowest end-to-end latency over packet networks.

Contributors to end-to-end latency are shown in Figure 3 and consist of:

- Packetization at ingress of 9500 MPR network
- Modem latency across each link
- Free space latency of all links between ingress and egress of the 9500 MPR network
- Process and buffer latency at egress of the 9500 MPR network

Figure 3. Alcatel-Lucent 9500 MPR end-to-end latency

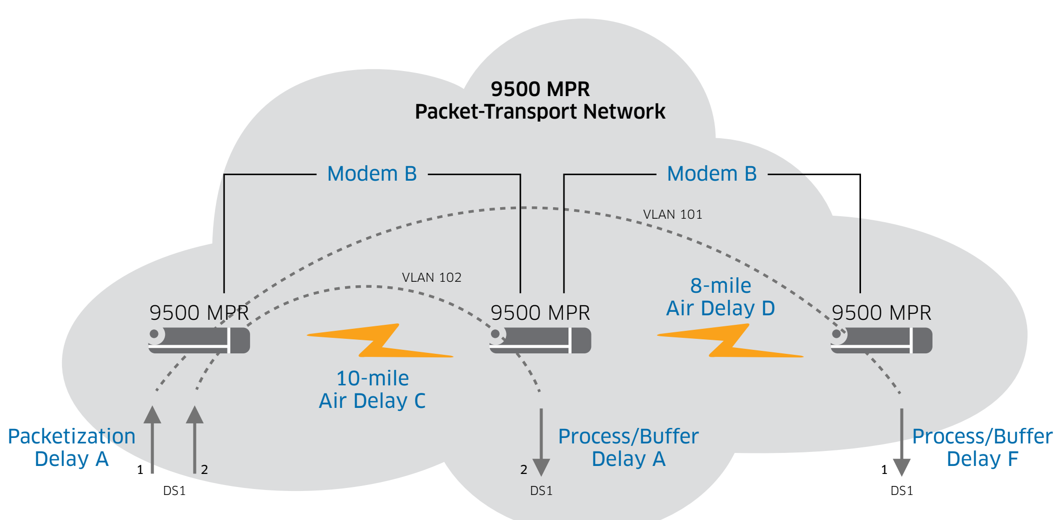


Table 1 shows the value of each contributor in Figure 2 for a low-latency service profile option.

Table 1. Alcatel-Lucent 9500 MPR latency contributors

LATENCY CONTRIBUTORS	DS1 LATENCY
Packetization delay [A]	135 µs
Modem 30 MHz/128 QAM [B] *	190 µs
Air delay [C/D]	5.38 µs / Mile
Process and buffer delay [E/F]	1.1 ms

* Values shown are associated with a 9500 MPR MPT-HL transceiver provisioned with 30/128 modem profile.

For each DS1 shown in Figure 3, end-to-end latency can be computed as:
DS1 #1: VLAN 101 Latency = B x 2 + $(A+C+D\ +F)$
DS1 #2: VLAN 102 Latency = $A+B+C+E$

Based on Figure 3, end-to-end values for latency are:
DS1 #1 Latency = 190 x 2 + 135 + (5.38 x C) + (5.38 x D) + 1100 = 1.71 ms
DS1 #2 Latency = 190 + 135 + (5.38 x C) + 1100 = 1.48 ms

Worst-case latency scenarios for CESoETH over microwave links would be encountered using lower modulation rates together with topologies involving numerous hops. Latency values for a 10-hop, 100-mile route can be expressed as follows:

TDM2ETH service profile:
DS1 latency = 190 x 10 + 135 + (5.38 x 100) + 1100 = 3.67 ms

Even for this 10-hop span, the latency of 3.67 ms would have no impact on TDM-based latency-sensitive applications. In fact, 9500 MPR deployments have reliably supported low-latency application requirements with latency values in excess of this number.

Bandwidth optimization

Bandwidth optimization is addressed by the MEF 8 optimization patent.

A common perception is that CESoETH packetization adds overhead to TDM traffic, resulting in inefficient use of over-the-air bandwidth. This does not need to be the case. By eliminating unnecessary overhead and applying frame header compression, the 9500 MPR can deliver better DS1 densities than traditional TDM radios.

The 9500 MPR service awareness identifies the MEF 8 frames to apply a patented technique that reduces the MEF 8 overhead before sending the MEF 8 Ethernet frames on the radio physical layer. This algorithm optimizes over-the-air bandwidth utilization.

