Channel Concept

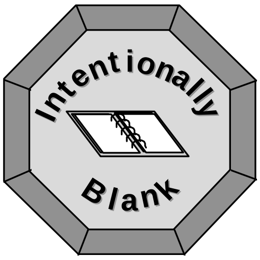
Chapter 2

This chapter is designed to provide the student with an overview of how the channel concept is used on the radio interface.

OBJECTIVES:

Upon completion of this chapter the student will be able to:

- describe different burst formats in the radio interface.
- describe the hierarchical frame structure.
- describe the content sent in different logical channels.
- describe the mapping of the logical channels.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2 Channel Concept

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GENERAL

Cell Allocation (CA) is the subset of the total frequency band that is available for one BTS. It can be viewed as the total transport resource available for traffic between the BTS and its attached MSs. One Radio Frequency CHannel (RFCH) of the CA is used to carry synchronization information and the Broadcast Control CHannel (BCCH). This can be any of the carriers in the cell and it is known as the BCCH carrier or the c_0 carrier.

Strong efficiency and quality requirements have resulted in a rather complex way of utilizing the frequency resource. This chapter describes the basic principles of how to use this resource from the physical resource itself to the information transport service offered by the BTS.

RADIO FREQUENCY CARRIERS

Table 2-1 shows the frequency bands allocated to each system.

Table 2-1 Frequency bands.

	GSM 900	GSM 1800	GSM 1900
Uplink	890 - 915 MHz	1710 - 1785 MHz	1850 - 1910 MHz
Downlink	935 - 960 MHz	1805 - 1880 MHz	1930 - 1990 MHz

Carrier separation is 200 kHz, which provides:

- 124 pairs of carriers in the GSM 900 band
- 374 pairs of carriers in the GSM 1800 band
- 299 pairs of carriers in the GSM 1900 band

Using Time Division Multiple Access (TDMA) each of these carriers are divided into eight Time Slots (TS). One TS on a TDMA frame is called a physical channel**,** i.e. on each duplex pair of carriers there are eight physical channels.

A variety of information is transmitted between the BTS and the MS. The information is grouped into different logical channels. Each logical channel is used for a specific purpose such as paging, call set-up and speech. For example, speech is sent on the logical channel Traffic CHannel (TCH). The logical channels are mapped onto the physical channels.

LOGICAL CHANNELS

The logical channels can be separated into two categories. They are traffic channels and signaling channels.

There are two forms of TCHs:

- Bm or full rate TCH (TCH/F) - this channel carries information at a gross rate of 22.8 kbit/s.
- Lm or half rate TCH (TCH/H) - this channel carries information at a gross rate of 11.4 kbit/s.

Signaling channels are subdivided into three categories:

- Broadcast CHannels (BCH)
- Common Control CHannels (CCCH)
- Dedicated Control CHannels (DCCH)

The following sections describe specific channels within these categories.

BROADCAST CHANNELS (BCH)

Frequency Correction CHannel (FCCH)

On FCCH, bursts only containing zeroes are transmitted. This serves two purposes. First to make sure that this is the BCCH carrier, and second to allow the MS to synchronize to the frequency. FCCH is transmitted downlink only.

Synchronization CHannel (SCH)

The MS needs to synchronize to the time-structure within this particular cell, and also ensure that the chosen BTS is a GSM base station. By listening to the SCH, the MS receives information about the frame number in this cell and about BSIC (see Appendix) of the chosen BTS. BSIC can only be decoded if the base station belongs to the GSM network. SCH is transmitted downlink only.

Broadcast Control CHannel (BCCH)

The MS must receive some general information concerning the cell in order to start roaming, waiting for calls to arrive or making calls. The needed information is broadcast on the

Broadcast Control CHannel (BCCH) and includes the Location Area Identity (LAI), maximum output power allowed in the cell and the BCCH carriers for the neighboring cells on which the MS performs measurements. BCCH is transmitted on the downlink only.

Using FCCH, SCH, and BCCH the MS tunes to a BTS and synchronized with the frame structure in that cell. The BTSs are not synchronized to each other. Therefore, every time the MS camps on another cell, it must listen to FCCH, SCH and BCCH in the new cell.

COMMON CONTROL CHANNELS (CCCH)

Paging CHannel (PCH)

At certain time intervals the MS listens to the PCH to check if the network wants to make contact with the MS. The reason why the network may want to contact the MS could be an incoming call or an incoming short message. The information on PCH is a paging message, including the MS's identity number (IMSI) or a temporary number (TMSI). PCH is transmitted downlink only.

Random Access CHannel (RACH)

The MS listens to the PCH to determine when it is being paged. When the MS is paged, it replies on the RACH requesting a signaling channel. RACH can also be used if the MS wants to contact the network. For example, when setting up a mobile originating call. RACH is transmitted uplink only.

