INTERNATIONAL TELECOMMUNICATION UNION

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THE INTERNATIONAL
TELEGRAPH AND TELEPHONE
CONSULTATIVE COMMITTEE

BLUE BOOK

VOLUME VI – FASCICLE VI.12

PUBLIC LAND MOBILE NETWORK
INTERWORKING WITH ISDN AND PSTN

RECOMMENDATIONS Q.1000-Q.1032

IXTH PLENARY ASSEMBLY
MELBOURNE, 14-25 NOVEMBER 1988

Geneva 1989

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Public Land Mobile Network
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1 The Questions entrusted to each Study Group for the Study Period 1989-1992 can be found in Contribution No. 1 to that Study Group.

2 In this Volume, the expression "Administration" is used for shortness to indicate both a telecommunication Administration and a recognized private operating agency.

3 The strict observance of the specifications for standardized international signalling and switching equipment is of the utmost importance in the manufacture and operation of the equipment. Hence these specifications are obligatory except where it is explicitly stipulated to the contrary.

The values given in Fascicles VI.1 to VI.14 are imperative and must be met under normal service conditions.

FASCICLE VI.12

Recommendations Q.1000 to Q.1032

PUBLIC LAND MOBILE NETWORK INTERWORKING WITH ISDN AND PSTN

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SECTION 1

PUBLIC LAND MOBILE NETWORK

Recommendation Q.1000

STRUCTURE OF THE Q.1000-SERIES RECOMMENDATIONS FOR PUBLIC LAND MOBILE NETWORKS

1 General

This Recommendation provides an overview of the Q.1000-Series Recommendations specifically aimed at specifying the requirements for the Public Land Mobile Network.

The purpose of the Q.1000-Series Recommendations is to provide smoothly:

1) realization of roaming and interworking between PLMNs,
2) portability of terminal equipments, and
3) independent evolution of each PLMN and terminal equipments.

In addition some Recommendations of other series are indicated in section 7 because of their interest to the Q.1000-Series.

2 General Recommendations on Public Land Mobile Networks

Q.1000: Structure of the Q.1000-Series Recommendations for Public Land Mobile Networks

This Recommendation gives an overview of the Q.1000-Series and some other Recommendations of interest to them.

Q.1001: General aspects of Public Land Mobile Networks

This Recommendation covers definitions, architectures and services in public land mobile networks.

Q.1002: Network functions

This Recommendation defines network functions requiring signalling on the radio path either as subscriber line signalling or as mobile management signalling necessary to support services and facilities provided by PLMNs.

Q.1003: Location registration procedures

This Recommendation identifies the procedures related to location registration, location cancellation, periodic registration and international mobile subscriber identity attach/detach operations.

Q.1004: Location register restoration procedures

This Recommendation describes methods that provide security of the data stored in the location registers and details procedures required to restore the location data and supplementary services data after a location register failure.

Q.1005: Handover

This Recommendation identifies the handling procedures between: radio channels of the same base station; base stations of the same MSC; base stations of different MSCs of the same PLMN; and base stations of MSCs in different PLMNs during handover operations.

3 Technical aspects of the services offered in the Public Land Mobile Networks

Q.1012: Handling of supplementary services

This Recommendation contains the stage 2 descriptions of the supplementary services which can be provided in a PLMN.

Note – This Recommendation is not published in the Blue Book. It will be finalized and brought into the accelerated procedure early in the next study period.

4 Interworking with ISDN/PSTN

Q.1031: General signalling requirements on interworking between ISDN or PSTN and a PLMN

This Recommendation specifies the general signalling requirements to be met in order to ensure a correct integration of the mobile service in the fixed networks.

Q.1032: Signalling requirements relating to routing of calls to mobile subscribers

This Recommendation specifies the signalling requirements that the fixed networks have to comply with, in order to route a mobile terminating call to the actual MSC.

5 Mobile application part

Q.1051: Mobile application part

This Recommendation describes network procedures and relevant protocols required to provide the functions listed in Recommendation Q.1002. The mobile application part is based on Signalling System No. 7.

6 Digital PLMN access interfaces

Q.1061: General aspects and principles relating to digital PLMN access signalling reference points

This Recommendation introduces the concept and definition of access signalling reference points which are used as the basis for the specification of signalling required at the Mobile Station and the Base Station.

Q.1062: Digital PLMN access signalling reference configurations

This Recommendation describes the reference configurations used to identify the various possible physical access arrangements to the digital PLMN.

Q.1063: Digital PLMN channel structures and access capabilities at the radio interface (Um reference point)

This Recommendation defines the set of channel types, access capabilities and channel configurations with respect to the radio interface.

7 Other Recommendations of interest to the Q.1000-Series

7.1 *Charging*

D.93: Charging and accounting in the international land mobile telephone service (provided via cellular radio systems)

This Recommendation covers principles for charging, accounting and settlements between PLMNs. An annex to the Recommendation gives examples of the practical use of the established principles.

7.2 *Numbering and Routing*

E.212: Identification plan for land mobile stations

This Recommendation covers definitions and mobile station identification plan principles. An annex to the Recommendation contains a list of mobile country or geographical area codes.

E.213: Telephone and ISDN numbering plan for land mobile stations in public land mobile networks (PLMN)

This Recommendation covers basic requirements for a numbering plan to be used for public land mobile networks.

E.214: The structure of the land mobile global title for the signalling connection control part (SCCP).

This Recommendation defines and describes the structure of the mobile global title.

Recommendation Q.1001

GENERAL ASPECTS OF PUBLIC LAND MOBILE NETWORKS

1 General

This Recommendation covers definitions, architectures and services in Public Land Mobile Networks.

The definition section is subdivided into basic, roaming and handover subheadings.

The architecture section covers examples of Public Land Mobile Network architecture in roaming and handover situations.

The services section covers introductory descriptions of basic and supplementary services that can be provided to the user.

2 Definitions

2.1 *Basic definitions*

2.1.1 **Public Land Mobile Services**

Telecommunications services provided to moving subscribers (terrestrial applications).

2.1.2 **Public Land Mobile Network**

A Public Land Mobile Network (PLMN) is established and operated by an administration or RPOA for the specific purpose of providing land mobile telecommunication services to the public. A PLMN may be regarded as an extension of a fixed network (e.g. PSTN) or as an integral part of the PSTN. In the first case, it can be considered as a collection of mobile services switching centre (MSC) areas within a common numbering plan (e.g. service access codes) and a common routing plan (e.g. definition of crossover point); in this case the MSCs are the functional interfaces between the fixed network and a PLMN for call set-up. In the second case, it can be considered as an assemblage of special logic in existing or future PSTN/ISDN stored program controlled digital local exchanges, conceptually integrated within a common numbering and routing plan.

Functionally the PLMNs may be regarded as independent telecommunications entities even though different PLMNs may be interconnected through the PSTN and PDNs for forwarding of calls or network information. A similar type of interconnection may exist for the interaction between the MSCs of one PLMN.

The location register system of a PLMN may be centralized, distributed or segmented. So long as we are concerned with functions of a PLMN, such as routing and interworking, the configuration and operation of the location register system have no influence on external networks.

The use of the concept PLMN is illustrated in Figure 1/Q.1001 where various PLMNs are shown with their interfaces to the fixed networks. It should be noted that a PLMN may have several interfaces with the fixed network (e.g. one for each MSC). Interworking between two PLMNs may be performed via an international gateway.

Figure 1/Q.1001 also shows the information paths between a PSTN and a PLMN and between two different PLMNs. The solid lines indicate a possible physical path between the PLMNs through the PSTN. The dotted line indicates that, for some interactions, an end-to-end information path (established through the physical path) may exist between the two PLMNs.

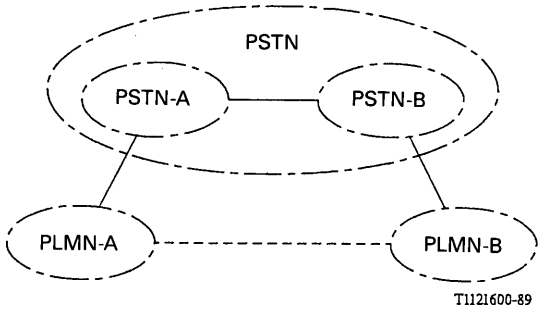


FIGURE 1/Q.1001

The use of the concept PLMN for country A and country B

2.1.3 Mobile Services Switching Centre

In an automatic system the Mobile Services Switching Centre (MSC) constitutes the interface between the radio system and the public switched telephone network. The MSC performs all necessary signalling functions in order to establish calls to and from mobile stations.

In order to obtain radio coverage of a given geographical area a number of base stations (radio transmitters/receivers) are normally required; i.e. each MSC would thus have to interface several base stations. In addition several MSCs may be required in order to cover a country. The definition of the MSC may be prefixed by the terms "land" or "maritime" if that is more suitable in a specific application.

2.1.4 base station

The base station (BS) is the common name for all the radio equipment located at one and the same place used for serving one or several cells.

2.1.5 mobile station

The mobile station (MS) is the interface equipment used to terminate the radio path at the user side. It includes terminal functions required to provide services to the user, e.g. terminal equipment and terminal adaptors.

2.1.6 cell

The area covered by a base station, or by a sub-system (sector antenna) of that base station corresponding to a specific logical identification on the radio path, whichever is smaller.

Every mobile station in a cell may be reached by the corresponding radio equipment of the base station.

2.1.7 base station area

The area covered by all the cells served by a base station.

2.1.8 location area

The location area is defined as an area in which a mobile station may move freely without updating the location register. A location area may comprise several cells.

2.1.9 MSC area

The part of the network covered by an MSC. An MSC area may consist of several location areas.

2.1.10 service area

The service area is defined as an area in which a mobile station is obtainable by another PLMN, PSTN or ISDN subscriber without the subscriber's knowledge of the actual location of the mobile station within the area. A service area may consist of several PLMNs. One service area may consist of one country, be a part of a country or comprise several countries. The location registration system associated with each service area must thus contain a list of all mobile stations located within that service area.

Figure 2/Q.1001 shows an example of the composition of a service area.

Note – This definition does not take into account any constraints on routing imposed by the international telephone network.

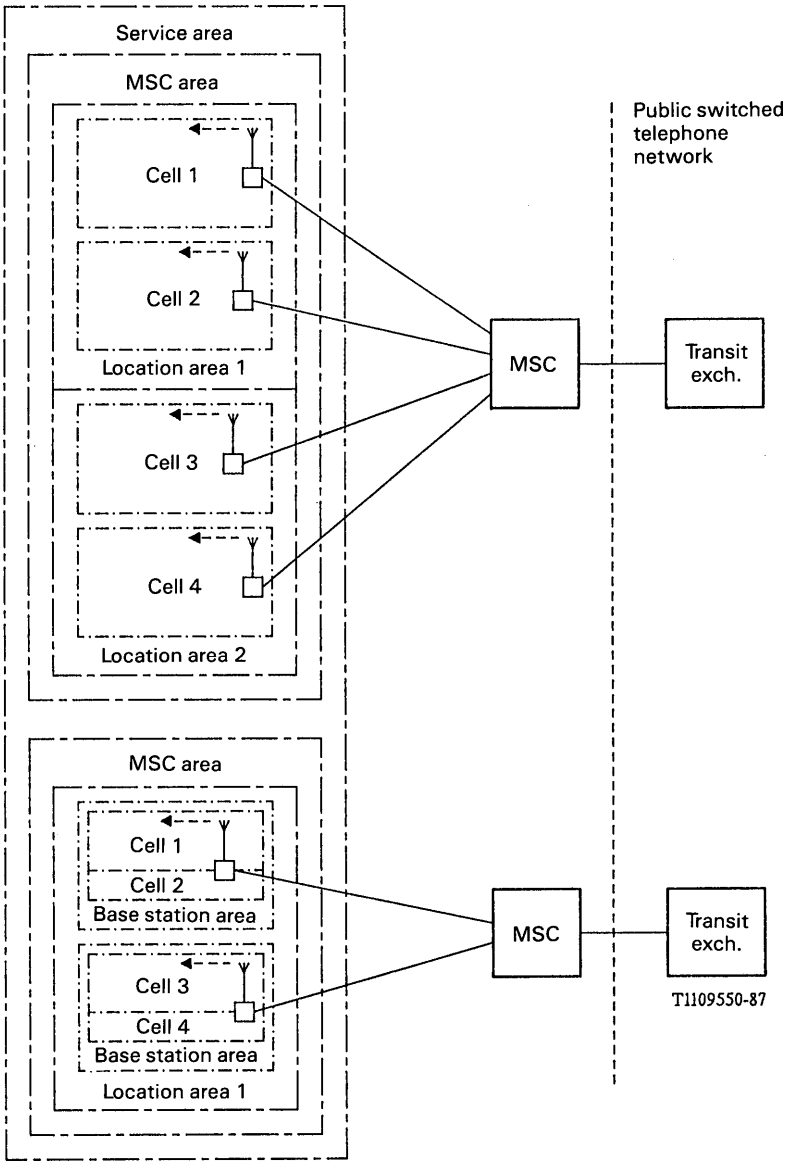


FIGURE 2/Q.1001

Use of the definitions.
In this example the service area consists of one PLMN

2.1.11 **system area**

The system area consists of one or more service areas with fully compatible MS-BS interfaces.

Note – The location registers of the individual service areas remain autonomous; updating of the location information is not performed when a roaming mobile station moves from one service area to another. The overall composition of the international land mobile system is shown in Figure 3/Q.1001.

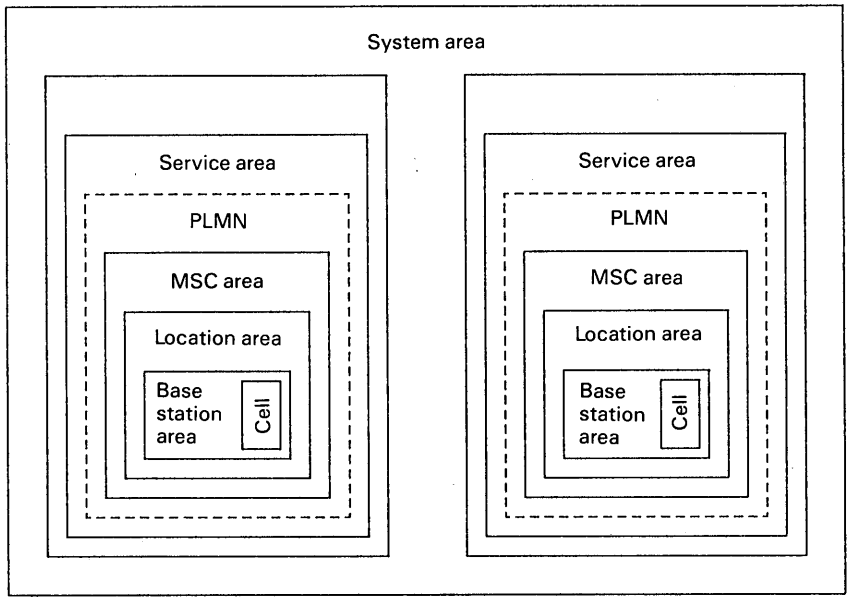


FIGURE 3/Q.1001

Composition of the system area

2.1.12 **Mobile Subscriber International ISDN Number**

The Mobile Subscriber International ISDN Number is defined as the number which has to be dialled in order to reach a mobile subscriber in a service area. See also Recommendations E.164 and E.213.

2.1.13 **international mobile station identity**

The mobile station's identification uniquely identifies the MS internationally. The identity is composed as defined in Recommendation E.212.

2.1.14 **radio traffic path**

The radio communication facility between a mobile station and a base station intended to carry a call and uniquely assigned to the mobile station during that call.

2.1.15 **radio control path**

The radio communication facility between a mobile station and a base station intended to carry all the information transfer between the mobile station and the MSC, in which area the mobile station currently is located, during the time that no radio traffic path between that base station and that mobile station is assigned.

2.2 *Roaming definitions*

2.2.1 **location register**

To establish a call to a mobile station the network must know where this mobile station is located. This information is stored in a function named location register. A mobile station is registered at one location register which functions as its home centre for charging and billing purposes and for administering its subscriber parameters.

2.2.2 **location information**

The location register should as a minimum contain the following information about a mobile station:

- international mobile station identity;
- actual location of the mobile station (e.g. PLMN, MSC area, location area, as required).

2.2.3 **home PLMN**

The PLMN in which a mobile station is permanently registered.

2.2.4 **home location register**

The location register to which a mobile station is assigned for record purposes such as subscriber information.

2.2.5 **home MSC**

The term home MSC (HMSC) may be used in cases where the home location register is implemented in an MSC.

2.2.6 **equipment Identity Register**

The register to which an international mobile equipment identity is assigned for record purposes.

2.2.7 **visited PLMN**

The PLMN, other than the home PLMN, in which a roaming subscriber is currently located.

2.2.8 **visitor location register**

The location register, other than the home location register used by an MSC to retrieve information for, for instance, handling of calls to or from a roaming mobile station, currently located in its area.

2.2.9 **visited MSC**

The term visited MSC (VMSC) may be used in cases where the visitor location register is implemented in an MSC.

2.2.10 **gateway PLMN**

The PLMN which receives a call from a fixed subscriber, via a public switched network, for extension to a mobile station. The gateway PLMN may vary for interconnection with different public networks.

The gateway PLMN could be the home PLMN or the visited PLMN or any other.

2.2.11 **gateway MSC**

The MSC which receives a call from a fixed subscriber, via a public switched network, for extension to a mobile station. The gateway MSC may vary for interconnection with different public networks.

The gateway MSC may be any MSC of the PLMN, including the HMSC or VMSC if the home and visited location registers are implemented in the MSC.

2.2.12 **designation method**

The calling subscriber must know the actual location area of any mobile station. The call is established according to the dialled information only, i.e. the call is not rerouted by the location register when the mobile station currently is in another location area.

2.2.13 **non-designation method**

The calling subscriber is not required to know the actual location area of the mobile station. The call is routed according to the dialled information and, if required, rerouted on additional information given by a location register.

2.2.14 **mobile station roaming number**

The network internal number used for routing of calls to the mobile station. See Recommendation E.213.

2.3 *Handover definitions*

2.3.1 **handover**

Handover is the action of switching a call in progress from one cell to another (or between radio channels in the same cell). Handover is used to allow established calls to continue when mobile stations move from one cell to another (or as a method to minimize co-channel interference).

2.3.2 **MSC-A (Controlling MSC)**

The MSC which first established the radio connection to or from a mobile station for mobile terminating or originating calls respectively. This MSC will be the call controlling MSC for the duration of the call also in cases where a call is handed over to another MSC.

2.3.3 **MSC-B**

The first MSC to which a call is handed over.

2.3.4 **MSC-B'**

The second (or subsequent) MSC to which a call is handed over.

Note – After the handover is completed and the circuit between MSC-A and MSC-B has been released. MSC-B' will look, from the point of view of MSC-A and the network, like MSC-B did before the handover.

2.3.5 **candidate MSC**

A Candidate MSC is an MSC which controls cells that could be candidates for receiving a call in case of a handover.

2.3.6 **target MSC**

The Target MSC is the MSC controlling the cell(s) selected as target(s) for a handover.

2.3.7 **serving MSC**

The Serving MSC is the MSC which handles the call at the moment.

2.3.8 **old serving MSC**

The old serving MSC is the MSC which was the serving MSC before a handover, other than MSC-A.

3 Architecture of the Public Land Mobile Network

3.1 *Configuration of a Public Land Mobile Network*

3.1.1 *General*

Figure 4/Q.1001 presents PLMN entities and the associated signalling interfaces. The specific implementation in each country (or PLMN, if more than one in each country) may be different; some of the functional entities may be combined in the same equipment and this may result in some interfaces becoming internal. The configuration of a PLMN must in any case have no impact on the relationship with other PLMNs. Example: PLMN entities and associated signalling interfaces are shown in Figure 5/Q.1001. To illustrate some implementation possibilities three examples of configurations are presented in Figures 6/Q.1001, 7/Q.1001 and 8/Q.1001. In addition, it can be mentioned that HLR and VLR can be physically implemented in the same equipment, as an integrated Location Register.

3.1.2 *Configuration example No. 1 (No co-location of functional entities)*

This configuration is presented in Figure 6/Q.1001. All functions are implemented in dedicated equipment. The interfaces within the PLMN are equipment external and therefore need the support of the Mobile Application Part (MAP) of Signalling System No. 7 to exchange the data necessary to provide the mobile service. All PLMN configurations can be deducted from this basic configuration. In instances where some functions are contained in the same equipment, the relevant interfaces become equipment internal to that equipment and the use of the MAP is not necessary. Some examples are given in §§ 3.1.3 and 3.1.4.

3.1.3 *Configuration example No. 2 (VLR co-located with VMSC)*

This configuration is presented in Figure 7/Q.1001. The Visited Location Register is co-located with or implemented in the VMSC for the following reasons. The main type of data stored in the VLR is the practical location information (i.e. location area) which has to be updated by the VMSC when the mobile station moves from one location area to another. The VMSC also has to interrogate the VLR at call set-up in order to know the relevant subscriber data (e.g. restrictions and supplementary services).

3.1.4 *Configuration example No. 3 (HLR and VLR co-located with a MSC)*

This configuration is presented in Figure 8/Q.1001. In cases where the HLR is implemented in the MSC, this MSC will become the HMSC for the subscribers managed by the Location Register. The two functions HLR and MSC are not of the same type: the HLR is a pure network data base function, interrogated when needed and the MSC is mainly in charge of call handling. The HMSC performs the call handling function for all its subscribers, as defined by their allocation to the HLR, when they are located in the HMSC area. Call set-up to mobile stations handled by the HMSC uses only the international mobile subscriber ISDN/PSTN number and no roaming number is allocated to these mobile stations.

3.2 *Interconnection between PLMNs*

As the configuration of a PLMN does not have any impact on other PLMNs, the specified signalling interfaces can be implemented between entities within a PLMN or between PLMNs, with or without intermediate interface equipment providing a gateway function at the application level.

A difference in the interface can be found at lower levels (SCCP), since different signalling networks can be involved in the exchange of messages and they are at least independent with respect to the signalling network addressing plan.

A specific interconnection with a PLMN gateway may be needed in cases where the organization and configuration of a PLMN does not meet the international specifications. The specific interconnection is used in this case to mask, from other PLMNs, a national configuration which is not in line with the international specifications.

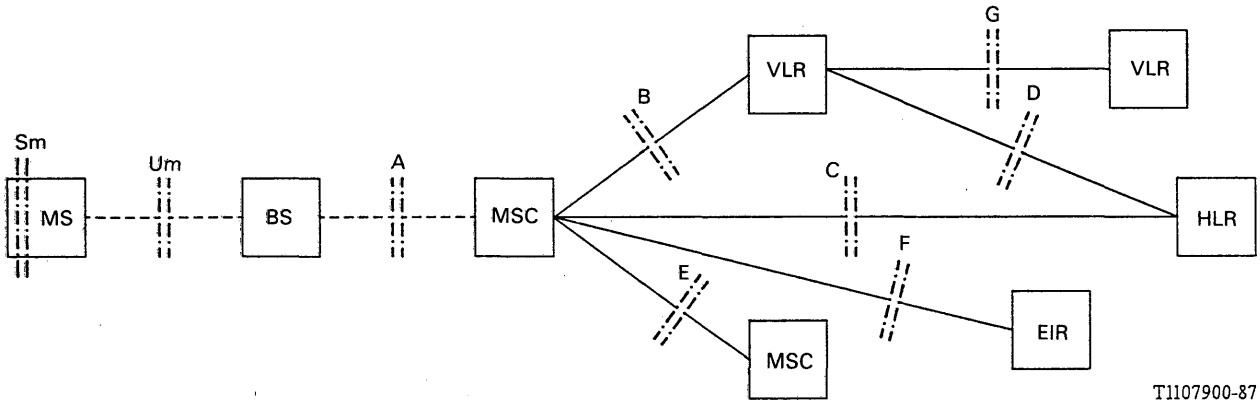


FIGURE 4/Q.1001

PLMN entities and associated signalling interfaces

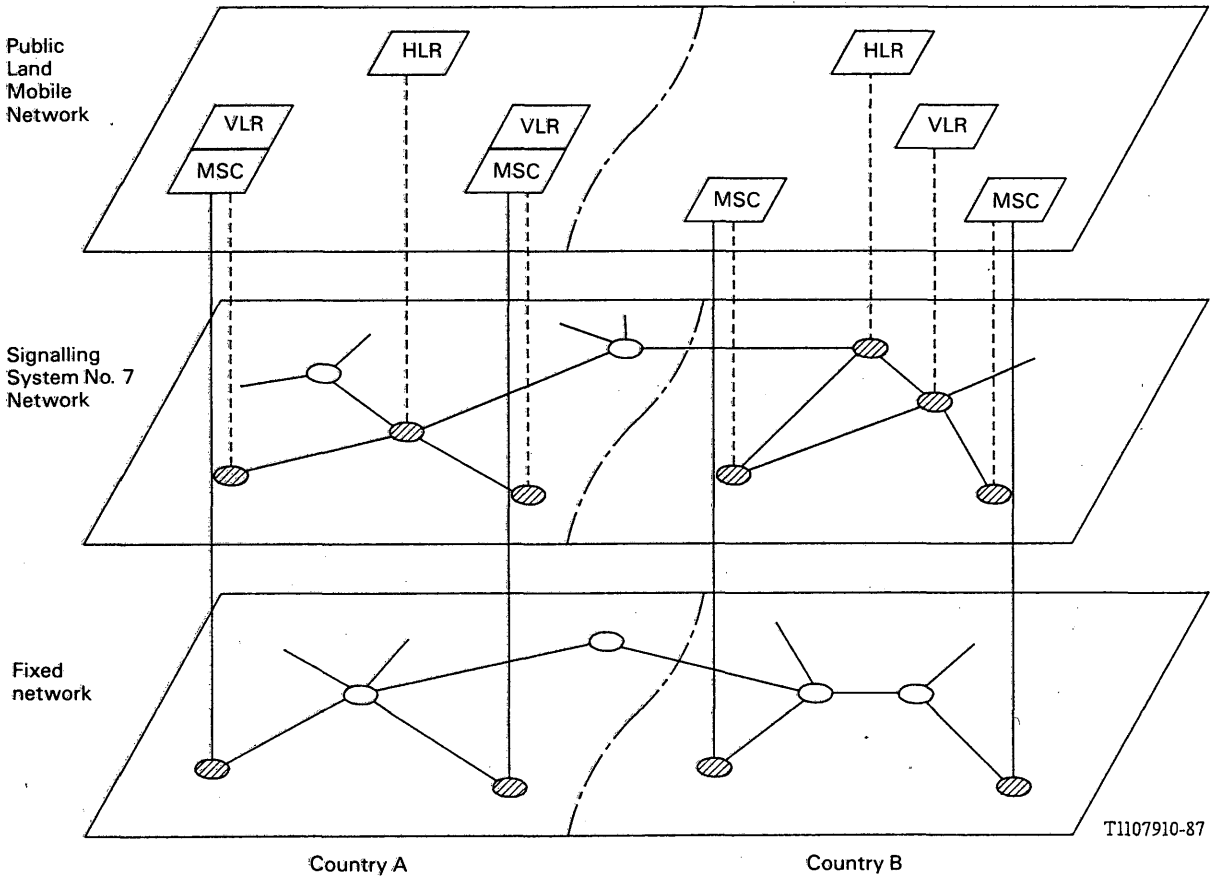


FIGURE 5/Q.1001

An example of interconnections of PLMNs and other networks

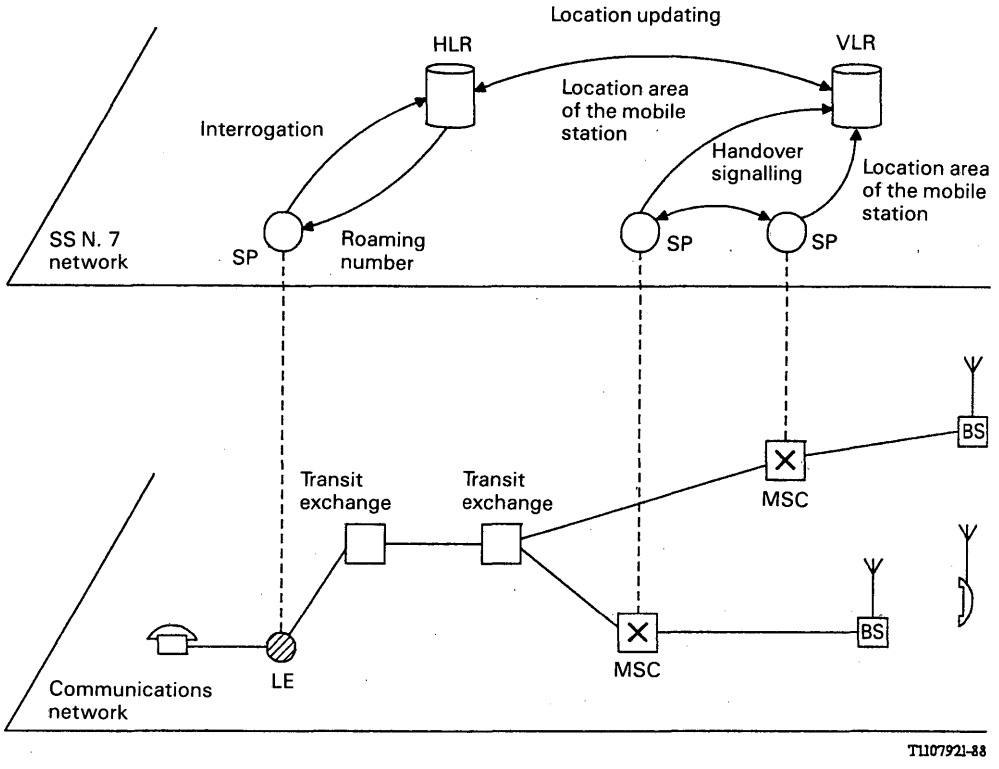


FIGURE 6/Q.1001

PLMN configuration example No. 1

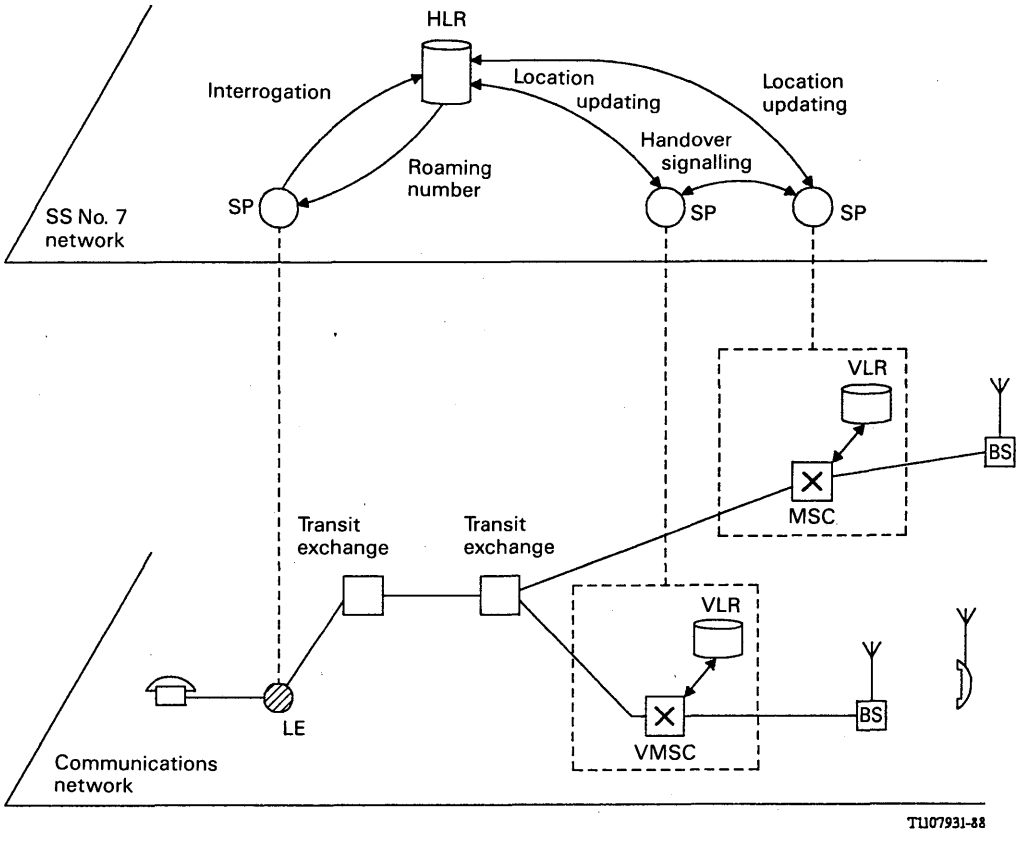


FIGURE 7/Q.1001

PLMN configuration example No. 2

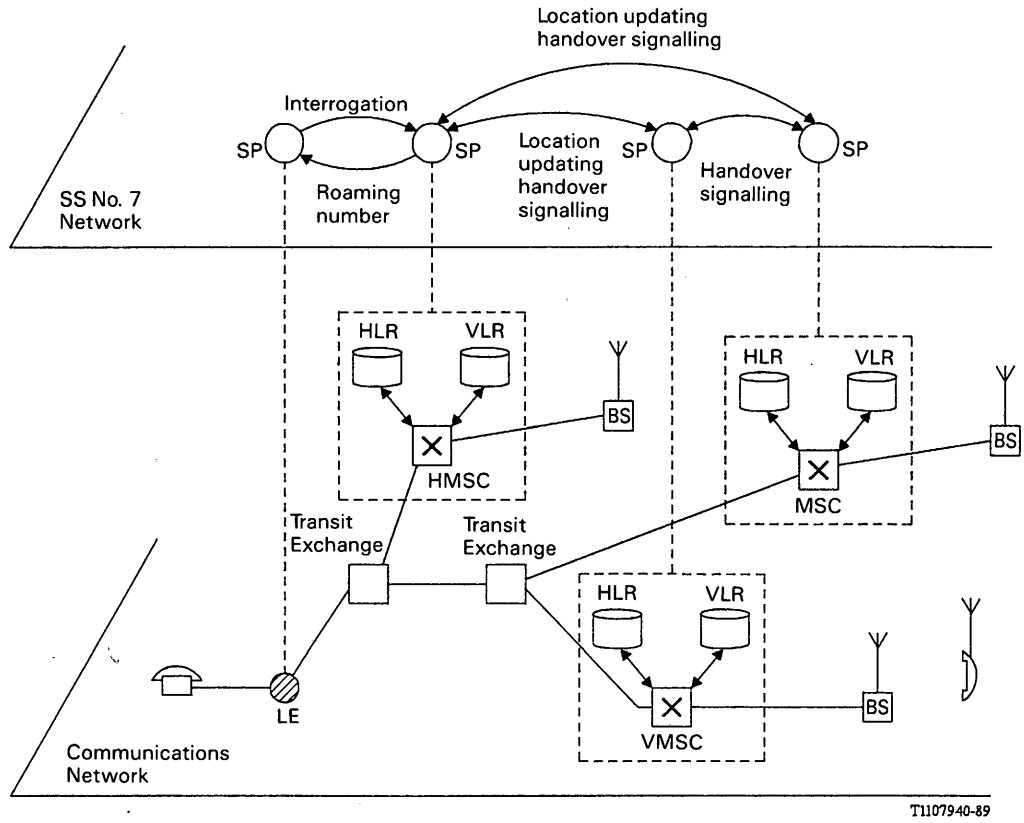


FIGURE 8/Q.1001

Configuration example No. 3

3.3 *PLMN interfaces*

3.3.1 *General*

The implementation of the public land mobile service with international roaming and handover implies the exchange of mobile specific signalling information between the equipment involved in the service. The introduction of Signalling System No. 7 and its signalling network will be an opportunity to transfer the data needed to support the Public Land Mobile Service. Signalling System No. 7 should be used to convey the information, where applicable. In addition some parts of the equipment will have signalling interworking with the fixed network. The descriptions given below are limited to the mobile application. The Mobile Application Part will be supported by the Transaction Capabilities.

