TECHNICAL UNIVERSITY – SOFIA

DIPLOMA PROJECT

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Topic:

SIZING OF A WI-FI NETWORK IN A APARTMENT BUILDING

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ABSTRACT

This final thesis is about how to size a wireless network in an apartment building. This building is made up of ground floor and six more floors and it is situated in the neighborhood of "La Milagrosa" in Pamplona.

This project has the following objectives or parts:

The first chapter tries to introduce us in the radio frequency world and after that it makes a small introduction about the wireless technologies.

In chapter two it is explained the hardware that is going to be used in the building, the characteristics more than anything. The most important equipments are one access point, the antenna of the AP and the receiver laptop.

Chapter three is reserved to the parameters and the calculations; we are going to study the link budget and then the data and VoIP services.

Chapter four is one economic balance that shows us how many money has to be invert at first moments and how many years are going to be needed to retrieve this first inversion.

Finally, in chapter five there is a keyword list and at the end of the project we can find the bibliography.

ACKNOWLEDGMENTS

I dedicate this final project to my family, especially to my mother and father for the effort that they have made and continue making in my education, and for supporting me with the decision to undertake the project away from home.

I also want to dedicate the text to my brother, and I extend this dedication to the rest of my immediate family, and friends who have accompanied me before and in this adventure too.

Last but not least, I want to thank to the Public University of Navarre for give me the chance to accept the scholarship Erasmus. Also I thank to my tutor here at the Technical University of Sofia, Georgi Iliev, who always has tried to be available for me and for all of my doubts and to my mentor, Vladislav Slavov, who has made my stay in Sofia easier.

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CHAPTER 1 – THEORICAL INTRODUCTION

1 INTRODUCTION

Since the growth of Internet in 1990, data communications networks started to be the center of the stage instead of voice communications as had been hitherto. Broadband connectivity has become available using the wired infrastructure of the telephone and CATV companies, but its coverage is far from being optimal, is far from the ubiquitous. Anyway while these systems can address the low speed data requirements, the high speed data communications requirements can not be easily and economically met using copper wires. For this problem the optical fiber could be the solution, but it is not very feasible have to take the fiber to all houses or businesses.

Nowadays, the development of telecommunications is being oriented to an intensive use of quality broadband systems. This development is being possible thanks to high capacities technologies of transmission, such as xDSL, optical fiber or coaxial cable directly taken to the subscriber home. Generally these systems, based on cable, have a high cost of installation (construction, installation and put in service). Moreover if the installation is in a rural area the cost is higher. To address this situation and some technology and topological limitations, the wireless installations are being the solution. These wireless alternatives allow a rapid deployment of infrastructure and less cost of operation and maintenance.

Within this environment, the Wi-Fi and WiMax standards are developed to create a sane competitive alternative to wired and broadband access and transport media. Besides, they are introducing better and newer telecommunication services around the “cuadru play” (voice, image, data and mobility).

Initially, Wi-Fi was designed for indoor environments as one alternative for the structured network cabling. On the contrary, WiMax was designed as a last mile solution in metropolitan networks (MAN) to provide service in a commercial way.

Nowadays the WiMax manufacturers offer two kinds of links:
→ Point-to-point: to connect each other subscriber sites and for connecting to the base stations over long distances.
→ Point-to-multipoint: to connect home or enterprises subscribers to the base station.

Should be noted that the complementarity between Wi-Fi and WiMax is clear. We can make a totally wireless telecommunication system with Wi-Fi in the access network and with WiMax in the transport network. For example, we can make the connection between the Wi-Fi hot spot and its respective operators through WiMax.

Besides the WiMax manufactures, in point-to-multipoint access solutions, are including the possibility of Wi-Fi access in their equipments, causing a higher commercial versatility.

2 RADIO FREQUENCY CONCEPTS

2.1 ELECTROMAGNETIC WAVE AND RADIO FREQUENCY ENERGY

The intent of this part is just to let know some basic and easy concepts about radio and radio frequency. Radio is a word that makes reference to reception and transmission of electromagnetic wave that contains information.

RF Energy: it can be defined as an Alternative Current (AC) signal that forms a moving field of electric and magnetic force. The magnetic lines of forces are always perpendiculars from the electrics lines of forces. Moreover, the both lines of forces are perpendicular to the direction of travel. The plane in which the wave travels it is called "wave front" and it can have any position with respect to the earth. We could see a good RF energy in figure 1.

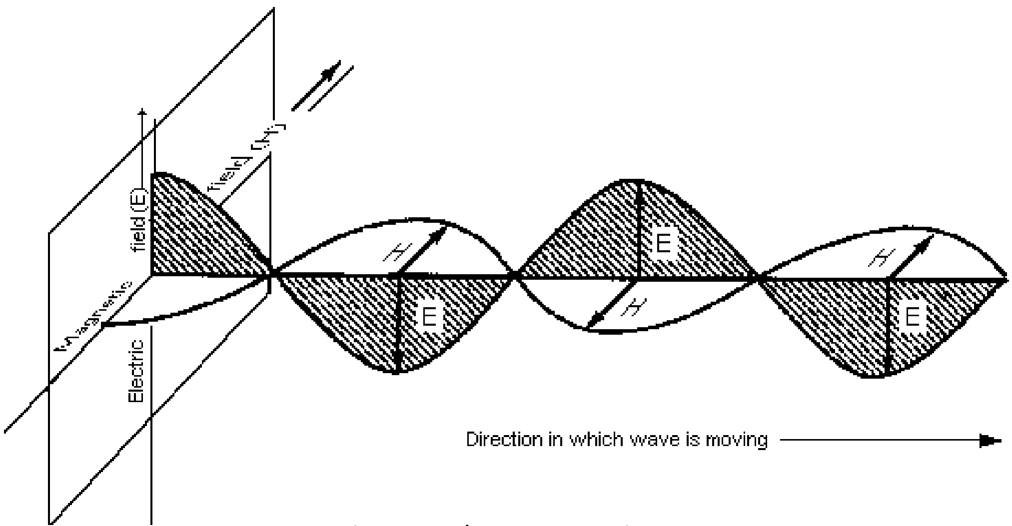

Figure 1: Electromagnetic wave

We can say that the RF field is defined by two important characteristics. The first one is the frequency (f) and the second one is the wavelength (w). These two characteristics are inversely proportional to each other. The first one is measured in Hertz and is the number of oscillations per second, so one hertz is a complete cycle of the sine wave per second. On the other hand the wavelength is used to be measured in meters and it is defined as the length of the sine wave.

In the atmosphere or in the space the relationship between these two parameters is the following: w=300/f (where “f” is the frequency in megahertz and “w” is the wavelength in meters). As we can see in figure 2, the amplitude is denoted by the maximum height above the zero-crossing.

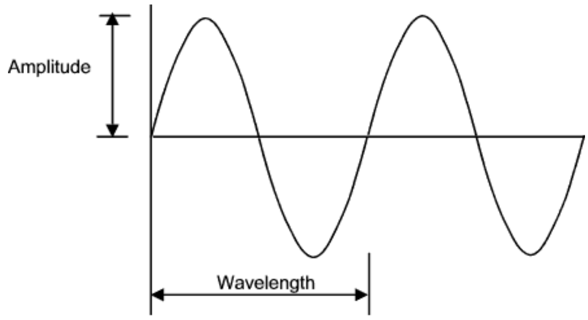

Figure 2: Amplitude and wavelength of a wave

2.2 RADIO FREQUENCY SPECTRUM

Radio spectrum refers to the part of the electromagnetic spectrum corresponding to radio frequencies (frequency lower than 300 GHz). Above 300 GHz, the absorption of electromagnetic radiation by Earth's atmosphere is so great that the atmosphere is effectively opaque, until it becomes transparent again in the near-infrared and optical window frequency ranges. In the following figure we are going to see what the locations of the radio frequencies are. As we could also see in the figure 3, if we keep increasing the frequency beyond the radio waves, the electromagnetic energy takes form of microwaves, infrared light and visible light. Moreover, if we follow increasing we could find ultraviolet light, X-rays, Gamma rays and Cosmic Rays.

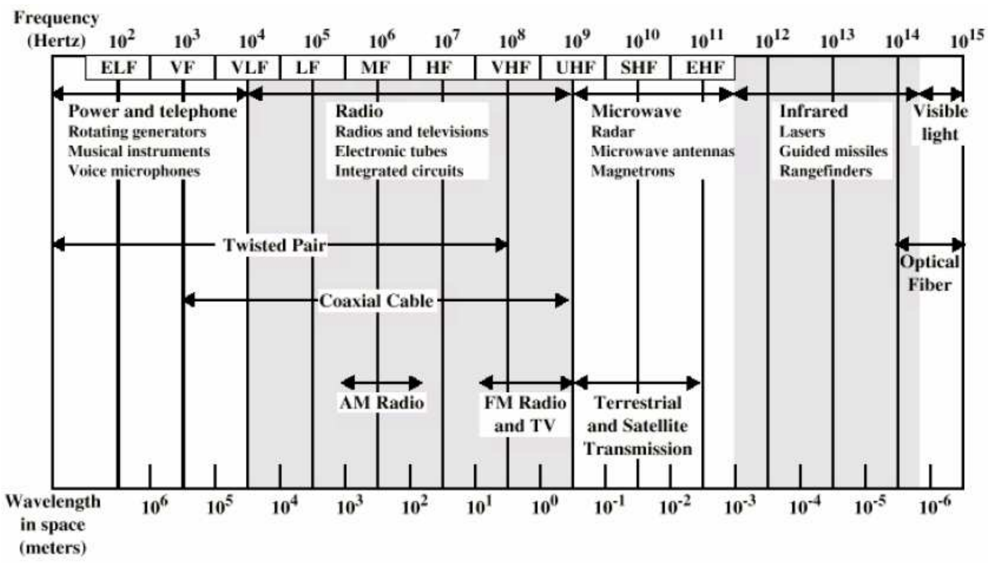

Figure 3: Radio Spectrum [4]

As the visible light that could be divided into different colours (depending on the wavelength), the radio frequency spectrum is divided into a number of frequency ranges (also called bands). Different parts of the radio spectrum are used for different radio transmission technologies and applications. Radio spectrum is typically government regulated in developed countries and, in some cases, is sold or licensed to operators of private radio transmission systems. In the table 1 below we are going to show the allocations of the bands and it's respectively relationships between the frequency and the wavelength.

