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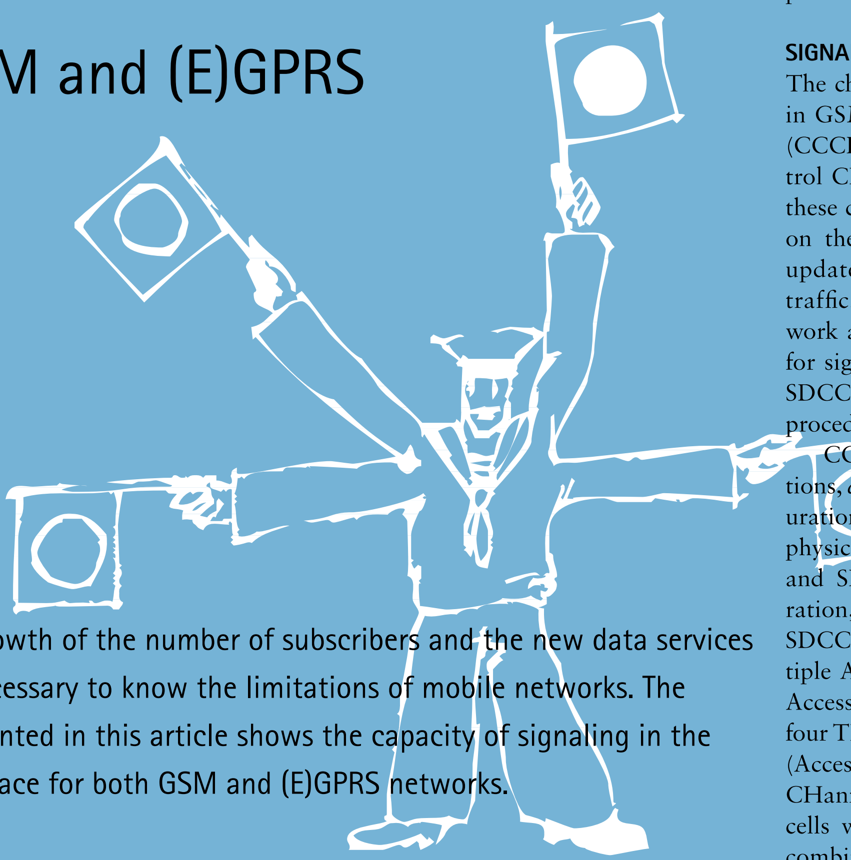
SIZING UP SIGNALING CAPACITY

in GSM and (E)GPRS



The fast growth of the number of subscribers and the new data services make it necessary to know the limitations of mobile networks. The study presented in this article shows the capacity of signaling in the radio interface for both GSM and (E)GPRS networks.

The new (E)GPRS ((Enhanced) General Packet Radio Service) data services require much signaling between mobile stations and networks, hence it must be known how to size the channels used for the signaling procedures involved, and what their limitations are. Likewise, (E)GPRS can either share the same resources for signaling used in GSM or have dedicated ones, so both possibilities are analyzed in terms of capacity. However, there are other advantages for using the latter option, which will be described here.

CAPACITY CRITERION

The usual way to size the traffic channels for voice calls in GSM is to use the Erlang-B formula, which associates a number of channels, a traffic load, and a blocking probability, while assuming a blocking probability equal to 2%. This means that two calls out of one hundred could be blocked due to a traffic channel congestion and the network would still be considered as exhibiting proper behavior. However, calls could also be blocked due to a lack of resources in the signaling channels. Thus, the capacity of the signaling channels should be derived for a determined blocking probability. There are several approaches to solve this problem.

The first intuitive idea is to use a low blocking probability for the signaling procedures, so that all the blocking is caused by lack of resources for traffic channels. In this way, a blocking probability ten times less can be used (0.2%). The second criterion could be to allow more blocking in order not to oversize the resources for signaling purposes. This method makes it reasonable to check the capacity of signaling channels for a blocking probability of 1% and 2%. Consequently, the capacity of the signaling channels will be obtained for a blocking probability of 0.2%, 1%, and 2%.

SIGNALING CAPACITY FOR GSM

The channels used for signaling purposes in GSM are Common Control CHannel (CCCH) and Stand-alone Dedicated Control CHannel (SDCCH). The capacity of these channels in GSM networks depends on the call establishments, the location updates, and the Short Message Service traffic. CCCH is used to access the network and to reserve the resources needed for signaling (one SDCCH channel), and SDCCH serves for the rest of the signaling procedure.

