Wireless Communications
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Lecture No. # 38
GSM and CDMA

Welcome to the next lecture on wireless communications. Today we will have a brief glimpse about the GSM standard. It's first of the two part lectures which will cover GSM and CDMA, the brief out line for the talk is as follows.

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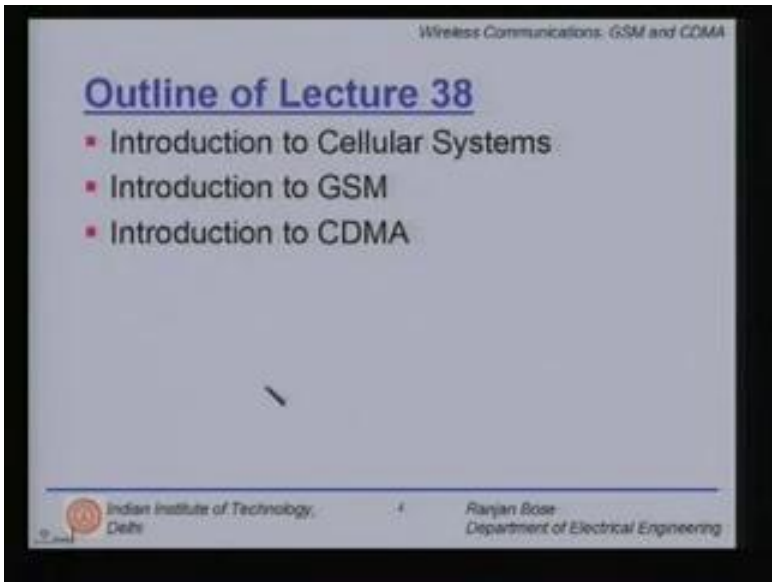

First we will talk about a very basic introduction to the GSM system from the perspective of cellular systems, frequency planning, how the calls are made and finally we will lay motivation to why CDMA will form a part of the next generation standards. Today it will be a bridge lecture which will lay motivation as to why GSM was introduced, why is it so successful and what leads us to migrate to CDMA. In the next lecture we will talk about CDMA.

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Now what is GSM? GSM stands for global system for mobile communications. This is the second definition, earlier there was a French definition to it. It's a set of ETSI standards specifying the infrastructure for a digital cellular service. The standard is used approximately in 85 countries across the world including Europe, Japan, Australia and also in India. Now a brief history 1991 first GSM network was launched, in 1992 most European GSM networks turned commercial, 1994 data transmission capabilities were launched. In 1995 about 156 members from 86 countries form the network, in 1996 120 networks in 71 countries, 1997 200 GSM networks in 109 countries. So exponential raise in the application and deployment of GSM networks. Now we have 44 million subscribers in counting.

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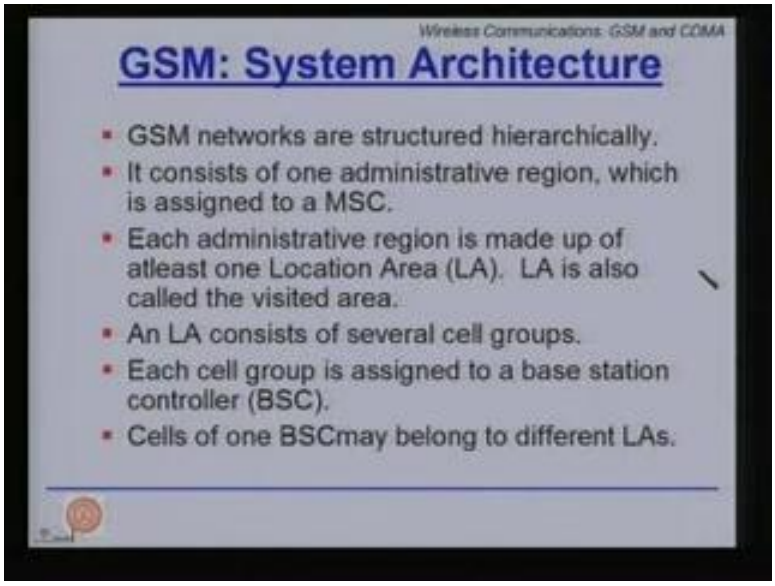

Now what is that makes GSM so successful? Let us talk about the GSM architecture; most important thing is GSM networks are structured hierarchically, we will soon talk about them. It consists of one administrative region which is assigned to a mobile switching center. In our previous lectures we have seen how a mobile switching center acts as a smart switch. Each administrative region is made up of at least one location area LA and LA is also called the visited area. Now coming to the hierarchically structure an LA consists of several cell groups and each group is assigned to a base station controller BSC. Cells of one base station controller may belong to different location areas. So this slide gives in general the hierarchical nature of the GSM network.

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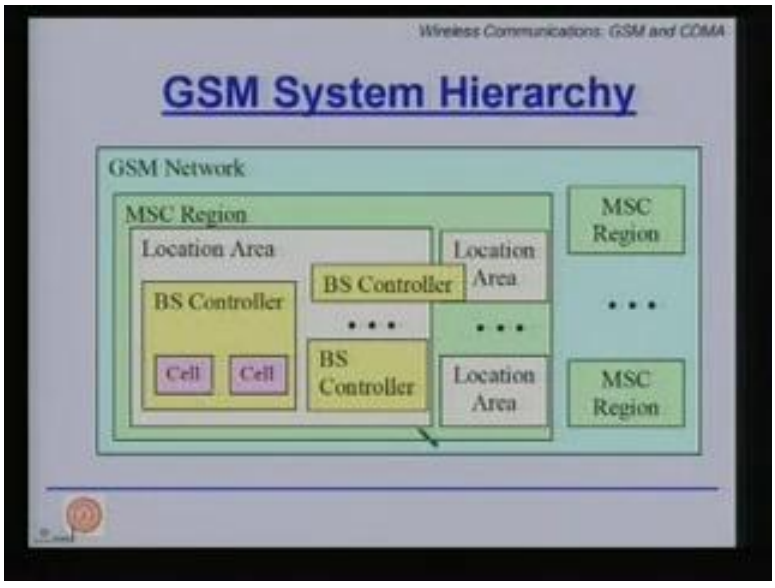

Graphically let's have a look at it, so here the biggest rectangle is your entire GSM network and if you start from this smallest unit it is the cell. Each cell has a base station and a cluster of cells are controlled by something called as a BSC or base station controller. Now we are not limited to a single base station controller I can have several of these base station controllers, each one having their own set of cells. A collection of base station controllers are within this location area LA. Again we are not limited to one location area I can have several location areas but please note it is possible that base station controller may overlap on two location areas as depicted by this rectangle. Again my mobile switching center region is comprised of several location areas and there are several of this MSC region. Totally they have the GSM networks, this is spread across the county and now globally.

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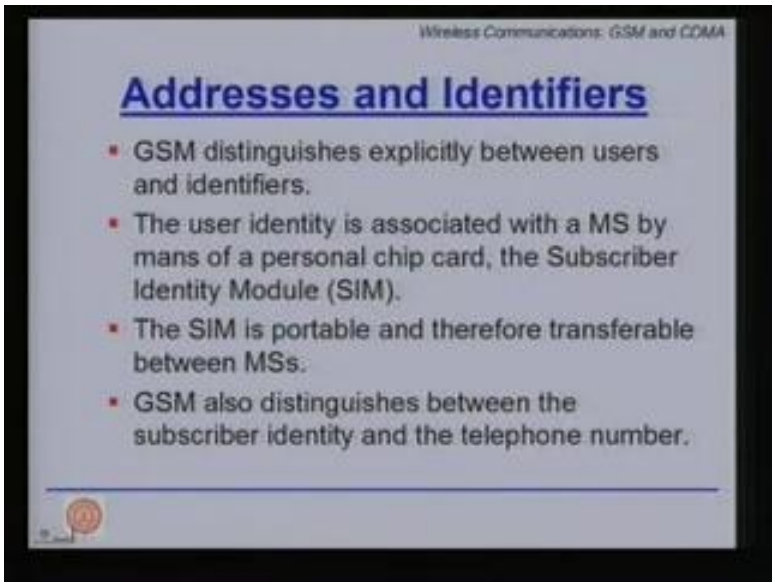

Now GSM is an elaborate standard, it goes to great lengths giving detail addresses and identifiers. In the next couple of slides we will quickly go over some of the addresses and identifiers used for GSM equipment users SIM cards etc. So GSM distinguishes explicitly between users and identifier. The user identity is associated with an MS mobile station by means of a personal chip card, the subscribers identity module called SIM also called the SIM card. The SIM is portable and therefore transferable between mobile stations or your handsets. GSM also distinguishes between the subscriber identity and the telephone number.

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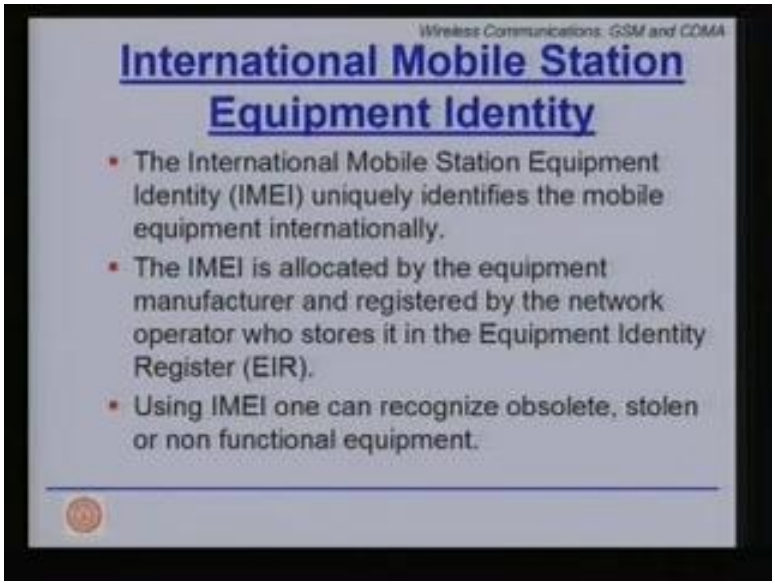

Now let us quickly talk about international mobile station equipment identity. What is that? This IMEI uniquely identifies the mobile equipment internationally. It is allocated by the equipment manufacture and registered by the network operator who stores it in the equipment identity register EIR. So every handset that you buy from the actual market, gray market, abroad internationally will have an IMEI number. Using an IMEI number one can recognize absolute, stolen or non functional equipment. If your handset is stolen and if you notify your service provider then it is possible in principle to deactivate service to that stolen handset whether it can be implemented in real life by users ISP's is questionable but it is possible to do it. then we talk about international mobile subscriber identity.

