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Data Transmission through Power Lines to the Final Consumer

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Abstract. Not observing the balance of the architecture with the environment and nature in today's architecture and city building causes some unpleasant results such as pollution of the environment, reduction of natural resources, climate changes and increasing reduction of energy resources. Paying attention to the climate conditions, human life environment ,introducing the different aspects of climate in architecture and building different urban spaces, passages, neighborhoods and buildings can be very important factors for making a healthy environment which provide comfort for human and not only cause energy saving but also entail building durability and making urban sustainable spaces. Therefore, the designers and architects try to find a suitable solution in designing environment friend buildings. One of these effective solutions is the issue about sustainability in architecture in which subjects like the environmental effects of building, green buildings, designing for recycling and so on are considered. So this research considers the criteria of a sustainable architecture which is compatible with the climate and environment in the city of Semnan as well as reviewing different bio environmental effects and aspects of the issue. At first, referring the library resources and collecting the required information from the synoptic stations of the city of Semnan, sustainability and principles of the nature and environment compatible architecture is explained by descriptive methods. Then, the conformity of the nature and climate compatible architecture is considered by the analytical and quantitative methods based on which the traditional architecture in the dry and desert areas like the city of Semnan is a sustainable architecture which is compatible with the nature and environment. From another hand, using the sustainable architecture and attending the natural resources and domestic materials in the different areas can not only cause energy saving in nonrenewable resources but also have the least destructive effect on the environment.

Keyword: environment, weather, architecture, sustainable construction, energy saving

1. INTRODUCTION

The main components of a PLC system, which is used widely in different levels of power systems, consist of [5]: RTU (Remote Terminal Unit): This system includes a number of analog and digital inputs and outputs. RTU has the main task of converting the sent signals to the transmittable signals via communication channel, which includes some parts such as CPU, analog and digital input and output cards, and the modem. The figure below

- Depicts a sample of industrial RTU.
- Communication equipments including High Frequency (HF) and Intermediate Frequency (IF) modulators and demodulators, appropriate amplifiers and filters (which are located within the PLC itself).
- Matching system should be equipped with telecommunication channel (power lines) or Line Matching Unit (LMU). To gain the maximum power transfer through the telecommunication channel and also preventing the reflection of the waves, the impedance of the transmitter and channel must be the same.
- A system to isolate the telecommunications equipments from high voltage suppliers (a capacitor called CVT is commonly applied for this purpose).
- Line Trap is planned to prevent flow of information to other parts (such as high voltage electrical substation) but for the telecommunication channel.

