GSM 900 - GSM 1800 / GSM 1900 Roaming Interoperability

Version 3.0.0

27 September 2012

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1. Introduction

1.1 SCOPE

This paper describes the technical background, roaming scenarios, possible problems to be encountered and solutions that can be found when a GSM900-GSM1800 customer roams in a GSM1900 network and reverse.

The paper also describes the practical solutions currently adopted and their possible coexistence.

1.2 ROAMING INTERWORKING DESCRIPTION

The GSM standard was conceived by ETSI in the perspective of becoming a European mobile telephony standard. European regulators who decided to allocate the 900 MHz band for the radio interface fixed the initial set of rules defining the basic technical criteria. The 900 MHz band was not suitable for high-density population areas, whereas the 1800 MHz spectrum portion had better traffic handling capabilities.

Unfortunately, these two bands were not available in countries like Canada and USA, and a new band (1900 MHz) was assigned to allow for implementation of the GSM standard in North America. Furthermore, the numbering plans and signalling protocols, as described in the GSM recommendations, were adapted to the European reality and not to these countries, so new addressing and signalling scenarios had to be conceived.

As long as dual band terminals are not available in the market, the simplest inter-working idea is represented by “plastic roaming” (i.e., roaming without a handset, but maintaining the GSM SIM card), but other difficulties, described in this document, are encountered and need to be solved.

1.3 ABBREVIATIONS

The following abbreviations are used throughout the document:

ANSI:	American National Standards Institute
CC:	Country Code (E.164 and E.214)
C7:	Code 7 (inter- network node signalling system)
DPC:	Destination Point Code (C7)
ETSI:	European Telecommunications Standards Institute
E1:	European Transmission Hierarchy
E.164:	ITU.T recommendation
E.212:	ITU-T recommendation
E.214:	ITU-T recommendation
GSM1900:	Global System for Mobile Communications (at 1900 MHz)
GSM900-GSM1800:	Global System for Mobile Communications (at 900-1800 MHz)
GMSC:	Gateway MSC
GT:	Global Title (SCCP C7)

GTT:	Global Title Translation
HLR:	Home Location Register
IMSI:	International Mobile Subscriber Identity (E.212)
ITU-T:	International Telecommunications Union Technical Committee
MAP:	Mobile Application Part
MCC:	Mobile Country Code (E.212)
MGT:	Mobile Global Title
MNC:	Mobile Network Code (E.212)
MSC:	Mobile services Switching Centre
MSIN:	Mobile Subscriber Identification Number (E.212)
MSISDN:	Mobile Subscriber ISDN Number
MTP:	Message Transfer Part (C7)
NC:	National Code (E.164)
NDC:	National Destination Code (E.214)
NPA:	North American Numbering Plan
NXX:	Digits that follows NPA
OSI:	Open Standard Interface
PLMN:	Public Land Mobile Network
PSTN:	Public Switched Telephone Network
SCCP:	Signalling Connection Control Part (C7)
STP:	Signalling Transfer Point
SIM:	Subscriber Identity Module
TT:	Translation Type (SCCP C7)
T1:	North American Transmission Hierarchy
TCAP:	Transaction Capabilities Application Part (C7)
VLR:	Visitor Location Register

2 Technical Background

This section describes the basic features of the systems considered in the document.

2.1 PROTOCOL STACK

For a better understanding of the potential problems that arise in the “plastic roaming” capability between GSM900-GSM1800 and GSM1900, the protocol stack, used by communicating entities inside a GSM network, needs first to be reminded (Fig. 2.1-1). Although the key issues covered in this paper will be reside in the SCCP layer, all the other layers involved in the process will be reviewed as well.

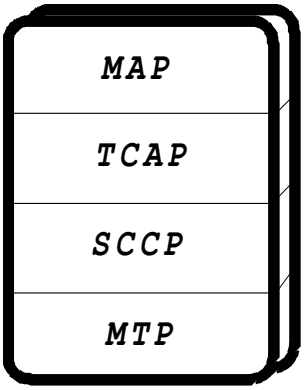

Figure 2.1-1 - Protocol stack

2.2 GSM900-GSM1800 PROTOCOLS

2.2.1 GSM900-GSM1800 protocol layer regulation

The GSM900-GSM1800 signalling standard is grounded on the ITU regulations. The three lower level layers, namely MTP, SCCP and TCAP are based on ITU-T recommendations Q.700 to Q.795. The upper layer, MAP, is based on the ETSI standard GSM 09.02.

