Abu Dhabi University

EEN 336 - Communication Systems

Research Project

Digital Cellular Technologies in Mobile Phones.

Author:
Muhammad Obaidullah 1030313

Supervisor:
Dr. Montasir Qasymeh

Section 1

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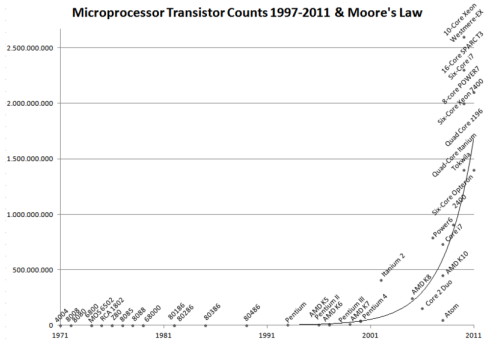
Abstract

This research paper discusses in detail some of the modern cellular data transfer technologies. In this research all the wireless telephone technologies from 1G to 4G will be discussed and the advantages of the latest generation over the past generation will also be discussed in details.

1 Introduction

Nowadays, every person on the planet has a mobile phone for communication. A person does not feel right without one. A day without mobile is like living a day in prehistoric time. A person feels incomplete, lacking, broken from the rest of the world, and stranded in an island.

'Mobile' word in mobile phone highlight the mobility or easy of transport of the phone. As the technology world progresses and recent advancement have been made, the electronic devices are becoming smaller and smaller following the Moore's Law. [6] Engineers are able to pack even more amount of transistors into a small area. The current transistor number of transitors in a typical Core i7 CPU is around 750 million. [8]



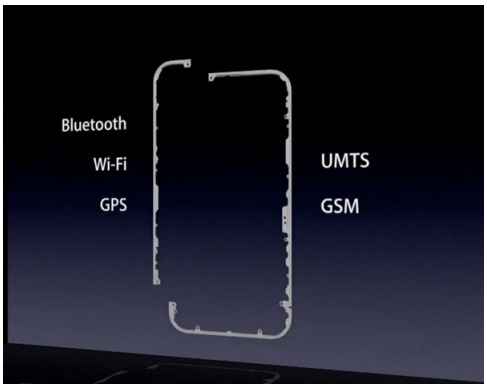
Mobile companies are racing with their competitors to support maximum number of mobile network technologies. This is challenging for the companies because of several following factors.

Limited Space Since the whole idea of 'mobile' is a device which is portable and small in size, the hardware inside the mobile needs to be tightly packed. On the other hand, engineers need to support many network technologies and need space for placing their circuits and hardware inside the mobile. The solution is to use microelectronics in the scale of nanometers. As the technology world advances, scientists and engineers are able to manufacture electronic components at even smaller scale. The current Core i5 and i7 semiconductor processors of Intel use the 32 nanometer technology.

Additionally, since different network technologies require different frequency band of operation, packing all antennas in mobile for different bands is a challenge. This brings up the next factor which affects the support for multiple network technologies.

Resonant Frequency of Antennas Before 2000, most of the mobile phones used a external monopole $\lambda/4$ antenna which came out of the mobile phone body. Since 2000, many mobile phone companies began to adopt the internal planar antenna types such as planar monopole, patch antenna, planar loop antenna. All of these planar antenna types have a advantage of being able to use the dielectric constant of the material on which they are placed causing the size of the antenna to reduce. Engineers and designers of the mobile phone have to use intelligent ways to design an antenna which resonates at all the required frequencies.

Internal antennas for the mobile phones are used dominantly in today's mobile phones because of their compactness, easy to produce, cost effective, and multiband support using coupled resonators. Additionally, internal antennas make the handset's external design independent of antenna which means the external shape of the mobile can be designed according to the consumer demands and then the antenna can be designed inside.



iPhone is one such example why having external antenna in mobiles is a bad idea. Immediately after release of iPhone 4, users reported having lost signals when iPhone was held in a particular manner. The cause was that when user held the phone, the users hand touched the antenna and changed the environment in which antenna was operating by changing permittivity. As a result, the resonant frequency at which the antenna operated was affected and signal was lost.

In response to this problem, apple rolled out a new update to the operating system which fixed and compensated the resonant frequency shift of the antenna. The reason Apple was able to fix the bug with a software update gives a huge clue that Apple is using software demodulation techniques for all of its supported network technologies. Changing and tweaking the parameters in the software demodulation equations to amplify the signal even more caused the problem to be fixed.

