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TELEPHONE NETWORK AND ISDN

QUALITY OF SERVICE, NETWORK MANAGEMENT AND TRAFFIC ENGINEERING

NETWORK GRADE OF SERVICE PARAMETERS AND TARGET VALUES FOR CIRCUIT-SWITCHED LAND MOBILE SERVICES

ITU-T Recommendation E.771

(Previously "CCITT Recommendation")

FOREWORD

The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of the International Telecommunication Union. The ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Conference (WTSC), which meets every four years, established the topics for study by the ITU-T Study Groups which, in their turn, produce Recommendations on these topics.

ITU-T Recommendation E.771 was prepared by the ITU-T Study Group II (1988-1993) and was approved by the WTSC (Helsinki, March 1-12, 1993).

NOTES

1 As a consequence of a reform process within the International Telecommunication Union (ITU), the CCITT ceased to exist as of 28 February 1993. In its place, the ITU Telecommunication Standardization Sector (ITU-T) was created as of 1 March 1993. Similarly, in this reform process, the CCIR and the IFRB have been replaced by the Radiocommunication Sector.

In order not to delay publication of this Recommendation, no change has been made in the text to references containing the acronyms "CCITT, CCIR or IFRB" or their associated entities such as Plenary Assembly, Secretariat, etc. Future editions of this Recommendation will contain the proper terminology related to the new ITU structure.

2 In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

CONTENTS

NETWORK GRADE OF SERVICE PARAMETERS AND TARGET VALUES FOR CIRCUIT-SWITCHED LAND MOBILE SERVICES

(Helsinki, 1993)

1 Introduction

This Recommendation proposes network Grade of Service (GOS) parameters for land mobile services. These parameters are defined assuming that the network and the network components are fully operational. GOS parameters and related target values are evolving as new technologies for mobile services are introduced.

The structure of this Recommendation is as follows. In this clause the GOS parameters from the fixed network that apply to mobile networks are identified for the case of three types of calls, distinguished according to the networks to which the calling and called parties are connected:

1) fixed network to mobile network calls (F-M);

2) mobile network to fixed network calls (M-F);

3) mobile network to mobile network calls utilizing the fixed network (M-M).

In clause 2 the end-to-end GOS objectives from Recommendation E.721 are introduced and additional parameters are defined that are particular to mobile services. The subsequent clauses describe the contribution of land mobile systems to the end-to-end GOS both in terms of existing situations and in terms of objectives to create an evolution towards a situation where F-M and M-F connections have similar end-to-end performance as fixed network connections.

The following traffic GOS parameters are recommended for mobile services:

1) post-selection delay;

2) answer signal delay;

3) call release delay;

4) probability of end-to-end blocking;

5) probability of connection cut-off due to unsuccessful land cellular handhover.

Pre-selection delay is not included because, depending on the type of call, either it is covered by existing Recommendations and the mobile aspect has no effect or it is left to the mobile operator(s) to set values. Other parameters unique mobile services (e.g. handover delay, location registration delay, authentication delay, etc.) are for further study.

Table 1 defines the scope of this Recommendation as a function of type of call and GOS parameter. Some parameters are not included for particular call types because their values are left to the mobile operator(s) to set. 'These are marked “X”.

2 Grade of Service parameters

2.1 General parameters

End-to-end GOS parameters and conditions they relate to are defined in Recommendation E.721. The general parameters that also apply to mobile operations are:

1) post-selection delay (en-bloc sending);

2) answer signal delay;

3) call release delay;

4) probability of end-to-end blocking.

The definitions of these traffic GOS parameters are given below. The delay GOS parameters are based on the message flows in Recommendation Q.931 and Signalling System No. 7 (ISUP) protocols as indicated, for example, in Figure A.I/E.713.

TABLE 1/E.771

Scope of Recommendation E.771 as a function of type of call and GOS parameter

Call type	F-M	M-F	M-M
GOS parameter			
Call setup			
Post-selection delay	E.771	E.771	E.771
Answer signal delay	E.771	E.771	E.771
Probability of end-to-end blocking Probability of blocking on the radio links Probability of blocking on PLMN to fixed network circuits	E.771	E.771	E.771
Call release			
Call release delay			
Calling party clears	E.771	X	X
Called party clears	X	E.771	X
X Outside the scope of E.771.			

