



The Benefits of Multiple Classes of Service for Ethernet Mobile Backhaul

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MEF Positioning Paper

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1 Introduction

1.1 Purpose of this Positioning Paper

Historically, Mobile Operators obtained connectivity between their Cell Sites and their on-net Aggregation Sites primarily by leasing TDM circuits (DS1s or E1s) from third party Access Providers. Increasingly, however, as bandwidth demands have grown, Carrier Ethernet is the target solution for mobile backhaul. Instead of leasing DS1s/E1s, the Mobile Operator leases Ethernet Virtual Connections (EVCs) from the Access Provider. Today, in the vast majority of cases, these EVCs are running a single Class of Service (Highest quality). This arrangement has come about primarily for operational simplicity. If the EVC behaves exactly like a DS1/E1 (just higher bandwidth), then the modifications to the Mobile Operator's networks, SLAs, OSSs and processes are minimized and they can more quickly get this solution to market.

While the use of Single-CoS EVCs is a viable and expedient way to get started, the MEF believes that the use of Multi-CoS EVCs for mobile backhaul is a much superior practice. This paper compares Single CoS backhaul to Multi-CoS backhaul, concluding that:

- Multi-CoS mobile backhaul results in **substantial cost savings** for both the Mobile Operator and the Access Provider.
- When implemented correctly, this lower cost Multi-CoS solution will result in **equivalent or better quality** (as experienced by the Mobile Subscriber) than the Single-CoS solution.
- The main challenge of Multi-CoS backhaul is increased operational complexity. But the difficulty of overcoming this challenge is justified in a large majority of cases.

This paper explains **WHY** the MEF holds this opinion. To allow a clear comparison, examples of a Single CoS and a Multi-CoS implementation are described. These examples have been carefully chosen to resemble very common, MEF-compliant, real-world networks. But there are many variations on how these networks can be implemented, and this paper makes no statement on the best practice associated with exactly **HOW** to implement them. Follow-on MEF best practice documents and technical specifications are in development to help standardize Multi-CoS mobile backhaul implementations.

1.2 Background

Mobile Operators today face a formidable challenge. As the customer demand moves from voice services to data services, the volume of data traffic crossing the Mobile Operator's network continues to grow exponentially, driving the cost of the network up with the demand. At the same time, however, the average revenue per user is remaining flat or increasing at a much smaller rate, severely impacting the profitability of their business. The majority of carriers already find themselves in the "Transition" section of the trend shown in Figure 1, with profits declining as data traffic grows.

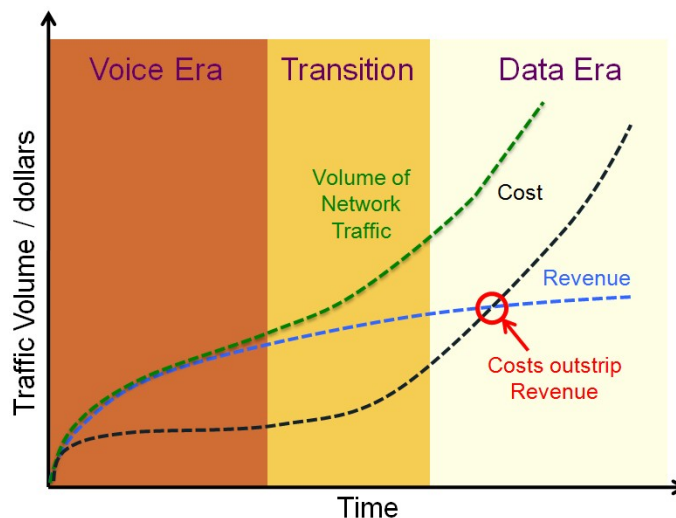


Figure 1 – Backhaul Bandwidth Growth and impact on Mobile Operator Profitability

Typically, among the largest on-going expenses that Mobile Operators face as traffic demands grow are the monthly charges paid to Access Providers (whether a third party or a division of the same operator) for backhaul circuits between the cell sites and the central handoff sites. As a first strategy to deal with this cost and associated bandwidth, there has been widespread adoption of Carrier Ethernet based services for Mobile Backhaul, displacing TDM based DS1/E1 services.

In the vast majority of cases today, each cell site is served by an Ethernet Virtual Connection (EVC) running a single (highest quality) Class of Service (CoS). This arrangement has come about primarily in the name of simplicity, trying to make the EVC behave in a way that is equivalent to a high-bandwidth TDM circuit (DS1/E1). But, as explained in this paper, such a solution prevents the use of one of the most powerful capabilities of Ethernet to reduce cost: The ability to engineer the network in the context of different traffic priorities.

1.3 Ethernet EVC Backhaul Topology

For the purposes of this discussion, the Ethernet EVC backhaul topology of Figure 2 is assumed. In this topology, a single point-to-point EVC provides connectivity between the RAN (Radio Access Network) BS CE and the RAN NC CE. For those unfamiliar with MEF terminology:

- Customer Equipment (CE) refers to the equipment located at the end-point of the EVC owned by the customer of that EVC, which, in this case, is the Mobile Operator. It is a physical device that is directly connected to the demarcation point of the Access Provider's network. For example, many Mobile Operators deploy a cell site router at the handoff to the Access Provider. Others might directly connect their Base Station (BS) equipment (e.g. an eNB in the case of LTE) to the demarcation point of the Access Provider. Either of these two devices would be referred to as a RAN BS CE.
- Similarly, a generalized term is required to refer to the site where the aggregated traffic from multiple RAN BS Sites is handed off to the Mobile Operator. Different operators have different terms for this site. However, since this is commonly where the Network Controllers (NCs) are deployed, MEF refers to this as the RAN NC site. Accordingly, the equipment that the Mobile Operator places at the demarcation to the Access Provider at this site (e.g. an Aggregation Router) would be referred to as a RAN NC CE.

As discussed above, this EVC topology is an example. Other variations (such as two EVCs per RAN BS Site for protection) are possible, but to allow for a simple comparison of Single CoS to Multi-CoS backhaul, the example in the figure is used for the remainder of this whitepaper.

