

ISSN 2047-3338

Comparative Study of WAN Services and Technologies in Enterprise Business Networks

Muhammad Shoaib Mazhar

Computer Science & Engineering Department, University of Engineering & Technology, Lahore, Pakistan
shoaibmazhar.uet@gmail.com

Abstract— An enterprise business network develops to incorporate more branch offices, internet business administrations, or worldwide operations, a small network like office LAN is never again adequate. It is impossible to handle requirements by LAN. This issue has made WAN an integral part of the enterprises because WAN offers various technologies and services to meet the requirements of the network. Geographically, WAN covers more area than other networks which arises problems of security and management. Purpose of this paper is to explore all major choices for structuring enterprise WAN. How a local business evolves to enterprise business? How evolving business affect network requirements and also provide general enterprise architecture. This paper provides basic knowledge of selecting the appropriate WAN services, technologies and suitable protocols for these technologies to meet the changing business requirements to enable integrated WAN services over a multi-area enterprise network.

Index Terms— LAN, WAN, MAN, UET, ATM and MPLS

I. INTRODUCTION

IN enterprise network [1] provide communication channel that assists to provide a connection between different PC's and related gadgets across departments and workgroup networks to help to understand and provide data accessibility across the network. The main purpose of the enterprise network to reduce intercommunication protocols, assists overall systems and devices interoperability, as well as the enhanced flow of data inside and outside the enterprise business network. In scope, an enterprise network may include types of networks differentiated on the base of geographical location. These types include local area network, wide area network and metropolitan area networks, depending on an organization's network requirements. However, WAN plays an important role in an enterprise network. It's important to choose correct WAN's services and technologies for growing business network. WAN doesn't only refer to the Internet, it's a combination of the Internet and enterprise WAN services such as MPLS, Frame Relay or ATM. The only difference is that the Internet provides connectivity to a huge range of resources while enterprise WAN services were designed to connect the enterprise's data centers and branch offices.

As Enterprise Business grow, they hire more employees, add more branches and regional offices, and expand the local business to global enterprise. These changes also affect companies' requirements for integrated devices, services, protocols and have a serious effect on their network requirements. This improved network must fulfill needs of the evolving business. To illustrate the concept of evolving business, an organization called Al-Khwarizmi Institute of Computer Science (KICS) example will be used. How its network requirements change as the company grows from a small local business into a global enterprise? This paper will give essential information of choosing the reasonable WAN's services, technologies and gadgets to meet the changing business requirements of a developing enterprise and make these WAN innovations to empower incorporated WAN administrations over a multi-area enterprise network.

II. LITERATURE SURVEY

M.A. Weinstein presents a lot of analyses that begin from the business objectives of the enterprise and guide them to a lot of specialized systems plan prerequisites and checking the accuracy of the determined architecture design. This paper centers around why and how to connect an enterprise's network requirements to center business needs and gives an overview of key examinations for deciding the enterprise network's requirements. These analyses lead to the effective implementation of an enterprise network [2].

Ping and Lin in their paper presented that enterprise networks are complex that includes the interconnection of a wide collection of computer systems with different correspondence channels. The real problems in the security of enterprise systems to demonstrate issues and procedures created to address them. Their emphasis is on the thoughts behind these strategies, which can be joined from numerous points of view to make arrangements that apply to various circumstances. In enterprise network, security is one of major concern for network administrator. They have explained all possible solution for these issues in details [3].

R.A. Mercer in his paper characterizes an enterprise network exceptionally as a corporate-wide network that

integrates the communications, handling, and capacity assets of the company and makes those assets accessible throughout the organization. The key design issue is how much the current EN will develop to new EN. At the technology level, the most consuming inquiry is the future job of ATM, which at this stage can be seen as either a technology that guarantees to incorporate the networks utilized for all types of communications or a technology that isn't ideal for any communication structure and is at best a compromise solution for enterprise network [4].

A) A Brief History of WAN

WAN is communications network whose range is multiple geographic locations. These networks can be private to associate different devices of a business or they can be progressively public to interface smaller networks together. Internet is nothing but a world's biggest WAN. Before diving further into the subtleties of the Next-age Enterprise WAN design (Fig. 1), it will be informative to take a look at the historical view of the Enterprise WAN advancements in technology. See Table I for details [5]–[7].

B) Classification of Network

A network is a collection of nodes associated together by different technologies. Imagine world without messages, long range interpersonal communication sites, web-based shopping, and many other benefits that technology has provided in all fields of life. The exchange of information and resources between distant user has become so easy by using various mediums and platforms of technology like email, visits, online talk, video phone calls, and video conferencing. Various types of the network have been explained further in this section [9]–[11].

