EisoAccess Solution- A Broadband (R)Evolution

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1 Legacy Metro Access Architecture

The explosion of high bandwidth applications over Internet has fuelled the deployment of broadband access by the service providers. Apart from Internet browsing at high speed, the multimedia applications like IP TV, video on demand, distance learning etc are driving the contents over the network to the residential homes. These applications require higher bandwidth. In small and medium enterprises (SME) and corporate sectors, new services like Layer 2 VPN, transparent LAN service, and storage area networks are the main driving applications behind broadband access.

The convergence of voice, data and video has caused a paradigm shift from TDM oriented networks to packet based networks. The packet based broadband access networks offer several advantages over TDM based networks in terms of scalability, bandwidth granularity and fast provisioning. On the other hand, legacy TDM networks offer guaranteed quality of service, fast protection and restoration and reliability. In the converged telecom scenario, the service providers are looking for network access architecture that would not only provide scalable high bandwidth but at the same time offer flexibility in provisioning, Quality of Service guarantees for real time traffic and protection and restoration capability. However, before we discuss the challenges involved in developing such a solution for broadband access architecture with these requirements, we first review the legacy Metro access architecture.

Typical Metro network architecture has many hierarchies. The metro access architecture can be roughly divided into three parts, namely First Mile, Metro Access and Metro Core.

1.1 First Mile Access Network

The first mile network part connects the subscriber/customer to the service provider's network. Though this is called First mile, typically, this part of the network may cover from few hundred meters to about 1-3 KM. The first mile network contributes in a significant way to the cost of per user provisioning. This part of the network is the most challenging to design. The design challenges involved are in terms of Quality of Service and high bandwidth in radical price point. Also the provisioning time per user should be very less for the service provider.

Several technologies are currently deployed in first mile. For residential home users, traditionally, the Internet access has been provided using dial-up, ISDN and more recently using ADSL as the technology of choice for the first mile. ADSL can provide standard telephony service using POTS splitter.

ADSL and its various versions have been quite popular as the broadband first mile access network in different parts of the world. The ADSL network consists of hub and spoke topology with ADSL modem as the CPE and the DSL Access Multiplexer (DSLAM) acting as the aggregator as shown in Figure 1. The dominant transport technology is ATM. However, the disadvantages of ADSL network are high cost primarily due to ATM based backhaul, low bandwidth and inflexible provisioning.

Recent advances in terms of IP based DSLAM has addressed most of these disadvantages of ADSL deployments. Also the development of ADSL2 and ADSL2+ is likely to address the bandwidth limitations of first generation ADSL technology.

For enterprises and corporate, the first mile access has been traditionally based on TDM based private lines like E1/E3 leased lines or STM1 interfaces for higher bandwidth as shown in Figure 2. These customers may also subscribe to E1 PRI interface for their PBX connectivity which can be easily provided in this TDM network. Due to the asymmetric nature of ADSL, the ADSL based systems have not been deployed for enterprises. However, the disadvantages of the TDM based first mile access are high cost, low bandwidth and large time for provisioning.

