White Paper: Carrier Ethernet

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Introduction

Ethernet has long been the de-facto standard in local area networks (LANs). Its simplicity and widespread use have made it a very popular technology in current data communications networks. Evolving from a pure LAN environment, Ethernet is now being used in wide area network (WAN) environments as well. This evolution presents several challenges, to address which new technologies are being developed under the name **Carrier Ethernet (CE)**. Carrier Ethernet is one of the areas being investigated within GN3 JRA1 Task 1.

There is a lot of ambiguity and confusion when network specialists talk about Carrier Ethernet and its different flavours, which this paper aims to dispel. It starts with a clarifying overview of the Carrier Ethernet area, including distinguishing between "Ethernet as a carrier service" and "Ethernet as a carrier's internal transport technology". It then discusses Ethernet over non-Ethernet and Ethernet over Ethernet, introduces some technology-agnostic Ethernet service definitions produced by the Metro Ethernet Forum (MEF), and briefly describes four current Carrier Ethernet technologies: Ethernet over Internet Protocol/Multi-Protocol Label Switching (EoIP/MPLS), Multi-Protocol Label Switching – Transport Profile (MPLS-TP), Provider Backbone Bridge – Traffic Engineering (PBB-TE) and Optical Transport Network (OTN).

Carrier Ethernet: What is under the umbrella?

Carrier Ethernet (CE) is a hot term in the communications world at present, but is another of those umbrella terms that, confusingly, are used to mean different things by different people. If you attend any major event dedicated to Carrier Ethernet, you'll find presentations mentioning not only Ethernet but other currently popular technologies like Multi-Protocol Label Switching (MPLS), Synchronous Digital Hierarchy (SDH), Optical Transport Network (OTN) and Dense Wavelength-Division Multiplexing (DWDM). This paper aims to explain what people may mean when they say "Carrier Ethernet" – not in all cases, of course, but at least in the majority of them.

"Carrier Ethernet" is, in fact, a contraction of the original term "Carrier *Grade* Ethernet". "Carrier Grade" or "Carrier Class" are terms used to refer to technologies and equipment that provide robust, reliable services at a level where a telecommunications carrier (such as BT) would deploy them on its wide area network. For the most part they are distinguishing terms for high-end equipment or technologies that would typically not feature in a local area network.

Carrier Ethernet is an attempt to expand Ethernet beyond the borders of local area networks and into the territory of wide area networks. The aim is to provide customers with a wide area service to connect sites together, in the same way that Asynchronous Transfer Mode (ATM), Frame Relay and X.25 services from carriers have done in the past. Carrier Ethernet is definitely not about the Ethernet within LANs that we are used to seeing at our desks and in server rooms.

The driving force behind this expansion is understandable: Ethernet has become the de-facto lower-layer network technology on LANs. Traditionally Ethernet frames were re-packaged into some other format for wide area transmission, only to be reassembled as Ethernet at the destination. So why not have Ethernet everywhere, and not only within LANs?

There is another, equally important reason for the Ethernet expansion: Ethernet interfaces are normally cheap by comparison with other technologies, as its popularity allowed for mass production and thus cheaper unit prices. Previously this financial advantage did not come without hidden costs: unlike other technologies, Ethernet does not have built-in sophisticated failure and error detection systems that enable accurate, and thus fast, tracing and rectifying of faults. The development of equivalent mechanisms for Ethernet is part of what triggered the Carrier Ethernet variant of the protocol.

In addition to the troubleshooting features, improvements to the classical shared-media Ethernet (e.g. the virtual local area network (VLAN) technology) were made in the 1990s to convert it into a ubiquitous LAN technology standard. Further standards are now being worked on for LAN-switched Ethernet to convert it into Carrier Ethernet. We will look at these improvements later. First it is useful to understand that there are actually two different areas under the Carrier Ethernet umbrella. One can be called “Ethernet as a carrier service” while the other is “Ethernet as a carrier’s internal transport technology”. While these areas obviously overlap – for example, when “Ethernet as a carrier’s internal transport technology” is used to provide “Ethernet as a carrier service” for customers – understanding this difference helps to sort out many Carrier Ethernet-related issues.

