國立交通大學

資訊科學與工程研究所

碩 士 論 文

以 SIP 為基礎的行動管理之研究

A Study of Terminal Mobility Management in SIP

研 究 生：任珍妮

指導教授：曾憲雄 教授

中華民國九十五年六月

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摘要

隨著日益普及的多功能行動裝置以及搭載於其上各式各樣推陳出新的即時應用與服務之快速發展，無縫的終端移動支援顯然成為行動管理當中最重要的需求。從跨網域移動行為的角度來觀察，無線網路環境底下的通話初始協定（Session Initiation Protocol，以下簡稱 SIP）存在了封包遺失和通話失敗兩項重要的議題，嚴重地造成通話的服務品質下降。然而，這兩大關鍵議題分別起因於以下三種問題的發生：（1）通話過程中發生移動；（2）所歸屬之網域行動資料庫發生異常；（3）通話之前發生移動。在這篇論文中，我們提出了一個系統化的行動解決方法，藉由移動用戶行為探勘所萃取出來的移動樣式以達到移動快速（延遲時間縮短）與平滑（通訊維持流暢）的目的。我們將此方法命名為 STAMP。在本文中，移動樣式被賦予 IP 網路封包交換的特性，使移動樣式能夠適時地輔助封包亦或通話請求訊息轉送至使用者目前所在的位置。經由 7 個模組所建構而成的 4 個階段，”STAMP”將透過兼具效率與效力的序列樣式探勘過程，依循各個問題專屬的最佳路徑，適性化地解決上述的三種問題。最重要的是，我們所設計的方法提升了 SIP 即時服務的品質。另外，更進一步將我們的方法 STAMP 在通訊信令所發生延遲、中斷的時間與相關文獻所提出來的方法 Shadow Registration 做比較與分析。

關鍵字：通話初始協定、終端移動、序列樣式探勘、STAMP

A Study of Terminal Mobility Management in SIP

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Abstract

With rapid development of widespread multi-function mobile devices and a variety of real-time services, seamless terminal mobility support becomes the most significant requirement in mobility management. Based on Session Initiation Protocol (SIP) over Wireless LAN, there exist two critical issues from the perspective of interdomain handoff, including packet loss and call failure, greatly diminishing the quality of service. These issues arise from *Mid-Call Mobility Problem*, *Home Registrar Failure Restoration Problem*, and *Pre-Call Mobility Problem*, respectively. In this article, we propose a systematic mobility scheme, **"STAMP"**, to achieve not only fast handoff but also smooth handoff, by means of extracted knowledge from mobile user behavior mining. The moving pattern here is endowed with the nature of IP network as an assistant to forward packets timely to the right place. Through 4 phases composed of 7 modules, each of the three problems is solved adaptively via an exclusive path in "STAMP" with effective and efficient sequential pattern mining processes. Above all, we enhance the quality of real-time SIP services. We also analytically compare the delay and disruption time for signaling associated with Shadow Registration and our solution.

Keywords: SIP, terminal mobility, sequential pattern mining, STAMP

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This thesis can be ascribed to several people. Above all, the first person is my advisor, Prof. Shian-Shyong Tseng (曾憲雄), who provided an interactive, enthusiastic, and critical discussion atmosphere. He insightfully guided me through all the difficulties in my thesis development. It is really hard to convey the most sincere thanks to my advisor in words.

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Jenny Ren

2006/6/16

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Chapter 1.
Introduction

1.1 Terminal Mobility

As the Wireless LAN deployment becomes more and more widespread along with a variety of novel multi-functional mobile devices springing up, most portable terminals have one goal in common, which is to provide users with terminal mobility support [1], [6], [11], [12], [13], [15]. ***Terminal Mobility*** means whenever a user changes a different base station under PCS network or different adjoining access point under IP network, it is supposed to keep both service continuity and availability. The word *service continuity* denotes the need of maintaining any ongoing sessions, while *service availability* implies the need of being reachable to other hosts.

Among all applications upon portable devices, particularly real time mobility services such as voice over IP and video streaming, seamless mobility is significant and strictly required [3], [4], [7]. Although the real time services transfer data in small packet size, each packet must be delivered continuously and immediately. To achieve ***Seamless Mobility***, fast handoff and smooth handoff are two concurrent indices to be met. *Fast handoff* indicates that duration of handoff latency should be reduced to be within a tolerable range; *smooth handoff* implies that the number of packet loss should be diminished to an insusceptible interruption. In brief, seamless terminal mobility is an essential requirement for all portable terminals with real time mobility services.

1.2 SIP

Why we focus our research on SIP specifically? Referring to Figure 1.1, this diagram illustrates the influential role of SIP from two aspects. The x-axis demonstrates various protocols of VoIP call signaling. The time each protocol proposed is increasingly up to date along with the x-axis. On the other hand, the y-axis displays several IP mobility protocols layer by layer in OSI stack. For instance, SIP locates at the highest layer, namely, application layer.

From x-axis, SIP overwhelms H.323 in that SIP is an XML-based call signaling protocol, which has benefits on readability, simplicity, interoperability, and flexibility. From y-axis, SIP advantages over Mobile IP because SIP is an application-layered mobility protocol, which is much easier to be deployed without too many changes on legacy hardware.

The industry also has a great tendency towards SIP. e.g., Microsoft Messenger is already SIP-based service; however, Skype and Google Talk continually promise they are going to follow SIP in the near future.

As mentioned above, SIP is blooming no matter from technical point of views or from the market trend. That's the motive why we discuss terminal mobility issues on SIP.

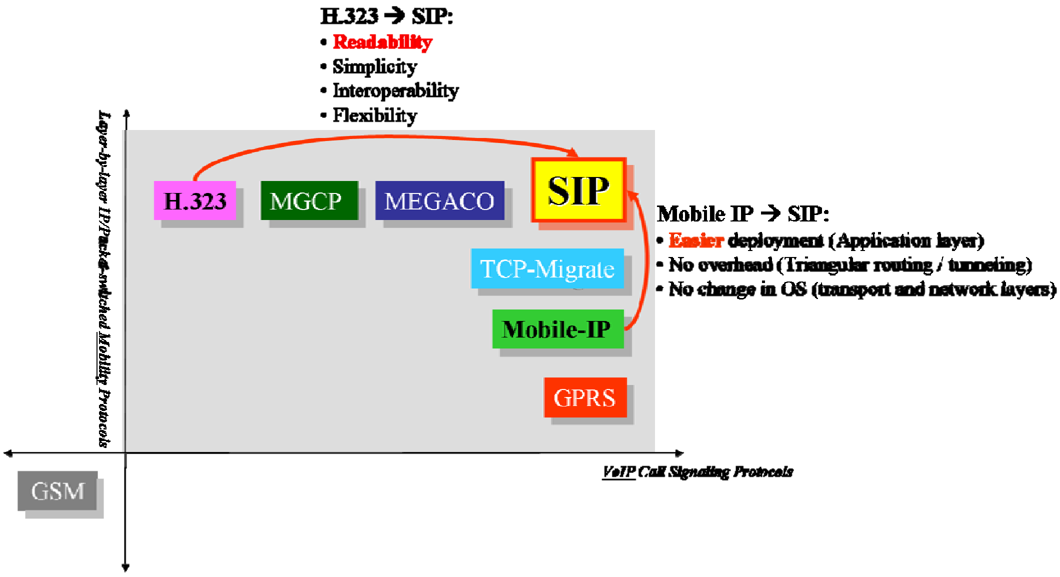

Figure 1.1 : Major Technologies in VoIP and Mobility Support

1.3 Problems in SIP

According to most researches on SIP mobility, there are some well-known phenomena, inclusive of Mid-Call Mobility and Pre-Call Mobility [2], [6], [11], [12], [15]. Beyond these familiar phenomena, we especially observe one common ground between SIP and conventional PCS network — they both have hierarchical mobility databases, to which periodical backup is indispensable. Whereas the Mobility Database Restoration has become a notable issue of concern in PCS [5], we can draw lesson from PCS and take action in SIP in the early stages to avoid the occurrence of similar disaster.

Problem1. Mid-Call Mobility (MCM)

- **Problem Definition**

Mid-Call Mobility Problem is that *"as soon as the mobile host moves to a different domain during the established session, the mobile host should* *re-INVITE the corresponding host to keep service continuity"*.

Thus, every time the mobile host moves to a neighboring domain while obtaining a new IP address, it sends re-INVITE to notify the corresponding host with new destination address so that up-coming traffic can get forwarded to the current location of the mobile. However, if the mobile host happens to be extremely far away from the corresponding host with limited wireless bandwidth, there could be considerable losses of packets owing to the delay of re-INVITE, which is named as "MCM Problem". i.e., for people seeing digital TV program or talking via VoIP service while moving, it's annoying that service interruption (i.e., packet loss) occurs in the process of handoff because signaling message (i.e., re-INVITE) get delayed, as depicted in Figure 1.2.

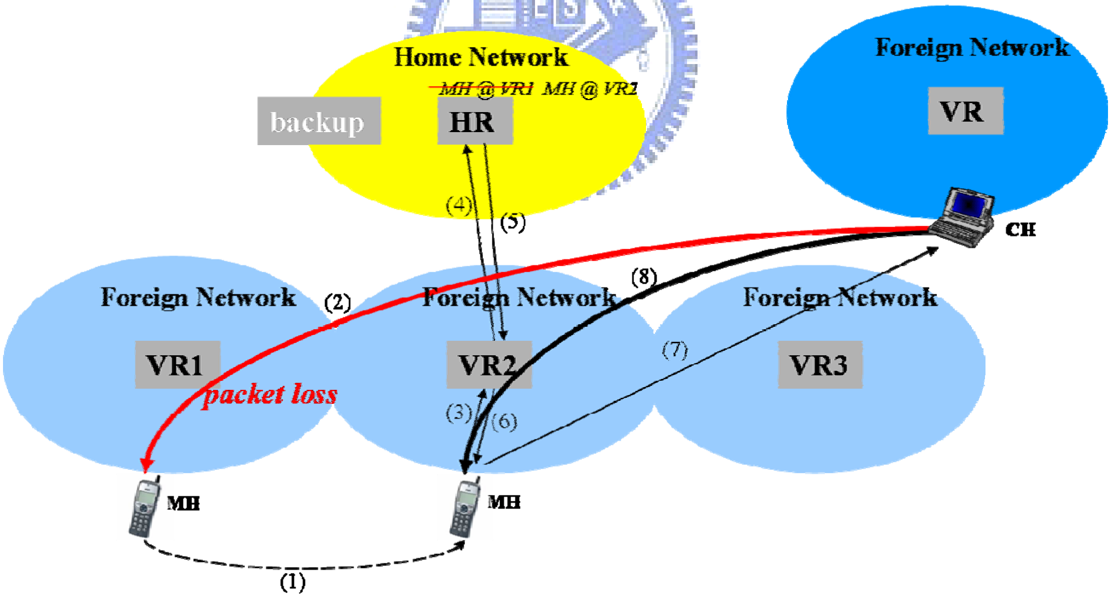

Figure 1.2 : Scenario of Mid-Call Mobility (MCM) Problem

As shown in Figure 1.3, MCM Problem physically means *"Packet Loss due to handoff latency of re-INVITE message"*.

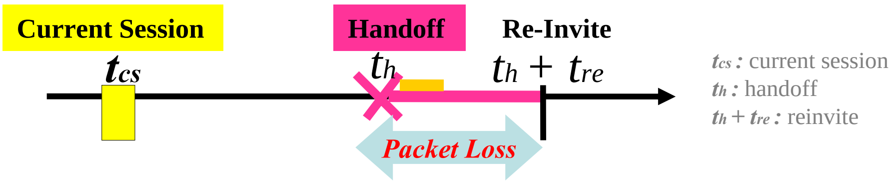

Figure 1.3 : Time-Flow Definition of Mid-Call Mobility (MCM) Problem

Problem2. Home Registrar Failure Restoration

- **Problem Definition**

Home Registrar Failure Restoration Problem is that *"Mobility Databases must maintain the current location information of users to guarantee continuous service availability to users. Malfunction of mobility databases may cause some location information to be lost. As a result, without any explicit restoration procedure, incoming calls to users could be rejected"* .

Hence, when the mobile host stays in some newly-moved domain for a long time, especially it's exactly not the same as where rescued from backup, there could be a very long duration of call failure owing to the HRFR Problem. Take one of the restoration schemes, Neuro-Fuzzy Inference System [5], for example. It learns the movement patterns of users in failure-free operations; after a failure, an inference process is initiated and the users' future location is predicted. This problem may occur in SIP at Home Registrar as if the disaster in PCS. Once this problem happens, call requests or other services may fail. Figure 1.4 illustrates this scenario in SIP.