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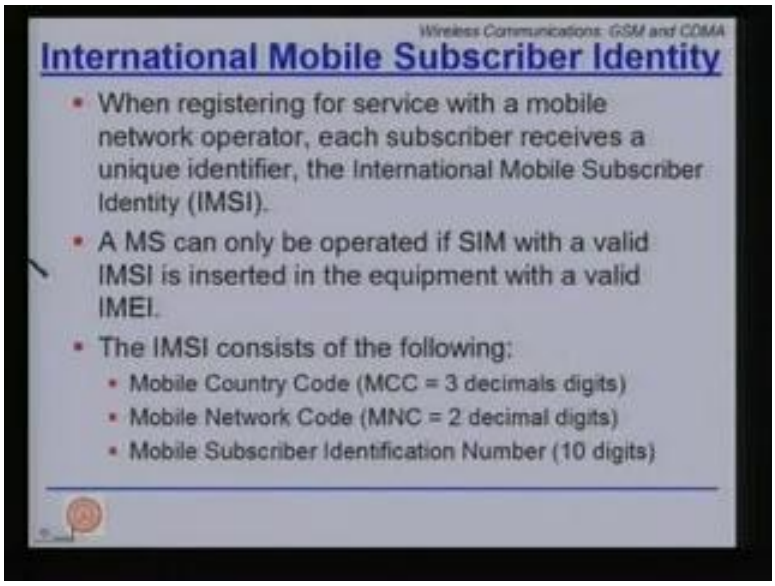

When registering for service with a mobile network operator each subscriber receives a unique number or identifier which is called the international mobile subscriber identity IMSI. A mobile station can only be operated if a SIM with a valid IMSI is inserted with an equipment with a valid IMEI. So you can independently make either the SIM card illegal or deny service to any IMEI which falls into the dubious category. This is one of the possible breakup, an IMSI consists of the following; you can have a country code, network code and subscriber identification number. So you can uniquely pin point, you can increase these fields also.

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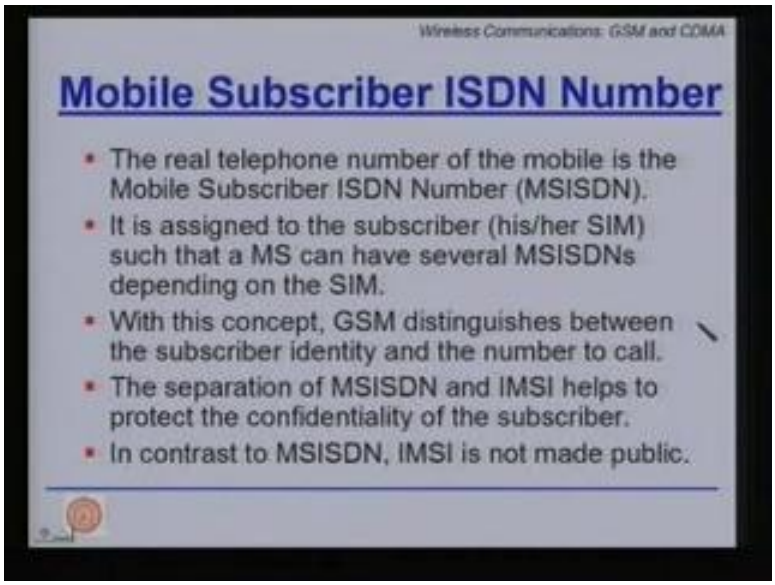

Now let us talk about the mobile subscriber ISDN number which is the MSISDN. The real telephone number of the mobile is the mobile subscriber ISDN number. It is assigned to the subscriber his or her SIM such that a mobile station can have several MSISDN's depending on the SIM. With this concept GSM distinguishes between the subscribers identity and the number to call. The separation of MSISDN and IMSI helps to protect the confidentiality of the subscriber. In contrast to the MSISDN, IMSI is not made public.

So a subscriber can hold several MSIDN's for the selection of different services. This is one of the features provided by GSM. What does it mean, that if the same handset, same SIM card I can enjoy couple of numbers for fax, voice, data, etc. The service desires that the resource needed to provide the service can be recognized form the MSISDN. So if I look at a number, I can immediately say whether it's a fax or it's a mobile or it's for data only.

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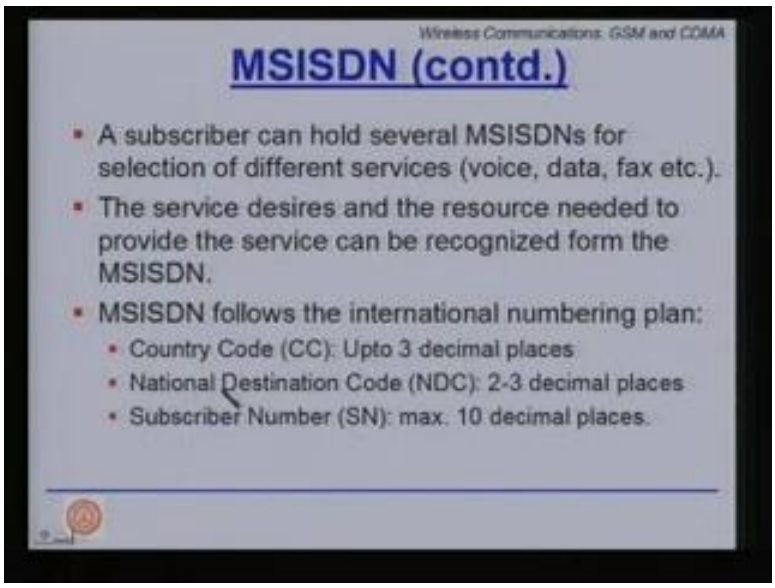

So the number itself gives me clear indication what kind of traffic will there be. Again the MSISDN can be broken up into a country code, a national destination code and the subscriber number and you can have more fields. Now let us talk about the mobile station roaming number. The MSRN is a temporary location dependent ISDN number. It is assigned by the locally responsible visited location register. We will talk about the visited location register VLR and the home location register HLR soon. Calls are routed to the mobile station using this MSRN, the mobile station roaming number. Again we have the similar structure of the MSNR, there is a country code followed by the national destination code and then the subscribers number.

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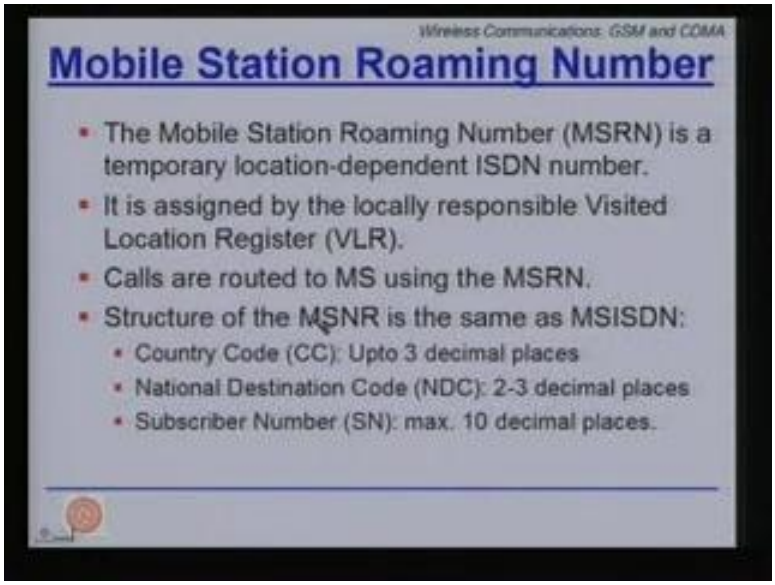

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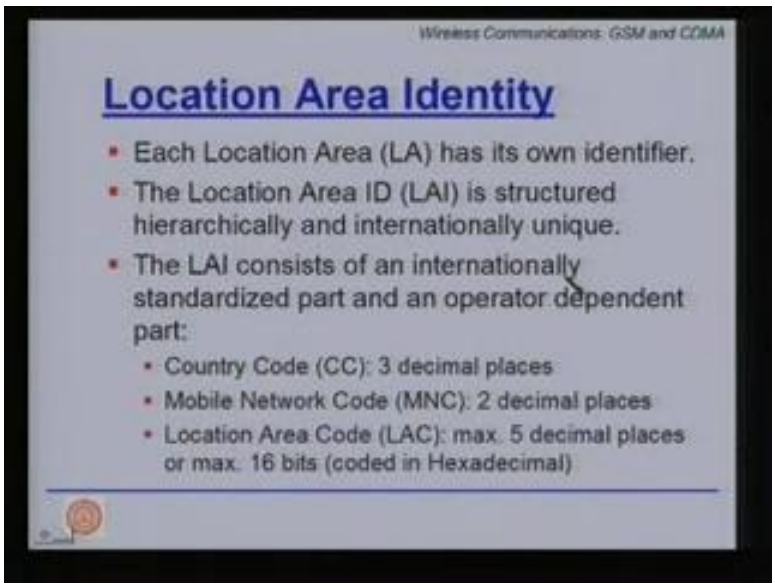

Location area identity; now we have seen in our previous slide that there is a location area. Each location area has its own identifier, so not only we are having identifiers for the equipment, for the SIM card, for the user but we also have identifiers for the location area. So that we can pin point exactly the location of a user in the network. The location area ID which is called the LAI is structured hierarchically and internationally and is unique. The LAI consists of an internationally standardized part and an operated dependent part so you have a country code, a mobile network code, location area code. So these breakup is a matter, of detailed what is important to understand is internationally, globally we can have an LAI which can uniquely point to which location area you are visiting.

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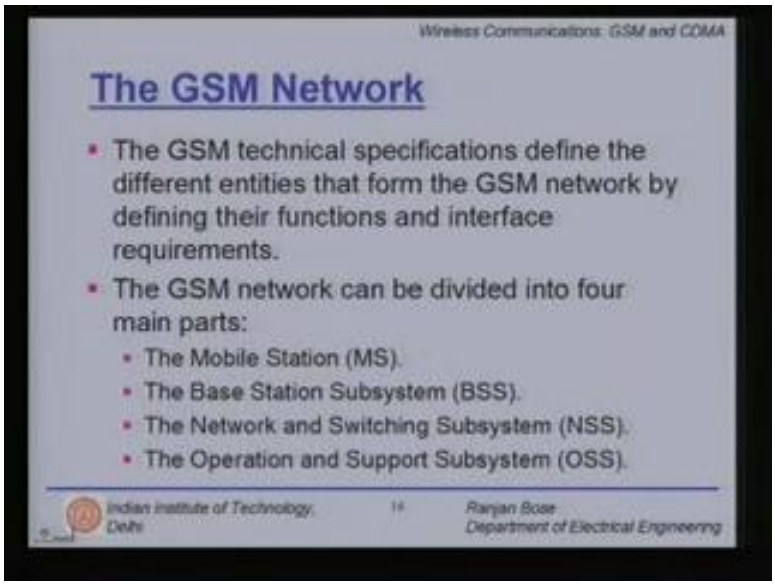

The GSM technical specifications define the different entities that form the GSM network by defining their functions and interface requirements. The GSM network can be divided into four main parts. What are these? The mobile station, the base station subsystem, the network and switching subsystem, operation and support subsystem. Please note we are talking about the entire network and when we are talking about the parts of the network, mobile station figures there, it's a part of the network. It helps manage part of the network as the mobile stations are becoming more and more intelligent a lot of decisions are being taken at the mobile station.

