Chapter 2

Powerline as Communication Media

2.1. Introduction

Search for alternative media for voice and data transmission has motivated to use powerline as communication media. But powerline, which has been designed and installed to supply 50/60 Hz power, is not quite suitable for high-speed communication. Unlike the other wired communication mediums such as the unshielded twisted pair (UTP) and coaxial cables, Low Voltage powerline presents an extremely harsh environment. Channel parameters namely noise, impedance mismatch and attenuation are found to be highly unpredictable and variables with time, frequency and location. Therefore, it is a real challenge to realize high rate data transmission over the low-voltage distribution network.

In this chapter, the different aspects of the low voltage home powerline to be used as a communication media have been discussed.

2.2. Channel Parameters Affecting Communication

2.2.1. Channel Noise

It is the background interference present on the channel or unwanted electrical or electromagnetic energy that carries no data or information but interferes with the information or data. Hence, noise degrades the quality of information and data by affecting data packets. Noise may be considered as the main source of transmission errors.

The noise may be classified as external or internal noise based upon the sources. External noise is generally picked up from electrical appliances in the vicinity, from electrical transformers, the atmosphere, on even from outer space. Normally this noise
does not seriously hamper the performance. However there are a number of electrical appliances or heavy current machines in use, external noise generated by them can affect communications. The external noise generated is inversely proportional to the frequency and is directly proportional to the wavelength and therefore has a remarkable impact on wireless systems than on wired systems.

Noise generated inside channels or receivers is known as internal noise. Internal noise is less dependent on frequency but has a significant effect at higher frequencies. Powerline channel is highly affected by its internal noise and also creates external noise for other equipments in its neighborhood.

2.2.2. Channel Bandwidth

Channel bandwidth may be defined as the range of frequencies at which a signal can be transmitted through a channel without suffering distortion. In order words, it is the volume of information per unit time that a computer, person or transmission medium can handle. Bandwidth is expressed as data speed in bits per second in digital systems and as the difference between highest frequency and lowest frequency in an analog system. Bandwidth determines how fast data flows on a given transmission path.

2.2.3. Channel Capacity

Channel capacity is the highest rate of information that can be reliably transmitted over a communications channel. Channel capacity is concerned with the information handling capacity of a given channel. It is affected by the attenuation of a channel, which varies with frequency as well as channel length, the noise induced into the channel, which increases with distance and non-linear effects such as clipping on the signal.

2.2.4. Transmission Time

It is the time required for transmitting a message through the channel. It is the size of the message in bits divided by the data rate in bits per second of the channel over
which the transmission takes place. It is also given as the packet length divided by the channel capacity.

2.2.5. Propagation Time

It is the amount of time needed for information to propagate from source to destination through the channel. It is the distance divided by the signal propagation speed. Channel latency depends on media characteristics, signal propagation speed, and transmission distance.

2.3. Different Types of Communication Media

There are two categories of communication media used:

- Guided or Bounded Media
- Unguided or Unbounded Media

2.3.1. Guided Media

Guided media are the physical links through which signals are sent confined to narrow path. These are also called bounded media. Guided media are made up of conductors (usually Copper) bounded by jacket material. Guided media offer high speed, good security and low cost. However, sometimes they cannot be used in long distance communication. There are three common types of Guided media that are used for the data transmission. These are

- Coaxial Cable
- Twisted Pairs Cable
- Optical Fiber Cable

2.3.1.1. Coaxial Cable

Coaxial cable is very common & widely used communication media. For example TV wire is usually a coaxial cable. Coaxial cable gets its name because it contains two
conductors that are parallel to each other. The center conductor in the cable is usually copper. The copper can be either a solid wire or stranded martial. Outside this central conductor is a non-conductive material. It is usually white, plastic material used to separate the inner conductor form the outer conductor. The other conductor is a fine mesh made from Copper. It is used to help shield the cable form EMI. Outside the copper mesh is the final protective cover as shown in Fig.

![Co-Axial Cable](image1.png)  ![UTP cable](image2.png)  ![STP cable](image3.png)

Figure 2.1. Co-Axial Cable Figure 2.2. UTP cable Figure 2.3. STP cable

The actual data travels through the center conductor in the cable. EMI interference is caught by outer copper mesh. There are different types of coaxial cable vary by gauge & impedance. Gauge is the measure of the cable thickness. It is measured by the Radio Grade measurement or the RG number. The higher the RG number, the thinner is the central conductor core, the lower the number the thicker is the core.