Access Grant CHannel (AGCH)

The networks assigns a signaling channel (Stand alone Dedicated Control CHannel (SDCCH)) to the MS. This assignment is performed on the AGCH. AGCH is transmitted downlink only.

DEDICATED CONTROL CHANNELS (DCCH)

Stand alone Dedicated Control CHannel (SDCCH)

The MS as well as the BTS switches over to the assigned SDCCH. The call set-up procedure is performed on the SDCCH, as well as the textual message transmission (short message and cell broadcast) in idle mode. SDCCH is transmitted both uplink and downlink.

When call set-up is performed, the MS is told to switch to a TCH.

Slow Associated Control CHannel (SACCH)

The SACCH is associated with SDCCH or TCH (i.e. sent on the same physical channel). On the uplink, the MS sends averaged measurements on its own BTS (signal strength and quality) and neighboring BTSs (signal strength). On the downlink, the MS receives information concerning the transmitting power to use and instructions on the timing advance. SACCH is transmitted both uplink and downlink.

Fast Associated Control CHannel (FACCH)

If a handover is required the FACCH is used. FACCH works in stealing mode meaning that one 20 ms segment of speech is exchanged for signaling information necessary for the handover. Under normal conditions the subscriber does not notice the speech interruption because the speech coder repeats the previous speech block.

Cell Broadcast CHannel (CBCH)

CBCH is only used downlink to carry Short Message Service Cell Broadcast (SMSCB) and uses the same physical channel as the SDCCH.

CHANNEL COMBINATIONS

Only certain combinations of logical channels are permitted according to the GSM recommendations. The figure below shows the way in which logical channels can be combined on to Basic Physical Channels (BPC). Numbers appearing in brackets after channel designations indicate sub-channel numbers. A sub-channel is formed by taking a part of a BPC within a multiframe structure and treating it as a separate resource.

(i)	TCH/F + FACCH/F + SACCH/TF
(ii)	TCH/H(0.1) + FACCH/H(0.1) + SACCH/TH(0.1)
(iii)	TCH/H(0) + FACCH/H(0) + SACCH/TH(0) + TCH/H(1)
(iv)	FCCH + SCH + BCCH + CCCH
(v)	FCCH + SCH + BCCH + CCCH + SDCCH/4(0...3) + SACCH/C4(0...3)
(vi)	BCCH + CCCH
(vii)	SDCCH/8(0...7) + SACCH/C8(0...7)
(viii)	TCH/F + FACCH/F + SACCH/M
(ix)	TCH/F + SACCH/M
(x)	TCH/FD + SACCH/MD

Where CCCH = PCH + AGCH + RACH

Figure 2-1 Permitted channel combinations.

SACCH/T means that SACCH is associated with a TCH while SACCH/C is associated with a control channel.

Where the SMSCB is supported, the CBCH replaces SDCCH sub-channel 2 in cases (v) and (vii) above.

A combined CCCH/SDCCH allocation (case v) above may only be used when no other CCCH channel is allocated.

The difference between channel combinations (ii) and (iii) is that combination (ii) addresses two different MSs, while combination (iii) addresses one single MS using both half rate traffic channels. For example, one for speech and the other for data.

Channel combinations from (viii) through (x) are used for multislot configurations (e.g. High Speed Circuit Switched Data, described in more detail in chapter 3), the postfix /M standing for “multislot”, /MD - “multislot downlink”.

In Ericsson’s GSM system the operator can also use the Adaptive Configuration of the SDCCH’s feature. Time slots can be automatically reconfigured by the BSC to support channel combinations (i) or (vii), depending on the traffic situation in the cell. This means that the number of TCH and SDCCH channels will change according to needs (heavy SMS traffic requiring high SDCCH capacity, multislot data transmission with big TCH needs, etc.) The reconfiguration is preformed per BPC and takes about two seconds.

MAPPING OF LOGICAL CHANNELS

FCCH+SCH+BCCH+CCCH

TS 0 of radio frequency c_0, downlink, of a cell allocation must support one of the channel combinations (iv) or (v) described in the previous section.

An idle MS searches for the frequency correction channel. When the MS finds the frequency correction burst it knows that this is time slot 0 on c_0. Note that the BCCH carrier, c_0, in one cell need not be equal to c_0 in another cell using the same channel allocation. c_0 is only used in GSM recommendations to name the frequency which carries the BCCH within a cell. In addition, c_0 need not be the lowest frequency used in the cell.

Channel combination (iv) multiplexing is shown in Figure 2-2. There is a cycle of 51 TDMA frames (0-50), although only time slot 0 from each frame is shown. The cycle means that the F, S, B structure is repeated after the idle frame (which appears in frame number 50). The four frames carrying CCCH information are called a paging block. In 51 TDMA frames there are 9 paging blocks.

