3 Air Interface

Objectives

After this chapter the student will:

- be able to describe the structure of the air interface.
- be able to understand the build-up of a burst.
- be able to recognise the different logical channels and their functions.
- be able to understand how the different logical channels are mapped on physical ones.

3.1 Introduction

The air interface, called ”Um” in the specification, is the most important interface in the GSM specification for two reasons:

- It needs to be completely specified to enable a mix of manufacturers of mobile stations to be used in a mix of systems from different suppliers.
- Spectral efficiency is absolutely fundamental to get economy in a system. Spectral efficiency is dependant on the number of simultaneous calls that can be made using a certain frequency band, but also on the resistance to interference which determines reuse distance and thereby the capacity limit of the network.

3.2 Access theory

This will be a brief description of the fundamental differences between a Frequency Division Multiple Access (FDMA), a Time Division Multiple Access (TDMA) and a Code Division Multiple Access (CDMA) technology.

FDMA - Frequency Division Multiple Access

FDMA is used for standard analogue mobile telephony. Each user is assigned a discrete slice of the RF spectrum. FDMA permits only one user per channel since it allows the user to use the channel 100% of the time. Therefore, only the frequency dimension is used to define channels. Spacing between the frequencies used is normally around 25-30 kHz for most of the analogue cellular system (25 kHz for NMT and TACS, 30 kHz for AMPS).

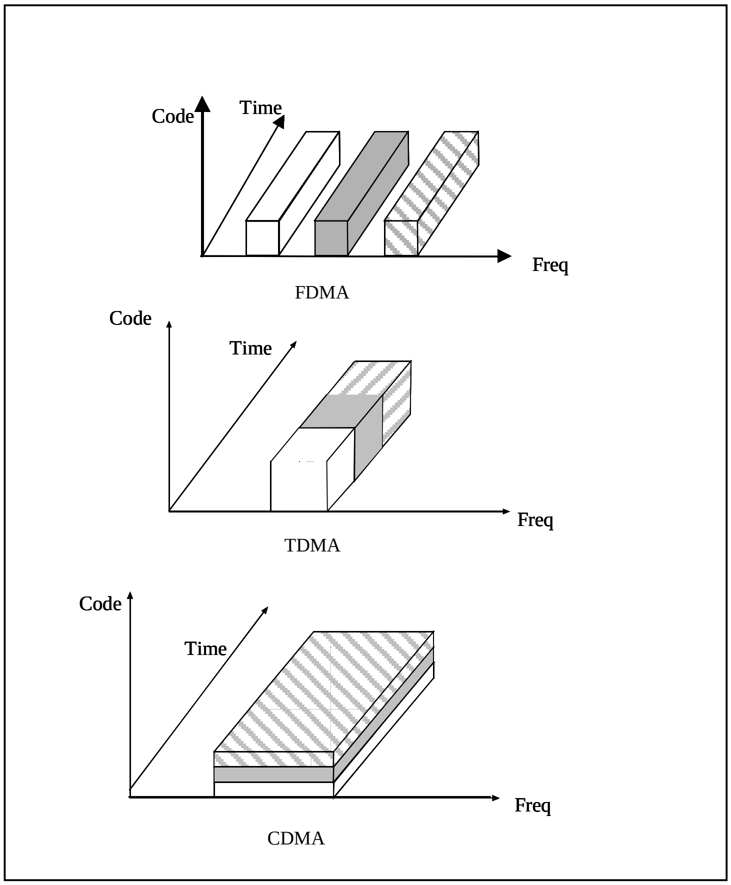
TDMA - Time Division Multiple Access

In TDMA the users are still assigned a discrete slice of RF spectrum, but multiple users now share that RF carrier on a time slot basis. Each of the users alternates their use of the RF channel. Frequency division is still employed, but these carriers are now further sub-divided into some number of time slots per carrier (3 for TDMA-AMPS, 8 for full rate GSM, 16 for half rate GSM).

A user is assigned a particular time slot on a carrier whether the other time slots are being used or not. The information flow is not continuous for any user, but is sent in burst. The bursts are re-assembled at the receiving end, and appear to provide continuous sound because of the speed of the process.

CDMA - Code Division Multiple Access

In CDMA there is no time division, and all users use the entire carrier, all the time. The allocated frequency segment for a CDMA carrier is considerably larger than for a carrier used in FDMA or TDMA (1.25 MHz per carrier). To distinguish the different users occupying the same frequency band simultaneously, each user is assigned a binary code.