The following two sections look at the options for, first, Ethernet as a carrier service, then for both Ethernet as a carrier service and Ethernet as a carrier’s internal transport technology.

Ethernet over Non-Ethernet

Customers usually don’t care what transport technology is used within a provider network as long as the provider offers a convenient user network interface (UNI).

For a global Ethernet service (i.e. Ethernet as a (global) carrier service), this means that the carrier network has an Ethernet user network interface which customers can use to connect their sites on Layer 2 as a VLAN. Ethernet service providers do not take into account any IP or other Layer 3 protocol information about customer networks – a Carrier Ethernet link simply transports frames between the two endpoints, giving the illusion that they are directly connected. However, different transport technologies can operate within the service provider network to underpin a global Ethernet service – e.g. Ethernet itself, IP/MPLS, or SDH/OTN/DWDM – which results in service diversity. To distinguish the first option, i.e. when an Ethernet service is delivered over an Ethernet provider network, the term **Carrier Ethernet Transport (CET)** is sometimes used.

As the process of converting Ethernet into a Carrier Ethernet Transport started not long ago (some of its carrier features are still not fully standardised), two more mature options from IETF and ITU-T for building an Ethernet service based on a non-Ethernet provider core are currently dominant within carrier networks.

- The **IETF option** defines two services: **Virtual Private Wire Service (VPWS)** and **Virtual Private LAN Service (VPLS)**. These services are built on a common mechanism called **Ethernet over MPLS (EoMPLS)**, which represents an efficient way of tunnelling Ethernet traffic through the MPLS provider core by means of **pseudowires (PWs)**, a generic mechanism developed by the IETF to emulate different transport services over an MPLS core. Both VPWS and VPLS assume that a provider network supports an IP/MPLS layer over which tunnels are established to create a solid base for connecting user sites in a predictable manner. VPWS provides point-to-point-type connections, while VPLS provides LAN-style any-to-any connectivity. Both VPWS and VPLS support user VLAN tags while providing connectivity between user sites.

- The **ITU-T option** is concerned with **Ethernet over Transport (EoT)**, where “transport” is a traditional carrier transport technology such as Plesiosynchronous Digital Hierarchy (PDH), SDH or OTN. ITU-T G.8011 [ITU-T G.8011] and other recommendations are written from a network perspective; they explain how Ethernet traffic should be carried through circuit-switched cores. Focusing on Ethernet as a major client resulted in a set of new SDH features which are sometimes referred to as Next Generation SDH (NG-SDH). ITU-T defined **Ethernet Private Line (EPL)** and **Ethernet Virtual Private Line (EVPL)** services, which are close to the definitions of VPWS and VPLS from a user perspective but based, of course, on different technology within the provider network.

Carrier Ethernet Transport (Ethernet over Ethernet)

Several strands of improvements aim to transform Ethernet into a carrier grade transport, also known as Carrier Ethernet Transport (CET). It is worth stressing that these strands target both the external (Ethernet as a carrier service for customers) and internal (Ethernet as a carrier’s transport technology – a reliable transport for connecting the provider’s routers) aspects of a provider’s activity. The main standards bodies working to improve Ethernet are the IEEE, the ITU-T and, to a lesser extent, the IETF. The strands are:

- **De-coupling of provider and user networks.** If a provider network and all customer sites worked as a single LAN, the result would be lively but hardly manageable. The IEEE has developed two standards: **Provider Bridge (PB)** and **Provider Backbone Bridge (PBB)**. PB separates provider VLAN tags from customer tags, while PBB goes further and separates MAC addresses as well by encapsulating a user Ethernet frame into a provider frame.