2.1.1 post-selection delay (en-bloc sending): Post selection delay (en-bloc sending) is defined as the time interval from the instant the first bit of the initial SETUP message containing all the selection digits is passed by the calling terminal to the access signalling system until the last bit of the first message, indicating call disposition is received by the calling terminal (ALERTING message in case of successful call).

NOTES

1 In the case of mobile-originated (i.e. M-F or M-M) connections the starting instant is the activation of the “Send” key in the calling terminal.

2 In case of automatic answering terminals the ALERTING message is replaced by the CONNECT message.

2.1.2 answer signal delay: Answer signal delay is defined as the time interval from the instant that the called terminal passes the first bit of the CONNECT message to its access signalling system until the last bit of the CONNECT message is received by the calling terminal.

2.1.3 call release delay: Call release delay is defined as the time interval from the instant the DISCONNECT message is passed by the user terminal which terminated the call to the access signalling system, until the RELEASE message is received by the same terminal (indicating that the terminals can initiate/receive a new call).

2.1.4 probability of end-to-end blocking: The probability of end-to-end blocking is the probability that any call attempt will be unsuccessful due to a lack of network resources.

NOTE – The lack of control plane resources during the call setup phase may also contribute to end-to-end blocking. This aspect is for further study.

2.2 Parameters particular to mobile systems

2.2.1 probability of connection cut-off due to unsuccessful land cellular handover: This parameter is the probability that a call in progress will be released by the system because of a handover attempt[1] which failed to find a free radio channel[2] in the target cell or because of a lack of free resources for establishing the new connection.

One of the unique characteristics of cellular systems is their ability to hand over calls in progress between cells, inter-cell handover. When a call is in progress, an analogue of the transmission quality of the radio channel – e.g. radio channel power level, BER (Bit Error Rate), etc. – associated with a mobile is monitored by the active BS controller. If the transmission quality drops below a predetermined level, indicating that the mobile may be leaving the cell, an automatic sequence of operations is initiated to hand over the call to a new cell/channel combination. Cells are, usually not regularly shaped in practice due to terrain and radio signal factors and their radio coverage must overlap to some extent. This overlap provides a window during which the handover should be completed without substantially affecting the quality of the connection in a pre-determined time interval.

For certain types of multiple access and of channel allocation (e.g. TDMA combined with Dynamic Channel Allocation) handover between channels of the same cell may be required, intra-cell handover. For certain other types of multiple access schemes (e.g. CDMA) intra-cell handover is not called for; however, the signal strength tolerance and the timeliness of the inter-cell handover may be more demanding.

Theoretically, reaching a service level below the design limits (as measured through radio channel power level, BER, etc.) does not necessarily mean that the call is cut off. However in some systems when a handover request is queued for more than a certain time, the call is released. This time takes into consideration both efficient network resource usage and inconvenience, to the user through exposure to low quality of the radio channel. The relationship between resource usage and user inconvenience is an important design issue which impacts traffic engineering. This relationship is for further study.

Some systems allow handover not only because the signal strength has deteriorated, but also as a means of load balancing among cells or because of user selection of a different network operator and/or service, provider. The handover initiation process and the probability of connection cut-off due to unsuccessful handover in this latter case are for further study.

Another reason for a handover to fail is that excessive transmission errors is encountered during the handover signalling. However this is a radio system design problem and not a concern for traffic engineering.

Handovers which involve moving from one MSC to another MSC possibly making use of the fixed network facilities are for further study.

Note – The probability of an unsuccessful handover is a critical parameter in a cellular system, as an unsuccessful handover affects a call already in progress. Future cellular systems will involve cells of much smaller size than those in current systems and hence more frequent handovers are likely to occur. The frequency of handovers will depend on factors such as cell size, average call holding time, average speed of the mobile user (which could vary with the time of the day, the area of the city, etc.), and geographical distribution and mobility behaviour of mobiles within the cells. The GOS specifications for the handover parameters need to be quite stringent, and how well and easily these requirements are met by a cellular system will depend on the efficiency and sophistication of the handover algorithm(s) and the processing capacity.

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[1] Handover (see 5.29/E.600)

"In mobile cellular systems, a system-driven change of the current association between an established connection and a channel (mobile to base station and/or base station to mobile) in the radio segment spanned by one cell. The change may result in an association between the connection and a new channel either in the same cell or in a different cell.

