DragonWave Inc.

Service Delivery Unit Network Design Guide

DragonWave

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Introduction

High-speed packet (IP, VPN, ATM…) based networks are the latest innovation in the world of communications. The capacity of these networks is increasing at a prodigious rate, fueled by the popularity of the Internet and decreasing costs associated with the technology. Worldwide data traffic volume has already surpassed that of the telephone network, and for many applications, the pricing of IP traffic has dropped below the traffics associated with traditional TDM service. There is an alternative method of exploiting IP networks for telephony service that is evolutionary rather than revolutionary. This method uses IP networks as a drop-in replacement for native TDM networks. It seamlessly interfaces to all existing equipment, such as legacy PBXs and switches, and inherently provides all the hundreds of telephony features and the PSTN quality to which customers have become accustomed.

The Service Delivery Unit (SDU), delivers a standards-compliant 16 x T1/E1 port extension capability to the AirPair and Horizon Ethernet platforms. The SDU-DS3 offers 2xDS3 service over Ethernet for head-end aggregation in multi-point configuration. DragonWave's SDU products seamlessly transport TDM traffic over Ethernet enabling customers to easily migrate to native IP networks while still supporting legacy TDM services, and meeting stringent synchronization requirements.

This technical note addresses the challenges associated with deploying such evolutionary technology.
The main challenges with deploying such evolutionary technologies are:

1. Clock Synchronization. How to maintain timing over an asynchronous Ethernet network?
2. Network Characteristics. How to handle networks are different with different composition of traffic and network topology, specifically packet delay variation, packet loss and overall latency?

Clock Synchronization

One of the key challenges in TDM transport is that the clock on both of the TDM segments of the link must be at the same frequency. Figure 1 illustrates the challenge. It shows a private leased line between two customer sites, connected by an emulated link across a carrier's packet network.

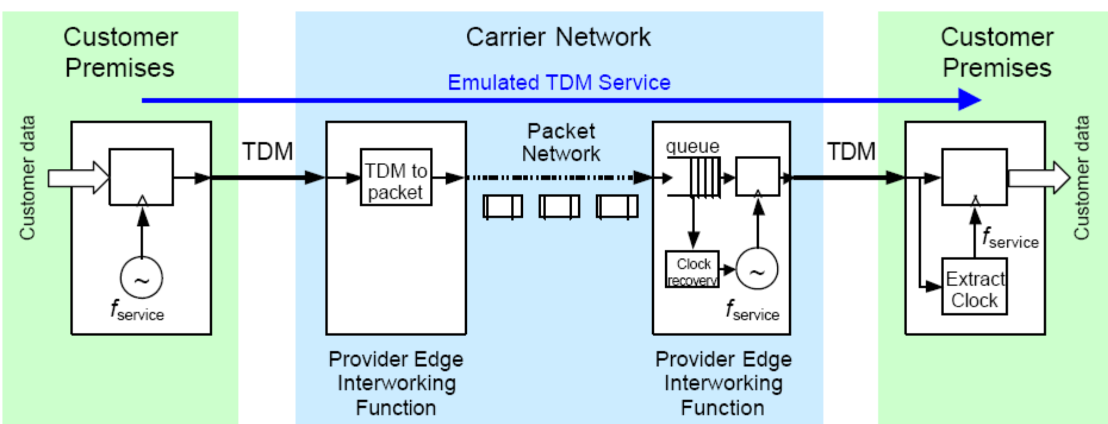
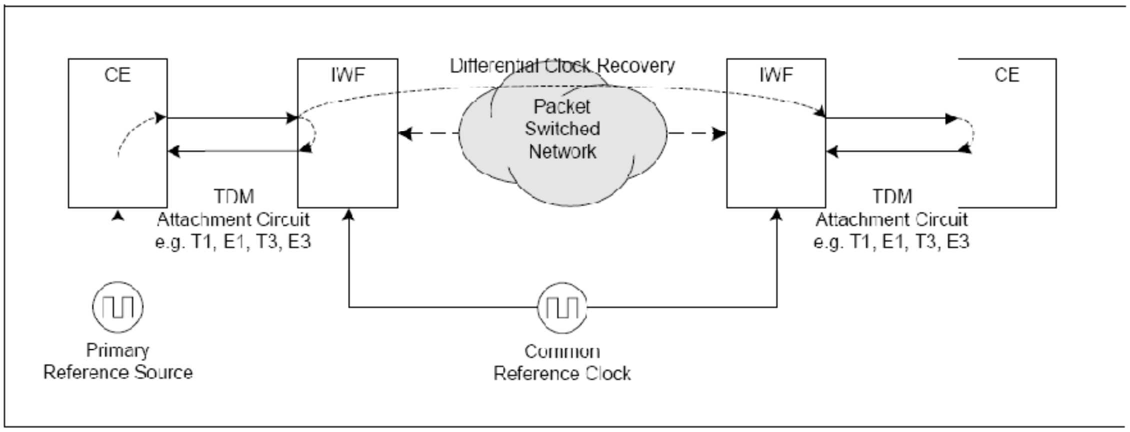


Figure 1 Emulated TDM Service

The TDM service frequency *fservice* at the customer premises must be exactly reproduced at the egress of the packet network. The consequence of a long-term mismatch in frequency is that the queue at the egress of the packet network will either fill up or empty, depending on whether the regenerated clock is slower or faster than the original. This will cause loss of data and degradation of the service.