CCCH has two possible configurations, *combined* and *non-combined* configurations, depending on whether or not the physical channel is shared between CCCH and SDCCH. In the combined configuration, the physical channel carries four SDCCH, 27 TDMA (Time Division Multiple Access) frames for RACH (Random Access CHannel), and three blocks out of four TDMA frames shared between AGCH (Access Grant CHannel) and PCH (Paging CHannel). This configuration is used for cells with low traffic loads. In the non-combined configuration, CCCH uses a full time slot, so RACH has 51 TDMA frames, and nine blocks of four TDMA frames are shared by AGCH and PCH. SDCCH is carried over another physical channel(s), with eight SDCCH subchannels per physical channel. This configuration is used for cells with normal or high traffic loads. Both configurations are described in Figure 1.

There are two basic procedures using these channels, one for a mobile-originated call (or message) and another for mobile-terminated call (or message), as depicted in Figure 2. For a mobile-originated call or message, the mobile station performs a random access on RACH. Then, the network reserves resources for the signaling of the call (or message) and sends an Immediate Assignment on AGCH. Thus, the mobile station can make use of the reserved resources (a SDCCH subchannel) and signals the establishment of the call (or sends a location update or an SMS message). When the mobile station finishes the signaling procedure, the resources are released. The signaling in a mobile-terminated call is performed in the same way, but a paging request is sent first by the network to the mobile station on PCH.

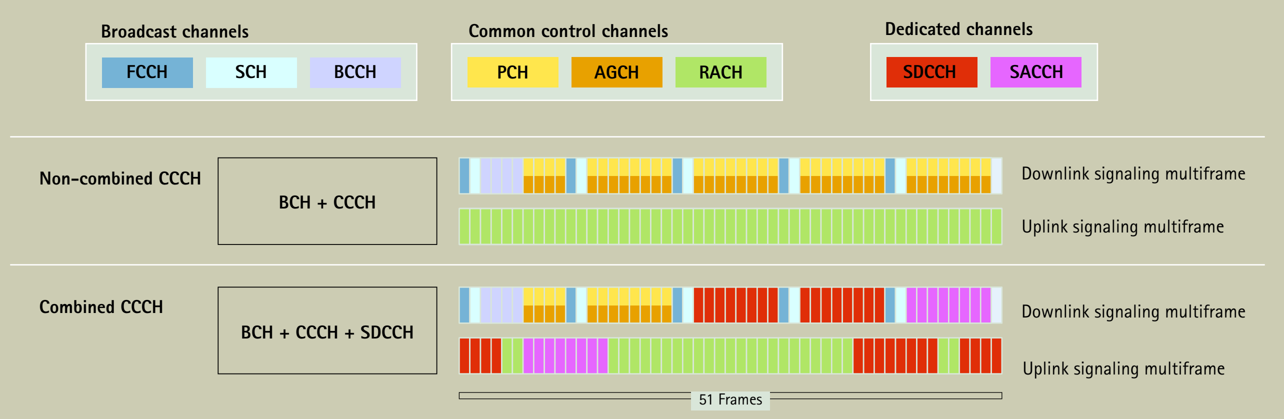


FIGURE 1: Multiframe structures for combined CCCH and non-combined CCCH configurations

• Modeling

The signaling procedures can be modeled using queue systems. If a request to send a message fails because there are no free resources then the request is queued to wait for these resources to be released. These queue systems are illustrated in Figure 3. The queue systems are complex (because they have more than one queue) so they cannot be represented analytically. Also, the use of timers and reattempts adds more complexity. Thus, a simulator was developed in order to determine the real capacity of these channels taking into account these and other issues, i.e., collisions in the random access (see **[1]**).

• Methodology

The procedure used to find out the capacity of the signaling channels is different for SDCCH and CCCH because, as it will be shown, the limitation for signaling in GSM networks is due to SDCCH. Thus, the other channels will be oversized and the capacity of SDCCH will be calculated by searching for the load which makes the blocking probability equal to the desired value, since almost all the blocking in a real configuration will be due to SDCCH. However, for CCCH, the capacity of each type of channel is calculated for a blocking probability of 0.1%, 0.5%, and 1% (half than allowed blocking). The reason for this decision is that it is easier to compute the capacity of each channel in a separated way, but in a real configuration the other channels can cause blocking. By using a smaller blocking probability it can be assumed that the blocking probability is not going to exceed 0.2%, 1%, and 2%, respectively.

• Results

Table 1 summarizes the results obtained with the simulator, with two assignments per AGCH block (using the Immediate Assignment Extended feature) and three pages per PCH block. The main conclusions are the number of transceivers that can be supported with these signaling channels depending on their configuration. They are calculated using the value of the capacity (with a blocking probability of 2%) for a given configuration, translating it to traffic load (Erlangs) and then computing, with the Erlang-B formula, the number of channels needed for a blocking probability of 2%.