Here the most common coaxial standards.

- 50-Ohm RG-7 or RG-11: used with thick Ethernet.
- 50-Ohm RG-58: used with thin Ethernet
- 75-Ohm RG-59: used with cable television
- 93-Ohm RG-62: used with ARCNET.

**Characteristics of coaxial cable**

- Low cost
- Easy to install
- Up to 10Mbps capacity
- Medium immunity form EMI
- Attenuation medium
Advantages coaxial cable

- Inexpensive
- Easy to wire
- Easy to expand
- Moderate level of EMI immunity

Disadvantage coaxial cable

- Single cable failure can take down an entire network
- Does not support speed more than 10Mbps

2.3.1.2. Twisted Pair Cable

The most popular LAN cable is the Twisted pair cable. It is of light in weight, easy to install, inexpensive and support many different types of networks. It also supports the speed up to 100 Mbps. Twisted pair cable is made of pairs of solid or stranded copper twisted along each other. The twists are provided to reduce effect to EMI and cross talk. The number of pairs in the cable depends on the type. The copper core is usually 22-AWG or 24-AWG, as measured on the American wire gauge standard. There are two types of twisted pairs cabling

- Unshielded twisted pair (UTP)
- Shielded twisted pair (STP)

2.3.1.2.1. Unshielded Twisted Pair (UTP)

UTP is more commonly used twisted pair cable. It can be either voice grade or data grade depending on the condition. UTP cable normally has an impedance of 100 ohm. UTP cost less than STP and easily available due to its wide use. There are five categories of cables available

Category 1: These are used in telephone lines and are low speed data cables.
Category 2: These cables support data speed up to 4 Mbps.
Category 3: These cables support data speed up to 10 Mbps.
Category 4: These are used for long distance communication and support speed up to 20Mbps.

Category 5: These are commonly used for LAN and support data speed up to 100 Mbps.

UTP cables consist of 2 or 4 pair of twisted cables. Cable with 2 pair use RJ-11 connector and 4 pair cable use RJ-45 connector.

Characteristics of UTP
- Low cost
- Easy to install
- High speed capacity
- High attenuation
- Effected by EMI
- Maximum length limit 100 meter

Advantages of UTP
- Easy installation
- Capable of high speed for LAN
- Low cost

Disadvantages of UTP
- Short distance due to attenuation

2.3.1.2.2. Shielded Twisted Pair (STP)

It is similar to UTP but has a mesh shielding that’s protects it from EMI which allows for higher transmission rate.

IBM has defined category for STP cable.

Type 1: STP features two pairs of 22-AWG
Type 2: This type include type 1 with 4 telephone pairs
Type 6: This type feature two pairs of standard shielded 26-AWG
Type 7: This type of STP consist of 1 pair of standard shielded 26-AWG
Type 9: This type consist of shielded 26-AWG wire

Characteristics of STP

- Medium cost
- Easy to install
- Higher capacity than UTP
- Higher attenuation, but same as UTP
- Medium immunity from EMI
- Maximum length limit 100 meter

Advantages of STP:

- Shielded
- Faster than UTP and coaxial cables

Disadvantages of STP:

- More expensive than UTP and coaxial
- More difficult installation
- High attenuation rate

2.3.1.3. Optical Fiber Cable

Optical Fiber Cable uses light signals to transmit data. In Optical Fiber Cable light moves only in one direction and for two-way communication to take place a second connection must be made between the two devices. It is actually two stands of cable. Each stand is responsible for one direction of communication. A laser at one device sends pulses of light through this cable to other device. These pulses translated into “1’s” and “0’s” at the other end.

In the center of fiber cable is a glass core. The glass core is surrounded by a glass cladding, which has a lower refractive index. The light from the laser at one end
moves through this glass to the other end by total internal reflection. No light can escape the glass core because of this reflective cladding. Fiber optic cable has bandwidth more than 2 Gbps (Gigabytes per Second).