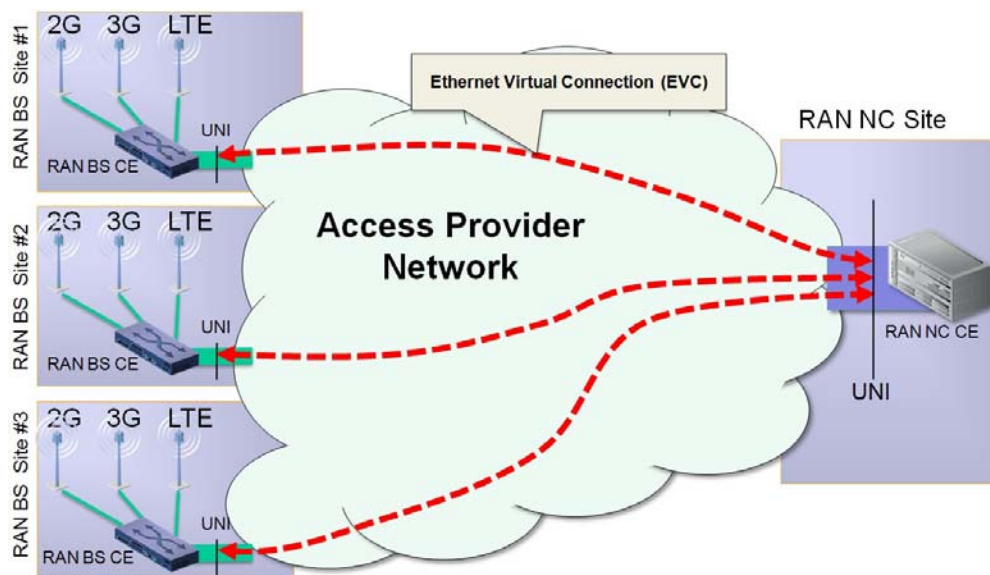


Figure 2 – Ethernet EVC Backhaul Topology

1.4 Mobile Operator Traffic Types

Modern mobile networks support multiple types of traffic, each of which has certain performance requirements across the backhaul.

Table 1 sets out a representative traffic profile for a 50Mbit/s backhaul circuit, and will be used as a basis in this paper to compare Multi-CoS backhaul with Single-CoS backhaul.

Traffic Type	Required Bandwidth (Mbit/s)	Required Performance across the Access Provider network		
		One-way Frame Delay (ms)	One-way Delay Variation ¹ (ms)	Frame Loss (%)
Synchronization	0.5	10	5	0.01%
Voice/Conversational & Control	3.5	15	5	0.01%
Streaming Media	6	20	10	0.01%
Interactive and Background	40	37	Not required	0.1%

Table 1 – Representative Traffic Profile Example

Different Mobile Operators may classify their traffic into different categories and may have different traffic mixes and performance targets than those shown in Table 1. There are many factors associated with defining this table for a particular Operator's traffic including products offered by this Operator, geographical region served, network architecture and target timeframe.

None-the-less, the values in this table have been carefully chosen to represent a very common, real-world traffic profile. The proportion of traffic in each class was derived from "Cisco's Global Mobile Traffic Forecast 2010-2015" [6]. Required performance limits for different traffic types were established using recent detailed technical work in MEF 22.1 and MEF 23.1.

Figure 3 shows a graphical view of this data. For simplicity, Delay Variation is not represented as it is strongly correlated with Delay. As can be seen from the figure, the vast majority of the traffic requires modest performance. Very stringent performance is required by just a tiny fraction of the traffic. As described later, this property of the traffic, valid in almost all mobile backhaul situations, can be exploited to the benefit of both the Mobile Operator and the Access Provider.

¹ Delay Variation is the term used in this document to describe what many refer to as "jitter". MEF technical specifications use the more formally defined metrics of Frame Delay Range and Inter-Frame Delay Variation to describe Delay Variation.

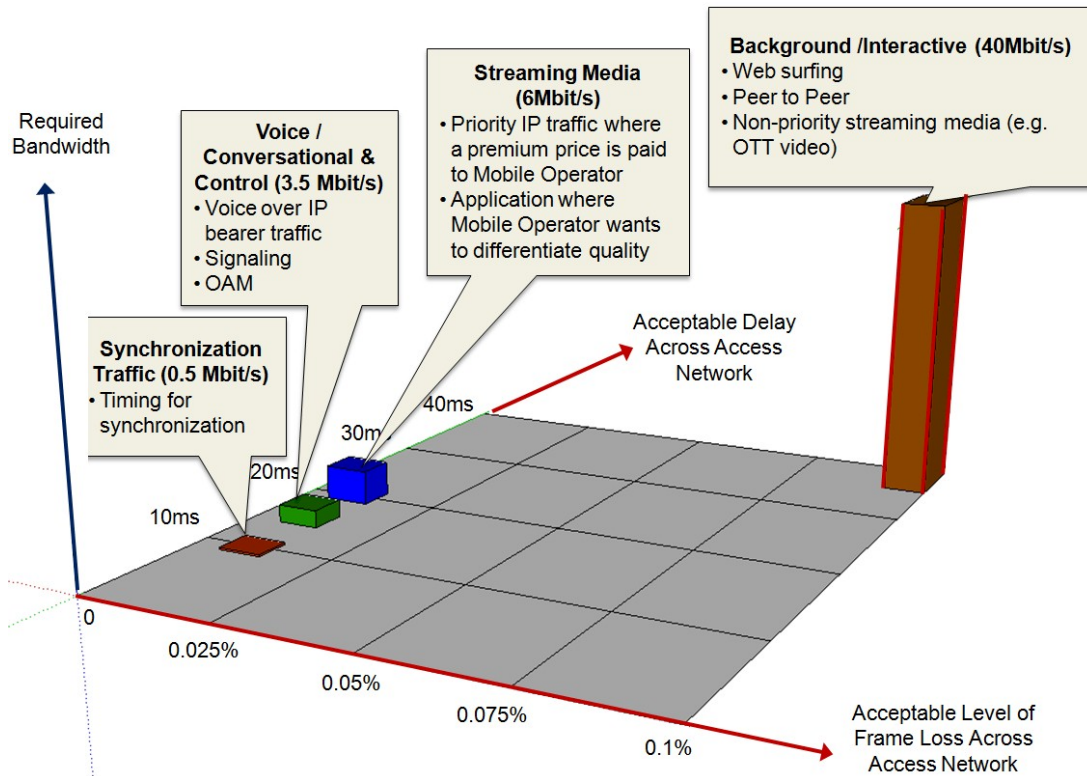


Figure 3 – Representative Traffic Profile example across the backhaul

2 Today's Implementation: Single-CoS Mobile Backhaul

2.1 Single-CoS Backhaul – Technical Overview

In the Single CoS Ethernet Mobile Backhaul alternative, each EVC in Figure 2 supports a single CoS. This does not imply that the Mobile Operator believes all of the traffic should be treated equally. Indeed, in the majority of cases (including the example used in this paper), the Mobile Operator has recognized the need to prioritize certain traffic over others. For example, voice traffic is known to be very delay sensitive. So to ensure voice quality, the Mobile Operator will try to ensure voice traffic does not have to “wait in line” for a large burst of Internet traffic.