FDMA, TDMA and CDMA

The International Cocktail Party

To illustrate the conceptual differences among the multiple access technologies, the "International Cocktail Party" analogy can be used. Picture a large room with a number of people, in pairs, who would like to hold conversations. The people in each pair only want to talk and listen to each other, and have no interest in what is being said in other pairs. In order for these conversations to keep place, however, it is necessary to define the environment for each conversation.

Dividing one large room into a number of small rooms creates the FDMA environment. A single pair of people would enter each small room for a conversation. When that conversation is complete, they would leave and another pair would be able to enter.

In a TDMA environment, each of these small rooms would be able to accommodate multiple conversations simultaneously. For example, with a 8 slot TDMA system each room would contain up to 8 pairs of people, with each pair taking turns talking. Think of each pair having the right to speak for 125 m seconds during each second.

In CDMA, pairs of people will enter the single large room. However if every pair uses a different language, the can all use the air in the room as a carrier for their voices. The analogy here is that the air in the room is the wideband "carrier" and the languages the codes used to identify the CDMA user.

Theoretically, we can continue adding pairs, each speaking a unique language (as defined by the unique code) until the overall background noise (interference from other users) makes it too difficult for some of the people to understand the other in the pair.

Therefore, the maximum number of users, or effective traffic channels, per carrier depends on the amount of activity that is going on in each channel. Additional user (or conversation, in our analogy) may be accommodated, but at the cost of more interference to the other users.

3.3 Structure

The frequency band specified for GSM is 890-915 MHz for the uplink (up to the base station) and 935-960 MHz for the downlink (down from base station). The corresponding bands used for GSM 1800 are 1710-1785 for the uplink and 1805-1880. One full duplex channel is made up of a pair of frequencies; one frequency for the uplink and one frequency for the downlink. The distance between the frequencies used for up- and downlink, the duplex distance, is 45 M Hz for GSM and 95 M Hz for the GSM 1800 system.

The frequencies on the up link are separated by 200 k Hz. The same goes for down link frequencies. This distance is called carrier spacing and will give us 124 carriers for GSM 900 and 374 for GSM 1800 in the frequency band stated above. Each of these carriers will fit 8 multiplexed time slots in the full rate version.

Let us define two types of channels used in the GSM vocabulary, a "Physical Channel" and a "Logical Channel":

a physical channel is one time slot on one carrier

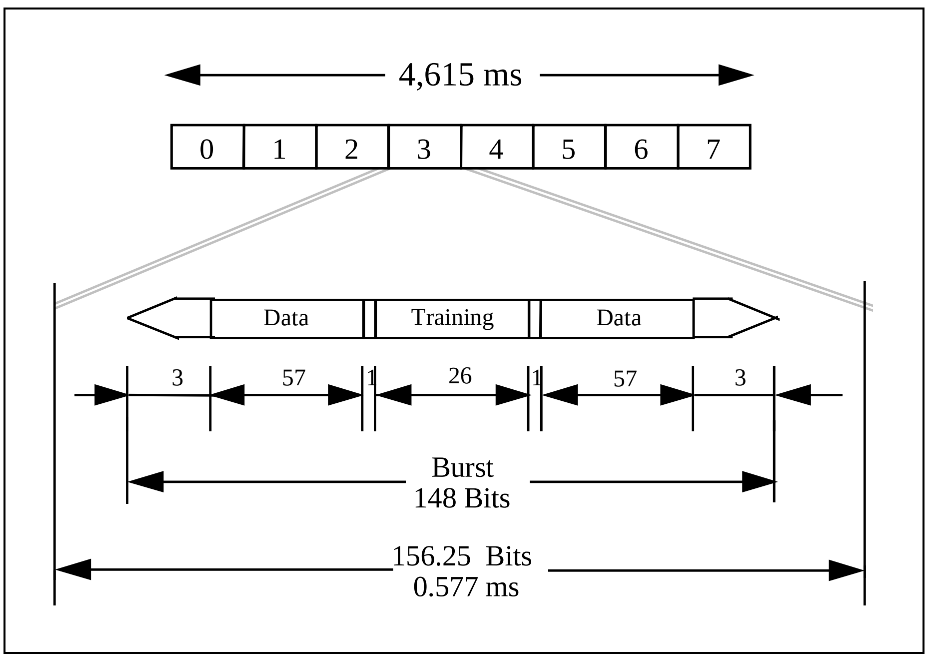
a logical channel is specific type of information carried by a physical channel

This means that all the different sorts of information, whether it is traffic or control signalling, will be sent on different logical channels. The logical channels are then mapped or multiplexed on the physical channels according to a certain structure. This structure will set the rules concerning when and on which physical channel the information will be sent.