3.3.2 *Interface between MSC and base station (A interface)*

The exact definition of the interface between a base station and its MSC depends on the division of functions between BS and MSC. Call handling as well as mobile station management may be split between the two entities.

However, the BS-MSC interface will in any case carry information concerning:

- Call handling
- Mobility management
- BS management
- Mobile station management

3.3.3 *Interface between MSC and VLR (B interface)*

The VLR is the location and management data base for the mobile stations roaming in the area controlled by the associated MSC or MSCs. The MSC interrogates the VLR whenever it needs information relating to a given mobile station currently located in the MSC area. When a mobile station initiates a location updating procedure with an MSC, the MSC informs its VLR which stores the relevant information in its tables. This procedure occurs whenever a mobile station roams to another location area. The MSC also informs the VLR when a subscriber for instance activates a specific supplementary service or modifies some information related to a service. The VLR stores these modifications and updates the HLR, if required.

3.3.4 *Interface between MSC and HLR (C interface)*

This interface is used to exchange signalling information for administrative and routing purposes.

In cases where charging information is transferred from an MSC, using Signalling System No. 7, this interface will be used.

In cases where the fixed network is unable to interrogate the HLR, an interrogation from a gateway MSC will be necessary in order to get the call routing information from the HLR, for instance the roaming number (if the mobile station is roaming).

3.3.5 *Interface between HLR and VLR (D interface)*

This interface is used to exchange the signalling information related to the location of the mobile station and to the management of the subscriber. The main service provided to the mobile subscriber is the capability to set-up or to receive calls within the service area. To support this, the location registers must exchange signalling information. The VLR informs the HLR of the location of a mobile station managed by the HLR and provides the HLR with the roaming number of that mobile station. The HLR sends to the VLR information needed to support the service to the mobile station. The HLR also informs a VLR which previously served the mobile station to delete all relevant information regarding a mobile station, which has roamed to an MSC area served by another VLR. Exchange of signalling information can also occur for instance when the mobile subscriber activates a supplementary service, when the subscriber wants to change some information related to his subscription or when the administration modifies some parameter of the subscription.

3.3.6 *Interface between MSCs (E interface)*

This interface is used mainly for handover related information exchange between MSCs. A handover is required when a mobile station moves from one MSC area to another during a call in order to continue communication. The MSCs exchange signalling information as a part of the process to determine the best cell for handover and finally to perform the handover if the best cell is in another MSC than the Serving MSC.

3.3.7 *Interface between MSC and EIR (F interface)*

This interface is used for information transfer between an MSC and the equipment identity register, EIR, related to management of national and international mobile equipment identities.

3.3.8 *Interface between VLRs (G interface)*

This interface is used for information transfer between VLRs when a mobile station registers in a new VLR using a temporary mobile station identity, TMSI, assigned by another VLR. This interface is used to retrieve the international mobile subscriber identity, IMSI, from the VLR which assigned the TMSI.

3.3.9 *Interface between BS and MS (Um interface)*

The exact definitions of the interface between base station and mobile station are not part of this specification.

However, the BS-MS interface is characterized by the Um reference point:

– the Um reference point is the traditional over-the-air radio-interface that is RF technology dependent and includes the physical aspects of the interface to the Base Station.

3.3.10 *Interface between user and network*

The Digital PLMN User-Network interface provides:

a) flexibility of user terminals with respect to Digital PLMN network interconnection:

b) flexibility of separate user terminal evolution and PLMN technology evolution; and

c) flexibility of definition and provisioning for PLMN basic bearer services, teleservices and supplementary services.

The definition of the User-Network interface is for further study.

4 Services in the public land mobile network

The services to be provided in a public land mobile network can be described according to the ISDN service definition principles (see Recommendation I.210) as basic services and supplementary services. Examples of these two types of services are telephone service and call forwarding unconditional respectively.

The basic services to be provided in the PLMN includes teleservices and bearer services, e.g. telephone and data services (for further study) as well as most other services provided in the ISDN (for further study).

The supplementary services to be provided are additional to one or more basic services.

5 List of Acronyms (Additional acronyms will be included)

BS	Base Station
EIR	Equipment Identity Register
GMSC	Gateway MSC
HLR	Home Location Register
HPLMN	Home PLMN
IMEI	International Mobile Equipment Identity
IMSI	International Mobile Station Identity
MAP	Mobile Application Part
MCC	Mobile Country Code
MNC	Mobile Network Code
MS	Mobile Station
MSC	Mobile Services Switching Centre
MSC-A	MSC with call control at handover
MSC-B	MSC to which a handover is done
MSC-B′	MSC to which a subsequent handover is done
MSIN	Mobile Station Identity
MTP	Message Transfer Part
NMSI	National Mobile Station Identity
PLMN	Public Land Mobile Network
SCCP	Signalling Connection Control Part
SP	Signalling Point
TMSI	Temporary Mobile Station Identity
VLR	Visitor Location Register
VPLMN	Visited PLMN

Recommendation Q.1002

NETWORK FUNCTIONS

1 - Introduction

This Recommendation defines network functions which may be necessary to support services and facilities provided by PLMNs. A summary of the network functions is given in Table 1/Q.1002. The table also indicates whether or not a function requires internetwork signalling between PLMNs (i.e., use of Mobile Application Part, Recommendation Q.1051).

TABLE 1/Q.1002

Overview of network functions

Class of network function (NF)	Network function	Interworking with MAP
NF needed for basic service provision	Call handling	X
	Subscriber authentication	X
	Emergency calls	–
	Supplementary services	X
Additional NF needed for call handling	Queuing	X
	Call duration limitation	–
	OACSU	–
	Mobile station with priority	–
	Mobile station with preference	–
	Security related services	X
NF needed for supporting cellular operation	Location registration	X
	Hand-over	
	– in the same BS	–
	– in the same MSC	–
	– in the same PLMN	X
	– between PLMNs	X
	Power control	–
	Dynamic channel allocation	(X)
Operation and maintenance oriented NF	Test loops	–
	Operation	X
	Maintenance	X
	Charging	X
	Traffic survey	(X)
	Malicious call identification	–
	Tracing of mobile stations	–

All functions require signalling on the radio path either as subscriber line signalling or as mobile management signalling.

2 Network functions for basic service provision

2.1 *Call handling*

This set of functions enables the establishment of communications between a mobile subscriber and another network subscriber in one of the following types of networks: PSTN, ISDN, PSPDN, CSPDN and other PLMNs.

2.1.1 *Call from MS registered in VLR*

This is the normal case where the call is routed according to the dialled number. After the call, the MSC shall send the charging information to the HLR, a billing entity and/or store the charging data on tapes or discs.

2.1.2 *Call from MS not registered in VLR*

When the VLR receives a request for call set-up parameters from an MSC for an MS originating call, where the MS is not registered in the VLR, the VLR shall initiate a location updating procedure toward the HLR and in response parameters are given concerning category, services and restrictions. The call is then set up as in § 2.1.1.

2.1.3 *Call to a mobile subscriber*

The call is routed (rerouted or forwarded) according to location data obtained from the HLR to the actual MSC.

2.1.4 *Call handling functions in HLR*

The HLR should accommodate call routing functions as described in § 2.1.3.

The HLR should also support control functions for handling of supplementary services.

2.1.5 *Call handling functions in VLR*

The VLR should provide subscriber parameters to the MSC as required for call handling.

The VLR should also support control functions for handling of supplementary services.

2.1.6 *Call handling functions in MSC*

The MSC should perform normal call routing and call control functions. The MSC will obtain subscriber parameters from its associated VLR.

The MSC should also be capable of performing handover as defined in § 3.2.

In some cases the MSC should be able to act as a gateway MSC.

2.2 *Subscriber authentication*

Authentication procedures should be implemented in order to protect the network from access by non-registered or fraudulent MSs. The authentication method is for further study.

A possible procedure could be as follows.

The procedure is based upon a challenge/signed response method which goes as follows:

- the fixed subsystem transmits a non-predictable number RAND (the challenge) to the MS;
- the MS calculates the signature SRES (the signed response) of RAND;
- the MS transmits the signature SRES to the fixed subsystem; and
- the fixed subsystem tests the signature for validity.

Authentication may take place in the following cases:

i) at location registration,

ii) at call set-up,

iii) when requesting operation of a supplementary service, or

iv) after handover.

2.3 *Emergency call*

2.3.1 *General*

The land mobile system should be capable of efficient handling of emergency calls from mobile stations. Signalling procedures on the radio path require further study.

2.3.2 The call should be routed automatically to an appropriate emergency centre based on the geographical location of the mobile station. For this purpose the accuracy of geographical location determination may be the cell serving the MS.

2.3.3 *Card operated stations*

It may be permissible to initiate emergency calls from card operated MSs also when the card is not inserted. This point is for further study.

2.4 *Supplementary services*

The support of supplementary services may require control procedures in HLRs, VLRs and MSCs in addition to the control procedures in the fixed network.

3 Network functions for supporting cellular operation

3.1 *Location registration*

3.1.1 *Definitions*

Location registration means that the PLMNs keep track of where mobile stations are located in the system area. The location information is stored in functional units called location registers. Functionally there are two types of location registers:

- the **home location register** where the current location and all subscriber parameters of a mobile station are permanently stored, and
- the **visitor location register** where all relevant parameters concerning a mobile station are stored so long as the station is within the area controlled by that visited location register.

See also Recommendation Q.1001 where the network architecture is described.

3.1.2 *Procedures*

Procedures related to location registration are specified in Recommendation Q.1003.

They comprise:

i) location register updating which enables the MS to inform the network that its location has to be updated, i.e. the MS has received a location area identity which is different from that contained in its memory. In order to avoid unnecessary updating, the current location area identity should be stored in a non-volatile memory in the MS;

ii) location cancellation which is used to delete an MS from a previous VLR;

iii) periodic location updating which enables the location of silent and stationary MSs to be updated at a reasonable rate; and

iv) as a network option, IMSI detach/attach operation which will enable MSs to inform the network that they have entered a power down/power up state.

The procedures also include mechanisms for restoration of location registers after failure. These procedures are defined in Recommendation Q.1004.

3.1.3 *Information stored in location registers*

Information to be stored in location registers is listed in Recommendation Q.1003.

3.2 *Handover*

3.2.1 *Definitions*

The following cases are considered:

i) handover between radio channels of the same base station;

Note – This capability could be used in the following situations:

– when the radio channel carrying the call is subject to interference or other disturbances; and/or

– when a radio channel or channel equipment carrying a call has to be taken out of service for maintenance or other reasons.

ii) handover between base stations of the same MSC in order to ensure continuity of the connection when an MS moves from one BS area to another;

iii) handover between base stations of different MSCs of the same PLMN; and

iv) handover between base stations of MSCs in difference PLMNs.

For cases iii) and iv) two procedures are defined:

a) **basic handover procedure** where the call is handed over from the controlling MSC (MSC-A) to another MSC (MSC-B); and

b) **subsequent handover procedure** where the call is handed over from MSC-B to MSC-A or to a third MSC (MSC-B').

3.2.2 *Procedures*

The procedures are described in Recommendation Q.1005.

3.3 *Power control*

For further study.

3.4 *Dynamic channel allocation*

For further study.

4 Additional network functions for call handling facilities

4.1 *Queuing*

4.1.1 *General*

Queuing of calls from fixed and mobile subscribers may be offered as an optional facility. Calls should only be queued when there is congestion on the radio path when the call arrives. The queuing facility is accommodated in the MSC.

4.1.2 *Queuing of MS originating calls*

When an MS originated call is placed in a queue, a queuing indicator should be provided to the MS as display information. The maximum time that the call will be kept in the queue should also be indicated. This would enable timers to be set in the MS in accordance with the queuing arrangements of each PLMN.

The MS should be marked as busy when the call is placed in the queue.

The call is cancelled when:

– the MSC receives a clearing message from the MS;

– there is time-out on the queuing time; or

– the VLR receives a location cancellation message from the HLR.

Note – It is for further study whether or not this is practicable.

4.1.3 *Queuing of MS terminating calls*

Queuing facilities for MS terminating calls may also be provided in the MSC. If so, general PSTN/ISDN specifications on abnormal release conditions and post dialling delays should be taken into account. Further study is required on interworking with the fixed network.

The MS should be marked as busy when the call is placed in the queue.

MS terminating calls should be released if a location cancellation message is received while the call is being queued.

Note – It is for further study whether or not this is practicable.

4.1.4 *Queuing conditions*

Not more than one call should be queued for each MS.

Calls should be queued and serviced in the order they arrive at the MSC, except for calls subject to some priority condition, e.g. calls which are handed over should have priority over normal calls and emergency calls should have priority over any other call.

Calls arriving when all positions in the queue are occupied, should be rejected with a congestion indication provided to the calling party.

Calls which have been queued for a time longer than the maximum queuing time should be released from the queue. MS terminating calls should be cleared with a congestion indication provided to the calling party.

4.2 *Call duration limitation*

4.2.1 *General*

This is an optional facility.

PLMNs may support functions whereby the call duration is limited in order to increase the call handling capacity of the PLMN. Call duration limitation may apply independently to each cell depending on the current traffic load of the cell. If possible, an indication should be provided to the subscribers that a call is subject to call duration limitation. Procedures are for further study.

4.3 *Off-air-call-set-up (OACSU)*

4.3.1 *General*

OACSU may be implemented in PLMNs in order to increase the call handling capacity of the PLMN.

OACSU may be implemented in PLMNs on an optional basis subject to the following conditions:

i) OACSU should not be used for calls to an international number;

ii) OACSU should not be used for incoming international calls;

iii) foreign MSs not supporting the OACSU procedure should be allowed to access the PLMNs where OACSU is used;

iv) MSs supporting OACSU should be capable of operating in PLMNs where OACSU is not implemented;

v) OACSU must not be used for calls involving an ISDN or a PDN or for non-voice services in the PSTN.

4.3.2 *Signalling procedures*

Interworking requirements for supporting OACSU are described in Recommendation Q.1031.

4.4 *Mobile stations with priority*

This is an optional facility.

It may be possible to offer priority for certain subscribers for:

- incoming calls;
- outgoing calls; or
- all calls.

Priority could comprise priority in queuing systems, preemption of outgoing calls in order to service a call with priority, etc.

Procedures for handling MSs with priority are for further study.

4.5 *Mobile stations with preference*

This is an optional facility.

Preference means that in certain circumstances only MSs with preference are allowed to access the network. The condition may be controlled by the BS by inserting a preference indication in the messages sent on the common signalling channel on the radio interface.

Procedures for handling of MSs with preference is for further study.

It should be possible to set the preference condition individually in each cell.

4.6 *Security related supplementary services*

PLMNs may offer encryption of information sent on the radio path. Procedures for encryption and key distribution are for further study.

4.7 *Discontinuous reception*

Discontinuous reception is a technique used to reduce the average battery consumption of mobile stations. The operation of this function is for further study.

4.8 *Discontinuous transmission*

Discontinuous transmission is a technique used to reduce the battery consumption of mobile stations. The operation of this function is for further study.

5 Operation and maintenance oriented network functions

5.1 *Test facilities*

The public land mobile systems may contain test facilities which can perform tests similar to those defined for the ISDN subscriber line.

Further study is required.

5.2 *Operation*

5.2.1 *General*

In PLMNs tasks related to system operation are divided among several functional units:

- home location registers,
- visitor location registers,
- MSCs,
- BSs,
- national operation and maintenance centres,
- encryption key distribution centres, and
- centres for management of equipment identities.

It should be noted that several of these functional units may be co-located or even be accommodated in the same physical equipment.

In addition, other aspects concerning system operation will be the responsibility of subscribers, MS manufacturers, sales agents, etc.

Tasks allocated to each of the functional units are described below.

5.2.2 *Responsibilities of HLRs*

The main responsibilities of the HLRs are:

i) subscriber administration, i.e. management of all subscriber parameters of MSs registered in the HLR. Subscriber administration also includes the possibility of making changes to subscription conditions and subscriber parameters. It may also include additional administrative functions related to CUGs and MSs with preference;

ii) charging administration, e.g. relaying of charging information from a foreign PLMN to the charging point in the home PLMN; and

iii) updating of VLRs.

5.2.3 *Responsibilities of VLRs*

The main responsibilities of the VLRs are:

i) management of mobile station roaming numbers;

ii) management of temporary mobile station identities, if implemented;

iii) subscriber administration of visiting MSs;

iv) updating of HLRs;

v) management of MSC areas, location areas and BS areas; and

vi) radio channel management (e.g. channel allocation tables, dynamic channel allocation management, channel blocking status).

Note – Some or all of the functions in vi) may be in the MSC or the BS. This is for further study.

5.2.4 *Responsibilities of MSCs*

The main responsibilities of the MSCs are:

i) routing administration;

ii) charging and tariff administration;

iii) traffic administration, e.g. traffic monitoring; and

iv) sending of relevant traffic and charging information to the HLR (see § 5.4).

5.2.5 *Responsibilities of national 0 & M centres*

The operational responsibilities of national O & M centres could be remote control and monitoring of the operation of functional units, e.g. remote management of subscriber parameters.

5.2.6 *Responsibilities of BSs*

For further study.

5.2.7 *Responsibilities of encryption key distribution centres*

For further study.

5.2.8 *Responsibilities of centres for management of equipment identities*

For further study.

5.3 *Maintenance*

5.3.1 *General*

Maintenance of PLMNs may require activities in several functional units. Some maintenance activities are autonomous, i.e. within one functional unit, and others require cooperation between several functional units. Functional units which may be involved in cooperative maintenance activities are:

- mobile stations,
- base stations,
- MSCs,
- visitor location registers,
- home location registers, and
- national operation and maintenance centres.

In some cases maintenance activities may require international cooperation. In such cases the maintenance responsibilities, the information exchanges and the activities required for restoration of service should be in accordance with rules set down for the PSTN/ISDN (M-Series of Recommendations).

5.3.2 *Maintenance responsibilities of MSs*

To some degree the MS should be capable of detecting faulty operation. When faults are detected, the MS should initiate internal testing and prevent accidental transmission.

5.3.3 *Maintenance responsibilities of the BSs*

The BS should monitor the radio path. If faulty operation is detected, information should be sent to the MSC and/or to a national operation and maintenance centre.

The BS may also have facilities for blocking and unblocking of radio channels and BS-MSC circuits.

5.3.4 *Maintenance responsibilities of MSCs*

The MSC should include maintenance facilities and support maintenance functions as for exchanges of the PSTN/ISDN. These functions include:

i) maintenance of the MSC-BS circuits and signalling links, including:
   - test, observation and measurement of MSC-BS (MSC-MS) protocols; and
   - blocking and unblocking of MSC-BS circuits and radio channels.

ii) maintenance of circuits to exchanges of the PSTN/ISDN,

iii) maintenance of signalling links to a signalling network,

iv) fault reporting to operation and maintenance centres, and

v) maintenance of their own equipment.

5.3.5 *Maintenance responsibilities of location registers*

The location registers will be responsible for:

i) maintenance of signalling links; and

ii) restoration after restarts including information exchange with other location registers.

5.3.6 *Maintenance responsibilities of operation and maintenance centres*

For further study.

5.4 *Charging*

The MSC and the BS must be capable of obtaining all information required for determining call charges for MS originating calls.

For charging of MS originating calls information as follows may be required:

- address of called party,
- IMSI,
- time of the call,
- charging rate for the called destination,
- call duration and possibly also parameters such as traffic volume and radio channel resources used,
- additional charges, e.g. for use of supplementary services,
- charging conditions, e.g. normal charging, debit card, credit card, and
- location of MS (e.g. cell, location area, MSC area).

For calls within the same PLMN the information is directed to the relevant billing entity. How this is achieved is a national concern, however, examples could be:

i) by use of the Mobile Application Part;

ii) by use of a public data network;

iii) by use of dedicated links;

iv) by use of physical transfer of magnetic tapes containing the billing information; or

v) a combination of the above.

Case i) above is specified in Recommendation Q.1051.

The need for Recommendations covering the other alternatives is a matter for further study. They may be required to permit different manufacturers equipment to interwork.

It should be noted that the use of the Mobile Application Part will only allow charging data on a per call basis to be transferred, though not necessarily immediately after the call has been terminated. For instance if the Mobile Application Part signalling or network processing load is such that the transfer of billing information would compromise normal call set-up procedures, then the transfer of billing information should be delayed until the signalling load decreases (e.g. overnight transmission of stored billing data).

In the longer term it is not clear, even if overnight transfer of billing information is used, whether the Mobile Application Part will have sufficient capacity, therefore a move to another technique will be necessary.

For calls involving a roaming mobile in a visited PLMN, the same techniques as above can be applied by bilateral agreement. For instance the situation could be imagined where a roaming service is opened between two networks, but the level of roaming traffic does not justify either the use of a public data network, or physical transfer of magnetic tapes, therefore the Mobile Application Part is used initially.

The destination for international billing information should be the relevant billing entity of the home network, however, when using the Mobile Application Part, addressing difficulties may mean that only the HLR can be addressed.

The MSC may support facilities for debit card calls. The signalling procedure on the radio path should support this type of operation.

The MSC may also support facilities for credit card calls. This involves facilities and procedures for authentication of the credit card number and transfer of the required information to the billing authority. The procedures will not be specified for the Mobile Application Part. On a national basis Signalling System No. 7, public data networks or other networks convenient for the administration may be used for these purposes.

For MS terminating calls where part of or the whole charge is to be paid by the MS, the information to be stored would be similar to that of MS originating calls. Further study is required.

5.5 *Traffic survey*

For further study.

5.6 *Malicious call identification*

If required and regulatory and technical constraints permit, the MSC may support the malicious call identification (MCI) facility for MS originating and MS terminating calls. The exact implementation of this facility will depend upon national variations of the signalling system being used.

5.7 *Tracing of mobile stations*

For further study.

Recommendation Q.1003

LOCATION REGISTRATION PROCEDURES

1 Introduction

This Recommendation specifies the procedures related to location registration. They include:

- location registration;
- location cancellation;
- periodic registration; and
- IMSI attach/detach.

The procedures in the MS, MSC, VLR and HLR are also given. The procedures utilize the Mobile Application Part (MAP) and details concerning the exchange of information are contained in Recommendation Q.1051.

2 Definitions

2.1 *Location registration*

Location registration means that the PLMNs keep track of where mobile stations are located in the system area. The location information is stored in functional units called location registers. Functionally there are two types of location registers:

- the **home location register** where the current location and all subscriber parameters of a mobile station are permanently stored; and
- the **visitor location register** where all relevant parameters concerning a mobile station are stored so long as the station is within the area controlled by that visitor location register.

See also Recommendation Q.1001 where the network architecture is described.

The action taken by a mobile station in order to provide location information to the PLMN will be referred to as *location updating.*

2.2 *Location area and MSC area*

The MSC area is composed of the area covered by all base stations controlled by the MSC. An MSC area may consist of several location areas.

A location area is an area in which mobile stations may roam without updating the location registers. A location area consists of one or more base station areas.

Paging procedures will be required on the radio path if the location area consists of more than one base station area. The paging procedure is used to determine the base station area in which the MS is located.

For further details of the network architecture and for definitions, see Recommendation Q.1001.

2.3 *Location area identification*

The location area idenfication plan is part of the base station identification plan. The base stations should be identified uniquely and the base station identity should include mobile country code, mobile network (PLMN) code, location area code and base station code within the location area where the location area identification consists of the first three elements. Furthermore, it is viewed that based on network considerations, the mobile country code and base station code may be optional in identifying where the location area identification is included in all messages sent on common signalling channels on the radio path.

2.4 *IMSI detach/attach operation*

IMSI detach operation is the action taken by an MS to indicate to the PLMN that the station has entered an inactive state (e.g. the station is powered down). IMSI attach operation is the action taken by an MS to indicate that the station has re-entered an active state (e.g. the station is powered up).

IMSI detach/attach operation is an optional facility in PLMNs.

2.5 *Use of the term mobile station (MS) in this Recommendation*

In order to simplify the text the term *mobile station (MS)* as used in relation to location registration refers to the entity where the IMSI is stored, i.e., in the card operated MSs the term *mobile station (MS)* refers to the card.

3 Procedures in the MS related to location registration

3.1 *Initiation of location register updating*

Automatic location updating should take place as follows.

The mobile station initiates location updating when it detects that it has entered into a new location area. The location area identification should be stored in a non-volatile memory in the MS so that the memory content does not disappear when the MS is turned off. This will avoid unnecessary location updating when the MS is still in the same location area when it is turned on again.

If the MS has lost the location information from memory, it will initiate location updating as soon as it is in an operational state and within radio coverage.

Location updating is also initiated on time-out of the timer T defined in § 3.2.

Location updating via manual intervention in the MS is for further study.

3.2 *Periodic location updating*

A timer T with the following characteristics could be optionally implemented in the MS:

i) timer T is reset to 0 and started when a signalling activity has taken place on the radio path;

ii) when the MS is powered down the current value of T is kept in memory, so that when the MS is powered up the timer starts running from the value thus contained in memory; and

iii) when timer T reaches its time-out value, the MS initiates a location updating.

Timer T thus measures the accumulated time between signalling activities in the MS while the MS is in the powered up state.

In order to ensure:

a) that the location of silent and stationary MSs are checked at a reasonable rate; and

b) that the timer T does not mature to time-out in the majority of cases.

The time-out value of timer T should be of the order of several hours (e.g. in the range of 12 to 24 hours). See also Recommendation Q.1004.

3.3 *Receiving acknowledgement from the PLMN*

The MS may receive either of the following acknowledgements from the PLMN.

i) *Location updated, roaming allowed.* In this case normal call handling operations will take place in the MS.

ii) *Location updated, roaming not allowed.* In this case, the MS will not be allowed to make calls. The MS should follow the procedure of §§ 3.1 and 3.2 above. The MS will resume normal operation if it receives a location updated, roaming allowed indication from the PLMN.

iii) *Updating failure,* indicating that the procedure in the PLMN failed. In this case, the MS should initiate a new updating after a given time. If this attempt fails, the MS should follow the normal procedures of §§ 3.1 and 3.2. When receiving the updating failure indication, the MS should be capable of normal call handling operation.

iv) *Insufficient identification,* indicating that the PLMN was not capable of identifying the MS. The MS should then initiate a new updating using the IMSI. The MS should follow the procedures of §§ 3.1 and 3.2 above.

v) *Not registered,* indicating that the MS is not known in the HLR. The MS should then reject any call attempts from the user. However, the MS should follow the normal procedures of §§ 3.1 and 3.2.

vi) *Illegal subscriber,* indicating that the MS is not allowed access to the system for authenticity reasons. The MS may follow the normal procedures of §§ 3.1 and 3.2.

3.4 *Procedure when acknowledgement is not received*

If the MS does not receive an acknowledgement (on layer 3) on an updating request, the MS may retransmit the message three times with at least ten seconds (see § 3.5) between consecutive attempts. If the procedure fails also for the third time, the general procedures of §§ 3.1 and 3.2 should be followed.

3.5 *Minimum time between location updatings*

The minimum time between consecutive location updatings should be ten seconds in order to avoid erroneous location information to be stored because of delays in the signalling network for information transfer via the mobile application part.

3.6 *IMSI detach/attach operation*

IMSI detach/attach operation is an optional facility in PLMNs. The facility is also optional in MSs.

The network should provide an indicator to the MS indicating whether or not IMSI detach/attach operation is allowed in a PLMN. MSs which are not equipped for IMSI detach/attach operation will ignore this indicator. MSs which are equipped for IMSI detach/attach operation shall operate in accordance with the received value of the indicator.

When IMSI detach/attach operation applies, an MS equipped for this type of operation and located in an area where roaming is allowed should send the IMSI detach signal to the MSC when the MS enters the inactive state (e.g. when the MS is powered down). When the MS again enters the active state, the IMSI attach signal is sent to the PLMN, provided that the MS is still in the same location area. If the location area has changed, the normal location upating of § 3.1 shall take place.

The IMSI detach signal will not be acknowledged from the PLMN.

The IMSI attach signal will be acknowledged from the PLMN. If the acknowledgement indicates that the MS is not registered or that the identification is insufficient, the MS should initiate the normal location updating procedure of § 3.1.

If the acknowledgement is not received, the MS should retransmit the IMSI attach signal after a given time. If the second attempt fails, the MS should follow the procedure of § 3.2. However, in this state the MS is allowed to make calls.

3.7 *Location updating after handover*

See Recommendation Q.1005.

3.8 *SDL description of the procedures in the MS*

Figure 1/Q.1003 shows state transition diagrams for procedures in the MS related to location updating. The diagrams are intended for guidance.

