2G, 3G Network Planning and Optimization...

Archives

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1.2 Multiple Access Technology and Logical Channel

1.2.1 GSM Multiple Access Technology

In cellular mobile communications system, since many mobiles stations communicate with other mobiles stations through one base station, it is necessary to distinguish the signals from different mobile stations and base stations for them to identify their own signals. The way to this problem is called multiple access technology. There are now five kinds of Multiple access technology, namely: Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA), Space Division Multiple Access (SDMA), and polar division multiple access (PDMA).
GSM multiple access technology focuses on TDMA, and takes FDMA as complement. The following only introduces FDMA and TDMA technologies.
I. FDMA
FDMA divides the whole frequency band into many single radio channels (transmitting and receiving carrier frequency pairs). Each channel transmits one path of speech or control information. Any subscriber has access to one of these channels under the control of the system.
Analog cellular system is a typical example of FDMA application. Digital cellular system also uses FDMA, but not the pure frequency allocation. For example, GSM takes FDMA technology.
II. TDMA
TDMA divides a broadband radio carrier into several time division channels according to time (or timeslot). Each subscriber takes one timeslot and sends or receives signals only in the specified timeslot. TDMA is applied in digital cellular system and GSM.
GSM adopts a technology combined with FDMA and TDMA.

1.2.2 TDMA Frame

The basic conception of GSM in terms of radio path is burst. Burst is a transmission unit consists of over one hundred of modulation bits. It has a duration limit and takes a limited radio frequency. They are exported in time and frequency window which is called slot. To be specific, in system frequency band, central frequency of slot is set in every 200 KHz (in FDMA). Slot occurs periodically in each 15/26 ms, which is about 0.577 ms (in TDMA).The interval between two slots is called timeslot. Its duration is used as time unit, called burst period (BP).
Time/frequency map illustrates the concept of slot. Each slot is expressed as one little rectangle with 15/26ms length and 200 KHz width. See Figure 1-1. Similarly, the 200 KHz bandwidth in GSM is called frequency slot, equal to radio frequency channel in GSM protocol.
Burst represents different meaning in different situation. Sometimes it concerns time – frequency “rectangle” unit, and sometimes not. Similarly, timeslot sometimes concerns time value, and sometimes means using one of every eight slots periodically.
Using a given channel means transmitting burst with a particular frequency at particular time, that is, a particular slot. Generally, the slot of a channel is not continuous in time.

Physical channel combines frequency division multiple access and time division multiple access together. It consists of timeslot flow that connects base station (BS) and mobile station (MS).The position of these timeslots in TDMA frame is fixed. Figure 1-2 shows the complete structure of TDMA frame, including timeslot and burst. TDMA frame is a repetitive “physical” frame in radio link.
One TDMA frame consists of eight basic timeslots, about 60/13≈4.615ms in total. Each timeslot is a basic physical channel with 156.25 elements, coving 15/26≈0.557ms.
There are two kinds of multiframes, consisting of 26 and 51 continuous TDMA frames respectively. Multiframes are applied when different logical channels are multiple used in one physical channel.
The 26 multiframe, with a period of 120 ms, is used in traffic channel and associated control channel. Among the 26 bursts, 24 are used in traffic and 2 are used in signaling.
The 51 multiframe, with a period of 3060/13≈235.385 ms, is specially used in control channel.
Many multiframes together form a super frame. Super frame is a continuous 51×26TDMA frame, that is to say, a super frame consists of fifty-one 26 TDMA multiframes or twenty-six 51 TOMA multiframes. The period of super frame is 1,326 TDMA frames, or 6.12 s.
Many super frames together form a hyper frame.
A hyper frame consists of 2,048 super frames with a period of 12,533.7s, or 3 hours and 28’ 53” 760’”. It is used in encrypted voice and data. Each period of hyper frame consists of 2,715,648 TDMA frames numbered from 0 to 2,715,648. The frame number is transmitted in sync channel.

1.2.3 Burst

Burst is the message layout of a timeslot in TDMA channel, which means each burst is sent to a timeslot of TDMA frame.
Different message in the burst determines its layout.
There are five kinds of bursts:
Normal burst: used to carry messages in TCH, FACCH, SACCH, SDCCH, BCCH, PCH and AGCH channels
Access burst: used to carry message in RACH channel
Frequency correction burst: used to carry message in FCCH channel
Synchronization burst: used to carry message in SCH channel
Dummy burst: transmitted when no specific message transmission request from system (In cells, standard frequency sends message continuously)
Each kind of burst includes the following elements:

Tail bits: Its value is always 0 to help equalizer judge start bit and stop bit to avoid lost synchronization.
Information bits: It is used to describe traffic and signaling information, except idle burst and frequency correction burst.
Training sequence: It is a known sequence, used for equalizer to generate channel model (a way to eliminate dispersion). Training sequence is known by both transmitter and receiver. It can be used to identify the location of other bits from the same burst and roughly estimate the interference situation of transmission channel when the receiver gets this sequence. Training sequence can be divided into eight categories in normal burst. It usually has the same BCC setting with cells, but when accessed to burst and synchronization bust, training sequence is fixed and does not change with cells. For example, in access burst, training sequence is fixed (occupying 41 bits). The 36-bit message digit of the random access burst includes BSIC information of the cell. BSIC settings of the same BCCH should be different, in order to avoid mis-decoding of random access burst from neighboring cells into local access.
Guard period: It is a blank space. Since each carrier frequency can carry a maximum of eight subscribers, it is necessary to guarantee the non-overlapping of each timeslot in transmission. Although timing advance technology (introduced later) is used, bursts from different mobile stations still show little slips; therefore, protection interval is adopted to allow transmitter to fluctuate in a proper range in GSM. On the other hand, GSM requires protection bits to keep constant transmission amplitude of the effective burst (except protection bits) and properly attenuate the transmission amplitude of mobile station. The amplitude attenuation of two sequential bursts as well as proper modulation bit stream can reduce the interference to other RF channels.
The following is a detailed introduction to the structure and content of burst:
Access burst
It is used for random access (channel request from network and switchover access).
It is the first burst that the base station needs in uplink modulation.
Access burst includes a 41-bit training sequence, 36-information bit, and its protection interval is 68.25 bits. There is only one kind of training sequence in access burst. Since the possibility of interference is rather little, it is unnecessary to add extra kinds of training sequences. Both training sequence and protection interval are longer than normal bursts in order to offset the bug of timing advance ignorance in the first access of mobile station (or switch over to another BTS) and improve demodulation ability of the system.
Frequency correction burst
It is used for frequency synchronization in mobile station, equal to an unmodulated carrier. This sequence has 142 constant bits for frequency synchronization. Its structure is pretty simple with all constant bits being 0. After modulated, it becomes a pure sine wave. It is used in FCCH channel for mobile station to find and modulate synchronization burst of the same cell. When mobile station gets the frequency through this burst, it can read the information of following bursts (such as SCH and BCCH) in the same physical channel. Protection interval and tail bit are the same with that of normal burst.
Synchronization burst
With a 64-bit training sequence and two 39-bit information fields, synchronization burst is used for time synchronization of mobile station in SCH channel. It belongs to downlink. Since it is the first burst required to be modulated by mobile station, its training sequence is relatively long and easy to be detected.
Normal burst
It has two 58-bit groups used in message field. To be more specific, two 58-bit groups are used to transmit subscriber data or voice together with two stealing flags. Normal burst is used to describe whether the transmitted is traffic information or signaling information. For example, to distinguish TCH and FACCH (when TCH channel is used as FACCH channel to transmit signaling, the stealing flag of the 8 half bursts should be set to 1. It has no other use in channels except in TCH channel, but can be regarded as the extension of training sequence and always set to 1.Normal burst also includes two 3-bit tails and a protection interval of 8.25 bits. The only bug is that the receiver has to store the preceding part of burst before modulation. Normal burst has a total of 26 bits, 16 of which are information bits. In order to get 26 bits, it copies the first five bits to the end of the training sequence and the last five bits to the head of the training sequence. There are eight kinds of such training sequence (these eight sequences have the least relevancy with each other). They correspond to different base station color code (BCC, 3 bits) respectively to distinguish the two cells using the same frequency.
Dummy burst
This kind of bust is sometimes sent by BTS without carrying any information. Its format is the same with normal burst. The encrypted bits are changed into mixed bits with certain bit model.

1.2.4 Logical Channel

In real networking, each cell has several carrier frequencies and each frequency has eight timeslots, proving eight basic physical channels. Logical channel carries out time multiplexing in one physical channel. It is classified according to the type of information in physical channel. Different logical channel transmits different type of information between BS and MS, such as signaling and data service. GSM defines different burst type for different logical channel.
In GSM, logical channel is divided into dedicated channel (DCH) and common channel (CCH), or traffic channel (TCH) and control channel (CCH) sometimes.
I. TCH
TCH carries coded voice or subscriber data. It is divided into full rate TCH (TCH/F) and half rate TCH (TCH/H) with 22.8 bit/s information and 11.4 Kbit/s information respectively. Using half of the timeslots in TCH/F can get TCH/H. A carrier frequency can provide eight kinds of TCH/F or sixteen kinds of TCH/H. Voice channel types are as follows:
Enhanced full rate speech TCH (TCH/EFS)
Full rate speech TCH (TCH/EFS)
Full rate 9.6 Kbit/s TCH (TCH/F9.6)
Full rate 4.8 Kbit/s TCH (TCH/F4.8)
Full rate ≤2.4 Kbit/s TCH (TCH/F2.4)
II. CCH
CCH is used to transmit signaling or synchronous data. It mainly consists of broadcast channel (BCCH), common control channel (CCCH), and dedicated control channel (DCCH).
III. BCCH
Frequency Correction Channel (FCCH)
It carries the information for frequency correction in mobile station. Through FCCH, mobile station can locate a cell and demodulate other information in the same cell, and recognize whether this carrier

