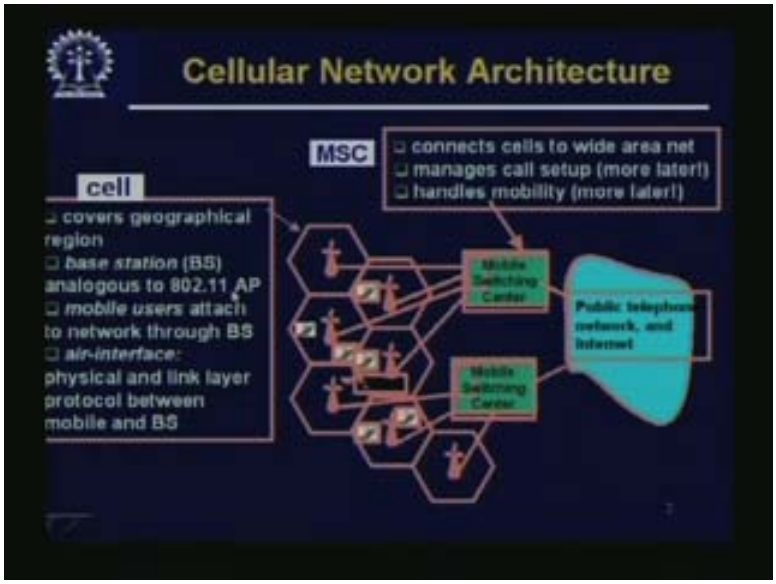
Computer networks
Prof: Sujoy Ghosh
Department of Computer Science and Engineering
Indian Institute of Technology, Kharagpur
Lecture Name -22
Cellular Networks

(Refer Slide Time: 0:55)

Good day. So, now we will start our discussion on terrestrial wireless networks. We have already seen one kind of wireless communication, which is through satellites. So it is microwave repeater and we know that. But there are two very important and rapidly expanding field in networking, which is terrestrial wireless networking. We will have two lectures on this. In the first lecture, we will discuss cellular networks. The cell phone, which has become ubiquitous nowadays and in the next lecture, we will talk about Wireless LANs: Wireless LANs are may be little bit of Wireless MANs also. So, today we will discuss about cellular networks.

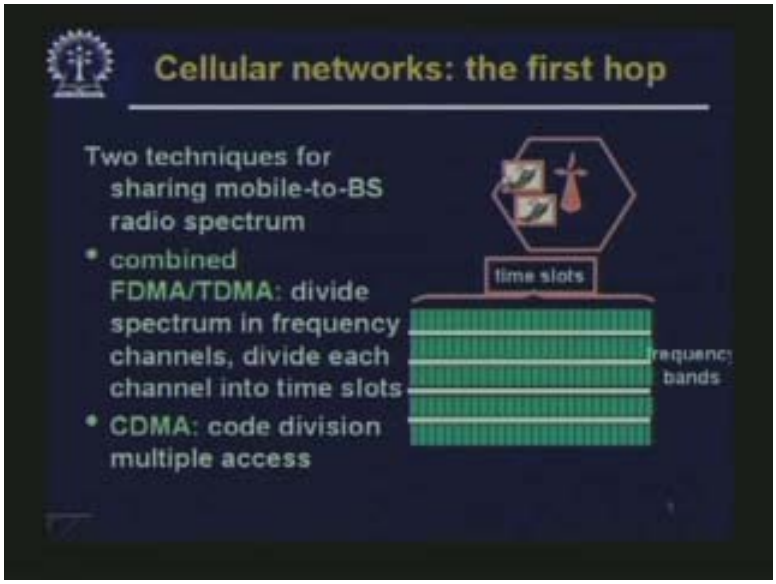
(Refer Slide Time: 01:49)



So just right away, let us learn some jargons. What is a cell? The cellular network is organized in the form of some cells and it covers a geographical region. It has base station analogous to 802.11 AP. AP is for access point. 802.11 is the wireless LAN technology. We will discuss about this in the next lecture. Anyway, the point is that there is a base station and it will have an antenna, some transmitters and receivers. It will be connected to the backbone through a line. May be this could also be a wireless line, but usually this could be a fibre optic line. In a circluar geographical location around this base station, mobiles will communicate with this base station and through this base station to the rest of the network. So mobile users attach to network through BS.

And air interface is the physical and link layer protocol between mobile and BS. That is called air interface between the mobile and base station. Now all these base stations are connected to the mobile switching center (MSC). The switching is essentially done over here. The MSC connects cells to Wide Area Network. The mobile switching center will be referred to as MSC, Base station as BS ,mobile switching center as MSC, MS, by the way, is a mobile station. MSC connects cells to Wide Area Network and manages call setup. More about that later and these MSCs will be connected to each other for a particular service provider. They will also connect to public telephone network and the internet etc. So one service provider, their network would be connected to another service provider's network. So somebody from this network can call the other network and so on. So we have the cells; we have the base stations; we have the mobile stations or MSs. We have the mobile switching center, MSC, and of course the PSTN at the back of it all. This part is usually wired.

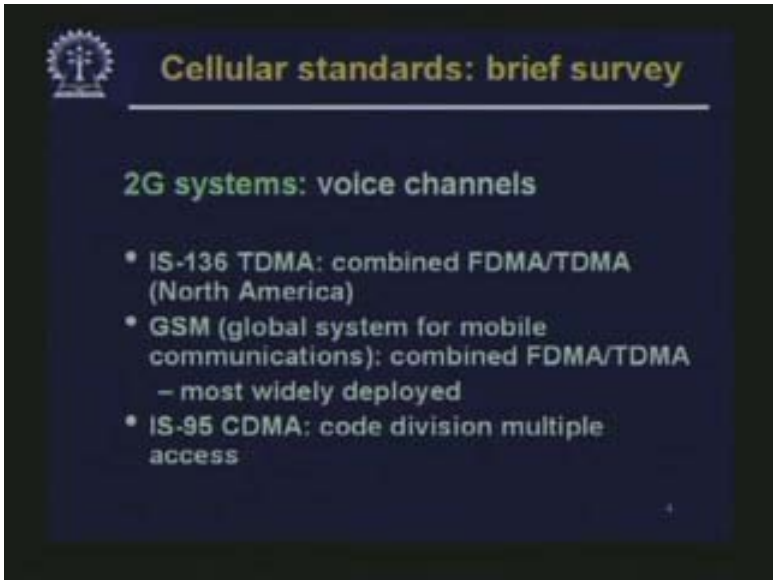
(Refer Slide Time: 04:30)



The first hop – we are now talking about the air interface between the mobile station and the base station. There are two techniques for sharing mobile to BS radio spectrum. There is certain radio spectrum, which is allocated to the base station and to the particular region that it has to be shared. Now, this is a question of multiple access and two techniques that we talked about earlier are FDMA, if you remember this is frequency division multiple access, and TDMA, time division multiple access. In cellular technology, what we usually do is that we combine FDMA and TDMA.

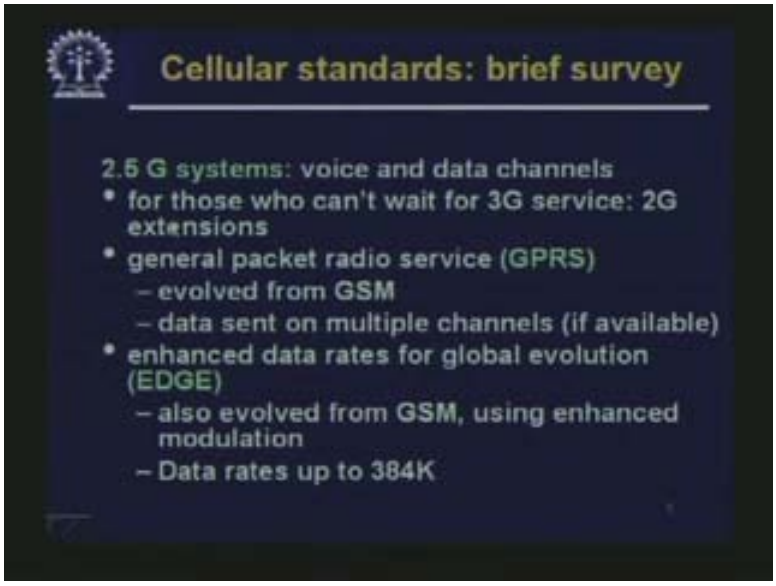
So divide the spectrum in frequency channels and divide each channel into time slots. If you say that these are the different frequency channels and each channel may be divided into number of time slots. We will do FDMA as well as TDMA on this. That is one kind of scheme – the so-called GSM utilizes this. We will be talking about how FDMA and TDMA are combined. The other technology is CDMA, which was designed by a company called VOLCOM in USA, which uses code division multiple access. We have already seen what code division multiple access is. So we will not get into the details of CDMA systems here. CDMA is another popular way of transporting data to the mobile devices. Both GSM and CDMA are used in many countries. For example, in our country also some service providers provide CDMA services, and few offer GSM services, some provide both, and so on.

(Refer Slide Time: 06:24)



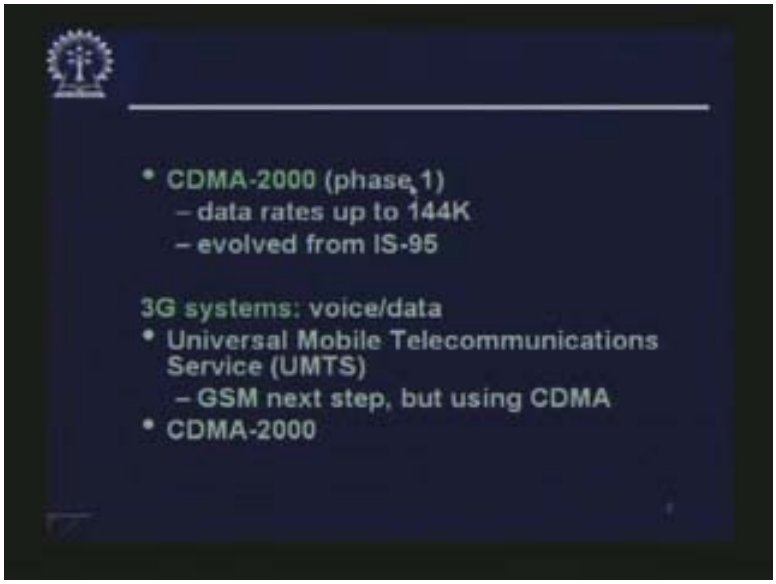
We will now discuss cellular standards as they stand today. Historically, we had only the cellular system that came from some amps in USA. Previously, there was only one cell from the analog system. From analog system, it came down to digital system in deamps and then we have these two systems of the 2G system – one is the GSM system and the other is the CDMA version. 2G systems are voice channels: IS-136 is TDMA, combined with FDMA, which is used in North America. GSM, which is more popular of these schemes, is the global system for mobile communications. It has combined FDMA/TDMA, which is most widely deployed. IS -95 is the code for CDMA systems, which use code division multiple access. So these are the 2G or second generation systems.

(Refer Slide Time: 07:20)



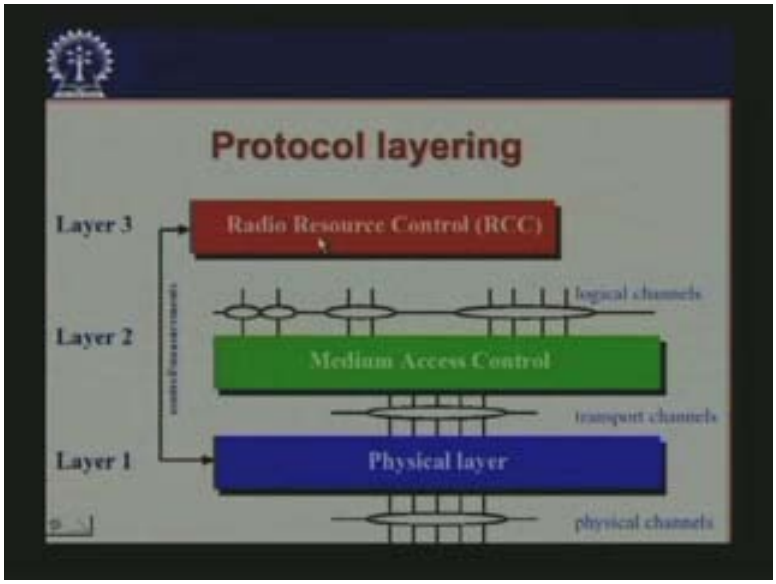
There are 2.5G systems. These were introduced because the 3G was promised quite some time back but the service providers really could not deliver it or crank it up to that extent. But, there was lot of demand for it. Voice was alright with 2G, but then the demand for data and other kind of multimedia services etc., was increasing. So people had to be given some data services. Instead of going all the way to 3G, people went to 2.5G. 2.5G systems have both voice and data channels. So, for those who cannot wait for 3G services, there are 2G extensions. One is GPRS. This is General Packet Radio Services evolved from GSM and the data is sent on multiple channels if available. It has an enhanced data rate for global evolution edge; also evolved from GSM using enhanced modulation data rates up to 384k.

