White Paper

Ethernet – The Next Generation WAN Transport Technology

May 2002

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Ethernet has grown in market share, supported IEEE-based and IETF-based standards, and bandwidth, surpassing various network transport technologies while maintaining a feasible cost structure. As the IEEE ratifies 802.3ae — the standard for 10 Gigabit Ethernet — OSI layer 2 for LAN, MAN, and WAN can now be united under a single medium, Ethernet. Carriers can now take advantage of Ethernet as a transport for their network backbone and their service media.

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1.0 Ethernet Transport and its Service Technology

To understand why Ethernet is a viable transport for the WAN, it's important to note the various technology that surrounds and supports Ethernet.

Ethernet's Circle of Technology

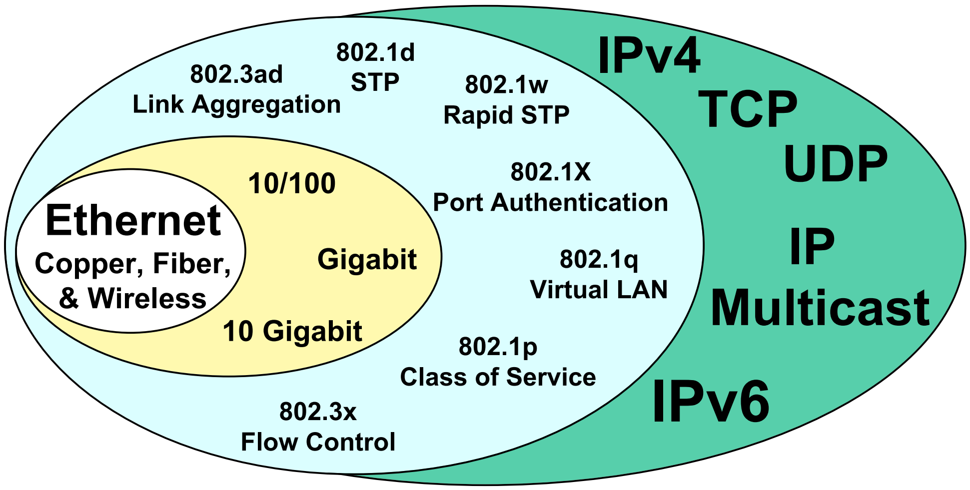

Figure - 1: Various Standards that Work with Ethernet.

Figure 1 shows Ethernet's circle of technology. At the core, Ethernet is supported within fiber, copper, and even wireless media. In addition, bandwidth support for Ethernet can range from half and full duplex 10 Mbps and 100 Mbps, to 1 Gigabit Ethernet, and soon, up to 10 Gigabit Ethernet. Half-duplex is not supported within 10 Gigabit Ethernet. Allowing for support of various media and varying bandwidth increases flexibility in deploying Ethernet-based network solutions.

With the aid of IEEE standards such as 802.1q or 802.1p, Ethernet has now become more robust and more resilient. For example, network managers have 802.1q to create "pockets" of networks that have their own broadcast domains. This deployment enables network managers to easily map their networks based on organizational and business domains. Likewise, Carriers offering Metro Services have used 802.1q to create separation for each of their customers while 802.1p offers a method for delivering low-latency VLAN-based services such as voice.

Finally, Ethernet is a major contributor to the explosive growth of the Internet. High-end servers rely on high-speed connectivity to service E-commerce and other popular web sites. IP, which is now the de facto standard for Layer 3, has always used Ethernet as the preferred medium for IP routing and switching. Users of IP have taken advantage of Ethernet's high-speed transport, enabling the delivery of services such as IP multicast-based multimedia or HDTV to the desktop.

The Circle of Technology that surrounds Ethernet continues to grow and it's the only Layer 2 technology that has kept up with the growing IP-based Service Technology. As 10 Gigabit Ethernet (802.3ae) becomes a standard, Carriers can now begin deployment of Ethernet as their transport medium for data, voice, and video traffic. This paper sheds light on why Ethernet is now becoming the next-generation WAN transport network technology.