To define a ”Burst” one would say that:

a burst is a formatted sequence of bits sent during one time slot

Due to the TDMA structure with timeslots, we do not send continuously but only in the designated time slots. The information sent during one time slot is formatted into a burst.



The burst is the formatted sequence of bits sent during one time slot

3.4 Bursts

The information is structured slightly different depending on what kind of logical channel it belongs to.

The bursts are of five types;

- normal burst
- access burst
- frequency correction burst
- synchronisation burst
- dummy burst

Normal burst

The normal burst is used for transmission of traffic and for some control signalling. The normal burst contains;

- 2 information fields, each with 57 bits, used for encrypted speech or data
- a training sequence to be used by the equaliser in the receiver
- 2 bits to indicate whether the burst is "stolen" to be used as a FACCH (see Logical Channels) or “non stolen” to be used for TCH.
- 3 bits in each end to serve as start and stop bits.

TB 3	Encrypted bits 57	1	Training sequence 26	1	Encrypted bits 57	TB 3	GP 8.25

The normal burst

Access Burst

The access burst is used whenever the MS wants to get in contact with the network. At that time it is not known how far away the MS is from the base station. If the mobile is far away, the access burst might arrive too late to fit in the assigned time slot. Therefore the access burst is as short as possible, to allow a certain delay without interfering with the next time slot.

TB 8	Information	Guard Period 68.25

The access burst

The other types of bursts are only sent downlink from the base station.

- The synchronisation burst is used to let the mobiles synchronise to the TDMA-structure, i.e. to know when certain information is broadcasted.
- The frequency correction burst is sent so that the MSs can tune their frequencies to the frequency sent out from the base station.
- The dummy burst is used when the base station is forced to transmit although it has no information to send. As a fact, there is a need for transmission in all time slots on certain carriers. The reason is that the MS uses those carriers for measurements in order to rank the base stations according to the received signal strength.

3.5 Logical channels

If we could we would probably want to fill all our available physical channels with traffic. However, control channels are required for setting up a radio connection, for setting up a call or controlling an MS during conversation.

These are the logical channels for control signalling;

ô FCCH, (Frequency Correction CHannel), On this channel a pure sine wave is transmitted. The first purpose is orientation for the mobile among all the yet incomprehensible information sent, a perfect sine wave could be found by the mobile. This will indicate where in the information flow it is listening. The second purpose is for the mobile to tune its frequency. Here the frequency correction burst is used.

ô SCH, (Synchronisation CHannel), This channel contains information about the number of the TDMA-frame monitored by the MS. SCH also contains the so called BSIC (Base Station Identity Code) that will inform the mobile station if it is listening to the correct frequency and aloud PLMN . The logical channel SCH is carried by a synchronisation burst.

ô BCCH, (Broadcast Control CHannel), contains general information about the cell, so that the MS knows how to behave. The information supplied could be maximum output power allowed at access, the frequencies of neighbouring cells for the MS to monitor, Location Area Identity, or whether the cell is barred etc. BCCH is transmitted downlink, point-to-multipoint.

ô PCH, (Paging CHannel), is monitored at certain intervals by every idle MS. If there is an incoming call, or a Short Message, the network will page the MS, using the PCH in all cells in the location area where the MS is registered. The PCH contains the MS identity number, the IMSI or TMSI. PCH is transmitted downlink, point-to-point.

ö RACH, (Random Access CHannel), is used by the mobile when making its first access to the system. By making that access, the MS is requesting a signalling channel. The reason for the access could be a page response, or initiation of a call. Since the distance between the MS and the base station is unknown, the access burst will be kept as short as possible so as not to interfere with the adjacent time slot. RACH is sent uplink, point-to-point.

ô AGCH, (Access Granted CHannel), is used for the acknowledgement of the access attempt sent on RACH. On this channel the MS will be assigned a signalling channel (SDCCH/SACCH) to continue the signalling according to the reason for the access. AGCH is sent downlink, point-to-point.

ôö SDCCH, (Stand-alone Dedicated Control CHannel), is the channel on which the actual signalling will take place. This may be used for call set-up, authentication, ciphering or transmission of text messages (Short Message and Cell Broadcast). This bi-directional channel is subdivided into eight (in some cases four) sub-channels so that each can handle the signalling needed by one MS. Thus, eight (or four) calls can be set up simultaneously. At call set-up, the MS will be assigned a TCH after the signalling on SDCCH is completed. SDCCH is transmitted up- and downlink, point-to-point.

