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5 G SYSTEMS

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5 G SYSTEMS

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It's better look back on life and say: "I can't believe I did that" than to look back and say: "I wish I did that".

Author

Carlos Angel Macías Bautista

RESUMEN

La comunicación es una dinámica interactiva debido a la constante evolución de la información. Especialmente en el campo de las telecomunicaciones, con el paso del tiempo y con la aparición de la Primera Generación y que nos permitió dar movilidad a la Comunicación Analógica. Luego, la principal contribución de la Segunda Generación fue el paso de la comunicación analógica a la comunicación digital juntamente con los mensajes de servicio agregados, conocidos como difusión celular. Posteriormente, la Tercera Generación introdujo el servicio de Internet móvil, mientras que el actual, 4G o "Long Term Evolution", proporciona un mejor ancho de banda inalámbrico que su predecesor y también un bajo costo de servicio. Con el paso del tiempo, Internet ha dado pasos gigantes, por lo que ahora nos encontramos a las puertas del estreno de una nueva tecnología.

La novísima tecnología llamada, quinta generación o "Internet de las cosas", cambiará muchos aspectos importantes de nuestras actividades cotidianas. El Internet de las cosas (IoT) tiene una gran capacidad de comunicación entre dispositivos, que ya no se referirá exclusivamente a computadoras, teléfonos inteligentes o tabletas, sino que abarcará una amplia gama de "cosas" o dispositivos electrónicos que monitorearán, comunicar y evaluar la información en tiempo real.

Esta nueva tecnología puede relacionarse de maneras muy distintas e innovadoras en el campo de la nanotecnología, aprovechando esta cooperación, se podrán desarrollar sensores y dispositivos muy pequeños con aplicaciones y resultados importantes. En el campo de la medicina, por ejemplo, con el desarrollo de estos pequeños sensores, los cuales podrán colocarse dentro del cuerpo humano sin ninguna molestia, se detectarán o incluso neutralizarán enfermedades, por ejemplo: la médula ósea es responsable del proceso de generación, desarrollo y maduración de células y, con la ayuda de las células precursoras, logran madurar y generar lo que conocemos como glóbulos rojos, glóbulos blancos y plaquetas que a su vez se relacionan y se conectan entre sí en un delicado equilibrio; Si los porcentajes de estas relaciones cambian, afectará el estado de salud de un paciente, produciendo muchas enfermedades graves. El desafío es diseñar sensores que puedan detectar este tipo de anomalía y proporcionar información continua sobre el estado del paciente al médico, con los datos recopilados se podrá evaluar más fácilmente y en el momento adecuado, las diferentes enfermedades. .

ABSTRACT

Communication is an interactive dynamic, information that is continually at change. Especially in the field of telecommunications, as time passed and with the appearance of First Generation, that allowed us to give mobility to Analog Communication. Second Generation's principal contribution was the passage from Analog Communication to Digital Communication and added service messages, also known as cell broadcast. Afterward, the Third Generation introduced the mobile Internet service, while the current one, 4G, or "Long Term Evolution", provides a better wireless bandwidth than its predecessor and also a low cost of service. With the passage of time, the Internet has given giant steps, so that now we found ourselves at the doors of brand-new technology.

The new technology of information -Fifth Generation or "Internet of Things"- will change many important aspects of our own daily-life activities. The Internet of Things (IoT) has a wide capacity of communication between devices, that will no longer refer exclusively to computers, smart-phones or tablets, but rather these will encompass a wide range of "things" or electronics devices that will monitor, communicate and evaluate the information in real-time.

5 G Systems can relate in very innovative ways to the field of nanotechnology and taking advantage of this cooperation we will be able to develop very small sensors and devices with important results as well. In the medicine field, for instance, with the development of these small sensors, that could be placed inside the human body without any discomfort, we would be able to detect or even neutralize diseases, for example: the bone marrow is responsible of the process of generation, development, and maturation of cells and, with the help of the precursor cells, manage to mature and generate what we know as red blood cells, white blood cells, and platelets that in turn relate and connect to each other in a delicate balance; if the percentages of these relationships change, it will affect the state of a patient's health, producing a lot of serious sicknesses. The challenge is to design a sensor that can detect this type of anomaly and provide continuous information about the state of the patient to the doctor, that with the data gathered would be able to assess more easily and at the right time the adequate treatment for the different diseases.

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INTRODUCTION

The 5G system is a revolution in velocity but the characteristic most relevant is that all things will be connected, to this is known as IoT (Internet of Things). The proliferation of connected objects and devices will cover a wide area of new services and associated business models, for this reason, it is called also the economic revolution. Renewable energy sector the power distribution networks of are more distributed than central power plants that are based on nuclear or fossil fuel. These new electricity distribution networks need supervision and the control for transmitting and process distributed data such as measures from smart meters in real-time, which can also help for water or gas distribution networks. 5G technology could support efficiently all these services and sectors. Future health-care application areas of interest as assets tracking and management in Hospitals, (tagging and tracking of equipment and consumables in the operating theatre, for instance). With this technology, it will be easier than the specialists can join from anywhere in the world a local surgeon remotely to perform certain procedures that require expert skills. Also, it will do remote monitoring of health or wellness data post-operation. In this same context for patients that still have not passed by an operating theatre, the smart health will follow their lifestyle and prevention of illness. In the automotive industry, automated driving will be a reality, being a key factor for the industry, to reduction of the latency, increase of reliability and higher throughput, in other words, automated driving will manage any eventuality in time real. This characteristic no won't be suitable without the provision of road safety and traffic efficiency services. IoT will contribute to collect additional data of these services (intention, soft and hard boundaries, enhanced perception field, speed, acceleration, environment). Media-Entertainment (M-E) is associated with the fact that people consume, interact, share, chat, talk, tweet, while walking, running, driving, commuting by subway or train, etc., during their media and entertainment enjoyment. 5G systems will improve progressively larger storage, increasing processing power, and better connectivity. Virtual reality as part of the entertainment will share 3D video, with 360 degrees of reach, real-time. So also, for example when being in a stadium and with glasses or helmets virtual, it will see different angles of interest in the field shared to a great among people. Quality of services is a key parameter for this type of entertainment for which IoT. provides low error rates in video, audio and also low latency. 5G Systems will be the economic revolution because as have been said before the technology will need of devices which can receive media services for viewing and listening, from stationary tv sets smart radio, personal computers, tablets - smart-phones, game consoles and especially the creation of an endless number of devices (for instance sensors which will being in our clothes, pets, traffic light, cars, under our skin, etc.), which is going to give jobs by millions of people. This work consists of three chapters.

In the first chapter, we will talk about the description of 5G system network, the evolution of Radio-Access Technologies, the design of cells, wireless infrastructures, heterogeneous networks.

In the second chapter, provide advantages and applications of the fifth generation. In the third chapter, is about of description hardware and frequencies used

Chapter 1

DESCRIPTION OF SYSTEM

The fifth-generation join all systems existing, will not replace 4G, from macro to small cells (micro, pico, and femto cells), being this one where has been having more development, therefore we can say that 5G systems simply enables a larger diversity of applications that 4G cannot perform.

1.1 OVERWIEW OF THE WIRELESS WORLD 5 G

In [8] 5 G Systems are the join of all networks existing, will not replace 4G, from macro to small cells (micro, pico,- and femto cells), being this one where has been having more development, therefore we can say that 5G systems simply enables a larger diversity of applications that 4G cannot perform. First in the Macro cells, we will talk a little bit about the evolution of radio-access technologies which led us to multiple access which are techniques for transmitting one or more signals by the same transmission medium, therefore having massive connections and take advantage of the spectrum efficiently. Nowadays the FDMA, TDMA, CDMA, OFDMA access techniques are the most popular in the world. TDMA (time division multiple access), a technique that shares the channel bandwidth (capacity that has a channel of communication to send information) in the domain time. This method uses different times for down-link and up-link data, the latter requires accurate timing synchronization. FDMA (frequency division multiple access), divides the spectrum assigned into sub-carries o channels. Each channel is set out to a user, while other users occupy others channels. CDMA (code division multiple access) use the previous techniques and uses codes in order to separate the users over the same channel and time. But the most popular technology used in the fourth generation is OFDMA. The term orthogonal in telecommunications means transmitter multiple signals and that don't interfere with each other, further assign subsets of sub-carriers for each user, improvement of resource use. The figure 1.1 depicts an overview of how it is conformed 5G systems.

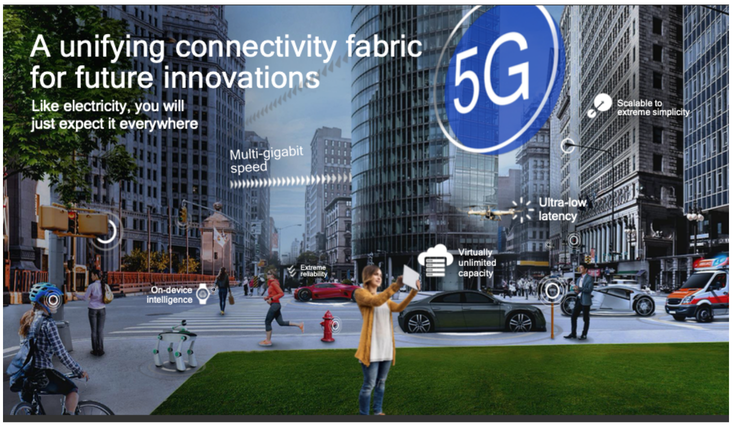

Figure 1.1: overview of how it is conformed 5G systems [1]

The wireless infrastructures another factor important because they contribute to the joint operation and exploitation of a heterogeneous, it utilizes a distributed base station architecture that physically separates the Remote Radio Unit and Base Band Unit, their targeted at the improvement of application provisioning. Heterogeneous network consists of different types of infrastructure elements (BS's), such as macro-, micro-, pico-, and femto-, BS's. and that it is capable of maintaining the service Heterogeneous networks offer multiple options numerous and diverse access points in terms of their capabilities, different spectrum portions that may be used.

Flexible spectrum management improves resource utilization, it gives the flexibility allocate spectrum to the RAT's, network operators have the freedom to flexibly allocate spectrum. In other words, is opportunistic spectrum access, in which secondary users are allowed to independently identify unused spectrum bands, at a given time and place, a use them while not generating harmful interference to primary license holders.

Machine-to-Machine communication is between several machines, sensors and actuators without any communications channel. All traffic generated from this kind of communication will management in a cognitive and intelligent way.

The Cloud-Radio Access Network (RAN) and Mobile Clouds Concepts are conformed by Front-haul, Back-haul, and Mobile core network, and his aim is to manage the growing demands of bandwidth and data rates of end-users in order to save energy on both the network and user's side

1.2 N-ORTHOGONAL MULTIPLE ACCESS

In [5] the radio access for Fifth Generation uses NOMA Non-Orthogonal-Multiple-Access, and whose main characteristic is assigning all sub-carriers for each user figure 1.2 (a) depicts these characteristics. Allowing each user to operate in frequency, time, code, and power, achieving higher spectral efficiency. What allows to reach high speed rates with higher bandwidth, the figure 1.2 (b) depicts an analogy for the bandwidth, where the amount of lanes represents the bandwidth, and the number of cars represent the amount of information that can be transported.

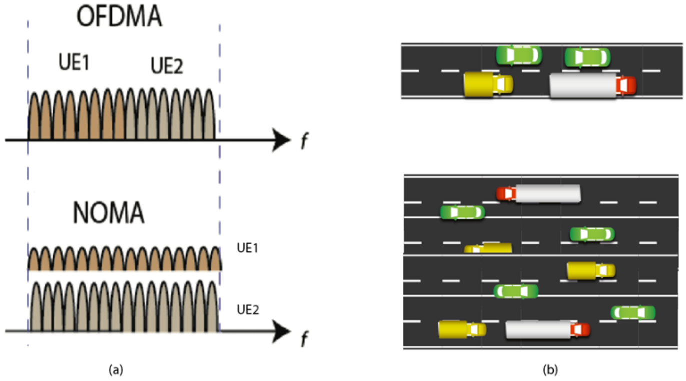

Figure 1.2: a) Spectrum sharing for OFDMA and NOMA for two users [5] b) Analogy of the Bandwidth

Use the same spectrum for all users, is possible through the successive interference cancellation (SIC) figure 1.3 , and superposition coding (SC) techniques, both in the at receptor and transmitter respectively. The information is sent into a single wave by the transmitter, this wave consists of several signals superimposed. When these information arrive at receiver, is decoded first the signal strongest and the others signals are considered as interferences. To recover the next signal less strong, the first information decoded is subtracted of input's signals, and after decoded. The same way for to recover the next signal. This is an iterative process, because it allows to recover the signal desired of multiple signals superimposed, for this reason is called successive interference cancellation.

