dialogic
innovatie • interactie

Feasibility study to assign 3-digit MNC codes to mobile network operators in the Netherlands

Report commissioned by:
Autoriteit Consument & Markt / Authority for Consumers & Markets (ACM), The Netherlands

Project:
2013.034

Publication number:
2013.034 - 1254

Publication date:
Utrecht, October 10th, 2013

Auteurs:
Dr. Ir. Ing. Rudi Bekkers
Ir. Jan van Rees (Inwilution)
Ir. David van Kerkhof

Table of Content

1 Introduction and approach

1.1 Research context

The Autoriteit Consument & Markt / Authority for Consumers & Markets (ACM) is, amongst other things, responsible for assigning numbers for telephony and telecommunication in the Netherlands. Apart from the relevant law and regulations (which entrust ACM with this task), several standards and recommendations are important in that respect: international agreements on numbering (like those of the ITU and the GSMA), technical standards (as drawn up within for instance ETSI and 3GPP) and the numbering plan as drawn up by the Ministry of Economic Affairs (Ministerie van Economische Zaken). These factors determine to a large extent which numbers and number series can be assigned. Yet, ACM, to a certain extent, also has freedom to employ its own rules, amongst others by means of issuing its own regulations, and applying certain restrictions. Assignment of numbers to market players happens at request, and ACM also monitors the rules associated with these numbers after assignment. The numbering plan for instance amongst others determines which type of parties can request numbers, and the applicant must make plausible that its request is aligned with reasonable market expectations.

In general, the available numbers to be assigned are getting scarcer. This is true for many types of numbers – of numbers for different applications – that OPTA assigns. Reasons for this scarcity are the dynamic character of the telecommunication market, and increased competition, among other things.

ACM would like to know whether it can conduct the assignment of MNC numbers for mobile networks more efficiently. These MNC numbers are used by operators of mobile telecommunication networks based on 2G, 3G and 4G standards[1]. These numbers are used both for the internal use in networks, as well as for roaming and other applications. The GSM standard was developed in the 1980s and provided only for a 2-digit MNC code. With this code length, every country could realize up to a hundred different mobile networks (coded 00 to 99). At that time this was believed to be a huge number, much larger than necessary: indeed, in the first decades, most countries had only two to five networks. Then the so-called PCS auctions took place in the United States at the end of the '90s. Many market players that won a regional license chose for a technology derived from GSM (known as PCS-1900). Because of that, the fear existed that 100 MNCs would appear to be too few codes in a country as large as the US. In response, the standard was modified to create the possibility to use 3-digit MNCs, specifically for the US.[2]

Whereas the scarcity of 2-digit MNC codes was foreseen in the US over 15 years ago, this concern is only a recent phenomenon in the Netherlands and other European countries. Currently, the three largest operators in the Netherlands (KPN, Vodafone and T-Mobile) have been assigned approximately seven MNC codes[3]. Furthermore, several MNCs are

---

[1] The most used standards in Europe are the 2G GSM standard (developed by ETSI), the 3G UMTS or W-CDMA standard (developed by 3GPP, of which ETSI is a part) and the LTE standard (also developed by 3GPP). Other than that, there are derived standards like DSC-1800, PCS-1900 and GSM-R.

[2] Even though older devices based on the GSM and DCS-1800 standard are not necessarily able to handle a 3-digit code.

[3] This is because several take-overs and fusions have taken place, involving parties that had been allocated their own MNC codes.

assigned to Mobile Virtual Network Operators (MVNOs) and Mobile Virtual Network Enablers (MVNEs). Note that not every active MVNO in the Netherlands has applied for its own MNC[4]. Recently, demand for MNCs can be observed from organizations that want to provide so-called 'private GSM services'. Furthermore, also large M2M-users are interested in having their own MNC, to diminish the dependency on the operator(s) they might contract for their services Finally, parties such as hospitals are also known to consider options to deploy private networks.

Table 1 shows an overview of all the currently assigned MNC codes in The Netherlands.

Table 1: MNC codes assigned by ACM in The Netherlands as of May 22, 2013. [5]

MNC	Assignee	Date of assignment	End date	Status
4	Vodafone Libertel B.V.	31/3/99		Assigned
20	T-Mobile Netherlands B.V.	31/3/99		Assigned
16	T-Mobile Netherlands B.V.	31/3/99		Assigned
2	Tele2 Nederland B.V.	6/6/00		Assigned
21	ProRail B.V.	17/1/02		Assigned
8	KPN Mobile The Netherlands B.V.	8/8/02		Assigned
12	KPN B.V.	28/8/02		Assigned
69	KPN Mobile The Netherlands B.V.	25/4/03		Assigned
10	KPN B.V.	28/6/04		Assigned
5	Elephant Talk Communications Premium Rate Services	3/7/07		Assigned
6	Mundio Mobile (Netherlands) Ltd	31/7/07		Assigned
7	Teleena Holding B.V.	23/11/07		Assigned
9	Lycamobile Netherlands Limited	12/3/09		Assigned
1	RadioAccess Network Services B.V.	18/5/09		Assigned
22	Ministerie van Defensie	18/6/09		Assigned
24	Private Mobility Nederland B.V.	22/3/10		Assigned
27	Breezz Nederland B.V.	15/2/10		Assigned
25	CAPX B.V.	14/4/10		Assigned
19	Mixe Communication Solutions B.V.	27/8/10		Assigned
13	Unica Installatietechniek B.V.	12/10/10		Assigned
15	Ziggo B.V.	1/9/09		Assigned
18	UPC Nederland B.V.	8/3/11		Assigned
67	RadioAccess B.V.	3/2/11		Assigned
23	ASpider Solutions Nederland B.V.	18/1/11		Assigned
3	Voiceworks B.V.	17/5/11		Assigned
17	Intercity Mobile Communications B.V.	4/7/11		Assigned
26	SpeakUp B.V.	26/8/11		Assigned
11	(*)		5/12/12	Phasing out
28	Lancelot B.V.	12/6/12		Assigned
60	(*)	4/9/12		Assigned
14	(*)		2/9/13	Phasing out
68	Roamware (Netherlands) B.V.	12/12/12	2/12/13	Assigned
64	Zetacom B.V.	12/3/13	11/3/14	Assigned
29	Private Mobile Ltd	22/2/13		Assigned
311	Shyam Telecom UK Limited	15/1/13		Assigned

(*): No name provided in register.

[4] An MVNO prefers its own MNC code to become less dependent of the network operator, but the network operator often prohibits an MVNO using a distinct MNC.

[5] Source: Nummerregister ACM, available at https://www.acm.nl/nl/onderwerpen/telecommunicatie/telefoonnummers/register-met-alle-nummers/.

1.2 Research questions

ACM wants to investigate how they can best serve the demand for MNCs – within the given frameworks and regulations like the numbering plan, and anticipating on the expected changes of the numbering plan. ACM is therefore interested in knowing to what extent it can assign 3-digit MNC numbers, because this could increase the numbering space significantly. For that reason, ACM has asked Dialogic to answer the following research questions:

Is it possible to assign 3-digit MNC codes in the Dutch context? If there are any limitations or conditions, what are these? What are the consequences for parties receiving a 3-digit code, and what are the possible consequences for other parties?

The following sub questions are formulated:

1. What do the technical standards of ETSI, 3GPP and possible other organizations recommend regarding 3-digit MNCs?
2. What do the numbering plans of the ITU and similar documents or organizations recommend regarding 3-digit MNCs?
3. What do concerned Dutch market players think of 3-digit MNCs? What is their understanding regarding possible limitations? Which legitimate technical arguments do they have regarding the possibilities and impossibilities?
4. Given the possible limitations, which series of 3-digit numbers are eligible to give out in the Netherlands, and how does this affect the space in the MNC numbering plan?
5. Are there any innovative possibilities to – within the given framework, such as the existing numbering plan (and anticipating on expected changes in this numbering plan) – serve the demand for MNCs as well as possible, such as a 'pool' or a shared MNC number? Can any incentives be created, or are there any effective regulations or limitations that ACM can adopt?

1.3 Approach

This research has been conducted in two parts. First, a desk study has been done to identify and analyse the most important (technical) documents to answer the research questions. These findings have been validated in six interviews, in which relevant Dutch market players have been asked to reflect on our findings. The interviews also directed the project team to other relevant documents, which have subsequently been taken along in the desk study.

1.4 Reading guide

In chapter 2, the role of the MNC number is introduced, as well as the organizations involved in its definition and administration. In chapter 3, we elaborate on the specific implementation of the MNC number and the discussion on the mixed use of 2- and 3-digit MNCs. Chapter 4 describes three 'market entry scenarios' for network providers, and the possible problems involved for these providers. Chapter 5 reflects on the validation of the findings with market players. Chapter 6 finally concludes and gives recommendations.

It is almost unavoidable that the text of this report has an explicit technical nature. While we tried to keep it accessible for readers without extensive knowledge of the 3GPP standards and their implementation, the body of this report will require some knowledge of mobile networks. The conclusion sections and the conclusions chapter, however, are written in a way that requires little if any prior knowledge.

2 The role of the MNC number and the organizations involved

2.1 The role of MCC and MNC numbers in mobile networks

From the earliest moment on, GSM and UMTS networks were designed to make maximal use of the existing, fixed telephony networks (PSTN) and all the facilities these networks already offered, including their signalling systems (generally known as SS-7), and their numbering plans and conventions. Still, there was one important element missing in those systems: support for mobility. This means that terminals not only move within their own network, but also roam in other networks. To fill this gap, a new set of mechanisms and numbers was developed, known as the GSM Mobile Application Part (GSM/MAP). In the context of this report, two of these numbers are particularly important: the Mobile Country Code (MCC) and the Mobile Network Code (MNC).

These two numbers, usually used together, fulfil two primary roles:

> (1) Allow mobile phones to inform the network about their identity, in particular the identity of the home operator where they have a subscription (this data is stored on the SIM card and sent to the network at a number of occasions, a mechanism known as 'location updates'),
>
> (2) Allow the network to inform mobile phones about its identity (by having each base station constantly broadcasting this identity).

Apart from these two fundamental roles of MCC/MNC as defined in the standards, these numbers are also used in quite a few supporting processes that are often not part of the standard, yet indispensable for a mobile network. One example is the exchange of roaming usage data for billing purposes.

While the definition of the MCC and MNC was defined in the standards as promulgated by ETSI (and later effectively taken over by 3GPP), a next question that arose was about who was to administer and assign/issue these numbers. It was decided that the International Telecommunication Union (ITU) was to be responsible for the MCC. This organization was already responsible for the country code prefixes in fixed networks (e.g. 31 for the Netherlands). While the MCC codes were a new and different set of codes (the Netherlands is assigned the number 204 here) it has some similarities to the fixed country codes. For instance, both numbering systems in principle assign one code to each nation state[6].

It was furthermore decided that the MNC would be administered by the relevant national authorities that also have responsibility for the national numbering plans. In the Netherlands this is the ACM, formerly OPTA. It is here that a prospective operator can apply for a network code. There are a few exceptional cases where the ITU was given the authority to assign MNC numbers, such as for satellite services, Antarctica, as well as for maritime purposes.

In addition, the GSM Association - representing the interests of mobile operators worldwide - keeps track of assigned MCC-MNC codes in the roaming database. However, it has no

[6] In practice there are exceptions.

authority to assign such numbers itself, and just collects that information from its members.

2.2 Organizations relevant for this study

As we will see in the following chapter, ETSI/3GPP, ITU and the GSM Association all have published documents or reports with definitions, recommendations, studies or consultations concerning the use of MNC numbers. In addition, also some other regional organizations that have an interest in the use of such numbers in regions outside Europe have published documents relevant to our study. Here it is important to note that there are other networks than GSM/UMTS/LTE that use the same underlying mobility and numbering plan (officially known as GSM/MAP).