ôö SACCH, (Slow Associated Control CHannel), is used to transfer signalling data while we have an ongoing conversation on a TCH or while the SDCCH is being used. This channel can carry about two messages per second in each direction. It is used for non-urgent procedures. On the downlink the MS is informed about what neighbouring cells to measure on for handover purposes. The MS is also ordered to use a certain power and timing advance. On the uplink the MS will report about measurements done. SACCH is transmitted up- and downlink, point-to-point.

ôö FACCH, (Fast Associated Control CHannel), is used when there is a need for higher capacity signalling in parallel with on-going traffic. FACCH works in "stealing mode", meaning that the transmitting side throws away a 20 ms segment of speech to fill the bursts with signalling information instead. When doing so, the transmitting side must set the "stolen bit indicator" to 1. When noting, on the receiving side, that the stolen bit indicator is set to 1, the bursts will be handled as signalling information. To lessen the disturbance of the speech, the last speech segment will be repeated. The FACCH is mainly used for handover commands. FACCH is transmitted both up- and downlink, point-to-point.

This is the logical channel for traffic:

ôö TCH, Traffic CHannel. The TCH could be of two types, full rate (TCH/F) and half rate (TCH/H). The TCH/F could be used for speech or for data. The bit rate for speech is 13 kbit/s (gross rate 22.8 kbit/s) while the corresponding rate for data is a maximum of 9.6 kbit/s. One TCH/F occupies one physical channel, while TCH/H occupies half a physical channel (i.e. every second time slot). This TCH/H may be used for approx. 5.6 kbit/s (gross rate 11.4 kbit/s) speech or data at 4.8 kbit/s or lower.

3.6 Mapping on physical channels

The control channels mentioned above are transmitted according to certain rules concerning what physical channel (frequency and time slot) to use and how often they are to be repeated. We say that logical channels are mapped, or multiplexed on the physical channels.

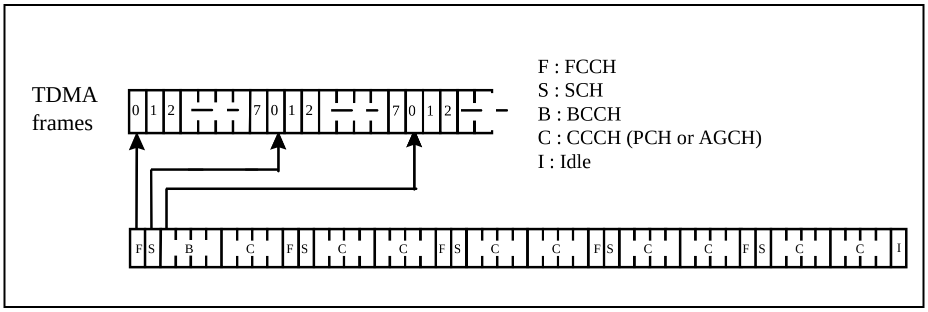
The TDMA-frames are grouped together into multi-frames that are then repeated cyclically. There are basically two types of multi frames; the 26 TDMA multi-frame used for traffic and the 51 TDMA multi-frame used for control signalling.

At a base station with n carriers, the carriers are called c_0, c_1, c_2,...$c_{n-1,}$ all having eight time slots. On time slot 0 on the c_0 carrier, we map a channel combination of only control channels

The Broadcast and Common Control CHannels

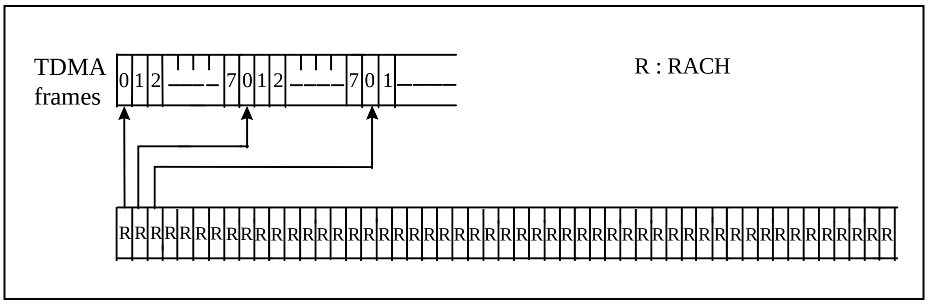
TS0 on c_0 are grouping the information into a 51 TDMA multi-frame. It contains:

- BCH, Broadcast channels
  FCCH, in the figure denoted F, always starts the multi-frame. It will be repeated every 10 TDMA-frames.
  SCH, here-denoted S, always follows FCCH. It will be repeated every 10 TDMA frames, just like FCCH.
  BCCH, here-denoted B, will come next. It needs 4 consecutive TDMA frames to transmit the information.
- CCCH, Common Control CHannels, that here are denoted by C. CCCH downlink could be either PCH or AGCH. Whatever it is, it will use a block of four consecutive TDMA frames. As shown in the figure, nine CCCH-blocks can be fitted in one 51 TDMA multi-frame.
- I stand for Idle, even though in this case it is really a dummy burst being transmitted. Since other MSs might be measuring signal strength by monitoring this physical channel, something must always be transmitted. Therefore, in TDMA frame 51, when we have nothing to send, a dummy burst will nevertheless be sent.