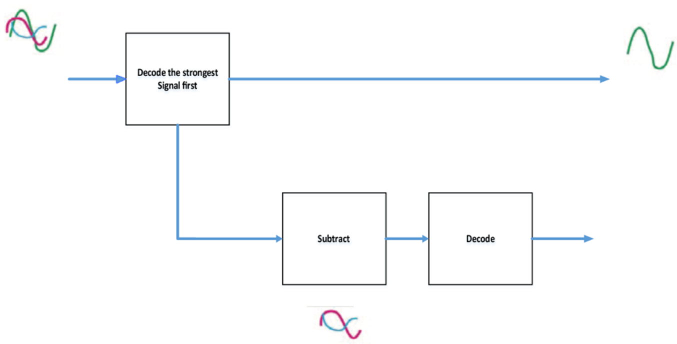

Figure 1.3: Successive interference cancellation [5]

1.2.1 Downlink and Uplink NOMA Transmission

The communication going from a base station (SB) to a user equipment is called downlink, and when it is going from a user equipment to a base station it's called uplink as depict the figure 1.4.

In NOMA downlink (figure 1.5.), the station base is responsible of to allocate the power levels to every user-equipment (UE). According to this technique will designate more power to user-equipment (UE_k) farther from the station base. Contrarily will allocate less power to user-equipment (UE_1) closest from the station base. Each UE uses SIC to come upon its own signal.

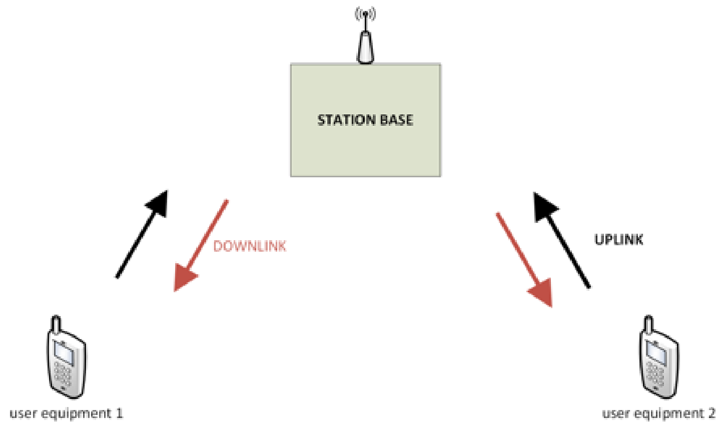

Figure 1.4: Downlink and uplink noma transmission [5]

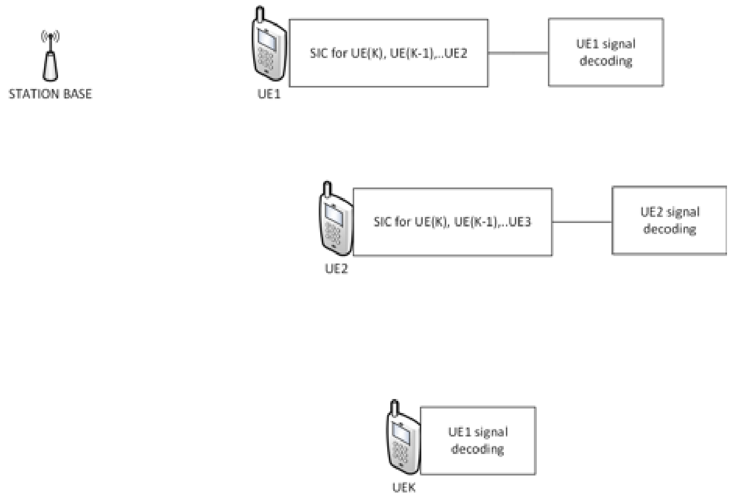

Figure 1.5: Noma Downlink for k users [5]

Mathematical model that NOMA uses in the base station for transmits a signal is according the next equation:

$$x(t) = \sum_{k=1}^{K} \sqrt{\alpha_k P_T x_k} \tag{1.1}$$

where;

- UE_k : information conveying OFDM waveform

- α_k : information conveying OFDM waveform
- P_T : is the total available power at the BS

Remembering that the power allocation coefficient varies according to the location of each UE, more power to UE farther from the station base. The reception for each UE_k correspond the next equation:

$$Y_k(t) = x(t)_{gk} + w_k(t) \tag{1.2}$$

where;

- g_k : is the channel attenuation factor for the link between BS and UE_k
- w_k : is the additive white gaussian noise at the UE_k

Hence, the Radio Signal to Noise (SNR) is defined for any UE as:

$$SNR_k = \frac{Psignal}{Pnoise} = \frac{P_k g_k^2}{N_o W + \sum_{k=1}^{K-1} P_k g_k^2} \tag{1.3}$$

Where;

- P_k:power allocated to each UE_k
- N_o : is the power spectral density of noise per unit of bandwidth $\frac{W}{Hz}$
- W:bandwidth

If there is a cancellation perfect for the last signal it decodes will be its signal:

$$SNR_k = \frac{Psignal}{Pnoise} = \frac{P_k g_k^2}{N_o W} \tag{1.4}$$

The total capacity is obtained, adding the capacity of NOMA and OFDM in the following way.

$$R_k(total) = R_{gk(NOMA)} + R_{k(OFDMA)} \tag{1.5}$$

$$R_k(total) = w \log_2 \left[1 + \frac{P_k g_k^2}{N_o W + \sum_{k=1}^{K-1} P_k g_k^2} \right] + w_k \log_2 \left[1 + \frac{P_k g_k^2}{N_K} \right] \tag{1.6}$$

$$R_k(total) = \sum_{K=1}^{K} R_k \tag{1.7}$$

A fairness index (F) is calculated which indicates how fair the system capacity is shared among the UE_s , that is, when F gets close to 1, the capacity for each UE gets close to each other.

$$F = \frac{\sum_(R_k^2)}{k \sum_(R_k^2)} \tag{1.8}$$

For Noma UPLINK (figure 1.6) the station base uses SIC technique for decodes the information sent by users. Therefore, the BS receives all signals sends by sent by each remote station or UE and multiplied these ones by an attenuation factor, determined by their position, added up to the white Gaussian noise. Every user optimizes their transmit powers according to their locations as in the downlink for this case they suppose an uniform distribution on the net (equal to W_t).

$$y(t) = \sum_{k=1}^{K} x_k(t) g_k + W(t) \tag{1.9}$$

Contrary to the downlink case, the first decoded signal is the closest to the

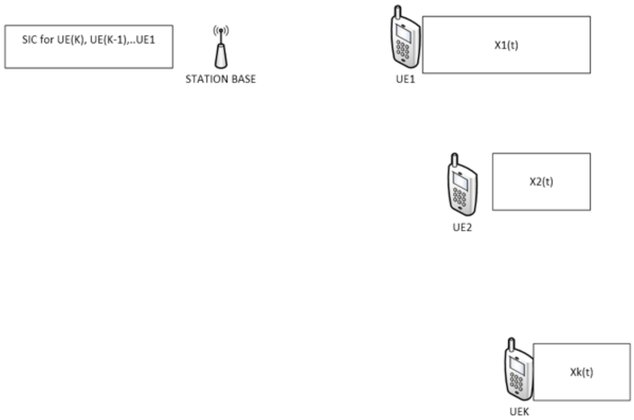

Figure 1.6: Noma Uplink for k users [5]

base station.

$$SNR_R = \frac{Pg_k^2}{N} \tag{1.10}$$

The last signal decoded will be the farther to the base station.

$$SNR_R = 1 + \frac{Pg_k^2}{N + \sum_{i=k+1}^{K} P_k g_k^2} \tag{1.11}$$

The same way that in downlink, the total capacity for uplink is obtained, adding the capacity of NOMA and OFDMA in the following way.

$$R_k = R_{k(NOMA)} + R_{k(OFDMA)} \tag{1.12}$$

$$R_k(total) = w \log_2 \left[1 + \frac{P_k g_k^2}{N_o W + \sum_{i=k+1}^{K} P_k g_k^2} \right] + w_k \log_2 \left[1 + \frac{P_k g_k^2}{N_K} \right] \tag{1.13}$$

$$R_k(total) = \sum_{K=1}^{K} R_k \tag{1.14}$$

1.3 HETEROGENEOUS NETWORKS

The Heterogeneous Networks (HetNet), are used with the aim to improve the coverage and network capacity, required for the new generation. The HetNet framework, works with many types of technologies, of which the most important are the massive multiple input multiple output (MIMO) and heterogeneous network technologies. The HetNet are conformed by Small-Cells (SC) and Macro-Cells (MC), these ones can exist in harmony despite had many significant technical issues. Working with small cells has great potential due its characteristics as:

- Provide higher data rates
- Low-power wireless access points
- Low deployment cost

Adding up the Macro-Cells and Small-Cells features get higher data rates, get better coverage and avail new services. On the HetNet, the MC share its spectrum with SC, but is MC who has access priority to spectrum, for this reason MC is called primary users/system whereas SC is denominated secondary users/system because can only to access when exist free space resources on MC.

For design these types of networks is required more dynamic planning for does not have interferences such as; sum-squared auto-correlation minimization (SAM) or an investigation into time-domain approach for OFDM channel estimation.

But, is the interference alignment (IA) technique, which tries to solve this type of interference in a better way.

In IA networks, the signals are constrained into the same subspaces at the unintended receivers through cooperative precoding, and the desired signal can be recovered at each receiver by eliminating the aligned interferences using decoding matrix

Recent researches assumed the knowledge of the cross-tier channel at the small cells. To solve this problem joint IA and cognitive communication technique in order to deal with the interference of small-cell user terminals (UT's) towards the macro-base station. NOMA uses superposition code and successive face cancellation in transmitter and receptor, respectively.

