Performance Analysis of Metro Ethernet Network (MEN) Services over Asynchronous Transfer Mode (ATM) Services for Enterprise

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Abstract

Metro Ethernet networks (MENs) technology has provided economic sustainability to small and big enterprises. Today, individual and organizations rely on ICT to perform daily operations. The costs of using these services determine the accessibility of the users. MEN is flexible to use compare with other switch network like ATM. In this paper, features of MEN technology are explored to determine its potentials in terms of flexible services' delivery to the customers. Also, bandwidth consumption is minimal even when the network is being expanded. We modelled and simulated two factors; availability and reliability for MEN and compare these results with ATM technology. The MEN technology performs better than ATM technology according to our results.

Keywords: *Metro Ethernet Services, Availability, Reliability, ATM switches, cost effectiveness*

1. Introduction

Ethernet metro network is the next stage in the evolution of telecommunications. It involves technical innovation, customer/end-user demand and strategic business practices. Understanding the service where it fits in the market and customer requirements can lead to a service with short and long term profitability, high customer retention, low operating and capital expenses and rapid deployment [1]

The sole purpose of the Ethernet service is to allow a telecommunication carrier to extend and interconnect customer-owned and operated facilities, utilizing greater flexibilities and cost effectiveness. For the service provider, Ethernet offers better scalability, flexibility and affordability than traditional telecommunication services [2]. Metro Ethernet service offers customers' higher capacity options with a lower cost of ownership. It offers improved operating margins and reduced operating complexity.

This reduced operating complexity provides for faster upfront provisioning as well as additions, moves and changes, all performed without time-consuming and expensive truck tolls. Other legacy services such as Frame Relay or ATM do not provide the flexibility in bandwidth increment that Metro Network (MEN) need. Furthermore, Ethernet is a popular protocol in all enterprise LANs. The choice of using Ethernet to interconnect remote sites of an enterprise is appealing for the following reasons: cost effectiveness, flexibility, rapid provision on demand and ease of interoperability.

A wide range of service providers now offers Metro Ethernet services [3]. Some providers have extended Ethernet service beyond the metropolitan area network (MAN) and across the wide area network (WAN). According to [4], thousands of subscribers already use Ethernet services and their numbers are growing rapidly. These subscribers have been attracted by the benefits of Ethernet services, which include:

- Ease of use
- Cost effectiveness
- Flexibility

These propositions have also been supported by [17] with rapid provision on demand in addition to the other benefits highlighted.

1.1 Ease of use

Ethernet services are provided over a standard, widely available and well-understood Ethernet interface. Virtually all networking equipment and hosts connect to the

network using Ethernet. So using an Ethernet service to interconnect such devices simplifies network operations; administration, management and provisioning (OAM&P).

1.2 Cost effectiveness

Ethernet services can reduce subscribers' capital expenses and operation expenses in three ways:

- First, due to its broad usage in almost all networking product, the Ethernet interface itself is inexpensive.
- Second, Ethernet services can often cost less than competing services due to lower equipment, service and operational costs.
- Third, many Ethernet services allow subscribers to add bandwidth more frequently.

1.3 Flexibility

Many Ethernet services allow subscribers to network their business in ways that are either more complex or impossible with alternative services. With managed Ethernet services, subscribers are able to add or change bandwidth in minutes instead of days or weeks and hours instead of weeks or months when using other access network services.

Ethernet service can be characterized into access, metro/MAN (metropolitan area networks) and WAN (wide area networks) service types, and by their enabling technologies [5]. Metro Ethernet service offers customers higher capacity options with a lower cost of ownership. It offers improved operating margins and reduced operating complexity. This reduced operating complexity provides for faster upfront provisioning as well as additions; moves and changes, all performed without time-consuming and expensive truck tolls.

One of the main caveats to an Ethernet service is that it does not require the same protection as carrier-grade voice and video services. By default, Ethernet services are unprotected requiring the customer's equipment to provide the protection. Many carriers do not have a thorough understanding of this basic concept resulting in critical and costly flaws in the deployment of their Ethernet services. Section 2 discusses the scientific overview of the paper, section 3 explains the system design framework and section 4 enumerates on results and discussions while section 5 draws the conclusion.

