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Broadband over Power Lines (BPL) for making Digital India

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ABSTRACT

To successful the dream of Digital India of our priminister Mr. Narendra Modi it is necessary to reach the internet connection in every house. It is possible by using Broadband over Power line (BPL) technology. In this paper various aspects of Broadband over Power line (BPL) in Communication Network have been presented. The objective of this paper is to highlight the BPL access technology in term of features, working, drawbacks, deployment & future challenges, advantages and scope etc. BPL is now a growing communication network technology which is quite fast hitting the competitive market of broad band internet services in international telecom environment. In addition, value added services like internet, voice, video applications etc. can also be provided by BPL. Broad band over power lines may also be an effective viable alternative for providing broadband in India. BPL technology has evolved rapidly over the past few years. This has been possible due to worldwide technological developments and innovations on broadband over power lines.

Keywords: Broadband over power line, Internet Access, Power-line, Power-Line Communications, Communication Network.

1. INTRODUCTION

Despite the spread of broadband technology in the last few years, there are significant areas in the India that don't have access to high-speed Internet. When weighed against the relatively small number of customers Internet providers would gain, the incremental expenditures of laying cable and building the necessary infrastructure to provide DSL or cable in many areas, especially rural, is too great. But if broadband could be served through power lines, there would be no need to build a new infrastructure. Anywhere there is electricity there could be broadband. The basic concept of this technology is that it offers high speed internet access to our homes through the commonly accessible electrical paths, thus eliminating the need of transmission of data over last mile through copper cable, short haul satellite systems, opticalfibre cable and wireless technologies such as Wi-Max, Wi-Fi etc.

In BPL technology, by combining the technological principles of Radio, wireless networking, and modems, a mechanism has been created where one can plug in his computer into any electrical outlet in his home to have instantaneous access to high speed internet.BPL uses the existing power grid infrastructure to provide high-speed, broadband Internet access to homes and businesses. It is a new innovation based upon existing Power-Line Communications (PLC) technology.

2. BACKGROUND AND CURRENT TRENDS

There are two basic means of providing communications services: wireless or wireline. On the wireline side, there are currently three means of

providing broadband services: digital subscriber line cable modem through cable company coaxial cable lines, and fibre to the X (FTTX) through optical fibre lines to home or business to deliver broadband services. With the advent of broadband over power lines (BPL), a fourth wired option is emerging that uses electric utility power lines. Power lines are attractive for communications purposes because they have an omnipresence that reaches most homes and businesses, even in the most rural areas. This ubiquity implies a possible reduction in both time and cost for broadband deployment. In this sense, power lines, like Radio Frequency (RF) spectrum, can be considered a very valuable national resource, or even a national treasure. And of course, there is the inside-home power line wiring that can literally revolve every outlet plug into a broadband communications access port. BPL is still a new technology in the communication fields by which broadband services can be provided throughout the country, as the power line network is thought to be everywhere. In India, especially the rural areas, where broadband services are still not available will have a chance to access broadband services through the BPL technology. The objective of this paper is to provide a comprehensive knowledge about broadband over power line and also to present implementation scenarios, challenges and implementation prospects over other technologies. Broadband over power line or BPL theoretically has the ability to enable data to be transmitted over power lines into homes and offices at data rates between 500 kilo bits per second (kbps) and 3 mega bits per second (Mbps), which is equivalent to most DSL and cable modem transmission rates . So, BPL provides an emerging alternative to conventional methods of obtaining high-speed Internet access. The key reason for the excitement concerning BPL technology is the fact that virtually every home and office is connected to a power grid and contains electrical wiring. Thus, any mechanism that provides the potential to transmit high-speed data over existing electrical wiring has the potential to provide a truly pervasive method to access the Internet. A number of foreign governments including USA, Australia, Austria, China, Finland, Hong Kong, Hungary, Ireland, Italy, Korea, Japan, Netherlands, Poland, and Switzerland are currently studying BPL technology or have permitted equipment trials. The outcomes have shown mixed results and have led some administrations to ban BPL systems while other administrations have allowed deployment under various conditions. A number of administrations have suspended BPL trials pending international developments. Many rural residents and rural entrepreneurs in India don't have access to DSL, FTTX, and Wireless, cable or other telephone medium. But mostly rural users in India have the (DSL) through telephone company telephone lines, power lines. BPL technology is desirable option for those residents who want to get broadband service. On the urban side, BPL may be used as another cheaper technology for broadband services. BPL for broadband application may be considered an effective and less costly solution as access network. The Broad Band Over Power Line communication network technologies are new for Indian telecom network and will grow extensively in near future.