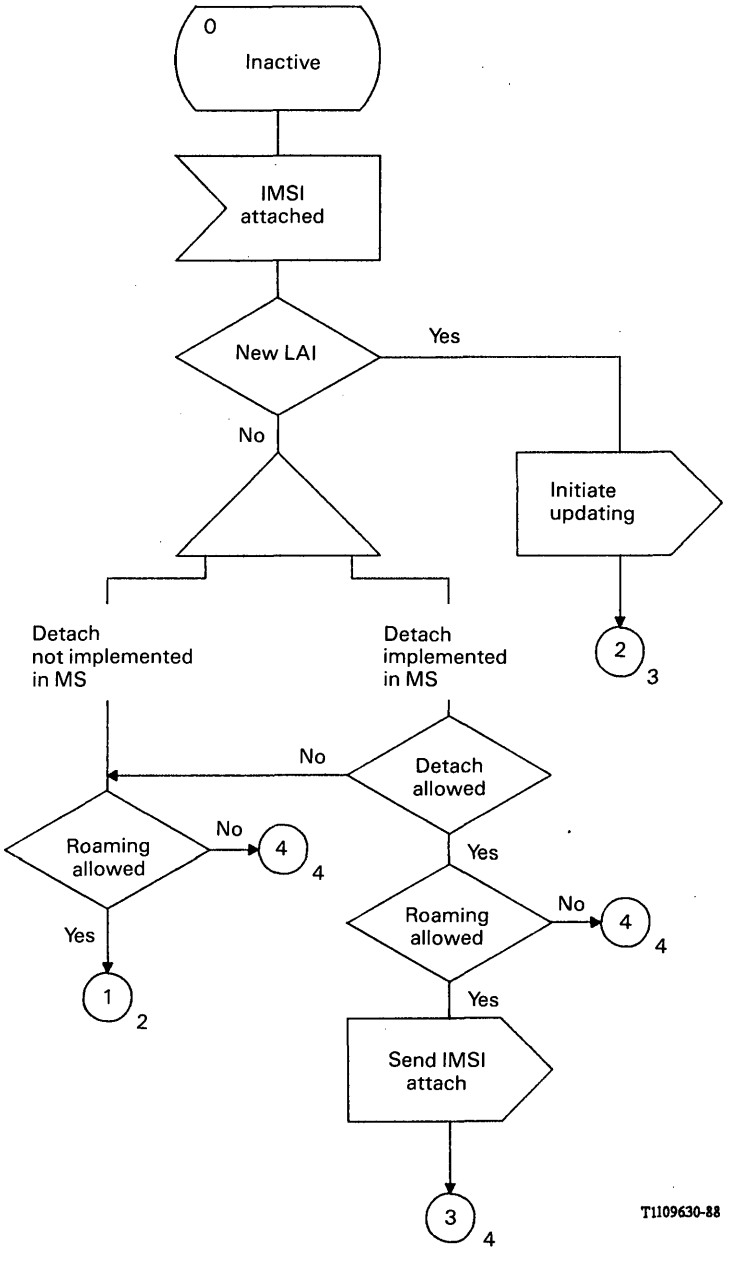


FIGURE 1/Q.1003 (Sheet 1 of 5)

Logic procedures in the MS for location updating

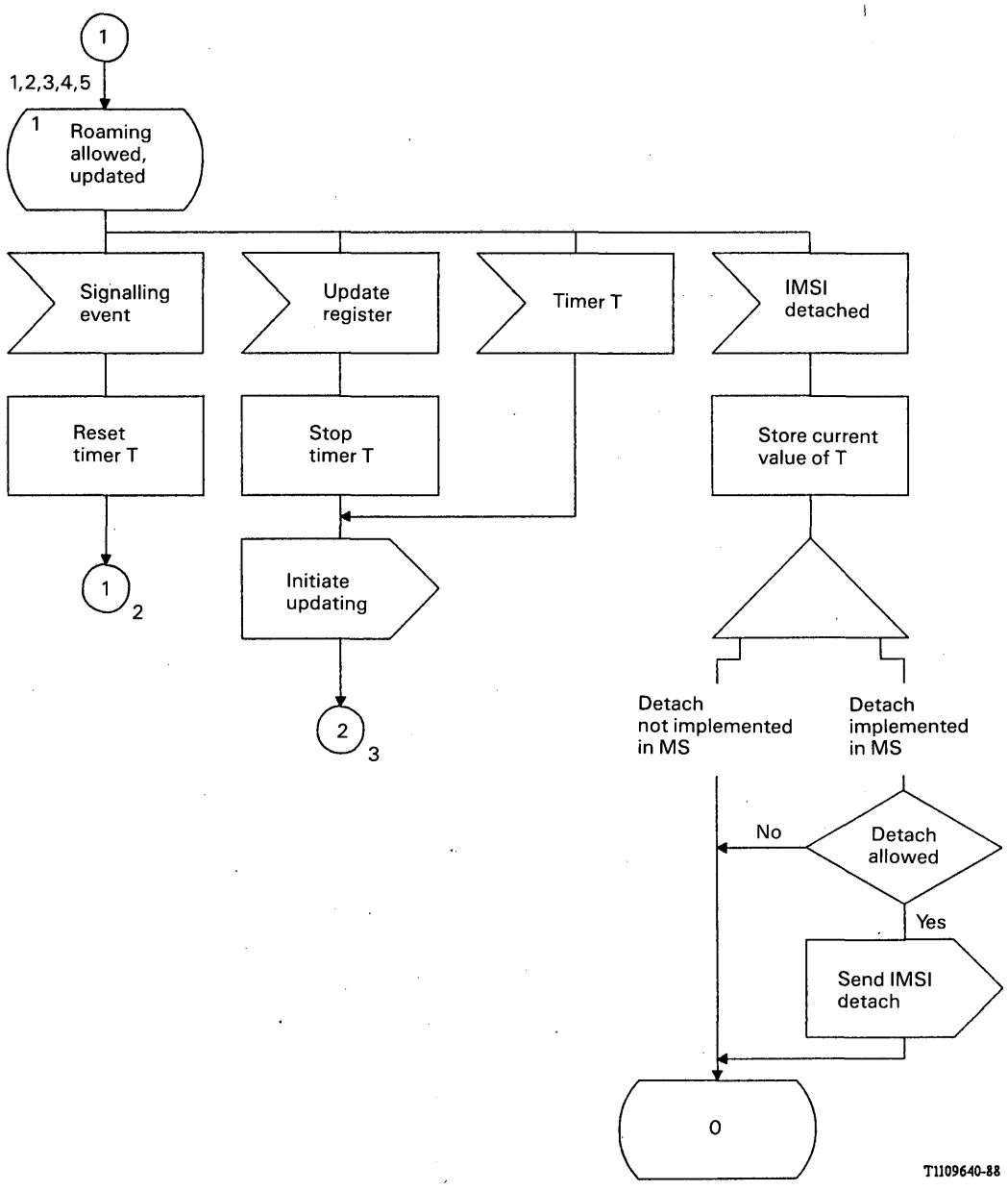


FIGURE 1/Q.1003 (Sheet 2 of 5)

Logic procedures in the MS for location updating

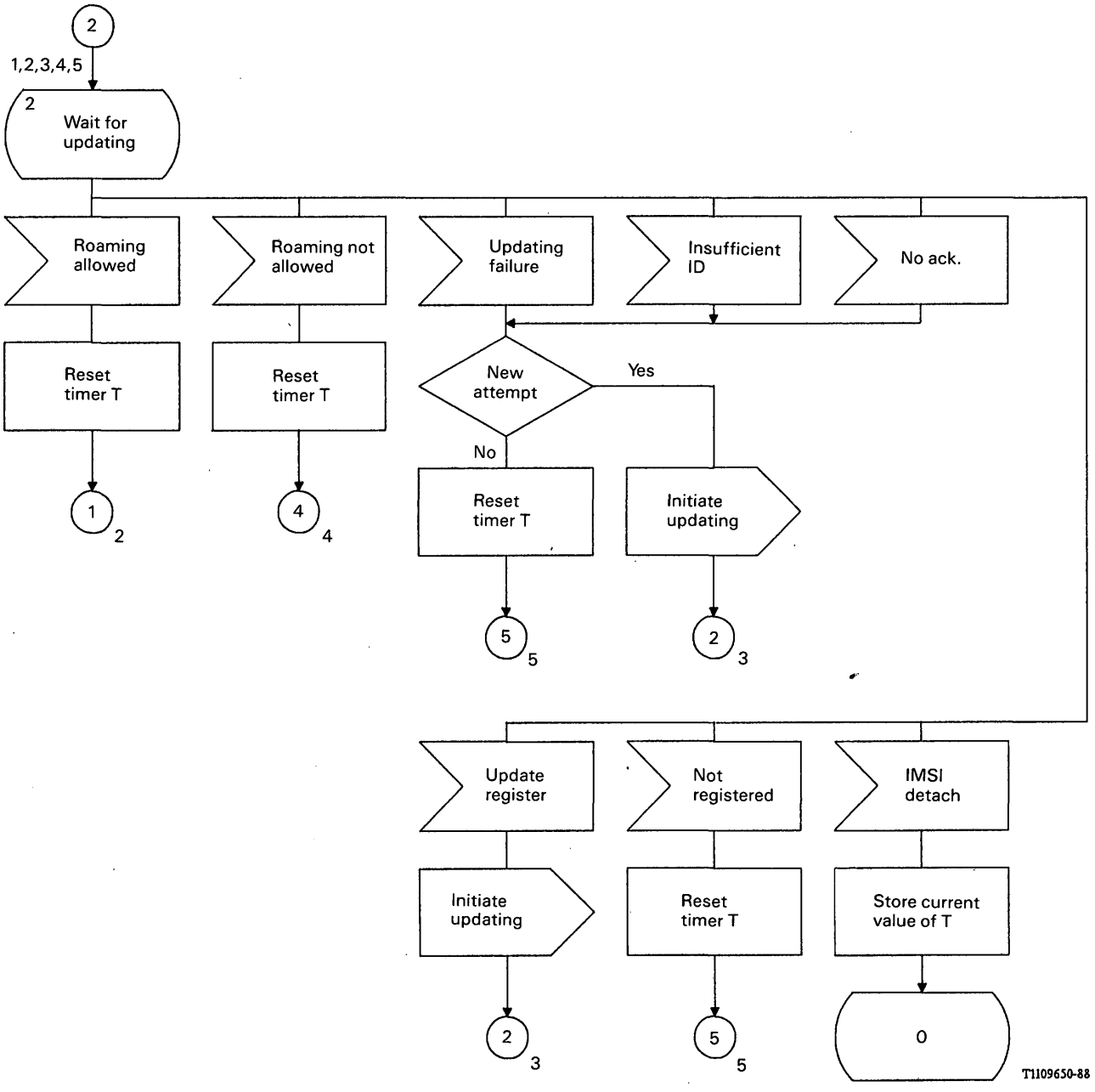


FIGURE 1/Q.1003 (Sheet 3 of 5)

Logic procedures in the MS for location updating

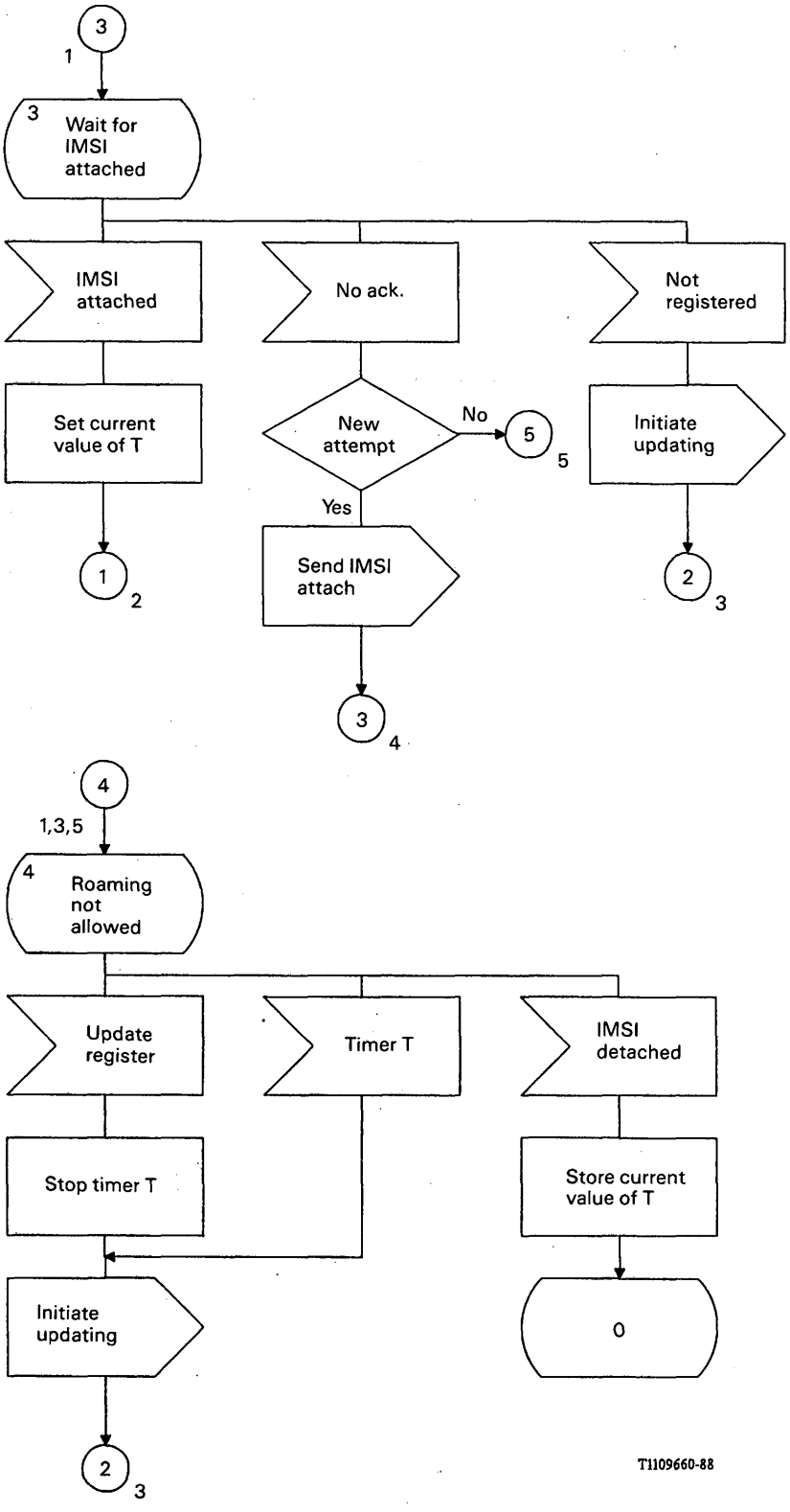


FIGURE 1/Q.1003 (Sheet 4 of 5)

Logic procedures in the MS for location updating

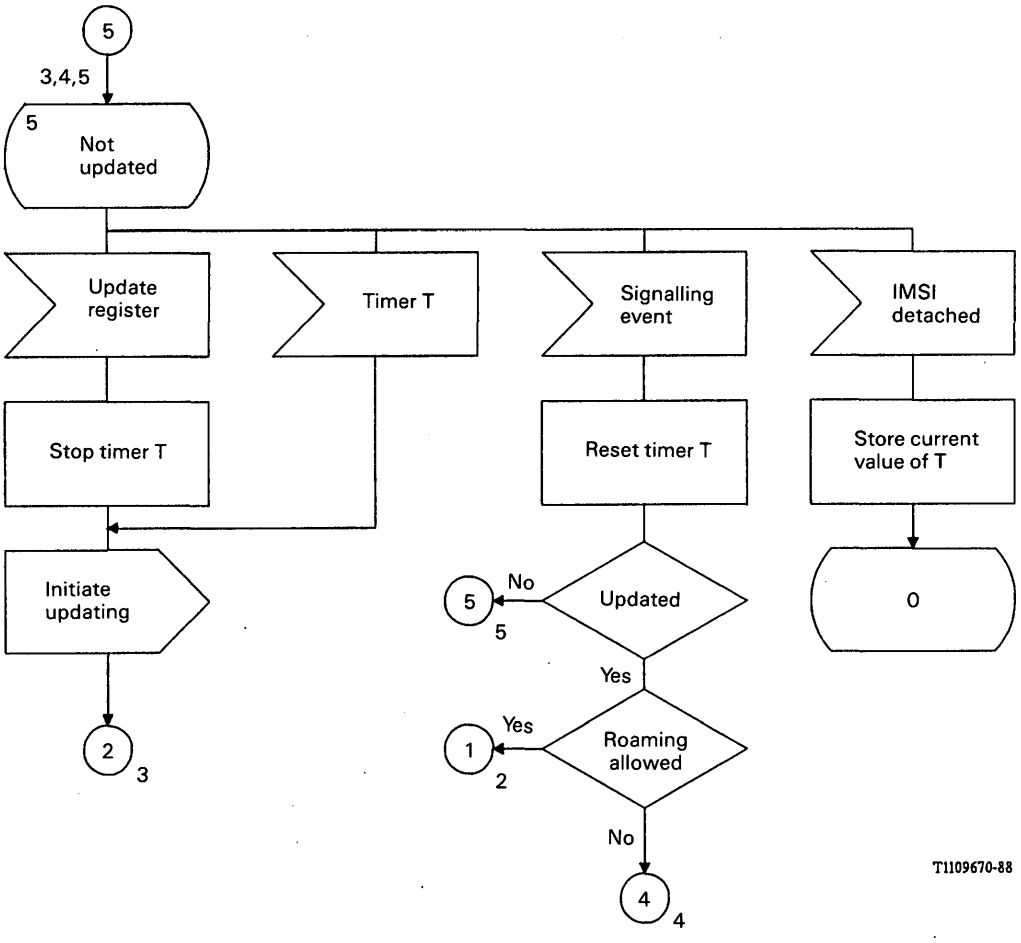


FIGURE 1/Q.1003 (Sheet 5 of 5)

Logic procedures in the MS for location updating

The following states are identified:

State 0: inactive

This state would in most cases correspond to the powered down state of an MS. The input signal IMSI attached may correspond to power up of the station.

State 1: Roaming allowed, updated

In this state the MS is fully operational.

State 2: Wait for updating

This is a transitional state where location updating takes place. In this state the MS cannot make or receive calls.

State 3: Wait for IMSI attached

This transitional state is only required in MSs which are designed for IMSI detach/attach operation. In this state the MS cannot make or receive calls.

State 4: Roaming not allowed

In this state the MS is not allowed to make calls (except emergency calls) and will not receive calls.

State 5: Not updated

This state is entered if the location updating or IMSI attach procedure fails. In this state the MS will not receive calls.

4 Procedures in the MSC/BS related to location updating

The MSC/BS will pass messages related to location updating between the MS and the VLR.

The MSC/BS will provide the location area identification and IMSI detach/attach supported information to the MS.

5 Procedures in the location registers

5.1 *Information to be stored in location registers*

The home and visitor location registers should contain information as defined in Annex A.

5.2 *Information transfer between MSCs/BSs and the associated visitor location register*

The procedures for information transfer between MSCs/BSs and the associated visitor location registers using Signalling System No. 7 are defined in Recommendation Q.1051.

5.2.1 *Normal location updating and IMSI detach/attach operation*

When receiving a location register updating message or an IMSI detach/attach message from an MS, the MSC/BS will convey the message to its associated visitor location register. The response from the location register will similarly be conveyed to the MS.

5.2.2 *Location updating as part of call set-up*

Location registration may also take place during call set-up if the request for call set-up comes from an MS which is not registered in the visited location register. This applies in particular to the case where a previous updating was unsuccessful. In such cases the MSC/BS should not establish the call until the location register updating has been completed.

Location register updating will also take place if the visitor location register receives signalling information from an unknown MS, e.g. a request for activation of a supplementary service.

5.3 *IMSI enquiry procedure*

The MS may either identify itself by the IMSI or the TMSI plus location area identification of the previous VLR. In the latter case the new VLR will enquire the IMSI from the previous VLR by methods defined in Recommendation Q.1051.

5.4 *Information transfer between visitor and home location registers*

5.4.1 *Interconnection of location registers*

Location registers may be interconnected by use of Signalling System No. 7 by procedures defined in Recommendation Q.1051. On a national basis other networks may be used for this purpose.

5.4.2 *Procedures for location registration*

Detailed procedures for exchange of location registration and location register updating information between visitor and home location registers are given in Recommendation Q.1051. Below follows an overview of these procedures.

5.4.2.1 *Location updating procedure*

This procedure is used when an MS registers with a visitor location register. It will also be used if the visitor location register has to reallocate the mobile station roaming number for an MS (see Recommendation E.213).

The visitor location register provides routing information to the home location register. This information consists of the mobile station roaming number which is used for routing of calls to the MS.

The home location register will then convey the subscriber parameters of the MS which need to be known by the visitor location register for proper call handling.

5.4.2.2 *Location cancellation procedure*

The procedure is used by the home location register to remove a mobile station from a visitor location register. The procedure will normally be used when the MS has moved to an area controlled by a different location register. The procedure can also be used in other cases, e.g. an MS ceases to be a subscriber of the home PLMN.

5.4.2.3 *Deregistration procedure*

If supported, the deregistration procedure is initiated by the VLR when it receives an IMSI detach request, see § 3.6. The corresponding IMSI is then deleted from the VLR tables. The HLR marks the subscriber as not registered and will reject all calls to that subscriber until a new updating procedure has taken place.

5.4.2.4 *Location information requested procedure*

This procedure enables a visitor register to enquire whether or not an MS is still to be kept in the register.

5.4.2.5 *Location information retrieval procedure*

By use of this procedure the home location register may obtain information on which of its MSs are registered with a visitor location register. The procedure may be used after a restart of the location register. The actual use of this procedure is for further study.

5.4.2.6 *Reset procedure*

The reset procedure is used for recovering from a restart of a home location register. A reset message is sent to visitor location registers so that recovery procedures can be initiated.

5.4.2.7 *Recovery procedure*

Recovery and restoration procedures for location registers are defined in Recommendations Q.1004 and Q.1051.

Recovery arrangements should be such that MSs with valid subscriptions are not deleted from the HLR as a result of HLR failure. The worst result of an HLR failure will thus be that some MSs are stored with errors in the temporary subscriber data.

5.5 *Overview state diagrams for location registers*

Figures 2/Q.1003 and 3/Q.1003 contain overview state transition diagrams for the home location register and the visitor location register, respectively, with regard to one MS. Reset procedures are not included in these diagrams, i.e. only the normal case is shown.

The state description is as follows.

i) *Home location register*

State 0: Null. In this state the MS has no subscription with the PLMN. Restart arrangements of the home location register should be such that this state is not reached for any MSs which have a subscription with the PLMN which is valid at the time of the restart.

State 1: MS not registered. In this state the location of the MS is not known. The MS is not offered any communication capabilities in this state.

State 2: MS in visitor location register (VLR), roaming allowed. In this state the MS is offered communication capabilities in the visitor location register in accordance with those established by the location updating procedure of § 5.4.2.1.

State 3: MS in visitor location register, roaming not allowed. In this state the MS is not offered any communication capabilities, except emergency calls, in the visitor location register. The home location register will contain an indication that the MS is in an area where the roaming not allowed condition applies. The visitor location register will not store any information concerning that MS.

ii) *Visitor location register*

State 0: Null. In this state the MS is not known to the visitor location register.

State 1: MS in visitor location register, roaming allowed. In this state the MS is offered communication capabilities in accordance with those established by the location updating procedure of § 5.4.2.1.

State 2: IMSI detached. In this state the MS is not offered communication capabilities.

5.6 *Additional updating procedures*

5.6.1 *Registration/erasure, activation/deactivation, invocation and interrogation of supplementary services*

The procedures defined in Recommendation Q.1051 enable MSs to register/erase, activate/deactivate, invoke or interrogate supplementary services in the visitor location register. The visitor location register conveys the necessary information to the home location register.

5.6.2 *Updating of other parameters*

Recommendation Q.1051 also contains procedures by which the home location register may update any set of subscriber parameters in a visitor location register if they are changed when the MS is in the area controlled by that visitor register. This may correspond to changes in subscription or of other parameters such as authentication parameters.

5.7 *Call handling functions of location registers*

5.7.1 *Retrieval of subscriber parameters on a per call basis*

All subscriber parameters are stored in the home location register. A subset of these parameters are stored in the visitor location register (see Annex A).

There are also cases where the visitor location register must obtain subscriber parameters on a per call basis from the home location register of the MS. The procedures are defined in Recommendation Q.1051.

5.7.2 *Interrogation procedures*

In fixed networks using the ISDN User Part of Signalling System No. 7 it may be possible for an exchange of the fixed network to retrieve routing information from the home location register of an MS prior to establishing a physical connection for a call. If this is not possible, a gateway MSC will perform this interrogation.

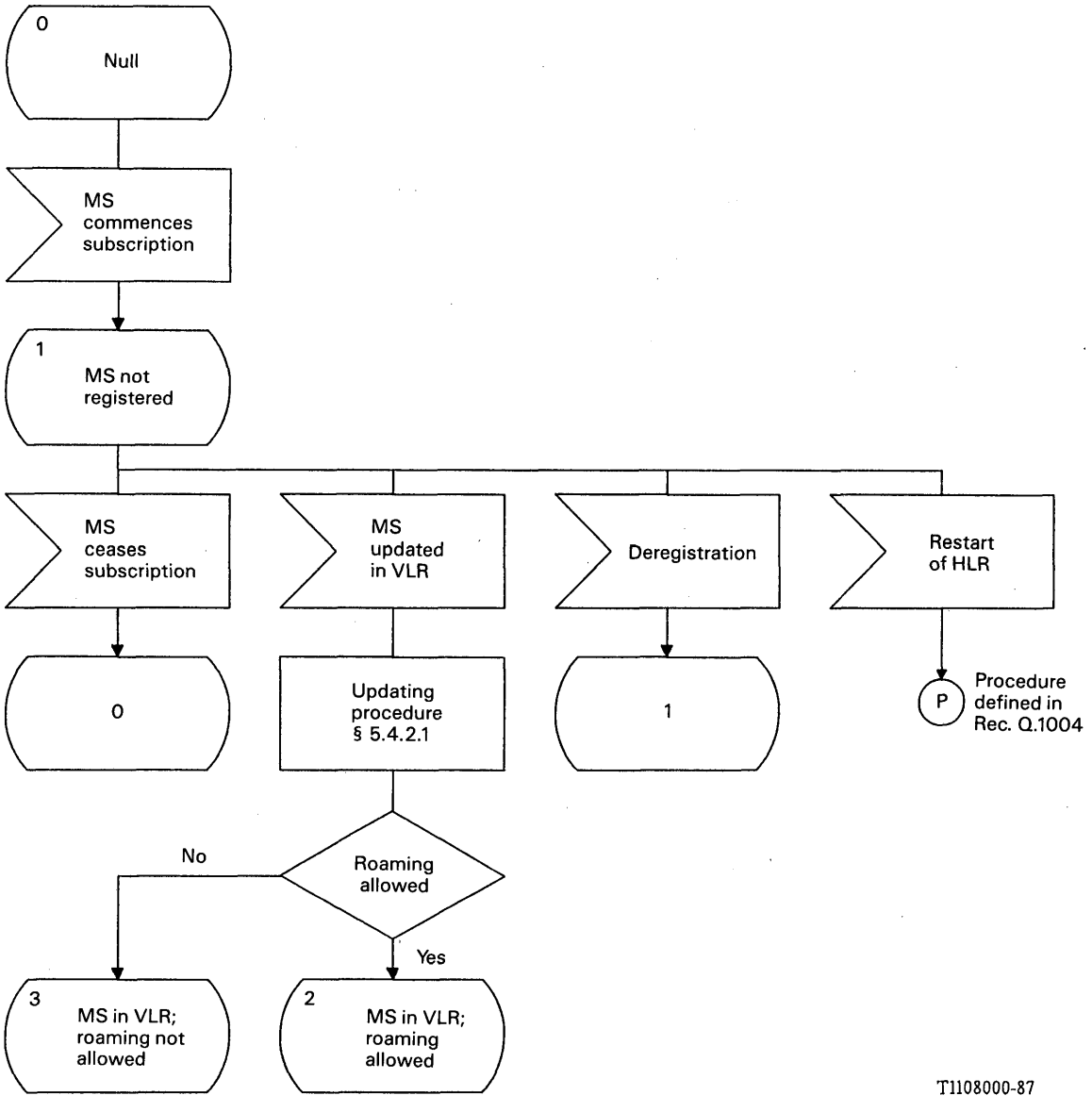


FIGURE 2/Q.1003 (Sheet 1 of 3)

State diagram for home location register

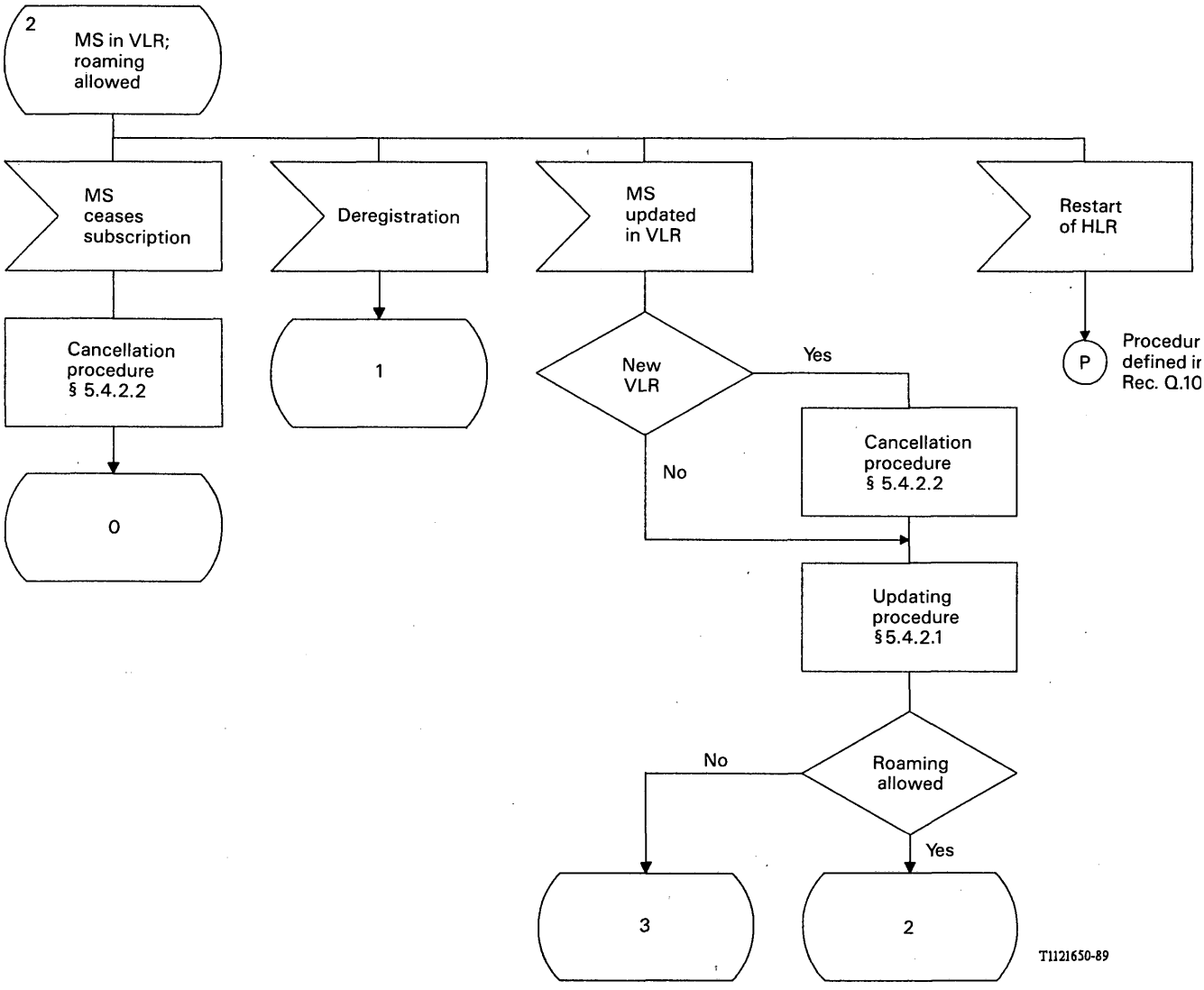


FIGURE 2/Q.1003 (Sheet 2 of 3)

State diagram for home location register

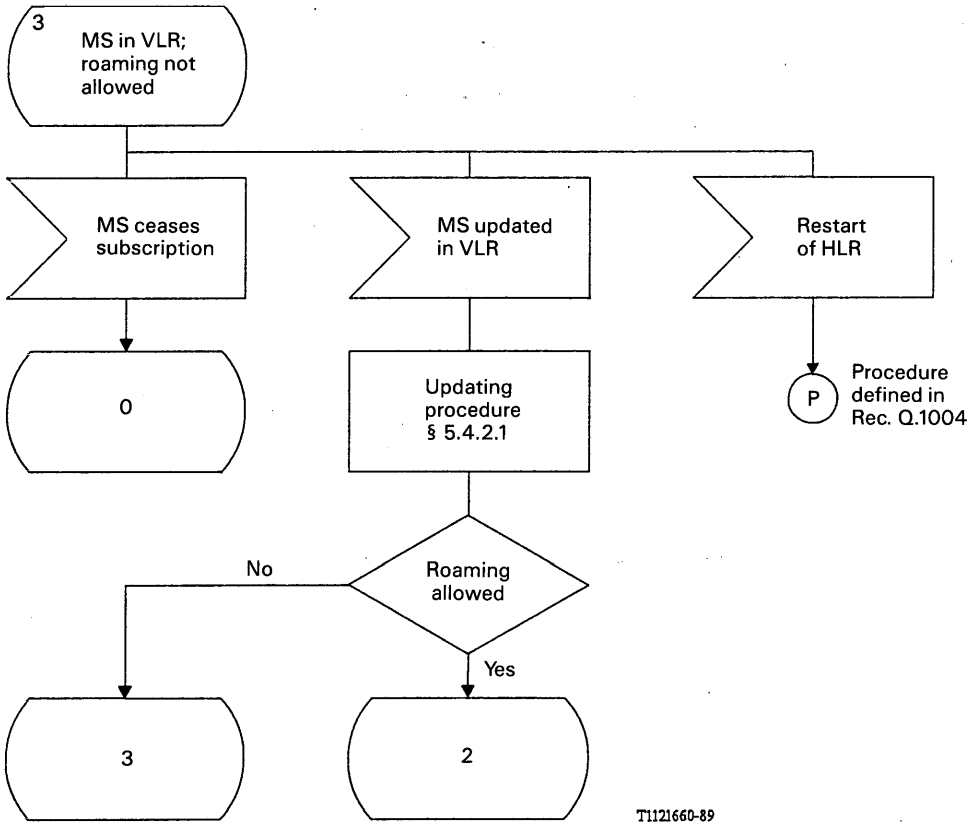


FIGURE 2/Q.1003 (Sheet 3 of 3)

State diagram for home location register

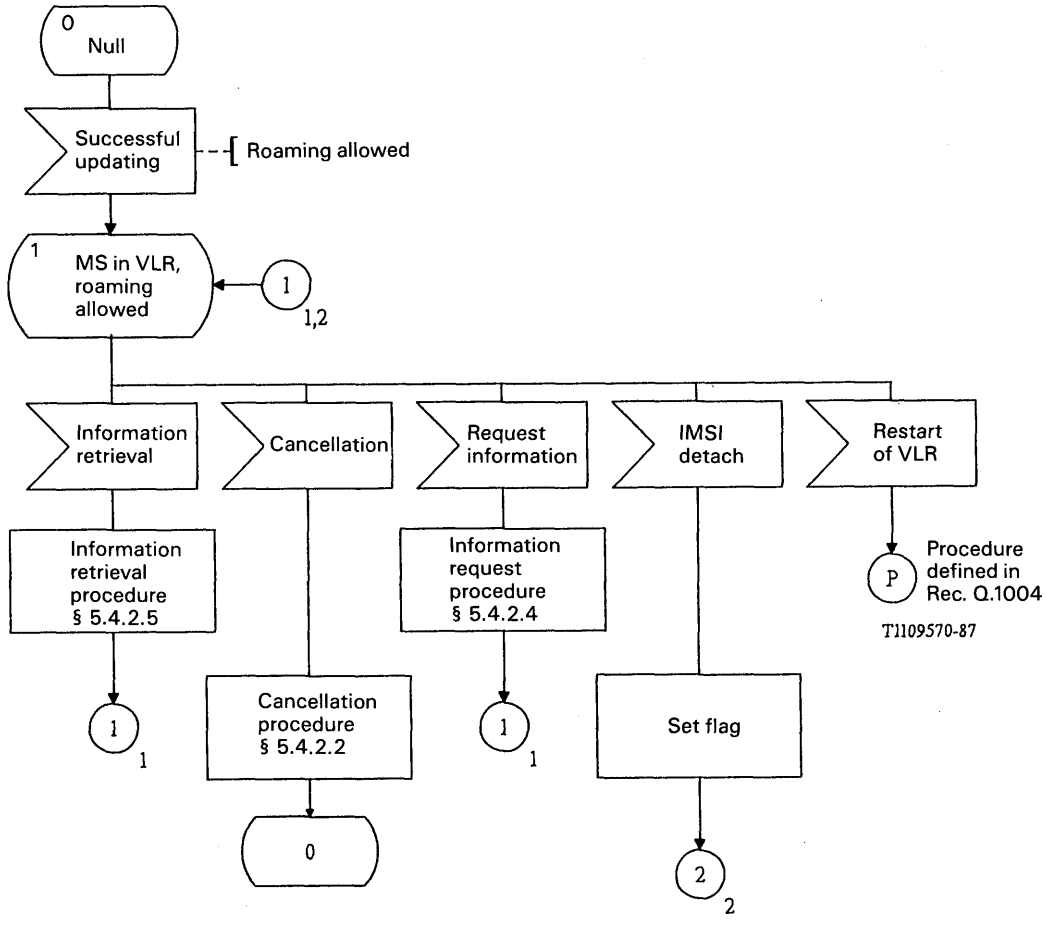


FIGURE 3/Q.1003 (Sheet 1 of 2)

State diagram for visitor location register

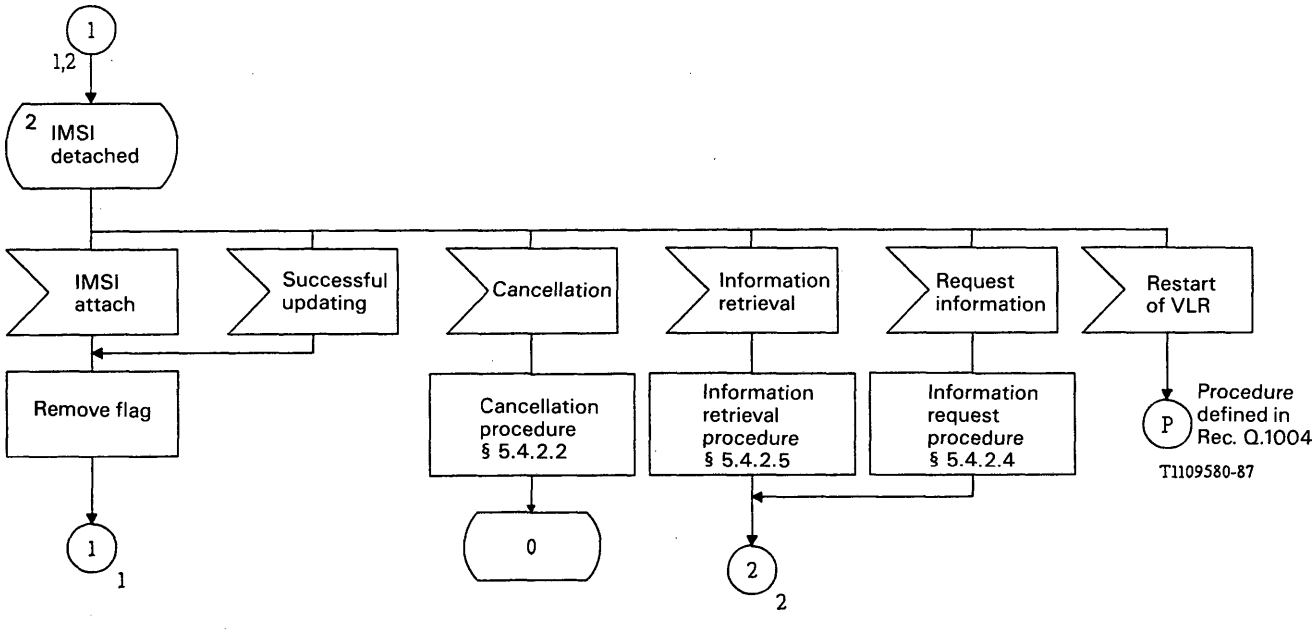


FIGURE 3/Q.1003 (Sheet 2 of 2)

State diagram for visitor location register

ANNEX A

(to Recommendation Q.1003)

Organization of subscriber data

A.1 *Introduction*

A.1.1 *Definitions*

For the purpose of this Recommendation the following terms are used.

mobile station (MS): either a physical equipment or a card for which subscriber data are stored.

subscriber data: all information concerning a specific MS which is required for service provisions, identification, authentication, routing, call handling, charging, operation and maintenance purposes. Some subscriber data are referred to as permanent subscriber data, i.e. they can only be changed by administrative means. Other data are temporary subscriber data which may change as a result of normal operation of the system. Some data are referred to as flexible length data, i.e. further values than those listed may be required in the future.