1) *Personal Area Network (PAN)*: PAN is that type of network which revolves around a solitary individual. The network is organized for an individual which can be in an office, a building or a house. It interfaces various peripherals, for example, PCs, phones, computer game consoles. It very well may be wired or wireless. The essential distinction among PAN and LAN is that PAN is for a unique individual while

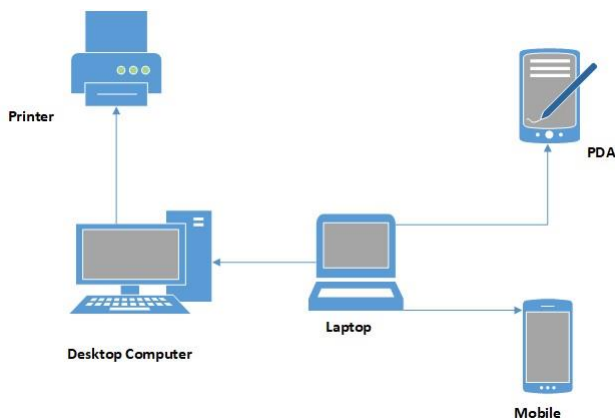


Fig. 1. Personal Area Network

LAN is for a group. Providing a medium to the individual to have access to their devices is major concern of PAN. The range of PAN is 10 meters (See Fig. 2).

2) *Local Area Network (LAN)*: LAN is an exclusive network which is utilized to give an association between PCs encased in a solitary structure, house, office, organization,

Table I: AN EVOLUTION OF WAN [8]

Sr No.	Year	Evolution of WAN
1	1970s to 1980s	X.25 were used in many companies as precursor what will become modern WAN. But X.25 networks were popular because remote mainframe. It was providing terminal access in the beginnings of the Enterprise WAN. It was first cloud service in widespread use.
2	1980s to 1990s	For connection of Personal Computers in different Local Area Network (LAN s) were prompted a shift toward the point-to-point Plain Old Telephone Service (POTS) lines or leased lines that reach speed up to 56k bps. These were typically DS0 connections, and then the more expensive lines were introduced called T1/E1 or T3/E3 but these connections were much more expensive. The technology used in the establishment was remote bridges. Later on. these bridges were replaced by Cisco routers at the end of each WAN. In this era, first public WAN was implemented.
3	Early 1990s	Frame Relay service was introduced, creating a cloud like service to give relief to organization from purchasing and managing their own individual link. ATM service were also introduced but fail to make a meaningful impression on the enterprise WAN.
4	Mid-1990s	Relay service offered less monthly costs, less physical connections to handle, allowed link bandwidth sharing connections, and cheap router hardware than alternative. Within 5 years, these mentioned benefits caused a revolution in the corporate WAN and contributed to its rapid growth even most conservative organization were migrated to this technology. It was the fastest uptake of any WAN service in history. VPNs and IPSec were also introduced and made connections over the Internet more secure.
5	2000s to 2010s	Multiprotocol Label Switching (MPLS) was launched. Data, voice, and video were sent on different networks. MPLS provided an IP-based solution for carriers to send on the same network. The take-up of MPLS started amidst the 2000s, and by today, while Frame Relay administration keeps on being accessible, the unmistakable dominant part of enterprises has moved their WANs to MPLS over the most recent couple of years. Because of the rise of public and private cloud services makes Software Defined WAN (SD-WAN) an increasingly feasible option for the enterprise network.

building, company relying on the prerequisite of the network. By giving an association between PCs, it permits the sharing of assets, for example, printers See Fig. 2. It can be wired or wireless. By using different available topologies of transmission, Wired LAN is constructing for the most part from point to point like the Ethernet. Wireless LAN is the network that associates different hubs utilizing wireless communication medium in a covered area, for example, in a solitary structure.

The benefit of utilizing a wireless communication medium is that there are no restrictions on clients. They can move freely within the range of network area. Because of its simple establishment process and simple use, it is generally utilized in homes and hospitals, etc.

In a comparison of wired and wireless LAN's network, the Wired LAN is high in operational speed and it is also less costly. It's transmission media are mostly copper wire or fiber optics and provide high bandwidth for users. It's complex and used for a limited range. On the other hand, Wireless LAN is much more expensive with lower operational speed. Its full package with lower bandwidth, easy implementation process, and radio waves or infrared is used for transmission media.

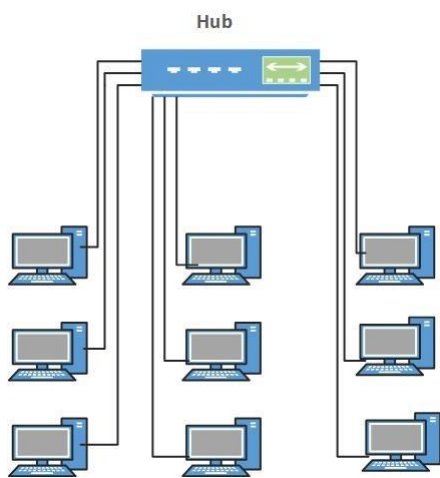


Fig. 2. LAN connecting 9 computers to a hub

3) *Wide Area Network (WAN)*: WAN gives a long-distant transmission of information, picture, sound and video data over substantial geographic areas that may include a whole country, a continent, or even the entire world. A WAN can be as complex as the core that associates the Internet or as simple as a dial-up line that interfaces a home PC to the Internet. First is referred to as a switched WAN and second as point-to-point WAN. Fig. 3 illustrates the difference between a switched and point-to-point WAN. The switched WAN associates the end framework to the router which associated with another LAN or WAN. The point-to-point WAN is a line leased from a service provider (ISP) which provide internet accessibility. A genuine Example of switched network WAN is asynchronous transfer network (ATM). Wireless WAN has become more popular.