3 Definition and discussions on MNC in 3GPP, ITU and other formal organisations

3.1 Definition of MNC in the 3GPP standards

This chapter starts with an introduction on how the MNC code is defined in the relevant specifications and other documents, and aims to generate the first insights into the possibility of using 3-digit MNC codes. As shown in the previous chapter, MNCs play two major technical roles in mobile networks. In Section 3.1.1 we will discuss the definition of the MNC as part of the mobile terminal identity (IMSI code), while in 3.1.2 we will discuss the definition of the MNCs as part of the broadcasted network identity (LAI/RAI).

At different points in time, the use of 3-digit MNCs has been proposed and discussed. In the second part of this chapter, we will go more into detail on how these discussions unfolded over time. In the context of this chapter, two important periods can be distinguished regarding the discussion about the number of digits of the MNC. Section 3.2 focuses on the period around 2001, just after the introduction of 3-digit MNCs for the MCCs of the United States. In this period, the demand for broader use of 3-digit MNCs was studied. As a part of this period, the case of the United States will be closely studied. Section 3.3 focuses on the period 2012-2013, when the ITU reopened the discussion on 3-digit MNCs. Section 3.4 ends with conclusions.

3.1.1 MNCs as part of the mobile terminal identity (IMSI code)

Mobile Network Codes (MNCs) play an important role in the provision of mobile services. The combination of the Mobile Country Code (MCC) and the MNC determines the operator and therefore plays a key role in the signalling within mobile networks. The first digits of the International Mobile Subscriber Identity (IMSI) consist of the MCC + MNC. The structure of the IMSI is described in the 3GPP standards as shown in Figure 1.

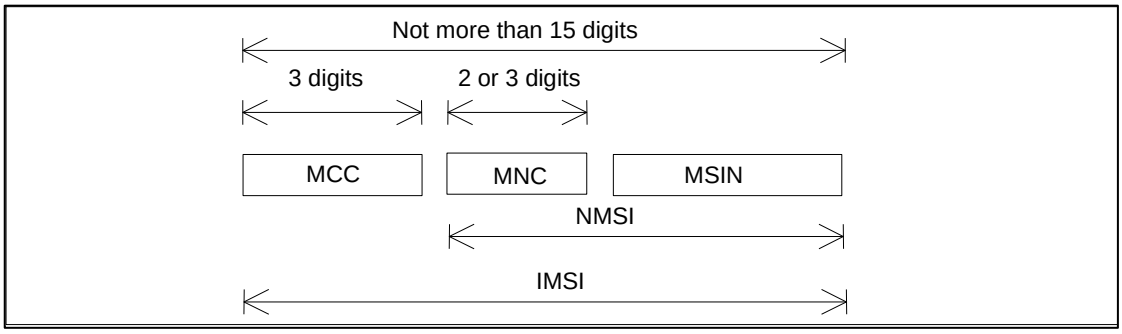

Figure 1: Structure of the IMSI. (Source: 3GPP TS 23.003)

Figure 1 already reveals that MNC may be either 2- or 3-digit of length. However, already in early days the standard was explicit that mixed use of 2- and 3-digit MNCs in one single

country (i.e. MCC) is not allowed. This is evidenced from the part of the specification shown in Box 1. This view has not changed over time, also the very recent versions of the standard include the very same text phrase, discouraging mixed MNCs.[7] From the above we conclude that both the older and the newer versions of the 3GPP standard allow for 2- or 3-digit MNCs, but in all cases the mixed usage of 2-digit and 3-digit MNCs within one MCC is not recommended and outside the scope of the specification.

```
IMSI is composed of three parts:

i)      Mobile Country Code (MCC) consisting of three digits. The MCC identifies uniquely the
country of domicile of the mobile subscriber;

ii)     Mobile Network Code (MNC) consisting of two or three digits for GSM applications. The
MNC identifies the home GSM PLMN of the mobile subscriber. The length of the MNC (two or three
digits) depends on the value of the MCC. A mixture of two and three digit MNC codes within a
single MCC area is not recommended and is outside the scope of this specification.

iii)    Mobile Subscriber Identification Number (MSIN) identifying the mobile subscriber
within a GSM PLMN.
```

Box 1: Elaboration on the structure of the IMSI. (Source: 3GPP TS 23.003 V3.15.0 (2006-09) Numbering, addressing and identification (Release 1999). Emphasis added.

The ITU plays a role in the administration and assignment of MCC codes and some MNC codes as well, as discussed in the previous chapter. Not surprisingly, the ITU has also adopted some definitions for these numbers. These can be found in their ITU E.212 standard. However, while this standard does mention that both 2- and 3-digit MNC codes are allowed, it does not further elaborate on mixed usage (see Box 2).

3.4 mobile network code (MNC): The MNC is the second field of the IMSI, it is two or three digits in length and is administered by the respective national numbering plan administrator. The MNC, in combination with the MCC, provides sufficient information to identify the home network.

Box 2: Explanation of the MNC in the ITU E.212 standard

3.1.2 MNCs as part of the broadcasted network identity (LAI/RAI)

Besides the usage of the MCC + MNC in the IMSI of the mobile user, this combination is also used in the mobile network to determine the identity of the network (i.e. the operator). This is done by means of the so-called Location Area Identification (LAI). Base stations send out this LAI frequently on their broadcast channels to all mobile telephones in a way shown in Box 3, where it is explained that the MNC number used in that process is essentially the same as the MNC number as stored on the SIM card, as discussed in the previous section.

[7] A very recent version of this standard,: 3GPP TS 23.003 V11.4.0 (2012-12), has exactly the same underlined text phrase as the one in Box 1.

The Location Area Identification shall be composed as shown in figure 3:

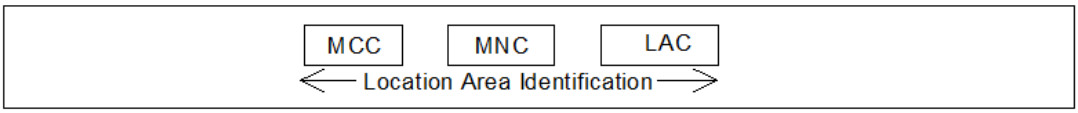

Figure 3: Structure of Location Area Identification

The LAI is composed of the following elements:

- Mobile Country Code (MCC) identifies the country in which the GSM PLMN is located. The value of the MCC is the same as the three digit MCC contained in international mobile subscriber identity (IMSI);
- Mobile Network Code (MNC) is a code identifying the GSM PLMN in that country. The MNC takes the same value as the two or three digit MNC contained in IMSI;
- Location Area Code (LAC) is a fixed length code (of 2 octets) identifying a location area within a PLMN. This part of the location area identification can be coded using a full hexadecimal representation except for the following reserved hexadecimal values:

  0000, and

  FFFE.

  These reserved values are used in some special cases when no valid LAI exists in the MS (see 3GPP TS 24.008 [5], 3GPP TS 31.102 [27] and 3GPP TS 51.011 [9]).

A specific GSM PLMN code (MCC + MNC) may be broadcast for mobile stations which are not compatible with SoLSA and which do not understand the exclusive access indicator (see 3GPP TS 23.073 [30]). The reserved value of the escape PLMN code is MCC = 901 and MNC = 08.

Box 3: Composition of the Location Area Identification (LAI). (Source: 3GPP TS 23.003 V11.4.0 (2012-12) Numbering, addressing and identification (Release 11)

More detailed information regarding the specific use of the 2- and 3-digit MNCs can be found in the 3GPP standards. This includes specifics with respect to the use and encoding of 2-digit MNCs in the 3-digit format as shown in Box 4. While this is already getting a bit more complex, this specification essentially defines that even though US networks are obliged by national regulations to use 3-digit MNCs, the process of broadcasting this MNC code over the air interface, which is the topic of this section, is still allowed to take place as a two digit code. The reason why operators may want to do so is because of certain problems anticipated with 3-digit MNC and is further discussed in Section 3.2.1.

MCC, Mobile country code (octet 2 and 3)

The MCC field is coded as in ITU-T Rec. E212, Annex A.

If the LAI is deleted the MCC and MNC shall take the value from the deleted LAI.

In abnormal cases, the MCC stored in the mobile station can contain elements not in the set {0, 1 ... 9}. In such cases the mobile station should transmit the stored values using full hexadecimal encoding. When receiving such an MCC, the network shall treat the LAI as deleted.

MNC, Mobile network code (octet 3 bits 5 to 8, octet 4)

The coding of this field is the responsibility of each administration but BCD coding shall be used. **The MNC shall consist of 2 or 3 digits. For PCS 1900 for NA, Federal regulation mandates that a 3-digit MNC shall be used. However a network operator may decide to use only two digits in the MNC in the LAI over the radio interface. In this case, bits 5 to 8 of octet 3 shall be coded as "1111". Mobile equipment shall accept LAI coded in such a way.**

NOTE 1: In earlier versions of this protocol, the possibility to use a one digit MNC in LAI was provided on the radio interface. However as this was not used this possibility has been deleted.

NOTE 2: **In earlier versions of this protocol, bits 5 to 8 of octet 3 were coded as "1111". Mobile equipment compliant with these earlier versions of the protocol may be unable to understand the 3-digit MNC format of the LAI, and therefore unable to register on a network broadcasting the LAI in this format.**

In abnormal cases, the MNC stored in the mobile station can have:

- digit 1 or 2 not in the set {0, 1 ... 9}, or

- digit 3 not in the set {0, 1 ... 9, F} hex.

In such cases the mobile station shall transmit the stored values using full hexadecimal encoding. When receiving such an MNC, the network shall treat the LAI as deleted.

The same handling shall apply for the network, if a 3-digit MNC is sent by the mobile station to a network using only a 2-digit MNC.

LAC, Location area code (octet 5 and 6)

In the LAC field bit 8 of octet 5 is the most significant bit and bit 1 of octet 6 the least significant bit.

The coding of the location area code is the responsibility of each administration except that two values are used to mark the LAC, and hence the LAI, as deleted. Coding using full hexadecimal representation may be used. The location area code consists of 2 octets.

If a LAI has to be deleted then all bits of the location area code shall be set to one with the exception of the least significant bit which shall be set to zero. If a SIM/USIM is inserted in a Mobile Equipment with the location area code containing all zeros, then the Mobile Equipment shall recognise this LAC as part of a deleted LAI.

Box 4: More detailed information regarding the encoding of the 2- and 3-digit MNCs. (source: 3GPP TS 24.008 V12.0.0 (2012-12)). Emphasis added.

Further down in the same document, similar statements are made for the data transmission modes for the standard (which is indicated by the use of the RAI location code instead of the LAI/LAC code used for voice services). These statements are shown in Box 5 and Box 6. The description that one specific part of an octet[8] has to be coded as '1111' essentially means that the third digit of the MNC is simply not used and the 3-digit MNC is effectively reduced to a 2-digit MNC in this scenario.

[8] An octet refers to a byte or 8 bits. Commonly used in such specifications.

MNC, Mobile network code (octet 6b bits 5 to 8, octet 6c)

The coding of this field is the responsibility of each administration but BCD coding shall be used. The MNC shall consist of 2 or 3 digits. If a network operator decides to use only two digits in the MNC, bits 5 to 8 of octet 6b shall be coded as "1111".

The contents of the MCC and MNC digits are coded as octets 6 to 8 of the *Temporary Mobile Group Identity* IE in Figure 10.5.154/3GPP TS 24.008.

