Investigation on Wireless Communications

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***Abstract*— This document investigates technical details and development on wireless communications.**

I. Introduction

This document investigates technical details and development on wireless communications. It will include popular technologies including FDMA, TDMA and CDMA. Data transmission and bandwidth of different generations will also be compared and discussed. Some potential risks and issues regarding to wireless communications will also be shown.

II. Main Content

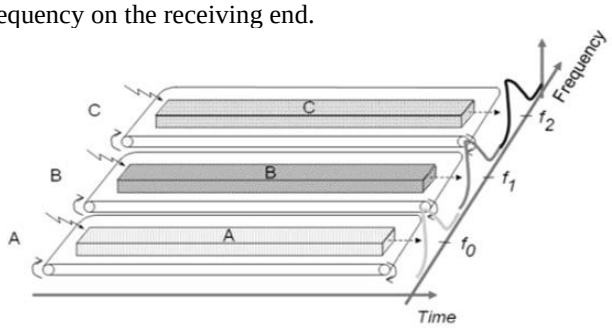
A. FDMA, TDMA and CDMA

1. Frequency Division Multiple Access (FDMA)

Frequency division multiple access is a channel access method used as a channelization protocol which is used in multiple-access protocols. Users are given one or several frequency bands or channels. It is particularly commonly used in satellite communication.

'FDMA is implemented at the media access control (MAC) layer of the data-link layer in the Open Systems Interconnection (OSI) reference model for networking protocol stacks. FDMA is based on the frequency-division multiplexing (FDM) technique used in wireless networking' (Thenetworkencyclopedia.com, 2018).

Guard bands are used in FDMA method. It is to minimize crosstalk between different channels. One specific band is given to one and will be received by identifying each of the frequency on the receiving end.



https://www.tutorialspoint.com/cdma/images/fdma.jpg

Transmission by mobile station:
824 MHz to 849 MHz

Transmission by base station:
869 MHz to 894 MHz

Two different frequency bands are used to allow full-duplex communication between base and mobile stations. Both of these bands are then divided into discrete channels that are 30 kHz wide in bandwidth.

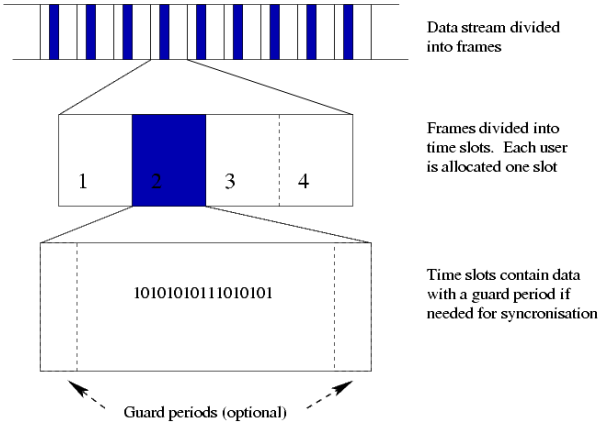
Advantages:
- Reduces the bitrate information and efficient numerical codes increases its capacity
- Reduces cost and lowers ISI
- No need for equalization
- It can be easily implemented
- Less number of bits are required for synchronization and framing

Disadvantages:
- The maximum flow rate per channel is fixed and small
- Guard bands lead to waste of capacity
- Hardware implies narrowband filters that increases cost

2. Time-Division Multiple Access (TDMA)

Time-division multiple access (TDMA) is a channel access method for shared-medium networks. It allows several users to share the same frequency channel by dividing the signal into different time slots. The users transmit in rapid succession, one after the other, each using its own time slot. This allows multiple stations to share the same transmission medium (e.g. radio frequency channel) while using only a part of its channel capacity. TDMA is used in the digital 2G cellular systems such as Global System for Mobile Communications (GSM), IS-136, Personal Digital Cellular (PDC) and iDEN, and in the Digital Enhanced Cordless Telecommunications (DECT) standard for portable phones. It is also used extensively in satellite systems, combat-net radio systems, and passive optical network (PON) networks for upstream traffic from premises to the operator.

