

Mobile Communications

Data services

3. Data services and General Packet Radio System

Politecnico di Torino 2006



Mobile Communications

The course structure

1. Basic elements

2. GSM and voice services

➡ 3. Data services and General Packet Radio System

4. Universal Mobile Telecommunication System

5. Network engineering

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This chapter is devoted to data services and related technical solutions. The importance of data services is increasing continuously.

The Global Packet Radio Transmission (GPRS) represents the true evolution of the GSM towards data services. The importance of GPRS resides in the adoption of the packet transmission over both the access and the switching segments. The packet transmission is the more suited for the statistical characteristics of the data traffic.

The charter devotes most of the attention to the elements representing an incremental value with respect to the GSM. Also the *Core Network* assumes a great importance, also for the fact that it anticipates most of the solutions adopted for the UMTS and referring to the IP context.

Some extensions will clarify applications and technological aspects.

Mobile Communications

Data Services and General Packet Radio System

3. Data Services and General Packet Radio System

- ➡ 3.1 Data services: new requirements and features
- 3.2 GPRS services
- 3.3 Radio transmission and Radio Resource Management
- 3.4 Core Network and IP
- 3.5 WLAN – technology and service configurations

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The sequence is self explanatory. Data services pose specific requirements to the basic features of a cellular network. GSM has already solved some of these questions, that are shown in section 3.1. The successive section deals with the modalities through which they are supplied. The new functions at the physical layer implemented in the GPRS are considered in section 3.3.

The most significant modifications concern the fixed part of the network, the Core Network. This network segment has implemented a *preliminary* integration with the IP context.

The last section considers the most significant characteristics of *Wireless LAN*, which are assuming a great importance in the context of wireless data. Some of their applications can complement the role of the classical cellular networks.

3 Data services and General Packet Radio System

3.1 Data services: new requirements and features

Short Message Service

Circuit Switched Data

High Speed Circuit Switched Data

Unstructured Supplementary Service Data

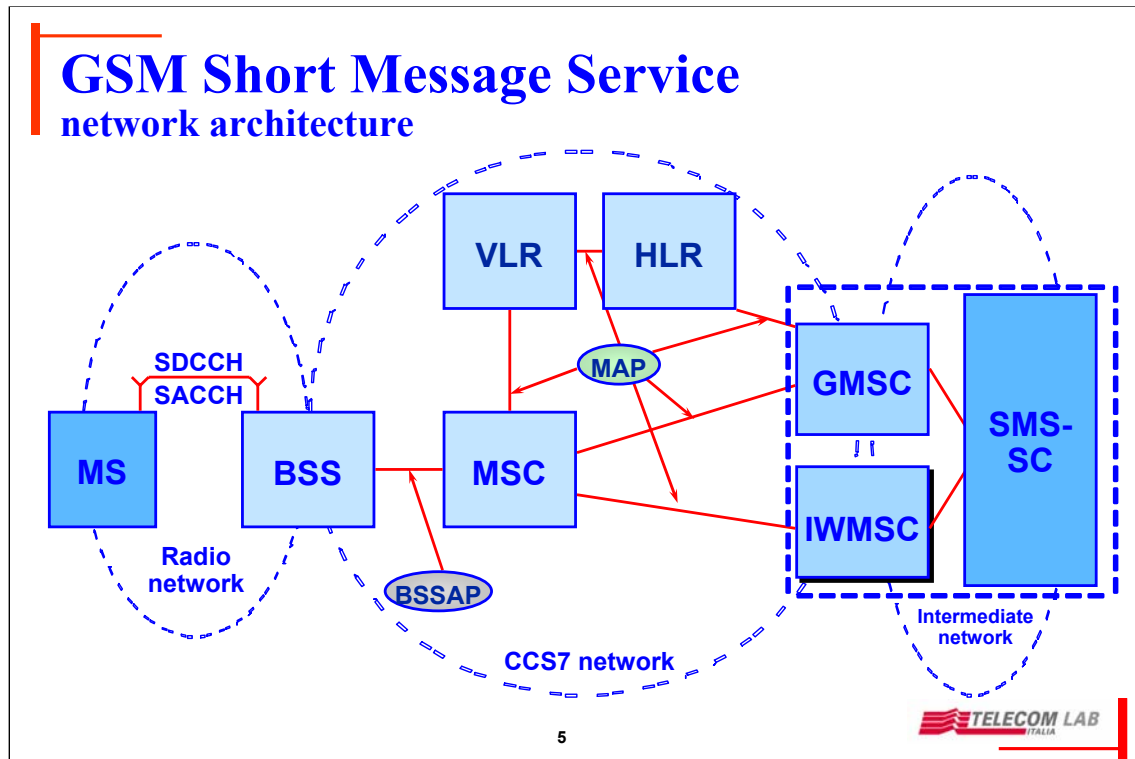
extensions:



SMS and localisation

As said, section 3.1 faces some of the solutions related to data services, such as resolved by the GSM system. The basic techniques and some applications are considered.

The extensions is dealing with a specific *data* problem, the localisation, that can be solved through the theoretical knowledge already developed in the cellular coverage and system functions previously considered.



A key factor facilitating the service innovation attitude towards data communication over mobile, is the possibility of using low bit rate transport capabilities over the control and signalling channels. For instance, the availability of the Short Message Service in the GSM system (figure) is already now a great opportunity to create new data services.

This feature can in fact be used by means of two available channels. The former, the *Slow Associated Communication Channel* (SACCH) a associated channel to a communication in progress. The latter, the *Stand Alone Dedicated Control Channel* (SDCCH) as a channel explicitly dedicated to the signalling process.

SMS is introducing a Store and Forward capability in the system. The communication takes place through a time disjunction between the transmission and reception instants: the system introduces a random delay. The use of SMS may have some limitations, due to the fact that it is loading the GSM signalling channels. They are reminded here:

- the variable delay undergone by messages
- the low priority assigned to these services
- the missing correlation between Mobile Originated and Mobile Terminated calls (this causes some difficulties in basing a protocol on SMS messages).

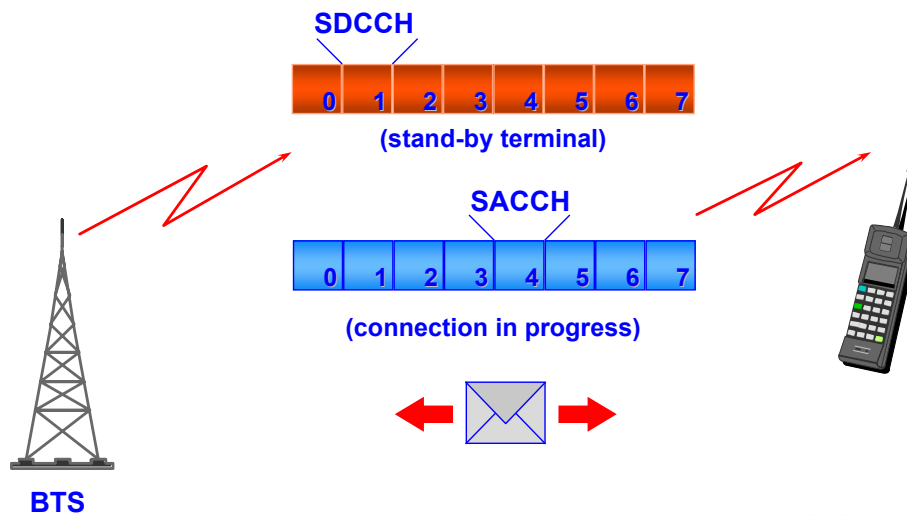
The figure represents the SMS architecture.