2. Scientific Overview

MEN provides a flexible, scalable and cost-effective alternative to private lines, frame relay and ATM connectivity solutions for WAN. Ethernet also responds faster and better to the high volume demand for new connections as compared to Private Line, Frame Relay and ATM [7]. This is because of the long waiting period to establish a dedicated physical connection. In the same vein, the ability to respond to customers' need and the cost efficiency drive Ethernet expansion to the carrier grade for MEN.

MEN as a network that bridges and connects geographically separated enterprise LANs; provides some advantages over ATM which include [2] infrastructure, equipment cost for MEN are significantly less than that of ATM. MEN presents a better customer-centric flexibility as well as coarseness of bandwidth granularity ahead of ATM. MEN is an asynchronous frame-based technology with a particular flexibility advantage over the cell-based ATM. MEN is relatively simple to integrate and interface with end-customer system to ethernet metro services as compared with ATM. MEN is more acceptable and dominant in enterprise and campus LAN compared with complexity of ATM.

In the recent years, MEN widespread acceptability as a WAN technology is due to the following reasons: WAN traffic explosion that continues to increase tremenduosly. Its automatic ability to detect and form routing links; widespread availability of ethernet interfaces in networking equipment; Application-Specific Integrated Circuit (ASIC) enabled lower cost of components with subsequent lower cost per Mbps; and the rapid standardization of ethernet services by the Metro Ethernet Forum .

2.1 Ethernet as an Aggregation and Switching Technology

According to [7], ethernet evolves from a LAN service interconnecting an enterprise workgroup to running the enterprise backbone and extends to Metro Area Network (MAN) which provides Ethernet services across MAN. As a result of the flexibility and cost-effectiveness nature of MEN, service providers have started to offer Metro Ethernet services that uses ubiquitous ethernet technology to deliver converged voice, video and data networking.

Van de Voorde et al. [11] highlighted the main features of carrier-grade in metro networks which include:

- Scalable, secure segregation of customers;
- Resilience;
- Multi-service support

- Operation, Administration and Maintenance (OAM)
- Quality of service (QoS)

These are further enumerated in the subsequent study.

2.1.1 Scalable and Secure Segregation

Within a metro network, the operator must be able to provide basic connectivity between two users, or between a number of users via a Virtual Private Network (VPN). However, it is essential that the traffic of customers between which no layer 2 connectivity is requested should be segregated to eliminate the possibility of hacking between them [7]. This secure connectivity should be established in a scalable way, meaning that there is no hard limit on the number of customers that can be connected to the network. However, the deployment of plain Ethernet poses a number of problems with respect to these requirements.

2.1.2 Multi-service support

In order to carry data services efficiently, metro nodes must support class-based scheduling and fairness. Fairness is defined as treating best-effort and excess traffic flows in an equal (or weighted) way [8]. To achieve fairness, it is necessary to support drop precedence in the event of congestion in the schedulers. In addition, a carrier-grade network should be able to offer services with guarantees on throughput and delay, as is the case for leased-line and real-time services.

2.1.3 Operation, Administration, and Maintenance (OAM)

One of the features that impose a high degree of obstruction to Ethernet from being a standalone carrier-grade technology is the lack of Operation, Administration, and Maintenance (OAM). Other technologies such as SONET and ATM have OAM capabilities within the data link layer [9]. OAM deals with the network performance monitoring and maintenance. It includes predefined variables about the status of the network such as delay, loss, jitter, and bandwidth availability that can be sent in-band or out-band. In-band signaling, like SONET/SDH, sends OAM information attached to the date. This is closer measurement of the network performance. However, there is a risk that the OAM information might affect and bias the measurement. According to [10], Out-of-band signaling sends the OAM information on a different path than the data path. Therefore, careful implementation must be enforced to ensure that the OAM frames are treated as closely as possible to the data frames in order to get an accurate reading.

2.1.4 Quality of service

One of the most important attributes that a carrier Ethernet must have is the support of end-to-end Quality of Service (QoS). It includes, but not limited to, bandwidth, delay, jitter, and packet loss guarantees. These guarantees must be made form an end-to-end point of view. Service Level Agreements (SLAs) are the agreements on these metrics that are negotiable between the client and the carrier to assure the end-to-end performance of voice, video and data applications. Metro Ethernet Forum [2] defines Quality of Service (QoS) specification via the following metrics: frame loss, delay, and jitter.