Designation	Abbreviation	Frequencies	Free-space Wavelengths
Very Low Frequency	VLF	9 kHz – 30 kHz	33 km – 10 km
Low Frequency	LF	30 kHz – 300 kHz	10 km – 1 km
Medium Frequency	MF	300 kHz – 3 MHz	1 km – 100 m
High Frequency	HF	3 MHz – 30 MHz	100 m – 10 m
Very High Frequency	VHF	30 MHz – 300 MHz	10 m – 1 m
Ultra High Frequency	UHF	300 MHz – 3 GHz	1 m – 100 mm
Super High Frequency	SHF	3 GHz – 30 GHz	100 mm – 10 mm
Extremely High Frequency	EHF	30 GHz – 300 GHz	10 mm – 1 mm

Table 1: Wavelength /frequency ratio of the radio frequency bands [1]

2.3 RF GENERATION AND TRANSMISSION

The RF signal is created by the transmitter, which is formed by lots of different elements: Oscillator, synthesiser, modulator, power amplifier and antenna. Figure 4 show the block diagram of the RF generation.

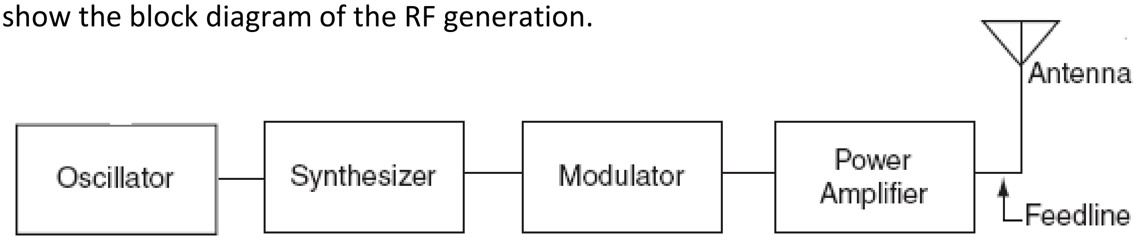

Figure 4: RF generation's block diagram [1]

● Oscillator:

The function of this element is basically to generate the base RF signal. We also could say that an electronic oscillator is an electronic circuit that produces a repetitive electronic signal. The most important characteristic is usually the frequency of their output signal. For instance, an RF oscillator produces signals in the radio frequency (RF) range of about 9 KHz to 300 GHz. To generate these signals, the oscillators are based on the principles of amplification, feedback and resonance. More exactly, one oscillator is an amplifier with one of its output connected to the input. On the other hand, the resonance is related with the size of the elements that are in the feedback loop, so if change some dimensions of any elements the frequency of tone will change.

● Power Amplifiers:

The function of this block, as its name says, is to create a higher power image of the signal that has in its input. So, it takes the low power signal that has been created by the oscillator and increased its level until it will be enough to be transmitted by the path across the transmitter and the receiver.

There are three important characteristics to take account in this part:

→ Power output: that is measured in watts.

→ Linearity: the operating parameters of the device that results in a linear gain relationship between the input and output. This parameter is often described by the "class" to which the amplifier belongs. A, AB, B, C, and D are the most common amplifiers class descriptors.

→ Efficiency: the ratio of power output to total power input. This value is expressed as a percentage and it is always less than 100%.

● Antennas and feed lines:

Now is time to connect the antenna with the transmitter or receiver. Usually the most used way is a coaxial cable, often called coax.

→ Coaxial cable, like twisted pair, consists of two conductors, but is constructed differently to permit it to operate over a wider range of frequencies. It consists of four elements: the center conductor, the dielelectric, the outer conductor and shield, and finally the outer jacket. A single coaxial cable has a diameter of from 0.4 to about 1 in. Because of its shielded, concentric construction, coaxial cable is much less susceptible to interference and crosstalk than is twisted pair. Coaxial cable can be used over longer distances and supports more stations on a shared line than twisted pair. One of the most important parameter of this kind of cables is the impedance. Lots of characteristic influence in the parameter, for instance, the diameter of the center conductor, the composition and diameter of the dielectric, the construction of the shield and the material of the outer jacket. In radio work the most common impedance is about 50-75 ohms.

The antenna is the last element of this part. There are many varieties of size and shapes. In general the antenna election is one of the most important parts when we want to implemented a wireless data system.

Antennas can be classified according to their directionality.

→ Isotropic: It generates a perfect sphere of energy around it that has equal intensity in all directions. It is an omnidirectional antenna (they created a field 360º around them). This kind of antennas is not real although the sun could be considered one of that.

→ Dipole: It is the simplest real-world antenna. Two equal length pieces of wire that are of a length that is resonant at the desired frequency (also omnidirectional).

→ Directional: These antennas concentrated its radiation in one direction; it can be approximate to a cone.

To specify the antennas we could use the gain of it. There are two possibilities, dBi and dBd. These terms are defined as dB of gain referred to an isotrope (dBi) and dB of gain referred to a dipole (dBd). Antennas behaviour is reciprocal, so they behave the same while transmitting or receiving.

2.4 RF RECEPTION

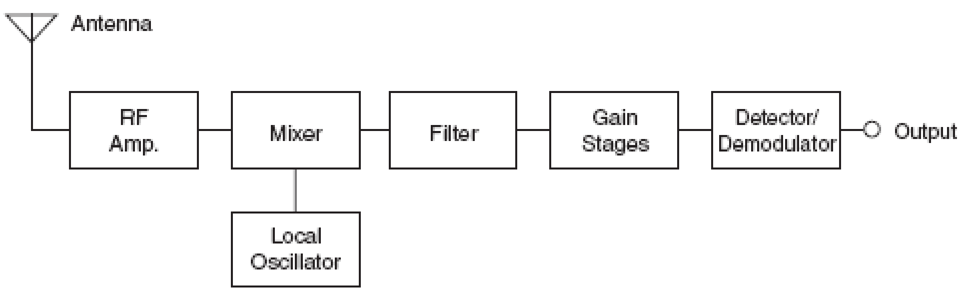

Figure 5: *RF reception's block diagram [1]*

The first step, as we could see in figure 5, is just to pass the EM field across the antenna in order to transformer it into an AC signal. After that, we have to introduce this signal into a RF amplifier because it has been attenuated by the environment. Moreover the signal in the antenna is also polluted by other RF sources. So the first thing that we have to do is use a bandpass filter in order to eliminated the signals that we do not want.

After that our signal has to go to the RF amplifier. This element is a weak-signal amplifier designed to deal with exceedingly small input signals. Two of the specifications that are used to define a RF amplifiers are sensibility (ability to discern a weak signal) and intercept point (how the devices behaves in the presence of large signals).

So now that the amplifier has increase the level of the signal is time to the mixer. The mixer has two inputs, one the signal from the RF amplifier and the other one signal from the local oscillator (LO). This element combines these two signals and gets 4 frequencies at the output. The first one is the frequency of the RF amplifier signal, the second one the LO frequency, the third one the sum of these two frequencies and the last one the difference between them.

The mix of signals goes trough a filter and after this, the allowed frequency enter in a series of amplifiers called intermediate frequency (IF) amplifiers.

3 WIRELESS TECHNOLOGIES

Thanks to the emergence and success of wireless communication protocols has been widely used in the use of such networks, mainly due to the interoperability of equipment from different manufacturers. This has led to develop products in a fast, making further that prices have been diminished due to the volume of production.

The different wireless technologies are often grouped based on the radius of action of each one of them as we can see in the figure 6. In follow pages we will study some of them (a little bit of WMAN and WLAN)

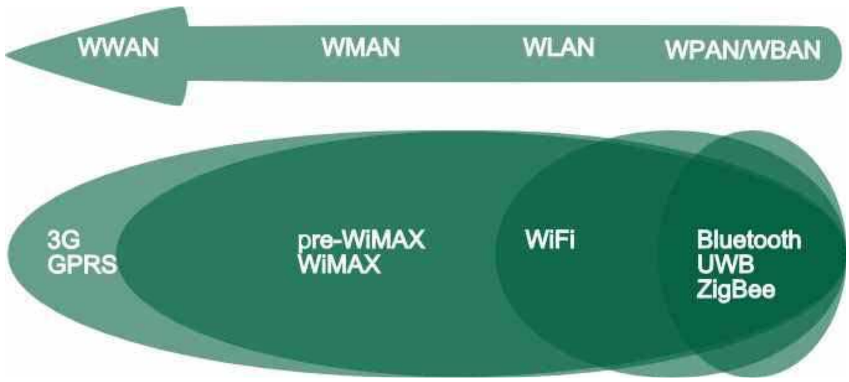

Figure 6: Different wireless technologies

3.1 ADVANTAGES OF WIRELESS

- Flexibility: They are flexible because they allow us to interconnect locations complicated, and besides can be adjusted easily to requirements imposed.

● Scalability: This quality refers to the ability to adapt and extend quickly the qualities of the network in terms of coverage and bandwidth is refers.

● Speed of deployment: The deployment of a wireless network is usually quite fast, especially if there is already equipment or a existing infrastructure (communication towers, street lights, water tanks located at high altitudes) that can be exploited to carry out the installation.

● Reduced cost: Depend on the case, but generally is less expensive deployment of a wireless network than a wired, especially if they join again the conditions mentioned in the previous section that there are some previous infrastructure to be exploited.