So here this is a bird's eye view of the GSM network architecture so you have the base stations subsystem and then there is a mobile station which is connected to the SIM and then you have the base transceiver stations BTS, base station controller. Here the network management system has the home location register, its where your service was originally registered at, the visited location register and it is again giving information to the mobile switching center. This is connected to the PSTN, the ISDN and other networks. This is precisely how a GSM network architecture looks.

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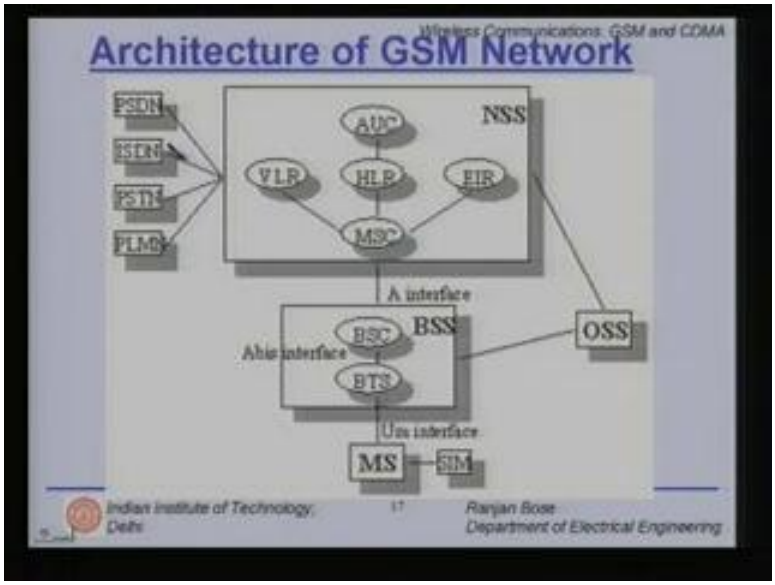

Now let's talk first about the mobile station. Mobile station consists of two main elements, the equipment and the SIM. We need both of them to make it work. The terminal of the mobile station, there are different types of terminals distinguished principally by their power and application. So we have the fixed terminals, these are kind of absolute now. They could radiate up to 20 watts, not good you had to be fixed to a car and your battery will be run out in no time. Then you have the GSM portable terminals, output power is 8 watts, handheld terminals these weights are decreasing drastically. The size and the weight of the handsets are going down every day and then these terminals emit up to 2 watts peek power and maximum allowed power can go down to 0.8 watts.

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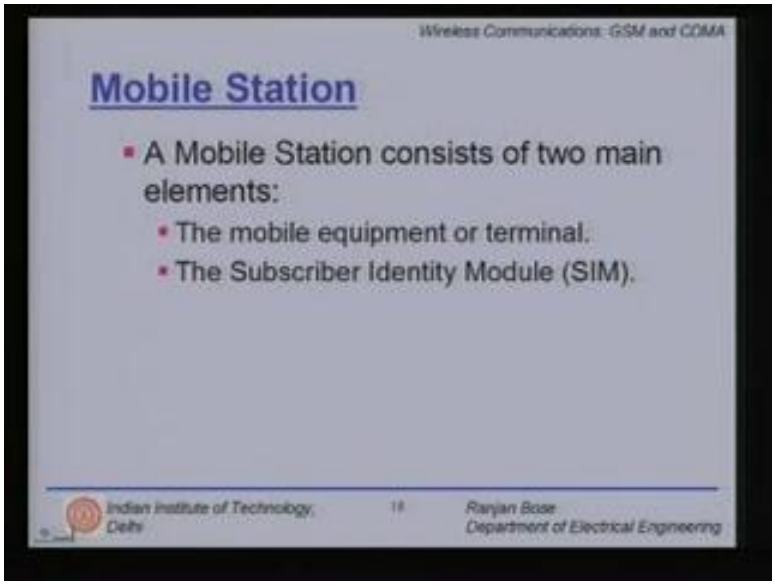

What is important to note here is that GSM gives provision for all of these kinds of terminals. It's that we are using these handheld terminals more frequently, more popularly.

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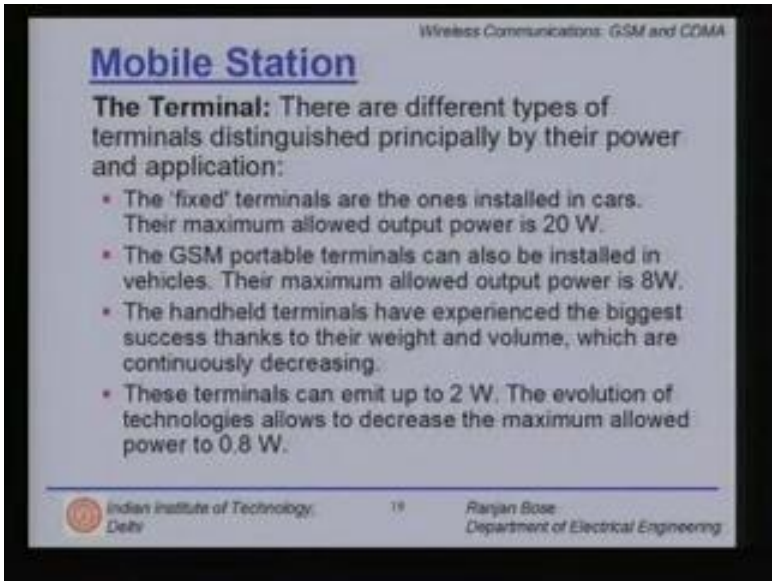

The other part of the mobile station is the SIM. SIM is a smart card that identifies the terminal so by inserting the SIM card into the terminal, the user can have access to all the subscribe services. Clearly without the SIM card, the terminal will not work and the SIM card is protected by a 4 digit personalized pin number. Now in order to identify the subscriber to the system the SIM card contains some parameters of the users such as the IMSI and another advantage of SIM is the mobility of the user. In fact the only element that personalizes a terminal is the SIM card.

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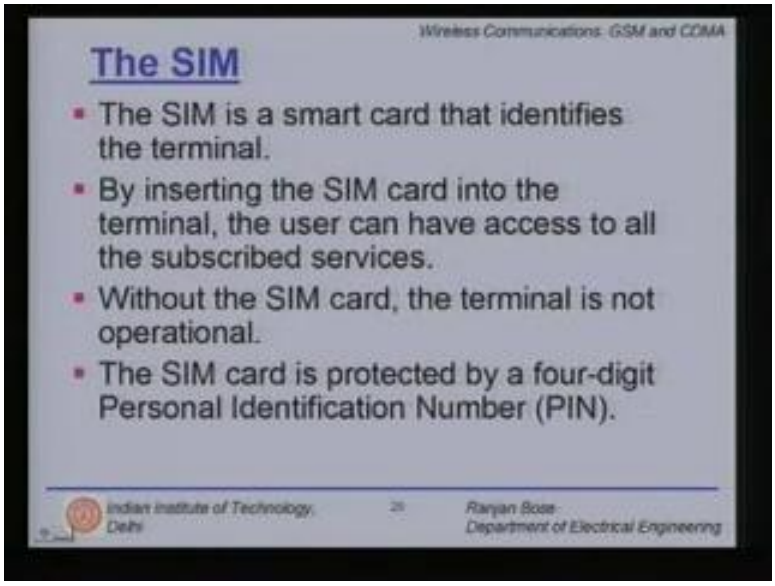

So you can take your SIM card move around inserted into any other terminal and start talking. Therefore a user can have access to its subscribed services in any terminal using the SIM card. Today more and more intelligence is being built in the SIM card, it has its own memory, it has its security features. So SIM card is becoming more and more important because it is fully loaded today with lot of features.

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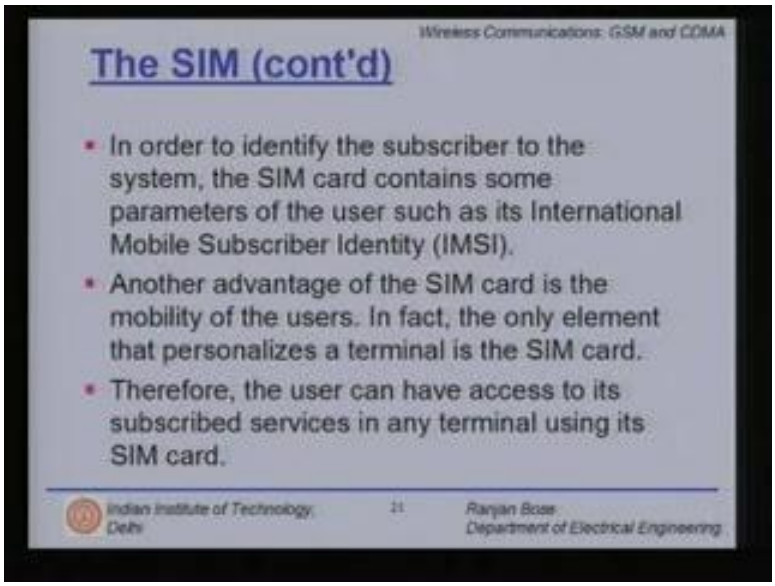

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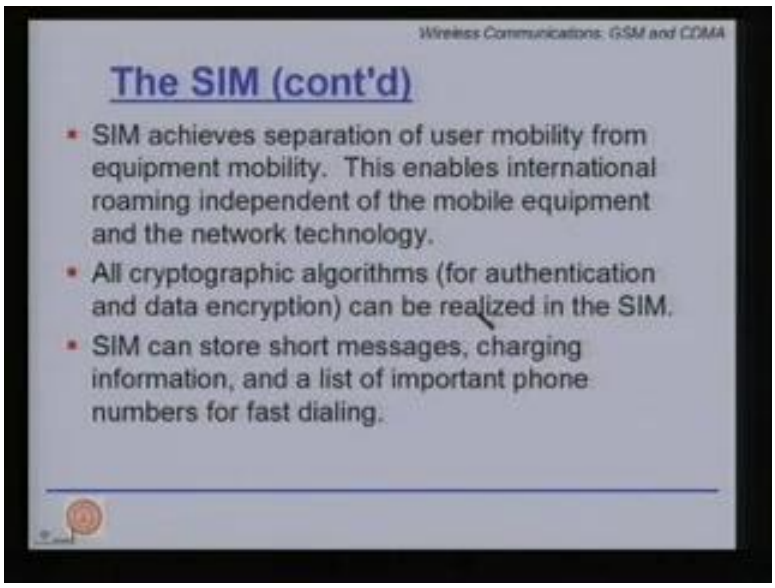

The SIM achieves separation of the user mobility from the equipment mobility, please note there are two different things. Just the movement, the ability to sit in the car with the handset and move around while talking is the equipment mobility but you can live the equipment home but take the SIM card with you go to the office and insert it in a another equipment and start talking that is the user mobility. This enables international roaming independent of the mobile equipment and the network technology. All cryptographic algorithms for authentication and data encryption can be realized in the SIM and so the newer versions of the SIM can claim that your data will be more secured because next generation cryptographic algorithms will be embedded in the SIM. The SIM can also store short messages, charging information, list of important phone numbers for fast dialing and several other things basically it is equipped with memory.