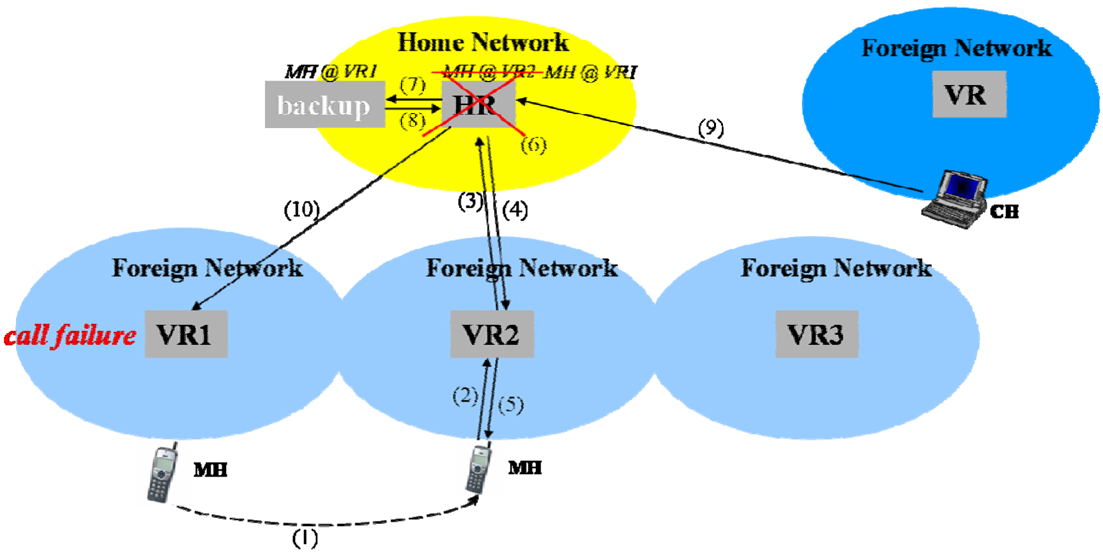

Figure 1.4 : Scenario of Home Registrar Failure Restoration (HRFR) Problem

As shown in Figure 1.5, HRFR Problem physically means "*Call Failure because of obsolete information resulting from Home Registrar (a mobility database in SIP) Failure*".

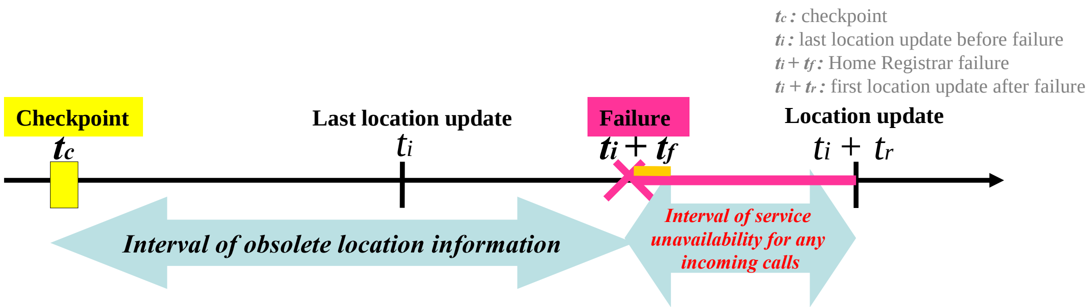

Figure 1.5 : Time-Flow Definition of Home Registrar Failure Restoration (HRFR) Problem

Problem3. Pre-Call Mobility

- **Problem Definition**

Pre-Call Mobility is that *"once the mobile host moves to a new domain, registration execution is required from mobile host to home network. Thus, each call request can be redirected to the current location of mobile host for service availability"*.

In other words, based on the hierarchical registration mechanism, PCM Problem could raise higher probability of call failure interval when mobile host moves far away from its home network. However, it's a big problem while being caller-sensitive on the one hand but callee-imperceptible on the other hand. i.e., for fast moving users such as drivers, they may actually desire driving direction and instruction via VoiceXML-based Web browsing or traffic reports. What if the registration can't be completed before the arrival of call requests at the home registrar or information on demand provided by location-based service? Call or service failure must occur. Figure 1.6 depicts the scenario of PCM Problem.

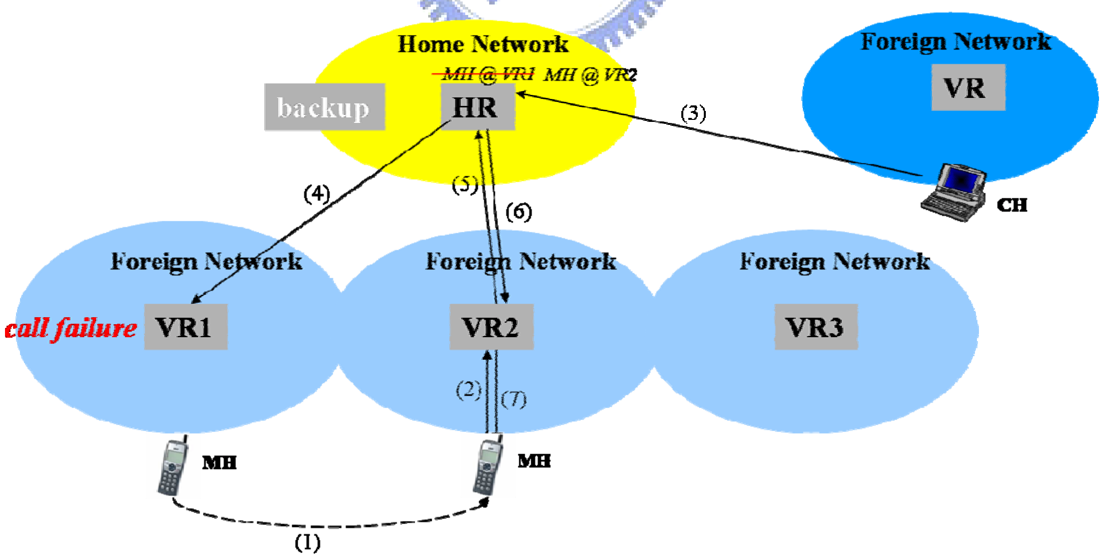

Figure 1.6 : Scenario of Pre-Call Mobility (PCM) Problem

As shown in Figure 1.7, PCM Problem explicitly means *"Call Failure owing to handoff latency of re-RGISITER message"*.

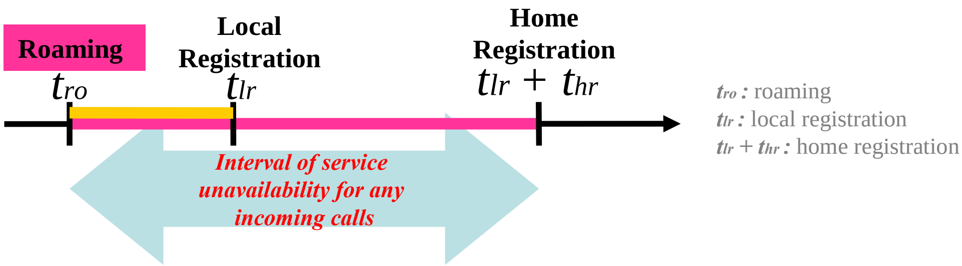

Figure 1.7 : Time-Flow Definition of Pre-Call Mobility (PCM) Problem

Overall, the significant issues in real-time traffic over wireless networks are fast handoff, low latency, and high bandwidth utilization. Consequently, Seamless Mobility is proved to be the core target on the three problems proposed. Our main theme here is to devise an approach to achieve both fast handoff and smooth handoff for the three problems mentioned above so as to support seamless terminal mobility in SIP-based VoIP services.

Chapter 2.
Related Work

From a comprehensive survey of Terminal Mobility Management in SIP over WLAN, most literatures show effort on the 1st (MCM) Problem. Since the MCM problem is most easily and frequently perceived by users, it is in urgent need of applicable solutions. The followings are two primary measures taken to solve the MCM Problem in SIP. The first approach in [7] is "Shadow Registration", which aims at fast handoff for Inter-domain Mobility by reducing handoff latency. The second approach in [3] is "RTP Translator", which targets at smooth handoff for Intra-domain Mobility by avoiding packet loss.

2.1 Shadow Registration

- **Preliminary:**

  The Mid-Call Mobility Problem discussed in [7] is based on the SIP architecture displayed in Figure 2.1. The terms *VR* and *HR* stand for Visited Registrar and Home Registrar; meanwhile, *AAAF* and *AAAH* means Foreign AAA Server and Home AAA Server. Before initiating the SIP session by sending the INVITE message to the Corresponding Node (CN), the Mobile Node (MN) in a visited network should finish the complete registration, as depicted in Figure 2.2.

- **Assumption:**

  The MN happens to be far away from its Home Network with some moves.

- **Cause & Effect:**

  The signaling for the Inter-domain handoff takes longer time and larger traffic than the Intra-domain handoff, resulting in noticeable disruption in VOIP sessions.

- **Solution:**

The *security association (SA)* between the MN and the AAA server in neighboring domains *is established a priori* before the actual handoff occurs. The signaling messages are shown in Figure 2.3.

Thus, once MN hands off to a neighboring domain, the registration request is processed locally within that domain without going all the way to the MN's AAAH. As a whole, Shadow Registration totally minimizes the handoff latency by $2(t_h - t_f)$ in Figure 2.4.

- **Comment:**

However, this article doesn't improve Smooth Handoff actively; furthermore, it should not establish SA with all the neighboring domains since SA might be considered as confidential information for mobile users.