The *SMS Service Centre* (SC) is a data base registering and delivering all the messages network generated.

The *SMS Gateway MSC* (GMSC) transports all the messages mobile terminated. The *SMS Interworking MSC* (IWMSC) the mobile generated ones.

Short Message Service (SMS)

Radio access channel

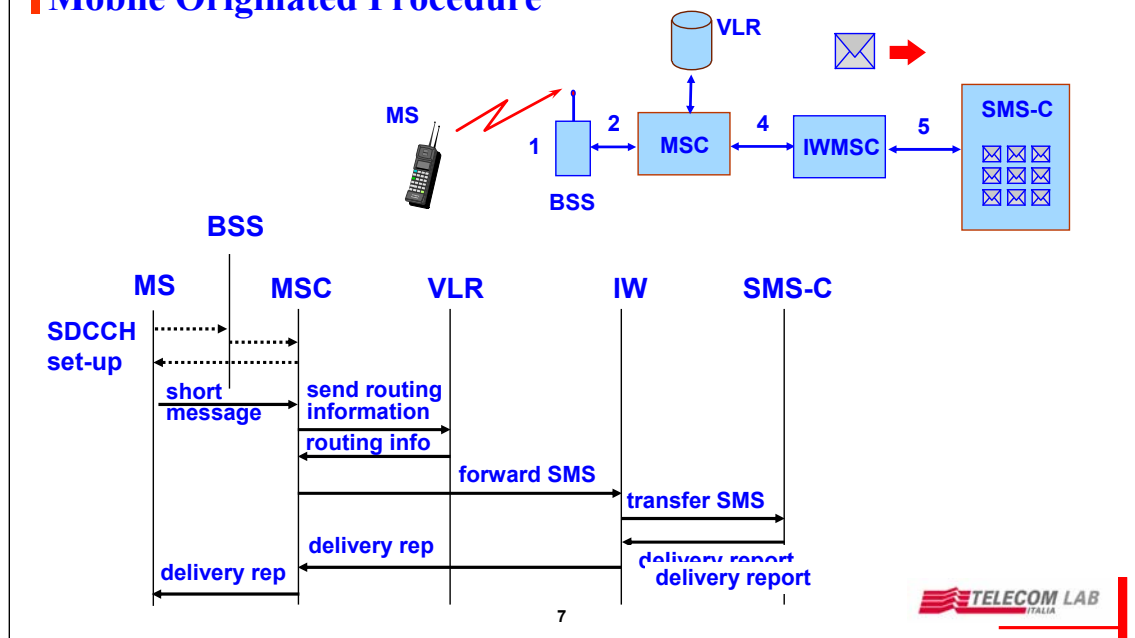


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The two channels SDCCH and SACCH are adopted by making use of a multi frame concept. The mechanism, concerns both the up and the down link. The two channels SDCCH and SACCH are adopted by making use of a multi frame concept. The mechanism, concerns both the up and the down link.

Short Message Service Mobile Originated Procedure



140 bytes can be carried by an SMS message. The equivalent information can consist of a string ranging from 160 to 70 characters, depending on the adopted coding scheme.

Point-to-point and point-to-multipoint services are available.

The former is executed through a couple of phases:

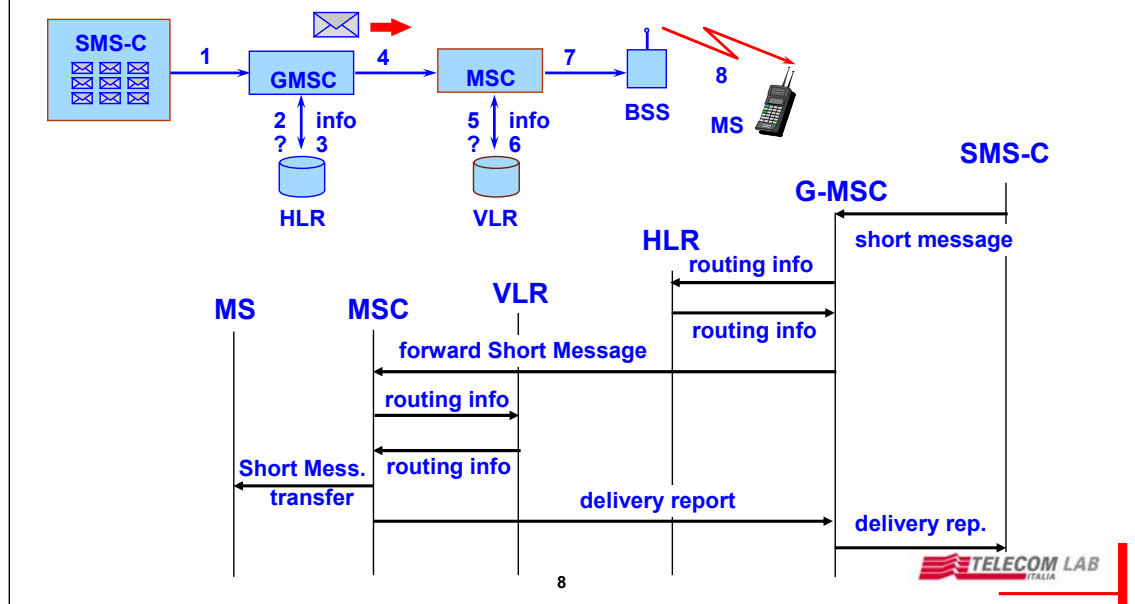
- message delivery to the SMS-C (the message is generated by the MS)
- message termination to the destination MS.

The figure reports the first phase. In the example, an SDCCH has to be set-up. In case of a communication already in progress, SACCH can be used to transmit the SMS.

All the high level messages represented in the figure belong to the MAP Protocol *Mobile Application Part* which is, by turn, based on the CCOTT #7.