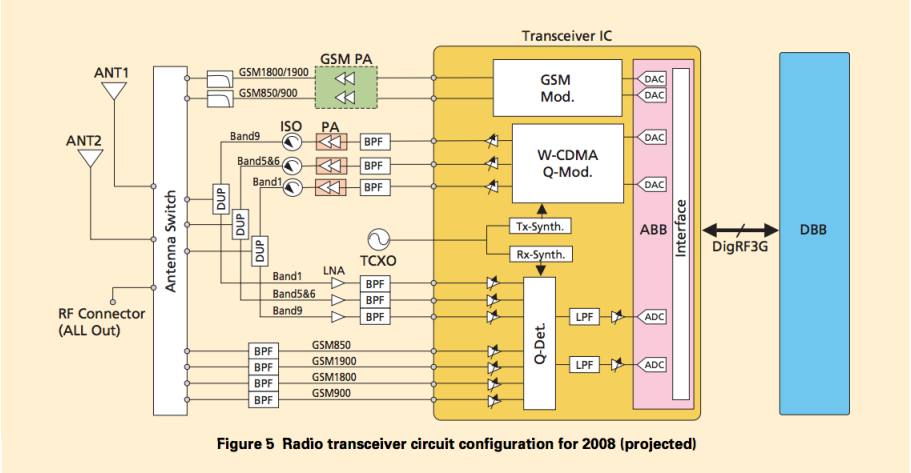


Figure 5 Radio transceiver circuit configuration for 2008 (projected)

Figure 1: This is the typical transceiver circuit that is used in mobile phones to support maximum and latest generation of modulation techniques [5].

Mobile phones have evolved through time to use different, intelligent and better techniques of communication. The first generation of mobile communication technology can be linked back to 1980s when analogue telecommunication standards were set. The 'G' in the wireless network refers to the generation of wireless technology that is being used. 1G refers to the group of wireless telecommunication technology which is analogue and from 2G onward the advantage of digital signal was apparent to the engineers and it was used.

In this research all the wireless telephone technologies from 1G to 4G will be discussed and the advantages of the latest generation over the past generation will also be discussed in details.

2 1st Generation

The first truly mobile system was NMT (Nordic Mobile Telephone) which was followed by a development of AMPS (Advanced Mobile Phone System) at Bell Labs in 1984. [4] All of these mobile network technologies used Frequency-Division Multiple Access (FDMA).

Figure 2: This is first mobile system NMT in 1981. [7]

This system had three disadvantages.

- Since each user is assigned a distinct frequency band for communication, the system can support only limited number of users at a time.
- Since the system was analogous, noise can often affect/overpower the signal power and cause the 'shhh' noise in the voice heard from the other side.
- The size of the components required to build one of these devices was huge which caused the overall size of the device to be huge.

The error correction protocols used by the 1st generation mobile networks were generally stronger than the land line networks in order to incorporate the uncertainty of the high interference from the free space.

3 2nd Generation

2nd generation of cellular technology brought a Voice and a low speed data transmission to and from the mobile. In order to get a 2G connectivity, each mobile should be equipped with a Subscriber Identity Module (SIM) in order to get an identity on the cellular network.

Code Division Multiple Access or simply CDMA has been around and evolved since World War II. It was invented by Hedy Lamarr, an Austrian-born lady actress, and inventor. The need for CDMA had risen due to two problems:

1. Frequency interference occurs when two transmitters/receivers are near and use the same frequency as each other.

2. A constant known frequency signal is easy to modulate, demodulate, and synthesize. [1]

Hedy Lamarr got the idea of the CDMA through the constantly changing notes she heard from a piano song. She thought that rather than sending a single note or single frequency to communicate which can easily be compromised, how about sending the message in constantly changing frequencies in a predefined/prearranged pattern. If the sender and receiver are synchronized or set to the same pattern then they will be able to communicate and other devices which are equipped with other patterns will not be able to listen to the message.

On 11th August of 1942, Hedy Lamarr got the patent on this communication system.[3] To this day, humongous amount of communication devices use CDMA including 802.11 wireless internet access and U.S. military Milstar satellite communication network.