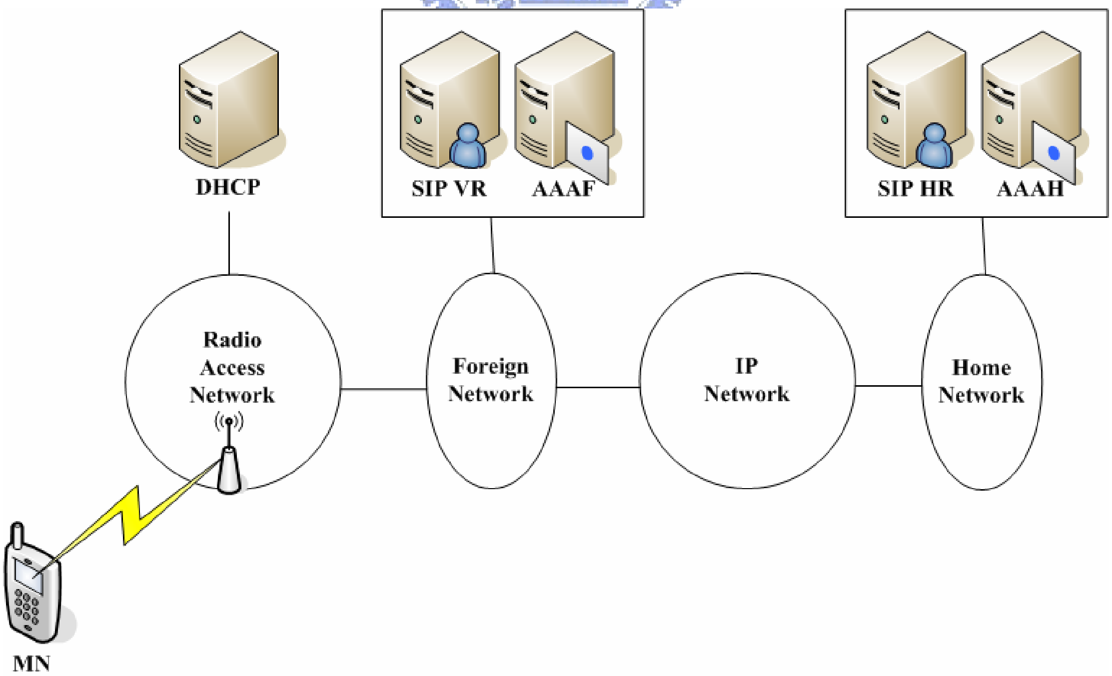

Figure 2.1 : SIP Architecture

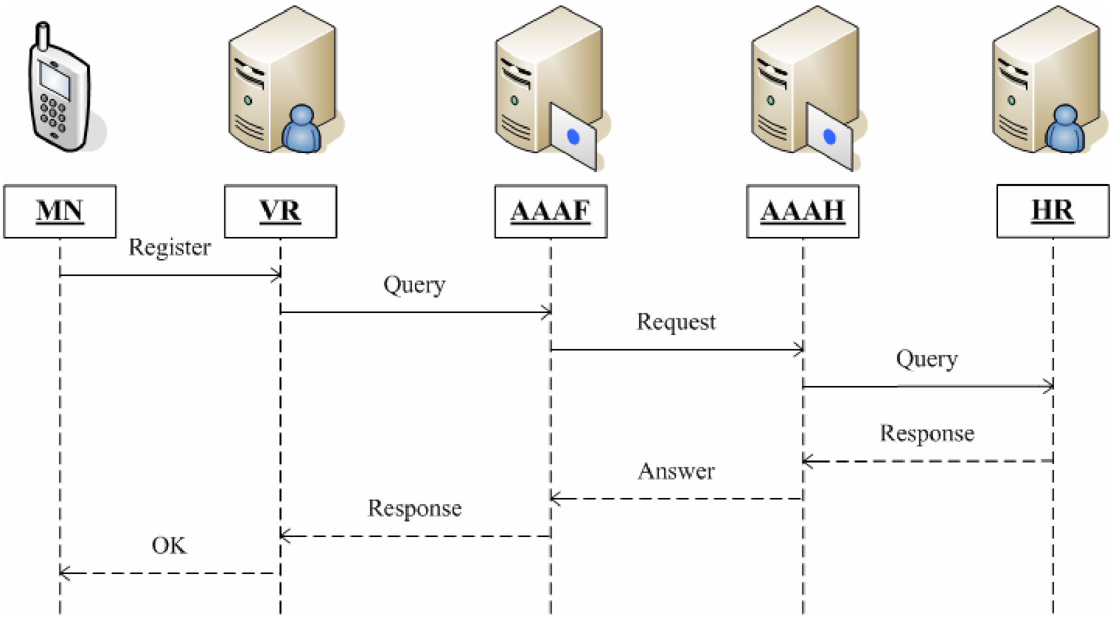

Figure 2.2 : SIP Registration

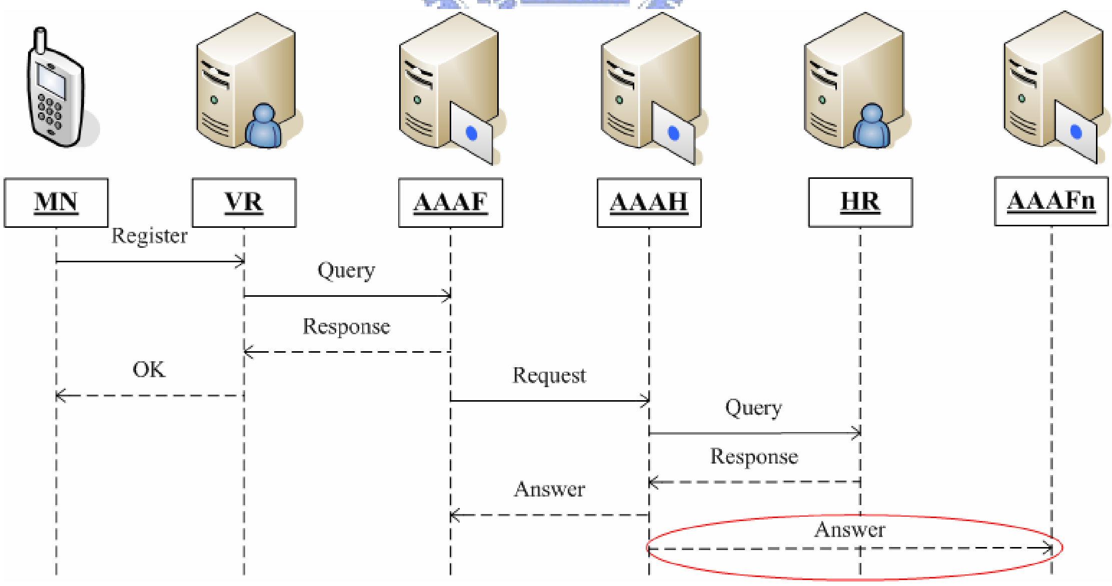

Figure 2.3 : SIP Inter-domain Handoff with Shadow Registration

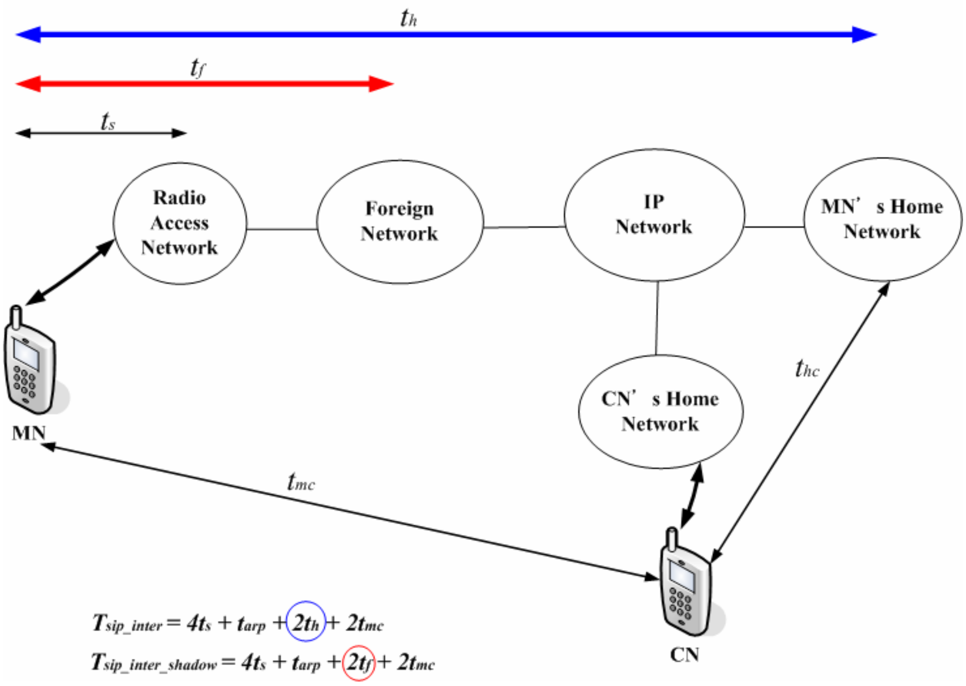

Figure 2.4 : SIP Inter-domain Mobility using Shadow Registration: A Mathematical Analysis Model

2.2 RTP Translator

- **Preliminary:**

Visited domains usually consist of several subnets. Whenever the Mobile Host (MH) moves to a new subnet, it sends a re-INVITE to the Corresponding Host (CH) with its new address. As a result, the new traffic gets forwarded to the new destination of the MH, as shown in Figure 2.5. However, the SIP re-INVITE message may get delayed owing to the distance between MH and CH as well as congestion in relation to the routing in the network. Therefore, during this period, the transient traffic is not received by MH until CH gets the re-INVITE message.

- **Assumption:**

MH happens to be far away from CH with some moves.

- **Cause & Effect:**

The re-INVITE request gets delayed due to path length or congestion so that it takes a long time before the data from CH gets redirected to the new address, resulting in transient data loss.

- **Solution:**

Utilize ***RTP translator*** to intercept and forward transient packet. RT1, RT2, and RT3 in Figure 2.6 are RTP translators in the respective subnets. The RTP translator in each subnet forwards the traffic associated with one IP address/port number to another IP address/port number within the same domain until the new data comes from the CH. Figure 2.7 illustrates the flow diagram for the RTP translator based fast-handoff approach.

In transit packets can be redirected to a unicast or multicast address based on the movement pattern of the mobiles and usage scenario.

- **Comment:**

On the one hand, this thesis focuses on Intra-domain handoff only (while Inter-domain handoff suffer much longer disruption); on the other hand, it doesn't show what the movement patterns look like and how/when to use these patterns in whatever scenarios.

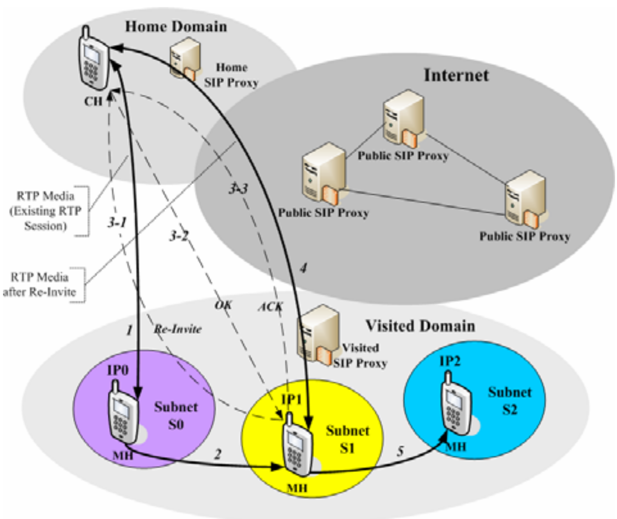

Figure 2.5 : Motivation for a SIP-based fast handoff applicability

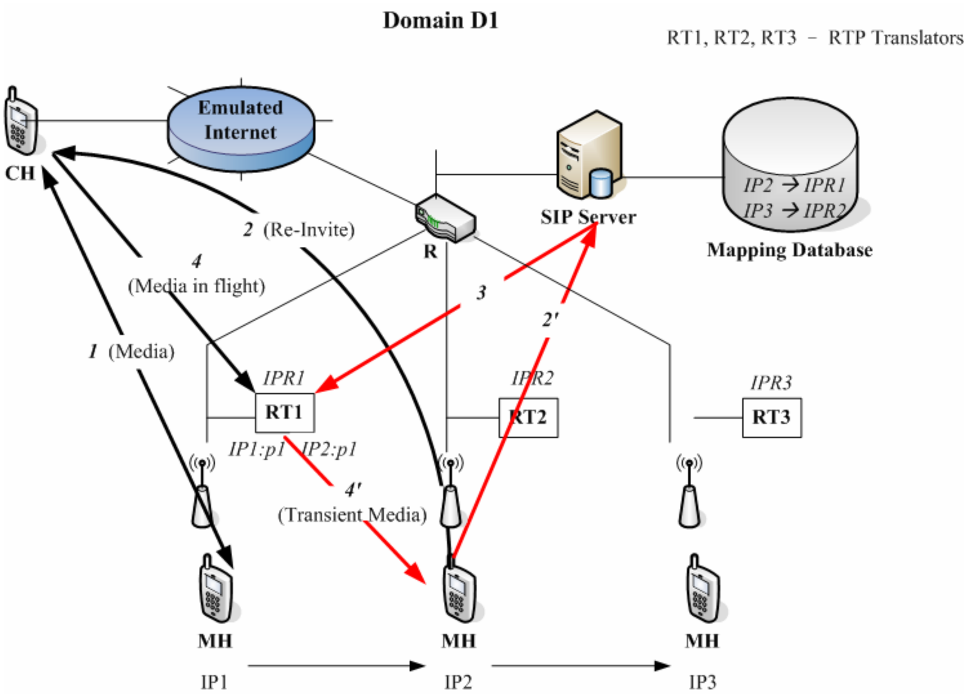

Figure 2.6 : RTP translator based fast-handoff

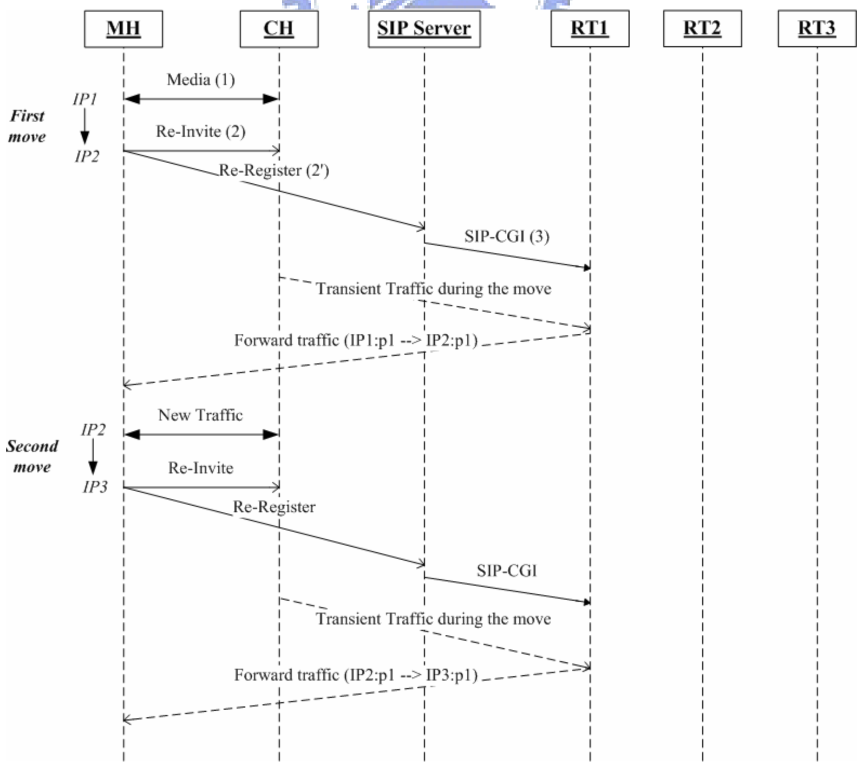

Figure 2.7 : Fast-handoff Flow

Chapter 3.
Methodology

Rapid growth of the wireless technology and mobile devices plus the emerging market on SIP applications have drawn greater significance these days on how to provide real-time services with seamless terminal mobility support. However, the following three issues show great concern in pursuing seamless mobility in SIP: 1. Packet Loss due to handoff latency of re-INVITE message in Mid-Call Mobility (MCM) Problem. 2. Call Failure because of obsolete information resulting from Home Registrar, a mobility database in SIP, Failure Restoration (HRFR) Problem. 3. Call Failure owing to handoff latency of re-RGISITER message in Pre-Call Mobility (PCM) Problem. As a result, how to achieve SIP-based seamless inter-domain mobility over Wireless LAN is imperative and to be solved on edge. Accordingly, we propose a systematic **Sequential Terminal Mobility Pattern Mining and Predicting** approach, called **STAMP**, in this chapter.