2.2 Metro Network Applications and Services

Service providers have traditionally relied on different networks to address customer and enterprise market needs. TDM/PSTN, and to some extent ISDN, have typically served the voice dominated consumer applications, while frame relay, ATM and TDM leased-line networks have served the more data intensive enterprise applications [11]. Moreover, the explosive growth in e-commerce, data warehousing, and supply chain management applications has fueled significant growth in the enterprise network connectivity and storage needs. To best support business and continuance and high bandwidth applications, server consolidation in data center facilities, and application hosting, most enterprises have upgraded their networks, replacing ATM, Frame Relay, and TDM private line with more efficient Ethernet (GE and 10GE) transport.

2.3 Asynchronous Transfer Mode (ATM)

ATM is a network technology based on transferring data in cells or packets of a fixed size. It is a connection-oriented technology as in figure 1, in which a connection is established between two endpoints before the actual data exchange begins [12]. Even though frame relay and ATM are widely used data transport protocols today, circuit switching equipment still processes approximately 80% of the carrier traffic mapped onto legacy SONET networking infrastructure [2]. The voice-optimized nature of these networks means that data traffic requires additional switches or routers to map data into time division multiplexed (TDM) channels for transport across the SONET/SDH network. The result is a complex, multi-tiered networking architecture, ineffective for data-centric metro and WAN environments. ATM cannot respond as fast as Ethernet to the high volume demand for new connections because of the long waiting period to establish a dedicated physical connection [13]. In addition, upgrading the current connection exposes the inefficiencies in Time Division Multiplexing (TDM), such as coarse granularity of bandwidth increments resulting in oversubscribing, requirement of new equipments, and changing to new service platforms and protocols.

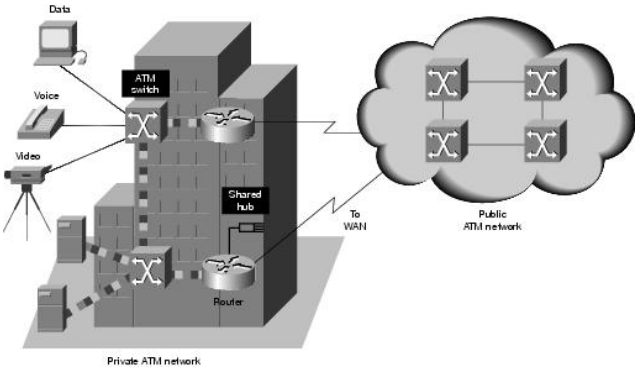

Figure1 Private and Public ATM Networks
Source: Internetworking Technology Overview

2.3.1ATM Services

Three types of ATM services exist: *permanent virtual* circuits (PVC), *switched virtual* circuits (SVC), and *connectionless service* (which is similar to SMDS).
A PVC allows direct connectivity between sites. In this way, a PVC is similar to a leased line [18].
Among its advantages, a PVC guarantees availability of a connection and does not require call setup procedures between switches. Disadvantages of PVCs include static connectivity and manual setup [18].
An SVC is created and released dynamically and remains in use only as long as data is being transferred. In this sense, it is similar to a telephone call. Dynamic call control requires a signaling protocol between the ATM endpoint and the ATM switch. The advantages of SVCs include connection flexibility and call setup that can be handled automatically by a networking device.
Disadvantages include the extra time and overhead required to set up the connection [18].

2.4 Availability

Availability refers to the amount of time the MAN connectivity performs the way it is supposed to. It is the ability of a system to be in a state to perform it required functions at a given instant of time assuming that the required external resources are provided. It is usually expressed in a percentage of uptime per day, week, month, or year. When Mean-Time-Between-Failures (MTBF) goes up, Availability goes up.

A system with only 3 minutes of service outage must have 99.999-percent availability. Availability was predicted using statistical models for all the system components, the simplest model for a component being binary [16]. The component was either in or out of service. Availability is calculated from failure rates, measured in mean time between failure (MTBF), and repair times, measured in mean time to repair (MTTR).

Using the following equation, availability is calculated using MTBF and MTTR:

Availability = MTBF / (MTBF + MTTR)

With this availability equation, a subscriber can clearly state the acceptable frequency and length of network outages.