(Refer Slide Time: 08:24)



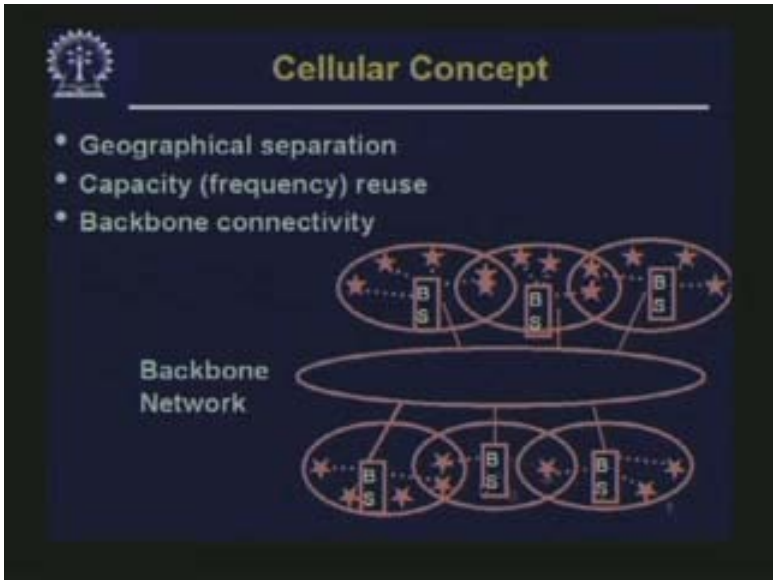
CDMA has its own version called CDMA 2000, that was phase 1; then there was phase 2 also. So data rates up to 144k evolved from IS-95, which is the CDMA system. 3G system includes both voice and data: one service it provides is UMTS. This is the name of the Standard Universal Mobile Telecommunications Service (UMTS). GSM is the next step, but using CDMA 2000. So, all these merge into the 3G systems. How exactly this merging will take place and how it will actually be deployed and become popular remains to be seen; but today you can get these data services on your cell phones, etc.

(Refer Slide Time: 09:12)



The protocol layering for cells is a little different. We will not go too much in to this. One is of course, the physical layer, which has to do with the physical channels. Then there is MAC, medium access control. We will talk about it, at least for GSM. So, there are these logical channels, transport channels, and then there is Radio Resource Control layer. That is the layer 3 particularly. This you might say is a protocol, but this does not go all the way that the OSI 7 layer. This is just for the cellular systems.

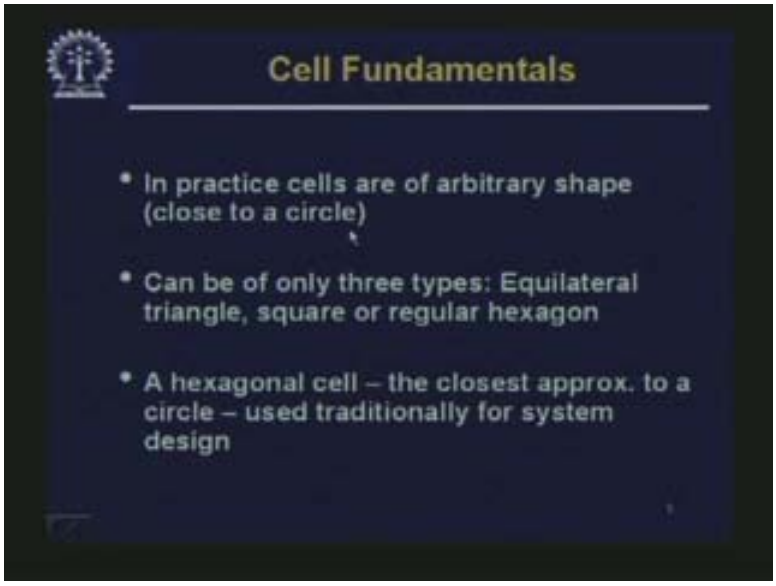
(Refer Slide Time: 09:47)



Our idea is that we have some base stations and each base station will cover some geographical area like it has been shown here.

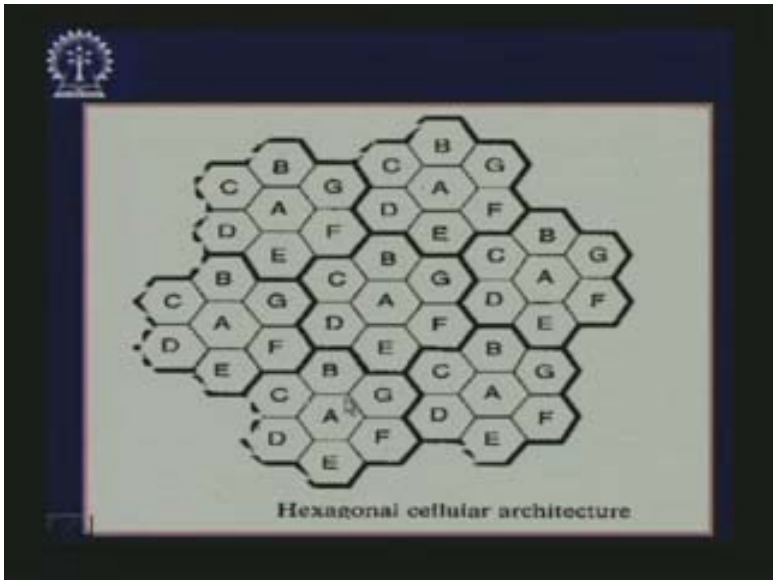
Different BS would be connected through a backbone network or through MSCs. We are trying to get the basic idea of the cell. The point is that, nowadays cell phones have become very popular. Its rate of penetration is much faster than the original telephones, and it is much faster than PCs also. So, cellular phones have become very popular, which means a lot of people want to use it and lot of people have cell phones. Many of them would want to talk at the same time. But how do you accommodate all these people talking at the same time? We do multiple access. But then, there is a limit to what you can do using same frequency spectrum. The idea was to do some kind of space division multiple access. In the sense that within one particular geographical area, we use a particular frequency band and then in another geographical area, which is far removed from there, so that these two do not interfere with each other, we use the same set of frequency band at the same time for a different set of users. The point is that these powers have to be controlled because, if they are very powerful, they will start interfering with each other. But if this power is controlled, then within that cell, that power is enough. But, it is not enough to interfere with each other. So, two different groups of users can use the same frequency band at the same time. This is the basic idea of breaking up a region into cells so that you can increase the number of people, who would be using this system. That is the basic concept of a cell.

(Refer Slide Time: 12:06)



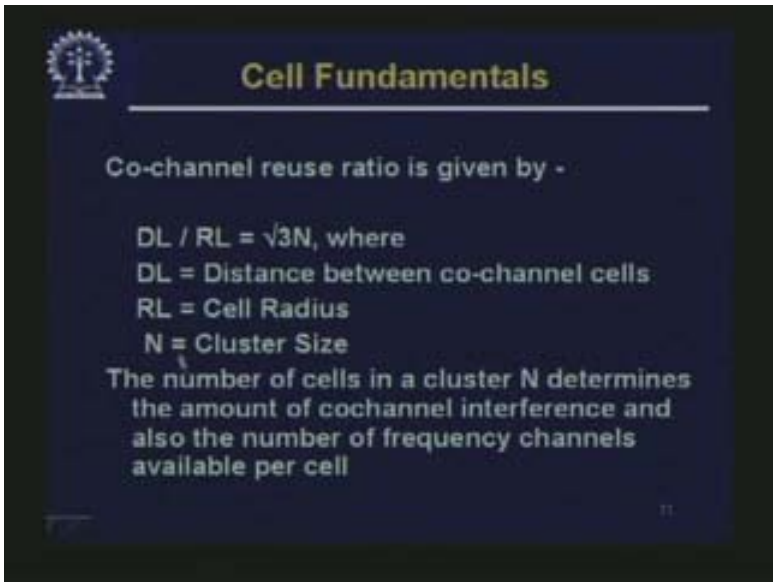
In practice, cells are may be of arbitrary shape. But they will be close to a circle because usually the kind of antenna used in base stations is omni directional antenna, in the sense that it gives the same power on all sides. It has the same sensitivity on all sides. If that is so, the area of influence would be a circle. But when many circles are put together they are pulling and they will intersect with each other. To solve this problem, we can use a tessellation. There are only three types of tessellations, which are possible – equilateral triangles, squares or regular hexagons. Out of these three, the regular hexagon is the closest to a circle. That is why usually the regular hexagons are used to represent a cellular structure. A hexagonal cell, the closest approximation to a circle, is used traditionally for system design. This is how a big geographical area may have been divided into a large number of cells – it looks like a beehive.

(Refer Slide Time: 13: 04)



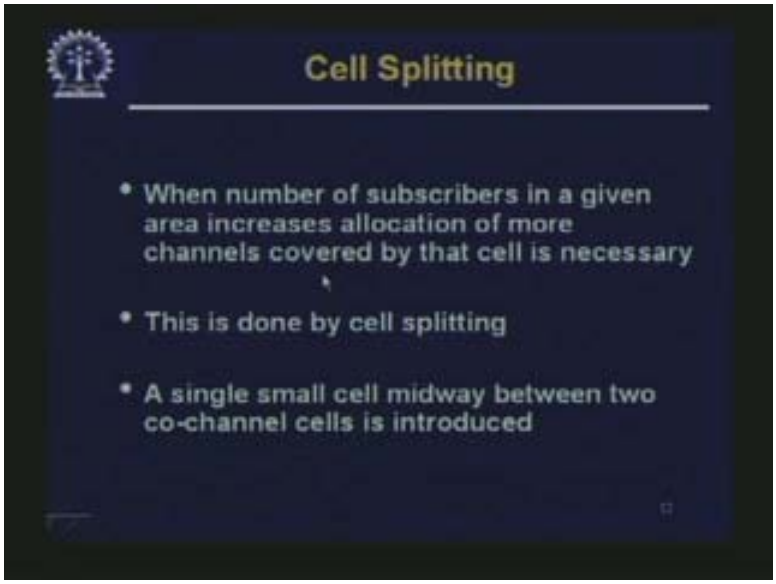
If you notice carefully some of the cells are dark and these cells are marked as A B C D E F G. So, these are seven. There are seven hexagons like this and these are actually different frequency ranges. These frequencies are again reused. For example, you have another A B C D E F G over here. This B and this B – although they use the same frequency ranges – are far apart. So, different groups of people can use it at the same. Once it gets into the base station, we usually take it to the fiber optic domain, where a large number of calls, simultaneous calls can be handled. This really shows you the frequency reuse. A, the set of frequency bands, which are associated with A, will also be reused here, here, and there and so on. That is how a hexagonal cellular structure is constructed and we do this frequency reuse.

(Refer Slide Time: 14:28)



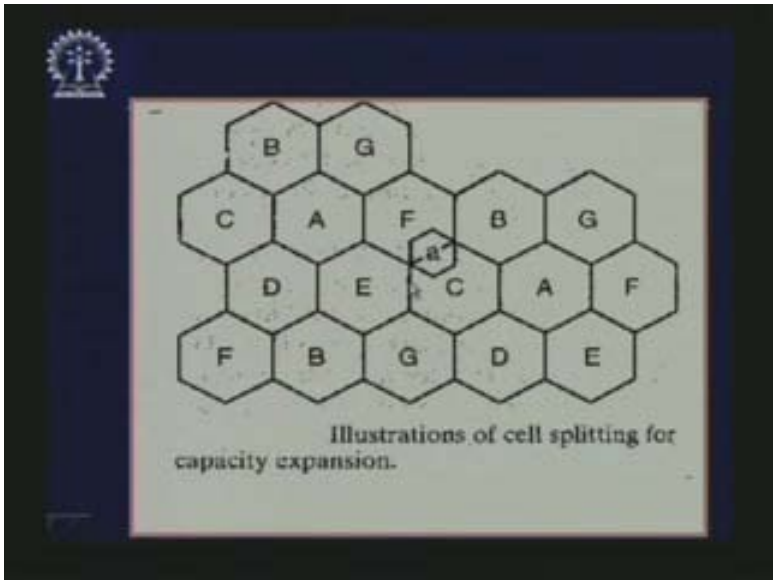
Co-channel reuse ratio is given by DL/RL is equal to √3N, where DL is the distance between co-channel cells, that means those who share the same channel. RL is cell radius; N is the cluster size. The number of cells in a cluster N determines the amount of co-channel interference and the number of frequency channels available per cell. This really comes from geometry.

(Refer Slide Time: 14:55)



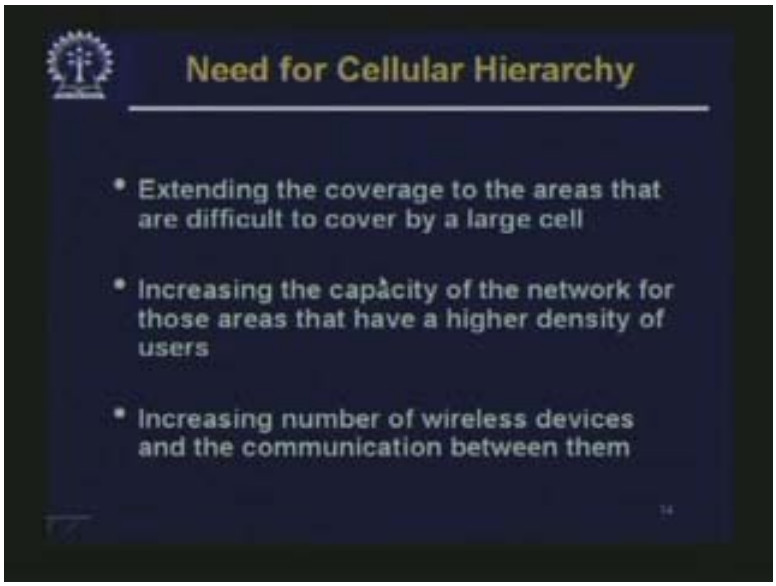
When the number of subscribers in a given area increases, allocation of more channels covered by that cell is necessary. What happens is that in one area, say a small town, one base station could satisfy people, who had these cellular phones or mobile phones. Now what happens is that, the number of people who wanted to use mobile phones kept on increasing and now we cannot serve them any longer. The number of requests, which are denied, keeps on increasing. How can we increase? May be break it up into two cells and then break it up into four cells and break it up into many more cells, depending on the clusters of users and the cells. Now, the same area has been divided into smaller cells. May be in the BS, you decrease the transmitter power so that they do not interfere with each other. So when the number of subscribers in a given area increases, allocation of more channels covered by that cell is necessary. This is done by cell splitting. A single small cell midway between two co-channel cells may be introduced.