4) *Metropolitan Area Network (MAN)*: MAN is type of network that which combines multiple networks of nearby building into a single network. The scope of this network lies between 5 to 50 kilometers. Geographically, MAN is intermediate network because it lies between LAN and WAN. It's range is higher than LAN but much less than WAN. It can be a wired network or wireless. A MAN may be possessed and worked by a solitary association, however, it, for the most part, will be utilized by numerous people and associations.

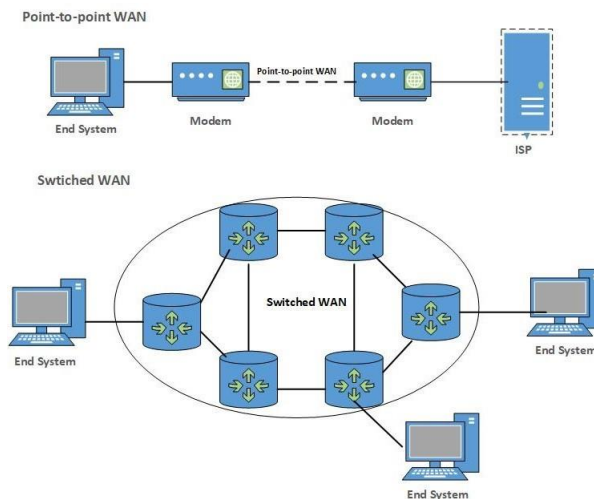


Fig. 3. WANs: a switched and point-to-point WAN

Case of MAN is the piece of the organization network that gives rapid DSL lines to the client. The network between various parts of a bank in a city, satellite broadcasting companies, air reservation likewise part of WAN. See Fig. 4 for MAN.

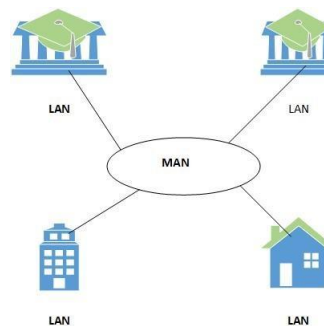


Fig. 4. MAN network

Today, it is very rare to see a LAN, A WAN or a MAN in isolation, they are connected to one another. When two or more network connected, they become INTERNET. These networks are part of Enterprise Network, so it is necessary to understand these networks. For details see Table II.

III. THE EVOLVING ENTERPRISE BUSINESS

For a growing company, employees are hired, new offices are opened based on customer demand, and small business converted to global enterprise business. This sudden change has a major effect on network requirements which also changes as the company continues to grow. The purpose of this section is to illustrate how growing organization's network meet the change of evolution of the business [12].

A) Networks and Businesses

Each business is exceptional. How an organization develops relies upon the kind of factors or services. But our focus is a network of these organizations. WAN services and technologies should be chosen to increase the efficiency of the

Table II: COMPARISON BETWEEN DIFFERENT COMPUTER AREA NETWORKS [9]

Parameter	LAN	MAN	WAN
Ownership	Private	Private or Public	Private or Public or Leased
Design Maintenance	Easy	Difficult	Difficult
Speed	High	Moderate	Low
Congestion	Less	More	More
Area Covered	limited to single building like hospital, library	Covers up to entire city.	WAN is network of networks. Its range has no limits we can say that network of entire world
Technology Used	Token Ring, Ethernet are commonly used	MAN is just collection of networks	WAN use these X.25, Frame Relay, ATM technologies
Propagation Delay	low	Medium	high
Communication Medium	Only media used by LAN is Coaxial Cable	MAN either use Optical Fiber or wireless or Coaxial Cable	WAN is larger network. Is uses Satellite Links
Bandwidth	Higher	Medium	Lowest
Cost	Cheap	Moderate Cost	Costly
Fault Resistance	High	low	low

business. Setting up and monitoring networks can speak to noteworthy establishment and working costs. To legitimize such a substantial cost, organizations anticipate that their networks should perform ideally and to have the capacity to convey a consistently expanding exhibit of services to help

efficiency and performance. To illustrate, we'll explain the evolving enterprise called Al-Khwarizmi Institute of Computer Science (KICS) as an example. In this section, we are going to explain the change. What are effects on network of company when a small local business shifts towards a global market [13].