With a packet network, that connection between the ingress and egress frequency is broken, since packets are discontinuous in time. Therefore, unless there is an external means of clock distribution, the inter-working function at packet egress will be required to recover the frequency of the original TDM service clock by some means.

Clock Recovery Techniques
There are two main methods of clock recovery in SDU products: differential and adaptive. Differential clock recovery uses a known common clock at either end of the packet network (e.g. a central office reference clock).

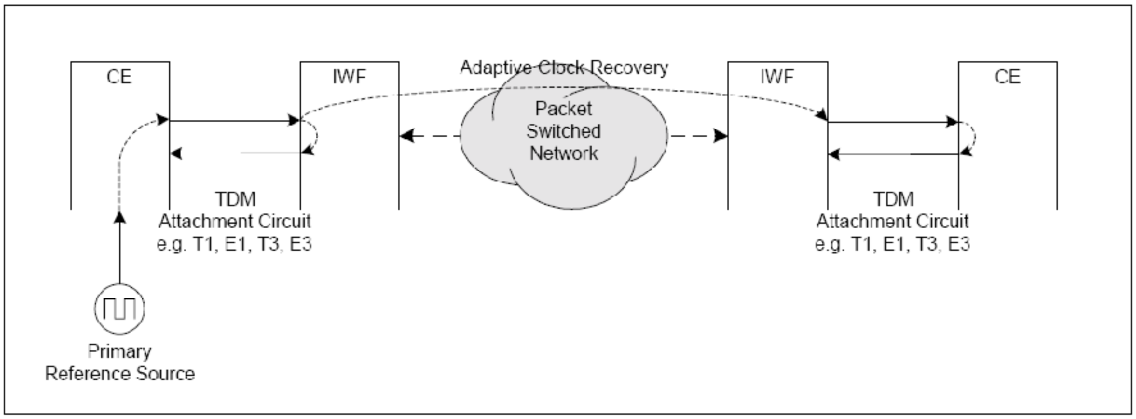


The difference between the TDM service frequency and the reference clock is then encoded, and transmitted across the packet network. The service frequency can then be easily regenerated by adding back in the reference frequency. However, where a common reference clock is not available, the clock rate must be inferred by averaging the arrival rate of the packets over a period. This averaging period has to be sufficiently long to remove jitter effects, caused by variation in the transit delay of packets across the network.

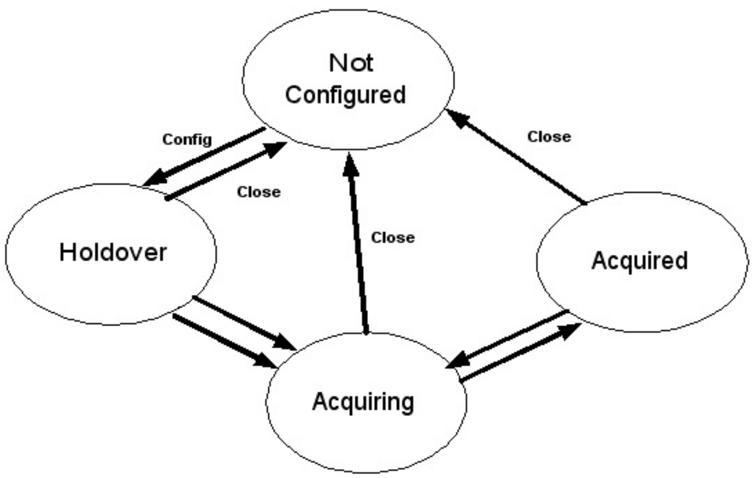
The disadvantage of this type of scheme is that, depending on the characteristics of the packet network, it may prove difficult to regenerate a clock that stays within the wander requirement of the TDM service clock.

DragonWave's SDU uses Timing-over-Packet (ToP) technology to ensure accurate timing and clock synchronization to be distributed across asynchronous packet infrastructures, allowing carriers to confidently support time-critical services over packet networks. This ToP technology is built on a processing engine and software solution that encodes and transmits a master clock over existing
Ethernet, IP and MPLS networks, and recovers the clock at client nodes. This technology enables the SDU to regenerate a high TDM clock fidelity.

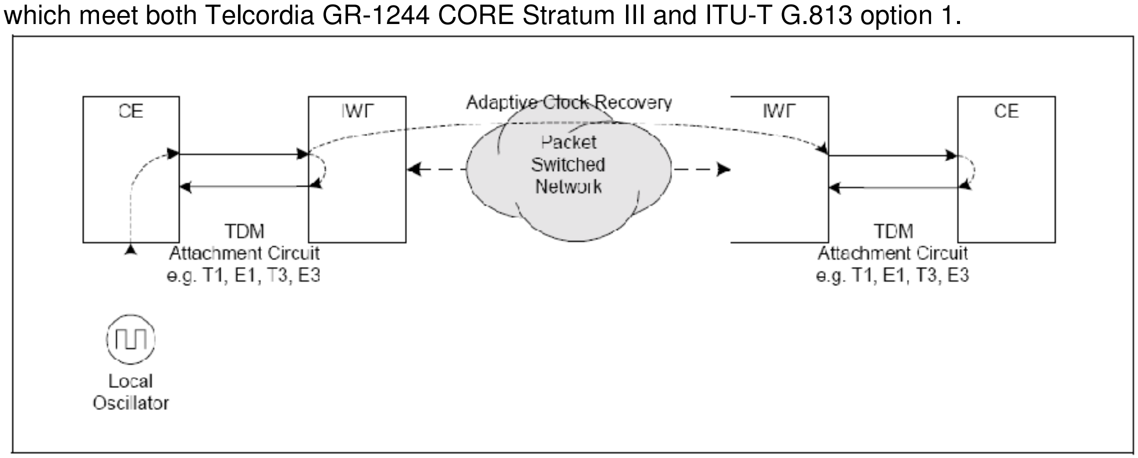
The ToP in SDU-16 uses adaptive cock recovery method to recover a clock from the packet switch network, and it recovers the clock using information embedded in the TDMoE packets. This information is used to deliver high performance clock synchronization and therefore better regenerated TDM clock fidelity.