A.1.2 *Storage facilities*

Subscriber data is stored in two types of functional units.

home location register (HLR): which contains all permanent subscriber data and all relevant temporary subscriber data for all MSs permanently registered in the HLR.

visitor location register (VLR): which contains all subscriber data required for call handling and other purposes for MSs currently located in the area controlled by the VLR.

Note – It is for further study whether other types of functional units containing MS parameters are to be included in this Recommendation or not. Such units could include encryption key distribution centres, maintenance centres, etc.

A.2 *Definition of subscriber data*

A.2.1 *Data related to identification and numbering*

A.2.1.1 **international mobile station identity (IMSI)**is defined in Recommendation E.212. It consists of three parts MCC, MNC and MSIN. The MCC consists of 3 digits and the MNC consists of 1 or 2 digits. The IMSI has variable length depending on national requirements. The maximum length is 15 digits.

Only numerical characters (0 through 9) are used in the IMSI.

The IMSI is permanent subscriber data, and is stored in both the HLR and the VLR.

Note – The IMSI for mobile PBXs is for further study.

A.2.1.2 **international mobile station number** is defined in Recommendation E.213. It is a PSTN/ISDN number and has a variable length which complies with the requirements of the PSTN/ISDN in each country.

The international mobile station number is permanent subscriber data.

The international mobile station number is stored in both the HLR and the VLR.

Note – Mobile station numbers for mobile PBXs are for further study.

A.2.1.3 **temporary mobile station identity (TMSI)** is assigned by the VLR and is used for identification of an MS within the area controlled by the VLR. The purpose of the TMSI is to support location confidentiality to mobile subscribers. TMSIs may not be allocated to all MSs, e.g. if the location confidentiality service is offered only on a subscription basis.

The TMSI is temporary subscriber data.

The TMSI is stored in the VLR.

A.2.2 *Data related to mobile station types*

A.2.2.1 *Mobile station category* comprises the following categories:

For further study.

Only one category is assigned for each MS.

Mobile station category is permanent subscriber data.

The length of the parameter is one octet.

Mobile station category is stored in the HLR and the VLR.

A.2.2.2 **mode of operation** defines whether or not the MS is card operated. Only two possibilities exist:

- card operated; and
- not card operated.

Mode of operation is permanent subscriber data.

The mode of operation is stored in the HLR and the VLR.

Note – It is for further study whether this data is required or not.

A.2.2.3 **preference** indicates whether or not an MS is given preference access to the PLMN under certain circumstances. This point is for further study.

Preference is permanent subscriber data.

Preference is stored in the HLR and the VLR.

A.2.3 *Data related to authentication*

For further study.

A.2.4 *Data related to roaming*

A.2.4.1 **mobile station roaming number** is defined in Recommendation E.213. It is a PSTN/ISDN number and has a variable length which complies with the requirements of the PSTN/ISDN in each country.

The mobile station roaming number is temporary subscriber data.

The mobile station roaming number is stored in the HLR and the VLR.

A.2.4.2 **location area identification** consists of three parts: MCC, MNC and LAC, where MCC is the Mobile Country Code and MNC is the Mobile Network Code of Recommendation E.212 and LAC is a Location Area Code identifying a location area within a PLMN. MCC and MNC are composed of numerical characters (0 through 9). LAC may have a variable length and may be coded using full haxadecimal representation.

The overall length of the location area identification is for further study.

The location area identification is temporary subscriber data.

The location area identification is stored in the VLR. It may also be required in the HLR; this is for further study.

A.2.4.3 **VLR address** is a PSTN/ISDN number and has variable length which complies with the requirements of the PSTN/ISDN in each country.

The VLR address is temporary subscriber data.

The VLR address is stored in HLR.

A.2.5 *Data related to supplementary services*

For further study.

A.2.6 *Mobile station status data*

A.2.6.1 **MS registered/deregistered** is a parameter indicating whether the MS is in the registered or deregistered state. The parameter takes the following values:

- registered, or
- not registered.

The parameter is temporary subscriber data. The parameter is stored in the HLR.

A.2.7 *Other subscriber data*

This is for further study.

A.3 *Subscriber data stored in HLR*

The following information should be stored in the HLR for each MS:

i) international mobile station identity (§ A.2.1.1);
ii) international mobile station number (§ A.2.1.2);
iii) mobile station roaming number (§ A.2.4.1);
iv) mobile station category (§ A.2.2.1) and mode of operation (§ A.2.2.2);
v) preference (if implemented) (§ A.2.2.3);
vi) authentication parameters (§ A.2.3);
vii) VLR address (if received) (§ A.2.4.3);
viii) location area identification (if required) (§ A.2.4.2);
ix) supplementary service type (§ A.2.5.1.1);
x) mobile station status data (§ A.2.6); and
xi) other subscriber data, if required (§ A.2.7).

A.4 *Subscriber data stored in VLR*

The following information should be stored in the VLR for each visiting MS:

i) international mobile station identity (§ A.2.1.1);
ii) international mobile station number (§ A.2.1.2);
iii) mobile station roaming number (§ A.2.4.1);
iv) temporary mobile station identity (§ A.2.1.3);
v) mobile station category (§ A.2.2.1) and mode of operation (§ A.2.2.2.);
vi) preference (if implemented) (§ A.2.2.3);
vii) authentication parameters (§ A.2.3);
viii) location area identification (§ A.2.4.2); and
ix) other subscriber data, if required (§ A.2.7).

A.5 *Accessing subscriber data*

It should be possible to retrieve or store subscriber data concerning a specific MS from the HLR by use of each of the following references:

- international mobile station identity; or
- international mobile station number.

It should be possible to retrieve or store subscriber data concerning a specific MS from the VLR by use of each of the following references:

- international mobile station identity;
- mobile station roaming number; or
- temporary mobile station identity.

LOCATION REGISTER RESTORATION PROCEDURES

1 Introduction

The data stored in the location registers are automatically updated and the main information is related to the location of the mobile station. The data is updated when the mobile station moves from one area to another. The loss of this information would have an important impact on the service provided to the relevant mobile subscribers. It is therefore necessary to define solutions to limit the perturbations following a register failure and to restore automatically these tables.

This Recommendation describes some methods that could be implemented in order to provide a good security of the data stored in the location registers and procedures that could be performed to restore the location data and supplementary services data after a location register failure.

However, the implementation of these methods and procedures are not mandatory and are open to technical innovation.

2 Technical realizations to achieve the objectives

To avoid a loss of all the data stored in a location register when a failure occurs, it is necessary to implement a periodic safeguard of the memories. This method is normally used in the telephone exchanges where a copy of the tables is made periodically in order to allow a restart if a control unit failure occurs. This back-up can be made on either a disc device or a magnetic tape.

3 Restoration of the location register memories

The perturbations due to a deterioration of the location tables and the restoration procedures are different if the equipment affected is a home or a Visitor Location Register.

3.1 *The visitor location register*

3.1.1 *Status of the data after a failure*

When a visitor location register failure occurs, some discrepancies between the actual location of the mobile station and the location information stored may appear in the following cases:

i) since the last safeguard, the mobile moved to another location area in the same MSC area; the allocated roaming number remains correct but the location area information is wrong;

ii) the mobile appeared in the MSC area after the last safeguard; this mobile is then unknown by the visited location register while the home location register stored a roaming number corresponding to this new location;

iii) the mobile left the MSC area; a roaming number is allocated in the visitor register but the updating was made in the home register;

iv) the mobile left the MSC area and then came back; for the visitor register, the mobile did not leave the MSC area and the previous roaming number is considered as correct by the visitor register while the home register stored another roaming number given during the last updating made before the failure. The location area information saved may not be the relevant one.

3.1.2 *Restoration procedures*

When a failure occurs, the data concerning only a small part of the mobiles located in the relevant area are lost. Therefore, it seems that a systematic restoration method such as a general interrogation of the home location registers would load the network and the equipments for so small a result.

The restoration process is then the following:

At the restart of the register each element of the memory is pointed out by an indicator. This indicator is turned out when the relevant location information has been checked.

a) *Outgoing calls*

When the restart occurs, each outgoing call from a mobile will initiate the checking operation of its location information:

- if the mobile is already registered in the MSC area, the location area information is updated, if necessary, but the location updating procedure is not initiated with the home register (case i) solved);
- if the mobile is unknown in this MSC area, a roaming number is allocated to that station and a location updating procedure is started with the home register (case ii) solved).

b) *Incoming calls*

Concerning the incoming calls, in the cases ii) and iv) described above, the roaming number received by the MSC in the IAM does not correspond to the right mobile station. In some cases, it is not allocated or it may be allocated to another mobile; this depends on the method used to allocate this number. The normal solution (see also note) to detect this difficulty is that the Initial Address Message received by the MSC during the call set-up contains also the international ISDN number of the called subscriber. If this is the case, the visitor location register can check the couple to detect a possible mistake. If an inconsistency is noticed, the MSC sends then an Unsuccessful Backward Message to inform the originating exchange that it is unable to complete the call. The VLR interrogates the relevant HLRs (the mobiles may be attached to two different HLRs) to correct its tables. Two interrogations have to be performed:

- one about the mobile station to which the VLR allocated this wrong roaming number (MS 1);
- the other about the station to which the call was destined (MS 2).

i) The MS 1 left its MSC area; the VLR erases it from its table and updates it by allocating the roaming number to MS 2 which is introduced in the VLR tables. The data attached to that station are requested from its HLR;

ii) The MS 1 is still in the MSC area:

- the VLR allocates a new roaming number to that station and then updates the relevant HLR;
- the MS 2 is introduced in the VLR table and the parameters attached to that station are requested from its HLR.

If the mobile station left its location area since the last safeguard, the paging message sent will remain unanswered and the mobile will be considered as lost or out of service. To improve the service, the call message may be sent in all the location areas controlled by the MSC. If the mobile answers, the location information is then updated. If not, the mobile is considered out of reach and the appropriate unsuccessful end-of-selection message is sent backwards.

If the mobile is switched off when it is called, the result is the same as the above.

Note – As a national option, the HLR may use the "send parameter from VLR" operation of MAP to obtain the MSRN from the VLR on a per call basis. This is normally allowed only within a PLMN.

c) *Particular cases*

In case iii), as the mobile leaves the area, no traffic is related to that mobile; restoration is then impossible and a roaming number is frozen for nothing. To solve this problem, if the validation of the location information does not occur after a certain delay (in the order of one day or more), the VLR may then interrogate the HLR to know if this station is still located in its area. This method can also solve cases ii) and iv) if the corresponding mobiles have a very low traffic.

3.2 *The home location register*

The deterioration of the data contained in the home location register is of concern not only for the PLMN but also for the whole service. The home location register needs the help of all the visitor registers in charge of the MSC areas where its mobiles are located.

When a restart of the home location register occurs, a specific reset message is sent to all the visitor location registers to inform them about the failure. As the home register is unable to know the addresses of all the visitor registers in service, the only solution is to send the message only to the registers known. The list is extracted from the tables saved previously; of course some modifications occurring since the last back-up are lost and therefore some visitor registers involved in the control of mobiles managed by this home register will not be contacted. But the number of registers forgotten will be very low. Another solution could be that the reset message is sent only to the "neighbour" VLRs; a specific table giving the addresses of these VLRs is then contained in the HLR memories. The content of that table is defined by the operating people according to the roaming traffic of the mobile managed by this HLR. In that case too, the number of forgotten registers will be very low.

After receiving this reset message, when a mobile concerned by the failure sends a radio message, to update its location, to set up an outgoing call, to answer an incoming call or a request coming from the MSC or to activate or request a supplementary service, the relevant visitor location register will initiate a location updating procedure with the home location register. The latter then updates its tables and validates the relevant data.

If, after a certain delay, the location of some mobiles is not confirmed, the home register interrogates the relevant visitor registers. If a positive answer can be obtained, the location information is validated. If not, because the mobile left the MSC area between the back-up and the failure, an alarm message may be given to the technical staff in order to inform them about the loss of the location of this subscriber.

3.3 *Periodic registration*

The delay to confirm the location of a subscriber after a failure depends on the traffic of this station. If a station is silent for a long time, it would be difficult to know if the location information stored is correct or not during this period.

A solution to reduce this delay is to force the mobile to send a message when it remains still during a long time. For that purpose, a time-out is reinitiated at each message sent by the mobile. When this time-out expires, the station sends a location updating message to the base station. A rough estimate of this time-out value may be a few hours (this value is to be fixed according to traffic simulations and it seems that it could be comprised between 12 and 24 hours); if the IMSI detach procedure when switched off is not used, to avoid an overload of the control channel in the morning, this time-out runs only when the station is switched on. With this method, the delay during which the mobile can be lost is less than the duration of this time-out. The interruption of the time-out when the station is switched off is not a problem because it is then unable to receive any call; therefore, the service provided to that subscriber is not degraded. If the IMSI detach procedure is used, the first message sent by the mobile when it is switched on is the IMSI attach; in that case the interruption of the time-out may or may not be implemented.

4 Restoration of the supplementary service parameters

As well as the location data, the supplementary service parameters may be disturbed when a register failure occurs. Therefore, it is necessary to define methods to restore them.

4.1 *VLR fault recovery*

a) When the VLR fails, the HLR is able to retrieve the activation status of the supplementary services. However, if the visitor location register does not require any information from the home location register in order to comply with a MS supplementary services activation request, the involved data are not available in the HLR when the VLR fails. This situation cannot appear if the location area is the only information in the VLR which is unknown from the HLR. Otherwise, it would be necessary to include in the deregistration request and in the location cancellation acknowledge messages sent by the VLR to HLR the parameters of activations which would be only known from the VLR.

b) After the restart of a VLR, risks of inconsistency appear between the tables of the VLR and of the HLR:

   – relating to incoming calls, the mobile may have recently modified activation status of supplementary services; reverse charging acceptance, diversion call on no reply, connect when free...;

– relating to outgoing calls, this method allows checking of other parameters; conditional barring of outgoing calls, preferential closer used group...

Two few mobiles are involved in this situation to justify the systematic interrogation of the HLR by the VLR so it is suggested that the VLR sends an information request message to the HLR if, and only if, one SS at least was registered in the saved tables of the VLR. This message must request from the HLR all parameters of supplementary services that are related to the mobile. Moreover, as soon as the data of supplementary services are validated in the tables of the VLR, an indicator has to be turned out.

The retrieval procedures are not influenced by handover.

4.2 *HLR fault recovery*

When the restart of a home location register occurs, the loading of a previously saved state is useful. However, the mobile may have changed its parameters of registration or activation since the last back-up of the HLR; these cases are presented here.

4.2.1 *Retrieval of SS-registration status*

If the mobile station changed recently, by administrative means, the list of the supplementary services for which it contracts a subscription, the operation can be lost by the system when the HLR fails. It seems important to avoid this situation with a high security.

When the MS requests, by signalling means, the HLR to provide a registration for a specific supplementary service, this capability being additional to that of providing subscriptions by administrative means, the HLR has to save this command with a high level of security, against an eventual HLR failure. After that, the HLR can send back a category/supplementary services information acknowledge message to the VLR.

4.2.2 *Retrieval of SS-activation status*

After the HLR failure, the information which is related to the activations of supplementary services by a not-registered station are available in no VLR.

Therefore, the reset message which is sent by the reinitialized HLR to all VLRs should contain implicitly an information request about the current activation status of the supplementary services. Since in some cases the VLR may not know these data, the relevant parameters should be held in the mobile equipment. To recover them, two possibilities are available:

– to include this request into a "search" message, from the VLR towards the MSC, and then to send a category/supplementary services information message to the HLR; however, the HLR cannot recover by this method the data associated with the non-registered mobiles;

– to wait for the next mobile originating message and to indicate to the mobile the loss of supplementary services status in the system; the simplest solution is that the information is only given after a status request message from the mobile; but the quality of the service would be improved if the information was introduced into a field of any originating mobile message acknowledgement. It may be envisaged, too, that the mobile station equipment or the subscriber card contain the description of all supplementary service parameters.

4.3 *MSC fault recovery*

No information is stored in the home or visitor location register for the following services:

– charging information (different forms of facilities);

– credit card call;

– debit card call;

– reverse charging, MS originating call;

– completion of calls to busy subscriber, MS orig. and term. calls.

All these services are invoked on a call per call basis; if the VMSC fails, the location registers cannot help the MSC to recover the contexts of the established calls. There is no difference with a normal fixed exchange.

HANDOVER PROCEDURES

1 Introduction

This Recommendation contains a detailed description of handover procedures to be used in PLMNs.

The following cases are considered:

i) handover between radio channels of the same base station;

Note – This capability is mandatory and could be used in the following situations:

- when the radio channel carrying the call is subject to interference or other disturbances, and/or
- when a radio channel or channel equipment carrying a call has to be taken out of service for maintenance or other reasons;

ii) handover between base stations of the same MSC in order to ensure continuity of the connection when an MS moves from one BS area to another;

iii) handover between base stations of different MSCs of the same PLMN; and

iv) handover between base stations of MSCs in different PLMNs.

The same procedures can be used on the radio path for all four cases.

Cases i) and ii) involve only one MSC.

Note – Depending on the handover criteria, case ii) may involve measurements in other MSCs.

Cases iii) and iv) involve more than one MSC. For these cases, two procedures are defined requiring the use of the mobile application part:

a) **basic handover procedure** where the call is handed over from the controlling MSC (MSC-A) to another MSC (MSC-B); and

b) **subsequent handover procedure** where the call is handed over from MSC-B to MSC-A or from MSC-B to a third MSC (MSC-B′).

In most respects case iv) is similar to case iii). However, any additional aspects of case iv) not covered by the specification of case iii) will not be included in this Recommendation for the time being.

The procedures in the mobile application part for supporting handover are specified in Recommendation Q.1051.

In the following, the controlling MSC will be referred to as MSC-A also when the handover only involves this MSC [cases i) and ii) above]. For cases iii) and iv), the controlling MSC (MSC-A) is the MSC on which the call was originally established.

All MSCs should be capable of acting as MSC-A and MSC-B.

2 Functional composition of MSCs and interfaces for handover

2.1 *MSC-A*

For handover the controlling MSC can be regarded as being composed of functional units as shown in Figure 1/Q.1005.

Signalling functions

1) The *BS/MSC (MS/BS) procedures MSC-A* for signalling between the MSC and the BS and between the MSC and the MS. The functional unit interfaces the BSs through interfaces A′ (to the previous BS) and, for case ii), also through interface A″ (to the new BS). Interworking with other functional units takes place through the internal interface X.

2) The *call control procedures MSC-A* for normal call control functions (interface B′) and for signalling and call control of connections to other MSCs (interfaces B″ and B‴). Interfaces B″ and B‴ apply only to handover cases iii) and iv) where interface B‴ is required for subsequent handover.

3) The *handover control procedures MSC-A* for overall control of the handover including interworking with other functional units (interfaces X, Y and Z).

4) The *MAP procedures MSC-A* for information exchange with other MSCs and location registers. This function is required for handover cases iii) and iv). The external interface is interface c and the internal interface to the handover control functions is interface Z. Interface C represents the interface to all entities with which MSC-A is communicating during handover (other MSCs, location registers).

Note – This functional unit may also be required for cases i) and ii) if measurements have to be performed in other MSCs for determining the new BS (see below).

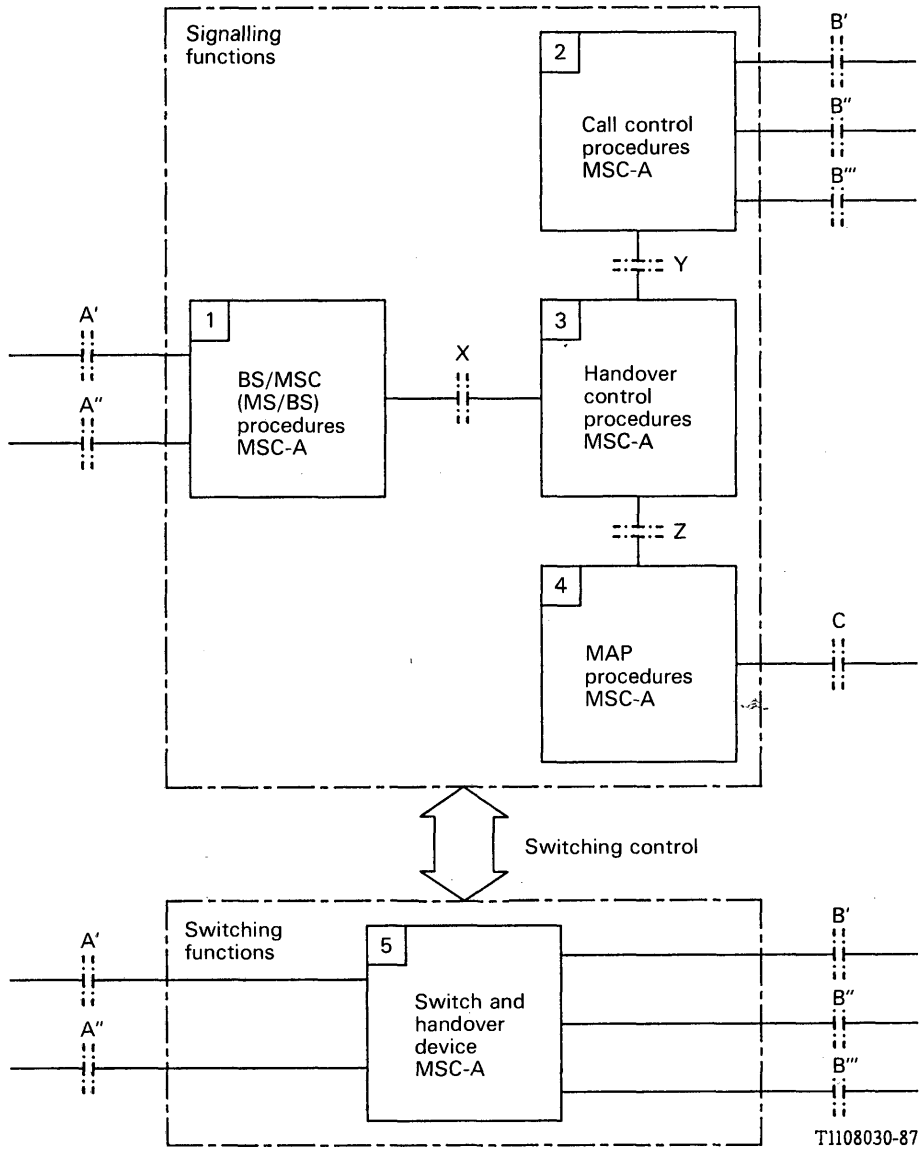
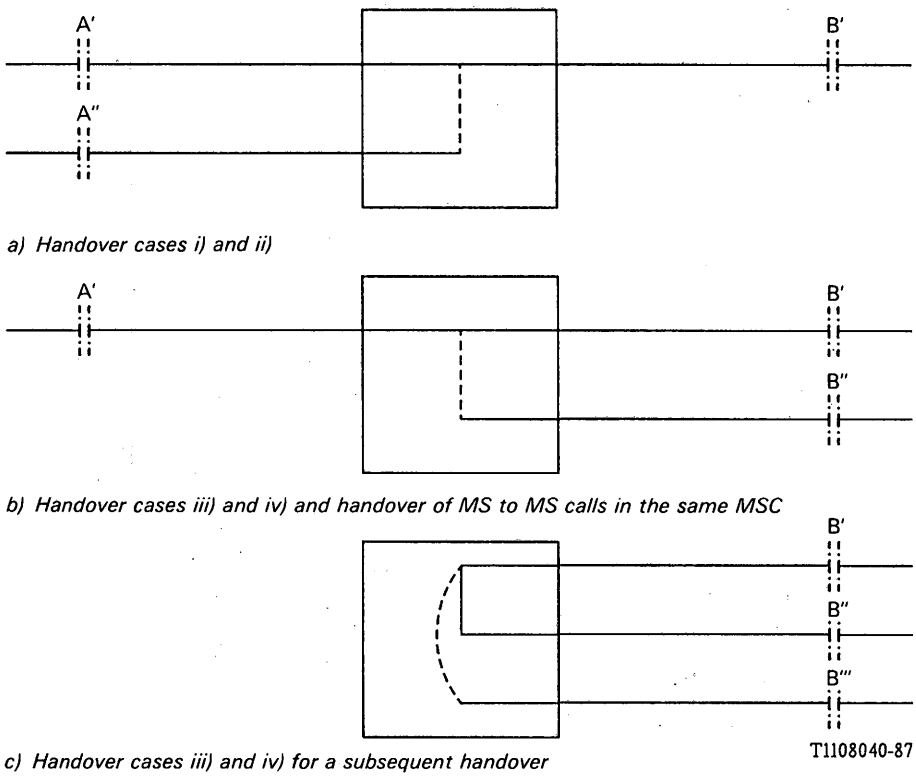


FIGURE 1/Q.1005

Functional composition of the controlling MSC (MSC-A) for supporting handover

Switching functions

5) The *switch and handover device MSC-A* for connecting the new path. This function is additional to normal switching functions in the MSC. The handover device has interfaces to the previous BS (interface A′) and the new BS (interface A″) for handover case ii). Interface B′ represents the original connection with the fixed network and interface B″ represents the new connection to and MSC-B for handover between MSCs (cases iii) and iv)). Interface B‴ represents the connection to a third MSC (MSC-B′) for subsequent handover from MSC-B to MSC-B′. The connections which can exist in the handover device are shown in Figure 2/Q.1005.



a) Handover cases i) and ii)

b) Handover cases iii) and iv) and handover of MS to MS calls in the same MSC

c) Handover cases iii) and iv) for a subsequent handover

Note – In *a)* and *b)* A′ is released after handover; in *c)* B″ is released after handover.

FIGURE 2/Q.1005

Connections in the handover device

The connection via interface A′ is released after completion of a successful handover (Figures 2a and 2b/Q.1005).

For MS to MS calls in the same MSC the configuration in Figure 2b/Q.1005 applies. Then interface B″ is not to another MSC but internal to MSC-A.

Case	Initial connection	Resulting connection
Figure 2a)/Q.1005	A′ to B′	A″ to B′
Figure 2b)/Q.1005	A′ to B′	B′ to B″
Figure 2c)/Q.1005	B′ to B″	B′ to B‴

2.2 *MSC-B*

The functional composition of an MSC acting as MSC-B is essentially the same as that of MSC-A. However, there are some differences. The functional units are as follows (see Figure 3/Q.1005).

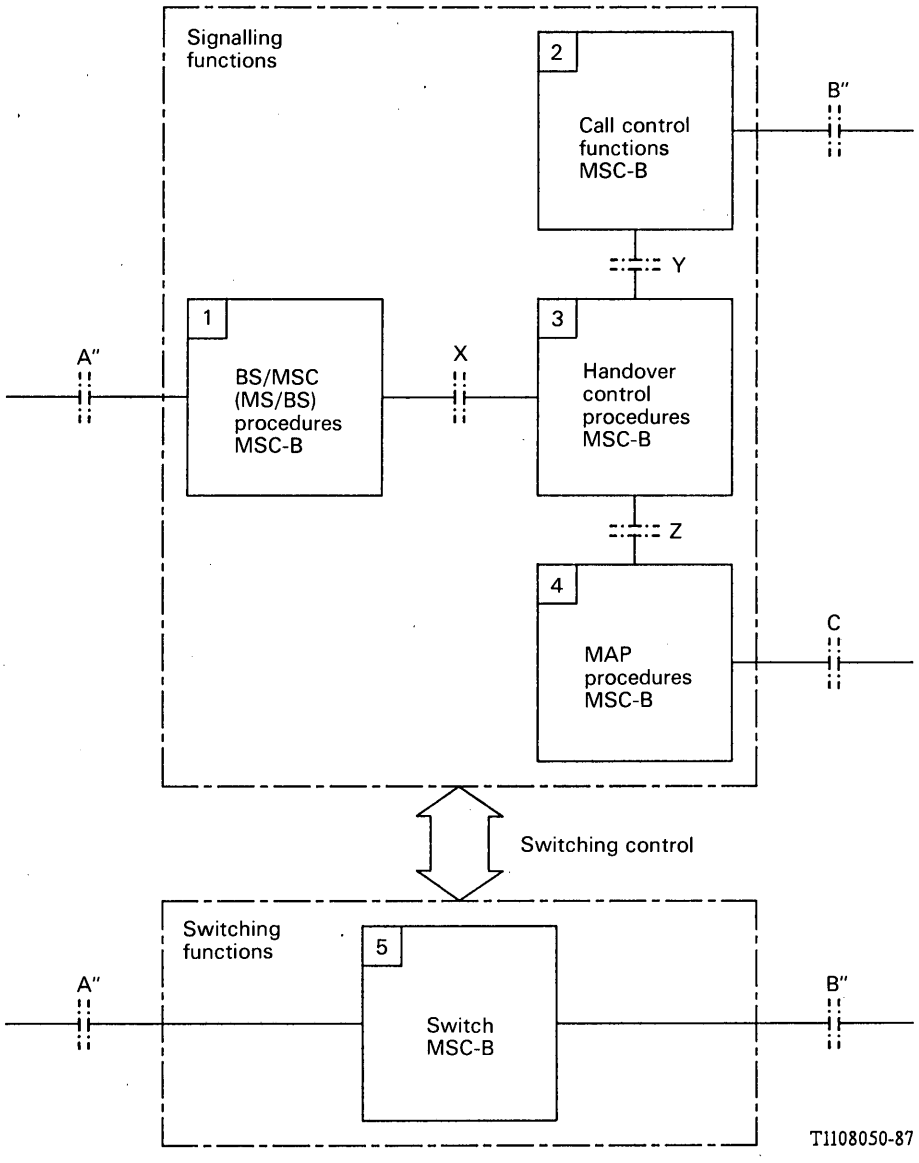


FIGURE 3/Q.1005

Functional composition of MSC-B for supporting handover

Signalling functions

1) The *BS/MSC (MS/BS) procedures MSC-B* for signalling between the MSC and the new BS and between the MSC and the MS (interface A").

2) The *call control procedures MSC-B* for normal call control functions and for signalling between MSC-A and MSC-B.

3) The *handover control procedures MSC-B* for control of the handover in MSC-B.

4) The *MAP procedures MSC-B* for information exchange with MSC-A and the VLR of MSC-B.

Switching functions

5) The *switch MSC-B* for connecting the circuit from MSC-A (interface B″) to the circuit to the BS (interface A″).

MSC-B will also require a handover device for subsequent handovers to BSs (or to another channel of the same BS) in the MSC area of MSC-B. Subsequent handovers to other MSCs will not require switching in MSC-B (see below).

3 Initiation

The decision that a handover shall take place can be made by both the MS and the BS by monitoring the channel quality. If the decision is made by the MS, a handover request message should be provided to the BS.