Figure 2.4. Optical Fiber cable

Characteristics Of Fiber Optic Cable:

- Expensive
- Very hard to install
- Capable of extremely high speed
- Extremely low attenuation
- No effect of EMI

Advantages Of Fiber Optic Cable:

- Fast
- Low attenuation
- No EMI interference

Disadvantages Fiber Optics:

- Very costly
- Hard to install

2.3.2. Unguided Media

Signals at different frequencies are used through free space to send information. However this type of communication suffers from a number of disadvantages including noise and security risk.
2.3.2.1. Radio Link Systems

This is a connection via a chain of transmitters and receivers. There are radio links for both analog and digital transfer. Analog radio systems can be used to transfer pulse-modulated signals while digital systems are purely designed for digital transmission.

Each radio link connection requires two radio channels, one in each direction. The transmission frequency and the receiving frequencies are separated by a few MHz. This is a very small difference, bearing in mind the frequency band used.

2.3.2.2. Satellite Systems

Satellite transmission is similar in principle to the ordinary radio link. Instead of having all the stations earthbound, some are sent up into the space. Communications Satellite rotates at almost exactly the same rate as the earth rotate. Compared to the radio link, the satellite has a considerably large range. They are used for both in the national network and in the international network.

There are only a few problems in the transmission characteristics of the satellite link. Due to the long distance that the signals have to travel, resulted in a delay (echo), which have to be counteracted by the echo suppressors. It has to be recognized that this is a communication between two floating bodies in space thus there is always a relative movement between the earth and the satellite which can cause errors in digital transmissions. However, this may be compensated for by intermediate storage of the information in buffer memories. The capacity of the telephone channels has increased compared to the time when the satellite was first launched into space. The Intelsat, which was first launched in 1965 have 75 duplex telephone channels but today the basic version of the new Intelsat VI satellite can handle 80000 telephone channels.

2.4. Home Wiring Cables and Their Characteristics

Copper or tinned copper is the most commonly used conductor in home wiring because it has minimum resistance at reasonable cost. Wires are grouped by gauge
numbers running from 00 to No. 40. The smaller the number, the thicker the wire is. For home use, the most common gauges are between 10 and 20. Larger wire carries more current. Forcing too much current through a wire will cause it to overheat and trip a breaker. Wire is also characterized by letters that correspond to the insulation type and electrical capacity. Grounding wire provides a path of least resistance from the frame or case of an appliance to the ground to guard against electric shocks. Both two and three conductor cables can be used as grounding wires.

2.4.1. Commonly Used Home Wiring Cables

- Triplex wires: Triplex is an aerial cable that the utility company uses to feed the power pole. This wire ties to the wires sticking out of the weather head.

- Main Feeder Wires: These wires are usually type THHN (Thermoplastic High Heat-resistant Nylon coated) wire and are rated for 125% of the load required. These are usually black insulated wires coming out of the service weather head.

- Panel Feed Wires: These wires are also type THHN, like the main feeders. A typical 100-amp service would have a #2 THHN set of wires. They would then be rated at 125 amps. This would protect the wires if the amperage were a full 100 amp.

- Non-Metallic Sheathed Wire (NM): This wire, commonly called Romex, is a plastic coated wire that has either two or three conductors and a bare ground wire. This is the typical wiring used in most homes. The rating for this wire is 15 amps, 20 amps, or 30 amps, depending on the installation.

- Single Strand Wires: When the home is piped, these types of wires are used. Single strand wire is insulated and many of these can be pulled into the same pipe. Normally, THHN Single Strand wires are used for this installation.

2.4.2. Structure of Home Wiring

An average residential unit is connected to the distribution transformer through a service drop. Starting from the service entrance, service cables go through a usage
meter and are terminated at the service enclosure box. Feeder cables are then used to connect the service enclosure box and the feeder panel.

Branch cables are used to connect lights and appliances to the feeder panel. A feeder panel can have a few dozens of branch cables all individually protected by circuit breakers. A ground is also created for each unit by inserting an electrode deep into the soil. The ground is bonded to the neutral at the feeder panel. Any branch cable can include the ground wire for leakage protection. The ground wire can be connected to metal enclosures of appliances. Any leakage on the metal enclosure will then go through the ground wire to neutral forming a short circuit and causing the circuit breaker to break. Depending on its dimension, the length of a branch cable can be as long as the sum of the depth, width, and height of a house. The longest branch in a house can range from 65 to 90 feet. Another important factor is that a distribution transformer is shared among a number of households. A transformer is usually shared by up to 25 households. Because of this shared nature, an in-home electrical wiring-based transmission system might interfere with a similar system of the neighborhood. A Media Access and Control protocol layer should be properly designed to avoid such interference. Furthermore, some encryption and authentication measures should also be considered for privacy issues.