3.2 DISADVANTAGES OF WIRELESS

● Interferences: The propagation of electromagnetic waves through the interface air implies the risk that they may interfere with each other. The solution is to legislate the use of radio spectrum in terms of frequency and power allowed in each of these frequencies.

● Instability of the physical environment: Electromagnetic propagation through the air interface is highly complex phenomenon that is affected by factors such as weather conditions, presence of background noise, uncontrolled interference and other modifications of the physical medium that make conditions of radio links usually have a large variability.

● Transmission speed and delays: The factors described in the above two points are what cause the transmission rates are lower and longer delays than in transmissions carried by wired means.

● Security: Data transmitted by the air interface are likely to be heard by anyone with adequate media. With the development of authentication and encryption mechanisms, this problem is solved, as long as these mechanisms are properly implemented.

3.3 CLASSIFICATION OF TECHNOLOGIES ACCORDING TO THE DEGREE OF MOBILITY

Wireless data networks are often divided into several categories according to how the networks are viewed by the user. Such characteristics as fixed or mobile, point-to-point (PTP) or point-to-multipoint (PTM), licensed or unlicensed, and standards-based or proprietary are used to define the network. In reality, there are only two distinct types of networks: fixed or mobile. For purposes of definition fixed networks include networks that connect two or more stationary locations. The nomadic user is nominally a fixed user constrained by the bounds of coverage available on the network. In a truly mobile system, the service will be ubiquitously available, and support use while the user is in motion.

• **Fixed networks:** As its name suggests, the teams lack any mobility, while always in a fixed location.

Point-to-point: The simplest topology is a permanent link between two endpoints. Switched point-to-point topologies are the basic model of conventional telephony. The value of a permanent point-to-point network is unimpeded communications between the two endpoints. The value of an on-demand point-to-point connection is proportional to the number of potential pairs of subscribers, and has been expressed as Metcalfe's Law.

Point-to-multipoint: A point-to-multipoint link is a specific type of *multipoint link* which consists of a central *connection endpoint* (CE) that is connected to multiple peripheral CEs. Any transmission of data that originates from the central CE is received by all of the peripheral CEs while any transmission of data that originates from any of the peripheral CEs is only received by the central CE. This term is also often used as a synonym for multipoint, as defined above.

• **Nomadic networks**: Normal use of this technology is a stationary position, but with the possibility to move easily though not ensure the operability of the teams on the move.

• **Mobile networks:** These technologies are designed to be used while we are in movement. It is designed for true mobility. The high speed mobile data network must provide ubiquitous coverage, and must support high velocity mobility.

3.4 WMAN (IEEE 802.16 WIMAX)

3.4.1 Introduction

WiMAX (Worldwide Interoperability for Microwave Access) is a wireless networking standard that work with the interoperability of products based on IEEE 802.16. WiMAX technology offers greater range and bandwidth than the family of WiFi standards and offers a wireless alternative to wired backhaul facilities and those of last mile, in addition to providing extensive coverage areas.

• Backhaul: Point to point antennas used to connect subscriber sites each other and the base stations over long distances.

• Last mile: Point to multipoint antennas used to connect subscribers home or business to the base station.

• Access cover large areas: Use base stations, stations subscribers, and Wi-Fi solutions, such as mesh networks, to cover a large area and provide access to 802.16e-2005 customers.

3.4.2 Related standards

In the following table we will show the best-known standards:

Standard WIMAX	Approved	Frequency	Purpose
IEEE 802.16	Dec. 2001	10 to 66 GHz	
IEEE 802.16a	Jan. 2003	2 - 11 GHz	Fixed Broadband
IEEE 802.16-2004	Jun. 2004	from 2 to 66 GHz	Support for Users
IEEE 802.16e-2005	Dec. 2005	2 - 6 GHz	Add Mobility

Table 2: Standards related to WiMax

3.4.3 Basic elements of a network

• Base station:

WiMax base stations are computers that are generally booths located in the climate and energy shields necessary. A base station can theoretically cover up to 50 kilometers, but in practice is reduced to about 10 kilometers when it is considered that customers are partners (in the case of point to multipoint). WiMax base stations can offer:

- Point to point connections (for backhaul or radio).
- Point-to-multipoint connections (for last mile ...).

• WiMax Antennas:

- Omnidirectionals: They are used if the users are in all the directions.
- Sector antennas: Only give coverage to narrow sectors. 60º, 90º and 120º are the most popular.

- Panels: they are used in point-to-point applications, for example backhaul, where a long distance and a high rate of data are required.

Figure 7: Different kinds of antennas

• Repeater:

The repeater WiMax is a bidirectional transceiver designed to extend WiMAX services to shadow areas not covered by the main base station, extending the coverage or avoiding obstacles in line of sight between a WiMAX base station and remote user terminals.

While WiMAX provides capacity NLOS (Non-line of sight) and NNLOS (near non line of sight), in certain cases (high-frequency networks) this is not large enough to cross barriers such as mountains or steep terrain depressions, or by extending WiMAX services within buildings.

• Terminal equipment:

- Outdoor CPE (user equipment): it consists of an outdoor unit (an antenna) and an internal modem.
- Indoor CPE: It is a modem self installable.
- CPE integrated: WiMax data card included within the electronic device.

3.4.4 Infrastructure

The installation of WiMAX base stations is simple and inexpensive, using hardware that will become standard.

A point to point network is the simplest model of wireless network, composed of two radios and two high gain antennas in direct communication between them. These types of links are commonly used in high efficiency connections or high capacity interconnecting links. These links are easy to install, but difficult to create with them a large network.

A point-to-multipoint link share a given node (on the uplink), which is characterized by omnidirectional antenna (or multiple sectors), and a termination points (or repeaters) with directional antennas with high gain. This type of network is easier to implement than the point to point network, since the fact of adding a subscriber only requires incorporating equipment in the client side, not having to change anything in the base station. Although each remote site must be within the signal radio range, in the case of WiMAX, it will not require that these points have to be placed in a direct line of sight.

3.4.5 Applications

The first products that have begun to appear on the market are aimed to high-speed links for connecting to public fixed networks or to establish point to point links.

Thus, WiMAX may be a suitable to connect Wi-Fi hotspot to networks of operators, without having to establish a fixed link. Wi-Fi equipment is relatively cheap but an E1 or DSL is expensive and sometimes can not be deployed, so the radio seems very reasonable alternative.

For businesses, is an alternative to consider, since the cost can be up to 10 times lower than in the case of using an E1 or T1. Currently there is talk of WiMAX for residential access, but could soon be a reality, replacing with great advantage to an ADSL or cable, and making the revolution of broadband reaches every home.

Another of their applications fit in serving remote rural areas, which are not reached by wired networks. It is a technology well suited to establish radio links, given its powerful and high capacity at a cost competitive with other alternatives.

In developing countries it is a good alternative for the rapid deployment of services, competing directly with network-based infrastructure of satellites, which are costly and have high latency. It is also a good solution for rapid deployment of telecommunications networks in the event of natural disasters such as floods.

3.5 WLAN (IEEE 802.11 WI-FI)

3.5.1 Introduction

Wi-Fi is a trademark of the Wi-Fi Alliance, the trade organization that adopts and certifies that it meets test standards 802.11. Describe WLAN products based on IEEE 802.11 standards.

Initially it was very common in wireless that the access points were from one specific manufacturer and client stations were from other one, so the communication was impossible. For this reason, the Wi-Fi Alliance has standardized with the label the market. All equipment bearing the mark of Wi-Fi can work together, regardless of manufacturer.

Keep in mind three important points about Wi-Fi networks:

- They are very easy to acquire.
- They are quite complex to configure manually although there are friendly interfaces.
- It is extremely important their protection.

3.5.2 Related standards

In the table 3 we will show the best-known standards:

Standard	**Approved**	**Frequency**	**Throughput**	**Max. Speed**
Legacy	1997	2.4 GHz	0.9 Mbps	2 Mbps
802.11a	1999	5 GHz	23 Mbps	54 Mbps
802.11b	1999	2.4 GHz	4.3 Mbps	11 Mbps
802.11g	2003	2.4 GHz	19 Mbps	54 Mbps
802.11n	End of 2008	2.4 – 5 GHz	74 Mbps	300 Mbps
802.11y	June of 2008	3.7 GHz	23 Mbps	54 Mbps

Table 3: Standards related to Wi-Fi

3.5.3 Basics

• Physical layer of 802.11

The physical layer comprises two sublayers:

- PLCP (Physical Layer Convergence Protocol): Responsible for coding and modulation.
  Preamble (144 bits = 128 + 16 start frame sync).

HEC (Header Error Control): CRC 32
Modulation (spread) DSSS, FHSS or OFDM.

-PMD (Physical Medium Dependence): It is the one who creates and controls the communication interface to the MAC layer (via the SAP Service Access Point).

This level is made up of two main elements:

- Radio: Receive and generates the signal.
- Antenna: A variety.

In the following table we could see the modulations of each standard.

Modulation	**Standard**
802.11	FHSS, DSSS, IR
802.11b	DSSS
802.11g	DSSS and OFDM
802.11a	OFDM
802.11n	MIMO-OFD

Table 4: Standard and used modulation

Now we are going to comment very briefly the used modulations.

IR:

This transmission media was designed and used in the first versions of the standards 802.11. Its spectrum is between 850 and 950 nm and has around 1 or 2 Mbps of speed using the PPM modulation.

The disadvantage of the IR is that the transmitter and the receiver have to be very close, they need line of sight.

DSSS (direct-sequence spread spectrum):

As with other spread spectrum technologies, the transmitted signal takes up more bandwidth than the information signal that is being modulated. The name 'spread spectrum' comes from the fact that the carrier signals occur over the full bandwidth (spectrum) of a device's transmitting frequency. Certain IEEE 802.11 standards use DSSS signalling.

Direct-sequence spread-spectrum transmissions multiply the data being transmitted by a "noise" signal. This noise signal is a pseudorandom sequence of 1 and −1 values, at a frequency much higher than that of the original signal.