1.3.1 System model

This model [12] (figure 1.7) is formed for k small-cells working inside the zone coverage of a macro-cell, for the downlink (BS sends information to UE) of a heterogeneous cellular network. The channel of communication between small cells is made with Radio-over-Fiber (RoF) techniques, which to merge the advantages of both optical and wireless communication techniques

- SBS_s:small-cell base stations
- MBS_s:macro-cell base stations
- MUE:macro UE
- SUE_k:small-cell user equipment k
- CU: Central Unit

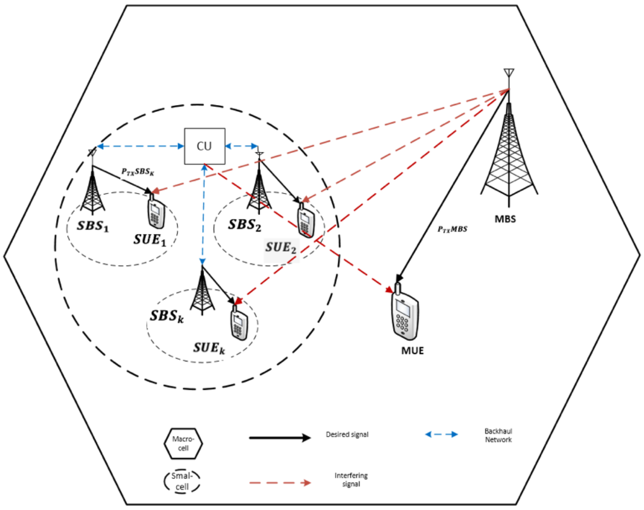

Figure 1.7: System model:N small cells within the coverage area of macro cell [12]

- Base Station
- UE: User Equipment

MIMO in 4G uses one-dimensional antenna arrays arrangement that limits the freedom of antennas, meaning it cn distinguish users in horizontal directional only. In contrast to this, MIMO in 5G supports more users simultaneously by incorporating a two-dimensional antenna array to cover both horizontal and vertical directions

1.4 THE WAVEFORM FOR 5G SYSTEMS

In [17] The 5G systems needs new waveforms because the old and current technologies won't satisfy the demands of next generation. The fifth generation plans to reach aims as: 10–100 times higher typical user data rates, 10–100 times more connected devices, 10 times lower network energy consumption, less than 1 ms end-to-end latency, and 10000 times higher mobile data traffic per geographical area. To achieve these objectives, the chosen waveform must accomplish with many re-equipment as; low power consumption, high data rates, spectrum, low latency, easy to implement, low-out-band emission and it must be compliant with massive multiple-input-multiple-output (MIMO) systems [1] All previous generation have some types of modulation for to be able transmitting information. Multi-carrier modulation is used as a principal method for this aim. MCM divide the frequency spectrum into multiple sub-carriers, and each of these ones is assigned to a device for transmission of its data. Allocation of sub-carriers have many advantages, one of which is that it can give service to many users, but, this type of modulation has restrictions, due to that can create interference on the frequencies that are next to the main band. Also, during the transmission there are interferences, such as multi-path propagation or Doppler effects. For Mitigating the interferences was create for instance the orthogonal frequency division multiplexing (OFDM) used in the fourth generation. OFDM can remove interferences when the users are working within close frequencies but whenever they are to the same base station. Between the advantages of OFDM are: the resilience to frequency, spectrum efficiency, channel equalization, flexibility to interference due using of cyclic prefix and its disadvantages are: out-of-band (OOB) may cause harmful interference to adjacent channels, high peak-to average power ratio (PAPR) can cause an increase in BER, loss of efficiency because uses cyclic prefix. The prototype filter of OFDM is the rectangle filter. A potential candidate for the fifth generation is filter bank multi-carrier (FMBC), in which focuses the spectral efficiency analysis.

Thinking how to reduce the inter-channel interferences, FBMC modulation had been studied, so it can be considered as an improved OFDM. FBMC has a negligible frequency spectral leakage which means no longer will affect the entire frequency bandwidth if not only to a small frequency range, also, it does not require redundant cyclic prefix, which improves the spectral efficiency. FMBC mainly has three kinds of modulation forms which can use to for having high speed, low latency, high spectrum. Cosine multi-tone; when exist an overlapping between neighbor frequencies when are transmitted at the same time, with CMT these ones can be eliminated and rising the bandwidth efficiency. A potential candidate for the fifth generation is filter bank multi-carrier (FMBC), in which focuses the spectral efficiency analysis.

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OQAM-OFDM: the communication systems are the real and imaginary parts of the complex quadrature amplitude modulation symbols. Between its characteristics are:

- Reduces the out-of-band interferences to neighboring spectrum bands
- Support the asynchronous transmission
- But its best ability is of suppressing the inter-symbol interference (ISI) and inter-channel interference (ICI) which improves the utilization efficiency of spectrum resources and increases the effective data rate.

Universal filtered multi-carrier (UFMC) is a waveform that join advantages and disadvantages of OFDM and FBMC of which are obtained characteristic as: Reduction of out-of-band (OOB), low requirement about time-frequency calibration and non-orthogonality. Which the other hand is not suitable for applications that needs synchronization, it has high carrier frequency offset due two things: frequency mismatch between transmitter, and receiver and effect Doppler.

Generalized frequency division multiplexing (GFDM): is a waveform that permits flexible time and frequency partitioning, using for this propitious different root-raised cosine (RRC) pulse-shaping filters for each sub-carrier. This reduces OOB emission significantly The spectral efficiency of GFDM is higher than that of OFDM because uses less Cyclic Prefix.

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	OFDM	**FBMC**	**GFDM**	**UFMC**
PAPR	High	High	Low	Medium
Out of Band	High	Low	Low	Low
Spectral efficiency	Medium	High	Medium	High
CP	Yes	No	Yes	No
Orthogonality	Yes	Yes	No	Yes
Synchronization requirement	High	Low	Medium	Low
Ease of integration with MIMO	Yes	No	Yes	Yes
Latency	Short	Long	Short	Short
Effect of Frequency offset	Medium	Medium	Medium	Medium

Table 1.1: Comparison of features among OFDM, FBMC, GFDM and UFMC [16]

A BER vs SNR simulation was performed between the four waveforms with their respective prototype filters. According to the filters implemented, and the results (figure 1.8) obtained can be determined that the wave that presents a better BER is the FBMC and in contrast the worst is the GFDM. An aspect to consider is that these prototype filters has their own advantages in different modulation structures, as mentioned before. Another figure (1.9) that help us understanding, how the waveforms behave with their respective filtering, is the frequency responses. The results go according to the advantages and disadvantages of the waveforms with their respective filters. As depicted on the figure of frequency responses of FBMC has a minimum out-off-band leakage but the biggest out of band is the OFDM, is important

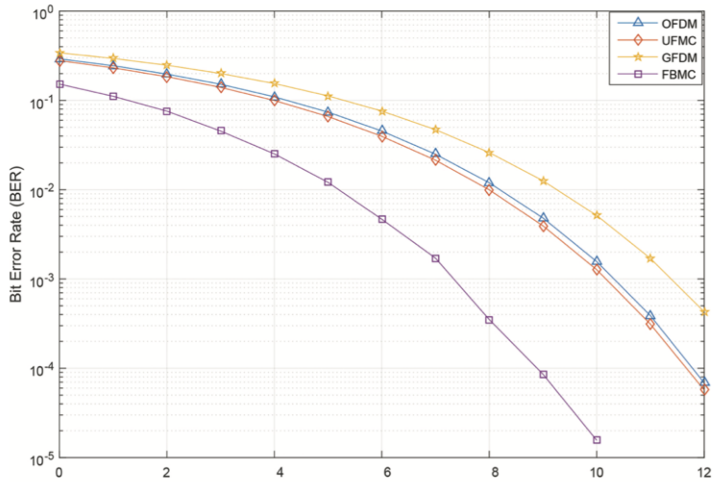

Figure 1.8: BER vs. SNR levels for FBMC-, OFDM-, GFDM-, and UFMC-based systems [16]

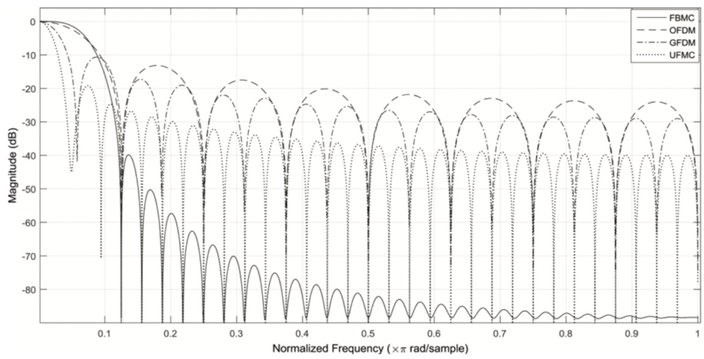

Figure 1.9: Frequency responses of prototype filters for FBMC, OFDM, GFDM, and UFMC [16]

to establish an interference model based on the side-lobe-radiation, which is determined by the power spectral density.

1.4.1 Spectral efficiency comparison in single-cell systems.

For evaluating spectral efficiency in single-cell systems (figure 1.10) of the same waveforms before (FBMC, OFDM, UFMC, GFDM), it will be based on the average capacity of available frequency bands and Resource Allocation strategy. The following model is taken into consideration:

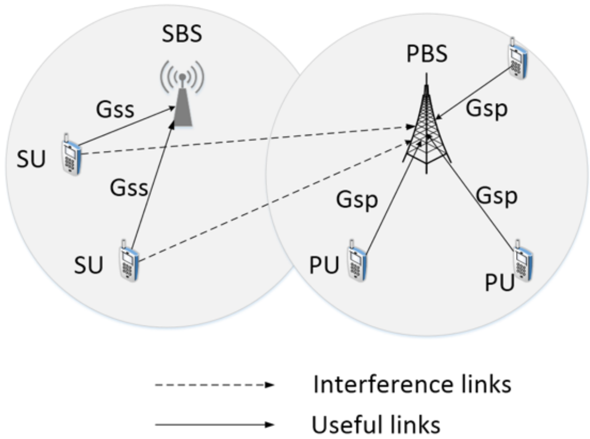

Figure 1.10: The system model of single CR cell including multiple users [16]

Where:

- SBS: Secondary base station
- SU: Secondary Users
- PBS: Primary Base Station
- PU: Primary Users
- Gss: Gain secondary-secondary

- Gsp: Gain secondary-primary

The cognitive radio networks are formed by many users and an access point called base, in base to this concept, we can make a primary and other secondary network for uplink, as depicted figure Model single CR, There are two problems presents between SUs and PUs, the spectral leakage and imperfect synchronization. Synchronization because in anytime PU's sub-carrier are occupied by the SU's sub-carrier leakage because he out-of-band radiation of sub-carrier will be regarded as interference. For resolve this problem was taken for example (figure 1.11) a bandwidth split into 48 sub-bands and and each of these divided in 18 sub- carriers. Each sub-band is identified with values of 1 or 0, which has a meaning, 1 for busy and 0 for idle. This way is easier for secondary users to check when a sub-band is available, in other words, SU are synchronized. Subcarrier assignment: is the bandwidth allo-

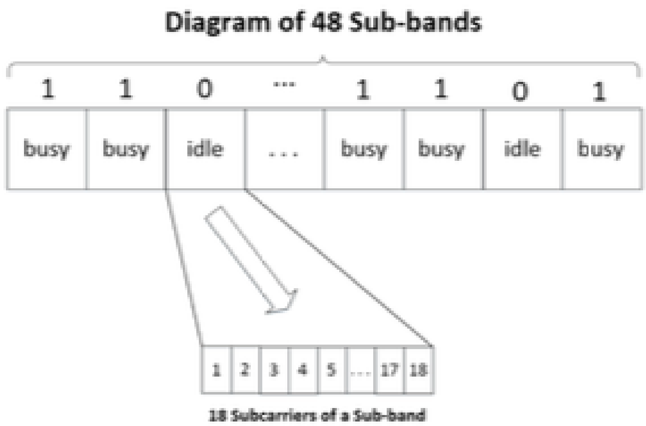

Figure 1.11: The Diagram of idle and occupied frequency bands [16]

cation to Secondary users, the number of sub-bands assigned to SUs must be equals or less to the number of free sub-bands.

For reach this aim we should by following these three steps

- First, suppose that each SU has the equal number of sub-bands
- Second, calculate the average capacity. Find the SU with minimal capacity and then sub-band number of SU.
- Third, if all available sub-bands are allocated, terminate. Else, repeat the step

For reach this aim we should by following these three steps Power allocation We use The Method of Lagrange Multipliers and Gradient Projection Method for the power allocation, these are method non-linear because it is already known that the carriers are assigned.

Channel state information (CSI) is a parameter very important because it describes how a signal propagates from the transmitter to the receiver, when there is a channel delays and the inaccuracy of channel gain estimation in agreement with the distance Results of the spectral efficiency comparison in single-cell systems.