Once a clock recovery context is configured, its status changes from **Holdover** to **Acquiring**, and finally to **Acquired** status. In an ideal network state, it takes approximately nine minutes for the clock recovery context to go into **Acquired** state from the time it's configured.



Once a clock enters **Acquired** state, it can go back to **Holdover** state if the PDV from the packet switch network is severe such as a network outage. The **Holdover** state will not cause any data slips, because the recovered clock has synchronized and a very stable Local Oscillator is used as the PRS. The LO's 24-hour holdover stability is less than or equal to ±0.37 parts per million(ppm), and 24-hour drift is less than or equal to ±0.04ppm, which meet both Telcordia GR-1244 CORE Stratum III and ITU-T G.813 option 1.



Internally, two clock recovery contexts are used by the SDU-16, and they serve as the back up of each other. The first context that goes into **Acquired** state will be used to clock the SDU-16. When the In-Service clock goes into the **Holdover** state, the In-Service clock will use the second context if its clock state is in **Acquired** state. This clock transition will occur in approximately in 5 hours at the **Holdover** state.

SDU-16 supports one clock domain, i.e, all tributaries' transmit clock use same clock source (either from BITS or a recovered clock). SDU-16 supports BITS and recovered clock from the packet switch network, and it automatically selects the best clock source. When BITS is enabled and the SDU does not have a LOS alarm, BITS will be used. The recovered clock will be used if BITS is not enabled, or the SDU have a LOS alarm.

Network Characteristics

The extent of the wander on an adaptively recovered clock is dependent on the characteristics of the packet network. TDMoE data is timing sensitive, and they should be given higher priority (e.g., 802.1p CoS 6 or CoS 7) to guarantee packet delivery. SDU-16 supports 802.1p and 802.1q on the tributary TDMoE traffic and on the user Ethernet traffic as well. Sufficient bandwidth needs to be allocated to TDMoE traffic to achieve acceptable performace.

There are several different effects in packet networks that may affect the recovery of a clock from a packet stream. These include:

- Packet Transfer Delay
  Packet transfer delay by itself is not usually a problem for the recovery of a clock. Long delay may cause a slight lag in response to changes in the master clock (e.g. clock re-arrangements at the master), but otherwise doesn't affect arrival rate of packets at the receiver.

- Packet Loss
  Packet loss is not usually an issue for clock recovery, as most techniques integrate over several seconds of data, hence packet loss can usually be compensated for. Isolated packet loss can cause errored seconds and severely errored seconds in the recovered TDM data stream.

- Packet Data Errors
  Packet data errors usually result in the packet being discarded due to a bad FCS (Frame Check Sequence) value in the layer 2 frame (e.g., Ethernet FCS), or a checksum error in the layer 3 header (e.g. IP or UDP checksums). Hence these are treated in the same way as packet loss.

- Extended Packet Loss
  Extended packet loss may result from a network outage. While the resilience of packet networks to network outages is improving, in many cases they don't have the 50ms restoration time of SONET or SDH networks, and outages may take a little while to restore. A clock recovery context must have the capability of going into a holdover condition in the event of a network outage to maintain the clock output.

- Packet Delay Variation (PDV)
  Delay variation can have several different causes, both from the design of switches and the nature of the physical layer connection between the different network elements. For example, random delay variation results from queuing within a network element. Queues are used to manage access to communication link (e.g., output port queues) or to manage the internal resources of a network element (e.g. the forwarding engine that decides how to process an incoming packet). With GigE connection, a 1518 bytes Ethernet packet takes at least 12.3µSec to go through a store-and-forward layer 2 switch.

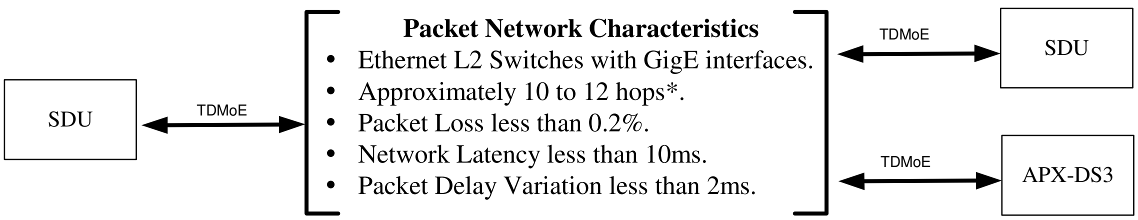
  (1518 bytes data + 8 bytes preamble + 12 bytes inter frame gap) /1000Mbps = 12.3µS