In Figure 2, which shows implementation of one RAN BS site from the perspective of the Mobile Operator, the Single-CoS EVC is shown as a purple box representing a bidirectional “pipe” between the RAN BS CE and the RAN NC CE. In this example, the Mobile Operator classifies their traffic into four different categories:

- **Synchronization Traffic:** Considered by this Operator to be the most Delay and Delay Variation sensitive traffic in the network
- **Voice & Control Traffic:** Considered the next priority – also highly Delay and Delay Variation sensitive
- **Streaming Media Traffic:** This could be a special application that this Operator offers for business customers or to carry their own video programming
- **Background/Interactive Traffic:** The most Delay and Delay Variation tolerant traffic and thus the lowest priority and longest queue

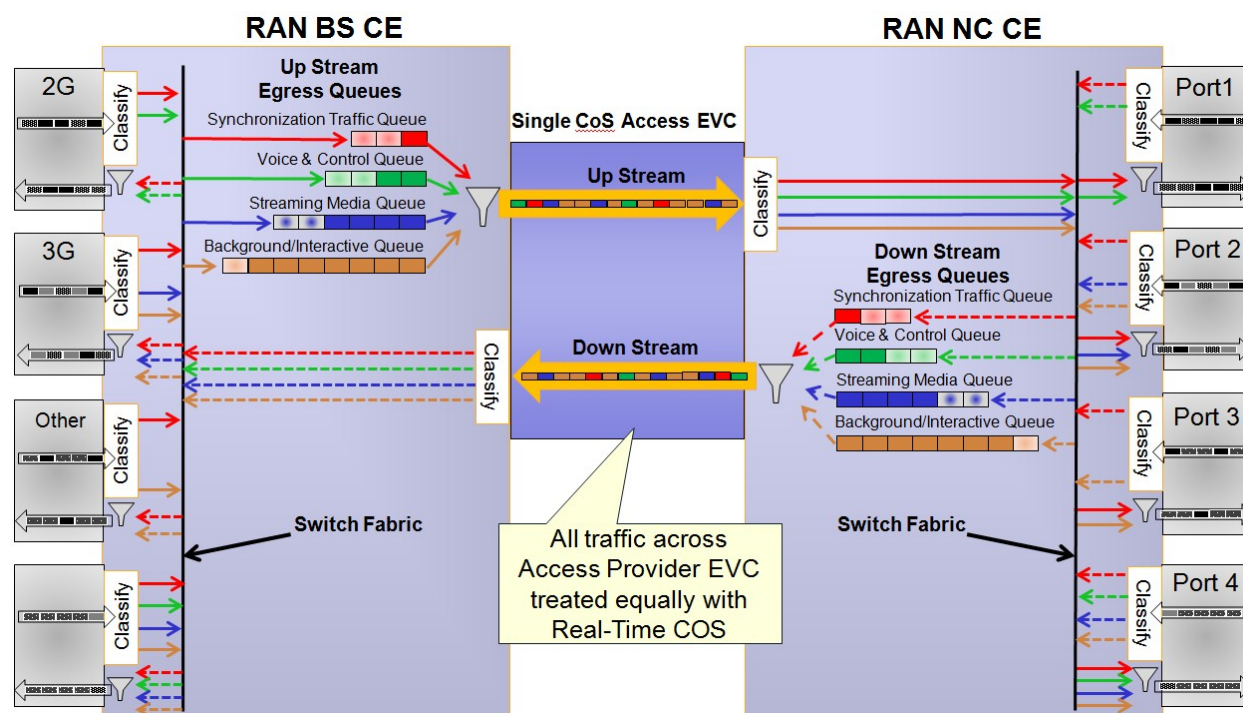


Figure 4 – Single CoS Ethernet Mobile Backhaul – Mobile Operator Perspective

Typically in a mobile backhaul network, congestion happens primarily in the downstream direction so a walkthrough in this direction is most appropriate. Referring to Figure 4, Ethernet frames are transmitted into the RAN NC CE from the ports on the right. These frames could have originated from the Internet, mobile network controllers, voice gateways, etc. These ingress frames are classified, meaning that a determination is made on the priority class of this Frame based on the frame origin and contents. The frame is switched to the appropriate egress port towards the EVC and placed into the appropriate queue for its class. On an ongoing basis, a queue-servicing algorithm, depicted by the funnel in the figure, is taking frames out of the appropriate queue and sending it on the EVC toward its destination.

This mechanism of prioritizing traffic is a defining feature of packet networks. It is very much like a lineup to check in at the airport. Rather than having all customers wait in a common queue, higher priority customers (e.g. frequent flyers or business class travelers) are put in a different queue and airline counter personnel service the two queues appropriately so that the higher priority customers do not have to wait as long.

The engineering of these queues and the queue-servicing algorithm is extremely important. The time waiting in these queues adds DELAY to the transit time of the frame. And the variation in this delay (when queues are full vs. empty) is the source of Delay Variation. In very high levels of congestion, a queue will become full and new frames destined for this EVC must be dropped resulting in FRAME LOSS. Modern Carrier Ethernet switches have very granular controls on this queuing. For example, the queues for the highest priority class may be engineered to be quite short as conversational traffic such as voice is very periodic (not bursty) and a small amount of frame loss has less impact on voice quality than delay or delay variation. The Background/Interactive queue (carrying Internet traffic), by contrast, would be engineered to be much larger since the traffic is very bursty and frame loss has a larger impact than delay and delay variation.

