EXPERT SYSTEMS IN ACCESS TELECOMMUNICATION NETWORKS

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ABSTRACT

EXPERT SYSTEMS IN ACCESS TELECOMMUNICATION NETWORKS

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The main purpose of this thesis is to construct an expert system which provides connections between backbone (telecommunication network) and many end-users by using different broadband access systems. Generally, Wireway and Wireless Access Systems and their sublevels are studied in the creation phase of access telecommunication networks. All of these systems are explored and compared depending on their properties such as architecture of the system, information rate, communication distance, security and features of various applications. The main system is designed as an expert system to find out the possible broadband access solutions and to select optimum access system depending on telecommunication networks' demands and conditions and the expert system is constructed by an expert system building tool.

Keywords : Broadband Access Telecommunication Expert System, Last-Mile Access.

ÖZ

TELEKOMÜNİKASYON ERİŞİM UZMAN AĞ SİSTEMLERİ

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Bu tez çalışmasının temel amacı, farklı özelliklerde telekomünikasyon erişim sistemlerinin kullanılması ile ana telekomünikasyon hattından son kullanıcılara ulaşımı sağlayan Telekomünikasyon Erişim Uzman Sistemini kurmaktır. Telekomünikasyon Erişim Sistemlerinin kuruluş aşamasında genel olarak kablolu ve kablosuz genişband telekomünikasyon erişim sistemleri ve onların alt konuları çalışılmıştır. Bütün sistemler sistem yapısı, veri kapasitesi, iletişim mesafesi, güvenilirlik ve çeşitli uygulamalarının özelliklerine göre araştırılmış ve karşılaştırılmıştır. Uzman sistem tarafından en uygun genişband erişim sistemi bulunup telekomünikasyon ağ sisteminin istek ve şartlarına göre en uygun sistem seçilerek ana sistem yapılandırılmış ve uzman sistem bir uzman sistem dizayn programı kullanılarak oluşturulmuştur.

Anahtar Kelimeler : Genişbant telekomünikasyon erişim uzman sistemi, son kullanıcı erişimi.

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SYMBOLS

ITU : International Telecommunication Union

FCC : The Federal Communications Comission

ISDN : Integrated services digital network

DSL : Digital Subscriber Line

ADSL : Asymmetric DSL

HDSL : High bit-rate DSL

IDSL : ISDN DSL

MSDSL : Multi symmetric DSL

RADSL : Rate adaptive DSL

SDSL : Symmetric DSL

VDSL : Very high speed DSL

HFC : Hybrid fiber-coaxial cable(a cable television distribution system)

PLC : Powerline communications

FTTH : Optical fiber to the home

FSO : Free space optics

LMDS : Local multipoint distribution system

WIMAX : Wireless Metropolitan Access Protocol

LOS : Line of sight

Gbps : Gigabit per second

Mbps : Megabit per second

Kbps : Kilobit per second

LAN : Local Area Network

CHAPTER 1

INTRODUCTION

Recently, the main driver toward broadband is the increasing demand for information. Broadband can provide several improvements to our lives because of the capacity to transfer large amounts of data in reliable and speedy mode over long distances. The old type analog signals are replaced by the digital 1s and 0s, so any kind of information can be sent over one wire to deliver phone service, video service, internet service over fast connections. These overall connections are called as broadband. Broadband is a chance to provide high quality data transmission and to offer different perspective to the overall internet infrastructure rather than narrowband connections. Broadband is an always on transmission technology and high speed uplink and downlink two-way service which provides transmission of high-quality voice and data services at the same time [1–13].

There are various broadband term definitions which depend on different organizations. Broadband is defined as a faster and reliable transmission capacity at a transmision speed of 1.5 to 2 Mbps rather than primary rate ISDN by ITU Recommendation I.113. The FCC determines broadband about 200 Kbps and the OECD defines with downlink capacity at least 256 Kbps [3–5, 10].

Access to broadband means infinity and to be able to reach directly all universe over fast connections from home. For example, two student which are from different countries can have same lecture resources over the internet at the same time. Also, broadband is used in diagnosis and treatment in medical science. Broadband communications support the link between high-speed services and various of applications. These applications can be put into six categories [4] :

* Telemedicine
* E-learning
* E-business
* E-goverment
* Telecommuting
* Media and entertainment

Telemedicine category includes health services, clinical applications and medical education using telecommunication networks. Some of the applications are tele-diagnosis, tele-dermatology, tele-ultrasound, tele-monitoring and tele-radiology.

E-learning category can be formed in asynchronous e-learning and synchronous e-learning. Asynchronous e-learning applications are computer-based training modules and multimedia database support system. Synchronous e-learning applications are remote lecture room and interactive home learning. E-business category supports advanced integration of information and telecommunication technologies to automate business processes and to provide connection between customers. E-goverment category applications include the information exchange between the goverment and the public and the usage of the internet to provide necessary information for the public to do tax payment, licences and so on.

Additionally, simple messaging, large file transfer, unidirectional real time services (radio, television broadcasting), interactive real time messaging services (interactive gaming, tele-education), video-conferencing, integrated business telecommunication services are some of the examples of other broadband applications [6, 12, 14].

The broadband connection can come end-users over the same wires that are used for telephone service or over Cable TV, a fiber optic link, electrical power lines, radio waves, satellite and so on. Each method has advantages and disadvantages depending on cost, speed, location and other criterion. For example, a song can be downloaded approximately half an hour with a dial-up system (56 Kbps) and it takes three minutes to download the song with broadband speed. Also, video services and voice over Internet Protocol service can be offered by broadband speeds.

Basic broadband network architecture includes complete set of different electronic telecommunication systems [4]. Generally, it can be separated into three parts such as backbone network, regional network and access network. Backbone and regional networks provide connection between Central Office and access network. These networks are mainly based on fiber optic cable structure. Broadband technology is used in backbone networks by fiber optic links in the world and the telecommunication network infrastructure must be extended to provide high-speed network services to end-users in access networks. The most important broadband limitation is the lack of digital last-mile connection to end-users, because some last mile connections between the subscriber and the local exchange/Head-end/Central Office are still analog in the world. This last mile connection can be referred as local loop. Thus, the telecommunication network infrastructure must have changed to provide access to all end-users by upgrading existing system or building new system infrastructure. There are several types of telecommunication network infrastructures and various broadband access systems which provide connection between end-users and the Central Office. They are used to solve this last-mile connection problem and each one has different characteristics due to several system features [6, 9, 15].

Broadband Access Systems can be considered such as Wireway Access Telecommunication Network Systems and Wireless Access Telecommunication Network Systems. Wireway Access Systems are subdivided into four parts such as xDSL, FTTH, HFC and Power-Line Systems. Wireless Access Systems are subdivided into four parts such as LMDS, FSO, Satellite and Wimax Systems. DSL, HFC and Power Line technologies are used by upgrading existing infrastructures. DSL and HFC technologies are provided over the telephone network. Power Line technology is offered by existing electrical grid infrastructure. The main advantage of using existing infrastructure can be faster deployment time rather than the new constructed infrastructures. Generally, existing infrastructures are used by Wireway Systems except FTTH System. FTTH technology can be preferred when unlimited bandwidth is needed, but it requires new system construction and long deployment time. Wireless Access Telecommunication Network Systems can be preferred solutions for rural and remote areas where particular upgrading of existing system can be costly. System flexibility, wider coverage and mobile system access properties can be provided by Wireless Systems [1-4, 6-8, 11, 13, 16-19, 20-25].

A next generation network must be designed as a mixture of several more high-quality and more complex technologies according to the range of service, cost options, bandwidth requirements for different applications. It must be constructed for multimedia communications, multichannel transport with high data rates, low delays, low packet loss and with QoS guarantee. Several broadband access technologies both in Wireline and Wireless types are developed to support next generation networking. However, the optical networking is the basic driver for the next generation networks and FSO System is an alternative technology to solve bottlenecks of today's electronic systems to support future applications. So, the replacement of the electronic infrastructure with optical system components is necessary to provide end-to-end optical networking and high quality applications. Nowadays, the laser technology, new optical components and systems are developing. Thus, the market share of FSO System increases from day to day and FSO System can be supposed as the optimum telecommunication system for its strong end-to-end networking capability. Another alternative technology to offer broadband services in an inexpensive manner rather than xDSL and HFC Systems is Wimax System. This technology can be preferred when cable installation for last mile connection is impossible and it's new developing technology in recent years.

Since, the World Telecommunication Network which covers all Wireway and Wireless Systems has a big complexity and increasing size, it needs to expert systems to solve this complexity and to facilitate its management. There are various methods of supporting and managing this network and the most effective method is using expert systems. The goal of this thesis is to implement an expert system in telecommunications field and to solve last mile connection problem with the construction of Access Telecommunication Expert System which controls the selection of optimum access telecommunication network system in access network field.

In the light of above discussion, the basic purpose in this thesis is to create an optimum or suitable access technology selection expert system that is a rule-based system. The construction procedure for this expert system follows the steps of knowledge acquisition process which is represented in Chapter 5 in more detail. The first step is determining the problem domain which is the last mile connection problem. Secondly, the related information about telecommunication systems, last mile technologies, access networks which are taken from a domain expert and the related information about expert systems, knowledge acquisition process, knowledge representation techniques and inferencing techniques are provided from another domain expert. In the third step, all the related information from two different fields are combined to prepare a preliminary document to use in knowledge representation part which is presented in Appendix A. Then, the network model of the main system is developed as a general view of Access Telecommunication Network Systems Structure Schema and as a supplementary material to Appendix A to use in rule production. The network model of this expert system is basically formed from Wireway and Wireless Access Systems and their subsystems. Each system is put into place of this structure which depends on different factors and limitations which are further presented in Appendix A and Appendix E. Some of the factors for the system are the basic infrastructure of each system, frequency of operation, bandwidth requirement, maximum deployment distance, main applications of access system, security of access system, access system cost, ease of system installation, licence requirement for frequency, weather condition, settlement feature and so on. This structure schema is used to facilitate system construction procedure based on domain expert's suggestions. The decision rules are derived as IF/THEN rules.

The network model of the system which is Access Telecommunication Network Systems Structure Schema is designed by using the expert system development tool EXSYS and the EXSYS shell is used to build the rule-based system. In the fifth step, decision rules of the Access Telecommunication Expert System is entered to the EXSYS system shell by the use of EDITXSP rule editor. Then the constructed system is run several times and some results are displayed in the resulting table which have different values for each run. As a last step, these results are evaluated and the verification of these results are performed by the domain expert. Finally it can be stated that in this thesis, rather than taking a programming approach, expert systems are used in the construction and design of access technology selection telecommunication system.

1.1 ORGANIZATION OF THE THESIS

In this thesis, the main purpose is to investigate different types of access telecommunication network systems and to construct an expert system which is used to select optimal access telecommunication network system as an inexpensive solution for last-mile connection problem which depends on different conditions. This thesis is constructed as follows. The first part is related with technical explanation of Broadband Access Telecommunication Network system types and their overall features. The second part is considered as Expert System construction for Access Telecommunication Network Systems.

In this section, general explanation of broadband term is given and the route of this thesis is determined. Then, the second section is established as an explanation of technical part of The Access Telecommunication Network Systems, Wireway and Wireless Access Network Systems. In the third and fourth sections, the expert system part of the system is designed and the knowledge base of the system is explained. In the fifth section, Expert System results are determined and as a last section conclusion part is constituted.

CHAPTER 2

ACCESS TELECOMMUNICATION NETWORK SYSTEMS

2.1 WIREWAY ACCESS TELECOMMUNICATION NETWORK SYSTEMS

In general the wireway access systems provide cable connection between the subscriber and the Central Office. Many broadband access technologies such as xDSL, HFC, FTTH and Power Line systems are developed to use as wired medium systems [2, 26–50]. Transmission medium is the physical connection between computers, people and other devices on a network environment. The compability of the network hardware and the medium is necessary. The OSI Reference Model is used to represent the network telecommunication with the specialized network hardware to support related services. Transmission medium runs at Layer1 of the OSI Reference Model. Transmission medium can be copper cable such as twisted-pair cable and coaxial cable or fiber optic cable or can be wireless such as radio frequencies, microwave, satellite and infrared. Generally, the main advantage of the copper cable medium is inexpensive than other mediums and its main disadvantage is that has the limited spectrum for advanced applications. Deployment of copper cable is more costly and slower rather than wireless medium. Fiber optic cable offers very high bandwith and it is resistant to various types of interferences and noise. Deployment of fiber optic cable is costly, because it requires special equipments. The wireless medium is an important alternative when the enviromental conditions don`t allow deployment of cable system or the operation is more costly, but it provides slow data rates. Transmission medium characteristics can be considered as five properties. These properties are frequency spectrum which the medium operates, performance error rate, distance between repeaters, security and cost. The frequency spectrum changes due to the medium type and it is related with the bit rate of the medium. For example, twisted-pair cable medium operates at 1 MHz and fiber optic cable medium operates at 75 THz. The error rate is the second characteristic of the transmission medium. Coaxial cable and fiber optic cable resist interferences more than twisted pair cable. The fiber optic cable is the most conserved cable for the electrical interference. The distance between the repeaters which is the main cost calculation characteristic for operating and constructing networks. Security can be provided by using encryption and authentication techniques. Also, there are other techniques to ensure security for different mediums. For example, fiber optic cable can use optical time domain reflectometer to detect unwanted access to the

system. Cost characteristics of the transmission medium can be divided into three types such as acquisition cost, installation cost and maintenance cost.

The most important twisted pair cable medium example is the public switched telephone network (PSTN). Twisted pair cable types are unshielded twisted pair cable (UTP) and shielded twisted pair cable (STP) due to the minimization of the outside interference effects property. Also, it can be divided into cable categories due to data rate properties such as Category 1, Category 2, Category 3, Category 4, Category 5, Category 5E, Category 6 and Category 7.

Applications of twisted pair cable is traditional analog telephone system and digital twisted pair example is Integrated Services Digital Network (ISDN) and xDSL systems. ISDN is used to provide end-to-end digital service using the public telephone networks in the world. Narrowband ISDN has two different specifications such as Basic Rate Interface (BRI) and Primary Rate Interface (PRI). BRI includes 2B+D channels and it offers 144 Mbps with loop length 5.5 kilometers over a single twisted pair. B channels are bearer channels that carry voice, data or other transmissions, D is the delta channel which is used for signalling and to carry low-speed packet-switched data. Application fields of BRI are residences and small businesses. PRI has 23B+D channels for North American and Japanese and 30B+D channels for other countries. PRI type is used for business systems over two twisted pair. Since, the BRI is not the most suitable solution for the internet access, some other solutions are created as an alternative such as xDSL systems.

Twisted pair cable advantages are high availability, low cost installation on premises and low cost for local changes and moves.

a. **High availability :** It means twisted – pair infrastructure is used all over the world.

b. **Low cost installation on premises :** The installation cost for twisted pair medium on premises is inexpensive.

c. **Low cost for local changes and moves :** Twisted pair wiring process is easy.

And the following properties are the disadvantages of the twisted pair cable medium.

a. **Limited frequency spectrum :** Twisted pair cable medium uses 1 MHz frequency spectrum.

b. **Limited data rates :** The data rate is 2 Mbps or less. At 100 meters, twisted pair cable can carry 100 Mbps.

c. **Short deployment distances between repeaters :** Since more components are needed for deployment, operational costs can be high.

d. High error rate : Twisted pair cable medium is highly effected from signal interference.

The second copper cable transmission medium is coaxial cable medium and information travels over a coaxial cable from a copper wire in the center of coaxial cable. The coaxial cable provides a higher transmission rate than twisted pair, because copper wire in the coaxial cable is thicker than in twisted pair cable. Coaxial cable medium offers more frequency spectrum rather than twisted pair cable medium. HFC architectures are the newer deployment types of coaxial cable medium and they support 750 MHz or 1000 MHz. Applications of coaxial cables are a telephony network in mid-1920s, deployment of coaxial copper cable as a submarine cable to carry international telecom traffic in the 1950s, constructing of coaxial cable based LANs in 1980s and recently it is used in community antenna (cable TV) in the HFC form in local loop. In HFC architecture, the fiber comes as close as end-user to neighborhood node from Central Office, then the service is distributed to each user by coaxial cable. One disadvantage of the HFC architecture with coaxial cable usage is deployment in bus topology. Since the bandwidth is shared between the number of end-users, this causes increment of congestion levels, security risks and noise.

Advantages of coaxial cable medium are greater channel capacity, greater bandwidth, low error rate, longer deployment distance between amplifiers.

a. Greater channel capacity : Since multiple channels offer high capacity to the various number of end-users and their sufficient frequency range provide greater throughput for broadband system.

b. Greater bandwith : Because of coaxial cable medium supports greater bandwitdh, a mixture of services can be supported easily at the same time.

c. Low error rate : Coaxial cable medium has insulation, so it has better performance and lower error rate rather than twisted pair cable.

d. Longer deployment distance between amplifiers

And the main disadvantages of coaxial cable medium are architecture deployment problems, upgrading of old architecture coaxial cable medium systems is necessary, noise problems, high installation costs and so on.

a. Architecture deployment problems : The bus topology structure of the coaxial cable medium causes congestion, security and noise risks.

b. Upgrading of old architecture coaxial cable medium systems is necessary: Cable systems which are designed for broadcasting purpose must be converted to bidirectional systems to support interactive communications.

c. Noise problems

d. High installation costs : Installation costs are high. Local moves, adds, changes and the termination of a coaxial cable can not be performed easily.

The other transmission medium is fiber optic cable. Fiber optic cable medium offers large amounts of bandwith. In fiber optic transmission, the digital bits enter the light device such as a laser diode. If the bit is 1, then the laser diode pulses light in that time slot, but if there is a 0 bit, then there is no light pulse. The three wavelengths such as 850, 1300 and 1550 nanometers (nm) for fiber optic transmission is provided by the EIA/TIA standards. Each of these bands widths are 200 nm and they offer about 25 Terahertz (THz) of capacity which means there is a 75 THz of total capacity on a fiber cable. There are two major types of fiber optic cable such as single mode and multimode. Fiber size is measured by the core diameter and cladding diameter. The current fiber size which is supported by the EIA/TIA standard is 62.5 /125 micron fiber. The core diameter of the multi mode fiber is 50 microns to 62.5 microns. The core diameter of the single mode fiber is 8 microns to 12 microns. Single mode fiber is more expensive rather than multi mode fiber and it offers high capacity and performance. It is preffered to use in long distance networks. Applications of fiber optic cable medium are usage of public and private backbone networks, to reach up to neighborhood nodes in HFC architecture (FTTC: fiber to the curb), to reach up to end-users directly in FTTH system, usage of fiber in LANs with FDDI (Fiber Distributed Data Interface) .

Advantages of fiber optic cable medium are very high bandwidth, advanced traffic carrying capacity, secure transmission, low in mass and weight.

a. Very high bandwith : Fiber optic cable offers high bandwith rather than other cable-based systems.

b. Advanced traffic carrying capacity

c. Secure transmission : There is a constant monitoring for the optical networking, so the light pulse distortion can be observed.

d. Low in mass and weight : Less human installation power is needed, since the fiber is low in weight and mass.

And the main disadvantages of fiber optic cable medium are high installation costs, special test equipments for installation, lack of enough manufacturing, physical damage of cable structure.

a. High installation costs

b. Special test equipment is required : It is required, because none of the test equipment which is used on an electrical network will work with fiber structure. An optical time domain reflectometer (OTDR) is needed.

c. Lack of enough manufacturing

d. Physical damage of cable structure : Fiber is a slim and sensitive medium, so it can be cut or damaged easily.

In the deployment of twisted pair cable and coaxial cable can have some limitations because of the frequency spectrum and their deployment can be more costly in some locations. In these cases, the bright solution can be microwave. One application for microwave is the replacement of leased lines in a private network with microwave systems, two LAN interconnection by using microwave, broadband access by LMDS technique in wireless local loop. Microwave is inexpensive and has a quick deployment time rather than wireline media.

Advantages of microwave are cost savings, configuration flexibility, high bandwidth.

a. Cost savings : Microwave usage is less expensive than leased lines.

b. Configuration flexibility : Microwave systems have portability feature.

c. High bandwidth : Microwave systems can support multimedia applications.

And the main disadvantages of microwave medium are line of sight requirement, susceptibility to environmental distortions, licencing requirement, environmental restrictions.

a. Line of sight requirement : The obstacles between buildings can effect the system.

b. Susceptibility to environmental distortions

c. Licencing requirement

d. Environmental restrictions : The microwave towers can not be allowed by some society.

The other transmission medium is satellite which is like microwave but not terrestrial. In satellite communications, the most important frequency bands are C-band, Ku-band, Ka-band and L-band. The C-band operates at 6 GHz uplink range and 4 GHz downlink range. Since the C-band operates in the lower frequency bands, it has resistance to weather conditions. The Ku-band operates at 14 GHz uplink and 11 GHz downlink. The advantage of Ku-band is the reserved frequency band allocation without interference of terrestrial systems. The disadvantage of Ku-band is that it can be effected from bad weather conditions, because it has higher frequency band allocation. The broadband access satellites operate in Ka-band. They operate at 30 GHz uplink and 20 GHz downlink. L-band operates in 390 MHz to 1550 MHz range. It is mostly used in VSAT (Very small aperture terminal) networks and mobile communications. The basic applications of the satellite are to provide services to remote areas, to provide point-to-multipoint communications in inexpensive manner, to provide remote monitoring and control, to establish two way data messaging, to distribute TV, video and multimedia.

Advantages of satellite are as follows:

a. Access to remote areas

b. Wide coverage

c. Costs which change with distance

d. Strong architecture

e. High bandwidth

And the main disadvantages of satellite are as follows:

a. High initial cost

b. Propagation delay

c. Environmental interference problems

d. Licencing requirements

e. Regulatory criterias

f. Atmospheric effects

2.1.1 DSL

DSL is a wireway transmission technology that transmits data over copper telephone lines by traditional phone service. A DSL subscriber modem is connected by copper wires to the central office where a DSL Access Multiplexer (DSLAM) is installed. Then the DSLAM transmits the signal from the copper telephone line to a network backbone. This service allows subscribes to have an "always-on" dedicated connection to the internet.

DSL service is provided by local telephone companies in 1996 and it is a transmission technology to support an always-on high-speed internet connection over the existing single telephone line. DSL carries voice, video and data at multi-megabit speeds over standard telephone wires simultaneously. It is a point-to-point line technology. The worldwide DSL subscriber base includes approximately **23 million subscribers** in 2005. DSL is created by **Bellcore (which is now Telcordia)** as a technique to filter out the background noise on copper twisted-pair wires and to allow good quality connections. DSL modems are limited in transmission distance and generally its distance range is up to 5.5 kilometers. It uses modulation techniques and echo cancellation to derive separate voice and data channels from one wire by frequency splitting and to provide full-duplex transmission over single electrical wire. DSL has power protection capability. When the electricity goes out, data service can be lost, but voice services retain.

2.1.1.1 xDSL Systems

DSL Technology has several types which are called as xDSL Technologies and they are distinguished from each other according to the speed and their transmission properties. xDSL Technologies are ADSL, HDSL, IDSL, MSDSL, RADSL, SDSL, VDSL, VDSL Plus and UADSL.

a. ADSL:

ADSL has been the most popular technology for providing broadband access to subscribers. ADSL was initiallly introduced in 1993 and now, it is used as the perfect solution for internet access. ADSL requires multiplexing equipment at the Central Office (CO) called a DSL Access Multiplexer (DSLAM) to collect traffic from backbone. At the subscriber side, a splitter must be installed on the side of the house at the demarcation point to separate voice and data. ADSL is the standard solution for providing broadband services to subscribers. The basic ADSL theoretically provides a downstream capacity up to 8 Mbps but commercial services are limited to 1-2 Mbps downstream and 16 Kbps to 1.1 Mbps upstream. ADSL uses frequency range up to 1.1 MHz.