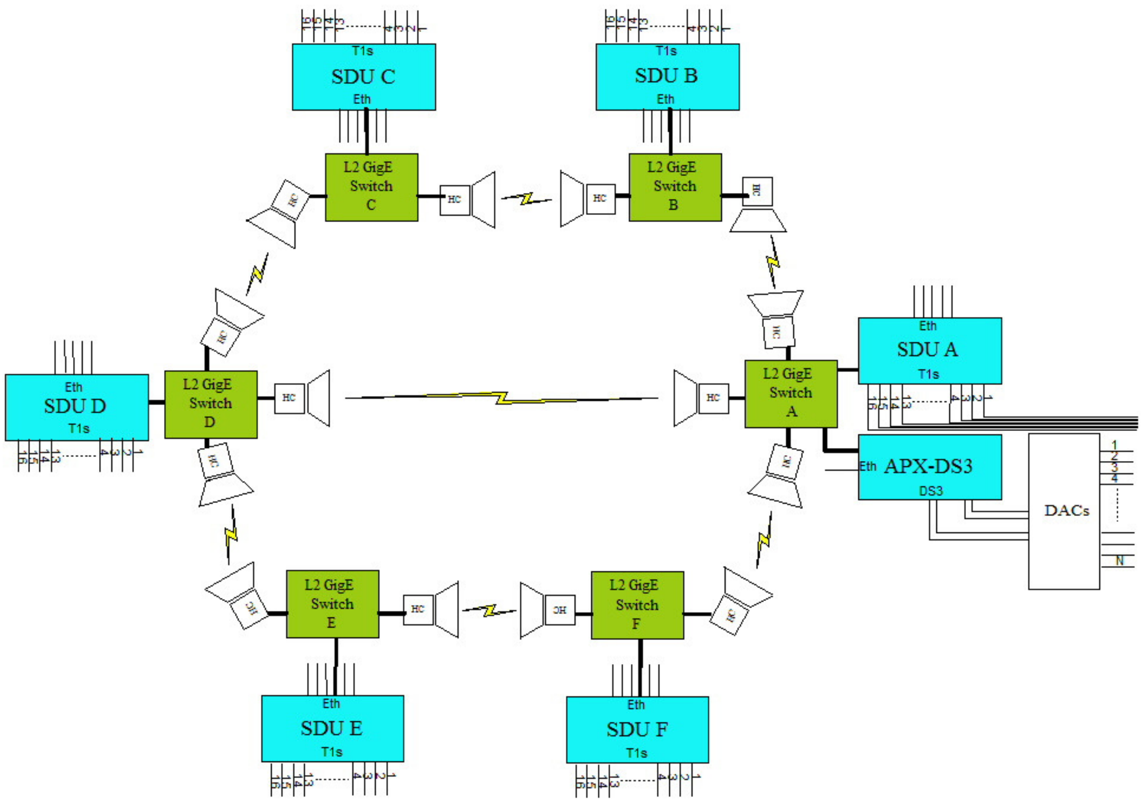
  The worst scenario is that when a TDMoE packet gets to a switch, another packet just started to transmit, and the best scenario is that whenever a TDMoE packet gets to a switch, no other packet is transmitting and it gets forwarded right away. The difference between the best and the worst scenario is 12.3µS. For 10 hops, the minimum accumulated PDV would be approximately 123µS. The total PDV accumulation will have to include all the switches interconnections as a microwave link will have larger packet variations than a fiber connection.

Lastly, congestion is the temporary increase in traffic load, leading to the network element or communication links becoming overloaded. The result is that packets may experience severe delays or be dropped altogether as queues in the network fill up to capacity. The duration of congestion events is variable, and may last for several seconds or minutes.

DragonWave Recommendation

Understanding the key network characteristics is important to ensure that your network can support TDMoE traffic. In the figure below, outline our key network characteristics your network must meet before deploying DragonWave's SDU devices. Failure to follow this recommendation can result in poor voice quality and an unsynchronized timing for the TDM circuit.





- Layer 2 Switches
  These Layer 2 Ethernet switches must support QoS to prioritize the TDMoE traffic, VLAN and have Gigabit Ethernet ports

- Number of hops[*].

  A switch is considered a single hop. A microwave link is also considered a hop. The number of hops for a SDU's TDM traffic to terminate on another SDU-16 or SDU-DS3 cannot exceed 12.
- Packet loss must be less than 0.2% of its throughput
- End to end network latency must be less 10ms
- Packet Delay Variation must be less than 2ms. Both SDU-16 and SDU-DS3 has a built in tool to assist in determining the PDV for the TDMoE traffic.

[*] The number of hops can reach up to 12 provided the total network PDV does not exceed 5ms.

In addition to meeting the network characteristics above, we also need to determine the size of the Jitter Buffer for your particular network. The Jitter Buffer is used to absorb the packet variation in the packet network and provide a synchronize timing to the TDM interface.