Short Message Service

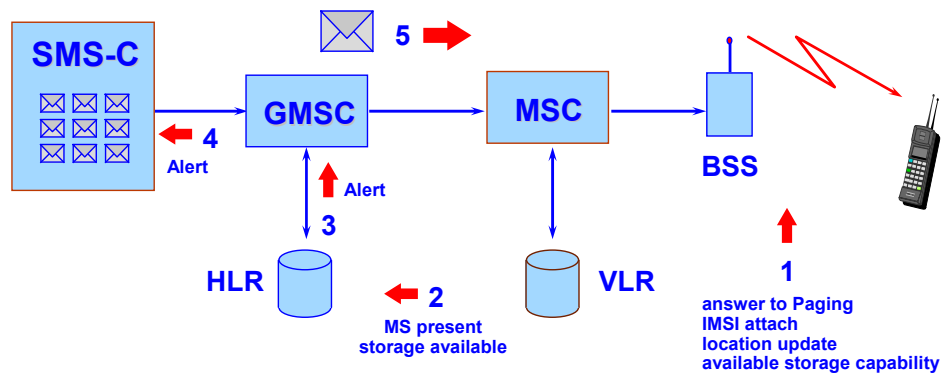
Mobile Terminated Procedure



The phase of message termination to MS is self-explanatory. The message delivery is performed over either of the channels SDCCH/SACCH, depending on the terminal status.

In case the destination MS is not registered, HLR informs the SMS-C of the need of re-sending the message as soon as possible, provided that the MS has performed the registration.

Short Message Service Alert Procedure



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If the terminal has not enough storage capability or in conjunction with some other block, it cannot receive any SMS. The subsequent terminal availability (to receive the message) is notified to the network through an alert. The procedure is activated in conjunction with one of these events:

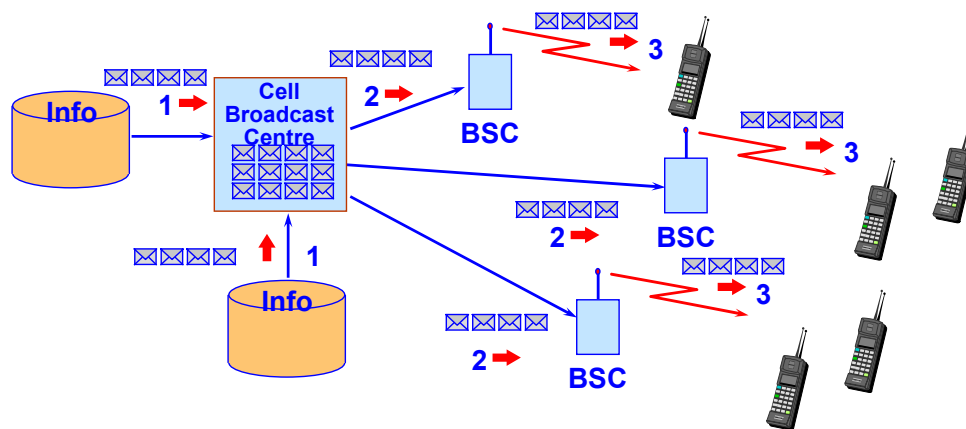
- acknowledgement to a paging message
- IMSI attach
- Location updating.

HLR/VLR inform the SMS-C of the MS availability to accept the message.

SMS service allows the concatenation of up to 255 messages. They are sent through a single access to the HLR and a single paging message. Not all the terminals support this kind of function.

Short Message Service

Cell Broadcasting



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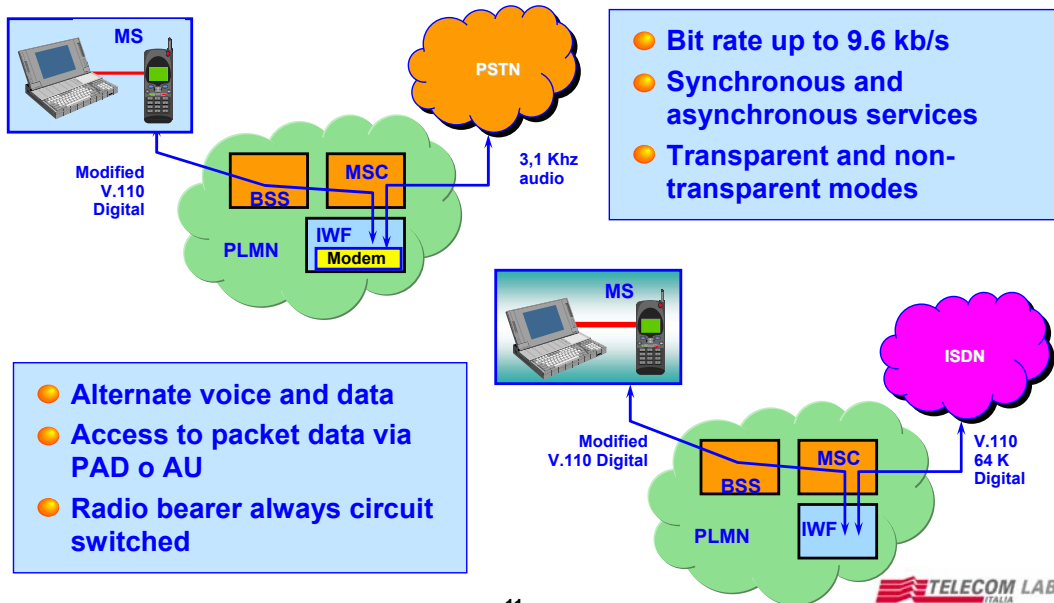
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The cell broadcast service allows to send SMS messages over entire geographical zones (one or more cells).

The broadcast Centre delivers the message to the appropriate BSCs in function of the area where the message has to be delivered, according to the sending party requirements.