(Refer Slide Time: 16:30)



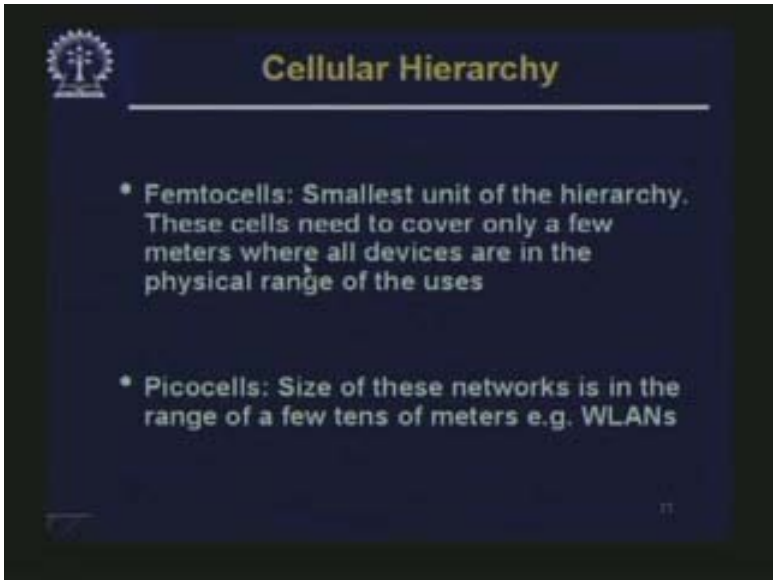
These are the small adhoc solutions to the problem. For example over here, you had a large number of cells. We created a small cell over here using A, which uses the same frequency bands as the already existing ones. You cannot use E, F, C, or B. But you can use A with other cells. So that is called cell splitting. These are ad hoc solutions, when a particular area has more number of users.

(Refer Slide Time: 16:54)



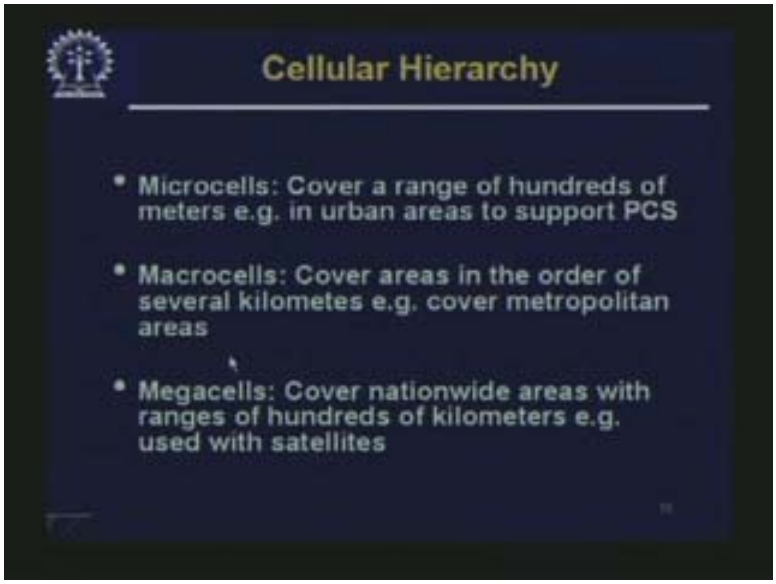
We now have a cellular hierarchy, the needs of which are: extending the coverage to the areas that are difficult to cover by a large cell; increasing the capacity of the network for those areas that have a high density of users; increasing the number of wireless devices and the communication between them.

(Refer Slide Time: 17:15)



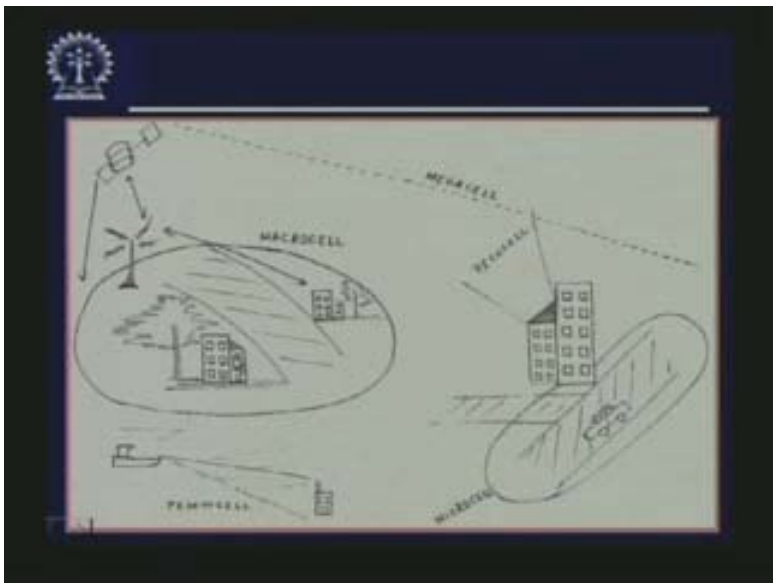
So, you have a large number of cellular hierarchies. One set of them are called Femto cells. These are the smallest unit in the hierarchy. So these cells need to cover only a few meters, where all devices are in the physical range of the users. This is also called Personal Area Networking. So I have something in my left pocket, something in my right pocket and something in my hand. These might communicate with each other. So, that is Personal Area Networking. Femtocells are small cells. Then we have Picocells, the size of their network is in the range of a few tens of meters. So, you can think of a small building as Picocell. For example, WLAN (Wireless LAN).

(Refer Slide Time: 18:05)



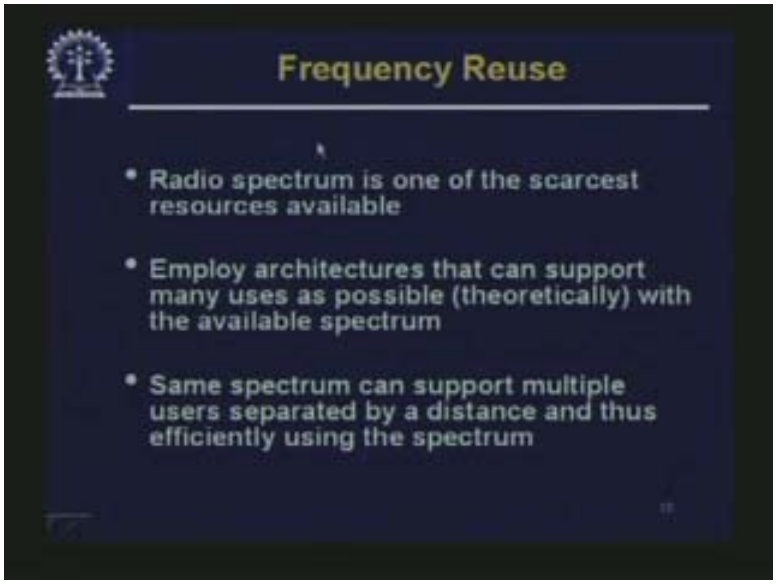
Micro cells cover a range of hundreds of meters; for example, in urban areas to support PCS or other technologies. PCS is another kind of mobile technology. Macro cells cover areas in the order of several kilometers, for example, a metropolitan area, or may be a small town. Mega cells cover nationwide areas. So, mega cells possibly are being serviced by a satellite.

(Refer Slide Time: 18:35)



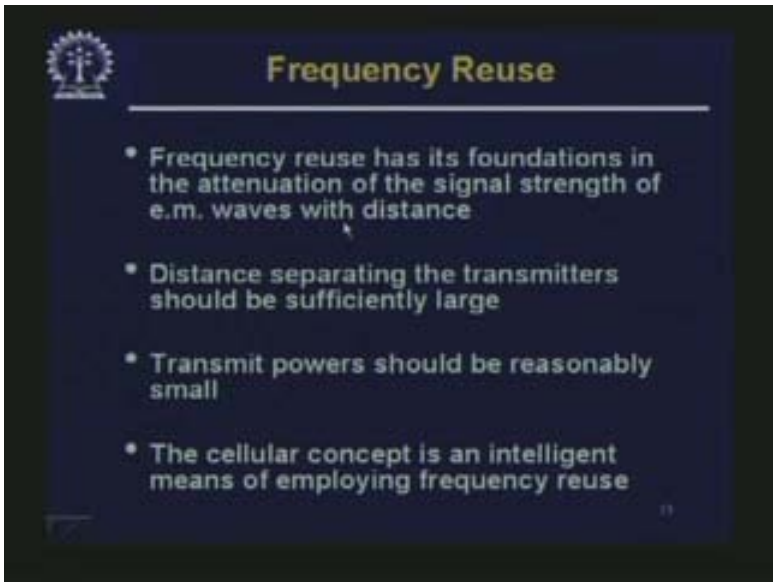
This is the picture of satellite, which may service a mega cell. Then, we have macro cell from this tower. Then we have pico cells, which have some access points etc inside a building and so on. Microcells for covering communication. So these ways of different kinds of technologies may be deployed for these different ranges of cells.

(Refer Slide Time: 19:05)



Frequency reuse: We have already talked about this. Radio spectrum is one of the scarcest resources available; because, there is so much demand for it for so many applications. So, employ architectures that can support as many uses as possible (theoretically) with the available spectrum. Same spectrum can support multiple users separated by a distance and thus efficiently be using the spectrum.

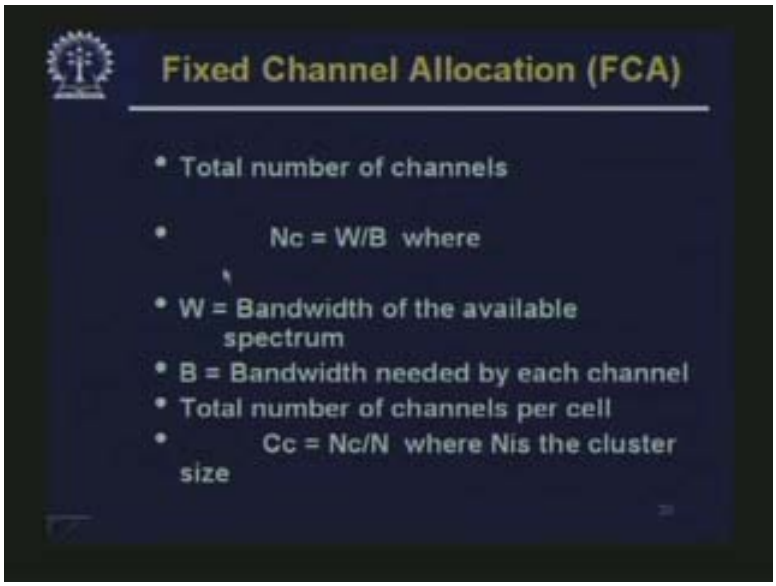
(Refer Slide Time: 19:33)



Frequency reuse has its foundations in the attenuation of the signal strength of EM waves with distance. So, if two points are at a distance from each other, this signal gets attenuated and does not interfere significantly with this one, although they are using the same frequency band.

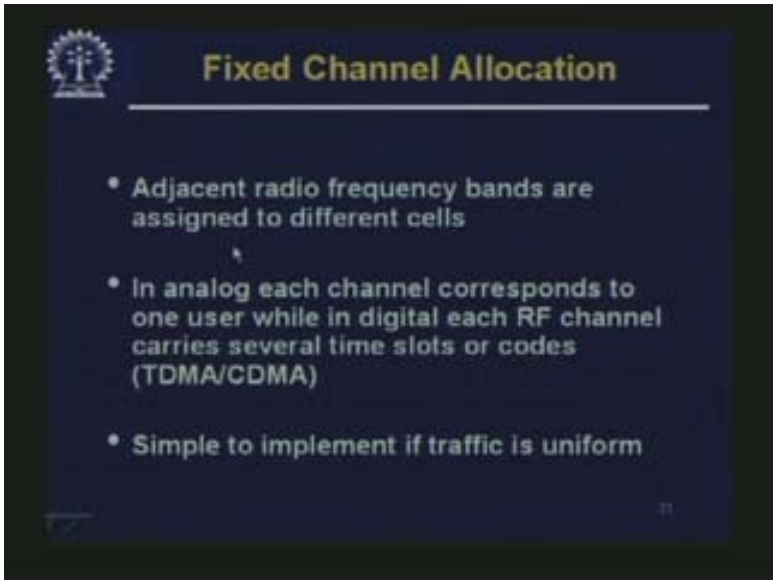
Usually, what will happen is that the service provider will be given some band of frequencies. Now, he has to use that and cannot stray from there, as that is the license agreement. So, what he will do is that, is depending on where his users are, and what the distribution is, what the density is like, he has to develop or plan a cellular infrastructure in this fashion using and reusing this frequency, the same frequency band, here and there to give the maximum amount of service. The distance separating the transmitters of this frequency reuse should be sufficiently large. Of course, this has to do with a transmitter's power. Transmit power should be reasonably small. The cellular concept is an intelligent means of employing frequency reuse.

(Refer Slide Time: 20:41)



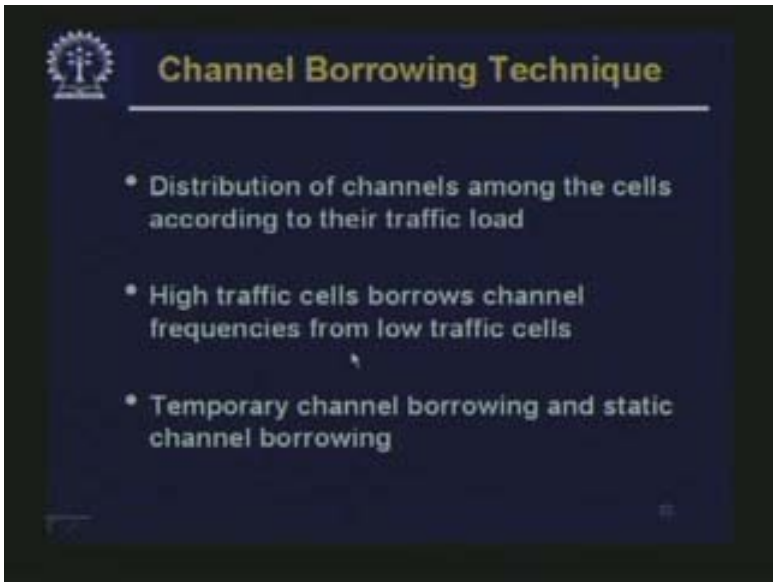
So what we have been talking about is something like a fixed channel allocation. That means for a particular cell, the channels that means, the frequency band associated with the cell is fixed. So, total number of channels is NC is equal to W/B, where W is the bandwidth of the available for spectrum. B is the bandwidth needed by each channel. The total number of channels per cell is Cc is equal to Nc/N, where N is the cluster size.

