# Experimental Demonstration of the Need for Carrier Ethernet in Mission Critical Networks

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**Abstract:** Comparison of circuit and packet-switched networks in handling delay-sensitive data reveals that the primary causes of latency are different in these two networks, and both can be mitigated by using Carrier Ethernet in Mission-Critical Networks.

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## 1. Introduction

Large Enterprises in non-telecom sectors like oil and gas, power, transportation and other industries which have geographically spread-out interlinked functional units operate their own communication networks for supporting operations. These networks were initially established with the primary purpose of transporting control systems data from field instrumentation to centralized process control systems over a SCADA network. A typical example would be the control of valve closure based on pressure sensor readings in a cross-country gas pipeline. Similarly, railway networks with heavy traffic have a dedicated train management system (TMS) for tracking and maintaining train running schedules. In addition to SCADA, such private networks have traditionally been used for telephone connectivity within and between interconnected facilities, used by operations and maintenance personnel. In addition to fixed telephony, radio-based voice communication is often trunked through the core network. With safety and security being of increased concern, newer applications such as network-wide CCTV are being implemented for both surveillance as well as video-based process monitoring. Today mission-critical networks are expected to carry a mix of services such as SCADA, telephony, radio, CCTV, physical intrusion detection, video-conferencing and enterprise IT applications, all of which share the total available bandwidth. Unlike carriers, pushing the limits of bandwidth is not the topmost priority. Instead, the key requirements for such networks are: 1. Resiliency and High Network Availability, 2. Multi-Service Provisioning, 3. Near Real-time Transmission, 4. Robust and Reliable Equipment, 5. Future-proof Technology.

In order to meet these stringent requirements, the networks have in the past relied on connection-oriented technologies like SONET/SDH. Besides guaranteed data arrival times, SONET/SDH networks have high availability due to link protection mechanisms and built-in equipment redundancy which provide <50ms switch-over times. Ethernet services are carried over these networks through standard processes like Generic Framing Procedure (GFP) and Link Capacity Aggregation Scheme (LCAS). In contrast, services can be directly switched over a network of Ethernet switches by skipping GFP and LCAS. In this paper, we present an experimental comparison of Ethernet transported over SDH backbone versus over a packet-switched deterministic Ethernet backbone, specifically from the view-point of mission-critical networks and propose a solution that takes the best of both. Our results show the benefit for carrier-grade Ethernet and build the case for this technology in non-telecom mission critical applications. Section 2 describes our experimental set up, while Section 3 captures results from our experiments. Section 4 summarizes the paper.


Figure 1. Commtel Networks Test-Bed comprising SDH nodes and Industrial Grade Ethernet Switches

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## 2. Description of Network Equipment and Test Setup

Two separate communication set-ups were used as a test-bed as shown in Fig. 1. The first set-up contained circuit-switched elements from two different vendors (say A and B) using SDH equipment of 2.5Gbps granularity, while the second set-up was completely packet-switched, consisting of industrial grade Optical Gigabit Ethernet switches.

The SDH nodes supported Ethernet over SDH in addition to traditional TDM services. The switching fabric of equipment from Vendor A was 20Gbps (Higher Order) and 10Gbps (Lower Order). The switching fabric from Vendor B was 7Gbps (Higher Order) and 2.5Gbps (Lower Order). The industrial grade Ethernet switches had a switch fabric of 5.6Gbps.

A simple linear SDH STM-1 network was constructed with one to three hops. SDH nodes from Vendor A formed the terminal nodes, from which Ethernet services were launched and terminated. The optical links between nodes were locally patched so that transmission delays were insignificant. The intermediate nodes, when present, were from Vendor B, and either the provisioned VC-12s or entire VC-4s were transparently passed through. Such scenarios are commonly encountered in industrial networks which expand in phases and use the best available and cost effective equipment at each phase, resulting in a mixed network. Such situations are also often encountered in the carrier space where networks from various operators need to be interconnected while traffic passes through seamlessly. An equivalent chain was formed with Gigabit Ethernet Switches. The performance of Ethernet traffic was tested over both the networks initially in no-excess-load conditions, followed by testing in the presence of controlled network traffic with different traffic loads, which would be a better indicator of performance in a live network.

## 3. Results and Discussion

Firstly, the baseline latency between two back-to-back SDH nodes (Vendor A) was measured at different data-rates and WAN bandwidths with a hard loop-back at the far-end. The latency increases linearly with frame size as expected. However, for a particular provisioned WAN bandwidth, the latency is practically independent of the traffic data rate, as seen in Fig. 2. This is true for both 10Mb/s and 100MB/s WANs over STM-1. The only outlier is at 100Mb/s traffic over 100Mb/s WAN. This is because the WAN was configured with only 46 VC-12s and the traffic approaches full-capacity. The same effect is not observed in the 10Mb/s WAN, which is configured with 5 VC-12s, thus allowing for some excess bandwidth to become available over the actual traffic. In contrast, the latency for a given traffic rate (in this case 2 Mb/s, which is the bandwidth provisioned for video streams from a single CCTV camera at 4-CIF resolution and 25frames-per-sec) improves significantly as the provisioned WAN bandwidth is increased. The RTD for 1518 byte frames is 13.9ms, 4.6ms and 1.5ms for 2Mb/s, 10Mb/s and 100Mb/s WAN respectively. However, exercising such an option will result in inefficient network utilization.

We also studied the effect on latency as the number of hops was increased. For a 10Mb/s service on a 100Mb/s WAN, the back-to-back RTD for frame-sizes of 64 bytes to 1518 bytes ranged from 0.6 to 1.5 ms, whereas upon addition of an intermediate node, the increase in RTD ranged from 8 to 17 μs. Clearly the latency added from intermediate SDH nodes becomes comparable to end-point latencies only when the number of hops is ~90 or more. The main contributor to latency therefore is the processing of Ethernet Frames in and out of the SDH data streams, and depends on the *provisioned* WAN bandwidth, irrespective of whether the link bandwidth is STM-1/OC-3, STM-4/OC-12 or more.

