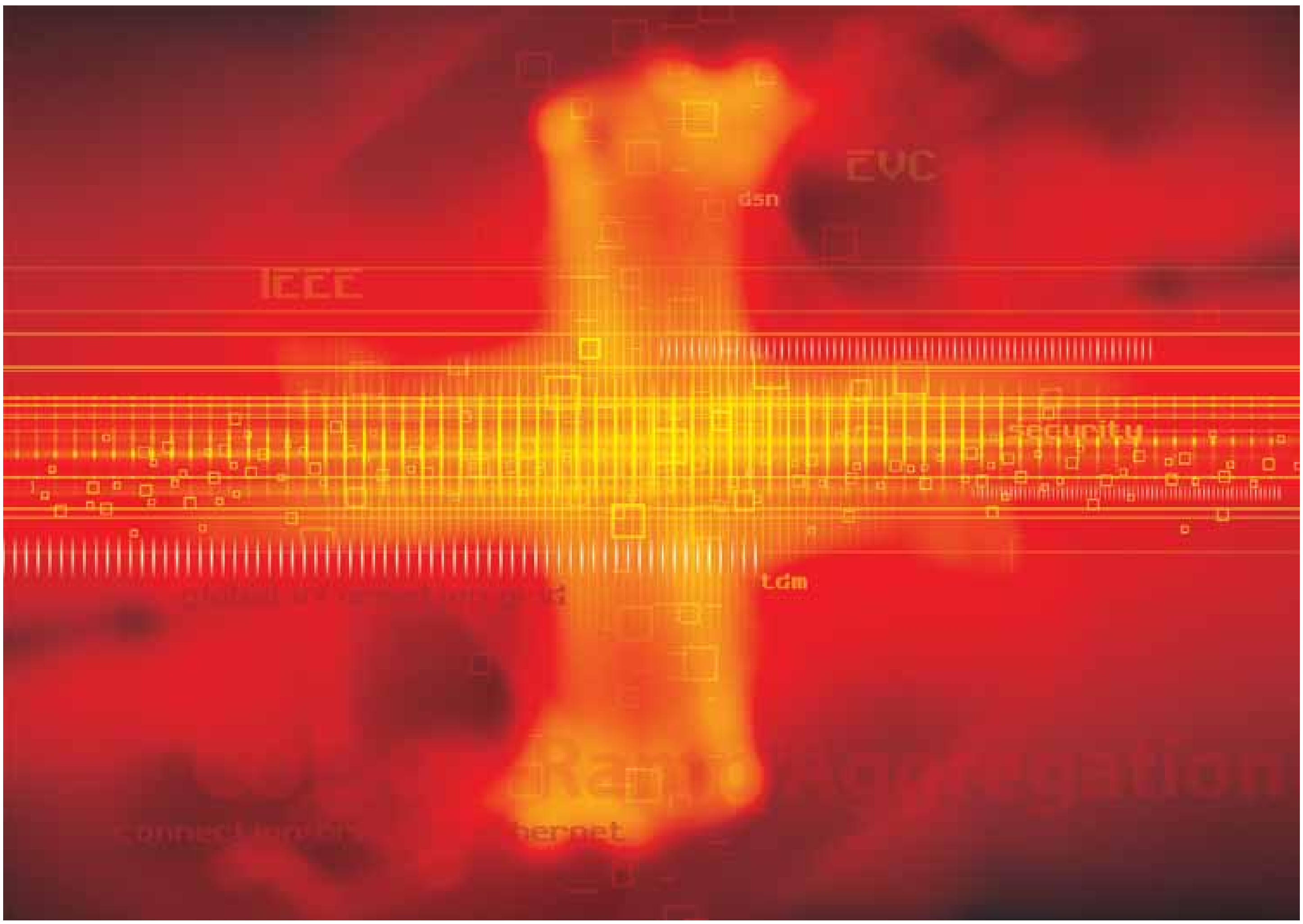
FUJITSU

Connection-Oriented Ethernet On-Ramp Aggregation for Next-Generation Networks



Introduction

The GIG and its component networks, including the DISN, form the state-of-the-art network foundation for DoD communications. This foundation is undergoing a migration from TDM- and ATM-based technologies to packet-based technologies in order to support network convergence.