This new signal (noise-like signal) can be used to exactly reconstruct the original data at the receiving end, by multiplying it by the same pseudorandom sequence.

<u>FHSS (frequency-hopping spread spectrum):</u>

Frequency-hopping spread spectrum (FHSS) is a method of transmitting radio signals by rapidly switching a carrier among many frequency channels, using a pseudorandom sequence known to both transmitter and receiver. It is utilized as a multiple access method in the frequency-hopping code division multiple access (FH-CDMA) scheme.

<u>OFDM (orthogonal frequency-division multiplexing):</u>

It is a method of encoding digital data on multiple carrier frequencies. OFDM is essentially identical to coded OFDM (COFDM) and discrete multi-tone modulation (DMT), and is a frequency-division multiplexing (FDM) scheme used as a digital multi-carrier modulation method. A large number of closely spaced orthogonal sub-carrier signals are used to carry data. The data is divided into several parallel data streams or channels, one for each sub-carrier. Each sub-carrier is modulated with a conventional modulation scheme (such as quadrature amplitude modulation or phase-shift keying) at a low symbol rate, maintaining total data rates similar to conventional single-carrier modulation schemes in the same bandwidth.

• Link layer of 802.11

Respecting the OSI model this layer could be separated into two sublayers:
- MAC (Medium access control): It uses CSMA/CA and it is the attendant of the flow control. Now we are going to see which its functions are: exploration, authentication, association, security, RTS/CTS, energy saving mode and fragmentation.
- LLC (logical link control).

3.5.4 Basic elements of a network

• Access points.

It is a wireless central device of a Wi-Fi network that through wave radio frequency (RF) receives information from different mobile devices and transmitted via cable to the network server wired or vice versa.

The 802.11 standard is rather vague and does not clearly define all functions to be performed in an Access Point and only describes them in a very superficial way. This resulted in that each manufacturer design at their discretion and, therefore, there are dozens of market Access Points with very different features and functionalities.

It is advisable to keep the access point in a high to have a good transmitter / receiver. It is possible that if we do not have speed transmitter / receiver is expected due to poor location access point, or obstacles that stand between the point of access and Wi-Fi device (walls, doors ...).

• Wireless network adapters.

They come in many different types such as laptops, PDAs, mobile phones... These may have different types of cards installed, mainly:

→ Wi-Fi PCI cards are added to the desktop, they allow a very efficient access, the only downside to this type of card is that it requires opening the computer.

→ PCMCIA cards are a useful model for laptops. Although initially most of these cards were only able to reach technology 802.11b, currently, there are PCMCIA cards for 802.11g and even 802.11n technology (ahead of final approval).

→ USB cards for Wi-Fi are the most modern type of card that there and easier to connect to a PC (either desktop or laptop), using all the advantages of technology USB. Moreover most of the current USB cards allow using Wi-Fi technology, and moreover, some of them already offer the possibility of using the technology called 802.11n, which is not yet standardized.

• Others.

There are also amplifiers and some antennas that could be add to the Wi-Fi network. They are usually incorporate to get more directionality and to improve the radio signal. There are directional, omnidirectional and sector antennas.

3.5.5 Infrastructure

To dimension a Wi-Fi network is important to plan previously all the necessary things.

→ Which kind of topology: ad-hoc, with access point, or structural, without it.

→ The position of the access points (take into account the existing infrastructure, the bandwidth and the environmental conditions).

→ Which frequency we are going to use (bear in mind the interferences).

→ Good level of security: the IEEE 802.11 standard describes the protocols and techniques of two options to build and use the RF wireless LAN.

1) The first one is Independent Basic Service Set (IBSS) without access point.
2) The second one is Basic Service Set (BSS) with access point.

These days there is a new type of network, which is a combination of the two previous, it is called Mesh network.

3.5.6 Information transmission

The information is carried by packets. The standard IEEE 802.11 defines three different kinds of packets:

<u>• Management packages</u>

They establish and maintain the communication. These are the most commons:

•Association request: It contains necessary information to the access point to consider the possibility of connexion. For example, it contains the information of the SSID of the Wi-Fi network.

•Association response: The access points send this packet to accept or to refuse the connexion request.

•Beacon: APs periodically send signals to advertise their presence and that all stations that are on the range know which access points are available.

•Authentication: Thanks to this packet the access point accepts or refuses the station that it is requesting the connection.

•Disassociation: It is a type of packet sent by the station when you want to terminate the connection, so the Wireless Access Point knows he can have the resources that had been assigned to that station.

• <u>Control packages</u>

•Request to Send (RTS): Its function is to avoid collisions. This is the first step before sending data packets.

•Clear to Send (CTS): Its function is to respond to the RTS. All stations that capture a CTS, know they must wait a while to pass because someone is already using the channel. There is a waiting time (time slot) that is different to the standard Wi-Fi 802.11b and 802.11g Wi-Fi for the standard.

•Acknowledgement (ACK): The receiving station of the packet, it checks if the received packet has errors. If it found correct, it sends an "ACK" with which the sender knows that the package was correct, because if not, you must send again. Once the other stations capture the ACK, they know that the channel is free and can try them send their packets.

• <u>Data packages</u>

These packages have a lot of "administrative" information, and also the data that we want to transmit through the wireless network access.

Generally, the Wi-Fi wireless network must use many data packets to transmit a data file. Much more when it is desired to transmit video. Data packets Wi-Fi have many fields with information necessary for transmission. One is the "Mac Address" of the receiving station and the sender, the BSSID, the sequence number of that package, etc...

3.5.7 Roaming

Wireless access points have a coverage radius of approximately 100 meters (although in practice can be very variable).

If we allow the roaming and mobility of users, it is necessary to place the access points so that there is overlap between the radiuses of coverage.

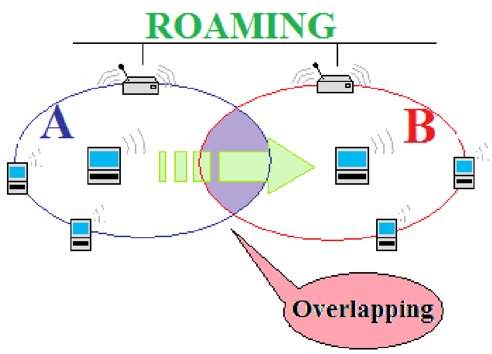

Figure 8: Roaming and overlap area

In the figure 8 we can see the area of overlap indicated by the red arrow and how we can move from A to B without losing the Wi-Fi signal. Initially the user is connected to the access point A and just in the next instant the user is connected to access point B.

4.5.8 Calculations of users by access point

As more users are connected, the bandwidth will be shared between them, and if the available bandwidth for each one is too small, the connection will be very poor.

For make the estimation it is necessary to know the users profile and what kind of applications they use, because the bandwidth consume can change a lot depending if they download or upload AutoCAD graphics for example or the only use internet to check text files.

Once you set the bandwidth needed for each group (accounting, engineering, designers ...) it is necessary to analyze the percentage of network utilization. For example, sellers may be visiting customers or talking on the phone and not using the internet all the time.

Formula to calculate the necessary access points:

$$\frac{\text{BW * Number of Users * Percentage of Use (\%)}}{\text{Progammed Speed}} \qquad (1)$$

Example of calculation in a Wi-Fi network:
Required BW: 1Mbps
Number of users: 100
Average network utilization: 25%
Estimated speed: 5’5 Mbps

$$\frac{\text{1 Mbps * 100 users * 0.25}}{\text{5.5 Mbps}} = \text{4.5 AP} \rightarrow \text{5 AP} \qquad (2)$$

4.5.9 Applications

These are some of the possible applications of this technology:

- Business private network services: corporate private networks, wireless extension, universities and educational campus environments that create an extended network for educational purposes, libraries that offer new possibilities in culture...

- Use personal or private community networks: typical household uses for the interconnection of personal computers.

- Architectural reasons (zoning laws, protection of historic buildings, etc...) Wireless solutions provide an easy implementation and high earning power. The use of wired systems can be a problem in cases of existing buildings, the land laws and municipal ordinances for the protection of historic buildings can multiply the costs and technical problems cause the manager to deploy wired networks.

- Hot Spot: It corresponds to the creation of electronic networks for the provision of wireless services, Internet access primarily in specific locations which concentrates a large number of potential customers, transit sites or public roads. Typically these types of service points are located at airports, train stations, shopping centers, hotels, subways, convention centers, cafes or restaurants.

There are available cities maps in those states where are the access points or hot spots, and if the network is open or closed, as we can see in this map of New York in figure 9. They make maps of volunteers circulating in their car with a portable Wi-Fi and GPS, detecting access points. This activity is called wardriving.