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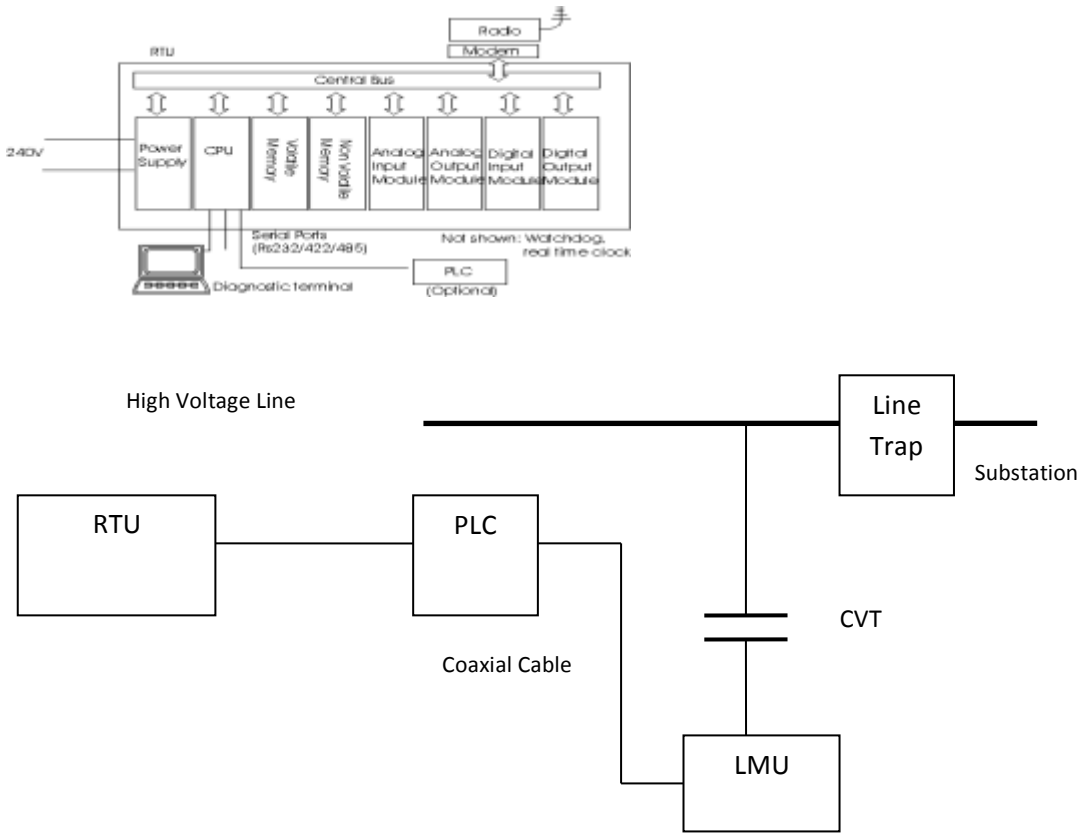

Figure 1.2: PLC Diagram Block in Transmission Line

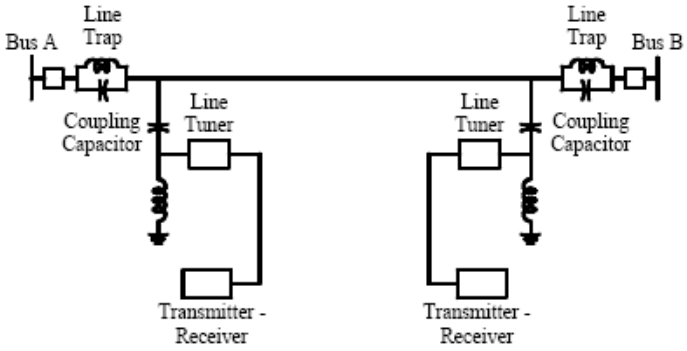

Figure 1.3: Single-line diagram of a power transmission line with PLC

The Structure of PLC Network

PLCs can be classified in three categories based upon the speed of information transmission and their applications.

- Low Speed PLC (2400 bps[1]) which is exploited in low and medium voltage distribution lines to fulfill different purposes such as security applications, remote measurement of the energy consumption, and also remote automating home equipments.

[1] bit per second

- Average speed PLC (up to 64 Kbps) which is exploited in medium and high voltage distribution lines to achieve the purposes such as security applications, remote controlling of the power plans and also putting the power plants and substations in touch with each other.
- High speed PLC (more than 1 Mbps) which is exploited in medium and high voltage distribution lines for the purposes of video and audio data transmission, Internet and communication between companies.

PLC technology taking advantage of power lines to provide the access to the Internet, transmit the information by mounting them on the high frequency waves on electric power lines. Indeed the career transmits the telecommunication data by adding them to the power signals operating at 50 or 60 Hz. The tele-data can also be transmitted using broadband over power lines at the data rate of one Megabit per second, or data transmission can be provided using narrow bandwidth at a much lower data rate. In both methods, each and every one of the outlet ports at home or office is connected by the modems to the computer.
The picture below illustrates the general principles of this technology. As it depicts in the following figure, the data signals mounted on the power lines is captured by modems and entered in the planned devices [8].