Depending on the radio sub-system arrangement the new BS, to which the call is to be handed over, can either be determined by the MS or the MSC. If determined by the MS, the indication of the BS candidates will be providing to the MSC by signalling on the radio path.

If the new BS is to be determined by the MSC, this may require measurements on its own BSs and BSs in other MSCs. Procedures defined in Recommendation Q.1051 are used for initiating measurements on BSs in other MSCs.

The initiation procedures are for further study.

4 General description of the procedures for handover to another MSC

4.1 *Basic handover procedure*

The procedure which takes place after initiation, i.e. after the identity of the new BS has been determined, is shown in Figure 4/Q.1005 for a successful handover. The procedure makes use of messages of the Mobile Application Part (MAP) of Recommendation Q.1051.

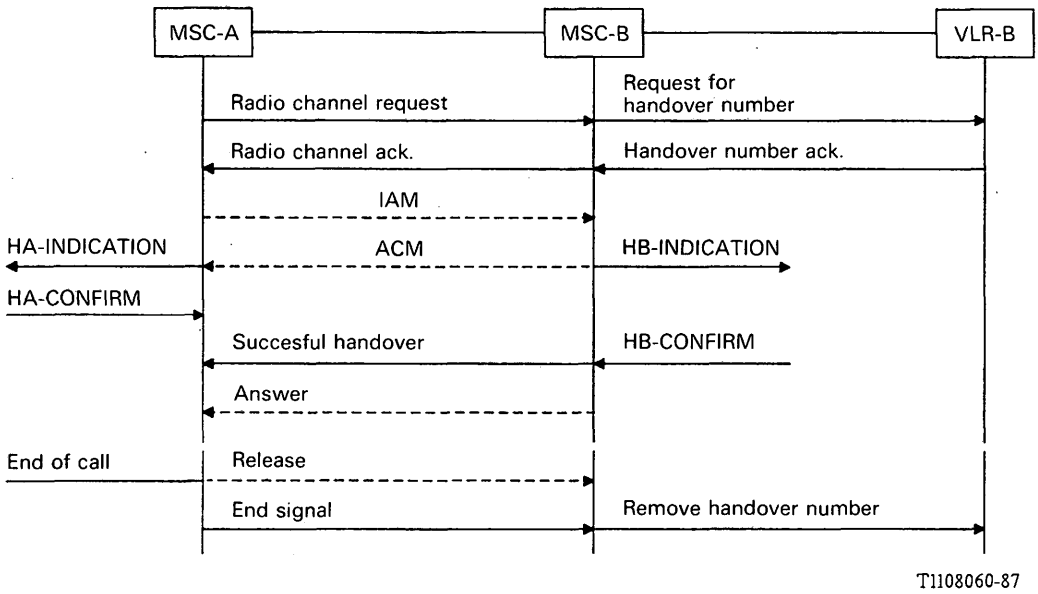


FIGURE 4/Q.1005

Basic handover procedure

Firstly, MSC-A sends a *radio channel request* message to MSC-B. The message will contain all parameters needed by MSC-B for allocating a radio channel (see Recommendation Q.1051). The message will also identify the BS to which the call is to be handed over. MSC-B will return the *radio channel acknowledge* message after having received the mobile station roaming number from its VLR (exchange of the messages *request for handover number* and *handover number acknowledge*). The roaming number is to be used for routing the call from MSC-A to MSC-B. If a traffic channel is available in MSC-B the *radio channel acknowledge* message will contain the identity of the new radio channel and the mobile station roaming number. Other parameters may also be included (see Recommendation Q.1051).

If there is no free traffic channel in MSC-B, this will be indicated to MSC-A and MSC-A will terminate the handover procedure. The existing connection to the MS will not be cleared.

At this point, MSC-A establishes a connection between MSC-A and MSC-B by signalling procedures supported by the network to which MSC-A is connected. In Figure 4/Q.1005 this is illustrated by the messages IAM (Initial Address Message) and the ACM (Address Complete Message) of Signalling System No. 7. MSC-B initiates the handover procedure on the radio path when the ACM is sent and MSC-B initiates the procedure when the ACM is received (illustrated by HB- and HA-INDICATION, respectively).

The connection is through-connected in MSC-A by use of a handover device. The through-connection is done and the old radio channel is released when MSC-A receives an acknowledgement from the MS (HA-CONFIRM) or when the *successful handover* message is received from MSC-B. MSC-B sends this message when it receives an acknowledgement from the MS (HB-CONFIRM).

In order not to conflict with the PSTN/ISDN signalling system(s) used between MSC-A and MSC-B, MSC-B must generate an answer signal when HB-CONFIRM is received.

If the connection between MSC-A and MSC-B cannot be established (e.g. an unsuccessful backward message is received instead of the ACM), MSC-A terminates the procedure without clearing the radio path.

MSC-A will have the overall call control until the call is cleared by the fixed subscriber or the MS and there are no further call control functions to be performed (e.g. servicing waiting calls). MSC-A then releases the connection to MSC-B and also sends an *end signal* message which terminates the MAP procedure. When receiving this message MSC-B will release all call control functions and send the message *remove handover number* to its VLR.

MSC-A may terminate the procedure at any time by sending the MAP message *handover cancellation* to MSC-B. If establishment of the physical connection between MSC-A and MSC-B has been initiated, the physical connection must also be cleared by procedures defined for the signalling system used between MSC-A and the fixed network. The VLR of MSC-B is also informed by using the *remove handover number* message.

The *handover cancellation* message is sent when MSC-A detects clearing or interruption of the radio path before the call has been established on MSC-B. The message is also sent in order to terminate the MAP procedure in MSC-B when it is not possible to establish a connection between MSC-A and MSC-B.

4.2 *Procedure for subsequent handover*

When an MS, after the call has been handed over from MSC-A to MSC-B, leaves the area of MSC-B during the same call, subsequent handover is necessary in order to continue the connection.

The following cases are identified:

i) the MS moves back to the area of MSC-A, and

ii) the MS moves into the area of a third MSC (MSC-B').

In both cases the call is redirected in MSC-A using the handover device; the connection between MSC-A and MSC-B can be released after a successful subsequent handover has been performed.

4.2.1 *Description of subsequent handover procedure*

i) *MSC-B to MSC-A*

The procedure which takes place after the initiation procedure has indicated that a handover has to be made back to MSC-A is shown in Figure 5/Q.1005 for the case of successful handover.

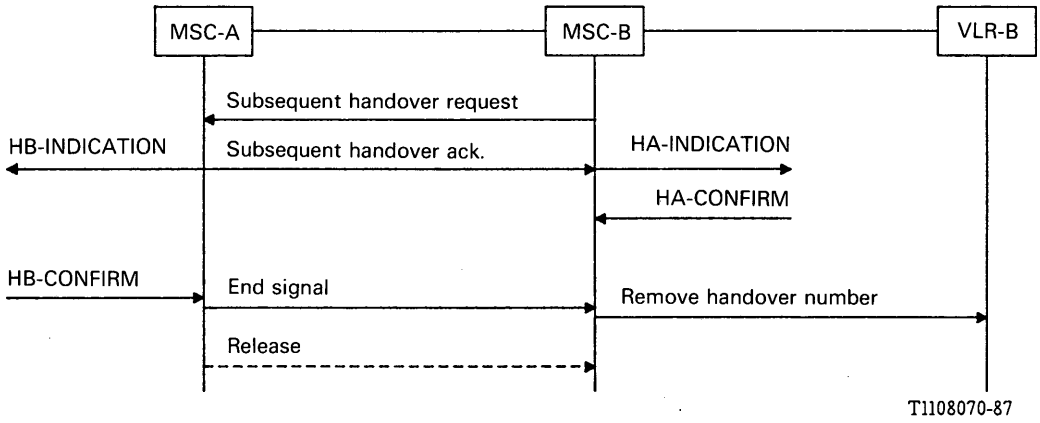


FIGURE 5/Q.1005

Subsequent handover procedure:
i) successful handover from MSC-B to MSC-A

The procedure is as follows.

MSC-B sends the *subsequent handover request* message to MSC-A indicating that the new MSC is MSC-A. Because MSC-A is the call controlling MSC, this MSC needs no roaming number for routing purposes; MSC-A can directly search for a free radio channel at the desired BS.

When a radio channel can be assigned in time, MSC-A will return the *subsequent handover acknowledgement* message containing the new radio channel number and possibly other information to MSC-B. If a radio channel cannot be assigned, a no channel available indication will be given to MSC-B and MSC-B has to maintain the connection with the MS as long as possible.

If a radio channel has been reserved in MSC-A, both MSC-A and MSC-B can start the handover procedure on the radio path (in Figure 5/Q.1005 indicated by the interworking messages HB-INDICATION and HA-INDICATION respectively).

After handover, MSC-A has to release the connection with MSC-B by the procedures relevant to the PSTN/ISDN signalling system(s) used between MSC-A and MSC-B.

MSC-A must also terminate the MAP procedure for the basic handover between MSC-A and MSC-B. This is done by MSC-A by sending the *end signal* message to MSC-B. When receiving this signal, MSC-B sends the *remove handover number* message to its VLR.

4.2.2 *Description of the subsequent handover procedure*

ii) *MSC-B to MSC-B'*

The procedure which takes place after the initiation procedure has indicated that the call has to be handed over to MSC-B' is shown in Figure 6/Q.1005 in the case of successful handover.

The procedure consists of two parts:

- subsequent handover as described in § 4.2.1 between MSC-A and MSC-B, and
- a basic handover procedure as described in § 4.1 between MSC-A and MSC-B'.

MSC-B sends the *subsequent handover request* message to MSC-A indicating a new MSC which is not MSC-A. The message contains the identity of MSC-B' and of the new BS. MSC-A then starts a basic handover procedure towards MSC-B'.

When MSC-A receives the ACM from MSC-B', MSC-A informs MSC-B that MSC-B' has started the handover procedure on the radio path by sending the *subsequent handover acknowledgement* message to MSC-B containing the new radio channel number. Now MSC-B can start the procedure on the radio path.

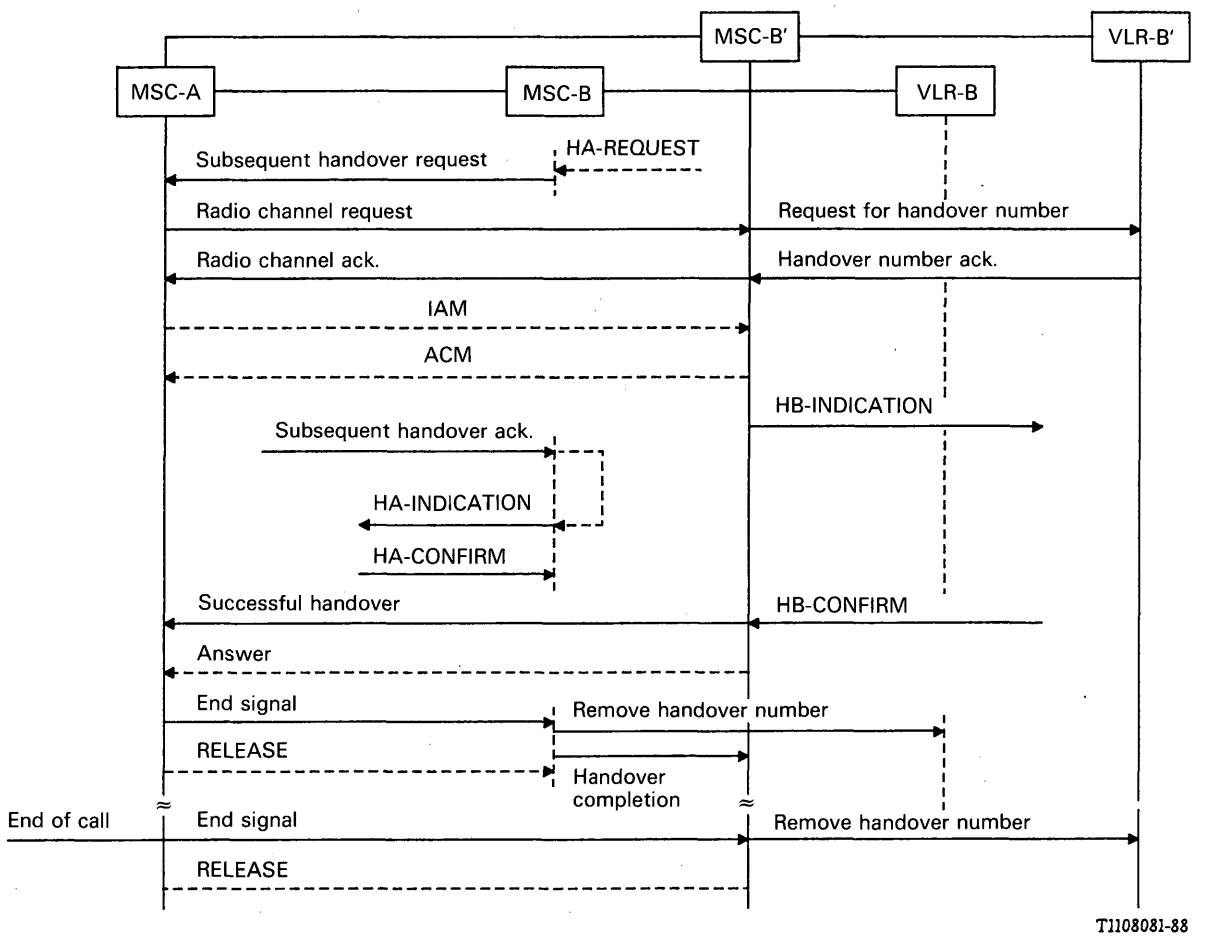


FIGURE 6/Q.1005

Subsequent handover procedure:
ii) successful handover from MSC-B to MSC-B'

For MSC-A the handover is completed when it has received the *successful handover* message from MSC-B'. The connection between MSC-A and MSC-B is released by normal clearing procedures applicable for the PSTN/ISDN signalling system(s) on the connection between MSC-A and MSC-B. MSC-A also sends the *end signal* message to MSC-B in order to terminate the original handover procedure between MSC-A and MSC-B. Receiving this message, MSC-B releases the radio path.

In case no radio channel can be allocated in time or the connection between MSC-A and MSC-B' cannot be established, MSC-A informs MSC-B by a *congestion* message. MSC-B has then to maintain the existing connection with the MS as long as possible. When necessary, MSC-A sends the *handover cancellation* message to MSC-B'.

When the MS again passes the MSC boundary, MSC-B' is considered as an MSC-B so that the subsequent handover procedures given above are applicable for any series of handover between MSCs.

4.3 *Handover procedure using subscriber information transfer (optional procedures)*

This procedure is a handover procedure with subscriber information transfer during handover. To realize this handover procedure, only the following additional procedure will be needed.

4.3.1 *Basic handover procedure (optional)*

In addition to the basic handover procedure, described in § 4.1, this optional procedure is illustrated in Figure 7/Q.1005. MSC-A sends a handover completion message which contains subscriber information as soon as MSC-A receives the successful handover message. MSC-B informs its VLR to send a roaming number to the HLR to support supplementary services (e.g., call waiting), after receiving the handover completion message.

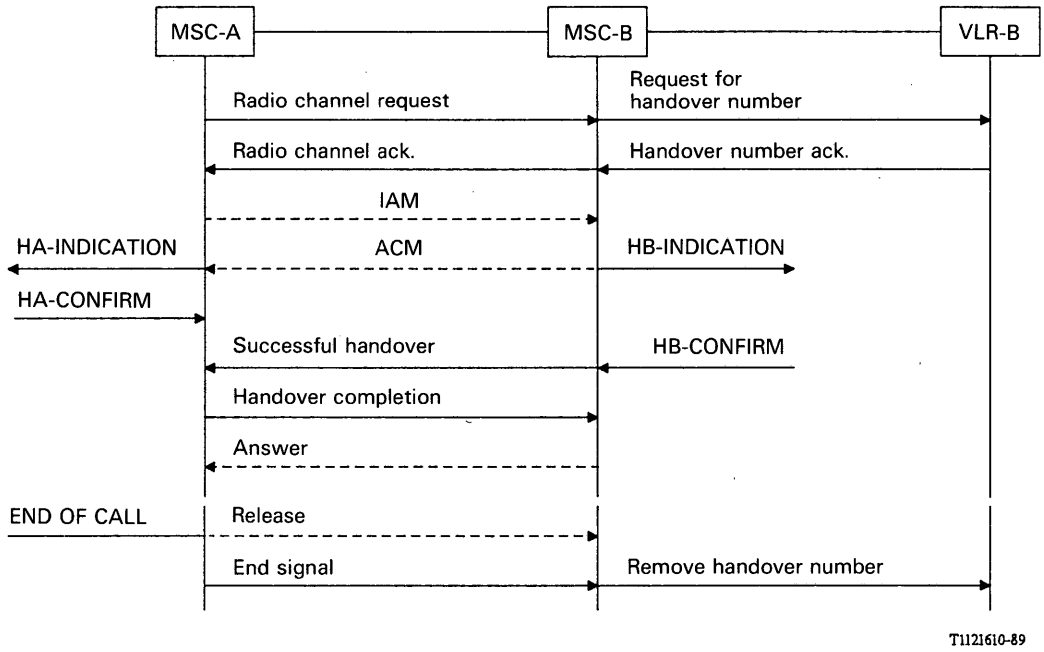


FIGURE 7/Q.1005

Basic handover procedure

4.3.2 *Subsequent handover procedure (optional)*

4.3.2.1 *Description of the subsequent handover procedure (optional)*

i) *MSC-B to MSC-A*

In addition to the subsequent handover procedure, described in § 4.2.1, this optional procedure is illustrated in Figure 8/Q.1005. When receiving the end signal, MSC-B sends the remove handover number message to its VLR and the handover completion message to MSC-A. MSC-A informs its VLR to send a roaming number to the HLR, after receiving the handover completion message.

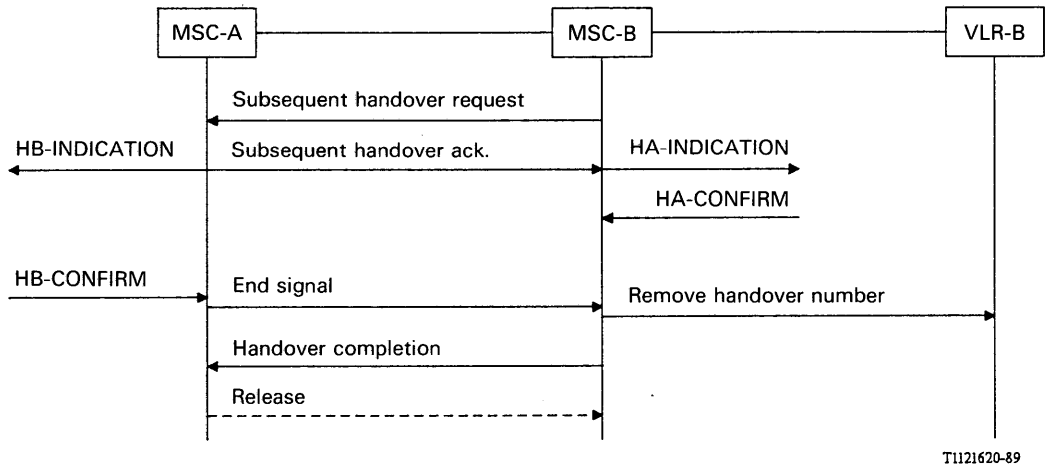


FIGURE 8/Q.1005

Subsequent handover procedure:
i) successful handover from MSC-B to MSC-A

4.3.3.2 *Description of the subsequent handover procedure (optional)*

ii) *MSC-B to MSC-B'*

In addition to the subsequent handover procedure, described in § 4.2.2, this optional procedure is illustrated in Figure 9/Q.1005. After receiving the end signal, MSC-B releases the radio path and sends handover completion message to MSC-B'. MSC-B' informs its VLR to send a roaming number to the HLR, after receiving the handover completion message.

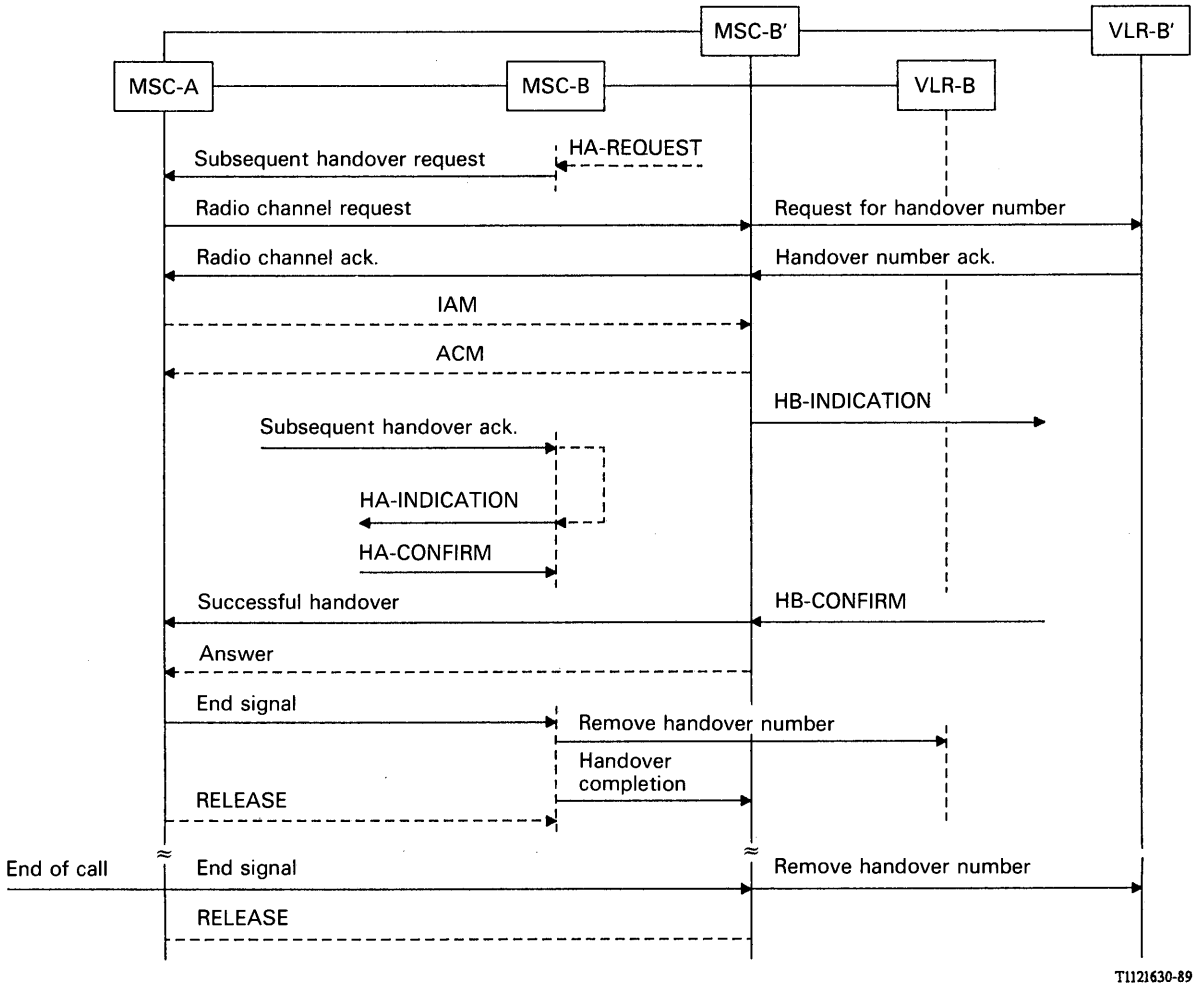


FIGURE 9/Q.1005

Subsequent handover procedure: ii) successful handover from MSC-B to MSC-B'

Note – Implementation of this procedure requires careful consideration of the handling of some supplementary services (e.g., call waiting, conference calling or call completion to busy subscriber) at handover, since these aspects have not been studied in detail. The procedure is not included in the current version of the MAP (Recommendation Q.1051).

5 Detailed procedures in MSC-A

5.1 *BS/MSC (MS/BS) procedures MSC-A (functional unit 1)*

The handover procedures in this functional unit consist of:

i) signalling between the MS and the MSC; and

ii) signalling between the BS and the MSC for
- initiation of quality measurements, and
- access management.

Signals sent to and received from functional unit 3 (handover control procedures MSC-A) are indicated in § 5.3 below.

5.2 *Call control procedures MSC-A (functional unit 2)*

Related to handover the call control procedures in MSC-A can be divided into two functional entities.

The first entity is the call control procedure as part of the normal interworking between the PSTN/ISDN and the PLMN; for an MS originating call MSC-A is the originating exchange, for an MS terminating call MSC-A is the destination exchange.

The second entity is the call control procedure for the connection between MSC-A and MSC-B in case of a handover from MSC-A to MSC-B. For the latter call control procedure the following applies.

Call set-up

The connection to MSC-B is set up by procedures relevant to the signalling system used in the PSTN/ISDN to which MSC-A is connected. The call is set up by using the MS roaming number received from MSC-B as part of the MAP procedures.

The call set-up direction will always be from MSC-A to MSC-B, i.e. also when the call was originally established by the MS. Functional unit 2 should therefore keep information on call set-up direction in order to be able to correctly interpret any clearing signals (see below).

The unit should indicate the address-complete condition to functional unit 3 and through connect without waiting for the answer signal from MSC-B. This applies also to signalling systems where address-complete signals are not supported. In such cases, an artificial address complete is established by functional unit 2.

Call clearing

The call clearing consists of two parts after inter MSC handover, clearing of the BS-MS connection and clearing of the inter MSC connection.

The MAP is used to transfer information between MSC-B and MSC-A in order to maintain full control with MSC-A. MSC-A determines, based on information received from MSC-B, the appropriate signals to be sent to the MS, and sends this information to MSC-B.

MSC-A shall initiate inter MSC connection release and send the *end signal* to release any resource attached to the call.

The clearing of the connection is by procedures relevant to the signalling system in the PSTN/ISDN to which MSC-A is connected.

When the Signalling System No. 7-ISDN User Part is used, the normal symmetric release procedures apply on both the connection to the fixed network and to MSC-B.

When a signalling system is used with a symmetric release possibility, some notice should be given to the clear-forward and clear-back procedures.

For *MS terminating calls* the following conditions apply on clear-forward and clear-back:

- when a clear-forward signal is received on interface B′ (see Figure 1/Q.1005), MSC-A clears the circuit to MSC-B by normal clear-forward procedures; and
- when a clear-back signal is received from MSC-B, MSC-A starts normal clear-back procedures towards the fixed network (interface B′) and sends the clear-forward signal on interface B″ in order to clear the connection with MSC-B.

  Note – This case corresponds to a fault situation. O&M actions are for further study.

For *MS originated calls* the following applies:

- when an MSC-A receives a clear-back signal from MSC-B, this signal must be interpreted as indicating clear-forward condition. MSC-A then clears both the connection on interface B′ (see Figure 1/Q.1005) and to MSC-B by normal clear-forward procedures; and

  Note – This case corresponds to a fault situation. O&M actions are for further study.

- when MSC-A receives a clear-back signal on interface B′, MSC-A should distinguish between national and international connections:
  - for *international* connections MSC-A sends a clear-forward signal on both interface B′ to the fixed network and interface B″ to MSC-B; and
  - for *national* connections a timer is started according to national practice for clear-back supervision and MSC-A proceeds as follows:
    i) if a clear-back signal is received from MSC-B, MSC-A interprets this as indicating a clear-forward condition and proceeds by clearing the connections on interface B′ and to MSC-B by normal clear-forward procedures, or
    ii) if the timer expires, MSC-A proceeds by normal clear-forward of the connections on interface B′ to MSC-B.

5.3 *Handover control procedures MSC-A (functional unit 3)*

The procedures of functional unit 3 are given in terms of SDL diagrams in Figure 10/Q.1005. For all signals sent to or received from another functional unit the source or sink of the signal is indicated (e.g. from 4, to 2, etc.).

The procedures of functional unit 3 include the following:

i) Initiation (states 1, 2 and 3). The initiation condition is shown by the signal HA-REQUEST. This may either be generated by the MS or the BS depending on the initiation condition (see § 3). The diagram includes all possibilities described in § 3, i.e. the MS identifies the new BS, or the new BS is identified by the MSC by measurements in adjacent BSs. These may include BSs in other MSCs.

The diagram also includes queuing when there is no channel available. Calls for which handover had been initiated should be queued with priority higher than normal calls. They should have lower priority than emergency calls.

ii) Handover of calls within the area of MSC-A, i.e. handover cases i) and ii) (states 1, 2, 3 and 4). MSC-A controls the procedures on both the previous and the new radio channel. Both signals HA-INDICATION and HB-INDICATION are required. The handover procedure is completed when HB-CONFIRM is received. If this signal is not received, the radio path and the connection on interface B′ are either released or the original connection is maintained depending on national choice.

The handover device is first set up so that all interfaces A′, A″ and B′ are connected (illustrated by the signal *set up handover device*). This is done when HA-INDICATION is sent. The device is connected in its final position (i.e. A″ to B′ for case ii)) (illustrated by the signal *connect handover device*) either when HA-CONFIRM is received or when HB-CONFIRM is received.

iii) Handover to MSC-B (states 1, 2, 5, 6 and 7). This procedure is the one described in § 4.1. The handover device is set up when MSC-A send the HA-INDICATION, i.e. the interfaces A′, B′ and B″ are connected. The device is connected in its final position (i.e. B′ to B″) when either the HA-CONFIRM signal is received from the MS or the successful procedure indication is received from functional unit 4.

iv) Subsequent handover to MSC-A (states 7 and 9). This procedure is described in § 4.2. When a handover to MSC-A indication is received from functional unit 4, the handover device is set up so that interfaces B′, B″ and A′ are connected. When HB-CONFIRM is received, the device is connected in its final position (i.e. B′ to A′).

If HB-CONFIRM is not received (expiry of timer T104), the handover device releases interface A′ and returns to a position where B′ and B″ are connected. A congestion indication is returned via functional unit 4 to MSC-B.

v) Subsequent handover to a third MSC (MSC-B′) (states 7 and 8). The procedure is described in § 4.2. The handover device is set up in its initial position, i.e. interconnection of interfaces B′, B″ and B‴, when the connection to MSC-B′ has been established (indicate by the signal connection established from functional unit 2). MSC-B is informed via functional unit 4 (send acknowledge) that the connection has been established and that the procedure on the radio path can be initiated. The device is connected in its final position (i.e. B′ to B‴) when a successful procedure indication in received from functional unit 4. MSC-B is informed that all procedures in MSC-B can be terminated (illustrated by the send-end signal indication). The device returns to the state where B′ and B″ are connected if the subsequent handover procedure fails.