Data transmission

Circuit Switched Data



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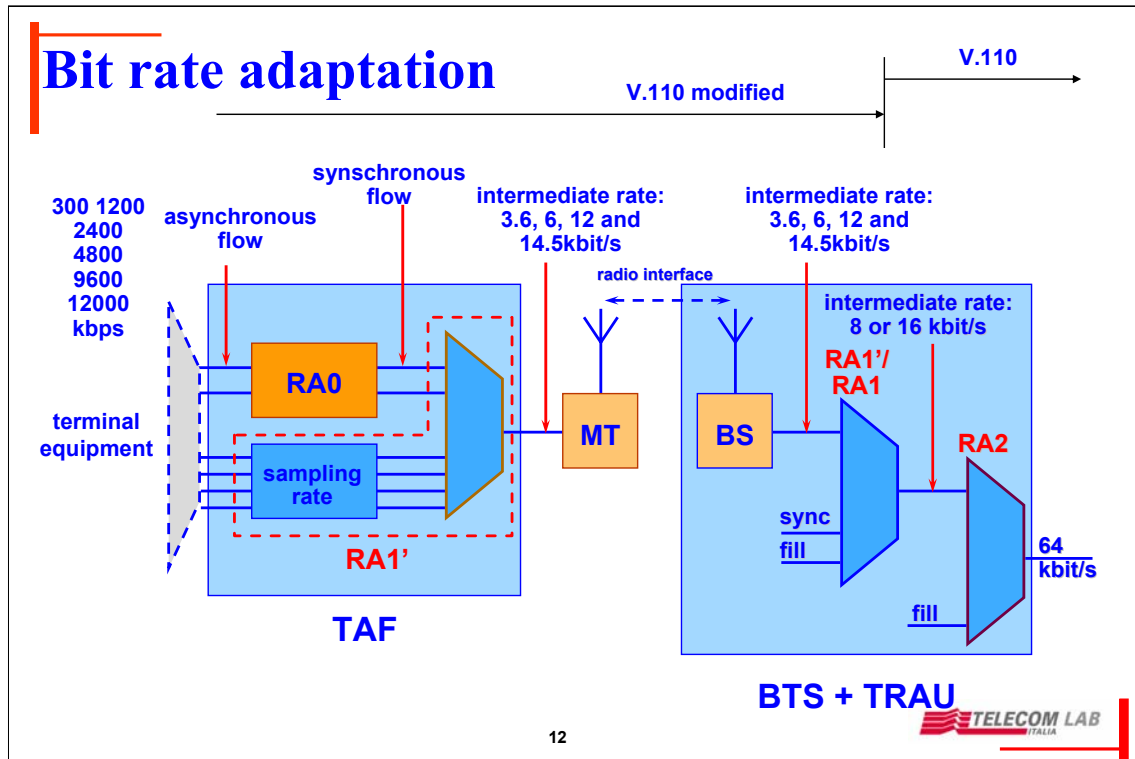
data services have started being introduced in the GSM through a circuit-switched based paradigm.

Standardisation has defined an interface between the MS and the PC and between the mobile network and the external networks.

The interconnection between a PC and the mobile terminal is guaranteed by the Terminal Adaptation Function (TAF). The latter takes care of the translation between the different data transmission modes over the interface.

The TAF can be allocated:

- As an autonomous function, between the Terminal Equipment and the mobile terminal
- In the TE
- In the MS.



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The connection between the TE belonging to the mobile network and the TE on the other side of the network is controlled by the two TEs involved transparently with respect to the network. Three adaptation steps are necessary:

- TE vs. GSM Tx/Rx mode (TAF is doing this job)
- Data bit rate adaptation vs. the 64 kbit/s switching scheme used in the MSC
- Mobile network-external network adaptation.

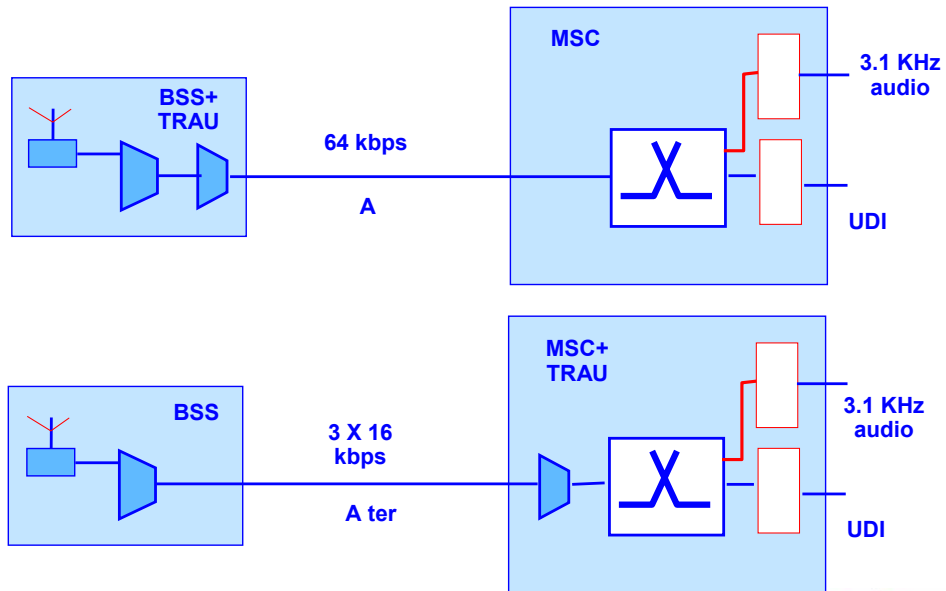
The TE transmits an asynchronous flow and in parallel a control flow used for the interworking with the external networks (e.g. with a modem).

The Rate Adaptation 0 (RA0) produces a synchronous flow. RA1 generates a bit stream through a sampling of the control flow. The two flows are then adapted for transmission over the radio interface.

The RA1'/RA1 adaptation function multiplexes the flows at the intermediate rate of 8/16 kbit/s. These flows are the multiplexed before being transported/switched at 64 kbit/s. RA2 is multiplexing the various flows on the latter stream. These adaptations are performed by the *Transmission Rate Adaptation Unit* (TRAU).

In the segment between BS and MSC it is needed to introduce streams that complement the radio flows according to the transmission schemes of the fixed network.

Bit rate adaptation



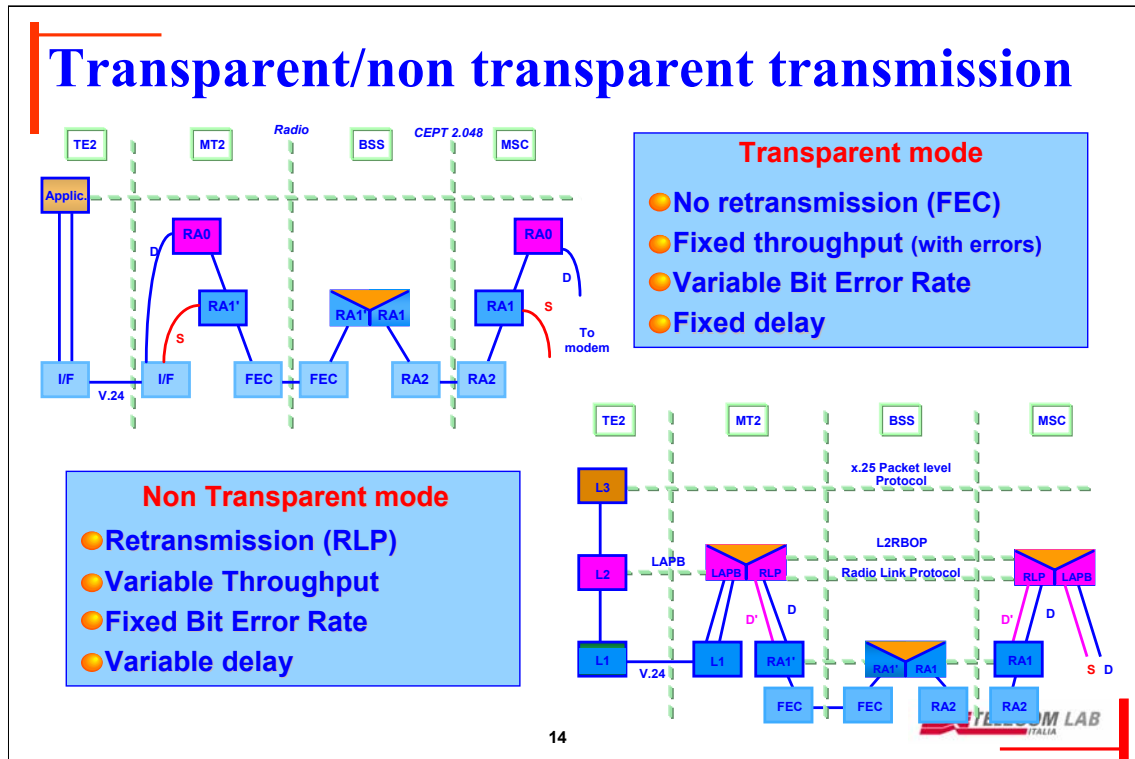
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The Transmission Rate Adaptation Unit (TRAU) can be located either in the BSC or the MSC (A interface is defined accordingly).

