CHALLENGES FOR BROADBAND DEPLOYMENT IN INDIA AND ROLE OF METRO ETHERNET

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ABSTRACT

In this article, we focus on the challenges and opportunities for broadband access deployment in India. We present an overview of the broadband scenario in India and the existing network architectures. We then review next generation technologies for broadband access including Metro Ethernet. We demonstrate how an optimal access architecture based on metro Ethernet can be developed for cost effective access infrastructure.

INTRODUCTION

The explosion of high bandwidth applications over Internet has fuelled the deployment of broadband access the world over. Apart from Internet browsing at high speed, multimedia applications like Internet Protocol TV (IPTV), video on demand, distance learning and Internet gaming are driving content over the network to the residential homes. These applications require substantially higher bandwidth than is available in conventional access. Likewise, in small and medium enterprises (SME) and corporate sectors, new services like Layer 2 Virtual Private Network (VPN), transparent Local Area Network (LAN) service and storage area networks (SAN) are going to be the main driving applications behind broadband access.

In recent times, India too has seen tremendous growth in its telecommunication infrastructure, especially in cellular telephony, due to some laudable efforts by the Government and the service providers. The deployment focus now is shifting towards broadband access services and in this regard, the Government of India has taken a number of proactive steps to boost the penetration and deployment of advanced telecommunications infrastructure in all parts of the country.

Broadband access is defined by the Telecom Regulatory Authority of India (TRAI) as "An 'always-on' data connection that is able to support interactive services including Internet access and has the capability of a minimum download speed of 256 kilo bits per second (kbps) to an individual subscriber from the Point of Presence (POP) of the service provider". It is expected that the "*availability of broadband services at affordable price-levels will have significant impact on gross domestic product (GDP) and attract new investment, create jobs and a larger more qualified labor pool, and increase productivity through infrastructure creation and access to new and improved services*." To this effect, the TRAI has set forth targets and guidelines in its Broadband Policy in 2004 [1] for service providers and other stake holders to grab this opportunity.

The challenges and the requirements of broadband access in India are radically different from the developed world. An affordability analysis [2] suggests that the Indian market is extremely cost sensitive. For example, a communications service provider in USA can expect to earn revenues to the extent of US$360 per year per household for 90% of households. In India, however, more than 90% of households may not be able to afford more than $100 (per household) for communication services. Further, in India, even a 256 kbps connection is deemed sufficient as broadband whereas countries like Canada rate broadband at 1500 kbps [3]. Clearly, there are wide gaps in service offerings and their affordability. While the potential of Indian market is huge, a new solution paradigm both in terms of technical and commercial framework is required to provide sustainable broadband access at affordable prices.

In this article, we focus on the challenges faced in developing and deploying optimal access network architecture for service providers in India. We begin with a review of the broadband deployment scenario in India and the problems that plague service providers. We also describe the technologies in use today for deployment and argue why these are less than effective in the Indian context. We then provide an overview of technological advancement that has taken place in next generation access networks in recent times. Finally, we explain how Ethernet based access networks can provide relief to some problems of service providers. We discuss a baseline set of technologies that result in a cost-effective and elegant system and that could potentially overcome the hurdles faced by the service providers in India while providing a rich mix of services.

BROADBAND SCENARIO IN INDIA

The current state of net-density and targets set by the Telecom Regulatory Authority of India as compared with other countries in Asia-Pacific are shown in Table 1. Note that we have computed the net-density based on the number of households in the country, and not per individual as is the case for tele-density, since that is a more appropriate comparison measure for broadband access services.