2.2.2 GSM SCCP addressing

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As shown in figure 2.1-1, the SCCP layer encapsulates the TCAP and MAP layers, and according to the OSI protocol stack, it corresponds to the transport level. For a better knowledge of message routing inside a GSM900-GSM1800 network, it is necessary to look more thoroughly within SCCP.

When a mobile customer accesses a GSM network (e.g., for updating its own location) the only information provided is the IMSI (International Mobile Subscriber Identity) which is structured according to recommendation ITU-T E.212: in other words, this number identifies unambiguously the mobile subscriber.

The information contained in IMSI is then used to request supplementary data to the HLR, in order to reconstruct the complete profile of the mobile customer being detected. This information will be exchanged by means of C7 signalling, encoded in the MAP protocol but transit in the present C7 networks needs a change in SCCP addressing, because these networks can only handle the ITU-T E.164 addressing (the same used for basic telephony). This change is performed according to recommendation ITU-T E.214, as described in the next paragraph.

The further dialogue between network entities like HLR, VLR, MSC etc. takes place by means of the individual E.164 addresses, since they are now fully equivalent to fixed network entities. The address used for routing SCCP messages is known as Global Title.

2.2.2.1 E.214 SCCP Global title derivation rule

The modification needed to obtain an E.214 address from the corresponding E.212 one consists in changing the MCC (Mobile Country Code) into the E.164 CC (Country Code) and the MNC (Mobile Network Code) into the E.164 NC (National Code), as shown in figure 2.2.2.1-1.

The MSIN field, which identifies the customer, given the Country and the Mobile Network, remains unchanged. The derivation rule clearly shows that E.214 is a compromise between pre-existing numbering (E. 212) and addressing (E.164) mechanisms.

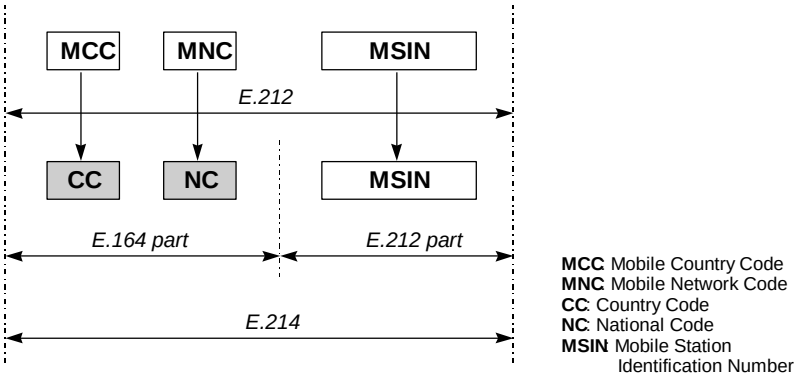

Figure 2.2.2.1-1 - SCCP Global title derivation rule

2.2.3 GSM location update scenario

As explained in par. 2.2.2, the GSM standard identifies a mobile customer respecting recommendation ITU-T E.212. In the first contact between customer and network, this is the only address known and it is naturally used to identify the HLR where the mobile customer profile is stored: obviously the VLR (Visitor Location Register) will also send its E.164 calling party address. Once the HLR is identified through its E.164 address, the dialogue between the two entities is established and, from this moment, proceeds using only the E.164 numbering plan (Fig. 2.2.3-1). The ITU-T recommendations define more than one possibility of interpreting the Global Title: this option is known as Global Title Translation Type and inside GSM it is always set to 0, i.e. no translation type is defined.