MNC, Mobile network code (octet 3 bits 5 to 8, octet 4)
The coding of this field is the responsibility of each administration but BCD coding shall be used. The MNC shall consist of 2 or 3 digits. For PCS 1900 for NA, Federal regulation mandates that a 3-digit MNC shall be used. However a network operator may decide to use only two digits in the MNC in the LAI over the radio interface. In this case, bits 5 to 8 of octet 3 shall be coded as "1111". Mobile equipment shall accept LAI coded in such a way.

NOTE 1: In earlier versions of this protocol, the possibility to use a one digit MNC in LAI was provided on the radio interface. However as this was not used this possibility has been deleted.

NOTE 2: In earlier versions of this protocol, bits 5 to 8 of octet 3 were coded as "1111". Mobile equipment compliant with these earlier versions of the protocol may be unable to understand the 3-digit MNC format of the LAI, and therefore unable to register on a network broadcasting the LAI in this format.

Box 5: Information on the encoding of 2- and 3-digit MNCs in the RAI (source: 3GPP TS 24.008 V12.0.0 (2012-12))

8	7	6	5	4	3	2	1	
	Location Area Identification IEI							octet 1
MCC digit 2				MCC digit 1				octet 2
MNC digit 3				MCC digit 3				octet 3
MNC digit 2				MNC digit 1				octet 4
LAC								octet 5
LAC (continued)								octet 6

Figure 10.5.3/3GPP TS 24.008 *Location Area Identification* information element

Box 6: Information on the encoding MCC and MNC digits in the LAI (source: 3GPP TS 24.008 V12.0.0 (2012-12))

Above-mentioned descriptions from a recent version of the 3GPP standard indicate the issues related to the different bit encoding for the third digit of the MNC and the potentially different implementations in the mobile telephones. The more relevant potential issue is as follows:

- Mobile phones capable to handle 2-digit MNCs only (at least for the non-US MCCs), might expect the third digit to be "1111" and might not be able to register on the network if the 3rd digit has a different value. While this is not necessarily a problem,[9] the question is whether those phones will continue searching for other networks or that there is potentially the risk of those phones stopping any search action and keep "hanging" on the 3-digit MNC network. That situation, not seeing '1111' digits 5 to 8 of octet 3 in a MCC which is supposed to code for 2-digit MNCs, is an unexpected outcome from the perspective of such a phone and just not well

[9] The network operator might decide to distribute only phones that work properly in this respect.

defined. Therefore the mobile phone behaviour might be subject to manufacturer dependent software implementation variations with the risk of unexpected or undesirable behaviour. There is just no guarantee what the phone should do in this situation. The desired and logical behaviour would be to continue searching for another, more suitable network, but that is not strictly defined.

3.2 Discussions on MNC around 2001

In the 2001 discussion regarding the use of 3-digit MNCs, the demand for broader use of 3-digit MNCs has been studied. This happened after the United States had been given permission to use 3-digit MNCs for their MCCs.[10] In 2001, 3GPP published a Liaison Statement on 3-digic MNC codes which anticipates several problems, especially in case of mixed use of 2-digit and 3-digit codes in the same country (MCC). The Liaison Statement is shown in Box 7. In this box we underline the mentioned problems, as we believe they are key to our study.

3-digit MNC code:

3GPP TSG CN WG1 reviewed the proposal relating to the introduction of 3 digit MNCs and provided the following observations which are supported by 3GPP TSGN:

- 3 digit MNC were first defined in R98. All implementations that are based on releases older than that do not support3 digit MNC.
- The mixture of 2 and 3 digit MNCs in the same MCC has been explicitly defined only for the MCC codes 310-316 which have been assigned for the USA.

In general the system implications of having mixed 2-digit and 3-digit MNCs under the same MCC are significant:

1. Mobiles implemented to specifications earlier than R98, which check the validity of any received MNC, will fail these checks if 3 digit MNCs are introduced.
2. Existing Mobile stations and SIM cards would have to be either upgraded or replaced.
3. Existing mobile implementations could potentially have problems with the displaying of 2 and 3 digit MNCs
4. While the cost of incorporating these changes in new equipment is not significant, the cost of upgrading ALL legacy equipment (which is necessary to support roaming) will be significant.
5. The introduction of 3 digit MNC will cause roaming, billing and service outages if existing equipment (mobile and network) is not upgraded.
6. Any updates to existing networks will require the change to be implemented country wide, in all PLMNs, to avoid inconsistent mobile behaviour within the networks.
7. Even though the software changes required are themselves not significant, it is possible that all currently deployed GSM/GPRS equipment will have to be upgraded. This will be a daunting task.

Box 7: Elaboration on the choice for the use of 3-digit MNCs (source: NP-010350 Liaison statement on Mobile Country Code and 3-digit Mobile Network Code, 13th – 15th June 2001)

[10] We use the plural form, since the United States has been granted multiple MCCs, i.e. 310-316.

Also the GSM Association for Europe[11] has investigated potential problems with 3-digit MNC codes. Their position is shown in Box 8 and Box 9.

At a workshop organised by ETO in September 2000, GSM Europe was assigned the task to carry out an assessment on the technical impact of introducing 3digit MNCs for the two following case scenarios:

- Co-existence behind the same E.212 country code of mixed 2 and 3 digit MNCs
- The use of separate (discrete) E.212 country codes: one for 2-digit and one for 3-digit.

Box 8: Introduction and conclusions of the assessment of the technical impact of introducing 3-digit MNCs (source: GSM Europe, Technical Assessment of Two Case Scenarios for the Introduction of 3-Digit MNCs, 2001)

V. Conclusions

GSM Europe has performed a technical assessment of the two possible scenarios for the introduction in Europe of 3 digit MNC. GSM Europe has identified a number of problems that would derive from the introduction of 3 digit MNC following scenario 1, whilst the impact on the existing operators if scenario 2 is selected would seem to be less severe.

Having carried out this assessment, GSM Europe is of the opinion that the introduction of 3 digit MNC would in either case require a technical effort which is not proportionate to the foreseen shortage of MNC that this introduction would solve.

It should be recognised that this shortage of MNC will not be experienced as a result of the coming into the market of UMTS operators since:

a) most of the existing GSM operators who have been granted a UMTS license will want to reuse the already allocated 2 digit MNC for the UMTS part of their network;

b) the allocation of UMTS licenses has shown that a maximum of between 4 and 6 UMTS network can be deployed in each country

Note finally that GSM Europe has been liaising with 3GPP regarding the feasibility and impact of the two scenarios. The response from 3GPP has been incorporated as an annex to the GSME assessment, as set out below.

Box 9: Introduction and conclusions of the assessment of the technical impact of introducing 3-digit MNCs (source: GSM Europe, Technical Assessment of Two Case Scenarios for the Introduction of 3-Digit MNCs, 2001)

The conclusion at that time was that there were few reasons speaking for the introduction of a 3-digit MNC, whereas it would imply many risks, complications and costs.

It is actually these insights that lead 3GPP to record the text in the standard which we started with in Chapter 3, which was: *"A mixture of two and three digit MNC codes within a single MCC area is not recommended and is outside the scope of this specification".*

[11] The European branch of the GSM Association, also called GSM Europe.

The door has been kept open to introduce a new MCC in a country though, and to use this MCC exclusively for 3-digit MNCs.

3.2.1 3-digit MNCs in the United States

As noted above, the US was the first country in the world to consider three digit MNCs. For this reason, we will now pay specific attention to the situation in that country.

At the time GSM-derived networks were introduced in the US, it was realized that the numerous (regional) licenses would easily result in a demand of over 100 MNCs, and thus more than the existing 2-digit MNC format could provide. The original intention in the US was operate fully with 3-digit MNCs. To ensure compatibility with existing terminal designs, however, a transition period was introduced during which a network is allowed to broadcast a 2-digit MNC instead of the new 3-digit code. As we will discuss below, this transitional period was supposed to be temporary in nature, but has been extended ever since as there is still concern that a 'pure' 3-digit scenario will cause problems.[12]

In respect to the US, the description in the 3GPP standard is as shown in Box 10. Again we see that networks are allowed to broadcast 2-digit instead of 3-digit MNCs (the hexadecimal code 'F' shown here is the same as the '1111' that is was mentioned in Box 4 which we discussed above).

Annex A (normative):
HPLMN Matching Criteria

With the introduction of PCS1900 with the regulatory mandate to allocate 3-digit MNC codes, additional functionality is required to identify the HPLMN.

Assumptions

An MNC code shall consist of 2 or 3 decimal digits. In NA PCS1900, all SIMs shall store 3 digit MNCs.

Any network using a 2 digit MNC code shall broadcast the hexadecimal code "F" in place of the 3rd digit.

For PCS1900 for North America, regulations mandate that a 3-digit MNC shall be used; however during a transition period, a 2 digit MNC may be broadcast by the Network and, in this case, the 3rd digit of the SIM is stored as 0 (this is the 0 suffix rule).

With the exception of North America during the transition period:

a) Within a single country (or area identified by a MCC) all networks shall broadcast a 2 digit MNC code, or all networks shall broadcast a 3 digit MNC code. A mixture of broadcast 2 and 3 digit MNC codes is not permitted within a single country (or area identified by a MCC).

b) A network which broadcasts a 2 digit MNC code, will issue SIMs with a 2 digit MNC code in the IMSI on the SIM. A network which broadcasts a 3 digit MNC code, will issue SIMs with a 3 digit MNC code in the IMSI on the SIM.

Box 10: Partial implementation of 3-digit MNC in the US with a transition period Source: 3GPP TS 23.122 V12.0.0 (2013-03)

In the US, the GSM standard has been adopted/specified by ATIS, a US standards body for telecommunications. The intention in the US was to operate fully with 3-digit MNCs. The *transition period* is the period during which the network is allowed to broadcast a 2-digit MNC while the SIM card contains a 3-digit MNC. This transition period has been extended ever since and the full introduction of 3-digit MNCs has not yet come about.

[12] Note that the scarcity problems in the US were to some degree solved in another way: by assigning multiple country codes to the US (namely MCCs 310 to 316).

Even the recent ATIS IMSI Guidelines (from 2010) still make special exceptions to allow the effective use of 2-digit MNCs (Box 11). These exceptions are in place until the relevant industry indicates *'full readiness for support of 3-digit MNCs'*.

International Mobile Subscriber Identity (IMSI) Assignment and Management Guidelines and Procedures 21

Addendum 1 -- Temporary Accommodation for GSM-Based and ANSI-41 CDMA-Based Wireless Networks

Currently GSM-based and ANSI-41 CDMA-based wireless public networks can handle only 2-digit MNCs. This limitation can be accommodated, until such time as GSM-based and ANSI-41 CDMA-based wireless public networks are modified to support 3-digit MNCs, through the following temporary assignment guideline:

Until the GSM-based and ANSI-41 CDMA-based industries, via a decision of ATIS IOC, indicate full readiness for support of 3-digit MNC:

- MNC codes in the format XX0, where X equals any of the decimal digits 0 through 9, are reserved for assignment to CMRS license holders choosing to deploy GSM-based or ANSI-41 CDMA-based technology. When a licensee meeting this requirement requests a code assignment and does not specify a 3-digit MNC, the next such code in numerical sequence will be assigned. Such codes from the next consecutive MCC should not be assigned until all such codes from the preceding MCC have been assigned.
- Notwithstanding the above, any licensee may explicitly request a 3-digit MNC. This can be assigned from any unassigned code in any block of 10 consecutive codes from which a 2-digit MNC has not already been assigned.

After the industry, via ATIS IOC, indicates full readiness for support of 3-digit MNC:

- 2-digit MNC codes will no longer be assigned to GSM-based or ANSI-41 CDMA-based wireless public networks. All assignments will be 3-digit MNC codes and can be made from blocks containing a previous 2-digit MNC code assignment.