Table 1 Net-density and Targets

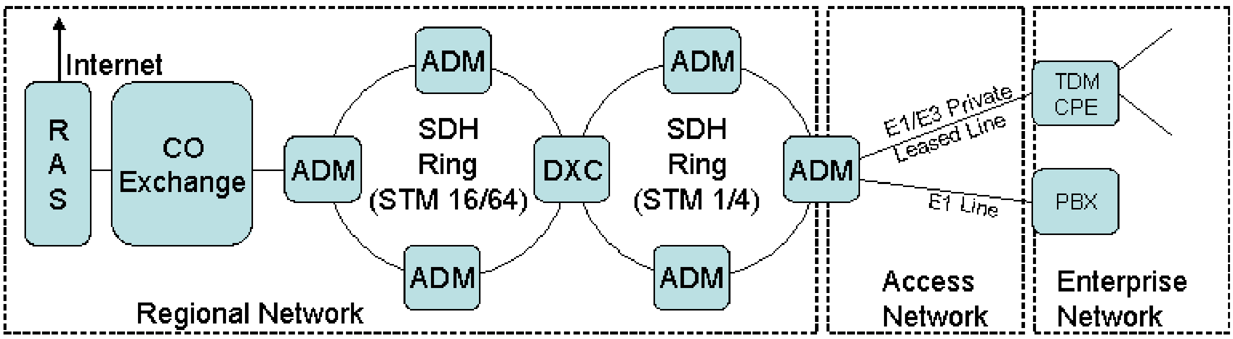
Parameter	Korea (end 2005)	China (end 2005)	India			
			(end 2005)	2005 Target	2007 Target	2010 Target
Households	14.3M	333M	192M	-	-	-
No of PCs (per 100 households)	11.3M (78.9)	36M* (10.81)	14M (7.29)	-	-	-
Dial-up connections (per 100 households)	0.06M (0.4)	51M (15.3)	6.7M (3.49)	6M (3.12)	18M (9.38)	40M (20.83)
Broadband connections (per 100 households)	11M (76.96)	64.3M (19.3)	0.903M (0.47)	3M (1.56)	9M (4.69)	20M (10.41)
Charges per 100kbps per month USD	0.25	2.52	7.88	-	-	-

Sources: [1][4][5][6][7].*Approximate value based on 2004 statistics.

It may be interesting to note that the Indian government expects dial-up connectivity to be the predominant form of Internet access even beyond 2010. Further, these targets seem quite conservative when compared to the current state of deployment in other Asian countries. It is possible that the TRAI has taken into consideration that from the 192 million households in the country, the urban and semi-urban areas only account for 53 million, whereas the rest reside in the 607,000 rural villages spread across the country where the tele-density even today is as low as 1.74. Serving this large chunk has been a major task for the government and telephone service providers over the last few years. We will show that with an improved technical architecture based on Ethernet, this may be achieved effectively.

Broadband service providers in India are pitted against a number of odds – poor infrastructure, diverse demographics, and high capital costs. In other countries, service providers have used the existing wired infrastructure, viz., the telephone network and the cable TV network, to boost broadband service deployment. In India, however, both these networks have problems. Next, we examine these cases and provide evidence as to why neither of these will be effective in achieving the set targets, let alone exceed them. We later describe a newer deployment model that has many cost advantages. To begin with, we briefly review the legacy Time Domain Multiplexing (TDM) model used even today by service providers for serving many enterprise customers.

Enterprise TDM based Model



RAS: Remote Access Server
CO: Central Office
ADM: Add-Drop Multiplexer
SDH: Synchronous Digital Hierarchy
DXC: Digital Cross Connect

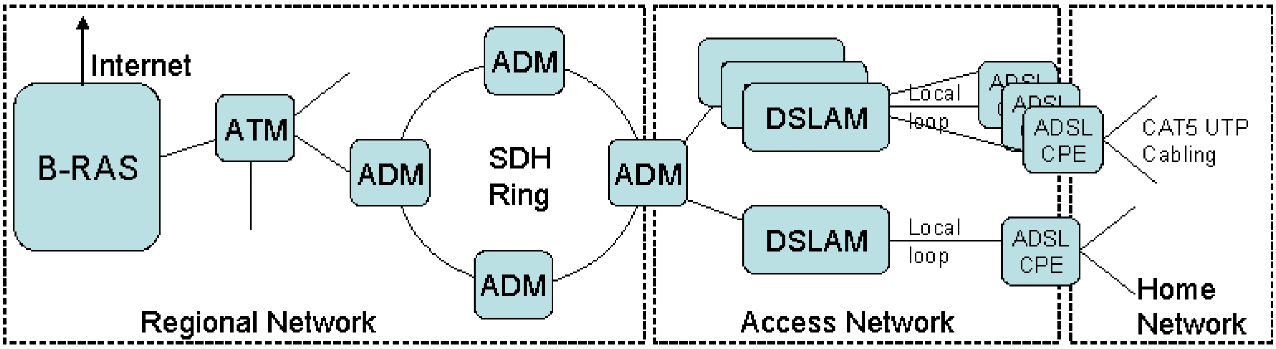
TDM: Time Domain Multiplexing
CPE: Customer Premises Equipment
PBX: Private Branch Exchange
STM: Synchronous Transport Mode