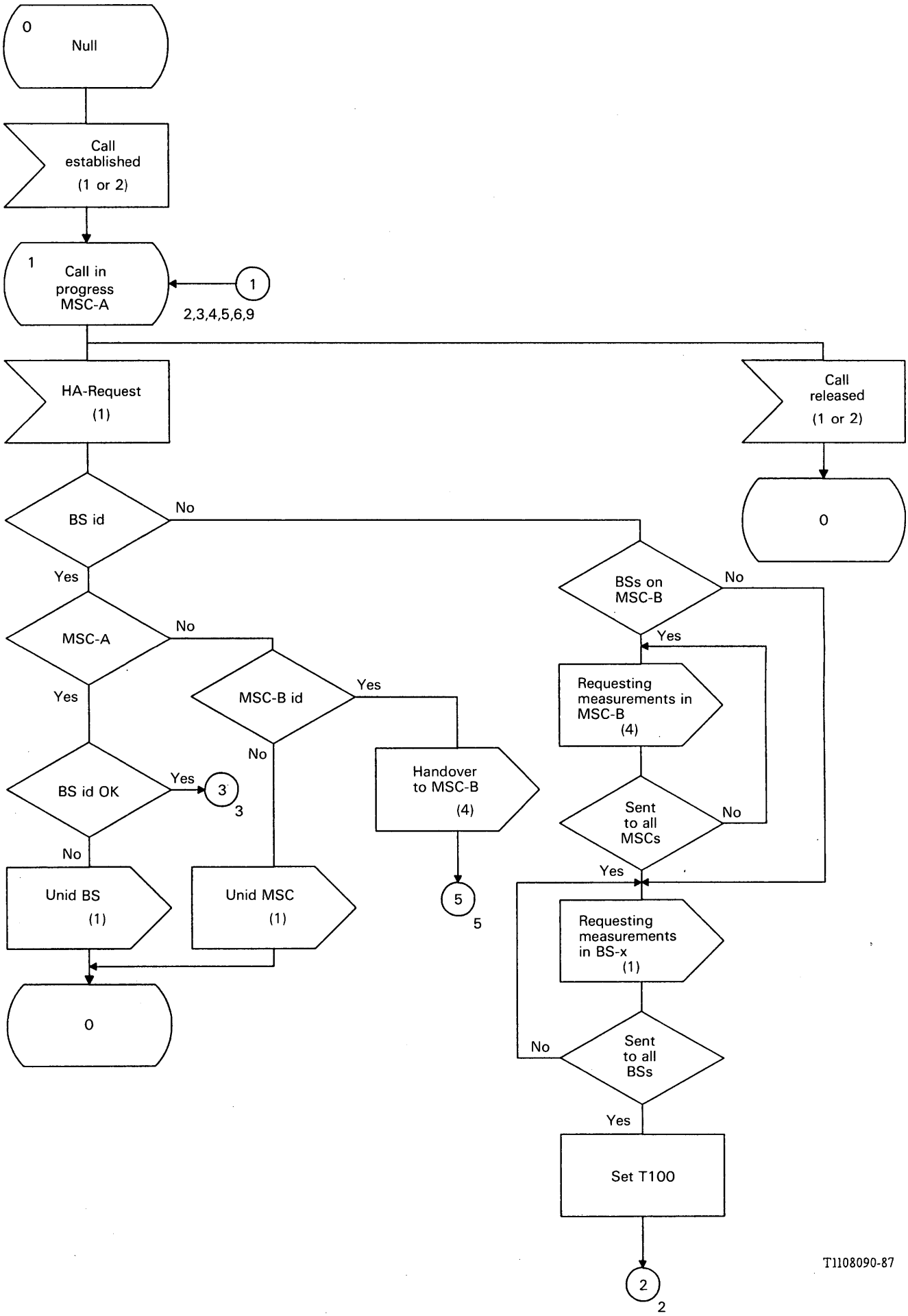


FIGURE 10/Q.1005
(Sheet 1 of 9)

Handover control procedure in MSC-A

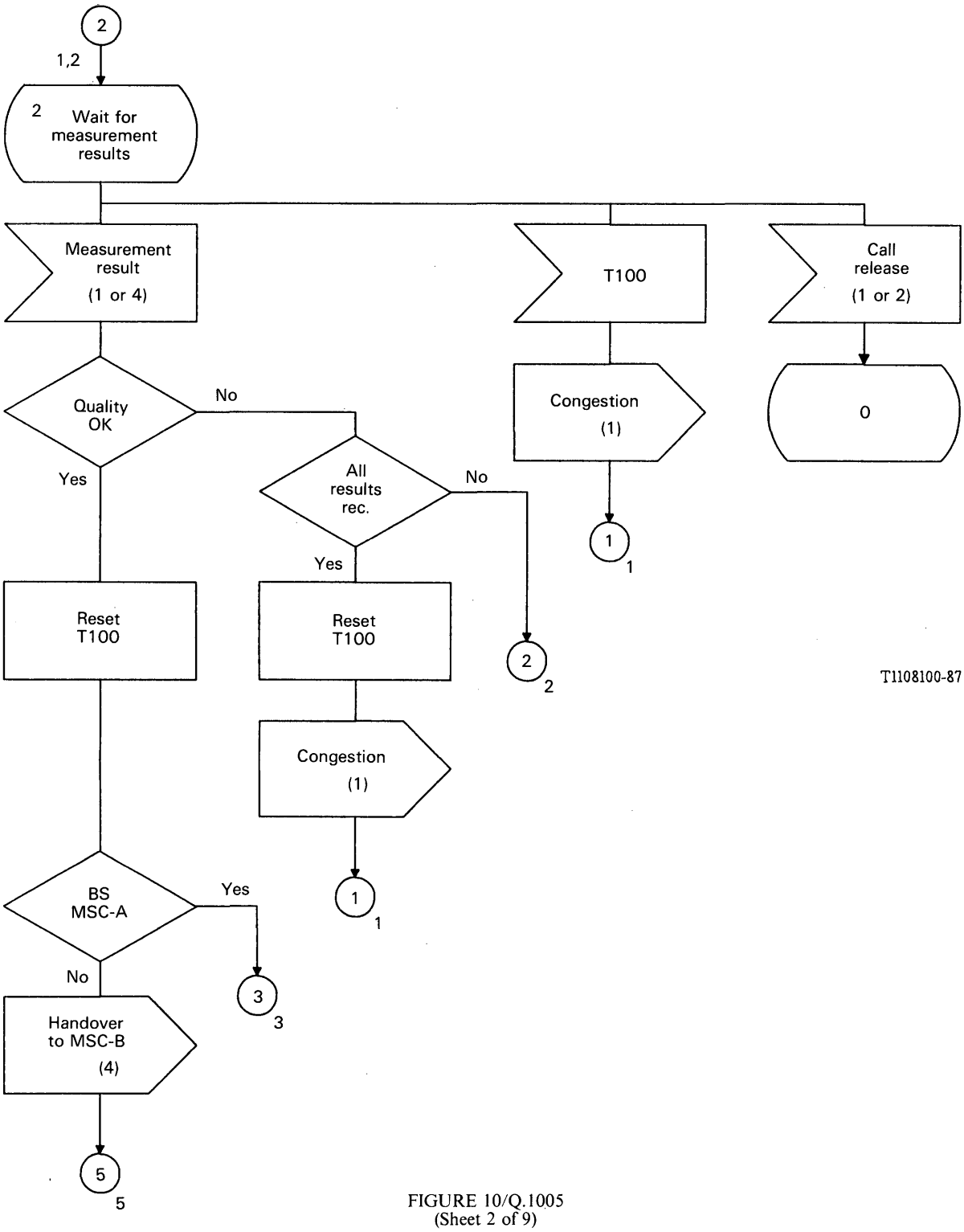


FIGURE 10/Q.1005
(Sheet 2 of 9)

Handover control procedure in MSC-A

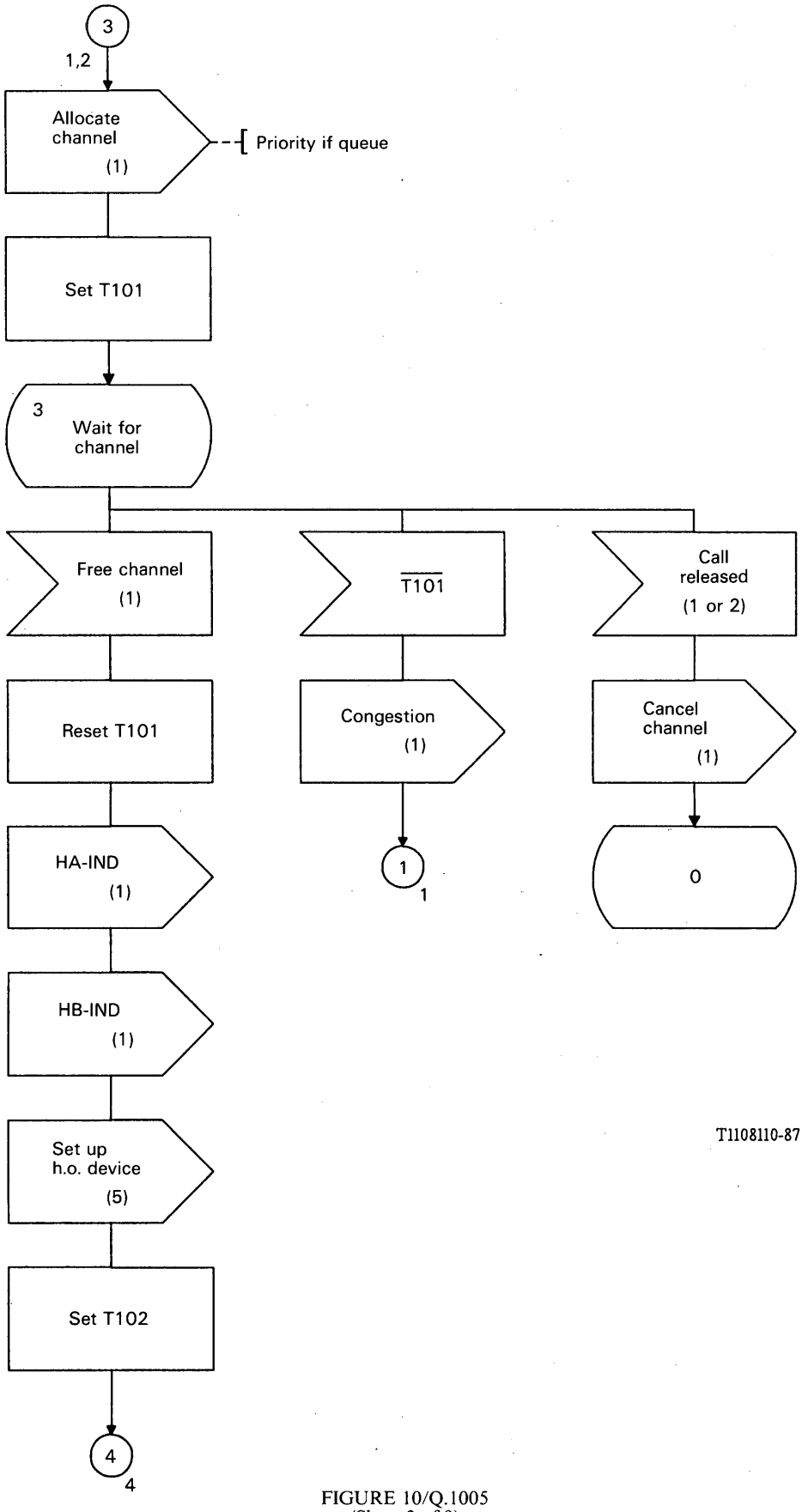


FIGURE 10/Q.1005
(Sheet 3 of 9)

Handover control procedure in MSC-A

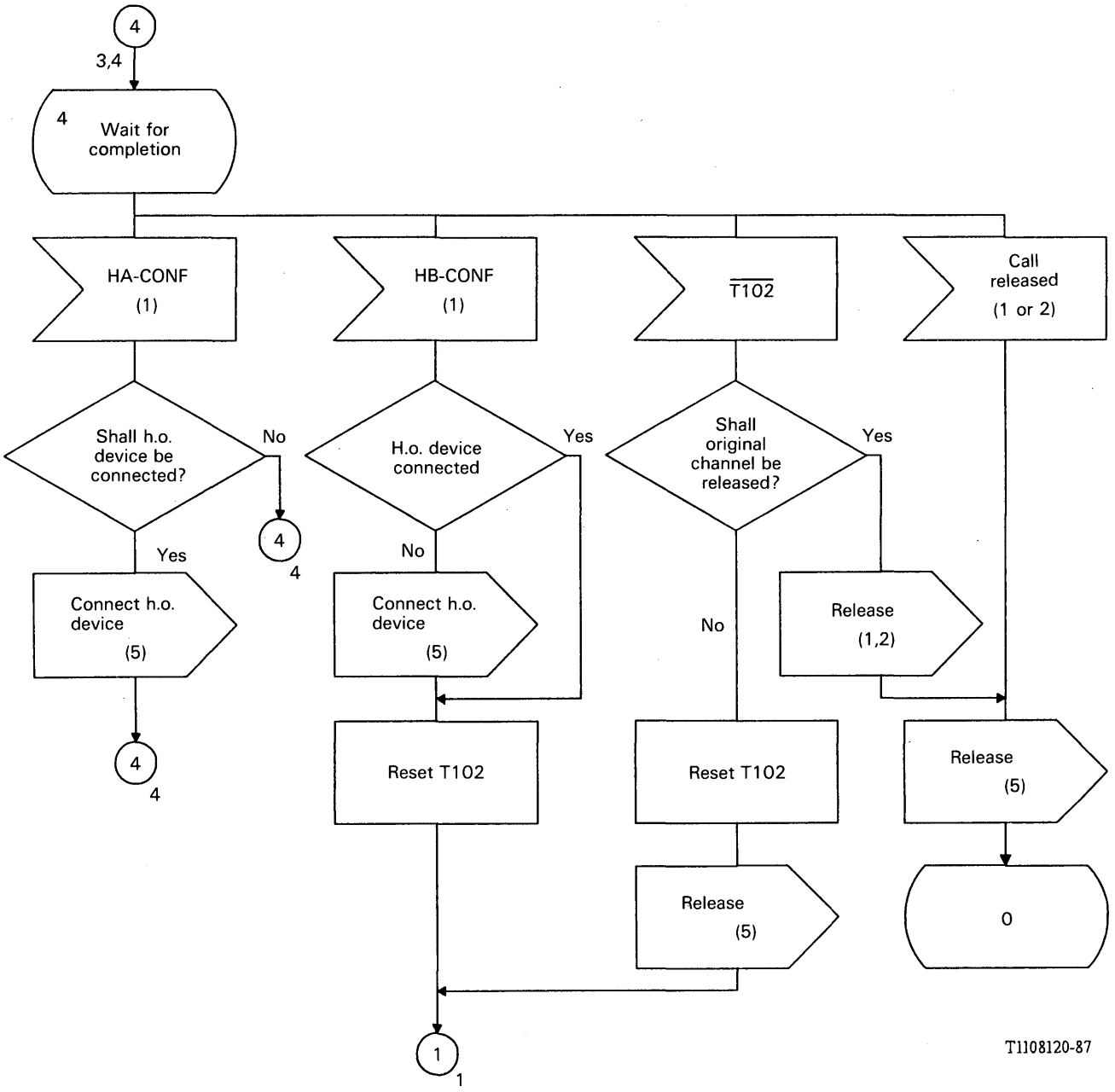


FIGURE 10/Q.1005
(Sheet 4 of 9)

Handover control procedure in MSC-A

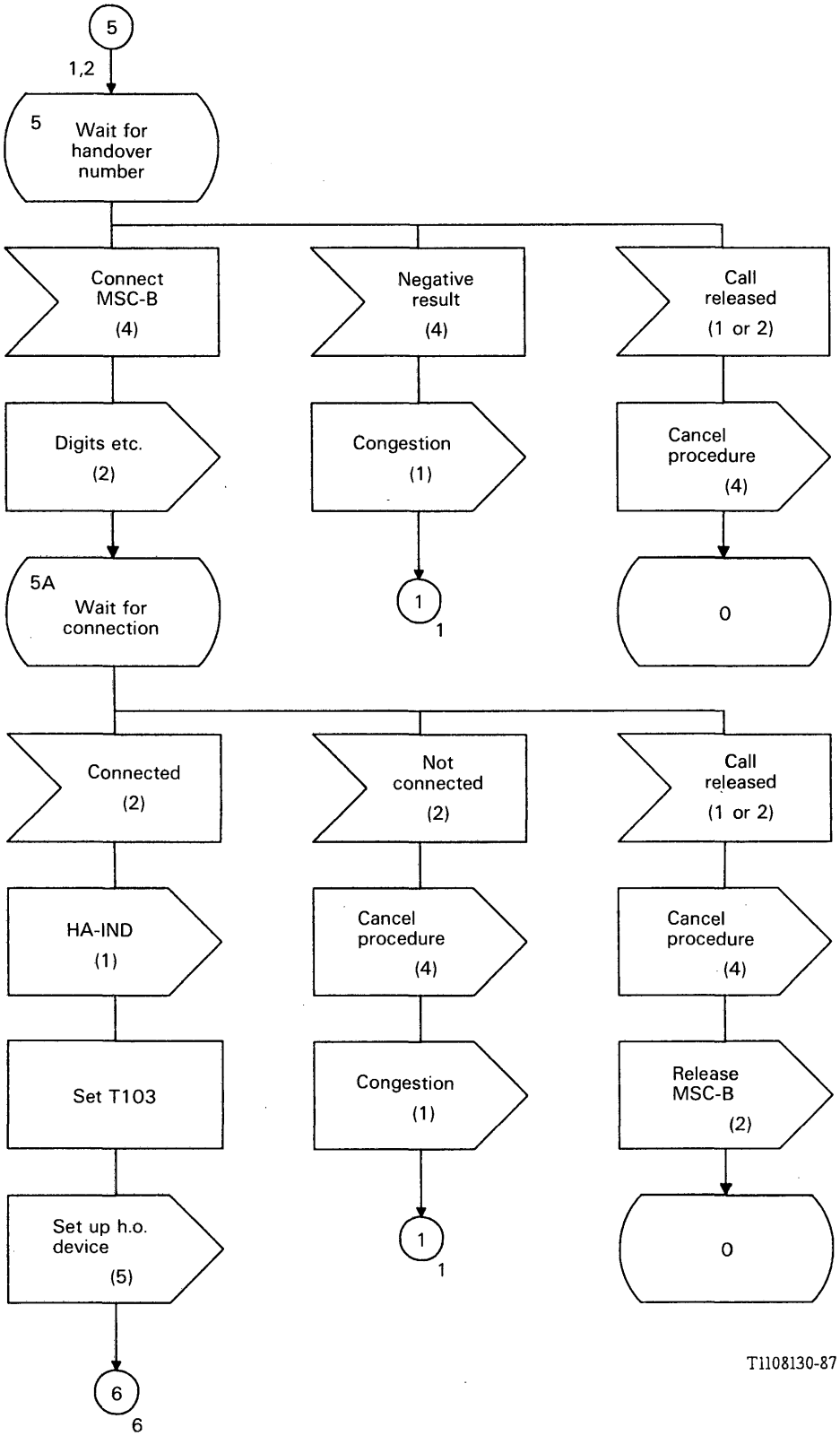


FIGURE 10/Q.1005
(Sheet 5 of 9)

Handover control procedure in MSC-A

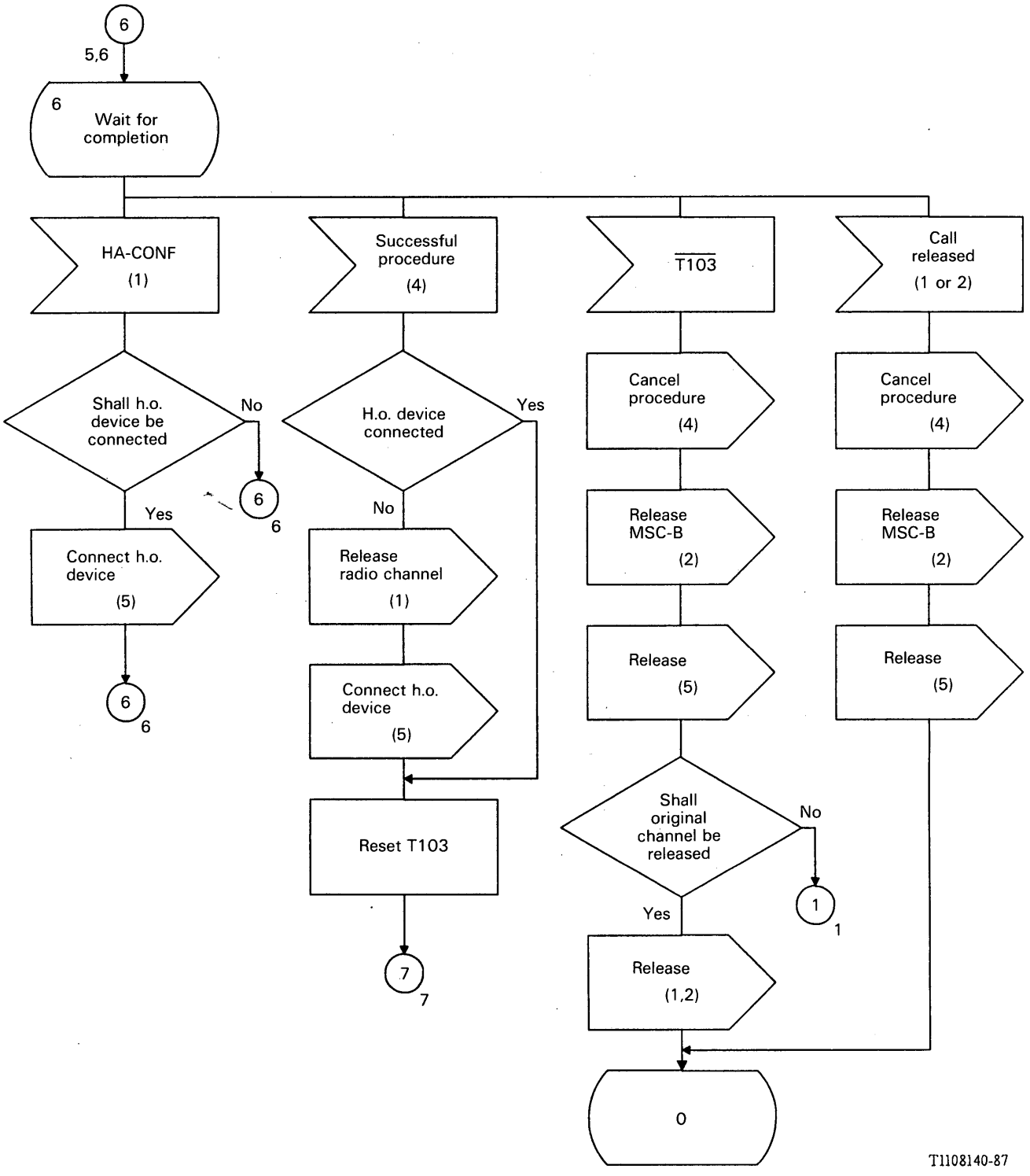


FIGURE 10/Q.1005
(Sheet 6 of 9)

Handover control procedure in MSC-A

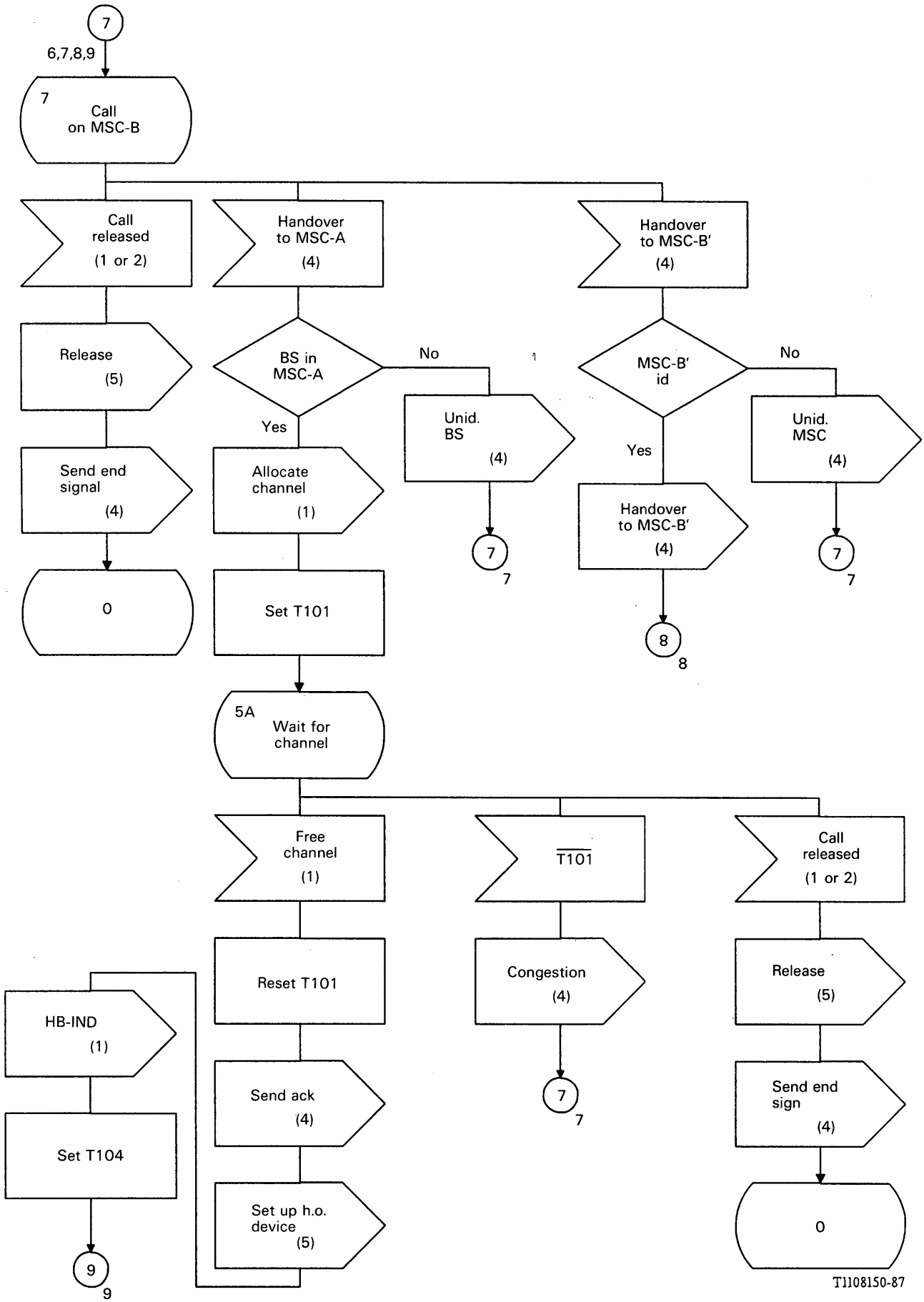


FIGURE 10/Q.1005
(Sheet 7 of 9)

Handover control procedure in MSC-A

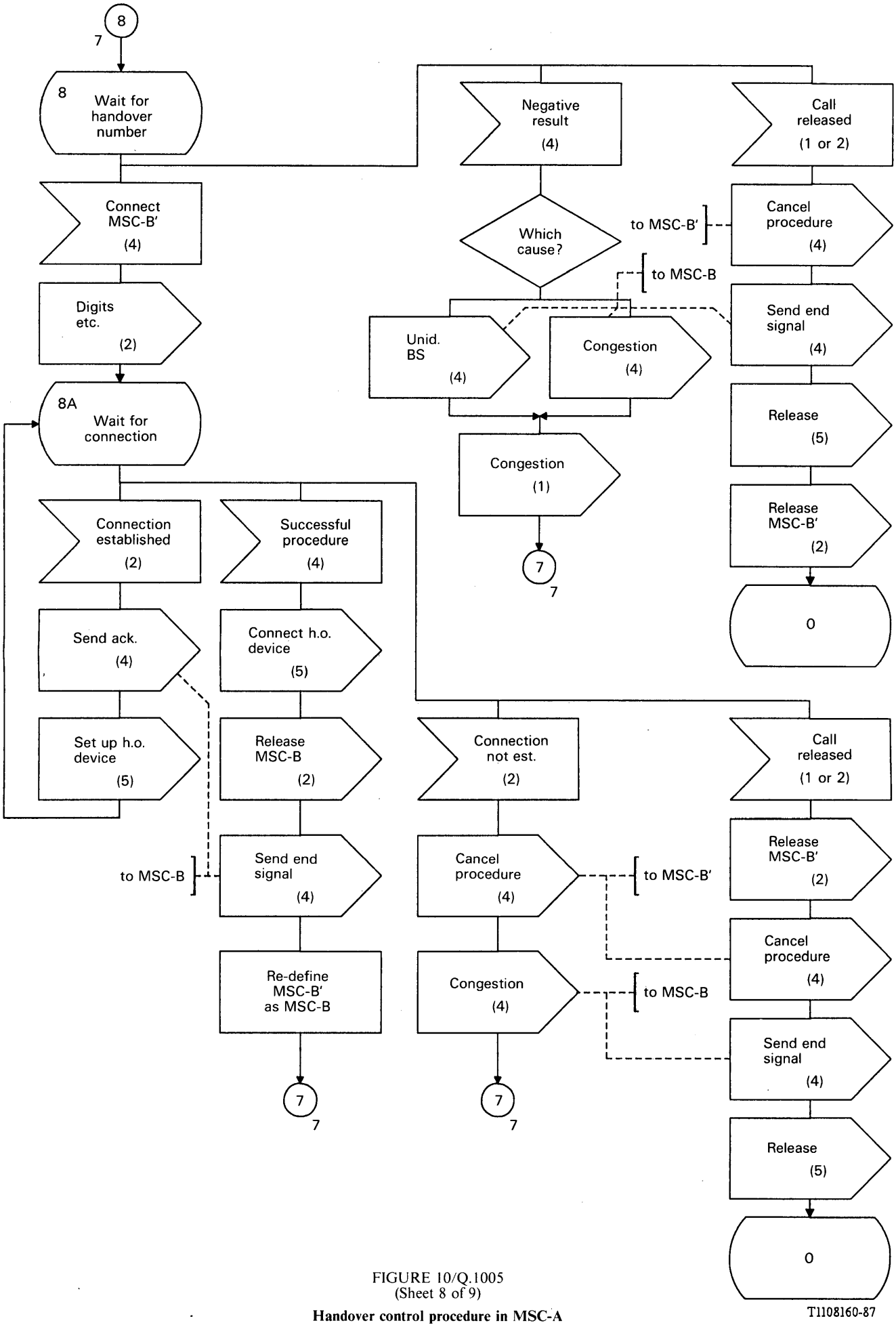


FIGURE 10/Q.1005
(Sheet 8 of 9)

Handover control procedure in MSC-A

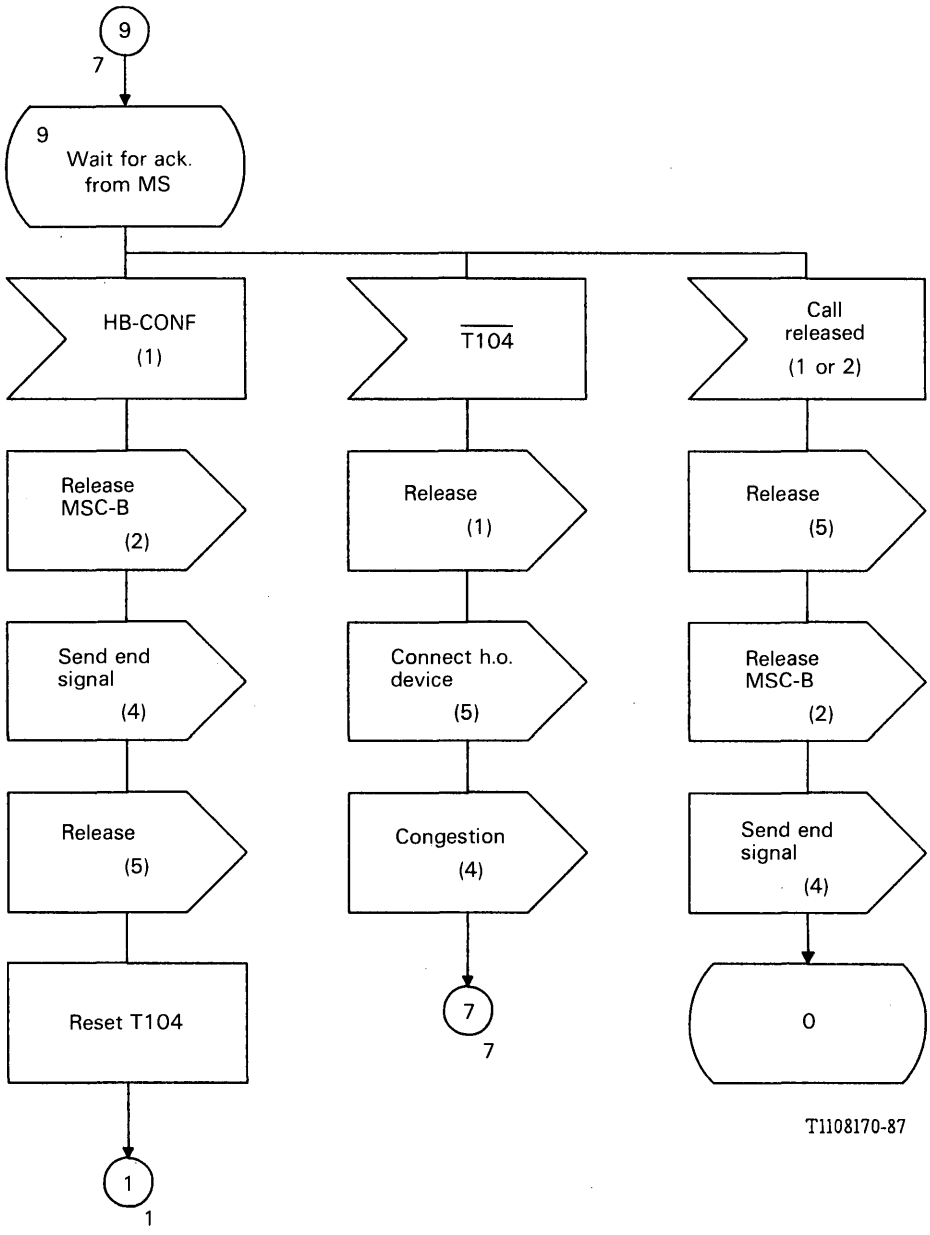


FIGURE 10/Q.1005
(Sheet 9 of 9)

Handover control procedure in MSC-A

Timers in MSC-A

The procedures are supervised by timers in order to avoid deadlock when responses are not received or the procedures fail. The following timers are defined:

T100: This timer supervises the time between sending a request for measurements to a BS or an MSC and the receipt of the results. Results received after time out are ignored. T100 = (FS)

T101: This timer supervises the queuing time for a free channel. If T101 expires, a no channel indication is generated. T101 = (FS)

T102: This timer supervises the time for handover completion for handover between BSs in MSC-A. If T102 expires, the radio path and the connection on interface B′ are released. T102 = (FS)

T103: This timer supervises the time between issuing a HA-INDICATION in MSC-A and receiving a successful procedure indication from MSC-B. If T103 expires, the handover procedure is cancelled and either the radio channel is released (if HA-CONFIRM has been received) or it continues on the old channel (if HA-CONFIRM has not been received). T103 = (FS)

T104: This timer supervises the time between sending an HB-INDICATION and receiving the HB-CONFIRM for a subsequent handover from MSC-B to MSC-A. If T104 expires, the new radio channel is released and the existing handover device connection to MSC-B is maintained. T104 = (FS)

5.4 *MAP procedures in MSC-A (functional unit 4)*

The MAP procedures for handover are defined in Recommendation Q.1051. They include:

- requesting measurements in other MSCs;
- procedures for basic handover; and
- procedures for subsequent handover.

These procedures are as outlined in § 4.

6 Detailed procedures in MSC-B

6.1 *BS/MSC (MS/BS) procedures MSC-B (functional unit 1)*

The handover procedures in this functional unit consist of:

i) signalling between the MS and the MSC; and

ii) signalling between the BS and the MSC for
   - initiation of quality measurements, and
   - access management.

Signals exchanged with functional unit 3 are indicated in § 6.3 below.

6.2 *Call control procedures MSC-B (functional unit 2)*

These procedures relate to the call control in MSC-B of the "handover" connection with MSC-A. For these procedures the following apply.

Call set-up

The connection is set-up by MSC-A. MSC-B should provide, if possible, the following backward signals:

- signals indicating unsuccessful call set-up and, if possible, the cause of call failure;
- address complete signal; and
- answer signal (see note).

  Note – The answer signal is not related to answering by the MS and it has no meaning in the handover procedure between MSC-A and MSC-B. But after successful handover this signal is needed for bringing the connection in the answered state in the intermediate PSTN/ISDN exchanges.

There will be no indication that the call applies to a handover. This information has to be derived from the MS roaming number received during call set-up in relation to the earlier radio channel request/radio channel acknowledgement procedure between MSC-A and MSC-B (MAP-procedure).

When the connection has been established an indication should be given to functional unit 3 (illustrated by the signal "connection established" in Figure 11/Q.1005).