3. OVERVIEW OF GRID STRUCTURE AND TOPOLOGY

A power grid basically consists of power plants or generators, transmission substations, transmission lines, power substations with transformers to change voltage levels, and distribution lines that collectively generate and carry the electricity from power plants all the way to wall plugs.Power plants are basically spinning electricity generators. Spinning can be performed by a steam turbine, and steam can be created by burning fossil fuel or from a nuclear reactor. A generator's output is three-phase alternating current (AC) power at voltage levels in the thousands. The three single phases are synchronized and offset by 120 degrees. Power P, transferred over lines and delivered to customers, is equal to the product of voltage V and current I ($P = IV$). Power loss in the line grows with the square of the current, that is, $P_{loss} = R_{line} \times I_2$, where R_{line} is the line resistance and depends on the line material and increases with the length of the line. For a given generated P and a given R_{line}, to reduce P_{loss}, current I must be made as small as possible. This means that the line voltage must be made as large as possible, especially for long-distance transmissions. Transmission substations located next to power plants use large transformers to step up generator output from thousands of volts to hundreds of thousands of volts (typically between 155,000 and 765,000 volts), thus allowing megawatts of power transmission over distances of 300 miles or more .At power substations, voltages are stepped down and lines are branched out to cover larger areas. This is performed successively, transforming and

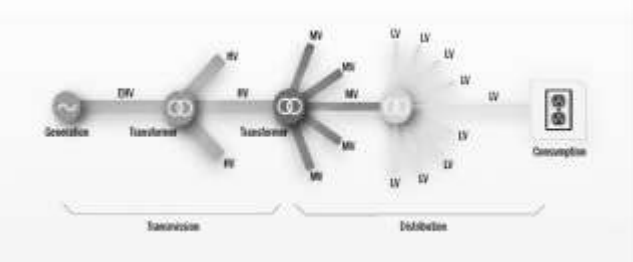

Figure 1: Transmission and distribution concept

branching out from extremely high voltage (EHV, typically 155 to 765 kilo volts or kV) to high voltage (HV, typically 45 to 155 kV), and then from HV to medium voltage (MV, typically 2 to 45 kV), and finally from MV to low voltage (LV, typically 100 to 600 V) for delivery to homes or businesses. The result is a tree-structured power distribution hierarchy. Basically, EHV and HV are used to transmit AC electric power, and MV and LV are used to distribute it. There are several different approaches to overcome the hurdles presented when transmitting data through power lines. When power leaves the power plant, it hits a transmission substation and is then distributed to high voltage transmission lines. When transmitting broadband, these high-voltage lines represent the first hurdle. The power flowing down high-voltage lines is between 155,000 to 765,000 volts. That amount of power is unsuitable for data transmission. It's too noisy. Both electricity and radio frequency (RF) are used to transmit data vibrating at certain frequencies. To transmit data cleanly from point to point; it must have a dedicated band of the radio spectrum to vibrate without interference. Hundreds of thousands of volts of electricity don't vibrate at a consistent frequency. That amount of power jumps all over the spectrum. As it spikes and hums along, it creates all kinds of interference. If it produces a spike at a certain frequency that is used for radio frequency data transmission, then it will cancel out that signal and the data transmission will be dropped or damaged on route.

4. BPL MAIN FEATURES

Many powerline devices use Othogonal Frequency Division Multiplexing (OFDM) to extend Ethernet connectionsto other rooms in a home through its power wiring. Adaptive modulation used in OFDM helps it to cope up with such a noisy channel as electrical wiring. Accepted international standard ITU-T G.hn for high speed local area networking over existing home wiring (power lines, phone lines and coaxial cables) uses OFDM with adaptive modulation and Low Density Parity Check (LDPC) FEC code. Thus PLC technology based on OFDM technique with adaptive modulation is quite consistent with envisaged ITU standards regulating BPL functioning. In order to achieve high bandwidth levels, BPL operates at higher frequencies than traditional power line communications, typically in the range between 2 and 80 MHz. The modulation technique of choice for BPL is Orthogonal Frequency Division Multiplexing. OFDM is superior to Spread Spectrum or Narrowband for spectral efficiency, robustness against channel distortions, and the ability to adapt to channel changes.