Figure 1: Enterprise TDM Model

For enterprises and corporate, the first mile access has been traditionally based on TDM based private lines like E1/E3 leased lines or Synchronous Transport Mode (STM)1 interfaces for higher bandwidth as shown in Figure 1. These customers may also subscribe to E1 Primary Rate Interface (PRI) for their Private Branch Exchange (PBX) connectivity which can be easily provided in this TDM network. The TDM lines are aggregated in the Synchronous Digital Hierarchy (SDH) network through Add-Drop Multiplexers (ADMs) and Digital Cross Connects (DXCs). The data finally reaches the Central Office (CO) Exchange where the voice traffic is sent onward to the Public Switched Telephone Network (PSTN) and the data traffic is passed to a Remote Access Server which connects to the Internet.

This deployment model uses expensive TDM circuits and suffers from slow provisioning. Moreover, it does not offer any flexibility to scale with needs of the customers. Also the reach of the E1/E3 lines is limited to 300m, unless it is extended by technologies like Symmetric High-speed Digital Subscriber Line (SHDSL) with telephone grade copper. However, if telephone copper is to be used, the DSLAM model described next is more efficient.

DSLAM Model



ATM: Asynchronous Transfer Mode
ADM: Add-Drop Multiplexer
SDH: Synchronous Digital Hierarchy
B-RAS: Broadband Remote Access Server
ADSL: Asymmetric Digital Subscriber Line
CPE: Customer Premises Equipment
DSLAM: DSL Access Multiplexer
CAT5 UTP: Category 5 Unshielded Twisted Pair

Figure 2: DSLAM Model

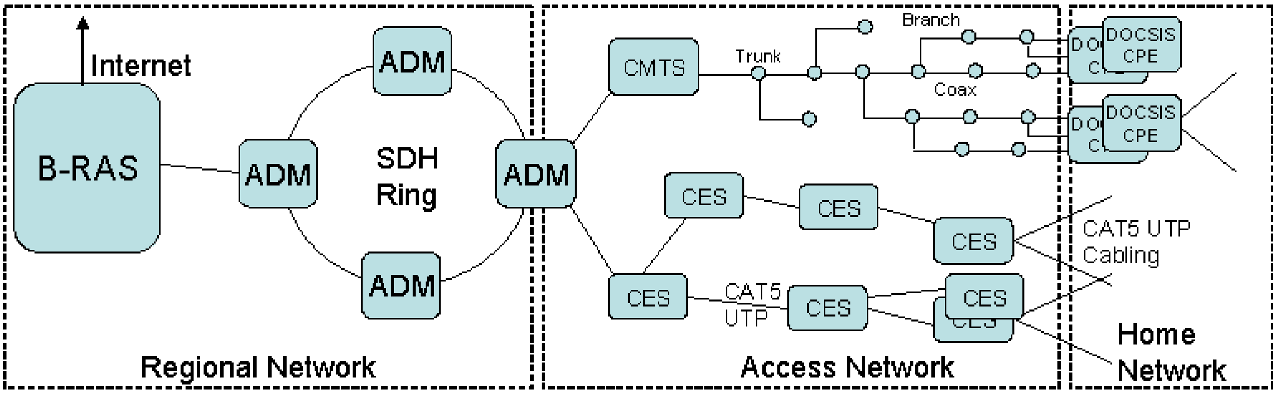
Figure 2 shows a Digital Subscriber Line (DSL) Access Multiplexer (DSLAM) based network model in use today. Broadband service providers use existing or newly installed copper pairs to deploy Asymmetric Digital Subscriber Line (ADSL) in the first mile access network through DSLAM systems. The DSLAMs are connected in the backhaul via a SDH network consisting of multiple hierarchies of SDH rings which are eventually connected to the Broadband Remote Access Server (BRAS) through Asynchronous Transfer Mode (ATM) switching network.