Table 2 highlights the superior TDM DS1 service densities that the 9500 MPR delivers when compared to that of a TDM microwave radio which carries DS1 circuit natively.

Table 2. DS1 density using a high-density profile option

RF CHANNEL	MODULATION	TRADITIONAL TDM	9500 MPR
10 MHz	128 QAM	29 DS1s (28 + 1 wayside)	31 DS1s
30 MHz	128 QAM	87 DS1s (84 + 3 wayside)	95 DS1s

BER improvement

BER improvement is addressed by the Packetization Effects on TDM Traffic patent.

When CESoETH frames are transmitted through a noisy medium such as the radio physical layer, bit errors can occur. If an CESoETH frame is affected with one bit error, this is detected by the frame check sequence (FCS) and the entire frame is dropped. As a result, one bit error can be multiplied into hundreds of errors from a TDM service perspective.

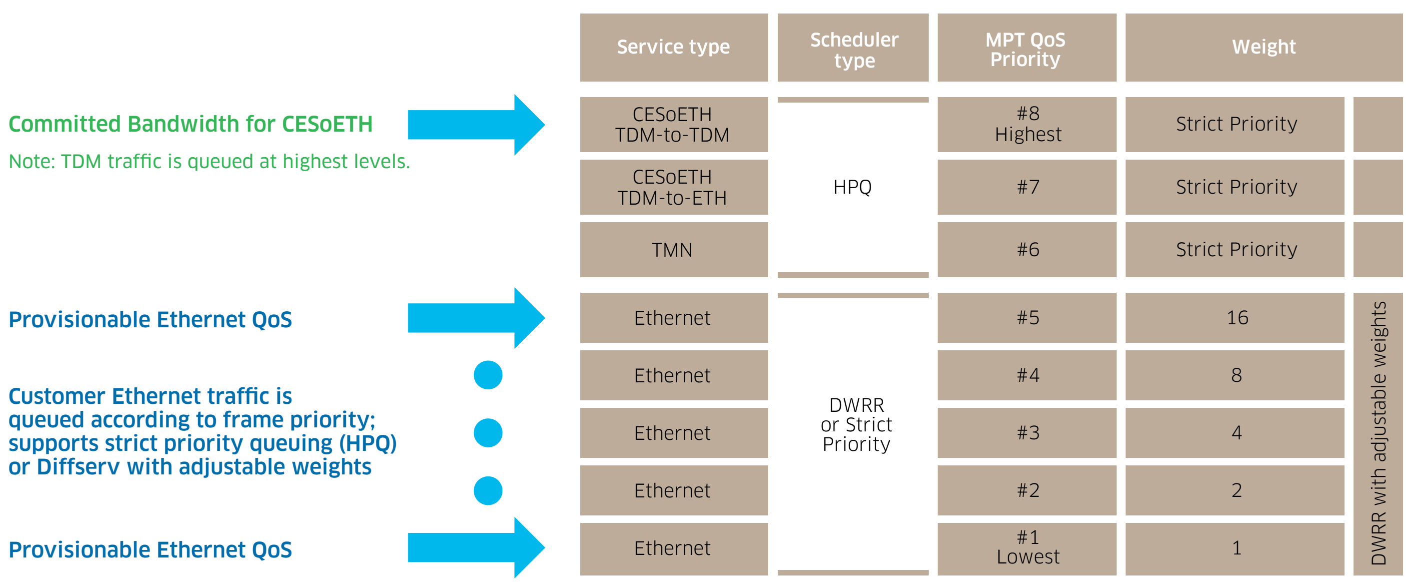
To stop this type of TDM service degradation, the 9500 MPR service awareness identifies the CESoETH frames, applies a patented technique to suppress the FCS over-the-air, and re-calculates FCS after the CESoETH frame is received.

CESoETH prioritization

The 9500 MPR allows for flexible traffic prioritization, including setting aside the highest priority queues used for CESoETH. This prioritization guarantees that dedicated bandwidth is available for TDM services regardless of Ethernet congestion or frame size of other applications.

Figure 4 shows an example 9500 MPR queuing assignment.

