Global System for Mobile Communications

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Outline I

Spectral Allocation I

- First-generation cellular networks, such as *AMPS*, quickly became highly popular, threatening to swamp available capacity.
- Second-generation systems have been developed to provide higher quality signals, higher data rates for support of digital services, and greater capacity.
- The following as the key differences between the two generations

Digital traffic channels I

- The most notable difference between the two generations is that first-generation systems are almost purely analog, whereas second generation systems are digital.
- In particular, the first-generation systems are designed to support voice channels using FM; digital traffic is supported only by the use of a modem that converts the digital data into analog form.
- Second generation systems provide digital traffic channels.
- These readily support digital data; voice traffic is first encoded in digital form before transmitting.
- Of course, for second-generation systems, the user traffic (data or digitized voice) must be converted to an analog signal for transmission between the mobile unit and the base station.

Encryption I

- Because all of the user traffic, as well as control traffic, is digitized in second-generation systems, it is a relatively simple matter to encrypt all of the traffic to prevent eavesdropping.
- All second-generation systems provide this capability, whereas first-generation systems send user traffic in the clear, providing no security.

Error detection and correction I

- The digital traffic stream of second-generation systems also lends itself to the use of error detection and correction techniques.
- The result can be very clear voice reception.

Channel access I

- In first-generation systems, each cell supports a number of channels.
- At any given time a channel is allocated to only one user.
- Second generation systems also provide multiple channels per cell, but each channel is dynamically shared by a number of users using *Time Division Multiple Access* (*TDMA*) or *Code Division Multiple Access* (*CDMA*).

Second-Generation Cellular Telephone Systems

	GSM	IS-136	IS-95
Year introduced	1990	1991	1993
Access method	TDMA	TDMA	CDMA
Base station transmission band	935 to 960 MHz	869 to 894 MHz	869 to 894 MHz
Mobile station transmission band	890 to 915 MHz	824 to 849 MHz	824 to 849 MHz
Spacing between forward and reverse channels	45 MHz	45 MHz	45 MHz
Channel bandwidth	200 kHz	30 kHz	1250 kHz
Number of duplex channels	125	832	20
Mobile unit maximum power	20 W	3 W	0.2 W
Users per channel	8	3	35
Modulation	GMSK	$\pi/4$ DQPSK	QPSK
Carrier bit rate	270.8 kbps	48.6 kbps	9.6 kbps
Speech coder	RPE-LTP	VSELP	QCELP
Speech coding bit rate	13 kbps	8 kbps	8, 4, 2, 1 kbps
Frame size	4.6 ms	40 ms	20 ms
Error control coding	Convolutional 1/2 rate	Convolutional 1/2 rate	Convolutional 1/2 rate forward; 1/3 rate reverse

Time Division Multiple Access I

- First-generation cellular systems provide for the support of multiple users with *Frequency Division Multiple Access* (*FDMA*).
- *FDMA* was introduced in our discussion of satellite communications and the principle is the same here.
- *FDMA* for cellular systems can be described as follows.
- Each cell is allocated a total of $2M$ channels of bandwidth δ Hz each.
- Half the channels (the reverse channels) are used for transmission from the mobile unit to the base station: f_c, $f_c + \delta$, $f_c + 2\delta$, $\cdots$,$f_c + (M-1)\delta$, where f_c is the center frequency of the lowest-frequency channel.

Time Division Multiple Access II

- The other half of the channels (the forward channels) are used for transmission from the base station to the mobile unit: $f_c + \Delta$, $f_c + \delta + \Delta$, $f_c + 2\delta + \Delta$, $\cdots$,$f_c + (M-1)\delta + \Delta$, where Δ is the spacing between the reverse and forward channels.
- When a connection is set up for a mobile user, the user is assigned two channels, at f and $f + \Delta$, for full-duplex communication.
- This arrangement is quite wasteful, because much of the time one or both of the channels are idle.
- As with *FDMA*, each cell is allocated a number of channels, half reverse and half forward.
- Again, for full duplex communication, a mobile unit is assigned capacity on matching reverse and forward channels.

Time Division Multiple Access III

- In addition, each physical channel is further subdivided into a number of logical channels.
- Transmission is in the form of a repetitive sequence of frames, each of which is divided into a number of time slots.
- Each slot position across the sequence of frames forms a separate logical channel.