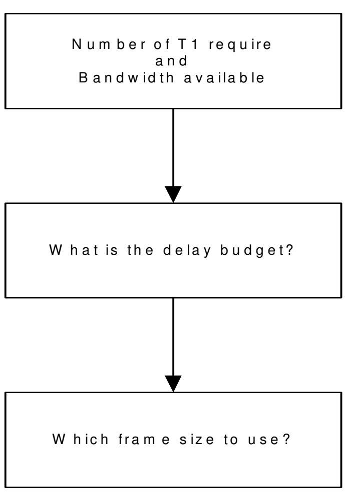
Calculating the size of the Jitter Buffer
Setting the jitter buffer require that we know the packet delay variation. A monitoring tool available in both the SDU-16 and SDU-DS3 can be utilized to provide us delay variation information. The command is "show jitter status". After issuing this command, a table will be displayed. The table contains information for each Trib's High and Low delay threshold.

The difference between the **High** and **Low** for each Trib is the delay variation for the Trib. Therefore, the Jitter Buffer setting for each Trib should be:

(**High** – **Low**) + 1ms = Jitter buffer

The additional one millisecond is simply to ensure that if the event that the network experience some congestion or other event that cause an increase of the network PDV, the Jitter Buffer will be able to deal with these uncertainties

Determining the correct frame size
The best way to determine which frame size to use is:

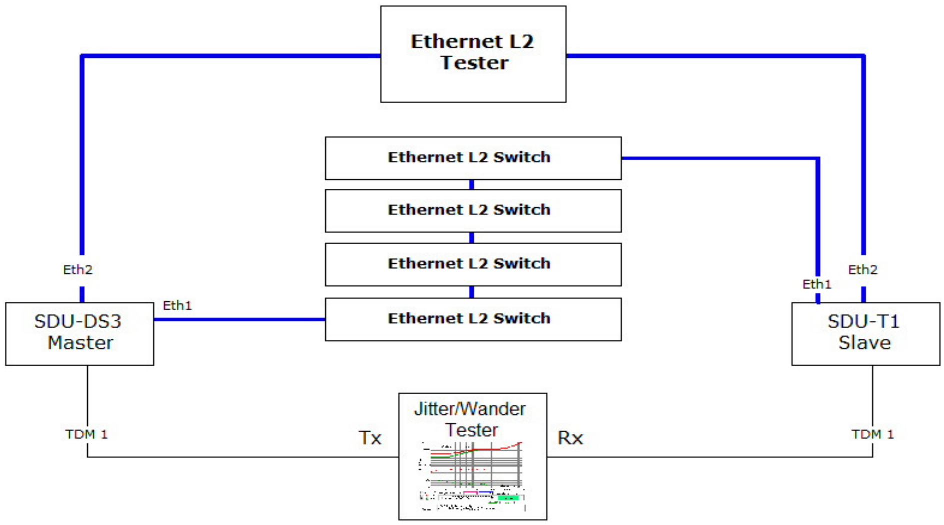


Firstly, consider the number of T1 required and the bandwidth available for the T1(s). See appendix C for more information

Second, determine the delay budget for the network. Using larger frame size will cause a longer delay versus a small frame size will have a shorter delay.

Finally, choose the most efficient frame size for the network. The larger frame size is more efficient. See appendix C for more information

Sample Lab Test Network Synchronization Results

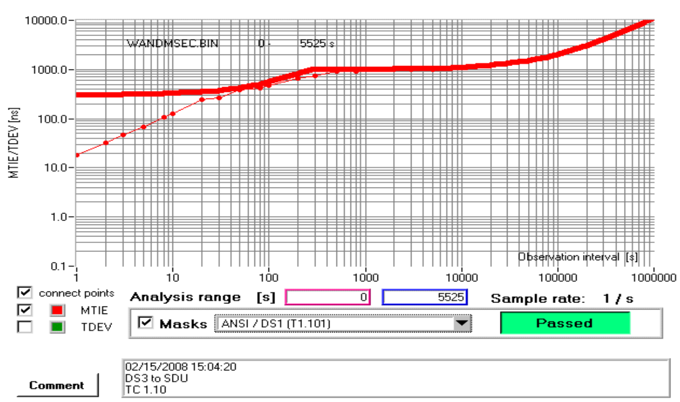


Configuration 1

In this configuration, with random Ethernet traffic with CoS 0 and the TDM traffic is tagged with CoS 7 and the measured MTIE was approximately 1.00E-6sec.

ITU Standard

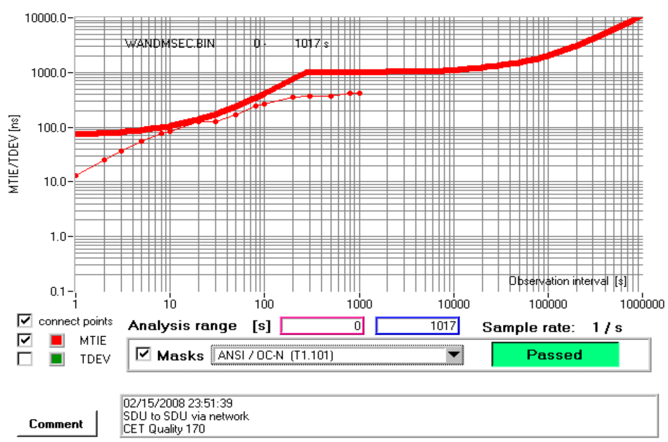
	G.8261/Y.1361	G.824	Test Result
MTIE ≤ 900s	**2.1 µs**	**8.4 µs**	**1.00 µs**
Jitter 10Hz – 40kHz		**0.5 UIpp**	**0.115 UIpp**
8kHz – 40kHz		**0.07 UIpp**	**0.022 UIpp**

