Allowing migration from one administrative network domain to another involve credential checks like identity, and authenticity. After that establishing user's credentials the network should be able to reroute connection and keep track of each user's locations as he/she moves. The GSM network provides a number of functions for efficient handling of roaming. These functions are handled through signaling protocols between the different components of the GSM networks mentioned above.

5.2.4 GSM Radio Resources

Before, discussing GSM protocols it is important to understand the radio resources and the need for managing these resources. Cellular concept is used for increasing capacity through spatial multiplexing. However, this multiplexing scheme is static in nature. When there is sudden increase in number of concurrent users, such spatial multiplexing technique can not adapt dynamically. If radio resources are not allocated in optimized manner to simultaneous users, communication quality as well as the capacity will suffer. So, network's ability to adjust to dynamicity of traffic will depend on how well radio spectrum is allocated among concurrent users.

The fundamental principles which form the basis of multiple radio access schemes like FDMA (Frequency Division Multiple Access), TDMA (Time Division Multiple Access) and CDMA (Code Division Multiple Access) are:

1. To accommodate as many simultaneous users as possible with the constraint that the signal noises are minimized.

2. To minimize the energy needed for information exchange.

FDMA allocates one carrier frequency, i.e., one channel per user. So, it is not an efficient sharing strategy for radio resources. CDMA provides higher capacity over TDMA, because it spreads information over the entire spectrum band. There is no concept of frequency or time slot allocation. The radio resources are allocated on the basis of random codes. Every user is assigned a distinct code per connection basis. The two common methods for spreading a data signal are frequency hopping (FH) and direct-sequence (DS). It is difficult to say which one performs better than other. However, in wide band spreading, DS has distinct advantage over FH when there are many users. In a wider band, DS exhibits a better interference susceptibility performance, higher power efficiency and the possibility to combine multi-path signals. This is the reason why UMTS networks employ WCDMA air interface. TDMA and FDMA suffer mainly from co-channel interferences as frequency reuse is very high. CDMA, on the other hand, suffers from inter-user uplink interferences when number of users become very high. In such situations both capacity and quality may suffer. We will discuss more about CDMA in section 5.5. TDMA allocates distinct time slots to simultaenous users with same carrier frequency. But the time slots are few in number, and have to be repeated frequently to give an illusion of a continuous radio connectivity between communicating parties. GSM uses TDMA with 8 slots on multiple frequency sub-bands (TDMA/FDMA).

A certain number of such frequency/time channels pre-assigned to each BS. There are two frequency bands: (i) 890-915MHz for uplink (mobile to BS), and (ii) 935-960MHz for downlink (BS to mobile). These bands are partitioned into 124 sub-bands (FDMA) starting at 890.2MHz and spaced by 200KHz. The spacing eliminates the possibility of a cell using adjacent channels. Each cell usually gets a fixed number between 1 to 15 of the carrier frequencies. An assigned physical channel of 200KHz is segmented by TDMA technique using fixed time allocations called time slots to create multiple logical channels. The time axis is divided into 8 equal time slots of duration 0.577ms. The time slots 0-7 form a frame. The recurrent pattern of a particular time slot in each frame constitutes a single logical channel. The repetition of one particular time slot occurs every 4.615ms which is the time interval for one frame.

GSM logical channels are built on the top of physical channels. Logical channels address the issues related to information exchanges betwee MS and BSS. As Figure 5.3 indicates, GSM distinguishes between traffic channels (reserved for user data) and control channel (reserved for network control messages). Some of the channels are unidirectional while others are bidirectional. The unidirectional downlink channels are for communication from BS to MS. Same TDMA structuring of channels is used for both down and up links. However, the numbering of the slots for traffic channels (TCH) is staggered by 3 time slots to prevent a mobile from transmitting and receiving at the same time. Traffic channels are defined using multiframe structures consisting of 26 TDMA frames with a recurrent interval of 120ms. Control channels are defined in a multiframe structure consisting of 51 TDMA frames having recurrent interval of 235.4ms.

GSM control or signaling channels are divided into three groups, namely,

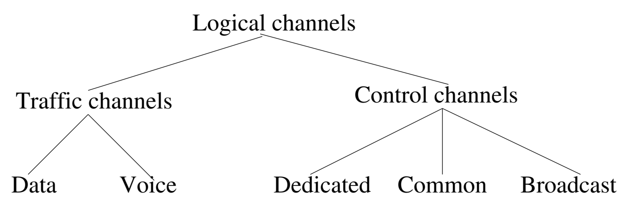

Figure 5.3: GSM channel classes.