- **Traffic engineering, bandwidth guarantees and quality of service.** Several standards have been or are being developed to support these very desirable and interrelated features. One of the key standards here is **Provider Backbone Bridge – Traffic Engineering (PBB-TE)**, which is based on the Nortel proprietary **Provider Backbone Transport (PBT)** technology and was approved by the IEEE as a standard in 2009. PBB-TE adds support to PBB for deterministic paths and thus provides the feature set needed for providing bandwidth guarantees, resilience and robust quality of service (QoS).

- **Resilience.** The main tool for supporting resilience in LANs – the Spanning Tree Protocol (STP) – does not satisfy the requirements of modern networks for fast switching to an alternative route when a failure occurs. Neither do the recent improvements of STP such as Rapid STP or Multiple STP. Currently the IEEE is working on two standards in this area, which are based on different approaches: PBB-TE, which uses a deterministic backup path concept (in SDH style) and **Shortest Path Bridging (SPB)**, which uses link-state routing protocols for finding the proper topology (in a similar fashion to link-state IP routing protocols).

- **Operations, Administration and Maintenance (OAM)** has probably been (and still is) the main concern of providers who are looking at Ethernet as a carrier technology. Classical Ethernet supports no OAM functionality at all; the recent standards 802.1ag and 802.3ah from the IEEE [IEEE 802.1ag, IEEE 802.3ah] and Y.1731 from the ITU-T [ITU-T Y.1731] bridge this gap.

Technology-Agnostic Ethernet Service Definitions

The **Metro Ethernet Forum (MEF)** produces the reference definitions of an Ethernet-like service. These describe a service from a customer point of view and are agnostic with regard to which technology a provider may use internally. This agnosticism is very useful as providers and their customers can use the MEF definitions to discuss and construct a particular service according to a customer's needs and a provider's capabilities without going into specific details of a particular technology such as MPLS or SDH.

In the MEF approach, a service is described by a number of attributes. The most important of these is the type of connectivity between sites: **E-LINE** (corresponds to IETF VPWS and ITU-T EPL/EVPL), **E-LAN** (corresponds to IETF VPLS) and **E-TREE** (a special hub-and-spoke case). Other important attributes for service construction include bandwidth guarantees, QoS parameters, security filters and conditions for preserving or mapping user VLAN tags.

Current Carrier Ethernet Technologies

The four main current Carrier Ethernet technologies are briefly described below.

Ethernet over Internet Protocol/Multi-Protocol Label Switching (EoMPLS)

Ethernet over Internet Protocol/Multi-Protocol Label Switching (EoIP/MPLS) belongs to the Ethernet over Non-Ethernet type of services. MPLS is used to transport Ethernet frames over a provider's backbone network, with pseudowires (PWE) acting as an emulated point-to-point connection over a packet switched network providing the interconnection of two nodes. An important feature of pseudowire technology is that the service-specific functions are located only on the edge of the provider network, while only MPLS label-switched paths (LSPs) are established in the core. This way the core routers do not need any knowledge about the services provided by the network, which increases the scalability of the services and reduces the complexity of the core routers.

EoMPLS is capable of delivering all three services (E-LINE, E-LAN and E-TREE) as defined by the MEF.

Multi-Protocol Label Switching – Transport Profile (MPLS-TP)

Multi-Protocol Label Switching – Transport Profile (MPLS-TP) is based on the same forwarding mechanisms as MPLS (LSPs and PWEs) but has enhanced OAM and protection capabilities, allowing it to become a true Carrier Class Transport Network Technology. MPLS-TP can be used for building Carrier Ethernet services in the same way as MPLS but with an improved transport functionality.

Provider Backbone Bridge – Traffic Engineering (PBB-TE)

Provider Backbone Bridge – Traffic Engineering (PBB-TE) is the third (and latest) standard developed by the IEEE, and eliminates some of the limitations of the first and second IEEE standards, Provider Bridge (PB) and Provider Backbone Bridge (PBB) respectively.