A handover request may be issued due to deteriorated transmission quality of th channel, as determined on the basis of a quality criterion (signal strength, carrier-to-interference ratio, etc), a process for measuring the quality, and a decision algorithm for determining when the quality target is no longer met. A handover request initiates a procedure for the selection of a new channel."

[2] Radio channels are transmission resources needed for supporting a connection through the radio interface.

2.2.2 Additional parameters

The definition of additional parameters (e.g. handover delay, location registration delay, authentication delay, etc.) requires further study.

3 Cellular systems

3.1 Post-selection delay

A mobile subscriber who wants to communicate with another party in the PSTN, or ISDN, i.e. establish a Mobile-to-Fixed (M-F) call, or to another mobile, i.e. a Mobile-to-Mobile (M-M) call, must be assigned one channel (e.g. FDMA or TDMA) at his serving base station in order to complete his call. This is normally accomplished by a signalling sequence which is sent first over one of several dedicated access channels[3)] (radio data links) common to all subscribers in the system and, next, over a land data link which connects the subscriber's BS controller to the home MSC[4)]. The random access signalling protocol is usually similar to the carrier sense multiple access with collision detection (CSMA-CD) scheme. Due to the nature of the access channel, it is possible to observe congestion and capacity waste when collisions occur. In the case of a mobile-terminated (i.e. F-M or M-M) call, a paging message is simultaneously sent by the MSC over the land data links to all BS controllers in the location area of the MSC registered in the HLR/VLR databases. The controllers relay the paging message over the paging channels assigned to their cells and, once the called mobile has recognized its page, it responds over the access channel.

In any PLMN, post-selection delay is one of the most important system performance criteria. The numerical limits of post-selection delay standards would depend on the type of call (i.e. F-M, M-M or M-F). The main factors which determine the delays experienced by a call being routed through the PLMN are (depending on the architecture of the PLMN):

- transmission delays for call initiation signals generated by mobile units (including retransmissions to resolve collisions);
- signalling delays on the land data link joining the MSC and each BS controller;
- switching and processing delays in the MSCs;
- signalling delays on the Common Channel System connection between MSC and location/registration databases.

The data link connection is usually based on the HDLC protocol with full duplex. Since contention exists in the data path, heavily loaded systems will experience higher delays. An important consideration is that large call setup delays on mobile-terminated calls (F-M, M-NI) can result in non-productive use of PSTN, or ISDN, resources.

Figure 1 shows an example of the call setup phases for an M-F connection in the case of interconnection of fixed and separate cellular mobile networks (see Figure 1/E 751); for an integrated fixed/mobile network a somewhat different call setup sequence may apply.

Another example of call setup schematic is shown in Figure 2 in the case of M-F connection and interconnection of fixed and separate mobile networks with a hierarchical arrangement of mobile switching centre functions. The figure shows the influence of Common Channel Signalling, including the information transmission delay between mobile switching centre and location register.

Further study is required to formulate standards for the contribution of mobile systems to post-selection delay.