When electrical devices are turned off, impedances of these devices are not attached to branch cables. Terminals of branch cables can be considered open ended except that some capacitors can still be attached for surge protection. These capacitors can have a capacitance of up to a few microfarads. When a light is on, its load resistance can be calculated according to its power rating. Most electrical loads are resistive, such as lights, or partially inductive, such as motors or voltage converting power supplies in appliances.

Depending on the time of the day and activities, the electrical load within a household is dynamic, which means that the total load resistance changes from time to time on the usage time scale of a few minutes by human intervention. On the other hand, many electrical devices with automatic control, such as a refrigerator or an air conditioner, can vary their load resistance on a time scale of a few seconds. Furthermore, some
devices such as a light dimmer or a motor speed controller can turn on and off an electrical device in a fraction of a second. An electronic dimmer switch uses a transistor-like device called a TRIAC to switch the electricity on and off 100 times each second.

2.5. Problems in Powerline

Home Powerline network is designed and installed only to supply power to the household and not for communication. So it suffers from many drawbacks. Problems are due to different types of loads and appliances connected, conductor with different diameters used, un-terminated conductor ends etc. Here, the problems of powerline, which affect high-speed data communication has been put forward. The main problems are

- Noise
- Signal Attenuation
- Signal distortion

2.5.1. Powerline Noise

Noise in the home powerline is mainly due to different types of appliances and loads connected and leakage current through ionized paths between conductors. Powerline noise is both time and frequency dependent. Unlike the other telecommunications channels, the powerline channel does not represent an Additive White Gaussian Noise (AWGN), whose power spectral density is constant over the whole transmission spectrum. The powerline noise can be classified as follows [11]:

![Figure 2.5. A.C. Power cycles](image-url)
• **Background coloured noise** (type1): This is the common type of noise present in all types of Communication channels. It has a comparatively low power spectral density (PSD) and decreases with frequency. The noise is mainly caused by summation of numerous noise sources of lower density and physical characteristics of the powerline. Unlike white noise, which has a continuous and uniform spectral density and is substantially independent of the frequency over the specified frequency range, the background coloured noise shows strong dependency on the considered frequency. Since colored background noise varies slowly over time, it can be regarded as background noise.
• **Narrowband Noise** (type 2): This type of noise is caused by the interference from the broadcast stations over the medium and short wave broadcast bands. It is of sinusoidal form, and has modulated amplitude. It occupies several relatively small and continuous sub bands over the frequency spectrum. Their amplitude generally varies over daytime and becomes higher when reflection properties of the atmosphere become stronger.

![Narrowband Noise](image)

Figure 2.8. Narrowband Noise

• **Periodic asynchronous impulse noise** (type 3): This noise is due to switched power supply in PCs and electronics equipments. It contains impulses that are repeated between 50 and 200 kHz. It creates a spectrum of discrete lines with frequency spacing according to the repetition rate. Because of its high repetition rate, this noise occupies frequencies that are too close to each other, and builds therefore frequency bundles that are usually approximated by narrow bands. They are not synchronized with AC supply.

![Impulse Noise](image)

Figure 2.9. Impulse Noise
• **Periodic synchronous impulse noise** (type 4): This noise is created due to devices like thyristor-controlled light dimmers operating synchronously with the main frequency. It is synchronous with the AC supply frequency. These are impulses occurring at twice the AC frequency appearing at every half cycle. Such impulses have a short duration, in order of microseconds, and have a power spectral density that decreases with frequency.

• **Non-periodic asynchronous impulse noise** (type 5): This type of noise is due to various switching operations and contact switching on loads. These impulses have duration of some microseconds up to a few milliseconds with an arbitrary inter-arrival time. They often have a shape similar to damped sinusoids or overlaid damped sinusoids. Their power spectral density can reach values more than 50 dB above the level of the background noise, making them the principle cause of error occurrences in the digital communication over PLC network.

Noise in the powerline channel can be expressed as the superposition of the above mentioned five types of noise and can be given as shown in the figure.