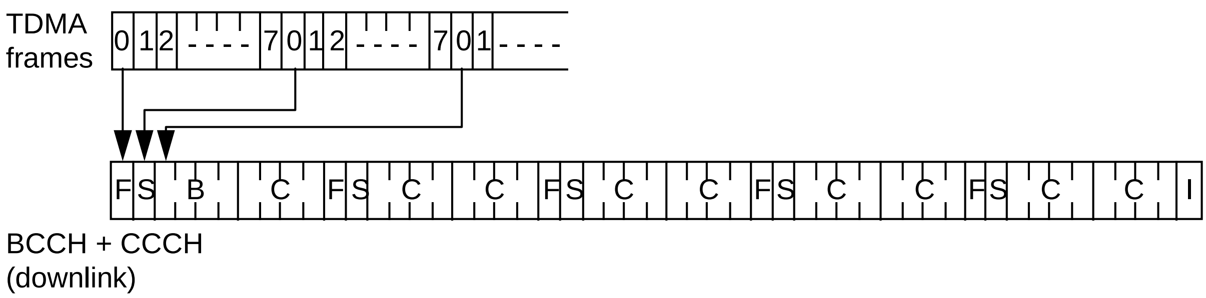


Figure 2-2 Multiplexing of channel combination (iv) on c_0 TS 0, downlink.

F (FCCH)	Frequency Correction CHannel
S (SCH)	Synchronization CHannel
B (BCCH - Norm)	Broadcast Control CHannel - normal
C (CCCH)	Common Control CHannel: Paging CHannel (PCH) or Access Grant CHannel (AGCH)
I	Idle

BCCH extended means that the first CCCH block can be used for transmission of system information instead of PCH or AGCH. The channels are shared on a block by block basis, and information within each block, when de-interleaved and decoded allows a MS to determine whether the block contains paging messages, system information messages or access grant.

TS 0 on uplink does not contain the channels above. It is used by MSs for access. This means that only the RACH is sent on this TS.

SDCCH+SACCH

Channel combination (vii), SDCCH and SACCH can be transmitted on any TS and any carrier, except for time slot 0 on c_0. The default time slot and carrier in Ericsson's GSM system is TS 2 on c_0.

Since the bit rate during call set-up and registration is low, using channel combination (vii) eight MSs can share one TS for signaling. The eight channels are called sub-channels.

Multiplexing of channel combination (vii) is shown in Figure 2-3. The structure shown is cyclic over 102 frames. The first four times that TS 2 occurs in the 51 TDMA frame, the channel is used for the first MS. The next four times TS 2 occurs, signaling for the second MS is exchanged, and so on. Note that the uplink and downlink patterns are time shifted, so that SDCCH sub-channel 0 is sent in frames 0-3 on downlink, and in frames 15-18 on uplink. The reason for this is to achieve more efficient communication, by giving the MS time to calculate its answers to the requests received on downlink SDCCH.