The PB and PBB standards solved the problem of the scalability and manageability of a provider network that uses Ethernet functionality both as a customer service and as an internal transport. However, important features like fast resilience and traffic engineering were left unaddressed. PBB-TE [IEEE 802.1Qay] is one of the solutions capable of delivering services combined with these features.

PBB-TE can be used as an internal transport technology for providing an Ethernet over Ethernet type of service.

Optical Transport Network (OTN)

Optical Transport Network (OTN) is the transport architecture that enables transport through the optical domain across the optical channel path, but it is not the photonic layer itself. The functionality of the transport layer is to provide "transparent transfer of data from a source end open system to a destination end open system" [ISO/IEC7498]; OTN consists of an optical and a digital architecture, which form a combined "optical transport technology".

For more detailed information about these technologies, please see the JRA1 T1 Deliverable DJ1.1.1 "Transport Network Technologies Study" [DJ1.1.1].

Using OTN as an internal transport for providing an Ethernet service is an example of the Ethernet over Non-Ethernet option.

The Wrap-Up

Carrier Ethernet is still evolving, and while some standards are complete, others are still being developed and tested.

All the CE technologies mentioned above try to address the improvements that are necessary to provide real carrier grade services: de-coupling provider and user networks; traffic engineering, bandwidth guarantees and QoS; resilience and OAM. All the technologies are capable of delivering services as defined by the MEF, and are being incorporated into more and more networks. As the technologies become more mature and services are rolled out, more experience is gained and more improvements identified.

During the GÉANT3 project, further experience will be gained, in lab environments, with all the CE technologies and the services they deliver. Expect more papers, which will give detailed descriptions of these experiences and their results.

References

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[IEEE 802.1ag]	IEEE Standard for Connectivity Fault Management, December 2007
[IEEE 802.1Qay]	IEEE Standard for Local and metropolitan area networks — Virtual Bridged Local Area Networks. Amendment 10: Provider Backbone Bridge Traffic Engineering
[IEEE 802.3ah]	IEEE standard for Ethernet in the First Mile, June 2004
[ISO/IEC7498]	ISO / IEC 7498: 1984
[ITU-T G.8011]	"Ethernet over Private Line" ITU-T Recommendation G.8011
[MEF]	http://metroethernetforum.org/index.php
[ITU-T Y.1731]	"OAM functions and mechanisms for Ethernet-based networks" ITU-T Recommendation Y.1731

Glossary

ATM	Asynchronous Transfer Mode
CET	Carrier Ethernet Transport
DWDM	Dense Wavelength-Division Multiplexing
EoMPLS	Ethernet over MPLS
EoT	Ethernet over Transport
EPL	Ethernet Private Line
EVPL	Ethernet Virtual Private Line
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IP	Internet Protocol
IP/MPLS	Internet Protocol/Multi-Protocol Label Switching
ITU-T	Inernational Telecommunication Union – Telecommunication Standardisation Sector
JRA1	Joint Research Activity 1: Future Network
JRA1 T1	JRA1 Task 1: Carrier Class Transport Network Technologies
LAN	Local Area Network
LSP	Label-Switched Path
MAC	Media Access Control
MEF	Metro Ethernet Forum
MPLS	Multi-Protocol Label Switching
MPLS-TP	Multi-Protocol Label Switching – Transport Profile
NG	Next Generation
NG-SDH	Next Generation Synchronous Digital Hierarchy

OAM	Operations, Administration and Maintenance
OTN	Optical Transport Network
PB	Provider Bridge
PBB	Provider Backbone Bridge
PBB-TE	Provider Backbone Bridge – Traffic Engineering
PBT	Provider Backbone Transport
PDH	Plesiosynchronous Digital Hierarchy
PW	Pseudowire
PWE	Pseudowire Emulation
QoS	Quality of Service
SDH	Synchronous Digital Hierarchy
SPB	Shortest Path Bridging
STP	Spanning Tree Protocol
UNI	User Network Interface
VLAN	Virtual Local Area Network
VPLS	Virtual Private LAN Service
VPWS	Virtual Private Wire Service
WAN	Wide Area Network