Mapping of logical channels on TS0 on c_0 downlink.

Next we will take a look at TS0 on c_0, but uplink. The only logical channel to be mapped here is the access channel RACH.



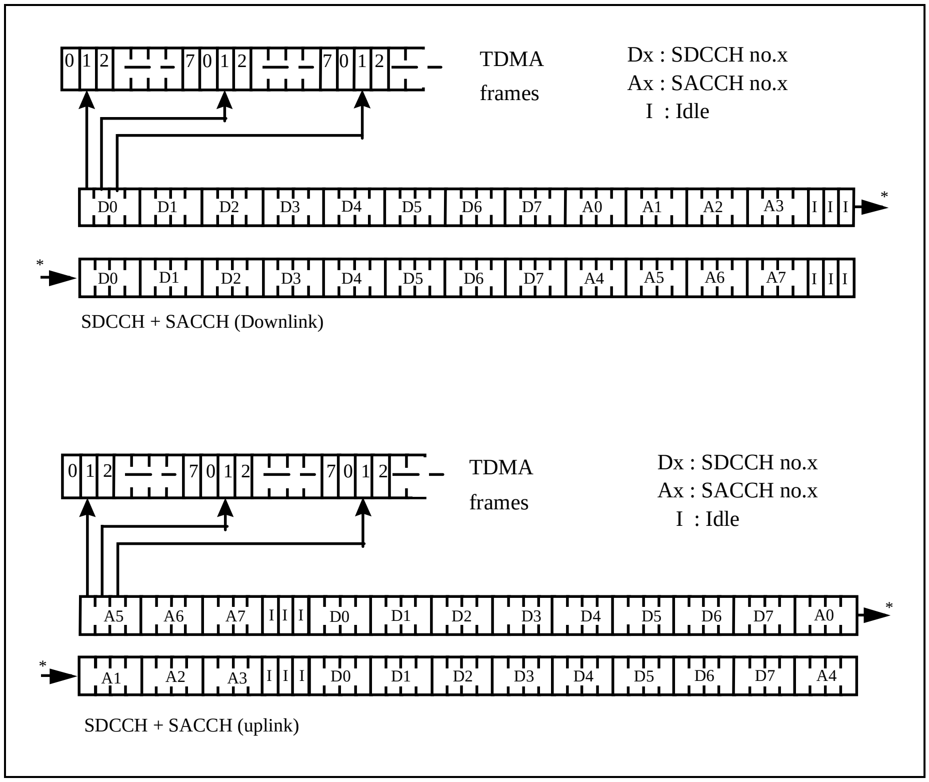
Mapping on TS0 on c_0 uplink.

The Dedicated Control CHannels

The Dedicated Control CHannels are usually mapped on TS1 on c_0, up- as well as downlink the information is grouped into 102 TDMA multi-frames. In these frames we will find:

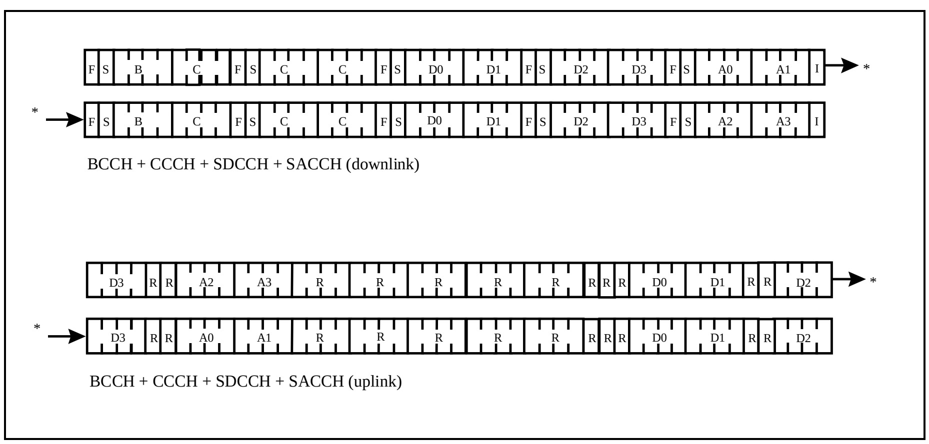
- SDCCH, here denoted as D, is divided into eight sub-channels. Each SDCCH sub-channel is occupying a block of four consecutive TDMA frames. As soon as the MS has finished using a certain SDCCH sub-channel, it can be used by another MS.
- SACCH, here denoted as A. For each SDCCH sub-channel there is a corresponding SACCH. This channel is used to transfer signalling information concerning measurements during call set-up.