Figure 4. Alcatel-Lucent 9500 MPR CESoETH QoS queues



Precise synchronization

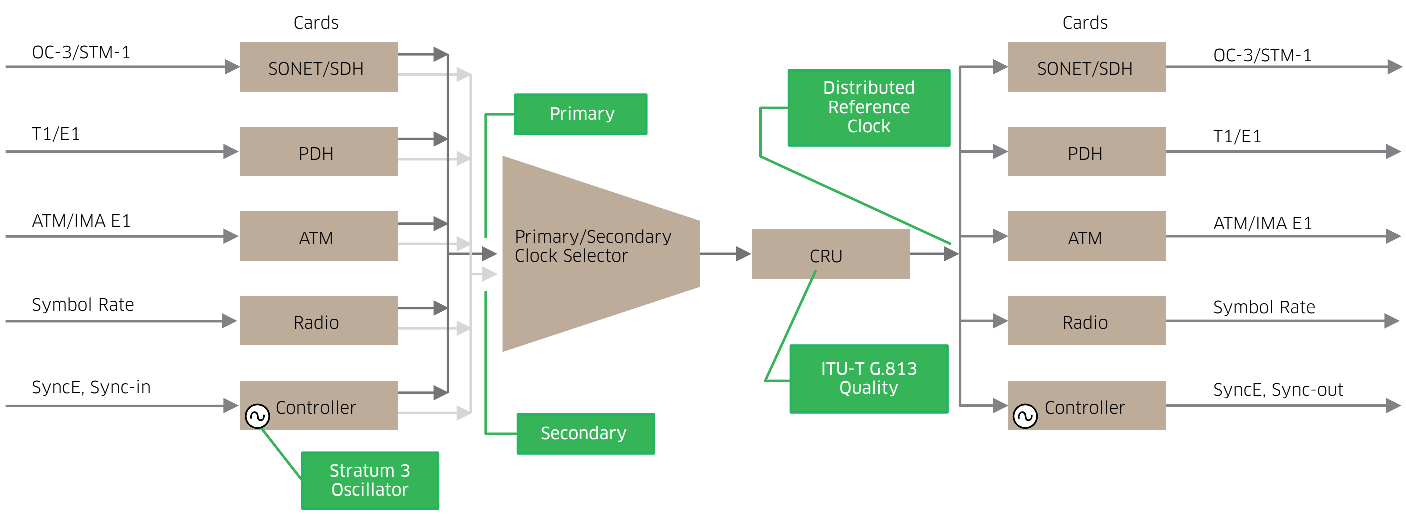
Efficient and precise synchronization over packet networks is addressed by the Network Synchronization in an Ethernet World patent.

The 9500 MPR supports patented microwave technology to transport a synchronization signal across a microwave radio link. The network clock is locked to the radio symbol rate (Layer 1), allowing a pair of 9500 MPR devices to relay a network-clock reference from one site over a microwave link to another site.

A key advantage of the 9500 MPR is its ability to accept timing from a primary reference clock (PRC) and distribute timing to the rest of the network with accuracy in compliance with ITU-T G.813 [4] and Telcordia GR-1244. The 9500 MPR has an embedded reference clock that is distributed to each board of the network element. The clock is generated in the clock reference unit (CRU) in the controller card.

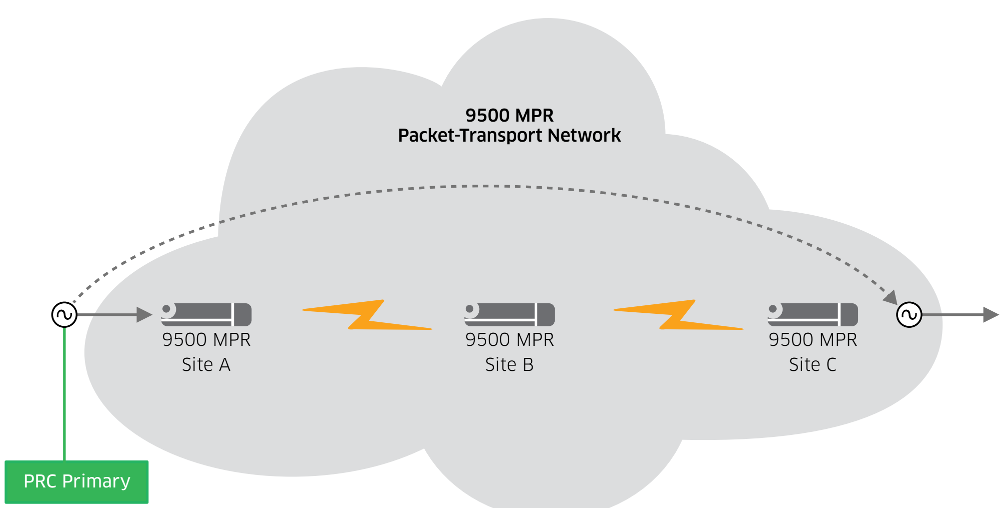
As shown in Figure 5, the primary and secondary clock provision can be locked to the internal stratum 3 oscillator, radio symbol rate, SynchE, any T1/E1, any SDH/SONET OC-3, or a dedicated BITS interface at 5 or 10 MHz.