frequency is BCCH or not.
Sync Channel (SCH)
After FCCH decoding, mobile station has to decode SCH information. This information contains mobile station frame synchronization and base station identification. Base station identification code (BSIC) occupies six bits, three of which are PLMN color codes ranging from zero to seven, and the other three are base station color codes (BCCs) ranging from zero to seven.
Reduced TDMA frame (RFN) occupies 22 bits.
BCCH
Generally, each BTS has a transceiver containing BCCH in order to broadcast system information to mobile station. System information enables mobile station to work efficiently in null state.
IV. CCCH
Paging Channel (PCH)
PCH is a downlink channel used to page mobile station. When the network wants to communicate with a certain mobile station, it sends paging information marked as TMSI or IMSI through PCH to all the cells in LAC area according to the current LAC registered in mobile station.
Access Grant Channel (AGCH)
AGCH is a downlink channel used for base station to respond the network access request of mobile station, that is, to allocate a SDCCH or TCH directly. AGCH and PCH share the same radio resource. Keep a fixed number of blocks for AGCH or just borrow PCH when AGCH requires without keeping special AGCH block (AGB).
Random Access Channel (RACH)
RACH is an uplink channel used for mobile station to request SDCCH allocation in random network access application. The request includes the reason to build 3-bit (call request, paging response, location update request and short message request) and 5-bit reference random number for mobile station to identify its own access grant message.
V. DCCH
Stand-alone Dedicated Control Channel (SDCCH)
SDCCH is a bi-directional dedicated channel used to transmit information of signaling, location update, short message, authentication, encrypted command, channel allocation, and complementary services. It can be divided into SD/8 and SD/4.
Slow Associated Control Channel (SACCH)
SACCH works with traffic channel or SDCCH to transmit subscriber information and some specific information at the same time. Uplink mainly transmits radio measurement report and the first layer head information; downlink mainly transmits part system information and the first layer head information. The information includes quality of communications, LAI, CELL ID, BCCH signal strength in neighboring cells, NCC limit, cell options, TA, and power control level.
Fast Associated Control Channel (FACCH)
FACCH works with TCH to provide signaling information with a rate and timeliness much higher than that provided by SACCH.
There is another control channel called cell broadcast channel (CBCH) besides the three control channels mentioned above. It is used in downlink and carries short message service cell broadcast (SMSCB) information. CBCH uses a physical channel same as SDCCH.
VI. Channel Combination
Logical channel is mapped to physical channel according to certain rules. The channel combinations specified in GSM protocol are as follows:
TCH/F + FACCH/F + SACCH/TF
TCH/H(0,1) + FACCH/H(0,1) + SACCH/TH(0,1)
TCH/H(0,0) + FACCH/H(0,1) + SACCH/TH(0,1) + TCH/H(1,1)
FCCH + SCH + BCCH + CCCH (main BCCH)
FCCH + SCH + BCCH + CCCH + SDCCH/4(0..3) + SACCH/C4(0..3)(BCCH combination)
BCCH + CCCH(BCCH extension)
SDCCH/8(0. .7) + SACCH/C8(0. .7)
VII. Uncombined BCCH/SDCCH and Combined BCCH/SDCCH
Paging information transmits in the timeslot 0 of BCCH. Timeslot 0 has the following sub channels:
Broadcast channel (BCH): FCCH, SCH, BCCH
CCCH: PCH, AGCH
DCCH (combined BCCH/SDCCH): SDCCH, SACCH, CBCH (if using cell broadcast)
Physical channel timeslot 0 is made of multiframes logically. Each multiframe is 235.4 ms in length. Multiframe has different channel configurations, such as combined BCCH/SDCCH and uncombined BCCH/SDCCH. Different configuration has different paging capacity.
Uncombined BCCH/SDCCH
Each frame of Uncombined BCCH/SDCCH can have nine paging blocks. The timeslot 0 of BCCH carrier frequency does not have SDCCH channel or CBCH channel.
Combined BCCH/SDCCH
Each multiframe of combined BCCH/SDCCH can have three paging blocks. The timeslot 0 of BCCH carrier frequency contains four SDCCH subchannels (no CBCH) or three SDCCH and one CBCH subchannel.
The configuration of combined BCCH/SDCCH has a great influence on paging capacity. Each multiframe has only three paging blocks instead of nine in uncombined BCCH/SDCCH, which means the paging capacity of cells with combined BCCH/SDCCH is only one third of that of cells with uncombined BCCH/SDCCH.

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