3.0 WAN: Ethernet's Final Frontier

Carriers have used SONET and ATM to deploy their service offering because of the many features within SONET and ATM. Although these technologies have vast feature sets, this section focuses on examining only those features that have made SONET and ATM the preferred WAN transport technology. These media provide the following:

- High-speed network connectivity and high availability
- Service differentiation
- Operations, Administration, and Management (OAM)

3.1 SONET – High Speed Network Connectivity and High Availability

Carriers have deployed SONET within their networks, not because SONET interfaces are low cost, but because of the availability of high-speed connectivity and their resiliency to network outages.

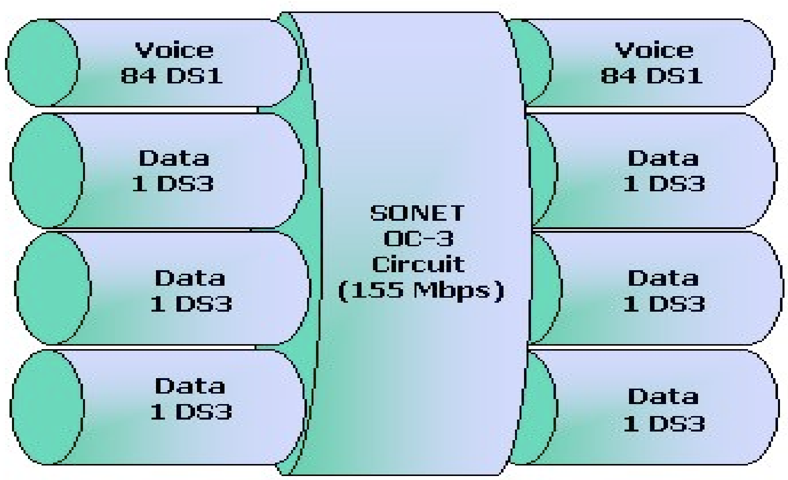

Figure – 2: Possible Break-Down of an OC-3 SONET Circuit.

Bandwidth for SONET ranges from a single STS-1/OC-1(51.840 Mbps) up to STS-768/OC-768 (39.813 Gbps). Bandwidth, as shown in figure 2, can be carved to carry various services. For example, an OC-3 circuit can be provisioned to carry 84 DS1 (1 DS1 = 1.544 Mbps) for voice services and 3 DS3 (1 DS3 = 45 Mbps) for data services.

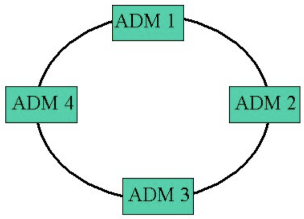

Figure – 3(a): Unidirectional Path Switched Ring.

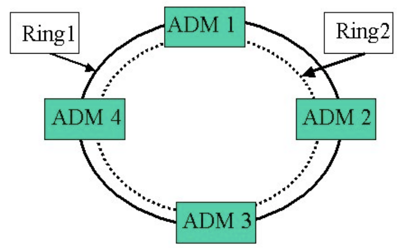

Figure – 3(b): Bi-directional Line Switched Ring.

In addition, Carriers employ SONET to create ring-based network topologies (see figure 3) to optimize fiber deployments and to use Automatic Protection Switching (APS) for network resiliency. APS delivers the following key high-availability features:

- 50 ms transition time from a failed primary to the secondary or backup link
- 1+1 linear non-revertive, which is an APS feature that lets the primary SONET link remain down even when service becomes available. To activate the primary link, a network technician manually overrides the feature during periods of scheduled network outages. This feature eliminates "flapping" between the secondary and primary link, when the primary link becomes available again just after it has failed.

3.2 ATM — Service Differentiation

ATM's strength is in its ability to deliver guaranteed service offerings for a given traffic type. For example, voice and video require low delay and low jitter. ATM can ensure delivery for each service through ATM Adaptation layer 1 (Constant Bit Rate [CBR] for Voice), layer 2 (Variable Bit Rate [VBR] for Voice and Video), layer 3 (Connection-oriented VBR), layer 4 (Connection-less oriented Services), and the most popular, layer 5.