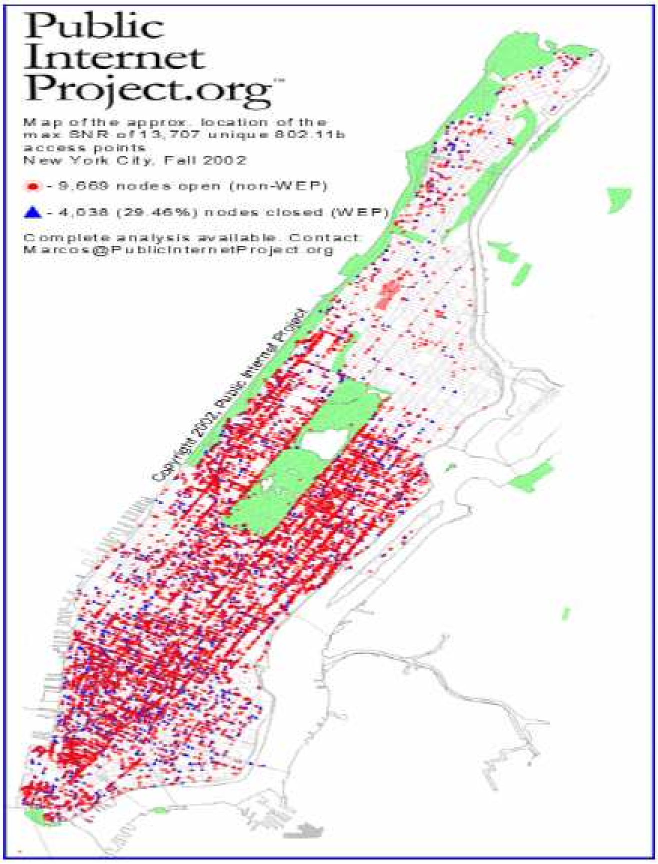

Figure 9: Open and closed access points from one part of New York City

CHAPTER 2 – HARDWARE DESCRIPTION

1 ACCESS POINT, TP-Link TL-WA901ND Access Point

Figure 10: Access point

<u>Software Specification:</u>

* Standards IEEE 802.11g IEEE 802.11n, IEEE 802.11b

* Wireless Signal Rates
  11N: Up to 300Mbps (Dynamic)
  11g: 54Mbps (dynamic)
  11b: up to 11Mbps (dynamic)

* Frequency Range 2.4-2.4835GHz

* Wireless Transmit Power 20dBm (MAX)

* Modulation Technology DBPSK, DQPSK, CCK, OFDM, 16-QAM, 64-QAM

* Wireless Mode
  AP Mode
  Multi-SSID Mode
  AP Client Mode
  Repeater Mode (WDS / Universal)
  AP Bridge mode (point to point or point to multipoint)

* Easy to set up a WPA encrypted secure connection with the push of a button QSS

* Supports Wi-Fi Multimedia (WMM) assures quality of VoIP and multimedia streaming.

<u>*Hardware specification:*</u>

* Interface 1 10/100 RJ45 Ethernet port, PoE Support *

* Power Supply Input: located in the country of sale

* Output: 12VDC / 1.0A Switching PSU

* Operating Temperature 0oC ~ 40oC (32oF ~ 104oF)

* Storage Temperature-40oC ~ 70oC (-40oF ~ 18oF)

* Relative Humidity 10% ~ 90%, no condensing

* Storage Humidity 5% ~ 95% without condensation

* Dimensions 6.9 * 4.7 * 1.1 inches (174 * 120 * 28.8 mm)

2 AP'S ANTENNA

* Detachable antenna enables strong updates of the antenna

* Antenna Omni Directional 4dBi x3

3 LAPTOP

Figure 11: Laptop

Communication:

* 10 / 100 / 1000 Gigabit Ethernet LAN
* Intel® Centrino® Advanced-N 6235, 2x2 802.11 abg/n (up to 300Mbps)
* Bluetooth V 4.0
* Sensitivity -84 dBm

I/O Port:

* VGA available
* HDMI available
* Headphone-out
* Mic-in available
* Internal Mic available
* Display Port available
* 2 USB 3.0, 2 USB 2.0
* 7-in-1 (MS, MS Pro, SD, SDHC, MMC, MMC plus, xD)
* RJ45 (LAN) available
* DC-In (Power Port) available

Multimedia:

* HD Audio
* Dolby Home Theatre®
* 4W Stereo Speaker (2W x 2)
* sub-Woofer
* 2.0 megapixel Webcam

Software:

* OS DVD
* System S/W Media
* Adobe Acrobat Reader
* Samsung Support Centre
* Microsoft Office Starter 2010
* Windows Live
* Norton Online Backup (30-day Trial)
* Skype
* Cyberlink Media Suite BluRay
* Cyberlink Youcam

CHAPTER 3 – CALCULATIONS

1 LINK BUDGET

Link budget is the accounting of all of the gains and losses from the transmitter, through the medium (free space, cable, waveguide, fiber, etc.) to the receiver in a telecommunication system. It accounts for the attenuation of the transmitted signal due to propagation, as well as the antenna gains, feedline and miscellaneous losses. Randomly varying channel gains such as fading are taken into account by adding some margin depending on the anticipated severity of its effects. The amount of margin required can be reduced by the use of mitigating techniques such as antenna diversity or frequency hopping.

The used equation is this one:

L (dB) = Ptx(dBm) + Gtx(dBi) - Prx(dBm) + Grx(dBi) + Gdv(dBi) - M(dB) (3)

Where, Ptx is the AP power, Gtx is the gain of the AP's antenna, Prx is the sensitivity of the receiver (in our case the sensitivity of the laptop), Grx is the gain of the receiver's antenna (if it exist), Gdv is the diversity (only if we are working with MIMO) and M is the fading margin.

First of all we have to choose which Wi-Fi standard we are going to use in our building and choose the AP and the laptops.

Wi-Fi standard:

802.11b
Freq. 2.4 GHz
Max Speed: 11 Mbps

AP Characteristics and laptops sensitivity:

Ptx = 20 dBm
Gtx = 4 dBi
Prx: -84 dBm

Our receivers are laptops, so the Grx is going to be 0 dBi and as we are not using MIMO the diversity (Gdv) is going to be also 0 dBi.

For the last parameter, fading margin M, we are going to take into account two possibilities:

1) The first one is an imaginary situation; M is going to take the value of 10 dB. But this is unusual situation because actually we are not in a free space building; there are roofs, walls (made by bricks for example) and lots of different obstacles.

L = 20 +4 - (- 84) + 0 + 0 - 10 = 98 dB **(4)**

And now we are going to apply the free space loss formula:

20 x Log (Freq. in MHz) + 20 x Log (Distance in miles) + 36.6 (5)

98 = 20 x Log (2400 MHz) + 20 x Log (D) + 36.6 (6)

98 = 67.6 + 20 Log (D) + 36.6 (7)

-6.2= 20 Log (D) (8)

-0.31= Log (D) (9)

D = 10^-0.31 (10)

D = 0.49 miles ≈ 0.79 Km

So, with just one access point it would be enough for the whole building. But we must remember that this is not a real situation.

2) The second possibility is more realistic, all the values are equals except for the fading margin that now is going to have a higher value, "M" is going to be 19 dB. With this change we are representing that there are some different things between our AP and the receiver laptops.

L = 20 +4 - (- 84) + 0 + 0 - 19 = 89 dB **(11)**

And now we are going to repeat the same process:

20 x Log (Freq. in MHz) + 20 x Log (Distance in miles) + 36.6 (12)

89 = 20 x Log (2400 MHz) + 20 x Log (D) + 36.6 (13)

89 = 67.6 + 20 Log (D) + 36.6 (14)

-15.2= 20 Log (D) (15)

-0.76= Log (D) (16)

D = 10^-0.76 (17)

D = 0.17 miles ≈ 0.28 Km

So, with just one access point it would be enough for the whole building, but, as we can see and comparing with the first possibility, the network area now is smaller. It is something logical because with more obstacles in the way, the waves suffer more attenuation and in consequence they loss power.

In the next table we are going to study the effect of the fading margin while we increase it and we left the other parameter in the same way:

Fading margin (dB)	Distance (Km)
10	0.79
15	0.44
19	0.28
22	0.2

Table 5: The effect of the fading margin in the distance

2 DIFFERENT SERVICES

In this headland we are going to study the required bandwidth for only two kinds of services. The first service is “data” and for the second one is “Voice over IP” (VoIP).

2.1 DETERMINATION OF THE BANDWIDTH FOR DATA

The first thing that we have to know is what kind of building we have. In our case it is a “home building”. As everybody knows the consumption of the bandwidth in one house each hour is different as we can see in figure 12.

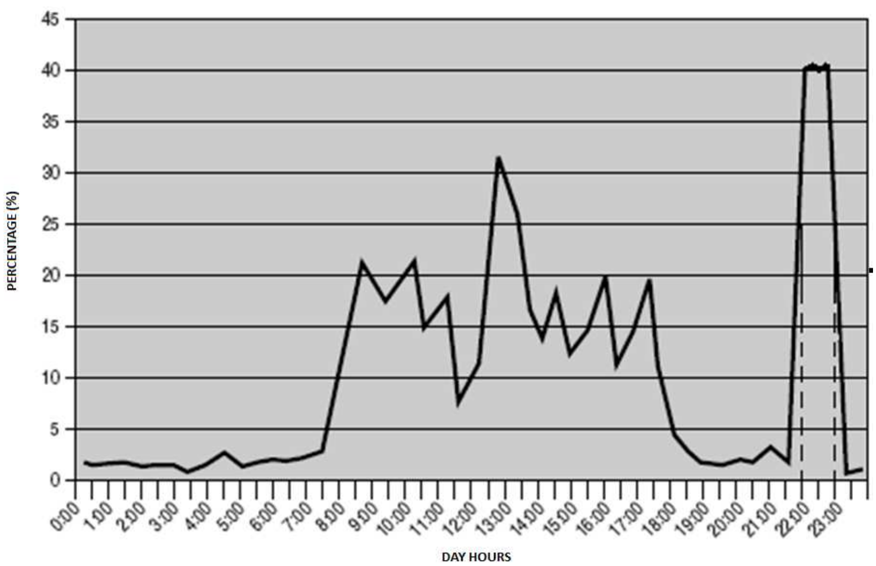

Figure 12: Consumption of home subscriber bandwidth in a different part of the day

Now to determinate the data per second in one house in the maximum load on network, we are going to follow the next reasoning:

Consider that a home subscriber network used to exchange information about 200GB per month. We can make the following accounts:

$$(200GB/month)*(8\ bits) = 1600\ Gbit/month \quad (18)$$

$$\frac{1600\ Gbit/Month}{30\ Days} = 53\ Gbit/Day \quad (19)$$

As we can see in figure 12, the statistics 40% of total use is at night, from 22:00 to 23:00. This is the period of maximum load on the network, so:

$$(53\ Gbit/day)*0.4=21.2\ Gbit/hour \quad (20)$$

$$\frac{21.2\ Gbit/hour}{3600\ sec} = 5.9\ Mbps \quad (21)$$

Summarizing, the data per second in one house in the maximum load on network is 5.9 Mbps.