This is a popular deployment model being used successfully in many countries around the world. However, due to the shortage of good quality copper infrastructure in India, this network model has limited reach. The installed base of copper in India is owned mostly by the incumbent telcos (state-owned telecommunication service providers-Bharat Sanchar Nigam Limited (BSNL) and Mahanagar Telephone Nigam Limited (MTNL)), totaling some 40 million lines. Of these 14 million are deployed in rural areas and of the 26 million lines remaining, only about 7 million [1] are technically fit for carrying DSL signals. The Broadband Policy targets required these incumbent telcos to provide at least 1.5 million broadband connections by end-2005. They were able to reach only 0.35 million by November 2005 [8]. To improve the roll-out, the TRAI also suggested that the incumbent telcos allow shared use of the installed copper - known as local loop unbundling - with the new competitive telcos (like Reliance Communications Infrastructure Limited, Videsh Sanchar Nigam Limited (VSNL), Bharti Televentures Limited, Sify Limited, etc), something that has also hardly happened [8]. Clearly, if the targets for broadband access are to be met using the DSLAM model by itself, a lot of new copper will have to be laid across the country. This is a very expensive and time consuming proposition resulting in a major hike in the per port cost.

Apart from the intensive use of copper, this network architecture makes use of high cost network elements in the SDH and ATM backhaul making the overall per port cost of the system unaffordable in India despite falling prices of ADSL equipments (including ADSL2+ and new generation IP DSLAM).

Cable TV and Local Service Provider Model

The cable TV network in India caters to about 65 million homes. This could have been used for broadband deployment using the Data over Cable Service Interface Specification (DOCSIS) standard as shown in Figure 3. This network is mostly owned by local area service providers who deploy the cables aerially looping them from building to building. Thus deploying and maintaining this network is operationally challenging. These local service providers have strictly guarded boundaries, thus depriving the customer any benefit due from service provider competition. Further, the cable infrastructure in most cities does not have the bi-directional amplification support required for broadband services. Broadband service deployments on the cable TV network in India have been less than 1% of the total Internet services. However, using the local cable TV operators as franchisees, a new business model has gained extensive popularity in urban areas.



ADM: Add-Drop Multiplexer
SDH: Synchronous Digital Hierarchy
B-RAS: Broadband Remote Access Server

CMTS: Cable Modem Termination System
DOCSIS: Data Over Cable Service Interface Specification
CPE: Customer Premises Equipment
Coax: Television grade Coaxial Cable
CES: Consumer grade Ethernet Switch
CAT5 UTP: Category 5 Unshielded Twisted Pair

Figure 3: Cable TV and Local Service Provider Model

Broadband service providers team up with the local cable TV service provider to provide a Local Area Network (LAN)-like Ethernet network infrastructure as shown in Figure 3. These local (cable TV) service providers deploy Ethernet networks in their neighborhoods with low cost consumer grade network elements, pulling Category 5 Unshielded Twisted Pair (CAT5 UTP) cable with the existing coaxial cable. To overcome the 100m Ethernet cable length limitation, a small low-cost Ethernet switch is added as a repeater wherever required, sometimes even exposed to the elements. The broadband service provider then terminates a connection from the metro core to the local service provider’s control room, from where it is distributed throughout the neighborhood.

While this model has served as a highly cost competitive solution and was considered as a major solution to accelerate broadband in India, it suffers from a number of important bottlenecks. Firstly, the entire network being enterprise grade Ethernet, no security or user isolation is provided and thus virus attacks and hacking attempts are quite rampant. This leads to frequent user downtime and thus service unavailability. The other problem is that since the access network is using unmanaged Ethernet elements, any downtime can only be reported by the subscribers themselves – there is no proactive network management. Thirdly, there is no traffic policing or rate limiting within this network creating an opportunity for a malicious user to disrupt the network with attacks on the Ethernet switches. There are also no quality-of-service guarantees and all users’ applications are treated equal causing unbounded packet latencies and perceivable loss of quality during voice and video sessions. This network also has no built-in redundancy causing major outages if any upstream device or link is faulty. This problem is further aggravated by the fact that since no network management system is present, the problem only gets detected and resolved when some subscriber actually calls in to register a complaint. Despite these drawbacks, such systems have been running in large part of urban India.