3.1 Motivation

Basically, moving pattern is already in widespread use in mobile computing environment [8], [14], [15], especially for optimizing the data allocation algorithm in conventional PCS network in the literatures [9], [10]. The results in [9] minimize the occurrences of costly remote accesses by incremental mining to exploit frequent user moving patterns. Moreover, Local-Optimized and Global-Optimized data allocation algorithms are developed respectively for individual mobile user and all mobile users in [10]. So far, as we know, there are no studies bringing “moving pattern” concept into SIP domain for terminal mobility yet. Moreover, the fact that

SIP operates over IP network, which is characterized by packet switching, gives moving pattern a different role in the pursuit of seamless mobility in SIP.

That is to say, rather than data allocation for fast handoff in PCS network only, moving pattern can further maneuver the feature of IP network to reduce packet loss via packet redirection for smooth handoff in SIP as well. One related work, RTP Translator, did take the advantage of packet switching even though it focuses on the mobility within one domain. However, Shadow Registration didn't take the advantage at all.

As a whole, with moving pattern, we can predict each mobile user's moving portfolio in advance. Based on the knowledge, on the one hand, packets or call requests will be forwarded to where the mobile user extremely likely to be, regarding Packet Loss in MCM Problem and Call Failure in PCM Problem. On the other hand, current locations will be recovered actively as complete as possible for Call Failure in HRFR Problem.

3.2 Idea & Goal

As the difficulty depends on which approach is most applicable to meet our case, we came up with some idea of choosing the most appropriate manner to solve these problems. So, here comes the heuristic, inferring which technology will meet our problems.

Heuristic: "Finding frequent patterns as long as possible".

Strictly speaking, the term "pattern" here represents "moving pattern". Consequently, the heuristic emphasizes: the longer the frequent pattern, the more irrefutable our prediction. Namely, longer prefix of rule contributes to greater accuracy and recall. Thus, the heuristic illuminates the axis of our methodology.

Figure 3.1 shows the WLAN topology in NCTU. Based on the predefined minimum support＝2, suppose Jenny has several patterns, *"LIB→ES"* with support ＝4, *"LIB→Dorm F2"* with support＝8, *"EC, LIB→ES"* with support＝3. And, if Jenny has already followed the path *"EC→LIB"*, and is currently at *"LIB"* then we will predict *"ES"* other than *"Dorm F2"* since the pattern *"EC, LIB→ES"* is not only large but also with longer prefix. If we only take the length-2 patterns into consideration, the probability Jenny heads for *"ES"* is $\boldsymbol{P(ES \mid LIB)} = \frac{4}{P(LIB)}$ while the probability for *"Dorm F2"* is $\boldsymbol{P(F2 \mid LIB)} = \frac{8}{P(LIB)}$. However, if we take the length-3 patterns into account, we can deduce that *"EC, LIB→Dorm F2"* is smaller than 2, the minimum support. As a result, the length-3 pattern *"EC, LIB→ES"* definitely has greater support than the non-pattern *"EC, LIB→Dorm F2"* ,even though the length-2 pattern *"LIB→Dorm F2"* has much greater support (support＝8) than *"LIB→ES"* (support＝4). Evidently, $\boldsymbol{P(ES \mid EC \rightarrow LIB) > P(F2 \mid EC \rightarrow LIB)}$ means the next step has higher probability to be *"ES"* other than *"Dorm F2"* under the same condition (i.e., Jenny has already moved from EC to LIB). In addition, the length-3 patterns contain more complete, even intact information than the length-2 patterns. After all, the longer the patterns, the higher priority they have. According to this heuristic, Sequential Pattern Mining is used as the core technology.

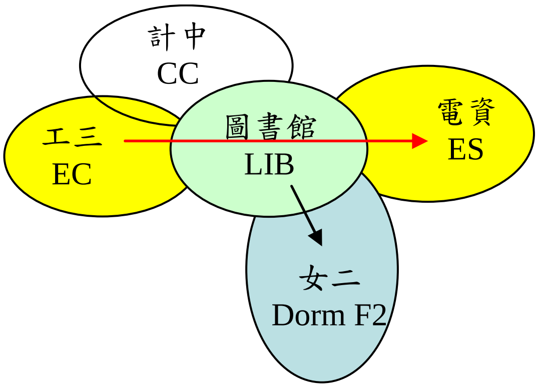

Figure 3.1：Simulated WLAN topology in NCTU. Each ellipse symbolizes a domain under academic network.

Goal:

Hence, our goal is to achieve fast handoff and smooth handoff in SIP-based Inter-domain Terminal Mobility over WLAN by utilizing the knowledge from mining results. Briefly, with Sequential Pattern Mining, Moving Pattern helps seamless mobility in SIP.

Contributions:

Above all, our contributions are “novel moving pattern usage”, “unprecedented mechanism”, and “complete solution”, primarily in three aspects. First, we take moving pattern for a novel role which helps packet redirection but not data allocation. Furthermore, we design three unprecedented activation strategies suitable for each problem. Lastly, we propose a total solution for the whole three problems systematically.

3.3 Moving Pattern & Calling Pattern

Seeing that we decide to use Sequential Pattern Mining as the key technology, inevitably, we are supposed to give a clear explanation of what kind of pattern will be explored. Once the pattern is explicitly defined, we are able to devise the mining methodology in detail. Hence, the following paragraph firstly describes the pattern in itself. Next, the relation between patterns will be explained. Nevertheless, before going to the pattern definition, we should take a look at the predecessor of moving pattern and calling pattern; that is, moving sequence and calling sequence.

Definition 1: Moving Sequence & Calling Sequence.

Moving Sequence is the trajectory where one mobile user moves within a reasonable time interval, denoted as $<X_1, X_2, \ldots, X_m>$, where each X_i represents one of the domains on the network topology; **Calling Sequence** is the path one mobile user moves during the same call or session, denoted as $<X_1, X_2, \ldots, X_k>$. Furthermore, a Calling Sequence is a subsequence of some Moving Sequence. The details are given in Definition 2 in Section 3.3 as well as Lemma 2 in Section 4.2.

Definition 2: Sub-sequence Relation.

- **Property 2.1.** **<u>Consecutive Subsequence</u>:** Assume there are two sequences $X=<x_1, x_2, \ldots, x_m>$ and $Y=<y_1, y_2, \ldots, y_n>$, X is a Consecutive Subsequence of Y $\Leftrightarrow \exists$ integers i and k, $0 \leqq i \leqq n-k \ni \forall k, 1 \leqq k \leqq m, x_k=y_{i+k}$.
  - ex: x is consecutive sub-sequence of y $\Leftrightarrow$ $x=<a, b, c>$, $y=<i, m, \underline{a}, \underline{b}, \underline{c}, f, g>$ rather than $x=<a, b, c>$, $y=<i, m, \underline{a}, \underline{b}, f, g, \underline{c}>$ because we care about what comes next immediately, but not what comes several after. Namely, what really counts is the next move at once.

Definition 3: Moving Pattern & Calling Pattern.

Moving Pattern is the track, where one mobile user *frequently* moves, denoted as $<X_1, X_2, \ldots, X_i>$. E.g., Jenny has the moving pattern *"<EC, LIB, ES>"*, regarded that she frequently moves from EC to LIB, and then to ES in return. Comparatively, **Calling Pattern** is the route, where one mobile user *usually* travels during a call session, denoted the same as Moving Pattern. E.g., Jenny has the calling pattern *"<LIB, Dorm F2>"* implies that she usually moves on the route while calling. Moreover, there are two common properties for both moving pattern and calling pattern.

- **Property 3.1.** **<u>Atomic</u>:** Either the Moving Pattern or the Calling

Pattern is an ordered list of items rather than itemsets.

- ex: The pattern such as *<(EC),(LIB),(ES)>* rather than *<(toast milk),(apple)>* meets the Atomic Property since people can concurrently buy different things, but can never show up at different places simultaneously.
- Since Atomic property exists, we simplify the notation of our pattern as *<EC, LIB, ES>* instead of *<(EC),(LIB),(ES)>*

- **Property 3.2.** **<u>Adjacent</u>:** Any two consecutive items in a pattern must be adjacent neighbors on network topology.
  - ex: The pattern such as *<EC, LIB, ES>* rather than *<EC, Dorm F2, ES>* conforms to the Adjacent Property because *(EC, LIB) & (LIB, ES)* are adjacent neighbors. But *(EC, Dorm F2)* are not adjacent neighbors.

3.4 STAMP

Now the pattern is clearly defined, we propose a total solution "STAMP", standing for the abbreviation of "Sequential Terminal mobility pAttern Mining and Predicting". The STAMP algorithm, as illustrated in Figure 3.2, is composed of four phases with seven modules for three problems by three paths. Overall, the objective of STAMP is to find the moving portfolios of those people who are at high-risk. That is, these people have higher moving or moving while calling frequency than others. And with these portfolios, we can solve each of the three problems online by predicting. The initial input of STAMP is all Moving Histories at the Home Registrar. Each **Moving History** is an individual registration list of location update while the mobile user moves into different domains, maintained by the Home

Registrar. The Moving History is composed of a tuple (location, time), recording "at which moment" this user moves into some different "domain", denoted as <(D_1, T_1), (D_2, T_2), …(D_i, T_i)>.

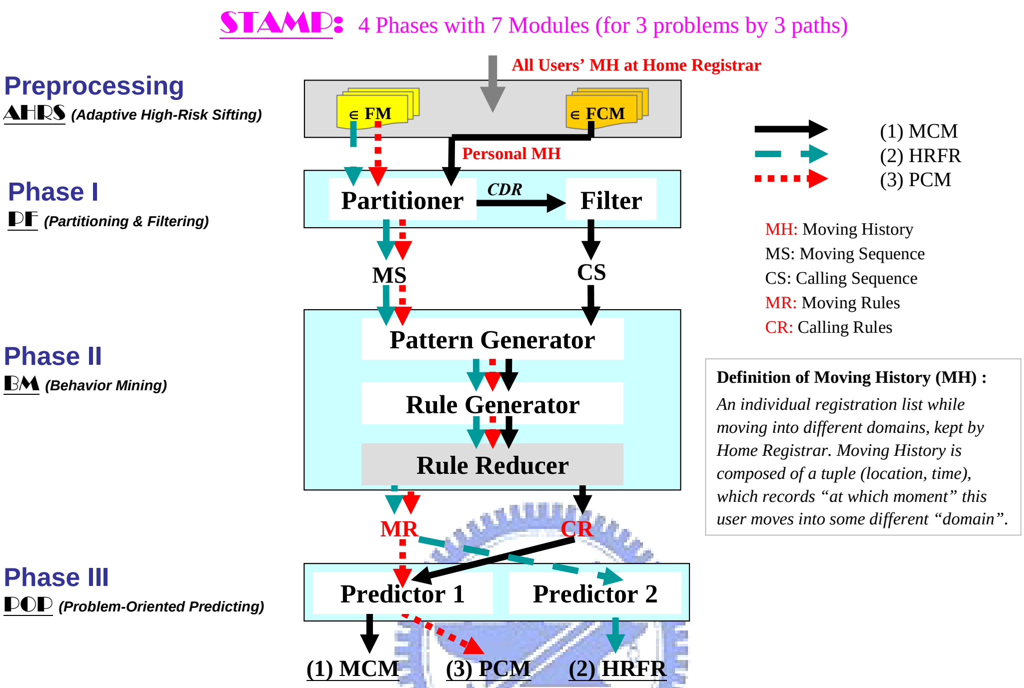

Figure 3.2 : Methodology Framework: Sequential Terminal Mobility Pattern Mining and Predicting.