Traffic across the EVC in this Single-CoS scenario, however, does **NOT** respect these differing priorities. Figure 5 shows two (of a set of) Access Provider Network Elements (NEs) in the path of the EVC between the cell site and the network controller site (only downstream traffic is shown). This Access Provider offers three different classes of service (called "High", "Medium" and "Low") and has set up queues in the network to respect these priorities. However, as this is a single CoS EVC, the Access Provider is not aware of the Mobile Operator's different traffic priorities. All the traffic on this EVC is to be treated equally. As a result, the Mobile Operator needs to purchase an EVC with performance characteristics

consistent with the very low delay, very low Delay Variation, and very low loss objectives that meet the needs of the most critical and time-sensitive traffic. This CoS is likely to be the highest performance and most expensive that the Access Provider offers.

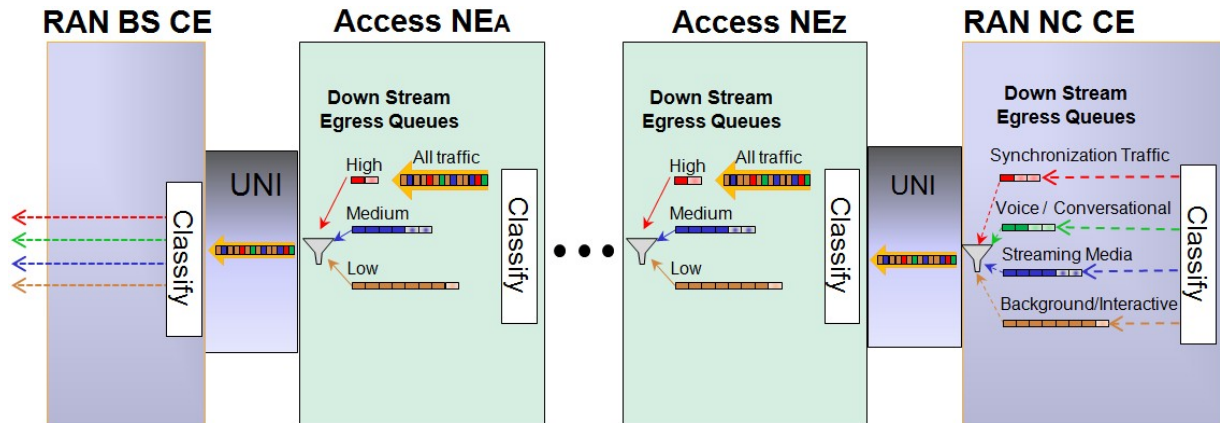


Figure 5 – Single CoS Ethernet Mobile Backhaul Example

In addition, the Mobile Operator needs to buy sufficient bandwidth on the EVC to support the sum of the four traffic types supported, e.g., 50 Mbps. Referring back to traffic profile shown in Figure 3, it should be obvious that the single-class EVC provides extremely high performance when the vast majority of the traffic does not require it. This is analogous to shipping all documents, materials, and products between two factories using overnight service even though only a tiny fraction of the documents are time critical.

Finally, this common single CoS arrangement is not likely to produce the TDM circuit behavior that is desired. Each CoS in a typical Ethernet network is designed to provide optimized performance for certain types of traffic:

- Short queues are used for traffic types like voice to ensure that the network does not introduce too much Delay and Delay Variation while transporting the Frames.
- Long queues are used for traffic that can handle higher levels of Delay and Delay Variation but is sensitive to frame loss (e.g. Internet and streaming traffic).

By making these queues longer, the network can handle the traffic bursts inherent in this type of traffic without dropping traffic. Unfortunately, in the single CoS model, the Access Provider only has one queue so it cannot engineer it to meet either type of traffic in an optimal fashion.

Instead, to ensure that Delay and Delay Variation targets are met (for the small amount of traffic that needs it), the queues must be kept short. However, normal mobile backhaul traffic patterns often have significant bursts of traffic. This would normally result in frame loss whenever these traffic bursts are larger than these small queues are capable of absorbing. To accommodate for this, the Access Provider's only alternative is to ensure that the links between the switches are significantly over-engineered. If the links are all high bandwidth and run at very low utilization levels, then the queues will be emptied out fast enough to minimize this Frame Loss. Back to the airline counter analogy, this would be like using a single line for all customers but tripling the number of counter staff. This is an extremely expensive solution (many staff will just be waiting during off-peak traffic) and it still does not generally result in as low a "Delay" and "Delay Variation" for the business class customers as a separate lineup.

Rate enforcement issues also arise in this scenario. To protect themselves against traffic bursts, Access Providers will often apply a Bandwidth Profile (i.e., policer or rate limiter) at the edge of the Access Provider network with a very small allowed burst size for High CoS traffic. Any significant traffic bursts (i.e., frames arrive close together or back-to-back at the line rate) are intentionally dropped on ingress. For the Mobile Operator, this appears as Frame Loss, impacting all traffic classes without distinction. Moreover, since this traffic is out-of-profile, it is not counted as part of the SLA performance measurement. The Mobile Operator can prevent some of this loss by shaping their traffic (i.e., delaying frames to limit bursting) before sending it to the Access Provider, but shaping will result in higher delay

and delay variation for traffic that waits in the shaper buffer including the delay-sensitive high priority traffic.

2.2 Implications for the Access Provider

Because the CoS supported on each single-class EVC is very high performance, the Backhaul Provider must allocate significant network resources for each EVC in order to meet the performance objectives.

