

Radio Frequency Operations and Technology

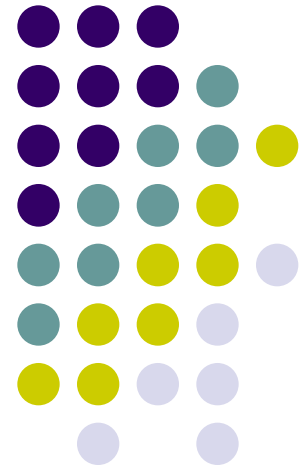
Mobile Device Investigations Program

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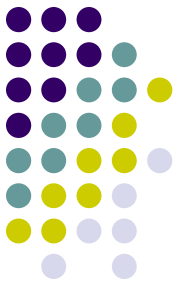
Senior Instructor

Technical Operations Division

DHS - FLETC



RF Operation and Technology

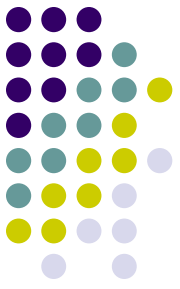


Radio propagation – the electromagnetic phenomenon discovered by Heinrich Hertz in the late 1880's. It's how energy travels through a given medium.

The medium can be air, water, twisted cable, fiber optics and the like. Radio signals travel at the speed of light through the air – 186,282 miles per second.

The only significant difference between cellular systems and conventional landlines is the radio link that connects the wireless network to the cell base station.

RF Operation and Technology



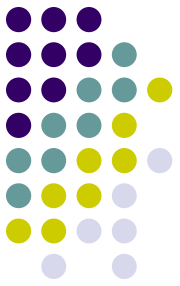
Different radio signals have different properties, i.e.
High frequencies and Low frequencies

Signal Refraction - signals bend through the
atmosphere

Signal Diffraction - signals bend around obstructions

Signal Reflection - signals bounce off obstructions or
solid objects

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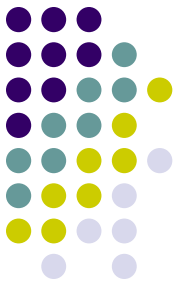


Examples of radio signal actions

- Diffraction Air careens over a moving car and off the back end
- Reflection Light bouncing off a mirror

Radio Frequency propagation refers to how well radio signals radiates or travels in free space.

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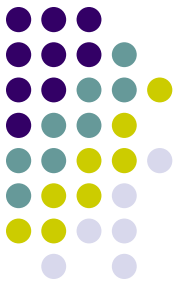


Wireless signals are basically omnidirectional

Omnidirectional; all directions, propagation is often described as waves.

Pebble In Water - size of pebble, water and enegey

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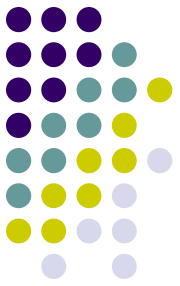


Radio Frequency coverage from any base station is determined by three factors;

1. The height of the antenna
2. The type of antenna used
3. The Radio Frequency Power Level emitted.

This is true no matter where the antenna is placed

Signal Fading and Ducting

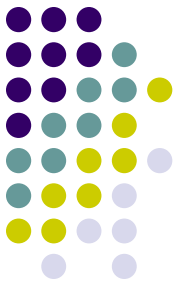


There are a number of things that may interfere with the propagation of a radio signal.

Some of the ongoing issues wireless carriers have to deal with are;

1. Ducting
2. Signal Fading

Ducting



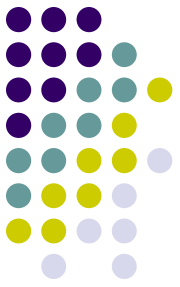
Ducting is defined as the trapping of RF in the boundary area between two air masses.

Ducting of RF is an atmospheric anomaly known as temperature inversion

Ducting is unavoidable because it is a natural meteorological phenomenon.

Downtilting or directing the RF toward the ground may compensate for ducting.

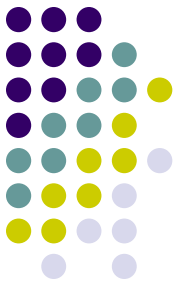
Absorption



Absorption describes how a radio signal is absorbed by objects

The greater the amount of absorption the less geographical area can be covered.

Organic material absorbs more wireless signals than in non-organic.