Before the three phases, there is a prior phase for preprocessing. Why we need preprocessing? The reason is we should take the resources available at the server into account. Thus, there is an adjustable parameter to control how many people we could rescue without any overhead at server side. During this preprocessing, we only select the moving histories of those people who belong to FM set or FCM set among all users' moving histories.

The First Phase is to transform raw data into available information for further mining. In other words, we will firstly define "what is a meaningful moving behavior". Based on the definition, the "Partitioner" module then partitions a long, meaningless personal Moving History into many valid Moving Sequences. Each moving sequence represents a moving behavior at one time. For people belonging to FCM set, the "Filter" module will further filter Calling Sequences via Call Detail Record. The **Call Detail Record** keeps all information of each session, including caller, callee, session time, and even the location (i.e., each SIP Server on behalf of its domain). Thus, each calling sequence stands for a moving behavior while calling.

The Second Phase is to discover moving portfolios from moving sequences or calling sequences. The "Pattern Generator" finds all the frequent moving or calling patterns in an efficient manner. The "Rule Generator" linearly transforms the patterns into rules for easier readability and advanced processing. We also propose a new module "Rule Generator" to avoid overlapped rules. However, this module remains a future work.

The Third Phase is to solve problems online. According to the heterology of the three problems, we design two predictors for rule prediction and ranking to find the best result for each problem. Since Mid-Call Mobility and Pre-Call Mobility are both urgent problems, they share the same predictor. And, for Home Registrar Failure Restoration problem, it has an exclusive predictor.

Finally, the STAMP algorithms are primarily separated into two sections for offline mining and online predicting, as described in Algorithm 1 and Algorithm 2. More details about each phase will be fully explained in Chapter 4.

Algorithm 1 : STAMP_Offline (Preprocessing, Phase I and Phase II)

Abbreviation:

MH: Moving Histories; *MS:* Moving Sequences; *CS:* Calling Sequences;

MP: Moving Patterns; *CP:* Calling Patterns; *MR:* Moving Rules; *CR:* Calling Rules;

CDR: Call Detail Records;

α: Threshold of moving frequency; β: Threshold of moving while calling frequency;

FM set: the mobile host set whose moving frequency $> \alpha$;

FCM set: the mobile host set whose moving while calling frequency $> \beta$;

PF (MH): Phase I with input of some Moving History;

BR (MS): Phase II with input of some Moving Sequence;

BR (CS): Phase II with input of some Calling Sequence;

FM_R: denotes the set of mobile host $\in$ FM set with their corresponding MR;

FCM_R: denotes the set of mobile host $\in$ FCM set with their corresponding CR

Input:

All Moving Histories in Home Registrar, Call Detail Records, α and β

Output:

FM_R and FCM_R

Pseudo Code:

```
STAMP_Offline (MH, CDR, α, β)
Begin
    Set FM set = φ, FCM set = φ, FM_R = φ, FCM_R = φ;
    For each MH, Do
        Set MS = φ, MR = φ, CS = φ, CR = φ;
        IF the moving frequency of this MH > α, Do
            // FM set ← MH;
            MS ← PF (MH, CDR);
            MR ← BR (MS);
            FM_R ← (MH, MR) ∪ FM_R;
        IF the moving while calling frequency of this MH > β, Do
            // FM set ← MH;
            CS ← PF (MH, CDR);
            CR ← BR (CS);
            FCM_R ← (MH, CR) ∪ FCM_R;
    Return (FM_R, FCM_R);
End
```

Algorithm 2 : STAMP_Online (Phase III)

Abbreviation:

MCM: Mid-Call Mobility Problem; *R_MCM:* prediction result of MCM;

HRFR: Home Registrar Failure Restoration Problem; *R_HRFR:* prediction result of HRFR;

PCM: Pre-Call Mobility Problem; *R_PCM:* prediction result of PCM;

Predictor1 (CR): Predictor 1 at Phase III with input of a set of Calling Rules;

Predictor1 (MR): Predictor 1 at Phase III with input of a set of Moving Rules;

Predictor2 (MR): Predictor 2 at Phase III with input of a set of Moving Rules;

Output: Output of prediction result set;

Input:

The set of mobile host $\in$ FM set with their corresponding MR;

The set of mobile host $\in$ FCM set with their corresponding CR

Output:

Adapted prediction results for MCM, HRFR and PCM Problems

Pseudo Code:

STAMP_Online (FM_R, FCM_R)

Begin

    While *every time a mobile host moves into a different domain,* ***Do***

        Set *Output* $=\phi$ ***;***

        IF *MH* $\in$ *FM set,* ***Do***

            R_PCM $\leftarrow$ *Predictor1 (MR);*

            Output $\leftarrow$ *R_PCM;*

        IF *MH* $\in$ *FCM set,* ***Do***

            R_MCM $\leftarrow$ *Predictor1 (CR);*

            Output $\leftarrow$ *R_MCM* $\cup$ *Output;*

        Return *Output;*

    While *every time backup after Home Registrar crash,* ***Do***

        Set *Output* $=\phi$ ***;***

        IF *MH* $\in$ *FM set,* ***Do***

            R_HRFR $\leftarrow$ *Predictor2 (MR);*

            Output $\leftarrow$ *R_HRFR;*

        Return *Output;*

End

Chapter 4.
Sequential Terminal Mobility Pattern Mining and Predicting (STAMP)

The literal meaning of “STAMP” indicates that once this algorithm is in use, no matter the transient packets or call requests will be definitely forwarded to where the user is most likely being located at present. The core of “STAMP” is to find the moving portfolios of those people who are at high-risk in advance so as to solve any of the three problems by adaptively online-predicting. Overall, the algorithm ultimately contributes to both fast handoff and smooth handoff for seamless mobility in SIP over WLAN.

4.1 Preprocessing — Adaptive High-Risk Sifting

Before getting into the principle part of “STAMP”, there is a prior phase for preprocessing. Why we need preprocessing? The reason lies in the reality that we should solve problems in an efficient way. Hence, the number of users for further phases depends on how many resources (power, load, and so forth) are currently available at the server. According to the performance status of the server, we can dynamically adjust the amount of users without any overhead at server’s side. (However, the parameter adjustment remains a future work.)

Since Adaptive High-Risk Sifting (AHRS) phase aims at rescuing high-risk people. We define two mobile host sets. One is Frequent Moving (FM) set, which stands for Frequent Moving mobile hosts. The other is Frequent Calling while Moving (FCM) set, which represents Frequent Calling while Moving mobile hosts.

For each user belonging to FM set, it implies the users with higher moving frequency than others. That is, users in FM set are high-risk of HRFR Problem and PCM Problem, resulting in call failures. As a result, for FM set, we focus on finding users' Moving Behavior. On the other hand, for each user belonging to FCM set, it suggests the users with higher calling while moving frequency than others. In other words, users in FCM set are high-risk of MCM Problem, resulting in packet loss. Consequently, for FCM set, our concern is to find uses' Calling Behavior. The main concept is illustrated in Figure 4.1

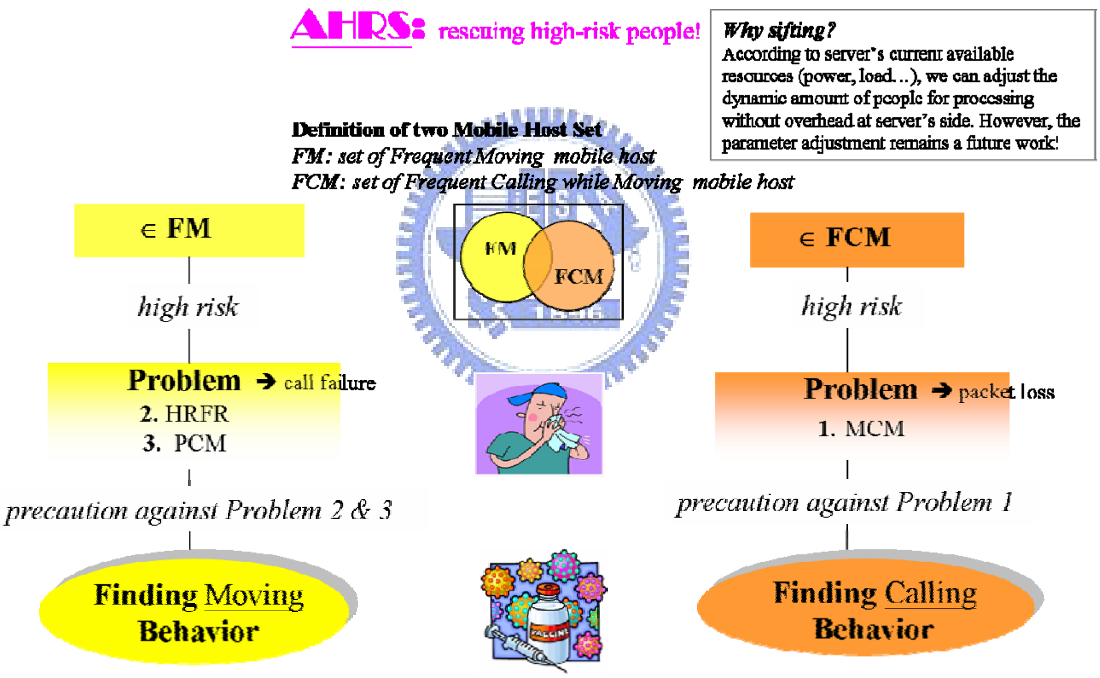

Figure 4.1 : Two sets of mobile users: FM set vs. FCM set

- **Moving Frequency**
  - **Parameter**: The Moving Frequency is defined as "Average Moving Occurrence Volume within per time period unit".
  - **ex:** Within last year, Jenny moved 5000 times but Anny moved 1500 times in total; in other word, Jenny moves more frequently

than Anny.

- **<u>Moving while Calling Frequency</u>**
  - **Parameter:** The Moving while Calling Frequency is defined as "Average Moving while Calling Occurrence Volume per call". i.e., Velocity = Moving Occurrence Volume in CDR / Call Volume in CDR.
  - **ex:** Within last year, Jenny moved 2000 times in 1000 calls (Velocity = 2) while Anny moved 1000 times in 125 calls (Velocity = 8); in other words, Anny moves while calling at a much higher frequency.
- **<u>Moving Distribution</u>**

  We suppose the moving distribution curve is depicted in Figure 4.2.

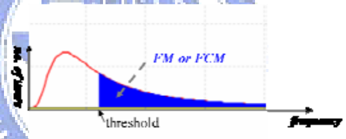

Figure 4.2 : Moving Frequency of FM or FCM set

4.2 Phase I — Partitioning & Filtering

We assume that the input of "STAMP" is the Moving History, on behalf of the individual registration lists, kept by Home Registrar. Each Moving History is composed of a sequence of tuples, (location, time), recording "at which moment" the certain user moves into some different "domain". As the input is a long record, it goes without saying that the reason why we need Phase I is obviously because the long record doesn't convey any explicit information about "one meaningful moving behavior", which is valuable information for further mining. Therefore, the objective of Partitioning & Filtering (P&F) phase is to transform these raw data into available information.

Firstly, the “Partitioner” module partitions a long, meaningless personal Moving History of whomever in FM or FCM set into many valid Moving Sequences. Each Moving Sequence represents a moving behavior at one time. The “Partitioner” segments out a meaningful Moving Sequence from the Moving History, based on two criteria: (1) If any two consecutive moving paths (D_{i-1} & D_i) are not adjacent domains, then partition for the first time; (2) If the residence time of each domain D_{i-1} (i.e., $\Delta T = T_i - T_{i-1}$) is longer than a predefined or statistical maximal window size, then partition for the second time. The former criterion implies strict consistency with the Adjacent Property of Moving Pattern & Calling Pattern Definition at Section 3.3. The latter criterion suggests that the meaningful Moving Sequence should be limited within a time space, such as the interval from registration to deregistration or per day.