These Figures 1.12 and 1.13 are evaluated from the perspective of SU: The relationship of capacity and distance between PBS and SBS is assessed in figure 1.12, where is as the distance increases, your average capacity increases, due the distance increases reduce the mutual interferences between the PU and the SU. FBMC has the best spectral efficiency. In Figure 1.13 All waveforms increase with increase of the user's sum power limitation, when there is a large power means that the more power is allocated to the spectrum idle, deriving in the expansion of channel capacity. The figures 1.14 and 1.15

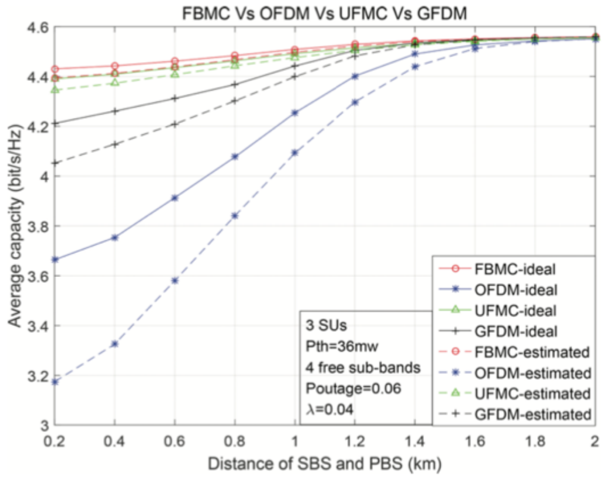

Figure 1.12: The relationship of capacity and distance between PBS and SBS [16].

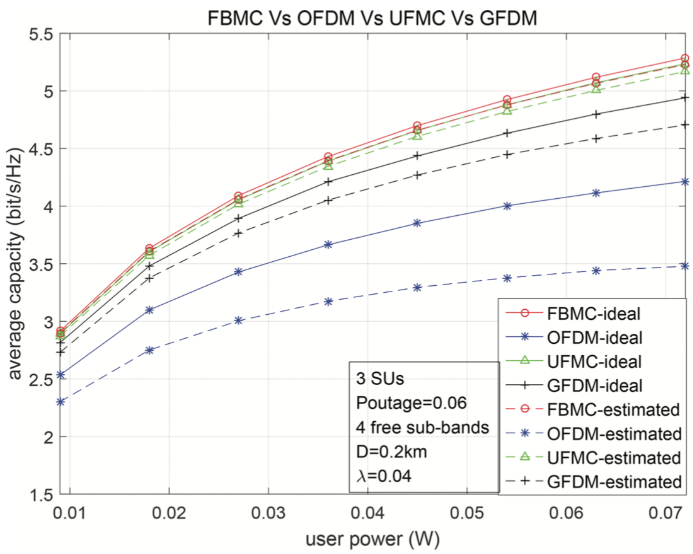

Figure 1.13: The relationship of capacity and the maximal power of SUs [16].

are evaluated from the perspective of PU. The figure 1.14: The interference threshold has a limit of in-band out-of-band interfering before a cognitive radio to consider can claim that it is experiencing harmful interference. In

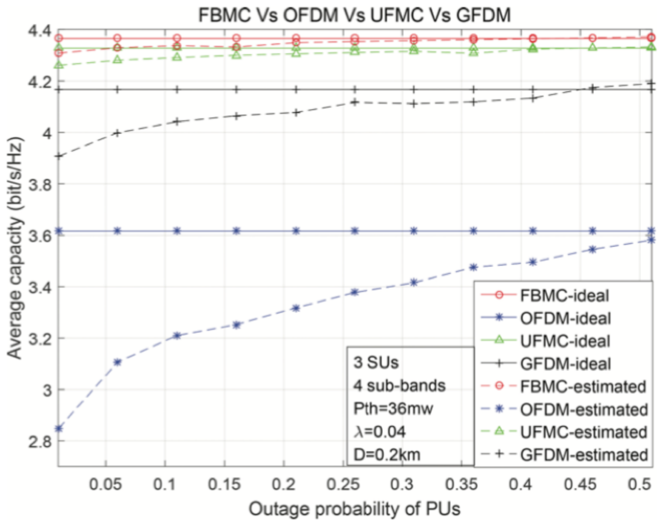

Figure 1.14: The relationship of capacity and interference threshold [16].

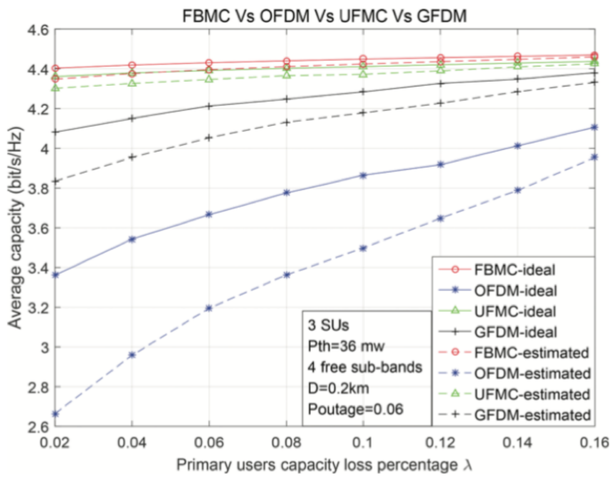

Figure 1.15: The relationship of capacity and the outage probability of PU [16].

this context, when there is less capacity loss in PUs, means that there is a lower interference threshold and better protection for primary system, the achievable capacity degrades due to the more strict access control. Figure 1.15 presents the probability than an outage will occur within a specified time period, in this case OFDM based in CR systems with estimated CSI, is worst case.

Chapter 2

ADVANTAGES AND APPLICATIONS

5G will provide capabilities, which will be an economy promoter by fostering new ways to organize the business sector (vertical industries, novel forms of service providers or infrastructure owners and provider. Next generation will provide access to a higher applications and services volume per geographical area, with a high efficiency, save energy, security and privacy.

2.1 Advantages

- 1000 X in user data rate reaching a peak terminal data rate >= to 10Gb/s

Today we can achieve more or less speeds between 1Gbps per second with 4G technology. The next generation will be able to offer standard speeds of 20 Gbps per second. For instance as the depict figure 2.1, downloading

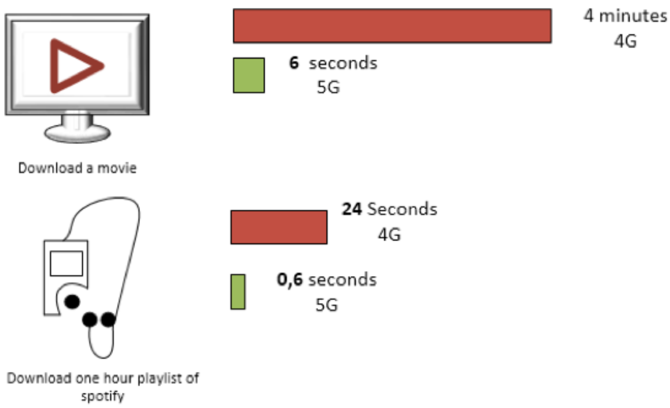

Figure 2.1: Comparison of download speeds between 4G and 5G technologies

a 15GB High Definition movie at the speed 500Mbps will take 240 seconds via 4G. However, at 20Mbps at the speed 500Mbps the same movie will only take 6 seconds to download. To download a full one-hour play list of (1.5 Gbytes) it lasts 24 seconds (with at the same previous speed for 4G), and 0.6 milliseconds with 5G.

- 1000 X in number of connected devices reaching a density >= to 1M terminals/km2

5G systems will have a great number of objects, sensors, actuators that are connected (>=10000 devices per km2) (figure 2.2). The number of joined objects will exceed the among of human beings in order of magnitude in next generation.

- 1,000 X in mobile data volume per geographical area reaching a target >= 10 Tb/s/km2

The volume density (figure 2.3) is defined as the whole number of correctly transferred bits received by all destination User Equipment from source Base

Figure 2.2: Objects, sensors, actuators that are connected at the same time

Figure 2.3: Volume density

Station or sent from all source User Equipment to destination Base Station, in a established geographical area. Thus, traffic volume density can have the following units: [Gbps/m2] or [Gbps/km2]. Good performance and coverage even in agglomerations, the 5G infrastructure allows more devices to be connected at the same time. Make more efficient use of the spectrum will help avoid bottlenecks when there are large crowds. 5G will provide huge improvements in capacity and boost user data rates [1]. For instance, it is expected that for the opening of the Tokyo 2020 Olympic and Paralympic Games of include virtual reality (Virtual Reality and its possible application as the "free point of view") and augmented reality (Augment Reality) for all people presents in the stadium.

- 1/10 X in energy consumption compared to 2010

On wearable devices has become a fundamental part for everyday activities and therefore the energy savings will be an important part of the next generation, whereby 5G will be designed for save more of ten times energy than the current technology (figure 2.4). Energy efficiency is also in the digital integrated circuits design, optimization the Energy/Power. Dynamic-power is when the circuit is operated at its maximum speed and it can be optimized with; multiple supply voltages, transistor sizing, technology mapping. Static-power is when the activity is low, mode idle, it can be optimized with; multiple threshold, transistor stacking. They will can find analog front-ends in microwave and millimeter frequency ranges, memories DSP-enabled optical transceivers for access and back-haul networks, and ultra-low power wireless sensors harvesting ambient energy, such as solar, thermal, vibration

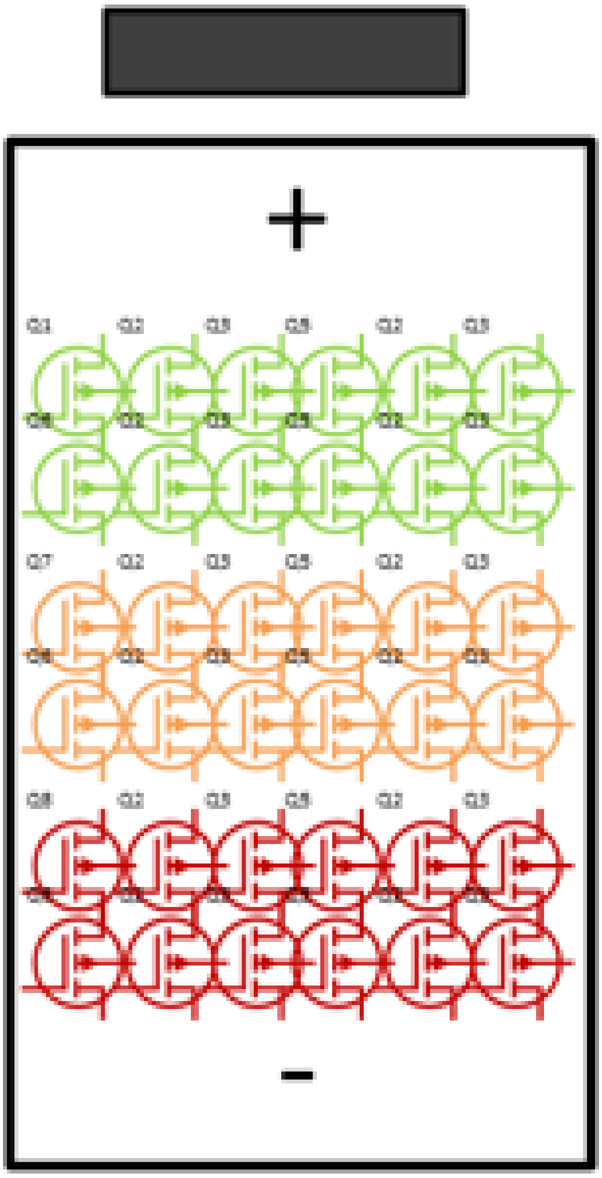

Figure 2.4: Battery-energy consumption

and electromagnetic energy. In addition, wireless power transfer technologies and optimization of sleep mode switching present another exciting alternative to battery-less sensor operation for M2M (machine to machine) and D2D

(Device-to-device) communications. [9]

- 1/5 X in end-to-end latency reaching 5 ms for e.g. tactile Internet and radio link latency reaching a target <= 1 ms for e.g. Vehicle to Vehicle communication.

Figure 2.5: End-to-end latency

Latency is the time it takes to transmit a packet from the base station toward a remote user and vice versa. Latency is a key factor in 5G connections, especially in operations on real time, like remote robot control, connected autonomous vehicles and interactive gaming. There are several factors that generate latency as; the distance between communication points, Internet access technology, capacity of the device from which we connect and the load of server to which we are connecting, among others. The optical fiber, which has the lowest latency, for this reason 5G technologies will use Radio-over-Fiber for its inter-connections between small-cell base stations. There are also other advances to reduce the latency as;

- New waveforms that are robust against time-offset and do not require signaling associated with time alignment.