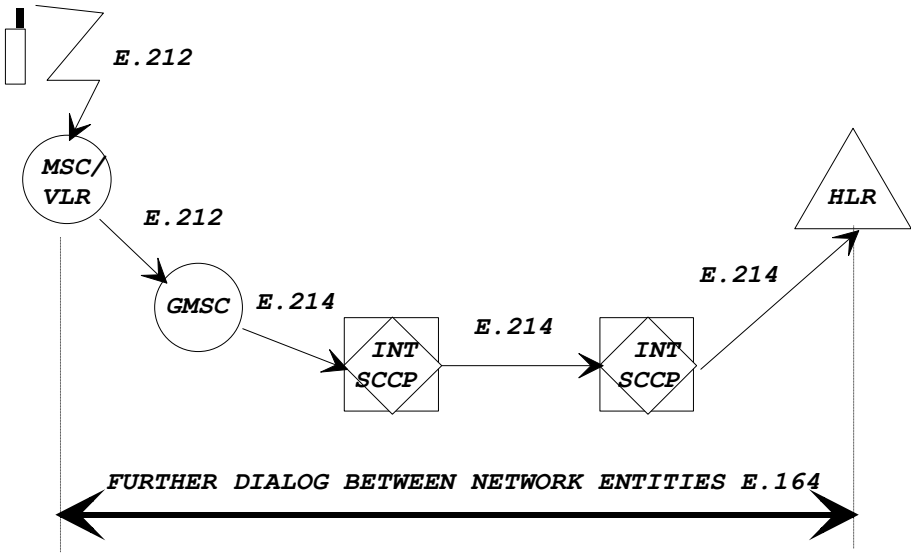

Figure 2.2.3-1 - GSM location update scenario

Fig. 2.2.3-2 shows the information exchanged in a location update procedure.

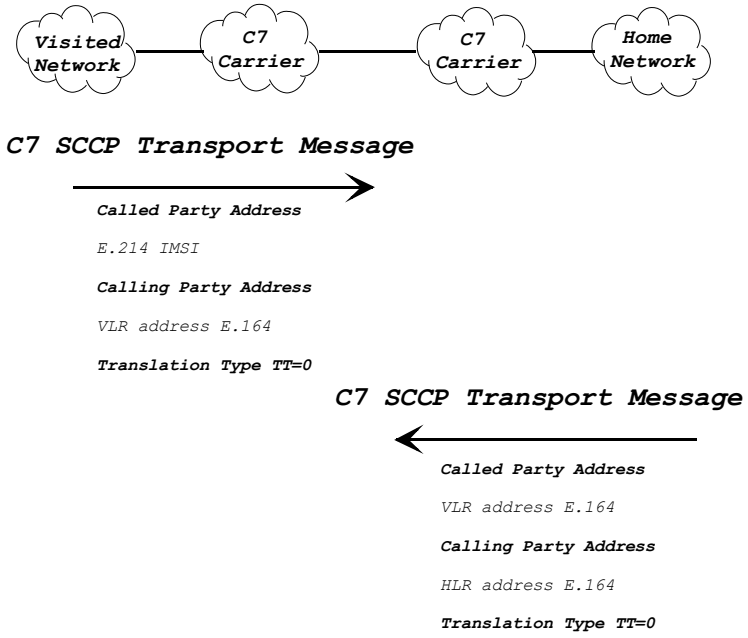

Figure 2.2.3-2 - GSM SCCP location update scheme

2.3 GSM1900 PROTOCOLS

2.3.1 GSM1900 protocol layer regulation

GSM1900 is a mobile system derived from the GSM standard and adapted to the North American regulation where C7 signalling is not based on ITU-T but on ANSI standards. In particular, the network and transport (respectively, MTP and SCCP) layers are based on recommendations T1.110-1992, T1.111-1992, T1.112-1992, T1.234-1992, T1.235. Global

Title Translation Types are specifically addressed in T1S1.3-9502104 for GTT=9 and T1S1.3-9512301 for GTT=10.

The two lower levels described are needed to cross C7 networks, but the upper levels are end to end protocols, that cross the intermediate nodes transparently with no local processing. For this reason, TCAP and MAP are exactly the same as used in the GSM standard: consequently, the main goal of this study is the conversion from ANSI into ITU-T (and reverse) for MTP and SCCP.

2.3.2 GSM1900 SCCP addressing

GSM protocols use GTT to route SCCP messages outside mobile networks, according to recommendation ITU-T E.214. This recommendation, however, is not implemented in North American networks, where E.212 is instead used directly and, furthermore, it will be shown later that E.214 is not compatible with the E.164 North American numbering plan. After the first contact, E.164 SCPP addressing is again used, as shown in fig. 2.2.3-1 for the conventional GSM scenario.

Another difference is that the GTT used for E.212 is 9 (not 10 as used for E.164): a conversion then needs to be performed between GSM900-GSM1800 and GSM1900.

2.3.3 GSM 900 location update scenario

The location update scenario in GSM 900 is slightly different from the GSM one, due to the particular aspects described in the previous paragraph.