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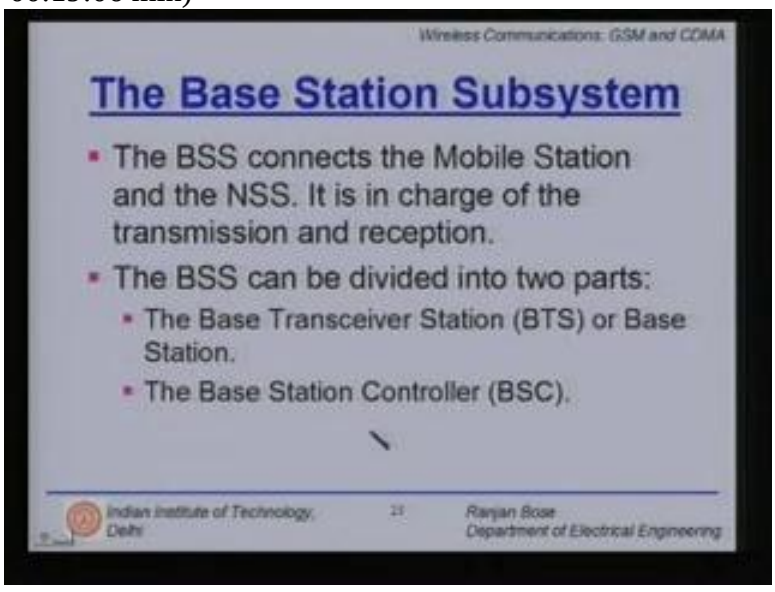

Now having discussed the mobile station subsystem, let's talk about the base station subsystem. The base station subsystem connects the mobile station and the NSS the network subsystem. It is in charge of the transmission and reception. The BSS can again be divided into two sub parts, the base transceiver station the BTS, we usually don't say the complete thing we say it's a base station instead of saying the whole word base transceivers station and of course we have the base station controller the BSC, together they form the base station subsystem.

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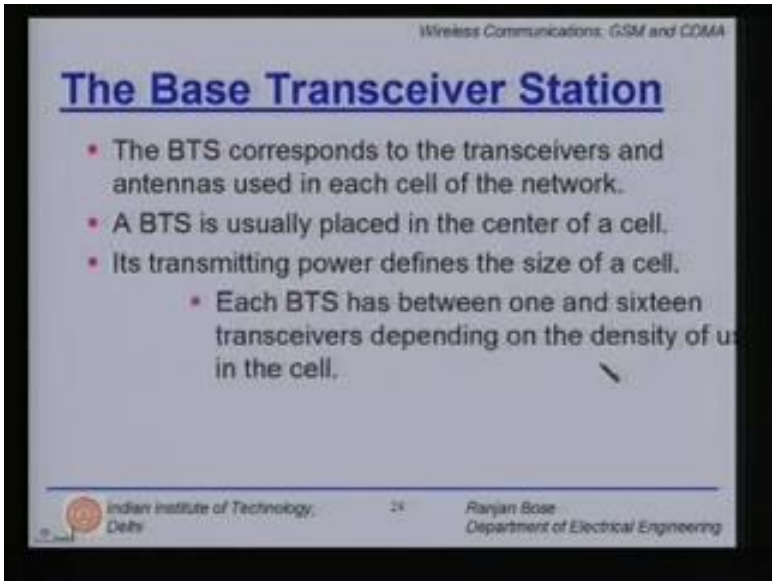

First let us talk about the base transceiver station. The BTS corresponds to the transceivers and antennas used in each cell of the network. A BTS is usually placed in the center of the cell. In our previous lectures we have seen that is not the only way to deploy it. It can all be at corner of cells or we can subdivide a cell, split the cells and put smaller base stations within the cell. Its transmitting power defines the size of the cell but we have also seen that the other factors which can decide how big the cell is the number of users, the link budget and the co-channel interference. Each BTS has between 1 and 16 transceivers depending upon the density of users in the cell.

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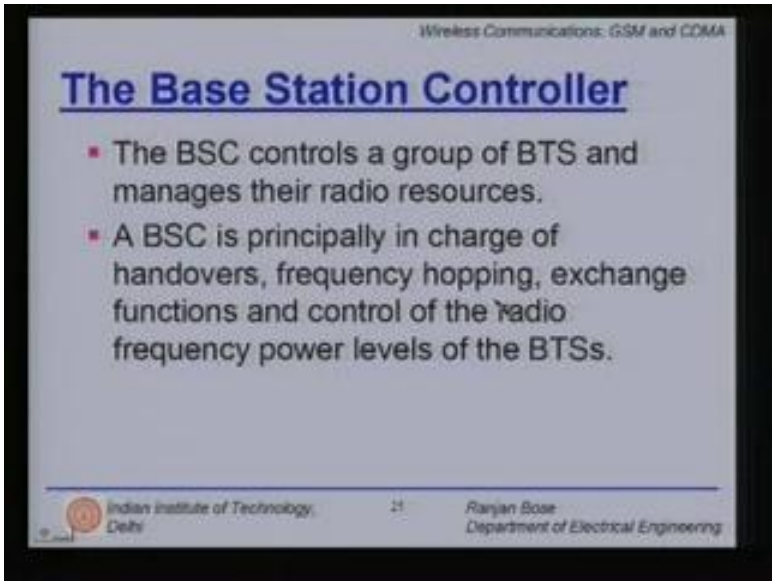

Now let us talk about the base station controller or BSC. The BSC controls a group of BTS and manages their radio resources. If we have seen this diagram before where there is one BSC running lines to several base stations. So a base station controller is principally in charge of handovers, frequency hopping, exchange functions and control of the radio frequency power levels of the BTS. So it is doing all the thinking, the smartness is primarily located at BSC or today some of the base stations can also take decisions.

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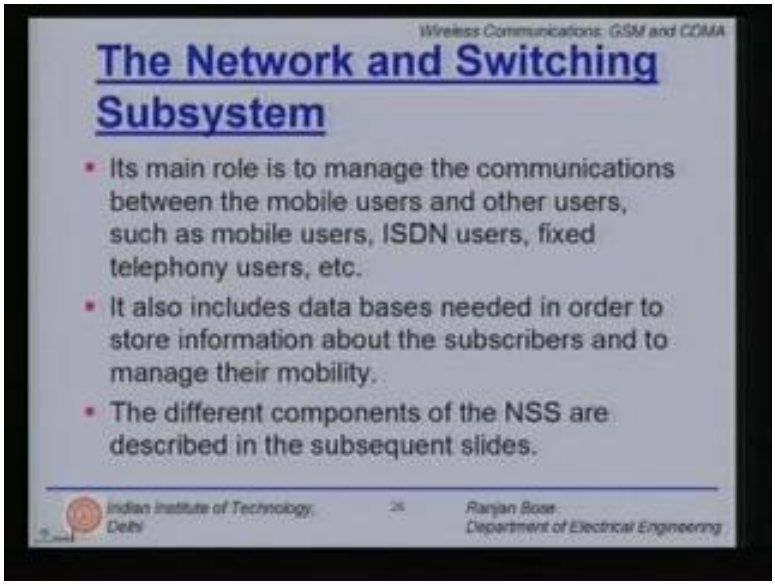

Now let us talk about the NSS or the network and switching subsystem. Its main role is to manage the communications between the mobile users and other users such as the mobile user, ISDN users, fixed telephone users etc. It also includes data bases needed in order to store information about the subscriber and to manage their mobility. In our previous diagram we had talked about the home location register and the visited location register. These are nothing but memory spaces wherein we keep the information about the mobile. The different components of the NSS are described in subsequent slides that we will see.
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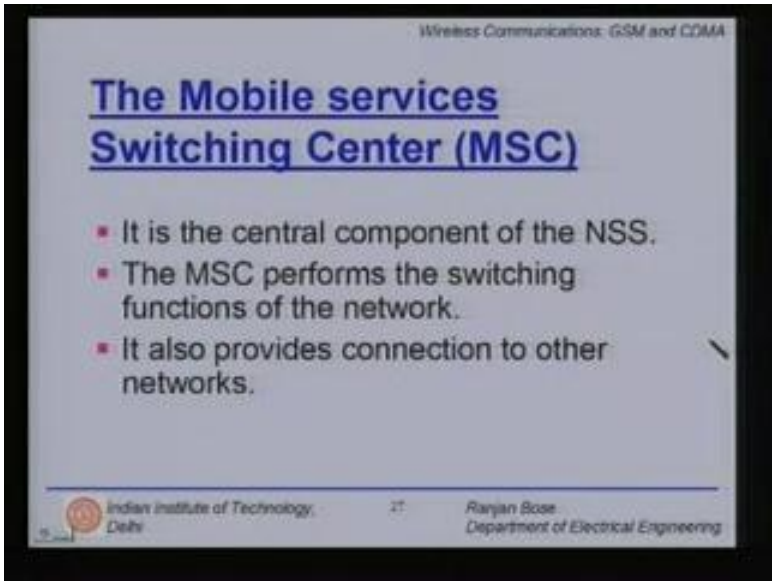

We now come to the mobile services switching center or MSC. It is the central component of the NSS. The mobile switching center performs the switching functions for the network. It also provides connections to the other networks primarily the PSTN or the public switched telephone network.
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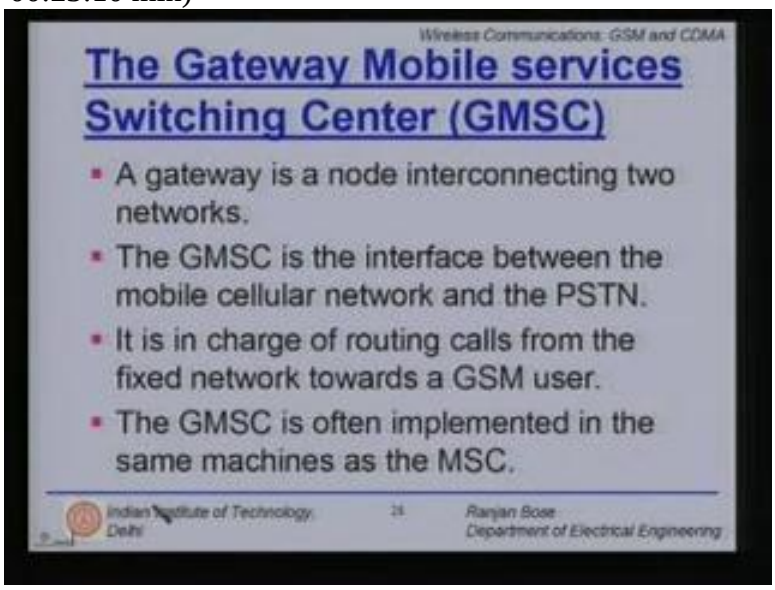

Now we also have the gateway mobile services switching center or GMSC. A gateway is a node interconnecting 2 networks, the GMSC is the interface between the mobile cellular network and the PSTN. So as I was mentioning the mobile switching center goes through the gateway mobile services switching center and it interfaces between the cellular network and the PSTN. What does it do? It is in charge of routing calls from the fixed network towards a GSM user. The GMSC is often implemented in the same machines as the mobile switching center.