Box 11: ATIS IMSI Guidelines for the use of 3-digit MNCs (source: IMSI Assignment and Management Guidelines and Procedures IMSI Guidelines, 2010)

One of the 2009 input documents to ATIS (Box 12) outlines the *reasons* to extend the support for 2-digit MNCs[13] beyond the deadlines set and until such point in time the industry is fully ready to handle 3-digit MNCs.

[13] Effectively by allocating XX0 as MNC.

ATIS IOC

TITLE:

2 Digit MNC in IMSI Guidelines

DATE:

October 19, 2009

SOURCE:

David Crowe

Senior Technical Consultant

CDG

dcrowe@cdg.org

ABSTRACT:

This contribution provides background on the reason why temporary accommodation for assigning 2 digit MNC codes in North America was needed and why it may still be needed.

RECOMMENDATION:

We recommend that ATIS IOC extend the temporary accommodation for 2 digit IMSI MNC assignments in the North American IMSI guidelines until an investigation into support for 3 digit MNC for both technologies is completed and determines whether a transition to 3 digit MNC is feasible, how this can be accomplished, and at what point during the transition 3 digit MNC assignments can be initiated.

2 Digit MNC in IMSI Guidelines

The latest version of the ATIS IOC IMSI guidelines (Version 8.0 – October 2006) allowed the allocation of 2 digit Mobile Network Codes (MNC) until July 1, 2008. This was accomplished by allocating only 3 digit codes XX0 and not the codes XX1 through XX9.

This accommodation was initially made at an IMSI Technical Summit held in Savannah, GA in February 2001. At that meeting, which resulted in the formation of the IOC, "It was agreed to continue the MNC XX0 Assignment Process for GSM Operators until July 1, 2003." This agreement was then extended through July 1, 2008. At that time it was not known that CDMA2000 also had the same restriction as GSM.

CDMA2000 technology still requires the use of 2 digit MNC codes and thus US-based CDMA2000 operators will require the accommodation to be extended. At present most operators are using Revision 0 specifications (e.g. 3GPP2 C.S0005-0 v3.0) which does not support the transmission of a third MNC digit. In addition, most operators are using MIN-based IMSI which only allows a 5 digit IMSI prefix (3 digit MCC plus 2 digit MNC) so even when Revisions C, D or E come into widespread use (which support the 3rd MNC digit) backwards compatibility may still make it difficult to support 3 digit MNC.

We understand that this restriction also exists in GSM. In February 2002 the GSMA stated that, "the workshop agreed that no further work was needed on the question of 3 digit Mobile Network Code." (apparently due to the belief at that time that IMSI would soon be made obsolete by 3G systems). Even today, 3GPP TS 24.008 version 9.0.0, for example, states that, "Mobile equipment compliant with these earlier versions of the protocol may be unable to understand the 3-digit MNC format of the LAI, and therefore unable to register on a network broadcasting the LAI in this format." It also indicates that some networks may only support 2-digit MNC and that failures may occur if a mobile station transmits 3 digits.

An additional issue that would need to be resolved before 3 digit MNC could be allocated is the transition. According to 3GPP TS 23.003, "A mixture of two and three digit MNC codes within a single MCC area is not recommended" (for GSM). The assignment of 3 digit MNC codes would result in this situation unless they were segregated in different MCC codes.

We believe that ATIS IOC should revise the IMSI guidelines to indicate that the "temporary" accommodation should be extended until both CDMA2000 and GSM specifications and all networks have been modified to allow the unrestricted use of 3 digit MNC even though this means that the accommodation may need to be extended for several more years into the future.

We do not feel that extending the accommodation for a fixed time period is a useful course of action.

We recommend that ATIS IOC extend the temporary accommodation for 2 digit IMSI MNC assignments in the North American IMSI guidelines until an investigation into support for 3 digit MNC for both technologies is completed and determines whether a transition to 3 digit MNC is feasible, how this can be accomplished, and at what point during the transition 3 digit MNC assignments can be initiated.

Box 12: Reasons for extending support for 2-digit MNCs (source: ATIS IOC input document: "2-digit MNC in IMSI Guidelines", 2009)

Finally some words about the situation in Canada, which in fact resembles the one in the US. The current practice according to the Canadian regulator appears to be that SIM-cards can use 3-digit MNCs, but that radio networks, where necessary, still use 2-digit MNCs.[14]

Altogether, we conclude that also in countries that mandate the use of (non-mixed) 3-digit MNCs, these countries still see problems in implementing this practice fully. While the 3-digit MNCs are obligatory in the IMSI cards, the operators are allowed to use 2-digit codes instead in the network broadcasts. This transition regime is extended time after time. This way, the US does not seem to benefit from the additional numbering space 3-digit codes offer.

3.3 Discussions on MNC around 2012-2013: the ITU Study Group 2 survey and beyond

In 2012, the discussion regarding 2- versus 3-digit MNCs has been revitalized by the ITU Study Group 2 (SG2).[15] This study group is home to Recommendation ITU-T E.164, the numbering standard that has played a central role in shaping the telecom networks of today. An equally important product of SG2 is Recommendation ITU-T E.212, which describes a system to identify mobile devices as they move from network to network. The international mobile subscriber identity (IMSI) is a critical part of the modern mobile telecoms system, allowing the identification of a roaming mobile terminal in a foreign network and subsequently the querying of the home network for subscription and billing information. As the world's foremost authority on international numbering, SG2 is responsible for the maintenance of ITU's International Numbering Resource (INR) database. A recent addition to the INR database is an online database of mobile country codes (MCCs) and mobile network codes (MNCs) assigned in compliance with ITU-T E.212.

[14] Source: Summary of Replies to TSB Circular 285: Possibility of parallel usage of 2- and 3-digit E.212 Mobile Network Codes (MNCs) under one geographic Mobile Country Code (MCC).

[15] ITU Circular TSB 285, May 2012, "Possibility of parallel usage of 2- and 3-digit E.212 Mobile Network Codes (MNCs) under one geographic Mobile Country Code (MCC)".

MCCs and MNCs are key building blocks to IMSI, used in combination to allocate unique identities to countries' mobile telephony installations and network operators.

In December 2012, ITU SG2 launched a questionnaire called *"TSB Circular 285: Possibility of parallel usage of 2 and 3 digit E.212 Mobile Network Codes (MNCs) under one geographic Mobile Country Code (MCC)"*. The ITU received 20 answers to the questionnaire and published a Summary of Replies in January 2013. This summary document shows that in most countries, the number of factually assigned MNCs is relatively low (50% of the countries assigned less than 10 MNCs, 90% assigned less than 45 MNCs, and there is one country with 83 and one country with 241 MNC allocations). Only 7 countries indicated a date on which they think they will be out of MNC number space. The first appears to be Sweden (2015), where SMS providers play a role in the use of MNCs. The next country follows in 2018 and the rest mentions dates much further in the future.

With regard to the mixed usage of 2- and 3-digit MNCs within one MCC, the feedback is negative:

> Regarding Question (e), "Are you aware of any issues that might arise if 3-digit MNCs are assigned in the future under your existing MCCs?", the majority of the responses indicated that:
>
> a. An existing MCC under which 2-digit MNCs were assigned should not be converted into an MCC under which 3-digit MNCs would be assigned.
>
> b. All MNC assignments under a particular MCC should have the same length, that is, all should be either two digits or three digits.

Box 13: Source: ITU, "Summary of Replies to TSB Circular 285: Possibility of parallel usage of 2 and 3 digit E.212 Mobile Network Codes (MNCs) under one geographic Mobile Country Code (MCC)".

Also here there is little support for the mixed usage of 2- and 3-digit MNCs. In the specific answers by ITU member countries, the visions however diverge strongly: some indicate significant and hardly foreseeable consequences for networks, mobile networks and billing/provisioning systems, yet others indicate they foresee little or no problems.

The Dutch contribution is fairly explicit and indicates that T-Mobile expects that 3-digit MNCs can be introduced relatively effortlessly, as long as there is no overlap in the MNCs (thus the 2-digit MNC cannot overlap with the first two digits of a 3-digit MNC).

The summary document mentions three countries that already make use of 2-digit and 3-digit MNCs within one MCC: Argentina, Nicaragua and Honduras. No particular problems were reported for these countries. While we were able to find specific number allocation information for Argentina (see the table below), we were not able to locate similar information for the two other countries.

722	10	ar	Argentina Republic	54	Claro/ CTI/AMX
722	330	ar	Argentina Republic	54	Claro/ CTI/AMX
722	320	ar	Argentina Republic	54	Claro/ CTI/AMX
722	310	ar	Argentina Republic	54	Claro/ CTI/AMX
722	2	ar	Argentina Republic	54	Nextel
722	20	ar	Argentina Republic	54	Nextel
722	34	ar	Argentina Republic	54	Telecom Personal S.A.
722	341	ar	Argentina Republic	54	Telecom Personal S.A.
722	70	ar	Argentina Republic	54	Movistar/Telefonica
722	7	ar	Argentina Republic	54	Movistar/Telefonica
722	1	ar	Argentina Republic	54	Movistar/Telefonica

Box 14: MNC codes for Argentina (source: www.mcc-mnc.com)

While Argentina has assigned 2- and 3-digit codes that share the same initial digits (e.g. 34 and 341), we note that they are assigned to the same operator. As a consequence, we do not know whether they are actually both used. Even if they are, the operator in question might have taken special precautions that would be more difficult to implement if the codes were assigned to different operators. As a result, we cannot draw strong conclusions from the Argentina situation.

Apart from the information from the ITU questionnaire, the website www.mcc-mnc.com does tell us that there are several other countries – mainly Caribbean Islands and Columbia – where mixed situations seem to exist:

342	600	bb	Barbados	1246	C & W BET Ltd.
342	810	bb	Barbados	1246	Cingular Wireless
342	750	bb	Barbados	1246	Digicel
342	50	bb	Barbados	1246	Digicel

346	140	ky	Cayman Islands	1345	Cable & Wireless
346	0	ky	Cayman Islands	1345	Cingular
346	06	ky	Cayman Islands	1345	Digicel Cayman Ltd.

732	11	co	Colombia	57	
732	102	co	Colombia	57	Movistar
732	103	co	Colombia	57	TIGO/Colombia Movil
732	111	co	Colombia	57	TIGO/Colombia Movil
732	1	co	Colombia	57	TIGO/Colombia Movil
732	101	co	Colombia	57	Comcel S.A. Occel S.A./Celcaribe
732	2	co	Colombia	57	Edatel S.A.
732	123	co	Colombia	57	Movistar

366	110	dm	Dominica	1767	C & W
366	20	dm	Dominica	1767	Cingular Wireless/Digicel

352	110	gd	Grenada	1473	Cable & Wireless
352	30	gd	Grenada	1473	Digicel

310	470	gu	Guam	1671	Docomo
310	370	gu	Guam	1671	Docomo
310	140	gu	Guam	1671	GTA Wireless
310	33	gu	Guam	1671	Guam Teleph. Auth.
310	32	gu	Guam	1671	IT&E OverSeas

338	20	jm	Jamaica	1876	Cable & Wireless
338	180	jm	Jamaica	1876	Cable & Wireless
338	50	jm	Jamaica	1876	DIGICEL/Mossel
338	5	jm	Jamaica	1876	DIGICEL/Mossel

358	110	lc	Saint Lucia	1758	Cable & Wireless
358	30	lc	Saint Lucia	1758	Cingular Wireless
358	50	lc	Saint Lucia	1758	Digicel (St Lucia) Limited

374	130	tt	Trinidad and Tobago	1868	Digicel
374	12	tt	Trinidad and Tobago	1868	Bmobile/TSTT

Box 15: List of countries with mixed 2- and 3-digit MNCs (source: www.mcc-mnc.com)

It is however doubtful whether these markets can be used as reference, since the Caribbean region is known for its somewhat peculiar practices regarding MCC/MNC use. An example of this is the extensive use of 'false' MCCs, because this simplified the rollout of one network for a large number of islands and moreover served large roaming advantages.