The external networks are reached:

- either through the IW function and a modem from the PSTN
- or the User Data Interface towards the other data networks.



Two data services have been defined within the GSM circuit-switched mode: Transparent and Non-Transparent modes.

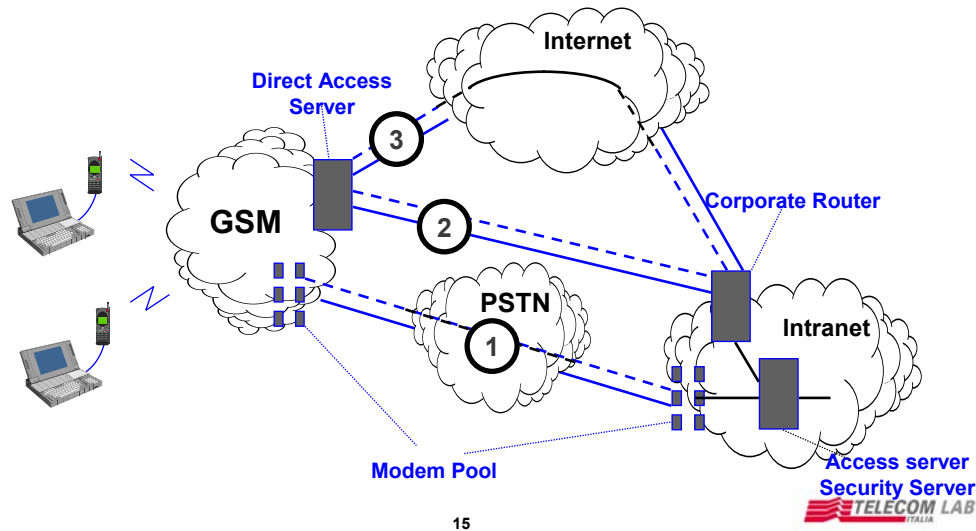
The former uses the native GSM channel encoding (no retransmission, just FEC). The figure depicts the two flows composing the overall communication, namely the Data (D) and the Synch/Control (S) flows.

The Non-Transparent mode adopts a data retransmission scheme. If the MT uses for instance a LAPB protocol for transmission/retransmission, the Radio Link Protocol (RLP) recovers all the needed features to be used over the GSM radio/access segment.

The network makes available the following bit rates:

- 14.4 and 9.6 kbit/s over a full rate channel (both transparent and non-transparent modes)
- 4.8 kbit/s over the half rate channel (both transparent and non-transparent modes); over full rate channel in transparent mode
- 2.4 kbit/s over half rate and full rate channels in transparent mode.

GSM access to Internet/Intranet



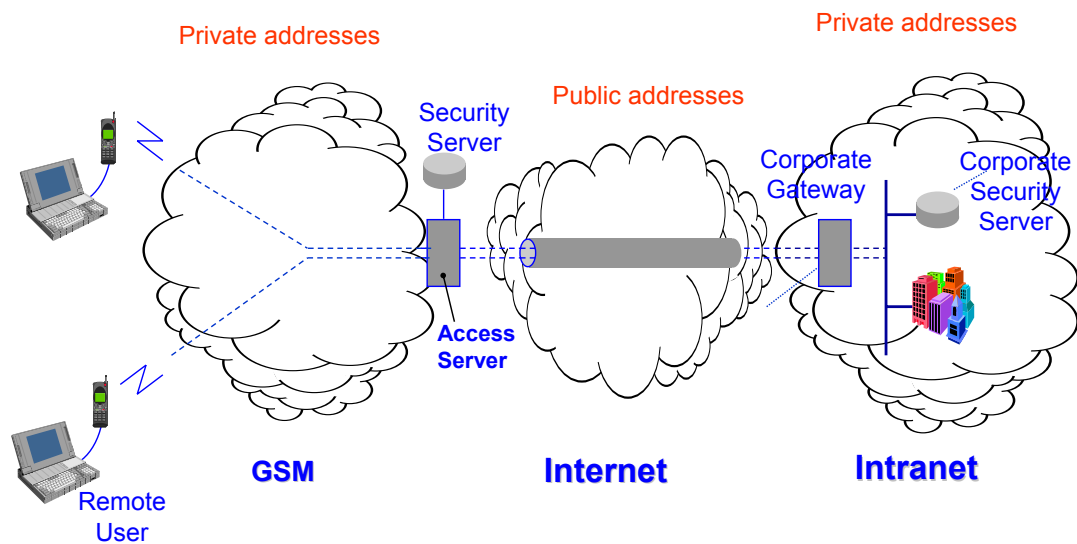
The interconnection GSM-IP adopts an Access Server (AS) in charge of converting a Circuit switched in a Packet switched stream. The access to IP may be realised:

through the PSTN (or ISDN) with dial-up procedures; in the former case, modems are used, and the AS is located in the IP network

through an AS hosted by the GSM network.

The access server converts flows of the kind V.110 or flows at 3.1kHz audio: those given by the inter working function belonging to the MSC.