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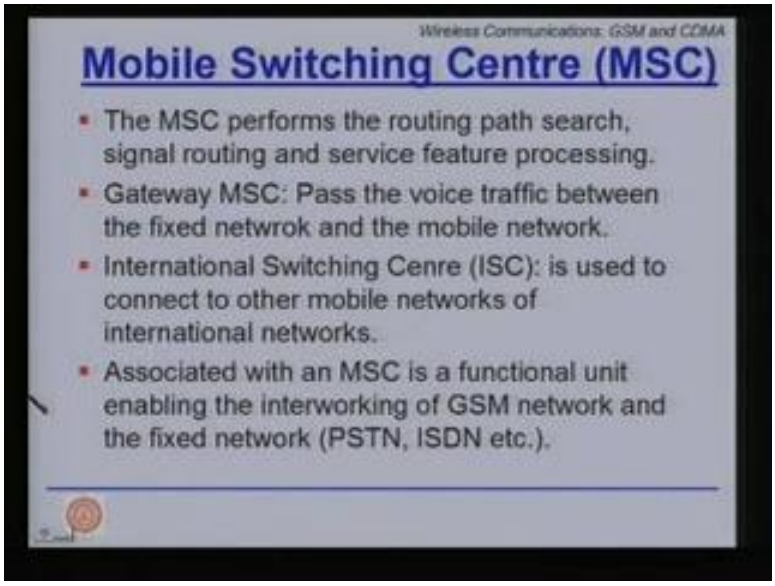

Now let us look at more details about the mobile switching center. The mobile switching center performs routing path search, signal routing and service feature processing. So the gateway MSC passes the voice traffic between the fixed network and mobile network we have seen that, there is an international switching center it is used to connect to other mobile networks of international networks and associated with an MSC is a functional unit enabling interworking of GSM networks and fixed networks. So basically this is a networks issue, how you connect to different kinds of networks, who does the connection. Now in NSS, the network switching subsystem we have the home and the visitor registers.

Let's talk about these briefly. The GSM network has several databases; two functional units are defined for the registration of subscribers and their current location. So as per the requirement of the mobile networks the subscribers can move around but when they move around we have to keep our database as to where they are, how much money do they have in their prepaid account, is it a stolen handset or not; all these data are their privilege customers, are they frequent caller customers. So all these information has to be put in some data bases and must move around as you move because we cannot keep roaming and try to contact our home location each time we want to avail the services.

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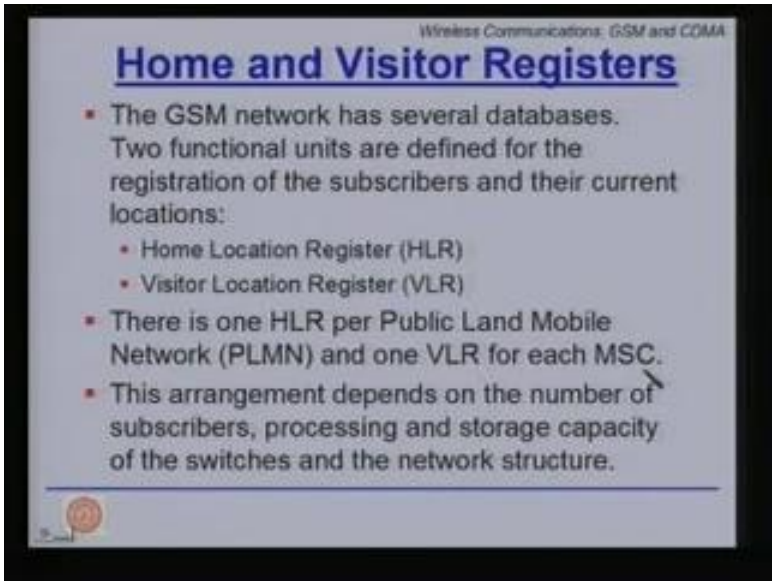

So we need our home location register and a visitor location register. There is one HLR or the home location register per public land mobile network and one VLR in each of the MSC's. This arrangement depends on the number of subscribers processing and storage capacity of the switches and the whole network structure. [Conversation between Student and Professor – Not audible ((00:26:36 min))] Question is what exactly do this HLR and VLR store? So these are the data bases, here we can store other than the identity of the user because it will be required to authenticate the call to check whether the person has paid and has enough money left to make that international call or a long distance call and also other features that if you want to disable certain things or any special features being provided to that user must also be there. [Conversation between Student and Professor – Not audible ((00:27:15 min))] The question is whether the IMEI number is also there? Yes it will be there and so all the information related to the IMEI number will also be stored and the information can be retrieved. Now more details about home location register.

The HLR has entries for every subscriber and every mobile ISDN number which has its home in the respective network. It stores permanent subscriber data and relevant temporary data or the subscribers permanently registered in the HLR. When we say permanent subscriber data all the data's features, additional benefits all that information and relevant temporary data all that features are being stored within the HLR.

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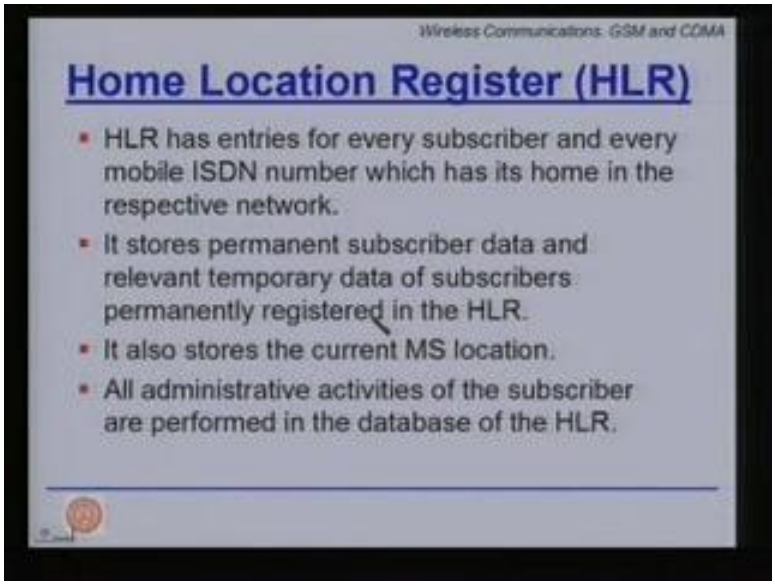

It also stores the current MS location because regardless of whether you are making of phone call not you are currently registered and HLR maintains where you are. All administrative activities of the subscribers are performed in the data base of HLR. So after you finish making the call, the amount of money left in your account will automatically be updated in HLR.

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Now you have the visitor location register or VLR, the VLR stores the data of all mobile station which are currently staying in the administrative area of the associated MSC. A VLR can be responsible for areas of more than one MSC. A mobile station roaming freely may be registered in a VLR of its home network or the Foreign network depending upon its current location.

So basically it's a note book, it's a memory area where your information gets transferred and noted once you switch on the phone in a Foreign destination. The mobile station registers itself up on entering an LA. The MSC passes the identity of the mobile station and the LAI to the VLR.

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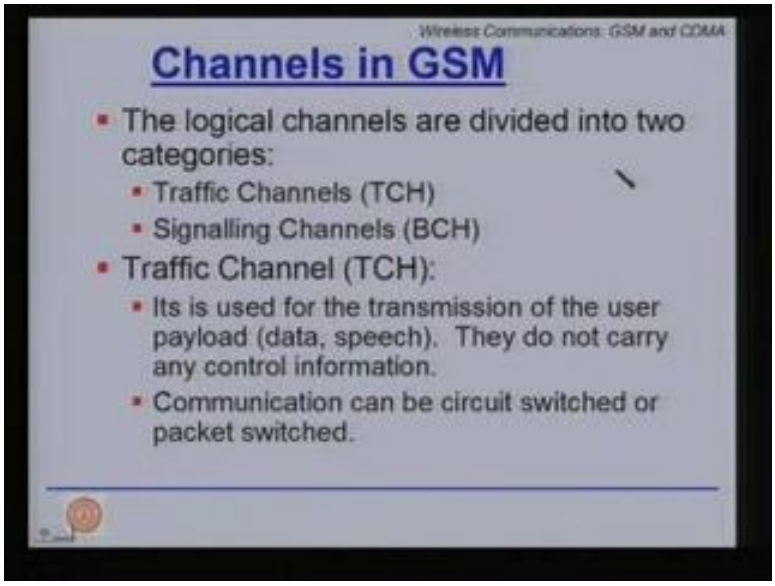

In the previous lectures we had talked about the public switched telephone networks where we saw the voice network and the signaling network, drawing parallel from that let's start talking about the various channels available in a GSM network. So the logical channels are divided into two categories traffic channels and signaling channels. We will denote the traffic channels as TCH and the signaling channel as BCH.

The traffic channel is used for the transmission of the user payload which could be data or speech. Earlier it was thought it will be primarily speech but with the advent of SMS and MMS we are finding the data is overtaking the speech transfer. These channels do not carry any control information, communication can be circuit switched or packet switched.

The broadcast channel BCH will be discussed in the later slides. The common control channel CCH is a unidirectional point to multipoint channel which performs access management functions assigning dedicated channels and paging. So we are now discussing the various types of sub channels and very briefly what do they do. We already know that two broad categories the traffic channel and the signaling channel. The dedicated or associated control channel is a bidirectional point to point signaling channel.

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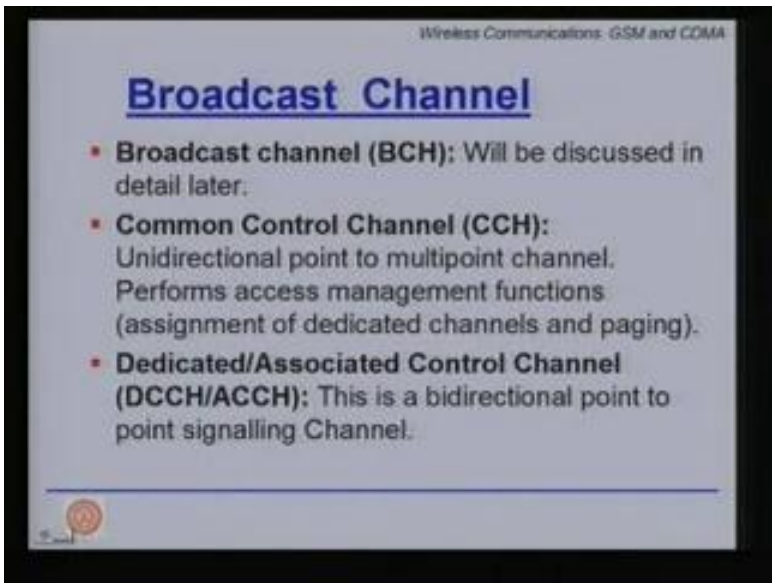

Let's talk about the broadcast control channel which is very important, this is a unidirectional point to multipoint channel between the base station and the mobile station. On this channel the following kinds of information is sent, radio channel configuration about the current cell nearby cells, synchronization information reduce its frequency and frame numbering, registration information LAI, CI, BSIC. So basically this is the broadcast channel where in the base station sends this information in a broadcast mode to all the users within the cell.