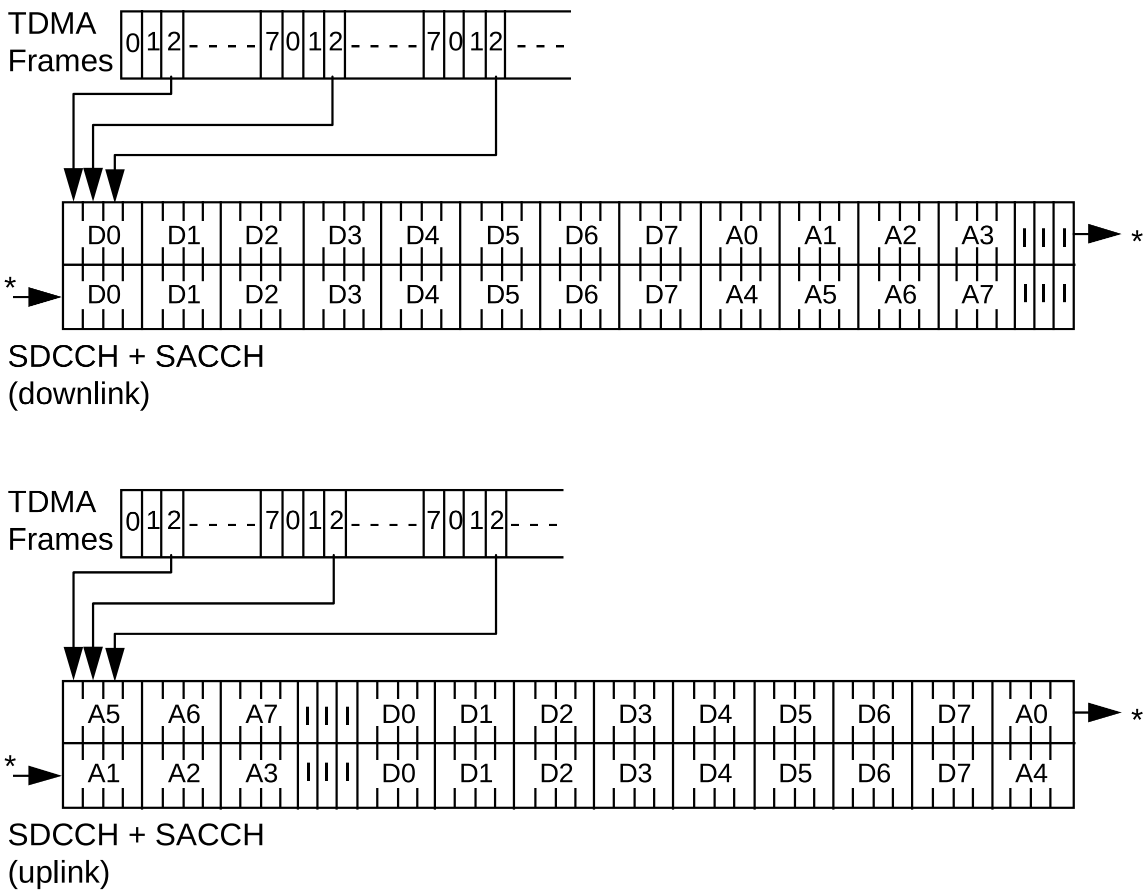


Figure 2-3 Multiplexing of dedicated control channels, downlink and uplink, channel combination (vii).

Dx (SDCCH)	Stand alone Dedicated Control CHannel
Ax (SACCH)	Slow Associated Control CHannel
x	Sub-channel number, 0-7
I	Idle

In Figure 2-3 TS 2 has been used for channel combination (vii).

TCH

With channel combinations (i), (iv) and (vii) used in a cell, TSs 0 and 2 on c_0 are occupied by the control channels. This leaves TSs 1 and 3 - 7 free for the use by TCHs.

TCHs are mapped onto the physical channels with the SACCH, as shown in Figure 2-4. In the figure the information in TS 1 forms a TCH. The repetition is cyclic over 26 frames, which means that the repetition time is 120 ms.

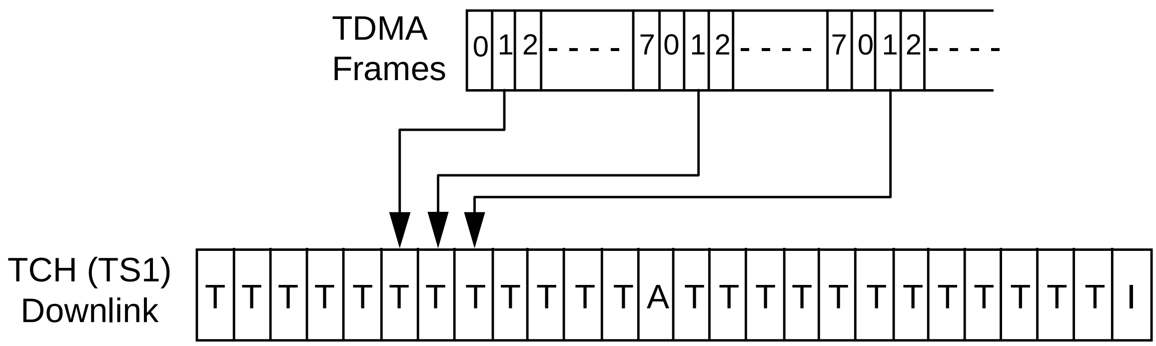


Figure 2-4 Multiplexing of TCH, channel combination (i).

T (TCH)	Traffic CHannel
A (SACCH)	Slow Associated Control CHannel
I	Idle

FACCH is also used together with the TCH, but it is not included in the figure because it works in stealing mode, stealing bursts of speech and replacing them with signaling.

When looking at all figures, except Figure 2-5, in this chapter showing the different channels, it is important to remember that only every eighth TS in each TDMA frame is shown.

Another way of describing the channel combinations (i), (iv) and (vii) is shown in Figure 2-5. Note that the repetition of channel combination (i), (ii) and (iii) is 26 TDMA frames, while for (iv) and (vi) it is 51 TDMA frames and for (v) and (vii) it is 102.