GSM access to Internet/Intranet



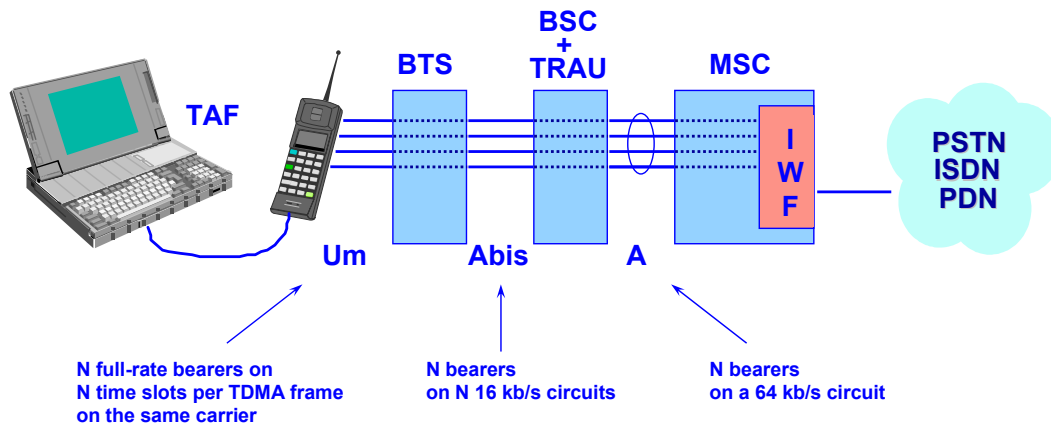
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In the connection with the IP network, TE and the Access Server are preliminary exchanging some messages needed to negotiate the data connection parameters and to assign the TE its (provisional) IP address. The subsequent phases (connection establishment and data exchange) are both managed through the Point-to-Point Protocol, able to encapsulate any other layer 2 protocol.

The transit takes place through the Internet network, through the usual tunnelling and security management mechanisms. The complete connection implies a suitable use on the private IP addresses.

HSCSD Architecture



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The HSCSD solution is based on a straightforward extension of the circuit switching principle through network upgrading that are in a complete continuity with the typical GSM functions and interconnection modes.

The basic capacity of 9.6 kbit/s can be increased by associating more than one bearer (traffic channel) to a single connection (multi bearer connection). A similar mechanism has been specified for the DECT system, even if different rules are driving the setting-up and handing-over of the elementary connection channels.

In the GSM system the multiple channels belonging to the same connection must be set-up on the same carrier, due to the technical peculiarities of the mobile terminal and the associated Layer 2 protocol.

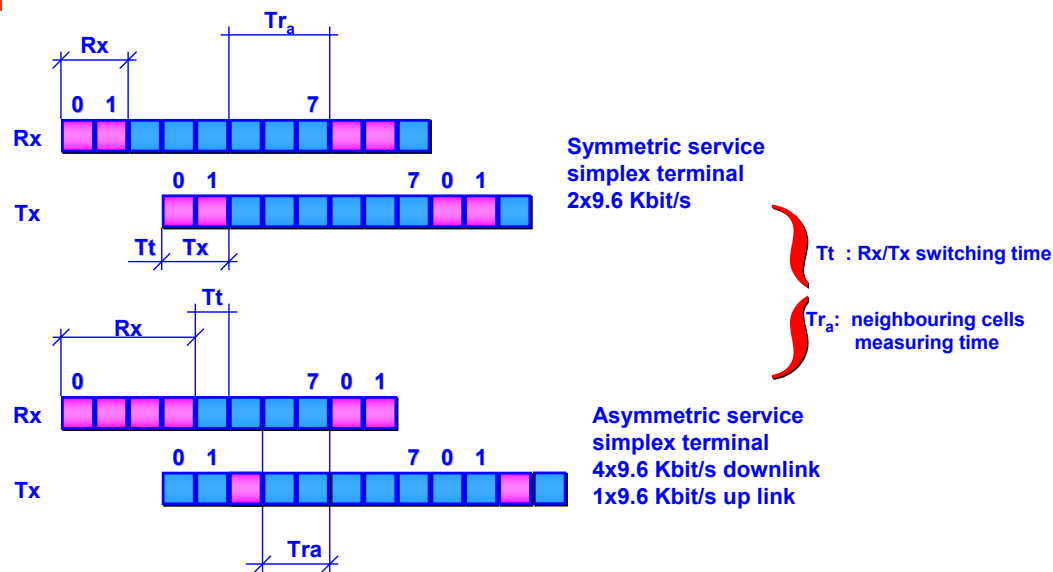
It is important to stress that the basic granularity of the connection can be 4.8 kbit/s or 2.4 kbit/s, depending on the adopted channel coding. The advantages of the HSCSD technique are paid in terms of radio resource efficiency. For instance, the handover between two neighbouring cells of a multi bearer connection can only be performed by switching of all its elementary channels at the same time. The basic modification introduced are:

- in the MT and the Interworking Function, where multiplexing (combining) functions have to be implemented; moreover, the splitting function of the elementary flows is needed; MT and IW are in charge of implementing the Radio Link Protocol (RLP)
- in the BSS new functions must guarantee the multiple handover arising over all the elementary bearers (the handover is performed simultaneously for all the bearers); if present, BSS must also control the frequency hopping functions.

The advantages of the HSCSD solution for a mobile operator are:

- the grade of service in terms of delay (availability of constant bit rate channels);
- the low complexity driving the definition of call acceptance policies;
- the (relatively) low complexity of the network upgrading needed to implement the services.

Time Slot Utilisation - Simplex Terminal



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Two types of connections are shown in the figure. They can be performed with a double simplex terminal (a single radio chain for Rx and Tx functions). Accordingly, both symmetric and non-symmetric connections are possible. In function of the terminal characteristics (availability and independence of the Rx/Tx chains; Rx/Tx switching times; measurement period of the contiguous cell signal) the HSCSD protocols are designed to set-up and maintain connections up to 8x9.6 kbit/s.

This is a limit at the flexibility level and reflects in a non-optimal use of the radio resources. In fact, the switching is driven by a *main channel* which is the reference point as for the measurement collection and the handover decision.

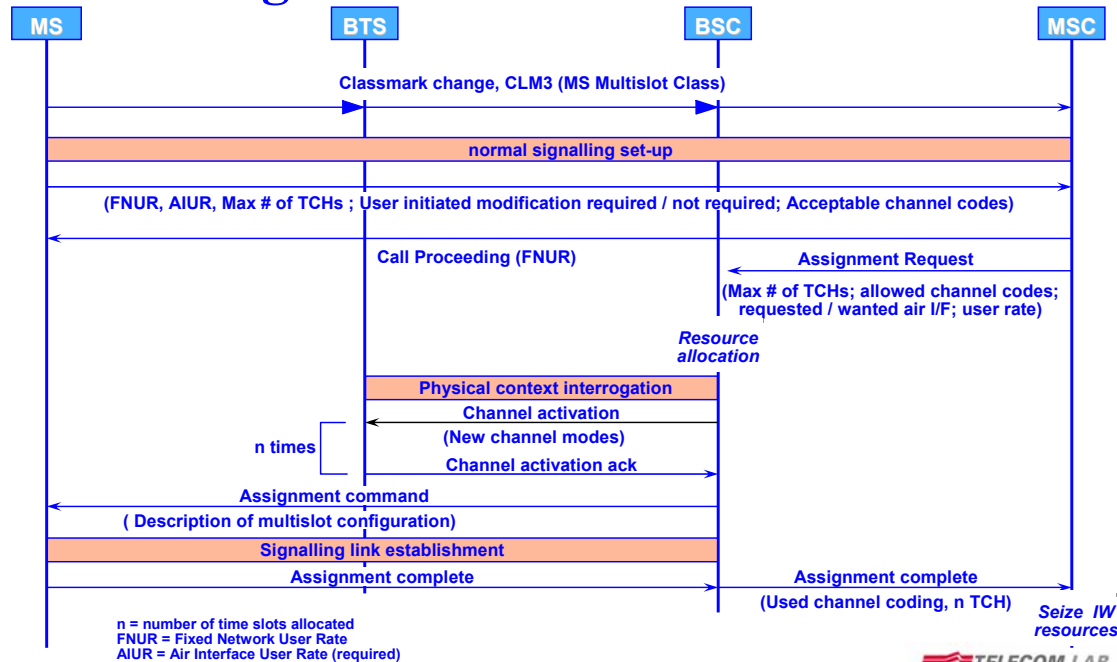
The HSCSD standard, however, introduces several features that should improve the operational flexibility of the system. For instance, any connection can be managed in a dynamic way: the associated radio resources can vary within given thresholds that are negotiated in the connection set-up phase.