Now, in table 5, we are going to see how would change the data per second if the gigabyte per month is another one.

135 GB/month	**200 GB/month**	**300 GB/month**	**400 GB/month**	**500 GB/month**
1080 Gbit/month	1600 Gbit/month	2400 Gbit/month	3200 Gbit/month	4000 Gbit/month
36 Gbit/day	53 Gbit/day	80 Gbit/day	107 Gbit/day	133 Gbit/day
14.4 Gbit/hour	21.2 Gbit/hour	32 Gbit/hour	42.8 Gbit/hour	53.2 Gbit/hour
4 Mbps	5.9 Mbps	8.9 Mbps	11.9 Mbps	14.8 Mbps

Table 6: Required bandwidth for different categories of subscribers

2.2 DETERMINATION OF THE BANDWIDTH FOR VOICE OVER IP (VoIP)

Voice over IP (VoIP, or voice over Internet Protocol) commonly refers to the communication protocols, technologies, methodologies, and transmission techniques involved in the delivery of voice communications and multimedia sessions over

Internet Protocol (IP) networks, such as the Internet. Other terms commonly associated with VoIP are IP telephony, Internet telephony, voice over broadband (VoBB), broadband telephony, and broadband phone.

First of all, we have to understand the process that suffers the voice in the service of VoIP. The laptop (or VoIP Smartphone, gateway…) will encrypt and encapsulate the voice into a suitable format for IP network. On the other hand, the receiver will do the inverse process, it will decapsulate and decode the data back into voice.

The combination of encoding and decoding is briefly called a codec. There are different types of codecs. They set a different voice quality and other necessary requirements as the bandwidth. The main idea is that if you want more quality you need more bandwidth.

In table 6 there are some basic types of codecs and their bit rate (bandwidth consumed).

Codec	**Bit rate**
G.711	64 kbps
Internet Low Bit rate Codec (iLBC)	15.2 kbps
G.729	8 kbps
G.726	32 kbps
G.729a	8 kbps
G.728	16 kbps

Table 7: Different VoIP codecs and bit rates

Some of the most used are G.711, G.729, G.726 and G.728. Most VoIP routers support some or all of these.

For our building we are going to use G.711 codec. It is an ITU-T standard for audio companding. It is primarily used in telephony. The standard was released for usage in 1972. Its formal name is Pulse code modulation (PCM) of voice frequencies. It is required standard in many technologies, for example in H.320 and H.323 specifications. It can also be used for fax communication over IP networks (as defined in T.38 specification). G.711, also known as Pulse Code Modulation (PCM), is a very commonly used waveform codec.

Codec affects bandwidth required for voice, because it determines the amount of payload into IP packets. In gateways we can adjust the size of the payload to regulate strip. By increasing the payload in the packet, it is sent fewer packets, thus we are saving bandwidth because of the small number of headers that are sent to a call.

First of all we are going to study the required bandwidth without taking into account the headers (only the speech information and taking samples every 10 ms). The required calculations are easy:

(80 octets/packet) *(100 packet/sec) = (8000 * 8 bits) / 1000 = **64 kbps** **(22)**

Secondly, we are going to add some headers. Each packet of G.711 is composed by 80 octets of information (one sample), 20 octets of IP (Internet Protocol, Internet layer), 8 octets of UDP (User Datagram Protocol, Transport layer) and 12 octets of RTP (Real time Transport Protocol, Application layer). As we can see, the calculation does not include link layer headers.

Now, if every 10ms we take a sample of the speech and If there is only **one** sample in a package, we get:

80 octets + 20 oc. IP header + 8oc. UDP + 12oc. RTP = 120 octets/packet (23)

(120 octets/packet) *(100 packet/sec) = (12000 * 8 bits) / 1000 = **96 kbps** **(24)**

Now we are going to take samples of the speech every 20ms and in each packet there are going to be **two samples**, in other words, the information part of the packet is going to have 160 octets, 80x2=160, so this is what we get:

(80 octets)*2 + 20oc. IP header + 8oc. UDP + 12oc. RTP =200 octets/packet (25)

(200 octets/packet) * (50 packet/sec) = (10000 * 8 bits) / 1000 = **80 kbps** **(26)**

The results show that there is 16 kbps difference between the two cases. As we can see, by changing the number of samples in a package, the required bandwidth changes, but it is a matter of compromise. When we increase the number of samples in the package, we are also increasing the delays.

CHAPTER 4 – ECONOMIC EVALUATION

In this chapter we are going to think that we are a great company that installs this kind of WLAN networks in buildings. So, first of all, we are going to study what is the price of the whole installation, and then we are going to think a reasonable fee for apartment in order to retrieve the money that we would have invested at first in a reasonable period of time. We have to make clear that this is not a real study.

1 COST OF THE INSTALLATION

As we can see in table 8, we have put 23 laptops in the estimate of this first inversion. This is because the company pays one of these laptops per house, that's mean that if the proprietary of the house wants more than one PC, he or she will have to pay it with his or her own money.

Units	Description	U. price	Subtotal
Devices			
1	TP-Link TL-WA901ND Advanced Access Point 11n	255,99	255,99
23	RF511 15.6" High Performance Laptop	706	16238,00
20	Flexible twisted pair (UTP) Category 6 with RJ45-Male connectors and rubber covers on both ends.	0,98	19,60
Installation			
8	Labor installing twisted-pair network Telecommunication Installer 2nd Category	16,2	129,60
16	Labor programming the network and supervising the installation Telecommunication Installer 1st Category	21,68	346,88

Table 8: Cost of installation

TOTAL= 16990, 07 €

1 PAYBACK

To recover this initial investment, the company was proposed two years. In the first the year, is thought to recover approximately sixty per cent of investment. Therefore, the remaining 40 percent will be recovered during the second year. From there, from the third year, all the collected money will be consider profit.

So, the first year each apartment will pay a fee, the second year they will pay a lower rate and from the third year, we will decide the rate to be paid per month.

According to this, we are going to calculate which the fees per month and per house are.

The retrieved money in the first year will be the 60% of the total 16990.07€, so:

16990.07 *0.6= 10294.04€ (27)

Therefore, per month:

10294.04/12= 849.50 € (28)

And finally, the fee that **one house** has to pay per month during the **first year** is:

849.50 /23= 36.93€ ≈ **40€/month** (29)

Secondly, the retrieved money in the second year will be the 40% of the total 16990.07€, so:

16990.07 *0.4= 6796.03€ (30)

Therefore, per month:

6796.03/12=566.33 € (31)

And finally, the fee that **one house** has to pay per month during the **second year** is:

566.33 /23=24.62€ ≈ **25€/month** (32)

From the **third year**, the fee of **one house** will be **23€/month**. So the retrieved money in one year is the next one:

23*23= 529 €/month (33)

529*12= **6348 €/year** (34)

KEYWORD LIST

· 802.11
· 802.16
· Access Network
· Access Point
· ADSL (Asymmetric digital subscriber line)
· Antenna
· Broadband
· CPE (Customer Premise Equipment)
· ETSI (European Telecommunications Standards Institute)
· FCC (Federal Communications Commission)
· FDD (Frequency Division Duplex)
· HiperLAN (Local Area Network)
· HiperMAN (Metropolitan Area Network)
· IEEE (Institute of Electrical and Electronics Engineers)
· IP (Internet Protocol)
· IPSec (IP security)
· ISDN (Integrated services Digital Network)
· ISM Band (Industrial, Scientific and Medical)
· MAC Layer (Media Access Control)
· Modulation
· NLOS (None Line of Sight)
· OFDM (Orthogonal Frequency Division Multiplexing)
· OFDMA (Orthogonal Frequency Division Multiple Access)
· OSI (Open System Interconnection)
· TDD (Time Division Duplex)
· UIT (International Telecommunication Union)
· UDP (User Datagram protocol)
·VoIP (Voice over IP)
· WiBro (Wireless Broadband)
· Wi-Fi
· Wi-Fi Alliance
· WiMAX
· WiMAX Forum
· Wireless
· WLAN (Wireless Local Area Network)
· WMAN (Wireless Metropolitan Area Network)

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SIZING OF A WI-FI NETWORK IN A BLOCK OF FLATS LOCATED IN A TOWN CENTER

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Abstract: This final thesis is about how to size a wireless network in an apartment building. This building is made up of ground floor and six more floors and it is situated in a town center. The fist step that we are going to analyze is the hardware that we are going to use. Secondly we will study one important parameter called "link budget" and then we will see the required bandwidth for services like data transfer and voice over IP in these kinds of houses. Finally we will see the necessary money to implement the Wi-Fi network and the necessary time to retrieve the money if we would be a company that used to invert money in this business.

Key words: AP (Access Point), IP (Internet Protocol), UDP (User Datagram protocol), VoIP (Voice over IP), Wi-Fi, WiMax, Wireless, WLAN (Wireless Local Area Network), WMAN (Wireless Metropolitan Area Network)

1. Introduction

Since the growth of Internet in 1990, data communications networks started to be the center of the stage instead of voice communications as had been hitherto. Broadband connectivity has become available using the wired infrastructure of the telephone and CATV companies, but its coverage is far from being optimal, is far from the ubiquitous. Anyway, while these systems can address the low speed data requirements, the high speed data communications requirements can not be easily and economically met using copper wires. For this problem, the optical fiber could be the solution, but it is not very feasible have to take the fiber to all houses or businesses.

Nowadays, the development of telecommunications is being oriented to an intensive use of quality broadband systems. This development is being possible thanks to high capacities technologies of transmission, such as xDSL, optical fiber or coaxial cable directly taken to the subscriber home. Generally these systems, based on cable, have a high cost of installation (construction, installation and put in service).