There are two ADSL standards such as **ADSL–1** and **ADSL–2**. ADSL–1 provides 1.5 Mbps downstream in the North American and T-carrier countries, 2 Mbps downstream in E-carrier countries and an upstream channel in both North American and European countries is up to 64 Kbps. The distance range is 4.5 to 5.5 kilometers (2.8 to 3.5 miles). New improved versions of ADSL are called **ADSL2** and **ADSL2+**. ADSL–2 provides 6 Mbps downstream in T-carrier countries and 8 Mbps downstream is used in ITU Standard observed countries. The upstream channel provides a range of 640 Kbps to 800 Kbps. The distance range is 2.8 to 3.5 kilometers (1.7 to 2 miles). ADSL2+ increases the bandwidth used for downstream transmission from 1.1 MHz to 2.2 MHz to achieve theoretical data rates up to 20 Mbps on short lines. The maximum ADSL2+ upstream data rate is about 1 Mbps. ADSL2+ allows service providers to improve their networks to support services such as digital TV and video-on-demand in a flexible way.

ADSL is standardized under **ITU G.992.1 and ANSI T1.413, Issue2**. Two different modulation schemes are used in ADSL such as **CAP and DMT**. CAP is based on the QAM (Quadrature Amplitude Modulation) Technique. CAP adapters are less expensive than DMT adapters, but CAP is more susceptible to interference. CAP is a single-carrier modulation scheme. ADSL services are CAP based in United States. DMT is better technique which is standardized by ANSI, ETSI and the ITU. DMT is a multicarrier technique and its spectrum is divided into 256 4 KHz carriers. When we compare CAP and DMT modulation schemes, DMT is less tolerance to interference and it is the preferred modulation scheme for DSL.

The major advantage of ADSL is that they can be run over the existing copper infrastructure. It also provides a dedicated line and guaranteed bandwidth, so bandwidth is not shared between subscribers, this property makes ADSL more secure and reliable data delivery option. ADSL is the least expensive type of DSL. One disadvantage of ADSL can be an access limitation depends on distance. If subscribers are outside the system distance, they can`t access to DSL service. The main applications of ADSL are to provide high-speed internet access to remote LANs, VoDSL (Voice over DSL) and video-on-demand services to end-users.

b. HDSL:

HDSL is the oldest DSL technique. It is symmetrical and full-duplex service that means equal bandwidth flows in both directions. HDSL technology uses two twisted-pair cables different than other xDSL technologies. The bandwidth rate for HDSL depends on T–1 and E–1 enviroments. In the T–1 enviroment, it offers 784 Kbps in each direction and in the E–1 enviroment, it offers 1.168 Mbps in each direction. HDSL is largerly used to provide digital services to business premises. HDSL distance range is 3.6 kilometers. HDSL is standardized under **ITU G.991.1 and ADSI T1E1.4, Tech Report 28**. HDSL is used to provide T–1/E–1 services to businesses at low costs.

HDSL2 specification was developed to provide high-speed bandwidth and the symmetry of HDSL to subscribers. It involves the use of a single twisted copper pair for distances up to 3.6 kilometers. HDSL2 is a symmetrical and full duplex service that offers up to 768 Kbps in each direction.

c. IDSL:

IDSL technology is basically ISDN system without the telephone switch. IDSL is a full-duplex, symmetrical service and it offers 128 Kbps in each direction. The distance limitation on IDSL is 5.5 kilometers (3.5 miles).

d. MSDSL:

MSDSL is a descendent of SDSL. MSDSL uses single twisted copper pair, which can be run up to 8.9 kilometers (5.5 miles) and it is a symmetrical, full-duplex service. MSDSL offers 8 variable line rates, ranging from 64 Kbps to 2 Mbps. The 64 Kbps or 128 Kbps data rate is supported at 8.9 kilometers (5.5 miles) and 2 Mbps is supported at 4.5 kilometers (2.8 miles).

e. RADSL:

RADSL can operate in symmetrical mode or asymmetrical mode. The downstream rates are from 600 Kbps to 7 Mbps and the upstream rates are from 128 kbps to 1 Mbps. The application distance is up to a maximum of 5.5 kilometers (3.5 miles). Most of the RADSL devices use DMT encoding technique.

f. SDSL:

SDSL is the more expensive type of DSL. This is often used as business DSL. It is more costly than asymmetrical options, but it provides more performance guarantee. SDSL is symmetrical and full-duplex service. SDSL supports multiple data rates up to T–1 or E–1 rates (1.5 Mbps or 2 Mbps). SDSL involves a single twisted copper pair that can operate up to 5.5 kilometers (3.5 miles).

g. VDSL:

VDSL is a very high capacity technology and it is a sister technology to the FTTC (Fiber to the Curb). VDSL can be run over twisted pair from the building to each department. VDSL is more complex than ADSL and it has several options for frequency band allocation and modulation techniques. While ADSL is designed for asymmetric transmission only, the VDSL standard includes both asymmetric and symmetric modes which are used both residential and business applications.

The goal of VDSL is to provide less power consumption, lower costs and much higher data rates than ADSL. VDSL provides 13 Mbps downstream and 2.3 Mbps at 300 to 1500 meters. VDSL uses frequency ranges up to 12 MHz. VDSL uses a single twisted copper pair and operates over very short distances. The key applications for VDSL are the next generation TV (HDTV, DTV and forms of interactive multimedia, high-speed internet access). VDSL is standardized under the ITU G.vdsl. title.

h. VDSL plus:

VDSL plus (VDSL2) is an extension technology of VDSL and uses higher frequencies over 12 MHz. It can provide transmission speeds up to 150 Mbps.

ı. UADSL:

Universal ADSL technology provides data rates up to 1.5 Mbps downstream and up to 384 Kbps upstream. The main difference between ADSL and UADSL is that UADSL doesn't require a splitter.

2.1.2 FTTH

A fiber optic connection is another transmission technology that is used to provide high speed internet access to subscribers. Fiber optics are long, thin transparent fibers of glass or plastic about the diameter of a human hair. Light-Emitting Diodes (LEDs) send light through the fiber to a detector that converts the light into an electrical signal. They are used to transmit light signals over long distances. New equipment and techniques provide to deliver fiber to the home at a lower costs. Installation costs of fiber can vary. Fiber-to-the-home installation average is $2900. Optical fiber is light weight, flexible cable and it provides extremely fast connection, but its availability and usage are limited. FTTH is an all-fiber option that provides a minimum of 155 Mbps in both directions. It is a point-to-point architecture with a dedicated connection from the home to the network. It provides extremely low maintenance cost over the life-time of the system rather than traditional networks. This is one reason why fiber such a favourite wireline solution. However the cost of FTTH deployment (installation cost) is still quite high. As the cost of deploying fiber decreases, FTTH will become an increasingly attractive solution due to its bandwidth and the resistance to the noise. Fiber extends from the Central Office or headend to homes in the application area and reaches up to the end-users directly**.**

The most significant advantage of FTTH is bandwidth, but other advantages of an all-fiber network include reliability, security and signal quality. Additionally, emerging optical technologies such as optical amplifiers and dense wavelength division multiplexing (DWDM) are used. The main disadvantage of FTTH is optical-to-electronic signal conversion necessary for every home and the

other disadvantage is the initial cost (installation cost) of the network is larger than copper based systems.

2.1.3 HFC

HFC systems uses both optical fiber and coaxial cable infrastructure. Optical fiber comes up to buildings, then it is distributed to the end-users by coaxial cable. Cable networks are the first broadband access services in the United States.

Many traditional cable networks are upgraded to HFC which is two-way architecture in order to support high-speed broadband connection over a cable modem platform. The HFC standard, DOCSIS 1.1 supports 40 Mbps downstream and 10 Mbps upstream shared data channels. The latest version DOCSIS 2.0 increase the upstream path up to 500 Mbps over DOCSIS 1.1. HFC system supports 256–500 Kbps upstream and 0.5-3 Mbps downstream at distance 100 km. It provides data, video and VoIP (voice over IP with adapter) services. The most important difference between DSL and HFC is that HFC is a multi-user shared bandwidth system.

2.1.4 POWER LINE

Broadband Power Line is the delivery of data communications over the existing electric power distribution network. Broadband power line (BPL) uses the power lines are owned and operated by the power companies. Data is transmitted over the lines as low voltage and to provide this transmission high frequency signals coupled on to the high voltage and low frequency power signal. Most BPL systems can achieve a 2-3 Mbps data rate, but they are limited in distance by the 1 km power grid. The applications power-line is high-speed internet access, VoIP, video and audio on demand, video conferencing, home-LAN connections and interactive TV.

2.2 WIRELESS ACCESS TELECOMMUNICATION NETWORK SYSTEMS

Wireless access systems use air instead of wire as a medium to provide connection between subscriber and Central Office. Wireless access solutions are LMDS, FSO, Satellite, Wimax systems [2, 34–36, 51–57].

2.2.1 LMDS

LMDS consists of a radio transmitter which sends signals on a combination of channels to many receivers of homes and businesses. Local Multipoint Distribution Service (LMDS) operates in a higher band of the UHF range (24 GHz – 38 GHz). It also offers a higher bandwidth then MMDS, but it is limited to a much shorter operating range around 5 km. LMDS is set up as a wired link from the base station to a local antenna, which then broadcasts to multiple local receivers. Each LMDS channel is limited to 155 Mbps and requires line-of-sight between the local antenna and receivers. LMDS can provide 10 Mbps or faster connections to customers who are using E1/T1 leased line connections between their LANs or to their ISPs. LMDS uses up to 622 Mbps by allocating a large spectrum (100-112MHz) to a single subscriber or usually 10 Mbps for each subscriber in order to maximize the number of subscribers.

LMDS provides wireless broadband service and it can have broader bandwidth but coverage is limited and components are more expensive. LOS (Line-Of-sight) is required. It is a point to multipoint system and there is a licence requirement for LMDS. LMDS provides digital two-way voice, high speed Internet access and data and video services.

2.2.2 FSO

Current microwave bandwidth is limited to 622 Mbps. As bandwidth demands increase and businesses require high-speed LANs, FSO becomes one of the most effective solution. The main disadvantage of wireless connections is that they offer less security than wireline connections. In fact, Free Space Optics is more secure than other wireless transmission technologies. Each FSO unit uses mainly high power laser sources and a lens that transmits light through the atmosphere to another lens receiving the information. Receiving lens is connected to a high-sensitivity receiver by an optical fiber. It is a full-duplex communication. Free Space Optics use infrared lasers for data rates between 100 Mbps to 2.5 Gbps over distances up to 2 km. FSO is a wireless optical transmission technique which operates over atmosphere. Two wavelengths can be used around 1550 nm (194 THz) and around 800 nm (375 THz). Optical pulse modulation and DWDM is applied. Line-of-sight (LOS) is required**.**

FSO systems are preferred because of their low installation costs and as a solution for interference problem of radio wave transmissions. FSO is used for

private applications because of line of-sight limitation and its susceptibility to external effects such as fog, absorption, scattering and physical effects.

2.2.3 SATELLITE

Telecommunication satellites receive signals from a ground station and send them down to another ground station which is located at a very long distance from the first station. It is microwave but not terrestrial. Satellites can transmit to and receive from a large area, thus generally used in point-to-multipoint and broadcast applications. It provides long distance telephone network among countries, TV Broadcasting, GPS Systems, VSAT Networks. Their performance varies with the weather condition similar to microwave systems.

Satellite comes in two modes: the older one-way (hybrid mode) and the newer two-way mode. In the one-way mode, download is occured by the satellite but upload is provided by a standard 56K telephone connection to a local telephone number. The one-way mode is used in Ku-band that with a 12 GHz downstream link and a 14 GHz upstream link. Although the upload is limited to 56 Kbps because of the telephone line, the download can be 1 Mbps and the normal satellite-TV dish antenna is used for downloading with a special antenna splitter/modem. Costs are quite variable and it is an alternative system to DSL in many areas where internet connectivity is provided by cable.

In the second two-way satellite modes, Direct Broadcast Satellite (DBS) uses geostationary satellites and VSAT technology for two-way high-speed data transmissions. They currently operate in the Ka-band with 30 GHz upstream link and 20 GHz downstream link. GEO's and broadband LEO's use Ka-band. Since GEO's disadvantage is that the satellite is 22,300 km away from Earth and they introduce a 250 ms delay in two-way transmissions. This level of latency is unacceptable for most broadband applications, so broadband LEO's can be preferred. Data rates are up to 155 Mbps with GEO's. Broadband LEO's offer 16 Kbps and 155 Mbps.

The main applications of GEO systems are one-way broadcast, VSAT systems and point-to-multipoint links. Broadband LEO's support data and multimedia files at up to 155 Mbps. Accessing the internet by satellite requires a different antenna than normal satellite-TV. Since satellites has many modes are available for internet connectivity, the choice depends on the needs for the speed of connection and cost considerations.

2.2.4 WIMAX

Wimax provides a communication path between a subscriber and a core network. This wireless broadband access standard supports the missing link for the "last mile" connection in metropolitan area networks where DSL has limited distance capability. Current WiFi standards support data transmissions rates of up to 54 Mbps per channel. WiFi is used as the wireless internet solution in homes.

Wimax is the WiFi cousin based on the IEEE standard 802.16 and is designed to deliver wireless broadband access over greater distances. Wimax is available in both NLOS and LOS configurations. NLOS operates in a point-to-multipoint mode and delivers data rate between 8-11 Mbps over 1-2 km. The LOS version operates as point-to-point system and delivers data rate between 8-11 Mbps over distances of 10-16 km. Wimax covers a couple of different frequency ranges. The IEEE 802.16 standard defines frequencies from 10 GHz to 66 GHz.

Wimax offers a Wimax-based network with the flexibility to support a variety of data transmitting rates such as T1 (1.5Mbps) and higher data transmitting rates of up to 70 Mbps on a single channel that can support thousands of users. Wimax supports ATM, IPv4, IPv6, Ethernet and VLAN services [58- 66].

CHAPTER 3

DEVELOPMENT OF AN EXPERT SYSTEM

This chapter is an introduction for expert systems and the basic structures of expert systems are explained. The general comparison between expert systems and other programing methods are performed. The application areas of expert systems are discussed and the advantages and disadvantages of expert systems are described.

3.1 WHAT IS AN EXPERT SYSTEM?

An expert system system is a computer program that uses knowledge and inferencing techniques to solve problems. The expert system is an improved tool which is based on decision-making property of a human expert. The most common form of an expert system is a program which is based on rules that analyse information about specific class of problems. Expert system is a knowledge-based and also rule-based system. Expert system is constructed to solve problems in the fields of accounting, medicine, process control, financial service, production, human resources and so on. Expert system concept is a branch of Artificial Intelligence (AI) that performs deep usage of knowledge to solve problems with assistance of a human expert.

The basic distinction between expert systems and traditional problem solving programs is the coding types. In traditional programs, the problem expertise is encoded in both program and data structures. Traditional computer programs use conventional decision-making logic with a limited knowledge. This knowledge is embedded as a part of the programming code and when the knowledge changes, the program is reconstructed. In the expert system application, the problem expertise is encoded only in data structures.

3.2 THE GENERAL ARCHITECTURE OF AN EXPERT SYSTEM

The general architecture of an expert system is basically constructed from a problem dependent part with data production and design which is called knowledge-base or rule-base and a problem independent part which is called inference engine.

The knowledge can be either expertise or it can be provided from books, magazines and knowledgeable people. Therefore, the expert system is called knowledge-based system or knowledge-based expert system. In the operation of an expert system, the user provides facts to the expert system and receives expertise (expert advice) in response. There are two basic components inside the expert system structure such as knowledge-base and inference engine.The knowledge base contains knowledge which is used by inference engine to produce results. These results are the expert system responses to user queries **(Figure1)**.

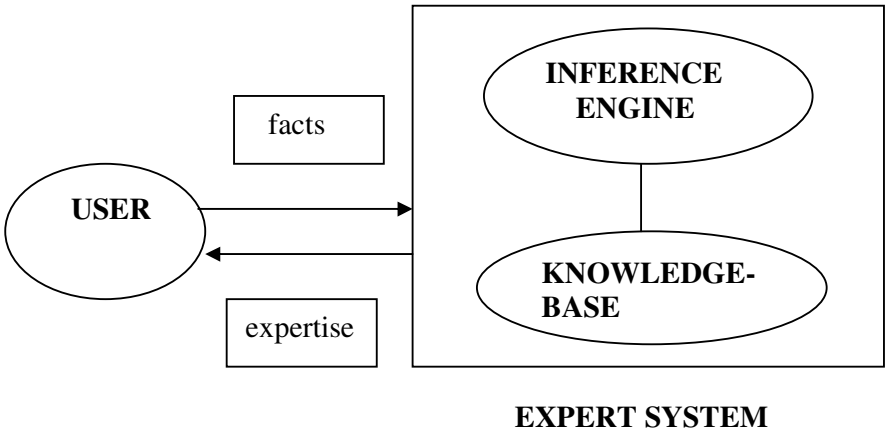

Figure 1: Expert System Architecture and Operation

Generally, there are three individuals which have interaction with the expert systems. The primary individual is the end-user who uses the system to solve his/ her problem. In the construction part of the system, there are two individuals such as the problem domain expert and a knowledge engineer. The problem domain expert who provides the domain expertise for the construction of knowledge base and the knowledge engineer who supports the experts in the representation of knowledge. The knowledge engineer enters this knowledge into an explanation module and defines the inference technique which is used to provide connection between knowledge base rules and results. Knowledge engineer represents the problem solving activity in the form of rules, so the knowledge-base expert system is called as rule-based expert system. The knowledge base stores the rules of the expert system which are created by the knowledge engineer from the domain expertise.

In the operation phase of the expert system, the expert system is seen as an interactive dialog by the user. The system offers a set of questions to the user. The user gives answer to each question. Then, the results are produced by the expert system which are compatible with the user's answers to questions. Knowledge engineers are interested with the knowledge representation and knowledge usage with the inference engine. They can use the knowledge acquisition procedures and suitable inference techniques to construct the rule-based expert system. Basic inference techniques are forward chaining and backward chaining and also they can be called as rule processing techniques [67, 68].

3.3 THE INFERENCE RULE

The inference rules are the basic elements of expert systems. They are produced by the knowledge engineers from a domain expertise and used by the inference engine to reach specific results with the selected inputs by the user. An inference rule structure has two parts an IF clause and a THEN clause. An expert system knowledge base is constructed from many inference rules and these rules can be called as decision rules, too. An example of an inference rule from this thesis knowledge base is below.

IF:

The upstream rate is 2.3 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is the next generation TV

THEN:

The optimum access telecom system is Wireway-xDSL-VDSL PLUS - Confidence=10/10

These rules are entered as separate rules by the knowledge engineer and the inference engine uses them together to reach results.

3.3.1 CHAINING

There are two main inference techniques such as forward chaining and backward chaining. They are also methods of reasoning.

a. **Forward Chaining :** This method is data driven and the order of the rules which are placed into the knowledge base is important. If there are three decision rules, each containing a different question (knowledge base qualifier) , question 1 will be asked first and the first decision rule in the knowledge base will be tested; question 2 will be asked and the second decision rule will be tested; question 3 will be asked and the third decision rule will be tested. The inference engine starts with data or facts and

searches the inference rules until the true IF clause is found. Then, it concludes THEN part and this process continues with rule order until the desired goal is reached.

b. **Backward Chaining :** This method is goal driven and the order of rules aren't important. The inference engine starts to work backwards with a list of goals and searches all inference rules until a THEN clause of a rule matches the desired goal and the true IF clause is found. EXSYS expert system development tool asks questions and tests THEN parts of rules which contain choices. EXSYS will start by searching for the decision rules which contain choice 1, ask these questions where choice 1 stands, and execute the decision rules where choice 1 appears in the THEN part in order. Then, it will search decision rules that contain choice 2, asks these questions where choice 2 stands and tests these decision rules. This procedure continues until all the remaining choices are finished. The three decision rules from the access telecommunication network knowledge base of this thesis appear downside are used as an explanation for the concept of backward-chaining (**Figure 2**).

RULE NUMBER: 8

IF:

The upstream rate is 1.54 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to provide T1/E1 services to businesses at low costs

THEN:

The optimum access telecom system is Wireway-xDSL-HDSL - Confidence=9/10

RULE NUMBER: 44

IF:

The downstream rate is 1.54 Mbps and the communication medium uses a copper twisted- pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to provide T1/E1 services to businesses at low costs

THEN:

The optimum access telecom system is Wireway-xDSL-HDSL - Confidence=9/10

RULE NUMBER: 96

IF:

The maximum deployment distance is 3.6 km and the oldest xDSL system is preferred

THEN:

The optimum access telecom system is Wireway-xDSL-HDSL - Confidence=10/10

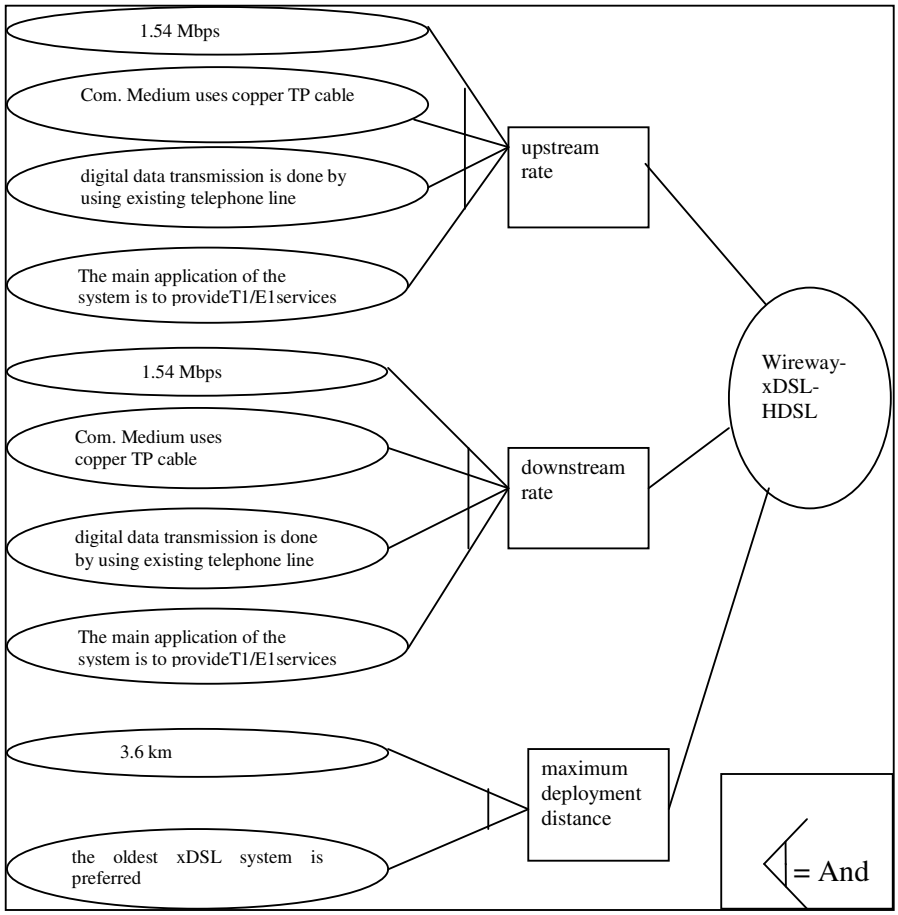

Figure 2 : Example AND --- OR Logical Representation Of Rule 8, Rule 44, Rule 96 For The Optimum Access Telecommunication Network System Decision With Backward Chaining Inferencing

Since decision rule number 8 contains the first occurrence for choice of Wireway-xDSL-HDSL with the given qualifiers which are related with questions, this decision rule is used; the question " The upstream rate is ? " is asked and the decision rule is tested by the EXSYS expert system development tool rule editor. The basic process of testing a decision rule starts with the evaluation of the IF part of the IF / THEN structure. When the IF statement in a decision rule is true, the THEN part is performed. When the IF part is false, the ELSE statement is performed. If there is no ELSE statement in a decision rule, EXSYS searches for any other decision rules which contain the Wireway-xDSL-HDSL choice.