5. BPL ARCHITECTURE

A BPL General Architecture and Schematic has been shown in fig2. Various network components have been indicated in the diagram between Broadband OFC Media Backbone/Wireless Media Backbone to User's work station.

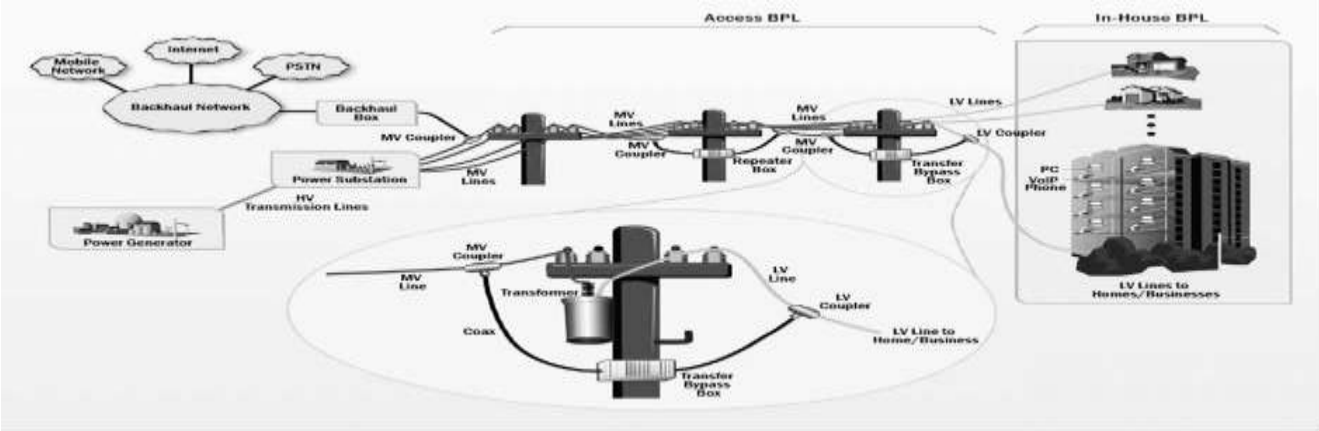

Figure 2: BPL Architecture

6. BPL WORKING

Broad band over power lines uses Power Line Communications (PLC) technology to provide broad band internet access over ordinary power lines. A computer (or any other device) would need only to plug a BPL "modem" into any outlet in an equipped building to have high speed internet access in this case. Internet signals using a fibre are dropped at medium voltage using a device called " head end" Once the data is dropped onto the medium voltage lines, it cannot travel too far before it degrades. To overcome the problem of degradation of data before it reaches its final customer destination in a healthy condition, special devices which act as repeaters are installed on the medium voltage lines to amplify the data for further smooth transmission. Finally internet is accessed by the end user using the plug in BPL modem.

7. THE FUNCTION OF BPL MODEMS

BPL modems use silicon chipsets specially designed to handle the workload of extracting data out of an electric current. These modems are capable of handling power noise on a wide spectrum. BPL modems are roughly the size of a comon power adapter and plugs into a common wall socket and an ethernet cable running to computer finishes th connection. There are various approaches available as far as last mile solution for BPL is concerned. While some carry the signal in with electricity on the power line, others use wireless links on the poles to send the data wirelessly into the homes. The BPL Modem simply plugs into the wall and then into subscribers computer. These modems are capable of speeds comparable to DSL or cable modems.