Figure 5. Alcatel-Lucent 9500 MPR network clock source selection



In the general case shown in Figure 6, the 9500 MPR at Site A is locked to a PRC to become the master timing source for the 9500 MPR packet-transport cloud. Site B is locked to the radio symbol rate associated with the link between Site A and Site B. Site C is locked to the radio symbol rate associated with the link between Site B and Site C. This architecture provides Site C with synchronization traceable back to the PRC at Site A.

Figure 6. Alcatel-Lucent 9500 MPR network clock source distribution



To support IEEE 1588v2 PTP[2] time and frequency[3] synchronization distribution, the 9500 MPR supports patented fragmentation and interleaving techniques to guarantee a synchronization mask of 16 ppb.

There are circumstances when the emulation of TDM services requires synchronization algorithms to recover the original TDM service clock frequency (referred to as the service clock).

Two typical methods employed for service-clock (TDM frequency) recovery are adaptive clock recovery (ACR) and differential clock recovery (DCR). The 9500 MPR supports both ACR and DCR.

- ACR is used when there is no common reference clock among the originating and destination network elements when the 9500 MPR cloud receives an MEF 8 flow from a third-party element in a different network. The 9500 MPR receives and backhauls the MEF 8 flow to a destination for de-encapsulation. The main tasks of the ACR algorithm are to filter out irregularities in the packet delay of frames crossing the network and to recover a stable clock source.
- The 9500 MPR employs DCR to recover the T1/E1 service clock in a 9500 MPR network where a common network clock synchronizes both originating and destination 9500 MPR devices. DCR uses timestamps in packets and a common reference-clock frequency, making the recovered clock less subject to impairments due to PDV in the packet network.

Given the extensive 9500 MPR synchronization feature set, TDM synchronization requirements can be reliably and accurately be supported over packet microwave networks.

CONCLUSION

With the innovative algorithms and techniques Alcatel-Lucent has developed, the Alcatel-Lucent 9500 MPR enables network operators to seamlessly migrate TDM services and applications to a packet network without compromising QoS. This enables a flexible and efficient evolution to an all-IP packet network that can support current and future service and application needs.

For more information about the Alcatel-Lucent 9500 MPR, go to
http://www.alcatel-lucent.com/products/9500-microwave-packet-radio

ACRONYMS

1588v2	IEEE 1588-2008
9500 MPR	Alcatel-Lucent 9500 Microwave Packet Radio
ACR	adaptive clock recovery
ATM	Asynchronous Transfer Mode
BER	bit error rate
BITS	Building Integrated Timing Source
CES	Circuit Emulation Service
CESoEth	Circuit Emulation Service over Ethernet
DCR	differential clock recovery
DWRR	Deficit Weighted Round Robin
FCS	frame check sequence
HOL	head-of-line
HPQ	High Priority Queuing
IEEE	Institute of Electrical and Electronics Engineers
IMA	inverse multiplexing over ATM
IP	Internet Protocol
ITU-T	International Telecommunication Union – Telecommunication Standard
MPT-HLC	Alcatel-Lucent 9500 MPR High Capacity Long-haul Cubic
MEF	Metro Ethernet Forum
MEF 8	MEF 8, Implementation Agreement for the Emulation of PDH Circuits over Metro Ethernet Networks
PDH	Plesiochronous Digital Hierarchy
PDV	packet delay variation
PRC	primary reference clock
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
SDH	Synchronous Digital Hierarchy
SONET	Synchronous Optical Networking
SyncE	Synchronous Ethernet
TDM	Time Division Multiplexing
TMN	Telecommunications Management Network
SF	Super Frame
SSM	Synchronous Status Message
TMN	Telecommunications Management Network
VLAN	Virtual Local Area Network
VoIP	Voice over IP

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