Since decision rule number 44 contains THEN part which is Wireway-xDSL-HDSL, the question " The downstream rate is ?" is asked, the decision rule is tested and IF part is verified. Then, the decision rule number 96 contains THEN part which is Wireway-xDSL-HDSL, the question " The maximum deployment distance is ? " is asked, the decision rule is tested and IF part is verified. EXSYS expert system development tool rule editor starts from the first decision rule again, but this time it searches other decision rules which contains another choices. EXSYS stops and displays results after all choices are tested.

3.3.2 CONFIDENCES

Expert systems offer a big chance with the usage of various confidence values different from 100 %. EXSYS expert system development tool offers three confidence systems (probability systems) such as **the 0 or 1 system, the 0 to 10 system and the -100 to + 100 system.**

a. **The 0 or 1 system :** There are only two probability systems such as 0 means absolutely no and 1 means absolutely yes in this system. Since this system contains only two values, it is not suitable when the confidence level is required.

b. **The 0 to 10 system :** Since the level of the confidence can be presented, this system is the most useful and preferred system. The degree of confidence values between 0 and 10 (resulting confidence values) are taken from knowledge base by EXSYS rule editor. The levels of confidence change from 1 (very probably no) to 9 (very probably yes). The values of 10/10 (absolutely yes) and 0/10 (absolutely no) lock out any other values. The values 1 through 9 don't lock a value and the average of these values are taken when results are displayed. 1 is entered as 1/10 and 9 is entered as 9/10 as a confidence factor in a decision rule. When displaying results the average of all confidence factors are taken and written as a resulting confidence factor for each result in a row in the resulting table.

For example, if three THEN parts with true IF statements have a choice with values of 3/10, 5/10 and 7/10, the resulting confidence value is the average of three decision values (3+5+7 / 3*10) or 5/10 and this value is displayed as

confidence factor 5 in the resulting table. If the value 10/10 is replaced the value 3/10, 10/10 will lock other confidence factors of rules and the resulting value will be 10/10.

c. The - 100 to + 100 system : This system supports various degrees of confidence factors. Since the – 100 to + 100 system doesn't lock in the values of +100, 0, -100, these values are also join the average calculation. This system has the calculation of dependent probabilities and the calculation of independent probabilities. The calculation of independent probabilities is done when the outcome of one event doesn't effect the outcome of the other event. The reverse is dependent probability.

The average of the independent probabilities are separately subtracted from 1 and the results are multiplied to obtain a product which is subtracted from 1. For example, if two values 50/100 and 80/100 are taken, then each value is subtracted from 1 (100/100). Then these values are multiplied and this value is subtracted from 1. The equation of these processes is 1-((1-50/100) * (1-80/100)) = 99 /100.

The calculation of dependent values are performed by multiplying the probability values to obtain the resulting probability. For example, if two values 80/100 and 90/100 are obtained, they are multiplied ((80/100) * (90/100)). This calculation result is 72/100.

3.4 ADVANTAGES AND DISADVANTAGES OF EXPERT SYSTEMS

Expert systems can

* Support permanent documentation of the decision process,
* Provide consistency of decision making,
* Reduce personnel costs,
* Centralize the decision making process,
* Reduce the amount of human errors.

Although there are several advantages of expert systems, there are some limitations. These are

* The problems of automating complex processes,
* The lack of flexibility to adapt the changing problem domains,
* The explanation of logic and reasoning problems which are performed by the domain expert.

3.5 EXSYS: EXPERT SYSTEM DEVELOPMENT TOOL

EXSYS is an expert system development shell. Expert system is a type of artificial intelligence program which provides interconnection between a user and a human expert to solve a problem. Expert systems are designed by knowledge engineers.

One of the expert system development tool is EXSYS. The educational version of EXSYS is provided free to all adopters with the rigths to perform copies for students. It can be used on an IBM PC, XT, AT or other compatible systems [69]. In this thesis, EXSYS Expert System Development Tool (1983–2000) and its rule editor which is EXSYS Rule Editor EDITXSP version 3.00 is used to establish the Access Telecommunication Knowledge Base and Access Telecommunication Network Expert System.

EXSYS asks the user questions which are related with a subject or domain. The user responds these questions by using the user interface of the EXSYS shell. The computer will continue to ask questions until it finishes all the questions which are entered as qualifiers by the knowledge engineer and after finishing all questions, system will reach a conclusion with answers of these questions. The conclusion can be single solution which depends on single THEN statement or list of possible solutions which depend on the selection of optimum solution in order. The computer can explain that how it reached its conclusion and the user can see the used rules to reach the related conclusion by clicking on the related result in the resulting table.

The derive information property of expert systems provide the user to arrive important logical conclusions about complex problems by combining small pieces of knowledge. The basic features to select EXSYS as an expert system in this thesis are flexibility to use the expertise, to perform decisions, solve problems more effectively and to design an expert system easily as a knowledge engineer. The process of developing expert systems is also called as **knowledge acquisition process** which is discussed in **Chapter 4**.

3.5.1 THE EXSYS RULE EDITOR

The educational version of EXSYS has EDITXSP rule editor. First step is to enter the EDITXSP rule editor for constructing the knowledge base of the system by knowledge engineer. The screen on monitor displays the EDITXSP Expert System Rule Editor Logo. The creating knowledge base procedure can begin after the successful entrance to EDITXSP is provided.

3.5.2 CREATING A NEW KNOWLEDGE BASE

This procedure consists of answering eleven questions which are independent from decision rule part of the knowledge base and it is starting operation to construct a knowledge base which is performed only one time. After this construction is established, the decision rules are entered to the system.

This construction contains eleven questions and the selections for the answers are determined by the constructer of the EXSYS. There are some questions which are answered by the knowledge engineer at the begining. These questions are:

QUESTION 1 : Do you wish to start a new file ? (YES / NO)

QUESTION 2 : What is the subject of the knowledge base ? (TEXT)

QUESTION 3 : Who is the author of the knowledge base ? (TEXT)

QUESTION 4 : What type of probability system do you want to select ? (MC: MULTIPLE CHOICE)

QUESTION 5 : Do you wish to change the threshold limit ? (YES / NO)

QUESTION 6 : What is the number of rules to use in data derivations ? (MC)

QUESTION 7 : What is the begining text ? (TEXT)

QUESTION 8 : What is the ending text ? (TEXT)

QUESTION 9 : Do you wish the user running this expert system to have the rules displayed? (YES / NO)

QUESTION 10 : Do you wish to have an external program called at the start of a run to pass data back for multiple variables or qualifiers? (YES / NO)

QUESTION 11 : What are the choices ? (TEXT)

After all these questions are answered and ENTER key is clicked two times the MAIN MENU appears **(Figure 3)**.

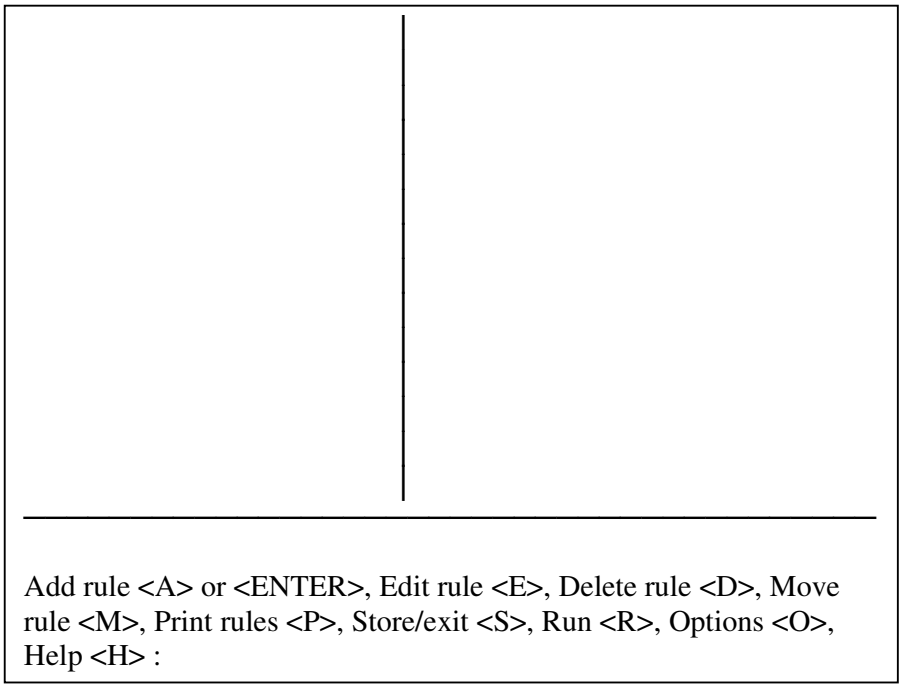

Figure 3: The Main Menu

The Main Menu includes ten commands. At this point, the knowledge base is saved by selecting Store/ Exit command and the knowledge engineer will exit the system. Then, the next procedure is adding decision rules to the knowledge base of the expert system and the knowledge engineer will enter the expert system again by using EDITXSP rule editor and after the name of the file, for example TEZ1 in this thesis is entered, the MAIN MENU is opened directly. So now, the decision rules can be added to the knowledge base.

3.5.3 ADDING A DECISION RULE TO THE KNOWLEDGE BASE

There are four steps to add a decision rule process. In this part, the addition of one decision rule is presented.

STEP 1: ENTER THE QUALIFIER

The starting process is to select Add rule command from the main menu. Then the letter "N" is typed and the qualifier can be added. The following rule is an example to demonstrate the addition of decision rule.

RULE NUMBER: 96

IF:

The maximum deployment distance is 3.6 km and the oldest xDSL system is preferred

THEN:

The optimum access telecom system is Wireway-xDSL-HDSL - Confidence=10/10

For decision rule 96, the qualifier is

" The maximum deployment distance is "

Now, this qualifier is typed and ENTER key is clicked.

STEP 2: ENTER THE QUALIFIER VALUE

This step is to enter qualifier values which completes the IF statement. For decision rule 96

" 3.6 km and the oldest xDSL system is preferred "

qualifier value is typed and ENTER key is clicked.

STEP 3: CREATE THE IF STATEMENT

The third step is to create IF part of the decision rule 96. For decision rule 96, the qualifier **" The maximum deployment distance is "** and the first qualifier value **" 3.6 km and the oldest xDSL system is preferred "** are combined to form the IF part which is **" The maximum deployment distance is 3.6 km and the oldest xDSL system is preferred "**. To create IF part, the related qualifier value number is selected and ENTER key is clicked, so the IF statement is constructed.

STEP 4: CREATE THE THEN STATEMENT

The last step is to create THEN part of the decision rule. The THEN statement contains a choice and an confidence factor which depends on the truth rate of the IF statement. Since the next step is to select a choice, C is typed to display Choice Menu. For decision rule 96, the related choice value is entered and

"The optimum access telecom system is Wireway-xDSL-HDSL – Confidence"

choice is selected, ENTER key is clicked.

Then the suitable confidence factor must be selected and matched with the choice.

CHAPTER 4

THE ACCESS TELECOMMUNICATION NETWORK EXPERT SYSTEM

The main purpose of establishing an expert system is to reach an optimum solution with the provided information from the human expert. The knowledge base of the expert system is constructed by knowledge engineers. They utilize from domain experts who are the human experts in a specific area to establish the knowledge infrastructure of the related system [67-73].

The knowledge engineer operates the knowledge acquisition process to construct the knowledge base of the expert system. In the construction phase of the knowledge base, the five basic steps are applied and these steps:

1. Knowledge engineer determines the subject of the expert system and looks for a human expert in the related field.

2. Knowledge engineer takes information from the domain expert by asking questions.

3. The provided information from the domain expert is transferred into facts which are used to produce decision rules in the knowledge base by knowledge engineer.

4. The decision rules are derived as IF / THEN structure to construct the knowledge base by knowledge engineer.

5. The testing operation of the knowledge base to control accuracy of the expertise.

STEP 1 : DETERMINATION OF A DOMAIN AND SEARCHING FOR A DOMAIN EXPERT

The first knowledge acquisition step is to find a subject and a domain expert. In this thesis, the main problem is to provide inexpensive optimum connection between backbone and end-users for last mile in Access Networks. The problem field is Telecommunication Networks and especially in Access Networks.

This problem can be solved in various ways and the main purpose is to find less costly solutions other than end to end fiber optic system. These solutions can be called as Broadband Access Telecommunication Systems.

The subject of knowledge base is Access Telecommunication Network and it is choosen as the problem field, because it is used to investigate the connection between access telecommunication network and backbone networks. Since this thesis subject is related with two domain fields Computer Engineering and Electronic and Communications Engineering fields, the sufficient information for this thesis is provided by two domain experts.

STEP 2: TAKING INFORMATION FROM THE DOMAIN EXPERT BY ASKING QUESTIONS

Knowledge engineer takes information from the domain expert by asking questions which are related with the subject and produces the knowledge base with expertise which is provided by the domain expert. The domain expert can give two types of knowledge such as structured and unstructured knowledge types. In this thesis, structured knowledge is supported from the books, technical reports and web sites. Unstructured knowledge is provided from two domain experts' experiences about expert systems and telecommunication networks.

STEP 3: PRODUCING THE DECISION RULES WITH DOMAIN EXPERTISE

The third step is to produce decision rules in the knowledge base with the provided information from domain expert. In the rule production phase, the knowledge engineer must determine the chaining method which is used to control decision rules in the knowledge base. Also, this chaining method is used to design knowledge base in the EXSYS Rule Editor.

Access Telecommunication Network knowledge base uses backward chaining method to control the knowledge base.

STEP 4: CONSTRUCTING THE KNOWLEDGE BASE

The decision rules are derived as IF/THEN structure to construct the knowledge base by knowledge engineer and this operation can be defined as fourth step of the knowledge acquisition process.

In this thesis, the constructing the knowledge base procedure consists of these steps :

1. Providing the EXSYS Expert System Development Tool.

2. Identification of problem field and transferring information from the domain expert.

3. Creation of decision rules for thesis knowledge base.

4. Entry of decision rules into the thesis knowledge base with the EXSYS Rule Editor to construct the thesis knowledge base.

5. Running and testing the thesis knowledge base.

6. Verification of the knowledge base to control the accuracy of the expertise.

7. Modification of the knowledge base due to the user desires.

8. The knowledge base documentation and printing.

The Access Telecommunication Network knowledge base asks user 21 questions (qualifiers) and reaches 23 results (choices). The user interface is used by the user to operate the system. The function of the user interface is to present questions which are input values of the system to the end-user and provide the end-user's responses to the inference engine. The user-interface must receive and interpret any values entered by the user. The user interface checks all responses and provides communication between the user and the inference engine with the use of User Interface Control Block.

STEP 5: TESTING OPERATION OF THE KNOWLEDGE BASE

The testing operation of thesis knowledge base can be performed by running and evaluating the expert system results. Also, the results for each run are matched with Access Telecommunication Network knowledge base.

4.1 KNOWLEDGE REPRESENTATION AND RULE PRODUCTION

There are two important reasons for knowledge representation. Expert systems are constructed by the rule or logic knowledge representation type. The development, quality, maintenance and speed of the expert system is affected from the knowledge representation. The EXSYS program reaches the results which are based on the logical representation of the knowledge by decision rules. A decision rule contains these parts:

IF Qualifier + Qualifier Value

THEN Choice + Probability Value

The procedure node interface receives information from the procedures coordinator and creates the appropriate procedure call at the background of the processing machine. A tree structure is the logical representation of the system and it used to represent inferencing mechanism in the system. Rule nodes are the nodes of these trees. The top node is goal node which contains the conclusion. The leaves of the tree are called as rule nodes. The tree can contain intermediate nodes between the leaf node and the goal nodes. The subgoal nodes can be demonstrated by logical operations such as AND operation and OR operation. The depth-first search mechanism is used when tracing the tree left to right in the backward chaining system. The tracing means traversing the tree, asking questions and calculating confidences when it operates **(Figure 4)**.

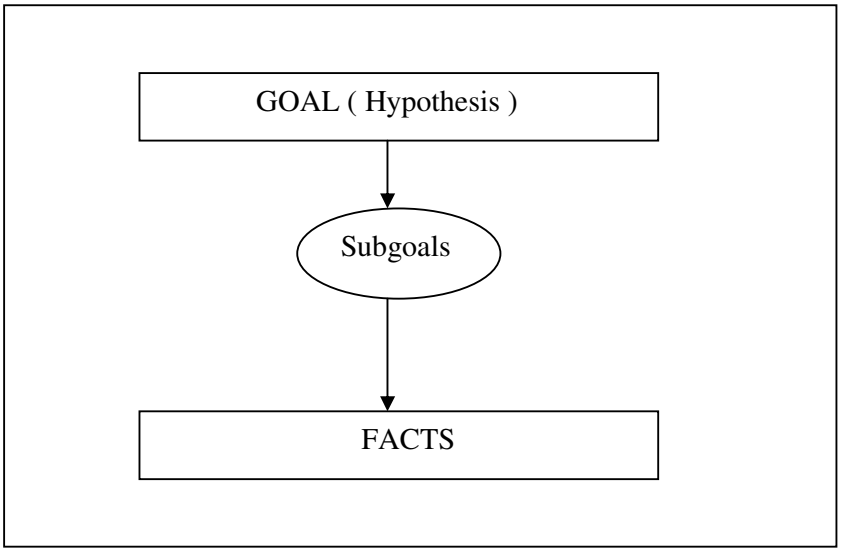

Figure 4 : Goal Tree Structure for Backward Chaining

The knowledge base structure of the system is mainly constructed from two nodes such as wireway and wireless, the wireway node is subdivided into four subnodes and wireless node is subdivided into four subnodes **(Figure 5)**.

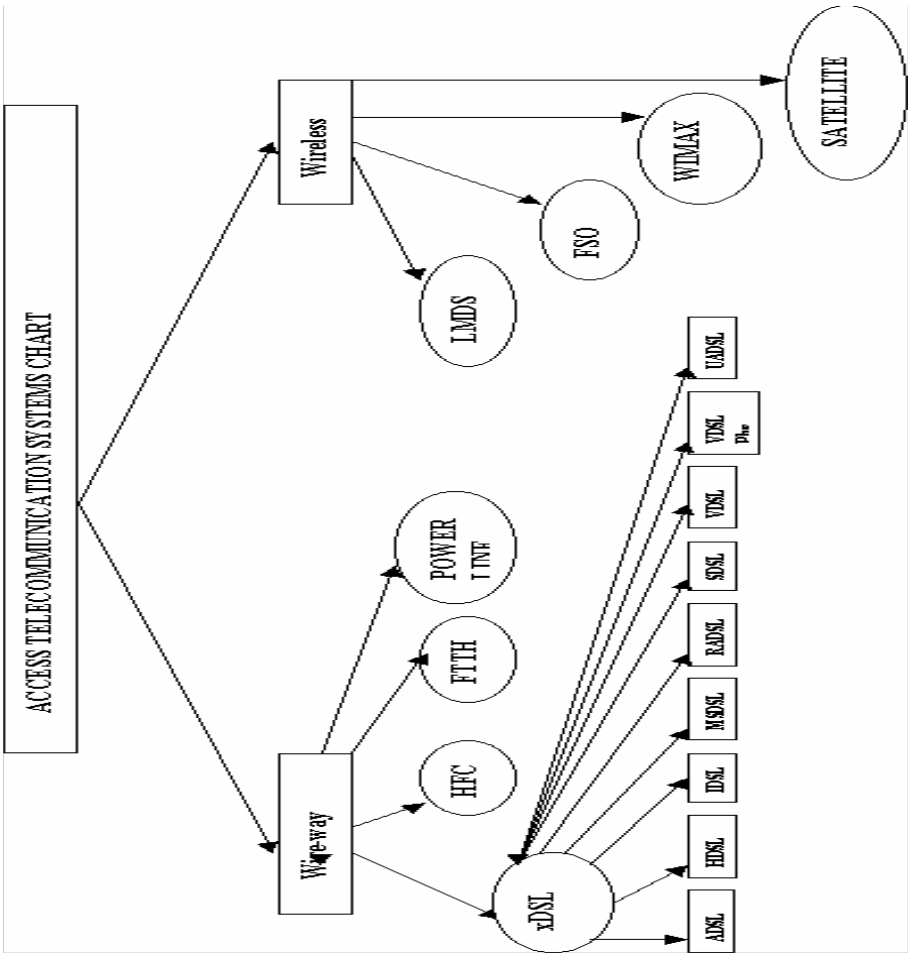

Figure 5 : Access Telecommunication Systems Chart

The knowledge base of this thesis is Access Telecommunication Network and it is developed to create an expert system by using the EXSYS Expert System Development Tool. This expert system is used to select the optimum access telecommunication network system depends on different features and external conditions.

The knowledge acquisition process of putting the decision rules into the knowledge base of access telecommunication network expert system is provided by the EXSYS rule editor. Decision rules are created because they route the EXSYS program to find the optimal access telecom system which are based on the logical representation of the provided information by the domain expert. IF/THEN structure is used to create decision rules. The IF statement includes a qualifier and a qualifier value. The THEN statement includes a choice and a probability value **(APPENDIX B)**. Backward Chaining method is selected by the EXSYS rule editor. In this method, EXSYS system asks the questions which depend on qualifiers and tests the THEN parts of the rules.

The choice and probability value are determined by the knowledge engineer which depend on the provided information by the domain expert. The access telecommunication network expert system uses 0 to 10 probability system. Since degrees of confidence are very probably no (1/10) and very probably yes (9/10), absolutely no (0/10) and absolutely yes (10/10), the optimal access telecom system choice takes probability values between 0 to 10 for each different choice and various access system types. In the access telecommunication network expert system, probability of (10/10) is used when the optimal access telecom system is exactly the given system, (0/10) is used when the optimal access telecom system is absolutely not the given system and the ranging probability values (1/10 to 9/10) are used due to the method of the greatest value covers all the other values. The nearest value which is most suitable to given qualifiers takes greatest value and the greatest value covers all the other values takes second greatest value and the other values match with probabilities in decreasing mode.

In the construction phase of this expert system, the steps are answering 11 expert system shell questions to construct the user interface of the access telecommunication network knowledge base, entering decision rules to the knowledge base, running the knowledge base and verification of the knowledge base. The knowledge base of the access telecommunication network expert system consists of totally 167 decision rules, 21 qualifiers and 23 choices. These rules are prepared from the domain expertise of the thesis subject **(APPENDIX C)**. Also, there are 3 types of rules which are separated due to their confidence values. For example, rules which have (0/10) and (10/10) confidence factors lock other rules which have (1/ 10 to 9 /10) confidence factors and they do not allow these confidence factors in the resulting table to be displayed.

4.2 CONSTRUCTING THE ACCESS TELECOMMUNICATION NETWORK EXPERT SYSTEM KNOWLEDGE BASE

The first step is to enter the EXSYS Rule Editor for constructing process of the knowledge base. When the EXSYS Rule Editor Logo appears, the constructing knowledge base procedure is started. Firstly, the user interface questions which are displayed by the Rule Editor must be answered. The following explanation represents the answering procedure of 11 questions.

QUESTION 1: Do you wish to start a new file?