In principle, the PLC technology is based upon both modulation and demodulation of data by a carrier signal operating at a high frequency range. In general, the coding method is generated according to the Orthogonal Frequency Division Multiplex (OFDM) method. Physical layers

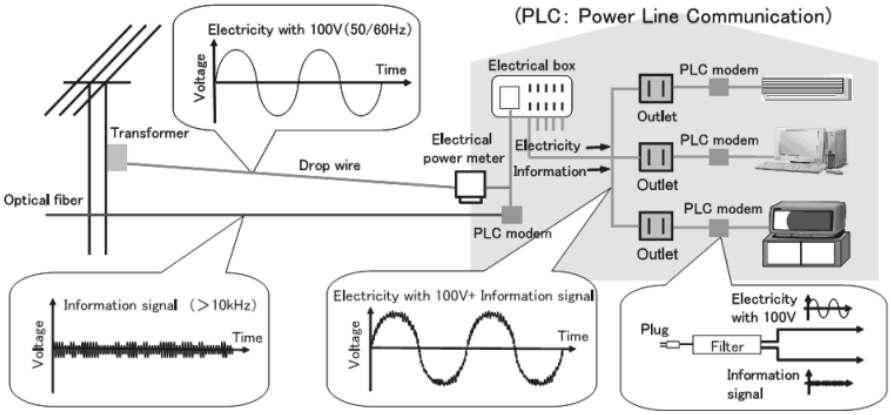

Figure 1.4: PLC General Principles

are also formed according to OFDM. However, its capability for preventing disturbance is the main designers' concern. Figure 1.4 portrays a schematic diagram of the general principles of the technology.

Network Access

Low voltage distribution system (400 V in Iran) is the access sector of the communication network and PLC is applied widely at this voltage level. In this sector of network, PLC modems or Customer Premise Equipments (CPEs) modems connect the domestic facilities to the PLC transformers through low voltage lines. The sockets are the junctions of consumer to the connection network. CPEs and Transformer Equipments (TEs) are placed at the home junction and MV/LV respectively, and both are part of distribution network [1,4].
The access network is composed of two parts.

- A part between CPE and repeaters, which is interconnected via power lines of the building and sometimes through low voltage network.

- A part between repeaters and TE, which is interconnected via low voltage network.
-

Repeaters are equipments being utilized along the transmission path to amplify the PLC signal (further explanations will be given in section 1.2.2.)

PLT modems can be linked with the LAN networks and establish the connection between plenty of users and the Internet, simultaneously. Small businesses find it truly useful. It also makes all normal home electric sockets to connection points to the Internet and VOIP.
The way of connection to the access network, home network, as well as some modern applications of PLC, such as electric energy management, remote control and remote home appliances monitoring, remote maintenance, electric, gas, water,... consumption measurement, all are shown in figure 1.9. The illustrated gateway demonstrates the connector between the home network and a wider communication network (the telecommunication outside the building)

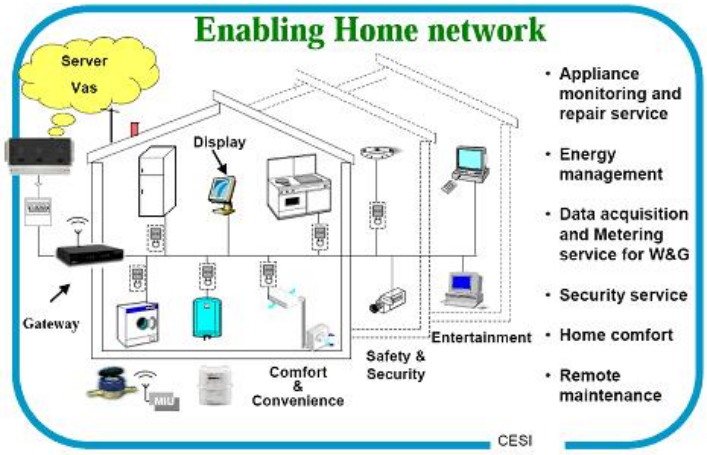

Figure 1.10 illustrates a typical low voltage distribution network in Germany. The LV (Trafo) transformer is the network center. Every electric cable at a length less than 1 km feeds 30-40 houses. Most conductors are underground, while in rural zones aerial wires may be used. Each costumer is connected by a sleeve to the electric cable.