Carrier C_0	Downlink								Uplink							
	0	1	2	3	4	5	6	7	0	1	2	3	4	5	6	7
Frame 0	F	T	D_0	T	T	T	T	T	R	T	A_5	T	T	T	T	T
	S	T	D_0						R	T	A_5					
	B	T	D_0						R	T	A_5					
	B	T	D_0						R	T	A_5					
	B	T	D_1						R	T	A_6					
	B	T	D_1						R	T	A_6					
	C	T	D_1						R	T	A_6					
	C	T	D_1						R	T	A_6					
	C	T	D_2						R	T	A_7					
	C	T	D_2						R	T	A_7					
	F	T	D_2						R	T	A_7					
	S	T	D_2						R	T	A_7					
12	C	A	D_3	I	A	I	A	I	R	A	I	I	A	I	A	I
	C	T	D_3						R	T	I					
	C	T	D_3						R	T	I					
	C	T	D_3						R	T	D_0					
	C	T	D_4						R	T	D_0					
	C	T	D_4						R	T	D_0					
	C	T	D_4						R	T	D_0					
	C	T	D_4						R	T	D_1					
	F	T	D_5						R	T	D_1					
	S	T	D_5						R	T	D_1					
	C	T	D_5						R	T	D_1					
	C	T	D_5						R	T	D_2					
	C	T	D_6						R	T	D_2					
25	C	I	D_6	A	I	A	I	A	R	I	D_2	A	I	A	I	A
	C	T	D_6						R	T	D_2					
	C	T	D_6						R	T	D_3					
	C	T	D_7						R	T	D_3					
	C	T	D_7						R	T	D_3					
	F	T	D_7						R	T	D_3					
	S	T	D_7						R	T	D_4					
	C	T	A_0						R	T	D_4					
	C	T	A_0						R	T	D_4					
	C	T	A_0						R	T	D_4					
	C	T	A_0						R	T	D_5					
	C	T	A_1						R	T	D_5					
	C	T	A_1						R	T	D_5					
38	C	A	A_1	I	A	I	A	I	R	A	D_5	I	A	I	A	I
	C	T	A_1						R	T	D_6					
	F	T	A_2						R	T	D_6					
	S	T	A_2						R	T	D_6					
	C	T	A_2						R	T	D_6					
	C	T	A_2						R	T	D_7					
	C	T	A_3						R	T	D_7					
	C	T	A_3						R	T	D_7					
	C	T	A_3						R	T	D_7					
	C	T	A_3						R	T	A_0					
	C	T	I						R	T	A_0					
	C	T	I						R	T	A_0					
50	I	T	I						R	T	A_0					

Figure 2-5 Mapping of logical channels on the BCCH-carrier.

Half rate channels

So far, this chapter has described full rate TCH and SACCH/T which uses all of the allocated resources (all 26 time slots in a multiframe). When half rate traffic channels are implemented in the system, traffic capacity will double. Two users share the same physical channel when channel combinations (ii) and (iii) are used. This is illustrated in Figure 2-6.

Using half rate channels, the Idle frame from the full rate channel will be used for SACCH signaling for the second MS. Since the MSs only use every other time slot for the call, the multiframe will contain 13 idle frames for each MS. Using channel combination (iii), one mobile can also be allocated two traffic channels. For example, one for speech and the other for data.

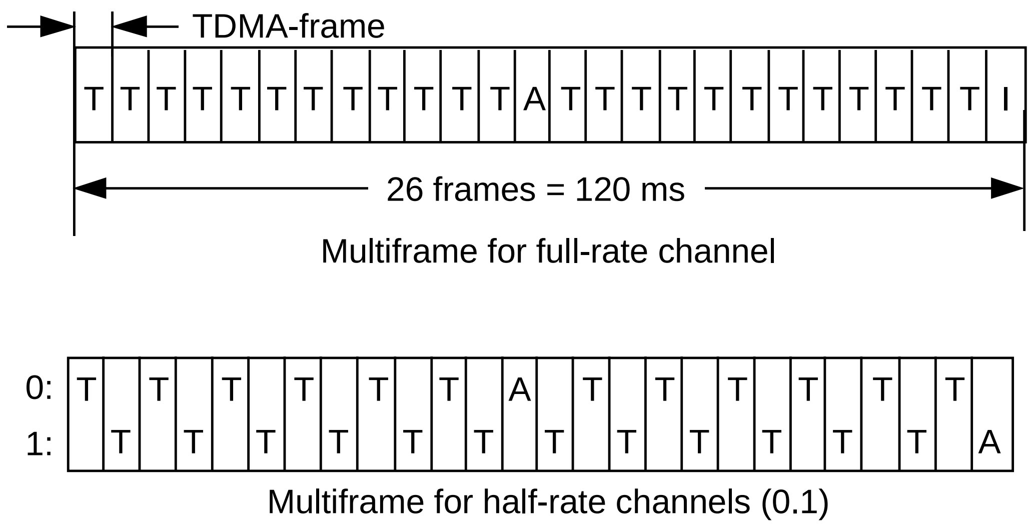


Figure 2-6 Traffic channels, full rate and half rate, channel combinations (i), (ii) and (iii).

COMBINED CCCH AND EXTRA PAGING CAPACITY

In low capacity areas where cells have only one carrier it may be practical to use only one TS for signaling, and the other seven for traffic. The disadvantage with this procedure is that the SDCCH signaling capacity and the paging capacity decrease: 4 SDCCH/SACCH and 3 paging blocks per 51 TDMA frames. Figure 2-7 illustrates channel combination (v). Channel combination (vi) is a complement to channel combination (iv) and is used in the opposite case from combination (v). T Center hat is, when more paging capacity than one TS can provide is needed, see Figure 2-8. All CCCHs must use TSs on radio frequency c_0 of the cell allocation. The first CCCH must use TS number 0, the second TS number 2, the third TS number 4 and the fourth TS number 6.