The choice YES is selected by knowledge engineer and TEZ1 filename is given to start a new knowledge base which is named TEZ1. So, the constructing Access Telecommunication Network knowledge base procedure for this thesis is started.

QUESTION 2: What is the subject of the knowledge base ?

Then, the subject of the knowledge base which is Expert Systems in Access Telecommunication Networks subject is entered.

QUESTION 3: Who is the author of the knowledge base ?

The author name is entered.

Author: Seda Sahin

QUESTION 4: What type of probability system do you want to select ?

This procedure asks the probability system which is used for the knowledge base. The choice 2 is selected, because knowledge base uses 0 to 10 system.

QUESTION 5: Do you wish to change the threshold limit?

The threshold limit is the limitation for the projection of the results. In TEZ1, display threshold is 1 and it means EXSYS displays choices which have the final confidence value is equal to or greater than 1 in results part. The threshold limit can change to avoid displaying some results.

QUESTION 6: What is the number of rules to use in data derivations ?

All rules are displayed for thesis knowledge base.

QUESTION 7: What is the begining text?

The begining text for this knowledge base is:

The knowledge base, Access Telecommunication Network is developed to create an expert system using the Exsys Expert System Development Package. This expert system is used to select the optimum access telecommunication network system that depends on different features and external conditions.

QUESTION 8: What is the ending text?

The ending text for this knowledge base is:

Ending text: Calculating Results

QUESTION 9: Do you wish the user running this expert system to have the rules displayed ?

The default of "NO" is selected, because knowledge base run faster if the rule display is off.

QUESTION 10: Do you wish to have an external program called at the start of a run to pass data back for multiple variables or qualifiers ?

Since this thesis don't use any external program, the default value "NO" is selected.

QUESTION 11: What are the choices?

The last procedure is to enter choices for the knowledge base.

****

After these 11 questions are answered, the MAIN menu is appeared by clicking "ENTER" key two times. Then this knowledge base is saved by choosing Store/Exit command.

The next process is adding the decision rules to the system, so the process is to enter the EXSYS Rule Editor and to type TEZ1. Then, the MAIN menu is appeared directly without answering 11 questions. At this time, the decision rules can be added to the knowledge base by choosing Add command in the MAIN menu. Addition of the example Rule number 96 is performed in Chapter 3 and all 167 rules are added to the system with the same procedure.

4.3 RUNNING THE ACCESS TELECOMMUNICATION NETWORK EXPERT SYSTEM

The Access Telecommunication Network (TEZ1 file) knowledge base contains 21 questions (qualifiers) which require answers. The running procedure is:

1. Reading the begining text **(STEP 1)**.
2. Answering multiple-choice questions and to select the qualifier value number which is desired to answer the questions **(STEP 2- STEP 22)**.
3. Reading the ending text **(STEP 23)**.
4. Displaying of the results with the matched qualifiers and choices.

STEP 1 : Reading the begining text

STEP 2 : The upstream rate

STEP 3 : The downstream rate

STEP 4 : There is

STEP 5 : The licence

STEP 6 : The system settlement

STEP 7 : The maximum deployment distance

STEP 8 : The installation cost for this connection per subscriber

STEP 9 : The equipment cost for this connection per subscriber

STEP 10 : The total expenditures for this connection per subscriber

STEP 11 : The operational monthly cost of video for this connection per subscriber

STEP 12 : The operational monthly cost of data for this connection per subscriber

STEP 13 : The operational monthly cost for consumer for this connection per subscriber

STEP 14 : The operational monthly cost for business for this connection per subscriber

STEP 15 : The equipment cost and monthly cost for this connection per subscriber

STEP 16 : The security

STEP 17 : The installation of access system

STEP 18 : The weather

STEP 19 : Buildings sway

STEP 20 : The flying objects

STEP 21 : The fog density

STEP 22 : The system

STEP 23 : Reading the ending text

After reading the ending text step is finished, the resulting table is displayed as choices with a dedicated average probability value. Also, decision rules of backward chaining inferencing mechanism for each choice in the resulting table can be seen by double clicking on the related choice.

4.4 IMPROVEMENT OF THE ACCESS TELECOMMUNICATION NETWORK EXPERT SYSTEM

The construction of decision rules are the most important part for my thesis and the first step is establishing Access Telecommunication Systems Chart. The decision rules are created with the usage of this chart. The expert system is constructed three times. At the first construction, EXSYS Corvid Expert System Development Tool (Demo version 1.2.4) was used to establish thesis expert system. Since it has 30 days time limitation, 150 logic block nodes limitation and high licence fee for unlimited time version have forced us to prefer another expert system development tool. So, in the second and third constructions, EXSYS Expert System Development Tool is used. In the third construction, this expert system is established more suitable to the users desires. The levels of users who use this system are generally subject related people in Computer Engineering or Electric and Electronic Engineering fields.

In the improvement phase of this system, the decision rules can be improved due to the users desires and the system can be redefined. Additional suggestions can be performed by domain experts and the users until the complete system architecture is established. Modifications are retested to control the operation of the system with the improved rules.

4.5 DETECTING ERRORS IN THE EXPERT SYSTEM

After the implementation of the system is completed, it must be tested. In the validation phase of this expert system, some errors and deficiencies can appear.

1. In the running phase of the expert system, user can select random questions of answers, so in the resulting part this can cause some incorrect results.

2. There is a deficiency in the calculating average probability operation of the EXSYS Expert System Tool. For example, three probability values are 9, 9, 10 and the average confidence factor of them (9 + 9+10/3*10) is 9.3/10 and this value is displayed as a confidence factor 10 in the resulting table, but it ought to 9 as an approximate value.

CHAPTER 5

RESULTS

As mentioned in the previous chapters EXSYS Expert System Development Tool (1983–2000) and its rule editor which is EXSYS Rule Editor EDITXSP version 3.00 is used to construct the access telecommunication expert system which is designed to determine which access system is suitable for the usage in access networks. The access telecommunication network system can be run many times, each time with different values **(APPENDIX D)**. Thus, the selection of the optimum access telecom system changes dependent on the user desires and input data. Basically, there are various parameters and limitations which affect the selection phase of the optimum access system. The selection operation for the optimum access telecom system starts with the consideration of some conditions which are mentioned in **APPENDIX E**.

The access telecommunication expert system investigates the answers of 21 questions which are mainly user inputs. Then, each answer is matched with the related rules to produce the resulting value in the resulting table which appears as the last step of the running procedure of the system. In the resulting table, the results are displayed in a decreasing order of the optimum access system confidence factor for each choice. The system reaches these results with searching answers of questions which are selected by the user and matching the decision rules with answers by using backward chaining inferencing method.

The running procedure for the access telecommunication knowledge base can be represented by the following sample run:

****

/*** SAMPLE RUN OF ACCESS TELECOMMUNICATION NETWORK EXPERT SYSTEM *****/**

***** INPUT DATA *****

The upstream rate is 1.54 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to provide T1/E1 services to businesses at low costs

The downstream rate is 1.54 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to provide T1/E1 services to businesses at low costs

there is other feature

the licence is not used

The system settlement is dense urban, urban,industrial suburban, residental suburban and the communication medium is twisted-pair cable

The maximum deployment distance is 3.6 km and the oldest xDSL system is preferred

The installation cost for this connection per subscriber is $14

The equipment cost for this connection per subscriber is $106

The total expenditures for this connection per subscriber is $500

The operational monthly cost of video for this connection per subscriber is $30-$80

The operational monthly cost of data for this connection per subscriber is other

The operational monthly cost for consumer for this connection per subscriber is other

The operational monthly cost for business for this connection per subscriber is other

The equipment cost and monthly cost for this connection per subscriber is other

The security is poor, because of the medium is twisted-pair cable

The installation of access system is easy, since it uses existing twisted-pair infrastructure

The weather is good

Buildings sway very fast

The flying objects do not effect the system

The fog density is other

The system is not effected from rain

***** OUTPUT *****

1 The optimum access telecom system is **Wireway-xDSL-HDSL**
VALUE=10

2 The optimum access telecom system is **Wireway-HFC**
VALUE=10

3 The optimum access telecom system is **Wireway-xDSL**
VALUE=10

4 The optimum access telecom system is **Wireway-xDSL-VDSL PLUS**
VALUE=8

5 The optimum access telecom system is **Wireway- xDSL- VDSL**
VALUE=7

6 The optimum access telecom system is **Wireway-xDSL-RADSL**
VALUE=6

7 The optimum access telecom system is **Wireway-xDSL-MSDSL**
VALUE=5

8 The optimum access telecom system is **Wireway- xDSL- SDSL**
VALUE=5

****

In this example, input data is entered by the user which is the answered knowledge base questions (qualifiers). After running the knowledge base, the expert system displays 8 output values. The number of output values can change for each run of the expert system which are related matching between the decision rules and qualifiers of the knowledge base of the expert system.

In the projection part of ouput values, the threshold value is determined as 1, so all output values which are greater than 1 will be displayed. The confidence factor 10 means the optimum access system can be HDSL, HFC, xDSL with the user inputs which provide to select each system with the use of different rules over knowledge base. The other suitable systems are ordered in a decreasing mode up to the least optimum access telecom confidence factor is presented. Since this expert system use backward chaining method, THEN parts of the decision rules are the most important parts of the access telecommunication knowledge base to find an optimum access telecom system type. In backward chaining, the expert system searches all the same THEN parts and verifies their IF parts. This procedure continues up to all decision rules are matched with the related resulting value which is projected in the resulting table. The explanation of each upper resulting value is performed as below.

RESULTING VALUE 1:

A. The User Input (which the user enters and the expert system uses to inference value 1):

The upstream rate is 1.54 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to provide T1/E1 services to businesses at low costs

The downstream rate is 1.54 Mbps and the communication medium uses a copper twisted- pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to provide T1/E1 services to businesses at low costs

The maximum deployment distance is 3.6 km and the oldest xDSL system is preferred

B. Decision Rules : R8, R44, R96

RULE NUMBER: 8

IF:
The upstream rate is 1.54 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to provide T1/E1 services to businesses at low costs

THEN:
The optimum access telecom system is **Wireway-xDSL-HDSL - Confidence=9/10**

RULE NUMBER: 44

IF:
The downstream rate is 1.54 Mbps and the communication medium uses a copper twisted- pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to provide T1/E1 services to businesses at low costs

THEN:
The optimum access telecom system is **Wireway-xDSL-HDSL - Confidence=9/10**

RULE NUMBER: 96

IF:
The maximum deployment distance is 3.6 km and the oldest xDSL system is preferred

THEN:
The optimum access telecom system is **Wireway-xDSL-HDSL - Confidence=10/10**

The confidence factor 10 means, the average of rules probabilities which are found from backward chaining application. To be able to achieve this result as the optimum access telecom system the Wireway-xDSL-HDSL choice is searched inside the access telecommunication knowledge base over 167 rules with backward chaining method. Rule8, Rule44 and Rule96 is used by the expert system to decide the optimum access telecom system is Wireway-xDSL-HDSL with the confidence factor of 10 (9+9+10/3*10=9.3 /10= approximate confidence factor 10 in resulting table).

C. The Resulting Value:

In the first output choice of this sample run, the expert system has reached the optimum access telecom system as HDSL with the confidence factor 10. System is verified, because of the related user inputs such as upstream rate, downstream rate, and maximum deployment distance values are matched with the related decision rules such as Rule8, Rule44 and Rule96 and as a result, the system has reached HDSL system as the optimum access telecom system. This system has reached HDSL system, because the user starts to answer upstream rate question firstly and it is a unique system which upstream rate is matched with the user entered input, then this matching procedure continues with backward chaining inferencing mechanism. Other suitable resulting values continue this question-rule matching procedure.

The decision making mechanism is performed by only the expert system and there isn't any external effect which influences the expert system's decision making mechanism.

RESULTING VALUE 2:

A. The User Input (which the user enters and the expert system uses to inference value 2):

The operational monthly cost of video for this connection per subscriber is $30-$80

B. Decision Rules : R119

The confidence factor is 10 for this resulting value. To be able to achieve this result the optimum access telecom system is Wireway-HFC choice is searched inside the access telecommunication knowledge base. Rule119 is used by the expert system to decide the optimum access telecom system is Wireway-HFC with the confidence factor of 10 (10 /1*10 =10=confidence factor 10 in resulting table).

C. The Resulting Value:

In the second output choice of this sample run, the expert system has reached the optimum access telecom system is HFC choice with confidence factor 10. System is verified, because of the related user input such as the operational monthly cost of video for this connection per subscriber is matched with the related decision rule such as Rule119 and as a result the system has reached HFC system as the suitable access telecom system. This system has reached HFC system, because the user answers the operational monthly cost of video for this connection per subscriber question and the related decision rule as an answer of this question is matched with the user entered input. HFC system is selected as a second system, because expert system traces answers of all input questions and reaches HFC system's decision rule with the related input value. Although, The Wireway-xDSL resulting value has matching operation of decision rule and input value before HFC system, the HFC system is selected as a second resulting value because of its matching procedure is finished in one step and Wireway-xDSL system applies backward chaining procedure in six steps. It uses backward chaining mechanism and after first matching, it jumps to other decision rules to be able to complete the chain and its matched input parts come after the HFC system's matched input part.

RESULTING VALUE 3:

A. The User Input (which the user enters and the expert system uses to inference value 3):

The system settlement is dense urban, urban, industrial suburban, residental suburban and the communication medium is twisted-pair cable

The installation cost for this connection per subscriber is $14

The equipment cost for this connection per subscriber is $106

The total expenditures for this connection per subscriber is $500

The security is poor, because of the medium is twisted-pair cable

The installation of access system is easy, since it uses existing twisted-pair infrastructure

B. Decision Rules : R82, R115, R116, R117, R130, R138

The confidence factor is 10 for this resulting value. To be able to achieve this result the optimum access telecom system is Wireway-xDSL choice is searched inside the access telecommunication knowledge base. Rule82, Rule115, Rule116, Rule117, Rule130 and Rule 138 is used by the expert system to decide the optimum access telecom system is Wireway-xDSL with the confidence factor of 10 (10+10+10+10+10+10/6 *10 =10=confidence factor 10 in resulting table).

C. The Resulting Value:

In the third output choice of this sample run, the expert system has reached the optimum access telecom system as Wireway-xDSL with confidence factor 10. System is verified, because of the related user inputs such as the system settlement, the installation cost for this connection per subscriber, the equipment cost for this connection per subscriber, the total expenditures for this connection per subscriber, the security, the installation of access system are matched with the related decision rules such as Rule82, Rule115, Rule116, Rule117, Rule130 and R138 and as a result the system has reached Wireway-xDSL system as the suitable access telecom system. This system has reached Wireway-xDSL system, because the user answers the related questions and the related decision rules as an answer of these questions are matched with the user entered input. Wireway-xDSL system uses backward chaining mechanism and after first matching, it jumps to other decision rules to be able to complete the chain and its matched input parts come after the HFC system's matched input part, so the Wireway-xDSL system is selected as a third suitable access telecom system.

RESULTING VALUE 4:

A. The User Input (which the user enters and the expert system uses to inference value 4) :

The upstream rate is 1.54 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to provide T1/E1 services to businesses at low costs

The downstream rate is 1.54 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to provide T1/E1 services to businesses at low costs

B. Decision Rules : R12, R49

The confidence factor is 8 for this resulting value. To be able to achieve this result the optimum access telecom system is Wireway-xDSL-VDSL PLUS choice is searched inside the access telecommunication knowledge base. Rule12 and Rule49 are used by the expert system to decide the optimum access telecom system is Wireway-xDSL-VDSL PLUS with the confidence factor of 8 (8+ 8 / 2 *10 = 8= confidence factor 8 in resulting table).

C. The Resulting Value:

In the fourth output choice of this sample run, the expert system has reached the optimum access telecom system as Wireway-xDSL-VDSL PLUS with confidence factor 8. System is verified, because of the related user inputs such as the upstream rate, the downstream rate are matched with the related decision rules such as Rule12 and R49 and as a result the system has reached Wireway-xDSL-VDSL PLUS system as the suitable access telecom system. This system has reached Wireway-xDSL-VDSL PLUS system, because the user answers the related questions and the related decision rules as an answer of these questions are matched with the user entered input. The Wireway-xDSL-VDSL PLUS system is selected as a fourth suitable access system before VDSL, RADSL, MSDSL and SDSL systems because of the upstream rate and downstream rate matching is more effective and the resulting probability value is found more suitable to given inputs by the expert system. Also, the greatest probability value is dedicated to VDSL PLUS for the related inputs in the knowledge base by using speed consideration. The construction method of this knowledge base is that the high speed systems operate in the fields of low speed systems and cover all low speed systems, so the confidence factors are dedicated to the systems by using this method. When this method is applied to the knowledge base, the other system considerations must not to be in contradiction. They must be harmonious. For example, if the expert system reaches the FTTH system as a high confidence

factor optimum access telecom system, but the system deployment field has not any fiber infrastructure. So, this system cannot be used as the optimum access telecom system and the expert system cannot be operated. Generally, the knowledge base of this project is constructed by taking into consideration these types of events, system parameters and conditions, limitations and so on.

RESULTING VALUE 5:

A. The User Input (which the user enters and the expert system uses to inference value 5):

The upstream rate is 1.54 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to provide T1/E1 services to businesses at low costs

The downstream rate is 1.54 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to provide T1/E1 services to businesses at low costs

B. Decision Rules : R11, R48

The confidence factor is 7 for this resulting value. To be able to achieve this result the optimum access telecom system is Wireway-xDSL-VDSL choice is searched inside the access telecommunication knowledge base. Rule11 and Rule48 is used by the expert system to decide the optimum access telecom system is Wireway-xDSL-VDSL with the confidence factor of 7 (7 + 7 / 2 *10 = 7= confidence factor 7 in resulting table).

C. The Resulting Value:

In the fifth output choice of this sample run, the expert system has reached the optimum access telecom system is Wireway-xDSL-VDSL with confidence factor 7. System is verified, because of the related user inputs such as the upstream rate, the downstream rate are matched with the related decision rules such as Rule11 and Rule48 and as a result the system has reached Wireway-xDSL-VDSL system as the suitable access telecom system. This system has reached Wireway-xDSL-VDSL system, because the user answers the related questions and the related decision rules as an answer of these questions are matched with the user entered input.

RESULTING VALUE 6:

A. The User Input (which the user enters and the expert system uses to inference value 6):

The downstream rate is 1.54 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to provide T1/E1 services to businesses at low costs

B. Decision Rules : R46

The confidence factor is 6 for this resulting value. To be able to achieve this result the optimum access telecom system is Wireway-xDSL-RADSL choice is searched inside the access telecommunication knowledge base. Rule46 is used by the expert system to decide the optimum access telecom system is Wireway-xDSL-RADSL with the confidence factor of 6 (6 / 1 *10 = 6= confidence factor 6 in resulting table).

C. The Resulting Value:

In the sixth output choice of this sample run, the expert system has reached the optimum access telecom system is Wireway-xDSL-RADSL with confidence factor 6. System is verified, because of the related user input such as the downstream rate is matched with the related decision rule which has 6/10 confidence factor in the knowledge base (equally 6 in the resulting table) such as Rule46 and as a result the system has reached Wireway-xDSL-RADSL system as the suitable access telecom system. This system has reached Wireway-xDSL-RADSL system, because the user anwers the related question and the related decision rule as an answer of this question is matched with the user input.

RESULTING VALUE 7:

A. The User Input (which the user enters and the expert system uses to inference value 7):

The upstream rate is 1.54 Mbps and the communication medium uses a copper twisted – pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to provide T1/E1 services to businesses at low costs

The downstream rate is 1.54 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to provide T1/E1 services to businesses at low costs

B. Decision Rules : R9, R45

The confidence factor is 5 for this resulting value. To be able to achieve this result the optimum access telecom system is Wireway-xDSL-MSDSL choice is searched inside the access telecommunication knowledge base. Rule9 and Rule45 is used by the expert system to decide the optimum access telecom system is Wireway-xDSL- MSDSL with the confidence factor of 5 (6+5/2*10 = 5.5/10 = approximate confidence factor 5 in resulting table).

C. The Resulting Value:

In the seventh output choice of this sample run, the expert system has reached the optimum access telecom system is Wireway-xDSL-MSDSL with confidence factor 5. System is verified, because of the related user inputs such as the upstream rate, the downstream rate are matched with the related decision rules such as Rule9 and Rule45 and as a result the system has reached Wireway-xDSL-MSDSL system as the suitable access telecom system. This system has reached Wireway-xDSL-MSDSL system, because the user answers the related questions and the related decision rules as an answer of these questions are matched with the user input.

RESULTING VALUE 8:

A. The User Input (which the user enters and the expert system uses to inference value 8):

The upstream rate is 1.54 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to provide T1/E1 services to businesses at low costs

The downstream rate is 1.54 Mbps and the communication medium uses a copper twisted- pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to provide T1/E1 services to businesses at low costs

B. Decision Rules : R10, R47

The confidence factor is 5 for this resulting value. To be able to achieve this result the optimum access telecom system is Wireway-xDSL-SDSL choice is searched inside the access telecommunication knowledge base. Rule10 and Rule47 are used by the expert system to decide the optimum access telecom system is Wireway-xDSL-SDSL with the confidence factor of 5 (6+5/2*10= 5.5/10= approximate confidence factor 5 in resulting table).

C. The Resulting Value:

In the eighth output choice of this sample run, the expert system has reached the optimum access telecom system is Wireway-xDSL-SDSL with confidence factor 5. System is verified, because of the related user inputs such as the upstream rate, the downstream rate are matched with the related decision rules such as Rule10 and Rule47 and as a result the system has reached Wireway-xDSL-SDSL system as the suitable access telecom system. This system has reached Wireway-xDSL-SDSL system, because the user answers the related questions and the related decision rules as an answer of these questions are matched with the user input.

CHAPTER 6

CONCLUSION

There are various options to determine the optimum access telecommunication network system. These systems can be distinguished from each other by their different infrastructures, system operations and other external conditions. In this thesis, several wireway network systems and wireless network system infrastructures are investigated and a general telecommunication network expert system is developed. The purpose of this expert system to select the optimal access telecommunication network system which depends on the given conditions and desires of subscribers.

In general, each of the network system infrastructure has advantages, so this makes it optimal solution in specific applications. Optical fiber means higher installation costs, it also means lower maintenance and lifecycle costs, and higher reliability, bandwidth and security. Fiber is not always the most expensive solution, and it can be the most inexpensive solution over the lifetime of the network. Free space optic allows theoretically the same transmission speed as FTTH system and transmission occurs over the air. The weather conditions especially fog limits affect its bandwidth and deployment distance. The satellite systems are used to broadcast TV and radio programs, but they are also used for communication and internet transmission purposes over remote distances. LMDS system is a high capacity technology operating in higher frequency range. The WiMAX network system provides broadband wireless connectivity to users and offers a wireless alternative to cable and xDSL network systems.

The optimal choice for a network designer depends on many factors such as system infrastructure, system type depends on medium, frequency of operation, bandwidth requirement for applications, system deployment distance, security of the system, system cost, ease of installation, licence requirement, settlement feature, number of system users and so on . In this thesis, the optimum access telecom system is constructed by taking into consideration of all these factors. EXSYS Expert System Development Tool has been used to create the knowledge base of the expert system because of its flexibility other than conventional systems. In this thesis, after running the access telecommunication network expert

system several times, the input data is matched with the related decision rules in the knowledge base to reach the optimum access telecommunication network system results and these results are confirmed by thesis domain experts. Therefore, this expert system can be considered as a working system. The expert system operates correctly which depends on different information for each system separately. As a conclusion, selection of the optimal access system is affected by several factors. So, it is not true to say "this is the optimum access telecommunication system". Increasing broadband demands provide delivery of the data, voice and video in triple mode, so access telecommunication systems must be compatible with the new and high quality future telecommunication systems and their suitable selection mechanisms remain a formidable task.