In German access and domestic networks, the cables are usually found in three types: Sector, Non-metallic sheathed, and the flat webbed cables (figure 1.11). The lines coming out of LV transformers are of sector type with various radial cross sections. Non-metallic sheathed cables or flat network cables are in use in the domestic system.
Some characteristics of the electrical wires transferring HF by using PLC are given in table 1.1. The impedance characteristics are clearly different due to the different geometry of the wires. The drop in these wires is significantly less than domestic wires [8.4].

Distribution Network

Distribution network makes the connection between the installed TE in the MV/LV stations. The connection is formed by various methods or sometime by a combination of methods.

- Medium voltage network connects different MV/LV stations using medium voltage to other PLC equipments. Just similar to the low voltage network, the connection can be made either underground or aerially.

Type of Cable	Description	Characteristic Impedance	Attenuation in dB/km at 1, 10 and 20 MHz
NAYY-J 4 x 150 SE	4-wire underground main line (150 mm²)	22 Ω at 1 MHz symmetric mode	12.9 / 46.5 / 51
NAYY-J 4 x 50 SE	4-wire underground line to the premises (50 mm²)	29 Ω at 1 MHz symmetric mode	16.8 / 53.8 / 58.9
NYM-J 3G x 1.5	3-non-metallic sheathed wires (1.5 mm²)	75 Ω at 150 kHz	17 / 85.5 / 146
NYIF-J 3G x 1.5 NYIF-J 5G x 1.5	3-flat-webbed wires (1.5 mm²) 5-flat-webbed wires (1.5 mm²)	183 Ω at 150 kHz from line to next line	23 / 105 / 180

Figure 1.11.The technical characteristics of cables

- Aside from optical fibers and medium voltage PLC, other technologies such as Local Multipoint Distribution System (LMDS) can be utilized as combined solution.

LMDS technology transmits data wirelessly. Its working frequency lies between 26 GHz and 29 GHZ. It also may be used with PLC. The main problem with LMDS technology is its short range, while in rainy days its range can hardly exceeds 1.5 miles.

MV/LV stations are usually connected to each other by either of following arrangements:

- Using an HV/MV station to connect the MV/LV stations through the ring. [Figure (1.12.)]
- Using MV links connecting two HV/MV stations allows a MV/LV station be fed by two HV/MV stations.

Regarding the ring structure of both architectures, if a failure occurs in any of the equipments, data transmission never disturbed. It should be noted that the optical fiber must be available in both HV/MV stations for the second arrangement.

Figure 1.12 shows how the telecommunication network should be connected to the electrical grid at MV voltage level. It also illustrates how the data is exchanged from MV/LV station to the consumers.

Developing medium voltage PLCs is the matter of great importance, as it enhances economic development and also develops the technology. We can connect different low voltage stations using current equipments, and devices can be found in the existing electrical grids, by the courtesy of medium voltage PLCs.

Connecting to the service provider networks (the Internet and Public Switched Telephone Networks (PSTNs))

We have to establish connections with the service provider networks in some parts of PLC distribution network to provide access to the Internet and telephone services. Other value-added services such as video and multimedia services can be added to this part of the network. These services can become available for costumers by PLC provider operators. In this case, the video services transmitting visual signals in Real Time format, say cable TV or High Definition Televisions (HDTVs), never need new cable wiring for sending data. Another benefit of this technology is the considerable flexibility maintained in the required equipments for connection, dependent on the suggested services. Of course switching equipments are needed in general. PLC is of other outstanding merit, i.e. there is no need that a costumer be switched to the operator of PSTN network over the telephone contact between two costumers, when both are located in different parts of a same distribution of the local network. Therefore, the voice services for two costumers in different parts of a same distribution network are free of charge

[1]. In addition to using PLC, Wireless Fidelity (WiFi) is also being developed to be used in CPEs. Having taken advantage of this technology, we can connect domestic equipments to the telecommunication network, which is in connection with the consumer building by electrical grid, wirelessly. The manufactures are in an intense competition with each other to produce CPE systems, while the technologies of CPEs are in continuous improvement (shape, weight, dimensions, etc.). Some samples of CPEs are shown in the following figures.