The Standard allows for the channel encoding to be changed along the connection. Moreover, the handover can take place with QoS degradation. The connection set-up takes place through a negotiation between the MT and the network. The set-up messages establish in particular:

- The available encoding schemes for the channel
- The requested bit rate
- The possibility of modifying the capacity along the connection
- The maximum number of channels which can be associated to the connection.

The connection can specify transparent and non-transparent transmission schemes.

Mobile originated call

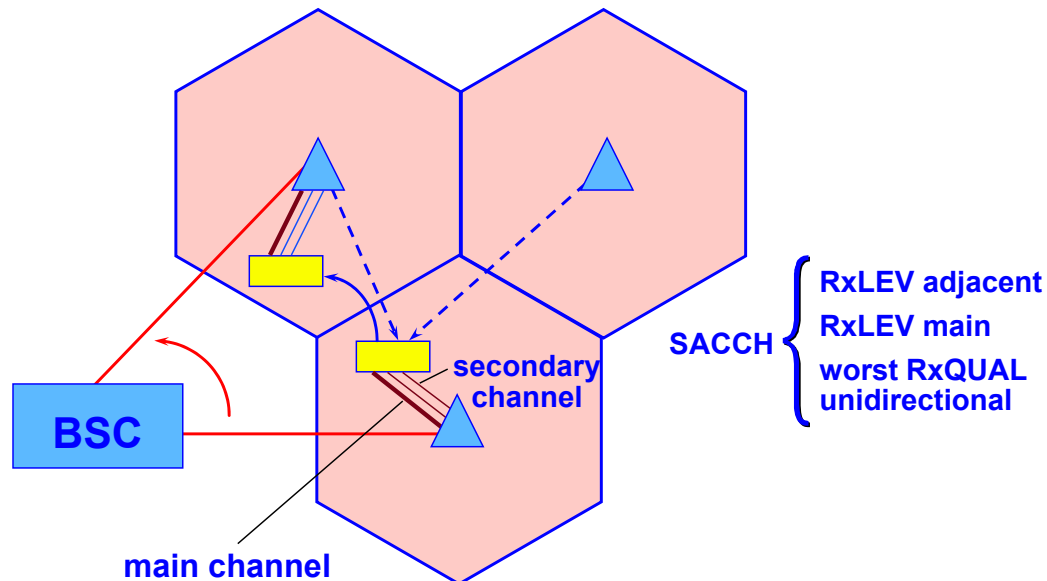


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The set-up of a connection evolves as depicted. The key aspect is the negotiation between MS and MSC. It regards the available encoders and the possibility that the terminal or the network decide to modify the overall configuration of the transmission.

The interactions are rather complex. This derives also from the aim of ensuring a good degree of flexibility in the radio resource management and the channel coding modes. The relationship mobile-network is maintained (associated signalling) through one only of the activated channels (see subsequent figure).

Radio functions for handover



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As said, *handover* is performed for all the elementary channels at a time. In conjunction, on the basis of the status of the new cell, and the interference conditions, the network can vary the transport capability, provided that it remains the minimum value established in the negotiation phase.

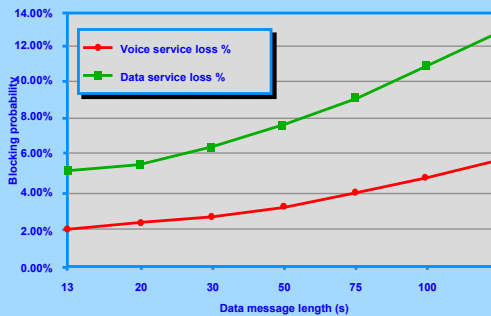
The *handover* mechanism relies on the usual measurements performed by the MS on the *broadcast* channels of the contiguous cells. As for the active channels within the HSCSD connection, one of them is defined as the *main*: it is the one in charge of collecting measurements. In addition the worst quality arising among the active bearers is also monitored.

Radio resource management represents the true critical aspect of the system. A significant limitation resides in the fact that HSCSD fully reproduces the circuit switching model, hence inheriting all its limitations in terms of channel efficiency in the presence of the typical statistics of data traffic.

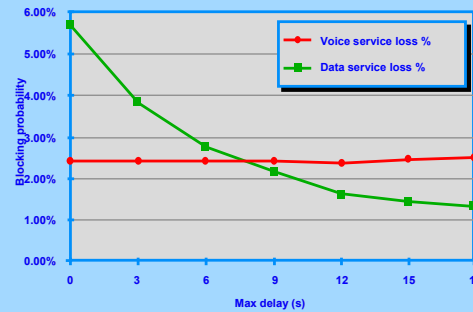
HSCSD - radio resource management

- Channels allocated on a single TRX, in consecutive time slots
- Non-transparent HSCSD calls can start with a lower bit rate than that requested (resource upgrade/downgrade procedure)
- Constraints on handover in case of transparent connections

Blocking without trunk reservation



Delay-based assignment



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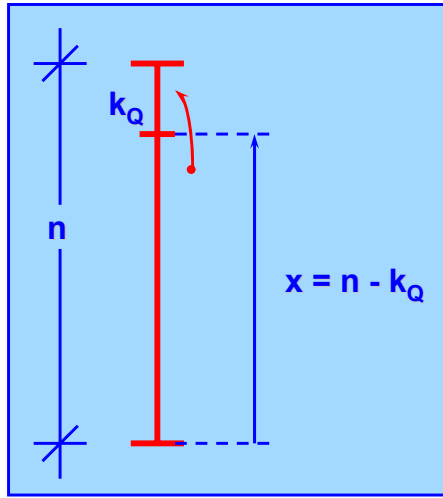
If, in a given service condition, data traffic is allowed to access the available resources without any control, it could undergo a significant quality drawback whenever the data connection capacity (number of elementary associated channels) overcomes the (one channel) voice capacity. The left-hand diagram shows the blocking probability behaviour in function of the length of the data message under the assumption that the data call is assigned a capacity of 2×9.6 bit/s. The example refers to a GSM cell dimensioned with three radio carriers.