REFERENCES

[1] Küçükoğlu, A. (2005) , *Access Telecommunication Systems*, *Ms. Thesis*, Çankaya University.

[2] Goleniewski, L. (2002) , *Telecommunications Essentials*, Addison- Wesley, United States of America, Canada.

[3] Commission of the European Communities (2004) , *Connecting Europe at High Speed: National Broadband Strategies,* COM (2004) 369 final, SEC (2004) 599, Brussels.

[4] Bauer J. M. , Gai P. , Kim J. , Muth T. A. , **Wildman S. S.** (2002) , *Foundations of Broadband Policy,* Michigan State University, Prepared for presentation at the Regional ITS Conference Madrid, Spain.

[5] Ismail S. , Wu I. (2003) , *Broadband Internet Access in OECD Countries: A Comparative Analysis,* A Staff Report of the Office of Strategic Planning and Policy Analysis and International Bureau.

[6] Commission of the European Communities (2005) , *Digital Divide Forum Report : Broadband Access And Public Support in Under-Served Areas*, Brussels.

[7] http://www.ipmall.info/hosted_resources/crs/IB10045_041122.pdf

[8] http://opencrs.cdt.org/getfile.php?rid=45250

[9] http://www.alcatel.com/doctypes/articlepaperlibrary/pdf/ATR2003Q4/S0312-Broadband-Access-EN.pdf

[10] http://europa.eu.int/information_society/eeurope/i2010/docs/implementation/ddf_report_final.pdf

[11] http://www.wise-intern.org/journal/2001/matthewbright2001.pdf

[12] http://www.miti.gov.mt/docs/broadband.pdf

[13] http://www.ist-bread.org/pdf/BREAD_Tutorial_AccessNetworks.pdf

[14] http://www.eurescom.de/~pub-deliverables/P600-series/P614/d14/D14.DOC

[15] http://www.ana.lcs.mit.edu/papers/PDF/LEA_2.2_ack_web.pdf

[16] http://www.oeaw.ac.at/ita/ebene5/local_loop_jc_ITS99.pdf

[17] Kant S. , Sahu H. R. , Bhaumik S. , Arora A. , *Ideal Fiber For Cost Effective Broadband Communication,* Sterlite Optical Technologies Limited, Maharashtra India - 431136.

[18] http://www.telenor.no/broadwan/publ/BROADWAN_Deliverable_D15_broadbandroadmap.pdf

[19] http://www.wallman.com/pdfs_etc/corning.pdf

[20] http://www.alcatel.com/bnd/dsl/19719_BB_Access_overview_2.pdf

[21] http://www.ebusinessclub.biz

[22] http://www.cnct.de/Whitepaper/Switching/BB-Access-Overview.pdf

[23]http://www.engineersaustralia.org.au/shadomx/apps/fms/fmsdownload.cfm?file_uuid=1E2A832E-EE03-1C77-0794-3A0437CDC7D1&siteName=ieaust

[24] BDRC Ltd (2001) , *The Development of Broadband Access Platforms in Europe Full Report,* prepared by BDRC Ltd, London.

[25] http://www.wibrace.org/telechargement/1126787730.pdf

[26] http://www.eda.gov/PDF/1G3lr_12_iowastate.pdf

[27] http://www.telsyte.com/feature/last_mile.htm

[28] http://www.patton.com/solutions/SN_WP_NetworkEvolutionPaper_v2.pdf

[29] http://www.brookings.org/views/papers/crandall/200305.pdf

[30] http://www.xilinx.com/bvdocs/whitepapers/wp130.pdf

[31] http://www.broadbandproperties.com/2005issues/may05issues/Sandy_Teger_and_Dave_Waks_A_Mayor_s_Guide.pdf

[32] http://www.tfi.com/pubs/ntq/articles/view/96Q3_A2.pdf

[33] http://www.aptsec.org/meetings/2004/ADF/ADF-INPUT/ICT%20Profile/Instep%20Pakistan.doc

[34] http://www.geneseeisd.org/publications/linkmich/Exhibit%20II.%20Technology%20Trends%20.pdf

[35] http://www.corning.com/docs/opticalfiber/wp6321.pdf

[36] http://www.seas.upenn.edu/~sjain2/Telecommunication%20Papers/Trends%20In%20Wireless%20Broadband.doc

[37] http://www.seas.upenn.edu/~sjain2/Telecommunication%20Papers/Cost%20Benefit%20of%20Last%20Mile%20BB.doc

[38] http://www.freepress.net/docs/broadband_report.pdf

[39] http://europa.eu.int/information_society/eeurope/i2010/docs/implementation/ec_study_buckley.pdf

[40] http://www.fcc.gov/oet/tac/april26-02-docs/BB-Access-Tech.pdf

[41] http://www.corning.com/docs/opticalfiber/bridging_the_last_mile_white_paper.pdf

[42] http://lhncbc.nlm.nih.gov/lhc/docs/published/2002/pub2002002.pdf

[43] http://www.ero.dk/documentation/docs/doc98/official/Word/ECCREP079.DOC

[44] http://www.sterliteoptical.com/pdf/050807%20IETE%20Pune%20OFC%20Paper.pdf

[45] http://www.ftthcouncil.org/documents/763530.pdf

[46] http://itc.mit.edu/itel/docs/2003/banerjee_sirbu.pdf

[47] http://www.mitretek.org/08-Kutz-TR2005.pdf

[48] http://www.powerlinetelco.net/docs/Broadband_Over_Powerline_White paper_3-15-05.pdf

[49] http://tprc.org/papers/2003/246/Tongia-PLC.pdf

[50] http://www.ipmall.info/hosted_resources/crs/RL32421_050204.pdf

[51] http://www.newtec.be/fileadmin/webfolder/Press_releases/The_Last_Mile_ via_DVB-RCS_by_Newtec.pdf

[52] http://www7.nationalacademies.org/cstb/wp_bb_montpetit.pdf

[53] http://www.frost.com/prod/servlet/cpo/11139757

[54] http://www.gvf.org/members_directory/documents/satellite_broad_net.pdf

[55] http://viasat.com/_files/_08fe203b613bc02b87de181a370e2bdf/pdf/BB economics.pdf

[56] http://www.electronicsforu.com/EFYLinux/efyhome/cover/jun2003/ FSO.pdf

[57] http://www.bechteltelecoms.com/docs/Article4.pdf

[58] http://www.itr-rescue.org/bin/pubdocs/mtg-weekly/9-16-05%20Alcatel_ WiMAX_White_Paper%20(Hassib).pdf?PHPSESSID=847dc3c8c2bef 88b9a

[59] http://www.siemens-mobile.de/repository/729/72939/Backgrounder_WiMAX.pdf

[60] http://www.lucent.com/livelink/090094038008a859_Brochure_datasheet.pdf

[61] http://www.rct.bg/files/DOWNLOAD/DOWNLOAD_102_sm.pdf

[62] http://www.wimaxforum.org/news/downloads/WiMAX-The_Business_Case-Rev3.pdf

[63] http://www.wimaxforum.org/news/downloads/WiMAXWhitepaper.pdf

[64] http://www.wi-fiplanet.com/tutorials/article.php/3348111

[65] http://userpage.fu-berlin.de/~jmueller/its/conf/porto05/papers/Smura.pdf

[66] http://www.wimaxforum.org/news/downloads/WiMAX_to_Bridge_the_Digitaldivide.pdf

[67] http://en.wikipedia.org/wiki/Expert_system

[68] Giarratano J. , Riley G. , (1989) , *Expert Systems, Principles and Programming,* PWS-Kent Publishing Company, Boston.

[69] Sprague G. K. , Ruth R. S. , (1988) , *Developing Expert Systems Using EXSYS,* Mitchell Publishing, Inc. , USA.

[70] Salo A. , Hamalainen R. P. , (1990) , *Seteli, The Strategy Expert for Telecommunication Investments,* IEEE EXPERT, IEEE Intelligent Systems, Vol. 5, No. 5, pp 14–22.

[71]Wills C. E. , Brown D. C. , Dunskus B. V. , Kemble J. , (1998) , *Evaluating network serviceability, Computer Networks and ISDN Systems,* Elsevier Science Ltd, The International Journal of Computer and Telecommunications Networking, Vol. 30, No. 24, pp. 2283-2291.

[72] Sandrasegaran K. , Prag K. , (1999) , *Planning point- to- multipoint rural radio access networks using expert systems, Expert Systems with Applications,* Elsevier Science Ltd. , Vol. 17, No. 3, pp. 145-166.

[73] Ceri S. , Tanca L. , (1990) , *Expert Design of Local Area Networks*, IEEE Intelligent Systems, Vol. 5, No. 5, pp 23-33.

APPENDIX A

ALL ACCESS TELECOMMUNICATION NETWORK SYSTEMS

ADSL:

1. **Basic Infrastructure Features of Access Telecommunication System:**

1.1 ADSL is the most popular version of xDSL and the last mile solution to provide internet services to residental customers**.** It is a copper-based broadband access technology.

1.2 It is asymmetrical.

1.3 ADSL requires multiplexing equipment which is DSLAM to collect backbone traffic at the Central Office(CO) and there is a splitter on the side of house to separate voice and data, so data service and telephone service can be given at the same time.

1.4 The major advantage of ADSL is that it uses the existing telephone network structure to provide high speed data and also it provides guaranteed bandwidth and disadvantage that it is a distance-sensitive and limited bandwidth technology.

1.5 It uses CAP and DMTmodulation techniques.

1.6 ADSL is standardized under ITU and ANSI.

1.7 The latest technologies emerge from the DSL classes are ADSL2+ and ADSL2++.

1.8 ADSL2++ is not supported by a standard. ADSL2+ is standardized. It provides transmission of sufficient bandwidth for video services over greater distances rather than VDSL.

1.9 ADSL2+:
Max. Upstream: 1Mbps **Max.Downstream :** 4 Mbps,
Max. Distance: 3.6 km, **Frequency Range:** Up to 2.2 MHz.

2. Access Tele-communication System Type Depends on Medium (wireline / wireless) :

2.1 Wireline /Twisted-Pair Cable Access System.
2.2 This technology one pair of wire which are separated from telephone line.

3. Frequency of Operation:

ADSL divides the bandwidth of TP Cable (1.1 MHz) into 3 bands such as, **1.** 0-4 KHz: It is used for regular telephone service for voice conversations, **2.** 25–160 KHz : It is used for upstream/communication, **3.** 240 KHz-1.1 MHz : It is used for downstream/ communication. So, frequency range is up to 1.1 MHz for ADSL.

4. Bandwidth Requirement (Data rate) :

4.1 Upstream: 640 Kbps
4.2 Downstream : 1.5 Mbps (if distance is 5.5 km, otherwise data rate can be up to 8 Mbps).

5. Maximum Deployment Distance for Access System:

Maximum deployment distance is 5.5 km.

6. The Main Applications of Access System:

6.1 Internet access and remote LAN access

6.2 High speed delivery of data, voice, multimedia.

6.3 VoDSL (voice over DSL)

7. Security of Access System:

Because of the used medium is TP, security is poor.

8. Access System Cost :

A. CAPITAL COSTS ($per subscriber)

Installation cost : $14

Equipment cost : $106

Loop qualification, cross-connect and testing : $50

DSLAM : $17

Line Card : $138

Marketing Acquisition: $175

Total Expenditures: $500 [40].

B. OPERATIONAL/MAINTENANCE COSTS:

Operational/Maintenance Costs: Operational costs include: service provisioning, sending someone when there is failure, qualifying / testing the loop, upgrading over copper lines, power consumption.

*Automated provisioning is prefered since it reduces the service cost. For example one estimate by LUCENT demonstrates the time spent for order entry, service verification, service provisioning, shipping, device registration, service activation take 3 hours and 25 minutes and costing is approximately $516. The customer waits 8–11 days for operational system. If the CPE is maked a retail item, having orders on the website and automated loop qualification is provided then cost is reduced to $324 and system is on within 3–4 days.

9. Ease of installation of Access System :

Easy, since it uses existing twisted-pair infrastructure.

10. Licence Requirement for frequency : ----

11.Weather Condition : ----

12. Settlement Feature:

Dense Urban, Urban, Industrial SubUrban, Residental Sub Urban [51].

13. No. of Access Users :

Single-User (No shared system).

14. Back up requirement depends on link reliability : ----

****

HDSL:

1. Basic Infrastructure Features of Access Telecommunication System:

1.1 HDSL is the oldest DSL technique and it is symmetrical, full-duplex service.

1.2 HDSL enables carriers to provide T1/E1 services at a reduced cost.

1.3 It uses 2B1Q encoding which is less susceptible to attenuation rather than CAP modulation technique.

1.4 HDSL is standardized under ITU and ADSI.

2. Access Tele-communication System Type Depends on Medium (wireline / wireless) :

Wireline / Twisted-Pair (TP) Cable Access System and this technology uses two pairs of wire which are separated from telephone line.

3. Frequency of Operation:

Up to 1.1 MHz.

4. Bandwidth Requirement (Data rate) :

Data rate is 1.54 Mbps in both directions (downstream and upstream, since symmetrical).

5. Maximum Deployment Distance for Access System:

Distance is 3.6 km.

6. The Main Applications of Access System:

It is used to provide T1/E1 services to businesses at low costs.

7. Security of Access System:

Because of the used medium is TP, security is poor.

8. Access System Cost:

A. CAPITAL COSTS ($per subscriber)

Installation cost : $14

Equipment cost: $106

Loop qualification, cross-connect and testing: $50

DSLAM: $17

Line Card: $138

Marketing Acquisition: $175

Total Expenditures: $500 [40].

9. Ease of installation of Access System:

Easy, since it uses existing twisted-pair infrastructure.

10. Licence Requirement for frequency : ----

11. Weather Condition : ----

12. Settlement Feature:

Dense Urban, Urban, Industrial SubUrban, Residental Sub Urban [51].

13. No. of Access Users:

Single-User (No shared system).

14. Back up requirement depends on link reliability : ----

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IDSL:

1. Basic Infrastructure Features of Access Telecommunication System:

1.1 IDSL is basically ISDN without the telephone switch.

1.2 It is symmetrical and full-duplex service.

1.3 It uses 2B1Q line encoding.

2. Access Tele-communication System Type Depends on Medium (wireline / wireless) :

Wireline / Twisted - Pair (TP) Cable Access System and this technology uses one pair of wire which are separated from telephone line.

3. Frequency of Operation:

Up to 1.1 MHz

4. Bandwidth Requirement (Data rate):

Data rate is 128 Kbps in both directions.

5. Maximum Deployment Distance for Access System:

Distance is 5.5 km.

6. The Main Applications of Access System:

Because of IDSL offers low data rate, it isn't prefered to use in applications.

7. Security of Access System:

Because of the used medium is TP, security is poor.

8. Access System Cost:

A. CAPITAL COSTS ($per subscriber)

Installation cost :$14

Equipment cost:$106

Loop qualification, cross-connect and testing: $50

DSLAM: $17

Line Card: $138

Marketing Acquisition: $175

Total Expenditures: $500 [40].

9. Ease of installation of Access System :

Easy, since it uses existing twisted-pair infrastructure.

10. Licence Requirement for frequency : ----

11. Weather Condition : ----

12. Settlement Feature:

Dense Urban, Urban, Industrial SubUrban, Residental Sub Urban [51].

13. No. of Access Users :

Single-User (No shared system).

14. Back up requirement depends on link reliability : ----

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MSDSL:

1. Basic Infrastructure Features of Access Telecommunication System:

1.1 It is a descendent of SDSL.

1.2 It is symmetrical full duplex service.

2. Access Tele-communication System Type Depends on Medium (wireline / wireless) :

Wireline / Twisted - Pair (TP) Cable Access System and this technology uses one pair of wire which are separated from telephone line.

3. Frequency of Operation:

Up to 1.1 MHz

4. Bandwidth Requirement (Data rate) :

4.1 Data rate is 2 Mbps in both directions at distance 4.5km.

4.2 Data rate is 64 or 128 Kbps at distance 8.9 km.

5. Maximum Deployment Distance for Access System :

Distance is **1.** 8.9 km or **2.** 4.5 km.

6. The Main Applications of Access System :

It is designed to provide an autorate plug and play configuration, which it adjusts automatically operating distance and line conditions.

7. Security of Access System:

Because of the used medium is TP, security is poor.

8. Access System Cost:

A. CAPITAL COSTS ($per subscriber)

Installation cost :$14

Equipment cost:$106

Loop qualification, cross-connect and testing: $50

DSLAM:$17

Line Card: $138

Marketing Acquisition : $175

Total Expenditures : $500 [40].

9. Ease of installation of Access System:

Easy, since it uses existing twisted-pair infrastructure.

10. Licence Requirement for frequency : ----

11. Weather Condition : ----

12. Settlement Feature:

Dense Urban, Urban, Industrial SubUrban, Residental Sub Urban [51].

13. No. of Access Users :

Single-User (No shared system).

14. Back up requirement depends on link reliability : ----

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RADSL:

1. Basic Infrastructure Features of Access Telecommunication System:

1.1 It is the popular version of ADSL that allows modem to adjust the speed of the connection depending on the length and quality of the line.

1.2 It is symmetrical. or asymmetrical.

1.3 It uses DMT encoding.

2. Access Tele-communication System Type Depends on Medium (wireline / wireless) :

Wireline /Twisted - Pair (TP) Cable Access System and this technology uses one pair of wire which are separated from telephone line.

3. Frequency of Operation :

Up to 1.1 MHz

4. Bandwidth Requirement (Data rate) :

4.1 Upstream: Up to 1 Mbps.
4.2 Downstream: Up to 7 Mbps.

5. Maximum Deployment Distance for Access System:

Distance is 5.5 km.

6. The Main Applications of Access System:

Since RADSL can adapt data rates dynamically, in the case of changes in line conditions, it can be prefered over a wide range of loop lengths and conditions.

7. Security of Access System:

Because of the used medium is TP, security is poor.

8. Access System Cost:

A. CAPITAL COSTS ($per subscriber)

Installation cost : $14

Equipment cost : $106

Loop qualification, cross-connect and testing : $50

DSLAM : $17

Line Card : $138

Marketing Acquisition: $175

Total Expenditures : $500 [40].

9. Ease of installation of Access System:

Easy, since it uses existing twisted-pair infrastructure.

10. Licence Requirement for frequency : ----

11. Weather Condition : ----

12. Settlement Feature :

Dense Urban, Urban, Industrial SubUrban, Residental Sub Urban [51].

13. No. of Access Users:

Single-User.

14. Back up requirement depends on link reliability : ----

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SDSL:

1. Basic Infrastructure Features of Access Telecommunication System:

1.1 It is symmetrical and full-duplex service. It is more costly rather than asymmetrical options, but it has more performance.

1.2 SDSL supports multiple data rates up to T1/E1 rates.

2. Access Tele-communication System Type Depends on Medium (wireline / wireless) :

Wireline / Twisted-Pair (TP) Cable Access System and this technology uses one pair of wire which are separated from telephone line.

3. Frequency of Operation:

Up to 1.1 MHz

4. Bandwidth Requirement (Data rate):

Data rates are up to 2 Mbps.

5. Maximum Deployment Distance for Access System:

Distance is 5.5 km.

6. The Main Applications of Access System:

6.1 It is often used as business DSL.

6.2 Main applications of SDSL include replacement of local repeater T1/E1 trunks, interconnection of PBXs, support of multirate ISDN, support for videoconferencing service and high speed residental service.

7. Security of Access System:

Because of the used medium is TP, security is poor.

8. Access System Cost:

A. CAPITAL COSTS ($per subscriber)

Installation cost : $14

Equipment cost : $106

Loop qualification, cross-connect and testing: $50

DSLAM : $17

Line Card : $138

Marketing Acquisition : $175

Total Expenditures : $500 [40].

9. Ease of installation of Access System:

Easy, since it uses existing twisted-pair infrastructure.

10. Licence Requirement for frequency : ----

11. Weather Condition : ----

12. Settlement Feature:

Dense Urban, Urban, Industrial SubUrban, Residental Sub Urban [51].

13. No. of Access Users:

Single-User.

14. Back up requirement depends on link reliability : ----

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VDSL:

1. **Basic Infrastructure Features of Access Telecommunication System:**

   1.1 VDSL is a very high capacity and sister technology to the FTTC (Fiber to the curb).

   1.2 It is asymmetrical.

   1.3 It uses DMT modulating technique.

2. **Access Tele-communication System Type Depends on Medium (wireline / wireless) :**

   Wireline / Twisted-Pair (TP) Cable Access System and this technology uses one pair of wire which are separated from telephone line.

3. Frequency of Operation :

Up to 12 MHz

4. Bandwidth Requirement (Data rate):

4.1 Upstream : 2.3 Mbps.
4.2 Downstream 13 Mbps.

5. Maximum Deployment Distance for Access System:

Distance is 1.5 km (300 to 1500 meters).

6. The Main Applications of Access System:

The key applications of VDSL are the next generation TV (HDTV, DTV) and high-speed internet access.

7. Security of Access System:

Because of the used medium is TP, security is poor.

8. Access System Cost:

A. CAPITAL COSTS ($per subscriber)

Installation cost : $14

Equipment cost : $106

Loop qualification, cross-connect and testing : $50

DSLAM : $17

Line Card : $138

Marketing Acquisition : $175

Total Expenditures : $500 [40].

9. Ease of installation of Access System:

Easy, since it uses existing twisted-pair infrastructure.

10. Licence Requirement for frequency : ----

11. Weather Condition : ----

12. Settlement Feature:

Dense Urban, Urban, Industrial SubUrban, Residental Sub Urban [51].

13. No. of Access Users :

Single-User.

14. Back up requirement depends on link reliability : ----

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VDSL PLUS:

1. Basic Infrastructure Features of Access Telecommunication System:

1.1 It is an extension technology of VDSL.

1.2 VDSL Plus is compatible with existing VDSL products.

2. Access Tele-communication System Type Depends on Medium (wireline / wireless) :

Wireline / Twisted-Pair (TP) Cable Access System and this technology uses one pair of wire which are separated from telephone line.

3. Frequency of Operation:

Up to 12 MHz.

4. Bandwidth Requirement (Data rate) :

It can provide theoretically transmission speeds up to 150 Mbps.

5. Maximum Deployment Distance for Access System:

Distance is between 300 to 1500 meters.

6. The Main Applications of Access System:

The key applications of VDSL are the next generation TV (HDTV, DTV) and high-speed internet access.

7. Security of Access System:

Because of the used medium is TP, security is poor.

8. Access System Cost:

A. CAPITAL COSTS ($per subscriber)

Installation cost : $14

Equipment cost : $106

Loop qualification, cross-connect and testing : $50

DSLAM : $17

Line Card: $138

Marketing Acquisition : $175

Total Expenditures : $500 [40].

9. Ease of installation of Access System:

Easy, since it uses existing twisted-pair infrastructure.

10. Licence Requirement for frequency : ----

11. Weather Condition : ----

12. Settlement Feature:

Dense Urban, Urban, Industrial SubUrban, Residental Sub Urban [51].

13. No. of Access Users:

Single-User.

14. Back up requirement depends on link reliability : ----

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UADSL:

1. Basic Infrastructure Features of Access Telecommunication System:

1.1 The essential difference between ADSL and UADSL is that UADSL doesn't require a splitter at the user end.

1.2 It is the lower-speed, consumer version of ADSL.

1.3 It supports data and telephone services are on the same wire and installing microfilters helps to take better performance of data.

2. Access Tele-communication System Type Depends on Medium (wireline / wireless) :

Wireline /Twisted-Pair (TP) Cable Access System and this technology uses one pair of wire which are separated from telephone line.

3.Frequency of Operation:

Up to 1.1 MHz.