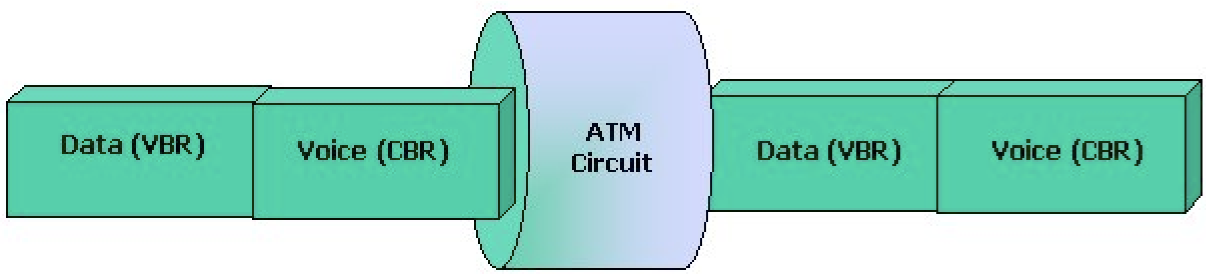

Figure – 4: Flexibility of ATM.

AAL 1 and 2 were strictly connection-oriented, while AAL 3, 4, and 5 can be set up as connection-less oriented.

3.3 OAM — Operation, Administration, and Management

Carriers value the amount of OAM information that comes with SONET and ATM. To understand the value of OAM, let's explore the process by which OAM is used in an operational environment.

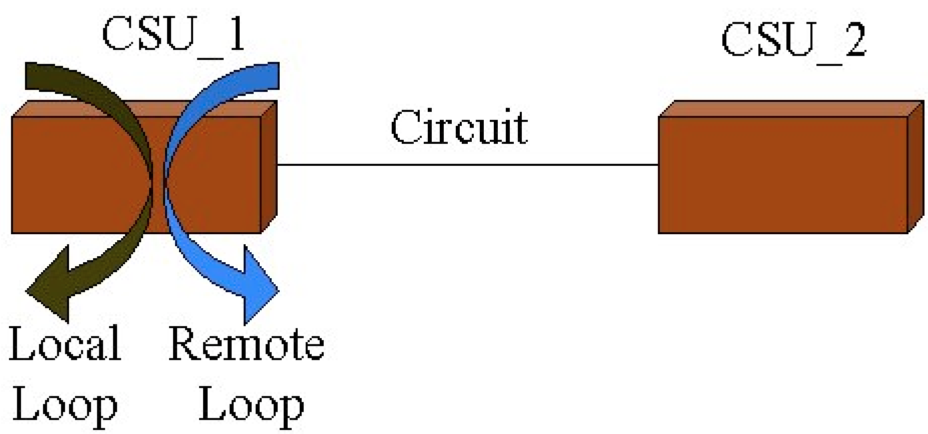

Figure – 5: Simple Point-to-Point Circuit.

Figure 5 shows a simple point-to-point circuit, a circuit made by two Carrier Service Units (CSU), which can be SONET ADMs or ATM switches. Network technicians have the ability to perform troubleshooting and testing from one side of the CSU (see CSU_1). Tests can be performed to verify whether errors are occurring locally (using a Local Loop) or being generated by the remote end (using a Remote Loop).

Using these simple built-in test suites, network technicians can easily identify where the problem is occurring by using simple "divide and conquer" techniques.

Having access to diagnostic information about the remote CSU (say CSU_2) within a local CSU (CSU_1), is a big part of OAM. This also includes being able to view and control CSUs from a remote management system, using an underlying protocol (e.g., TL/1 or SNMP).

SONET and ATM were designed to include this diagnostic information in their architecture. For SONET, diagnostic information is embedded (Transport Overhead) within each payload. For ATM, diagnostic information is in the OAM cells.

In addition, controlled behavior such as APS can be performed based on this diagnostic information. For example, SONET ADMs will activate APS if K1 or K2 errors are received, ensuring a higher degree of resiliency to network outages.