![Figure 2.10 Classes of Powerline Noise](image)

Measurements have shown that the first three types of noise usually remain stationary for longer periods of seconds, minutes and even sometimes for hours. So, due to their common characteristics they are grouped together and called General Background Noise [19]. On the other hand noise type 4 and 5 are of very short duration and of high amplitudes. They are in general called Impulse Noise. Due to their high PSD, they are the main cause of bit error and burst errors.
2.5.1.1. General Background Noise

For modeling Powerline General Background Noise, it is considered as the superposition of the coloured background noise and all the narrowband noise. In this case, no difference is made between the short-wave radios and the other narrowband disturbances in the form of spectral lines, because normally the spectral lines are found in bundled form. For the modeling, these bundles of disturbances are approximated by their envelope. The Periodic Asynchronous Impulse noise is also considered as narrowband noise with very low Power Spectral Density (PSD). This is because, for its high repetition rate, it occupies frequencies that are close to each other and their frequency bundles are approximated by a narrowband occupation.

\[
N_{GBN}(f) = N_{CBN}(f) + N_{NN}(f) \quad (2.1)
\]

\[
N_{GBN}(f) = N_{CBN}(f) + \sum_{k=1}^{R} N_{NN}^{(k)}(f) \quad (2.2)
\]

where \( N_{CBN}(f) \) is the PSD of the general background noise,
\(N_{cn}(f)\) is the PSD of the colored background noise,
\(N_{nn}(f)\) is the PSD of the narrowband noise and
\(N_{nn}^{(k)}(f)\) is the PSD of the subcomponent \(k\) generated by the interferer \(k\) of the narrowband noise.

The measurement have shown that, for modeling of the Colour Background Noise PSD, the first order exponential function is more adequate and may be given by

\[
N_{CBN}(f) = N_0 + N_1 e^{\frac{-f}{f_1}}
\]  
(2.3)

With \(N_0\) the constant noise density, \(N_1\) and \(f_1\) are the parameters of the exponential function, and the unit of the PSD is dB\(\mu V/Hz^{1/2}\).

The experimentally found approximated values for PSD of Colour Background Noise can be given by

\[
N_{cn}(f) = -35 + 35 \cdot e^{\frac{-f}{3\text{ MHz}}} \text{ for residential environment} \quad (2.4)
\]

\[
N_{cn}(f) = -35 + 35 \cdot e^{\frac{-f}{8\text{ MHz}}} \text{ for industrial environment} \quad (2.5)
\]

For approximation of the narrowband noise interferers, the parametric Gaussian function is used, whose main advantages are the few parameters required for specifying the model. Further more, the parameters can be individually found out from the measurements, which have shown only a small variance

\[
N_{NN}^{(k)}(f) = A_k e^{\frac{-(f-f_{0k})^2}{2B_k^2}} \quad (2.6)
\]

The function parameters are \(A_k\) for the amplitude, \(f_{0k}\) is the center frequency and \(B_k\) is the bandwidth of Gaussian function.

2.5.1.2. Impulse Noise

Short time variance in the powerline environment is due to Impulse noise, which may be synchronous or asynchronous in nature as described above. Out of these, the Non-periodic Asynchronous Impulse Noise is dominant in nature. These are caused by
switching transients located anywhere in the powerline network. Investigations and measurements [12] have shown that the Non-periodic Asynchronous Impulse Noise has a shape with a sharp rising edge followed by a damped oscillation with an overall duration of about 50μs. The Periodic Synchronous Impulse Noise does not show such clear structure. Its amplitude is only about 0.1 V and its overall duration is about 90μs with an abrupt ending.

Figure 2.12. Asynchronous Impulse Noise  Figure 2.13. Periodic Impulse Noise

Impulse Energy, $E_{imp}$ and Impulse Power, $P_{imp}$ are the two parameters that are considered for characterization of the impact of the impulses on the data communication. Impulse Energy $E_{imp}$ can be calculated from the time signal $n_{imp}$, considering the arrival time $t_{arr}$ and the width $t_w$ of the impulse event.

$$E_{imp} = \frac{t_w}{t_{arr}} \int_{t_{arr}}^{t_{arr}+t_w} n_{imp}(t)^2 dt$$

(2.7)

The impulse energy is influenced by the form of the signal course as well as by the width of the impulse. In order to compare the impulse event with the background noise, the mean power of the impulse is more suitable. The impulse power $P_{imp}$ can be determined by

$$P_{imp} = \frac{1}{t_w} \int_{t_{arr}}^{t_{arr}+t_w} n_{imp}(t)^2 dt$$

(2.8)