Frequency Bands and Modulation Methods

PLC transmission technology operates within 1.6 - 30 MHz. The multiple carriers are managed simultaneously to gain its maximum operational power. PLC bandwidth is separable in two distinct parts (sub-bands), namely, access part and domestic part. Each of them is allocated to different connection parts. The access part of the low frequency sub-band uses up to 12 MHz, because of the longer distances and noisy environment in this part, therefore a lower frequency is chosen to minimize the interference, while the domestic part usually operates at higher frequencies (12-30 MHz).

In PLC technologies, the characteristics of the wires should be optimized and should provide a wide information capacity to minimize the injected energy, as well so that the level of electromagnetic radiation meets the Electromagnetic Compatibility (EMC) standards. During modulation process, telecommunication signals are mounted on the carrier signals and are transmitted through the channel. Indeed, the modulation process makes the data transmittable on the channel. There are many modulation ways to be chosen in PLC commuting system, each has its advantages and disadvantages.

PLC transmission methods has not been standardize in international societies yet. However, modulation methods can be categorized into following groups:

- Direct Sequence Spread Spectrum Modulation (DSSS)
- Orthogonal Frequency Division Multiplex (OFDM)
    - Narrow band modulation of which (Gaussian Minimum Shift Keying) GMSK is a variant.

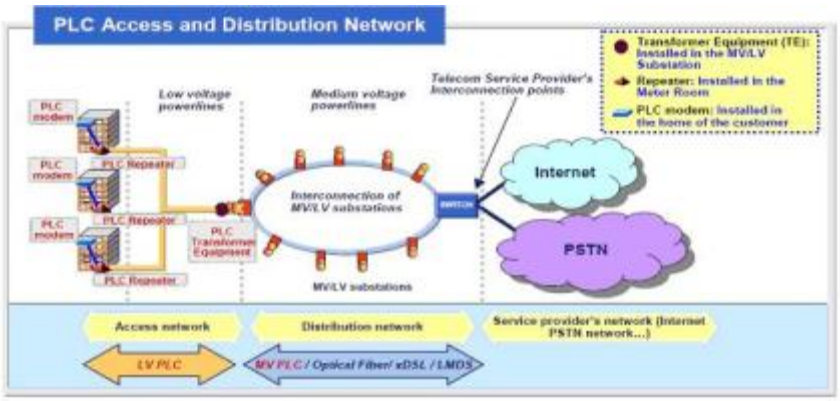

Figure 1.13. How the Internet and PSTN connect to the PLC network

DSSS

DSSS method is widely used in military applications to prevent aliens' penetration. This method creates a low spectral density by distributing signals over the whole frequency band. It also shows enough strength to prevent all types of interferences by suitable narrow bandwidth multipath and propagation delay. Therefore it is appropriate for transmitting data at low speed. The method is simple and economical, also is a part of Wireless LAN and IEEE802 standards.