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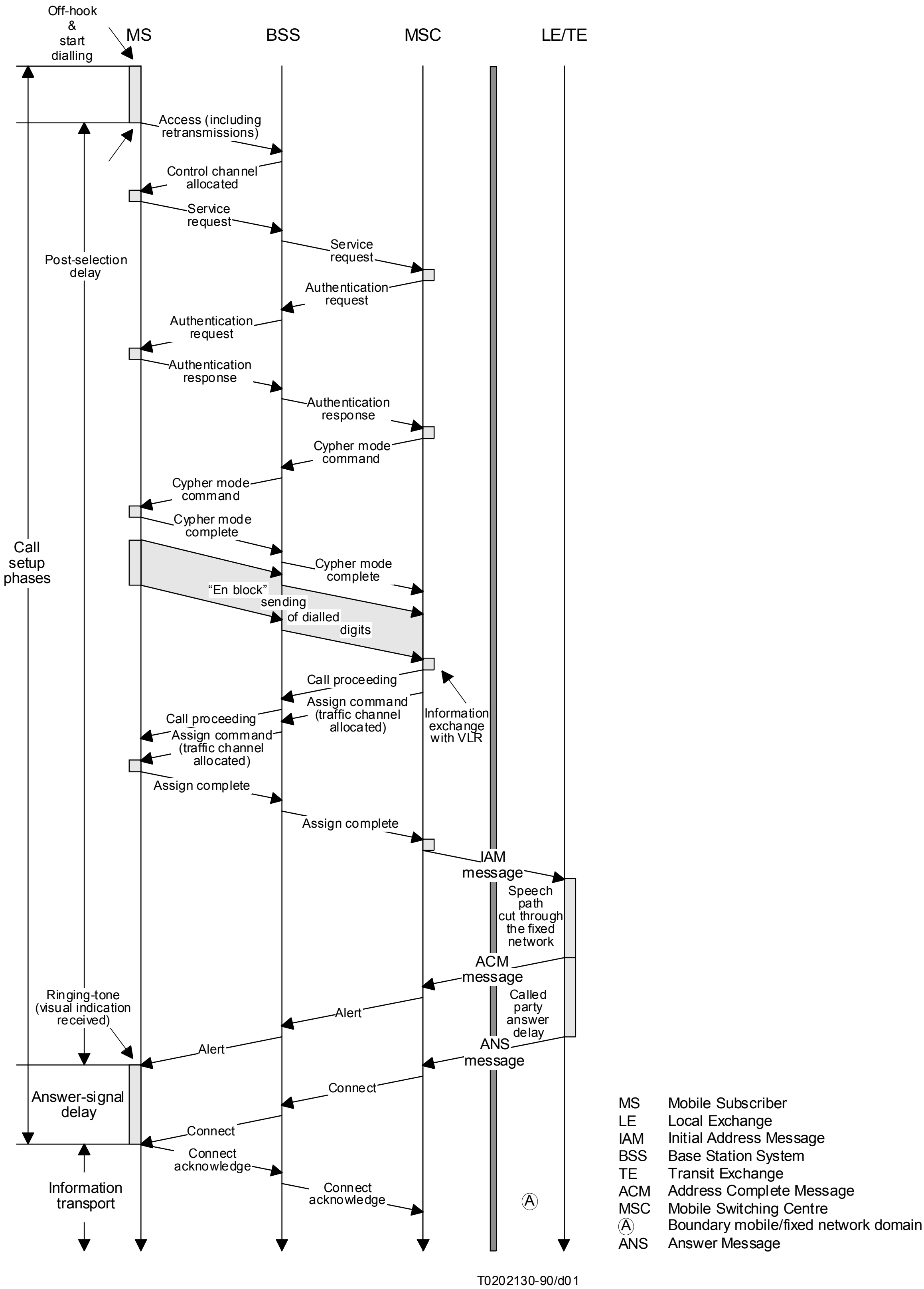
3) Also, the access function may use a "marked idle" concept, to gain flexibility of assigning resources; the TDMA concept is especially suited to this type of logical operation.