Among the networks affected are the DSN for non-secure dial-up voice telephone service; the DRSN that provides high-quality secure voice/conferencing for senior decision makers; the NIPRNet (for non-secure exchanges); SIPRNet (for secure exchanges); the DMS; and the DVS network. All require a secure and manageable network infrastructure provisioned to support real-time, assured services.

This paper describes the way in which the DoD is relying on Connection-Oriented Ethernet (COE) to facilitate a geographically-distributed, protocol-simple, IP-based network architecture, that provides the quality of service, network aggregation efficiencies, and security that's needed.

As networks become part of the GIG, a secure, manageable access and on-ramp infrastructure is vital. Today, access networks consist of a highly heterogeneous mix, chiefly dominated by TDM and ATM technologies and a combination of copper- and fiber-based last miles.

To enable the new generation of high-bandwidth applications, it is necessary to migrate the access infrastructure from these legacy technologies to Ethernet-centric approaches. These approaches are designed to reduce cost, while delivering the highest degree of security and deterministic performance.

In addition to lower cost, security and determinism, the Ethernet-centric "on-ramp" network must achieve several objectives:

- Simplify management
- Accommodate diverse first/last mile access technologies
- Provide the highest degree of resiliency and availability

Ethernet is so ubiquitous in large part due to low capital cost, networking efficiency, operational simplicity and universal interoperability delivered at Layer 1 and Layer 2. This ubiquity of course extends outside the LAN. In Wide Area Networking, Ethernet implementations take the form of connectionless native Ethernet bridging or Ethernet encapsulated into a connection-oriented TDM technology, such as SONET/SDH or OTN.

Making Ethernet Connection-Oriented

To bring the cost and flexibility benefits of Ethernet to wide area networking, the industry made an enormous number of modifications, enhancements and extensions to classic Ethernet protocols, resulting in "Carrier Ethernet." Most of these enhancements focused on extending the classic connectionless Ethernet protocol to a service provider environment. Carrier Ethernet brought about new capabilities in:

- OAM (IEEE 802.1ag, IEEE 802.3ah, ITU-T Y.1731)
- Survivability (ITU-T G.8031, IEEE 802.3ad, IEEE 802.1s)
- Scalability (IEEE 802.1ad, IEEE 802.1ah)
- Speed and distance (IEEE 802.3ae]

In addition, equipment vendors "beefed up" enterprise-class Ethernet hardware and software platforms to provide a number of WAN-compatible features.

The Essential Functions of Connection-Oriented Ethernet

In order to make Ethernet connection-oriented, the following functions are required:

- Predetermined EVC paths
- Resource reservation and admission control (CAC)
- Per-connection (EVC) traffic engineering and traffic management

The ability to predetermine the EVC path through the Ethernet network is fundamental to making Ethernet connection-oriented. In classic connectionless Ethernet bridging, Ethernet frames are forwarded in the network according to the MAC bridging tables in the learning bridge. If a destination MAC address is unknown, the bridge floods the frame to all ports in the broadcast domain. Spanning tree protocols like IEEE 802.1s are run to ensure there are no loops in the topology and to provide network restoration in the event of failure. Depending upon the location and sequence of network failures, the path that EVCs take through the network may be difficult to predetermine.

Predetermining the EVC path (through either a management plane application or an embedded control plane) ensures that all frames in the EVC will pass over the same sets of nodes. Consequently, intelligence regarding the connection as a whole can be imparted to all nodes along the path.

Resource reservation and CAC is the next critical function. With the EVC path through the network explicitly identified, the actual bandwidth and queuing resources required for each EVC are reserved in all nodes along the path. This is vital to ensure the highest possible performance in regard to packet loss, latency and jitter. CAC ensures the requested resource is actually available in each node along the path prior to the establishment of the EVC during the initial provisioning process.