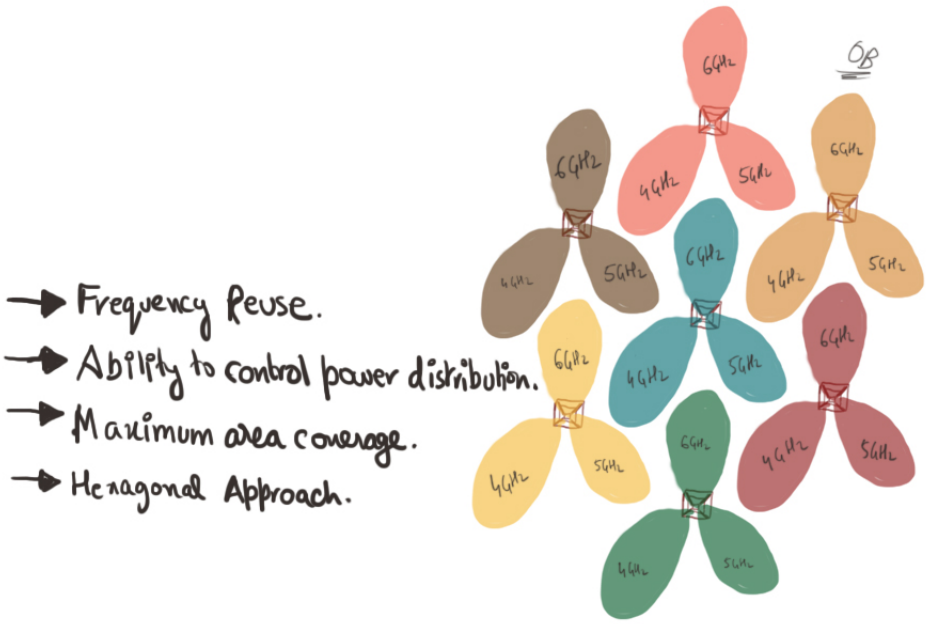


Figure 3: The figure describes the overall cellular system that was put up after 1 generation of network. [7]

There are many base transceiver stations located all around the city for sending and receiving cellular and voice data. These case transceivers are then connected to the base station controller which decides the frequency of operation of each base transceiver and the gain of each individual transceiver connected to it to control and maximize the area of coverage by allocating radio channels among the base transceiver stations. The base station control also manages the hand-offs between the base transceivers and tries to compliment the power loss of the signal from the mobile.

All the base station controllers are connected to the mobile switching services center which is basically called an exchange nowadays. This exchange is also connected to the database which stores all kind of related information such as the equipment identity and authentication.