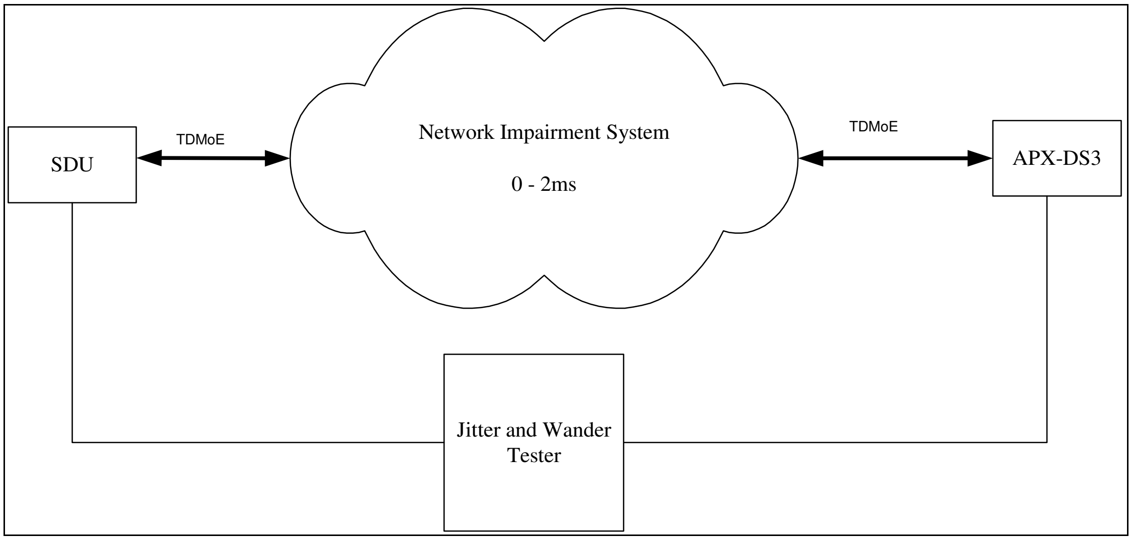


Configuration 2

In this configuration, a Horizon Compact microwave is interconnected between two Ethernet switches. The normal Ethernet traffic is tagged with CoS 0 is sent to both the L2 switches as well as the SDU. This setup will create multiple congestion point for the TDM traffic and the measured MTIE was approximately 465.6E-9sec.

	ITU Standard		
	G.8261/Y.1361	**G.824**	**Test Result**
MTIE ≤ 900s	**2.1 µs**	**8.4 µs**	**0.4656 µs**
Jitter 10Hz – 40kHz		**0.5 UIpp**	**0.122 UIpp**
8kHz – 40kHz		**0.07 UIpp**	**0.009 UIpp**





Configuration 3

In this configuration, a Network Impairment system is used to create the packet delay to confirm if the clock recovery for the SDU is compliant to the ITU G.8261/Y.1361.

	ITU Standard		
	G.8261/Y.1361	**G.824**	**Test Result**
MTIE ≤ 900s	**2.1 µs**	**8.4 µs**	**0.679 µs**
Jitter 10Hz – 40kHz		**0.5 UIpp**	**0.118 UIpp**
8kHz – 40kHz		**0.07 UIpp**	**0.017 UIpp**

Appendix A

ITU-T Standard G.8261/Y.1361

SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS
Ethernet over Transport aspects – Quality and availability targets

SERIES Y: GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS AND NEXT-GENERATION NETWORKS
Internet protocol aspects – Transport

Table 1/G.8261/Y.1361 – Deployment Case 1: 2048 kbit/s interface output wander limit

Observation interval, τ [s]	MRTIE requirement [μs]
$0.05 < \tau \leq 0.2$	$10.75\ \tau$
$0.2 < \tau \leq 32$	9 * 0.24 = 2.15
$32 < \tau \leq 64$	$0.067\ \tau$
$64 < \tau \leq 1000$	18 * 0.24 = 4.3
NOTE – For the asynchronous configuration, the maximum observation interval to be considered is 80 s. The specification between 80 s and 1000 s for the asynchronous interfaces is for further study.	

Table 2/G.8261/Y.1361 – Deployment Case 1: Wander limit for 1544 kbit/s interface

Observation interval, τ [s]	MTIE [μs]
$\tau \leq 0.1$	No requirement (See Note)
$0.1 < \tau \leq 0.47$	$4.5\ \tau$
$0.47 < \tau \leq 900$	2.1
$900 < \tau \leq 1930$	2.33 * 10e-3 τ
$1930 < \tau \leq 86\,400$	4.5
NOTE – This region is covered by jitter requirements	

Table 3/G.8261/Y.1361 – Case 2A: 2048 kbit/s interface output wander limit

Observation interval, τ [s]	MRTIE requirement [μs]
$0.05 < \tau \leq 0.2$	$40\ \tau$
$0.2 < \tau \leq 32$	8
$32 < \tau \leq 64$	$0.25\ \tau$
$64 < \tau \leq 1000$ (Note)	16
NOTE – For the asynchronous configuration, the maximum observation interval to be considered is 80 s. The specification between 80 s and 1000 s for the asynchronous interfaces is for further study.	