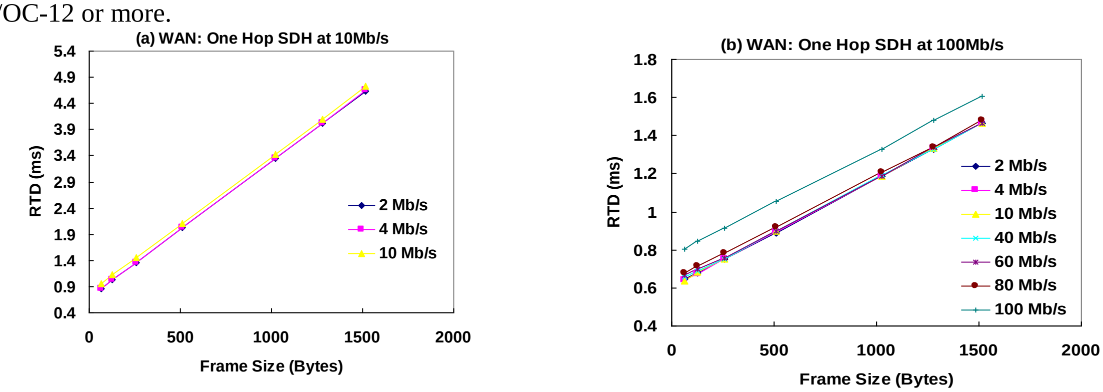


Fig. 2. Baseline latency of Ethernet over SDH STM-1 (Vendor A) at various traffic rates

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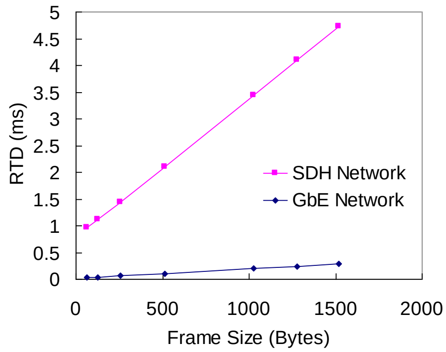


Fig. 3. Latency of a 10Mb/s service over SDH and Ethernet.

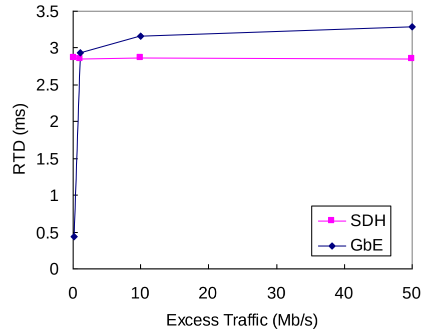


Fig. 4. Latency of a 10Mb/s service in presence of live traffic.

A comparison between the SDH network and the Gigabit Ethernet network carrying a 10Mb/s service under no excess traffic conditions is shown in Fig. 3. For 1518 byte frames, the RTD through the switch network was 283 μs as compared to ~4.7 ms for SDH. *Thus, baseline latency in the fully Ethernet based network is well over an order of magnitude better than an SDH network*. Thus, a major advantage is obtained by directly transporting Ethernet as compared to framing it on TDM. The key of course is to use industry grade or carrier-grade Ethernet transport.

Of greater interest to real networks would be the performance in the presence of other traffic being transported over the same links. For this, a 10Mb/s service, equivalent to five CCTV streams, was monitored while sharing simulated traffic from 0.1 Mb/s to 50 Mb/s. The provisioned bandwidth in both cases was limited to 100Mb/s for the purpose of comparison. The results in Fig. 4 demonstrate that while the baseline latency of the GbE network is low, it increases rapidly and exceeds the latency of the SDH network in the presence of even 1 Mb/s of extra traffic. Packet jitter also begins to appear when the bandwidth is shared. On the other hand, SDH provides a dedicated bandwidth of 5 VC-12s for the test service, which remains practically unaffected by other traffic in the link.

From these tests, it is evident that SDH/SONET networks provide dedicated bandwidth for uninterrupted service, but have high latency due to processing of Ethernet frames. Switched networks have low inherent latency which however depends on amount of shared traffic. Carrier Ethernet using new and emerging standards like PBB-TE and MPLS-TP would combine the best of the two, by providing dedicated end-to-end bandwidth for individual services while avoiding delays due to framing procedures. Further, Carrier Ethernet supports full FCAPS features and fast switching times, enabling fully managed networks with high network availability while providing MEF compliant services. Hence, Carrier Ethernet is well suited to be adopted in place of existing circuit-switched networks, particularly at a time when delay-sensitive traffic such as CCTV and VoIP are increasingly adopted by mission-critical networks.

## 4. Conclusion

We evaluated the performance of Ethernet over circuit-switched and packet-switched networks under no-load and under live traffic conditions. The results indicate that while circuit switched networks have low switching latency (~10 μs), a considerable delay of several milliseconds is added due to framing procedures at ingress and egress nodes. Switched networks have inherently lower latencies (of the order of ~100 μs) since they directly transport Ethernet without TDM framing steps. However, in the presence of live traffic, we observed that delay in packet-switched networks increases rapidly and overtakes that of circuit-switched networks which provide dedicated bandwidths for different traffic schemes. We conclude that Carrier Ethernet, which allows for provisioning of bandwidth similar to circuit-switched networks, as well as according to CoS, makes use of the inherently low packet switching latency and will yield better network performance while enabling several new features in mission-critical applications.

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