Mobile Wireless TDMA Design Considerations I

- This analysis motivates some of the design decisions made for GSM.
- The overall objective is to determine the length and composition of the traffic channel time slot that will provide effective speech and data transmission with efficient use of the radio spectrum.
- Let us consider the following set of requirements:
  - **Number of logical channels (number of time slots in TDMA frame):** 8; this appears to be the minimum to justify the additional costs of multiplexing.
  - **Maximum cell radius (R):** 35 km, to give a sufficiently high traffic level in rural areas.
  - **Frequency:** Region around 900 MHz; this is commonly allocated to mobile radio applications.

Mobile Wireless TDMA Design Considerations II

- **Maximum vehicle speed (V_m):** 250 km/hr, or 69.4 m/s, to accommodate mobile units on high-speed trains.
- **Maximum coding delay:** Approximately 20 ms, to avoid adding unduly to delays within the fixed network, which may involve satellite links. Above 20 ms, voice conversation becomes difficult.
- **Maximum delay spread (Δ_m):** 10 μs (in mountainous regions); this is the difference in propagation delay among different multipath signals arriving at the same antenna.
- **Bandwidth:** Not to exceed 200 kHz, corresponding to 25 kHz per channel (the current spacing for analog *FM* cellular systems in Europe).

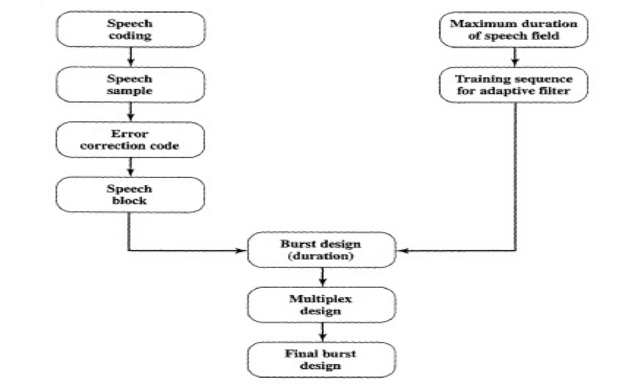
- Figure suggests the steps to be considered in designing the *TDMA* time slot.
- We use this as a guide in the following discussion.

Mobile Wireless TDMA Design Considerations III

- The speech coder must provide satisfactory speech quality at minimum data rate.
- The traditional form of speech coding to produce a digital bit stream is *Pulse Code Modulation* (*PCM*), which results in a data rate of 64 *kbps*.
- This rate is undesirably high for use in cellular radio.
- With current technology, a data rate of 12 *kbps* is reasonable for producing good-quality speech reproduction.

Mobile Wireless TDMA Design Considerations IV

Steps in Design of TDMA Time Slot



Mobile Wireless TDMA Design Considerations V

- If we restrict the coding delay to 20 *ms*, then it would be acceptable to form the encoded speech into blocks of 20 *ms* duration, or speech samples of 240 bits.
- Data at 12 *kbps* could also be blocked in 240 bit units.
- Error correction can then be applied to the 240 bit blocks.
- For second-generation digital systems, convolutional error-correcting codes are commonly used with a code rate of $1/2$.
- This overhead raises the number of bits in a block to 480.
- In addition, there is a constraint factor of 5, meaning that 4 bits must be added to the data block to account for the length of the shift register.
- This brings the speech block length to 488 bits.

Mobile Wireless TDMA Design Considerations VI

- With the parameters chosen so far, the minimum bit rate for an eight-channel system is

$$\frac{8\ \textit{channels} \times 488\ \textit{bits}/\textit{channel}}{20 \times 10^{-3}\ s} = 195.2\ \textit{kbps}$$

- In fact, the bit rate will be somewhat higher to take care of other design considerations.
- This means that a data rate of greater than 200 *kbps* will need to be carried in the available bandwidth of 200 *kHz*.
- In practice, such data rates cannot be achieved without the use of adaptive equalization.