TDMA is a type of time-division multiplexing (TDM), with the special point that instead of having one transmitter connected to one receiver, there are multiple transmitters.



https://upload.wikimedia.org/wikipedia/commons/f/f9/Tdma-frame-structure.png

Characteristics:
- Shares single carrier frequency with multiple users
- Non-continuous transmission makes handoff simpler
- Slots can be assigned on demand in dynamic TDMA
- Less stringent power control than CDMA due to reduced intra cell interference
- Higher synchronization overhead than CDMA
- Advanced equalization may be necessary for high data rates if the channel is "frequency selective" and creates Intersymbol interference
- Cell breathing (borrowing resources from adjacent cells) is more complicated than in CDMA
- Frequency/slot allocation complexity
- Pulsating power envelope: interference with other devices

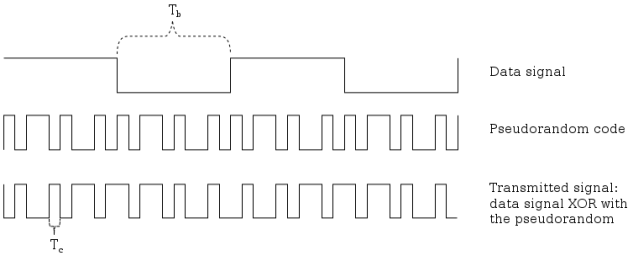
Advantages:
- The radio part of the mobile only needs to listen and broadcast for its own time slot

Disadvantages:
- They create interference at a frequency which is directly connected to the time slot length
- The "dead time" between time slots limits the potential bandwidth of a TDMA channel

3. Code-Division Multiple Access (CDMA)

Code-division multiple access (CDMA) is a channel access method used by various radio communication technologies. CDMA is used as the access method in many mobile phone standards. IS-95, also called "cdmaOne", and its 3G evolution CDMA2000, are often simply referred to as "CDMA", but UMTS, the 3G standard used by GSM carriers, also uses "wideband CDMA", or W-CDMA, as well as TD-CDMA and TD-SCDMA, as its radio technologies.

CDMA is a spread-spectrum multiple-access technique. A spread-spectrum technique spreads the bandwidth of the data uniformly for the same transmitted power. A spreading code is a pseudo-random code that has a narrow ambiguity function, unlike other narrow pulse codes. In CDMA a locally generated code runs at a much higher rate than the data to be transmitted. Data for transmission is combined by bitwise XOR (exclusive OR) with the faster code. The figure shows how a spread-spectrum signal is generated.



https://upload.wikimedia.org/wikipedia/commons/thumb/7/7e/Generation_of_CDMA.svg/760px-Generation_of_CDMA.svg.png

Advantages:
- CDMA is robust against fading and noisy environment
- It is difficult for hackers to decipher the CDMA code used over traffic channel
- Easy to add users
- Minimizes chances of call drop or disconnection
- Nationwide roaming is possible without any issues

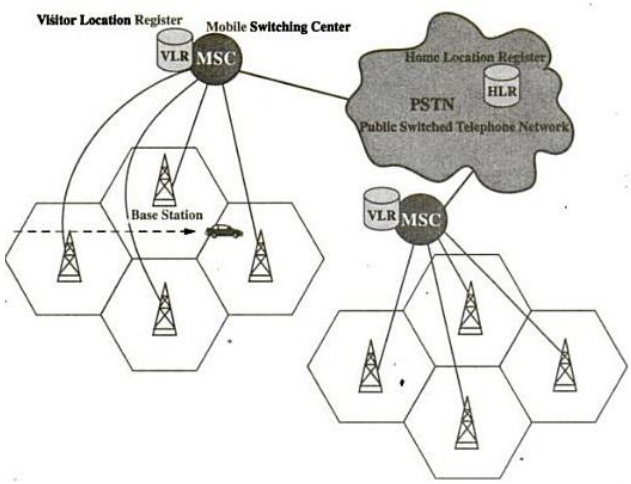
Disadvantages:
- The subscribers which are farthest from BS will incur more attenuation and hence will lose the orthogonality and hence it will be difficult to recover the data
- Precision code synchronization is needed to recover the original baseband signal
- Increase in number of users will decrease the overall QoS
- Self Jamming is observed in CDMA system due to loss of orthogonality of PN codes or spreading sequences of different subscribers

B. Communication and 'Roaming' Service

1. Communication while Moving

A mobile phone connects over a cellular network of specialized base stations known as cell sites. A cell phone offers full Duplex Communication and transfer the link when the user moves from one cell to another. As the phone user moves from one cell area to another, the system automatically commands the mobile phone and a cell site with a stronger signal, to switch on to a new frequency in order to keep the link.

The cellular service area is divided into hexagons. These hexagonal areas are served by Base stations which are responsible for establishing the last mile connection to the mobile station or the mobile equipment.



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As the mobile station is in a new service area relevant entry in Home location Register and Visitor location register are updated and a new channel is assigned to the mobile station so that it can continue the call without interruption. In case a channel is not available an existing channel maybe divided, or the request queued.

Thus, a device is able to continue its connection when moving to a new area without disruption.

2. Roaming

Roaming service is the ability to get access to the internet when away from home location (usually across nation). This is made possible through ISP (Internet service providers) who have cooperative agreements to grant each other's customers local access to the Internet. For example, one typical mobile device (home location China) uses China Unicom's stations and services in China. When the device moves to Australia, instead of staying with China Unicom, it switches to Optus (which corporates with China Unicom) stations for better connectivity and services. This enables the device to enjoy the same quality service even far away from its home location (though this may cause huge additional costs).