NEXT GENERATION ACCESS TECHNOLOGIES

In the previous section, we have discussed existing access architectures in India. We now review next generation access technologies and then argue how we can design a cost-effective architecture.

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 (QoS) guarantees for real time traffic and protection and restoration capability. Toward this goal, several new architectures have emerged.

Next Generation SDH

With an increase in IP traffic, SDH networks have evolved to Next Generation (NG) SDH networks where Ethernet frames are encapsulated in SDH payloads. Next Generation SDH essentially has Ethernet tributaries in addition to E1s and E3s. The protocol defines mapping of SDH payload to SDH channels which are either higher-order or lower-order virtual containers (VC). A key mechanism is Virtual Concatenation (VCAT) which deals with allocation of non-contiguous VC. All other features of SDH networks like 50 ms protection and restoration are retained. The NG SDH also defines flow control mechanism to address rate mismatch between standard Ethernet interface and SDH bandwidth. Next Generation SDH deployments have become quite popular with those carriers who already have a large installed base of SDH. NG SDH networks are a good choice of deployment when the predominant traffic is still circuit switched. However, NG SDH may become inefficient 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.

Optical Ethernet and MPLS

Optical Ethernet (or Ethernet over Fiber) rings with 1/10 Gigabit per second (Gbps) Ethernet interfaces are advocated to be the most efficient way of data transport in metro access. Several efforts have been directed to develop metro access technology by leveraging the potential of Ethernet. The Ethernet based broadband access reduces the cost of provisioning in a significant way due to relative technical simplicity and large installed base. It also provides advantages in terms of flexibility, ease of interworking and high bandwidth at a competitive cost. Through rate limiting, Ethernet can offer a wide range of data rates from 128 Kbps to 10 Gbps.

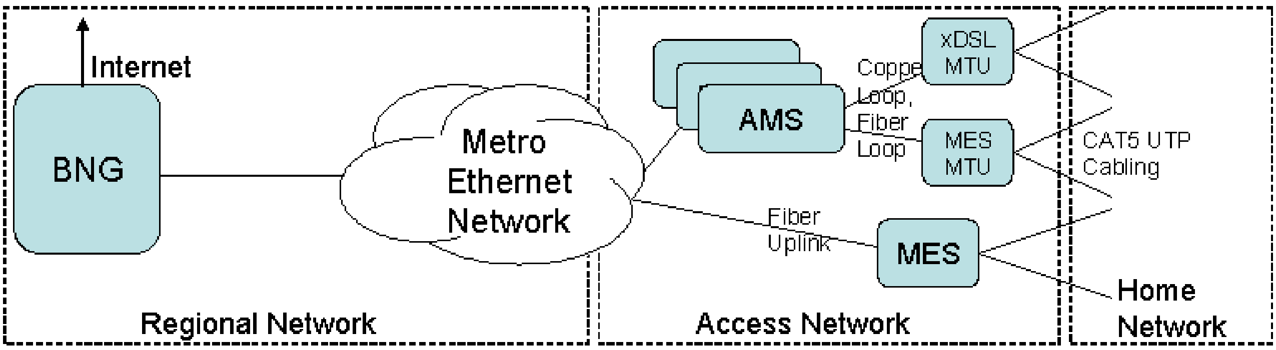
However, Ethernet in its native form does not have carrier class features like quality of service guarantees, admission control, protection and restoration, performance management or support of multi-service transport. Some of these limitations of Ethernet have been addressed by various equipment vendors and standards bodies such as the IEEE. These include enhancing the Ethernet switches with QoS features, and Service Level Agreement (SLA) management and applying the Virtual Local Area Network (VLAN) concept to implement Ethernet virtual circuits. The concept of stacked VLANs has been used to overcome the 4096 space limitation of VLANs. Rapid Spanning Tree Protocol (RSTP) based on the IEEE 802.1w can be used for protection and restoration. IEEE has also standardized a new Provider Bridge architecture (IEEE 802.1ad) and is in the process of introducing new standards (Operations, Administration and Maintenance (OAM) capabilities in IEEE 802.1ag, large virtual circuit space in IEEE 802.1ah, etc.). This would enable Ethernet to have carrier class Metropolitan Area Network (MAN) features. More details about these issues are given in [9].