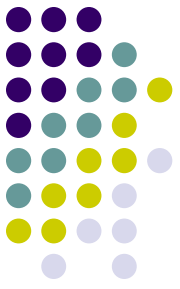


Absorption

Absorption can be compensated for in the following ways:

1. By using higher-gain antennas
2. By using higher RF power levels in order to cover the same geographic area
3. By decreasing the distance between Base Stations

Free Space Loss

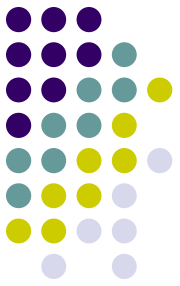


Free-space Loss or Path Loss describes the attenuation of a radio signal over a given distance.

The higher the frequency the greater the free space loss. PCS carriers operating at 1.9MHz will have greater loss than wireless carriers operating at 850 MHz.

Power Levels of a Base Station signal and antenna gain will determine when a wireless signal will fade

Multipath/Rayleigh Fading

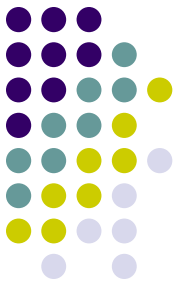


Multipath or Rayleigh Fading; how the transmitted base signal reacts to physical features or structures creating multiple signal paths.

Using the pebble in the water analogy, think of rocks, sticks or other objects in the water.

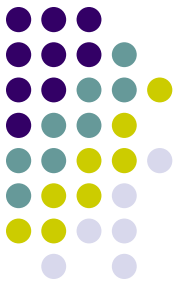
Multipath/Rayleigh fading will occur in both directions.

Multipath/Rayleigh Fading



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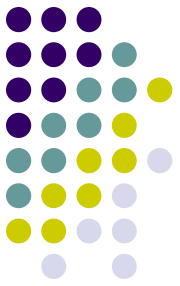
Multipath/Rayleigh Fading



Obviously strongest signal will always be the signal directly from the mobile unit to the Base Station.

The indirect signals will arrive at the base either in phase or out of phase with the direct signal.

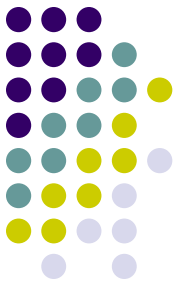
Wireless Frequency Bands



The radio frequency assigned to the early cellular industry was the mostly unused 850 MHz UHF television spectrum.

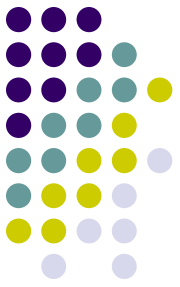
The 850 MHz radio propagation is beneficial for the following reasons;

Wireless Frequency Bands



- It has a very short wavelength, about 12 inches
- It tends to be line of sight, unlike shortwave radio signals
- It is easily reflected off objects.
- It is easily absorbed by foliage, which can be good or bad. It can help with frequency reuse or in certain urban areas or highways it can degrade the signal.

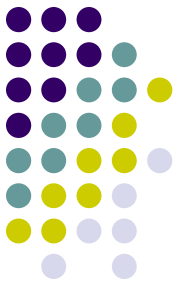
Wireless Frequency Bands



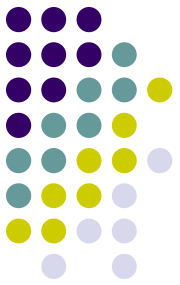
The 1.9 MHz signal used by PCS carriers is good for wideband services, but has penetration problems as it relates to buildings and the like.

The 1.9 MHz signal does not propagate as well as the 850 MHz signal because it has an even shorter wavelength.

Wireless Frequency Bands



- It has a very short wavelength, less than 12 inches
- It tends to be line of sight, unlike shortwave radio signals
- It is easily reflected off objects.

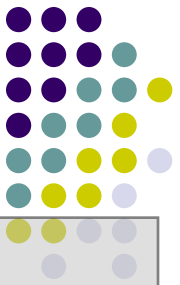


In-Building Coverage

Due to the nature of building construction and structure it is often difficult receive and maintain RF inside.

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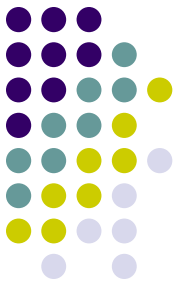
In-Building Coverage



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This method is also used to provide WiFi Hotspots.