In North America, mobile operators have been always allowed to also operate their own C7 circuits, without interconnecting with dedicated C7 carriers. Hence, SCCP connections between mobile networks are considered as nationals, while in GSM (see also fig. 2.2.3-1) they are necessarily international, since roaming always occurs between different countries.

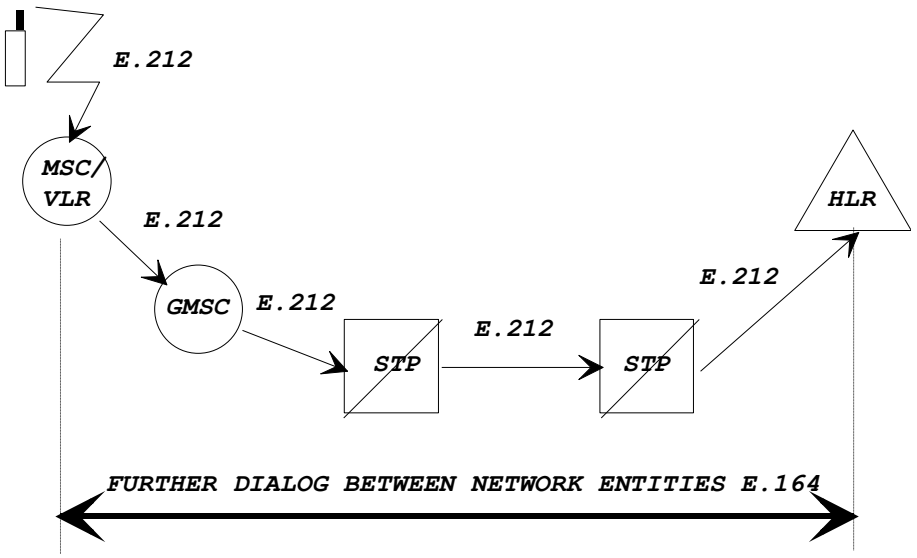

Figure 2.3.3-1 - GSM1900 location update scenario

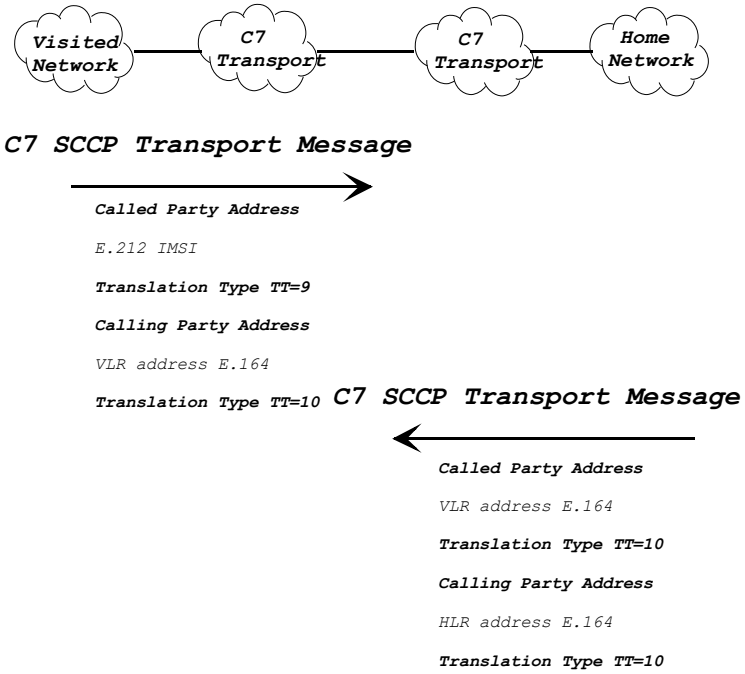

Figure 2.2.3-2 - GSM1900 SCCP location update scheme

2.4 DESCRIPTION OF INTERWORKING PROBLEMS

In the interconnection between GSM900-GSM1800 and GSM1900, problems mainly originate from the different standard used for MTP and SCCP, as previously described. These problems are now analysed and the possible solutions for each of two involved protocol layers are discussed.

2.4.1 Problems related to MTP compatibility

Although the basic C7 idea is the same for ITU-T and ANSI, unfortunately implementations differ. However, this type of conversion is normally performed for basic telephony in order to communicate between Europe and North America and a further treatment is out of the scope of this document.