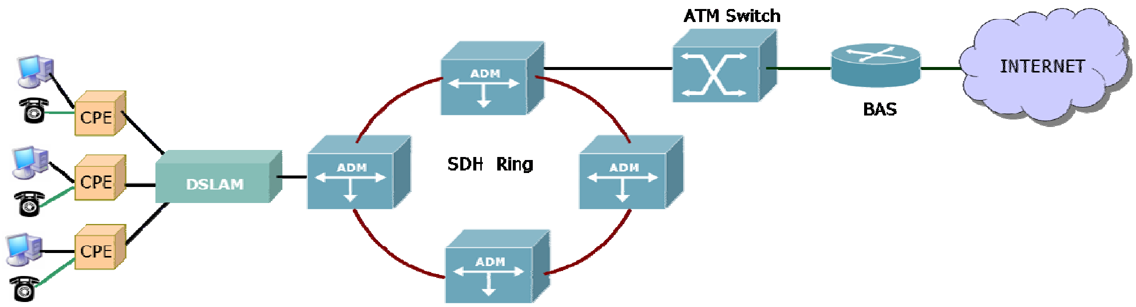

Figure 1: ADSL Based Broadband Access

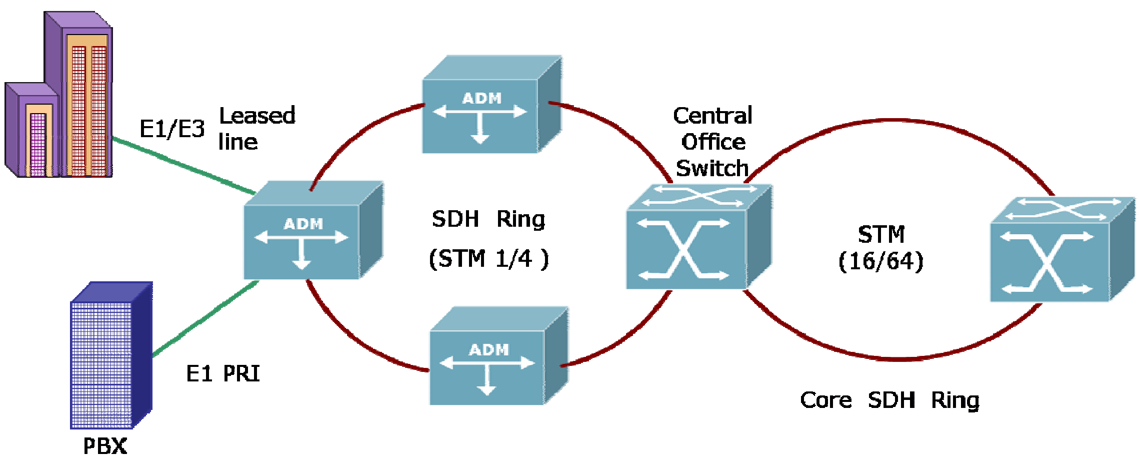

Figure 2: TDM Based Access Network

1.2 Metro Access

This part of the network provides the aggregation point for customers. The various building nodes (DSLAM/ Remote Terminals (RT)) are aggregated at the CO side. The building nodes may be connected together in a ring fashion. This building aggregation ring, traditionally, are SDH rings with STM 1/4 interfaces. With requirement of capacity expansion, the carriers have upgraded some of these rings to STM 16 also.

1.3 Metro Core

The building aggregation nodes (BAN) or CO are connected together to form a Metro Core ring. The legacy networks typically have these rings based on SDH with STM 16/64 interface as shown in Figure 2. The traffic from the Metro Core is transported over national and international networks.

2 Next Generation Metro Access

2.1 Metro Access

As discussed above, the legacy networks have used optical fiber with SDH transport in Metro Access and Metro core. SDH based networks have been optimized for TDM traffic.

2.2 Next Generation SONET/SDH

With an increase in IP traffic, SDH networks have evolved to Next Generation SDH networks. In Next Generation (NG) SONET/SDH (Figure 3), the Ethernet frames are encapsulated in SDH payloads. Next Generation SDH essentially has Ethernet tributaries in addition to E1 and E3. All other features of SDH networks like 50 ms protection and restoration are retained. The NG SDH defines framing mechanism for encapsulating Ethernet packets and flow control mechanism to address rate mismatch between standard Ethernet interface and SDH bandwidth.

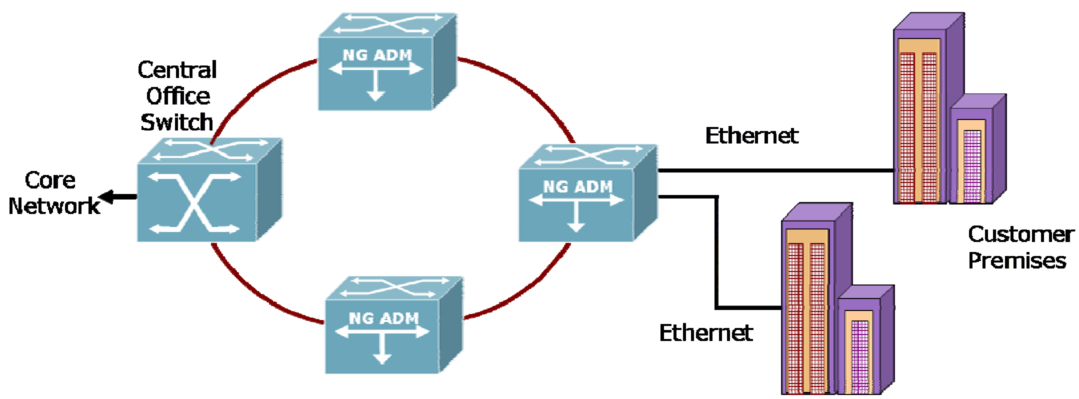

Figure 3: Next Generation SDH

Next Generation SONET/SDH deployments have become very popular in those Carriers who already have installed base of SONET/SDH networks. NG SONET/SDH networks are a good choice of deployment when the predominant traffic is still circuit switched. NG SONET/SDH may turn out to be an inefficient means of transport if the predominant traffic is bursty packet switched data. In such a scenario, metro networks based on Optical Ethernet may turn out to be more advantageous.

2.3 Optical Ethernet

Optical Ethernet rings with 1/10 Gigabit Ethernet interfaces, have, recently been advocated to be the most efficient way of data transport in Metro Access (Figure 4). Several efforts have been directed recently to develop Metro access technology by leveraging the potential of Ethernet. There are many advantages of Ethernet based access in Metro networks. The Ethernet based broadband access reduces the cost of provisioning in a significant way. It also provides advantages in terms of flexibility, ease of interworking and high bandwidth at a competitive cost.

However, Ethernet in its native form does not have carrier class features like quality of service guarantees, admission control, protection and restoration, performance management, support of multi-service transport. Some of these limitations of Ethernet have been addressed by various equipment vendors. These include enhancing the Ethernet switches with QoS features and SLA management. Ethernet does not have any concept of Virtual Circuit like ATM. However, by exploiting Point to Point VLAN capability of IEEE 802.1Q, an Ethernet Virtual Circuit can be emulated. But VLAN poses the problem of providing only 4096 virtual circuits. To address this solution, the concept of stacked VLAN with Q-in-Q feature has been introduced that would allow aggregation of VLAN based circuits into a trunk [2].