Once the path has been determined and the resources allocated, the traffic engineering and traffic management functions ensure that the requested connection performance is actually delivered. After packets have been classified on network ingress, there are a variety of traffic management functions that must be provided in any packet-based network. These include:

- Policing
- Shaping
- Queuing
- Scheduling

Packet classification is the processes of identifying the EVCs to which incoming frames belong. The ingress equipment can examine a variety of Ethernet and IP layer information to make this decision. Once the incoming frame is classified, policing is then applied to ensure that all frames coming into the network conform to the traffic contract, known as the bandwidth profile, agreed to on connection setup. Two-level, three-color marking allows incoming frames that conform to the CIR to be admitted to the network, frames that exceed even the EIR to be discarded immediately, and frames that exceed the CIR but not the EIR, to be marked for possible discard later should the network become congested. An EVC can be subject to a single policer if the bandwidth profile is applied to the entire EVC. EVCs can also include bandwidth profiles for each of many classes of service (CoS) within the EVC. In this case, a single EVC can be subject to multiple policers.

The Heart of Connection-Oriented Ethernet

The shaping, queuing, and scheduling granularity determines whether each individual EVC enjoys the significant performance benefits of COE or achieves statistical performance as with the case of connectionless Ethernet.

When an Ethernet frame in a packet-switched packet network waits for a transmission opportunity on an egress port, it is queued along with other connections that are also bound for the same port. A scheduler determines which frame is transmitted next and there may be a shaping function. The critical question becomes how will these frames will be queued, scheduled and shaped and at what level of granularity: per card, per port, per EVC connection or per CoS within a connection?

In many implementations of Carrier Ethernet traffic management, Ethernet frames from many EVCs are placed into a single set of egress queues and therefore, visibility into individual EVCs is lost. When this occurs, the network begins to play "priority roulette" where all EVCs in a single priority class essentially get random access to transmission opportunities and consistency in the service quality of individual connections decreases.

Connection performance can only be guaranteed by providing policing, scheduling, and egress shaping functions down to the granularity of an individual CoS class within an EVC.

By providing the three essential functions of predetermined EVC paths, resource reservation and admission control, and per-connection traffic engineering and management, Ethernet connections can enjoy a level of service quality on a par with Ethernet over SONET/SDH, but with the aggregation efficiency and flexibility of native Ethernet.

Protection Switching

With Ethernet frames now flowing in a connection-oriented manner across the network, it becomes possible to provide dedicated, deterministic automatic protection switching functionality, including 10 ms failure detection and 50 ms protection switching speed, on par with that provided by SONET/SDH.

The ITU G.8031 Ethernet Linear Path Protection standard creates dedicated protection resources, enabling the same deterministic characteristics (bandwidth profile and loss, latency, and jitter performance) as the working path resources. By utilizing 802.1ag continuity check messages, an Ethernet or lower-layer failure or degradation is detected within 10 ms. Having detected failure or degradation, the G.8031 protocol is used by the network elements to switch to the dedicated protection resource within 50 ms, ensuring the TDM-comparable availability over arbitrary Ethernet network topologies and long distances.

The Technology Choices

Several existing and emerging technologies can realize COE. These technologies include:

- Ethernet Tag Switching
- 802.1Qay (PBB-TE)
- MPLS-TP
- T-MPLS
- PW/MPLS

When choosing a COE approach for aggregation and on-ramp network infrastructure, the selection often comes down to:

1) How many protocol layers are required in the network?

2) Is a routed IP data plane and associated control plane complexity required?

Ethernet-centric approaches, such as Ethernet Tag Switching and PBB-TE, can be implemented without additional MPLS layers such as pseudowires or LSPs, making them simpler to integrate into OSS systems. They also have the benefit of requiring fewer protocol layers of OAM for inventory, fault and performance management.

Additionally, Ethernet-centric approaches eliminate the need for software-intensive IP data planes deep into the aggregation network. In many large environments, again typified by the DoD, this has significant implications. Because there are thousands of remotely deployed elements in the network, the introduction of an IP control plane would greatly increase the complexity of software maintenance, troubleshooting and provisioning, thus increasing the operational cost.