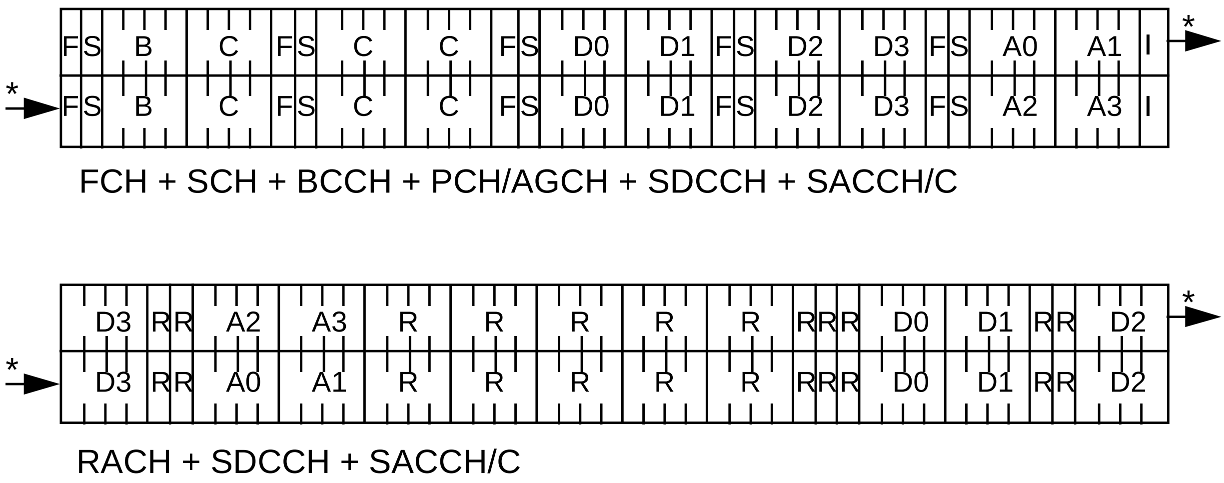


Figure 2-7 Multiplexing of all logical control channels on one TS, channel combination (v).

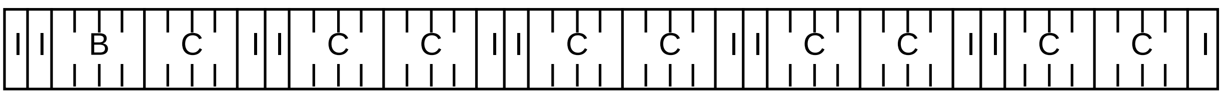


Figure 2-8 Channel combination (vi).

Paging Groups

From system information (see chapter 5) MSs get information about the number of BPCs supporting CCCH, if combined mapping is used, and the number of 51 multiframes in a paging cycle (i.e. the number of 51 multiframes between transmission of paging messages to the same paging group). The MSs calculate which CCCH and which paging group they belong to using this information and the IMSI number (described in GSM TS 05.02). MSs in a specific paging group listen for paging messages and make random accesses on the specific CCCH only.

The maximum number of 51 multiframes in a paging cycle is 9. Using non-combined mapping this yields a maximum of 81 (9×9) paging groups (for each BPCs supporting CCCH). If combined mapping is used the maximum number of paging groups is 27 (9×3)

To ensure that an MS has satisfactory access to the system, a variable number of the available CCCH blocks in each 51 multiframe can be reserved for AGCH only. In Ericsson's GSM system, no blocks are reserved for AGCH, since AGCH has priority over PCH. CCCH blocks are also reserved if BCCH extended or CBCH is used. The number of blocks reserved is found in the system information, so that the MS can determine the number of paging groups available.

TIME SLOTS AND TDMA FRAMES

A TS has a duration of 3/5200 seconds (577 µs). Eight TSs form a TDMA frame, with approximately 4.62 ms duration. At the BTS the TDMA frames on all of the radio frequency channels in the downlink direction are aligned. The same applies to the uplink.

The start of a TDMA frame on uplink is, however, delayed by a fixed time corresponding to three TS periods as shown in Figure 2-9. The reason for this delay is to allow the same TS number to be used in both uplink and downlink directions without requiring the MS to receive and transmit simultaneously.