IEEE is also standardizing Provider Bridge architecture (IEEE 802.1ad) with several features that would enable Ethernet to have Metropolitan Area Network (MAN) features.

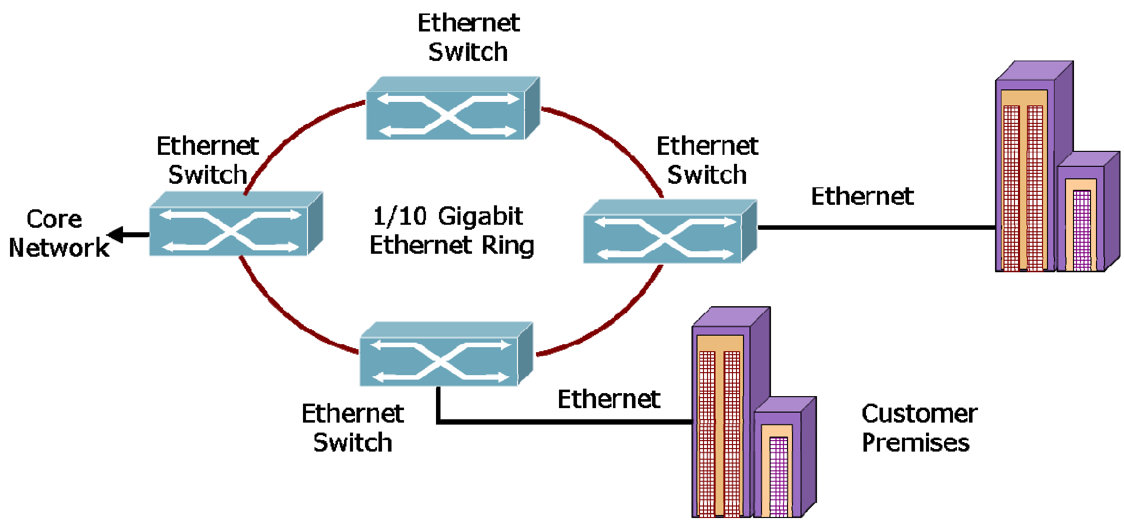

Figure 4: 1/10 Gigabit Ethernet Ring

To accelerate the deployment of Ethernet based access networks, Metro Ethernet Forum (MEF) [1], an association of equipment vendors, solution providers and carriers, has been launched. MEF has standardized a set of Ethernet services also called E-Line and E-LAN. Since almost all enterprises have Ethernet as their local area networks, E-LAN provides a powerful service for connecting together several branches of an enterprise to provide a Layer 2 VPN. These Ethernet services provide an additional impetus for deploying Metro Ethernet network and services.

MPLS can also be used as the underlying transport mechanism for deploying Metro Ethernet network. The IETF has defined the concept of pseudowire (PW). An Ethernet PW can enable Ethernet frames to be carried over MPLS network. Mechanisms have been defined for encapsulating Ethernet frames over MPLS [Martini Draft]. The IETF has also defined mechanisms for providing Virtual Private LAN Service (VPLS) that emulates an Ethernet LAN over MPLS network.

MPLS can provide many carrier class features like scalable aggregation and end to end QoS by provisioning guaranteed bandwidth Label Switched Path (LSP). MPLS offers circuit setup and traffic engineering capabilities. MPLS traffic engineering can offer protection and restoration by provisioning Backup LSP and mechanisms like Fast Reroute. The IETF is also considering TDM circuit emulation over MPLS network. Thus MPLS network bridges the gap for deploying Ethernet services. MPLS based Metro Core with “Ethernet over MPLS PW” seems to be the preferred technology for deploying next generation Metro Access and Core Networks. An excellent introduction to these concepts can be found in [2].

2.4 First Mile- Ethernet

The demand for deploying optical fiber in first mile access is also increasing due to growth in bandwidth requirements. To enable triple play of voice, video and data, many Greenfield service providers are laying fiber to the building. Multi-Tenant Unit (MTU) or Multi-Dwelling Unit (MDU) based Ethernet devices can be used to provide 10/100 Mbps interfaces directly to the customers in the building over Cat-5 cables.

These switches may be connected over fiber to the larger aggregation switches in a hub and spoke topology. In hub and spoke topology, protection may be achieved using 802.3ad link aggregation or dual homing [2].

Alternately, these switches may be connected together in a ring fashion. These access rings, however, may require to have protection and restoration mechanism. The standard technique to achieve protection and restoration is IEEE 802.1w Rapid Spanning Tree protocol. The difficulty, however, is that the rapid spanning tree protocol does not achieve resilience time of 50 ms. The challenge therefore is to develop solutions that would achieve fast resilience time, Many proprietary solutions have been proposed by some vendors that claim to achieve 50 ms resiliency.

3 Challenges Before Service provider

As discussed above, Ethernet over Fiber seems to be the technology of choice for next generation broadband networks. Fiber based access networks with MPLS as the transport technology in the core is likely to address all challenges of scalability, QoS, multi-service transport and protection and restoration.