To address this situation and some technology and topological limitations, the wireless installations are being the solution. These wireless alternatives allow a rapid deployment of infrastructure and less cost of operation and maintenance. Besides, they are introducing better and newer telecommunication services around the "cuadru play" (voice, image, data and mobility).

Initially, Wi-Fi was designed for indoor environments as one alternative for the structured network cabling. On the contrary, WiMax was designed as a last mile solution in metropolitan networks (MAN) to provide service in a commercial way.

We should note that the complementarity between Wi-Fi and WiMax is clear. We can make a totally wireless telecommunication system with Wi-Fi in the access network and with WiMax in the transport network. For example, we can make the connection between the Wi-Fi hot spot and its respective operators through WiMax.

2. Hardware Description

In this project the used hardware is very simple. We have to take into account that we are going to name only the indoor devices, so the three important thing that we need are; one AP (access point) with its corresponding antenna and the receiver, in our case, we have decided that they are going to be laptops.

3. Link Budget

Link budget is the accounting of all of the gains and losses from the transmitter, through the medium (free space, cable, waveguide, fiber, etc.) to the receiver in a telecommunication system. It accounts for the attenuation of the transmitted signal due to propagation.

The used equation is this one:

$$L = Ptx + Gtx - Prx + Grx + Gdv - M \quad (1)$$

Where, Ptx is the AP power, Gtx is the gain of the AP's antenna, Prx is the sensitivity of the receiver (in our case the sensitivity of the laptop), Grx is the gain of the receiver's antenna (if it exist), Gdv is the diversity (only if we are working with MIMO) and M is the fading margin.

We are going to work with the Wi-Fi Standard 802.11b and the characteristics of our devices are going to be the next ones:

· AP power: Ptx = 20 dBm
· AP antenna gain: Gtx = 4 dBi
· Sensitivity of laptop: Prx: -84 dBm

Our receivers are laptops, so the Grx is going to be 0 dBi and as we are not using MIMO the diversity (Gdv) is going to be also 0 dBi.

But the most important parameter in Eqn. (1) is the last one. Fading margin is the amount by which a received signal level may be reduced without causing system performance to fall below a specified threshold value.

First of all we are going to study an imaginary case. M (fading margin) is going to be 10 dB. We say that it is an imaginary case because the value of 10 dB is reserved for open space calculations without obstacles. If we replace all the values we have got this:

$$L = 20 + 4 - (-84) + 0 + 0 - 10 = 98\text{dB} \quad (2)$$

And now we are going to apply the free space loss formula, Eqn. (3), to get the coverage of our wireless network. As we can see the only value that we do not know is the distance of the coverage, because the frequency we know that is 2.4 GHz (Standard 802.11b).

$$L = 20 \cdot \log(\text{frq.MHz}) + 20 \cdot \log(\text{dist.miles}) + 36.6 \quad (3)$$

$$D = 0.49 \text{ miles} \approx 0.79 \text{ km} \quad (4)$$

As we say, this is an unreal situation but in Table 1, we are going to see the effect that has in the distance, the increasing of the fading margin. This would be the real indoor situations with obstacles (roofs, walls, objects…) between the AP and the receiver.

Table 1. The fading margin effect in the distance.

Fading margin (dB)	Distance (Km)
10	0.79
15	0.44
19	0.28
22	0.2

We can see that if we increase the fading margin, the distance gets smaller.

4. Required Bandwidth for Data Transfer

The first thing that we have to know is what kind of building we have. In our case it is a "home building". As everybody knows the consumption of the bandwidth in one house each hour is different. As we can see in Fig. 1, the maximum load is at 22:00 and the value is 40 %.

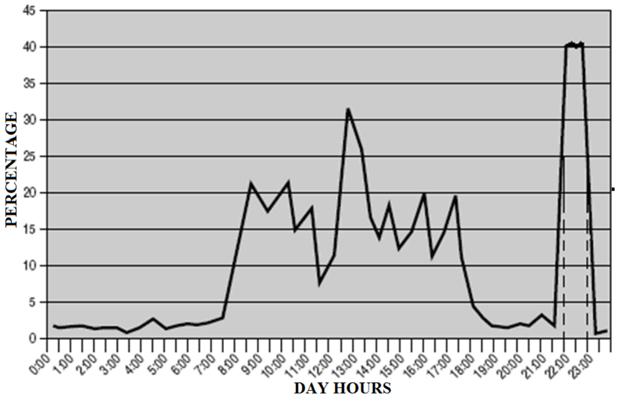

Fig. 1 Consumption of home subscriber bandwidth in a different part of the day

Now, to determinate the data per second in one house in the maximum load on network, we are going to follow the next reasoning:

Consider that a home subscriber network used to exchange information about 200GB per month. We can make the following accounts.

$$(200\text{GB/month})*(8\text{bits})=1600\text{Gbit/month} \quad (5)$$

$$\frac{1600\text{Gbit/Month}}{30\text{Days}}=53\text{Gbit/Day} \quad (6)$$

$$(53\text{Gbit/day})*0.4=21.1\text{Gbit/hour} \quad (7)$$

$$\frac{21.2\text{Gbit/hour}}{3600\text{sec}}=5.9\text{Mbps} \quad (8)$$

Now, in Table 2, we are going to see how would change the data per second if the gigabyte per month is another one.

Table 2. Required bandwidth for different categories of subscribers

300 GB/month	**400 GB/month**	**500 GB/month**
2400 Gbit/month	3200 Gbit/month	4000 Gbit/month
80 Gbit/day	107 Gbit/day	133 Gbit/day
32 Gbit/hour	42.8 Gbit/hour	53.2 Gbit/hour
8.9 Mbps	11.9 Mbps	14.8 Mbps

5. Required Bandwidth for VoIP

Voice over IP (VoIP, or voice over Internet Protocol) commonly refers to the communication protocols, technologies, methodologies, and transmission techniques involved in the delivery of voice communications and multimedia sessions over Internet Protocol (IP) networks, such as the Internet. Other terms commonly associated with VoIP are IP telephony, Internet telephony, voice over broadband (VoBB), broadband telephony, and broadband phone.

First of all, we have to understand the process that suffers the voice in the service of VoIP. The laptop (or VoIP Smartphone, gateway…) will encrypt and encapsulate the voice into a suitable format for IP network. On the other hand, the receiver will do the inverse process, it will decapsulate and decode the data back into voice.

The combination of encoding and decoding is briefly called a codec. There are different types of codecs. They set a different voice quality and other necessary requirements as the bandwidth. The main idea is that if you want more quality you need more bandwidth.

In Table 3 there are some basic types of codecs and their bit rate (bandwidth consumed).

Table 3. Different VoIP codecs and bit rates

Codec	**Bit rate**
G.711	64 kbps
iLBC	15.2 kbps
G.729	8 kbps
G.726	32 kbps

For our building we are going to use G.711 codec. It is an ITU-T standard for audio companding. It is primarily used in telephony. The standard was released for usage in 1972. Its formal name is Pulse code modulation (PCM) of voice frequencies.

Codec affects bandwidth required for voice, because it determines the amount of payload into IP packets. In gateways we can adjust the size of the payload to regulate strip. By increasing the payload in the packet, it is sent fewer packets, thus we are saving bandwidth because of the small number of headers that are sent to a call.

First of all we are going to study the required bandwidth without taking into account the headers (only the speech information and taking samples every 10 ms). The required calculations are easy:

$$\left(\frac{80\text{oct}}{\text{packet}}\right)*\left(\frac{100\text{pck}}{\text{sec}}\right)=\frac{8000*8\text{bit}}{1000}=64\text{kbps} \qquad (9)$$

Secondly, we are going to add some headers. Each packet of G.711 is composed by 80 octets of information (one sample), 20 octets of IP (Internet Protocol, Internet layer), 8 octets of UDP (User Datagram Protocol, Transport layer) and 12 octets of RTP (Real time Transport Protocol, Application layer). So, per packet we have got 120octets. As we can see, the calculation does not include link layer headers.

$$\left(\frac{120\text{oct}}{\text{packet}}\right)*\left(\frac{100\text{pck}}{\text{sec}}\right)=\frac{12000*8}{1000}=96\text{kbps} \qquad (10)$$

Finally, we are going to take samples of the speech every 20ms and in each packet there are going to be **two samples**, in other words, the information part of the packet is going to have 160 octets, 80x2=160, so in each packet, adding the headers, there are 200 octets.

$$\left(\frac{200\text{oct}}{\text{packet}}\right)*\left(\frac{50\text{pck}}{\text{sec}}\right)=\frac{10000*8}{1000}=80\text{kbps} \qquad (11)$$

The results show that there is 16 kbps difference between the last two cases. As we can see, by changing the number of samples in a packet, the required bandwidth changes, but it is a matter of compromise. When we increase the number of samples in the package, we are also increasing the delays.

6. Economic Evaluation

In our case we have included in the first inversion 23 laptops (one per house), one AP and the required antenna. Moreover we have added 24 hours of labor for the installation and programming of the network. So the total of the inversion is 16990, 07 €.

To retrieve the money, the first year each house will pay a fee of 40€/month. Then, the second year the fee will be less, it will be 25€/month. In these two years we will have recovered the first inversion (the first year the 60% and the second year the 40%). So, finally, from the third year, all money will be for profits, and the fee that each house will have to pay will be 20€/month.

Acknowledgement

I dedicate this final project to my family, especially to my mother and father for the effort that they have made and continue making in my education.

I also want to dedicate the text to my brother, and I extend this dedication to the rest of my immediate family, and friends.

Last but not least, I want to thank to the Public University of Navarre for give me the chance to accept the scholarship Erasmus. Also I thank to my tutor at the Technical University of Sofia, Georgi Iliev, and to my mentor, Vladislav Slavov, who has made my stay in Sofia easier.