Lemma 1: Every two consecutive items in a Moving Sequence $\boldsymbol{\beta} = <b_1, b_2, \ldots, b_n>$, i.e., b_i & b_{i+1}, are adjacent domains.

Proof: Based on the definition of Adjacent Property of Moving Patterns and Calling Patterns in Section 3.3 as well as the fact that a mobile user could never cross a non-neighboring domain, it is easy to know the lemma is true.

□

Moreover, for people belonging to FCM set, the “Filter” module will further filter Calling Sequences via Call Detail Record. Each Calling Sequence stands for a moving behavior while calling.

Lemma 2: For every Calling Sequence $\boldsymbol{\alpha} = <a_1, a_2, \ldots, a_m>$, there exists a Moving Sequence $\boldsymbol{\beta} = <b_1, b_2, \ldots, b_n>$ such that the Calling Sequence $\boldsymbol{\alpha}$ is the Consecutive

Subsequence of the Moving Sequence β, denoted by $\alpha \subseteq \beta$.

Proof: Each Calling Sequence records the moving behavior of a mobile user within the same call session, and is filtered from some Moving Sequence by the Call Detail Record, so the above lemma is true.

□

Theorem 1: Given a mobile user *p*, there exists a Moving History γ_p of the mobile user, a set of Moving Sequences $M_p = \{\beta_1, \beta_2, \ldots, \beta_m\}$, and a set of Calling Sequences $C_p = \{\alpha_1, \alpha_2, \ldots, \alpha_n\}$, such that $\alpha_i \subseteq \beta_j \subseteq \gamma_p$, where $1 \leqq i \leqq n$, $1 \leqq j \leqq m$, and i, j belong to integer.

Proof: It follows from the Adjacent Property, Lemma 1, and Lemma 2, thoroughly constituting the Phase I — Partitioning and Filtering, thus it is definitely true.

□

The whole process of both Partitioner and Filter modules is illustrated in the following example, Figure 4.3. Regarding the phase operation, refer to Algorithm 3.

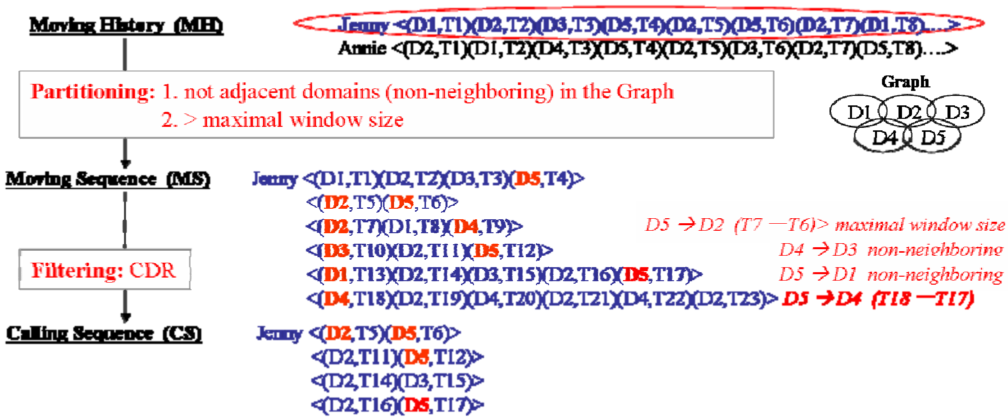

Figure 4.3 : Example of Phase I - Partitioning & Filtering

Algorithm 3 : PF (Phase I: Partitioning & Filtering)

Abbreviation:

H: a Moving History; *S:* a set of Sequences; *P:* a set of Patterns; *R:* a set of Rules;

Input:

A Moving History & Call Detail Records

Output:

A set of Sequences

(If MH ∈ FM set then output a set of Moving Sequences; otherwise, Calling Sequences)

Pseudo Code:

PF (H, CDR)

Begin

S ← Partitioner (H); *//based on* ***Lemma 1*** *described in Section 4.2*

IF *MH ∈ FCM set,* ***Do***

S ← Filter (S, CDR); *//based on* ***Lemma 2*** *described in Section 4.2*

Return *S;*

End

4.3 Phase II — Behavior Mining

Since the earlier phase splits up individual Moving History into many Moving Sequences, the input of Phase II are well prepared. The goal of Behavior Mining (BM) phase is to find out moving portfolios of any user in FM or FCM set.

Firstly, the "Pattern Generator" module discovers frequent moving or calling patterns from Moving Sequences or Calling Sequences. Secondly, for the sake of easier readability and advanced process, the "Rule Generator" module transforms patterns into rules in a linear manner. E.g., pattern <D1, D2, D3> will be transformed into rules <D1→D2, D3>, and <D1, D2→D3>. Finally, the "Rule Reducer" module gets rid of the overlapped rules and keeps the complete ones. E.g., <D2→D3> and <D1, D2→D3> are overlapped. Thus the rule with shorter prefix or postfix length, namely <D2→D3>, will be removed and only <D1, D2→D3> will be kept. Since the last module remains a future work, the whole process of Behavior Mining phase is simply illustrated in the following example, Figure 4.4. Concerning the phase operation, refer to Algorithm 4.

Figure 4.4 : Example of Phase II – Behavior Mining

Algorithm 4 : BR (Phase II: Behavior Mining)

Abbreviation:

S: a set of Sequences; *P:* a set of Patterns; *R:* a set of Rules; *R':* a set of reduced Rules;

Input:

A set of Sequences

Output:

A set of Reduced Rules

(If MH∈ FM set then output a set of Moving Rules; otherwise, Calling Rules)

Pseudo Code:

BR (S) *// if MH∈ FM set then BR (MS); otherwise, BR (CS).*

Begin

P ← PatternGenerator (S); *//based on **Lemma 3** described in Section 4.3*

R ← RuleGenerator (P);

R' ← RuleReducer (R);

***Return** R';*

End

Particularly, the following lemma accelerates the candidate generation in the Pattern Generator module.

Lemma 3 (<u>Pseudo Apriori</u>): A moving sequence $X=<x_1, x_2,\ldots, x_m>$ of length m has m-k+1 subsequences of length k, 1≦k≦m.

Proof: If we are going to generate a length-m candidate sequence, we only have to check whether the (m-k+1) length-k subsequences are frequent instead of $\frac{C_k^m}{K!}$. The key idea is that "Consecutive", the Sub-sequence Relation, has a great impact on "Pseudo Apriori" because "Consecutive" limits the relation between super vs. sub sequence. Thus, Pseudo Apriori is significant during the process of candidate generation because Pure Apriori fails generating and pruning candidates efficiently in our moving sequential pattern mining. Based on the "Consecutive" property, "Pseudo Apriori" is more appropriate as the guideline for moving behavior mining in SIP domain. ex: <*a, b, c*> is a candidate length-3 sequence → all the length-2 subsequences must be frequent. Since <*a, c*> is not a length-2 subsequence of <*a, b, c*> anymore in Pseudo Apriori, the length-2 subsequence set of our concern is only {<*a, b*><*b, c*>}.

□

Besides, the Candidate Generation process within Pattern Generator module takes advantage of the network topology so as to enhance both efficiency and effectiveness during mining. We utilize both network topology of Graph and Large (N-1), resulting in a Hybrid manner of Behavior Mining. Since it is the time that matters, we then represent the Graph by adjacency matrix data structure, supposing there are enough memory and storage at the server.

Here we compare our Hybrid manner among different candidate generation manners, as illustrated in Figure 4.5, Figure 4.6, and Figure 4.7.

- **<u>Pure Graph</u> vs. <u>Pure Large (N-1)</u> vs. <u>Hybrid</u>**
  - How ***efficient*** is the candidate generation process?
    - How many candidates are generated in all? → least is best.
    - ex: PG (55) vs. PL (38) vs. H (32)
  - How ***effective*** are the candidates?
    - What percentage of candidates is certainly to be large? → largest is best.
    - ex: PG (29%) vs. PL (42.1%) vs. H (50%)