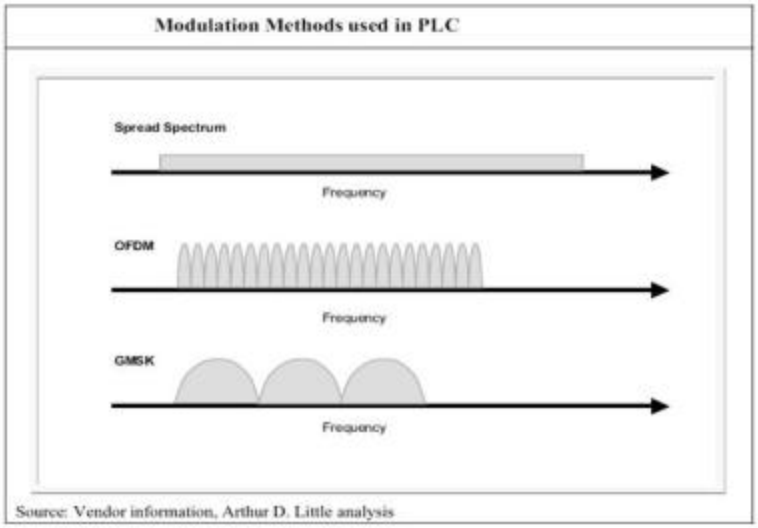

Figure 1.20. Three conventional methods for modulation used in PLC

OFDM

OFDM Technique consists of a large number of narrow bandwidth carriers locating close to each other (with a small gap to avoid interference), the signal is spread over the entire bandwidth. This technique does both the modulating and multiplexing. Utilizing a large number of carriers

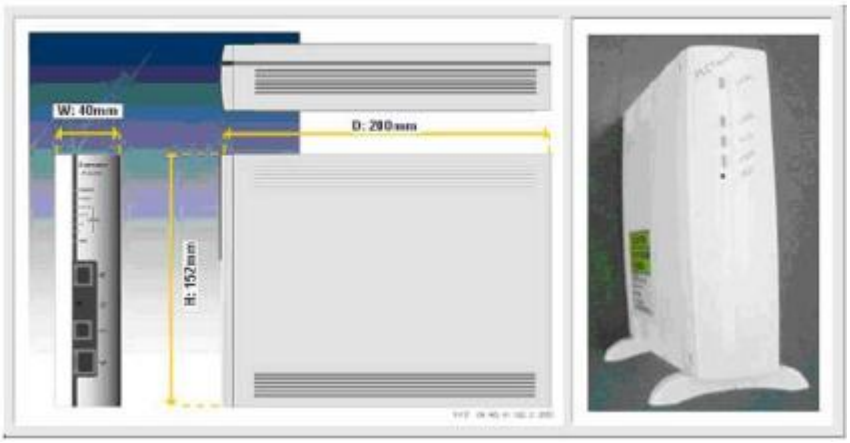

Figure 1.15. A CPE modem.

(More than 1200 carriers) bring flexibility that if a carrier suffers from a disorder, the disorder can be ignored and other carriers keep on their operation remaining immune from disorder. Therefore this technique provides a reliable communication. OFDM is resistant to Frequency Selective Fading Channels and long emissions. OFDM also remove the Inter Symbol (ISI) created by multipath propagation, which is the main problem in high speed PLCs. OFDM generally brings high efficiency.

OFDM poses serious problem of complexity and it needs completely linear power amplifiers to avoid interference at high frequency bands.

OFDM is not an entirely new technology and it has been already used in other commuting systems such as Asymmetric Digital Subscriber Line (ADSL), Digital Audio Broadcasting (DAB), Terrestrial Digital Television (TDT), and Digital Video Broadcasting (DVB).

GMSK

GMSK is an especial type of narrow band modulation carrying data in carrier phase which results in fixed signal packets. This method makes it possible to utilise the simpler amplifiers without creating any distorting harmonics. Simultaneous management of different carriers in frequency bands leads to different transferring speed. This modulation is resistant to the external parasites and has been already used in the products of ASCOM Company.

Comparing PLC with Other Transferring Data Technologies

In this section, we first introduce other methods for data transferring at different levels, and then we draw a comparison between PLC system and other methods.

Optical Telecommunication Network

Communication by optical fibers is so helpful in monitoring and controlling in electrical industry, particularly regarding the fast data transmission and data immunity against electrical noise existing in the telecommunication environments. However optical fibers are at a disadvantage of inability to control the aerial equipments of the distribution network. Studies show that using optical fibers for telecommunication environment is of secondary importance [1,9].