Important Applications for Connection-Oriented Ethernet

Generally speaking, there are two primary applications for COE:

- Delivery of TDM-comparable quality Ethernet services
- Deterministic Ethernet-based access to IP network services

TDM-Comparable Quality Ethernet Private Line Services

The MEF has defined two general types of point-to-point Ethernet services—EPL and EVPL. EPL services have a single EVC connecting the ingress and egress ports across the network. This type of service is typically delivered over SONET/SDH networks. EVPL services are more flexible in that they have more than one EVC per port, so a single Ethernet port at a hub location can have multiple EVCs that connect to different remote locations.

When EVPL services are provided over connectionless Ethernet networks, the service quality is often lower than that delivered by traditional TDM private line circuits. The degradation results from the hop-by-hop nature of the traffic management, the need to account for unexpected Ethernet flooding, and the reliance upon spanning tree protocols for Ethernet protection and restoration. In addition, connectionless Ethernet networks often place significant requirements and restrictions on the on-premises communications equipment. These restrictions include requiring the on-premises device to shape traffic, requiring the device to be a router, and limiting the amount of latency-sensitive traffic that can be introduced onto the network over an Ethernet UNI port. With COE technology, TDM-equivalent quality EVPL services can be delivered along with 50 ms protection switching, and all significant connectionless Ethernet restrictions can be removed from the on-premises networking equipment.

Access to IP/MPLS Services

A COE aggregation network can provide highly aggregated EVPL connections to IP edge routers, eliminating much of the cost normally associated with channelized OC-N interfaces on those edge routers.

In the past, it was possible to realize cost-effective TDM services by deploying a single, common aggregation and transport infrastructure based on connection-oriented SONET/SDH technology. Creating a highly efficient and secure next-generation packet network requires a single aggregation and on-ramp solution for point-to-point Ethernet services and Ethernet access to all IP services.

This aggregation infrastructure, based on Ethernet-centric COE, holds the promise of delivering the cost-effectiveness of statistical multiplexing and large-scale Ethernet aggregation, combined with the performance quality and manageability of SONET.

Conclusion

Connectionless networking approaches have been vital for "plug and play" multipoint-to-multipoint applications, and have also been used for general-purpose aggregation of Ethernet traffic, although at a lower service quality penalty. The connection-oriented SONET and OTN encapsulations have been vital for providing high-quality Ethernet point-to-point services and infrastructure transport, but they cannot provide the economic benefits of statistical multiplexing and port aggregation.

COE technology has created the first general-purpose Ethernet aggregation and transport network infrastructure for all applications. COE offers TDM-comparable quality Ethernet services, secure Ethernet access to IP services, and delivers the robustness and performance guarantees of Layer 1 SONET/SDH/OTN encapsulation, while preserving the aggregation and statistical multiplexing economics of native Ethernet.

Term	Definition
ATM	Asynchronous Transfer Mode
CAC	Connection Admission Control
CIR	Committed Information Rate
COE	Connection-Oriented Ethernet
CoS	Class of Service
DISN	Defense Information Systems Network
DMS	Defense Messaging System
DoD	Department of Defense
DRSN	Defense Red Switch Network
DSN	Defense Switch Network
DVS	DISN Video Services
EIR	Excess Information Rate
EPL	Ethernet Private Line
EVC	Ethernet Virtual Circuit
EVPL	Ethernet Virtual Private Line
GIG	Global Information Grid
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
ITU-T	International Telecommuncations Union-Telecommunication Standardization Sector

Term	Definition
LAN	Local Area Network
LSP	Label Switched Path
MAC	Medium Access Control
MEF	Metro Ethernet Forum
MPLS-TP	Multiprotocol Label Switching-Transport Profile
ms	millisecond
NIPRNet	Non-Secure Internet Protocol Router Network
OAM	Operations, Administration and Maintenance
OSS	Operations Support System
OTN	Optical Transport Network
PBB-TE	Provider Backbone Bridging-Traffic Engineering
PW	Pseudowire
SDH	Synchronous Digital Hierarchy
SIPRNet	Secret Internet Protocol Router Network
SONET	Synchronous Optical Network
T-MPLS	Tunneled-Multiprotocol Label Switching
TDM	Time Division Multiplexing
UNI	User Network Interface
VLAN	Virtual LAN
WAN	Wide Area Network

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