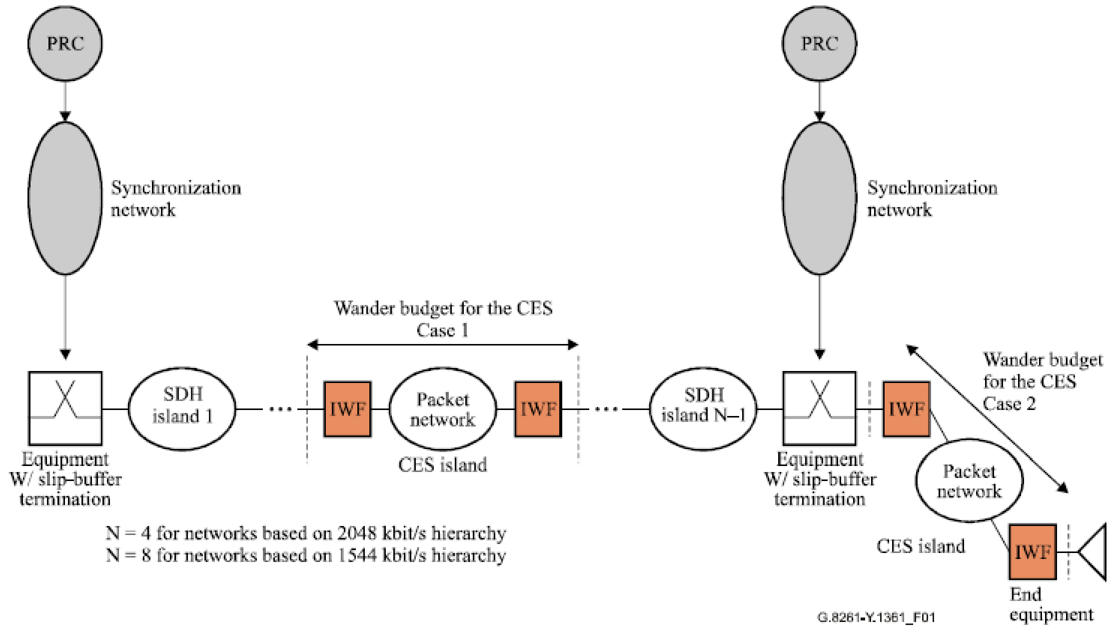


Figure 1/G.8261/Y.1361 – Network models for traffic and clock wander accumulation: Deployment Case 1 and Case 2

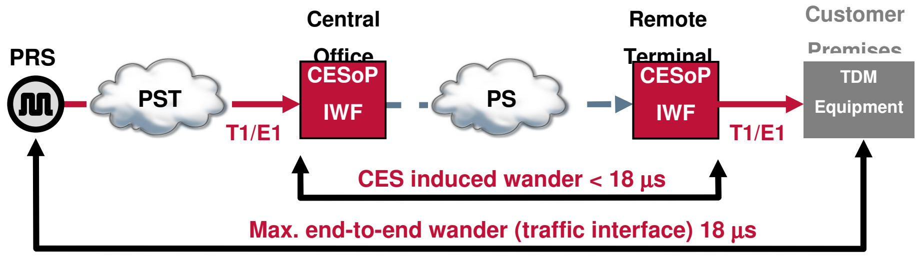
Appendix B

ITU-T G.823 and G.824 Standard

Standards for Synchronization

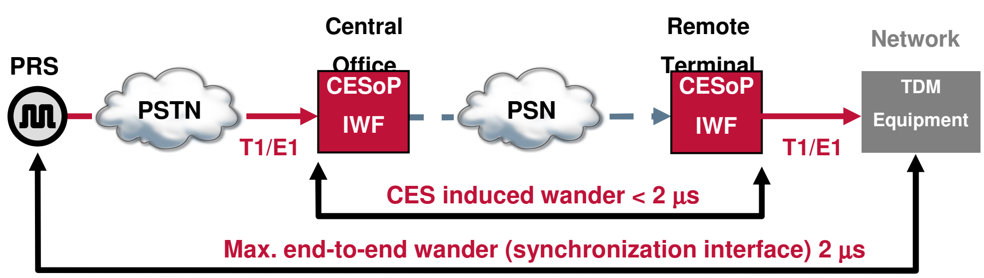
- E1 standards (2.048 Mbps)
- Traffic Interface (G.823, Table 2)
  - 18 µs over 1000s

- T1 standards (1.544 Mbps)
- Traffic interface (T1.403, section 6.3.1.2)
  - 8.4 µs over 900s
  - 18 µs over 24 hours



- E1 standards (2.048 Mbps)
- PDH Synchronization interface (G.823 - Table 12)
  - 2 µs over 2000s
  - 5.33 µs over 100,000s

- T1 standards (1.544 Mbps)
- Reference interface (T1.101, section 7.2.1)
  - 1 µs over 2000s
  - 2 µs over 100,000s



Network Type	Frequency Accuracy	Wander limit	Observation period	Reference
2.048 Kbit/s interface (E1)	= 32 ppm (G.703, Table 4)	9 µs	0.2 to 32 s	G.823 (03/2000), table 2
		18 µs	64 to 1000 s	
1.544 Kbit/s interface (T1)	= 50 ppm (G.703, Section 9.1)	8.4 µs	≤ 900 s	G.824 (03/2000), table 2
		18 µs	900 to 86400 s	

Appendix C

Ethernet Bandwidth Usage

Ethernet Bandwidth consumption

Total Ethernet bandwidth consumed by TDM data is a sum of bandwidth consumed by each tributary. Following table shows Ethernet bandwidth consumed by a tributary.