1. Broadcast CHannels (BCH),
2. Common Control CHannels (CCCH), and
3. Dedicated Control CHannels (DCCH).

BCH and CCCH are used for synchronization, exchange of information and setting up calls. These channels occupy slot 0 in a frame and repeat back very 51 frame times. When more capacity is required slots 2, 4, or 6 can be used. There are four different types of broadcast channels (BCH): (i) Frequency Correction CHannel (FCCH), (ii) Synchronization Control CHannel (SCCH), (iii) Broadcast Control CHannel (BCCH), and (iv) Cell Broadcast CHannel (CBCH). FCCH is used by physical layer to tune mobile terminal to the right radio frequency of the base station. After locking int BS frequency MS can count the number of slots to the synchronization channel which comes 8 slots after the FCCH. SCCH helps mobile terminals to synchronize with the BS and it also carries identity of BS. BCCH is used by BSs to communicate information to mobiles which include system parameters, access parameters, and channel configuration. CBCH is used for transmission of cell broadcast messages such as weather and traffic reports. It is a downlink channel.

The common control channels support establishing links between mobile stations and network. The important CCCH are random access channel (RACH), access grant channel (AGCH), paging channel (PCH) and notification channel (NCH). RACH is a purely uplink channel used by the mobiles to access of services such as voice call, SMS, responding to paging and sending registration. It is accessed in a competitive multiple access mode using the principles of slotted ALOHA. PCH is a downlink channel which is used for searching or paging a mobile device by its IMSI or TMSI. AGCH is another downlink channel used to grant accesses when a mobile has either been successfully paged on PCH or it has initiated a request through RACH. It sets

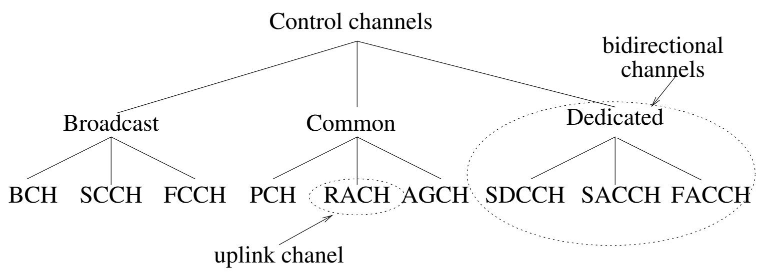

Figure 5.4: GSM logical channel structure.

up signaling by assigning a stand-alone dedicated control channel (SDCCH) or a TCH to a mobile station. Another downlink channel known as NCCH is used to notify a group of mobiles about voice broadcast service.

Dedicated control channels (DCCH) are used for power control, timing and call related information. Three types of DCCH are available, namely, Stand-alone Dedicated Control CHannel (SDCCH), Slow Associated Control CHannel (SACCH) and Fast Associated Control CHannel (FACCH). A SDCCH channel is maintained between a mobile station (MS) and a BS for exchange of message relating to call establishment, authentication, location update, SMS, etc. Slow Associated Control CHannel (SACCH) is alway associated with a TCH or SDCCH. It used for informing MS about frequencies of neighboring cells, time synchronization and power control on downlink. On the uplink it is used for sending signal measurements and other parameters from MS that aids in arriving at handover decisions. It can be used to transmit SMS if the associated with a TCH. This is the reason why a SMS can be delivered when the user is busy with a call.

A Fast Associated Control CHannel (FACCH) is associated with a TCH. FACCH is not actually a control channel, it is a TCH that turns momentarily into a control channel. Essentially stealing some time slots from associated TCH. After the use of FACCH is over the channel turns back into the traffic channel. FACCH is used for call signaling including call disconnect, handover as well as call setup. Figure 5.4 provides the classification different GSM control channels.

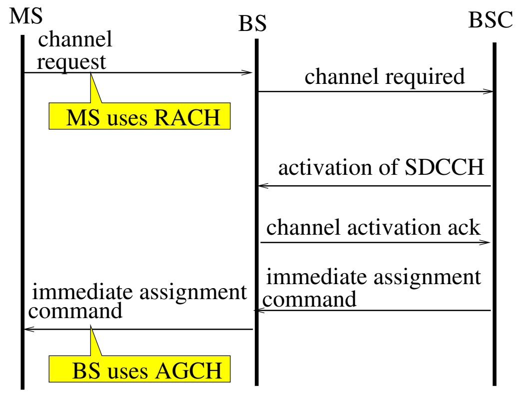

Figure 5.5: Signaling for acquiring SDCCH.

5.3 Call setup

In GSM there is a distinction between the calls originate from a mobile and the calls that terminate at a mobile. The first type of call is an outgoing call while the second one is an incoming call.

The service requests initially occur on stand-alone dedicated control channel (SDCCH). After a traffic channel (TCH) is assigned to MS and voice transfers occur. Figure 5.5 illustrates the details of signaling mechanism for acquiring SDCCH. Mobile initially sends radio resource channel assignment message on RACH for assignment of a SDDCH. The request carries the reason as mobile originated call and also the id of the mobile. BSS sends a response called immediate assignment on AGCH. The response contains information about the allocation of SDCCH.