1) *Small Office (Single LAN):* Al-Khwarizmi Institute of Computer Science (KICS) is situated inside Engineering University of Lahore known as UET for directing innovative work exercises in the fields of IT. It was imagined as an establishment for cutting edge and high caliber connected research working in a joint effort with enterprises and other scholastic foundations on national and universal dimensions to realize the IT unrest in Pakistan and help construct an information-driven economy. We endeavor to assemble proficient and skillful analysts at one stage and furnish them with a positive and persuasive condition for making imaginative advances and items.

In the early years, KICS's was planning to have full advanced projects. First, it necessary to have a feasibility report of the project then the company decides the actual cost of the project. For its small office, uses a single LAN to share devices and information, such as a printer, fax machines, and servers. To save the cost of different phone lines of employees, the company decided to deploy inexpensive VoIP service in the organization which takes LAN network to a new level. The company connects to the Internet through DSL, which is provided by the local SPs. KICS started to purchase and install much software and server like FTP, Email, etc. form the same SPs to save cost from the company. Fig. 5 illustrate a small office with different peripherals [13], [14].

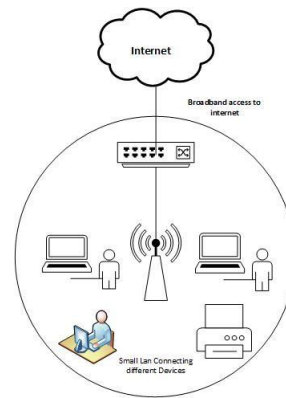


Fig. 5. Small Office LAN

2) *Campus (Multiple LANs):* In 2006, KICS shifted its focus from digitals systems to IT. It started to affiliation with different worldwide industries and It also established and successfully established a campus of Huawei in Model Town Lahore. In 2011, KICS started working on different labs and centers in multiple fields of IT. So, as the evolution in the business occurs, the network of the organization is not a simple task to handle. Now a small office network is not acceptable which leads to smaller networks for each different lab and building. These smaller networks are combined

together to make campus network of the organization [15]. Fig. 6 shows KICS's expanded campus LAN.

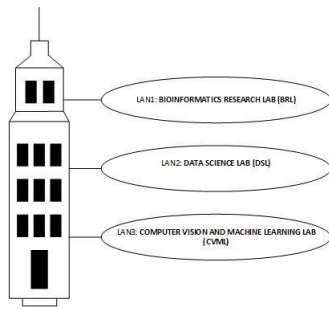


Fig. 6. Campus (Multiple LANs)

3) *Branch (WAN)*: In the last few years, KICS has developed more than 20 different research labs in various fields of IT. It has also managed to add four technology centers in the structure. KICS has got a reputation at the national and international level because it most often arranges various conferences, workshops, training, and technical courses. For distanced projects, the KICS has managed to open many regional and branch offices. Fig. 7 illustrates the concept of branch WAN. This circumstance displays new difficulties

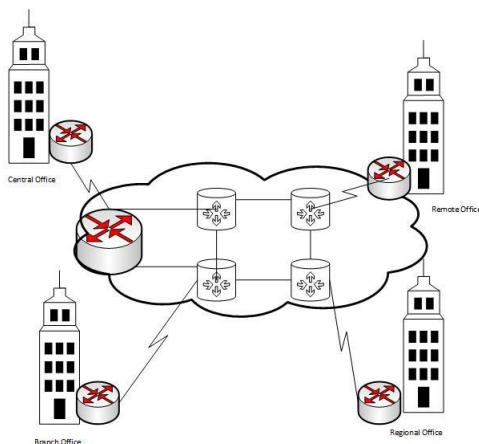


Fig. 7. Campus (Branch (WAN))

for the network. To deal with the conveyance of data and services all through the company, KICS presently has a server farm, which houses the organization's different databases and servers. Sometimes, the organization chooses to utilize private devoted lines through its nearby service provider. Notwithstanding, for the workplaces that are situated in different nations, the Internet is currently an alluring WAN association choice [16].

4) *Distributed (Global)*: KICS has increased staff in each field. including many with doctorates, post-graduates, and graduates from different fields. It's mostly work is combined with many national and international companies. It shows that requirements of a network of KICS have become more complex. In this growing enterprise, the employee is

hired from different regions and countries. Cost of the network has become more expensive than it was just a small office in 2002. Each company wants to lower the cost of network and all services and technologies it provides to the customer. KICS also hire employees who want to work while sitting at home. To meet these prerequisites, the system must give the vital merged administrations and secure Internet WAN availability to remote workplaces and people. Fig. 8 provides a general overview of global business network.

As we watch KICS's system requirements can change drastically as the organization develops after some time. Conveying representatives spares costs from multiple points of view, in any case, it puts expanded requests on the system. Not exclusively should a system meet the business's everyday operational necessities, yet it likewise should probably adjust and develop as the organization changes. System architects and directors address these difficulties via cautiously picking organize advances, conventions, and specialist co-ops, and by improving their systems [17].