As an example, consider the network shown in Figure 6:

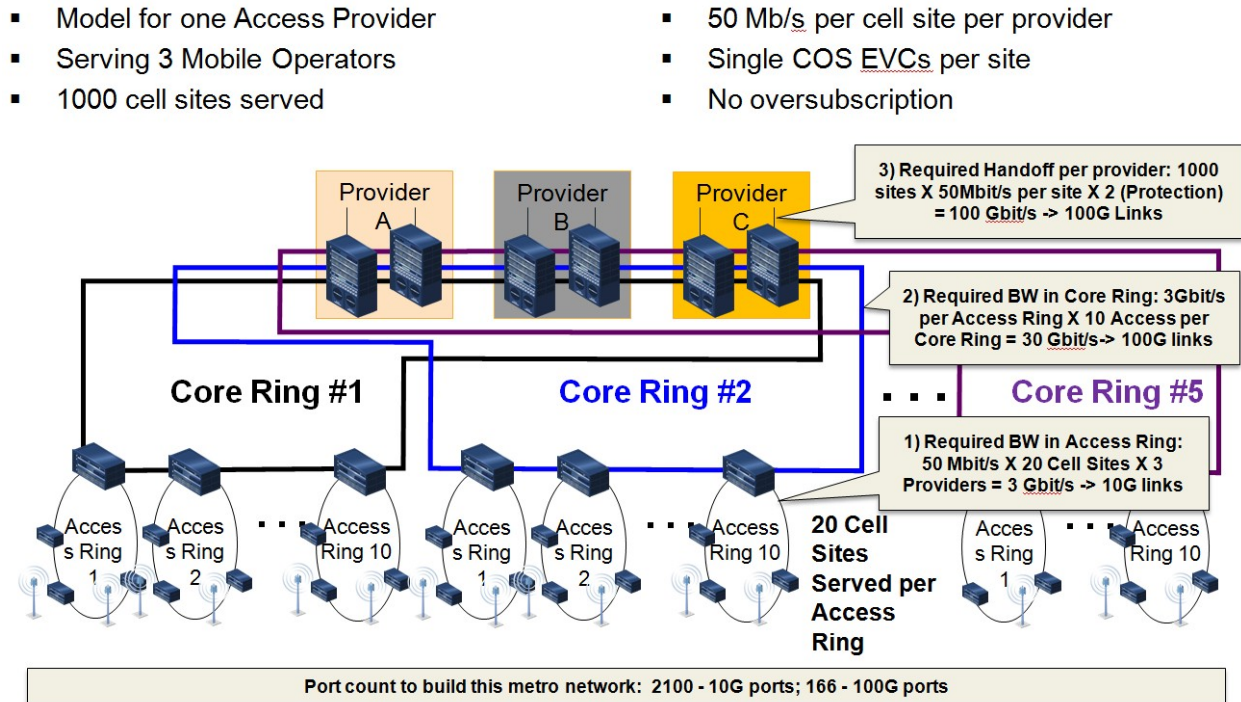


Figure 6 – Example Access Network (Selling Single-CoS EVCs)

In this example, there are 50 Ethernet access rings, each reaching 20 cell sites. There are 5 Ethernet core rings, each reaching 10 access rings and connecting to 3 Mobile Operators at each cell site. To ensure that the links run at low enough utilization to handle traffic bursts, this Access Provider chooses not to oversubscribe their “High” class of service.

First consider the access rings. With 50 Mbps and 20 cell sites, the access ring must support 1 Gbps per Mobile Operator. So with 3 Mobile Operators, each link in the ring needs to support 3 Gbps. With 21 switches in each access ring, there are 42 ports per access ring which means 42 10 Gigabit Ethernet ports per access ring.

Each core ring must support 10 access rings, which means that each link in a core ring must support 30 Gbps. With 12 switches per core ring, this means that each core ring has 24 ports and these ports need to be 100 Gigabit Ethernet.

This example is not unrealistic. As the amount of Mobile Backhaul traffic grows, Access Providers are being forced to seriously consider upgrades to 100 Gbps Ethernet or to overbuild their metro network into multiple rings. The expense associated with such a shift is extremely high so any opportunity to defer such an expense would be extremely valuable.

The opportunity lies in statistical multiplexing. While the network engineered as above (no oversubscription) requires 100 Gbps links, the actual measured average utilization on the existing 10 Gbps metro networks remains very low today. This is because, in the real world, it is very rare for all cell

sites to simultaneously be running at their maximum rate. This dichotomy is forcing Access Providers to consider oversubscribing their highest class of service.

However, oversubscription in the context of single-CoS mobile backhaul is far from optimal. Traffic levels are unpredictable. News events can cause significant surges in traffic. Protection switches can suddenly move a large amount of traffic from one part of the network to another. And, as discussed in section 2.1, even at low average utilization levels, traffic bursts can cause the short queues of the highest traffic class to overflow and lose frames. For the vast majority of traffic (See Figure 3) such degradation of service would have minimal impact on the user experience, but with single-CoS mobile backhaul, ALL traffic is impacted including such critical traffic as network signaling and timing. In this case, the impact could be huge. As a result, oversubscription of the highest class must be practiced with great care and can only produce marginal gains because of the added risk.

3 Multiple CoS Ethernet Mobile Backhaul

Different Access Providers have different multi-CoS capabilities. Some may support two classes (a minimum of two is mandated by MEF 22.1); some support three or even four. Some require that all traffic in a given EVC be of a single class requiring multiple EVCs to be provisioned across the backhaul to achieve multi-CoS. There are many alternatives that may be employed to gain multi-CoS benefits in these cases. For the remainder of this paper, however, it is assumed that the access provider is capable of supporting a single EVC that supports three Classes of Service that it defines as HIGH, MEDIUM, and LOW. It is also assumed that the performance guarantees associated with these classes is as shown in the table below. This offer is consistent with that recommended in MEF 22.1 (Note MEF 22.1 and MEF 23.1 allows some variation in the metrics and values shown below).

Class of Service Label	Objectives offered as part of SLA for Traffic of this class		
	One-way Frame Delay (ms)	One-way Frame Delay Range (FDR ²) (ms)	Frame Loss (%)
HIGH	10	5	0.01%
MEDIUM	20	10	0.01%
LOW	37	None	0.1%

Table 2 – Access Provider's Multi-CoS Service Offer

The implications for the Mobile Operator and Access Provider are discussed below.

3.1 Multi-CoS Backhaul – Technical Overview

The Mobile Provider requirements described in Table 1 are mapped against the Access Provider Service Offering as shown in Table 2. In this case, by mapping the top two classes into the Access Provider's HIGH class, and mapping the others one to one, the Mobile Operator gets the quality guarantees required for each type of traffic.