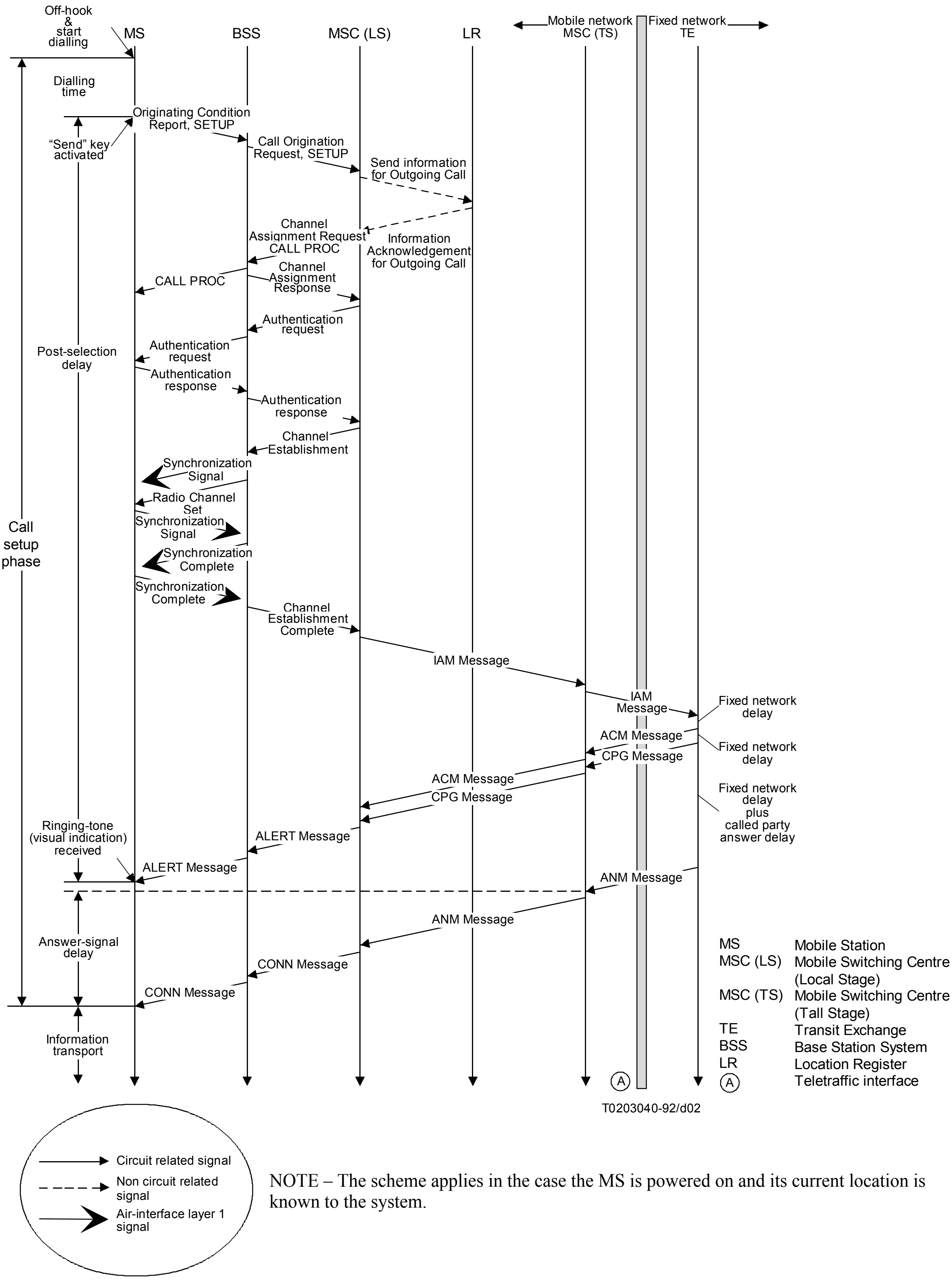
4) The MSC function may be only conceptual; in physical form, this may be a digital central office with Intelligent Network capabilities, as in the case of integrated mobile-fixed network operation.



NOTE – The scheme applies in the case the MS is powered on and its current location is known to the system.

FIGURE 1/E.771

Call setup phases for M-F connection and interworking of fixed and separate mobile networks



NOTE – The scheme applies in the case the MS is powered on and its current location is known to the system.

FIGURE 2/E.771

Call setup phases for M-F connection and interconnection of fixed and separate mobile networks in the case of hierarchical arrangement of mobile switching center functions

3.2 Answer signal delay

For further study.

3.3 Call release delay

For further study

3.4 Probability of end-to-end blocking

The contribution of cellular systems to the probability of end-to-end blocking, includes two components particular to the mobile systems. These are:

- probability of blocking on the radio channels; and
- probability of blocking on PLMN to fixed network circuits.

In existing mobile systems, blocking on radio channels is typically in the order of 5 – 10% and PLMN to fixed network circuits have been engineered to 1%.

Mobile systems should evolve towards a situation in which the contribution of the mobile network is comparable to the existing standards for fixed network trunk groups. For example:

- radio channel blocking less than 1%;
- PLNLN to fixed network circuit blocking less than 0.5%.

With these values, the blocking contribution of the mobile system would provide M-F and F-M connections with a medium length fixed network extension with an end-to-end blocking increase similar to the increase that would be experienced by adding a remote switching unit to the fixed network.

3.4.1 Probability of blocking on the radio channels

The basic dimensioning problem in cellular systems is to decide how many radio channels are required in each cell to provide a pre-specified blocking GOS. Independently of how channels are assigned to cells, a cell is provided with a pool of radio channels and four streams of arriving traffic, representing F-M, M-F, M-M calls, and handover attempts competing for the channels. In general, most cellular systems give preference to handover attempts either by assigning them higher priority or by serving them on a delay basis. The other calls (i.e. F-M, M-F, M-M) art normally served on a loss basis.

The two main factors that have an impact on radio channel blocking performance are:

- characteristics (e.g. mean and variance) of traffic offered to each cell;
- characteristics of handover traffic into and out of each of the cells (e.g. mean and variance).