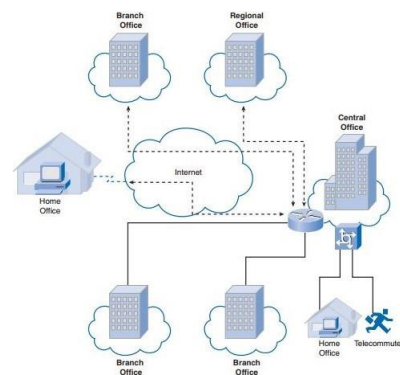


Fig. 8. Distributed (Global)

IV. THE ENTERPRISE ARCHITECTURE

All businesses need various kinds of networks, contingent upon how the business is sorted out and its business objectives. Frequently networks develop in an aimless manner as new parts are included which affect the requirement of the network. After some time, those networks become unpredictable and costly to handle. it is difficult to maintain networks because of its a mixture of old and new technologies. If networks do not provide the expected performance, it's not a good sign for the network administration [18].

To help administration, we have presented a Cisco Enterprise general Architecture which has various steps of growth in business and is structured to give network administrators a complete plan for network growth as the business evolves with time. By following the recommended guide, IT directors can plan upcoming network model for their company. For enterprise architecture see Fig. 9 which indicates how all modules effects the enterprise network.

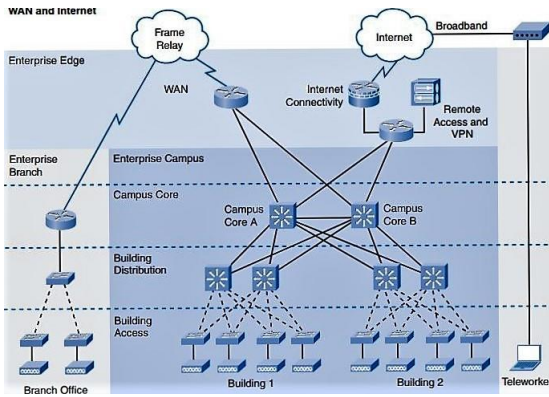


Fig. 9. Enterprise Architecture [19]

This above architecture consists of various modules. Each of them has a fixed place in overall architecture and each has a different network structure with different network applications and services to provide as illustrated in Fig. 9.

A) Enterprise Edge Architecture

This module gives collaboration between the campus module and others so all data can be circulated easily between the clients and workers. Major aspect of this module is WAN and MAN technologies. The purpose of this module is to received traffic for all over the architecture and sent it to campus module [20] as illustrated in Fig. 10.

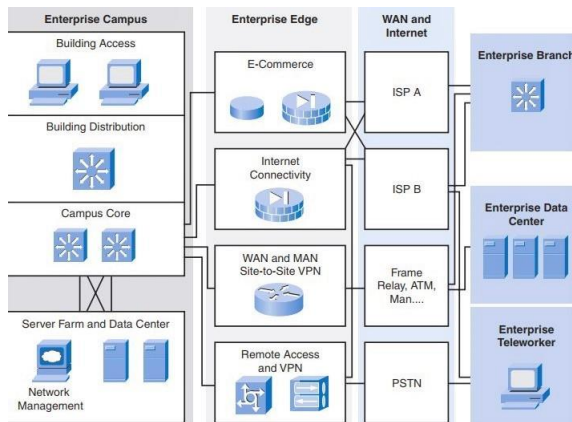


Fig. 10. Modules of Enterprise Architecture [18]

B) Enterprise Campus Architecture

It is an association of one enterprise network which contains multiple smaller LANs in a single or multiple building. In the KICS, the campus traverses' different floors of a similar office. This design illustrates techniques to make an adaptable network. The design is particular and can without much of a stretch extend to incorporate extra campus structures or floors as the enterprise develops. This module is additionally ordered into four submodules as illustrated in Fig. 10. First, user has to connect himself via the end-user system to the distribution module of the organization. Second, by using layer switch this distribution module provides summarized access control and

quality control. Third, this submodule provides a connection between this office and enterprise edge module. fourth, now user has access to DNS, Email server, FTP server, and other application. This module focusses on the connections between users, the campus network, enterprise Edge modules, and multiple servers [20].

C) Enterprise Branch Architecture

Services found in campus modules are expanded in multiple locations and areas. In a single branch can be divided into subbranches. Main purpose is expansion of business to global market. Technologies implemented in module is the focus of interest here [20] as illustrated in Fig. 10.

D) Enterprise Data Center Architecture

Data centers give the executives to numerous data frameworks that are essential to present day business tasks. Workers, accomplices, and clients depend on data and assets in the data focus to successfully make, team up, and collaborate. In the course of the most recent decade, the ascent of the Internet and electronic advancements has made the data focus more significant than any other time in recent memory, improving efficiency, upgrading business forms, and quickening change. The enterprise data focus oversees and keeps up incorporated data frameworks for the whole enterprise [20] as illustrated in Fig. 10.

E) Enterprise Teleworker Architecture

Numerous businesses today offer an adaptable workplace to their representatives, permitting them to work from home from home workplaces. To work from home is to use the network assets of the enterprise from home. This module suggest that a teleworker can connect to enterprise using broadband Internet connection. Only threat is security of assets he uses remotely. So, this module provides a secure connection for these kinds of workers (as illustrated in Fig. 10 [20]).