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SIZING OF A WI-FI NETWORK IN AN APARTMENT BUILDING

DIPLOMA PROJECT

June 2012, Sofia

SIZING OF A WI-FI NETWORK IN AN APARMENT BUILDING

Leire Erro Vicente

Public University of Navarre

Faculty of Industrial and Telecommunication Engineering

Diploma Project

(March-May)

Supervisor: Georgi Iliev

Technical University of Sofia

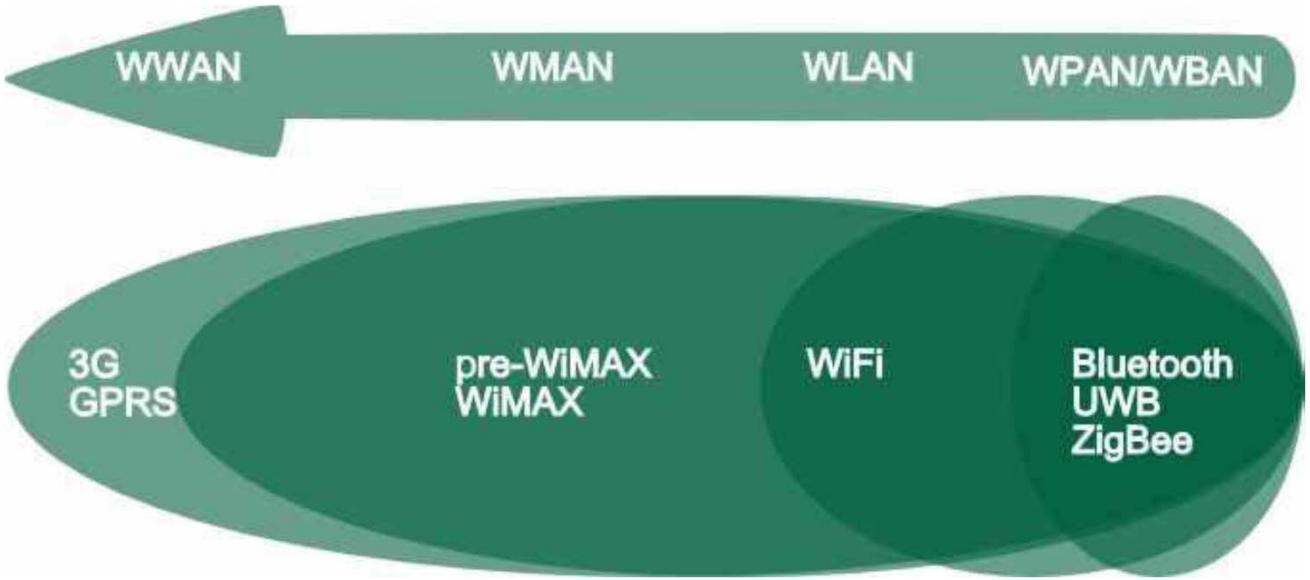
INTRODUCTION: Wireless

ADVANTAGES	DISADVANTAGES
Lower cost	Interferences
Speed of deployment	Instability of the environment
Flexibility Can be adjusted easily to requirements imposed	→ Transmission delays

INTRODUCTION: Wireless technologies

Based on the radius of action:

WLAN→ Wireless Local Area Network



INTRODUCTION: Wi-Fi

Wi-Fi is a trademark of the Wi-Fi Alliance, the trade organization that adopts and certifies that the equipment complies with standard **802.11** made by IEEE (**Institute of Electrical and Electronics Engineers**)

INTRODUCTION: Wi-Fi 802.11

Standard	Frequency	Max. Speed
Legacy	2.4 GHz	2 Mbps
802.11a	5 GHz	54 Mbps
802.11b	**2.4 GHz**	**11 Mbps**
802.11g	2.4 GHz	54 Mbps
802.11n	2.4-5 GHz	300 Mbps
802.11y	3.7 GHz	54 Mbps

HARDWARE

ACCESS POINT with its antenna (Transmitter)

- Access point power

Ptx = 20 dBm

- Antenna gain

Gtx = 4 dBi

HARDWARE

LAPTOP (Receiver)

- Laptop sensitivity

Prx: -84 dBm

CALCULATIONS

- LINK BUDGET
- REQUIRED BW FOR DATA
- REQUIRED BW FOR VoIP

LINK BUDGET

Link budget is the **accounting of all of the gains and losses** from the transmitter, through the medium to the receiver in a telecommunication system.

The used equation is this one:

$$L\ (dB) = Ptx(dBm) + Gtx(dBi) - Prx(dBm) + Grx(dBi) + Gdv(dBi) - M(dB)$$

Where, Ptx is the AP power, Gtx is the gain of the AP's antenna, Prx is the sensitivity of the receiver, Grx is the gain of the receiver's antenna, Gdv is the diversity and M is the fading margin (that represents the losses through the way).

LINK BUDGET

We need two steps to know the distance between Tx and Rx

M=10dB→without obstacles

1) L = 20 +4 - (- 84) + 0 + 0 - 10 = 98 dB

And now we use the free space loss formula to know the distance from the transmitter to the receiver of our Wi-Fi network:

2) 98=20 x Log (Freq. in MHz) + 20 x Log (Distance in miles) + 36.6

LINK BUDGET

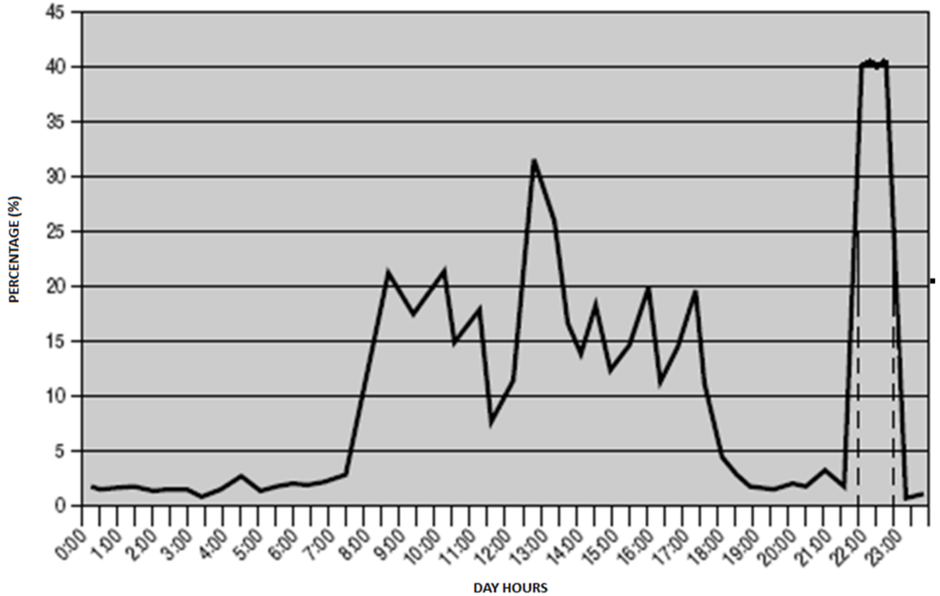
Fading margin (dB)	Distance (Km)
10	0.79
15	0.44
19	0.28
22	0.2

REQUIRED BW FOR DATA

Determinate the data per second in one house in the maximum load of the day.

→ Exchange information per month.

→ 40% of total use is at night (22:00)



REQUIRED BW FOR DATA

(200GB/month)*(8 bits) = 1600 Gbit/month

$$\frac{1600\ \text{Gbit/Month}}{30\ \text{Days}} = 53\ \text{Gbit/Day}$$

(53 Gbit/day)*0.4=21.2 Gbit/hour

$$\frac{21.2\ \text{Gbit/hour}}{3600\ \text{sec}} = 5.9\ \text{Mbps}$$

REQUIRED BW FOR DATA

Required bandwidth for different categories of subscribers

135 GB/month	**200 GB/month**	**300 GB/month**	**400 GB/month**	**500 GB/month**
1080 Gbit/month	1600 Gbit/month	2400 Gbit/month	3200 Gbit/month	4000 Gbit/month
36 Gbit/day	52 Gbit/day	80 Gbit/day	107 Gbit/day	133 Gbit/day
14.4 Gbit/hour	21.2 Gbit/hour	32 Gbit/hour	42.8 Gbit/hour	53.2 Gbit/hour
4 Mbps	**5.9 Mbps**	**8.9 Mbps**	**11.9 Mbps**	**14.8 Mbps**

REQUIRED BW FOR VoIP

Commonly refers to the transmission of voice communications and multimedia sessions over Internet Protocol (IP) networks, such as the Internet.

Codec G.711

→80 octets of information per sample

Codec	Bit rate
G.711	64 kbps
Internet Low Bit rate Codec (iLBC)	15.2 kbps
G.729	8 kbps
G.726	32 kbps
G.729a	8 kbps
G.728	16 kbps

REQUIRED BW FOR VoIP

→Every 10ms one sample of information

80 octets + 20 oc. IP header + 8oc. UDP + 12oc. RTP = 120 octets/packet

(120 octets/packet) *(100 packet/sec) = (12000 * 8 bits) / 1000 = **96 kbps**

→Every 20ms two sample of information

(80 octets)*2 + 20oc. IP header + 8oc. UDP + 12oc. RTP =200 octets/packet

(200 octets/packet) * (50 packet/sec) = (10000 * 8 bits) / 1000 = **80 kbps**

16 kbps difference between the two cases

When we increase the number of samples in the package, we are also increasing the delays.

CHOOSE a good COMPROMISE

ECONOMIC EVALUATION

1 Access Point→ 255,99€

23 Laptops→ 16238,00€

Installation costs→ 476,48€

TOTAL= 16990, 07 €

ECONOMIC EVALUATION

→FIRST YEAR (60%)

40 €/month per house=10294.04 €

→SECOND YEAR (40%)

25 €/month per house=6796.03 €

→THIRD YEAR (profits)

23 €/month per house=6348 €

THANK YOU FOR YOUR ATTENTION