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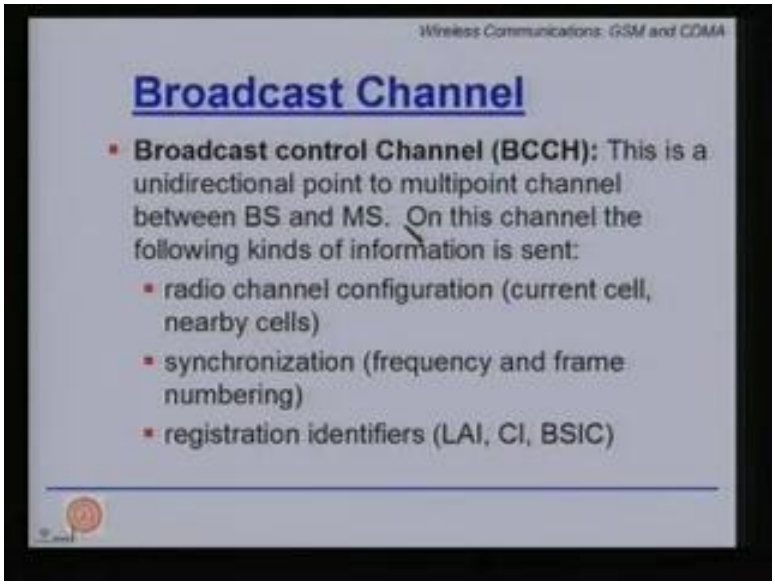

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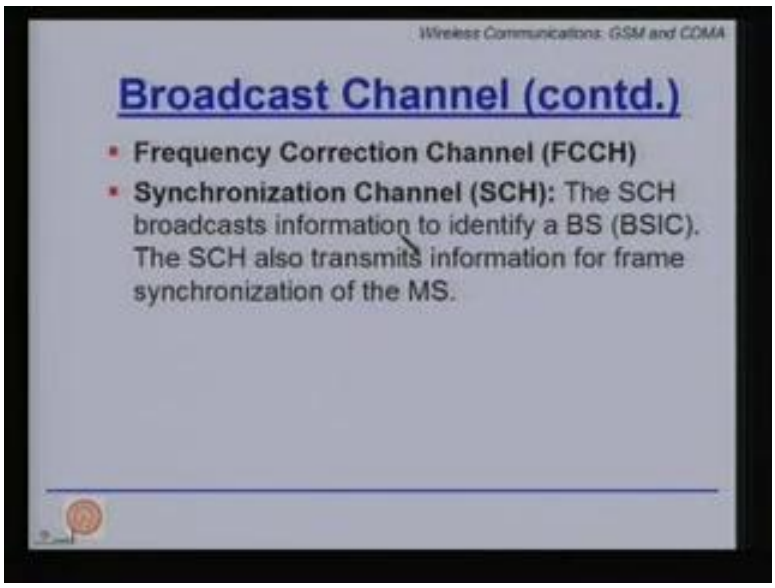

Now continuing with the broadcast channels we have the frequency correction channel or FCCH, the synchronization channel SCH which basically broadcast information to identify a base station. The synchronization channel also transmits information for frame synchronization which is important.

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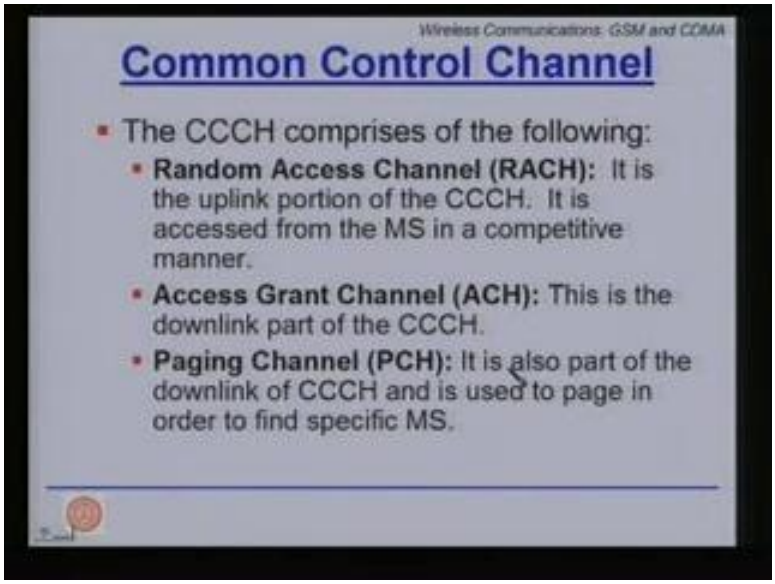

Let us now talk about common control channels, the three categories RACH or random access channel, access grant channel ACH and paging channel. If you talk about the random access channel it is the uplink portion of the CCCH control channel, it is accessed from the mobile station in a competitive manner.

So these are the common control channels, the access grant channel is the downlink part of the common control channel CCCH. The paging channel is a part of the down link CCCH and is used to page in order to find specific mobile station when a call is initiated.

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Talking about the dedicated and associated control channels we have a standalone dedicated control channel, the slow associated control channel, and fast associated control channels. These have different specified utilities and these are being listed here. The details can be found out from any standard textbook dealing with GSM. Now we move over to the modulation for GSM.

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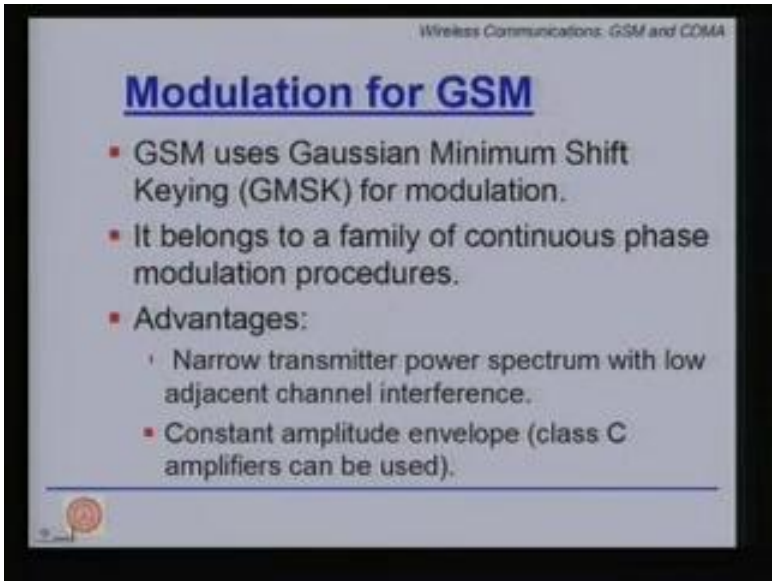

In our previous lectures when we discussed GMSK and other standard modulation techniques we had mentioned that it is useful for GSM, let's revisit that for the sake of completion. GSM uses Gaussian minimum shift keying for modulation, we have seen this before. GMSK belongs to a family of continuous phase modulation procedures. What are the advantages? Narrow transmitter power spectrum with low adjacent channel interference and it's a constant amplitude envelope so you can use a cheap class C amplifier.

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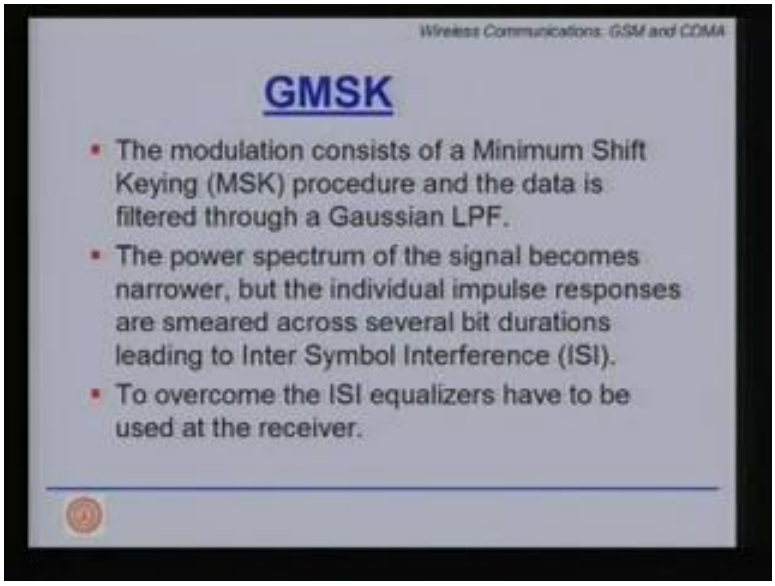

So GMSK modulation consists of minimum shift keying procedure and the data is then filtered through a Gaussian LPF. The power spectrum of the signal becomes narrower but the individual impulse response are smeared across several bit durations leading to some inter symbol interference. To overcome this ISI equalizers have to be used at the receiver.
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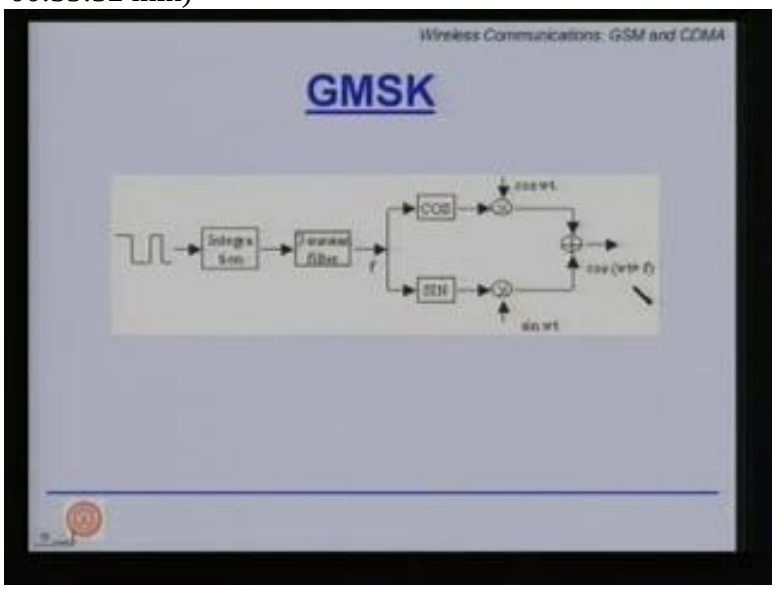

So here is a block diagram of how GMSK can be implemented so you have a Gaussian filter here and then there is an in-phase and quadrature components then you multiply out and send out the GMSK. The details of this has already been discussed when we talk about the GMSK modulation technique.