Mobile Wireless TDMA Design Considerations VII

- In a mobile environment, adaptive equalization will require the inclusion of a new training sequence each time the mobile unit moves a distance sufficient to potentially cause changes in transmission path characteristics.
- Let us assume that a training sequence is included in each time slot.
- A rough criterion suggested in [JONE93] is that the phase angle of the carrier signal should be restricted to a change of $1/20$th of a wavelength (an angle of $\eta/10$) after the training sequence.
- At 900 *MHz*, the wavelength is 0.333 *m*.
- We can calculate

$$\text{Maximum transmission duration} = \frac{\lambda/20}{V_m} = \frac{0.333/20}{69.4} = 0.24\ ms$$

Mobile Wireless TDMA Design Considerations VIII

- We can take better advantage of the training sequence by transmitting 0.24 *ms* of speech or data both before and after the training sequence and using the training sequence on the combined 0.48 *ms* of data.
- Next, we need to determine the length of the training sequence.
- In the design of an equalizer for a multipath signal whose bandwidth is about equal to the bit rate (200 *kHz*, 200 *kbps*), a rule of thumb is that the number of taps on the equalizer should be equal to 6 times the number of bits transmitted in the maximum dispersal time ($\Delta_m = 0.01$ *ms*).
- Thus, the amount of time in the time slot devoted to the training sequence is 0.06 *ms*.

Mobile Wireless TDMA Design Considerations IX

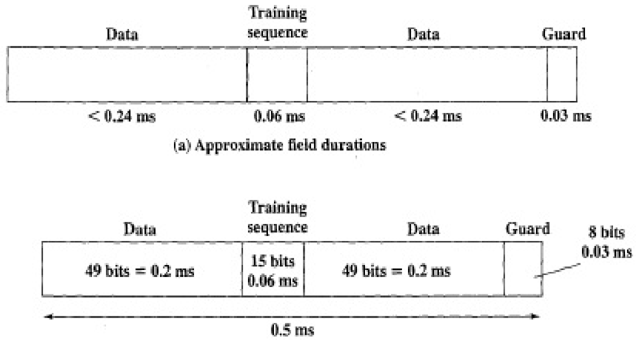
- Now consider that a guard interval is needed at the end of each time slot to account for the differing amounts of delay between different mobile units and the base station.
- Because eight mobile units share the same *TDMA* frame, it is necessary to adjust the timing of the transmissions of the mobile units so that the transmission from one unit does not interfere with adjacent time slots.
- It is the responsibility of the base station to provide synchronization information to each mobile unit to adjust relative delays to enforce the time slot structure of the *TDMA* frame.
- However, the mobile units may be moving relative to the base station and relative to each other, so a guard time is inserted in each time slot to account for these discrepancies.

Mobile Wireless TDMA Design Considerations X

- When a mobile unit first makes a connection through the base station, the base station can provide the mobile unit with timing information based on the current propagation delay between the mobile unit and the base station.
- We would also like to add a guard time sufficient to avoid the need to frequently update this synchronization information.
- We can calculate the guard time as follows.
- The average telephone call is about 130 seconds, so the radial distance toward or away from the base station that a mobile unit could cover is $130\ s \times 69.4\ m/s = 9022\ m$.
- The change in propagation delay caused by a movement of this distance is $\frac{9022\ m}{3\times10^8\ m/s} = 0.03\ ms$.

Mobile Wireless TDMA Design Considerations XI

TDMA Time Slot



(a) Approximate field durations

(b) Approximate field sizes

Mobile Wireless TDMA Design Considerations XII

- Figure (a) shows the tentative time slot design.
- The next step is to fit a coded data block into a convenient number of time slots, together with the training sequence and guard bits.
- We have a maximum duration of a time slot of approximately 0.57 *ms*.
- With 8 time slots per frame, that gives a frame time of about 4.6 *ms*.
- We said that we wanted to send data with a coding delay of 20 *ms*, so if we round the frame time down to 4 *ms* (time slot $=$ 0.5 *ms*), then we could conveniently send a block of speech in five successive slots on the same channel.
- A speech block consists of 488 bits, so each time slot would need to hold $488/5$ or about 98 data bits.

Mobile Wireless TDMA Design Considerations XIII

- This yields a bit rate of $98/0.4 = 245$ *kbps*.
- At this data rate, the minimum number of training bits required is 0.06 *ms* $\times$ 245 *kbps* $= 14.7$, which on rounding becomes 15 bits.
- Similarly, the minimum number of guard bits is 0.03 *ms*$\times$$245$ *kbps* $=$ 7.35, which on rounding becomes 8 bits.
- The resulting frame structure is shown in Figure (b).
- We have 121 bits transmitted in 0.5 *ms* for a channel bit rate of 242 *kbps*.