Frequency Coordination

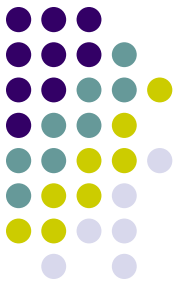


Frequency Coordination is the effort by carrier RF Engineers to place base stations in an orderly fashion to minimize interference.

This is done by adhering to the Distance to Reuse ratio within their own system.

RF Engineers from the various carriers often coordinate with each to comply with the FCC mandates.

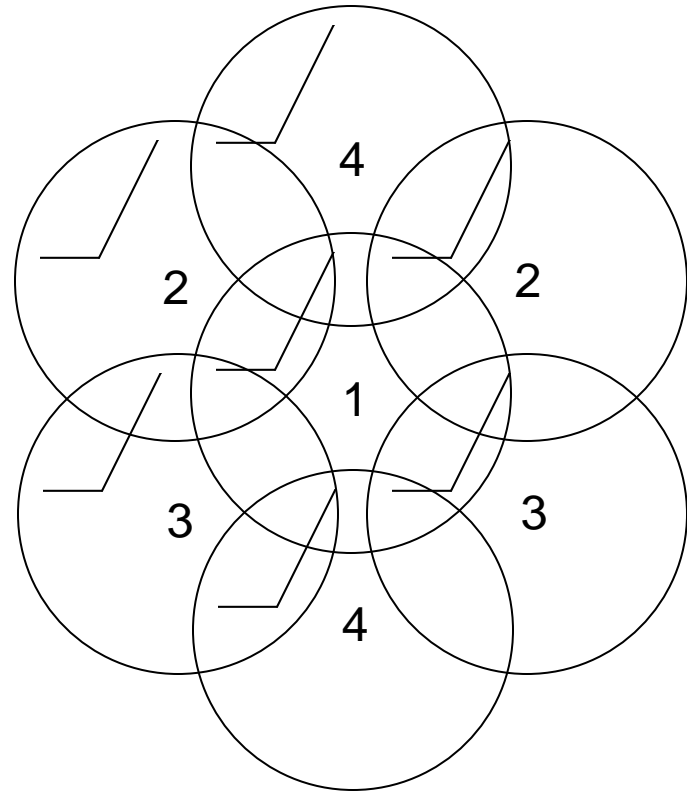
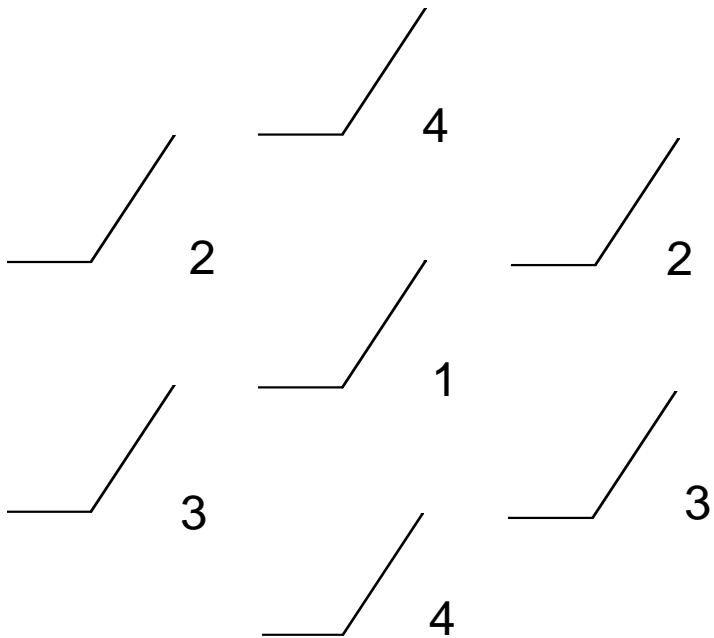
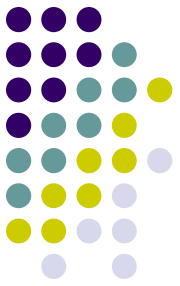
System Interference



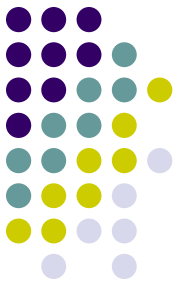
Interference is defined as any adverse interaction between two or more radio signals that cause noises or cancels out each other.