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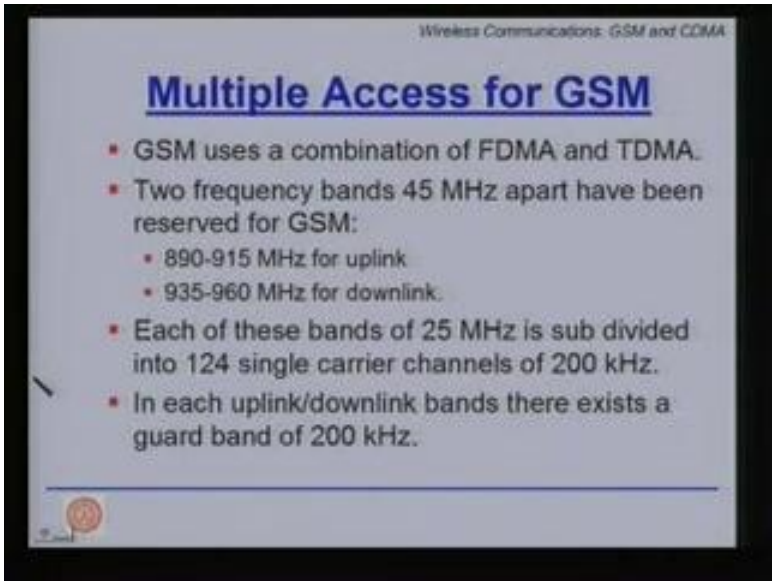

Now let us talk about multiple access for GSM. GSM uses a combination of FDMA and TDMA. The two frequency bands 45 megahertz apart have been reserved for GSM, one is the 890 to 915 megahertz for uplink and 935 to 960 megahertz for downlink. Each of these bands is of 25 megahertz is then further sub divided into 124 single carrier channels of 200 kilohertz. In each uplink or downlink bands there exists a guard band of 200 kilohertz.

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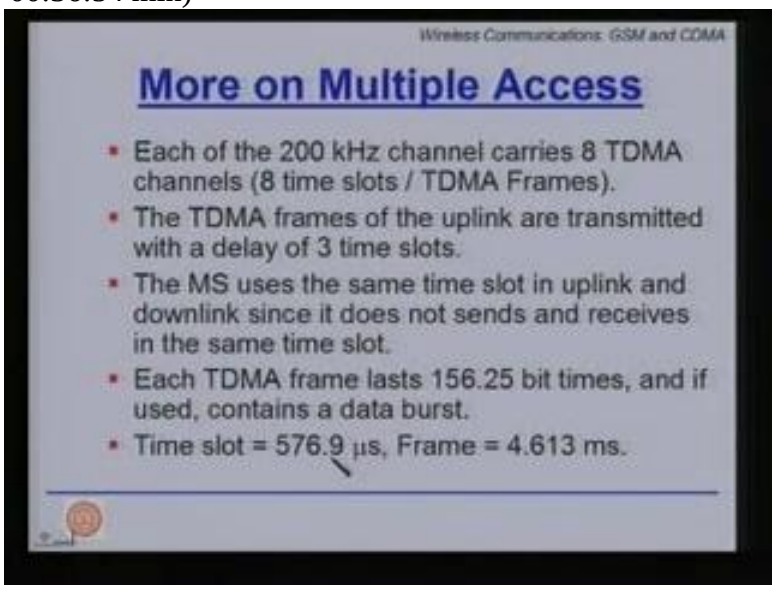

Now each of the two hundred kilohertz channel carries 8 time division multiple access channels that is 8 time slots. Now the TDMA frames of the uplink are transmitted with a delay of 3 time slots. The mobile station uses the same time slot in uplink and down link since it does not sent and receive in the same time slot. Each of the TDMA frame lasts 156.25 bit times and if used contains a data burst. Time slot is 576.9 micro seconds and the frame length is 4.613 milliseconds, this is the TDMA part of the GSM network.

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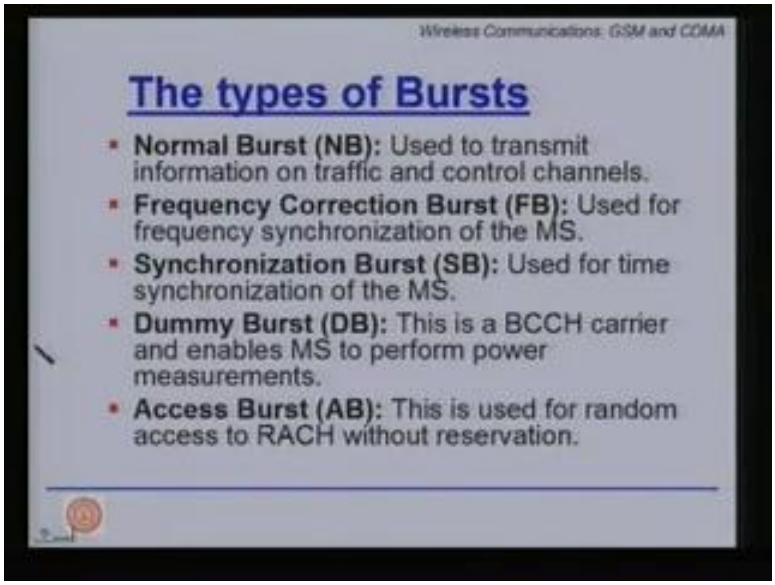

Now let us talk about the type of burst, when we talk about burst we are talking about data burst. We have the normal burst used to transmit information on traffic and control channels and we have frequency correction burst used for frequency synchronization of the mobile station. Then we have synchronization burst used for time synchronization of the mobile station, you can also have a dummy burst this is the BCCH carrier and enables mobile station to perform power measurements.

You could also have an access burst used for random access without reservation. We can have these kinds of data transverse and being labeled differently depending upon the application. So whenever you get a time slot in the TDMA, you send out of burst which could be of any of these types. Now let us go back to the frequency allocation plan, we know that two frequency bands of 25 megahertz in each one have been allocated in GSM in the 890 to 915 has discussed before and 935 to 960 but not all the countries can use the whole GSM frequency bands.

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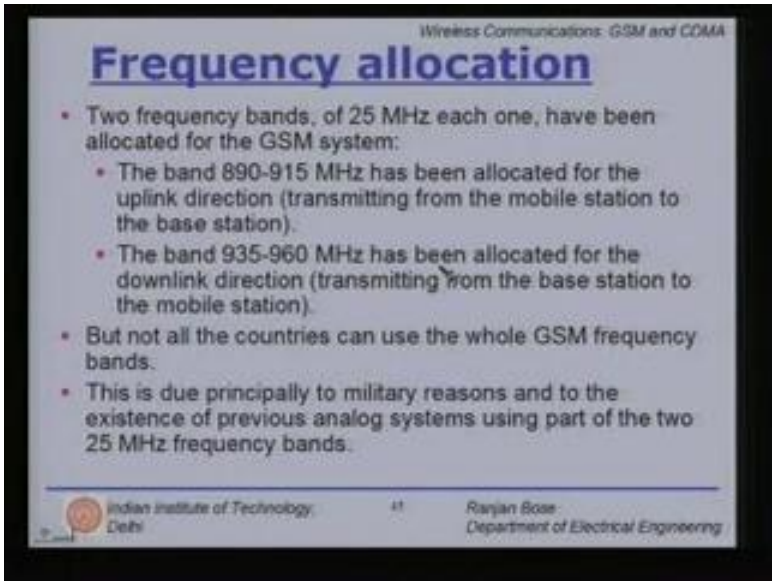

This is due principally military reasons and to existence of previous analog systems using part of the two 25 megahertz frequency bands. So this is what is in the standards depending upon individual countries part of the bands may be used. Now we know that a mix of FDMA and TDMA is being used in GSM.

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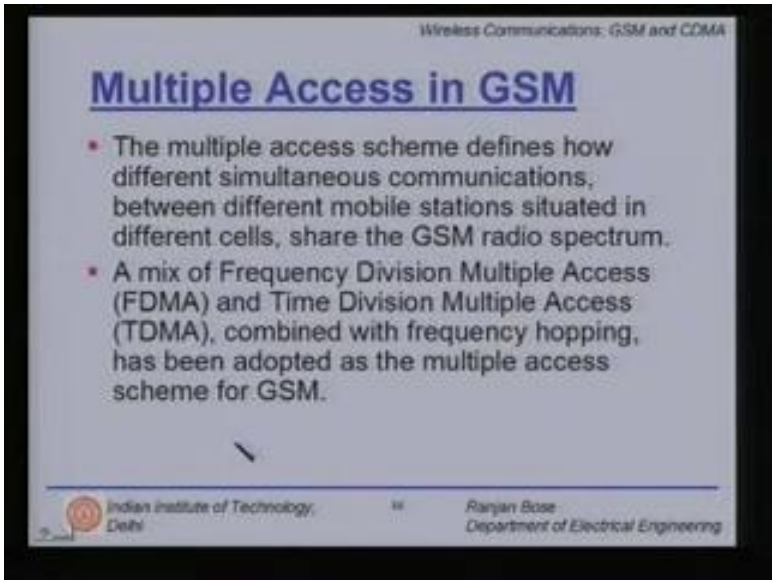

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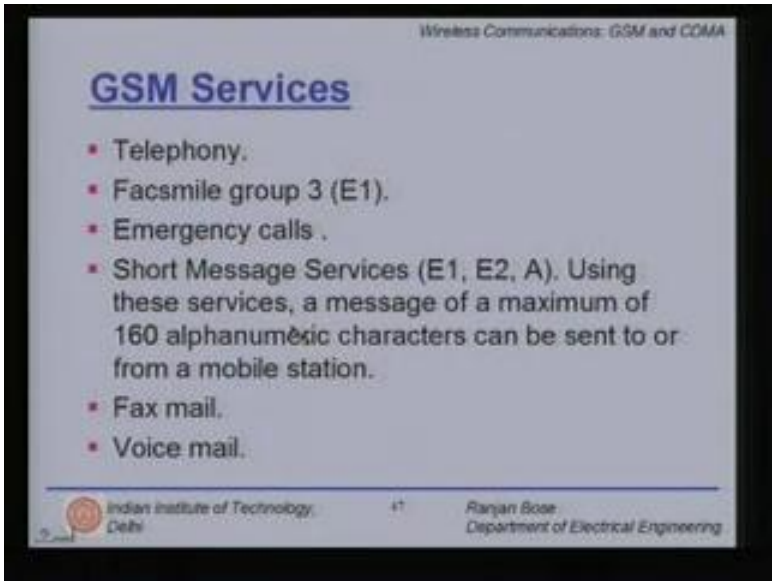

Let's talk about the services being provided by GSM because a standard also tells you what are the different kinds of services which can be obtained using that kind of a network. Telephone is what it started with but then we can also send group 3 fax, you can make emergency and SOS calls. This is the most popular one the short message service or SMS, using these service a message of maximum 160 alphanumeric characters can be sent or received, fax mail, voice mail. So all of them are being laid out in the GSM standard depending upon a network operator some or all may be provided for you.