4.Bandwidth Requirement (Data rate) :

4.1 Upstream : 512 Kbps

4.2 Downstream: 1.5 Mbps

5. Maximum Deployment Distance for Access System:

Distance is 7.5 km.

6. The Main Applications of Access System:

It supports internet access. and delivery of data and voice.

7. Security of Access System:

Because of the used medium is TP, security is poor.

8. Access System Cost:

CAPITAL COSTS ($per subscriber)

Installation cost : $14

Equipment cost : $106

Loop qualification, cross-connect and testing : $50

DSLAM : $17

Line Card : $138

Marketing Acquisition : $175

Total Expenditures : $500 [40].

9. Ease of installation of Access System:

Easy, since it uses existing twisted-pair infrastructure.

10. Licence Requirement for frequency : ----

11. Weather Condition : ----

12. Settlement Feature:
Dense Urban, Urban, Industrial SubUrban, Residental Sub Urban [51].

13. No. of Access Users:

Single-User.

14. Back up requirement depends on link reliability : ----

****

HFC:

1. Basic Infrastructure Features of Access Telecommunication System:

1.1 Many traditional cable networks are upgraded to HFC two-way architecture in order to support advanced services and broadband access over a cable modem platform.

1.2 It uses existing cable TV network infrastructure.

1.3 It is asymmetric service.

1.4 HFC Standard, DOCSIS 1.1 supports 40 Mbps downstream, 10 Mbps upstream shared data channels. The latest version DOCSIS 2.0 increase the upstream path up to 500 Mbps over DOCSIS 1.1.

2. Access Tele-communication System Type Depends on Medium (wireline / wireless) :

Wireline / Hybrid Fiber Coaxial Cable Access System

3. Frequency of Operation:

7-860MHz

4. Bandwidth Requirement (Data rate) :

4.1 Upstream : 256-500 Kbps

4.2 Downstream : 0.5-3 Mbps

5. Maximum Deployment Distance for Access System :

Distance is typically up to 100 km.

6. The Main Applications of Access System:

It supports data, video and voice over IP(with VoIP adapter).

7. Security of Access System:

Good (It is more secure rather than TP cable solutions).

8. Access System Cost ($per subscriber) :

8.1 Equipment Cost : $120-$160

8.2 Operational Cost (Service Costs) :
***Monthly cost, video :** $30-$80
***Monthly cost, data :** $40-$60

9. Ease of installation of Access System:

Easy, since the medium is coaxial cable and deployment is fast with relatively low installation costs.

10. Licence Requirement for frequency : ----

11. Weather Condition : ----

12. Settlement Feature:

Dense Urban, Urban, Industrial SubUrban, Residental Sub Urban [51].

13. No. of Access Users :

Multi-User (shared system).

14. Back up requirement depends on link reliability : ----

****

FTTX:

1. Basic Infrastructure Features of Access Telecommunication System:

1.1 FTTX is a general term and means to bring fiber closer to the subscriber.

1.2 FTTC (fiber to the curb or cabinet) or FTTN (fiber to the node) is to bring fiber from the local exchange to a node or to the curb and the equipment, which is positioned in a street cabinet (curb) converts signals from optical to electronic and provides connection between final node to the subscriber with twisted copper pair.

1.3 FTTB (fiber to the building) and FTTP (fiber to premises) are to bring fiber as far as the building and then it is distributed among between the subscribers over twisted pair or using wireless technology.

1.4 FTTH (fiber to the home) is to bring fiber directly each home and it is an optimal fiber access solution. It is a point- to-point architecture.

1.5 The major advantage of FTTH is unlimited bandwidth and disadvantage is new fiber access network overlay requirement and high intallation costs.

2. Access Tele-communication System Type Depends on Medium (wireline / wireless) :

Wireline / Fiber Optic Access System. Fiber Cable can be in two modes such as **a. Single Mode Fiber**, **b. Multimode Mode Fiber**.

3. Frequency of Operation:

In THz.

4. Bandwidth Requirement (Data rate) :

Up to 1 Gbps per channel per fiber.

5. Maximum Deployment Distance for Access System:

Distance is 20 km.

6. The Main Applications of Access System:

Broadband Service Applications: high-speed data, video, multimedia.

7. Security of Access System:

Because of the used medium is fiber optic cable, security is good.

8. Access System Cost:

A. CAPITAL COSTS ($per subscriber for 100 + Mbps)

CPE: $550

Fiber: $1400

Splitter and install: $175

PoP/Co equipment and install: $775

Total Expenditures: $2900 [40].

9. Ease of installation of Access System:

Difficult, since the medium is fiber cable, special test equipment is required to installation.

10. Licence Requirement for frequency : ----

11. Weather Condition : ----

12. Settlement Feature:

Long Haul, Dense Urban, Urban, Industrial Sub Urban [51].

13. No. of Access Users:

Single-User.

14. Back up requirement depends on link reliability : ----

****

LMDS:

1. Basic Infrastructure Features of Access Telecommunication System:

1.1 It is line-of-sight (LOS)microwave technology.

1.2 LMDS consists of a radio transmitter (an antenna) at the each base station to transmit in a point to multipoint type over a wide coverage area and it consists of fiber from Central Office to each base station, then air is used as a medium between base stations and subscribers.

1.3 LMDS offers more economical solution for wide area coverage rather than point- to- point microwave links. LMDS is a very localized service. It is distance limited and also it is limited by the available radio spectrum. Since the range of radio signals is limited to nearly 8 km due to higher free space attenuation.

2. Access Tele-communication System Type Depends on Medium (wireline / wireless):

Wireless/ Microwave System.

3. Frequency of Operation:

LMDS operates in 24 GHz–38 GHz.

4. Bandwidth Requirement (Data rate) :

Data rate is up to 155 Mbps per base station and 10 Mbps to customers.

5. Maximum Deployment Distance for Access System:

Distance is 5 km.

6. The Main Applications of Access System:

LMDS provides digital two-way voice, high speed internet access and data, video services.

7. Security of Access System:

Poor (depends on medium).

8. Access System Cost:

CPE : $2000

License: $100

Base Station: $40

CPE maintenance: $300

Backhaul : $40

Network maintenance: $30

Total annual cost: $2510 [40].

9. Ease of installation of Access System:

Easy, since the medium is microwave, it provides portability and reconfiguration flexibility.

10. Licence Requirement for frequency:

There is licence requirement for LMDS.

11. Weather Condition : The system is effected from rain.

12. Settlement Feature:

Urban, Industrial SubUrban, Residental Sub Urban [51].

13. No. of Access Users:

Multi-User.

14. Back up requirement depends on link reliability : ----

****

FSO:

1. Basic Infrastructure Features of Access Telecommunication System:

1.1 It is an optical wireless system which uses low-powered infrared sources or lasers and provides point-to-point connections at data rates comparable to fiber-based systems without need to license spectrum.

1.2 It requires perfect line-of-sight (LOS).

1.3 It uses a light signal instead of radiowave and it is full-duplex communication.

1.4 It uses two infrared wavelenghts around 1550 nm (194 THz) and 800 nm (375 THz).

1.5 It uses optical pulse modulation and DWDM techniques.

1.6 It is not cost effective for the wide area coverage due to the point-to point nature.

1.7 It is susceptible to outer effects such as weather (snow, rain, fog, heat) and passing objects (birds).

2. Access Tele-communication System Type Depends on Medium (wireline / wireless) :

Wireless / Optical wireless System

3. Frequency of Operation:

In THz frequencies.

4. Bandwidth Requirement (Data rate) :

Data rate is between 10 Mbps and 1.25 Gbps (100 Mbps to 2.5 Gbps over distances up to 2 km).

5. Maximum Deployment Distance for Access System:

Distance is up to 4kms.

6. The Main Applications of Access System:

6.1 Now, It is a strong alternative inside last-mile broadband access solutions for internet access and voice.

6.2 It is used to connect enterprise LANs across nearby buildings.

7. Security of Access System :

Because of the external effects security is poor.

8. Access System Cost:

Price/month ($per subscriber)

***Equipment Cost+Monthly cost :** $555 ($4/ Mbps/ monthly)

*FSO LAN-LAN connectivity cost is $26000 for equipment and installation and no monthly fee for 640 meters [40].

9. Ease of installation of Access System:

Difficult. Since new system will be installed.

10. Licence Requirement for frequency :---

11. Weather Condition: The key problem with FSO is fog and other problems are flying objects and buildings.

12. Settlement Feature:

Dense Urban, Urban [51].

13. No. of Access Users:

Single-User.

14. Back up requirement depends on link reliability:

14.1 If the weather is bad, Then the range of the link is reduced or redundant (i.e wired) infrastructure is deployed .

14.2 If buildings sway little, then autotracking mechanisms are required to ensure focusing between beams.

14.3 If the flying objects effect the system frequently, then meshed architecture should be deployed to provide better reliability.

****

WIMAX:

1.Basic Infrastructure Features of Access Telecommunication System:

1.1 WIMAX is the latest broadband technology which is designed to provide WiFi type point-to multipoint connectivity over a much wider area as a last-mile broadband wireless access solution.

1.2 There are two types of WIMAX:

a. **LOS (line of sight) :** It is point-to-point operation. This type has much better link capability (802.16).

b. **NLOS (non-line of sight) :** It is point-to-multipoint operation. So this type offers large-scale consumer broadband services (802.16a).

1.3 WIMAX is based on the 802.16 standard to provide mobile wireless broadband connectivity.

1.4 Practical bit rate is 2 Mbps per suscriber and maximum NLOS cell size is limited to 1- 2 km.

2. Access Tele-communication System Type Depends on Medium (wireline / wireless) :

Wireless / Mobile wireless broadband system.

3. Frequency of Operation:

Frequency range is **LOS :** 10-66 GHz, **NLOS :** 2-11 GHz

4. Bandwidth Requirement (Data rate) :

Data rate is

LOS : 2.8 to 11.3 Mbps per downlink and uplink for per CPE.

NLOS : 2.8 to 11.3 Mbps per downlink and uplink for per CPE.

5. Maximum Deployment Distance for Access System:

Distance is

LOS:10-16km

NLOS:1-2km

6. The Main Applications of Access System:

WIMAX is the next generation broadband solution for backhauling WiFi hot spots and metro access coverage. and supports ATM, IPv4, Ethernet and VLAN services.

7. Security of Access System:

Because of the shared system security is poor.

8. Access System Cost:

Price/month ($per subscriber)

Equipment Cost (CPE) : $40-$500

Monthly cost: $150 initial [40].

9. Ease of installation of Access System:

Easy. Since WIMAX has lower deployment costs in rural areas, but in urban areas deployment can be very costly. Wireless systems are more flexible and so more easier to deploy.

10. Licence Requirement for frequency:

This system is both licenced and unlicenced.

a. The two licensed bands are 3.3-3.8 GHz and 2.3-2.7 GHz

b. The one unlicenced band is 5.725-5.85 GHz.

11. Weather Condition : The key problem with FSO is fog and other problems are flying objects and buildings.

12. Settlement Feature:

Industrial SubUrban, Residental Sub Urban, Rural [51].

13. No. of Access Users :

Multi-User.

14. Back up requirement depends on link reliability :

****

SATELLITE:

1. Basic Infrastructure Features of Access Telecommunication System

1.1 Telecommunication satellites receive signals from a ground station and send them down to another ground station located at a very long distance from the first station.

1.2 It is microwave but not terrestrial.

1.3 Similar to microwave systems (i.e LMDS) their performances are depends on the weather condition**.**

1.4 Satellites have 2 modes:

a. Hybrid Mode (Oneway) : Download is occured by the satelllite but upload is provided by standard 56K telephone connection.

b. Two-way satellite mode : DBS (Direct broadcast satellites) uses geostationary satellites and VSAT technology for two-way high-speed data transmissions.

2. Access Tele-communication System Type Depends on Medium (wireline / wireless) :

Wireless / Satellite System

3. Frequency of Operation :

Frequency range is :

1) Ku-band : (one way systems)
Uplink:14 GHz
Downlink:12 GHz

2) Ka-band : (Two way systems)
Uplink: 30 GHz
Downlink:20 GHz

4. Bandwidth Requirement (Data rate) :

Data rate is :

1) Ku-band : (one way systems)
Uplink:56 Kbps
Downlink:1 Mbps
2) Ka-band : (Two way systems) : up to 155 Mbps.

5. Maximum Deployment Distance for Access System:

Distance is up to 1000–36000 km.

6. The Main Applications of Access System:

6.1 Satellites can transmit to and receive from a large area, thus generally used in point-to-multipoint and multicast and broadcast applications.

6.2 It provides long distance telephone network among countries, television broadcasting, GPS systems, VSAT Networks.

7. Security of Access System:

Security is poor, because of the external effects such as weather conditions.

8. Access System Cost:

Equipment Cost : $750-$1000

Operational Cost (Service Costs) : Monthly fee : $70 [40].

9. Ease of installation of Access System:

Easy, since the medium is like microwave, it provides portability and reconfiguration flexibility and rapid deployment.

10. Licence Requirement for frequency: There is licence requirement.

11. Weather Condition : ----

12. Settlement Feature :

Rural, Remote [51].

13. No. of Access Users :

Single-User.

14. Back up requirement depends on link reliability:

****

POWER LINE :

1. Basic Infrastructure Features of Access Telecommunication System:

1.1 It provides high speed internet access over electrical grid.
1.2 It uses shared media structure similar to cable modem system.
1.3 It uses existing power lines.
1.4 Power line upgrades are expensive.

2. Access Tele-communication System Type Depends on Medium (wireline / wireless):

Wireline / TP System

3. Frequency of Operation:

Frequency range is 1-30 MHz.

4. Bandwidth Requirement (Data rate) :

Data rate is 2-3 Mbps.

5. Maximum Deployment Distance for Access System :

Distance is 1 km power grid.

6. The Main Applications of Access System:

The applications of powerline is high-speed internet access, VoIP, video and audio on demand, video conferencing, home - LAN connections and interactive TV.

7. Security of Access System:

Since it is shared system, security is poor.

8. Access System Cost :

Price/month ($per subscriber)

***Monthly cost for consumer :** $20-$30

***Monthly cost for business :** $60-$360 [40].

9. Ease of installation of Access System:

Easy, since it uses existing power-line infrastructure.

10. Licence Requirement for frequency : ----

11. Weather Condition : ----

12. Settlement Feature:

Rural, Backhaul [51].

13. No. of Access Users:

Multi-User.

14. Back up requirement depends on link reliability:

****

APPENDIX B

KNOWLEDGE BASE QUALIFIERS AND CHOICES FOR THE ACCESS TELECOMMUNICATION EXPERT SYSTEM

Subject:
EXPERT SYSTEMS IN ACCESS TELECOMMUNICATION NETWORKS

Author:
SEDA SAHIN

Starting text:

The knowledge base, Access Telecommunication Network is developed to create an expert system using the Exsys Expert System Development Package. This expert system is used to select the optimum access telecommunication network system depends on different features and external conditions.

Ending text:

CALCULATING RESULTS

Uses all applicable rules in data derivations.

Probability System: 0 - 10

DISPLAY THRESHOLD: 1

QUALIFIERS:

1 The upstream rate is

640 Kbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main applications of the system are high speed delivery of data, voice, multimedia and VoDSL.

1.54 Mbps and the communication medium uses a copper twisted- pair cable And the digital data transmission is done by using existing telephone line and the main application of the system is to provide T1/E1 services to businesses at low costs

128 Kbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and system is basically ISDN without the telephone switch structure is used

2 Mbps at distance 4.5 km and the communication medium uses a copper twisted - pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to design an autorate plug and play configuration which adjusts operating distance and line conditions

64 or 128 Kbps at distance 8.9 km and the communication medium uses a copper twisted - pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to design an autorate plug and play configuration which adjusts operating distance and line conditions

1 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and system is mostly used over wide range of loop lengths

2 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and system is often used as business DSL

2.3 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is the next generation TV

150 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is the next generation TV and system is an extension technology of VDSL

512 Kbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and system is lower speed consumer version of ADSL

256-500 Kbps and the communication medium uses a hybrid fiber coaxial cable structure

1 Gbps per channel per fiber and the communication medium uses a fiber-optic cable structure up to user-end

2-3 Mbps and the system provides services over electrical grid

10 Mbps and the communication medium uses air and the system is microwave system

between 10 Mbps-1.25 Gbps and the communication medium uses air and the system type is optical wireless system

2.8 to 11.3 Mbps per CPE and the communication medium uses air and the system type is mobile wireless system at distance 10-16 km

2.8 to 11.3 Mbps per CPE and the communication medium uses air and the system type is mobile wireless system at distance 1-2 km

56 Kbps and the communication medium uses air and download is occured by satellite but upload is provided by standard 56K telephone

up to 155 Mbps and the communication medium uses air and system uses DBS and VSAT technology for two-way high speed data transmission

2 The downstream rate is

1.5 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main applications of the system are high speed delivery of data, voice, multimedia and VoDSL

1.54 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to provide T1/E1 services to businesses at low costs

128 Kbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to provide T1/E1 services to businesses businesses at low costs

2 Mbps at distance 4.5 km and the communication medium uses a copper Twisted - pair cable and the digital data transmission is done by using existing Telephone line and the main application of the system is to design an autorate plug and play configuration which adjusts operating distance and line conditions

64 or 128 Kbps at distance 8.9 km and the communication medium uses a Copper twisted –pair cable and the digital data transmission is done by using Existing telephone line and the main application of the system is to design an autorate plug and play configuration which adjusts operating distance

7 Mbps and the communication medium uses a copper-twisted pair cable and the digital data transmission is done by using existing telephone line and system is mostly used over wide range of loop lengths

2 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and system is often used as business DSL

13 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is the next generation TV

150 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is the next generation TV and system is an extension technology of VDSL

1.5 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and system is lower speed consumer version of ADSL

0.5-3 Mbps and the communication medium uses a hybrid fiber coaxial cable Structure up to 1 Gbps per channel per fiber and the communication medium uses a fiber optic cable structure up to user-end

2-3 Mbps and the system provides over electrical grid

10 Mbps and the communication medium uses air and the system type is microwave system

between 10Mbps-1.25 Gbps and the communication medium uses air and the system type is optical wireless system

2.8 to 11.3 Mbps per CPE and the communication medium uses air and the system type is mobile wireless system at distance 10-16 km

2.8 to 11.3 Mbps per CPE and the communication medium uses air and the system type is mobile wireless system at distance 1-2 km

56 Kbps and the communication medium uses air and download is occured by the satellite but upload is provided by standard 56K telephone connection

up to 155 Mbps the communication medium uses air and system uses DBS and VSAT technology for two-way high speed data transmission

3 there is

a fiber link to the building up to user-end
an ADSL infrastructure
dedication of frequency
other feature

4 the licence is

used and system uses a LOS microwave technology

used and telecommunication satellites receive signals from a ground station and send them down to another ground station located at a very long distance from first station

used and used bands are 3.3-3.8 GHz and 2.3-2.7 GHz and system is a mobile wireless technology

not used

5 The system settlement is

dense urban, urban , industrial suburban, residental suburban and the communication medium is twisted-pair cable

dense urban, urban, industrial suburban, residental suburban and system is multi-user hybrid fiber-coaxial cable system

long haul, dense urban, urban, industrial suburban and the communication medium uses fiber optic cable structure

rural, backhaul and the communication medium uses existing electrical grid cable structure

urban, industrial suburban, residental suburban and system uses LOS microwave technology

dense urban, urban and system is an optical wireless system

industrial suburban, residental suburban, rural and system is mobile wireless system

rural, remote and system is long distance wireless system

6 The maximum deployment distance is

5.5 km and the most popular version of xDSL system is used

3.6 km and the oldest xDSL system is preferred

5.5 km and the communication medium is twisted - pair cable and system is basically ISDN without switch

4.5 km at data rate 2 Mbps and the communication medium is twisted-pair cable and the descendent of SDSL systems is preferred

8.9 km at data rate 64 or 128 Kbps and the communication medium is twisted-pair cable and the descendent of SDSL systems is preferred

5.5 km and the communication medium is twisted-pair cable and system has the modem that allows modem to adjust the speed of the connection

5.5km and the communication medium is twisted-pair cable and it is often used as business DSL

1.5 km and the communication medium is twisted- pair cable and the main application is next generation TV between 300 to 1500 meters and the communication medium is twisted-pair and it is an extension technology of VDSL

7.5 km and the communication medium is twisted-pair cable and system is lower speed consumer version of ADSL typically up to 100 km and the communication medium is hybrid fiber-coaxial cable 20 km and there is a fiber link to the end-user

1 km power grid and the communication medium is existing electrical grid

5 km and the system type is LOS microwave system

up to 4 km and the system type is optical wireless system

10-16 km and the system type is mobile wireless system

1-2 km and the system type is mobile wireless system

1000-36000 km and the communication medium is air and the long distance communication system is used

7 The installation cost for this connection per subscriber is

$14
other

8 The equipment cost for this connection per subscriber

$106
$120-$160
$40-$500
$750-$1000
other

9 The total expenditures for this connection per subscriber is

$500
$2900
$2510
other

10 The operational monthly cost of video for this connection per subscriber

$30-$80
other

11 The operational monthly cost of data for this connection per subscriber

$40-$60
other

12 The operational monthly cost for consumer for this connection per subscriber is

$20-$30
$150
$70
other

13 The operational monthly cost for business for this connection per subscriber is

$60-$360
other

14 The equipment cost and monthly cost for this connection per subscriber is

$555
other

15 The security is

poor, because of the medium is twisted-pair cable
poor, since system uses existing electrical grid
poor depends on the rainy medium and the communication medium is air and system is microwave system
poor, because of the external effects and the system is optical wireless system

poor, because of the long distance application area and the communication medium is air
good rather than twisted-pair cable solutions and the communication medium is hybrid fiber coaxial cable
good, because of the medium is fiber optic cable
poor, since system is a multiuser mobile wireless system
other

16 The installation of access system is

easy, since it uses existing twisted-pair infrastructure
easy, since the medium is coaxial cable and deployment is fast with relatively
low installation costs
difficult, since the medium is fiber cable and special test equipment is required to install
easy, since it uses existing electrical grid infrastructure
easy, since system is LOS microwave system that provides portability and reconfiguration flexibility
difficult, since new optical wireless system will be installed
easy and system has lower deployment costs for rural areas and system type is mobile wireless system
easy, since the medium is like microwave this feature provides portability and reconfiguration flexibility and rapid deployment and the maximum deployment distance is 1000-36000 km
other

17 The weather is

bad, so the range of the link is reduced or redundant infrastructure is deployed and system type is optical wireless system
good

18 Buildings sway

little, so autotracking mechanisms are required to ensure focusing between beams and system type is optical wireless system
very fast

19 The flying objects effect

the system frequently, so meshed architecture should be deployed to provide better reliability and system type is optical wireless system
not effect the system

20 The fog density is

high in system usage area and system type is optical wireless system
other

21 The system is

effected from rain and system type is microwave wireless system
not effected from rain

CHOICES:

1 The optimum access telecom system is Wireway-xDSL-ADSL

2 The optimum access telecom system is Wireway-xDSL-HDSL

3 The optimum access telecom system is Wireway-xDSL-MSDSL

4 The optimum access telecom system is Wireway-xDSL-RADSL

5 The optimum access telecom system is Wireway-xDSL-SDSL

6 The optimum access telecom system is Wireway-xDSL-VDSL

7 The optimum access telecom system is Wireway-xDSL-VDSL PLUS

8 The optimum access telecom system is Wireway-xDSL-IDSL

9 The optimum access telecom system is Wireway-xDSL-UADSL

10 The optimum access telecom system is Wireway-HFC

11 The optimum access telecom system is Wireway-FTTH

12 The optimum access telecom system is Wireway-POWERLINE

13 The optimum access telecom system is Wireless-LMDS

14 The optimum access telecom system is Wireless-FSO

15 The optimum access telecom system is Wireless-LOS-WIMAX

16 The optimum access telecom system is Wireless-NLOS-WIMAX

17 The optimum access telecom system is Wireless-ONE-WAY-SATELLITE

18 The optimum access telecom system is Wireless-TWO-WAY-SATELLITE

19 The optimum access telecom system is Wireless-SATELLITE

20 The optimum access telecom system is LICENCED-WIMAX

21 The optimum access telecom system is Wireway-xDSL

22 The optimum access telecom system is Wireless-WIMAX

23 the optimum access telecom system

APPENDIX C

DECISION RULES FOR THE ACCESS TELECOMMUNICATION NETWORK EXPERT SYSTEM

RULE NUMBER: 1

IF:

The upstream rate is 640 Kbps and the communication medium uses a Copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main applications of the system are high speed delivery of data, voice, multimedia and VoDSL

THEN:

The optimum access telecom system is Wireway-xDSL-ADSL - Confidence=9/10

RULE NUMBER: 2

IF:

The upstream rate is 640 Kbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main applications of the system are high speed delivery of data, voice, multimedia and VoDSL

THEN:

The optimum access telecom system is Wireway-xDSL-HDSL - Confidence=5/10

RULE NUMBER: 3

IF:

The upstream rate is 640 Kbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main applications of the system are high speed delivery of data, voice, multimedia and VoDSL

THEN:

The optimum access telecom system is Wireway-xDSL-MSDSL - Confidence=6/10

RULE NUMBER: 4

IF:

The upstream rate is 640 Kbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main applications of the system system are high speed delivery of data, voice, multimedia and VoDSL

THEN:

The optimum access telecom system is Wireway-xDSL-RADSL - Confidence=4/10

RULE NUMBER: 5

IF:

The upstream rate is 640 Kbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main applications of the system are high speed delivery of data, voice, multimedia and VoDSL

THEN:

The optimum access telecom system is Wireway-xDSL-VDSL - Confidence=6/10

RULE NUMBER: 6

IF:

The upstream rate is 640 Kbps and the communication medium uses a uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main applications of the system are high speed delivery of data, voice, multimedia and VoDSL

THEN:

The optimum access telecom system is Wireway-xDSL-VDSL - Confidence=7/10

RULE NUMBER: 7

IF:

The upstream rate is 640 Kbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main applications of the system are high speed delivery of data, voice, multimedia and VoDSL

THEN:

The optimum access telecom system is Wireway-xDSL-VDSL PLUS - Confidence=8/10

RULE NUMBER: 8

IF:

The upstream rate is 1.54 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to provide T1/E1 services to businesses at low costs

THEN:

The optimum access telecom system is Wireway-xDSL-HDSL - Confidence=9/10

RULE NUMBER: 9

IF:

The upstream rate is 1.54 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to provide T1/E1 services to businesses at low costs

THEN:

The optimum access telecom system is Wireway-xDSL-MSDSL - Confidence=6/10

RULE NUMBER: 10

IF:

The upstream rate is 1.54 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to provide T1/E1 services to businesses at low costs.