Tributary type	Vlan enabled	Ethernet packet size	Ethernet bandwidth consumption (Mbps)	Efficiency
T1 unframed	No	Small	3.023667	0.510638242
T1 unframed	No	Medium	1.839933	0.839160991
T1 unframed	No	Large	1.684921	0.916363438
T1 unframed	Yes	Small	3.152333	0.48979597
T1 unframed	Yes	Medium	1.865667	0.827586059
T1 unframed	Yes	Large	1.697175	0.90974708
T1 framed	No	Small	3.008	0.513297872
T1 framed	No	Medium	1.8304	0.843531469
T1 framed	No	Large	1.67619	0.921136625
T1 framed	Yes	Small	3.136	0.492346939
T1 framed	Yes	Medium	1.856	0.831896552
T1 framed	Yes	Large	1.688381	0.914485534

Notes:

1. Framed format includes SF (Super Frame) and ESF (Extended Super Frame)
2. Small Ethernet packet has 48 bytes of TDM data as payload, medium packet has 240 bytes, and large packet has 504 bytes
3. Assumes 12 bytes of Inter Frame Gap and 8 bytes of Preamble

Total Ethernet Consumption for unframed T1

Number of T1	Small(MB) No Vlan	Small(MB) Vlan	Medium(MB) No Vlan	Medium(MB) VLAN	Large(MB) No Vlan	Large(MB) Vlan
1	3.023667	3.152333	1.839933	1.865667	1.684921	1.697175
2	6.047334	6.304666	3.679866	3.731334	3.369842	3.39435

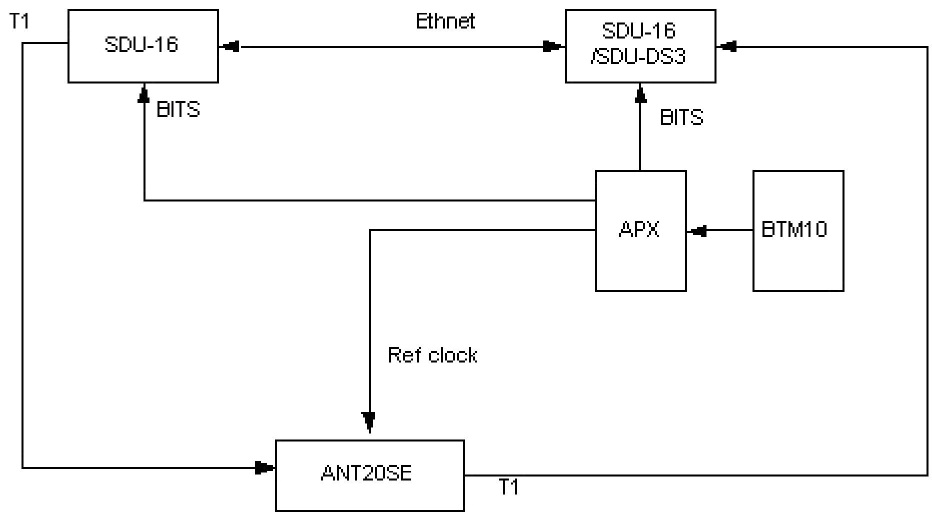
3	9.071001	9.456999	5.519799	5.597001	5.054763	5.091525
4	12.094668	12.609332	7.359732	7.462668	6.739684	6.7887
5	15.118335	15.761665	9.199665	9.328335	8.424605	8.485875
6	18.142002	18.913998	11.039598	11.194002	10.109526	10.18305
7	21.165669	22.066331	12.879531	13.059669	11.794447	11.880225
8	24.189336	25.218664	14.719464	14.925336	13.479368	13.5774
9	27.213003	28.370997	16.559397	16.791003	15.164289	15.274575
10	30.23667	31.52333	18.39933	18.65667	16.84921	16.97175
11	33.260337	34.675663	20.239263	20.522337	18.534131	18.668925
12	36.284004	37.827996	22.079196	22.388004	20.219052	20.3661
13	39.307671	40.980329	23.919129	24.253671	21.903973	22.063275
14	42.331338	44.132662	25.759062	26.119338	23.588894	23.76045
15	45.355005	47.284995	27.598995	27.985005	25.273815	25.457625
16	48.378672	50.437328	29.438928	29.850672	26.958736	27.1548

Appendix C

SDU Delay

SDU Delay

Jitter Buffer (mSec)	Measured (mSec)		
	ESF large	ESF medium	ESF small
1	no link	1.72	1.72
2	3.09	2.97	2.72
3	5.72	4.22	3.72
5	5.72	6.72	5.72
8	10.97	9.22	8.72
10	10.97	11.72	10.72
15	16.22	16.72	15.72
20	21.47	21.72	20.72
25	26.72	26.72	25.72
30	31.97	31.72	30.72



Reference

1. ITU-T G.8261/Y.1361
2. ITU-T G.823
3. ITU-T G.824
4. Zarlink Application Note 205
5. Zarlink Application Note 59
6. Zarlink Application Note 45

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