V. WAN TECHNOLOGY OVERVIEW

WAN has a various number of protocols and technologies which revolves around the physical layer and data link layer. ISO, TIA, and EIA are main authorities which play the role in defining and managing these standards. WAN revolves around first two layers of OSI model. WAN has different technologies to pick to fulfill network requirement of the enterprise. This section provides basic knowledge of WAN devices and protocols on each layer for a general enterprise architecture [21].

A) Physical Layer concept in WAN

In the following section, the WAN physical layer kept a few gadgets and technologies for the enterprise network. A WAN uses data link layer to provide by access or connect the multiple far offices of an organization. This layer provide connection between the organizations and different SP's.

Fig. 11 illustrates in further detail in the accompanying rundown and how these WAN technologies are arranged in enterprise network [22]. These are common terminologies used in each common enterprise network.

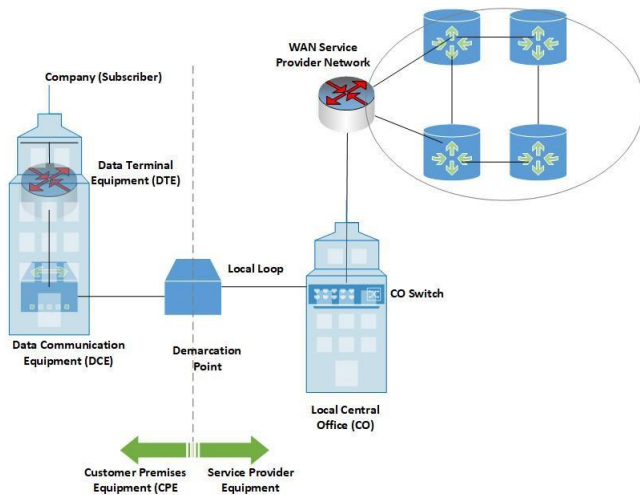


Fig. 11. WAN Physical Layer Terminology

B) WAN Data Link Layer Concepts

WANs require data link layer protocols to set up the link over the communication line from the sending to the getting gadget. This area portrays the basic data link protocols that are utilized in the present enterprise networks to execute WAN associations. Data link layer protocols characterize how data is exemplified for transmission to remote destinations furthermore, the instruments for transferring the subsequent edges. An assortment of advances is utilized, for example, ISDN, Frame Relay, or ATM. Fig. 12 represents the difference between these advancements. A considerable lot of these protocols utilize a similar essential surrounding instrument, HDLC, an ISO standard, or one of its subsets or variations. ATM is not quite the same as the others, since it utilizes little fixed-estimate cells of 53 bytes (48 bytes for data), not at all like the other bundle exchanged advancements, which utilize variable measured packet. These are the most well-known

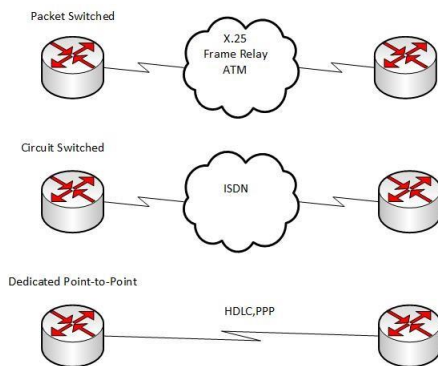


Fig. 12. Data Link Layer Protocols

WAN data-link protocols HDLC, PPP, ATM and Frame Relay. ISDN and X.25 are more seasoned data-link protocols that are less often utilized today. Be that as it may, ISDN additionally utilized while provisioning a VoIP network utilizing PRI links. X.25 is the pertinence of Frame Relay. Too, X.25 is still being used in modern countries across the world where packet data networks (PDN) are utilized to transmit transaction in banks [23], [24].

C) WAN Switching Overview

A network is a lot of associated gadgets. This various device connection emerges the issue of interfacing them to make balanced communication way. One arrangement is to make a point-to-point association between each pair of gadgets (a work topology) or between a focal gadget and each other gadget (a star topology). These strategies, be that as it may, are illogical and doesn't have any significant bearing to extremely substantial networks. The number and length of the links require a lot of foundation to be cost-productive, and most of those links would be inert more often than not. Different topologies utilizing multipoint associations, for example, a transport, are precluded due to the separations among gadgets and the complete number of gadgets increment past the limits of the media and hardware. Generally, three techniques for exchanging have been significant: circuit exchanging, bundle exchanging, and message exchanging. The initial two are usually utilized today. The third has been eliminated as a rule communication yet at the same time has networking applications. We would then be able to isolate the present networks into three general classifications: circuit-exchanged networks, parcel exchanged networks, and message-exchanged. Parcel exchanged networks can additionally be partitioned into two subcategories-virtual-circuit networks and datagram networks [25] as shown in Fig. 13.