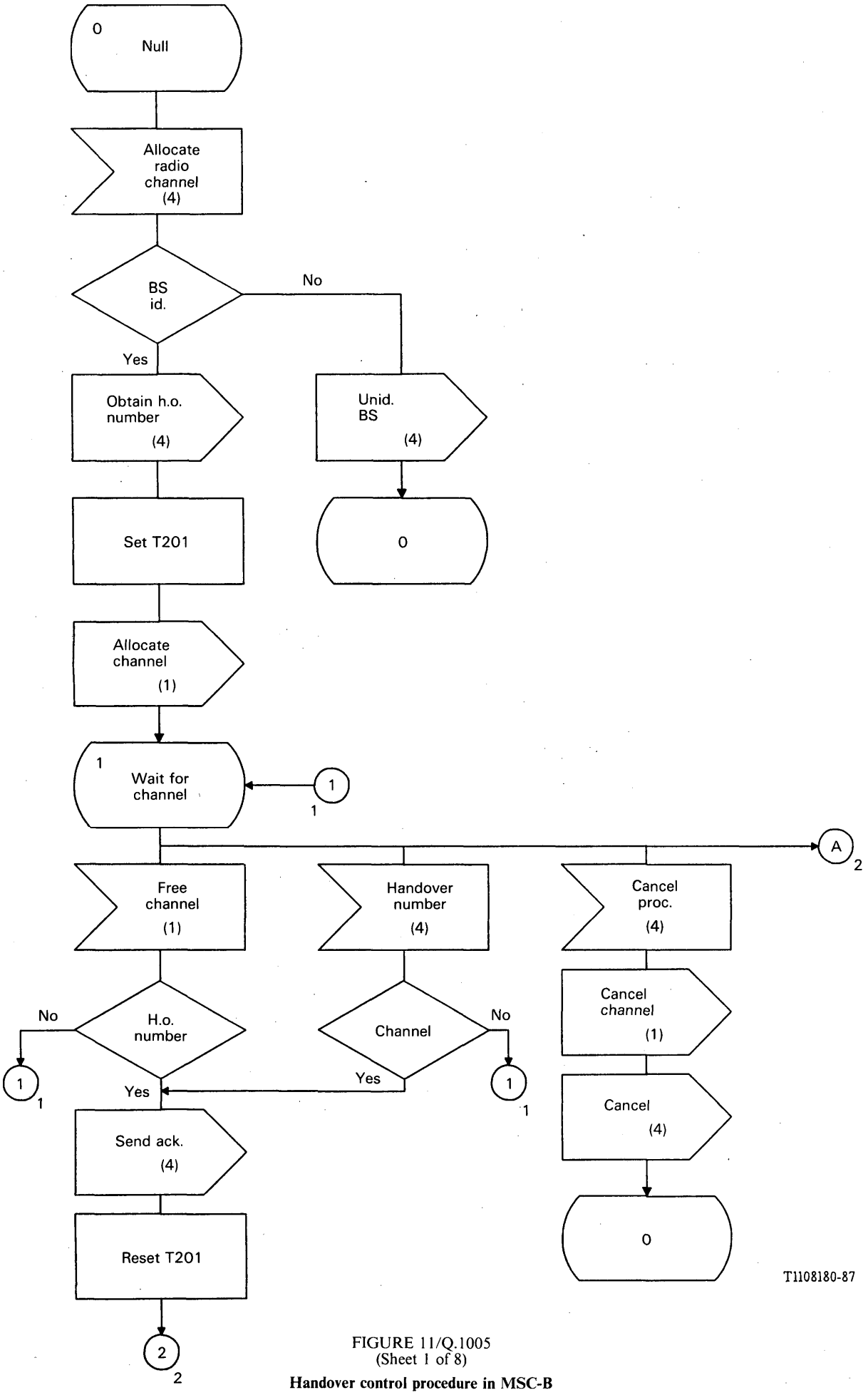


FIGURE 11/Q.1005
(Sheet 1 of 8)

Handover control procedure in MSC-B

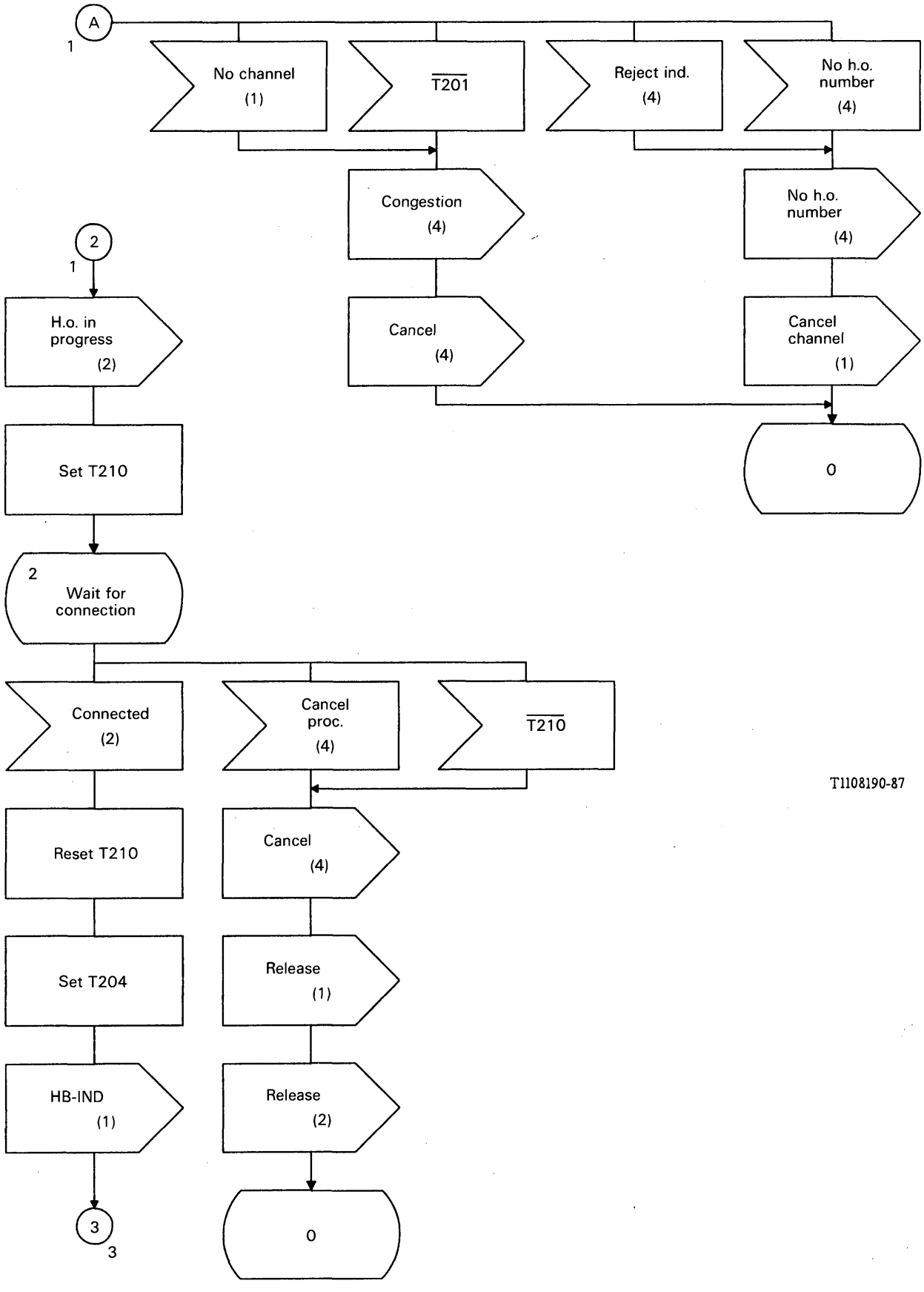


FIGURE 11/Q.1005
(Sheet 2 of 8)

Handover control procedure in MSC-B

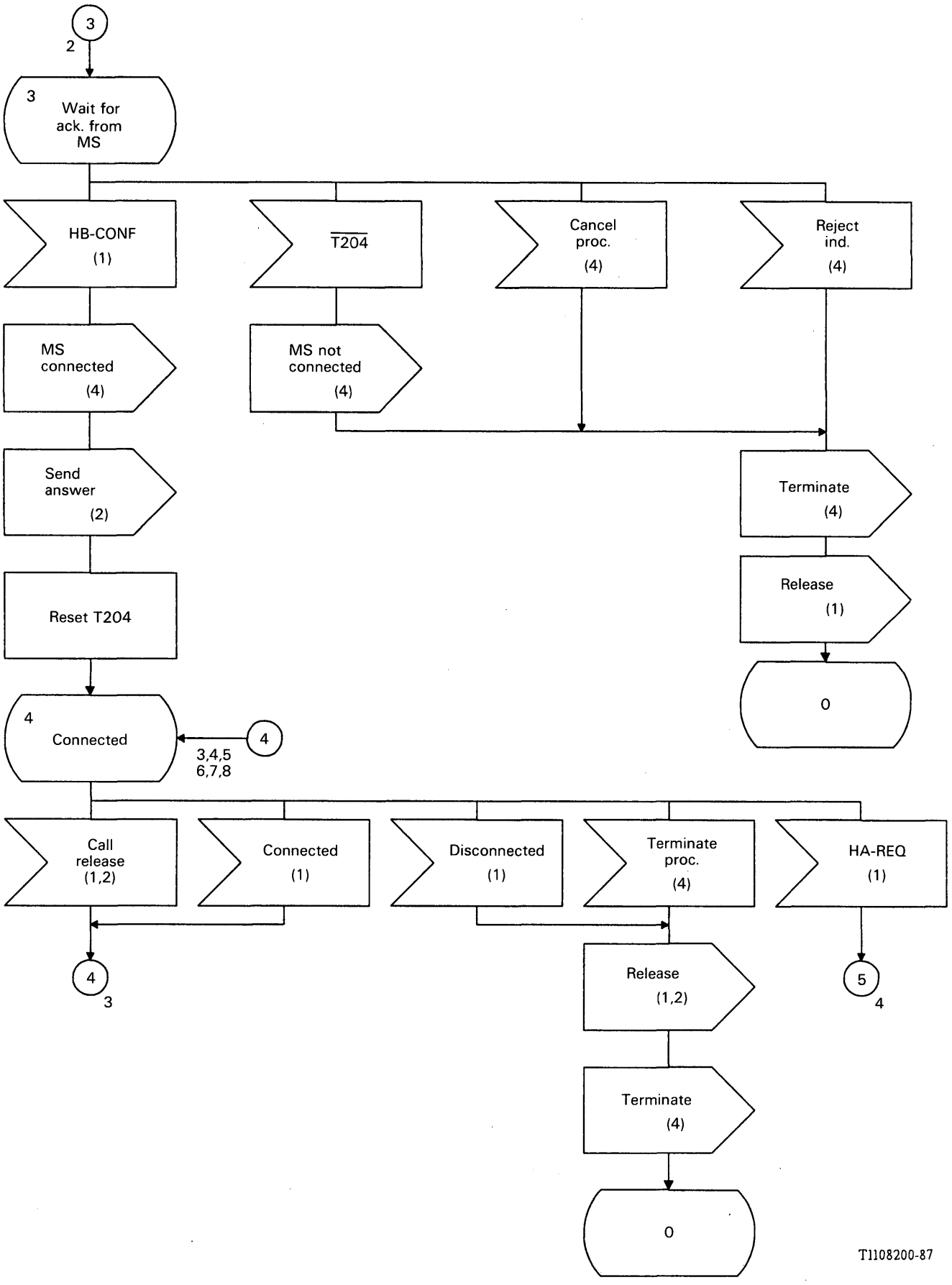


FIGURE 11/Q.1005
(Sheet 3 of 8)

Handover control procedure in MSC-B

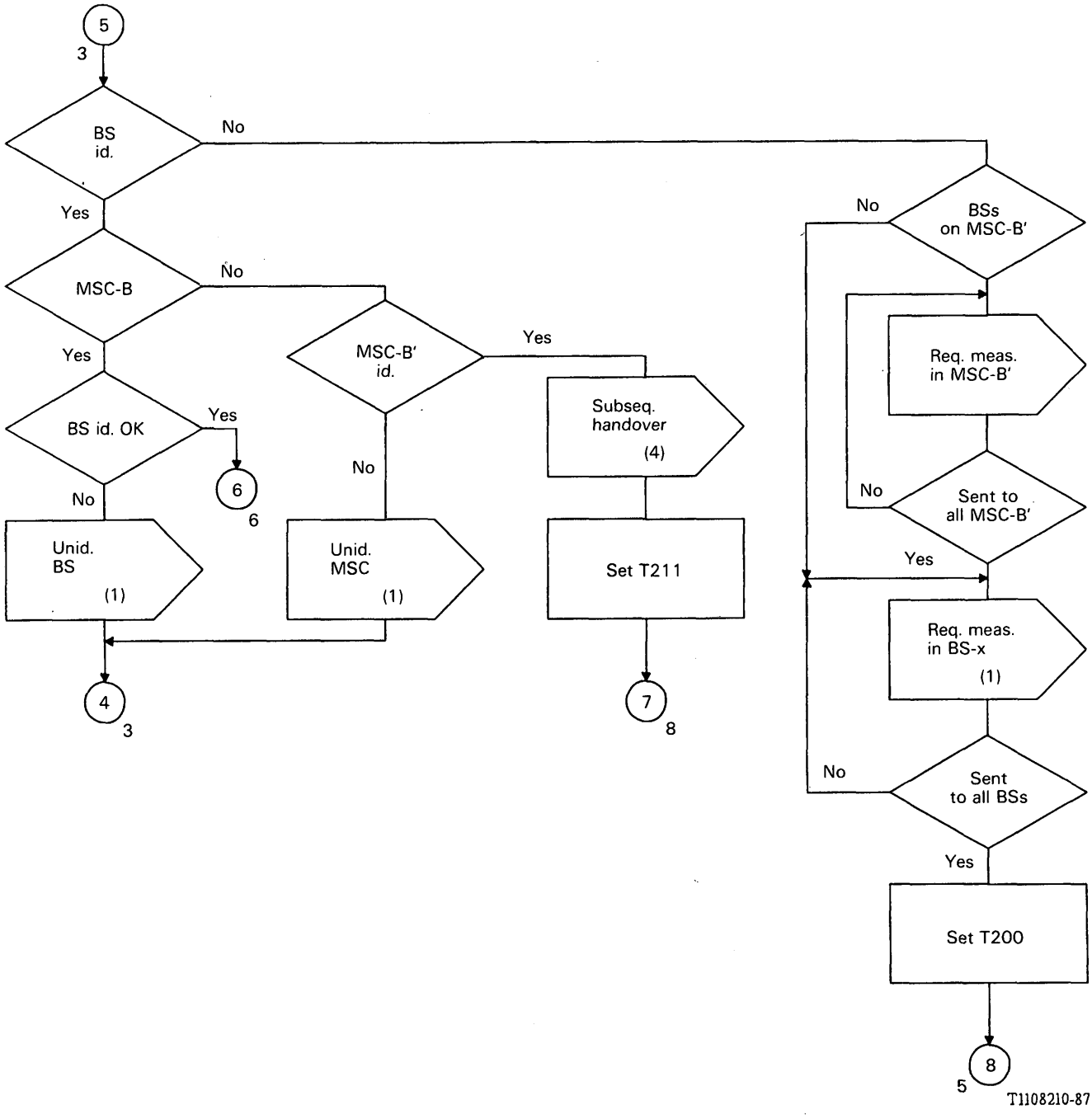


FIGURE 11/Q.1005
(Sheet 4 of 8)

Handover control procedure in MSC-B

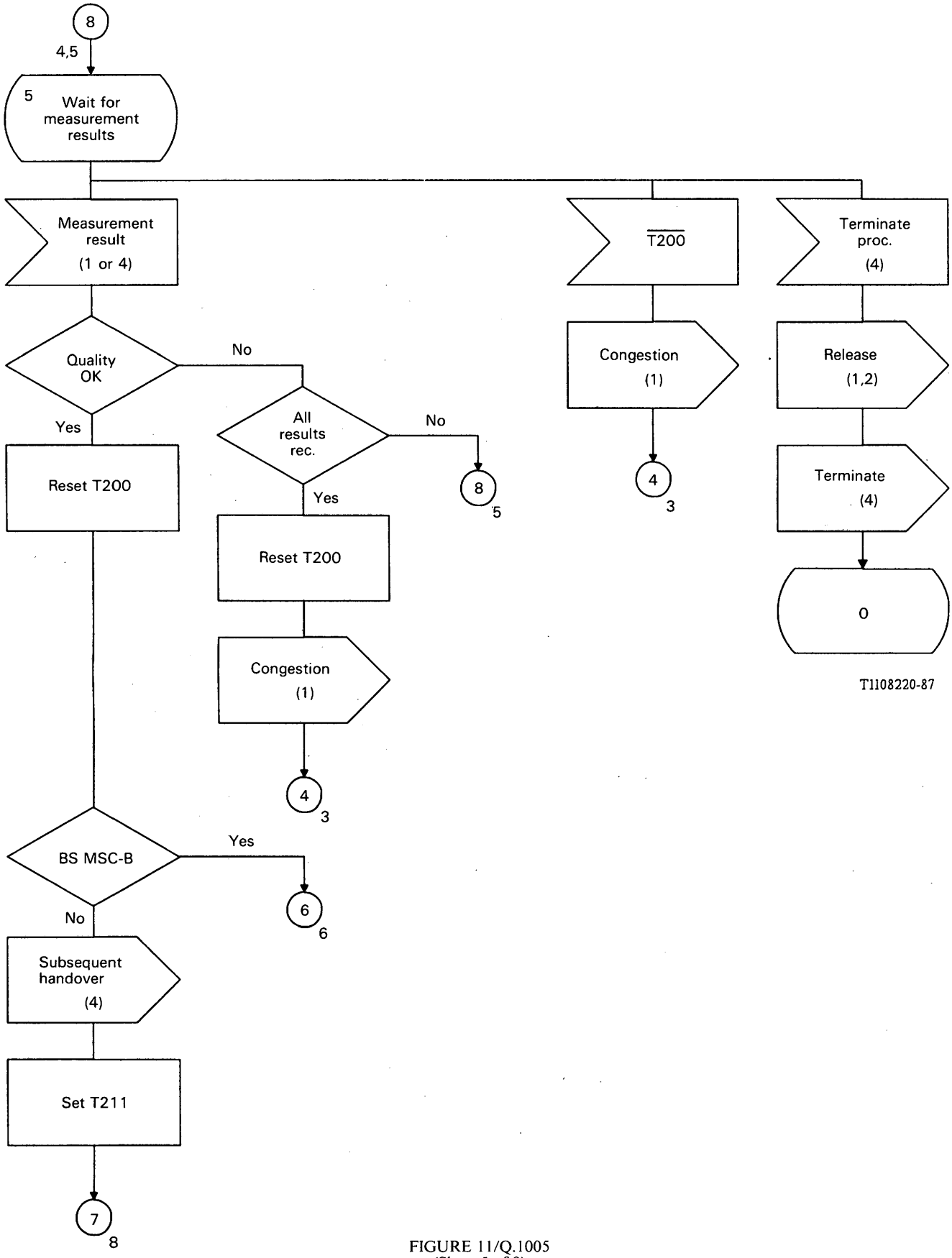


FIGURE 11/Q.1005
(Sheet 5 of 8)

Handover control procedure in MSC-B

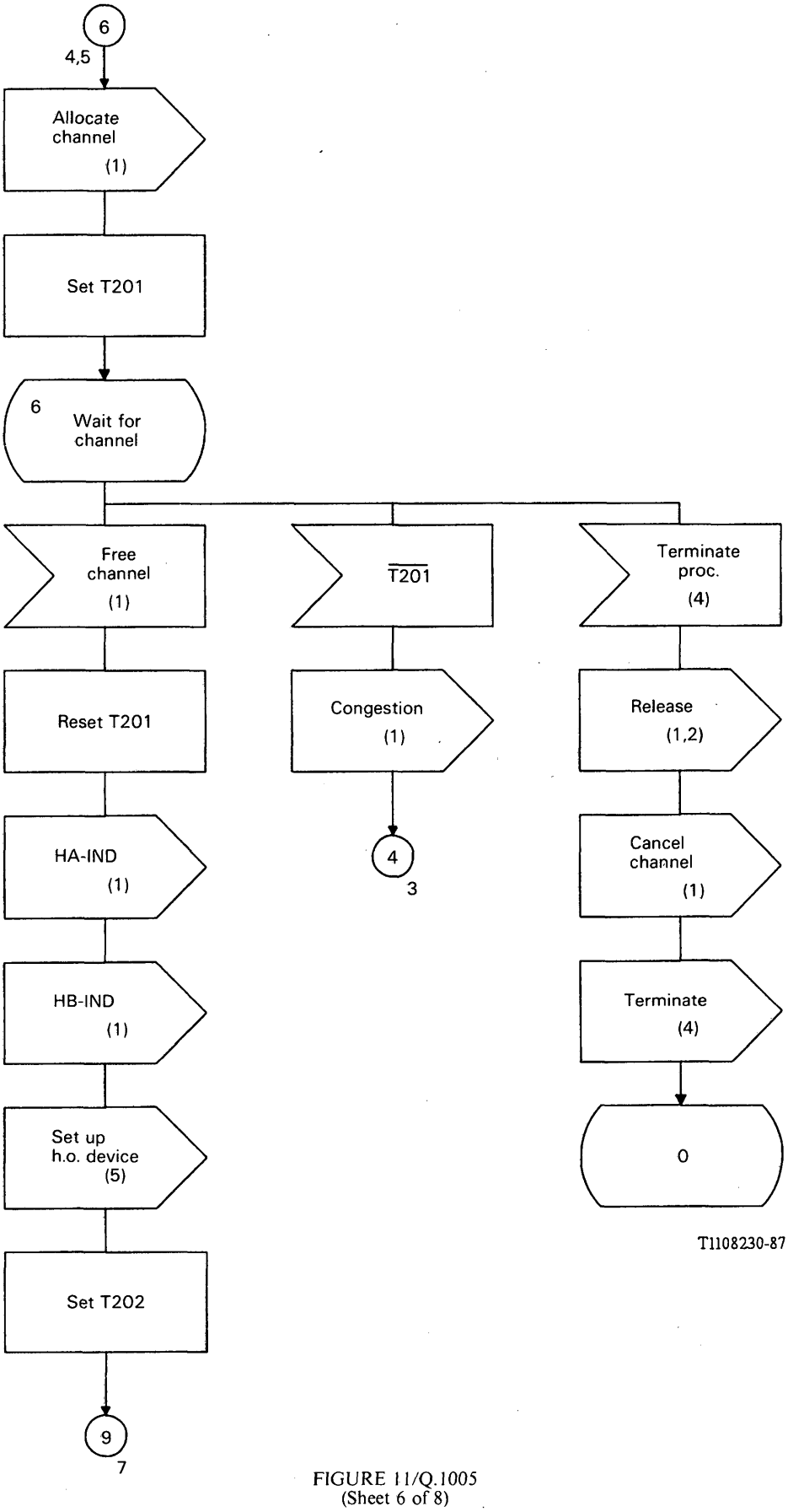


FIGURE 11/Q.1005
(Sheet 6 of 8)

Handover control procedure in MSC-B

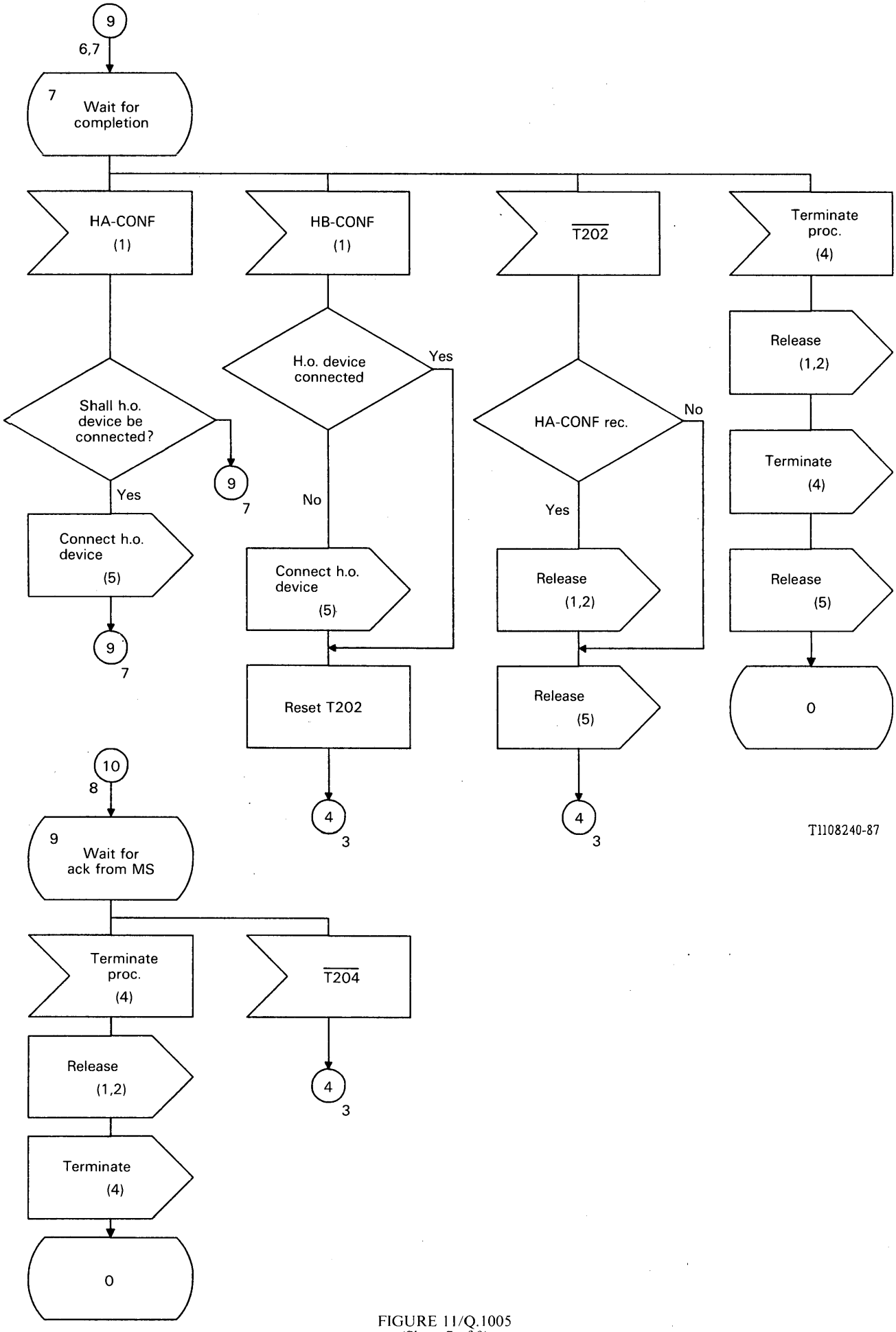


FIGURE 11/Q.1005
(Sheet 7 of 8)

Handover control procedure in MSC-B

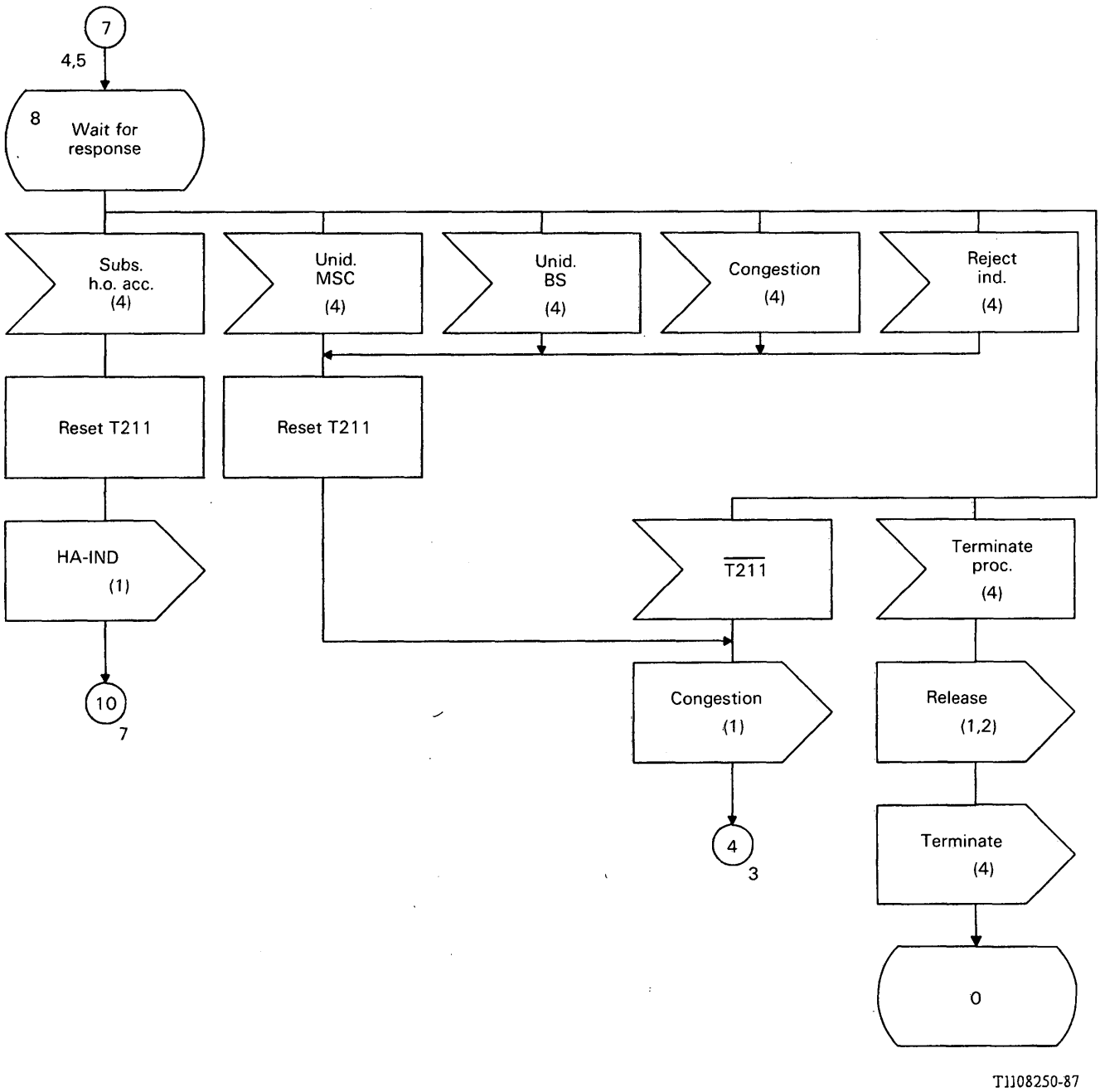


FIGURE 11/Q.1005
(Sheet 8 of 8)

Handover control procedure in MSC-B

Call clearing

The call clearing consists of two parts after inter MSC handover, clearing of the BS-MS connection and clearing of the inter MSC connection.

The MAP is used to transfer information between MSC-B and MSC-A in order to make it possible for MSC-B to send the appropriate signals and still leave the call control to MSC-A.

MSC-A initiates release of the connection between MSC-A and MSC-B.

MSC-B is only allowed to initiate inter MSC connection release after the *end signal* is received.

When the Signalling System No. 7-ISDN User Part is used, the normal symmetric release procedures apply.

When a signalling system is used without a symmetric release possibility, the following applies.

- When MSC-B receives a clear-forward signal from MSC-A, it shall release the radio path.
- In fault situations, e.g. machine malfunction or loss of the connection on interface A, MSC-B may send a clear-back signal to MSC-A.

6.3 *Handover control procedures MSC-B (functional unit 3)*

The procedures of functional unit 3 are given in the form of SDL diagrams in Figure 11/Q.1005. For all signals sent to or received from another functional unit the source or sink of the signal is indicated (e.g. from 4, to 2, etc.).

The procedures in functional unit 3 include the following.

i) Handover from MSC-A (states 1, 2, 3 and 4). This case includes initiation by MSC-A (indicated by the allocate radio channel signal received from functional unit 4) and allocation and establishment of the new radio channel. The procedure is outlined in § 4.1.

ii) Subsequent handover within the area controlled by MSC-B (states 4, 5, 6 and 7). This procedure is essentially the same as that of ii) of § 5.3.

iii) Subsequent handover to another MSC (MSC-A or MSC-B') (states 4, 8 and 9). The initiation procedure is essentially the same as that of i) of § 5.3. The HA-INDICATION is now generated by MSC-B after a subsequent handover accepted indication is received from MSC-A (via functional unit 4). The procedure is terminated in MSC-B when MSC-B receives a terminate procedure indication from functional unit 4.

Timers in MSC-B

The procedures are supervised by timers in order to avoid deadlock when responses are not received or the procedures fail. The following timers are defined.

T200: This timer is the same as T100 (§ 5.3).

T201: This timer is the same as T101 (§ 5.3).

T202: This timer is the same as T102 (§ 5.3).

T204: This timer is the same as T104 (§ 5.3).

T210: This timer is used to supervise the time for establishing a connection from MSC-A to MSC-B after an allocate radio channel request has been received. When T210 expires, the allocated channel in MSC-B is released. T210 = (FS)

T211: This timer is used to control the time between requesting a subsequent handover and receiving the response from MSC-A. If T211 expires, the existing connection with the MS is maintained. T211 = (FS)

6.4 *MAP procedures MSC-B (functional unit 4)*

The MAP procedures for handover are defined in Recommendation Q.1051. They include:

- requesting measurements in other MSCs,
- procedures for basic handover,
- procedures for subsequent handover, and
- procedures for obtaining and releasing MS roaming number for handover from the VLR.

These procedures are outlined in § 4.

7 Authentication

Authentication will be performed after handover (for further study).

8 Handling of supplementary services

This is for further study. MAP procedures for supporting such functions are contained in Recommendation Q.1051.

MSC-A will maintain call control until all operations, i.e. the existing call and any supplementary service operation have been terminated. At this instant, MSC-B is informed by the *end signal* message of the MAP that all functions in MSC-B can be released.

If the call waiting service is provided for the called MS, and there are calls waiting at the time of a handover to another MSC, these calls should be established by MSC-A using normal call forwarding to MSC-B. If the MS requests holding of the existing call and connection of a waiting call, the MAP is used to provide the necessary exchange of information between MSC-A and the MS.

9 Location updating after handover

MSC-B (or VLR-B) should not initiate automatic updating of the HLR at the end of the call. The procedures in the MS should be such that the MS should initiate updating after the call has been completed and the MS has tuned to a common control channel.