2.4.1 Network-Level Availability

Network redundancy is the best way to ensure high availability. Because of their mass production, Ethernet systems are fairly inexpensive compared to traditional WAN systems such as ATM switches or SONET add/drop multiplexers (ADMs). Therefore, a service provider is likely to have redundant systems along with redundancy built into the systems themselves [13].
An end-to-end connection from one WAN edge router to another was traced in Figure 1. The simplest design has many single points of failure and calculated availability of 99.938 percent, or about 325 minutes (more than 5 hours) of outage each year. Adding redundancy significantly improves this failure rate, down to about 30 seconds per year.

2.4.2 Value-Added Services

After deploying the infrastructure for Metro Ethernet Access Services, service providers can generate new revenue streams by offering value-added services, including:

- VoIP over Ethernet, such as voice tie lines, IP PBX interconnection and business voice services
- Video streaming over Ethernet services, such as video multicasting on demand, stock price streaming, and video conferencing
- IP VPN Connectivity to Branch Offices
- Security Services such as Managed Firewall and Intrusion Detection Services
- Storage and Offsite Disaster Recovery Mirroring
- Data Center Connectivity and Managed Hosting

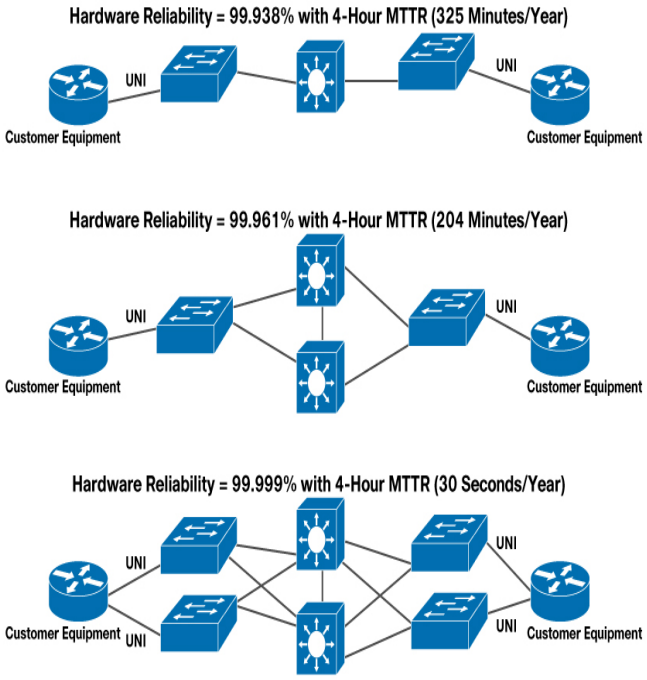

Figure 2 End to end connectivity

Service providers can offer Metro Ethernet Access Services as standalone offerings or in tiered bundles. For example, a bundle for midsized businesses might include the following [14]:

- Metro Ethernet Internet access with voice, managed security, and VPN services
- "Always on" Internet access from 20–50 Mbps with 50 mailboxes and a Class C address block
- Site-to-site VPN with remote access VPN for tele-workers and mobile workers
- Managed IP telephony services.

Ethernet services in the metro are taking off in popularity as enterprises increase their demand for higher bandwidth and more cost-effective connectivity than existing Wide Area Network (WAN)
Using Metro Ethernet equipment for this new service infrastructure is appealing to service providers because of its lower cost and simpler operational characteristics compared with alternative equipment [15].

2.5 Reliability

This is the ability of a system to perform its required functions under stated conditions for a specified period of time. It is quantified as Mean Time (MT). Reliability numbers vary strictly, and to make meaningful comparisons, the assumptions and methodology must be understood.

Reliability is important for the following reasons:

- *Reputation*: A company's reputation is influenced by its product reliability
- *Customer satisfaction*: while a reliable product may not affect customers' satisfaction, an unreliable product may affect customers' satisfaction, hence reliability is a mandatory requirement for customers' satisfaction
- *Warranty cost*: If a product fails to perform its functions within the warranty period, the replacement and repair cost may negatively affect profit and also gain negative attention
- *Repeat business*: A concentrated efforts towards reliability shows existing customers that the manufacturer is serious about the product and is committed to customers' satisfaction
- *Cost analysis*: Manufacturers may take reliability data and combine with other cost information to illustrate the cost-effectiveness of their products. This life cycle cost analysis can prove that although the products initial cost is higher, the overall life-time cost is higher than that of its competitors because of their products require less repair
- *Customers requirement*: Many customers demand that their suppliers have an effective reliability program

3. System Design Framework

This session of project takes a critical look at the method and tools employed in the project. The development analysis and design process are essentially discussed, with a view at getting the best and appropriate results. The model developed was analyzed and the appropriate conclusion was drawn.