(Refer Slide Time: 21:22)



Adjacent radio frequency bands are assigned to different cells as shown. In analog each channel corresponds to one user while in digital each RF channel carries several time slots or codes. So, you are doing either TDMA or CDMA. So, if you are doing this, the naturally FDMA TDMA combine or CDMA uses spread spectrum technology. So, it's simple to implement. So, fixed channel allocation is simple to implement if traffic is uniform.

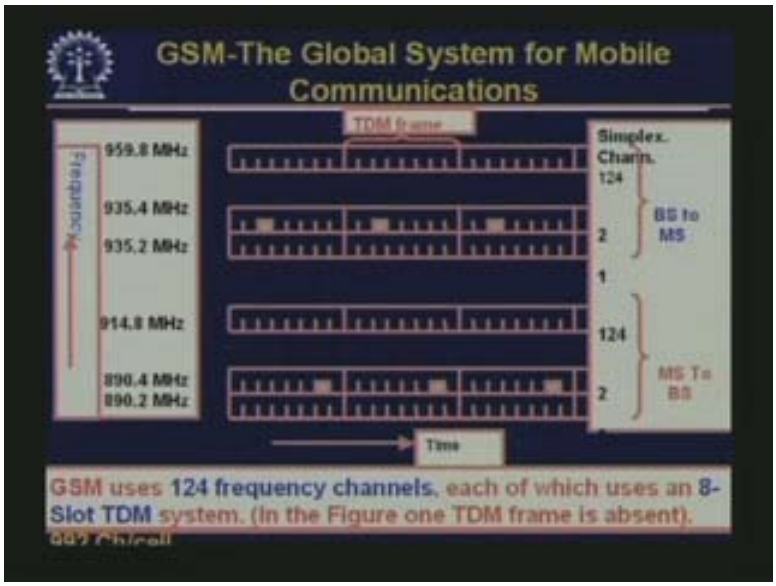
(Refer Slide Time: 21:54)



But then, sometimes traffics are not uniform – there may be two cells, which are side by side. So, this has been given one band. One has been given another band of frequencies. They do not interfere with each other. But, we find for each cell.

Let us say, to start with, we are given with equal bandwidth to each of the cells. Now, I find that in one particular cell, the user density is much higher, whereas in adjacent cell, the user density is lower. So, I could use some more bandwidth in this cell and I could do with a little less bandwidth here. So, what could do is that, a part of this frequency band can borrow from the adjacent cell. So, that is called Channel Borrowing technique. High traffic cells borrow channel frequencies from low traffic cells. Temporary channel borrowing and static channel borrowing. This could be a permanent feature or this could be the feature of a day. For example, in the central business district, it might become very busy during the day time. So, it may borrow channels from the side, whereas after the evening the use may fall drastically. In that case, one cell can give out channels to others. Not only sort of giving channels to other people. So, this could be static as well as it could be temporary.

(Refer Slide Time: 23:25)

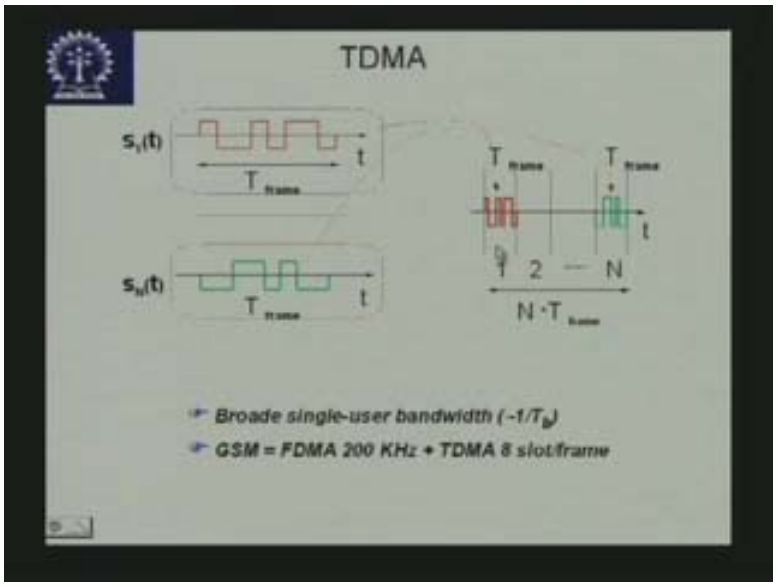


This is suitably complex picture of GSM, i.e. the Global System for Mobile communications. So, this just to show you how these TDMA and FDMA are combined. So, you see there are 124 simplex channels in the GSM system. Now, each of the simplex channels actually carries a series of TDMA frames and each of the frames is divided into 8 parts, which is how a large number of channels can be given. There are two parts: one is the up linking and another is the down linking, that means, from BS to MS – Base Station to the Mobile Station or from the Mobile Station to the Base Station.

So you have two different frequency bands for these – one band for this BS to MS communication and another band for MS to BS communication. In each band, there are a number of frequency channels and each frequency channel is again divided into so many slots: eight slots for simultaneous communication. So this one and this one are same channels, but this and this are two different channels for a particular mobile station. So from base station, it may be using this particular time slot in this particular channel, that is, from the base station to the mobile station.

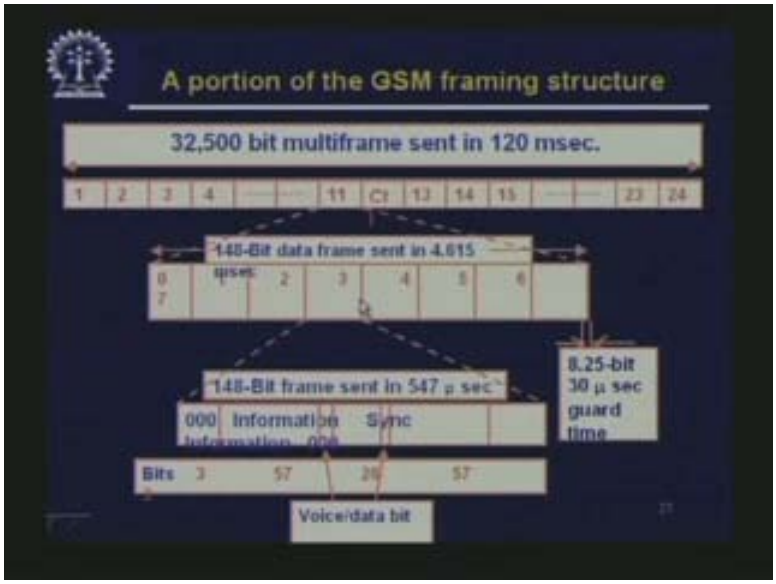
The same one, from the mobile station to the base station, will be using another channel and actually another time slot, because there is some technical problem in giving the same time slot in this channel as well as the other channel. So, you give it a different time slot over here. So, in this particular time slot of this particular channel, the mobile station is communicating with its base station. So, that is how it goes. GSM uses 124 frequency channels, each of which uses an 8-slot TDM system. And there is a frequency band at which it operates; this is also fixed. This is in the 959.8 MHZ range. You need not remember these figures, but this is the general scheme of the way TDMA and FDMA are combined together.

(Refer Slide Time: 26:27-)



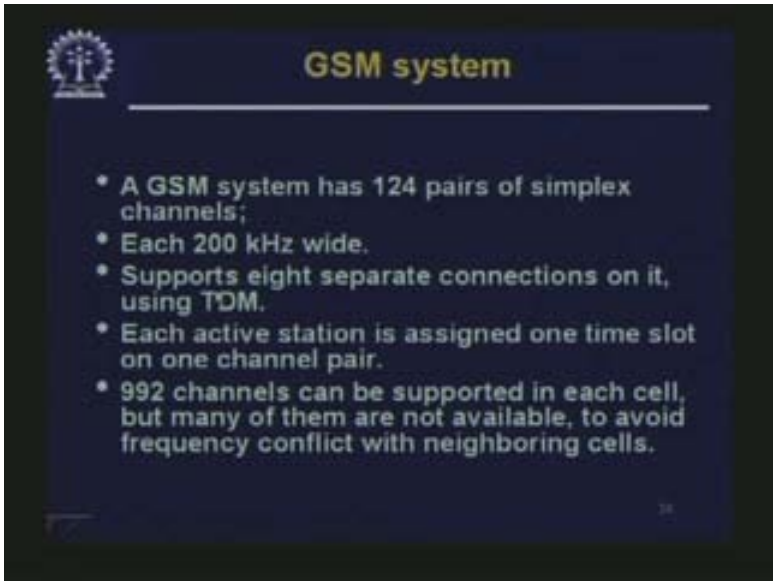
Suppose this is $S_1(t)$ and this is the signal which comes from source 1 and this is the signal from source n, $S_n(t)$. This is some other source. What is happening is that in the T_m slots, the first slot – S_1 – gets the first slot and S_n gets the nth slot. So, they are pushed into this in the same frequency band, and as time progresses, they function just like in a TDMA system. So, this is the TDMA part. So, GSM is equal to FDMA 200 KHZ; that is the GSM system.

(Refer Slide Time: 27:16)



This is a portion of the GSM framing structure. So, how they are framed? Actually, this is a somewhat complicated scheme. Some of these frames are used for control purpose and others for communication: one group for base to mobile and other from mobile to base, etc. So, there is a scheme for this. We will not go into the details of this.

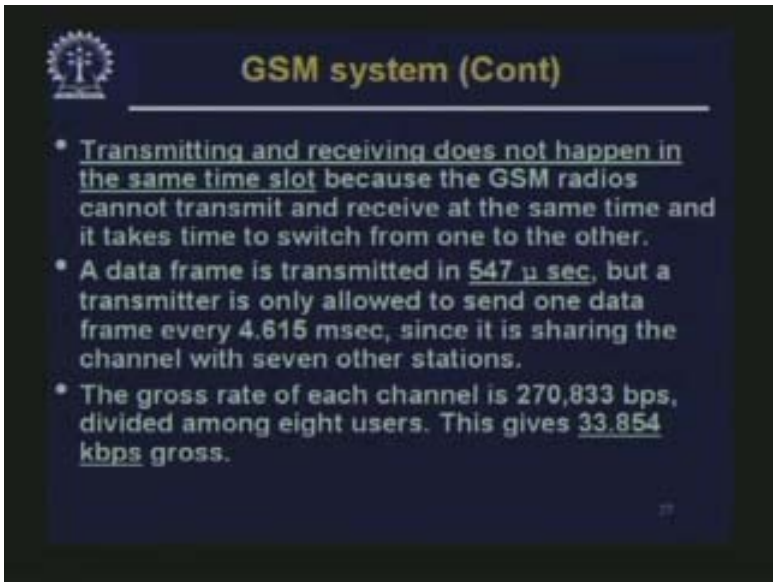
(Refer Slide Time: 27:47)



A GSM system has 124 pairs of simplex channels. They are in pairs because one goes from BS to MS and the other from BS to MS. Each of these is 200 kilo hertz wide and supports 8 separate connections on it, using TDM.

So, each active station is assigned to one time slot on one channel pair. 992 channels can be supported in each cell, but many of them are not available to avoid frequency conflicts with neighboring cells.

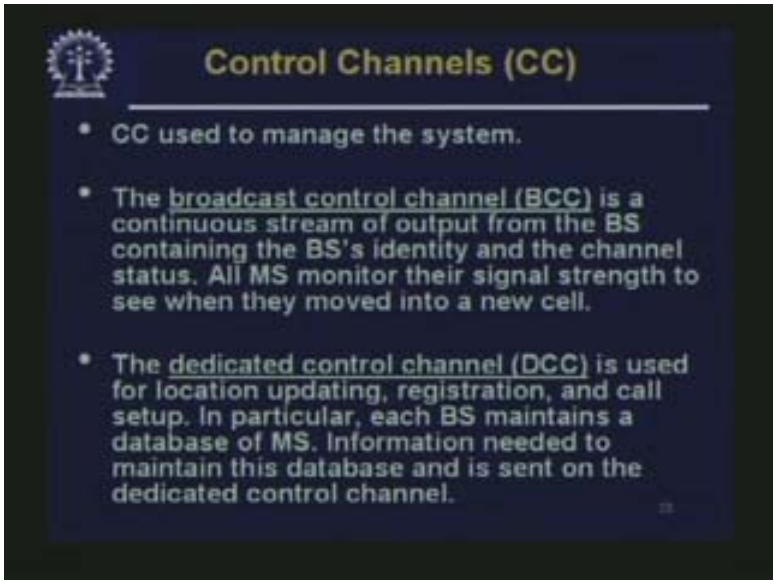
(Refer Slide Time: 28:18)



Transmitting and receiving does not happen in the same time slot because the GSM radios cannot transmit and receive at the same time and it takes time to switch from one to another. That is why different time slots are given. A data frame is transmitted in 547 microseconds, but a transmitter is only allowed to send one data frame every 4.615 milliseconds, since it is sharing the channel with seven other stations. The gross rate of each channel is about 270 or about 271 kbps divided among eight users. This gives about 33 or 34 kbps gross. CC i.e., control channels are used to manage the system if somebody is getting only 33 or 34 kbps. Previously, we have been talking about voice channel requiring 64 kbps.