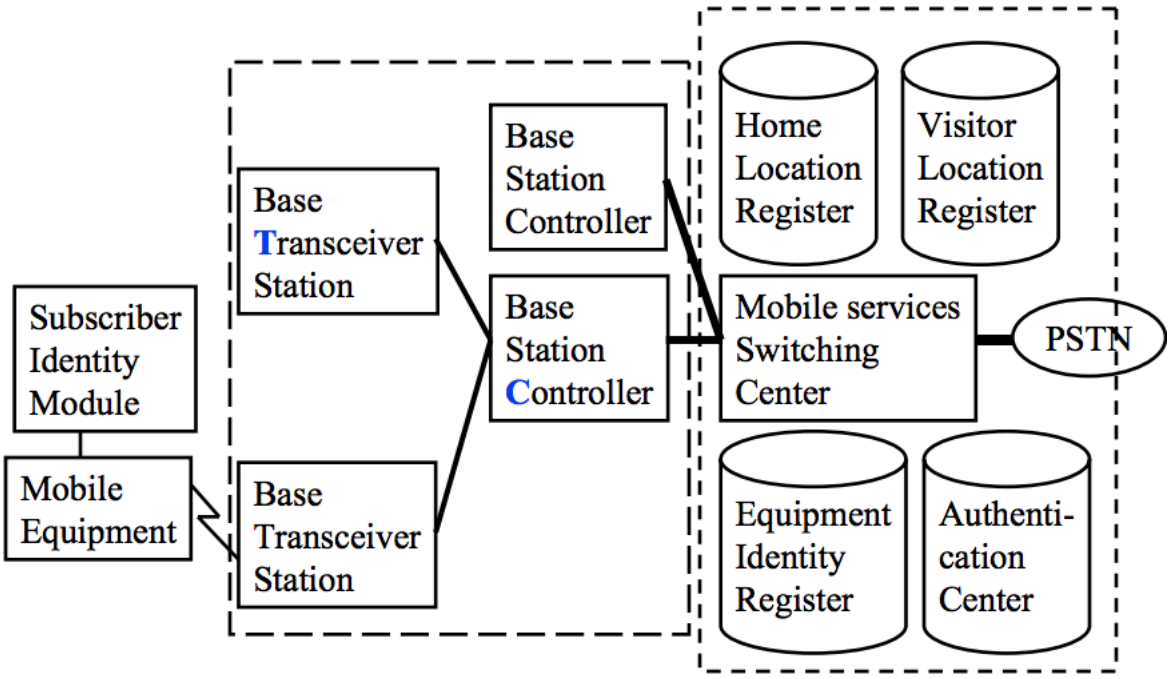


Figure 4: The figure describes the overall cellular system that was put up after 1 generation of network. [7]

3.1 CDMA-One (2G - IS95a): for data transfer

In 2G, the Code Division Multiple Access uses the entire allocated spectrum of frequencies and supports 22-24 calls per carrier. Each user is allocated a code of spreading. The surrounding cells can use the same frequency spectrum but have to go with different codes of spreading.

Power control of the signal sent and received to the mobile is very critical since CDMA filters the signal based on power put into a code signal. This poses a challenge for the network users but it allows more number of users to be supported than Time Division Multiple Access (TDMA) or Global System for Mobile (GSM).

3.1.1 Why CDMA-One is not used in 2G for voice transmission

A human voice frequency typically ranges from 300 Hz to 3400 Hz. Digital systems allow some guard bands for effective reconstruction of the voice signal making the bandwidth 4000Hz. In order for a system to digitize this signal, it should sample it at nyquist rate.

$$f_s = 4000\ Hz \times 2 = 8000\ Hz = 8\ KHz \tag{1}$$

CDMA - One limits the users to use channels with data rate from 4.8 kpbs to 14.4 kbps. Assuming that the signal is digitized using 256 levels. Each sample will have 8 bits making the bit rate

$$Bit\ Rate = 8 \times 8000 = 64Kbps \tag{2}$$

3.2 TDMA: for voice transmission

2G uses TDMA for allowing multiple users to access at a time by dividing time into slots and allocating it to a user at a time. TDMA was used for two types of transmission techniques, AMPS and GSM.

3.2.1 GSM

Federal Communications Commission allowed Global System for Mobile Communication (GSM) allocated 1900Mhz frequency band and there are currently 280 GSM networks in 100 countries around the globe.