The numerical limits of radio channel blocking standards will depend upon the type of call. Blocking for M-F calls within a cellular system is defined as the probability that no free radio channel is available to provide a path between the calling mobile and the network. Similarly, blocking for F-M calls is defined as the probability that no radio channel is available to provide a path between the network and the called mobile. Finally, blocking for M-M calls is the probability that no free radio channel is available to establish a path either between the calling mobile and the MSC or between the MSC and the called mobile, or both.

Certain configurations of mobile systems based on integrated mobile and fixed network operation may involve the presence of a Mobile Customer Premises Network, thus resulting in a two-hop air interface (see Annex B/E.751). In these cases, the possibility of blocking on the radio channels is the compound effect of the blocking characteristics on the two hops. Nevertheless no relaxation of the targets for the contribution to the end-to-end blocking is proposed in this situation.

Moreover, the intelligence for controlling the mobility functions may be allocated in a hierarchical fashion in the mobile domain (in the case of separate fixed and mobile networks – see Annex A/E.751) or in the fixed network domain (in the case of integrated mobile and fixed networks – see Figure 3/E.751). The implications of such arrangements on a possible blocking probability allocation for the entire mobile domains is for further study.

Determining the number of radio channels need for an acceptable GOS requires not only the consideration of traffic parameters and estimation of signal interference between cells, but also the assessment of factors such as cost/performance trade-offs and potential impact on the fixed network (PSTN/ISDN).

Traffic characteristics in PLMN may differ considerably from those of fixed networks, e.g. in high density areas traffic variations may be quite large due to subscribers' roaming. Measurement issues and methods for mobile traffic characterization are for further study.

3.4.2 Probability of blocking on PLMN to fixed network circuits

A very large proportion of cellular calls must pass through the PSTN, or ISDN. There are a number of alternative architectures for the landline segment of the PLMN serving a metropolitan network. Among them are: MSC being treated like a PABX, connected by a dedicated trunk group to a single local exchange; MSC serving the area with the status of a local exchange; MSC being treated like a local exchange and connected to a transit exchange (see Recommendation E.220). Standard teletraffic methods apply to these situations, provided the number and locations of the MSC and the BS controllers are pre-specified. Blocking in the PLMN to PSTN, or ISDN, circuits is the probability that no free circuit is available to establish a path between the PLMN and the PSTN, or ISDN. The blocking of the PLMN-PSTN, or PLMN-ISDN, interconnection trunks basically depends on the volume of traffic that is offered to the trunk group. This traffic is usually smooth (i.e. a peakedness factor of less than one).

Technically, there is no difference between the PLMN to PSTN, or ISDN, interconnecting circuits and the inter-exchange circuits in the PSTN, or ISDN.

3.5 Probability of connection cut-off due to unsuccessful land cellular handover

An example of the way that events and times associated with handover determination, request, and handling could be inter-related is represented in Figure 3.

Future study is required to assess the relationship between handover failure, transmission performance through the radio interface, and the probability of connection cut-off due to unsuccessful land cellular handover.

3.6 Target values for GOS parameters

Table 2 gives the target values for the GOS parameters that land mobile systems should evolve towards. As noted in 3.4, systems in service in 1990 are recognized as being unable to achieve these targets in practice.