The dynamic change of the noise scenario during an impulse event may be measured by the relation between the mean power of the background noise, $P_N$ and the impulse
power, $P_{\text{imp}}$. The mean power $P_n$ of a sample of a background noise signal $n(t)$ over the observation time $T_B$ can be given by

$$P_n = \frac{1}{T_B} \int_0^{T_B} n(t)^2 \, dt$$  \hspace{1cm} (2.9)

Impulse noise has a high impact on data transmission through the powerline channel. So it becomes important to gain statistical information about the probability of impulse width, impulse amplitude and inter-arrival time. One approach to model the impulses is a pulse train with a generalized impulse $\text{imp}(t)$ with unit amplitude and unit width. The train of impulses $n_{\text{imp}}(t)$ with pulse width $t_w$, pulse amplitude $A$ and arrival time $t_{\text{arr}}$ can be described as

$$n_{\text{imp}}(t) = \sum_i A_i \text{imp} \left( \frac{t - t_{\text{arr}}}{t_w} \right)$$  \hspace{1cm} (2.10)

![Figure 2.14. Measured impulses in the time domain in PLC network](image)

The statistical properties for $A$, $t_w$ and $t_{\text{arr}}$ are found by investigation and measurements. The measurements have shown that about 90% of the detected impulses have amplitude between 100mV and 200mV. Only less than 1% exceeded maximum amplitude of 2V. Also during measurement only about 1% of the impulses had a width exceeding 500 $\mu$s and only 0.2% exceeded 1 ms. The largest detected impulse width was about 5.7 ms. The time span between two impulses called Inter-arrival time, $t_{\text{LAT}}$ is
Measurements have shown that about 30% of the detected impulses had an inter-arrival time of 10 ms or 20 ms, which indicate that they are synchronous to the mains frequency. More than 90% of the recorded inter-arrival time were below 200 ms. Many recorded inter-arrival time were below 5 ms due to burst like impulsive events.

2.5.2. Signal Attenuation

Signal attenuation is the weakening of the signal along the communication channel. Attenuation of signals in a home/office powerline environment may occur for various reasons. It is dependant on the type of the cable used. Attenuation is more significant in longer lines and increases with increasing frequency. The signal becomes weaker also while passing through the breaker panels and get divide in multiple paths. The various reasons for attenuation may be given as

- Conductor length
- Multi-path propagation of signals
- Impedance mismatch / Variable conductor length

2.5.2.1. Conductor Length

All the types of channels exhibit signal attenuation characteristics as the conductor length increases, which mean that signal attenuation is directly proportional to the conductor length. Signal attenuation becomes more acute as the signal frequency increases. From investigation by measurements [20] carried out for powerline channel it has been found that attenuation is about 10 dB at 10 MHz, 15 dB at 20 MHz and 20 dB at 30 MHz for a 25 m length cable.

2.5.2.2. Multi-path Propagation of Signals

Multiple branches of a home/office wiring system are connected through multiple joints. Signal, while passing through joints suffers from fading due to multi-path propagation. Experiments have shown that the powerline signal suffers more
attenuation while more number of load paths are connected rather than the amount of the load connected.

2.5.2.3 Impedance Mismatch Due to Variable Conductor Diameter

Powerline electrical network contain wires of different diameter for different utility segments. While passing through the joints of wires of different diameters, signal suffers reflection and a part of the signal energy is reflected back. Hence the propagating signal becomes weaker. The reflected signal also causes distortion to the incident signal.

2.5.3. Signal Distortion

Because of the presence of a number of junction and branching points, the signal undergoes reflection. Due to different path lengths and reflection coefficients, signals arrive at the receiver staggered in time and with different amplitudes, and the receiver receives replicas of the original transmitted signal with different attenuations and time delays. This is called the multi-path distortion.

2.6. Conclusion

The design of the powerline cable is meant for carrying electrical power and not to carry the digital signal of a LAN. Also the installation method of the house wiring system creates inherent problems. To overcome the problems of noise, signal attenuation and distortion physical layer approach like selective noise avoidance and selecting suitable modulation will certainly improve the situation. The Media Access and Control protocol layer should be properly designed to avoid noise and to implement error correction and retransmission.