This generally occurs when transmitting RF to close to each other or on the same frequency.

Cochannel Interference

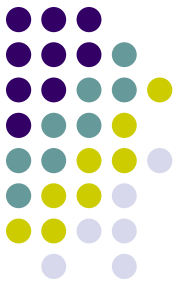


Cochannel Interference



The RF Engineer considers the following when planning cell placement

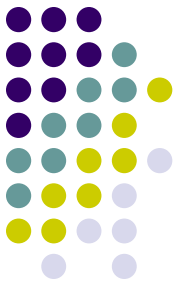
1. RF power levels at cochannel cell sites
2. Geographic distance between cochannel cells
3. Types of antennas used at cochannel cells



Cochannel Interference

Options available to the RF Engineer to reduce or eliminate cochannel interference;

1. Downward tilting antennas when and where appropriate
2. Used reduced-gain antennas
3. Decrease RF output at base stations
4. Reduce the height of the tower

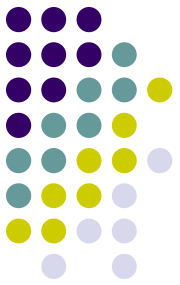


Channel Interference

Other types of Channel Interference are;

Adjacent Channel Interference – the inability of a mobile unit to filter signals of adjacent channels assigned to nearby cells

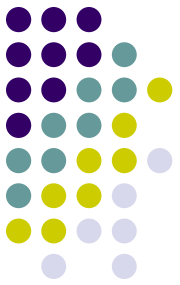
Intermodulation Interference or IM – IM describes the effect of several signals mixing together to produce unwanted signals or no signals.



Radio Frequency Channelization

All carriers no matter what air interface must break up their assigned radio spectrum into usable portions.

Each standard has it's own method of doing so. Regardless of the air interface technology certain functions must be handled.



Paired Channels

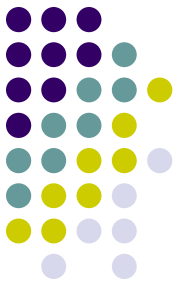
All wireless conversations require paired channels to function.

Mobile or portable phones conduct simultaneous two-way transmissions. This is known as Full Duplex.

One channel is used for transmitting and one channel is used to receive.

Depending on the technology, the frequency may be the same or they maybe different.

Paired Channels



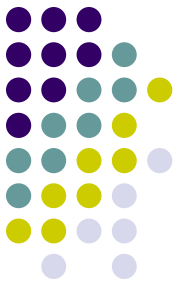
When the frequency is the same this is known as Time Division Duplexing.

When the frequency is not the same it is known as Frequency Division Duplexing.

The only time duplexing will not take place is when there is one-way transmissions as in SMS or streaming media.

The channel from the base station to the mobile unit is known as the downlink or forward channel.

The channel from the mobile unit to the base station is known as the uplink or reverse channel.



Channel Spacing

Channel Spacing refers to the actual bandwidth space that is allocated to every wireless channel allocated out of the total spectrum amount.

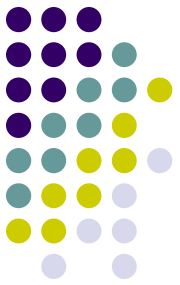
The following are the standard Channel Spacing for the listed air interfaces;

AMPS – 30 KHz or 60KHZ for downlink and uplink

GSM - 25 KHz or 50 KHz for downlink and uplink

CDMA – since CDMA uses spread spectrum technology and is assigned 1.25 MHz per channel. More Later!!!!

Control Channels

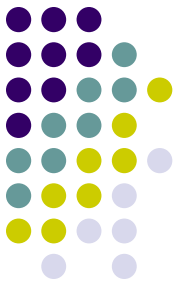


Understanding the function of the Control Channel is one of the most important artifacts a Law Enforcement will need to know.

The Control Channel performs numerous function that leaves evidence of a mobile users activities.

The Control Channel handles the administrative functions and overhead of a wireless systems.

Since the wireless carrier must know at all times if a subscriber is in their service area or not constant contact will the Control Channel is necessary.