After the mobile acquires a SDDCH, MS sends service request message DTAP-CM (Direct Transfer Application Call Management) request to BSS. DTAP is a BSS map protocol message used for communication with MSC and VLR. This message is sent to BSS which forwards it to MSC. The service request message includes type of service, i.e., mobile originating call (MOC) request, TMSI/IMSI, IMEI, authorization, cipher, etc. Following this, MS also sends DTAP-CL (call control) message to MSC/VLR which includes called party's number, information about bearer's capabilities such a half rate, full rate, etc. MSC then queries VLR to get information about the callee. VLR checks callee's information to finds whether the call can proceed and VLR replies to MSC's query accordingly.

If the call is allowed, MSC sends a DTAP-CL call proceed message to MS. Now MSC also has to alert BSS that call can proceed. So, it sends a BSS map assignment request message to BSS. This message has details concerning channel type and also the time slot on A interface (between MSC and BSS). BSS then sends RR channel assignment command to MS. The message has traffic channel identity, time slot of the radio traffic channel, frequency hopping information, and also the transmit power of the MS. MS responds with assignment complete message. The message exchanges up to this point occur over SDCCH. But once BSS receive assignment complete message from MS, it allocates traffic channel between MS and MSC and deallocates SDCCH from MS. BSS also sends a BSS map assignment complete message to MSC. At this point MSC/VLR send a network setup message to PSTN which includes dialed number and also the details of the trunk to be used for the call. PSTN then rings the destination number, and after finding the same, it send network allotting message to MSC/VLR.

From now onwards FACCH is used for the control signals. MSS/VLR sends a DTP-CL alerting message to MS, and MS is able to hear the ring tone. Once destination takes the call, PSTN sends a call connect message to MSC. MSC in turn sends DTAP-CC (call connect) message to MS. MS sends back a DTAP-CC connection acknowledgement message to MSC and the full voice path has been established between caller and the callee.

The signaling requirements and MOC call setup process is illustrated by Figure 5.6.

5.3.1 Mobility Management

Mobility management is the key issue in GSM network. We have discussed the issue of mobility management with respect to generic cellular network earlier in section **??**. The requirement for channel switching in GSM network and the way channel switchings or the handoffs are managed are not very different. So, our focus here is on the handoff procedure specific GSM.

Handoff involves three basic steps, namely,

1. Signal measurements,
2. Handoff decision, and
3. Handoff execution.

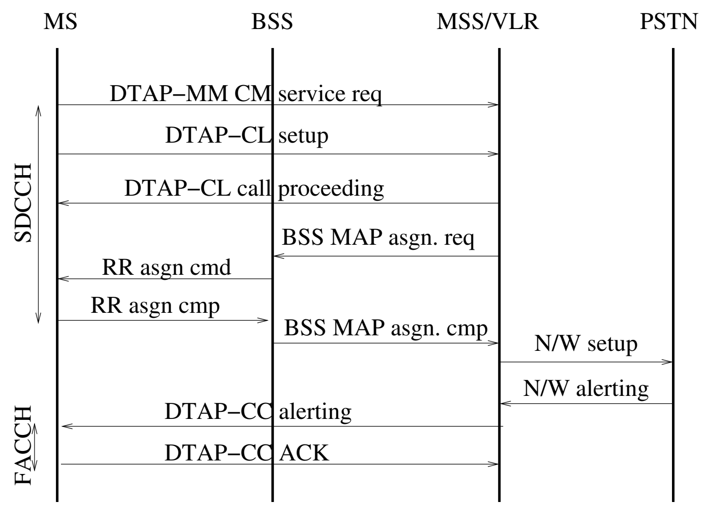

Figure 5.6: Signaling for call setup.

Signal measurements report is transmitted periodically by MS. MS gather measurement values of 16 neighboring BSs and sends a report containing six strongest measurements over one of the 4 interleaved SACCHs. Handover decision and selection of target cell is made either by BSC or MSC. BSC makes a decision if the cell to which MS should be handed over is under its control. Otherwise BSC sends its global cell id and a BSS map message for *handover request* to MSC. MSC then sends a BSS map message for *handover request* to new BSC. The message includes channel type and whether queueing is premissible or not.

The new BSC on receiving the request sends a BTSN channel activation message to its BS. It includes handover reference number (HRN), handover type, channel number and type. Once BS's acknowledgement is received the new BSC sends acknowledgement to MSC's handover request message with HRN or handover reference number. MSC new responds to the old BSC with handover command. The old BSC in turn sends handover command to MS over FACCH. MS sends a handover access message to the new BS over FACCH. The new BS on the receipt of this message sends a BTSN handover detected message to the new BSC. The new BSC then sends BSS map handover detection message to the MSC. After this BS send physical information message providing the physical channels to be used for transmission by MS. MS responds by set asynchronous balance (SABM) layer-2 message to the