2.4.2 Problems derived from SCCP compatibility

GSM900-GSM1800/GSM1900 inter-working is the first application that requires interconnection between ITU-T and ANSI standards at SCCP level: therefore there are no previous rules or experience to follow. Conversion is not so difficult to achieve, due to the reduced number of messages carried by SCCP: furthermore, not the whole set of messages is used, because only SCCP class 0, i.e. the basic connectionless class, is needed.

The SCCP message mapping will be implemented in the converter in a proprietary mode. The main problem relating to the SCCP layer is the difference in addressing methods and it is handled in the next paragraphs.

2.4.2.1 Usage and ambiguity of E.214 derivation

The North American region is considered as a single country from the point of view of telecommunications. Canada and the USA share the E.164 country code 1 and, inside each Country, the following digits, called NPA (North American Numbering Plan), are assigned on a per geographical basis, without a separation between the two countries.

In the case of E.212 Mobile Country Code, several codes are assigned to the North American region, located, at present, in the range 3XX. Furthermore the MNC (Mobile Network Code) may be replicated inside each 3XX code (e.g. 310-022 and 311-022 are two valid assignments).

With these constraints, application of a straightforward derivation rule of par. 2.2.2.1 & 2.2.3 (with the same E.164 Country Code for the whole North American region) does not resolve the ambiguity depicted in figure 2.4.2.1-1, where on the GSM translation the NDC cannot be derived univocally. The same occurs on the GSM1900 translation, when retrieving the MCC.

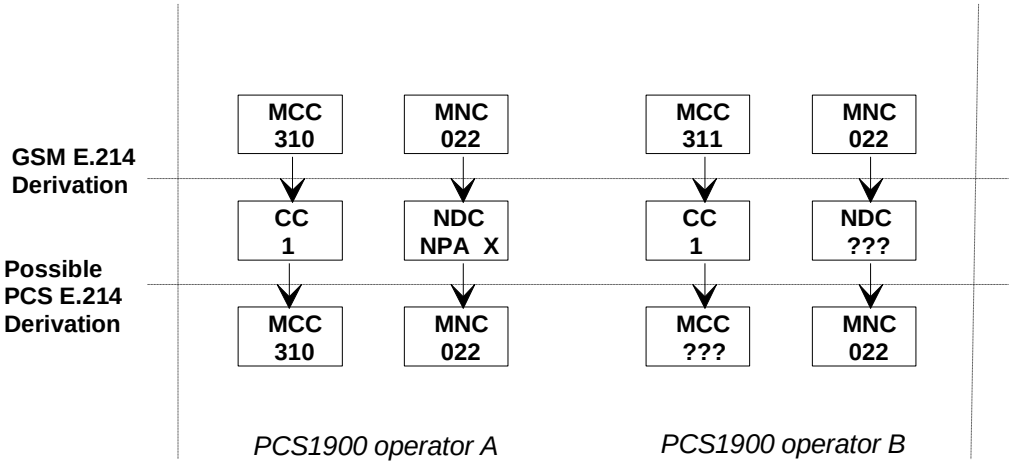

Figure 2.4.2.1-1 - Translation ambiguity using E.214

A solution to this problem is supplied, at present, by a modified translation of E.214, where MCC and MNC are jointly analysed to dissolve the previously identified ambiguities (Fig. 2.4.2.1-2), because the MCC+NDC couple is always unique.

If two or more GSM1900 operators are located in the same geographical area, they might share the same NPA code and more digits are needed – NXX - to distinguish an operator from the other(s).

This type of conversion is unambiguous and could be implemented in a signalling converter for retrieving the correct address of a GSM1900 operator.