The uplink looks similar to the downlink for TS1, c_0 . The only difference is that the uplink is a number of TDMA frames delayed in relation to downlink.



Mapping on TS1 on C_0 downlink and uplink.

Also specified is a channel combination that combines all the control channels into one time slot, following a 102 TDMA frame repeating pattern. This combination is mostly used in cells with only one frequency.

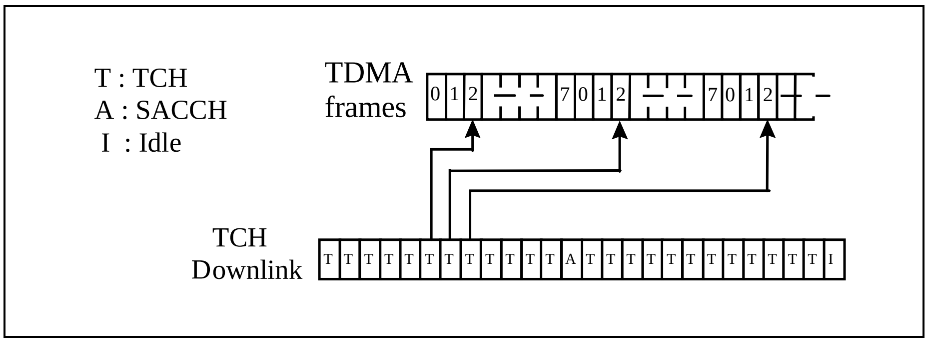


Alternative mapping on TS0 on C_0 downlink and uplink.

The Traffic channels

On TS2-TS7 on the c_0 and on TS0-TS7 on all the other carriers, the information is grouped into 26 TDMA multi-frames. In these multi-frames we will find;

- TCH, denoted as T, containing data or speech.
- SACCH, denoted A, carrying the control signalling necessary during traffic, for instance measurement data, power orders, or timing advance orders.
- Idle frames, denoted I. This is not a logical channel. This is only to indicate that the transmitter is off during this particular TDMA frame. This short period of silence is used by the MS to read BSIC, sent out from one of the neighboring cells base stations.

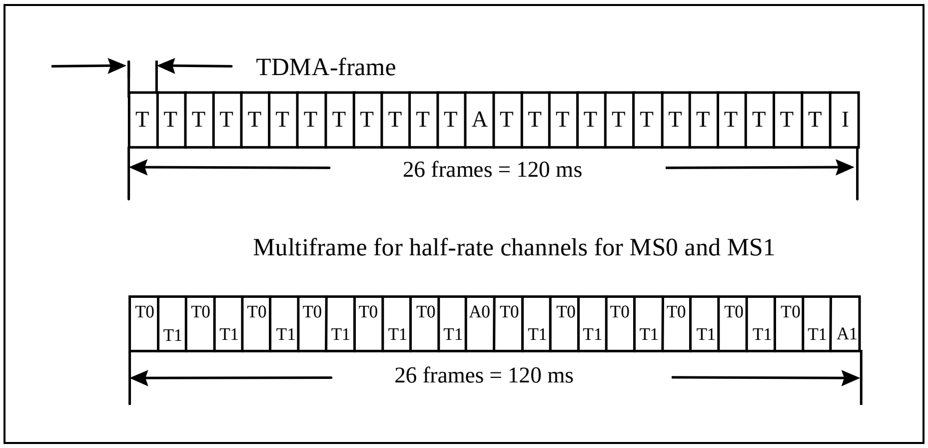


Mapping on TS2-7 on c_0 or TS0-TS7 on any other carrier, downlink.

<u>The half rate Traffic channels</u>

For half rate the bit rate needed per traffic channel will be cut from 13 k bit/s down to approximately half to enable up to twice as much traffic.