4.0 Ethernet as a WAN Transport Technology

Ethernet and the various IEEE 802.1 standards (see figure 1) address a Carrier's WAN transport requirements. Deploying Ethernet is cost effective over SONET and ATM, allowing Carriers to reduce their costs and increase their revenue. This section addresses how the following key transport requirements can be met using Ethernet and the various IEEE standards:

- High-speed network connectivity, high availability, and scalability
- Service differentiation using 802.1q and 802.1p
- Operation, Administration, and Management (OAM) for Ethernet

It's important to note that standards within 802.1, which is the management infrastructure for 802.3, are numerous and are not all covered in this section.

4.1 High Speed Network Connectivity, High Availability, and Scalability

Ethernet has support for 10 Mbps, 100 Mbps, 1 Gbps, and soon 10 Gbps. Likewise, half and full duplex speeds are supported for 10 Mbps, 100 Mbps, and 1 Gbps. Therefore, high speed network connectivity within a Carrier's network can easily be provided by Ethernet. In addition, vendor offerings now include features such as "Rate Limiting" that allow Carriers to offer Ethernet services with varying bandwidth requirements from 256 Kbps up to 1 Gbps.

High availability, which helps Carriers deliver 99.999% network uptime, can be achieved by using 802.1w or Rapid Spanning Tree Protocol (RSTP). Figure 7 shows a simple Ethernet network topology that consists of three Ethernet switches (A, B, and C), which are 40 Km from one another and are connected using fiber.

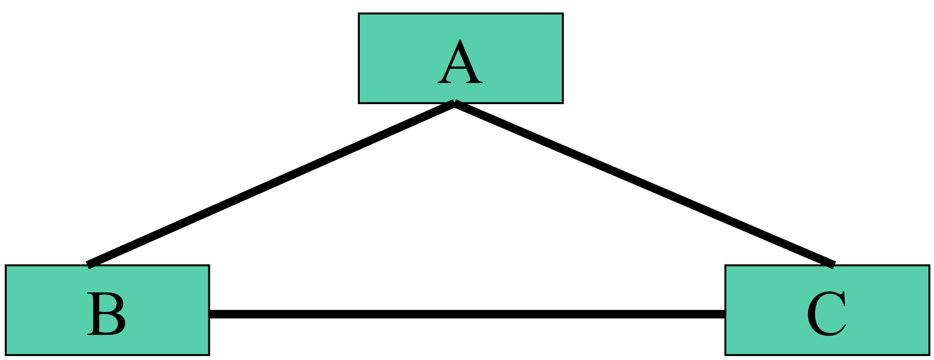

Figure – 6: Three-Node Switch.

With 802.1w, Carriers can fully optimize the network topology shown in figure 7 by creating two logical virtual LANs (VLAN). Figure 7(a) shows VLAN10 with traffic moving clockwise with segment B-to-A as the back-up segment, and figure 7(b) shows VLAN20 with traffic moving counter-clockwise with segment C-to-A as the back-up segment. Like any IP routing protocol, RSTP has facilities for modifying STP properties and interface costs, which can assist in implementing traffic engineering within an Ethernet network.

In addition, Carriers can ensure that all of the fiber segments (A-B, B-C, and C-A) are fully used. Likewise, the back-up links for VLAN10 and VLAN20 provide resiliency against network outages. For example, VLAN10's backup segment (B-to-A) is automatically activated within sub-seconds after any of the primary segments (A-to-C or C-to-B) fails.

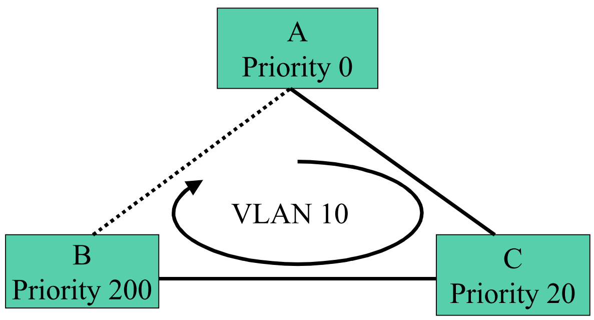

Figure – 7(a): Provisions for VLAN 10.