After the ITU SG2 activity took place, the Swedish Post and Telecom Authority (PTS) has published the conclusions of their national consultation. The Swedish MNC plan of May 31st 2013 does not state anything with respect to 3-digit MNCs. Just some blocks of 2-digit MNCs are being reserved for future use. The supporting material shows the following:

Two-and three-digit mobile network codes

The recommendation mentions no theoretical obstacle regarding a mixed use of two-and three-digit mobile network codes in the same geographic mobile country code. ITU-T has been studying the issue further on the practical ability to combine two-and three-digit mobile network codes

The majority of the organizations that responded to the ITU-T's referral sees great difficulty in mixing the 2 - and 3-digit MNC s in the same geographical MCC. Problems consists e.g. of older GSM networks that can only handle 2-digit MNCs and the technical specifications from standardization organization 3GPP

The need for MNCs for new applications only specifies the use of 2-digit MNCs. Further studies around mixed use will not be done within the ITU-T and implementing this nationally therefore is not recommended.

Box 16. Position of the Swedish Post and Telecom Authority on the use of three digit MNC codes/ Selected text fragments, translated by Google Translate[16]

Basically the lack of global support for 3-digit MNCs seems to result in a conclusion "not recommended", not facts showing this is technically not possible. Also the response of Telia, Sweden's largest operator, seems to favour the 2-digit MNC approach, as shown below:

Telia welcomes PTS deciding not to go ahead with the earlier proposal for mixed use of 2 - and 3-digit MNC. Telia has objected to the proposal on the sharing of MNC for closed networks and testing purposes, and mentions that the consequences should be further analysed.

Box 17. Response of Telia on the position of PTS in Sweden, as translated by Google Translate.[17]

The United Kingdom, which hosts a lot of private GSM networks, has taken a different approach to tackle the issue. The spectrum for private GSM has been awarded to 10 market players and each of them has a 2-digit MNC.

Another reference case identified is India. Reportedly there have been over 100 3-digit MNCs allocated in the MCC 405, mixed with 2-digit MNCs (see Appendix C). However, overlap between the two first digits has been avoided: the first two digits of the assigned 3-digit MNCs never overlap with an assigned 2-digit MNC. While we must assume that the Indian situation is working without significant problems, we have not been able to find additional evidence on this. Contact with the CEO of an Indian GSM network equipment vendor indicate no known problems with 3-digit MNCs in India while using it at a very large scale and with many different mobile phones.

---

[16] Source: PTS (2013). Allokering och reservering av mobila na□tkoder. Available at http://www.pts.se/upload/Beslut/Telefoni/2013/12-6489-beslut-allokering-reservering-MNC-130530.pdf.

[17] *Source: Sammanställning remissvar och kommentarer till remissvar avseende förslag till allokering och reservering av mobila nätkoder, PTS, Sweden. Available from http://www.pts.se/upload/Remisser/2012/Telefoni/12-6487/12-6487-remissammanstallning-allokering-reservering-MNC-130530.pdf.*

3.4 Conclusions

Literature and standardisation documents cannot provide a definite answer as to whether the mixed usage of 2- and 3-digit MNCs within one MCC is possible. The standards itself note that such a mixed usage is "not recommended and is outside the scope of this specification". In addition, there might be problems in important systems that are not part of the standard (for instance legacy equipment and back-office systems such as billing). The problems of using (non-mixed) 3-digit codes in the US – and the fact that they continue to extend a transition regime which essentially makes them 2-digit codes after all – are already indicative for some of the problems in this arena. The responses to a recent ITU survey on (mixed) use of 3-digit MNCs resulted in a lot of critical reactions too.

At the same time, there does not appear to be any indisputable evidence that it is impossible to do. There are signals that – perhaps under specific conditions – a mixed usage is actually possible without significant problems. One important signal is the fact that there are countries already doing so, apparently without major problems. But all in all, on the basis of the information gathered here, caution is advised. In the next chapters, we will look at market entry scenario's in the Netherlands, and validate the findings with Dutch and foreign market players.

4 Analysis of market entry scenarios for 3-digit MNCs or MNC sharing in the Netherlands

In this chapter, we apply the knowledge that was presented in the previous chapters and apply it in a number of real-life market entry scenarios that would fit in the current Dutch situation.

4.1 Real-life market entry scenarios for MNC applicants

Organizations applying for an MNC can have different reasons to do so, depending on the type of use or prospective users. We assume that in any case an applicant will provide SIM cards to its own subscribers, containing the MNC it has obtained. Note that in line with most literature we will use the term 'subscriber' in a very broad sense, which includes not only regular subscribers for telecom services, but also all other parties that are provided with SIM cards, such as pre-paid customers, M2M users, and more. Similarly, we will use a broad meaning for the word operator, which we use here for any party that has obtained an MNC, no matter whether it has its own radio network or is a MVNO. Finally, below we will also use the word phone in a broad sense; referring to any device with an SIM card installed, including tablets, ebooks, game consoles, M2M devices, etc.

In the context of this study, we differentiate between different relevant dimensions:

1. Whether or not the operator allows its own subscribers to roam into other networks (national or international)
2. Whether the operator wants to serve roaming subscribers coming from other networks

On the basis of the above dimensions, we can distinguish the real-life use scenario shown in Table 2. Note that a fourth scenario (not allowing subscribers to roam yet serving external roamers) is theoretically also possible but does not seem to be a very likely desire of network operators and is thus skipped in this chapter.

Table 2. Market entry scenarios

	Allow subscribers to roam	**Serving external roamers**
(1) Full-fledged public network	Yes	Yes
(2) Private network without roaming	No	No
(3) Private network with roaming	Yes	No

We now shortly elaborate on these entry scenarios.

Scenario 1: Full-fledge public network. For the context of this study, we assume that parties that want to build a full-fledged mobile network in the Netherlands (e.g. those that

won a spectrum license) will not be willing to accept three digit MNC codes in the first place. However, it is not likely there will be many future applicants in this category and the current number space still has room to provide two digit MNCs to the few future applicants that do pop up in this category. Hence we will not further investigate this scenario.

Scenario 2: Private network without roaming. In this scenario, the operator does not need its own subscribers to be able to roam into any other network. Its users might be in fixed locations (e.g. stationary M2M applications) or might only use their devices in predefined areas (e.g. campuses, plants, hospitals complexes, etc.). We assume the operator has no desire to offer roaming to subscribers of other (international) networks. This is a relevant scenario in which there might be a substantial demand for MNCs, which will be further studied below.

Scenario 3: Private network with roaming. In this scenario, the operator wants its own subscribers to be able to roam into other networks. This may be either be national roaming, where the operator has limited geographic coverage yet wants its subscribers to call from any location in the country, or where the operator has an MVNO agreement. This may even be international roaming, where the operators have engaged in roaming agreements with operators from other countries. We again assume the operator has no desire to offer roaming to subscribers of other (international) networks. This is a normal scenario for regular voice phones, but also for other devices, such as an M2M device fitted in a car. This is also a relevant scenario in which there might be a substantial demand for MNCs, which will be further studied below.

Below, we will examine the possibilities and limitations of assigning three digit MNC codes in the Netherlands for scenario (2) and (3) above. As we will also see, another important aspect is whether the operator wants to be able to serve any suitable phone brand and model, versus controlling the phone type and only support the use of devices that have been specifically selected / tested for use on the network. This aspect will be discussed within each of the scenarios we discuss below. In addition, we will also add a scenario where operators share a single MNC code.

4.2 3-digit MNC for private networks without roaming

The point of departure for this scenario is an independent operator A with a private mobile network A, which users only use with their SIM-card provided by its operator A. Since the operator has a 3-digit MNC, the SIM card also has a 3-digit MNC in it.

Possible risks:

- A telephone with a 3-digit MNC SIM tries to perform a location update on another mobile network B (for instance because it does not 'see' its home network). Under normal circumstances this location update would be rejected, by network B sending a 'forbidden network' reject code to the terminal.[18] [19]
    - Error scenario: the telephone 'hangs' on the regular network because the network B does not recognize the 3-digit MNC and subsequently does not send the correct 'reject code'. If network B sends the 'forbidden network' reject code then the phone will list the network as forbidden in the SIM card and will not try to register on this network again as long as it is in the "forbidden" list on the SIM card. However if network B does not recognize

[18] Unless a (national) roaming agreement has been concluded with that operator.

[19] In Appendix B, the various reject codes that are specified in the standard are discussed

this type of 3-digit MNC (not being from a US MCC) and does not send an appropriate 'reject' code then the phone could continue to 'hang' on this network.

  - Possible solution: Operator A, who provided 3-digit MNC SIM card, can program the concerned network beforehand as a 'forbidden network' in the SIM card, so the device does not even try to register on that network at all.

- A telephone with a 2-digit MNC SIM (for instance provided by operator B) tries to perform a location update on the private mobile network A (which has a 3-digit MNC). Under normal circumstances this location update would be rejected, unless a (national) roaming agreement has been made. The private mobile network must be deemed able to send the correct 'forbidden network' reject code, also to SIM cards with a 2-digit MNC.
  - Error scenario: A software bug in mobile telephones, as a result of which the telephone with a 2-digit MNC SIM card gets stuck on the private network with a 3-digit MNC. While such problems have been experienced in some cases elsewhere, [20] it is unknown whether these kinds of software bugs occur in the existing population of mobile telephones in the Dutch context.
  - Possible solution: none, really. That makes this situation the worst controllable and hardest assessable risk.

Conclusion for '3-digit MNC for private networks without roaming' scenario

In this scenario, the operator can ensure good functioning of its own services as long as it carefully selects both infrastructure and terminals. Together with its suppliers, it can check that all equipment functions correctly in this specific context, and together they could address specific issues if they come up later. Should the operator want its subscribers to use any phone on the market (opposed to just phones it selected and tested) then the operator takes some risk.

There is, however, a potential problem with phones used by subscribers of other networks that accidentally try to log on to the network when roaming. Some of these phones might suffer from a software implementation issue that make them unintended 'hanging' on networks with a 3-digit MNC. If such a phone accidently 'tries' the network in question (and gets properly rejected because the network provides no such roaming), it might nevertheless get stuck and unable to move to another network. While such problems have been reported at times, it is hard to say how incidental they were. As such, the extent of this potential problem is still unknown. Trials might be a way to detect if those problems do exist in the Netherlands.

[20] There have been comparable problems with unlocked T-Mobile US devices being sold on different networks on the Caribbean Islands. These devices worked fine as long as there was no PCS 1900 network on the island. However, once a PCS 1900 network was deployed, these devices got stuck on the PCS 1900 MHz network, even when its 'own' network was available on 900/1800 MHz. It may be clear that this behaviour is not 3GPP standard compliant, but we cannot exclude the possibility that similar problems arise with a 3-digit MNC within an MCC that the device sees as an MCC with 2-digit MNCs.

4.3 3-digit MNC for private networks with roaming

This scenario is identical to the one above (and thus shares the same concerns), but additionally provides roaming to its own clients. Such roaming can be realized in two ways:

- Dual SIM cards (or dual IMSI on a single SIM card),
- National roaming in which the MNO accepts the MCC/MNC of the private mobile network.[21]

The supplier of the private mobile network could deal with device problems by providing its customers only with devices that have been tested and found to be working well in this context. Also possible problems in the back-office systems can be solved between the MNO and the supplier of the private mobile network.

Conclusion for '3-digit MNC for private networks with roaming' scenario

This scenario shares the findings for the scenario above: the operator should carefully select its infrastructure and terminals, and there might be a problem of phones of other operators unintended get stuck (probably a very incidental problem but the actual extent is not known).

