

## Expansion of Wireless Networks using IEEE 802.3af Protocol in Protected Areas

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### Abstract

The wireless networks are preferred due its advantages such as scalability, infrastructure and cost among the current technologies. The differentiation of physical conditions leads to the adaptation of wireless networks with other technologies. With the concept of smart city, many sensors controlling the life areas of the people and enabling the flow of information have to communicate with each other in a common computer network. The construction of smart cities with wireless technologies creates the necessity of broadening the network in the studies made in this field. In this study, data carrying problems based on physical places in wireless networks established in historical places are emphasized. It is aimed to decrease losses in wireless signal levels with topologies.

**Keywords:** Wireless Networks, PoE, Smart Networks, WLAN

### 1. Introduction

In the past, the computer networks were defined as the communication of at least two computers. However, this definition is out of date because a computer network is based on the physical and logical communication of at least two devices in today's technology [1]. Especially, while designing physical topology in cable networks, it is benefited from wireless networks to broaden the network. The low effective costs and physical conditions negatively affect the design of scalable networks. Especially in historical and touristic places, the difficulties of technical infrastructure works show the indispensability of wireless networks. For the computer networks to be structured in places such as castles, historical mansions, hostleries and historical places used as museums etc., the necessity of using wireless technologies is important in terms of increasing the productivity of topologies [2]. The unsuitable architectural conditions are mainly observed in historical places. In such places, in which a network infrastructure is designed with a certain extent, architectural conditions affect the transmission of wireless signals negatively. This situation causes different alternatives and scenarios. Thanks to the rapid and effective development of wireless technologies, it is easier to broaden the network.

### 2. Background

The function of connecting wide areas led to the spread of wireless networks. As there is no physical cabling, the concepts of efficiency and information security come into question. The

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information security is narrowed with today's cyber definitions. Information security is defined as the transmission of data from one point to another by protecting its integrity [2]. It is very important for wireless networks because technology is affected from the outer environment during the transmission of the signal. In order to enable effective and uninterrupted communication in wireless networks, the analysis of radio propagation especially in indoor places is very important. The focal point of designers in the applications is "propagation path loss" related with the electromagnetic wave enabling the communication between transmitter and receiver, as well as using the limited frequency band effectively. It is possible to determine the range of the system - in other words, to find how an efficient data transmission speed can be enabled – with path loss analysis. In path loss analysis, under which power levels the broadcast is made based on the frequency band and cell type that the transmitter source in the propagation environment functions, should be searched [3].

**Table 1.** Wireless Standards [4]

Standards	802.11	802.11b	802.11b +	802.11a/h/j	802.11g	802.11n
Frequency Range	2.4 GHz	2.4 GHz	2.4 GHz	5 GHz	2.4 GHz	2.4 + 5 GHz
Data Rate	2 Mb / s	11 MBit / s	22 MBit / s	54 Mbps	54 Mbps	300 Mbit / s
Compatible Standards	802.11b	+ 802.11b / g	802.11b / g	-	802.11b / b +	802.11b / g

As it is seen in Table 1, the most important parameter in the standards used in wireless communication is data transfer speed. It is very important to obtain high data speeds in high frequencies and to enable the secure transfer of the data in terms of data security and integrity. In order to answer the questions related with the coverage area in the design of today's wireless communication system, two important feature of the system should be analyzed. These are the dynamic range of the system and the propagation loss of electromagnetic wave, respectively. The dynamic range of the system is known by the designer. This is the definition of maximum loss of the signal – occurred in the communication channel between transmitter and receiver without losing its functionality - in terms of dB [7]. The propagation loss is the loss of energy on the path that the signal follows while going to the receiver. For this reason, the propagation loss is called as "path loss". The Free Space Propagation Model is used to calculate free space loss related with wireless system and to determine the signal power if there is no obstacle, in other words, if there is a direct line of sight [8].

Free Space Loss:

$$PL_{fs}(dB) = 10 \log \frac{P_t}{P_r} = -10 \log \left( \frac{G_t G_r L^2}{(4\pi)^2 * d^2} \right) \quad (1)$$

is defined in Figure (1).  $P_t$  is transmitter power,  $P_r$  is receiver power,  $G_t$  is transmitter antenna gain,  $G_r$  is receiver antenna gain,  $L$  is system loss independent from the propagation, ( $L \geq 1$ ) and  $\lambda$  are wave length in terms of meter.

While detecting the propagation loss in wireless communication systems, indoor applications such as cellular communication systems and wireless networks are also very important. Indoor propagation environment is very different from outdoor propagation environment due to high

weakening and low transmitter power originated from the distance between transmitter and receiver, internal walls and furniture. For the path loss calculations of environments, in which there is a direct line of sight between transmitter and receiver, Keenan-Motley and Logarithmic Distance empirical models are used.