Advantages of Optical Fibers

- Switching Operations (Turning on and off) of the power system brings no effect on the transmitting path of the optical fibers.
- Blocking the effects of electromagnetic interferences.
- With no restriction upon access to any number of channels.
- High speed data transmission.
- Low bit error rate.
- High rate access to channel.
-

Disadvantages of Optical Fibers

- High cost of exploitation.
- High cost of construction.
-

Satellite Telecommunications network

Nearly 40 years elapsed since the first communication satellite has been put in the Earth orbit to establish connection as a repeater between two points of the United States of America. Since then, satellite telecommunication has been witnessing significant advances in the technology of microwave frequency, antenna and the signal processing. At first, the telecommunicating satellites have been used solely for the research activities, astronomy, international point to point telecommunications, and military purposes. However, today satellites are being used widely in private networks commonly, owing to the fact that many problems of ground stations have been settled, such as economical construction of low-noise amplifiers at high frequencies and therefore a drop in the number of ground stations antennae, new methods in designing and constructing the planar antenna and reducing their dimensions, making semiconductor power amplifiers and signal processing hardware being able to support the complicated protocols, as well as having solved the economical and weight concerns [9].

Given the fact that any satellite network consists of two aerial and ground parts, a high degree of confidence and security should be noticed for both parts. In general, many considerations are taken into account prior to the launch of the satellite to be put in the orbit, to assure high reliability of satellites. Hence, some issues, such as the possibility of developing abilities and improving the quality of the equipments, catch great interest. The security of satellites in space, particularly in a synchronic orbit, should be inviolable.

The advantages of Satellite Telecommunication

- Intrinsic ability to Point-To-Multipoint and Multipoint –To-Point communications.
- Independence of distance.
- Applicability in different capacities.
- Smooth and rapid implementation.
- Facilitated maintenance and possibility of remote monitoring.
- High degree of reliability.
- Rapid and simple development including new services.
- Being able to support different protocols.
- Providing access to entire or partial capacity of the network for each and every one of the stations.
- Effective network management.
-

Disadvantages of the Satellite Telecommunication Network.

- Significant delay in satellite link (250 ms)
- Dependence on space section.
- Variable operational and maintenance costs.
- Sensitivity to the climate conditions especially to precipitation gradient.
-

xDSL

xDSL provides a high speed connection using regular telephone cables for the Internet users. In most countries a pair of copper cables is used for installing the telephone network. Copper cable enjoys a wider bandwidth more than what is used in telephone conservations (a large width of the bandwidth is not used) xDSL benefits unused bandwidth with no negative impact on the quality of the audio conversations (matching particular frequencies to do special operations) [1].

xDSL Advantages

- One can use telephone line for phone conservations while connecting to the Internet.
- Speed of connection is so higher than the regular modems (1.5 Mb)
- There is no need to new cabling and the existing telephone lines can be already used.
- The xDSL company provides the modem for the costumer while installing the line.
-

xDSL Disadvantages

- Data is received at higher rate than the sending rate.
- xDSL service is not available everywhere.

PLC as a communicative technology goes into competition with other technologies at the level of distribution and access. It can be also used along with other access technologies as a complement.

PLC is the main competitor against other present technologies in the market demand (like Hybrid Fiber Coaxial (HFC) and xDSL), especially for its quick implementation and provided

services. Indeed, getting benefit from the existing infrastructures in PLC technology, the network can be quickly developed and the availability of the services may be expanded as fast as other technologies.
Lastly, the table 1.2 provides a quantized comparison between PLC and other technologies (4: excellent, 0:poor)

Table 1.2

	PLC	xDSL	HFC	Fixed Wireless Access (FWA)	Satellite	Fiber to the Building (FTTB)
Investment per consumer	3	3	1	1	0	0
Profit per consumer	3	3	1	2	1	3
Capacities and Services	3	3	3	3	1	4
Implementation Speed	3	3	1	3	0	1
Provisioning	2	2	2	1	4	1
Regulation	1	3	4	2	1	4
High technologies and Standards	1	2	3	2	2	4

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