The roaming process includes 'location update' which is the mechanism used to determine the location of a mobile station in the idle state (connected but with no active call). Then it goes through the process of 'handover' and 'handoff' to transfer the session from one channel to another.

Types of handover:

- Hard handover

Is one in which the channel in the source cell is released and only then the channel in the target cell is engaged. Thus, the connection to the source is broken before or 'as' the connection to the target is made—for this reason such handovers are also known as break-before-make. Hard handovers are intended to be instantaneous in order to minimize the disruption to the call. A hard handover is perceived by network engineers as an event during the call. It requires the least processing by the network providing service. When the mobile is between base stations, then the mobile can switch with any of the base stations, so the base stations bounce the link with the mobile back and forth.

Advantage:

At any moment in time one call uses only one channel. The hard handover event is indeed very short and usually is not perceptible by the user. The phone's hardware does not need to be capable of receiving two or more channels in parallel, which makes it cheaper and simpler.

Disadvantage:

If a handover fails, the call may be temporarily disrupted or even terminated abnormally. Re-establishing this connection may not always be possible

- Soft handover

one in which the channel in the source cell is retained and used for a while in parallel with the channel in the target cell. In this case the connection to the target is established before the connection to the source is broken, hence this handover is called make-before-break. The interval, during which the two connections are used in parallel, may be brief or substantial. For this reason, the soft handover is perceived by network engineers as a state of the call, rather than a brief event. Soft handovers may involve using connections to more than two cells: connections to three, four or more cells can be maintained by one phone at the same time. When a call is in a state of soft handover, the signal of the best of all used channels can be used for the call at a given moment or all the signals can be combined to produce a clearer copy of the signal. Softer handovers are possible when the cells involved in the handovers have a single cell site.

Advantage:

The connection to the source cell is broken only when a reliable connection to the target cell has been established and therefore the chances that the call will be terminated abnormally due to failed handovers are lower. Simultaneously channels in multiple cells are maintained and the call could only fail if all of the channels are interfered or fade at the same time. Fading and interference in different channels are unrelated and therefore the probability of them taking place at the same moment in all channels is very low. Thus, the reliability of the connection becomes higher when the call is in a soft handover.

Disadvantage:

More complex hardware in the phone, which must be capable of processing several channels in parallel. Use of several channels in the network to support just a single call. This reduces the number of remaining free channels and thus reduces the capacity of the network.

C. Capacity of Transmission of Different Generations

1G:
This is the first generation of wireless cellular technology.
The maximum speed of 1G is 2.4 Kbps
This means it only supports voice only transmissions. It is also prone to drops and disconnections.

2G:
2G upgrade introduced call and text encryption and new data services.
The maximum speed of 2G is 50 Kbps (GPRS) or 1 Mbps (EDGE).
2G is capable of transmitting much more data and with the new technology encryption becomes possible, making it more secure. With 2G we can transmit low quality images. This is where MMS came out.

3G:
3G upgrade brings much more bandwidth which made video calls possible.
The maximum speed of 3G is 2 Mbps (stationary) and 384 Kbps (moving).
3G helped the development of video calls and mass social media. Viewing high quality images and browse through pages like on broadband became possible with the help of 3G.

4G:
4G is the current most popular technology.
The maximum speed of 4G is 1 Gbps (stationary) and 100Mbps (moving).
4G brings much more bandwidth compared to 3G. This makes lots of services now available on mobile devices. High quality video streaming and gaming services now become popular.

To investigate the transmission capacity of different generations, some typical data of images and videos is captured:

Images (by file size):
A sticker sized JPEG: 1-50 Kb depending on colour depth
Normal quality JPEG: around 500 Kb
High resolution JPEG: around 2Mb

Videos (by bit rate):
360p 30fps: 1 Mbps
720p 30fps: 5 Mbps
1080p 30fps: 8 Mbps
1080p 60fps: 14 Mbps
1440p 60fps: 25 Mbps

According to the data observed above, we can now investigate what a certain generation is capable of:

1G:
With a maximum speed of 2.4 Kbps (under the best condition), it can hardly transmit a single image (even the lowest quality ones). Hence it is only capable of basic voice calls.

One main difference between 1G and next generation 2G is that 1G uses analog radio signals while 2G uses digital radio signals. Another difference is that 1G uses FDMA and 2G uses TDMA. For FDMA, the maximum flow rate per channel is fixed and small. Moreover, guard bands in FDMA lead to waste of capacity. Therefore, 1G has extremely limited bandwidth and is only capable of traditional voice calls. The disadvantage of analog and limited bandwidth eventually led to 2G taking over 1G network.