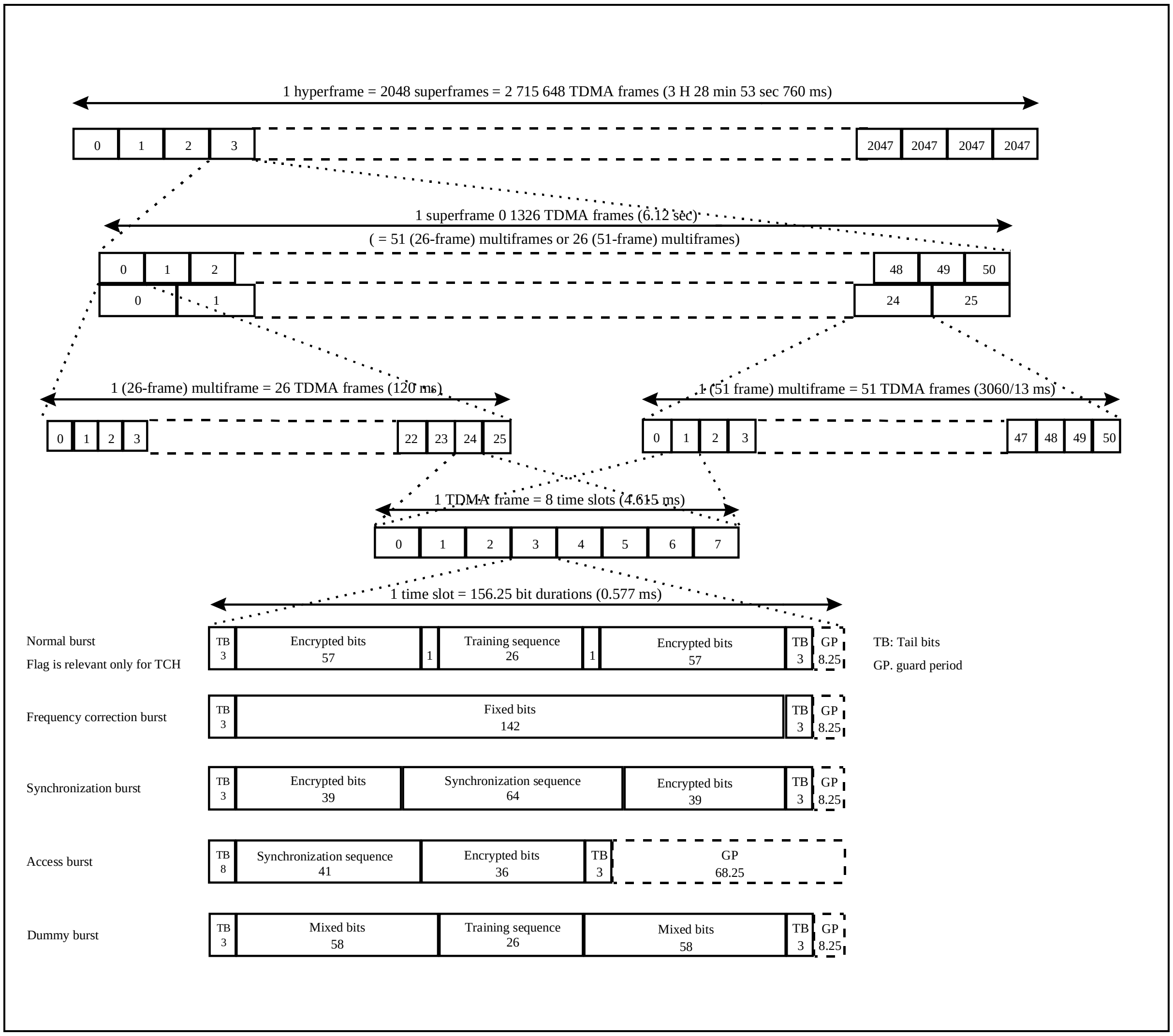
To keep the structure of the air interface unchanged, the half rate channels will still use a burst of the same structure, fitted in a time slot of the same size. Since only half the capacity is needed for speech in a half rate MS, it will use only every second time slot. This means that the MS is left with plenty of time to do other things, such as measuring the signal strength of the neighbouring base stations.



Mapping of full and half rate traffic channels

One half rate MS can also be assigned both half rate channels in a physical channel. This is if the MS is using one channel for speech and one for data.