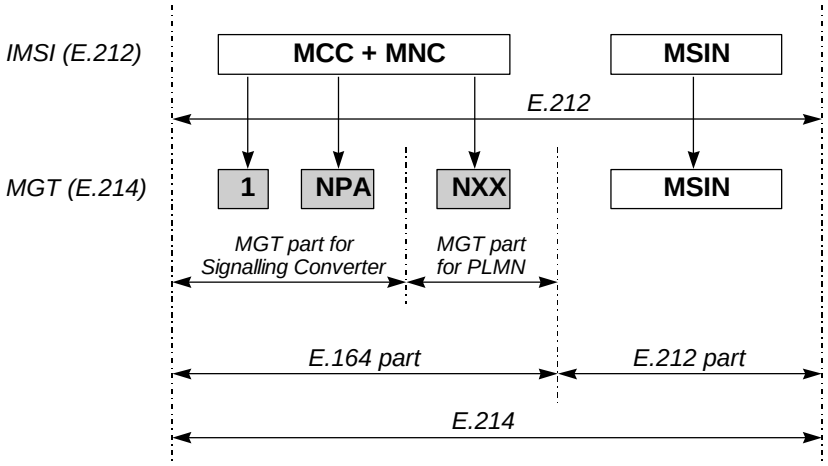

Figure 2.4.2.1-2 - Unambiguous translation using modified E.214

2.4.2.1.1 Problems derived from the usage of modified E.214

The E.212 IMSI is limited to a maximum number of 15 digits, and for North America the MCC+NDC pair is 6 digits long. Hence (see also fig. 2.4.2.1-2), 9 digits remain available for MSIN. The E.214 also fixes 15 digits length and considering that 1+NPA+NXX is 7 digits long, the current MSIN structure would generate a 16 digits long number, with the need to truncate one digit, if full NXX is used. In this case, MSIN is not transmitted completely, but this is irrelevant for SCCP routing purpose, as well as to identify the mobile subscriber, because IMSI is obviously transmitted at the MAP layer.

Some GSM1900 North American operators identify the HLR associated to the subscriber at the end of IMSI: this means that truncation of one digit, to allow the E.214 modified conversion, will cause this address to get lost. The possible solution is to use only NX (2 digits) instead of NXX (3 digits). At present, however, NPA alone is enough, because no NPA sharing between GSM1900 mobile operators was detected.

2.4.3 NPA codes assigned per geographical basis

Summarising, NPA codes are assigned in North America on a geographical basis, not per Operator, as it is common practise in GSM networks. The couple 1+NPA could be assimilated to the E.164 Country Code in the rest of the countries.

As explained above, in the GSM standard E.164 SCCP addressing is used for routing purposes in the dialogue between network entities as well as for routing SMS (Short Message Service), because the destination E.164 address is the only data that the sender knows, prior to sending this kind of messages.

Problems are encountered wherever two operators share the same NPA code and/or one operator is present in more than one geographical area, naturally with two or more NPA codes. In the former case, the solution is to extend analysis to NXX - or NX -; in the latter, each MSC or network element could have a different address prefix (this is not the case in GSM networks, where the E.164 prefix for network elements is always the same). So whenever a new network element is activated the information needs to be communicated to

all roaming partners. Furthermore, the number of entries in the GT translation tables will considerably increase, with consequent administrative difficulties and possibility of inconvenient.

3. ROAMING CONVERSION

Considering the problems and solutions described, a physical network model could respond to the diagram of fig. 3-1. In this picture it is mainly noticed the need to make a conversion between the ANSI and ITU-T worlds, which implies the rate conversion from E1 to T1, and the C7 MTP & SCCP conversion from either standard.

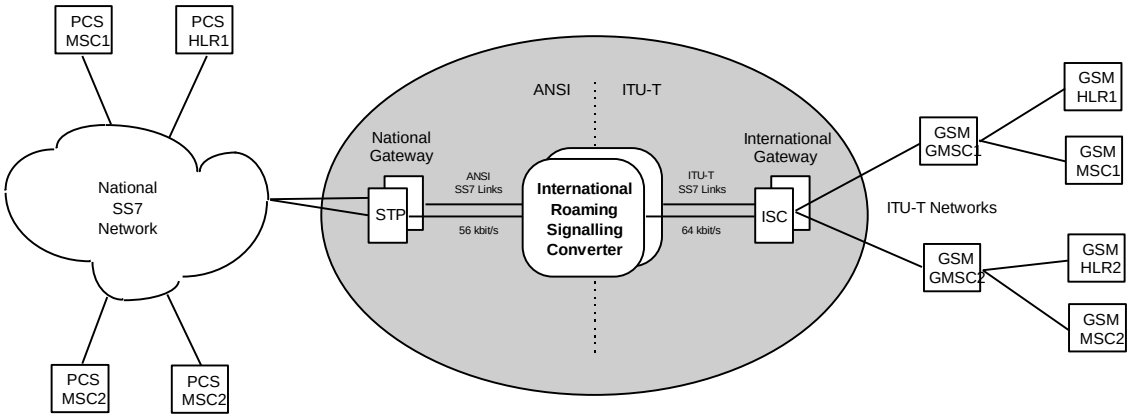

Figure 3-1 - Physical network model for roaming converters

3.1 SCCP ADDRESSING FOR A GSM900-GSM1800 MOBILE ROAMING IN A GSM1900 NETWORK

The scenario of fig. 3.1-1 is in agreement with the section “Technical Background”.