- Flexible frame design for multiplexing of Transmission Time Intervals (TTI), refers to the duration of a transmission on the radio link, with different lengths on the same spectrum resources.

- mm-wave (also called millimeter band) is the band of spectrum between 30 gigahertz (GHz.) and 300GHz. allows the use of short TTI's, which leads to inherently low latency

- Multi-mode connectivity and spatial diversity.

Considering the architecture of the network, we can also reduce the latency.

- Partitioning of the end-to-end path into segments for ultra-low latency (i.e. processing directly in the base station), low latency (i.e. processing in the edge cloud) and high latency (i.e. processing in a central cloud) [5G-NORMA].

- Introduction of Mobile Edge Computing (MEC) that offers processing capacity near the base station for local application level processing.

- Dynamic reconfiguration of hardware and software platform components reducing redundancy of functions and balancing of latency against other metrics such as energy efficiency.

- Introduction of intelligent caching schemes for reducing application level latency.

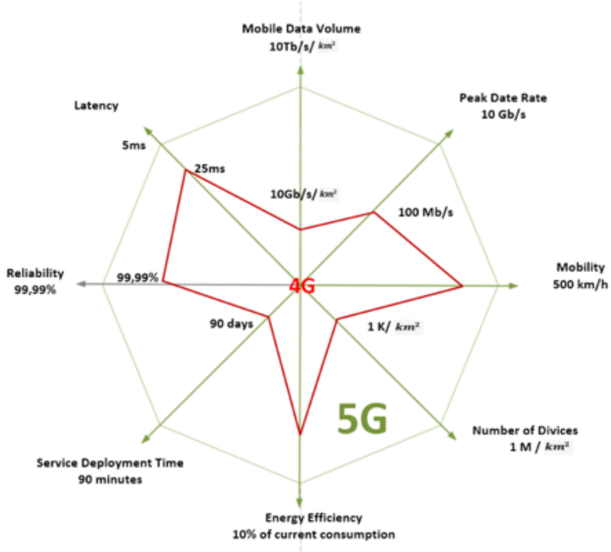

Figure 2.6: Comparison between 4G and 5G systems [11]

2.2 Applications

2.2.1 Smart City

A Smart city basically is exchange of large amounts of information with the target of to automate most of daily events of a city, relating the infrastructure to human capital. A smart city gives solutions to problems of mobility, security and energy saving, interacting between the web, citizens and cities, in order to get a sustainable progress More than 80% of people will live in the cities in the future, for this reason, a city must become in a smart city and raising the standards of live. In the field of public services, a city must have integrated system that can to control: quality, flow, pressure on and distribution of the water. Using technologies as smart water meters, district and building water re-use, digital water distribution control and leak detection. Manage public transportation, for instance, to have information about estimated time of arrival of the next bus, air quality information systems, traffic management System. Many cities are implementing technologies as smarts traffic lights that can to convey information about traffic jam, and also possible road alternatives to advance to its destination. Smart parking send data, about which parking slot is open, and which is occupied, to a smart-phone app for drivers, besides gives a map how arrive to the parking space. Another option is to use vehicles electric since local pollution and noise levels are reduced.

2.2.2 Smart Agriculture

The smart agriculture is the area that is constantly growing, benefiting in first place to farmers as a have better control of each process of production. The aim of the smart agriculture is to collect data as, soil quality, weather conditions, crop's growth progress, cattle's health, etc. This data will help to predict measurements and events, for having a sustainable increase in farming productivity and income, that is to say save time and money. In the locomotion area will development autonomous vehicles, as tractors, that can move into in roads of difficult access and if the access won't possible, it could use aerial vehicles, as drones. These vehicles can be optimized for specific tasks. In the field of the harvest will be developed soft grippers used for selectively harvesting grapes, tomatoes, raspberries and apples, etc. Significant advances in satellite- or drone- based remote sensing capabilities open opportunities in monitoring crop growth status with unprecedented temporal and spatial resolutions while at an affordable cost.

2.2.3 Smart Health

Health-care must be a priority during any stage of our life and much more with the appearance of many diseases. In that sense health field represent one of the most attractive areas of application for the IoT because has a potential solution on health-care systems. For instance, could be used to monitor non-critical and critical patients. At home rather than in hospital, reducing resources on hospital such as doctors and beds if it's about non-critical patients even gives or improvement better health-care for those living in rural areas. The health care is priority in anywhere of the world, in that sense health field represent one of the most attractive areas of application for the IoT because has a potential solution on healthcare systems. World Health Organization define to health care as the transfer of health resources and health care by electronic means. Indicators in the healthcare system as the demand of hospital beds, doctors, nurses, and Average Length of Stay, suggest a change in this area. The smart health systems, the treatment or care can be done in homes, rural areas. Gather information about health as lifestyle and illness, could lead us faster to the root of illness issue, prevention and compensation and support. Areas the most impact are: Wireless patient monitoring, Mobile system access, Medical devices, Smart Pharmaceuticals, Robotics, Telehealth-care, Ambient Assisted Living prevention, lifestyle and wellness. The pharmaceutical industry could be one of the key drivers with serious effort for the treatment of chronic diseases such as asthma Chronic Obstructive Pulmonary Disease, thereby reducing the number of patients in hospitals. Currently the robotics systems have a system latency of around

180 ms. but to latencies beyond 200 ms affect the performance of surgeons and beyond 250 ms it is very difficult for surgeons to operate at all. The 5G can be cause many changes for smart health, both for health (insurance) providers and for users or patient's.

2.3 STATE OF ART

2.3.1 Smart City

Figure 2.7: Smart City

A smart city (figure 2.7) must have an early alert system, which monitoring and evaluating data as earthquakes, hurricanes, rains, landslides, eruptions, fires, etc. An earthquake is produced by the tectonic plates friction, which propagate its energy in waves form and travel through the earth's crust, causing the shaking that we feel. There are many types of waves: The P longitudinal wave are the first in to reach the earth's crust, its velocity is of 6km/s, and it isn't really dangerous. After the transverse waves arrive or S, its velocity is of 4 km/s, these ones are simply oscillating up and down about their individual equilibrium positions as the wave passes. Finally appear on the scene the superficial waves which are the sum of S and P waves, which are the slowest and dangerous The instrument that measure these parameters is called seismometer, many seismometers can be installed in many strategic points as tectonic faults. A seismometer is system made up of a magnet and a coil. One of these two elements is rigidly fixed to the ground in such a way that it will move along with the earth's surface in response to seismic movements. The mass hangs from the fixed spring, then when there is a relative movement between the coil and the magnet, an electromotive force is produced between the terminals of the coil. Being the voltage corresponding to the electromotive force proportional to the force of movement. For detecting the three types of waves there are three systems N-S, E-O and vertical (Z) This data is digitizing, processing and to send in real time a headquarters. For instance, the USGS has a system called ShakeAlert design by Berkeley's university, which gather the seismometer data. This information is processed by a computerized system who that issue the alert. For example, when an S wave is detected by the system send how much time people have until the earthquake reaches its location. This alert can be send for any method of broadcasting, tv, radio, mail, social networks etc. Unfortunately for people who are close to the epicenter the response time is very short. So far it is impossible to determine where and when an earthquake will occur, but we can improve the way to detect the probabilities to reach a time around 40 seconds with which we could empty elevators, stop trains and other actions that would reduce damage and injuries due to these natural disasters. There are many cities living together to volcanoes, the modern scientific monitoring of a volcano uses different and complementary methods. The most common are the detection of seismic activity, the measurement of soil deformation, the study of chemical changes of gas emissions in fumaroles, thermal sources and the systematic observation of volcanic activity.

2.3.2 Smart Agriculture

In [13] low populated areas we can use the wireless regional area network (WRAN), due to in these areas does not need much broadband and interfering radio frequencies are less common. In general terms there are three ways of to pollinate, but the most important method is the zoophile when it is run by an animal. In this context bees have an important role in the pollination of crops, about of 3/4 of what we eat, moreover play a vital role in maintaining the planet's ecosystems. The percent of pollination of crops made by bees is decreasing, due to many factors as pesticides, climate change, intensive agriculture, loss of biodiversity and pollution. In order to provide data about of health status of a beehive, applications are developed. Temperature and humidity are decisive for the development and survival of bees, so it is necessary to know what is happening with these factors inside the bee hives. Weight can give information to beekeeper about of the evolution of the colony and its production of honey. But, without doubt sound is one of the most important factors in bee analysis For example, the buzz of a healthy bee is not the same as that of a sick bee or the buzz when bees are preparing for swarming. The application is constituted with smart sensors that gather up data of temperature, humidity, weight and sound. These data are transmitted directly from the beehive to the beekeeper thought of wireless regional area network (WRAN). In this way he beekeeper to receive the hive's data, on your smartphone or tablet app to knowledge whether the bees are healthy or no. Also, will take decisions when needed. This avoids unnecessary trips to the hives. This is how smart agriculture is making an important contribution to ensuring the survival of the species.

2.3.3 Smart Health

Figure 2.8: Smart Health

- Wearable pulse sensors as photoplethysmographic (figure 2.9), which send a low-intensity infrared green light into the artery and only the amount not absorbed by the blood of light is received by a photo-diode. The heart beats, capillaries expand, and contract based on blood volume changes in consequence the voltage signal from PPG is proportional to the quantity of blood flowing through the blood vessels.[15]

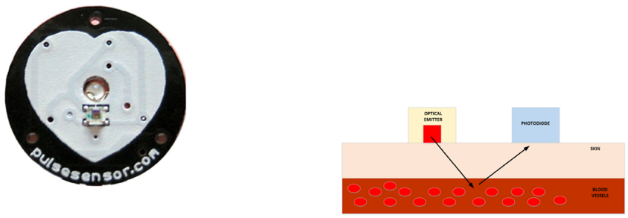

Figure 2.9: Photoplethysmographic pulse sensor [15]

- A respiratory sensor can give us information about of number of breaths a patient takes per minute in other words respiration rate, with this data we can identify illness as; heart attack, tuberculosis, asthma, lung cancer, and more. Echo-cardiogram is It's a type of ultrasound scan, which means that send out high-frequency waves that create echoes when they bounce off different parts of the body and with which make pictures of your heart. An echo-cardiogram helps doctors decide on the best treatment for these conditions. Ultrasound sensor works at frequencies above 20kh that is up to where the human ear is able to listen, and its operation is based on the piezoelectric effect, that is to say it is capable of generating an electrical potential in response to a mechanical deformation. A sound wave generated by piezoelectric effect, is a mechanical vibration that travel longitudinally without displacement of particles. Velocity of propagation depends of the viscosity and elasticity of the medium. The specific acoustic is similarity to electric impedance, then is the ratio of acoustic pressure to particle speed. In this sense for instance sound wave pass thought that go from blood to fat has a specific acoustic almost equal, not so when it goes through the bone.[15]

- Body temperature sensor is used to detect hypothermia, fever, etc. We talk of two sensors more uses to measure temperature, NTC and PTC,these ones have a suitable range of temperature with acceptable levels of error [15]. In recent investigations are being developed thin film RTD's with flexible polymers, that can be attached to human skin, but for there is a problem, because don't have the same behave like bulk platinum. It is due that physical properties of materials change when their size is reduced to the nanometer scale. There is other design which uses a temperature embedded in textiles. Design and fabrication of Temperature Sensing Fabric is made with a platinum wire of less than 25 mm in diameter [7].

  Design and fabrication of Temperature Sensing Fabric (figure 2.10) is made with a platinum wire of less than 25 um in diameter. Temperature sensing fabric (TFS) has been developed by embedding fine metallic wire into the structure of textile material.

