Reducing International Roaming Call Costs with Multiple Mobile Phone Numbers

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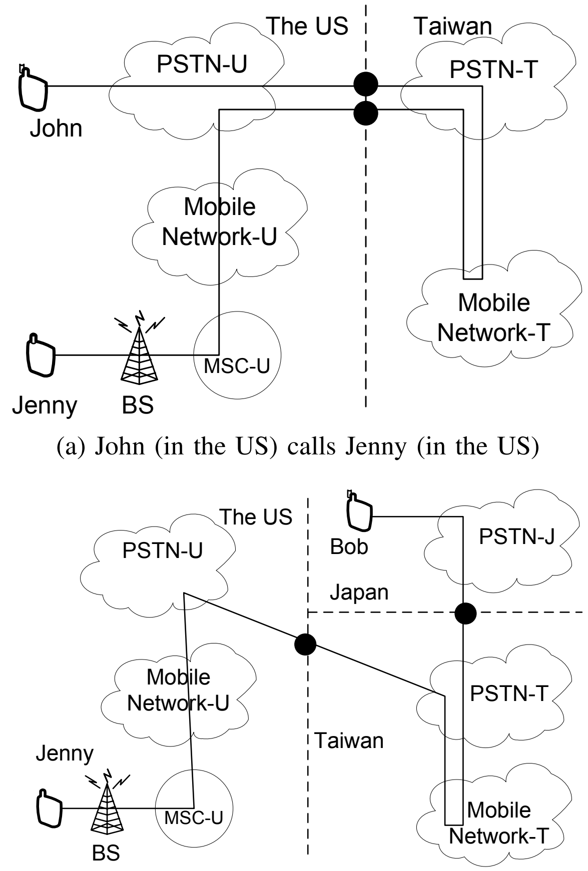
Abstract—**In the existing commercial mobile operation, call setup to an international roaming subscriber is indirectly routed through the home network of the subscriber, which results in the usage of two expensive international telephone trunks. Through multiple mobile phone number assignment, this letter proposes a novel approach that eliminates the non-necessarily international trunk usage, and effectively reduces the network costs for international roaming calls.**

Index Terms—**International roaming, mobile telecommunications service, mobility management, tromboning, voice over IP (VoIP).**

I. INTRODUCTION

A BUSINESS person Jenny travels between the US, Japan and Taiwan. Jenny subscribes to mobile phone service from a Taiwan mobile operator, and is assigned a mobile phone number `Mobile-T`. Suppose that Jenny visits the US, and her friend John calls her from the US. Following the standard 3GPP procedure exercised by all commercial telecommunications operators [1], the call is tromboningly routed from the US to Taiwan and then back to the US as illustrated in Fig. 1 (a), which results in two expensive international trunk usage (see the bullets in the figure). If Bob calls Jenny from Japan, then the call is indirectly routed from Japan to the US through Taiwan (Fig. 1 (b)).

To resolve this issue, Jenny may also subscribe to the US mobile service and is assigned another mobile phone number `Mobile-U`. Therefore, people in the US can dial `Mobile-U` to reach Jenny directly without the tromboning routing. The problem here is that the mobile service cannot be automatically switched between `Mobile-U` and `Mobile-T`. Unless John knows exactly where Jenny is, he is not sure which mobile phone number of Jenny should be dialed. In [2], we proposed the "single mobile phone number" (SMN) solution where Jenny is assigned a fixed telephone number for every country that Jenny frequently visits. A caller in country A can reach Jenny by dialing Jenny's fixed number of country A. With SMN, the tromboning call path issue is resolved. Jenny only needs to maintain a mobile phone number (say, from Taiwan), and have a fixed phone number for each of the countries she frequently visits. In this solution, the call setup signaling is still tromboning, and may be disconnected due to long setup time as in the 3GPP mechanism. In this letter, we show that if we assign Jenny a mobile and a fixed phone numbers for each country, then the tromboning call setup signaling can also be eliminated. This new solution is called the "multiple mobile phone number" (MMN) approach.



(a) John (in the US) calls Jenny (in the US)

(b) Bob (in Japan) calls Jenny (in the US)

Fig. 1. 3GPP call setup to international roaming subscriber.

II. THE MMN SOLUTION

In the MMN solution, Jenny is assigned a fixed and a mobile phone numbers in each of the countries she frequently visits. Such multiple phone number assignment is very common for international business people. The fixed phone numbers are distributed to the pubic, and the mobile phone numbers are used internally for MMN call setup. Suppose that Jenny uses her US mobile phone number `Mobile-U` when she visits the US. In the MMN solution, `Mobile-U` is called the *active number*, and all calls to Jenny (through dialing of the fixed phone numbers) are routed to `Mobile-U`. In this solution, the existing telecommunications network equipments are not