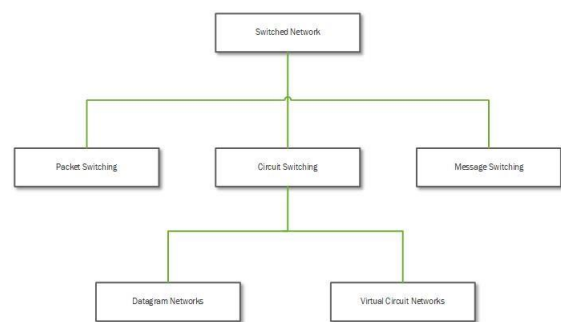


Fig. 13. Types of WAN Switching

1) **Packet Switching:** packet switching divides message into many smaller packets. These packets are sent on the network following different path and order. When they reach at destination, packets are arranged in order and combined to get actual data. There are two ways to deal with this link assurance [26]. In Fig. 14, messages of variable length are divided into fixed-length packets which are sent to the destination. Each packet may take a different path through the

network and must be reassembled into messages as they arrive.

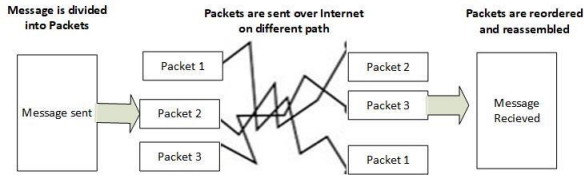


Fig. 14. Packet Switching

Packet switching cost is much lower than circuit switching because the internal links among the different middle nodes are shared. Because links are shared between the different user, it causes more delays and jitter packet-switched networks than in circuit-switched networks. These networks in modern technology allow satisfactory transport of voice and even video communications in the presence of these delay carrying shared network.

2) *Circuit Switching*: In circuit switching network a dedicated path is established among multiple nodes and then communication between different channels takes place. This process is completed in three steps which include a circuit establishment, data transfer and circuit disconnect.

When the association is set up, the information exchange is straightforward. The fundamental element of such an association is, that it gives a fixed information rate channel and the two end users must work in light of present conditions, It is viewed as wasteful contrasted with bundle exchanging on the grounds that channel limit is totally committed for the term of the association. On the off chance that there is no information at any snapshot of time, channel limit goes squandered. Besides, setting up of association requires significant investment. Fig. 15 demonstrates a circuit exchanged system in which PC A, B and C are associated with PC D, E and F through four switches. In the event that these PCs are to be associated with a point-to-point association, 9 devoted lines are required which will bring about high line cost. The four switches interfacing these PCs hence give committed connections by diminishing the line cost. The four switches interfacing these PCs consequently give devoted connections by lessening the line cost. Here I, II, III and IV are the circuit switches or hubs. Hubs I, III, IV are associated with PCs while II is just steering hub.

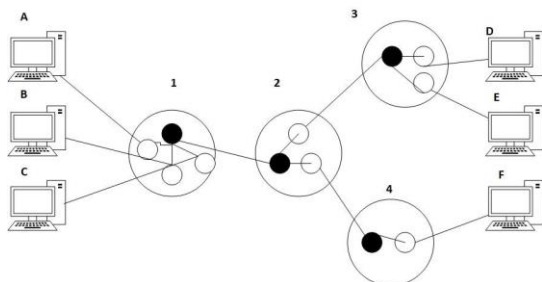


Fig. 15. Circuit Switching

In circuit exchanging the steering choice is made when way is set up over the system. After the connection has been set between the sender and beneficiary, the information is sent always over the connection. For the whole span of correspondence, this connection stays dynamic. This connection or way is separated exactly when information transmission among sender and beneficiary is finished. Circuit exchanging occurs at the physical layer. Prior to starting correspondence, the stations must hold a spot of advantages for be used during the correspondence. These benefits can be switch pads, switch getting ready time, switch input/yield ports. These benefits remain dedicated during the entire term of information exchange [27].

VI. CONCLUSION

At the end of our article, we are summarizing the findings to which we have come. The Enterprise Network, as it keeps on developing, its significance and impact in corporate systems administration will proceed to develop and they procure more workers, open branch workplaces, and venture into worldwide markets. Enterprise Architecture has various phases of a business' development and is intended to give network organizers a guide for network development as the business travels through various stages. The network administrator can follow these given outlines to meet changing requirements of evolving enterprise which has been clarified in this article by Al-Khwarizmi Institute of Computer Science (KICS) developing enterprise model. Of the above features and benefits of this paper is to provide all general knowledge of WAN's services, technologies and devices required and make enterprise network to identify and describe the appropriate WAN technologies to enable integrated WAN services over a multi-location enterprise network.