Global System for Mobile Communications I

- Before the *Global System for Mobile Communications* (*GSM*) was developed, the countries of Europe used a number of incompatible first-generation cellular phone technologies.
- *GSM* was developed to provide a common second-generation technology for Europe so that the same subscriber units could be used throughout the continent.
- The technology has been extremely successful and is probably the most popular standard, worldwide, for new implementations.
- *GSM* first appeared in 1990 in Europe.
- Similar systems have now been implemented in North and South America, Asia, North Africa, the Middle East, and Australia.

Global System for Mobile Communications II

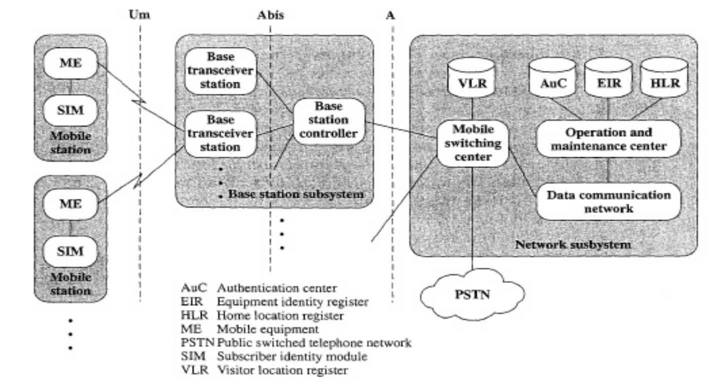
- The *GSM* Association claimed over a billion subscribers world-wide by early 2004, the bulk of these in Europe and Asia Pacific, but with growing market share in North and South America.

GSM Network Architecture I

- Figure shows the key functional elements in the *GSM* system.
- The boundaries at *Um*, *Abis*, and *A* refer to interfaces between functional elements that are standardized in the *GSM* documents.
- Thus, it is possible to buy equipment from different vendors with the expectation that they will successfully interoperate.
- Additional interfaces are also defined in the *GSM* standards, but need not concern us here.

GSM Network Architecture II

Overall GSM Architecture



Mobile Station I

- *A* mobile station communicates across the *Um* interface, also known as the air interface, with a base station transceiver in the same cell in which the mobile unit is located.
- The *Mobile Equipment* (*ME*) refers to the physical terminal, such as a telephone or *Personal Communications Service* (*PCS*) device, which includes the radio transceiver, digital signal processors, and the *Subscriber Identity Module* (*SIM*).
- The *SIM* is a portable device in the form of a smart card or plug-in module that stores the subscriber's identification number, the networks the subscriber is authorized to use, encryption keys, and other information specific to the subscriber.
- The *GSM* subscriber units are totally generic until an *SIM* is inserted.

Mobile Station II

- Therefore, a subscriber need only carry his or her *SIM* to use a wide variety of subscriber devices in many countries simply by inserting the *SIM* in the device to be used.
- In fact, except for certain emergency communications, the subscriber units will not work without a *SIM* inserted.
- Thus, the *SIM*s roam, not necessarily the subscriber devices.

Base Station Subsystem I

- A *Base Station Subsystem* (*BSS*) consists of a base station controller and one or more base transceiver stations.
- Each *Base Transceiver Station* (*BTS*) defines a single cell; it includes a radio antenna, a radio transceiver, and a link to a base station controller.
- A *GSM* cell can have a radius of between 100 *m* and 35 *km*, depending on the environment.
- A *Base Station Controller* (*BSC*) may be collocated with a *BTS* or may control multiple *BTS* units and hence multiple cells.
- The *BSC* reserves radio frequencies, manages the handoff of a mobile unit from one cell to another within the *BSS*, and controls paging.

Network Subsystem I

- The *Network Subsystem* (*NS*) provides the link between the cellular network and the public switched telecommunications networks.
- The *NS* controls handoffs between cells in different *BSS*s, authenticates users and validates their accounts, and includes functions for enabling worldwide roaming of mobile users.
- The central element of the *NS* is the *Mobile Switching Center* (*MSC*).

Network Subsystem II

- It is supported by four databases that it controls:
  - **Home Location Register (HLR) database:** The *HLR* stores information, both permanent and temporary, about each of the subscribers that “belongs” to it (i.e., for which the subscriber has its telephone number associated with the switching center).