The configuration of the Mobile Operator CE devices is similar to that for the Single CoS Ethernet Mobile Backhaul alternative. The primary added configuration is ensuring that each Frame it passes to the Access provider is marked with the appropriate priority for that Frame. In this example, it does so by marking the Priority Code Point (PCP) bits in the Frame as per Table 3.

Mobile Operator Traffic Type	Access Provider CoS	PCP Value
Synchronization	HIGH	5
Voice and Control	HIGH	5
Streaming Media	MEDIUM	3
Background/Interactive	LOW	1

Table 3 – Class of Service Identifiers for each Traffic Type

² Frame Delay Range is one of the MEF specified terms describing Delay Variation. It represents the delta between a Frame delivered with the minimum Frame Delay and that of the longer Frame Delay associated with a percentile in a particular time interval.

Figure 7 shows some of the details of Multiple CoS Ethernet Mobile Backhaul alternative. As can be seen in the figure, the Access Provider is made aware of the priority level of each frame and can thus treat each with appropriate priority ensuring appropriate performance of all traffic.

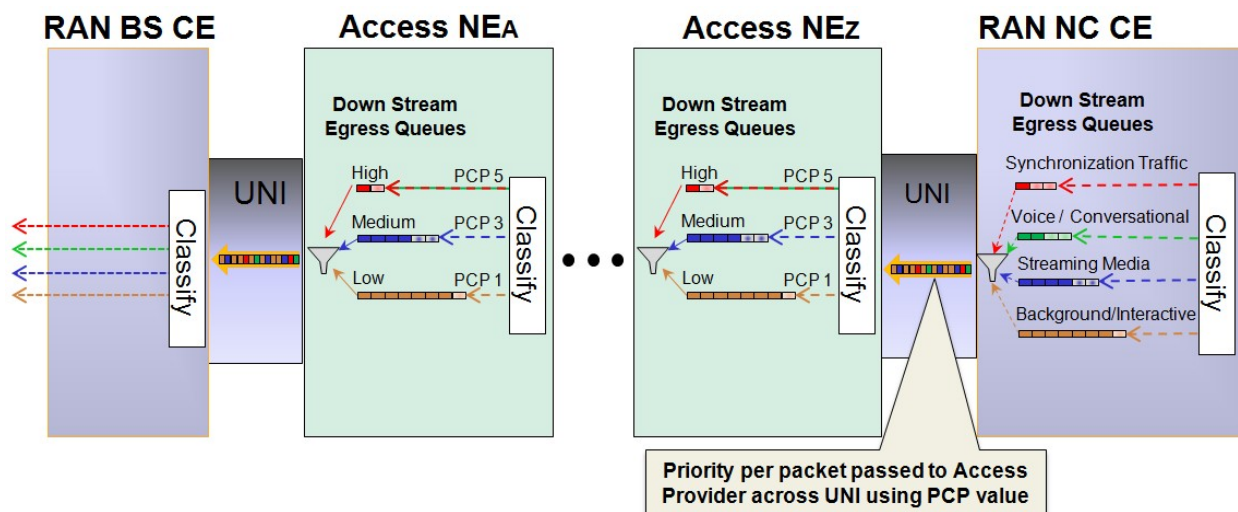


Figure 7 - Multi-CoS Mobile Backhaul Example

3.2 Implications for the Access Provider

Since the priority associated with each frame is now available to the Access Provider, the Access Provider networks can be engineered to appropriately prioritize the traffic across their network.

To see the implications for the Access Provider, we use the access network example from Figure 7. Because the Access Provider is aware of the different Classes of Service, the network design can be adjusted accordingly. In particular, the design can exploit the statistical nature of the Streaming Media traffic and the Background/Interactive traffic to exploit the statistical advantage of sharing bandwidth across multiple traffic streams.³

Table 4 shows an example of how the Access Provider could take into account the statistical advantage. Note that this does not change the bandwidth offered to the Mobile Operator (e.g. the Mobile Operator is still given a CIR of 40 Mbit/s for LOW traffic) or the offered SLA (performance guarantees). These are just the statistical factors that the Access Provider uses internally to engineer their network.

Traffic Type	Bandwidth (Mbps)	Statistical Factor	Effective Bandwidth (Mbps)
HIGH	4.0	1.00	4.0
MEDIUM	6.0	0.50	3.0
LOW	40.0	0.20	8.0
Total	50.0		15.0

Table 4 – Example Bandwidth Requirements per Cell Site

If we repeat the calculations for each ring as in Section 2.2 but using the effective bandwidth from Table 4, we find:

- Each link in an access ring needs to support 900 Mbps and thus 42 Gigabit Ethernet ports are needed.
- Each link in a core ring needs to support 9 Gbps and thus 24 10 Gigabit Ethernet ports are needed.

³ Designing for statistical advantage is sometimes referred to as “Over-Subscription.” Unfortunately this term conjures up negative images from the movie *The Producers* with Nathan Lane (or Zero Mostel) selling 500% in shares of a Broadway show. In fact, designing for statistical advantage has been good practice since the beginning of switched communications networks.

To provide clarity, the Figure below repeats these calculations.