- Blood Pressure sensor is used to detect the hypertension that is determined by increased pressure in the arteries. Few years ago, many

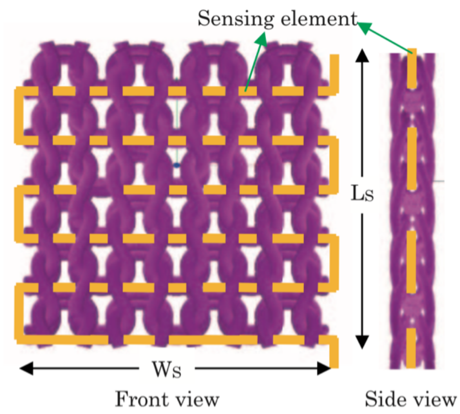

Figure 2.10: TSF showing inlaid sensing wire in a rib knitted structure TSF: temperature sensing fabric. [7]

works have developed for measure an accurate of blood pressure. These devices are based on the relation of time, namely, is the time taken by volume of blood to travel between the heart and an organ, in form of the pulse transit time PPT. There is a delay time that is measured with a electrocardiogram (ECG), recording device and pulse oximeter at a peripheral organ photoplethysmographic(PPG). Has yet been developed devices for accurately measuring blood pressure continuously using a comfortably wearable device. This new technology can relate in very innovative ways to the field of nano-technology and taking advantage of this cooperation we will be able to develop very small sensors and devices with important results as well. In the medicine field.

Chapter 3

HARDWARE

3.1 Smart Antenna Systems

In [14] an antenna is a device that converts radio frequency electric current to electromagnetic waves, which are designed for to transmission and / or reception electromagnetic waves. The electric field plane determines the polarization or orientation of the radio wave. The main characteristics of an antenna are; gain, radiation pattern, efficiency and polarization. The figure 3.1 show Antenna radiation pattern in polar domain. The main lobe contains the maximum energy radiated towards the receiver. Side lobes are any other radiation lobes except the main lobe and a back lobe is a side lobe which points in the opposite direction of the intended users. The radiated energy that arrives of users is called as beam-width and is define as the angular separation between two same points on the either side of the maxim of main lobe. The directivity of an antenna describe how well antenna can radiate in a particular direction.

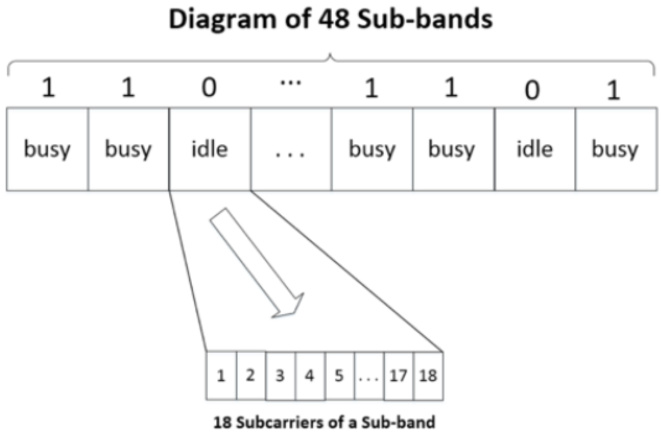

Figure 3.1: Irradiation Part od antenna [10]

There are many types of antennas, but there are two antennas particularly that can you help us understanding the behavior of these ones. [10] Omnidirectional antenna: its form of radiation all directions, being a disadvantage because restricting frequency reuse. To design a network with an omnidirectional antenna can cause many problems due to high burden of power of network nodes whereby may phenomenon as low battery depletion and interference.

Directional antenna: its form of radiation is in one direction, that which is advantage in the sense of reduction of packet delay [4] There are four categories of multibeam antennas;

- SIMO: single input, multiple outputs; where multiples antennas are used at the receiver, and one antenna is used as the transmitter.

- MISO :single output, multiple inputs; where multiples antennas are used at the transmitter, and one antenna is used as the receiver .

- MIMO: multiple input, multiple outputs; where multiple antennas are used at both receiver and transmitter(figure3.2).

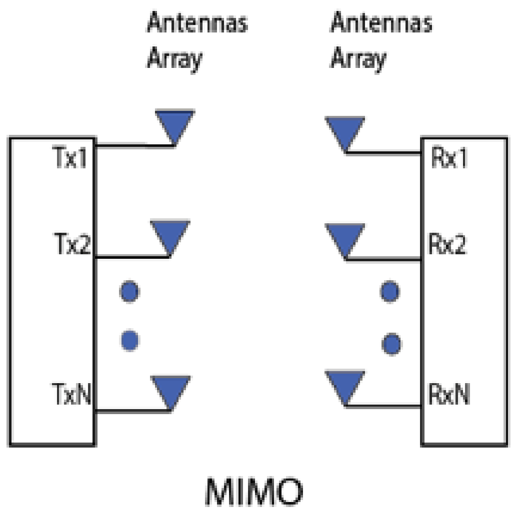

Figure 3.2: MIMO antenna [4]

Unfortunately, this technology doesn't satisfy the requirements for the next generation. The requirements of 5G systems, about broadcast antenna technology on the quality, capacity and coverage, steer its attention towards the design of smart or multi-beam antennas. That means a mixture of the omni-directional and directional antenna (only for best understand). [1]. 5G systems will work in an underutilized spectrum in 6-300GHz range, but in this range the electromagnetic wave suffers loss and blockage in the free-space (much more sensitive to obstacles), hence degrades the signal noise ratio (SNR). This shortcoming is overcome with the design of multi-beam antennas which are capable of generating a number of concurrent and independent beams. The multi-beam antennas has several characteristics.

- It has a high angular selectivity whereby permitting frequencies reuse.
- Taking advantage of the much smaller wavelength at the mmW frequencies, more antennas can be incorporated into an aperture with the same physical area
- The narrow beams emitting into different directions will undergo uncorrelated multi-path channels, i.e., the beam-space MIMO thereby further improving the link reliability and reducing the outage probability.

3.1.1 Passive Multi-beam Antennas

A finite number fixed and predefined of well-isolated input ports. Each port, backed by a transceiver (Tx/Rx), controls a single narrow beam pointing at a predefined direction. which has the next characteristics [14];

- The coverage that is the area where the communication link between a user and the base station can be carry out, is determined by the number of beams determines the range of coverage.
- Capacity is number of users a system that can support in certain area.
- Resolution is limited by the beam-width.
- The scanning range, polarization, gain, side-lobe level, bandwidth, port isolation, and efficiency.

3.1.2 PMBA's Based on Reflectors

PMBA's are based quasi-optics component with a continuous aperture, which use the Fourier transform in redistributing energy from the impinging free-space propagating wave to the required aperture distribution. As illustrated in figure 3.3, consists of a dish reflector, with a focal length of F and a diameter of D, and multiple feeding antennas, separated by a distance of d [14].

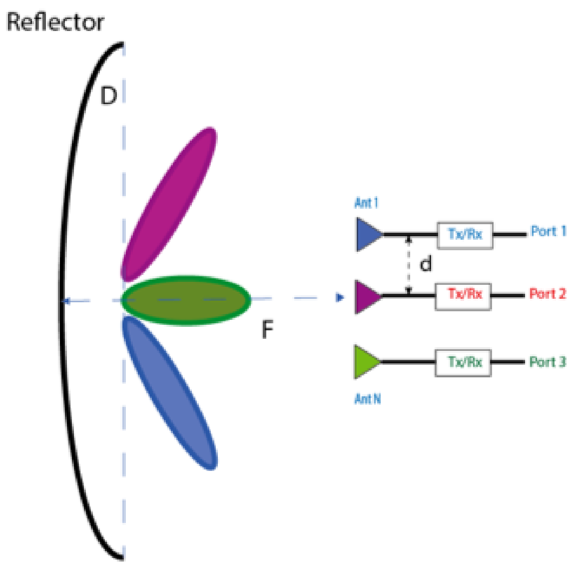

Figure 3.3: PMBA's Based on Reflectors [14]

3.1.3 PMBA's Based on Lenses

Are lens-based component figure 3.4, where one side of lens is illuminated by the input waves emitted from the feeding antenna, while the other side of the lens serves as the radiating aperture. It has been designed a new

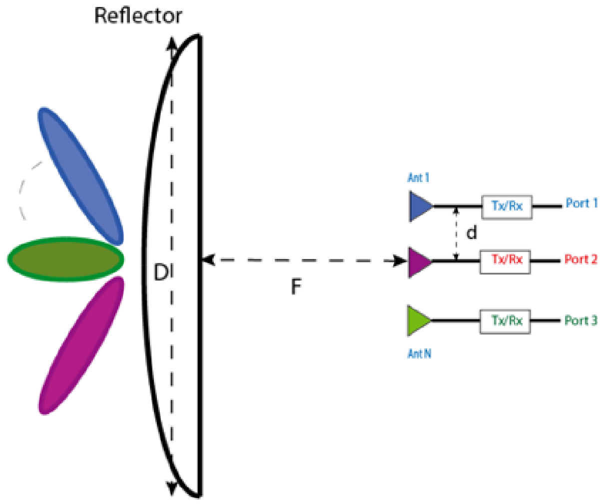

Figure 3.4: Conventional homogeneous lens [14]

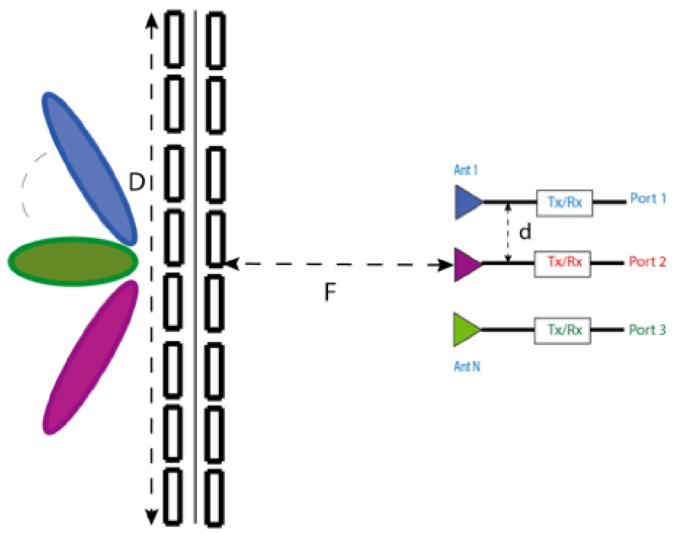

Figure 3.5: Configurations of a planar transmit-array fed by an array of antennas for producing N beams [14]

antenna with the aim reduce the weight and size, as depicted figure 3.5, it has a planar lens can be viewed as a hardware that performs the discrete Fourier transform on the incident wave which is a linear combination of plane waves impinging from different angles [14].

3.1.4 PMBA Based on Beam-forming Circuits

PMBA Based on Beam-forming Circuits, passive beam-forming circuit is a versatile approach that can be fully integrated with an array of antennas into a single substrate. The number of antennas determines the angular resolution and the overall gain of the system also increase, while the number of ports is a factor of spatial selectivity. A typical beam-forming NxM Bulter matrix, consisting of fixed phase shifters, crossovers, and 90° hybrid couplers, can produce a number of N orthogonal beams radiated from a uniform linear array (ULA) of M elements, as shown in figure 3.6. Basically, the Butler

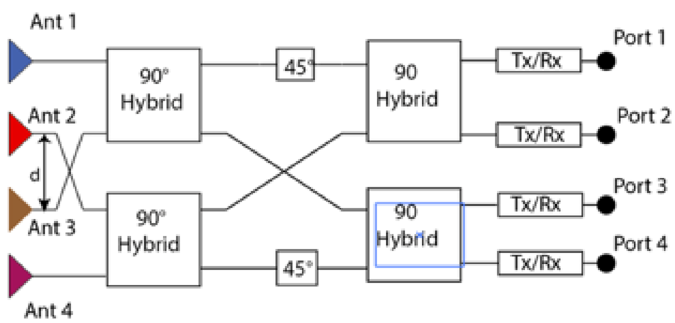

Figure 3.6: A typical beam-forming NxM Butter matrix [14]

matrix performs a hardware fast Fourier transform. The main limitation of the traditional Butler matrix is that both N and M have to be a power of two.[2]

3.1.5 MBPAA with RF Phase Shifting

Multi-beam Phased-Array Antennas Can be passive and active , a passive MBPAA (figure 3.7) is formed by N RF channels, M elements separated one distance d and multiplexer. Beam phase shifting (BPF) join to M elements with N RF channels and its function is refers to the displacement of two signals in a time domain and can vary from 0 to 360 also may or may not be of the same frequency. The total number of phase shifters is equal to the number of beams and the number of antenna element NxM. The transceiver joins the different beams with the N RF channels, each transceiver is composed for a duplexer, a low noise amplifier and a power amplifier, altogether they control the power level of a single beam [14]. For having a better power efficient when

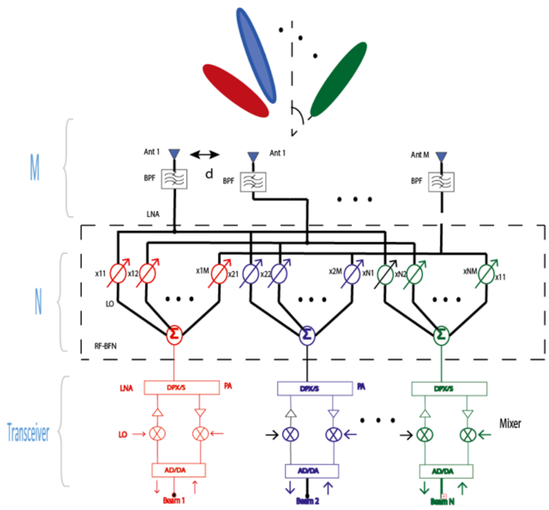

Figure 3.7: MBPAA Passive [14]

number of beam increases, it has been designed the active MBPAA's (figure 3.8) which has LNA, Pa and mixer between N RF channel and M elements.