However, today, the service providers are faced with many challenges in evolving towards this goal of an ideal next generation network. The followings capture some of these.

3.1 Incumbent Service Provider

Incumbent services providers may already have installed based of SDH networks in metro access and core. They may upgrade this network to NG SDH. They also have installed base of copper in the first mile access network covering a distance from about 500 meters to about 1 Km at some places (For some places, the loop length may be more than 1 Km and extend up-to 3-4 Km. In such cases, the service providers may find

ADSL2 as good option for residential users). These service providers would like to deploy Ethernet in First Mile Access networks that would integrate with NG SDH network. At the same time, they would also like to provide TDM quality voice services (standards Plain Old Telephony Service) as this continues to constitute a bulk of their service offerings. As a result, these service providers are looking for a network architecture that would not only provide existing legacy services like voice but also next generation services based on Metro Ethernet. Moreover, these service providers would like their investment in the equipment and solution to be future-proof in the sense that the solution should be up-gradable to next generation architecture with incremental cost.

3.2 Greenfield Service Provider

The Greenfield service providers may not have installed base of SDH network and therefore can directly leap-frog to deploy fiber based Metro Ethernet network. However, while Fiber to every building is the ultimate goal to enable triple play services, the deployment scenarios in the field are very complex. It may not be possible to deploy fiber to each and every building due to various local factors including the problem of laying and maintaining the fiber plant in a given geography. Thus there may be deployment of copper for last few hundreds of meters. It thus means that the solution should have capability of various interfaces like broadband Ethernet (based on QAM/DMT), VDSL, Ethernet over Cat 5 and the emerging new standard IEEE 802.3ah apart from fiber interfaces.

3.3 Other Service Provider

Some service providers fall between the above two categories. These service providers have deployed a mix of networks. They have installed SDH network for legacy telephony services and also have overlay IP/MPLS network for broadband Internet access. Typically the remote terminals (RT) are attached to the SDH rings. RT provides legacy POTS services over copper. An ideal RT would be one that provides legacy voice services and broadband data services in the First Mile access where the voice is transported over SDH network and IP traffic is backhauled over IP/MPLS network. We will see later how our solution can address these challenges in a cost effective manner.

Moreover, the service providers are also concerned with port-fill rate of Metro Ethernet devices. In the current Metro Ethernet deployment, the Ethernet switches deployed in the basement of a building may not have all ports occupied leading to higher cost per port. This demands that the devices should have appropriate aggregation hierarchies leading to an optimal cost per port for the operators.

The Greenfield providers would also like to deploy legacy services to some SME customers like E1 PRI interfaces (for PBX connectivity). This mandates that the solution should be able to perform circuit emulation of E1 over Metro Ethernet network while providing other value added data services.

The other generic requirements of broadband access architecture can be described as follows-

Flexible and Fast Deployment- The architecture should be flexible to deploy in various deployment scenarios. The service providers should be able to provision the interfaces rapidly without any *truck rolls*.
Scalable Layer 2 Aggregation-The architecture should be able to effectively aggregate the layer 2 traffic from customers in a scalable manner. The solution should provide isolation of customers' traffic also.

Quality of Service-The service providers should be able to provision guaranteed quality of service for voice and video. It should also be possible to perform usage based billing.

4 EISOACCESS SOLUTION

As discussed above, the requirements of service providers are very diverse and complex. It is therefore very challenging to develop a unified architecture that addresses most of these requirements in one single integrated framework. Eisodus Networks has developed EisoAccess solution to meet these goals.

Eisodus has developed architecture for QoS management and scalable aggregation for Ethernet services in First Mile Access network. As shown in Figure 5, the architecture comprises of two kinds of nodes-

1. ENODE
2. ESLAM

ENODE is an intelligent MDU device which provides the first level of aggregation. The second level of aggregation is provided by ESLAM.