THEN:

The optimum access telecom system is Wireway-xDSL-SDSL - Confidence=6/10

RULE NUMBER: 11

IF:

The upstream rate is 1.54 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to provide T1/E1 services to businesses at low costs.

THEN:

The optimum access telecom system is Wireway-xDSL-VDSL - Confidence=7/10

RULE NUMBER: 12

IF:

The upstream rate is 1.54 Mbps and the communication medium uses a uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to provide T1/E1 services to businesses at low costs.

THEN:

The optimum access telecom system is Wireway-xDSL-VDSL PLUS- Confidence=8/10

RULE NUMBER: 13

IF:

The upstream rate is 128 Kbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and system is basically ISDN without the telephone switch structure is used

THEN:

The optimum access telecom system is Wireway-xDSL-IDSL - Confidence=10/10

RULE NUMBER: 14

IF:

The upstream rate is 2 Mbps at distance 4.5 km and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to design an autorate plug and play configuration which adjusts operating distance and line conditions

THEN:

The optimum access telecom system is Wireway-xDSL-MSDSL - Confidence=10/10

RULE NUMBER: 15

IF:

The upstream rate is 64 or 128 Kbps at distance 8.9 km and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to design an autorate plug and play configuration which adjusts operating distance and line conditions

THEN:

The optimum access telecom system is Wireway-xDSL-MSDSL - Confidence=10/10

RULE NUMBER: 16

IF:

The upstream rate is 1 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and system is mostly used over wide range of loop lengths

THEN:

The optimum access telecom system is Wireway-xDSL-RADSL - Confidence=9/10

RULE NUMBER: 17

IF:

The upstream rate is 1 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and system is mostly used over wide range of loop lengths

THEN:

The optimum access telecom system is Wireway-xDSL-HDSL - Confidence=6/10

RULE NUMBER: 18

IF:

The upstream rate is 1 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and system is mostly used over wide range of loop lengths

THEN:

The optimum access telecom system is Wireway-xDSL-MSDSL - Confidence=7/10

RULE NUMBER: 19

IF:

The upstream rate is 1 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and system is mostly used over wide range of loop lengths

THEN:

The optimum access telecom system is Wireway-xDSL-SDSL - Confidence=8/10

RULE NUMBER: 20

IF:

The upstream rate is 1 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and system is mostly used over wide range of loop lengths

THEN:

The optimum access telecom system is Wireway-xDSL-VDSL - Confidence=5/10

RULE NUMBER: 21

IF:

The upstream rate is 1 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and system is mostly used over wide range of loop lengths

THEN:

The optimum access telecom system is Wireway-xDSL-VDSL PLUS - Confidence=4/10

RULE NUMBER: 22

IF:

The upstream rate is 2 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and system is often used as business DSL

THEN:

The optimum access telecom system is Wireway-xDSL-SDSL - Confidence=10/10

RULE NUMBER: 23

IF:

The upstream rate is 2.3 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is the next generation TV

THEN:

The optimum access telecom system is Wireway-xDSL-VDSL - Confidence=9/10

RULE NUMBER: 24

IF:

The upstream rate is 2.3 Mbps and the communication medium uses a copper twisted-pair cable and the digita l data transmission is done by using existing telephone line and the main application of the system is the next generation TV

THEN:

The optimum access telecom system is Wireway-xDSL-VDSL PLUS - Confidence=10/10

RULE NUMBER: 25

IF:

The upstream rate is 150 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is the next generation TV and system is an extension technology of VDSL

THEN:

The optimum access telecom system is Wireway-xDSL-VDSL PLUS - Confidence=10/10

RULE NUMBER: 26

IF:

The upstream rate is 512 Kbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and system is lower speed consumer version of ADSL

THEN:

The optimum access telecom system is Wireway-xDSL-UADSL – Confidence=10/10

RULE NUMBER: 27

IF:

The upstream rate is 256-500 Kbps and the communication medium uses a hybrid fiber coaxial cable structure

THEN:

The optimum access telecom system is Wireway-HFC - Confidence=10/10

RULE NUMBER: 28

IF:

The upstream rate is 1 Gbps per channel per fiber and the communication medium uses a fiber optic cable structure up to user-end

THEN:

The optimum access telecom system is Wireway-FTTH - Confidence=10/10

RULE NUMBER: 29

IF:

The upstream rate is 2-3 Mbps and the system provides services over electrical grid

THEN:

The optimum access telecom system is Wireway-POWERLINE - Confidence=10/10

RULE NUMBER: 30

IF:

The upstream rate is 10 Mbps and the communication medium uses air and the system is microwave system

THEN:

The optimum access telecom system is Wireless-LMDS - Confidence=10/10

RULE NUMBER: 31

IF:

The upstream rate is between 10 Mbps-1.25 Gbps and the communication medium uses air and the system type is optical wireless system

THEN:

The optimum access telecom system is Wireless-FSO - Confidence=10/10

RULE NUMBER: 32

IF:

The upstream rate is 2.8 to 11.3 Mbps per CPE and the communication medium uses air and the system type is mobile wireless system at distance 10-16 km

THEN:

The optimum access telecom system is Wireless-LOS-WIMAX - Confidence=10/10

RULE NUMBER: 33

IF:

The upstream rate is 2.8 to 11.3 Mbps per CPE and the communication medium uses air and the system type is mobile wireless system at distance 1-2 km

THEN:

The optimum access telecom system is Wireless-NLOS-WIMAX - Confidence=10/10

RULE NUMBER: 34

IF:

The upstream rate is 56 Kbps and the communication medium uses air and download is occured by satellite but upload is provided by standard 56K telephone

THEN:

The optimum access telecom system is Wireless-ONE-WAY-SATELLITE - Confidence=10/10

RULE NUMBER: 35

IF:

The upstream rate is up to 155 Mbps and the communication medium uses air and system uses DBS and VSAT technology for two-way high speed data transmission

THEN:

The optimum access telecom system is Wireless-TWO-WAY-SATELLITE - Confidence=10/10

RULE NUMBER: 36

IF:

The downstream rate is 1.5 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main applications of the system are high speed delivery of data, voice, multimedia and VoDSL

THEN:

The optimum access telecom system is Wireway-xDSL-ADSL - Confidence=9/10

RULE NUMBER: 37

IF:

The downstream rate is 1.5 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main applications of the system are high speed delivery of data, voice, multimedia and VoDSL

THEN:

The optimum access telecom system is Wireway-xDSL-HDSL - Confidence=4/10

RULE NUMBER: 38

IF:

The downstream rate is 1.5 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main applications of the system are high speed delivery of data, voice, multimedia and VoDSL

THEN:

The optimum access telecom system is Wireway-xDSL-MSDSL - Confidence=5/10

RULE NUMBER: 39

IF:

The downstream rate is 1.5 Mbps and the communication medium uses a Copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main applications of the system are high speed delivery of data, voice, multimedia and VoDSL

THEN:

The optimum access telecom system is Wireway-xDSL-RADSL - Confidence=6/10

RULE NUMBER: 40

IF:

The downstream rate is 1.5 Mbps and the communication medium uses a copper twisted - pair cable and the digital data transmission is done by using existing telephone line and the main applications of the system are high speed delivery of data, voice, multimedia and VoDSL

THEN:

The optimum access telecom system is Wireway-xDSL-SDSL - Confidence=5/10

RULE NUMBER: 41

IF:

The downstream rate is 1.5 Mbps and the communication medium uses a copper twisted – pair cable and the digital data transmission is done by using existing telephone line and the main applications of the system are high speed delivery of data, voice, multimedia and VoDSL

THEN:

The optimum access telecom system is Wireway-xDSL-VDSL - Confidence=7/10

RULE NUMBER: 42

IF:

The downstream rate is 1.5 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main applications of the system are high speed delivery of data, voice, multimedia and VoDSL

THEN:

The optimum access telecom system is Wireway-xDSL-VDSL PLUS - Confidence=8/10

RULE NUMBER: 43

IF:

The downstream rate is 1.5 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main applications of the system are high speed delivery of data, voice, multimedia and VoDSL

THEN:

The optimum access telecom system is Wireway-xDSL-UADSL - Confidence=4/10

RULE NUMBER: 44

IF:

The downstream rate is 1.54 Mbps and the communication medium uses a copper twisted- pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to provide T1/E1 services to businesses at low costs

THEN:

The optimum access telecom system is Wireway-xDSL-HDSL - Confidence=9/10

RULE NUMBER: 45

IF:

The downstream rate is 1.54 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to provide T1/E1 services to businesses at low costs

THEN:

The optimum access telecom system is Wireway-xDSL-MSDSL - Confidence=5/10

RULE NUMBER: 46

IF:

The downstream rate is 1.54 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to provide T1/E1 services to businesses at low costs

THEN:

The optimum access telecom system is Wireway-xDSL-RADSL - Confidence=6/10

RULE NUMBER: 47

IF:

The downstream rate is 1.54 Mbps and the communication medium uses a copper twisted- pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to provide T1/E1 services to businesses at low costs

THEN:

The optimum access telecom system is Wireway-xDSL-SDSL - Confidence=5/10

RULE NUMBER: 48

IF:

The downstream rate is 1.54 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to provide T1/E1 services to businesses at low costs

THEN:

The optimum access telecom system is Wireway-xDSL-VDSL - Confidence=7/10

RULE NUMBER: 49

IF:

The downstream rate is 1.54 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to provide T1/E1 services to businesses at low costs

THEN:

The optimum access telecom system is Wireway-xDSL-VDSL PLUS - Confidence=8/10

RULE NUMBER: 50

IF:

The downstream rate is 128 Kbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to provide T1/E1 services to businesses at low costs

THEN:

The optimum access telecom system is Wireway-xDSL-IDSL - Confidence=10/10

RULE NUMBER: 51

IF:

The downstream rate is 2 Mbps at distance 4.5 km and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to design an autorate plug and play configuration which adjusts operating distance and line conditions

THEN:

The optimum access telecom system is Wireway-xDSL-MSDSL - Confidence=9/10

RULE NUMBER: 52

IF:

The downstream rate is 2 Mbps at distance 4.5km and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to design an autorate plug and play configuration which adjusts operating distance and line conditions

THEN:

The optimum access telecom system is Wireway-xDSL-RADSL - Confidence=6/10

RULE NUMBER: 53

IF:

The downstream rate is 2 Mbps at distance 4.5km and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to design an autorate plug and play configuration which adjusts operating distance and line conditions

THEN:

The optimum access telecom system is Wireway-xDSL-SDSL - Confidence=5/10

RULE NUMBER: 54

IF:

The downstream rate is 2 Mbps at distance 4.5km and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to design an autorate plug and play configuration which adjusts operating distance and line conditions

THEN:

The optimum access telecom system is Wireway-xDSL-VDSL - Confidence=7/10

RULE NUMBER: 55

IF:

The downstream rate is 2 Mbps at distance 4.5km and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to design an autorate plug and play configuration which adjusts operating distance and line conditions

THEN:

The optimum access telecom system is Wireway-xDSL-VDSL PLUS - Confidence=8/10

RULE NUMBER: 56

IF:

The downstream rate is 64 or 128 Kbps at distance 8.9km and the communication medium uses a copper twisted -pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to design an autorate plug and play configuration which adjusts operating distance

THEN:

The optimum access telecom system is Wireway-xDSL-MSDSL - Confidence=10/10

RULE NUMBER: 57

IF:

The downstream rate is 7 Mbps and the communication medium uses a copper-twisted pair cable and the digital data transmission is done by using existing telephone line and system is mostly used over wide range of loop lengths

THEN:

The optimum access telecom system is Wireway-xDSL-RADSL - Confidence=9/10

RULE NUMBER: 58

IF:

The downstream rate is 7 Mbps and the communication medium uses a copper-twisted pair cable and the digital data transmission is done by using existing telephone line and system is mostly used over wide range of loop lengths

THEN:

The optimum access telecom system is Wireway-xDSL-VDSL - Confidence=7/10

RULE NUMBER: 59

IF:

The downstream rate is 7 Mbps and the communication medium uses a copper-twisted pair cable and the digital data transmission is done by using existing telephone line and system is mostly used over wide range of loop lengths

THEN:

The optimum access telecom system is Wireway-xDSL-VDSL PLUS - Confidence=8/10

RULE NUMBER: 60

IF:

The downstream rate is 2 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and system is often used as business DSL

THEN:

The optimum access telecom system is Wireway-xDSL-SDSL - Confidence=9/10

RULE NUMBER: 61

IF:

The downstream rate is 2 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and system is often used as business DSL

THEN:

The optimum access telecom system is Wireway-xDSL-MSDSL - Confidence=6/10

RULE NUMBER: 62

IF:

The downstream rate is 2 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and system is often used as business DSL

THEN:

The optimum access telecom system is Wireway-xDSL-VDSL - Confidence=7/10

RULE NUMBER: 63

IF:

The downstream rate is 2 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and system is often used as business DSL

THEN:

The optimum access telecom system is Wireway-xDSL-VDSL PLUS - Confidence=8/10

RULE NUMBER: 64

IF:

The downstream rate is 13 Mbps and the communication medium uses a copper twisted -pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is the next generation TV

THEN:

The optimum access telecom system is Wireway-xDSL-VDSL - Confidence=9/10

RULE NUMBER: 65

IF:

The downstream rate is 13 Mbps and the communication medium uses a copper twisted -pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is the next generation TV

THEN:

The optimum access telecom system is Wireway-xDSL-VDSL PLUS - Confidence=8/10

RULE NUMBER: 66

IF:

The downstream rate is 150 Mbps and the communication medium uses a copper twisted-pair cable and the digita l data transmission is done by using existing telephone line and the main application of the system is the next generation TV and system is an extension technology of VDSL

THEN:

The optimum access telecom system is Wireway-xDSL-VDSL PLUS - Confidence=10/10

RULE NUMBER: 67

IF:

The downstream rate is 1.5 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and system is lower speed consumer version of ADSL

THEN:

The optimum access telecom system is Wireway-xDSL-UADSL - Confidence=9/10

RULE NUMBER: 68

IF:

The downstream rate is 1.5 Mbps and the communication medium uses a copper twisted –pair cable and the digital data transmission is done by using existing telephone line and system is lower speed consumer version of ADSL

THEN:

The optimum access telecom system is Wireway-xDSL-RADSL - Confidence=8/10

RULE NUMBER: 69

IF:

The downstream rate is 0.5-3 Mbps and the communication medium uses a hybrid fiber coaxial cable structure

THEN:

The optimum access telecom system is Wireway-HFC - Confidence=10/10

RULE NUMBER: 70

IF:

The downstream rate is up to 1 Gbps per channel per fiber and the communication medium uses a fiber optic cable structure up to user-end

THEN:

The optimum access telecom system is Wireway-FTTH - Confidence=10/10

RULE NUMBER: 71

IF:

The downstream rate is 2-3 Mbps and the system provides over electrical grid

THEN:

The optimum access telecom system is Wireway-POWERLINE - Confidence=10/10

RULE NUMBER: 72

IF:

The downstream rate is 10 Mbps and the communication medium uses air and the system type is microwave system

THEN:

The optimum access telecom system is Wireless-LMDS - Confidence=10/10

RULE NUMBER: 73

IF:

The downstream rate is between 10Mbps-1.25 Gbps and the communication medium uses air and the system type is optical wireless system

THEN:

The optimum access telecom system is Wireless-FSO - Confidence=10/10

RULE NUMBER: 74

IF:

The downstream rate is 2.8 to 11.3 Mbps per CPE and the communication medium uses air and the system type is mobile wireless system at distance 10-16 km

THEN:

The optimum access telecom system is Wireless-LOS-WIMAX - Confidence=10/10

RULE NUMBER: 75

IF:

The downstream rate is 2.8 to 11.3 Mbps per CPE and the communication medium uses air and the system type is mobile wireless system at distance 1-2 km

THEN:

The optimum access telecom system is Wireless-NLOS-WIMAX - Confidence=10/10

RULE NUMBER: 76

IF:

The downstream rate is 56 Kbps and the communication medium uses air and download is occured by the satellite but upload is provided by standard 56K telephone connection

THEN:

The optimum access telecom system is Wireless-ONE-WAY-SATELLITE - Confidence=10/10

RULE NUMBER: 77

IF:

The downstream rate is up to 155 Mbps the communication medium uses air and system uses DBS and VSAT technology for two –way high speed data transmission

THEN:

The optimum access telecom system is Wireless-TWO-WAY-SATELLITE - Confidence=10/10

RULE NUMBER: 78

IF:

there is a fiber link to the building up to user-end

THEN:

The optimum access telecom system is Wireway-FTTH - Confidence=10/10

RULE NUMBER: 79

IF:

the licence is used and system uses a LOS microwave technology

THEN:

The optimum access telecom system is Wireless-LMDS - Confidence=10/10

RULE NUMBER: 80

IF:
the licence is used and telecommunication satellites receive signals from a ground station and send them down to another ground station located at a very long distance from first station

THEN:
The optimum access telecom system is Wireless-SATELLITE - Confidence=10/10

RULE NUMBER: 81

IF:
the licence is used and used bands are 3.3-3.8 GHz and 2.3-2.7 GHz and system is a mobile wireless technology

THEN:
The optimum access telecom system is LICENCED-WIMAX - Confidence=10/10

RULE NUMBER: 82

IF:
The system settlement is dense urban, urban, industrial suburban, residental suburban and the communication medium is twisted-pair cable

THEN:
The optimum access telecom system is Wireway-xDSL - Confidence=10/10

RULE NUMBER: 83

IF:
The system settlement is dense urban, urban, industrial suburban, residental suburban and system is multi-user hybrid fiber-coaxial cable system

THEN:
The optimum access telecom system is Wireway-HFC - Confidence=10/10

RULE NUMBER: 84

IF:
The system settlement is long haul, dense urban, urban, industrial suburban and the communication medium uses fiber optic cable structure

THEN:
The optimum access telecom system is Wireway-FTTH - Confidence=10/10

RULE NUMBER: 85

IF:
The system settlement is rural, backhaul and the communication medium uses existing electrical grid cable structure

THEN:
The optimum access telecom system is Wireway-POWERLINE - Confidence=10/10

RULE NUMBER: 86

IF:
The system settlement is urban, industrial suburban, residental suburban and system uses LOS microwave technology

THEN:
The optimum access telecom system is Wireless-LMDS - Confidence=10/10

RULE NUMBER: 87

IF:
The system settlement is dense urban, urban and system is an optical wireless system

THEN:
The optimum access telecom system is Wireless-FSO - Confidence=10/10

RULE NUMBER: 88

IF:
The system settlement is industrial suburban, residental suburban, rural and system is mobile wireless system

THEN:
The optimum access telecom system is Wireless-WIMAX
- Confidence=10/10

RULE NUMBER: 89

IF:
The system settlement is rural,remote and system is long distance wireless system

THEN:
The optimum access telecom system is Wireless- SATELLITE
- Confidence=10/10

RULE NUMBER: 90

IF:
The maximum deployment distance is 5.5 km and the most popular version of xDSL system is used

THEN:
The optimum access telecom system is Wireway-xDSL-ADSL - Confidence=9/10

RULE NUMBER: 91

IF:
The maximum deployment distance is 5.5 km and the most popular version of xDSL system is used

THEN:
The optimum access telecom system is Wireway-xDSL-IDSL - Confidence=7/10

RULE NUMBER: 92

IF:
The maximum deployment distance is 5.5 km and the most popular version of xDSL system is used

THEN:
The optimum access telecom system is Wireway-xDSL-MSDSL - Confidence=8/10

RULE NUMBER: 93

IF:
The maximum deployment distance is 5.5 km and the most popular version of xDSL system is used

THEN:
The optimum access telecom system is Wireway-xDSL-RADSL - Confidence=7/10

RULE NUMBER: 94

IF:
The maximum deployment distance is 5.5 km and the most popular version of xDSL system is used

THEN:
The optimum access telecom system is Wireway-xDSL-SDSL - Confidence=7/10

RULE NUMBER: 95

IF:
The maximum deployment distance is 5.5 km and the most popular version of xDSL system is used

THEN:
The optimum access telecom system is Wireway-xDSL-UADSL
- Confidence=7/10

RULE NUMBER: 96

IF:
The maximum deployment distance is 3.6 km and the oldest xDSL system is preferred

THEN:
The optimum access telecom system is Wireway-xDSL-HDSL - Confidence=10/10

RULE NUMBER: 97

IF:
The maximum deployment distance is 5.5 km and the communication medium is twisted-pair cable and system is basically ISDN without switch

THEN:
The optimum access telecom system is Wireway-xDSL-IDSL - Confidence=10/10

RULE NUMBER: 98

IF:
The maximum deployment distance is 4.5 km at data rate 2 Mbps and the communication medium is twisted - pair cable and the descendent of SDSL systems is preferred