In Keenan-Motley (KM) model, the path loss is found by adding a linear factor to the free space path loss, in terms of dB. This factor is detected as empirical and found in the studies. KM Model, known as Linear Path Weakening or Devasirvatham Model, is given with the following equation.

$$PL_{KM}[dB] = PL_{fs} + a \cdot d \quad (2)$$

(2) Here  $d$  is distance,  $PL_{fs}$  is free space path loss and  $a$  is linear weakening coefficient. Along with theoretical and measure-based propagation models, Logarithmic Distance model shows that the average signal taken is decreasing with the distance in both outdoor and indoor radio channels. The average big-scale path loss for a certain transmitter-receiver distance can be stated as the function of path loss coefficient as follows:

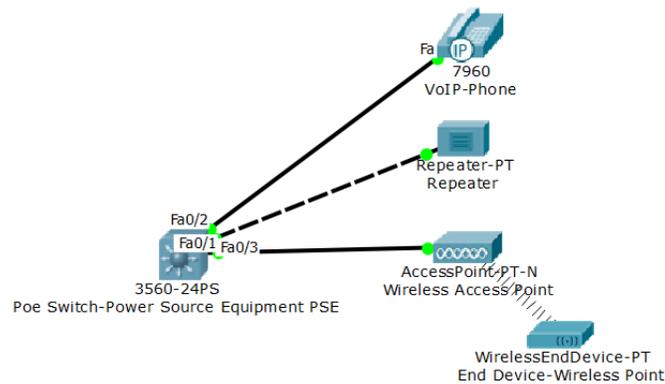
$$\overline{PL}(d) = \overline{PL}(d_0) + 10 \cdot n \cdot \log\left(\frac{d}{d_0}\right) \quad (3)$$

(3) Here “ $n$ ” is the path loss coefficient stating that the path loss changes with the distance and its value is dependent on the propagation environment.  $d_0$  is the reference distance that the measures near the transmitter are made and  $d$  is the distance between the transmitter and the receiver. The over-lines in the equation indicate the averages of all path losses possible for a certain value of  $d$ . [12]

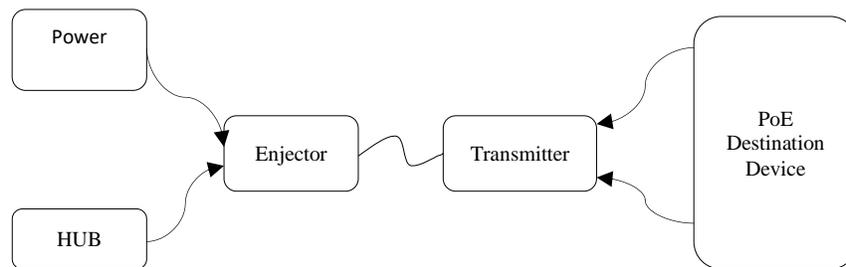
### 3. IEEE 802.3af Protocol

Power over Ethernet (PoE) means systems in which electrical signals are carried as well as data in an Ethernet cable. PoE (IEEE 802.3af) technology, developed by Cisco in 2000s, spread with VoIP technology. Especially, the spread of wireless networks is used to transmit powers to the wireless access points in places where there is no network and electrical infrastructure in local terms and to transmit wireless network signals in physical areas where wireless signals are weak or insufficient. [5]

As it is seen in Figure 1, the network devices functioning compatible with 802.3af protocol, also function with each other in a compatible way. We see that the wireless access points - mainly switch devices and VoIP telephones - are also used widely. The working principle is as follows: Data signals are carried through electric lines by overlapping data signals on electrical signals. The system is composed of two components; system source device and target device in which the power is carried. The data signals taken from Power Source Equipment (PSE) are carried with electrical signals through Powered Device (PD). The data signals are distributed to the electric line of places having same electric lines. With PoE devices, produced with different brand and models as cabled and wireless, data is transmitted through an Ethernet cable completely without requiring any additional cable or plug.



**Figure 1.** Powered Devices PDs IEEE 802.3af



**Figure 2.** Injector and Transmitter PoE Diagram [6]

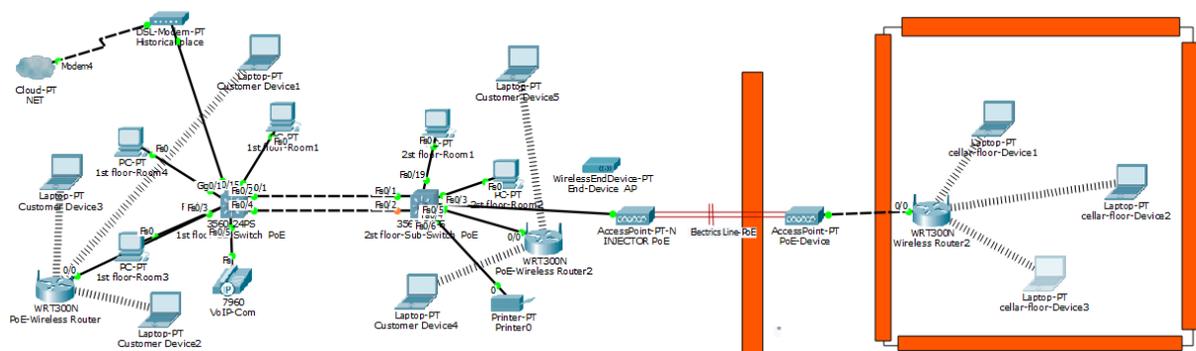
In Figure 2, there is a working principle of a device supported by 802.3af protocol. The data signals can be received with a receiver by injecting data signals overlapped on an electrical signal through current electrical line. With wireless networks, the usage areas of PoE technologies gradually increase. One of its main advantages is the use of one cable in the communication between switch and target devices. Easy and simple establishment removes the barriers such as positioning the device based on the distance between the device and electrical power source. The devices used as a target can be moved to the any point of the network. As there is no line voltage directly affecting the devices, it creates a secure environment.