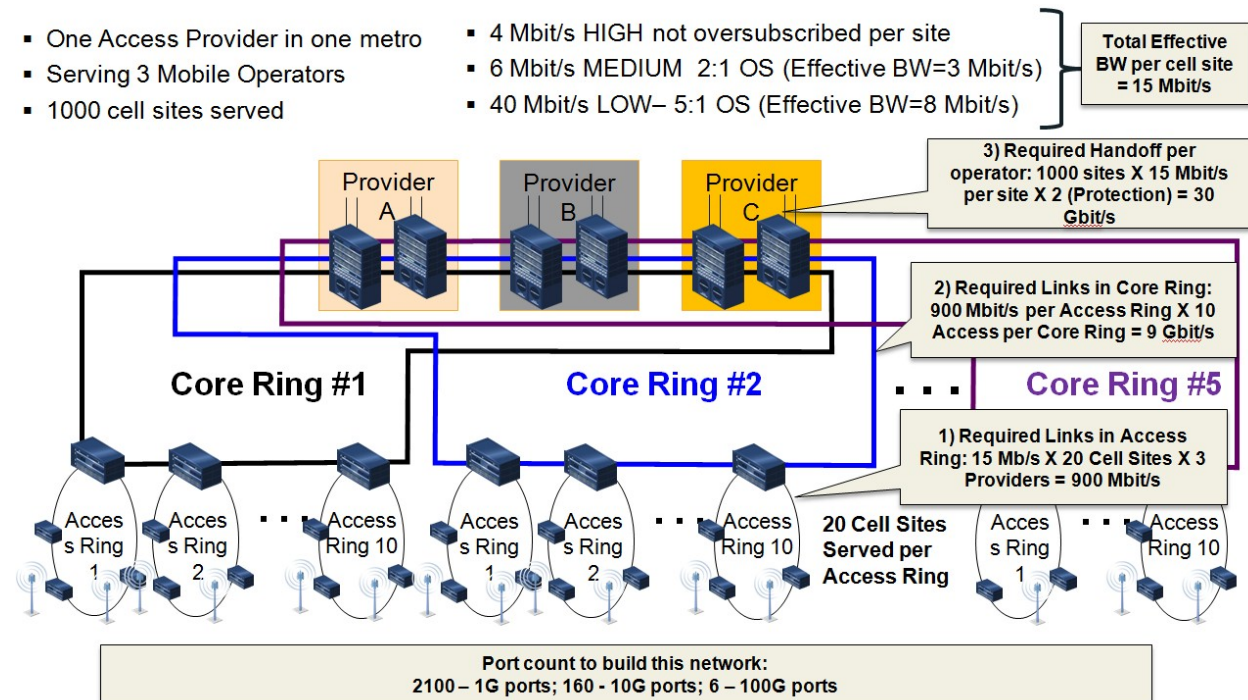


Figure 8 – Example Access Network (Selling Multi-CoS EVCs)

4 Comparing the Two Alternatives

In terms of network configuration, the difference between the two alternatives to the Mobile Operator is modest. For the Access Provider, the difference in network configuration is extremely significant. Table 5 summarizes the calculations of link speeds and ports from Sections 2.2 and 3.2. As can be seen, for this example, the reduction in required network resources is dramatic for the Multiple CoS Ethernet Mobile Backhaul alternative. This implies that the Access Provider will reap significant economic benefits. It is important to note that despite the cost reduction in the Access Provider network, the quality of experience of the end-user in any real-world traffic scenario would be equivalent (assuming – as in all cases – both parties engineer their network properly). Indeed, in some cases such as dealing with bursty data traffic, the performance may be better since the Backhaul Provider can engineer these queue lengths to be longer to handle the bursts, without adding Delay and Delay Variation to traffic that is sensitive to these performance attributes. Note that traffic within the Low CoS is expected to be bursty and to be the majority of the traffic (80% in this example).

Alternative	Access Ring		Core Ring	
	Link Speed	Ports	Link Speed	Ports
Single CoS	3 Gbps	42 10 GigE	30 Gbps	24 100 GigE
Multiple CoS	0.9 Gbps	42 GigE	9 Gbps	24 10 GigE

Table 5 – Example Comparison of Link Speeds and Ports

Of course in any specific situation, a number of factors, such as access network design, will modulate the economic benefits of the Multiple CoS Ethernet Mobile Backhaul alternative. Furthermore the degree with which such benefits are shared with the Mobile Operator will depend on many non-technical factors. In the long term it is assured that lower costs lead to lower prices in competitive markets like Carrier Ethernet. In addition, getting the traffic into the proper traffic management categories (e.g., CoS based queues) is the only way for the Access Provider to preserve the required performance across all applications. The result will be improved quality of experience for the end users and more economic

backhaul. Real-world examples have shown monthly recurring charge reductions for the Mobile Operator on the order of 25%.

5 Structuring Multi-CoS Service Level Agreements

Poor performance across the backhaul network can adversely affect the quality of experience of the end user. Mobile Operators protect themselves against such issues by specifying Service Level Agreements (SLAs) with the Access Provider that define acceptable performance attributes of the EVCs across the backhaul and penalize the Access Provider when they are not met.

5.1 Challenge 1: Definition of Performance Attributes

One challenge is in clearly defining the terminology used to describe these performance attributes. The term “jitter”, for example, while widely used, has no accepted international standard for its definition. This means that if a Mobile Operator and Access Provider enter into an SLA with a target for “jitter”, the two parties could define and measure the “jitter” very differently resulting in a contract that may not be enforceable. As a result, it is strongly recommended that the SLA between the Mobile Operator and the Access Provider use and refer to industry standard performance metric definitions as laid out in MEF 10.2[2], MEF 10.2.1[3] and ITU-T Y.1563[4]. While there is not yet full adoption of these standards, this should be the starting point of negotiations.

5.2 Challenge 2: Establishing SLA Targets for these Performance Attributes

A second, and even more daunting challenge is in defining acceptable targets for these performance metrics. How much delay is too much? How much frame loss will result in poor user experience? This challenge applies to both Single-CoS and Multi-CoS mobile backhaul, but there are fewer metrics to negotiate with Single-CoS since the targets apply to all traffic.

To help address this challenge, considerable work has recently been completed in the MEF with updates of MEF 22 (Mobile Backhaul Implementation Agreement)[5] and MEF 23 (Carrier Ethernet Class of Service)[1]. This work entailed:

- Examining approximately 40 end user applications (VoIP, web surfing, T1 emulation, streaming video, Tele-Presence, etc.). For each of these applications, detailed research was performed to understand what the end-to-end performance requirements needed to be for a high quality user experience.
- Upon understanding the end-to-end requirements, analysis was done to determine what portion of this end-to-end target could be safely allocated across the Access Provider network.
- Applications of similar type were grouped together and a standardized set of Performance targets was established for cases where an Access Provider offers one, two, three or four classes of service.