Network Subsystem III

- **Visitor Location Register (*VLR*) database:** One important, temporary piece of information is the location of the subscriber. The location is determined by the *VLR* into which the subscriber is entered. The visitor location register maintains information about subscribers that are currently physically in the region covered by the switching center. It records whether or not the subscriber is active and other parameters associated with the subscriber. For a call coming to the subscriber, the system uses the telephone number associated with the subscriber to identify the home switching center of the subscriber. This switching center can find in its HLR the switching center in which the subscriber is currently physically located. For a call coming from the subscriber, the *VLR* is used to initiate the call. Even if the subscriber is in the area covered by its home switching center, it is also represented in the switching center's *VLR*, for consistency.

Network Subsystem IV

- **Authentication Center Database (AuC):** This database is used for authentication activities of the system; for example, it holds the authentication and encryption keys for all the subscribers in both the home and visitor location registers. The center controls access to user data as well as being used for authentication when a subscriber joins a network. GSM transmission is encrypted, so it is private. A stream cipher, A5, is used to encrypt the transmission from subscriber to base transceiver. However, the conversation is in the clear in the landline network. Another cipher, A3, is used for authentication.

Network Subsystem V

- **Equipment identity register database (EIR):** The *EIR* keeps track of the type of equipment that exists at the mobile station. It also plays a role in security (e.g., blocking calls from stolen mobile stations and preventing use of the network by stations that have not been approved).

Radio Link Aspects I

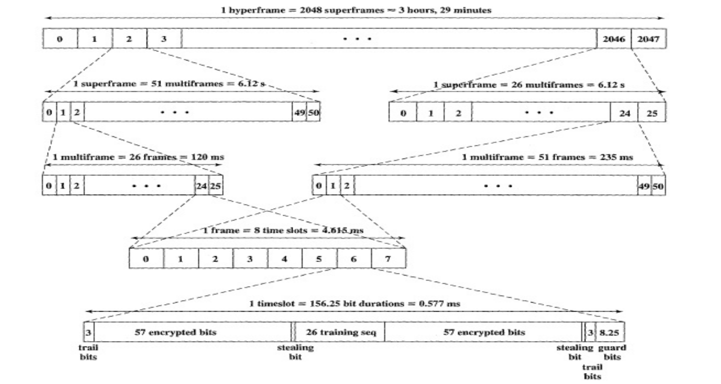
- The *GSM* spectral allocation is 25 *MHz* for base transmission (935-960 *MHz*) and 25 *MHz* for mobile transmission (890-915 *MHz*).
- Other *GSM* bands have also been defined outside Europe.
- Users access the network using a combination of *Frequency Division Multiple Access* (*FDMA*) and *Time Division Multiple Access* (*TDMA*).
- There are radio-frequency carriers every 200 *kHz*, which provide for 125 full-duplex channels.
- The channels are modulated at a data rate of 270.833 *kbps*.
- As with *AMPS*, there are two types of channels, traffic and control.

TDMA Format I

- *GSM* uses a complex hierarchy of *TDMA* frames to define logical channels.
- Fundamentally, each 200 kHz frequency band is divided into 8 logical channels defined by the repetitive occurrence of time slots.
- At the lowest level is the time slot, also called a burst period, which has a duration of $15/26$ ms, or approximately 0.577 ms.
- With a bit rate of 270.833 $kbps$, each time slot has a length of 156.25 bits.

TDMA Format II

GSM Frame Format



TDMA Format III

- The time slot includes the following fields:
  - **Trail bits:** Allow synchronization of transmissions from mobile units located at different distances from the base station, as explained subsequently.
  - **Encrypted bits:** Data is encrypted in blocks by conventional encryption of 114 plaintext bits into 114 ciphertext bits; the encrypted bits are then placed in two 57-bit fields in the time slot.
  - **Stealing bit:** Used to indicate whether this block contains data or is "stolen" for urgent control signaling.

TDMA Format IV

- **Training sequence:** Used to adapt the parameters of the receiver to the current path propagation characteristics and to select the strongest signal in case of multipath propagation. The training sequence is a known bit pattern that differs for different adjacent cells. It enables the mobile units and base stations to determine that the received signal is from the correct transmitter and not a strong interfering transmitter. In addition, the training sequence is used for multipath equalization, which is used to extract the desired signal from unwanted reflections. By determining how the known training sequence is modified by multipath fading, the rest of the signal is processed to compensate for these effects.
- **Guard bits:** Used to avoid overlapping with other bursts due to different path delays.