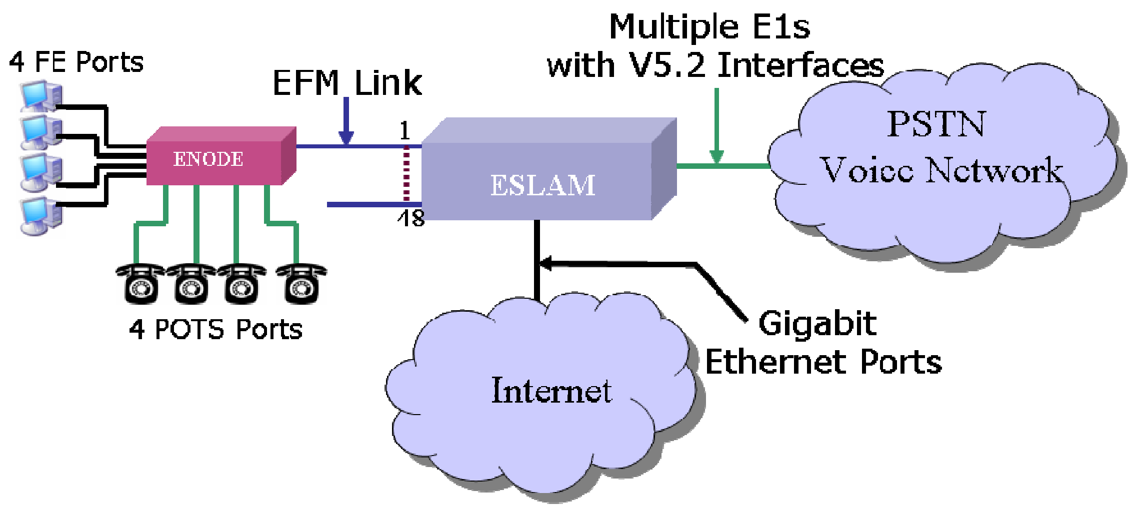

Figure 5: EisoAccess Solution

4.1 ENODE

ENODE is slated to be located on the floor of a building as MDU. It has 4 Data ports and 4 POTS ports. ENDOE has the following features-

1. ENODE provides the first level of aggregation. The four data customers and four voice customers are aggregated at this node. The node provides QoS features like bandwidth reservation, priority queuing and isolation of customers' traffic.
2. An Ethernet circuit with traffic management features conforming to MEF specification (MEF 10) can be established through service provisioning features of Element Management System.

3. The port of an ENODE defines an Ethernet UNI between the subscriber and the First Mile Access Network.
4. The node also performs TDM loop emulation in the first mile through an efficient proprietary protocol called Ethernet Adaptation Layer (EAL) that would integrate with MEF's Circuit Emulation mechanism in Metro Access (MEF 8).
5. The uplink of ENODE can have variety of physical interfaces like QAM based broadband Ethernet, Ethernet over Cat 5, Ethernet over Fiber etc to suit various deployment scenarios.
6. The ENODE is also remotely powered from ESLAM leading to operational simplicity.

ENODE has only 4 data ports and 4 voice ports to provide an optimal first level aggregation. In alternate configuration as shown in Figure 7, ENODE has support for E-1 PRI through MEF style circuit emulation. Some of the unique features that distinguish an ENDOE from competitive MTU/MDU switch available from other vendors are-

1. ENDOE can have several PHY interfaces for uplink.
2. ENODE has support for TDM loop as well as circuit emulation.
3. ENDOE is remotely powered.
4. The port aggregation provides the right kind of first level aggregation.

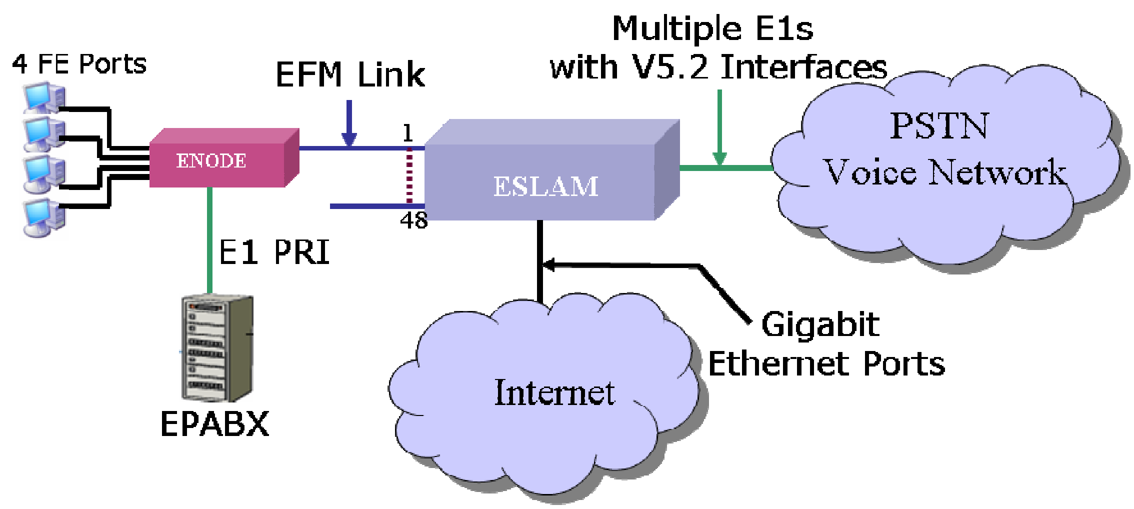

Figure 6: EisoAccess Solution with E1 Interface

4.2 ESLAM

The ESLAM provides the second level of aggregation in the First Mile hierarchy. ESLAM is a chassis based system with line cards that can be configured for different PHY interfaces. The following are some of the features of ESLAM-

1. ESLAM has four different kinds of line cards- line card with QAM based broadband Ethernet interface, line card with 10/100 Base TX Ethernet, line card with 10/100 Base FX interface and Gigabit Ethernet line card.
2. ESALM offers a rich set of SLA and bandwidth management features for provisioning MEF services like E-Line and E-LAN.
3. It also provides interface to the TDM network through V5.2 protocol over multiple E1 interfaces.
4. ESLAM has standard management features including RMON, SNMP and hierarchical CLI.