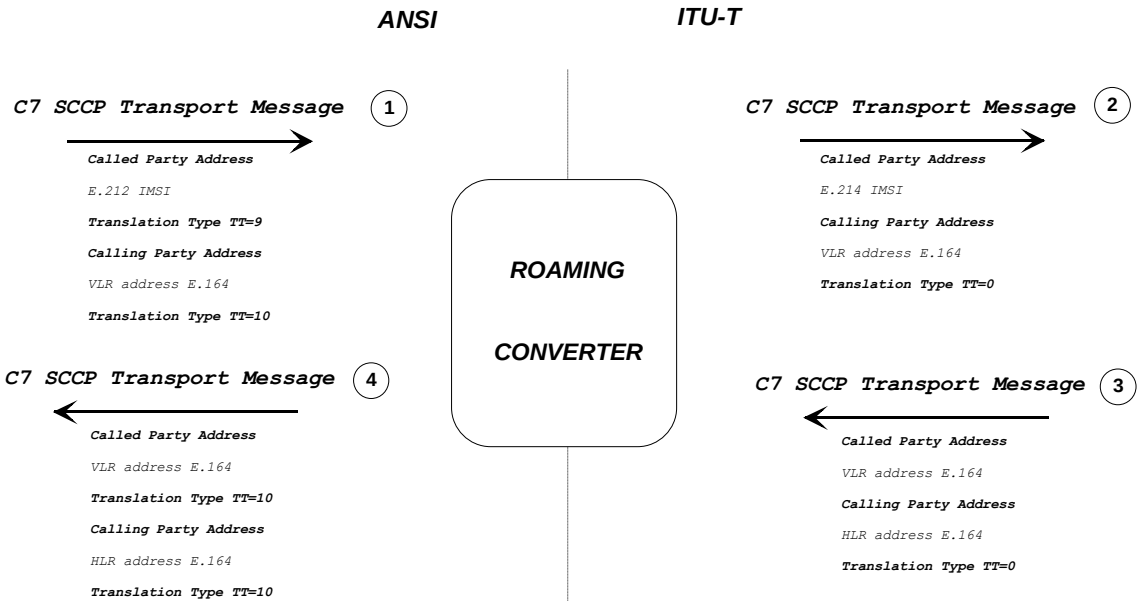

Figure 3.1-1 - SCCP addressing conversion for a GSM900-GSM1800 mobile roaming in PCS1900 network

3.2 SCCP ADDRESSING FOR A GSM1900 MOBILE ROAMING IN A GSM900-GSM1800 NETWORK

In this case the scenario is exactly the opposite, and modified E.214 is used according to par. 2.4.2.1.