TDMA Format V

- The time slot format shown in Figure is called a normal burst and carries user data traffic.
- Other burst formats are used for control signaling.
- Moving up the frame format hierarchy, 8-slot *TDMA* frames are typically organized into a 26-frame multiframe.
- One of the frames in the multiframe is used for control signaling and another is currently unused, leaving 24 frames for data traffic.
- Thus, each traffic channel receives one slot per frame and 24 frames per 120 *ms* multiframe.
- The resulting data rate is

$$\frac{\frac{114\ bits}{slot} \times \frac{24\ slots}{multiframe}}{\frac{120\ ms}{multiframe}} = 22.8\ kbps$$

TDMA Format VI

- The *GSM* specification also allows half-rate traffic channels, with two traffic channels each occupying one time slot in 12 of the 26 frames.
- With the use of halfrate speech coders, this effectively doubles the capacity of the system.
- There is also a 51-frame multiframe used for control traffic.

Speech coding I

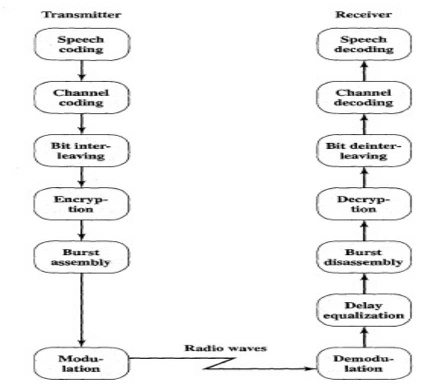
- The speech signal is compressed using an algorithm known as *Regular Pulse Excited - Linear Predictive Coder* ($RPE - LPC$).
- In essence, data from previous samples are used to predict the current sample.
- Each sample is then encoded to consist of bits representing the coefficients of the linear combination of previous samples plus an encoded form of the difference between the predicted and actual sample.
- The result of the use of this code is to produce 260 bits every 20 ms, for a raw data rate of 13 *kbps*.

Speech coding II

- From the point of view of the quality of the speech produced by this encoding, the bits in the 260-bit block can be divided into three classes:
  - **Class Ia:** 50 bits, most sensitive to bit errors
  - **Class Ib:** 132 bits, moderately sensitive to bit errors
  - **Class II:** 78 bits, least sensitive to bit errors

Speech coding III

GSM Speech Signal Processing



Speech coding IV

- The first 50 bits are protected by a 3-bit *Cyclic Redundancy Check* (*CRC*) error detection code.
- If an error is detected, the entire sample is discarded and replaced by a modified version of the preceding block.
- These 53 bits plus the 132 class Ib bits, plus a 4-bit tail sequence, are then protected by a convolutional (2, 1, 5) error correcting code, resulting in $189 \times 2 = 378$ bits.
- The remaining 78 bits are unprotected and are appended to the protected bits to produce a block of 456 bits, with a resulting data rate of $456/20\ ms = 22.8\ kbps$, which is the *GSM* traffic channel data rate.
- To add protection against burst errors, each 456-bit block is divided into eight 57-bit blocks, which are transmitted in eight consecutive time slots.

Speech coding V

- Because each time slot can carry two 57-bit blocks, each burst carries data from two different speech samples.
- Following these steps, the speech data are encrypted 114 bits at a time, assembled into time slots (burst assembly), and finally modulated for transmission.
- The modulation scheme, *Gaussian Minimum Shift Keying* (*GMSK*), is a form of *Frequency Shift Keying* (*FSK*).

Data Encoding I

- Digital data are processed in a similar fashion as applied to speech signals.
- Data are processed in blocks of 240 bits every 20 *ms*, for a data rate of 12 *kbps*.
- Depending on the way logical channels are defined, the actual supported data rates are 9.6, 4, 8, and 2.4 *kbps*.
- Each block is augmented by four tail bits.
- A (2, 1, 5) convolutional code is used to produce a block of $244 \times 2 = 488$ bits.
- Then 32 bits of this block are dropped (puncturing) leaving a block of 456 bits.

