Cellular communication:

Cellular systems are widely used today and cellular technology needs to offer very efficient use of the available frequency spectrum. With billions of mobile phones in use around the globe today, it is necessary to re-use the available frequencies many times over without mutual interference of one cell phone to another.

It is this concept of frequency re-use that is at the very heart of cellular technology. However the infrastructure technology needed to support it is not simple, and it required a significant investment to bring the first cellular networks on line.

Early schemes for radio telephones schemes used a single central transmitter to cover a wide area. These radio telephone systems suffered from the limited number of channels that were available.

Often the waiting lists for connection were many times greater than the number of people that were actually connected. In view of these limitations this form of radio communications technology did not take off in a big way. Equipment was large and these radio communications systems were not convenient to use or carry around.

The need for a spectrum efficient system

To illustrate the need for efficient spectrum usage for a radio communications system, take the example where each user is allocated a channel. While more effective systems are now in use, the example will take the case of an analogue system. Each channel needs to have a bandwidth of around 25 kHz to enable sufficient audio quality to be carried as well as enabling there to be a guard band between adjacent signals to ensure there are no undue levels of interference. Using this concept it is only possible to accommodate 40 users in a frequency band 1 MHz wide. Even of 100 MHz were allocated to the system this would only enable 4000 users to have access to the system. Today cellular systems have millions of subscribers and therefore a far more efficient method of using the available spectrum is needed.

Cell system for frequency re-use

The method that is employed is to enable the frequencies to be re-used. Any radio transmitter will only have a certain coverage area. Beyond this the signal level will fall to a limited below which it cannot be used and will not cause significant interference to users associated with a different radio transmitter. This means that it is possible to re-use a channel once outside the range of the radio transmitter. The same is also true in the reverse direction for the receiver, where it will only be able to receive signals over a given range. In this way it is possible to arrange split up an area into several smaller regions, each covered by a different transmitter / receiver station.

These regions are conveniently known as cells, and give rise to the name of a "cellular" technology used today. Diagrammatically these cells are often shown as hexagonal shapes that conveniently fit together. In reality this is not the case. They have irregular boundaries because of the terrain over which they travel. Hills, buildings and other objects all cause the signal to be attenuated and diminish differently in each direction.

It is also very difficult to define the exact edge of a cell. The signal strength gradually reduces and towards the edge of the cell performance will fall. As the mobiles themselves will have different levels of sensitivity, this adds a further greying of the edge of the cell. Therefore it is never possible to have a sharp cut-off between cells. In some areas they may overlap, whereas in others there will be a "hole" in coverage.

Cell clusters

When devising the infrastructure technology of a cellular system, the interference between adjacent channels is reduced by allocating different frequency bands or channels to adjacent cells so that their coverage can overlap slightly without causing interference. In this way cells can be grouped together in what is termed a cluster.

Often these clusters contain seven cells, but other configurations are also possible. Seven is a convenient number, but there are a number of conflicting requirements that need to be balanced when choosing the number of cells in a cluster for a cellular system:

- Limiting interference levels
- Number of channels that can be allocated to each cell site

It is necessary to limit the interference between cells having the same frequency. The topology of the cell configuration has a large impact on this. The larger the number of cells in the cluster, the greater the distance between cells sharing the same frequencies.

In the ideal world it might be good to choose a large number of cells to be in each cluster. Unfortunately there are only a limited number of channels available. This means that the larger the number of cells in a cluster, the smaller the number available to each cell, and this reduces the capacity.

This means that there is a balance that needs to be made between the number of cells in a cluster, and the interference levels, and the capacity that is required.

Cell size

Even though the number of cells in a cluster in a cellular system can help govern the number of users that can be accommodated, by making all the cells smaller it is possible to increase the overall capacity of the cellular system. However a greater number of transmitter receiver or base stations are required if cells are made smaller and this increases the cost to the operator. Accordingly in areas where there are more users, small low power base stations are installed.

The different types of cells are given different names according to their size and function:

- ***Macro cells:*** Macro cells are large cells that are usually used for remote or sparsely populated areas. These may be 10 km or possibly more in diameter.

- ***Micro cells:*** Micro cells are those that are normally found in densely populated areas which may have a diameter of around 1 km.