In addition, possible problems in the roaming situation can be addressed in consultation with those partners with whom the operator has made roaming agreements. Obviously, this is easier when the operator has just one national roaming partner or a few international roaming partners than when it wants to have roaming with multiple operators in each country around the globe.

4.4 Sharing (2-digit) MNCs between multiple private networks

One suggested, alternative solution to address scarcity of MNC codes would be for private operators to share a single MNC. While sharing can be envisioned for both 2-digit and 3-digit MNC codes, the sharing of 2-digit MNC codes might create enough room to alleviate the need to move to 3-digit MNC codes altogether.

Sharing MNCs by definition implies that the sharing networks do not overlap in a geographical sense. The sharing networks may also be owned by different network operators.

While such sharing is technically possible, there are a few points of special interest:

- The sharing operators should not overlap in terms of location area codes;
- The sharing operators should not overlap in terms of IMSI subscriber numbers assigned to clients;
- The sharing operators should preferably make sure not to send a 'forbidden network' reject code to any of the clients of the other networks that share the same MNC codes. The 3GPP has explicitly described such a situation and mobile phones should never store the home network as 'forbidden' but whether this has been implemented properly in all mobile devices is less certain.[22] If the mobile phone would accept the

[21] Alternatively, a scenario can be envisioned where the home network and roaming network are swapped. More specifically: an MVNO deal is made between the supplier of the mobile system and an MNO that only uses the IMSIs of the MNO that can 'roam' on the private mobile network. In this scenario also, the supplier of the mobile system has the responsibility for solving complications.

[22] In 3GPP TS 23.122-840 (Release 8), this situation is described as follows: *"If a message with cause value "PLMN not allowed" is received by an MS in response to an LR request from a VPLMN, that*

home network as 'forbidden' network then the terminal in question will afterwards not be able to find its own home network anymore. Instead, the sharing operators should preferably send 'softer' reject codes to such clients, such as the #12 'Location Area Now Allowed' code. Appendix B presents an overview of all the reject codes as defined by the 3GPP standard.

The above points require some coordination between the sharing private GSM operators. While we do not want to anticipate the on-going discussion on MNC sharing in the Netherlands, we would like to emphasize that this coordination involves a limited technical complexity. For instance, should ACM decide to allow up to 100 sharing operators in one MNC code, it could ensure that each of them uses an unique assigned two digit code between 00 and 99 for the first to digits of the MSIN (the national number code that follows just after the MNC digits; see Figure 1).[23] These assigned codes would also facilitate these operators to go into roaming agreements where each of them can be correctly distinguished from the other operators that share the same MNC.[24] This example shows how the necessary coordination of one of the aspects, the IMSI codes, can we done with relative ease.

Conclusion for 'Sharing MNCs between multiple private networks' scenario

This scenario is quite attractive from the point of view of the private GSM operator. It does not have any of the problems of the two previous (mixed 3-digit) scenario's. While this solution does require some coordination between the parties at stake, we argue that this coordination is quite feasible.

4.5 Conclusions

This chapter investigated the possible issues when using 3-digit MNCs for two realistic scenarios of introduction of private GSM networks in the Netherlands. The main findings are as follows:

For **private networks without roaming,** most identified issues could be addressed by the private GSM operator by carefully selecting equipment. But there is a potential risk for users of other networks in case their phones have a software implementation problem that causes that their phones cannot properly find their own home networks any more. While this problem is probably rare, it is hard to estimate the actual size of the problem.

For **private networks with roaming**, the findings here are similar to the scenario above. But the coordination is going to be somewhat more difficult, as the virtual GSM operator will also need to coordinate the use of equipment and testing with all the roaming providers (national and international) with which it wants to get engaged with.

VPLMN is added to a list of "forbidden PLMNs" in the SIM and thereafter that VPLMN will not be accessed by the MS when in automatic mode. A PLMN is removed from the "forbidden PLMNs" list if, after a subsequent manual selection of that PLMN, there is a successful LR. This list is retained when the MS is switched off or the SIM is removed. The HPLMN (if the EHPLMN list is not present or is empty) or an EHPLMN (if the EHPLMN list is present) shall not be stored on the list of "forbidden PLMNs".

[23] Adding a (single) assigned number just after a 2-digit MNC could achieve the same goal

[24] The roaming partner, however, should have the ability to analyse the digits following the MNC code in order to distinguish between the sharing operators. We have been informed by market parties, however, that this is not a real issue.

Concerning the **sharing of MNCs between different private GSM operators**, we see no principle objections, although we do stress that these sharing operators do need to coordinate their behaviour in terms of (1) geographical coverage, (2) location area allocation, (3) IMSI number allocation and (4) preferably the reject codes they send to terminals from clients of other networks that are part of the MNC code sharing.

5 Validation of our findings with market players

The above-mentioned findings have been presented to six market players, to get to know their opinion and ask whether they had any additions to these aspects. The companies interviewed to are presented in Appendix A.

5.1 Responses to the identified risks

The main result is that all parties endorse the viewpoints that we have. All interviewed parties acknowledge that the largest risk is that handsets will not properly function when a 3-digit network becomes operational. Unfortunately, none of the market players can give a further assessment of the magnitude and/or impact of this risk. Malfunctioning handsets would imply a programming error, but experience has taught the interviewees that regarding the implementation of the signalling of MNC codes, such a risk cannot be excluded. The solution proposed by several interviewees is to conduct a pilot project, where these potential problems can be analysed.

Further feedback was sought from the Indian reference case since India reportedly has large-scale mixed 2-digit and 3-digit MNCs in one MCC. The contacted CEO of a local Indian GSM network infrastructure vendor clearly indicated that in India no problems have been experienced with mobile phones 'hanging' on GSM networks with 3-digit MNCs. Further information on the India case would be useful.

Upon sharing MNCs, the most important risk is that networks send out hard reject codes, such as a 'forbidden network' code. This is some kind of prisoner's dilemma: a party using a shared MNC would ideally send out such a hard reject code to diminish the signalling load on its network, but this 'forbidden network' code would cause a significant problem for the handsets when they return to their home network: the forbidden reject code prevents them from trying to connect to their home network. The same holds vice versa, thus it would be in the interest of both parties if these forbidden network codes are not used. As a matter of fact, the 3GPP standard explicitly states that handsets should never be able to put their own network on the forbidden network list, but as the interviewees stated earlier, the correct implementation of this standard cannot be guaranteed.

All interviewees agree that the usage of overlapping IMSIs (basically an IMSI with a 2-digit MNC which is equal to another IMSI with a 3-digit MNC) seems to be a bad idea. One interviewee for instance explicitly states that this would make roaming to the public network problematic within their current set-up, since duplicated IMSIs might appear. We can thus safely conclude that ACM should not distribute 3-digit MNCs of which the 2-digit MNC is already allocated.

5.2 Other interview findings

Besides the responses to the identified risks, the interviewees gave other valuable information. This paragraph gives some of these findings.

Some market players indicate to gladly accept 3-digit MNCs instead of 2-digit MNCs. Others indicate that they are not ready to accept the risks – such as handhelds that react problematically – and therefore only want a 2-digit MNC. The question is how such parties

would react when they are told that getting a 2-digit MNC will be out of the question for them. In that case they will probably have to reassess their views on receiving 3-digit MNCs.

Given that private GSM networks potentially have problems with some handsets, it could be argued that there is a potential solution to let private GSM network providers distribute their own handsets. Some interviewees however indicate that such a policy is not accepted by their customers. In the recent trend of 'Bring your own Device (BYOD)', these handsets policies are regarded as "old-fashioned".

In the case of continued use of 2-digit MNCs and sharing of MNCs there is a potential need for coordination of the IMSI ranges everyone uses to avoid issuing the same IMSI twice. Although theoretically this would not necessarily be an issue between pure private networks, most interviewees expect roaming with the public mobile network for the private GSM/LTE users requiring unique IMSI's. There is no uniform idea about who should manage this coordination. The main options mentioned are:

- ACM itself,
- A stand-alone entity (though this is often considered unattractive due to cost, complexity and desired independency of private networks),
- Vendors of private GSM systems. In the current market there are only a few vendors of private GSM systems so potentially they could each manage a 2-digit MNC.

The interviewed MNO indicated capability to handle both 3-digit MNC users on GSM and UMTS as well as shared 2-digit MNC users as long as they have unique IMSIs and are divided in proper ranges allowing for routing to the corresponding home network. Analysis of several digits below the MCC-MNC is technically possible.

6 Conclusions and recommendations

Conclusions

Introducing 3-digit MNCs has been suggested as a way to address future scarcity of national network codes for mobile networks. While the use of such 3-digit MNCs was already mandated in the US more than a decade ago, this study shows that the US situation is considerably more complex than it might seem at first appearance. In fact, the US is currently still in a 'transition regime' which allows 2-digit MNCs, and this transition regime is extended time after time. As such, the current situation in the US more resembles a 2-digit MNC scenario than a 3-digit one.

Mixing both 2- and 3-digit MNCs in one single country, as would be the case in the Netherlands, creates an even more complex situation. In fact, the technical standards discourage such a mixed use, and there are also concerns regarding legacy equipment and back-office systems. Despite this lack of official support in the standards, some countries in the world did introduce mixed use, without apparent major problems. But this does not preclude there may be some issues and restrictions associated with such a choice, even though the limited feedback obtained from the reference case in India indicates no real problems have been encountered there.

Considering a number of real-life market entry scenarios of 3-digit MNCs in the Netherlands, this study identified a number of possible issues and problems, as well as ways to address these. These have been validated with a number of market actors. Table 3 provides an overview of potential problems and solutions associated with introducing 3-digit MNCs. For the sake of simplicity, we will refer here to the party that received a 3-digit MNC as the 'Private GSM operator', but of course it might plan other type of services too.

Table 3. Potential problems associated with introducing 3-digit MNCs, and their solutions

Potential problem	***Short description***	***Who can suffer from this potential problem***	***Possible solution***
Incompatible terminals	Not all terminals may work well with a 3-digit MNC home network	Private GSM operator	Limit private GSM network usage only to selected / tested terminals
Duplicated IMSI's	Duplicated IMSI's cause problems when private GSM users roam in public networks. Networks cannot handle two identical IMSI's	User of private network and operator of public network	Ensure that the first two digits of new to be allocated 3-digit MNCs do not overlap with already allocated 2-digit MNCs
'Hanging' terminals	Terminals of users of other networks may not properly interpret 3-digit MNC code broadcasted by private GSM network. Problematic software in mobile phones could cause	1. Any existing operator already operating in the geographical area where new private GSM network is launched	Use small-scale testing to be able to timely observe whether this problem is really present, and for which terminal models.

	the effect that these terminals cannot properly find their home network (or other roaming network) any more	2. Any existing operator worldwide whose subscribers roam into area where Private GSM network is operating	
3-digit use in roaming and billing relations	Equipment and interfaces that handle all technical aspects of roaming (call records, accounting) may not support 3-digit MNC codes	Those parties that wish to enter into roaming agreements (e.g. private GSM operator and its roaming partner).	Check and if necessary adjust or update existing systems. These costs may be larger for incumbents with extensive legacy equipment

An alternative approach towards addressing scarcity of MNC numbering space would be to have different (new) operators sharing a single MNC code. Also for this, we identified potential problems as well as solutions, shown in Table 4. Again, we will simply refer to private GSM networks, with the same caveat as mentioned above.