5. ESLAM has built in support for MEF style circuit emulation.

The ENODEs with variety of physical interfaces can be connected to the ESLAM in a hub and spoke topology. The ESLAM themselves can be connected together in a ring fashion to form First Mile Access ring. In alternate scenario, ESLAM can be attached to an existing SDH/IP/MPLS based ring. The readers are referred to [3] for detailed specifications.

4.3 EisoEMS

The EisoAccess architecture is remotely managed through EisoEMS. EisoEMS performs customer and service provisioning including provisioning for Ethernet Virtual Circuit (EVC) with traffic management features. It also performs performance management, fault management, configuration management and alarm correlation. The EMS is based on object model that conforms to emerging MEF standard (MEF 7) [4].

4.4 TDM Voice in EisoAccess

Providing TDM quality voice capability in EisoAccess architecture is a unique feature of the solution. Currently, MEF is standardizing Circuit Emulation over Metro Ethernet. However, there is no effort towards architecting Loop Emulation. Eisodus Networks has developed a protocol called Ethernet Adaptation Layer (EAL)[1] [5] that provides Loop Emulation for providing standard POTS interfaces to the subscriber. EAL interfaces to V5.2 protocol for PSTN connectivity at the aggregation node ESLAM. For circuit emulation, EAL has MEF standards style features [6] and will be able to interwork with MEF conforming devices. Eisodus Networks has also developed innovative algorithm for frequency synchronization over Metro Ethernet network.

5 EisoAccess Value Propositions and How Service providers Can Benefit from Eisodus?

The above EisoAccess solution offers several advantageous propositions that position us in a unique way versus our competitors. These value propositions can be outlined as below-

1. EisoAccess solution offers flexible interfaces in the same architecture. For Greenfield deployment, these interfaces could be fiber and Cat-5. For other deployment, an appropriate choice of interfaces can be configured to give optimal utilization of copper and fiber plant. We will discuss this issue further in the next sub-sections.
2. EisoAccess solution provides seamless integration with TDM network by offering TDM loop emulation and circuit emulation. It also has V5.2 interface.
3. EisoAccess solution can provision standard MEF services like E-Line and E-LAN and offers a QoS enabled architecture for next generation services like Voice over IP and IP TV.

Thus the architecture is positioned in a unique way between pure IP DSLAM solutions on the one hand and pure fiber based Ethernet solution on the other hand. It enables

[1] EAL is a registered trademark of Eisodus Networks.

optimal utilization of external cable plant offering a very cost effective way of provisioning not only the standard voice services but at the same time Ethernet services in the same solution. We now discuss how these value propositions can be successfully exploited by the service providers in different deployment scenarios. We discuss four case studies.

5.1 Case 1- Service Provider with Installed NG SDH network

In this case, the service provider already has an installed base of NG SDH network. The NG SDH with Ethernet interfaces are deployed in the customer premises and the leased line connectivity is provided over the Ethernet tributary. These customers can also be provided with E1/E3 connectivity for PBX etc. This deployment is very effective for premium corporate customers and deployed by some service providers.

This mechanism of provisioning service may, however, turn out be inefficient if there are multiple corporate customers in a high rise building or there are multiple SME located in adjoining buildings. In such cases, the service provider may deploy EisoAccess solution as shown in Figure 7. As shown in the figure, the NG SDH equipment may be installed in the basement of a building and ESLAM could be co-located with this equipment. The customers could be served as shown in the figure.

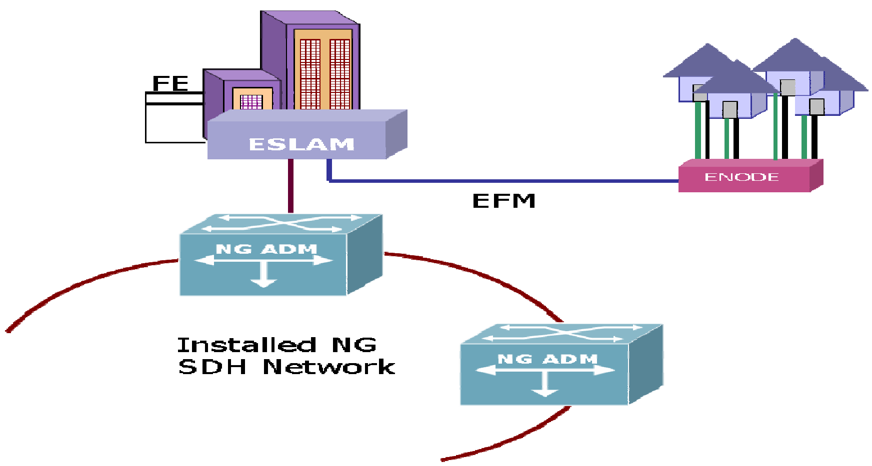

Figure 7: Deployment of EisoAccess Solution in Service Provider with Installed NG SDH

5.2 Case 2- Service Provider with Next Generation Ethernet network (Fiber + Copper)

In this case, the service provider is a Greenfield service provider who has installed IP/MPLS based transport network in Metro Core and Access. The core network may have several Metro Access rings attached to it. Each Metro access node may parent First Mile Access ring. The switches in the first mile access ring will be connected to the customer location through Cat-5 spurs. While this deployment is an ideal Metro Ethernet deployment, there are several practical problems associated with this. The standard access switches in the First Mile rings have typically 24 ports or 12 ports. However, the occupancy of the ports may not be more than 6 in a building (This is based on actual experiences of service providers in India). Moreover, there may be several customers in the adjoining buildings who may want to subscribe but may not be within 100 meters range for Cat-5. These customers can not be served unless another First Mile fiber is deployed to all these building which is usually not cost effective.