Despite these advancements, an all Ethernet network continues to suffer from scalability and service provisioning issues. There are also traffic engineering bottlenecks as spanning tree allows only one loop free path which can result in uneven load distribution. Multiprotocol Label Switching (MPLS) can address the limitations of VLAN space, scaling with spanning tree, and other traffic engineering challenges**.**

MPLS can 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 thereby emulating a single Ethernet link between two end points. Pseudowire emulation edge to edge (pwe3) control protocol signals a pseudowire. Mechanisms have been defined for encapsulating Ethernet frames over MPLS (RFC4448). 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 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 Carrier Ethernet services. To accelerate the deployment of Ethernet based services, Metro Ethernet Forum (MEF), has also been formed.

TOWARDS AN OPTIMAL ACCESS ARCHITECTURE



BNG: Broadband Network Gateway

xDSL: Any Digital Subscriber Line
AMS: Access Multiplexer/Switch
CPE: Customer Premises Equipment
MES: Metro Ethernet Switch
MTU: Multi-Tenant Unit
CAT5 UTP: Category 5 Unshielded Twisted Pair

Figure 4: Next Generation Access Architecture

Among the various architectures discussed above, optical Ethernet (fiber based Ethernet networks) in first mile with MPLS as the transport technology in the core has the potential to address various challenges of scalability, QoS, multi-service transport and protection and restoration. However, today, the service providers in India are faced with many challenges in evolving towards this goal of an ideal next generation network.

State-owned incumbent services providers already have installed base of SDH networks in metro access and core and they are upgrading this network to NG SDH. They also have an installed base of copper in the first mile access network covering a distance from about 500 meters to about 3-4 Km at some places. These service providers may find ADSL2 a suitable option for residential users. However, as already discussed, a large part of this copper plant is unusable for carrying DSL signals and as we will outline below, the DSLAM model becomes an expensive model.

MES Architecture

The Greenfield service providers may not have installed base of SDH network and therefore can directly leap-frog to deploy fiber based Ethernet network. These service providers may have MPLS as the transport core and Ethernet in access network. Metro Ethernet switches can be deployed in the basement of a building and the subscribers of the building are served from the building switch. We call this architecture as Metro Ethernet Switch (MES) model as shown in Figure 4. In the MES model, service providers are most concerned with the port-fill rate of these Ethernet devices. In the current Metro Ethernet deployment, the Ethernet switches (typically having 16 or 24 ports) may not have all ports occupied (due to length limitations or in lower density areas) leading to higher cost per port.

While fiber to every building (FTTB) is the ultimate goal to enable triple play (data, voice and video) services, the deployment scenarios in the field are very complex. Due to various topographical and local factors, it may not be possible to deploy fiber to each and every building. Thus, in some places, there have been deployments of new copper plant for last few hundreds of meters-possibly up to 1 Km. To serve the diverse array of scenarios equally well, the optimal solution should have capability of using various access technology interfaces like Ethernet over CAT5, Ethernet over Fiber, Very high-speed DSL (VDSL), and the emerging new standard IEEE 802.3ah interfaces. This leads to the following architecture.

DSL/MES-MTU architecture

In this section, we provide the specifications of an optimal architecture that is very cost competitive for broadband deployment in India. This architecture has two levels of aggregation hierarchies-

1. Multi-Tenant Unit (MTU)
2. Access Multiplexer/Switch (AMS)

MTU provides the first level of aggregation and may have 4-8 Ethernet ports which are connected to the subscribers. 4-8 ports provide an optimal first level of aggregation from the point of port-fill rate and would offer MEF compliant user to network interface (UNI) between subscriber and the access network. The uplink of MTU may have variety of interfaces like VDSL, Ethernet over fiber etc. We refer to DSL uplink based MTU as DSL MTU and fiber uplink based MTU as MES MTU in Figure 4.