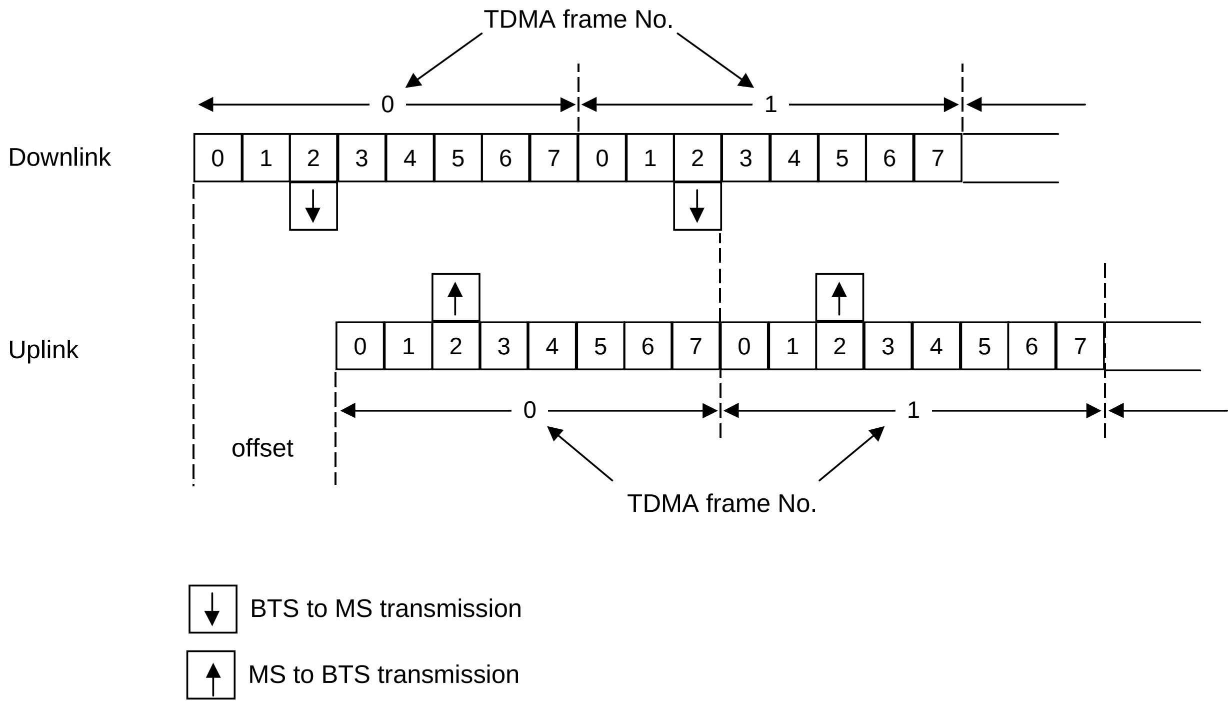


Figure 2-9 TDMA offset.

HYPERFRAMES, SUPERFRAMES AND MULTIFRAMES

Figure 2-10 shows all the frame structures. The longest recurrent time period of the structure is called hyperframe and has the duration of 3 h 28 min 53 sec 760 ms. The TDMA Frame Numbers (FN) are numbered from 0 to 2 715 647. Such a long period is needed for the support of cryptographic mechanisms.

One hyperframe is divided into 2048 superframes, which have a duration of 6.12 seconds.

The superframe is itself subdivided into multiframes. There are two types of multiframes in the system:

- 26 frame multiframe (51 per superframe) with a duration of 120 ms, comprising 26 TDMA frames. This multiframe is used to carry the logical channels TCH, SACCH and FACCH which are described in this chapter.
- 51 frame multiframe (26 per superframe) with a duration of 235.4 ms, comprising 51 TDMA frames. This multiframe is used to carry the logical channels FCCH, SCH, BCCH, CCCH, SDCCH, SACCH, and CBCH which are described in this chapter.