In such scenario, EisoAccess solution can be very effectively used. As shown in Figure 8, the First Mile Access network now has two hierarchies. The ESLAMs would be connected in a First Mile access ring. The ESALM is located in the basement of a building. The subscribers in the same building could be directly served from ESLAM over Cat-5 spurs. The subscribers located at few hundred meters could be served over the copper by ENODE as shown in the figure and the ESLAM having QAM based broadband Ethernet ports. The ENODE has only 4 data ports. By choosing an appropriate combination of ENDOE and ESLAM ports, optimal port occupancy can be achieved.

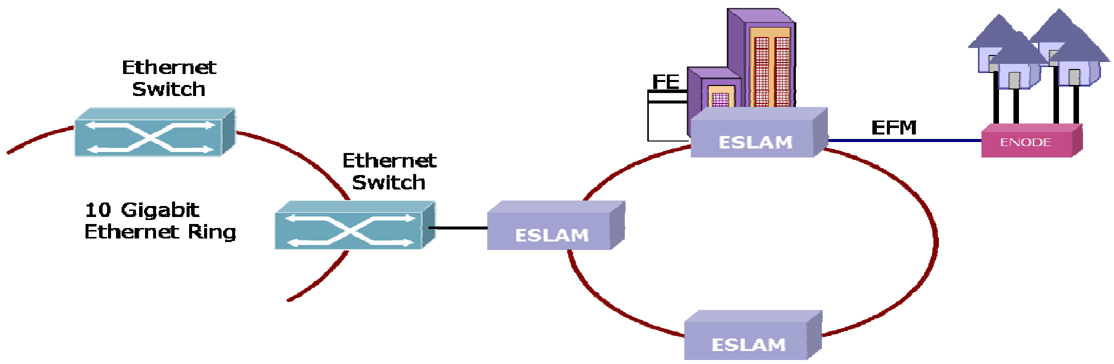

Figure 8: Deployment of EisoAccess Solution in Service Provider with Next Generation Ethernet Network

5.3 Case 3- Service provider with legacy SDH network and overlay IP/MPLS network

In this case, the service provider has a legacy SDH network for providing standard telephony service (Figure 9). The service provider may provide broadband service using a separate overlay IP/MPLS.

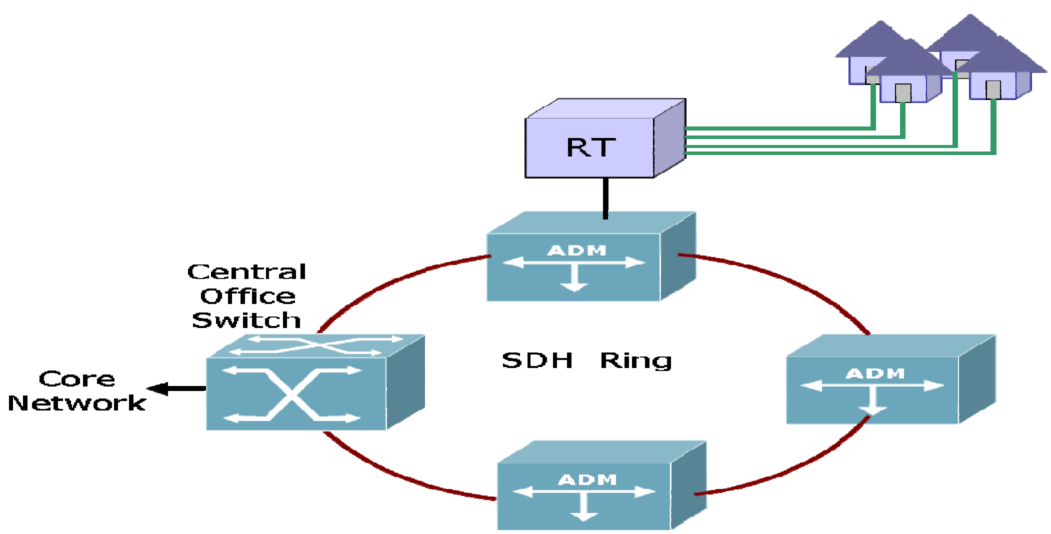

Figure 9: Service Provider with Legacy Network

In the First Mile access part for standard telephony service, separate copper wires are laid between the RT and the customers. The broadband service can be provided using IP DSLAM based solutions, the traffic of which is backhauled over IP/MPLS network. This solution turns out to be expensive for the following reasons- (a) For providing services, separate copper wires need to be laid (b) Typically, DSL CPEs do not provide any aggregation leading to high cost.