Data Encoding II

- A bit interleaving scheme is then used to spread the data over multiple bursts, again to reduce the effects of burst noise.
- The 456 bits are spread over 22 bursts in the following fashion:
  - The 1^{st} and 22^{nd} bursts carry 6 bits each.
  - The 2^{nd} and 21^{st} bursts carry 12 bits each.
  - The 3^{rd} and 20^{th} bursts carry 18 bits each.
  - The 4^{th} through 19^{th} bursts carry 24 bits each.
- The result is that each burst carries information from 5 or 6 consecutive data blocks.

Slow Frequency Hopping I

- We have said that a given traffic channel is assigned a given frequency channel for transmission and reception.
- This is not strictly correct.
- *GSM* and many other cellular schemes use a technique known as slow frequency hopping to improve signal quality.
- Each successive *TDMA* frame in a given channel is carried on a different carrier frequency.
- Thus, the transmission frequency is changed once every 4.615 *ms*.
- Because multipath fading is dependent on carrier frequency, slow frequency hopping helps to compensate.

Slow Frequency Hopping II

- Slow frequency hopping also reduces the effects of cochannel interference.
- Note that this is a form of spread spectrum communication.

Delay Equalization I

- Because mobile units are at different distances from the base station within a cell, their transmissions suffer differing amounts of delay.
- This phenomenon creates a design issue, because up to eight mobile units share the same *TDMA* frame.
- Thus, the timing of frame slots is criticaL The base station provides a control signal to synchronize the timing of the various mobile units.
- Within the slot format, the tail bits and guard bits provide a margin to prevent the overlap of data bits from one time slot to another.
- The base station can adjust the timing of any active mobile unit by control signals that instruct the mobile unit to increment or decrement its timing.

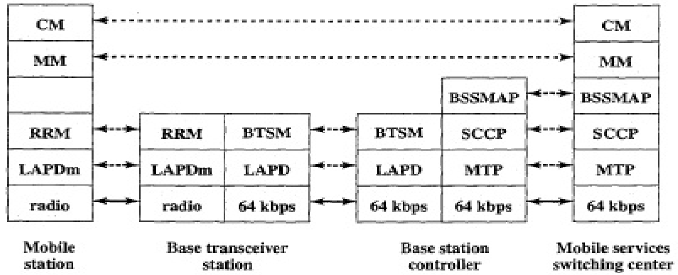
1 Global System for Mobile Communications

GSM Signaling Protocol Architecture I

- Figure summarizes the protocols used between the main elements of the network architecture.
- The lowest layer of the architecture is tailored to the physical link between entities.
- Between the mobile station and the base transceiver station, the radio link discussed in preceding subsections carries higherlevel data inside the *TDMA* format.
- Between other entities a standard 64-kbps digital channel is used.

GSM Signaling Protocol Architecture II

GSM Signaling Protocol Architecture



BSSMAP = BSS mobile application part
BTSM = BTS management
CM = connection management
LAPD = link access protocol, D channel
MM = mobility management
MTP = message transfer part
RRM = radio resources management
SCCP = signal connection control part

GSM Signaling Protocol Architecture III

- At the link layer, a data link control protocol known as *LAPDm* is used.
- This is a modified version of the *LAPD* protocol defined for the *Integrated Services Digital Network* (*ISDN*).
- The remaining links use the normal *LAPD* protocol.
- In essence, *LAPD* is designed to convert a potentially unreliable physical link into a reliable data link.
- It does this by using a cyclic redundancy check to perform error detection and *Automatic Repeat Request* (*ARQ*) to retransmit damaged frames.
- Above the link layer are a number of protocols that provide specific functions.

GSM Signaling Protocol Architecture IV

- These include:
  - **Radio resource management:** Controls the setup, maintenance, and termination of radio channels, including handoffs
  - **Mobility management:** Manages the location updating and registration procedures, as well as security and authentication
  - **Connection management:** Handles the setup, maintenance, and termination of calls (connections between end users)
  - **Mobile Application Part (MAP):** Handles most of the signaling between different entities in the fixed part of the network, such as between the *HLR* and *VLR*
  - **BTS management:** Performs various management and administrative functions at the base transceiver station, under the control of the base station controller

GSM Signaling Protocol Architecture V

- The *MAP* does not run directly on top of the link layer but rather on top of two intermediate protocols, *SCCP* and *MTP*.
- These latter protocols are part of Signaling System Number 7, which is a set of protocols designed to provide control signaling within digital circuit-switching networks, such as digital public telecommunications networks.
- These protocols provide general functions used by various applications, including *MAP*.