THEN:
The optimum access telecom system is Wireway-xDSL-MSDSL - Confidence=10/10

RULE NUMBER: 99

IF:
The maximum deployment distance is 8.9 km at data rate 64 or 128 Kbps and the communication medium is twisted-pair cable and the descendent of SDSL systems is preferred

THEN:
The optimum access telecom system is Wireway-xDSL-MSDSL - Confidence=10/10

RULE NUMBER: 100

IF:

The maximum deployment distance is 5.5 km and the communication medium is twisted-pair cable and system has the modem that allows modem to adjust the speed of the connection

THEN:

The optimum access telecom system is Wireway-xDSL-RADSL - Confidence=10/10

RULE NUMBER: 101

IF:

The maximum deployment distance is 5.5km and the communication medium is twisted-pair cable and it is often used as business DSL

THEN:

The optimum access telecom system is Wireway-xDSL-SDSL - Confidence=10/10

RULE NUMBER: 102

IF:

The maximum deployment distance is 1.5 km and the communication medium is twisted - pair cable and the main application is next generation TV

THEN:

The optimum access telecom system is Wireway-xDSL-VDSL - Confidence=10/10

RULE NUMBER: 103

IF:

The maximum deployment distance is between 300 to 1500 meters and the communication medium is twisted - pair and it is an extension technology of VDSL

THEN:

The optimum access telecom system is Wireway-xDSL-VDSL PLUS - Confidence=10/10

RULE NUMBER: 104

IF:

The maximum deployment distance is 7.5 km and the communication medium is twisted-pair cable and system is lower speed consumer version of ADSL

THEN:

The optimum access telecom system is Wireway-xDSL-UADSL – Confidence=10/10

RULE NUMBER: 105

IF:

The maximum deployment distance is typically up to 100 km and the communication medium is hybrid fiber-coaxial cable

THEN:

The optimum access telecom system is Wireway-HFC - Confidence=10/10

RULE NUMBER: 106

IF:

The maximum deployment distance is 20 km and there is a fiber link to the end-user

THEN:

The optimum access telecom system is Wireway-FTTH - Confidence=10/10

RULE NUMBER: 107

IF:

The maximum deployment distance is 1 km power grid and the communication medium is existing electrica l grid

THEN:

The optimum access telecom system is Wireway-POWERLINE - Confidence=10/10

RULE NUMBER: 108

IF:
The maximum deployment distance is 5 km and the system type is LOS microwave system

THEN:
The optimum access telecom system is Wireless-LMDS - Confidence=10/10

RULE NUMBER: 109

IF:
The maximum deployment distance is up to 4 km and the system type is optical wireless system

THEN:
The optimum access telecom system is Wireless-FSO - Confidence=10/10

RULE NUMBER: 110

IF:
The maximum deployment distance is 10-16 km and the system type is mobile wireless system

THEN:
The optimum access telecom system is Wireless-LOS-WIMAX - Confidence=10/10

RULE NUMBER: 111
IF:
The maximum deployment distance is 1-2 km and the system type is mobile wireless system

THEN:
The optimum access telecom system is Wireless-NLOS-WIMAX - Confidence=10/10

RULE NUMBER: 112

IF:
The maximum deployment distance is 1000 – 36000 km and the communication medium is air and the long distance communication system is used

THEN:
The optimum access telecom system is Wireless-SATELLITE - Confidence=10/10

RULE NUMBER: 113

IF:
there is an ADSL infrastructure

THEN:
The optimum access telecom system is Wireway-xDSL-ADSL - Confidence=10/10

RULE NUMBER: 114

IF:
there is dedication of frequency

THEN:
The optimum access telecom system is Wireless-LMDS - Confidence=10/10

RULE NUMBER: 115

IF:
The installation cost for this connection per subscriber is $14

THEN:
The optimum access telecom system is Wireway-xDSL - Confidence=10/10

RULE NUMBER: 116

IF:
The equipment cost for this connection per subscriber $106

THEN:
The optimum access telecom system is Wireway-xDSL - Confidence=10/10

RULE NUMBER: 117

IF:
The total expenditures for this connection per subscriber is $500

THEN:
The optimum access telecom system is Wireway-xDSL - Confidence=10/10

RULE NUMBER: 118

IF:
The equipment cost for this connection per subscriber $120-$160

THEN:
The optimum access telecom system is Wireway-HFC - Confidence=10/10

RULE NUMBER: 119

IF:
The operational monthly cost of video for this connection per subscriber $30-$80

THEN:
The optimum access telecom system is Wireway-HFC - Confidence=10/10

RULE NUMBER: 120

IF:
The operational monthly cost of data for this connection per subscriber $40-$60

THEN:
The optimum access telecom system is Wireway-HFC - Confidence=10/10

RULE NUMBER: 121

IF:
The total expenditures for this connection per subscriber is $2900

THEN:
The optimum access telecom system is Wireway-FTTH - Confidence=10/10

RULE NUMBER: 122

IF:
The operational monthly cost for consumer for this connection per subscriber is $20-$30

THEN:
The optimum access telecom system is Wireway-POWERLINE - Confidence=10/10

RULE NUMBER: 123

IF:
The operational monthly cost for business for this connection per subscriber is $60-$360

THEN:
The optimum access telecom system is Wireway-POWERLINE - Confidence=10/10

RULE NUMBER: 124

IF:
The total expenditures for this connection per subscriber is $2510

THEN:
The optimum access telecom system is Wireless-LMDS - Confidence=10/10

RULE NUMBER: 125

IF:
The equipment cost and monthly cost for this connection per subscriber is $555

THEN:
The optimum access telecom system is Wireless-FSO - Confidence=10/10

RULE NUMBER: 126

IF:
The equipment cost for this connection per subscriber $40-$500

THEN:
The optimum access telecom system is Wireless-WIMAX - Confidence=10/10

RULE NUMBER: 127

IF:
The operational monthly cost for consumer for this connection per subscriber is $150

THEN:
The optimum access telecom system is Wireless-WIMAX Confidence=10/10

RULE NUMBER: 128

IF:
The equipment cost for this connection per subscriber $750-$1000

THEN:
The optimum access telecom system is Wireless-SATELLITE - Confidence=10/10

RULE NUMBER: 129

IF:
The operational monthly cost for consumer for this connection per subscriber is $70

THEN:
The optimum access telecom system is Wireless-SATELLITE - Confidence=10/10

RULE NUMBER: 130

IF:
The security is poor, because of the medium is twisted-pair cable

THEN:
The optimum access telecom system is Wireway-xDSL - Confidence=10/10

RULE NUMBER: 131

IF:
The security is good rather than twisted-pair cable solutions and the communication medium is hybrid fiber coaxial cable

THEN:
The optimum access telecom system is Wireway-HFC - Confidence=10/10

RULE NUMBER: 132

IF:
The security is good, because of the medium is fiber optic cable

THEN:
The optimum access telecom system is Wireway-FTTH - Confidence=10/10

RULE NUMBER: 133

IF:
The security is poor, since system uses existing electrical grid

THEN:
The optimum access telecom system is Wireway-POWERLINE - Confidence=10/10

RULE NUMBER: 134

IF:
The security is poor depends on the rainy medium and the communication medium is air and system is microwave system

THEN:
The optimum access telecom system is Wireless-LMDS - Confidence=10/10

RULE NUMBER: 135

IF:
The security is poor, because of the external effects and the system is optical wireless system

THEN:
The optimum access telecom system is Wireless-FSO - Confidence=10/10

RULE NUMBER: 136

IF:
The security is poor, since system is a multiuser mobile wireless system

THEN:
The optimum access telecom system is Wireless-WIMAX - Confidence=10/10

RULE NUMBER: 137

IF:
The security is poor, because of the long distance application area and the communication medium is air

THEN:
The optimum access telecom system is Wireless-SATELLITE - Confidence=10/10

RULE NUMBER: 138

IF:
The installation of access system is easy, since it uses existing twisted-pair infrastructure

THEN:
The optimum access telecom system is Wireway-xDSL - Confidence=10/10

RULE NUMBER: 139
IF:
The installation of access system is easy,since the medium is coaxial cable and deployment is fast with relatively low installation costs

THEN:
The optimum access telecom system is Wireway-HFC - Confidence=10/10

RULE NUMBER: 140

IF:
The installation of access system is difficult, since the medium is fiber cable and special test equipment is required to install

THEN:
The optimum access telecom system is Wireway-FTTH - Confidence=10/10

RULE NUMBER: 141

IF:
The installation of access system is easy, since it uses existing electrical grid infrastructure

THEN:
The optimum access telecom system is Wireway-POWERLINE - Confidence=10/10

RULE NUMBER: 142

IF:
The installation of access system is easy, since system is LOS microwave system that provides portability and reconfiguration flexibility

THEN:
The optimum access telecom system is Wireless-LMDS - Confidence=10/10

RULE NUMBER: 143

IF:
The installation of access system is difficult, since new optical wireless system will be installed

THEN:
The optimum access telecom system is Wireless- FSO - Confidence =10/10

RULE NUMBER: 144

IF:

The installation of access system is easy and system has lower deployment costs for rural areas and system type is mobile wireless system

THEN:

The optimum access telecom system is Wireless-WIMAX- Confidence=10/10

RULE NUMBER: 145

IF:

The installation of access system is easy, since the medium is like microwave this feature provides portability and reconfiguration flexibility and rapid deployment and the maximum deployment distance is 1000-36000 km

THEN:

The optimum access telecom system is Wireless-SATELLITE - Confidence=10/10

RULE NUMBER: 146

IF:

The weather is bad,so the range of the link is reduced or redundant infrastructure is deployed and system type is optical wireless system

THEN:

The optimum access telecom system is Wireless-FSO - Confidence=10/10

RULE NUMBER: 147

IF:

Buildings sway little,so autotracking mechanisms are required to ensure focusing between beams and system type is optical wireless system

THEN:

The optimum access telecom system is Wireless-FSO - Confidence=10/10

RULE NUMBER: 148

IF:

The flying objects effect the system frequently, so meshed architecture should be deployed to provide better reliability and system type is optical wireless system

THEN:

The optimum access telecom system is Wireless-FSO - Confidence=10/10

RULE NUMBER: 149

IF:

The fog density is high in system usage area and system type is optical wireless system

THEN:

The optimum access telecom system is Wireless-FSO - Confidence=10/10

RULE NUMBER: 150

IF:
The system is effected from rain and system type is microwave wireless system

THEN:
The optimum access telecom system is Wireless-LMDS - Confidence=10/10

RULE NUMBER: 151

IF:
there is other feature

THEN:
the optimum access telecom system - Confidence=0/10

RULE NUMBER: 152

IF:
The equipment cost for this connection per subscriber other

THEN:
the optimum access telecom system - Confidence=0/10

RULE NUMBER: 153

IF:
The operational monthly cost of video for this connection per subscriber other

THEN:
the optimum access telecom system - Confidence=0/10

RULE NUMBER: 154

IF:
The operational monthly cost of data for this connection per subscriber other

THEN:
the optimum access telecom system - Confidence=0/10

RULE NUMBER: 155

IF:
The security is other

THEN:
the optimum access telecom system - Confidence=0/10

RULE NUMBER: 156

IF:
The installation of access system is other

THEN:
the optimum access telecom system - Confidence=0/10

RULE NUMBER: 157

IF:
The total expenditures for this connection per subscriber is other

THEN:
the optimum access telecom system - Confidence=0/10

RULE NUMBER: 158

IF:
The operational monthly cost for consumer for this connection per subscriber is other

THEN:
the optimum access telecom system - Confidence=0/10

RULE NUMBER: 159

IF:
The operational monthly cost for business for this connection per subscriber is other

THEN:
the optimum access telecom system - Confidence=0/10

RULE NUMBER: 160

IF:
the licence is not used

THEN:
the optimum access telecom system - Confidence=0/10

RULE NUMBER: 161
IF:
The system is not effected from rain

THEN:
the optimum access telecom system - Confidence=0/10

RULE NUMBER: 162

IF:
The equipment cost and monthly cost for this connection per subscriber is other

THEN:
the optimum access telecom system - Confidence=0/10

RULE NUMBER: 163
IF:
The weather is good

THEN:
the optimum access telecom system - Confidence=0/10

RULE NUMBER: 164
IF:
Buildings sway very fast

THEN:
the optimum access telecom system - Confidence=0/10

RULE NUMBER: 165

IF:
The flying objects not effect the system

THEN:
the optimum access telecom system - Confidence=0/10

RULE NUMBER: 166

IF:
The fog density is other

THEN:
the optimum access telecom system - Confidence=0/10

RULE NUMBER: 167

IF:
The installation cost for this connection per subscriber is other

THEN:
the optimum access telecom system - Confidence=0/10

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APPENDIX D

RESULTS FROM THE EXPERT SYSTEM

RESULT 1:

*** INPUT DATA ***
The upstream rate is 1.54 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to provide T1/E1 services to businesses at low costs

The downstream rate is 1.54 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to provide T1/E1 services to businesses at low costs

there is other feature

the licence is not used

The system settlement is dense urban, urban, industrial suburban, residental suburban and the communication medium is twisted-pair cable

The maximum deployment distance is 3.6 km and the oldest xDSL system is preferred

The installation cost for this connection per subscriber is $14

The equipment cost for this connection per subscriber $106

The total expenditures for this connection per subscriber is $500

The operational monthly cost of video for this connection per subscriber $30-$80

The operational monthly cost of data for this connection per subscriber other

The operational monthly cost for consumer for this connection per subscriber is other

The operational monthly cost for business for this connection per subscriber is other

The equipment cost and monthly cost for this connection per subscriber is other

The security is poor, because of the medium is twisted-pair cable

The installation of access system is easy, since it uses existing twisted-pair infrastructure

The weather is good

Buildings sway very fast

The flying objects effect/not effect the system

The fog density is other

The system is not effected from rain

*** OUTPUT ***

1 The optimum access telecom system is Wireway-xDSL-HDSL
VALUE=10

2 The optimum access telecom system is Wireway-HFC
VALUE=10

3 The optimum access telecom system is Wireway-xDSL
VALUE=10

4 The optimum access telecom system is Wireway-xDSL-VDSL PLUS
VALUE=8

5 The optimum access telecom system is Wireway- xDSL- VDSL
VALUE=7

6 The optimum access telecom system is Wireway-xDSL-RADSL
VALUE=6

7 The optimum access telecom system is Wireway-xDSL-MSDSL
VALUE=5

8 The optimum access telecom system is Wireway- xDSL- SDSL
VALUE=5

RESULT 2:

*** INPUT DATA ***
The upstream rate is 128 Kbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and system is basically ISDN without the telephone switch structure is used

The downstream rate is 128 Kbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to provide T1/E1 services to businesses businesses at low costs

there is other feature

the licence is not used

The system settlement is dense urban, urban, industrial suburban, residental suburban and the communication medium is twisted-pair cable

The maximum deployment distance is 5.5 km and the communication medium is twisted-pair cable and system is basically ISDN without switch

The installation cost for this connection per subscriber is $14

The equipment cost for this connection per subscriber $106

The total expenditures for this connection per subscriber is $500

The operational monthly cost of video for this connection per subscriber other

The operational monthly cost of data for this connection per subscriber other

The operational monthly cost for consumer for this connection per subscriber is other

The operational monthly cost for business for this connection per subscriber is other

The equipment cost and monthly cost for this connection per subscriber is other

The security is poor, because of the medium is twisted-pair cable

The installation of access system is easy, since it uses existing twisted-pair infrastructure

The weather is good

Buildings sway very fast

The flying objects effect /not effect the system

The fog density is other

The system is not effected from rain

*** OUTPUT ***

1 The optimum access telecom system is Wireway-xDSL-IDSL
VALUE=10

2 The optimum access telecom system is Wireway-xDSL
VALUE=10

RESULT 3 :

*** INPUT DATA ***
The upstream rate is 2 Mbps at distance 4.5km and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to design an autorate plug and play configuration which adjusts operating distance and line conditions

The downstream rate is 64 or 128 Kbps at distance 8.9km and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is to design an autorate plug and play configuration which adjusts operating distance

there is other feature

the licence is not used

The system settlement is dense urban, urban, industrial suburban, residental suburban and the communication medium is twisted-pair cable

The maximum deployment distance is 8.9 km at data rate 64 or 128 Kbps and the communication medium is twisted-pair cable and the descendent of SDSL systems is preferred

The installation cost for this connection per subscriber is $14

The equipment cost for this connection per subscriber $106

The total expenditures for this connection per subscriber is $500

The operational monthly cost of video for this connection per subscriber other

The operational monthly cost of data for this connection per subscriber other

The operational monthly cost for consumer for this connection per subscriber is other

The operational monthly cost for business for this connection per subscriber is other

The equipment cost and monthly cost for this connection per subscriber is other

The security is poor, because of the medium is twisted-pair cable

The installation of access system is easy, since it uses existing twisted-pair infrastructure

The weather is good

Buildings sway very fast

The flying objects effect /not effect the system

The fog density is other

The system is not effected from rain

*** OUTPUT ***

1 The optimum access telecom system is Wireway-xDSL-MSDSL
VALUE=10

2 The optimum access telecom system is Wireway-xDSL
VALUE=10

RESULT 4 :

*** INPUT DATA ***

The upstream rate is 1 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and system is mostly used over wide range of loop lengths

The downstream rate is 7 Mbps and the communication medium uses a copper-twisted pair cable and the digital data transmission is done by using existing telephone line and system is mostly used over wide range of loop lengths

there is other feature

the licence is not used

The system settlement is dense urban, urban, industrial suburban, residental suburban and the communication medium is twisted-pair cable

The maximum deployment distance is 5.5 km and the communication medium is twisted-pair cable and system has the modem that allows modem to adjust the speed of the connection

The installation cost for this connection per subscriber is $14

The equipment cost for this connection per subscriber $106

The total expenditures for this connection per subscriber is $500

The operational monthly cost of video for this connection per subscriber other

The operational monthly cost of data for this connection per subscriber other

The operational monthly cost for consumer for this connection per subscriber is other

The operational monthly cost for business for this connection per subscriber is other

The equipment cost and monthly cost for this connection per subscriber is other

The security is poor, because of the medium is twisted-pair cable

The installation of access system is easy, since it uses existing twisted-pair infrastructure

The weather is bad, so the range of the link is reduced or redundant infrastructure is deployed and system type is optical wireless system

Buildings sway little, so autotracking mechanisms are required to ensure focusing between beams and system type is optical wireless system

The flying objects effect /not effect the system

The fog density is high in system usage area and system type is optical wireless system

The system is not effected from rain

*** OUTPUT ***

1 The optimum access telecom system is Wireway-xDSL-RADSL
VALUE=10

2 The optimum access telecom system is Wireless-FSO
VALUE=10

3 The optimum access telecom system is Wireway-xDSL
VALUE=10

4 The optimum access telecom system is Wireway-xDSL-SDSL
VALUE=8

5 The optimum access telecom system is Wireway-xDSL-MSDSL
VALUE=7

6 The optimum access telecom system is Wireway-xDSL-HDSL
VALUE=6

7 The optimum access telecom system is Wireway-xDSL-VDSL
VALUE=6

8 The optimum access telecom system is Wireway-xDSL-VDSL PLUS
VALUE=6

RESULT 5 :

*** INPUT DATA ***

The upstream rate is 2.3 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is the next generation TV

The downstream rate is 13 Mbps and the communication medium uses a copper twisted-pair cable and the digital data transmission is done by using existing telephone line and the main application of the system is the next generation TV

there is other feature

the licence is not used

The system settlement is dense urban, urban, industrial suburban,residental suburban and the communication medium is twisted-pair cable

The maximum deployment distance is 1.5 km and the communication medium is twisted-pair cable and the main application is next generation TV

The installation cost for this connection per subscriber is $14

The equipment cost for this connection per subscriber $106

The total expenditures for this connection per subscriber is other

The operational monthly cost of video for this connection per subscriber other

The operational monthly cost of data for this connection per subscriber other

The operational monthly cost for consumer for this connection per subscriber is other

The operational monthly cost for business for this connection per subscriber is other

The equipment cost and monthly cost for this connection per subscriber is other

The security is poor, because of the medium is twisted-pair cable

The installation of access system is easy, since it uses existing twisted-pair infrastructure

The weather is good

Buildings sway very fast

The flying objects effect / not effect the system

The fog density is other

The system is not effected from rain

*** OUTPUT***

1 The optimum access telecom system is Wireway-xDSL-VDSL
VALUE=10

2 The optimum access telecom system is Wireway-xDSL-VDSL PLUS
VALUE=10

3 The optimum access telecom system is Wireway-xDSL
VALUE=10

APPENDIX E

THE ACCESS TELECOMMUNICATION NETWORK EXPERT SYSTEM LIMITATIONS WHICH ARE BASED ON SYSTEM PARAMETERS

1. The settlement feature for the access telecom system is the first consideration. The system can be seen very suitable to deploy , but this system cannot be deployed because of unsuitable settlement to set up the system. For example, the fiber optic system such as FTTH can be determined as an optimum access telecom system, but if the underground cable deployment cannot be be performed, the system cannot be set up. xDSL, HFC, Power Line, FSO, LMDS, Satellite and Wimax Systems do not need underground cable installation.

2. The weather condition is another important consideration especially for FSO and LMDS systems. FSO is susceptible to outer effects such as fog, birds and buildings. Also, LMDS is effected from rain. So, FSO and LMDS systems can not be used if they are effected from external conditions. There are some solutions to decrease the effect of outer influences for FSO and LMDS systems. For FSO system, if the weather is very foggy, then the range of the link is reduced or redundant infrastructure will be deployed, if the buildings sway little to the FSO system, then some autotracking mechanisms will be used to provide focusing between beams, if the flying objects effect the system, then meshed FSO architecture can be deployed. Also, the usage of repeater nodes to provide line of sight is another solution, it increases the cost and performs difficulties in decision making process and system evaluation.

3. Internal system characteristics can cause limitations on the system deployment, but these problems can be solved . For example, FSO has limitation on the link length and this limitation can be overcome by using another FSO system as a repeater. Thus, the limited distance of FSO which is 4 km can be extended up to 9 km or 13,5 km by using additional FSO systems as a repeater [1].

4. Licence requirement is an important factor for LMDS, Satellite and Licenced –Wimax systems. The transmission of data using these systems can be provided by the occurence of licence, otherwise the usage of these systems are not allowed.

5. LOS (Line of sight) is a necessary factor between communication nodes for FSO, LMDS and LOS-Wimax systems.

6. The deployment distance between communication nodes can be the distinctive factor, because every system is deployed in different ranges. For example, FTTH system can support very long distance which is 20 km, but FSO and LMDS systems have limited distance range which is approximately 4 km. Also, FSO distance limitation can be exceed by improvement of a laser technology which overcomes to spread of beams. Thus, a direct line without spreading can be provided by laser technology which increases the distance range for FSO systems. LMDS distance limitation can be overcome by development of the antenna technology.

7. Since FTTH system has high bit rate data transmission for long distances, it can be considered as an optimum access telecom system, but the cost factor is the most effective limitation for FTTH system.

8. The security concept is another factor for selecting optimum access telecommunication system. xDSL system is not a secure system because of the used medium which is twisted – pair cable. HFC system is more secure rather than xDSL system because of the used medium is coaxial cable. Although FTTH system is a secure system because of the used medium is fiber optic cable , it can be cut and connected to an illegal receiver by illegal people, so this operation decreases the worth of optical fiber cable. In LMDS system, the spread of electromagnetic waves occur very frequently in a wider coverage, so this factor decreases security for the system. FSO is a secure system, but it can be effected from external factors such as fog, flying objects, buildings and this can cause decrease of security.