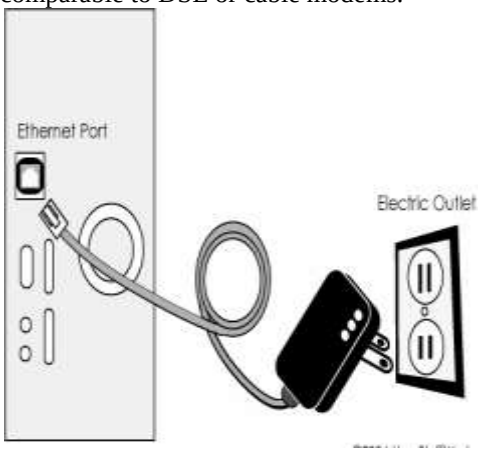

Figure 3: Modem Connection

8. POWER LINE COMMUNICATION (PLC) TECHNOLOGY

BPL systems function by coupling radio frequency energy to the existing electrical power lines. For deliverance of high speed data communication to customers, technology is based on high density advanced modulation using Othogonal Frequency Division Multiplexing (OFDM) modulation technique. To ensure that download and upload speeds are customer specific, data transmission is made configurable. The system is capable of working in the frequency band of 10-30 Mhz, amidst harmonics and distortions in the supply on line so that problems of noise and power quality do not arise. The strength of signal should not be less than 30 dB in any case throughout the network. This is achieved by optimizing the usage of repeaters. PLC communication technology uses High Density Advanced Modulation at each sub carrier of the OFDM signal. It uses the highest number of sub carriers (1536) for any technology used in any wire communications at each of the possible operation modes (10, 20 and 30 MHz). In this technology a modulation density of 2to 10 bits per sub carrier is added. This technology ensures highest quality communications even in the face of interference and this is particularly achieved by adapting number of bits for each and every carrier in real time to obtain high reliability and maximum performance. The number of bits to be adapted for each and every carrier depends upon the condition of the transmission medium and the signal received. As a consequence of using high density configurations, PLC delivers speeds of up to 200 Mbps throughout data journey for bandwidth hungry applications like BPL. PLC is based on OFDM technique mainly because of immunity of OFDM towards interference which is an issue of serious nature encountered while transmitting data over mediums such as power lines. OFDM is not a new modulation technique and is being used in many other communication systems such as ADSL, VDSL, DAB, DVB etc. Besides, implementation of OFDM modulation in PLC results in highest level of spectral efficiency and performance of any wireline communication technology in the market.

9. OFDM MODULATION

Orthogonal frequency-division multiplexing (OFDM) is a frequency multiplexing scheme utilized as a

digital multi carrier modulation method. In this technique, a large number o closely spaced orthogonal sub carriers are used to carry data. The data is further divided into several data cannels, one for each sub carrier. Each sub carrier is then modulated with a conventional modulation scheme. Low symbol rate helps in maintaining total data rates similar to conventional modulation schemes in the same range of bandwidth.

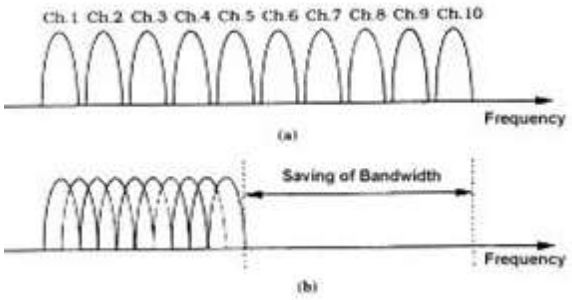

Figure 4: OFDM Signal

The orthogonality of sub carriers in OFDM scheme enables it to achieve distinct advantages over conventional modulation schemes in that it eliminates serious issues of cross talk and interference between sub channels. Besides, inter carrier guards are not required in OFDM scheme. OFDM technique has acquired added significance in broad band internet access because of its ability to deal with issues of attenuation of high frequencies, narrow band interference and frequency selective fading. The overriding feature of OFDM is that in this technique many slowly modulated narrow band signals rather than one rapidly modulated wide band signal is used and this helps in simplification of channel equalization.