3.7 Appendix



Summary of frames and bursts

Downlink

	0	1	2	3	4	5	6	7
TDMA frame 0	F	D_0	T	T	T	T	T	T
	S	D_0	T	T	T	T	T	T
	B	D_0	T	T	T	T	T	T
	B	D_0	T	T	T	T	T	T
	B	D_1	T	T	T	T	T	T
	B	D_1	T	T	T	T	T	T
	C	D_1	T	T	T	T	T	T
	C	D_1	T	T	T	T	T	T
	C	D_2	T	T	T	T	T	T
	C	D_2	T	T	T	T	T	T
	F	D_2	T	T	T	T	T	T
	S	D_2	T	T	T	T	T	T
12	C	D_3	A	I	A	I	A	I
	C	D_3	T	T	T	T	T	T
	C	D_3	T	T	T	T	T	T
	C	D_3	T	T	T	T	T	T
	C	D_4	T	T	T	T	T	T
	C	D_4	T	T	T	T	T	T
	C	D_4	T	T	T	T	T	T
	C	D_4	T	T	T	T	T	T
	F	D_5	T	T	T	T	T	T
	S	D_5	T	T	T	T	T	T
	C	D_5	T	T	T	T	T	T
	C	D_5	T	T	T	T	T	T
	C	D_6	T	T	T	T	T	T
25	C	D_6	I	A	I	A	I	A
	C	D_6	T	T	T	T	T	T
	C	D_6	T	T	T	T	T	T
	C	D_7	T	T	T	T	T	T
	C	D_7	T	T	T	T	T	T
	F	D_7	T	T	T	T	T	T
	S	D_7	T	T	T	T	T	T
	C	A_0	T	T	T	T	T	T
	C	A_0	T	T	T	T	T	T
	C	A_0	T	T	T	T	T	T
	C	A_0	T	T	T	T	T	T
	C	A_1	T	T	T	T	T	T
	C	A_1	T	T	T	T	T	T
38	C	A_1	A	I	A	I	A	I
	C	A_1	T	T	T	T	T	T
	F	A_2	T	T	T	T	T	T
	S	A_2	T	T	T	T	T	T
	C	A_2	T	T	T	T	T	T
	C	A_2	T	T	T	T	T	T
	C	A_3	T	T	T	T	T	T
	C	A_3	T	T	T	T	T	T
	C	A_3	T	T	T	T	T	T
	C	A_3	T	T	T	T	T	T
	C	I	T	T	T	T	T	T
	C	I	T	T	T	T	T	T
50	I	I	T	T	T	T	T	T
			I	A	I	A	I	A

Uplink

	0	1	2	3	4	5	6	7
TDMA frame 0	R	A_5	T	T	T	T	T	T
	R	A_5	T	T	T	T	T	T
	R	A_5	T	T	T	T	T	T
	R	A_5	T	T	T	T	T	T
	R	A_6	T	T	T	T	T	T
	R	A_6	T	T	T	T	T	T
	R	A_6	T	T	T	T	T	T
	R	A_6	T	T	T	T	T	T
	R	A_7	T	T	T	T	T	T
	R	A_7	T	T	T	T	T	T
	R	A_7	T	T	T	T	T	T
	R	A_7	T	T	T	T	T	T
12	R	I	A	I	A	I	A	I
	R	I	T	T	T	T	T	T
	R	I	T	T	T	T	T	T
	R	D_0	T	T	T	T	T	T
	R	D_0	T	T	T	T	T	T
	R	D_0	T	T	T	T	T	T
	R	D_0	T	T	T	T	T	T
	R	D_1	T	T	T	T	T	T
	R	D_1	T	T	T	T	T	T
	R	D_1	T	T	T	T	T	T
	R	D_1	T	T	T	T	T	T
	R	D_2	T	T	T	T	T	T
	R	D_2	T	T	T	T	T	T
25	R	D_2	I	A	I	A	I	A
	R	D_2	T	T	T	T	T	T
	R	D_3	T	T	T	T	T	T
	R	D_3	T	T	T	T	T	T
	R	D_3	T	T	T	T	T	T
	R	D_3	T	T	T	T	T	T
	R	D_4	T	T	T	T	T	T
	R	D_4	T	T	T	T	T	T
	R	D_4	T	T	T	T	T	T
	R	D_4	T	T	T	T	T	T
	R	D_5	T	T	T	T	T	T
	R	D_5	T	T	T	T	T	T
	R	D_5	T	T	T	T	T	T
38	R	D_5	A	I	A	I	A	I
	R	D_6	T	T	T	T	T	T
	R	D_6	T	T	T	T	T	T
	R	D_6	T	T	T	T	T	T
	R	D_6	T	T	T	T	T	T
	R	D_7	T	T	T	T	T	T
	R	D_7	T	T	T	T	T	T
	R	D_7	T	T	T	T	T	T
	R	D_7	T	T	T	T	T	T
	R	A_0	T	T	T	T	T	T
	R	A_0	T	T	T	T	T	T
	R	A_0	T	T	T	T	T	T
50	R	A_0	T	T	T	T	T	T
			I	A	I	A	I	A

Mapping of logical channels on C_0