Now, the 64 kbps happens to be if you are doing a plain vanilla PCM. That means we have explained, how it is encoded by sampling it at eight samples and eight levels for each sample – that gives us 64 kbps. The point is that, it is not the only coding scheme. Actually, there are more advanced coding schemes. We did not find time to discuss those coding schemes. Using those coding schemes, good quality voice transmission can be achieved, using a much lower bandwidth. This 33.854 kbps is actually enough, if you are doing your coding in a smart fashion.

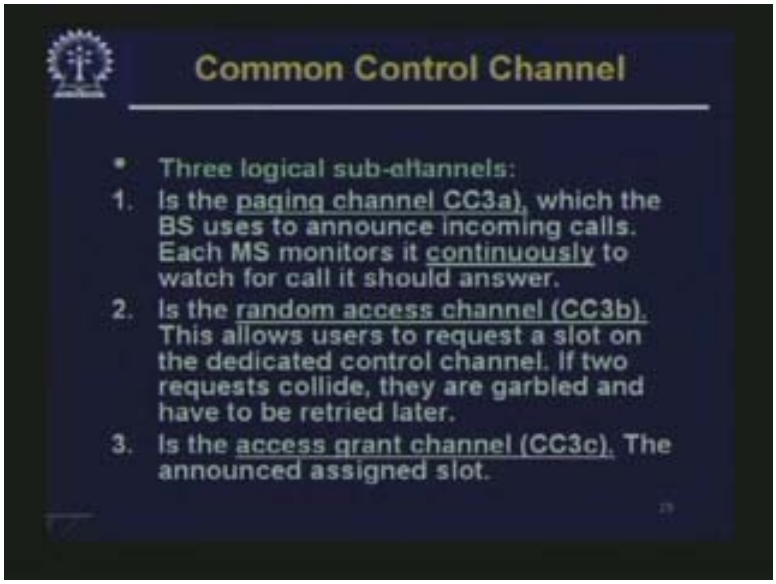
(Refer Slide Time: 30:17)



As I said, apart from the user channels, there are some control channels. CC is used to manage the system. The Broadcast Control Channel (BCC) is a continuous stream of output from the base station containing the BS's identity and the channel status. All mobile stations monitor their signal strength to see when they moved into a new cell. The point is that the mobile station, when it gets these broadcasts from BS, by just sensing how much transmitter power it is getting, it can identify whether it is near this particular BCC, what this particular BS is, or what its identity is, or whether it is near some other BS. In some systems like CDMA, this power is very crucial even for decoding purposes.

That is one thing which is being broadcast and to listened by all the MS. The dedicated control channel is used for location updating, registration, and call setup; in particular, each BS maintains a database of mobile stations, which are in its area. So, information needed to maintain this database is sent on the dedicated control channel. So, the point is that these mobile stations are moving. They move from one cell to another, from the vicinity of one base station to the vicinity of another base station. So, the set of MS, which are now currently under this, that information in some schemes is collected on the side from time to time and there is a database, which is associated with the BS. This is centrally communicated. That is important for locating a person. We come to that later on.

(Refer Slide Time: 32:20)



And then there is a common control channel which has got three logical sub channels. That is the paging sub channel, paging channel, in which the BS uses to announce incoming calls. Each MS monitors it continuously to watch for the call it should answer. The point is that, if there is a call, and MS is in the area of some BS and then somebody wants to call to this MS, which one particular MS has to be alerted. So, there is a paging for that MS from the BS and the MS is always listening to it.

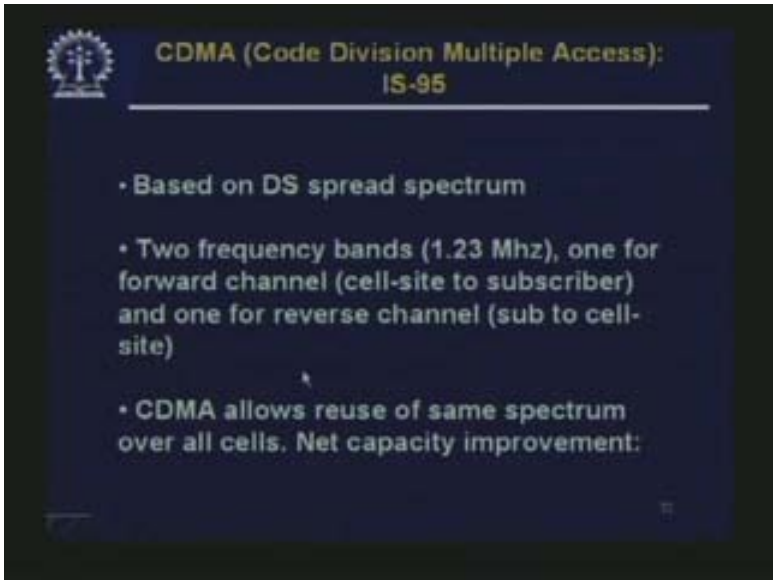
So, whenever it hears the page for itself, it gets alerted. So, the other is the random access channel. This allows users to request a slot on the dedicated control channel. If two requests collide, they are garbled and have to be retried later on. So, this is the part of the call set-up. So, it is the first part of call set-up. It tries to put a request in the random access channel for a slot in the dedicated control channel. When it gets a slot in the dedicated control channel, it can go away with the further steps of call set-up. Next is the access grant channel.

(Refer Slide Time: 33:34)

In GSM the channel multiplexing is FDM plus with eight TDM slots. Uplink is this much and channel bandwidth is200 KHz. So, DCS has certain frequency range etc. Channels are broadcast and the channel rate is 13 kbps.

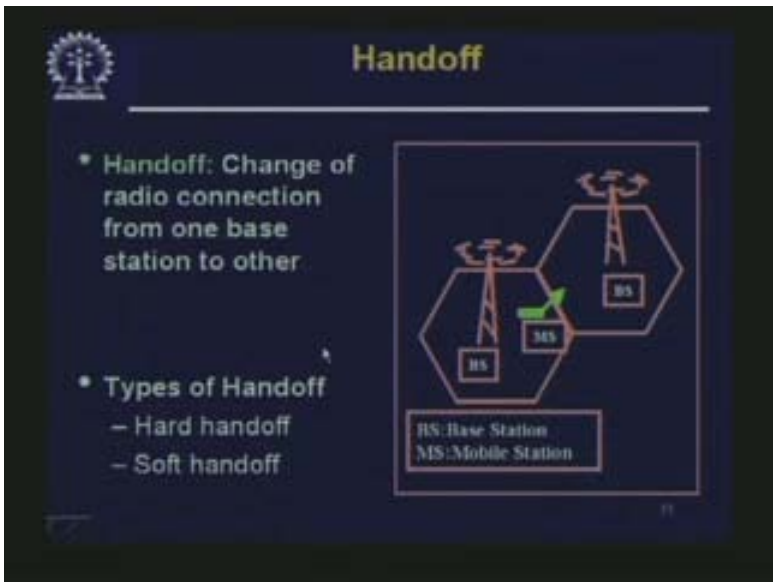
(Refer Slide Time: 33:52)

(Refer Slide Time: 34:04)



We have already seen what CDMA is – it is based on DS spread spectrum, that is, the Direct Sequence Spread Spectrum. It has two frequency bands, one for forward channel and one for reverse channel and one frequency band, a wide band actually that is shared. That means it uses orthogonal codes by a number of handsets or number of mobile stations. So, CDMA allows use of same spectrum over all cells. It also gives net capacity improvement. Although which system is better – CDMA or GSM – is still not clear.

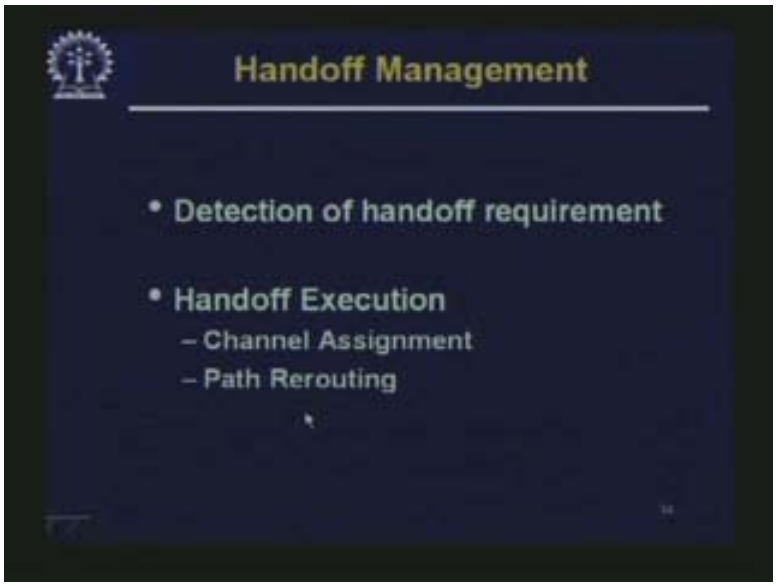
(Refer Slide Time: 34:43)



There are certain issues in the cellular infrastructure, which have to be handled. We will quickly discuss each of them. The most important one is handoff.

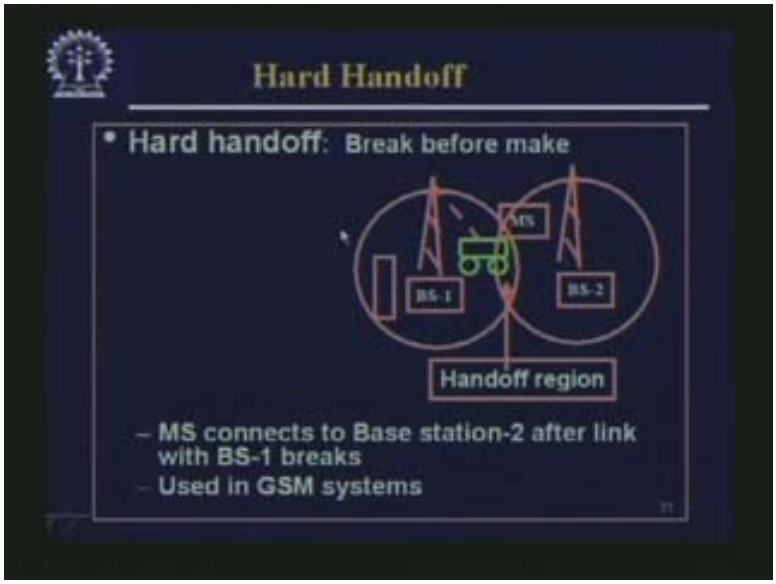
Because you may be talking on your mobile phone while moving, may be moving in a car. So, what will happen is that, the car eventually will pass out of the range of one base station and move in to the range of another base station. So, you have to hand off. That means previously all communication from this mobile station was being handled by this particular base station, as it moves in to the area of another base station, this call has to be handed off from one BS to the other BS. Handoff changes of radio connection from one base station to another will happen. But this not such a simple scheme and we will see why. There are two types of handoff: hard handoff and soft handoff.

(Refer Slide Time: 35:41)



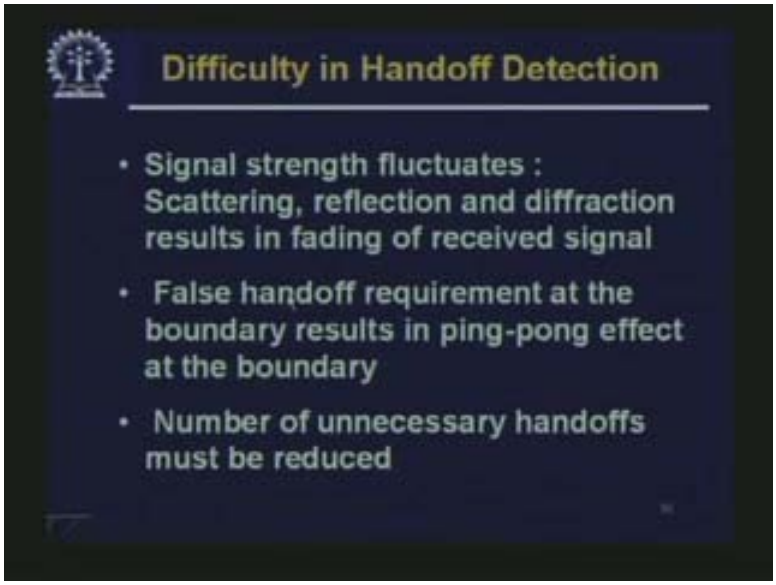
This handoff has to be managed. In order to manage the handoff, we have to detect that handoff requirement has arisen because the mobile station has moved and then you have to execute the handoff, in the sense that you have to do the channel assignment and you may have to do some path rerouting and there may be problems in this section also. For example, when you move into a new cell, all the channels over there may be busy and so you may not have any extra channel, which has to be given to this ongoing call. So, there are various schemes for handling – may be you drop this. That is the simplest thing to do, that you do not allow it or maybe you keep some guard channels specifically for these kinds of cases. But this detection of handoff requirement is a troublesome affair.

(Refer Slide Time: 36:34)



As I said, there are two types of handoff: hard handoff and soft handoff. Hard handoff is break before make. This is used in GSM system – that means you break this connection and set up the new connection with the BS in whose area you are moving. MS connects to base station 2 after link with base station 1 breaks, and this is the region where the handoff will take place.

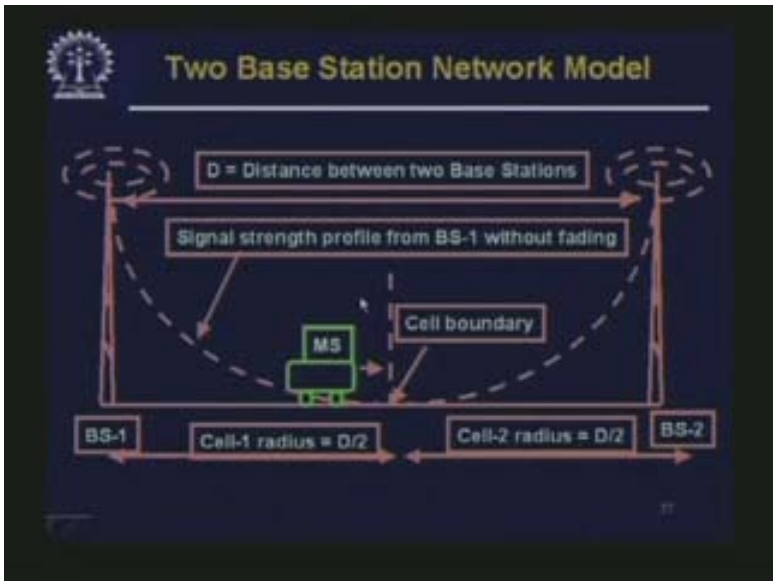
(Refer Slide Time: 37:05)



The difficulties in handoff detection are the following. The signal strength fluctuates. This is a very challenging area of mobile system design – the signal area fluctuates due to various reasons: scattering, reflection and diffraction results in fading. There are fast fading and slow fading of the receiving signal.