In such networks, EisoAccess solution provides unique advantages in terms of providing cost effective aggregation (Figure 10). The ENODE with 4 data ports and 4 voice ports can be located in the building premises and these ports can be aggregated over single copper wire. Moreover, the data services can also be integrated as ENODE provides a first level of aggregation. Enterprises and customers requiring E1 PRI/ V.35 connectivity may also be provided through ENODE as shown. The V5.2 interface provides added advantage.

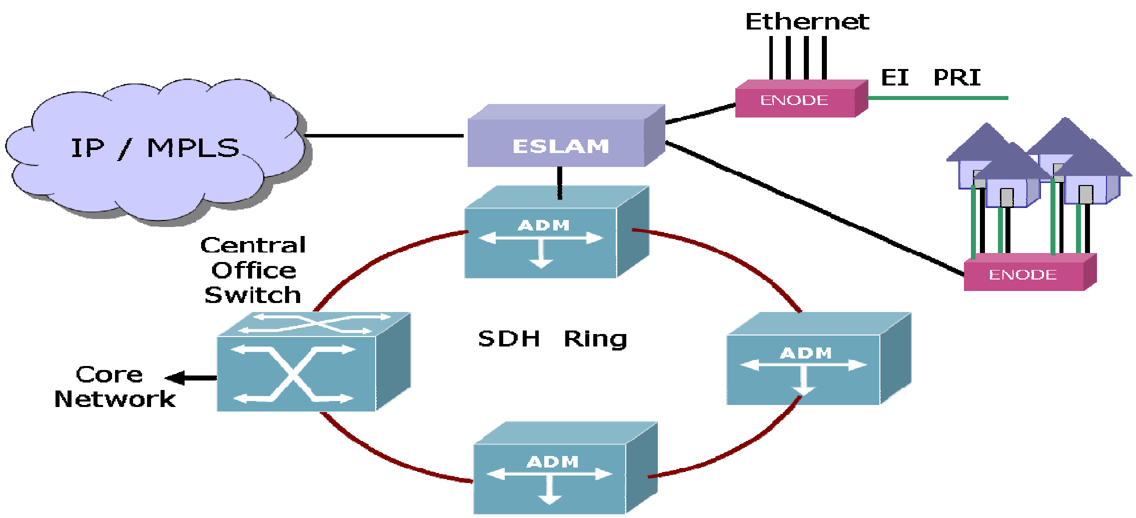

Figure 10: Deployment of EisoAccess Solution in Network with Legacy SDH Network and Overlay IP Network

5.4 Case 4- Greenfield service provider with Fiber based network

This is a future next generation network where the goal of providing fiber to every home is to be achieved. In this configuration, ESLAM is populated with fiber ports only. The ENODE also has fiber uplink. The ENODE has Cat-5 spurs to the individual customers for providing 10 Mbps kind of data rate for triple play applications.

6 CONCLUSIONS

Broadband access infrastructure has been advocated as the key to economic development. Triple play services like integrated voice, video and Internet data are going to be the major applications for residential users while Layer 2 VPN, Storage Area Networks etc will be the driving force for corporate and enterprises. Fiber to the Home (FTTH) and Fiber to the building (FTTB) based on Metro Ethernet appears to be the dominant choice for every service provider but there is still a long way to achieve this goal at-least in emerging markets like India. The legacy voice services like standard POTS, E1 PRI/V.35 still continue to be the service offerings while the market of broadband applications and services is growing. The service providers are looking for network architecture that can evolve towards a fiber based Metro Ethernet network. In this article, we have discussed how challenging this task is. We have discussed several technology options for the service providers and the associated challenges involved with these technologies. We have also described the EisoAccess solution developed by Eisodus Networks and demonstrated how this solution can be successfully exploited in various deployment scenarios.

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ACRONYMS

Acronyms	Explanation
ADSL	Asymmetric Digital Subscriber Line
ATM	Asynchronous Transfer Mode
BAN	Building Aggregation Node
CPE	Customer Premises Equipment
CO	Central Office
CLI	Command Line Interface
EFM	Ethernet in First Mile
IEEE	Institute of Electrical and Electronics Engineering
IETF	Internet Engineering Task Fore
IP	Internet Protocol
ISDN	Integrated Services Digital Network
LAN	Local Area Network
LSP	Label Switched Path
MEF	Metro Ethernet Forum
MPLS	Multiprotocol Label Switching
MTU	Multi-Tenant Unit
MDU	Multi-Dwelling Unit
PRI	Primary Rate Interface
PBX	Private Branch Exchange
POTS	Plain Old Telephony Service
PSTN	Public Switched Telephone Network
RMON	Remote Monitoring protocol
QAM	Quadrature Amplitude Modulation
SDH	Synchronous Digital Hierarchy
SONET	Synchronous Optical Network
SME	Small and Medium Enterprises
SNMP	Simple Network Management Protocol
STM	Synchronous Transfer Multiplexing
TDM	Time Division Multiplexing
VDSL	Very High Speed Digital Subscriber Line
VLAN	Virtual Local Area Network
VPN	Virtual Private Network