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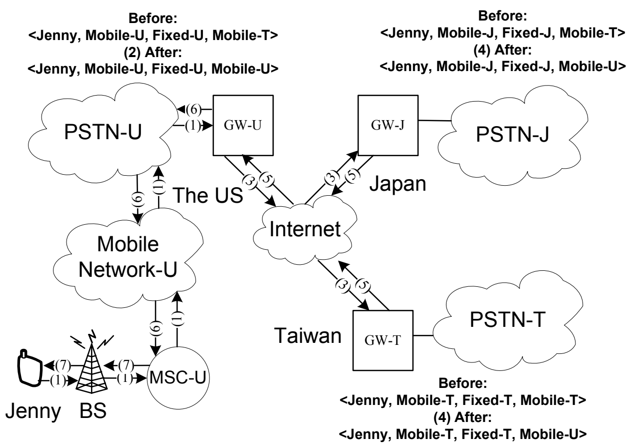


Fig. 2. The MMN architecture and the registration procedure.

modified. A new component called Public Switched Telephone Network (PSTN) Gateway (GW) is introduced. A PSTN GW is a Session Initiation Protocol (SIP)/Real-time Transport Protocol (RTP) server [2] that connects to the PSTN through leased lines, and is assigned a block of fixed phone numbers that are allocated to the MMN roaming subscribers. Jenny's fixed phone number Fixed-U, for example, is allocated from the phone number block of the US PSTN GW. Fixed-U does not connects to any fixed telephone set, but is used for routing to Mobile-U.

As shown in Fig. 2, a PSTN GW is deployed in each of the countries involved in the MMN solution.

A PSTN GW connects to the PSTN through Signaling System Number 7 (SS7) protocol, and connects to the Internet through the SIP/RTP protocols [3]. Every PSTN GW maintains a location database. In this database, every MMN roaming subscriber has a record of the format <Subscriber ID, L-M, L-F, A-M>. For example, if Jenny visits Taiwan, then Jenny's record in the US PSTN GW is

- **Subscriber ID field**: Jenny
- **L-M** (**L**ocal **M**obile phone number) **field**: Mobile-U
- **L-F** (**L**ocal **F**ixed phone number) **field**: Fixed-U
- **A-M** (**A**ctive **M**obile phone number) **field**: Mobile-T

Suppose that Jenny frequently visits the US, Japan and Taiwan. Let the PSTN gateways of the US, Japan and Taiwan be GW-U, GW-J and GW-T, respectively. When Jenny visits Taiwan, her location records in GW-U, GW-J and GW-T are <Jenny, Mobile-U, Fixed-U, Mobile-T>, <Jenny, Mobile-J, Fixed-J, Mobile-T> and <Jenny, Mobile-T, Fixed-T, Mobile-T>. Suppose that Jenny uses a standard WCDMA handset. In Taiwan, Jenny's handset is inserted the Taiwan SIM card, and Mobile-T is active; that is, all calls to Jenny are routed to Mobile-T (to be elaborated later). When Jenny moves from Taiwan to the US, she replaces the Taiwan SIM card by the US SIM card. Then her active number becomes Mobile-U. To ensure that all calls to Jenny are routed to Mobile-U, Jenny needs to manually perform the registration procedure by dialing the fixed telephone number Fixed-U. We will show how this procedure can be automatic later. The registration procedure is described as follows:

Step R.1. Jenny dials the number Fixed-U. The handset first connects to the base station (BS) and then the mobile switching center MSC-U. Based on the destination number Fixed-U, MSC-U routes the call to GW-U through the standard SS7 IAM message.

Step R.2. Based on the caller ID Mobile-U and the destination ID Fixed-U indicated in the IAM message, GW-U identifies that Jenny visits the US, and sets the A-M field of Jenny's location record as "Mobile-U".

Step R.3. GW-U then sends the SIP REGISTER message to GW-T in Taiwan through the Internet.

Step R.4. When GW-T receives the SIP REGISTER message, it updates the A-M field of Jenny's location record as "Mobile-U".

Step R.5. GW-T returns a SIP 200 OK message to GW-U. Steps R.3-R.5 are also exercised between GW-U and GW-J in Japan to modify Jenny's location record in GW-J.

Step R.6. GW-U replies an SS7 ACM message to MSC-U. The flag value of the ACM message is utilized to indicate the status of the registration procedure. For example, we may set the busy flag if the registration is successful, or the "wrong number" flag for registration failure.

Step R.7. Upon receipt of the ACM message with the busy flag, MSC-U informs the handset that the destination is busy, and the handset knows that the registration is successful. At this point, GW-U, GW-T and GW-J know that Jenny's active number is Mobile-U.

The above registration procedure exchanges standard SS7 and SIP messages without modifying the existing telecommunications equipments. The trick we play is to utilize the standard IAM and ACM message exchange for registration (which is free of charge). We assume that Jenny never dials Fixed-U except for registration. This assumption is reasonable because both Fixed-U and Mobile-U map to the same handset, and Jenny is not supposed to dial to herself.