Automatic updating by MSC-B (or VLR-B) is for further study.

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SECTION 3

INTERWORKING WITH ISDN AND PSTN

Recommendation Q.1031

GENERAL SIGNALLING REQUIREMENTS ON INTERWORKING BETWEEN THE ISDN OR PSTN AND THE PLMN

1 Introduction

The purpose of this Recommendation is to present the general requirements for the PSTN and the ISDN as well as for the mobile network to be met in order to ensure a correct integration of the mobile service in the fixed network.

This Recommendation covers only the signalling aspects of the interworking between the mobile service and fixed network.

2 General requirements

2.1 *Requirements for the mobile system*

In order to be integrated in the fixed network the PLMN must comply with the following requirements:

a) The MAP which supports information exchanges between the nodes of the mobile service uses the facilities of Transactions Capabilities of Signalling System No. 7. Therefore the equipment of the mobile network must comply with the specification of the interface between TCAP and the application user. If TCAP functions are integrated in the mobile network equipment, the latter must comply with the relevant specifications (Recommendations Q.771 to Q.774).

b) FOR MAP messages routing purpose, the mobile nodes must provide the SCCP via TCAP with an address complying with the relevant specifications (Recommendations Q.711 to Q.714).

c) For call set-up, the MSCs must interface with the fixed exchanges. In the detailed interworking Recommendations, the fixed network signalling considered are Signalling System No. 7 and its User Parts (TUP or ISUP). The MSCs must comply with the same signalling interface specifications as the fixed exchanges.

d) The PLMN and the signalling on the radio path must provide the information needed to ensure a correct interworking with the fixed network. The interworking in the MCSs must occur with a minimum loss of information.

e) The PLMN nodes must interface with the No. 7 signalling network. For that, they must comply with the MTP specifications (Recommendations Q.701 to Q.707).

2.2 *Requirements for the fixed network*

The adaptations of the fixed network needed for the integration of the mobile service have to be minimized. However, some facilities foreseen for other services will also facilitate the access to the mobile service or the operation of the PLMN.

a) The implementation of the No. 7 signalling network could be useful for the mobile service. Before the No. 7 Signalling System is implemented, a dedicated signalling network, using a subset of Signalling System No. 7, could be used as an interim solution for transporting the data between functional units of PLMNs.

b) It will be useful that, in addition to the signalling network, the SCCP facilities be available in order to avoid a specific implementation of such a service in the PLMN equipments.

c) The interrogation procedure based on TCAP prior to connection set up to a mobile would save circuits resources in the network and would increase the service quality provided to the fixed calling subscriber by e.g., reducing the post dialling delay in such kinds of calls. From a signalling point of view the best way is to introduce this procedure as near as possible to the local originating exchanges (see Recommendation Q.1032).

3 Interworking with the PSTN for call set-up

The interworking with the Telephone User Part of Signalling System No. 7 is the only case considered here.

Particular aspects:

a) The fixed telephone network provides an end-to-end transparent link at least for speech use. It is then possible to have a data transmission communication on a telephone call. This would not be the case with a mobile subscriber: the radio path would not be transparent. Therefore, if a calling subscriber wishes to have a data transmission call with a mobile it would be necessary to inform the network concerning the precise characteristics of this transmission: the mobile system will then be able to replace the speech coder by a data coder adapted to the type of transmission modem used. One solution could be that the mobile station has one telephone number per type of data transmission service it can use.

b) The usual routing of a call to a mobile includes a re-routing according to the roaming number allocated to that mobile. This number is temporarily allocated and difficulties could appear in some cases such as a failure of a register. It would then be useful that the number dialled by the calling subscriber appears in the Initial Address Message received by the VMSC. This transmission can be used as a solution to avoid the allocation of one roaming number for each telephone number in the case of data transmission to a mobile station.

4 Interworking with the ISDN for call set-up

Since the radio path cannot economically provide a transparent 64 kb/s channel to mobile subscribers all the time, all the ISDN services foreseen in the fixed network will not be available to the mobile subscribers. The Quality of Service in land mobile networks may also in some cases not meet the Quality of Service requirement for certain ISDN services. Therefore some service limitations need to be introduced in the access to mobile stations.

Different methods may be foreseen to implement this limitation:

a) The interrogation is used also to check the service capabilities of the mobile access. This procedure can also be used to perform a compatibility check between the parties. But this test is only possible if the HLR knows the relevant characteristics of the mobile station and cannot be used with card operated stations; in that case a mobile subscriber can use different stations.

b) The simplest solution is that normal mobile call set-up be processed and controlled by the incoming MSC. As such the incoming MSC can also provide a compatibility check for card operated stations.

c) The call setup is normally performed up to the mobile. The IAM contains the characteristics of the service requested and on the terminal needed by the calling party. The network, MSC included, is transparent in the compatibility check. This method is the same as that defined in the ISDN.

5 Impact of the off-air call set-up on the interworking

The use of the off-air call set-up in the PLMN has an impact on the interworking with the fixed network. Both outgoing and incoming calls have to be considered: the consequences are not the same.

As it was stated before, the use of the Off-Air Call Set-Up procedure is optional and must be limited to national telephone calls only (see Recommendation Q.1002).

5.1 *Definition of the off-air call set-up*

To save the radio resources the radio traffic channel may be allocated to the communication only when both calling and called parties are present i.e., at the answer instant. This method called "Off-Air Call Set-Up" (OACSU) has some implication on the interworking with the fixed network. The consequences are not the same whether the mobile subscriber is the calling or the called party.

5.2 *Outgoing call from a mobile station*

Upon initiation of an outgoing call, a traffic channel is allocated to the communication when the called subscriber answer is received in the MSC. In some cases, no idle traffic channel may be available when necessary. Therefore, an appropriate announcement must be given to the called party when no idle traffic channel is available within a certain interval upon receipt of the called party's answer.

Whenever the announcement is used, it must always be played through in its entirety, even if a traffic channel becomes available before it is completed.

If the ADDRESS COMPLETE message indicates that there will possibly be no ANSWER message upon the connection of the called party (e.g., ADC without any information), the radio path must be established immediately upon receipt of the ADC.

Due to interworking constraints coming from the characteristics of the different signalling systems used in countries, the OACSU technique should only be used for national calls.

5.3 *Incoming call to a mobile station*

For incoming calls, the impact is not so important, but some rules must be applied in order to limit the influence on the service quality.

Concerning the sending instant of the answer message, the normal operating rules apply. If the call is successfully set-up to the mobile station, the answer message must be sent to the originating exchange only when the traffic channel is established upon recognition of the called party connection.

6 Special arrangements

6.1 *Control of speech processing and echo control devices*

For further study.

6.2 *Interworking for non-voice calls*

For further study.

Recommendation Q.1032

SIGNALLING REQUIREMENTS RELATING TO ROUTING OF CALLS TO MOBILE SUBSCRIBERS

1 Introduction

When a subscriber wants to call a mobile subscriber, the fixed network needs to know the actual location of the MS in order to route the connection to the relevant Mobile Services Switching Centre (see Recommendation Q.1003 on location registration). This contribution tries to present the signalling requirements the fixed network has to comply with for that purpose. The document considers the different assumptions concerning the capabilities of the fixed exchanges to perform some signalling procedures prior to call set-up.

This Recommendation assumes that the routing analysis requirements specified in Recommendation Q.107*bis* are fulfilled.

This Recommendation assumes that the ISDN number of the mobile contains a specific National Destination Code. The cases where the mobile numbering plan is fully integrated in the fixed numbering plan are for further study.

2 General routing rules

The number dialled by the calling subscriber contains no indication concerning the actual location of the called MS. Therefore, to set up the complete connection, it is necessary to know the location of the MS and the routing address to be used, i.e. the Mobile Station Roaming Number. The only equipment able to provide this information is the Home Location Register. Therefore to route the call to the Mobile Services Switching Centre where the MS is located, it is necessary to interrogate the HLR.

The preferred procedure with regard to signalling is the following:

1) When a subscriber wants to call a mobile station he dials the ISDN number of that station.
2) The local exchange (or a transit exchange) analyzes the number dialled and recognizes the mobile service National Destination Code indicating that the call is destined to a mobile subscriber. In general this complete routing analysis can be made for the national calls only: when the outgoing exchange recognizes that the calling subscriber dialled the international prefix, it routes the call directly to the outgoing International Switching Centre (ISC) without any further analysis. This ISC can then recognize the mobile national destination code.
3) If the result of routing analysis shows that it is necessary to get additional information to set up the complete connection to the MSC where the called station is located, then this information must be obtained from the HLR in charge of the mobile subscriber. If the interrogation procedure is implemented in an exchange referred to in 2) above, this exchange then performs the interrogation of the Home Location Register. The HLR sends back the roaming number of the called MS. This procedure is supported by the Transaction Capabilities of Signalling System No. 7.
4) The connection is then set up in the fixed network to the MSC according to the roaming number of the MS.

3 General requirements for the fixed network

To route a call up to a mobile subscriber, an interrogation of the HLR must be performed in order to get the roaming number allocated to that MS. This interrogation procedure is supported by the Transaction Capabilities of Signalling System No. 7. The preferred solution is that the local exchanges be adapted to TC, and able to perform this interrogation: then they can route the call directly to the called mobile according to the roaming number they obtain from their interrogation of the HLR. The following section of this document shows possible solutions if this assumption is not fulfilled.

As it is described below, in the case where there are no interrogation facilities in the fixed network, on recognition that a call is destined to a mobile subscriber, the routing is first performed to a Gateway MSC. The interrogation of the HLR is then performed by the MSC and the call proceeds according to the Roaming Number received.

Section 5 deals with the routing of calls to foreign mobile stations: usually, in this case, the local exchange does not analyze the national part of the called address and routes directly to the outgoing International Switching Centre which then performs the correct routing of the call.

4 *Signalling aspects on routing a call to a mobile managed by a home PLMN situated in the same country*

4.1 *The originating exchange is adapted to the interrogation procedure* (Figure 1/Q.1032)

If the originating local exchange is able to perform the interrogation procedure, the call set-up occurs as it is specified in section 2 of this document.

4.2 *The originating exchange is not adapted to the interrogation procedure*

If the originating exchange is unable to use TCAP, the following cases can be considered:

- the interrogation procedure is performed by a transit exchange;
- the call is re-routed by a Gateway MSC.

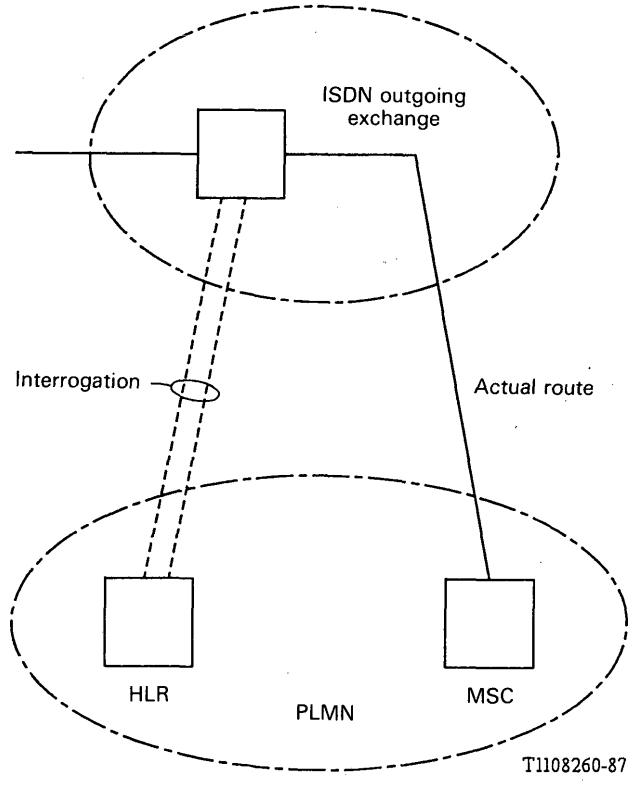

FIGURE 1/Q.1032

General interrogation procedure
Interrogation done by outgoing ISDN exchange

4.2.1 *The interrogation is performed by a transit exchange* (Figure 2/Q.1032)

If the originating exchange is unable to perform the interrogation of the HLR, the connection is set up to a transit exchange. This exchange analyzes the address received (the ISDN number of the subscriber) and notices that the call is destined to a mobile subscriber. It then performs the interrogation of the HLR and routes the call as it is described in section 2.

4.2.2 *The call is re-routed by a Gateway MSC* (Figure 3/Q.1032)

If the fixed network is unable to interrogate the HLR in order to route the call to the actual location of the MS, the connection is set up to a Gateway MSC.

The Gateway MSC interrogates the HLR of the called MS (using MAP in general cases). It receives back the roaming number of the subscriber. With this address, the GMSC set up a connection via the telephone (or ISDN) network to the MSC where the mobile is located. If the called subscriber is abroad, the connection is normally set up via the international network.

5 Routing a call to a foreign mobile subscriber

As for a normal telephone call, the calling subscriber, when he wants to join a foreign mobile subscriber, dials the international access prefix first. His local exchange, according to this prefix, routes the call directly to the outgoing International Switching Centre without any further analysis of the number dialled.

The routing of the call is then performed by the outgoing international Switching Centre. Two assumptions can be envisaged:

- the outgoing International Switching Centre recognizes that the called party is a mobile subscriber and can perform the interrogation of the HLR;
- the outgoing International Switching Centre is unable to perform the interrogation of the HLR.

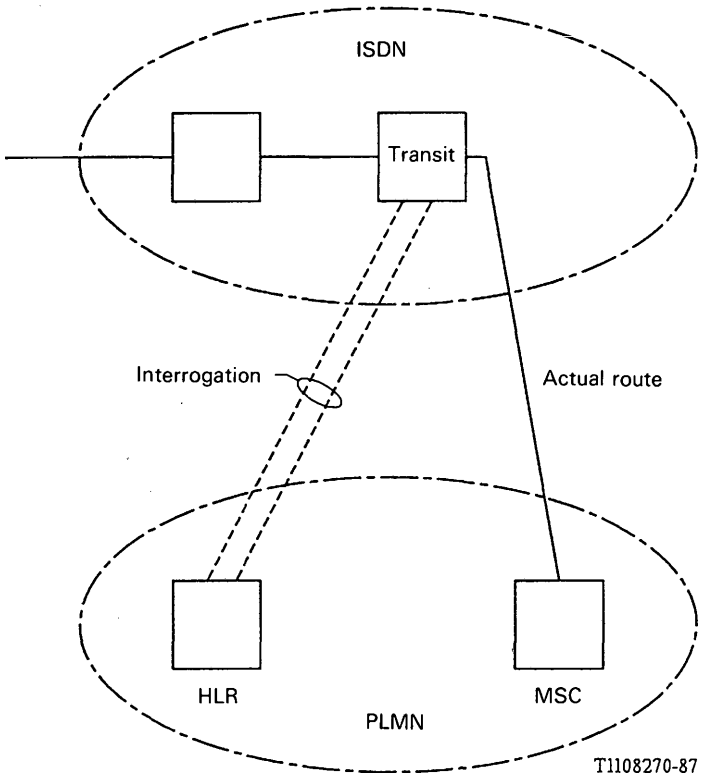

FIGURE 2/Q.1032

Interrogation is done by a transit exchange

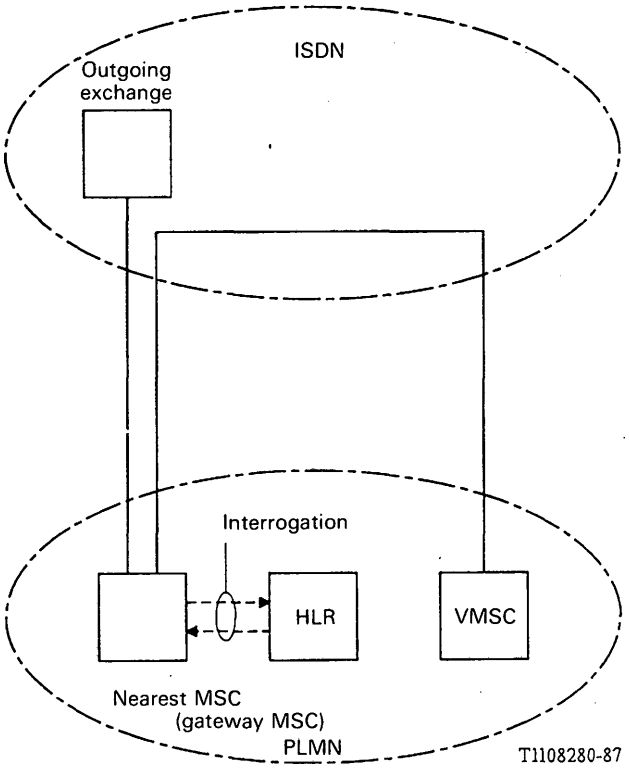

FIGURE 3/Q.1032

Routing to nearest MSC using call forwarding combined with interrogation within the PLMN

5.1 *The outgoing ISC can perform the interrogation of the HLR* (Figure 4/Q.1032)

When the outgoing International Switching Centre receives the call, for routing purposes it analyzes the digits of the country code and the first digits of the national significant number of the called party address. It can then notice that the call is destined to a mobile subscriber and needs a preliminary interrogation transaction prior to setting up the connection.

With the roaming number, the ISC then routes the call to the MSC where the mobile is actually located. The connection is set up via the international network if the MS is not in the same country as the calling subscriber.

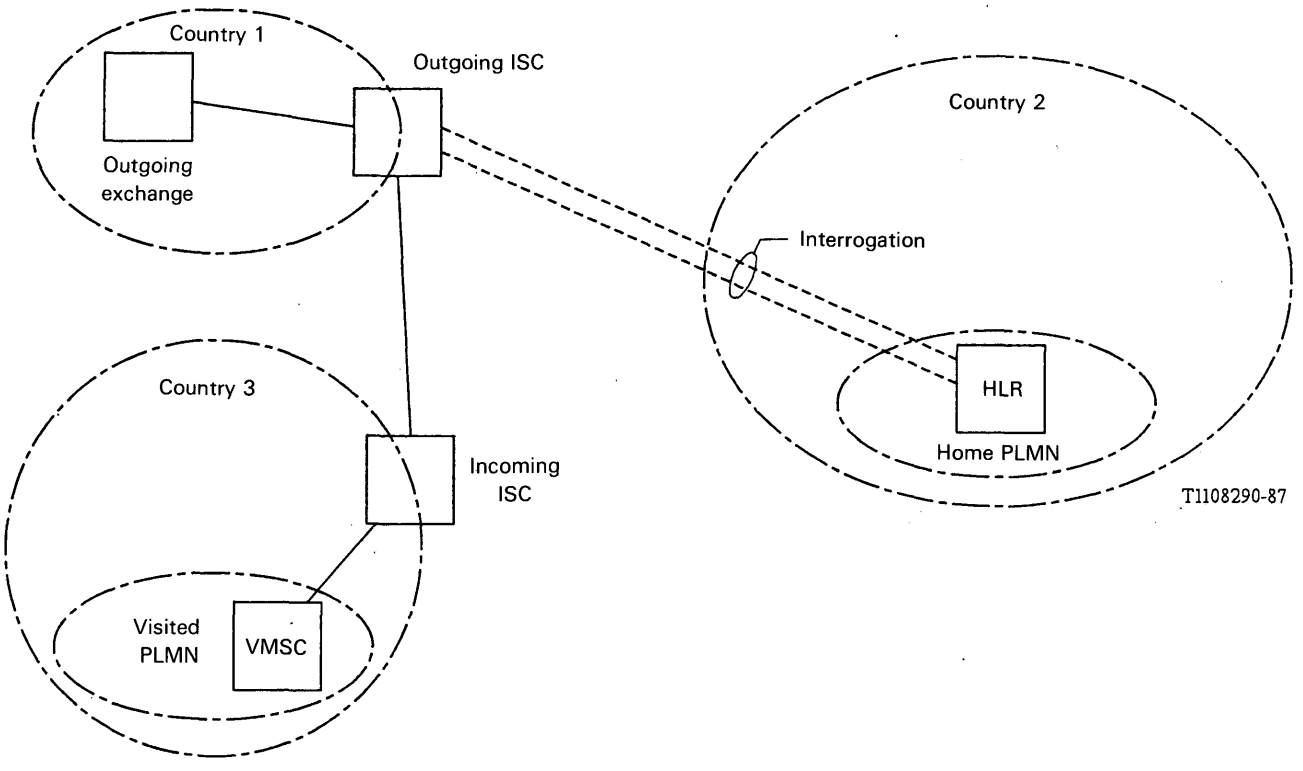

FIGURE 4/Q.1032

Re-routing by the outgoing ISC

5.2 *The outgoing International Switching Centre is unable to perform the interrogation of the HLR* (Figure 5/Q.1032)

If the outgoing International Switching Centre is unable to perform the interrogation procedure, it routes the call to the incoming ISC of the country where the Home PLMN of the called mobile is situated according to the telephone (or the ISDN) number dialled by the calling subscriber.

The incoming ISC receiving the call notices that it is destined to a mobile. The following assumptions can be envisaged:

- this ISC can perform the interrogation;
- this ISC is unable to perform the interrogation: therefore the interrogation has to be made either by a national transit exchange or by a Gateway MSC.

In this assumption where the actual routing has to be made in the home country of the mobile, the connection may comprise two international links in tandem if the subscriber is roaming abroad. Therefore it would be better that the interrogation is performed in the outgoing country; this method would limit the length of the complete connection. The worst case will appear when the called mobile is roaming in the country of the calling subscriber: the complete connection comprises two international links in tandem instead of a simple national routing.

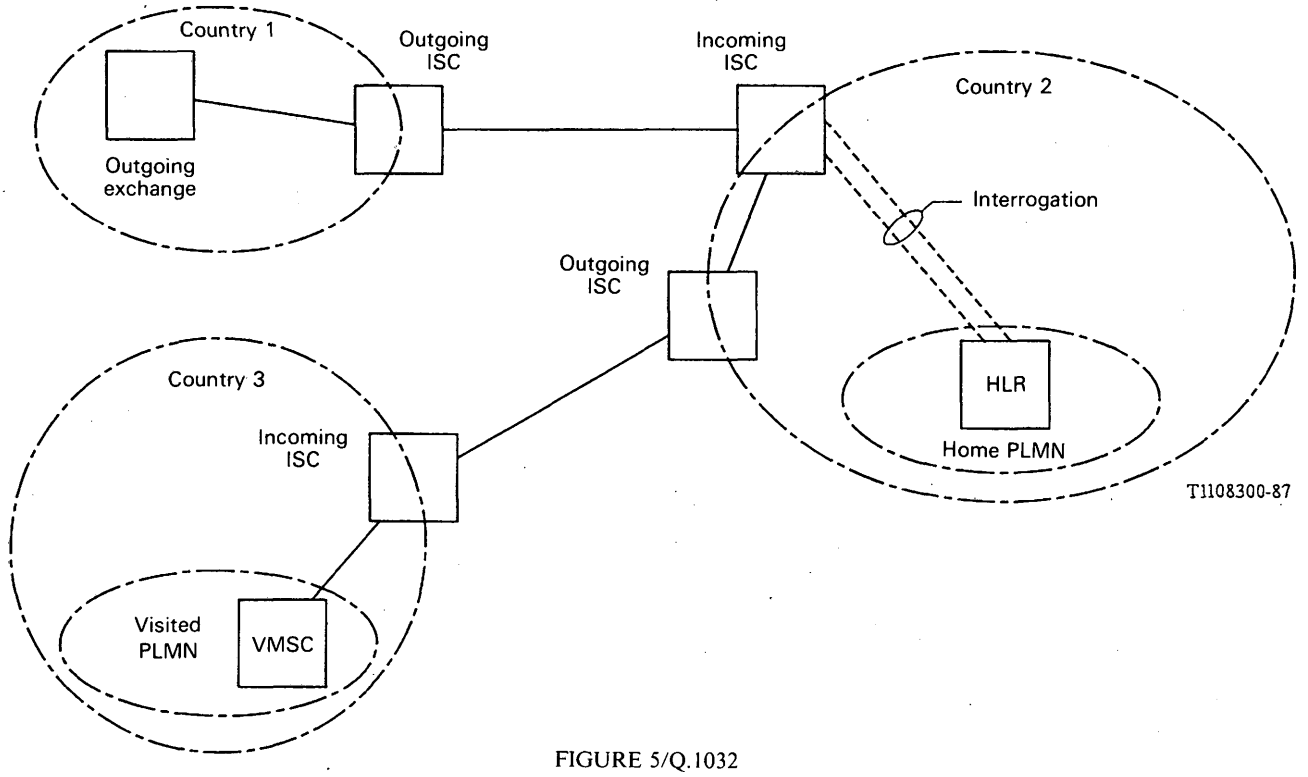

FIGURE 5/Q.1032
Re-routing by the incoming ISC

5.3 *The International Switching Centre recognizes that it is a call to an MS but cannot perform the interrogation*

In this case, the International Switching Centre routes the call to a Gateway MSC which performs the interrogation:

- if the GMSC is accessed by the outgoing ISC, see Figure 6/Q.1032.
- if the GMSC is accessed by the incoming ISC, see Figure 7/Q.1032.

6 Alternative solution: re-routing of the call after clearing the previous connection (Figure 8/Q.1032)

The ISUP provides a backward message to indicate that the call should be re-routed and containing the new address. This facility may be used in the case where a foreign MS is called and no interrogation functions are available in the fixed network to get the Roaming Number from the HLR. A long international connection may be established before the location of the MS is determined but this facility could allow the call to be "dropped back" to the suitable MSC.

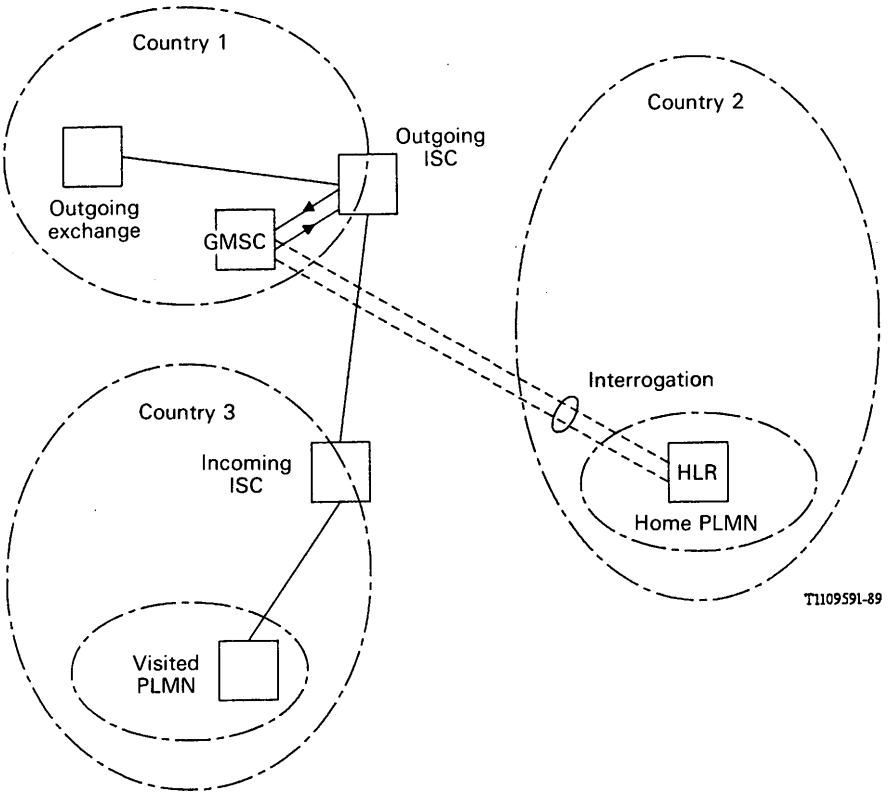

FIGURE 6/Q.1032

Re-routing by a GMSC, when accessed by the outgoing ISC

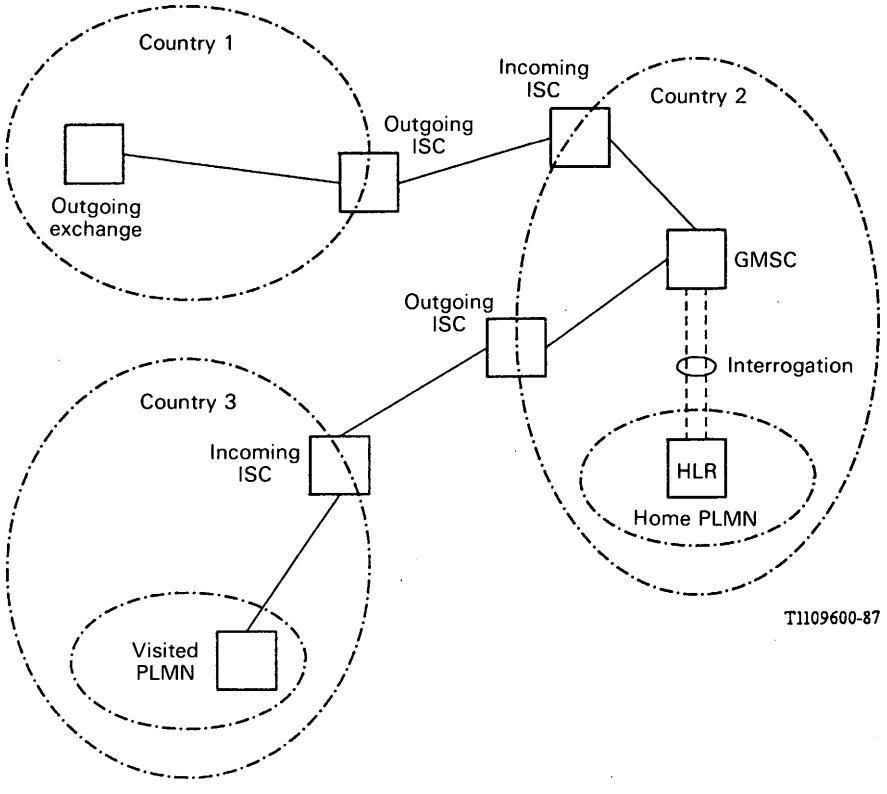

FIGURE 7/Q.1032

Re-routing by a GMSC when accessed by the incoming ISC

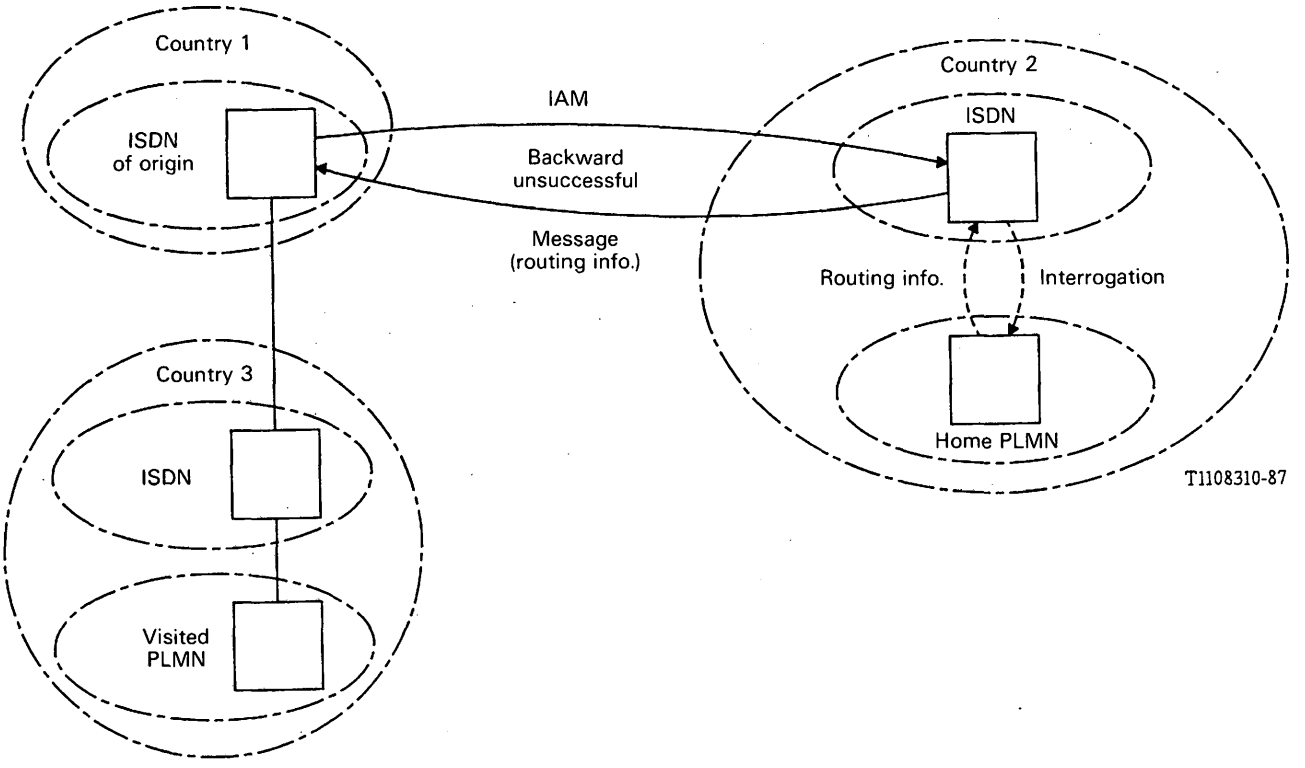

FIGURE 8/Q.1032

Re-routing by the ISDN of origin

7 Unsuccessful call set-up

7.1 *Roaming not allowed*

If the MS is roaming in an area where it is not allowed to have calls, the location is not stored in the HLR and an indication is set. When a call is set up to this subscriber, the HLR will return an unsuccessful indication to the originating exchange.

7.2 *Restart of the HLR*

After a restart, the HLR considers that the information coming from the back up is still valid. If an interrogation is related to a subscriber whose information is not yet restored, the HLR gives back the Roaming Number it has in its tables. If there is a mistake, the restoration procedure specified in Recommendation Q.1004 will re-establish the correct information.

7.3 *Mobile station roaming number unallocated*

If the incoming MSC receives a call which roaming number is declared unallocated by the VLR, it sends back an unsuccessful call set-up indication to the outgoing exchange. This situation may occur after a restart of the HLR or of the VLR (see Recommendation Q.1004).

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