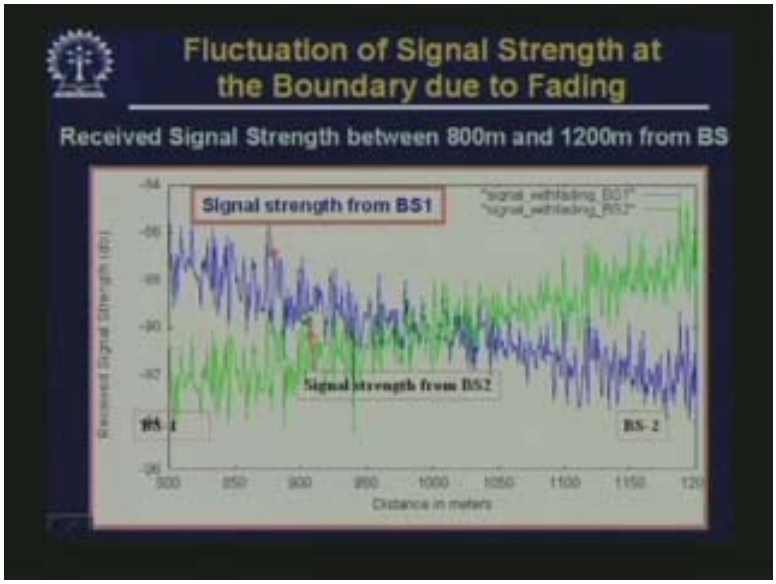
There are false handoff requirements at the boundary; there is a ping pong effect at the boundary. That means what might happen is that it may hand off from BS 1 to BS 2, then again from BS 2 to BS 1, again from BS 1to BS 2. This kind of ping pong might be going on. So, the number of unnecessary handoffs must be reduced because handoffs have a price paid, actually, keeping both channels busy on both sides. There are other kinds of overheads to this.

(Refer Slide Time: 37:59)



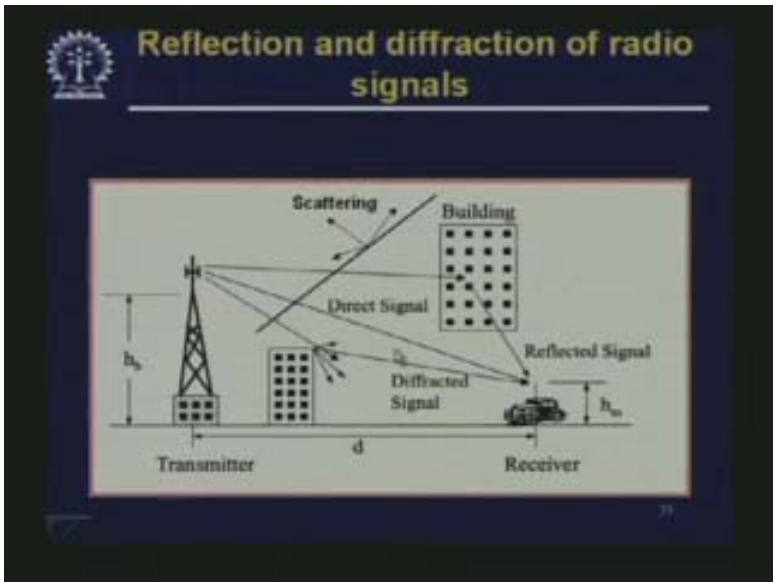
Let us look at a very simple model. Actually the situation is much more complex because, there are number of base stations – maybe three base stations and you may be equidistant from all the three at a particular point. So, you may have an even more difficult problem. But let us look at a simple problem. Suppose D is the distance between two base stations. So, ideally we would like that the signal strength from BS1 is following like this and the signal strength from BS2 is going like this. As you move from BS1 to BS2, as the MS is moving at the cell boundary, it just switches from BS1 to BS2. But the actual picture is something like this.

(Refer Slide Time: 38:42)



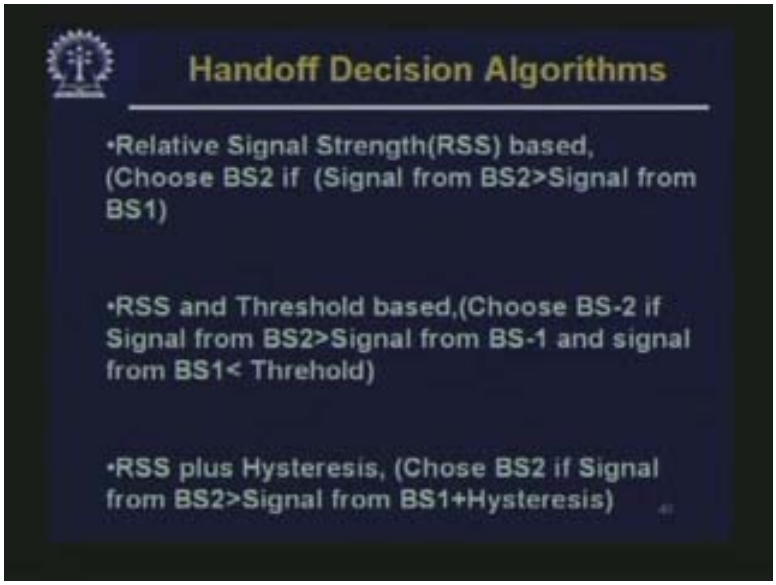
This is the point is that the signal strength from BS1 is varying, very fast. Why does it vary? I will just tell you. I had just mentioned it, but I will tell it again. This is varying like this. The signal strength from BS2 is also varying like this. So this has been plotted from, let us say, 800 to 1200 regions. So, there is a solid region at least from 950 to 1050. There is a region of 100 m, where you really do not know who is stronger. So the signal is varying all the time. What might happen is that you might now decide to move from BS1 to BS2, and then you find that BS1 has become much stronger and BS2 has become much weaker. So, it might switch from BS2 to BS1 and this might go on as a ping pong effect. So, this is a very difficult problem.

(Refer Slide Time: 39:45)



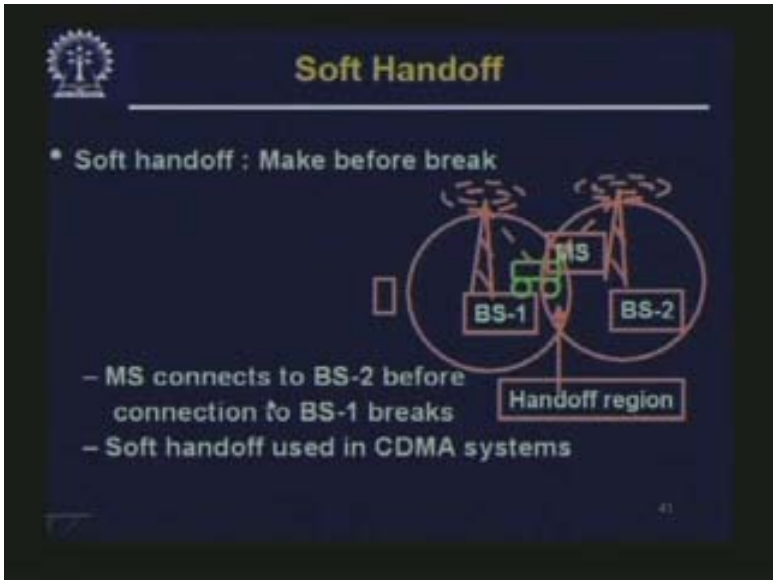
And as I said, why is it that it varies in this fashion? There are various reasons for this: one is that you are moving. This mobile station is actually moving. Now whatever signal it gets, it may get some direct signal, it may get some reflected signal, it may get some scattered signal and all these signals may start interfering with each other. So, actually what might happen is what is called multipath fading? That means, the same signal may have arrived from source to destination through two different paths – may be through two reflections – and they may be out of phase because of the different distances, which may be allowed. If they are precisely out of say, 180° out of phase, then you are going to have distractive interference or they may be in phase; they may strengthen each other. So, in a very short span of time, as the mobile is moving, you may find a very largely fluctuating signal. There are other reasons for this fading etc. We will not go into the detail of this.

(Refer Slide Time: 41:04)



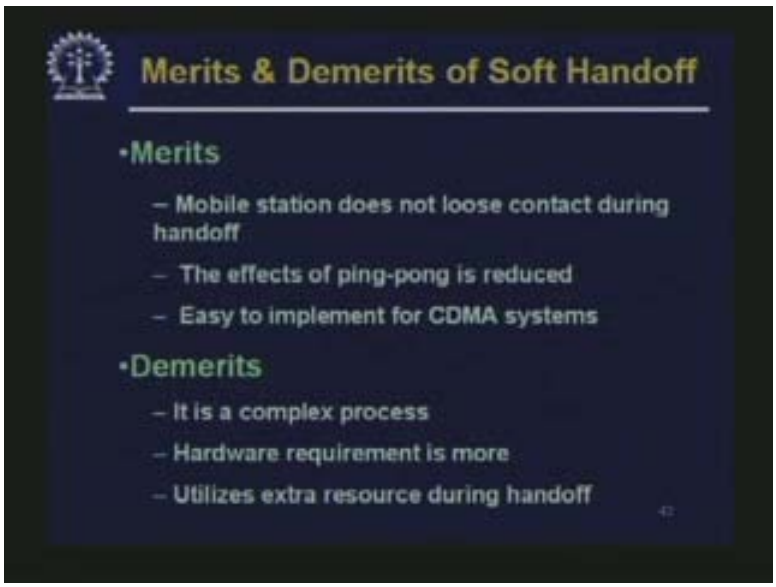
So, there is a problem of handoff. So, for the handoff decision there is various algorithms which have been proposed. I will just mention them. One is relative signal strength, which is the simplest first thing. You will think that whichever is weaker, we leave that, and whichever is stronger it will chose that one. So, choose BS2 if signal from BS2 is greater than the signal from BS 1. But as we saw, with just this, there may be lot of ping pong effect and lot of unnecessary handoffs. You can use this same RSS, that is, received signal strength, and some threshold base. That means we choose BS2 if the signal from BS2 is greater than the signal from BS1 and the signal from BS1 is less than a threshold, which means that although BS2 is stronger, if BS1 is above the threshold, which is still working, then we do not do a handoff. Another thing is RSS plus hysteresis, that is, received signal strength. Just being greater is not enough; it has to be greater by a certain amount of hysteresis. The hysteresis means base1 persists as the BS2 is becoming stronger in base 1 and then there are other kinds of other combinations. People have tried for getting a good handoff decision.

(Refer Slide Time: 42:22)



As I said, this hard handoff is used in GSM, whereas in CDMA system, they use soft handoff. This is "make before break" – that means you make a connection to that coming in the next base station, before you release the connection with the previous base station. So, MS connects to BS2 before connection to BS1 breaks. This is called soft handoff.

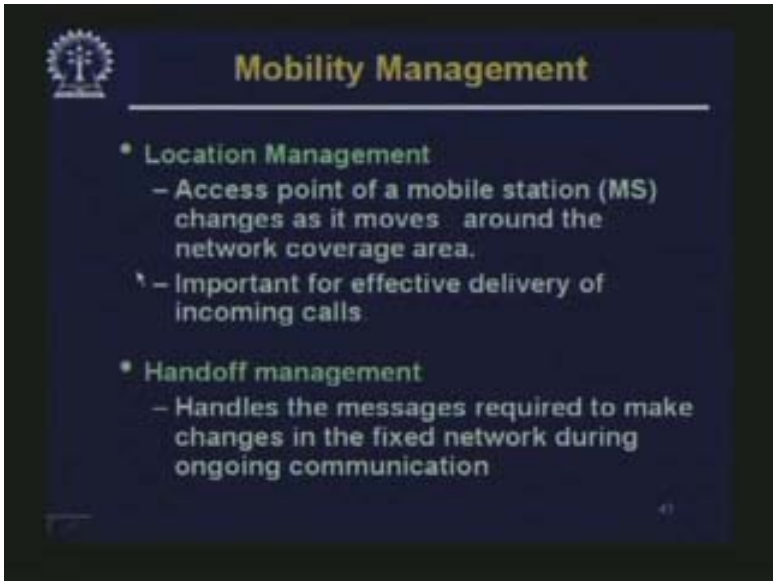
(Refer Slide Time: 42:51)



We will now discuss the merits and demerits of soft handoff. Merits are: mobile station does not loose contact during handoff; the effects of ping pong are reduced; and it is easy to implement for CDMA systems. The demerits are: it is a complex process.