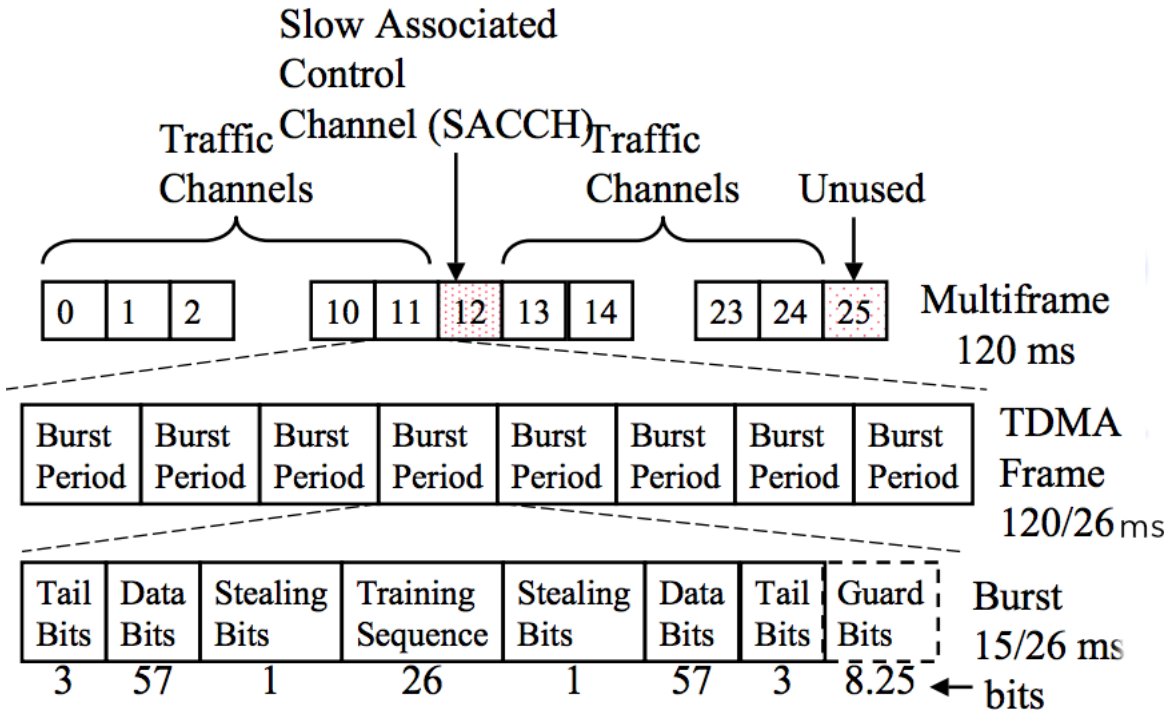


Figure 5: The figure describes the working of GSM Radio Link. [7]

The TDMA GSM works by supporting 23 users on traffic channels in a multiframe of 25 slots and duration of 120ms. Each multiframe except for the 12th and the 25th contains a frame called as burst period in which the data is sent in one go and then there is a waiting time. This burst time is given by $\frac{120}{26}ms$. The 12th frame appears in the middle of all the frames so that if the receiver is slow in processing the data, it can catch up. The last multifram is unused to give some time to the receiver to process the information and also keep a gap between the current and the next multiframe.

4 3rd Generation

3G is the third generation of mobile communications technology and supports services and provide information at the transfer rate of 200 Kbits/s. This is the generation which is widely in use nowadays. Many mobile devices nowadays provide higher than technical requirements of 3G standard.

4.1 UMTS: for voice transmission

The UMTS system was first offered publicly in 2001 and was later standardized by 3GPP. It is now in use in several countries including Europe, Japan, and China. Mobile phone technology nowadays has evolved to use hybrid of UMTS and GSM for voice transmission.

UMTS supports maximum theoratical data transfer rate of 42 Mbits/s. The requirement of human voice transmission is about 64 Kbits/s according to the above calculations. Speeds of UMTS are typically faster than the single GSM circuit switched network. Since 2006, in many of the countries are switching to High Speed Downlink Access or more commonly known as HSDPA which supports transfer speeds of upto 21 Mbits/s.

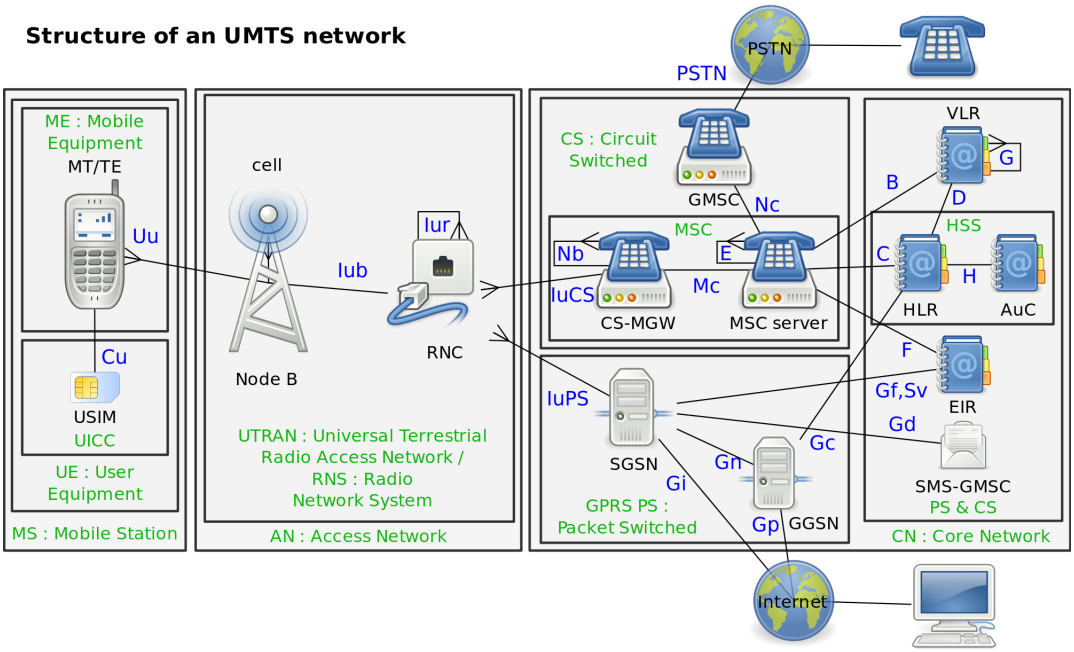


Figure 6: The figure describes the working of a UMTS network [7]