#### 4. Related Work

In this study, a computer network was widened through an established wireless network topology in a place where physical cabling could not be applied. With a computer network established on a historical place, internet signals were brought even to the remotest points of the old structure. With PoE devices connected additionally to the same physical structure on the electrical signals, the topology was widened. The network topology of the study is given in Figure 6. The place where the physical topology is established is a 200 year-old historical mansion located in Safranbolu, the heritage city. The historical structure is still used as an accommodation place for tourism. The historical place consists of 2 independent buildings and a multi-purpose structure used as restaurant in front of these buildings. A computer network was designed in a place, which has a diameter of

circle, nearly 35 m. As it is a historical structure, cabling and positioning devices are prohibited. For this reason, in line with current data and energy line, a computer network was established in the two-story part of the building used for accommodation. As cabling could not be made particularly in the parts used as vault previously, wireless access points were positioned in these areas. However, due to the thickness of building walls and unsuitable inner plans of the building in physical terms, problems occurred while detecting appropriate dipole angles of wireless devices. Due to the architectural reasons and because of not capturing an appropriate angle, the signal power spread weakly and wireless signal could not be received in the remotest points.

In Figure 3, the network topology of the study is given. In current network topology, wireless access points can be seen. With switch devices positioned between two independent buildings, the network is scaled. The data is carried with the help of 802.3af supported devices as a wireless signal to the places called as dead points. The dynamic structure of the system in the building caused various propagations in electromagnetic wave. In order to remove signal weakening and solve problems based on outer factors, it was benefited from PoE technology (Power over Ethernet). The transfer of signals received through tandem switches to the remotest dead points through electric lines was enabled with network topology above. The data signal received with the help of injector through a switch was transferred on the electric line of the building. For the stories and dead points having same electrical infrastructure physically, data signals were sent to the indoor electric transmission line with the help of injector. On the other side, with PoE receiver distinguishing data signals from electric lines, data signals can be read in a secured way.



**Figure 3.** The extended final status System with PoE Devices

With the topology applied in the building, data signals were transferred without making any physical renovation in the building under protection. One of the most important points here is the architecture of the application field. In the physical environment strengthened with thick and solid walls, the transfer of data with minimum loss was made it possible with PoE devices. In the table below, the comparison of signal powers with the signals received from wireless devices can be seen. Access Points were affixed to the end points of PoE devices used for providing the transmission of wireless signals to the dead points. When the signals read in these access points were compared, it was observed that loss percentages were very low.

**Table 2.** Wireless Signal Levels Measured in AP and PoE

<b>RSSI dBm</b>	<b>High RSSI dBm</b>	<b>Signal% (without PoE)</b>	<b>High Signal% (without PoE)</b>	<b>Signal% (with PoE)</b>	<b>High Signal% (with PoE)</b>
-69	-68	50	60	88	92
-80	-76	20	28	89	93
-79	-76	18	28	87	92
-81	-76	16	28	93	95
-80	-75	20	30	95	95
-76	-73	28	34	95	96
-70	-68	40	60	86	92
-86	-75	8	30	94	96
-100	-80	0	20	93	96

In Table 2, result values of the application are given. In these measures made when the expected wireless data signals could not be received, it was observed that the signal quality was low at the beginning. When the results were reviewed after the adaptation of 802.3af supported wireless access points to the current network topology, it was observed that the data transfer speeds reached to the expected level.

## 5. Conclusions

In this application, studies were made physical places under architectural protection. For the areas having difficulties of cabling and positioning devices, a solution was found with the help of devices supporting 802.3af standard. With the help of IEEE 802.3af supported devices established in the areas called as dead point in terms of signal propagation and surrounded with high and thick walls, the signal level was read in normal values. The data signals transferred through current electric lines were transmitted to the remotest points as far as possible. Thereby, the wireless data signals were transmitted to the areas on which it was difficult to apply topology in architectural terms. By analyzing the signal propagation of the devices, results towards the design of productive topologies were obtained. With the designed topology, the productivity rates of values were obtained. It was reached to a conclusion that it is appropriate to use devices supporting IEEE 802.3af standard in the studies to be made in historical and touristic places.

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