Table 4. Potential problems associated with sharing MNCs, and their solutions

Potential problem	***Short description***	***Who can suffer from this potential problem***	***Possible solution***
'Forbidden network' problems	If multiple networks use the same MNC, then certain 'location update reject messages' received in alien networks can cause trouble for the terminal to get access to its home network	Private GSM network operator whose clients leave its own service area	Coordination between all parties that share a common MNC so that they use the appropriate reject codes
Overlapping LAI number ranges	If networks use overlapping LAI codes, terminals might not behave properly	All private GSM networks that share an MNC	Introduce a governance mechanism that prevents overlapping LAI codes
Overlapping IMSI number ranges	If terminals use overlapping IMSI numbers, they cannot be associated properly anymore with their own network operator	All private GSM networks that share an MNC	Introduce a governance mechanism that prevents overlapping IMSI codes
Shared MNC codes in roaming and billing relations	Equipment and interfaces that handle all technical aspects of roaming (call records, accounting) may not support shared MNC codes	Those private GSM operators that wish to enter into roaming agreements, as well as their roaming partners	Check and if necessary adjust or update existing systems. These costs may be larger for incumbents with extensive legacy equipment

Recommendations to ACM

On the basis of our findings, we make the following recommendations:

1. Overall, an approach of sharing 2-digit MNC codes between different operators seems to be more attractive than an approach of introducing 3-digit MNC codes. This is true both from the perspective of the new entrant, that of the existing players, and that of the ACM as regulator and guardian of the public interest. MNC sharing will require some governance mechanisms, to ensure that sharing networks (a) do not overlap geographically, (b) do not overlap in terms of Location Area Codes and in terms of IMSI numbers, and (c) do respect certain configuration aspects (such as sending 'soft' reject codes to clients of other

operators that share the same code). This governance will therefore take some effort, and decisions need to be made about the respective role of the stakeholders. But creating this governance is quite feasible, and the costs of this governance will be relatively small compared to the costs and risks associated with introducing 3-digit MNC codes. In the Netherlands, new legislation to allow the sharing of MNC codes is, in fact, already in preparation. The intended beneficiaries for this purpose are M2M-providers, but this legislation can also be used for the benefit of private GSM providers. Should shared MNC operators wish to offer (national or international) roaming, they do need to coordinate some specific aspects with their prospective roaming partners, but this is no harder (and typically easier) than the roaming aspects 3-digit operators would need to deal with.

2. Should ACM nevertheless decide to introduce 3-digit MNCs, then she should be well aware that she is taking some risks and accepting some uncertainties. While some countries apparently do already assign mixed 2- and 3-digit MNCs, the official standards discourage such a choice. Also the extensive, recent discussions in ITU and the policy positions that several countries have taken after these discussions do not encourage the adoption of 3-digit MNCs.[25] While the most imminent problems the operator might have using a 3-digit MNC number can – for most market entry scenarios – be addressed by this operator, its suppliers, and if necessary, its roaming partners, this does involve costs and limitations. This likely includes a more limited choice of handsets, which may not be easy to explain to the users of private GSM networks, which may want to accommodate existing or favourite handsets themselves.[26] It also likely includes additional requirements on suppliers and roaming partners. While the effect of such additional requirements might differ between individual suppliers and roaming partners (some might already have ensured proper 3-digit operation, other will still need to test and perhaps even make adaptations), it will put the 3-digit MNC operator in a more difficult bargaining situation than one with a 2-digit MNC. There is also the risks that costs that other parties need to make for compliance testing and possible adaptations would be passed on to the new operator, directly or indirectly.

3. Should ACM decide to introduce 3-digit MNCs, it is at least advised not to have the first two digits of such new 2-digit MNCs to overlap with already assigned 2-digit MNCs.

4. Should ACM decide to introduce 3-digit MNCs, then it is also advised to promote conducting a small scale pilot or trial, in order to determine whether users of existing mobile networks do not experience problems when such a new network is activated (the 'Incompatible terminals' problem as listed in Table 3). We believe this is particularly important as this problem may impact current users of existing networks, not just the users of the new networks. While the anticipated problems identified in this report are probably rare, it is hard to estimate the occurrence of such problems without a pilot. The parameters for the pilot should be well chosen to maximize the learning effect (for instance

---

[25] While such discussions may in part have been influenced by the views of large incumbent operators, which also have a strategic interest in discouraging new entry into their market, this does not mean that their argument do not have technical merit.

[26] If a private GSM network cannot support existing terminals, the client might just as well turn to a DECT based solution.

by including coverage of the new network in an underground parking lot where existing networks have no coverage). Existing operators should be informed and asked to report (with sufficient detail) any unusual problems in the area in question.

5. Should ACM decide to introduce 3-digit MNCs for M2M users only, then the risks associated with networks broadcasting a 3-digit MNC do not apply. The remaining issues are just negotiation issues between the M2M party and the MNO.

Appendix A – list of interviewees

Market player	Function
Vodafone	Manager high level design
ASPIDER	Vice-president
ASPIDER	Network architect
Dimension Data	Business Development Media & Communications
Dimension Data	Senior Technical Consultant
Shyam Telecom	Product manager
Zetacom	Technical Consultant
Strict	Principal consultant

Appendix B – Cause fields of Location Update Reject messages

In document TS 24.008-840, the 3GPP standard defines a number of different 'reject codes' which a network can send to a mobile terminal if the network declines to offer services. The table below shows the different reject codes, including their cause (why they are sent), as well as how the mobile terminal is supposed to react to receiving such a reject code. (More details can be found in the source document.)

Reject code and reason	***Appropriate action by mobile phone***
# 2: IMSI unknown in HLR; # 3: Illegal MS; or # 6: Illegal ME	The mobile station shall set the update status to ROAMING NOT ALLOWED (and store it in the SIM/USIM according to subclause 4.1.2.2), and delete any TMSI, stored LAI and ciphering key sequence number and shall consider the SIM/USIM as invalid for non-GPRS services until switch-off or the SIM/USIM is removed.
# 11: PLMN not allowed	The mobile station shall delete any LAI, TMSI and ciphering key sequence number stored in the SIM/USIM, reset the attempt counter, and set the update status to ROAMING NOT ALLOWED (and store it in the SIM/USIM according to subclause 4.1.2.2). The mobile station shall store the PLMN identity in the "forbidden PLMN list". The MS shall perform a PLMN selection when back to the MM IDLE state according to 3GPP TS 23.122 [14]. An MS in GAN mode shall request a PLMN list in GAN (see 3GPP TS 44.318 [76b]) prior to performing a PLMN selection from this list according to 3GPP TS 23.122 [14].
# 12: Location Area not allowed	The mobile station shall delete any LAI, TMSI and ciphering key sequence number stored in the SIM/USIM, reset the attempt counter, and set the update status to ROAMING NOT ALLOWED (and store it in the SIM/USIM according to subclause 4.1.2.2). The mobile station shall store the LAI in the list of "forbidden location areas for regional provision of service". The MS shall perform a cell selection when back to the MM IDLE state according to 3GPP TS 43.022 [82] and 3GPP TS 25.304 [98]. NOTE 1: The cell selection procedure is not applicable for an MS in GAN mode.
# 13:Roaming not allowed in this location area	The mobile station shall reset the attempt counter, and set the update status to ROAMING NOT ALLOWED (and store it in the SIM/USIM according to subclause 4.1.2.2). The mobile station shall store the LAI in the list of "forbidden location areas for roaming". The mobile station shall perform a PLMN selection instead of a cell selection when back to the MM IDLE state according to 3GPP TS 23.122 [14]. An MS in GAN mode shall request a PLMN list in GAN (see 3GPP TS 44.318 [76b]) prior to performing a PLMN selection from this list according to 3GPP TS 23.122 [14].
# 15: No Suitable Cells In Location	The mobile station shall reset the attempt counter, set the update status to ROAMING NOT ALLOWED (and store it in the SIM/USIM according to

Area	subclause 4.1.2.2). The mobile station shall store the LAI in the list of "forbidden location areas for roaming". The mobile station shall search for a suitable cell in another location area in the same PLMN according to 3GPP TS 43.022 [82] and 3GPP TS 25.304 [98]. NOTE 2: The cell selection procedure is not applicable for an MS in GAN mode.
# 25: Not authorized for this CSG	The MS shall reset the attempt counter, and set the update status to ROAMING NOT ALLOWED (and store it in the SIM/USIM according to subclause 4.1.2.2). The MS shall remove, from the allowed CSG list stored in the MS , the CSG ID of the cell where it has attempted to camp. The MS shall search for a suitable cell in the same PLMN according to 3GPP TS 43.022 [82] and 3GPP TS 25.304 [98]. NOTE 3: CSG is applicable only for UMTS.

Source: 3GPP TS 24.008-840 (Release 8)

Appendix C – MCC/MNC list of India

India has two different MCC in use:

- In the 404 MCC range, only 2-digit MNCs are assigned
- In the 405 MCC range, 2-digit MNCs are assigned up to number 70, and 3-digit MNCs are assigned starting at 750. As such, the first two digits of the latter MNCs never overlap with an assigned 2-digit MNC.

While the 404 range is not interesting in the context of this study, we do show the 405 range below, where the mixed use of 2-digit and 3-digit codes can be seen:

MCC	MNC	Network	Operator or brand name	Status
405	1	Reliance Telecom (Andhra Pradesh)	Reliance Telecom	Operational
405	3	Reliance Telecom (Bihar)	Reliance Telecom	Operational
405	4	Reliance Telecom (Chennai)	Reliance Telecom	Operational
405	5	Reliance Telecom (Delhi)	Reliance Telecom	Operational
405	6	Reliance Telecom (Gujarat)	Reliance Telecom	Operational
405	7	Reliance Telecom (Haryana)	Reliance Telecom	Operational
405	8	Reliance Telecom (Himachal Pradesh)	Reliance Telecom	Operational
405	9	Reliance Telecom (Jammu & Kashmir)	Reliance Telecom	Operational
405	10	Reliance Telecom (Karnataka)	Reliance Telecom	Operational
405	11	Reliance Telecom (Kerala)	Reliance Telecom	Operational
405	12	Reliance Telecom (Kolkata)	Reliance Telecom	Operational
405	13	Reliance Telecom (Maharashtra)	Reliance Telecom	Operational
405	14	Reliance Telecom (Madhya Pradesh)	Reliance Telecom	Operational
405	15	Reliance Telecom (Mumbai)	Reliance Telecom	Operational
405	17	Reliance Telecom (Orissa)	Reliance Telecom	Operational
405	18	Reliance Telecom (Punjab)	Reliance Telecom	Operational
405	19	Reliance Telecom (Rajasthan)	Reliance Telecom	Operational
405	20	Reliance Telecom (Tamilnadu)	Reliance Telecom	Operational
405	21	Reliance Telecom (Uttar Pradesh (East)	Reliance Telecom	Operational
405	22	Reliance Telecom (Uttar Pradesh (West)	Reliance Telecom	Operational
405	23	Reliance Telecom (West Bengal)	Reliance Telecom	Operational
405	24	HFCL INFOTEL (Punjab)	HFCL INFOTEL	Operational
405	25	TATA Teleservices (Andhra Pradesh)	TATA Teleservices	Operational
405	26	TATA Teleservices (Assam)	TATA Teleservices	Operational
405	27	TATA Teleservices (Bihar)	TATA Teleservices	Operational
405	28	TATA Teleservices (Chennai)	TATA Teleservices	Operational
405	29	TATA Teleservices (Delhi)	TATA Teleservices	Operational
405	30	TATA Teleservices (Gujarat)	TATA Teleservices	Operational
405	31	TATA Teleservices (Haryana)	TATA Teleservices	Operational
405	32	TATA Teleservices (Himachal Pradesh)	TATA Teleservices	Operational
405	33	TATA Teleservices (Jammu & Kashmir)	TATA Teleservices	Operational
405	34	TATA Teleservices (Karnataka)	TATA Teleservices	Operational
405	35	TATA Teleservices (Kerala)	TATA Teleservices	Operational
405	36	TATA Teleservices (Kolkata)	TATA Teleservices	Operational
405	37	TATA Teleservices (Maharashtra)	TATA Teleservices	Operational
405	38	TATA Teleservices (Madhya Pradesh)	TATA Teleservices	Operational
405	39	TATA Teleservices (Mumbai)	TATA Teleservices	Operational
405	40	TATA Teleservices (North East)	TATA Teleservices	Operational
405	41	TATA Teleservices (Orissa)	TATA Teleservices	Operational