It focuses majorly on the development of metro Ethernet services for enterprise using figure 1 as a typical Metro Ethernet Network architecture. It illustrates the connectivity between customers' sites and the metro network. The two sites are connected using switches and routers. Availability, reliability and cost effectiveness are modeled and simulated. Perform evaluations were carried out and the two technologies were compared with each other.

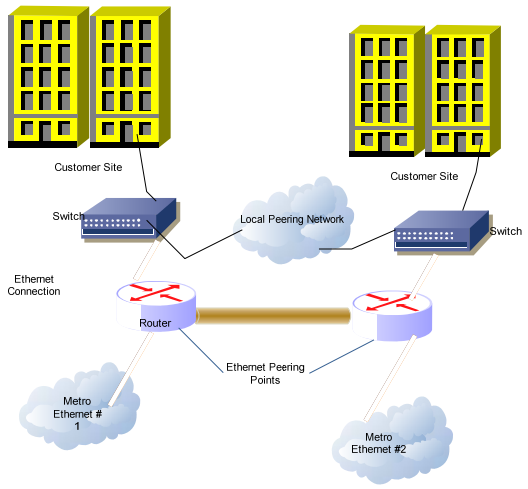

Figure 3: A Typical Metro Ethernet Network architecture

3.1 Simulation

Simulation is an imitation of real thing, state of affairs or process. The act of simulating generally entails representing certain key characteristics or behaviors of a selected physical or abstracts system. Simulation is used in many contexts including modeling of systems in order to gain insight into their functioning [12].

a) Correct Choice: Simulation allows for testing of designs and every aspect of a proposed change or addition without committing resources to acquisition. This is critical, because once the hard decisions have been laid, or the material-handling systems have been installed, changes and corrections can be extremely expensive
b) Time Compression and Expression: By compressing or expanding time, simulation allows through investigation of phenomena
c) Exploration of possibilities: One of the greatest advantages of using simulation technique is that once a valid simulation model is developed, new procedures or methods can be employed without expense

The simulation programs were written in MATLAB and the models were simulated with MATLAB 7.5.0 R2007b.

Availability

a_atm = atm_mtbf./(atm_mtbf + mttrvalue); (1)
a_metro = metro_mtbf./(metro_mtbf + mttrvalue); (2)

Reliability

r_atm = exp (-timevalue./atm_mtbf); (3)
r_metro = exp (-timevalue./metro_mtbf); (4)

Availability = MTBF / (MTBF + MTTR) (5)

MTBF=TOTAL TIME/(NO OF FAILURES) = T/R (6)

Once the MTBF has been obtained, the probability that a module would be operational is:

$$\mathbf{R(t) = e^{-t/MTBF}} \quad (7)$$

Cost effectiveness

Cost is critical to the use of any technology; this study considered operational expenses and capital expenses ATM and MEN. These influence what technology to adopt and our analysis reflect that MEN is appropriate for ease deployment.

4. Results and Discussion

This section explains how an enterprise can improve *availability*, *cost* and *reliability* by using Metro Ethernet features advantages over Asynchronous Transfer Mode.

It discussed how the technical objectives of a MAN connection could be addressed by Metro Ethernet. It examined *scalability*, Availability, Flexibility, security, Cost-effectiveness, adaptability and affordability. These provide specific answers to explain why Metro Ethernet is a viable option for an enterprise MAN, other than ATM.

From the Availability graph function below figure 3 shows Availability function Vs MTTR, it could be seen that for every value of Mean-Time-To-Repair (MTTR), there is a corresponding increase in Availability of Metro Ethernet Technology than ATM Technology and an increase in the MTBF value leads to a corresponding increase in availability. This shows that for these various values of MTTR, Metro Ethernet is more available than ATM technology. Metro Ethernet is in color green while ATM is in color blue.

Again from reliability function, shown in figure 4 could be deduced that for every value of Operational Time, the reliability of Metro Ethernet technology increases correspondingly. It shows that Metro Ethernet is more reliable than ATM.