Consider, for example, a VoIP call as one of the applications analyzed. The MEF standards establish through secondary research that it will be excellent quality if the “speaker-to-ear” one-way delay is less than 150ms and the “speaker-to-ear” one-way jitter is less than 1ms. Since it is nearly impossible to meet a 1ms delay variation target across an IP network, VoIP clients implement a “de-jitter buffer” on the receiving client, which buffers incoming frames (typically up to 50ms is buffered) and then reconstructs the voice signal for the receiver, eliminating most of the Delay Variation introduced by the IP network. This jitter buffer allows up to 50 ms of Delay Variation across the end-to-end network, but consumes, on average, 25ms of end-to-end delay across the network, leaving a maximum delay of 125ms across the IP network. Similarly, the use of a packet loss concealment algorithm allows Frame Loss across the IP network to be up to 0.1% while still ensuring excellent voice quality. Of course, the delay and delay variation across the Access Provider network is only a portion of the end-to-end IP network and the VoIP traffic is grouped with other applications requiring similar performance. In the end, the document places the VoIP traffic in the “Voice, Conversational and Control” class of traffic. Standardized performance requirements for traffic in this class sets the one-way Frame Delay (FD) to 10ms, the Frame Delay Range (FDR) to 5ms, and the Frame Loss Ratio (FLR) to 0.01% across the Access Provider network. From these numbers, it should be very clear that as long as the Access Provider network delivers frames

across the network with this level of performance, the Mobile Operator should be able to assure excellent end-user quality for VoIP traffic.

The work to do this analysis involved both Mobile Operators and Access Providers to establish targets which strike a careful balance. The targets are stringent enough to ensure that if the Access Provider meets them, the mobile backhaul will not negatively impact the end-user experience in any way. At the same time, they are relaxed enough to allow the Access Provider to efficiently traffic engineer their network making effective use of the capital they have invested.

As these MEF standards are just emerging, it cannot be expected that all Mobile Operators will immediately require services that are compliant with these SLA targets or that all Access Providers will immediately offer services with an SLA that meets these targets. However, given the extent and quality of work undertaken in the MEF, it is strongly recommended that these targets be positioned as a starting point for negotiations between the Mobile Operator and the Access Provider.

5.3 Example Objectives for an SLA

The MEF documents provide a certain level of flexibility on which performance attributes to use to describe the performance across the Access Provider network (e.g. "Delay Variation" can be specified either by using Frame Delay Range (FDR) or Inter-Frame Delay Variation (IFDV)). There is also flexibility in which classes to use for which applications and variations on targets based on geographical distances. The reader is urged to review these documents to help them establish appropriate SLA metrics and targets for their specific business.

However, as an example, Table 6 shows a simplified version of how the SLA might be structured for the Single-CoS and Multi-CoS mobile backhaul services compared in this white paper. Based on the detailed MEF analysis, either of these alternatives will deliver an equivalent end-user experience. The Multi-CoS SLA is, indeed, somewhat more complex. But it is the position of the MEF that the benefits of the Multi-CoS to both the Mobile Operator and the Access Provider as outlined in this paper outweigh the challenges of dealing with this additional complexity.

Service Type	Service Class	Committed Information Rate (CIR)	One-way Frame Delay (FD)	One-way Frame Delay Range (FDR)	Frame Loss Ratio (FLR)
Single CoS Mobile Backhaul	All Traffic	50Mbit/s	10ms	5ms	0.01%
Multi-CoS Mobile Backhaul	HIGH	4Mbit/s	10ms	5ms	0.01%
	MEDIUM	6Mbit/s	20ms	10ms	0.01%
	LOW	40Mbit/s	37ms	No SLA	0.1%

Table 6 – Example SLAs for services compared in this paper

6 Summary and Conclusions

While the use of Single-CoS EVCs is a viable and expedient way to get started, the MEF believes that the use of Multi-CoS EVCs for mobile backhaul is a much superior practice.

- Multi-CoS mobile backhaul results in **substantial cost savings** for both the Mobile Operator and the Access Provider.
- Implemented correctly, this lower cost Multi-CoS solution will result in **equivalent or better quality** (as experienced by the Mobile Subscriber) than the Single-CoS solution.
- The main challenge of Multi-CoS backhaul is increased operational complexity for the mobile operator. However, in many cases, the Mobile Operator already handles much of this complexity since they are using multiple CoS within their own network. As a result, the difficulty of overcoming this challenge is justified in a large majority of cases. Emerging industry standards, especially MEF 22.1 and MEF 23.1, and upcoming MEF best-practices papers will provide a blueprint on how to implement Multi-CoS mobile backhaul to help minimize this complexity.

7 Glossary and Terms

A glossary of terms used in this document can be found online at www.metroethernetforum.org/glossary.

Other terms used in this document

Term	Description
Access Provider	Service provider who provides the enabling access service on behalf of the Mobile Operator
CE	Customer Equipment. In the context of this document, this represents equipment owned by the Mobile Operator at the demarcation point to the Access Provider
CIR	Committed Information Rate
CoS	Class of Service
Delay Variation	The variation in Frame Delay across the Access Provider network
eNB	eNodeB: The base station associated with an LTE deployment as defined by 3GPP.
ENNI	Ethernet Network Network Interface
EVC	Ethernet Virtual Connection
Frame Delay (FD)	The Frame Delay (also FD) across an Access Provider network as defined in MEF 10.2
Frame Delay Range (FDR)	A MEF 10.2 defined term describing Frame Delay Variation
Frame Loss Ratio (FLR)	A MEF 10.2 defined term describing percentage of frames lost across the access provider in a particular time interval
Inter-Frame Delay Variation (IFDV)	A MEF 10.2 defined term describing Frame Delay
LTE	Long Term Evolution – Fourth generation wireless architecture as specified by 3GPP
Mobile Operator	Service Provider who is responsible for and has a service agreement with the end user customer (whether consumer or Enterprise buyer)
NE	Network Element
PCP	Priority Code Point
RAN-BS	Radio Access Network – Base Station
RAN-NC	Radio Access Network – Network Controller
SLA	Service Level Agreement
UNI	User Network Interface

8 References

Reference Details
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[6] Cisco Global Mobile Traffic Profile 2010 – 2015 http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.html

9 About the MEF

The MEF is an industry Standards Organization with approximately 100 Service providers of a total of 190 member companies and is the industry's defining body for Carrier Ethernet. Defined by five attributes: Standardized Services, Reliability, Quality of Service, Service Management and Scalability Carrier Ethernet has become the service and transport technology of choice for Enterprise business applications and more recently for mobile backhaul applications. In 2011 the MEF celebrated its tenth anniversary and has developed more than 30 technical specifications. More at www.metroethernetforum.org.

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