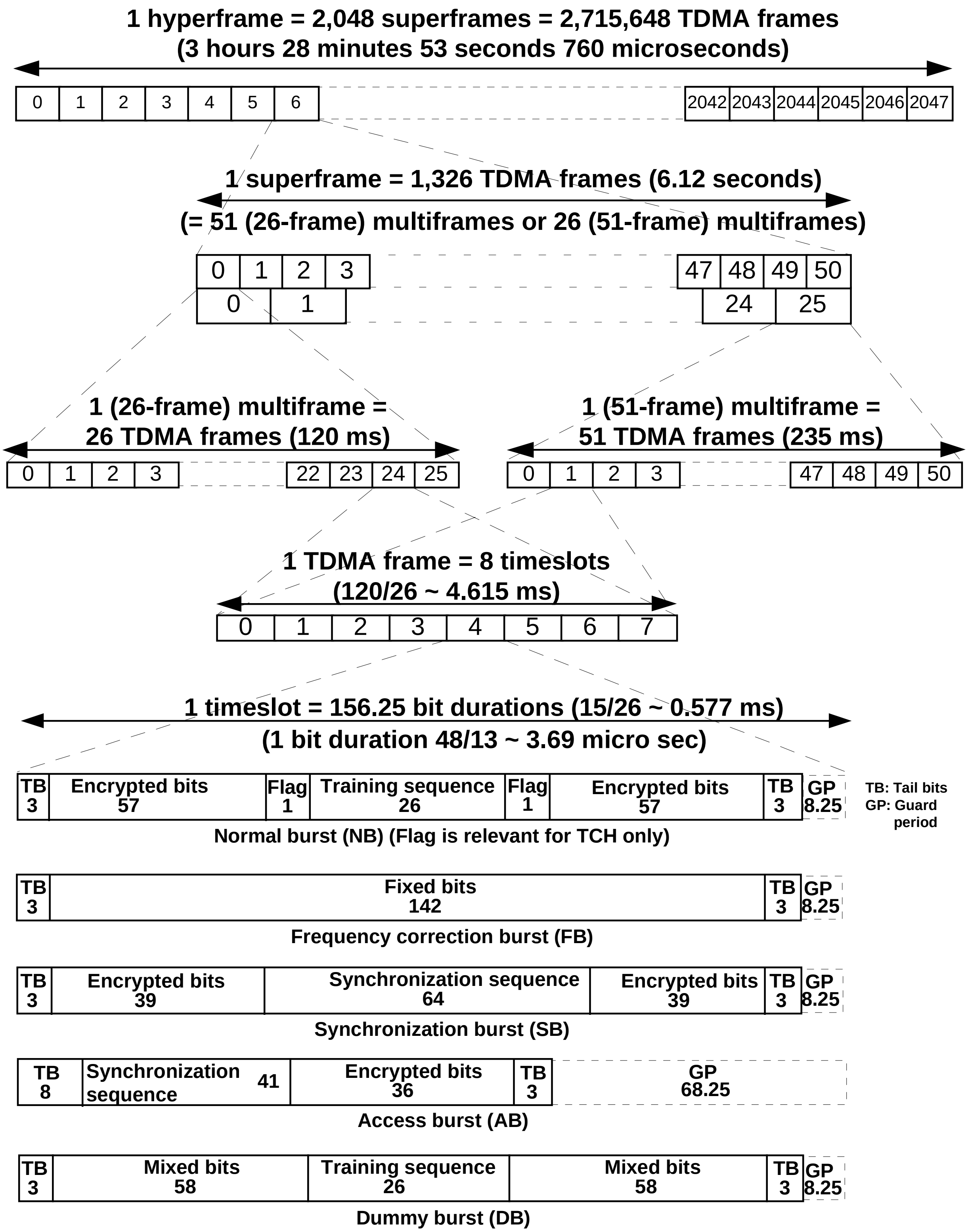
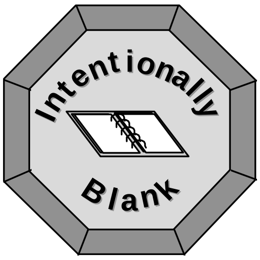


Figure 2-10 Bursts and frames.

BURST FORMATS

The bit rate over the air interface is 270.8 kbps. This gives a bit time of 3.692 µs (48/13 µs). The time interval of a TS thus corresponds to 156.25 bits. The physical content of a TS is called a burst. There are five different types of bursts. A diagram of these bursts is shown in Figure 2-10.

- Normal Burst (NB): This burst is used to carry information on traffic and control channels. For TCH it contains 114 encrypted bits, and includes a guard time of 8.25 bit duration (30.46 µs). The stealing flag is relevant only for TCH which is described in this chapter.
- Frequency correction Burst (FB): This burst is used for frequency synchronization of the MS. It consists of zeroes only. The repetition of FBs is also named Frequency Correction CHannel (FCCH) which is described in this chapter.
- Synchronization Burst (SB): This burst is used for time synchronization of the MS. It contains a long training sequence and carries the information of the TDMA Frame Number (FN) and Base Station Identity Code (BSIC). The repetition of synchronization bursts is also called Synchronization CHannel (SCH) which is described in this chapter.
- Access Burst (AB): This burst is used for random access and handover access. It is characterized by a long guard period (68.25 bit duration or 252 µs), to cater for burst transmission from a MS that does not know the timing advance at the first access (or at handover). This allows for a cell radius of 35 km. The access burst is used on the Random Access CHannel (RACH) and on the Fast Associated Control CHannel (FACCH) at handover.
- Dummy Burst: This burst is transmitted on radio frequency c_0 when no other type of burst is to be sent. This means that the base station always transmits on the frequency carrying the system information, thus making it possible for the MSs to perform power measurements on the BTS in order to determine which BTS to use for initial access or which to use for handover. In order to achieve this, a dummy page and a dummy burst is defined in the GSM recommendations. CCCH is replaced by the dummy page, when there is no paging message to transmit. This dummy page is a page to a non-existing MS. In the other TSs not being used, a dummy burst with a pre-defined set of fixed bits is transmitted.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