However, the cost analysis was shown in figure 5. The graph shows that over the years the cost of expanding the Metro networks continues to increase over some early years of study, but gradual decrease over subsequent

years. ATM increases and gradual decrease in price over years but still costlier than MEN.
The most significant advantage of Metro Ethernet over the other technologies such as ATM is its capability of delivering a very high amount of bandwidth at a lower unit cost. In addition, the technology is evolving into a more mature state where provisioning QoS, monitoring, reliability and availability are readily achievable. Ethernet physical layer or MAC layer is not likely to be a source of the problem when a system fails, so migrating to Ethernet service does not affect system-level availability.

One of the biggest strengths of a Metro Ethernet WAN is its bandwidth capacity. Another big advantage is its capacity to be upgraded without physical intervention (as long as the service already in place does not run at maximum interface wire speed).

Of course there are trade-offs associated with these goals. For example, meeting strict requirements for performance can make it hard to meet a goal of affordability.

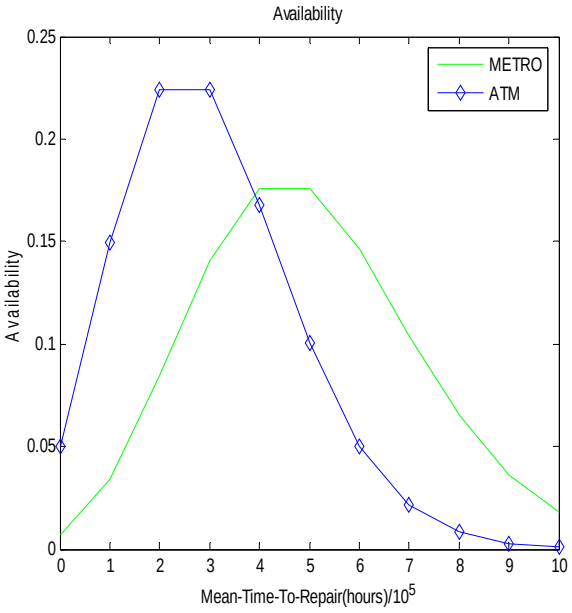

Fig. 3 Graph of Availability Function Vs MTTR

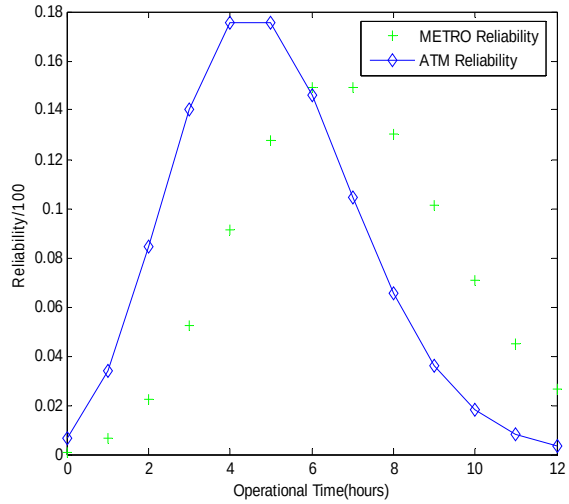

Fig. 4 Graph of Reliability Function Vs Operational Time

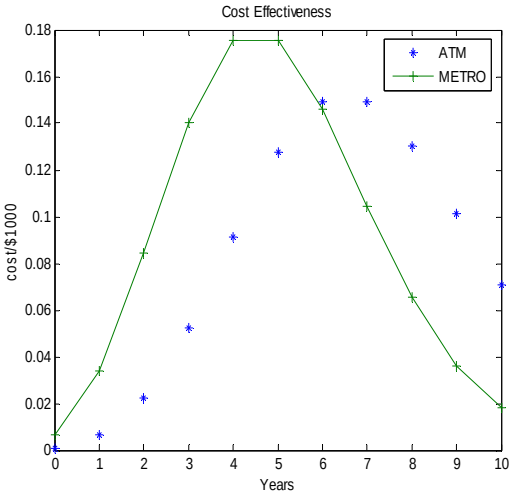

Fig. 5 Cost Comparative Analyses of ATM Technology and Metro Ethernet Technology

5.0 Conclusion and Future Work

Metro Ethernet service is more available and reliable than ATM technology. Metro Ethernet is a viable option for an enterprise MAN, other than ATM. Enterprise should adopt metro Ethernet service.

Further work can be done to improve on the simulation results such as in the area of development of a billing system for the metro Ethernet services for enterprise.

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