4.2 CDMA2000

CDMA 2000 also known as C2K is a 3G technology whcih is used to send voice, data and signaling data through a channel to mobile phones and cell sites. The packet speeds supported by this technology is of upto 153 Kbits/s.

Code Division Multiple Access uses the idea of giving a unique code to be sent alongside each bit. So each information bit is accompanied by a digital code and all of these codes should be

orthogonal and unique for each communication link. The unique code represents the device to which the sender is trying to communicate. At the receiver side, the same code is multiplied with the incoming signal and the information bit is retrieved.

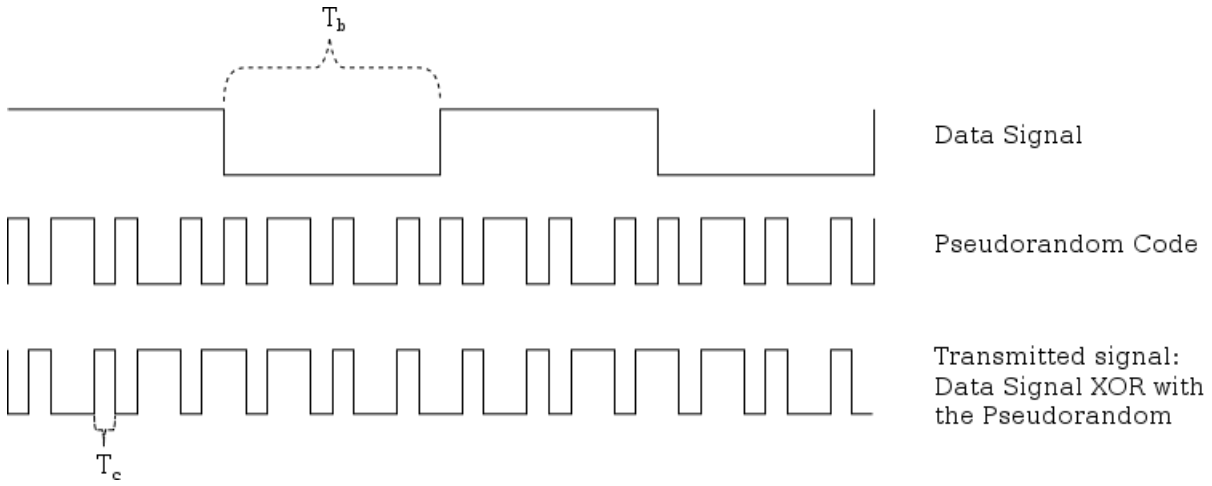


Figure 7: The figure describes the working of a CDMA. The unique code represents the device to which the sender is trying to communicate. At the receiver side, the same code is multiplied with the incoming signal and the information bit is retrieved.

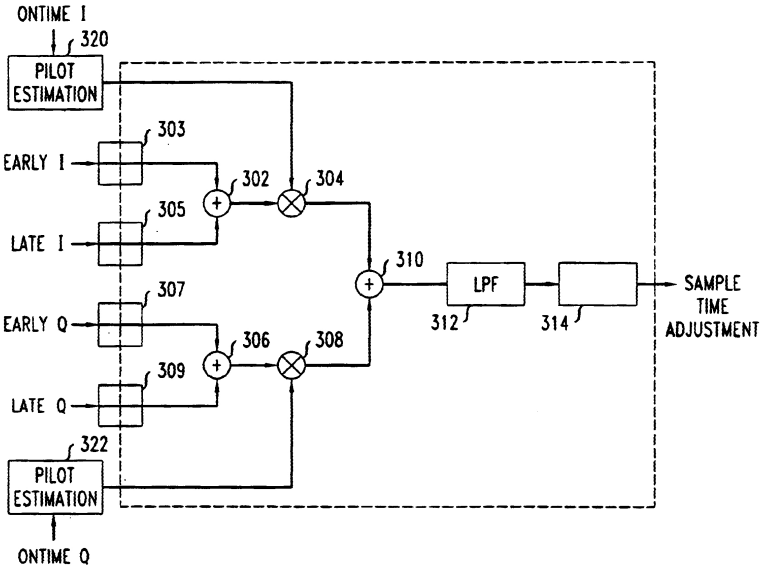


Figure 8: The figure shows the circuit of a tracking loop of a code division multiple access.