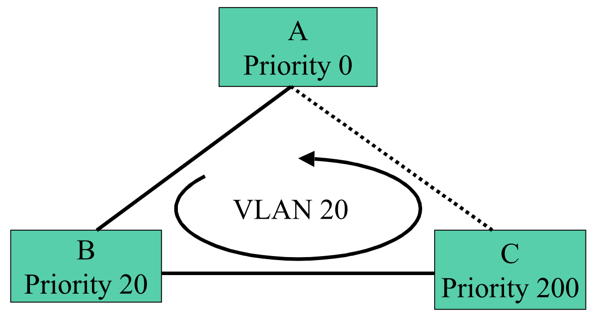

Figure – 7(b): Provisions for VLAN 20.

Coupling 802.1s with the VLAN solution, Carriers can begin to aggregate customer VLANs into a group. 802.1s allows Carriers to group VLANs together and associate a single STP with the group. For example, the groups can be made up of the following:

- VLAN2 – VLAN1024 can be bundled into Group STP1
- VLAN1025 – VLAN 2024 can be bundled into Group STP2

Figure 8 shows the implementation of 802.1s and 802.1w combined. Carriers can now increase the number of supported "Customer VLANs" within their networks.

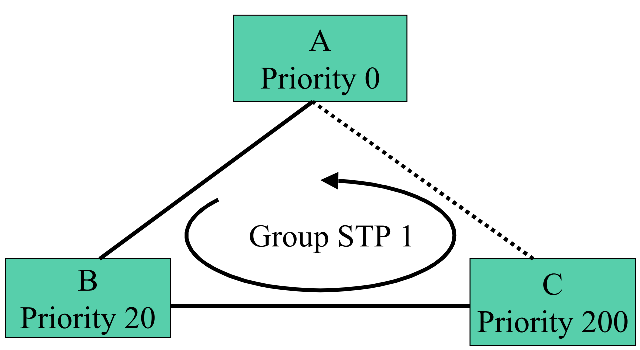

Figure – 8(a): Provisions for Group STP1.

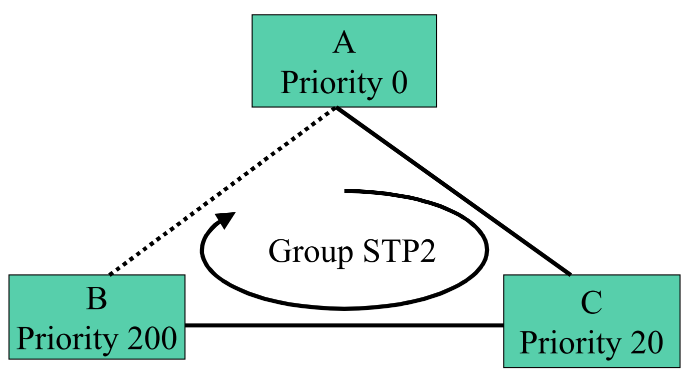

Figure – 8(b): Provisions for Group STP2.

Although these protocols (802.1w, 802.1s, and 802.1q) can help Carriers meet their high availability requirements, it's important to note that having a well-executed and well-documented network operational process is 80% of the requirement for ensuring high availability for the network.

4.2 Creating Service Differentiation Using 802.1q/p

Class of Service (CoS) within Ethernet is defined by 802.1p. With 802.1q and 802.1p, Carriers can create high-priority VLAN-based service offerings such as voice services. Figure 9 shows a simple network topology that illustrates how 802.1p can be used to deliver VLAN-based services. "Customer 2" is shown to have a point-to-point data service, which is similar to a point-to-point TDM circuit.