Any network that is implemented in the GSM they can send the more than one sixty like it's not in standard but still. [Conversation between Student and Professor – Not audible ((00:41:02 min))] Question being asked is can any network which is using GSM standard give you an SMS facility which is not short messaging limited to 160 alphanumeric characters but go beyond it. So those which are migrating through GPRS and then towards edge have now started including larger but the original GSM standard only made provision for 160 alpha numeric characters. So this is from the standard, yes you can improve a point.

Now GSM we know is fairly popular as we saw in one of the earlier slides, it is populate as spread across the globe and now steps have been taken to convert this 2 G standard in to 2.5 G then to 2.75 G. So GPRS and edge are the steps in those directions. Clearly there are some certain disadvantages of GSM which will make it entrenched in the second generation. It can go up to 2.75 and beyond but it will never touch the 3 G standards.

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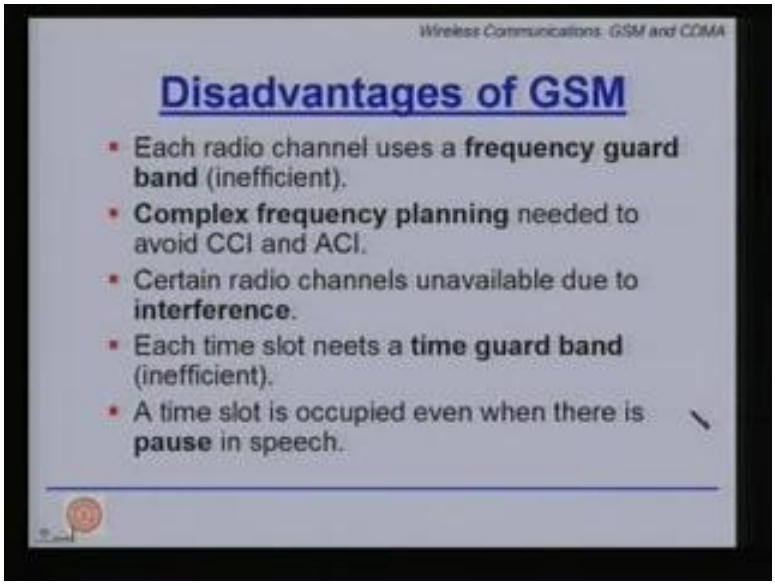

Let us see what are the disadvantages of GSM. First of all it is slightly waste full in terms of its multiple access, each radio channel uses a frequency guard band which is inefficient. Then we have seen that complex frequency planning is required to avoid co-channel and adjacent channel interference. In the earlier part of this course we had spent quite a lot of time talking about frequency planning, cluster size and how the capacity of the cellular system depends upon, how close your reuse frequency can be but as you reduce the reuse distance, you start getting higher and higher co-channel interference and your system starts getting interference limited.

So there is a tradeoff between capacity and the amount of interference we can handle and thereby you have to resort to complex frequency planning strategies. We also have the provision of self splitting centralization but then again they lead to complex frequency planning. Certain radio channels are unavailable due to interference, standard problem. Then again since it uses a combination of FDMA and TDMA we have to give time slot as time guards. So every time slot has to have a guard band before and after so that you don't emerge into the next adjacent time slot, this is again inefficient. A time slot is occupied even when there is a pause in the speech when we talk about the CDMA standards, we will see that how the pauses of the speech are used to send data for somebody else.

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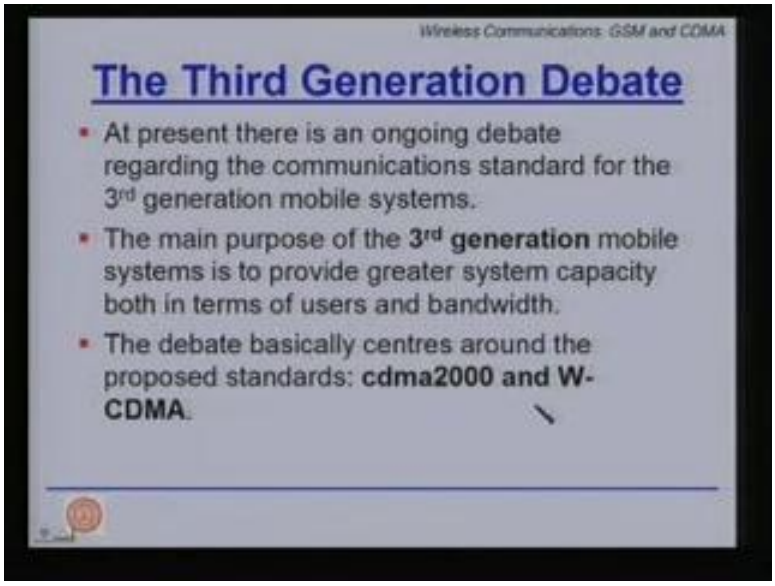

Let us now quickly go over the third generation debate which was a hot topic two years back, now it is kind of being settled but for the sake of posterity let's understand that. Even though I am saying there is an ongoing debate, this debate has kind of settle down about the 3 G systems. The main purpose of the third generation mobile system is to provide greater system capacity both in terms of users and bandwidth. Please note there is a lot of information hidden in this point. How do you differentiate between 2 G and 3 G, what makes something 3 G? It's the number of users that you can support the bandwidth allocation which will result in the data rates, the mobility whether the user can go in a fast train and still check the email at a certain data rate things like that makes 3G different from 2G.

The debate about the third generation mobile standard is between the CDMA 2000 and WCDMA. Today we know both coexist and we couldn't converge to one world standard, however the general multiple access scheme has been finalized and it will be CDMA. We will see in our lectures during with CDMA 2000 and WCDMA that they are not many significant differences between CDMA 2000 and WCDMA. In India we have embraced CDMA 2001 x.

Now let's go back to Shannon's theory and talk about the system capacity. Shannon's theory predicts that the maximum amount of information that can be transmitted over any channel with a given bandwidth and SNR is given as C equal to b log 1+ SNR. So the capacity C grows linearly with bandwidth and logarithmically with SNR. So the optimal usage of a given bandwidth is obtained when the signals are noise like and maximum SNR is maximized at the receiver.

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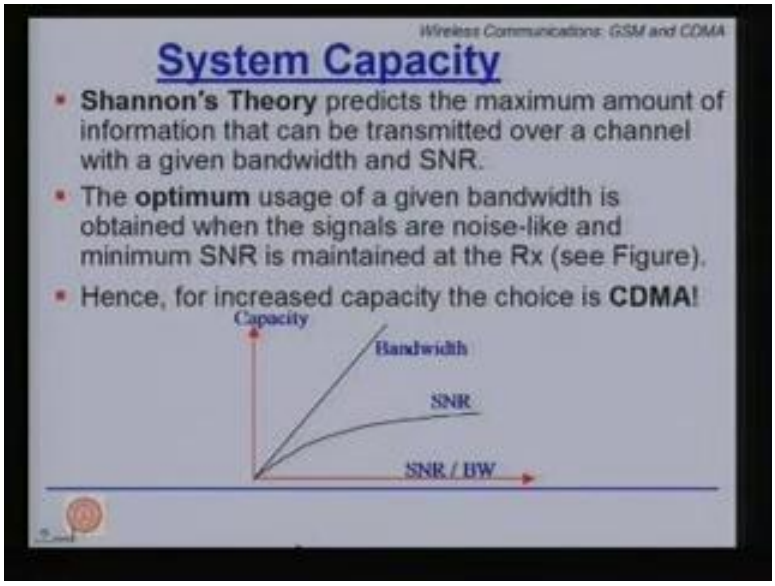

Hence we know that if you have on this axis SNR then with the capacity grows logarithmically with SNR and if you plot on this axis bandwidth then the capacity grows linearly with bandwidth. The idea is to have a system which uses a large bandwidth and lower SNR almost noise like and that is answered by CDMA which uses excess bandwidth over and beyond what is required to send your voice and data because we are going to use a large bandwidth and at the same time, since we do not have infinite signal power we reduce the strength of the signal there by exchange the resource of SNR and by old bandwidth and that system CDMA is going to give us a more or a greater capacity. Hence CDMA is the choice for the next generation wireless systems. Let us now quickly summarize what we have done so far, with the background of cellular systems we have introduced GSM.

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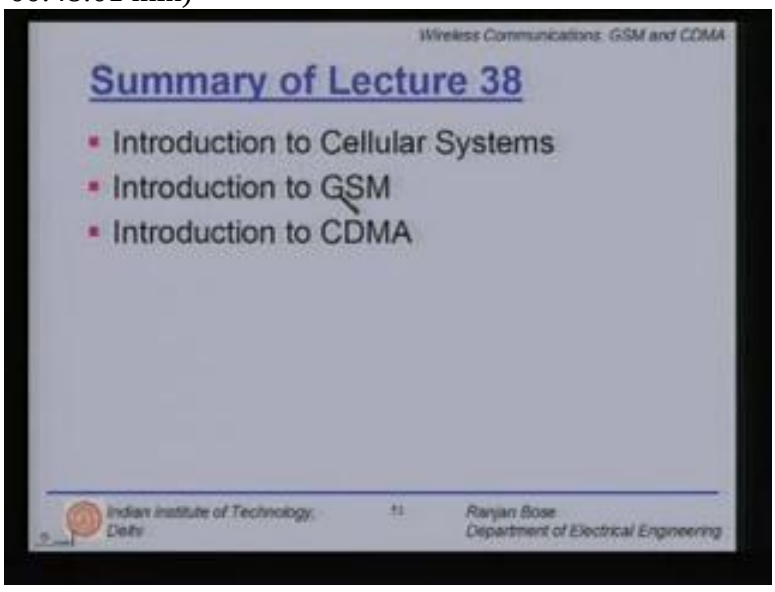

We talked about the hierarchical nature of GSM so the GSM is positioned in such a manner that you start with a cell and then you have the base station controller and then there you have the location area and then the mobile switching center reaches and finally the entire GSM network which spreads across the country or across several countries. Now we also noticed an important factor of GSM standard that it uses a lot of identifiers, it has identifiers for the equipments, for the SIM card, different users, the phone numbers depending upon you are using a fax or a voice or a data service location area identifier, base station identifier and the host of other identifiers plus we looked at the notion of the visited location resist register and the home location register which allows you the roaming facility within GSM.

We will also spend some time looking at the SIM card and how it is almost like a smart card which has authentication capabilities as well as memory to store some of the important phone numbers and messages. We looked at in brief the modulation techniques used for GSM, in later slides we can talk about the error control coding which is diploid for GSM standards when we talk about error control coding also for CDMA, we can have a comparison of that.

Finally we discussed why GSM is not good enough and what motivates us to go towards CDMA for the third generation mobile systems. So the 3G is not just the choice of multiple access it is a lot more. 3G is a set of services a set of quality control that has to be obeyed and whatever technology is required is deployed. In the next lecture we will try to talk about CDMA, how CDMA is more efficient than GSM, how is a CDMA system deployed, the advantages disadvantages and why beyond CDMA we have to look at the 4 generation mobile systems. Let us conclude the lecture here.