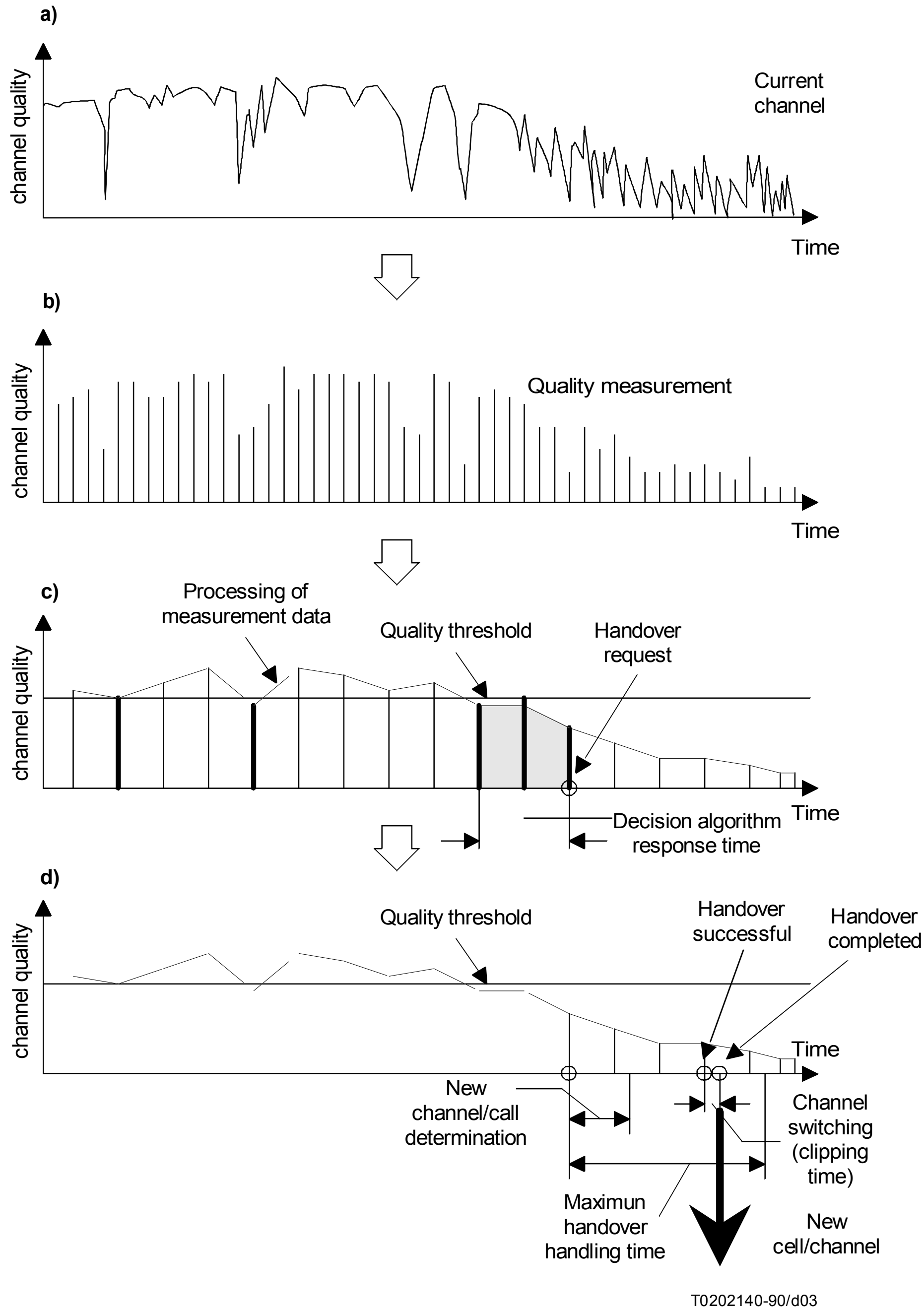


FIGURE 3/E.771

An example of handover handling: a) varying channel quality, b) quality measuring process, c) measurement processing and handover request issuing, d) handover handling and GOS parameters

TABLE 2/E.771

Target values for GOS parameters (provisional)

Call type	F-M		M-F		M-M	
GOS parameter						
	Normal load	High load	Normal load	High load	Normal load	High load
Call Setup						
Post-selection delay	f.s.	f.s.	f.s.	f.s.	f.s.	f.s.
Answer signal delay	f.s.	f.s.	f.s.	f.s.	f.s.	f.s.
Probability of end-to-end blocking						
Probability of blocking on the radio links	(10^{-2})	f.s.	(10^{-2})	f.s.	f.s.	f.s.
Probability of blocking on PLMN to fixed network circuits	$(5)\ (10^{-3})$	f.s.	$(5)\ (10^{-3})$	f.s.	f.s.	f.s.
Call Release						
Call release delay						
Calling party clears	f.s.	f.s.	X	X	X	X
Called party clears	X	X	f.s.	f.s.	X	X
User Information Transport						
Probability of connection cut-off due to unsuccesful land cellular handover (per call)	$(5)\ (10^{-4})$	f.s.	$(5)\ (10^{-4})$	f.s.	f.s.	f.s.

f.s. Further study

X Outside the scope of E.771

NOTE – Values in the table relate to mean values; percentile values, where applicable, are for further study

4 Non-cellular systems

For further study.

5 History

Recommendation first published in 1993.

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