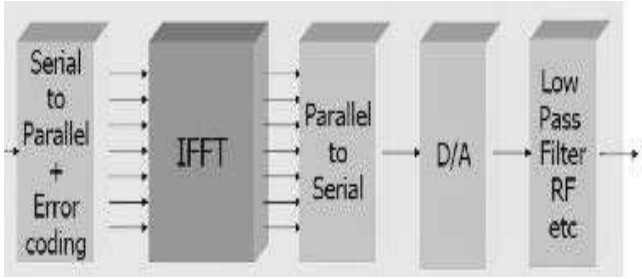

Figure 5: OFDM Transmitter

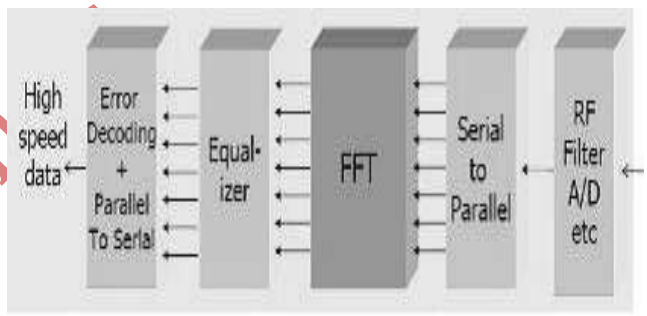

Figure 6: OFDM Receiver

10. BENEFITS OF THE BPL OVER OTHER ACCESS METHODS

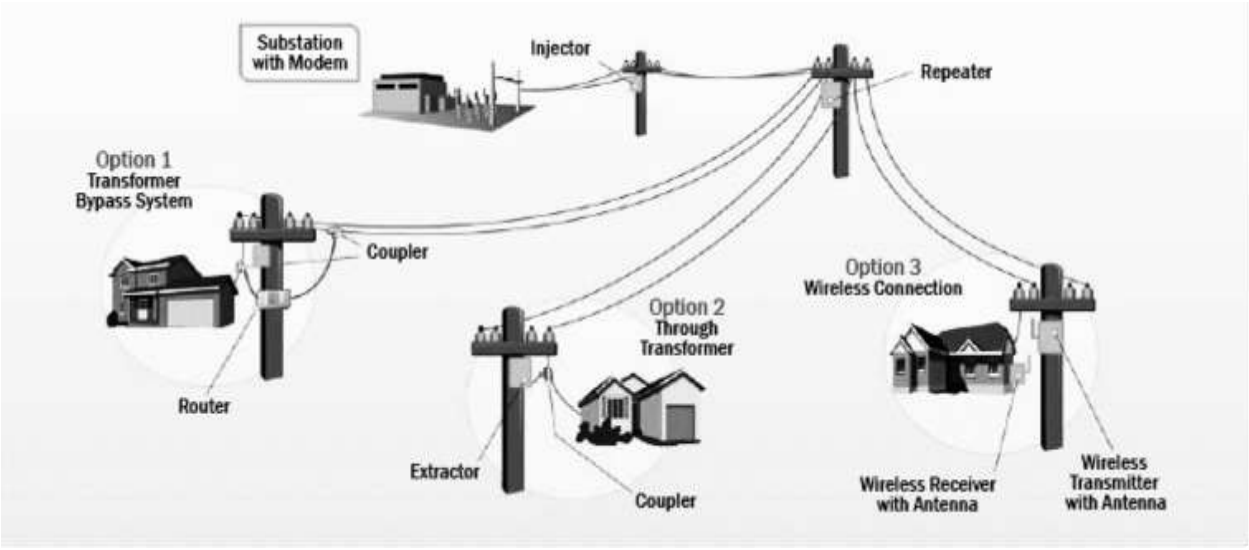

Figure 7: BPL Distribution

10.1 Benefits for Service Providers

A major advantage for the utility companies is that most of the infrastructure is already in place because the technology relies on the existing power grid. This enhances the cost-effectiveness of rolling out power line communications. Only the substation server equipment and customer conditioning service units need to be installed
in order to establish a digital power line network .Another important aspect to consider for providers is that of coverage; the power grid is everywhere. The low voltage power grid has a unique feature; it is comprised of an already existing networked infrastructure to billions of private customers as well as businesses. The power grid has the greatest availability of any other solution that exists today.

10.2 Benefits for the End Users

The equipment needed to set up BPL in home is cheaper on average than that of other broadband solutions such as DSL and cable modem. The equipment uses existing power outlets in the home making it a lot easier to set up and is very simple as it is plug and play. There is no need for complicated wiring and additional installations; and it is possible to move computers and appliances anywhere. The uplink and downlink speeds are similar. This is especially important for the uplink as the speed is higher than the DSL and Cable. For users in rural areas who cannot receive DSL or cable modem services, BPL can provide an all-in-one service-telephone, cable television, and high-speed data.