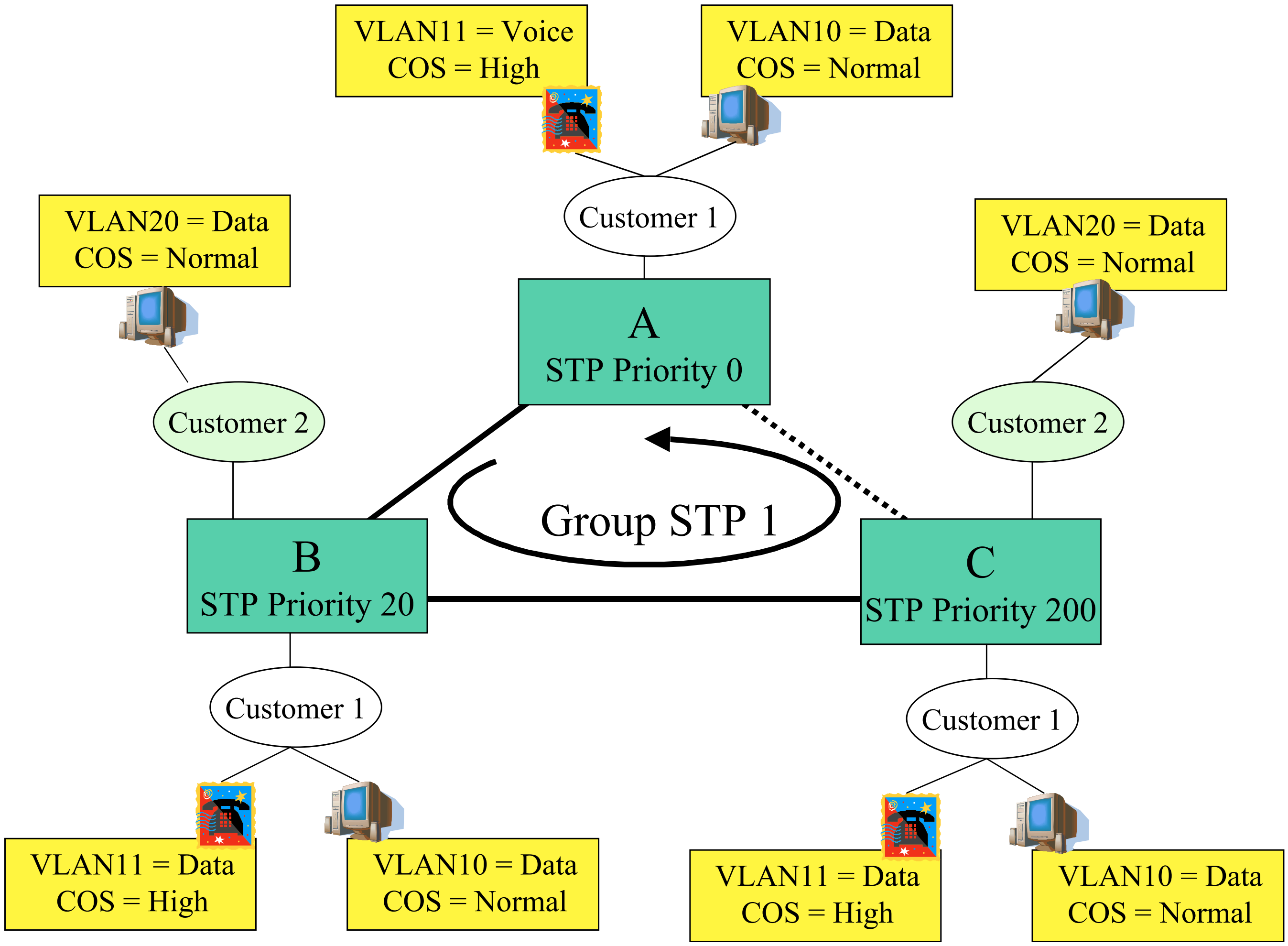

Figure – 9: Delivering Service Differentiation Within Ethernet.

Unlike a TDM circuit, multipoint-to-multipoint connectivity can easily be addressed by 802.1q and still deliver service differentiation with 802.1p. As shown in figure 9, "Customer 1" has three sites and each site has a data and voice service. Voice service is associated with VLAN11, which has a high CoS to ensure lower latency and less jitter. In addition, multipoint-to-multipoint data service for "Customer 1" is readily available and associated with VLAN10 (different VLAN).

Although the traffic for both "Customer 1" and "Customer 2" is within a shared network infrastructure, 802.1q allows for logical representation while ensuring a higher degree of traffic separation and security.