AMS provides the second level of aggregation and can be connected to various MTUs in hub and spoke topology. The AMS may have 1/10 Gbps uplink which would connect to metro core network (based on NG SDH for incumbent or pure metro Ethernet network for Greenfield). The switches can also be connected together in ring topology. The MTU and the access switch are required to offer a rich set of SLA and bandwidth management features and ability to offer Metro Ethernet Forum services like E-Line and E-LAN. The access switch can have variety of physical interfaces like VDSL, Ethernet over CAT5 and Ethernet over Fiber. These interfaces can be configured in an optimal fashion to suit various deployment scenarios. For example, in one deployment scenario, AMS can be located in the basement of a building where the fiber is terminated. The subscribers located in the same building can be connected directly to the access switch over CAT5. The subscribers located in adjoining buildings (located at distances up to 1 Km) can be connected using DSL MTU. For additional bandwidth and reach, an MES MTU connected to the AMS via fiber uplink can be used. This flexibility of interfaces allows optimal utilization of copper and fiber plant. This also addresses effectively the problem of port-fill rate.

Solutions based on multiple aggregation level such as described above are available from some equipment vendors. Recently, a venture backed technology start-up in India, Eisodus Networks [10], has developed solution with a very similar architecture. It has many other interesting features like remote powering of MTU, flexible interfaces etc and is currently deployed in the network of one of the largest service providers in India.

Capital Expenditure Comparison

From various primary and secondary markets surveys, we have captured the sources of capital expenditure per port that a service provider would spend in each of the above deployment models. Note that these are indicative estimates compiled only to produce a meaningful cost comparison. Table 2 shows the various cost heads (as illustrated in respective figures) in the first mile access network architectures. All costs are quoted in US dollars, per customer port with fully populated devices.

Table 2 Cost Comparison

Parameter	**DSLAM**	**LSP**	**MES**	**DSL MTU**	**MES MTU**
Port Density	384	512	24	384	384
DSLAM Port	$20	-	-	-	-
CPE	$16	-	-	-	-
MTU Port	-	-	-	$20	$20
CES Port	-	$2	-	-	-
MES Port	-	-	$20	-	-
AMS Port	-	-	-	$8	$12
Copper Loop	$40	-	-	$5	-
Fiber Loop	-	-	-	-	$8
CAT5 cabling	$2	$40	$30	$20	$20
Fiber Uplink	$2	$2	$10	$2	$2
Total per port	$80	$44	$60	$55	$62

A few points to note specifically: the copper cost for the DSL MTU model is one-eighth that of the DSLAM model, the average length of CAT5 cabling for a subscriber connected to a DSL MTU or MES MTU is lower than that connected to a MES due to lower port count and closer proximity, the cost of fiber uplink connectivity for an MES is higher due to lesser amortization over subscriber ports.

Though the DSLAM model is the most expensive, it is being widely used in many countries around the world. One could argue that the price of the DSLAM solution is shown artificially high above since the DSLAM model uses an existing copper base. However, if we consider the dearth of DSL capable copper [1], it is clear that many additional lines must be installed only for broadband deployment. This is because increase in voice communications line has been primarily in cellular telephony - the number of cell phone subscribers crossed 100 million in mid 2006 - and increase in 'fixed line' communications is being registered mostly through fixed wireless telephony.

The LSP model, being the least expensive is also gaining popularity in areas where residential subscribers are migrating from dial-up to broadband, where they tend to overlook the problems with the LSP model in favor of the cost factor.

The MES model seems to be quite cost competitive with the others, but suffers from two drawbacks - low port-fill rate as described earlier leading to higher effective cost per port and low device port-density resulting in higher cost for upstream devices in the Metro core. On the other hand, the new emerging technologies and deployment scenarios with the DSL MTU and MES MTU model suit India better both in the urban and semi-urban areas providing a mix of cost advantages and excellent technological benefits.

CONCLUSIONS

In this article, we have provided an overview of various challenges involved in deployment of broadband access in emerging economies like India. Broadband access infrastructure has been advocated as the key to economic development. As we have observed, the potential for broadband business in India is very large. Even the conservative target for urban and semi-urban area makes it an attractive market for equipment vendors and service providers. Fiber to the building (FTTB) based on Metro Ethernet appears to be a promising choice for broadband deployment but there is still a long way to achieve this goal. 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 also performed the cost comparisons for various deployment architectures.

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