The recommended distribution of blocks shared between AGCH and PCH are one PCH block and two AGCH blocks for combined configuration, and four PCH blocks and five AGCH blocks for non-combined configuration. These distributions have approximately the same capacity for PCH and AGCH, because if they have

SPEAKING IN SIGNALS

AGCH	Access Grant CHannel (GSM)	**PCH**	Paging CHannel (GSM)
BCH	Broadcast CHannel	**PCCCH**	Packet Common Control CHannel (GPRS)
BCCH	Broadcast Control CHannel (GSM)	**PDTCH**	Packet Data Traffic CHannel (GPRS)
CCCH	Common Control CHannel (GSM)	**PPCH**	Packet Paging CHannel (GPRS)
(E)GPRS	(Enhanced) General Packet Radio Service	**PRACH**	Packet Random Access CHannel (GPRS)
FCCH	Frequency Control CHannel (GSM)	**RACH**	Random Access CHannel (GSM)
GSM	Global System for Mobile communication	**SACCH**	Slow Associated Control CHannel (GSM)
PACCH	Packet Associated Control CHannel (GPRS)	**SDCCH**	Stand-alone Dedicated Control CHannel (GSM)
PAGCH	Packet Access Grant CHannel (GPRS)	**SGSN**	Serving GPRS Support Node (GPRS)
PBCCH	Packet Broadcast Control CHannel (GPRS)	**TDMA**	Time Division Multiple Access

different capacity, one of these channels would limit the capacity while the other would be oversized.

SIGNALING CAPACITY FOR (E)GPRS

There are two possibilities for signaling in (E)GPRS: using the existing CCCH or including a new one, Packet Common Control CHannel (PCCCH). The procedures for both possibilities are similar to those for GSM, but paging messages are sent only if the mobile station is in Mobility Management STANDBY state, which it enters when a timer expires after it finishes transmitting and/or receiving data. This is due to the fact that the SGSN (Serving GPRS Support Node) has no exact knowledge of the location of the mobile station, so the network has to send a paging message in all the cells inside the routing area in order to contact the mobile station. Also, the downlink assignment messages are sent on (P)PCH.

In order to obtain the blocking due to (E)GPRS data sessions, the following types of communications have been implemented in the simulator: e-mail downloading, web browsing, and WAP. It is assumed that all these traffic sources have the same probability of occurrence.

• GSM & (E)GPRS sharing CCCH

The main objective is to find out the remaining capacity in this channel that can be used for signaling purposes in GPRS without decreasing the performance for GSM calls. In order to obtain this free capacity some simulations have been performed using the maximum GSM traffic load in a large cell, which is obtained for a Base Transceiver Station with twelve transceivers and using the Erlang-B blocking probability for the traffic channels (12 TRXs x 8 channels/TRX – 1 channel for CCCH = 95 traffic channels). Using the Erlang-B formula, this maximum GSM load for a blocking probability of 2% is 83.2 Erlangs.

The simulations were performed for two examples of configurations: combined configuration with twelve SDCCH subchannels, and non-combined configuration with eight SDCCH subchannels. Table 2 summarizes these results.

• Conclusions about CCCH

With the traffic models used, the average amount of data per session is 4.4e5 bits. In order to give a first approximation of the number of additional TRXs that can be supported for (E)GPRS sessions, it is assumed that the TRXs are transmitting/receiving all the time and using CS-2. With such an assumption, one TRX can transmit 3.3e8 bits per hour. In this way, one TRX can carry 750 sessions per hour. Thus, the number of TRXs that can be supported, with one CCCH and this high GSM load, are one to two for combined configuration and two to six for non-combined configuration, depending on the allowed blocking probability.

• (E)GPRS using PCCCH

The Packet Common Control Channel (PCCCH) is a new channel introduced for (E)GPRS capable cells. The physical channel that carries it has twelve available blocks in the uplink direction and another twelve in the downlink direction. They are shared by PRACH (Packet Random Access CHannel), PACCH (Packet Associated Control CHannel) and PDTCH (Packet Data Traffic CHannel) in the uplink, and by PBCCH (Packet Broadcast Control CHannel), PAGCH (Packet Access Grant CHannel), PPCH (Packet Paging CHannel), PACCH and PDTCH in the downlink. However, the PCCCH traffic takes priority over the PDTCH / PACCH traffic, so it can be assumed that the maximum capacity is given by this number of blocks.

For these simulations the average number of pages per PCH block was three, and only one assignment per AGCH block was used, since the Immediate Assignment Extended feature is not supported by PCCCH.