There are many techniques for obtaining exactitude and power distribution

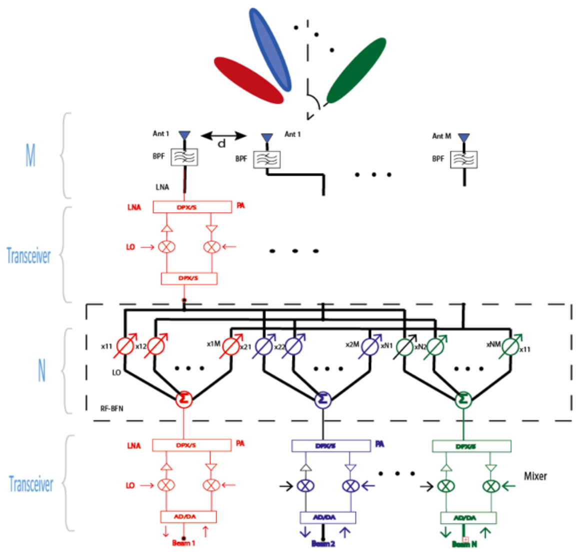

Figure 3.8: MBPAA Active [14]

on the phase shifting in all the uniform linear array;

- Transmission lines with P-I-N diode .
- Solid - State phase shifters based on CMOS o GaAs technologies.
- Attenuators and others

In this sense it has been development the heterojunction AlGaAs/ GaAs pin diode which are capable of enhances the RF diode and microwave performance. For instance, the AlGAAs which are formed by two diverse semiconductors materials and that have different fermi levels. This combination creates a difference in band-gap between P+ anode region and adjacent intrinsic region. This difference in band-gap enables a barrier height to be generated, which both enhances forward injection of holes from the P+ anode into the I-region and retards the back injection of electrons from the I-region into the P+ anode. This results in a P-I-N structure that has a significantly higher concentration of charge carriers reducing the RF resistance in the I-region of the heterojunction PIN device. To use GaAs technology is more beneficial than SiGe technology for several reason, small array, less power dissipation, reduction in ray die cost, low insertion loss, high power levels, good matching.[AlGaAs PIN diode multi-octave, mmW switches] Whereby we can have a whole of systems that use antenna arrays with at least few hundred antennas, simultaneously serving multiple terminals in the same time frequency resource. Both along the M- and N axis; these antenna elements are equally spaced between any successive pair of elements and this spacing is usually expressed in wavelengths.

3.1.6 Active Digital Multi-beam Antennas

The Active Multi-beam Antenna (figure 3.9)is composed of; uniform linear array of elements M whereby is generated N beams, the beam-forming is done by Digital signal processing (DPS), improving the accuracy and reliability of beam scanning [14]. Operation in reception mode (figure 3.10);

- The RF signal vector is converted and sampled at the BB via an analog-to-digital (ADC)converter.
- In the digital domain, a combining weighting matrix W.
- The output of the nth beam.

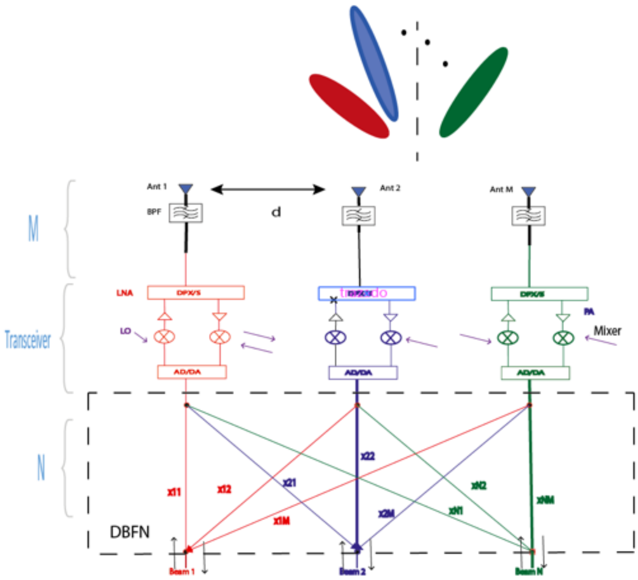

Figure 3.9: Full DMBA with M elements, M channels, and N beams [14]

In transmitting mode, the BB digital signal for each beam is multiplied by the conjugate transpose of the weighting vector, after this signal pass through a Analog- digital converter, in order for obtaining analog signal then it can be radiated by the ULA. The gain array is important because has direct relation with the signal noise ratio and the resolution of ADC converter. The field-programmable gate array (FPGA), which can handle millions logic calculations per second because has great among of gate, can produce more beams and array elements. Other way of improving the active DMBA (figure 3.11) is reducing the number of RF elements and this in turn it can lower the cost and complexity of system.

The design and development of antennas for wireless communication is a key research area. Which go oriented to challenges as : Beam-forming algorithm , digital processing hardware ,mmW component, array channel

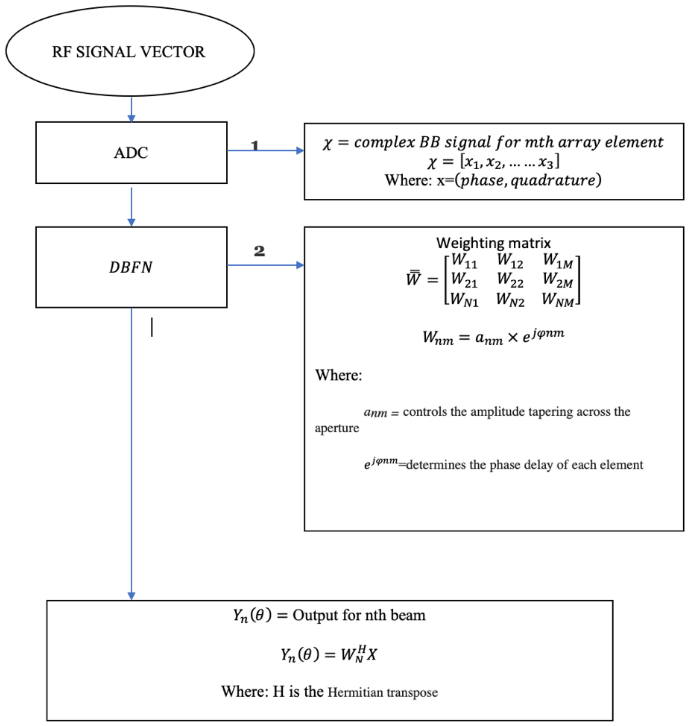

Figure 3.10: Operation in reception mode for a Full DMBA with M elements, M channels, and N beams

and system implementation.

3.2 Short-Range Wireless Communications

In [3] A wide range of frequency as depict the figure () bands are required for 5G standards to provide high-speed data transmission. Accordingly, standards for next generation personal area networks (PAN). In this context there are two main scenarios. IoT, which targets sensory and data collecting use cases such as smart grid, health, and environmental measurements and monitoring transportation. This scenario is mainly characterized

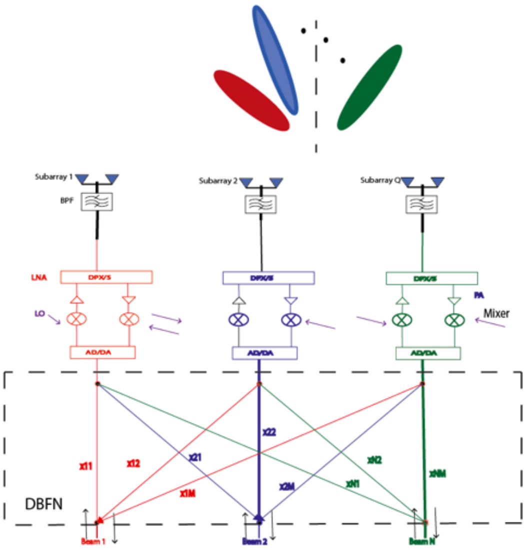

Figure 3.11: Fixed sub-array DMBA with M elements, Q channels, and N beams [14]

by small data packets and massive connections of devices with a limited power source. Tactile Internet which focuses on special applications and use cases IoT and vertical industries with real-time constraints such as Internet of vehicles. These new applications require very low end-to end latency and high reliability.

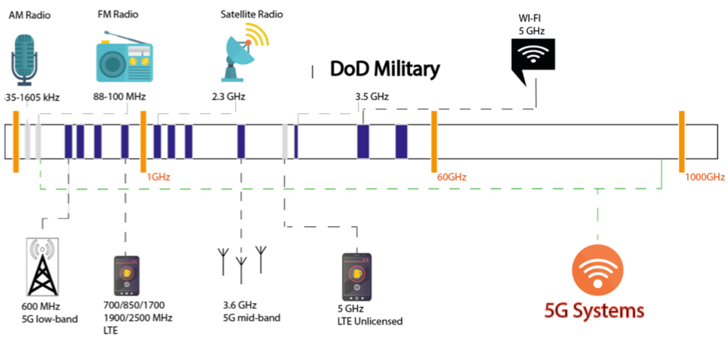

Figure 3.12: 5G frequency bands

- Frequency vs Data Rate.

  Why to works to high frequencies allow to us reach to higher date rates ?

  According to the Shanon-Hartley theorem Ec. 3.1

$$C = B\log_2\left(1+\frac{S}{N}\right) \tag{3.1}$$

where C is the capacity of channel in bits per second, B is the bandwidth of the channel in Hertz, and S/N is the signal-to-noise ratio. Between B and C, there is a direct relation, which means that as the bandwidth of the channel increases thereby increasing the information rate. The same way, As S/N increases, increase the information rate, by last if S/N $\rightarrow \infty$ it could have an infinite information rate no matter what of bandwidth. According the ec 3.2

$$\frac{S}{N} = \frac{Pr}{Pn} = \frac{Pr}{BNo} \tag{3.2}$$

SNR is the ratio between the received signal power Pr and the receiver noise Pn, thus there is a trade off between bandwidth and SNR On the other hand the band-width is a function of its center frequency and α B=αfo, α has a value typical of 1% is recent radio systems. Therefore, the higher the frequency is the higher data rate can be realized.

3.2.1 Ultra Wide Band Networks

Ultra Wide band (UWB) technology works on short-range radio links and occupies more than 500MHz bandwidth in the 3.1 to 10.6 GHz (figure 3.13) .Its way of transmission is not the traditional way (no modulated on a continuous waveform), send the information through impulse (of the order of picoseconds), saving energy. According to Shannon's law , the higher the bandwidth is the higher channel capacity.