4.3 Operation, Administration, and Management for Ethernet

Ethernet's answer to OAM has been Simple Network Management Protocol (SNMP), which is the de facto standard network management protocol within IP and for most network equipment. SNMP, specifically version 3, offers a robust OAM solution for managing Ethernet-based network equipment. SNMP version 3 delivers the ability to encrypt SNMP Packet Data Units (PDU), ensuring a higher level of security for managing network equipment.

Network management applications that use SNMP for service provisioning and network troubleshooting are widely available, allowing Carriers to rapidly deploy services. Rapid deployment of services enables Carriers to quickly deliver their goods to customers and meet SLA requirements.

In addition, standards such as RFC 3176 offer a solution for acquiring network traffic flows. This solution, which enables billing and accounting, allows Carriers to acquire detailed call data records (CDRs) for any network traffic flows from Layer 2 up to Layer 7. Acquiring CDR from Layer 2 up to Layer 7 network flows enables a Carrier to move from flat-rate or byte-based billing to an application-based billing model. For example, Carriers can have options to charge users based on specific applications such as email transaction (SMTP or POP3), Web transaction (http), or SMS (Internet Messaging).

5.0 Warp Speed into the Final Frontier with 802.3ae (10GigE)

Finally, the most enticing solution that helps catapult Ethernet into the fore as the next WAN transport technology is 802.3ae — the standard for 10 Gigabit Ethernet. Here's why:

- 802.3ae will be a standard.

  A standard ensures that vendor solutions will be abundant and interoperable, making adoption rate quicker. The 10GEA has successfully demonstrated 10 Gigabit Ethernet interoperability at N+I Vegas using 19 network devices and pieces of equipment representing a comprehensive range of products from 13 companies including network systems, test equipment, components, fiber optics and cabling. This demonstration shows that 10 Gigabit Ethernet is ready and available.

- Ethernet now adds 10 Gigabit Ethernet to its bandwidth portfolio.

  Bandwidth is key and 10 Gigabit Ethernet will be needed within a Carrier's network to accommodate the growing traffic, which will be fueled once Ethernet becomes available as a service medium (access) from Carriers.

  Making Ethernet available as a service medium (access) allows Enterprise to simplify their network infrastructures. For example, WAN IP routing within an Enterprise network, which often consists of multiple IP subnets, can be simplified by using a single IP subnet or a single IP hop. Simplifying IP network topologies using Ethernet also invigorates the rapid deployment of applications within an Enterprise's wide area network.

- 802.3ae includes the WAN Interface Sub-layer, which supports OC-192.

  Adding the WAN PHY, which is a "plug-in" to an OC-192 SONET interface, within 802.3ae has created an omnipresence for Ethernet within Layer 2. Carriers can leverage their existing SONET investment to expand and deliver Ethernet services cost-effectively.

- Carriers can easily profit by using Ethernet, which is cost effective to deploy, as a service medium (access) for Enterprises.

  Most Carriers have Enterprises as their main customers, and Enterprises have been wanting increased bandwidth similar to the bandwidth that they enjoy within their Ethernet-based LAN and MAN environments.

  Having Ethernet as a service medium allows Enterprises to purchase cost-effective and high-speed bandwidth, and eliminate the cost required for managing TDM circuits. Likewise, Carriers and their ability to account and bill for network traffic flows from Layer 2 up to Layer 7 can now increase revenue by offering additional application services to their customers.

6.0 Closing Thoughts

802.3ae — the standard for 10 Gigabit Ethernet — will make Carriers re-think their networking needs. Profitability and a requirement for increased revenue are the main focus in today's economy. Ethernet as a core network infrastructure within a Carrier's network and as a service medium for a Carrier's customer delivers the following:

- Ethernet offers a cost effective solution while allowing for incremental investments. This can help Carriers increase their return on investment.

- Ethernet is an ideal transport for delivering numerous and profitable services, while accurately accounting and billing these services. This can help Carriers build more profitable service offerings and increase their revenue.

- Ethernet is an attractive and welcome solution for Enterprise customers. Enterprises have used Ethernet technology for the longest time and having Ethernet for the WAN simplifies networking needs. Offering Ethernet-based WAN access to Enterprise customers is a feasible solution and an easy solution to sell.

Ethernet is now a viable WAN transport and is the best option for Carriers.