• Conclusions about PCCCH

The recommended distribution of blocks that are shared between PAGCH and PPCH is that which makes the capacity of these channels approximately equal. Thus, seven blocks should be reserved for PAGCH and the remaining four blocks for PPCH, as is shown in Table 2. As commented before, one TRX can carry about 750 sessions per hour, so with this distribution of the shared blocks, from six to eight additional TRXs dedicated entirely for (E)GPRS can be supported with one PCCCH.

• Comparing CCCH and PCCCH

As was uncovered, PCCCH has more capacity than CCCH. However, using non-combined configuration and a blocking probability of 2%, the capacity of these two channels are similar. Also, the capacity of CCCH was calculated with a high load of GSM calls. Thus, if this load decreases, the remaining capacity for (E)GPRS communications would increase.

Nevertheless, PCCCH has other advantages that make it recommendable. For instance, the signaling for GSM and (E)GPRS are independent (with some exceptions). The frequency lists and the cell reselection criteria are also different for both of them, allowing the operator to chose the cells that can be selected in each case. ■

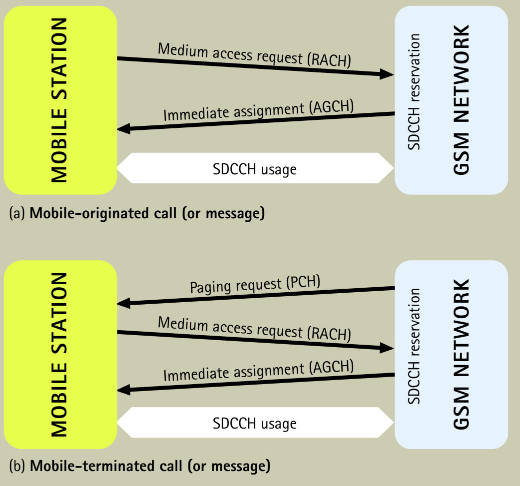


FIGURE 2: Signaling procedures for (a) mobile-originated and (b) mobile-terminated calls (or messages) in a GSM network

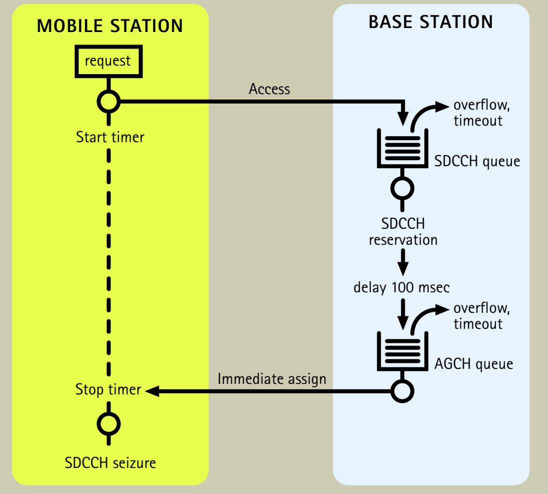


FIGURE 3: Example of a signaling procedure modeled with queue systems

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TABLE 1. **Capacity of signaling channels for GSM**

Blocking probability	CCCH shared between GSM & (E)GPRS		PCCCH		
	Combined configuration (+12 SDCCH)	Non combined configuration (+8 SDCCH)	PRACH (12 blocks)	PAGCH	PPCH
0.2 %	985	1 450	6 175	4 375 (7 blocks)	4 500 (4 blocks)
1.0 %	1 315	3 975	8 025	4 850 (7 blocks)	6 450 (4 blocks)
2.0 %	1 350	4 350	9 325	6 450 (8 blocks)	5 900 (3 blocks)

TABLE 2. **Capacity of signaling channels for (E)GPRS**

CHANNEL	CONFIGURATION	CAPACITY calls per hour for a blocking probability of 0.2%	CAPACITY calls per hour for a blocking probability of 1%	CAPACITY calls per hour for a blocking probability of 2%	SUPPORTED TRXs for a blocking probability of 2%
SDCCH	4 subch.	765	945	1 235	5
	8 subch.	2 465	3 680	4 085	15
	12 subch.	5 015	6 335	7 015	26
	16 subch.	6 125	8 515	9 810	36
	20 subch.	9 015	11 375	12 550	45
RACH	Combined configuration	35 925	47 950	53 200	150
	Non combined configuration	49 550	68 000	77 825	272
AGCH (2 assignment messages/block)	Recommended combined configuration (2 blocks)	38 600	45 200	45 750	150
	Recommended non combined configuration (5 blocks)	125 800	126 250	126 825	272
PCH (3 paging messages/block)	Recommended combined configuration (1 block)	35 875	37 125	43 425	150
	Recommended non combined configuration (4 blocks)	144 400	150 100	156 950	272