405	42	TATA Teleservices (Punjab)	TATA Teleservices	Operational
405	43	TATA Teleservices (Rajasthan)	TATA Teleservices	Operational
405	44	TATA Teleservices (Tamilnadu)	TATA Teleservices	Operational
405	45	TATA Teleservices (Uttar Pradesh (East)	TATA Teleservices	Operational
405	46	TATA Teleservices (Uttar Pradesh (West)	TATA Teleservices	Operational
405	47	TATA Teleservices (West Bengal)	TATA Teleservices	Operational
405	48	INDIAN RAILWAYS GSM-R (ALL CIRCLES)	Indian Raylways	Operational
405	51	Bharti Airtel Ltd (West Bengal)	Airtel	Operational
405	52	Bharti Airtel Ltd (Bihar)	Airtel	Operational
405	53	Bharti Airtel Ltd (Orissa)	Airtel	Operational
405	54	Bharti Airtel Ltd (Uttar Pradesh (East)	Airtel	Operational
405	55	Bharti Airtel Ltd (Jammu & Kashmir)	Airtel	Operational
405	56	Bharti Airtel Ltd (Assam)	Airtel	Operational
405	66	Vodafone (Uttar Pradesh (West)	Vodafone	Operational
405	67	Vodafone (West Bengal)	Vodafone	Operational
405	70	Idea (Bihar)	Idea	Operational
405	750	Vodafone (Jammu & Kashmir)	Vodafone	Operational
405	751	Vodafone (Assam)	Vodafone	Operational
405	752	Vodafone (Bihar)	Vodafone	Operational
405	753	Vodafone (Orissa)	Vodafone	Operational
405	754	Vodafone (Himachal Pradesh)	Vodafone	Operational
405	755	Vodafone (North East)	Vodafone	Operational
405	756	Vodafone (Madhya Pradesh)	Vodafone	Operational
405	799	Idea (Mumbai)	Idea	Operational
405	800	Aircel (Delhi)	Aircel	Operational
405	801	Aircel (Andhra Pradesh)	Aircel	Operational
405	802	Aircel (Gujarat)	Aircel	Operational
405	803	Aircel (Karnataka)	Aircel	Operational
405	804	Aircel (Maharashtra)	Aircel	Operational
405	805	Aircel (Mumbai)	Aircel	Operational
405	806	Aircel (Rajasthan)	Aircel	Operational
405	807	Aircel (Haryana)	Aircel	Operational
405	808	Aircel (Madhya Pradesh)	Aircel	Operational
405	809	Aircel (Kerala)	Aircel	Operational
405	810	Aircel (Uttar Pradesh (East)	Aircel	Operational
405	811	Aircel (Uttar Pradesh (West)	Aircel	Operational
405	812	Aircel (Punjab)	Aircel	Operational
405	813	Telenor Unitech (Haryana)	Uninor	Operational
405	814	Telenor Unitech (Himachal Pradesh)	Uninor	Operational
405	815	Telenor Unitech (Jammu & Kashmir)	Uninor	Operational
405	816	Telenor Unitech (Punjab)	Uninor	Operational
405	817	Telenor Unitech (Rajasthan)	Uninor	Operational
405	818	Telenor Unitech (Uttar Pradesh (West)	Uninor	Operational
405	819	Telenor Unitech (Andhra Pradesh)	Uninor	Operational
405	820	Telenor Unitech (Karnataka)	Uninor	Operational
405	821	Telenor Unitech (Kerala)	Uninor	Operational
405	822	Telenor Unitech (Kolkata)	Uninor	Operational
405	823	Videocon (Andhra Pradesh)	Videocon	Operational
405	824	Videocon (Assam)	Videocon	Operational
405	825	Videocon (Bihar)	Videocon	Operational
405	826	Videocon (Delhi)	Videocon	Operational
405	827	Videocon (Gujarat)	Videocon	Operational
405	828	Videocon (Haryana)	Videocon	Operational
405	829	Videocon (Himachal Pradesh)	Videocon	Operational
405	830	Videocon (Jammu & Kashmir)	Videocon	Operational
405	831	Videocon (Karnataka)	Videocon	Operational

405	832	Videocon (Kerala)	Videocon	Operational
405	833	Videocon (Kolkata)	Videocon	Operational
405	834	Videocon (Madhya Pradesh)	Videocon	Operational
405	835	Videocon (Maharashtra)	Videocon	Operational
405	836	Videocon (Mumbai)	Videocon	Operational
405	837	Videocon (North East)	Videocon	Operational
405	838	Videocon (Orissa)	Videocon	Operational
405	839	Videocon (Rajasthan)	Videocon	Operational
405	840	Videocon (Tamilnadu)	Videocon	Operational
405	841	Videocon (Uttar Pradesh (East)	Videocon	Operational
405	842	Videocon (Uttar Pradesh (West)	Videocon	Operational
405	843	Videocon (West Bengal)	Videocon	Operational
405	844	Telenor Unitech (Delhi)	Uninor	Operational
405	845	Idea (Assam)	Idea	Operational
405	846	Idea (Jammu & Kashmir)	Idea	Operational
405	848	Idea (Kolkata)	Idea	Operational
405	849	Idea (North East)	Idea	Operational
405	850	Idea (Orissa)	Idea	Operational
405	852	Idea (Tamilnadu)	Idea	Operational
405	853	Idea (West Bengal)	Idea	Operational
405	854	LOOP (Andhra Pradesh)	LOOP	Operational
405	855	LOOP (Assam)	LOOP	Operational
405	856	LOOP (Bihar)	LOOP	Operational
405	857	LOOP (Delhi)	LOOP	Operational
405	858	LOOP (Gujarat)	LOOP	Operational
405	859	LOOP (Haryana)	LOOP	Operational
405	860	LOOP (Himachal Pradesh)	LOOP	Operational
405	861	LOOP (Jammu & Kashmir)	LOOP	Operational
405	862	LOOP (Karnataka)	LOOP	Operational
405	863	LOOP (Kerala)	LOOP	Operational
405	864	LOOP (Kolkata)	LOOP	Operational
405	865	LOOP (Madhya Pradesh)	LOOP	Operational
405	866	LOOP (Maharashtra)	LOOP	Operational
405	867	LOOP (North East)	LOOP	Operational
405	868	LOOP (Orissa)	LOOP	Operational
405	869	LOOP (Punjab)	LOOP	Operational
405	870	LOOP (Rajasthan)	LOOP	Operational
405	871	LOOP (Tamilnadu)	LOOP	Operational
405	872	LOOP (Uttar Pradesh (East)	LOOP	Operational
405	873	LOOP (Uttar Pradesh (West)	LOOP	Operational
405	874	LOOP (West Bengal)	LOOP	Operational
405	875	Telenor Unitech (Assam)	Uninor	Operational
405	876	Telenor Unitech (Bihar)	Uninor	Operational
405	877	Telenor Unitech (North East)	Uninor	Operational
405	878	Telenor Unitech (Orissa)	Uninor	Operational
405	879	Telenor Unitech (Uttar Pradesh (East)	Uninor	Operational
405	880	Telenor Unitech (West Bengal)	Uninor	Operational
405	881	S TEL (Assam)	S TEL	Operational
405	882	S TEL (Bihar)	S TEL	Operational
405	883	S TEL (Himachal Pradesh)	S TEL	Operational
405	884	S TEL (Jammu & Kashmir)	S TEL	Operational
405	885	S TEL (North East)	S TEL	Operational
405	886	S TEL (Orissa)	S TEL	Operational
405	887	Sistema Shyam (Andhra Pradesh)	Sistema Shyam	Operational
405	888	Sistema Shyam (Assam)	Sistema Shyam	Operational
405	889	Sistema Shyam (Bihar)	Sistema Shyam	Operational

405	890	Sistema Shyam (Delhi)	Sistema Shyam	Operational
405	891	Sistema Shyam (Gujarat)	Sistema Shyam	Operational
405	892	Sistema Shyam (Haryana)	Sistema Shyam	Operational
405	893	Sistema Shyam (Himachal Pradesh)	Sistema Shyam	Operational
405	894	Sistema Shyam (Jammu & Kashmir)	Sistema Shyam	Operational
405	895	Sistema Shyam (Karnataka)	Sistema Shyam	Operational
405	896	Sistema Shyam (Kerala)	Sistema Shyam	Operational
405	897	Sistema Shyam (Kolkata)	Sistema Shyam	Operational
405	898	Sistema Shyam (Madhya Pradesh)	Sistema Shyam	Operational
405	899	Sistema Shyam (Maharashtra)	Sistema Shyam	Operational
405	900	Sistema Shyam (Mumbai)	Sistema Shyam	Operational
405	901	Sistema Shyam (North East)	Sistema Shyam	Operational
405	902	Sistema Shyam (Orissa)	Sistema Shyam	Operational
405	903	Sistema Shyam (Punjab)	Sistema Shyam	Operational
405	904	Sistema Shyam (Tamilnadu)	Sistema Shyam	Operational
405	905	Sistema Shyam (Uttar Pradesh (East)	Sistema Shyam	Operational
405	906	Sistema Shyam (Uttar Pradesh (West)	Sistema Shyam	Operational
405	907	Sistema Shyam (West Bengal)	Sistema Shyam	Operational
405	912	Etisalat DB (Andhra Pradesh)	Etisalat DB	Operational
405	913	Etisalat DB (Delhi)	Etisalat DB	Operational
405	914	Etisalat DB (Gujarat)	Etisalat DB	Operational
405	915	Etisalat DB (Haryana)	Etisalat DB	Operational
405	916	Etisalat DB (Karnataka)	Etisalat DB	Operational
405	917	Etisalat DB (Kerala)	Etisalat DB	Operational
405	918	Etisalat DB (Maharashtra)	Etisalat DB	Operational
405	919	Etisalat DB (Mumbai)	Etisalat DB	Operational
405	920	Etisalat DB (Punjab)	Etisalat DB	Operational
405	921	Etisalat DB (Rajasthan)	Etisalat DB	Operational
405	922	Etisalat DB (Tamilnadu)	Etisalat DB	Operational
405	923	Etisalat DB (Uttar Pradesh (East)	Etisalat DB	Operational
405	924	Etisalat DB (Uttar Pradesh (West)	Etisalat DB	Operational
405	925	Telenor Unitech (Tamilnadu)	Uninor	Operational
405	926	Telenor Unitech (Mumbai)	Uninor	Operational
405	927	Telenor Unitech (Gujarat)	Uninor	Operational
405	928	Telenor Unitech (Madhya Pradesh)	Uninor	Operational
405	929	Telenor Unitech (Maharashtra)	Uninor	Operational
405	930	Etisalat DB (Bihar)	Etisalat DB	Operational
405	931	Etisalat DB (Madhya Pradesh)	Etisalat DB	Operational
405	932	Videocon (Punjab)	Videocon	Operational

Source: http://mcclist.com/mobile-network-codes-country-codes.asp

Contact:
Dialogic
Hooghiemstraplein 33-36
3514 AX Utrecht
Tel. +31 (0)30 215 05 80
Fax +31 (0)30 215 05 95
www.dialogic.nl