REFERENCES

- [1] B. Pai, S. Krishnaswami, and T. Chui, "Optical exchange method, apparatus and system for facilitating data transport between WAN, SAN and LAN and for enabling enterprise computing into networks", US Patent App. 09/935,800, August 2003.
- [2] M. A. Weinstein, "Planning enterprise networks to meet critical business needs", in Proceedings of IEEE Enterprise Networking Mini-Conference (ENM-97), pp. 3-13, June 2011.
- [3] P. Lin and L. Lin, "Security in enterprise networking: A quick tour", IEEE Communications Magazine, vol. 34, pp. 56-61, January 2009.
- [4] R. A. Mercer, "Overview of enterprise network developments", IEEE Communications Magazine, vol. 34, pp. 30-37, Jan 2013.
- [5] J. DICKEY, "History of WAN - Introduction", <https://www.talari.com/blog/history-of-wan-introduction/>, January 30, 2014. [Online; accessed 19-March-2019].
- [6] S. Birch, "A brief history of the Wide Area Network: An Infographic", <https://www.irisns.com/a-brief-history-of-the-wide-area-network-an-infographic/>, April 5th, 2016. [Online; accessed 20-March-2019].
- [7] "History of Lan And Wan Computer Science Essay", <https://www.ukessays.com/essays/computer-science/history->

- of-lan-and-wan-computer-science-essay/, 5December-2016. [Online; accessed 20-March-2019].
- [8] A. Gottlieb, "A Brief History of the Enterprise WAN", <https://www.networkworld.com/article/2222089/a-brief-history-of-the-enterprise-wan/>, APRIL 06, 2012. [Online; accessed 20-March-2019].
- [9] H. Rajveer Kaur, "Comparative analysis of different area network types", IJRASET, vol. 6, March 2018.
- [10] "Why we need computer networks? Need for Computer Networking", <http://www.omniseu.com/basic-networking/why-we-need-computer-network/>, January 30, 2014. [Online; accessed 21-March-2019].
- [11] "Computer network", https://en.wikipedia.org/wiki/Computer_network/, 8 April 2019. [Online; accessed 24-March-2019].
- [12] K. Zhou, P. Qiu, and L. Wang, "Research on construction of enterprise knowledge organization network model," in 2008 4th International Conference on Wireless Communications, Networking and Mobile Computing, pp. 1–4, Oct 2018.
- [13] "Al-Khwarizmi Institute of Computer Science (KICS)", [https://en.wikipedia.org/wiki/Al-Khawarizmi_Institute_of_Computer_Science_\(KICS\)](https://en.wikipedia.org/wiki/Al-Khawarizmi_Institute_of_Computer_Science_(KICS)), 26 January 2019. [Online; accessed 24-March-2019].
- [14] H. Mittal, M. Jain, and L. Banda, "Monitoring local area network using remote method invocation," Int J Comp. Sci Mob Com. (IJCSMC), vol. 2, no. 5, 2013.
- [15] M. N. B. Ali, M. E. Hossain, and M. M. Parvez, "Design and implementation of a secure campus network", International Journal of Emerging Technology and Advanced Engineering, vol. 5, no. 7, pp. 370–374, 2015.
- [16] H. L. Bosco and D. C. Dowden, "Evolution of the wide area network," Bell Labs technical journal, vol. 5, no. 1, pp. 46–72, 2000.
- [17] Y. Zhao and Z. Deng, "A design of wan architecture for large enterprise group based on MPLS VPN", in 2012 International Conference on Computing, Measurement, Control and Sensor Network, pp. 340–342, IEEE, 2012.
- [18] J. Tiso, K. T. Hutton, D. Teare, and M. D. Schofield, Designing Cisco Network Service Architectures (ARCH): Foundation Learning Guide. Cisco press, 2011.
- [19] S. Macdonald, "Network Hierarchy." <http://www.macedesign.net/academic/ts5325/ts5325-Submitted/u03a1-network-hierarchy/>. [Online; accessed 24-March2019].
- [20] A. Reid, J. Lorenz, and C. A. Schmidt, Introducing Routing and Switching in the Enterprise, CCNA Discovery Learning Guide: Intr Rout Swit Ente CCNA Dis 1. Cisco Press, 2008.
- [21] V. Bob, Accessing the WAN, CCNA Exploration Companion Guide. Pearson Education India, 2008.
- [22] Y. Helmy and T. Nabhan, "Accelerating network performance by striping and parallelization of TCP connections", Oct 23, 2007. US Patent 7,286,476.
- [23] B. Vachon and R. Graziani, Accessing the WAN, CCNA Exploration Companion Guide: Acce WAN CCNA Expl Comp Gd 1. Cisco Press, 2008.
- [24] R. J. Vetter, "Atm concepts, architectures, and protocols," Communications of the ACM, vol. 38, no. 2, pp. 30, 1995.
- [25] A. B. Forouzan, Data communications & networking (SIE). Tata McGraw-Hill Education, 2007.
- [26] life wire, "How Packet Switching Works on Computer Networks", <https://www.lifewire.com/packet-switching-on-computer-networks-817938>. [Online; accessed 24-March-2019].
- [27] D. Thakur, "Circuit Switching", <http://ecomputernotes.com/computernetworkingnotes/swithing/circuit-switching>. [Online; accessed 24 March-2019].