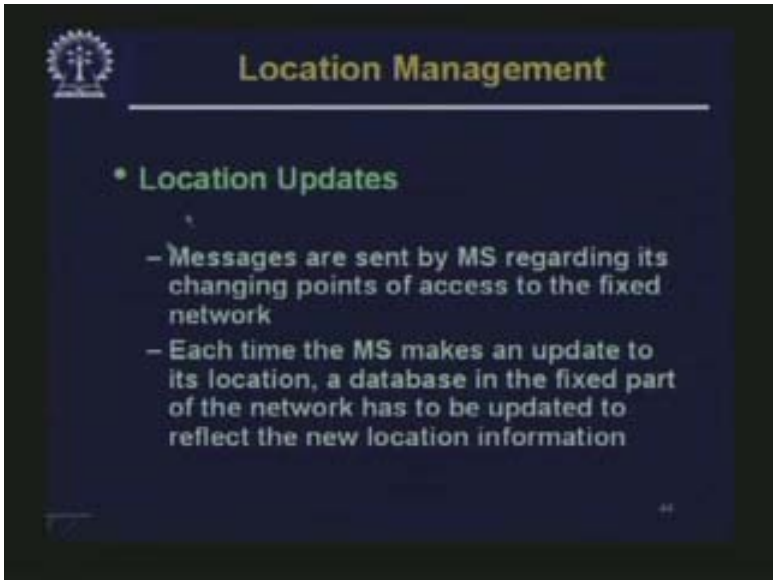
So, hardware requirement is more and that means your hardware cost may also go up; and it utilizes extra resource during handoff.

(Refer Slide Time: 43:16)



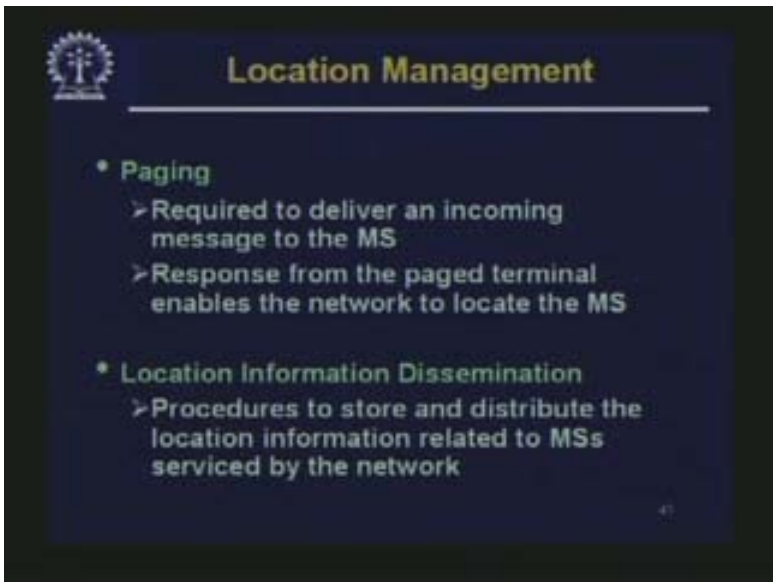
[43:16]Now, we come to the question of mobility management. How do you manage mobility in a local in a MS? That is because, one of the very fascinating thing about mobile connection. I have called somebody on the mobile, who I assumed is just local. That is who is in the same area as i am. It just so happens, that he is in a place far away. He is visiting some place. May be Rajasthan or something. , as he is very far away. Now I will expect that the system would somehow locate him in Rajasthan and then allow me to talk to him. So, that is again a non-trivial problem. There are various approaches to this problem. We will just once again touch on this. So, this is called mobility management. One is location management access point of a mobile station changes as it moves around the network coverage area and important for effective delivery of incoming cells and other is handoff management. We have already talked about it. Now, for location management, one approach through location updates. That means messages are sent by MS that is a mobile station regarding its changing points of access to the fixed network. So, that is to the fixed network, that is sort of time of time it tells that. Ok. This is where some central database is updated.

(Refer Slide Time: 44:23)



Each time the MS makes an update to its location a database in the fixed part of the network has to be updated to reflect the new location information. So, that for a particular MS, if you go to the data base and find out what is the last point, where he said, that he was. Of course what he might have done is that he might have switched off his mobile and then moved to somewhere else and then put it on or something. . So, put it on again. So, that is not still solved the entire problem 100%. But this is one approach to solve it.

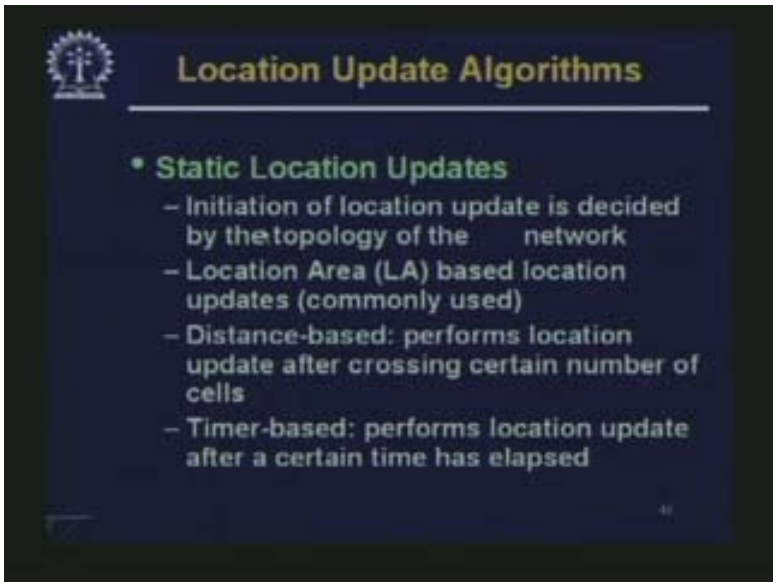
(Refer Slide Time: 45:22)



The other this thing is the paging. You know what is paging? Paging means that sort of broadcast it. Well broadcast means broadcast it everywhere.

We do not want to broadcast it everywhere. So, you broadcast it only to certain places. So what we do is that, we broadcast that there is a call for such. So, that is what we page and if that paging is being done in a cell, where the MS is actually present and that the MS will respond, that is what will happen. So, that is another scheme required to deliver an incoming message to the MS. Response from the paged terminal enables the network to locate the MS. The other thing about location management is location information dissemination. Procedures to store and distribute the location information related to MS are serviced by the network. That is the issues over. That I am not going detail in any of these, as no time.

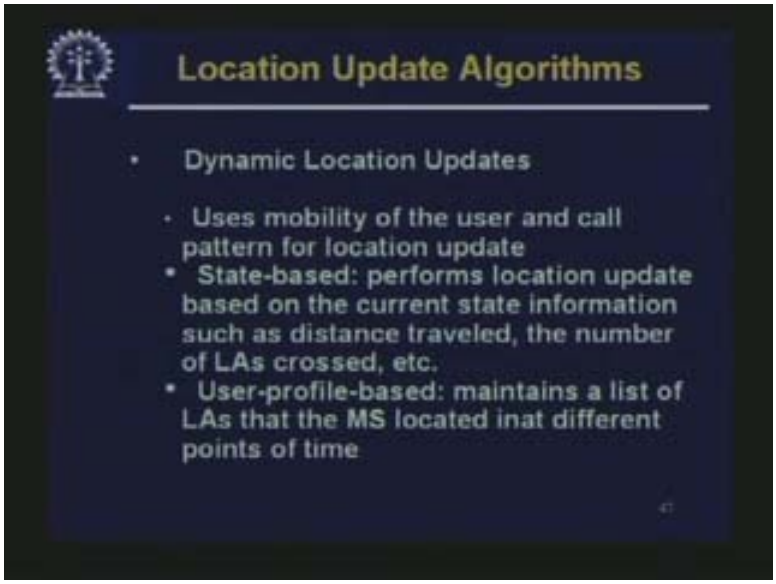
(Refer Slide Time: 46:27)



And for the location update, you may do static location update. That means initiation of location update is decided by the topology of the network and location area based location updates which is commonly used. What a location area is and distance based, which performs location update after crossing certain number of cells or timer- based, performs location update after a certain time has elapsed. So, the question is that how frequently do you update this? Because, if collecting all the data all the time and just updating it all the time, that will consume an enormous amount of resources. You have to optimize somehow.

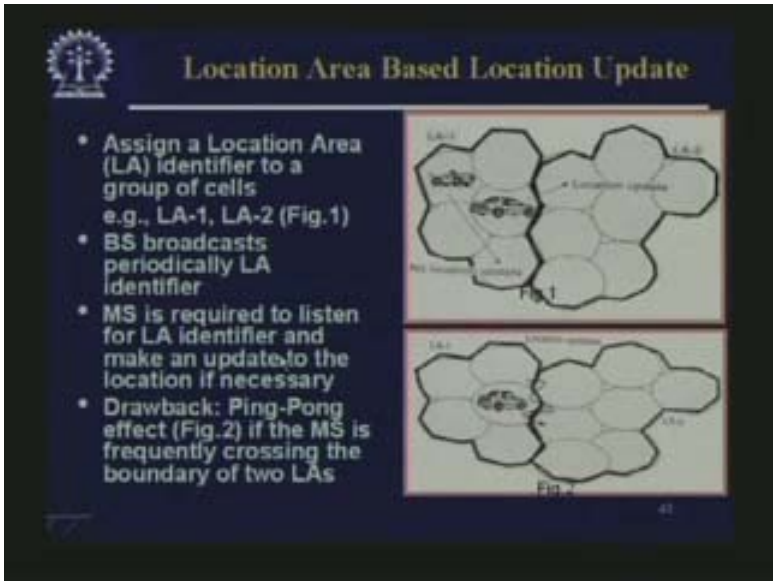
That this is the point is that if we not doing frequently enough, your data in the database going to stay and then when you want to actually search for somebody, then you might have to search around a large area. Ideally what would you liked is that when a call is there for somebody, we know that exactly in that particular cell that mobile station is there. So, we go and page over there. He responds ok. That is the idea. But this idea will never work. Because, you cannot keep it updated on all the time and you cannot collect and keep all the information. So, you have to do some kind of optimization over there, which means that you actually looking for one particular mobile. You have to search not in just one cell, but may be in several cells. So, that is where location area comes in that location. Area is collection of cells, we will come to that.

(Refer Slide Time: 48:04)



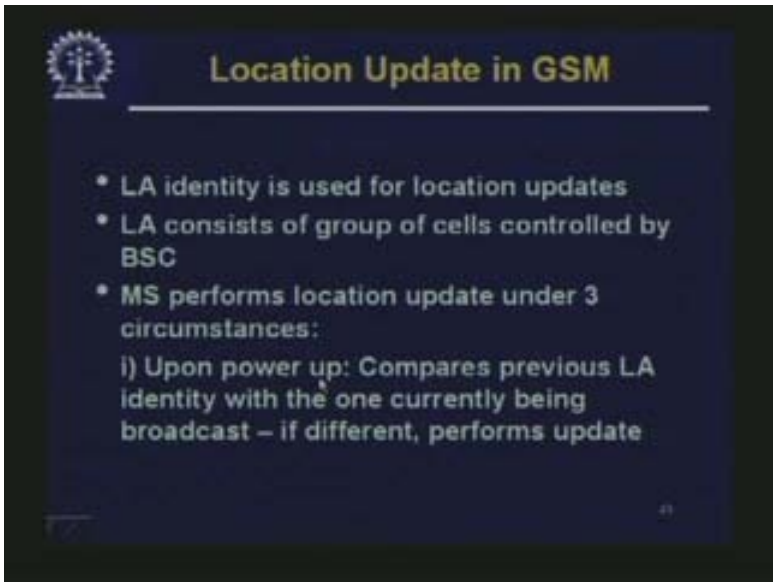
The other is dynamic location update. It uses mobility of the user and call pattern for location update. So, if you know the mobility of the user and some call pattern etc, you may be able to predict that where this particular user may be. It is more likely that he will be there. So, it state-based: performs location update, based on the current state information such as distance travelled, the number of LAs crossed, etc or user profile based, which is more difficult, not exactly used at the moment maintains. A list of LAs that is location areas that the MS located in at different points of that time usually. So, usually during office hours I will be found in my office. In that particular area. So, that may be known and that may be a guess. But then gathering this information and keeping this information for all users, this is not a mean task.

(Refer Slide Time: 49:03)



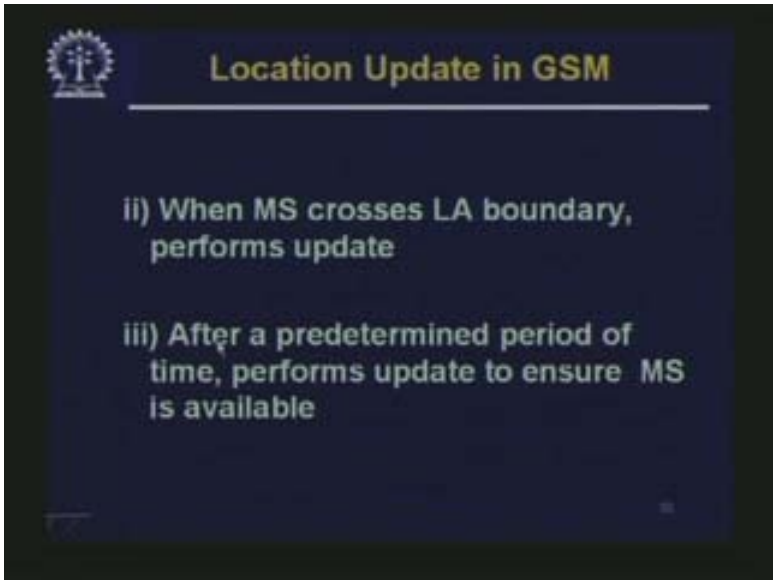
So, this is the location area based location update. So, as you see that a bunch of cells together form a location area. So, this is the location area 1 containing 1 2 3 4 5 cells. This location area 2 containing 7 cells and so on. So, assign a location area identifier to a group of cells LA 1, LA2. BS broadcasts periodically LA identifier. So, it is enough to trying to fill a particular cell. You are trying to fill it down to a location area. So, BS broadcast it, whichever location it is in MS is required to listen for LA identifier and make an update to the location if necessary. Drawback is once again, there may be ping pong effect. This fellow is moving like this. So, it going from location area 1 to 2, 1 to 2 etc. That is always the thing. You cannot eliminate this completely.