11. IMPLEMENTATION CHALLENGES

Power lines were not designed for data transmission; they were created to deliver power at 50 to 60 hertz (Hz). Broadband data are transmitted at different frequencies, so the data and electricity can travel in the same wire; however, several obstacles have to be overcome to enable high-speed and long-distance transmission of data on power lines.

11.1 The Nature of the Power Grid

The most obvious challenge to implement BPL arise from the fact that power line grids were originally developed to transmit electrical power from a small number of sources (the generators) to a large number of sinks (the end customers). Power grids were neither designed nor devised for communications purposes. The main challenges to BPL are the extremely harsh & unpredictable nature of power grid and the time-and-location-variable characteristics of the power line channel, and potential interference arising from the power grid. Because power lines are not twisted and have no shielding, they can produce electromagnetic radiation that is easily detected by radio receivers. For the same reasons, power lines can also easily pick up nearby radio frequency signals. Thus, addressing mutual interference is not only a challenge, but becomes a valid regulatory concern.

11.2 Power Line Noise

The power line noise is typically time, location, and frequency dependent. Time-variable behavior is mainly due to the dynamically changing nature of the load connected to the power lines. Line branching, the number and types of branches, the lengths of line segments, the types of power line equipment connected (such as capacitor banks and transformers), and the kind of loads connected, all affect power line characteristics.

11.3 Channel Attenuation

Attenuation or reduction of signal strength occurs either on longer lengths of distribution feeders, or when a given feeder changes configuration several times such as from overhead to underground or from cross arm to a more compact configuration. Attenuation must be overcome to enable long-distance data transmission. Higher frequency data signals are typically attenuated much more seriously than lower frequency signals. Signals lose energy as they propagate for several reasons including the change in impedance on the line at every connection, splice, taps, stand off or even a location where the line is close to something else.

11.4 Attenuation Problems at the Distribution Transformers

Low frequency signals, obviously including electricity at 60 Hz can easily pass through the distribution step down transformer. But high frequency signals, which for BPL are typically in the 2 to 80 mega hertz (MHz) range, are obstructed or severely attenuated by the transformer. Although some of the signals get through, signal components can be so weak that they are difficult to detect or reconstruct. Accordingly, many BPL technologies
suppliers simply bypass the transformer.

11.5 Potentially Harmful Radio Frequency Interference (RFI)

Radio frequency interference has been one of the most serious potential obstacles to BPL. BPL systems have been shown to produce RF interference with nearby radio receivers, within up to 75 meters for mobile radios and 150 meters for fixed radios, according to the American Radio Relay League

(ARRL). Also, various elements or structures in or near the power lines readily become radiator or antennas at the high frequencies at which BPL data are transmitted. This presents a problem of interference with a variety of radio services.

12. CONCLUSION

In a Country like India where broad band penetration is extremely low and the costs of laying down copper cable or providing short haul satellite for providing broad band for its final leg of journey is very high, providing broad band over power lines holds a great promise, provided issues relating to interference etc are sorted out. Even in advanced Countries like USA, Europe etc., the larger issues of interference remain unaddressed because of absence of stringent regulatory measures. Even in the absence of these regulatory measures, BPL is gaining ground in these Countries despite strong protests from those agencies which are vulnerable to interference because of BPL.

In our Country where serious financial constraints exist in terms of heavy investments to be made for laying copper or installing satellite as a mode of final broad band transmission, giving serious consideration and priority to BPL would be worthwhile, while addressing other pertinent issues. Another great potential that BPL holds in future is that it can be used as a backhaul for wireless communications, for instance by hanging Wi-Fi access points or cell phone base stations on poles, thus allowing end users within a certain range to connect with the equipment they already have. Besides, low maintenance costs and lesser installation time make BPL a worth technology for increasing broad band penetration. The Broad Band over Power Line communication network technologies are new for Indian telecom network and will grow extensively in near future for higher capacity applications e.g. Triple Play services (telephony, data and TV etc.). Also BPL is a better option with less cost for network operators.

BPL is already on the scene with commercial products readily available. Green Energy technologies like Solar, Wind etc. may be used as Power Line solutions. Combination of BPL with FTTX, DSL, PON etc. may be economic solution for access networks in future.

13. ACKNOWLEDGMENT

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