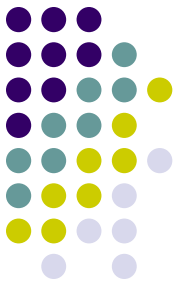
Control Channels

The Control Channel completes this task by having contact with the;

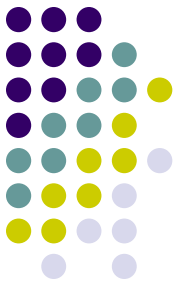
- mobile unit
- cell base stations
- base station controllers
- the mobile switching center

Some of the administrative task assigned the Control Channel are as follows;

Control Channels



1. Setup wireless calls, mobile originated or terminated (destined), locating mobile phones to make contact with them.
2. Collecting information for billing operations
3. Collecting traffic measurements on base stations
4. Autonomous mobile registration, registering the phones on the system (both home and roaming)
5. Initiating and assisting with call handoff



Control Channels

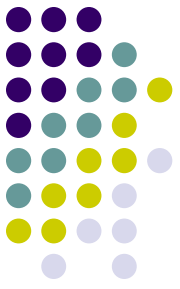
Each channel set in a wireless network has a Control Channel.

When a mobile unit is powered on it seeks out the Control Channel.

The carrier sets one of it's strongest frequencies as the Control Channel when they launch.

The mobile unit re-tunes to the Control Channel periodically to maintain a strong connection with the Control Channel.

RF Technologies



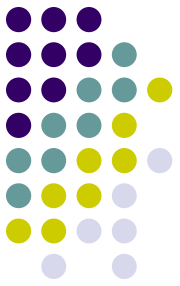
There are other technologies in use that are being incorporated into the wireless cellular and mobile device arena.

Bluetooth – The most well known of the technologies. These devices are designed to offer wireless connectivity to devices with a wide range of capabilities.

Bluetooth enables any electrical device to wirelessly communicate on the unlicensed 2.5MHz frequency. It is envisioned to replace cable connections using a single radio link.

Bluetooth is a short range enabling technology.

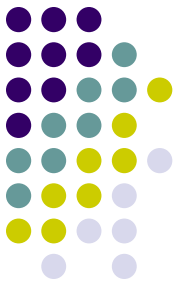
RF Technologies



A number of equipment companies such as IBM, Intel, Nokia, Toshiba, Ericsson, Microsoft and later Motorola form the Special Interest Group (SIG).

The SIG agree to share technology and require that all participants integrate and market the Bluetooth technology.

RF Technologies



Bluetooth has a range of 10 – 100 meters and supports point to point data transfer. This data includes voice channels as well.

Bluetooth uses frequency hop schemes, which allows it to work in high interference areas.

RF Technologies

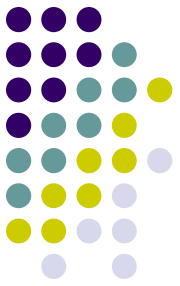


Ultra-Wideband Wireless or UWB – UWB is a digital pulse technology designed to transmit large amounts of data over a wide spectrum of frequency bands.

UWB carries large amounts of data in distances up to 230 feet at very low power levels.

The digital pulses produced by UWB are timed precisely over the very wide spectrum at the same time.

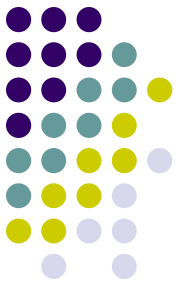
RF Technologies



One company, Time Domain uses a microchip manufactured by IBM, reports sending 1.25 million bits per second.

Time Domain reports the potential for sending data in the billions of bits per second.

UWB wireless technology is defined as any wireless transmission scheme that occupies a bandwidth of more than 25 percent of a center frequency or 1.5 MHz.



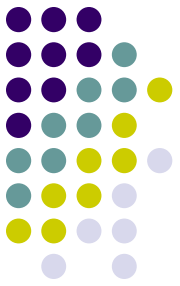
RF Technologies

UWB can also be defined as wireless communications technology that can transmit data at speeds between 40 megabits and 60 megabits per second.

The two main difference between UWB and other narrowband or wideband systems;

1. The bandwidth of UWB is greater than any other current technology used for communication
2. UWB is typically implemented in a carrierless fashion, meaning it is not constricted by the RF allotment schemes.

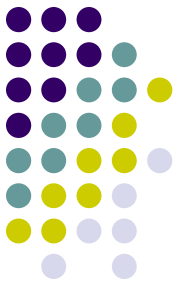
RF Technologies



There are four major trends pushing UWB;

1. Growing demand for wireless data capabilities at higher bandwidth but lower cost and power usage
2. Congested spectrums that is segmented and licensed by regulatory authorities
3. The growth of high-speed wired access across the Internet in businesses, homes and public spaces
4. Shrinking semiconductor cost and power consumption for signal processing.