After Jenny arrived at the US, John in the US calls Jenny. The call setup procedure works as follows (see Fig. 3 (a)):

Step U.1. John dials the number Fixed-U. The originating switch of John (i.e., Switch-U) issues an IAM message to GW-U. GW-U uses Fixed-U to retrieve the location table, and obtains Jenny's active number Mobile-U.

Step U.2. GW-U replaces the IAM destination ID by Mobile-U, and forwards this message to MSC-U, the target MSC of Jenny's handset.

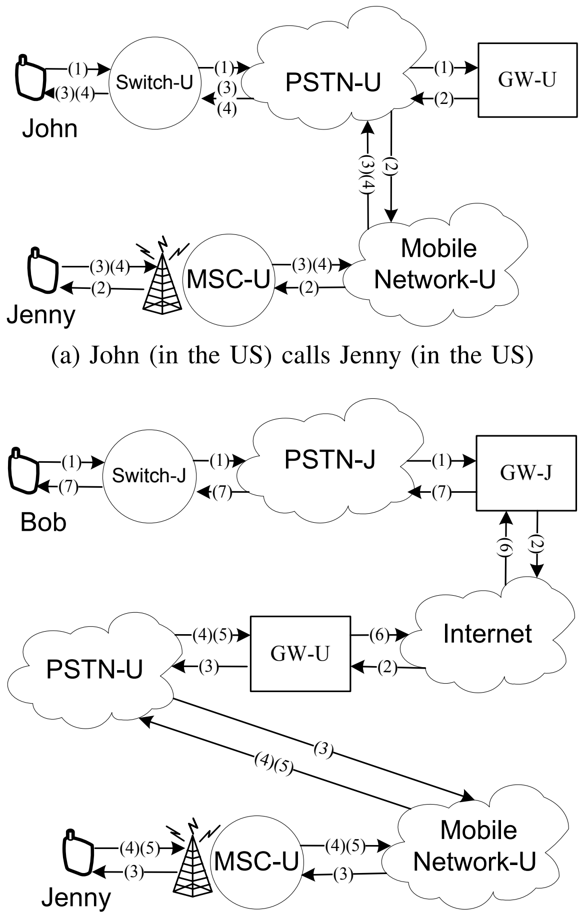
Step U.3. When Jenny's handset is paged, an SS7 ACM message is sent from MSC-U to Switch-U.

Step U.4. When Jenny picks up the phone, an SS7 ANM message is sent from MSC-U to Switch-U. The call is connected.

In Fig. 3 (a), the tromboning signaling/voice paths in Fig. 1 (a) are eliminated.

After Jenny arrived at the US, if Bob in Japan calls Jenny, the call setup procedure works as follows (see Fig. 3 (b)):

Step J.1. Bob dials the number Fixed-J. The originating switch of Bob (Switch-J in Japan) issues an IAM message to GW-J. GW-J uses Fixed-J to retrieve the location table, and obtains the number Mobile-U from the



(a) John (in the US) calls Jenny (in the US)

(b) Bob (in Japan) calls Jenny (in the US)

Fig. 3. MMN call setup to international roaming subscriber.

corresponding A-M field.

Step J.2. From the country code of `Mobile-U`, GW-J learns that Jenny is in the US. Therefore, it sends the SIP INVITE message to GW-U through the Internet.

Step J.3. According to the SIP destination ID `Mobile-U`, GW-U sends the IAM message to MSC-U.

Step J.4. When Jenny's handset is paged, an SS7 ACM message is sent from MSC-U to GW-U.

Step J.5. When Jenny picks up the phone, an SS7 ANM message is sent from the MSC-U to GW-U.

Step J.6. GW-U sends SIP 200 OK to GW-J.

Step J.7. GW-J sends SS7 ACM and ANM to Switch-J, and the call is connected.

In Fig. 3 (b), the indirect routing of the 3GPP procedure (through Taiwan; see Fig. 1 (b)) is avoided.

III. Discussion and Summary

This letter proposed a novel solution "Multiple Mobile Phone Number" (MMN) that can effectively reduce the costs of call setup for international roaming subscribers. Several issues merit further discussions:

- Phone Number Assignment: In the 3GPP solution, a roaming subscriber only uses one mobile phone number. In MMN, a roaming subscriber is assigned a fixed and a mobile phone numbers for each country. We note that in both SMN and MMN, these telephone numbers can be automatically assigned by the solution providers through the "business service package".
- SIM card: If GSM/WCDMA mobile service is considered, then we need one SIM card for each mobile phone number (if the numbers are assigned by different mobile operators). When the subscriber moves to another country, he/she needs to replace the SIM card of the handset. Recently, there is a *universal card* solution where various SIM cards can be burned into one card. This solution is commercially available and can be effectively used in the MMN approach.
- Registration: The registration procedures for MMN can be manually initiated by the subscriber when he/she visits a new country. The registration can also be conducted automatically by the handset as described in [2]. In this case, we need to install a simple software into the handset, which can be a Java program for a standard smart phone that is commercially available.

As a final remark, MMN is pending US and ROC patents.

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