2G:
When you do not have access to EDGE, the maximum rate is 50 Kbps. This allows you to transmit some low-quality images and stickers or emojis. However transmitting videos is not possible at this point.
When Edge is available, it will be capable of transmitting some higher quality images. You can even transmit some videos of very low quality. You can go on some video sites under this network condition, but it takes quite a while for the video to load up.

As mentioned before, 1G network uses analog signals and FDMA causes a lot of wasted resources resulting in its limited bandwidth. A lot of changes have been made to upgrade to 2G network. TDMA is used instead of FDMA. 2G uses digital radio signals instead of analog signals. 2G networks support encryption and are significantly more efficient on the spectrum enabling much greater wireless penetration levels. The higher bandwidth of 2G enables services like SMS and MMS, allowing the transferred data to be only readable by the intended receiver.

3G:
With the 384 Kbps rating even when moving, 3G network is capable of transmitting good quality images. This is where live chatting become really popular. Image transfers makes communication much easier at this point. With the 2 Mbps transfer rate when stationary, low quality video streaming becomes possible. 3G brings the possibility for mobile devices to browse regular web pages like on a computer with broadband.

3G network transferred from TDMA to CDMA, a technology that is robust against poor environment for signal transmission. Poor environment like noise and high

temperature hugely affects the transmission of digital signals. Technologies used in 2G does not perform well under these circumstances thus resulting poor overall bandwidth for transmission. 3G uses CDMA which creates much stronger and stable connection allowing faster transfer and enhanced stability to avoid drop outs and disconnections. The development of 3G network enables multi-media services on mobile devices.

4G:

This is where mobile network become lightning fast. The 100 Mbps speed is capable of extreme high-quality video steaming, not to mention images. There are nearly no restrictions on 4G network. You can now use your mobile device just like any computer connected to ethernet. Connections also became much more reliable and live steaming and gaming became possible with the help of 4G.

4G network does not provide such 'revolutionary' technology upgrades compared to previous 3G network. Thus, some doubted whether they should call this '4G' when they first appeared. 4G network is an upgrade from 3G which significantly increases the bandwidth to provide optimal mobile network service.

Modern 4G network uses all-Internet Protocol packet-switched networks giving it ultra-broadband access (gigabit speed).

The advantages of packet switching are:

- Efficient use of network
- Easily get around broken bits or packets
- Circuit Switching charges users only on the basis of duration of connectivity.
- High data transmission in a packet switching is very easy
- All the packets not follow same route in packet switching
- Packet switching use digital network and enables digital data to be directly transmitted towards destination.

Packet Switching dramatically increases the transmission efficiency providing ultra-fast and reliable mobile networks. And this leads to 4G being able to provide ultimate multimedia service on mobile network like live steaming and gaming.

D. Issues and Risks

1. Issues

- Wireless communications are prone to jamming and interference. For example, routers these days usually have multiple bands for it to work perfectly when multiple devices are connected to it wirelessly. This is because if they all use the same band, they will cause interference with each other. This will result in unreliable connections and low transfer speeds. Or even worse, the devices will constantly lose connection. Another case that might be caused by this issue is: one can easily disrupt wireless connections in a certain area using specialised devices. As far as we are concerned, these devices are not hard to obtain nowadays.

- Although wireless networks today are almost perfect to use, there's still issues regarding connection stability and speeds. Radio waves travel through the air and across obstacles without any sort of physical protection. Simple interference might cause the certain part of the signal to be lost, resulting in disconnections or corruptions. If you want reliability, wired network is still the way to go. Wireless network may never be as stable as wired network.

2. Risks

- One risk using wireless network is apparent: Hackers. As mentioned in the section above, signals do not have any sort of physical protection. Any one can actually get that signal which is transferred. The protection is actually the coding layer which is decryptable in some way. An average person will certainly not able to decrypt the data easily. But an experienced hacker might be able to. A huge number of news regarding to data leaks suggest that data is not secure today. This might not affect a normal person's life, but it is definitely a sort of risk to be considered.

- Hackers can get the data that is transferred through the air. They can also modify it for some purpose. Virus is a thing that can destroy a whole system. And it is easily distributable through wireless network. Devices now synchronises data anywhere, anytime thanks to the ultra-fast 4G network. Our devices do it silently without our notice. This can pose a huge issue. If a hacker modifies the data that is transferred or more specifically, they put virus across a certain wireless network. Huge number of devices will be affected, and this will cause a total chaos.

III. CONCLUSIONS

Mobile communication networks have been hugely developed through the three decades. From the voice-only 1G network to the freedom 4G network, lots of new technologies were implemented to create a faster and more reliable network. Roaming services made moving not a problem for data connections. With the help of mobile networks, the world is now truly connected without minimal limitations. Years have passed since the 4G release and we can all look forward to the next generation 5G network.

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