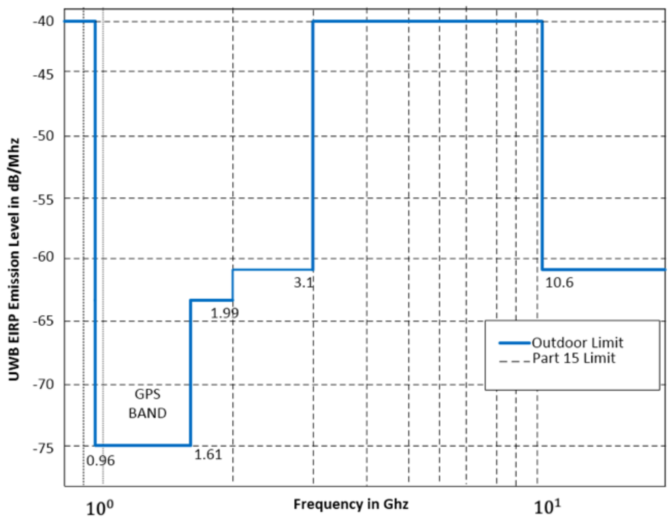

Figure 3.13: FCC spectrum mask for UWB [2]

3.2.2 UWB Technologies:

- Data in the IR-UWB communication systems can be modulated using different modulation schemes. The first one is the bi-phase modulation (BPM) wherein the data is encoded in the polarity of the impulse PAM (pulse-amplitude modulation) and PPM (pulse position modulation) are very easy for implementation but are sensitive to noise. Direct-sequence UWB (DU-UWB) has a system design simple and optimum power efficiency. Works with narrow pulses and time-domain signal processing. DU-UWB is a technique which has the simplest system design and optimum power efficiency, using for this aim the binary phase-shift keying (BSFK). BSFK has two output phases; the data symbol 1 is indicated in the phase value of zero degrees, and the data symbol 0 is indicated in the phase value of 180 degrees.

- Multiband-Orthogonal Frequency Division Multiplexer Technique Finding a realistic solution to avoid pulse-related issues of impulse radio (IR) UWB drives the MB-OFDM scheme that combines OFDM modulation and multiband transmission . The MB-OFDM (figure 3.14) uses a 128-point inverse fast Fourier transform (IFFT) and FFT with a subcarrier spacing of 4.125 MHz (528 MHz /128). Each data subcarrier is modulated by a quadra- ture phase-shift keying (QPSK) symbol. Zero-padded suffix of length 32 samples (60.61 ns) and a guard interval of five samples (9.47 ns) are used to prevent multi-path or inter-block interference and guarantee band switching time, respectively. Modulation can use time- and frequency-domain spreading of an order of two by repeating identical data in time- or frequency domain, respectively. Maximum data rate of 480 Mb/s can be provided. The multiband mechanism of MB-OFDM pro- vides five band groups over 3.1–10.6 GHz and each band group consist of three different bands except the last group that is composed of two bands. In addition, a time-frequency code (TFC), that specifies a sequence of frequency bands for OFDM symbol transmission, is used to interleave information data over a band group.

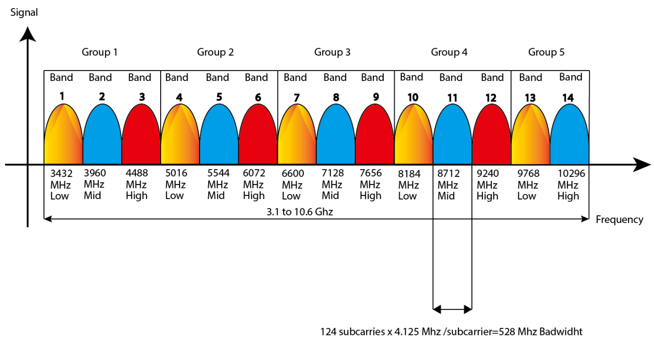

Figure 3.14: UWB standard Spectrum allocation for MB-OFDM [6]

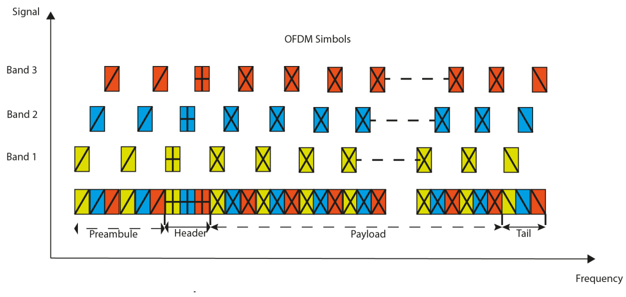

Figure 3.15: MB-ODFM packet

3.2.3 60 GHz Millimeter Wpan

Works with medium and short-range wireless communication, but in this range, there are channels higher path problems than the lower microwave bands. It means that there is an increase attenuation by 7.5-15 dB/km beyond 2Km in Outdoor Channel Effects. Instead, in the Indoor Channel Effects, the interference is decreased, because it has great broadband, high data rates, which allow increase frequency reuse factors and space efficiency. It uses a short wavelength that permits realize small products, as antennas and RF components, with high performance [3].

3.2.4 ZigBee Technology

Zigbee is a wireless technology that has a low throughput, low-cost, low-power wireless IoT networks. The Zigbee 's IEEE 802.15.4- 2003 standard operates on the physical radio specification and operates in unlicensed bands including 2.4 GHz, 900 MHz, and 868 MHz. Each band is assigned 16 channels, 10 channels, and a single channel for industrial, scientific and medical bands respectively [3]. The Bit-to-symbol block conversion: The bit to symbol map block converts the serial bit stream into a sequence of a multi-level pulse, group every 4 information bits into a symbol. The symbol- to- chip block converts one symbol in multiple chips. A chip is a pulse of a direct-sequence spread spectrum. Each 4 bit-symbol is mapped to one of 32-chip Pseudorandom (PN)sequences according to 16 quasi-orthogonal. This PN sequences for additional successive symbols are concatenated together and the aggregate resulting sequence is modulated using OQPSK (offset quadrature phase-shifting keying).In 915/868 Mhz. is used the modulation OQPSK figure 3.16

Differential encoding block is used for encoding for representing binary data, such as "0" and "1", which is an exclusive-or operation of the current input bit with the immediately prior input bit. The bit-to chip block converter provides a conversion of the bit a direct-sequence spread spectrum

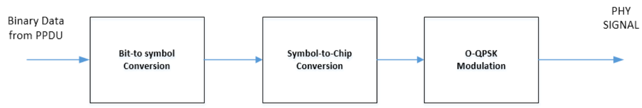

Figure 3.16: The block diagram of 2,4GHz

chip at a much faster rate than the user data rate. A raised-cosine filter is applied at the BPSK modulator to shape the signal (figure3.17).

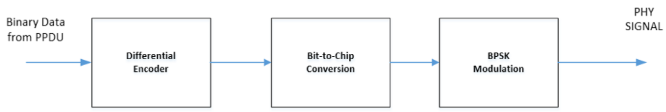

Figure 3.17: The block diagram of 915/868 Mhz

ZigBee uses access Carrier Sense Multiple Access with Collision Access (CSMA-CA) with re-transmission if messages sent are not acknowledged. ZigBee networking is classified into three different types: periodic, intermittent, and repetitive low-latency data. According to these traffic types, an optimized network configuration can be chosen because the power consumption depends on networking structure and device typ. Generally, ZigBee networks are suitable for low duty cycle and communications for long battery life. ZigBee has several topologies Fig which are conformed by; The coordinator initiating and managing the devices over the network. The routers permit data to pass to and for through them to other devices. End devices access limited to communicate with the parent nodes consequently the battery power is saved. The star topology is used in industries where all the end-point devices are needed to communicate with the central controller. The mesh topology has redundancy the main factor required in industries. The cluster network is used to deploying the wide-scale Wireless Sensor Networks. The implementation of the robust algorithm for the multi-hopping

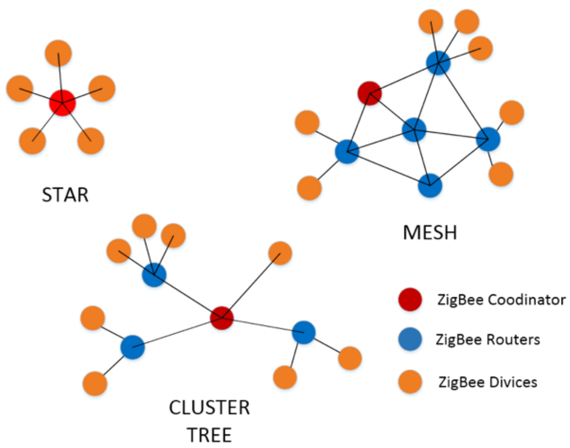

Figure 3.18: Zigbee Topologies

networks, that is used to counter interference, due to repeatedly and rapidly changing the transmitter frequency, this implementation is a problem due to limited resources as memory, power, and computational capacity. Device implementation must consider characteristics as hardware and software of the ZigBee. Multi-month of multi-year battery life, ZigBee works with low-duty cycle affecting the power consumption in sleep or power-down mode affecting the battery life. According to these modes, be can design devices avoiding leakage current.

Systems	**UWB**	**60 GHz WPAN**	**Zig-Bee**
Standard status	Dissolved in IEEE	In progress	Aproved
		57-64GHz(Japan)	2.4-2.4835 GH[1]
Frequency allocation	3.1-10.6 GHz	59-66 GHz(US)	921-928 MH[2]
		57-66GHz(Europe)	868-868.6 MH[4]
Channel bandwidth	>=500 MHz	No yet available	2,[1],0.6,[2],0.3 MHz[4]
Number of RF channel	2[5]	4(IEEE 802.15.3.C)	16,[1],10[2],1[4]
	14[6]		
	100 Mb/s(10 m)	2 Gb/s(at least)	$250Kb/s$,[1]
Maximum date rate	200 Mb/s(4 m)	>=3 Gb/s(optional)	$40Kb/s$,[1]
	480 Mb/s(optional)		$20Kb/s$,[4]
Modulation	DSSS,[5],OFDM,[6]	No Yet available	BPSK[2,4] OQPSK[1]
Latency	Short	Long	Short
Maximum coverage m	$\sim$ 10 m	$\sim$ 20 m	$\sim$ 20 m
Chanel access	Hybrid Multiple	Access	CSMA/CA
	(Random	Access	

[1] 2.4 GHz band ZigBee
[2] 915 MHz band ZigBee
[3] under consideration
[4] 868 MHz band ZigBee
[5] DS-UWB
[6] MB-OFDM

Table 3.1: Summary of characteristics of UWB, 60GHz millimeter-wave-based WPAN,and ZigBee. [3]

3.2.5 Conclusions

- The minimization of current and spectral leakage, both in nano-electronics and in telecommunications respectively, plays an essential role. There are many techniques to decrease current leakage. Instead in telecommunications, FBMC achieves high spectral efficiency because we can works with many appliances wearables when these ones as close as possible and work at the same time, using the total bandwidth as efficiently as possible [16].

- The technique multi-access Noma will be allowed many mobile users to operate at the same bandwidth and at the same time, thanks to the assignment of power levels for each user, what gives better performance in terms of capacity, energy efficiency and spectral efficiency [5].

- To achieve a successful implementation on NOMA, you must spend some time, as it happened with LTE in the fourth generation. This multiple access technique is very flexible because can be implemented with some other diversity techniques like MIMO [5] .

- The fifth-generation works too with heterogeneous networks, macro-cells, and small cells that coexist with the same spectrum, what it generates a significant interference between networks, this problem can be mitigated with interference alignment and space-frequency block codes [12].

- The antennas play a role essential in the fifth generation, in such a way, the technology of full DMBAs has a performance and flexible beamforming capability best than MBAs and MBPs, but this one still high-power consumption and economic cost. As time done by, the antennas will improve its algorithm beamforming for maintaining a high SNR [14].

- The architecture and technology chosen for the signal processing hardware are very important, should have a high data throughput, due it have a great among of information, for this reason,which must have a fast conversion speeds data (DAC and ADC)[14].

Appendix A

Body Language

Appendix B

title

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