5 4th Generation: The future

The 4G mobile phone technology allows the users to get very very high transfer rates and it is still not well established. Humongous amount of research and development is going on in the field and the candidate technologies to be deployed are being decided.

Mobile WiMAX is one of the technology which is also one of the first releases of Long Term Evolution (LTE) standard.

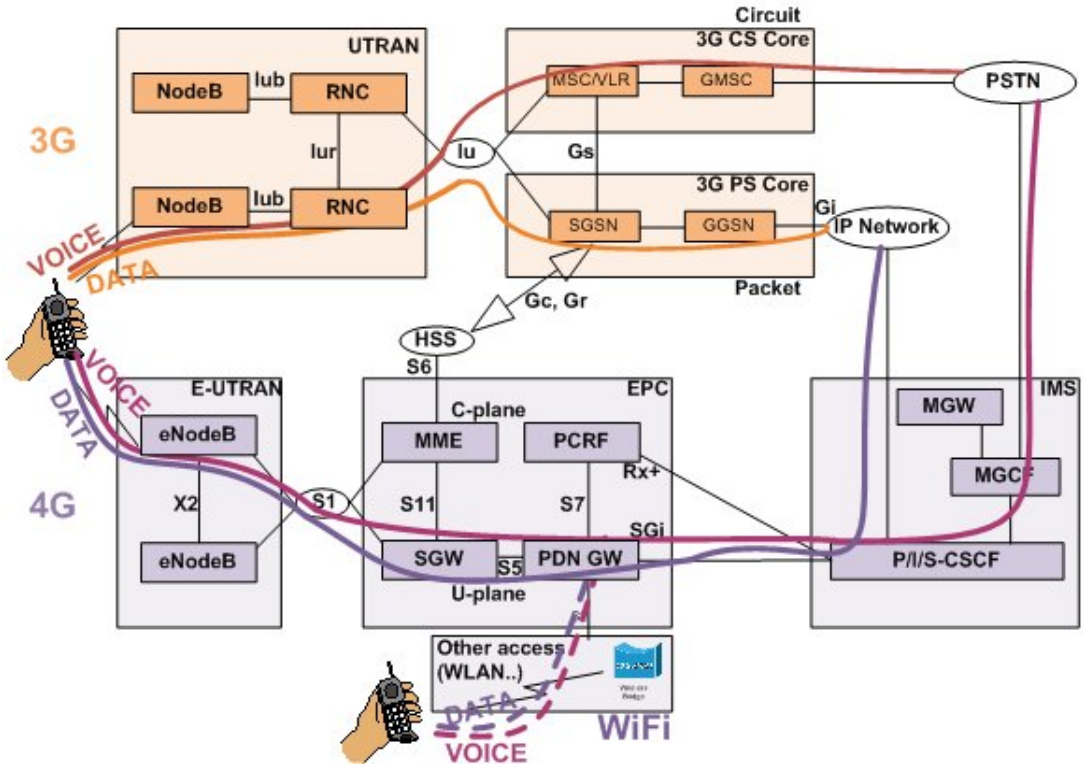


Figure 9: The figure shows a route comparison between the typical 3G connection and a 4G connection in terms of both, voice and data.

6 Conclusion

All in all, the research focuses on many aspects of mobile technologies and how they have evolved to send ever more amount of data quickly through the network. Additionally, the problem of supporting humongous amount of users through a single channel at a time has lead into engineers and scientists to discover intelligent ways to modulated and demodulate the data.

Code Division Multiple access was a huge leap into the forward direction because of its ability to support many users at a time on the same frequency band. CDMA is also very difficult to block and interfere because of its coding schemes. There is some still on-going research and development in the fields of CDMA.

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