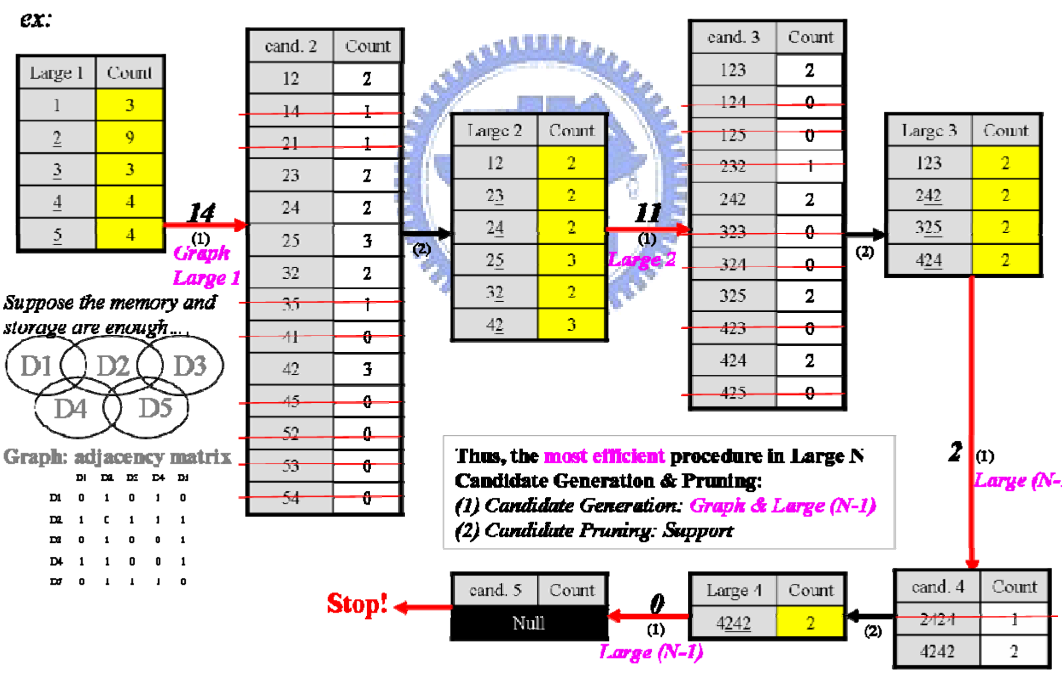

Figure 4.5 : Example of Candidate Generation – Hybrid

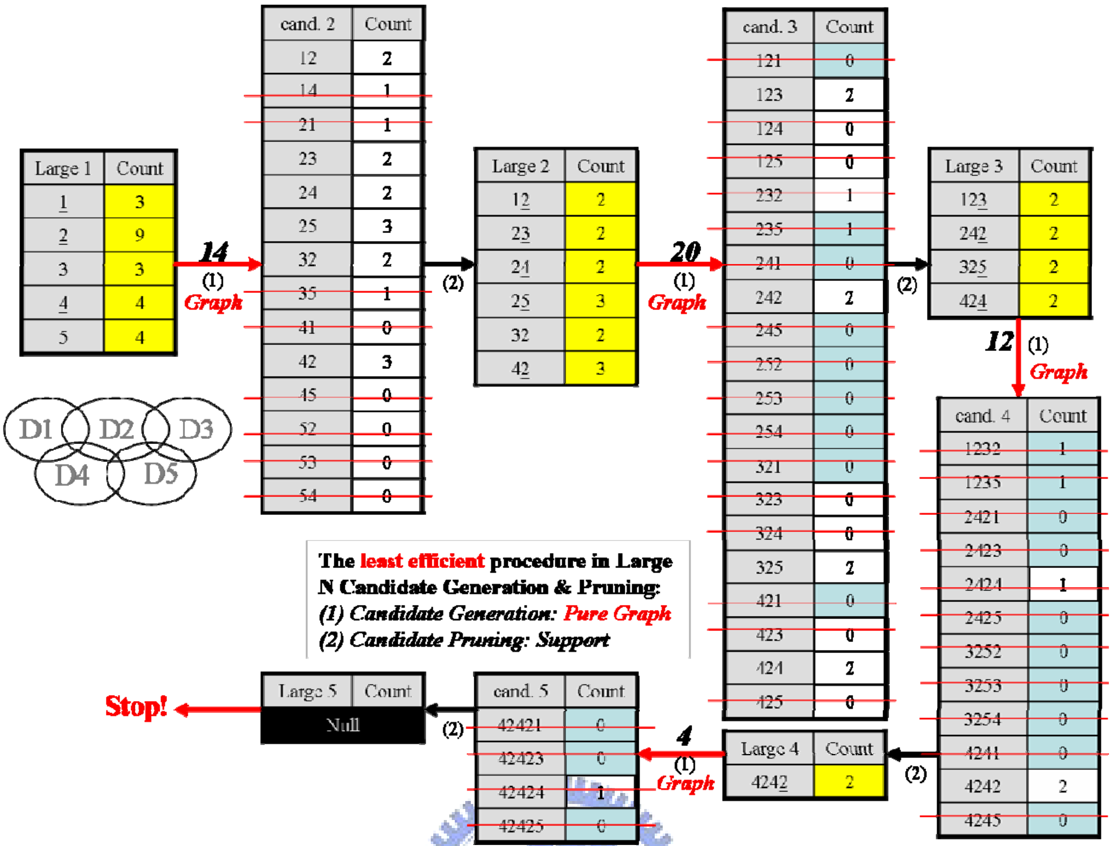

Figure 4.6 : Example of Candidate Generation – Pure Graph

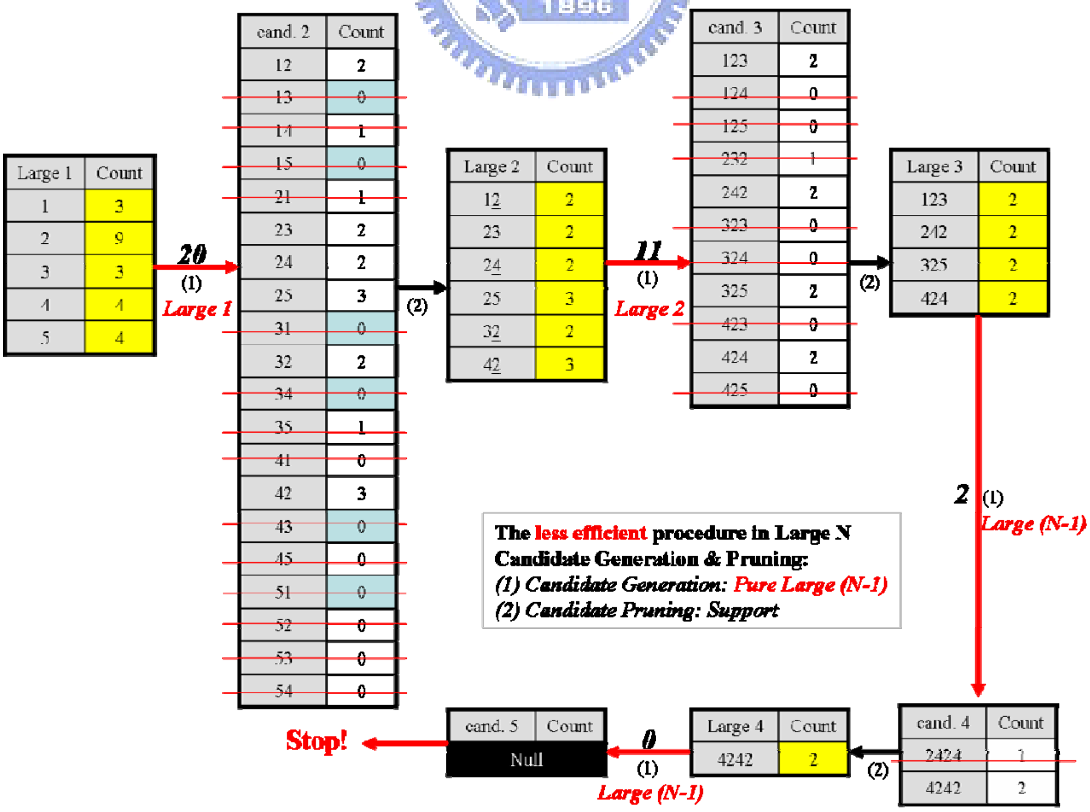

Figure 4.7 : Example of Candidate Generation – Pure Large (N-1)

According to the above, “Hybrid” exceeds in efficiency as well as in effectiveness from performance perspective. That is why we use “Hybrid” instead of “Pure Graph” or “Pure Large (N-1)”.

4.4 Phase III — Problem-Oriented Predicting

Now that Phase I and Phase II have turned original individual Moving History into Moving or Calling Sequences and finally into Moving or Calling Rules, the rules undoubtedly become the input of Phase III. Why we need Phase III? The ground for Phase III is that we can solve each of the three problems online adaptively by Problem-Oriented Predicting with rules from Phase II.

The implication of the so-called “Problem-Oriented Predicting” is that we take the characteristic of each problem into account. The observation shows a key distinction between these problems: the 1st (MCM) and 3rd (PCM) Problems are both critically urgent in common; however, the 2nd (HRFR) Problem is not so exigent as MCM and PCM Problems. As a result, three problems are classified into two groups according to their demands. In accordance with these two problem groups, we devise two modules by the name of predictors: Predictor 1 targets on MCM as well as PCM Problem; Predictor 2 aims at HRFR Problem, respectively.

Before going into details of how each predictor functions, we can take a quick review on the Problems in SIP at Section 1.3.

Predictor 1: *for problem 1st (MCM) or 3rd (PCM)*

Scenario: *If Jenny has followed the path <D1, D4, D2> and is currently at D2…*

Question: *Where is her next step?*

Solution by Predictor 1:

- **Rule Firing:** Prefix.consecutive==true && Postfix.length==1

Rules can only be <D2→?>; <D4, D2→?>; <D1, D4, D2→?>; but the rule can never be <D1, D2→?>, because D1 and D2 are inconsecutive in this scenario.

- **Rule Ranking:** longest Prefix.length → highest Rule.support

  if the rules fired are <D2→D3>, <D2→D5> and <D4, D2→D4>, then <D4, D2→D4> will be ranked first. So the output is D4.

- **Solution:** Home Registrar will tell D2 Jenny will probably head for "D4" so as to forward packets or call requests at the moment.

Predictor 2: *for problem 2nd (HRFR)*

Scenario: *If Jenny has followed the path <D1, D4, D2> from backup after crash…*

Question: *However, is Jenny really in D2 now? (i.e., Jenny haven't moved since last backup)*

- **Rule Firing:** Prefix.consecutive==true

  Rules can only be <D2→?, ?...>; <D4, D2→?, ?...>; <D1, D4, D2→?, ?...>.

- **Rule Ranking:** Postfix[i] << Postfix[i+1], i++,

  where 0 < i < Max(Postfix.length+1)

  if the rules fired are <D2→D3>, <D2→D5>, <D4, D2→D4, D2>, <D4, D2 →D5>, and <D1, D4, D2→D4, D2>, the output will be <step1: (D3, D4, D5), step2: (D2)>.

- **Solution:** Home Registrar will firstly query D3, D4, and D5 simultaneously and then D2 incrementally until HR restores the current location.

Each of the two predictors in Phase III is algorithmically presented in Algorithm 5 and Algorithm 6. These two algorithms along with the Algorithm 2 in Section 3.4 contribute to the coherence of STAMP online predicting.

Algorithm 5 : Predictor1 (Phase III - 1st module)

Abbreviation:

R: a set of Rules;

PR: prediction results;

Input:

A set of Rules

Output:

Adapted prediction results of MCM and PCM Problems

Pseudo Code:

Predictor1 (R) *// If PCM then Predictor1 (MR); if MCM then Predictor1 (CR)*

Begin

For *each Rule,* ***Do***

IF *the prefix of the rule is consecutive & the postfix length of the rule equals 1,* ***Do***

The rule R is fired;

Rank all fired rules according to first priority (rules with longest prefix length ranks first);

For *the rules with same prefix length,* ***Do***

Rank rules by second priority (rules with highest support ranks first);

Return *PR;*

End

Algorithm 6 : Predictor1 (Phase III – 2nd module)

Abbreviation:

R: a set of Rules;

PR: prediction results;

Input:

A set of Rules

Output:

Adapted prediction result for HRFR Problem

Pseudo Code:

Predictor2 (R)

Begin

For *each Rule,* ***Do***

IF *the prefix of the rule is consecutive,* ***Do***

The rule is fired;

Rank all fired rules according to postfix positions from 0 to maximal postfix length;

Return *PR;*

End

4.5 Mechanism Activation

Below, Figure 4.8 describes the summary of relationships among problems, activation strategies, patterns of different roles, and even the mobile host sets.

For **MCM Problem**, whenever the mobile host of ***FCM set*** makes an Inter-domain Mobility and registers at the home registrar, the prediction results in terms of ***sequential calling patterns*** are sent from the home registrar to the current domain SIP server along with the authentication information. Therefore, once the user makes another Inter-domain Mobility, the calling patterns will assist the previous domain in intercepting and forwarding media packets to the predicted domain(s) in case of packet loss before delayed re-Invite reaches the corresponding host. With these calling portfolios, the reduction amount of packet loss increases when the mobile host becomes more far away from the corresponding host becomes in distance.

For **HRFR Problem**, as soon as the home registrar gets crashed, the SIP server will query the predicted domains of those mobile users of ***FM set***, recovered from backup, in terms of ***sequential moving patterns*** incrementally. The mission is to restore current & complete location information in case of obsolete location information to any upcoming call request before the mobile user makes another Inter-domain Mobility and location update.

For **PCM Problem**, whenever the mobile host of ***FM set*** makes an Inter-domain Mobility and registers at the home registrar, the prediction results in terms of ***sequential moving patterns*** are sent from the home registrar to the current domain SIP server along with the authentication information. Therefore, once the user makes another Inter-domain Mobility, the moving patterns will assist the previous domain in forwarding call requests to the predicted domain(s) in case of call failure before delayed re-Register arrives the home registrar. With these moving portfolios, the decrement of call failures increases while the mobile host becomes more distant from the corresponding host.

Adaptive Terminal mobility Mining

	Problems	Activation Strategies	Mining	MH Set
1	*Mid-Call Mobility (MCM)*	Every time MH registers at HR, sequential calling patterns are multicast to this current domain in case of packet loss before re-Invite	Calling Pattern	FCM
2	*HR Failure Restoration (HRFR)*	Once the HR get crashed, sequential moving patterns are used to query predicted domains so as to restore complete location information in case of obsolete location to call request	Moving Pattern	FM
3	*Pre-Call Mobility (PCM)*	Every time MH registers at HR, sequential moving patterns are multicast to this current domain in case of call failure before re-Register arrives HR		

Vulnerability Mapping of MH Set vs. Problem

Figure 4.8 : Problem-Oriented Activation Strategies

Chapter 5.
Evaluation

In Chapter 4, we have presented our method, STAMP, which solves well-known SIP mobility problems (Mid-Call Mobility & Pre-Call Mobility) and notable mobility database failure problem (Home Registrar Failure Restoration). In STAMP, the preprocessing phase is efficient because it dynamically selects high risk users to do further STAMP algorithm; the rest phases after preprocessing provide adaptive solutions for each problem.

For MCM & PCM Problem, STAMP mobility scheme is mainly evaluated by the mathematical analysis model introduced from Shadow Registration in [7]. On the other hand, for HRFR Problem, our scheme certainly performs a better quality of service compared with the original condition without any preventives.

Before going into more details, there are some assumptions on WLAN deployment for STAMP. The reason is: for MCM & PCM Problem, the SIP Server and In-bound Router should know when the user makes Inter-domain Mobility so as to activate STAMP and start forwarding packets or requests! The WLAN assumptions and mobility cases are basically depicted in Figure 5.1.

Assumptions

- Only each access point (i.e., AP) under border subnet such as “b-Subnet 3” or “b-Subnet 1” in Domain A, the AP will inform the In-bound Router and SIP Server if the user leaves.
- All APs have to inform the domain In-bound Router and SIP Server if any user moves into the coverage of this AP.