The problem is how to reserve the radio resources to guarantee that for each service class (characterised with the required capacity) the pre-assigned grade of service is fulfilled. This topic becomes more difficult to solve with the widening of the service differentiation in terms of required capacity.

If the data traffic does not poses stringent constraints on the maximum allowed transmission delay, the operator can choose call acceptance criteria defined on a “delay-based” service. In this case, a maximum resource waiting time is driving the call acceptance process.

The right-hand diagram shows how, being the message to be transmitted of a given length, the blocking probability decreases with the increase of the threshold assigned to the maximum delay allowed.

Trunk reservation mechanism



Q: service classes

k_i ; $i = 1, \dots, Q$ service i bandwidth

$x = \sum_{i=1}^Q x_i k_i$ system status

a_i : acceptance threshold for class i

until $x \leq n - k_Q$ all call types are accepted

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The Quality of Service control (QoS is here represented by the blocking probability) in a context where resources are shared among several service classes (each characterised by a specific bit rate and a QoS constraint) has been extensively tied to the definition of the B-ISDN first and, more recently, the IP.

Let Q be the number of service classes and k_i the bandwidth requested for the i -th service class (k_i is the number of elementary channels needed for the bit rate of class i). If the arrival process of each service stream is poisson, it can be easily demonstrated that the state probability (the probability that the n available channels carry x_1 sessions of class 1, x_2 sessions of class 2, ..., x_Q sessions of class Q) is:

$$p_{\{x_1, x_2, \dots, x_Q\}} = K \cdot \prod_i \frac{A_i^{x_i}}{x_i!}$$

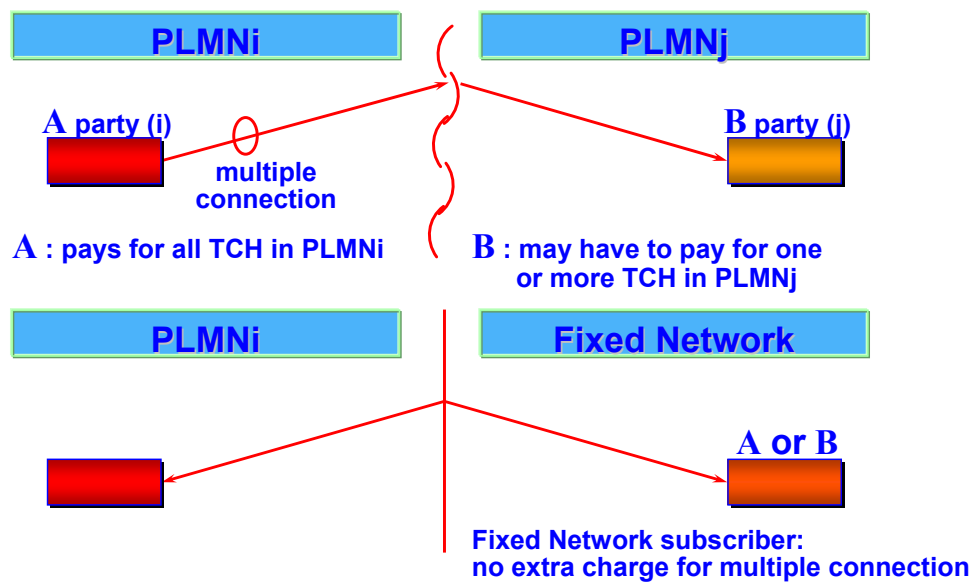
$$\{x_1, x_2, \dots, x_Q\} : \sum_i x_i \cdot k_i \leq n$$

where K is the normalisation constant and A_i the traffic offered by the class i service.

The figure is reporting the simple case where the acceptance policy is not introducing any discrimination between the service classes: calls are accepted in such a way that each class is subject to the same blocking probability. This condition is realised if, regardless the class, each incoming call is accepted until the overall state is:

$$x = \sum_i x_i \cdot k_i \leq n - k_Q$$

Charging principles



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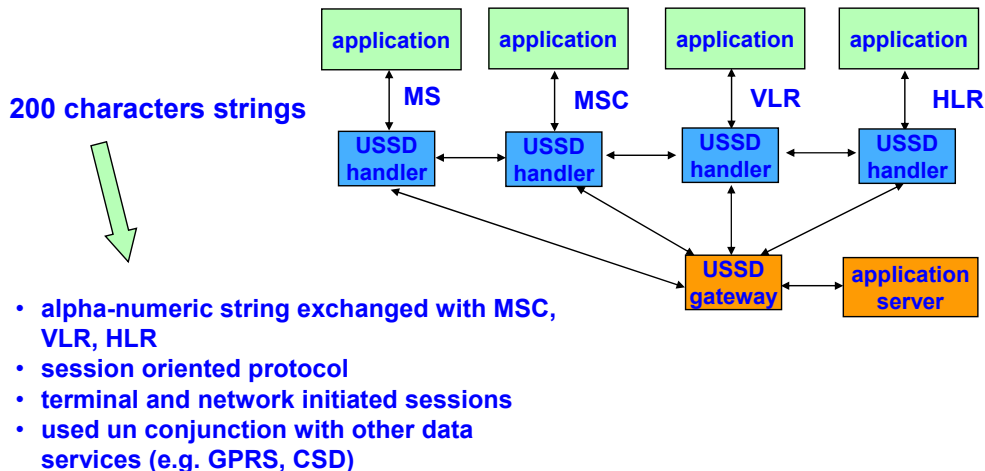
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HSCSD represents a good example of how it is possible in general to obtain greater transport capabilities from a system that was initially designed for lower capacities and for other service classes.

This expedient didn't result in a successful economical outcome, even if the majority of Operators has installed the relevant Sw modules. The main reasons of the limited success:

- the limited diffusion of HSCSD terminals
- the impact (required resources) on the voice services, making HSCSD suited for data traffic only for those Operators who can rely on a redundant bandwidth
- the missed compatibility with the UMTS
- the pricing complexity (see figure).

Unstructured Supplementary Service Data



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The *Unstructured Supplementary Service Data* (USSD) is defined over the same signalling channels where SMS is defined. USSD enables the exchange of alphanumeric strings that can reside in MSC, HLR or VLR (besides, naturally in the MS). The same MS may play directly in relation to any application server, transparently with respect to the network.

USSD-based applications can suitably integrate master services built-up according to the *client-server* paradigm. In fact, USSD can rely (through the appropriate security tools) on some data available in the network devices above mentioned. In this sense, USSD exposes an additional value with respect to the SMS. Conversely, it does not use, as the latter, the *store and forward* capability, showing a greater reliability attitude.