- ***Pico cells:*** Picocells are generally used for covering very small areas such as particular areas of buildings, or possibly tunnels where coverage from a larger cell in the cellular system is not possible. Obviously for the small cells, the power levels used by the base stations are much lower and the antennas are not position to cover wide areas. In this way the coverage is minimised and the interference to adjacent cells is reduced.

- ***Selective cells:*** Sometimes cells termed selective cells may be used where full 360 degree coverage is not required. They may be used to fill in a hole in the coverage in the cellular system, or to address a problem such as the entrance to a tunnel etc.

- ***Umbrella cells:*** Another type of cells known as an umbrella cell is sometimes used in instances such as those where a heavily used road crosses an area where there are microcells. Under normal circumstances this would result in a large number of handovers as people driving along the road would quickly cross the microcells. An umbrella cell would take in the coverage of the microcells (but use different channels to those allocated to the microcells). However it would enable those people moving along the road to be handled by the umbrella cell and experience fewer handovers than if they had to pass from one microcell to the next.

In any cellular system or cellular technology, it is necessary to have a scheme that enables several multiple users to gain access to it and use it simultaneously. As cellular technology has progressed different multiple access schemes have been used. They form the very core of the way in which the radio technology of the cellular system works.

There are four main multiple access schemes that are used in cellular systems ranging from the very first analogue cellular technologies to those cellular technologies that are being developed for use in the future. The multiple access schemes are known as FDMA, TDMA, CDMA and OFDMA.

Requirements for a multiple access scheme

In any cellular system it is necessary for it to be able have a scheme whereby it can handle multiple users at any given time. There are many ways of doing this, and as cellular technology has advanced, different techniques have been used.

There are a number of requirements that any multiple access scheme must be able to meet:

- Ability to handle several users without mutual interference.

- Ability to be able to maximise the spectrum efficiency

- Must be robust, enabling ease of handover between cells.

FDMA - Frequency Division Multiple Access

FDMA is the most straightforward of the multiple access schemes that have been used. As a subscriber comes onto the system, or swaps from one cell to the next, the network allocates a channel or frequency to each one. In this way the different subscribers are allocated a different slot and access to the network. As different frequencies are used, the system is naturally termed Frequency Division Multiple Access. This scheme was used by all analogue systems.

TDMA - Time Division Multiple Access

The second system came about with the transition to digital schemes for cellular technology. Here digital data could be split up in time and sent as bursts when required. As speech was digitised it could be sent in short data bursts, any small delay caused by sending the data in bursts would be short and not noticed. In this way it became possible to organise the system so that a given number of slots were available on a give transmission. Each subscriber would then be allocated a different time slot in which they could transmit or receive data. As different time slots are used for each subscriber to gain access to the system, it is known as time division multiple access. Obviously this only allows a certain number of users access to the system. Beyond this another channel may be used, so systems that use TDMA may also have elements of FDMA operation as well.

CDMA - Code Division Multiple Access

CDMA uses one of the aspects associated with the use of direct sequence spread spectrum. It can be seen from the article in the cellular telecoms area of this site that when extracting the required data from a DSSS signal it was necessary to have the correct spreading or chip code, and all other data from sources using different orthogonal chip codes would be rejected. It is therefore possible to allocate different users different codes, and use this as the means by which different users are given access to the system.

The scheme has been likened to being in a room filled with people all speaking different languages. Even though the noise level is very high, it is still possible to understand someone speaking in your own language. With CDMA different spreading or chip codes are used. When generating a direct sequence spread spectrum, the data to be transmitted is multiplied with spreading or chip code. This widens the spectrum of the signal, but it can only be decided in the receiver if it is again multiplied with the same spreading code. All signals that use different spreading codes are not seen, and are discarded in the process. Thus in the presence of a variety of signals it is possible to receive only the required one.

n this way the base station allocates different codes to different users and when it receives the signal it will use one code to receive the signal from one mobile, and another spreading code to receive the signal from a second mobile. In this way the same frequency channel can be used to serve a number of different mobiles.

OFDMA - Orthogonal Frequency Division Multiple Access

OFDMA is the form of multiple access scheme that is being considered for the fourth generation cellular technologies along with the evolutions for the third generation cellular systems (LTE for UMTS / W-CDMA and UMB for CDMA2000).

As the name implies, OFDMA is based around OFDM. This is a technology that utilises a large number of close spaced carriers.