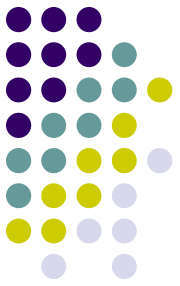
RF Technologies



UWB advantages are;

1. High throughput
2. Effectiveness in environments with high levels of multipath fading
3. Short range high data rate
4. Carries a large amount of data with low power consumption
5. Impressive accuracy measuring positions of objects and people

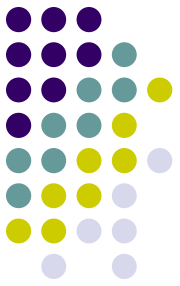
RF Technologies



UWB advantages are

6. Has the ability to carries signals through doors and other obstacles that tend to reflect signals.
7. Can Directly modulate a baseband pulse
8. Can be made nearly all digital
9. Low probability of intercept or interference
10. Low Cost
11. Flexibility in the form of dynamic tradeoff; throughput for distance

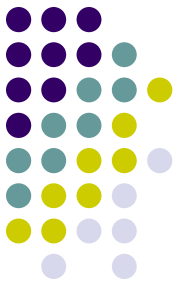
RF Technologies



UWB can be used to provide connectivity to

1. WPAN – Wireless Personal Access Networks
2. Desktops and Laptops
3. Printers, scanners, and storage devices
4. Mobile devices
5. Mobile phones, MP3 players, PDAs, etc

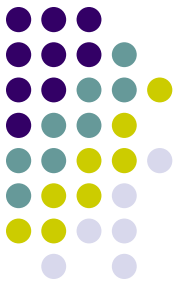
RF Technologies



UWB can be used to provide connectivity to

6. Handheld handsets, 3G handsets
7. Wireless DVD, HDTV and wireless television
8. Cameras and camcorders
9. Wireless infrastructure for smart homes
10. Control Centers for automating security and heating systems, remote control of appliances and home entertainment systems

RF Technologies

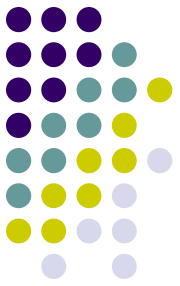


UWB pulse technology has proven effective in the areas of radar and sensor technology. It can be adapted for use in;

1. Motion Detection
2. Radar imaging for objects buried underground or behind walls
3. Radar imaging in the medical field
4.

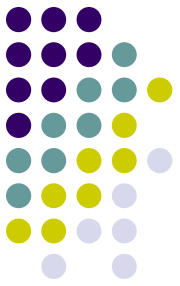
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- 5.
6. Rescue application

RF Technologies



Current wireless carrier protest the use of UWB based on that argument that because they transmit on all frequencies, they may cause interference within their wireless networks.

UWB proponents argue because it transmit across such a wide spectrum and at such low power rates it will be impossible for it to interfere with current wireless networks

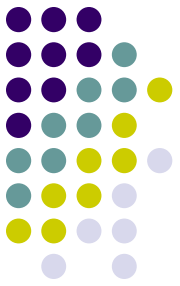


RF Technologies

UWB seeks to replace Bluetooth as a short range connection technology, as well as;

1. Code Division Multiple Access (CDMA)
2. Global System for Mobile Communication (GSM)
3. General Packet Radio Service (GPRS)
4. Enhanced Data GSM Environment (EDGE)
5. Wideband-CDMA (W-CDMA)

RF Technologies

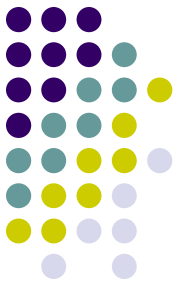


Two other RF technologies are Software Defined Radio (SDR) and Cognitive Radio (CR).

Software Defined Radio uses a software package to administer the all the functions used in wireless communication.

Everything from RF and channel selection, to handoff and logging is handled independently by the software program.

RF Technologies



Cognitive Radio uses software as well but has the ability to store and react to the users dominate needs and typical environment.

This is achieved by either pre-set codes or an algorithm created by the software manufacturer.

The cognitive radio seeks to think and react.

More on both technologies later if time permits.