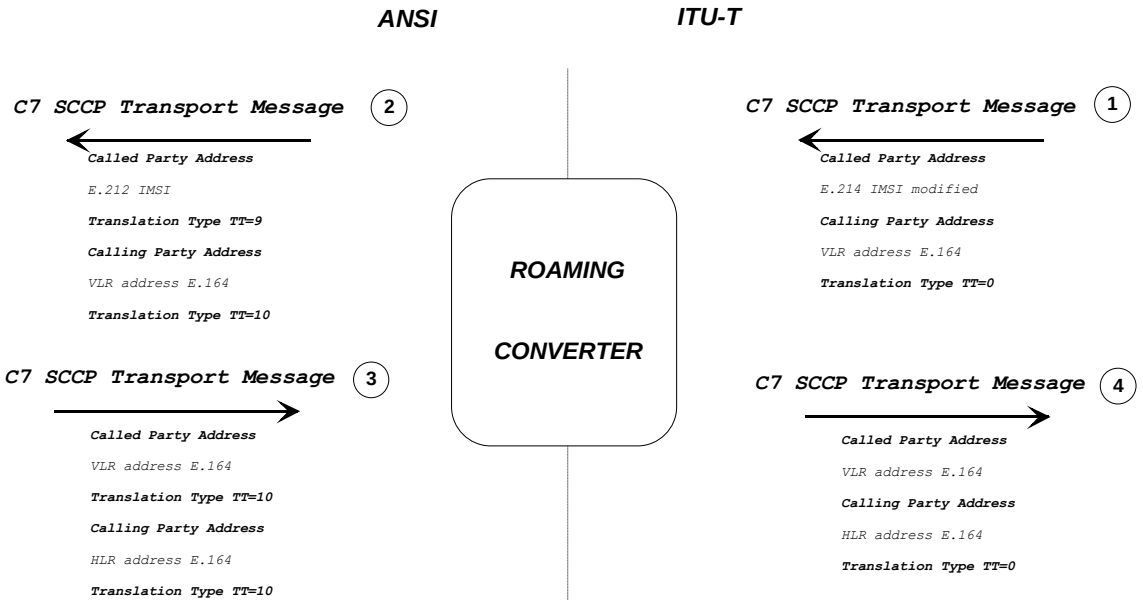

Figure 3.2-1 - SCCP addressing conversion for a GSM1900 mobile roaming in a GSM900-GSM1800 network

3.3 SUPPLEMENTARY SERVICES INTERWORKING

T.B.D.

4. NUMBERING PLANS ALLOCATION RULES

Section 2 showed that, in order to solve a possible ambiguity in the E.214 addressing, its derivation rule needs to be modified. The problem of assigning NPAs on a geographical basis has been highlighted as well, with the consequence of keeping track of new network elements, to avoid the loss of SCCP messages. Due to the difficulty of this task and with the purpose of limiting entries in the GT translation tables, the following rules are suggested to NAIG members:

1. If more than one PCS1900 mobile operator shares the same NPA code, the NXXs assigned to each of them should differ at least in the second digit. This rule will avoid the analysis of the third NXX digit and the need for truncating. An example can be helpful:

Straightforward assignment

514 (NPA) + 906 (NXX)
514 (NPA) + 905 (NXX)

Recommended assignment

514 (NPA) + 906 (NXX)
514 (NPA) + 916 (NXX)

2. The different NPA prefixes for SCCP network node addresses To reduce as much as possible. If one operator has more than one NPA assigned, all the network node addresses should be kept on a few, preferably one, NPA codes. This rule will avoid the need to keep track of network deployment and the risk of SCCP message loss.

5. FUTURE ENHANCEMENTS

5.1 USAGE OF E.212 INSTEAD E.214

The use of E.214 in GSM networks was motivated from the fact that C7 carriers used the same routing tables for E.164 and E.214, because the header digits were exactly the same. The C7 switch performance has increased significantly nowadays, and it is more and this makes it more and more questionable to use a conversion that has to be converted again when the destination mobile network is reached. The proposal is consequently to use only E.212 along the entire path and avoid the need of modifying E.214.

APPENDIX 1: C7 access to roaming converters

Basically, a C7 SCCP network entity can be accessed in two ways. One by means of a DPC (Destination Point Code), i.e. the address defined on MTP, and the other by means of the SCCP Global Title.

When the DPC is used, the SCCP layer is crossed transparently, and each network node crossed sees this DPC and decides if it is for itself or not; in the latter case, it routes the message to another node until the destination node is reached.

When a GT (Global Title) is used, the address of the destination node needs not to be known, only the next SCCP relay: this node will route the message to the next one, and so on until the final node is reached.

Most GSM operators do not have the right to transport C7 signals in international networks and are only allowed to reach the SCCP node belonging to an official C7 carrier. This justifies that the roaming converter is accessed by means of SCCP GT.

APPENDIX 2: Description of existing converters

At present there are 3 converter operators, all of them make use of the solutions pointed up in previous sections, the only particularity is that one of them uses a special Translation Type on North American side.

The way of addressing the converter also changes from one solution to another because two of them are accessible by means of DPC, and the third one by SCCP GT.

APPENDIX 3: Charging

Some mobile operators (see appendix 1), cannot be identified as international C7 carriers. Hence, it is recommended to charge them upon identification of the SCCP GT instead of DPC, because in most countries the DPC of the official carrier would be the same for all mobile operators and this would make it impossible to distinguish between them.