(Refer Slide Time: 49:59)



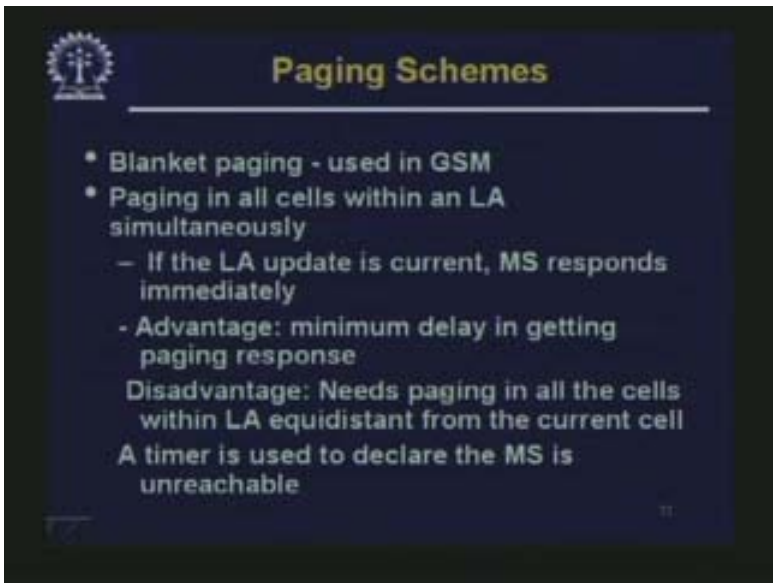
Location update in GSM. LA identity, that is it takes the location based approach. Identity is used for location updates. LA consists of a group of cells controlled by BSC and MS performs location update under 3 (1).circumstances upon power up, compares previous LA identity with the one currently being broadcast- if different, performs update.

(Refer Slide Time: 50:22)



(2)When MS crosses LA boundary, performs update. (3)After a predetermined period of time, performs update to ensure MS is available. So that you do all the three things simultaneously. So that would make sort of judgment about, what is this time interval, after which it will go automatically or of course, other two are simple.

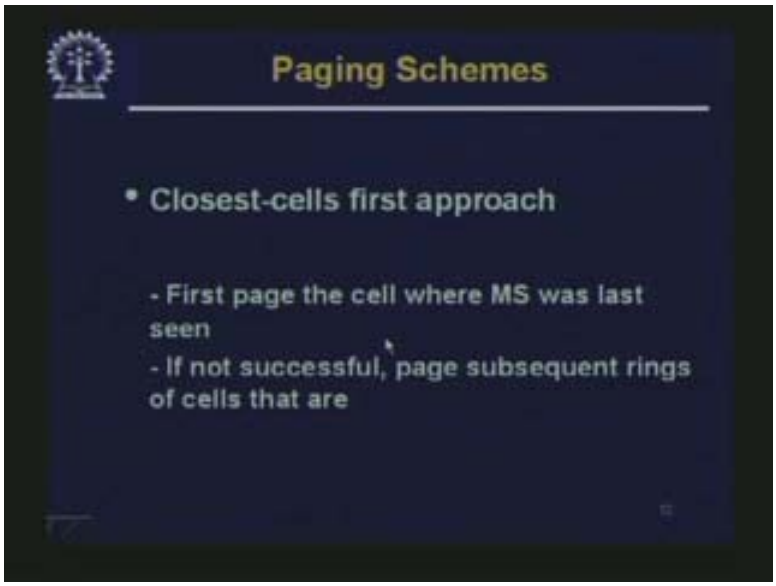
(Refer Slide Time: 50:53)



And then in for paging schemes, you can do blanket paging, that means when you know the location you just page everything. All the cells paging in all cells within an LA simultaneously. If the LA update is current, MS responds immediately.

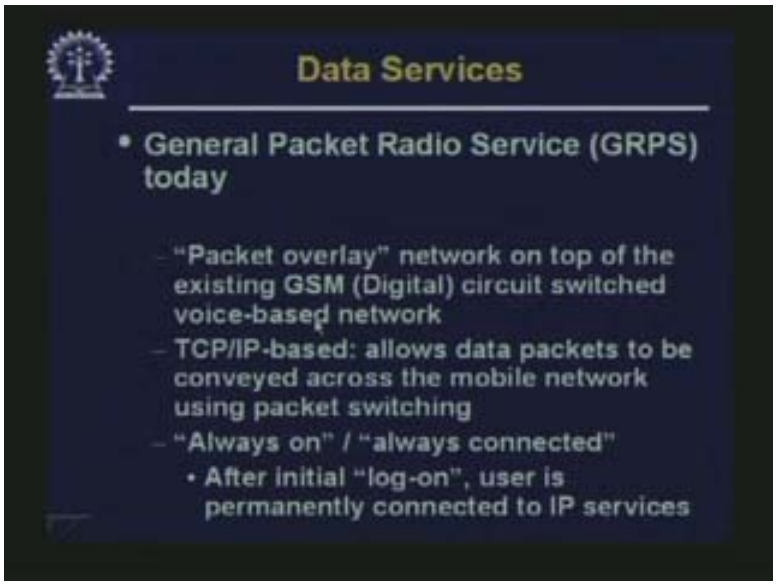
Advantage is minimum delay in getting paging response and disadvantage is it needs paging in all the cells within LA equidistant from the current cells. A timer is used to declare the MS is unreachable.

(Refer Slide Time: 51:22)



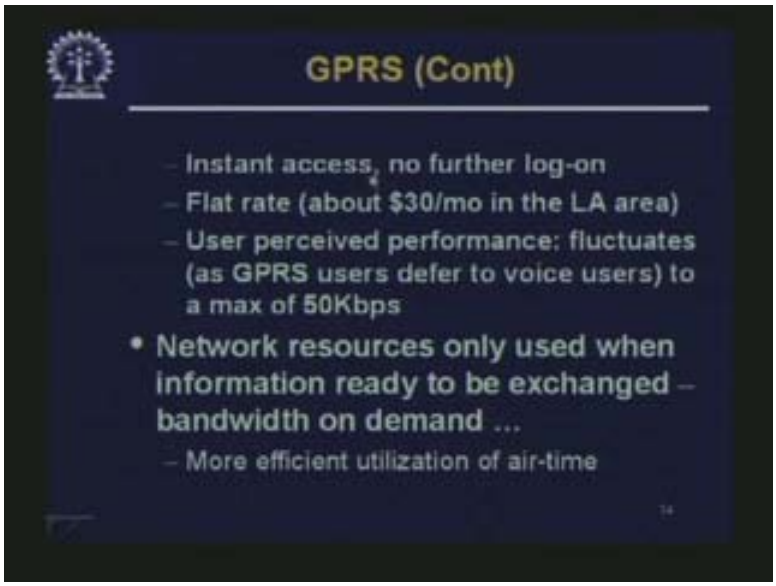
All it could be that closest cells approach. First page the cell where MS was last seen. If not successful, page subsequent rings of cells those are. So, this is all trying to reduce the overhead and give the maximum response time etc. So, all these different schemes are there.

(Refer Slide Time: 51:40)



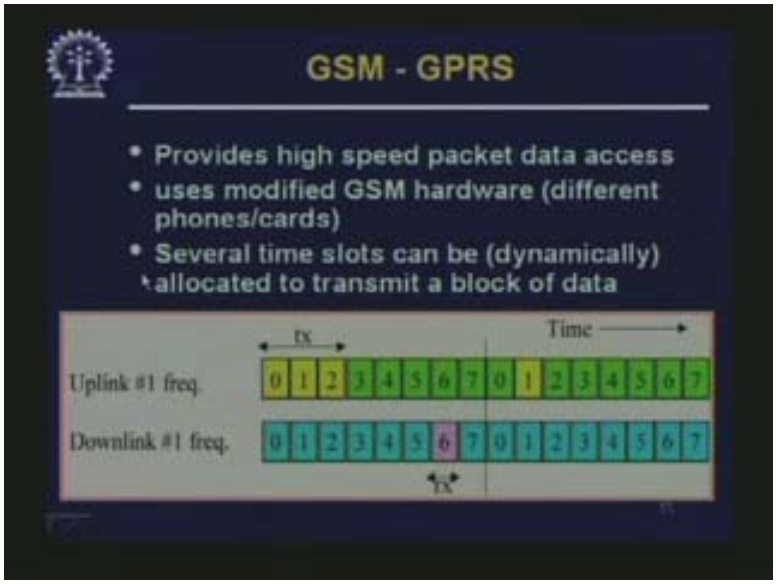
And finally we will not go in to the details of these. As i said that, now everybody wants news on their handsets. Not only news they want to access, to the internet through the handsets, which means we will have to give some data service and that is why service providers also move from [Noise] 2G to 2.5G systems wherein from the GSM family. It, the general packet radio system GPRS and CDMA to CDMA2000. So, GPRS is a really "packet overlay" network that means on the same network, there is a packet service, which is going on available frequency bands. Network on top of the existing GSM digital circuit switched voice based network. So, it is TCP/ IP based. The protocol based is same as the TCP IP which we will learn later. It allows data packets to be conveyed across the mobile network using packet switching and it is "Always on". " Always connected" type of thing and after initial "log-on", user is permanently connected to the IP services, that is the GPRS.

(Refer Slide Time: 52:54)



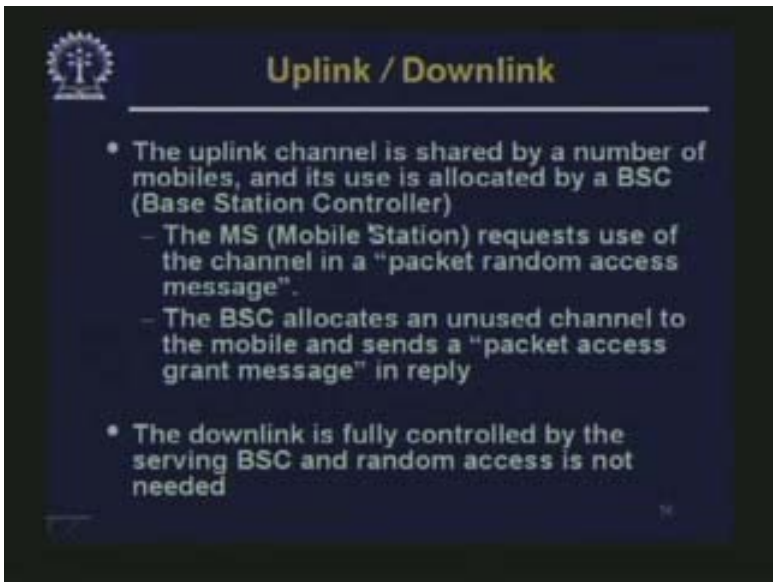
Instant access, no further log on and usually the rates also gives a flat rate. User perceived performance: fluctuates (as GPRS users defer to voice users). So, voice users have a preference. So, because data may delay that is may be acceptable to a maximum of [Noise] 50kbps. Network resources only used when information ready to be exchanged bandwidth on demand. So, more utilization of air time that is the GPRS.

(Refer Slide Time: 53:23)



So, this provides high speed frequency... So, uplink is on the particular frequency band and downlink is on particular frequency band and these are all packet services which provide high speed packet data access. This uses modified GSM hardware (different phones or cards) are required. That is you have particular kind of set that handle GPRS. Several time slots can be dynamically allocated to transmit a block of data. So, if the packet is large, so several time slots may be used for that.

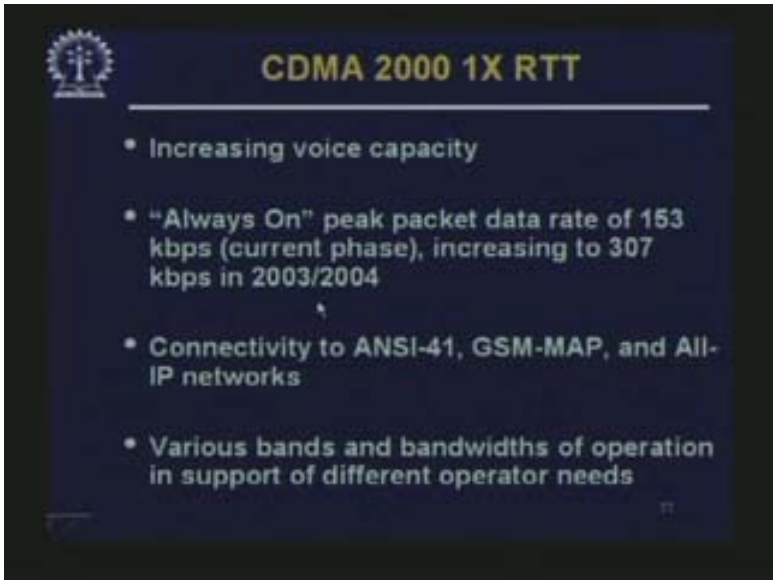
(Refer Slide Time: 53:53)



The uplink channel is shared by a number of mobiles, and its use is allocated by a BSC, base station stream.

The downlink is of course fully controlled by the serving BSC and random access is not needed in the uplink. Of course multiple access will still because, so many people want to send the request for data. The MS requests use of the channel in “a packet random access message”. The BSC allocates an unused channel to the mobile and sends a “packet access grant message” etc.

(Refer Slide Time: 54:26)



CDMA 2000 is once again is the CDMA version of it. Increasing voice capacity. Once again this is always on peak packet data rate of 153 kbps which is quite high. Connectivity to ANSI -41and GSM-MAP, which we need not to bother. Various bands and bandwidths of operation in support of different operator needs.

(Refer Slide Time: 54:50)

It is expected that actually that, this CDMA 2000 1X RTT is backward compatible with CDMA1 system, which was the previous original CDMA system. Improved service multiplexing and QOS management and variable transmission rates and it is expected that in future what is going to happen is that, as data demand is definitely going to grow, so these will sort of move from these interim 2.5G system to the 3G systems. I. CDMA is already being employed. This is part of our big network architecture. This converged network architecture, which is slowly emerging and in the next lecture, what we are going to do is that we are going to discuss Wireless networking in the LAN setup. In the sense purely in this, we are talking about voice and voice added to data. Next, we are going to talk about data and may be data plus wires that is a separate issue. Thank you.