Two Cases

- **Upper case (*Inter-domain Mobility*):**

  Absence information is sent to the In-bound Router and SIP Server under Domain A from AP 3-2, but no AP sends any presence information of this user within a tolerable interval. **Thus, STAMP is activated!**

- **Lower case (Intra-domain Mobility):**

  Absence information is sent to the In-bound Router and SIP Server under Domain A from AP 3-2, and AP 3-1 sends presence information subsequently. **Thus, STAMP is *not* activated!**

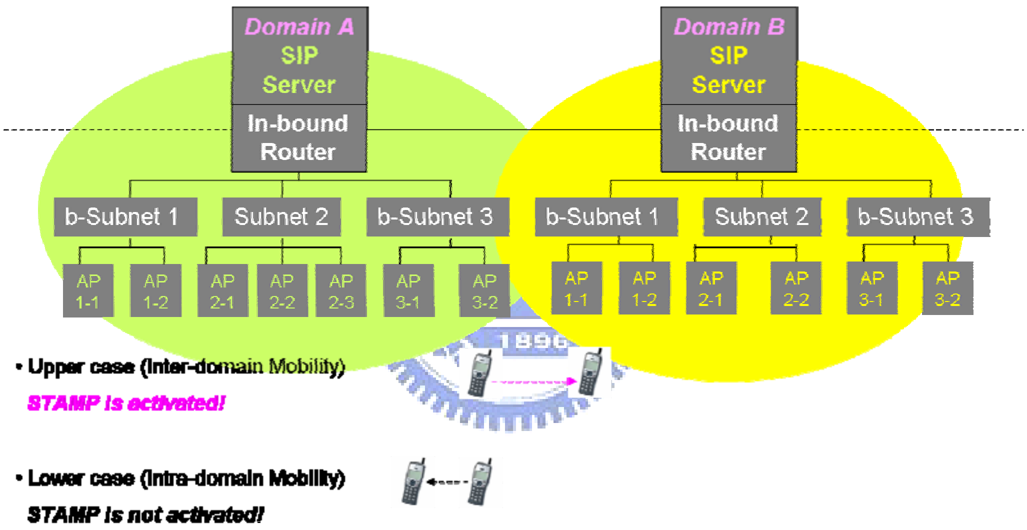

Figure 5.1 : Inter-domain Mobility: STAMP activation time

Based on the above mentioned, the evaluation for each problem is as the following.

5.1 Evaluation of Problem1. Mid-Call Mobility

For MCM Problem, we apply STAMP to *Original SIP* and *SIP with Shadow Registration* by two schemes (i.e., ***SIP with STAMP*** as well as ***SIP with STAMP & Shadow Registration***, accordingly), as depicted in Figure 5.2. Firstly, ***SIP with***

STAMP outperforms Original SIP by ***2tmc***. The RTP translator is activated after being informed by any access point so as to start intercepting and forwarding media packets according to the prediction result from STAMP. Then the user starts receiving media packets while the authentication retrieval reaches the new domain. Figure 5.3 and Figure 5.4 display more detail operations. Secondly, ***SIP with STAMP & Shadow Registration*** also outperforms SIP with Shadow Registration by ***2tmc***. The operation is almost the same as ***SIP with STAMP***. The only difference lies in the fact that authentication is retrieved at local (new) domain because of Shadow Registration. Figure 5.5 and Figure 5.6 illustrate the operations in detail. Moreover, Figure 5.7 displays the mathematical model in Shadow Registration and compares our contribution with Shadow Registration.

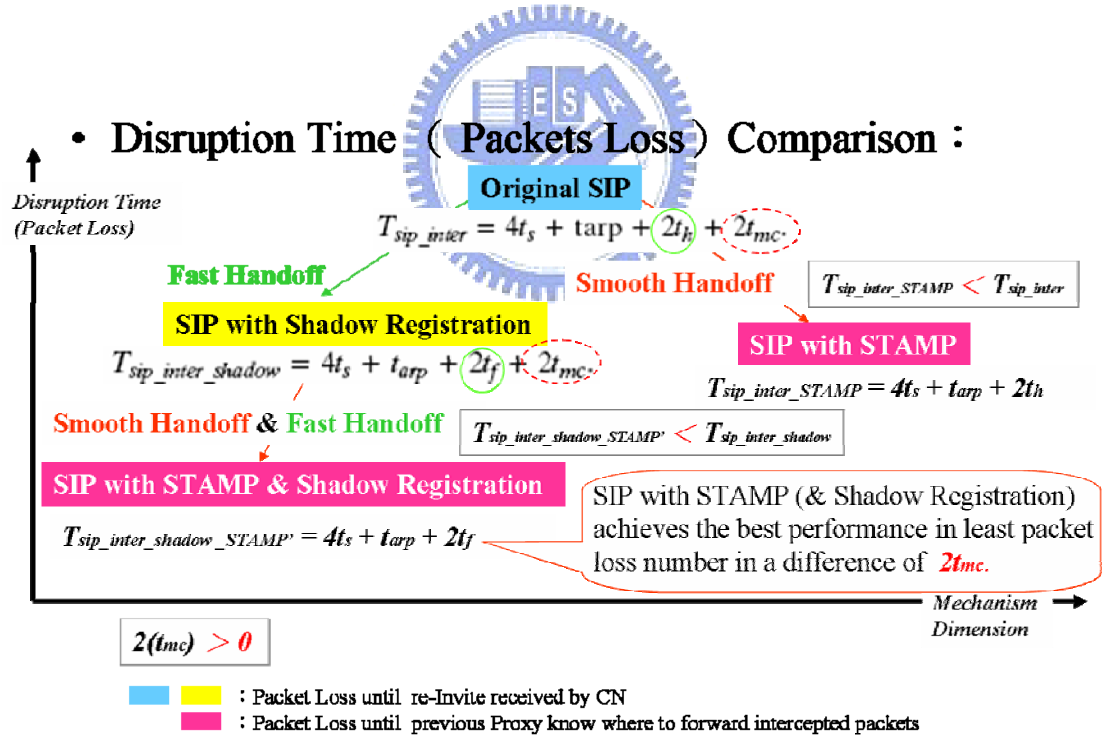

Figure 5.2：MCM Problem Evaluation – Disruption Time Comparison

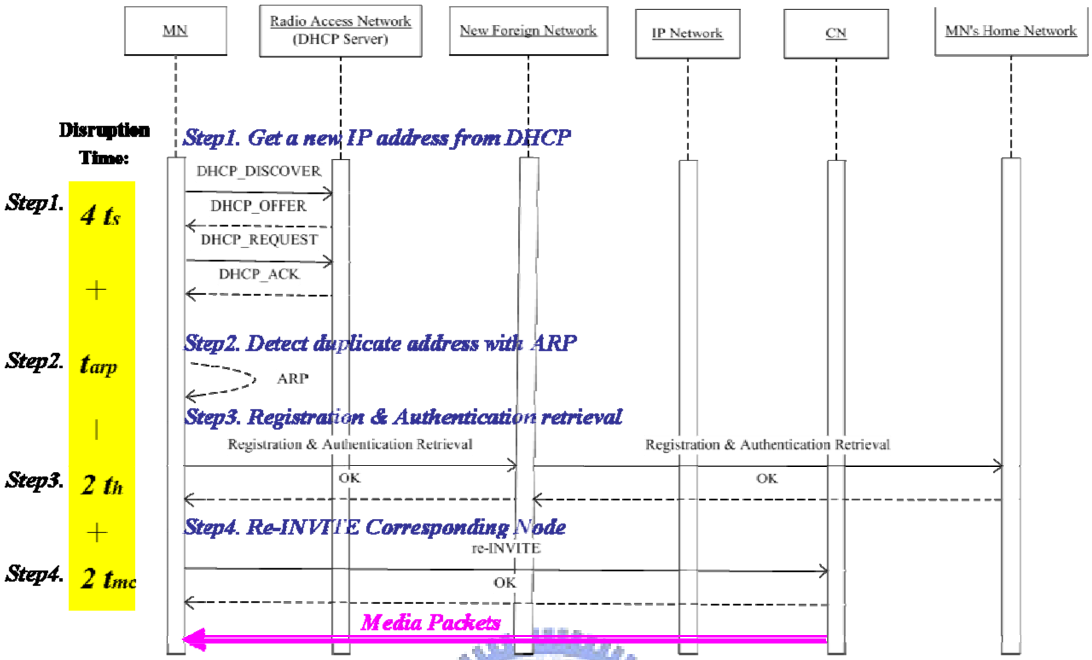

Figure 5.3：Operation Sequence: Original SIP

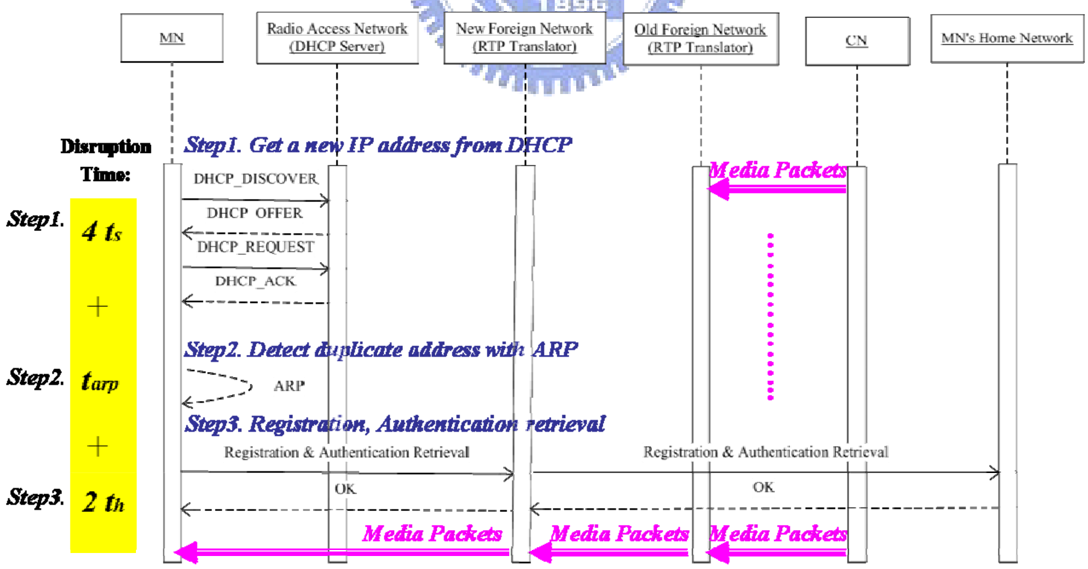

Figure 5.4：Operation Sequence: SIP with STAMP

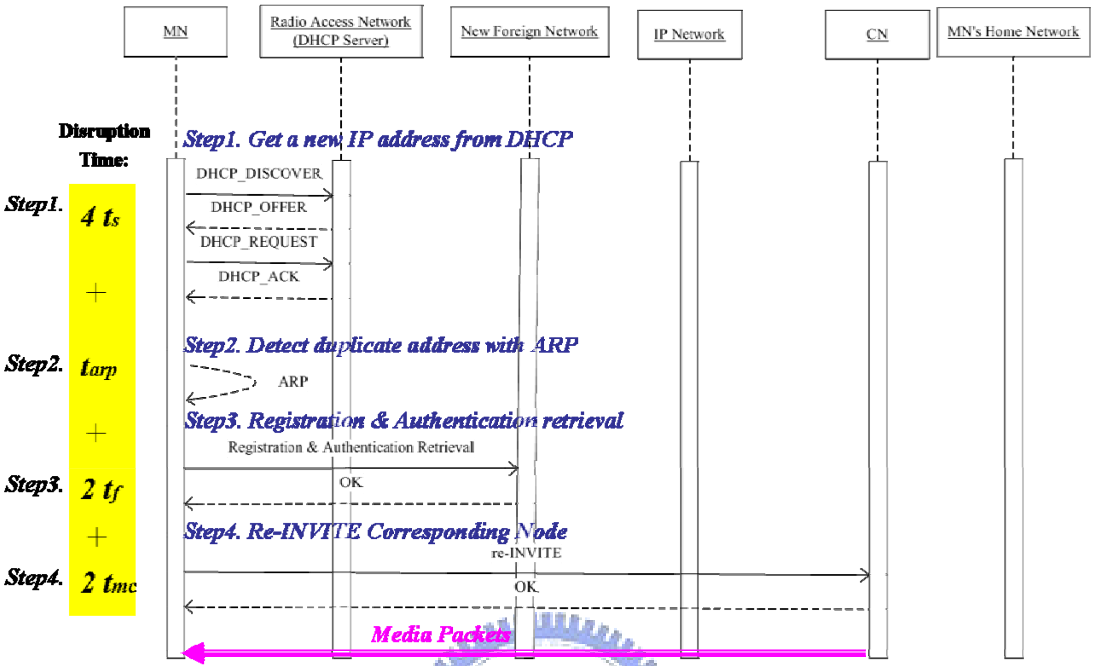

Figure 5.5：Operation Sequence：SIP with Shadow Registration

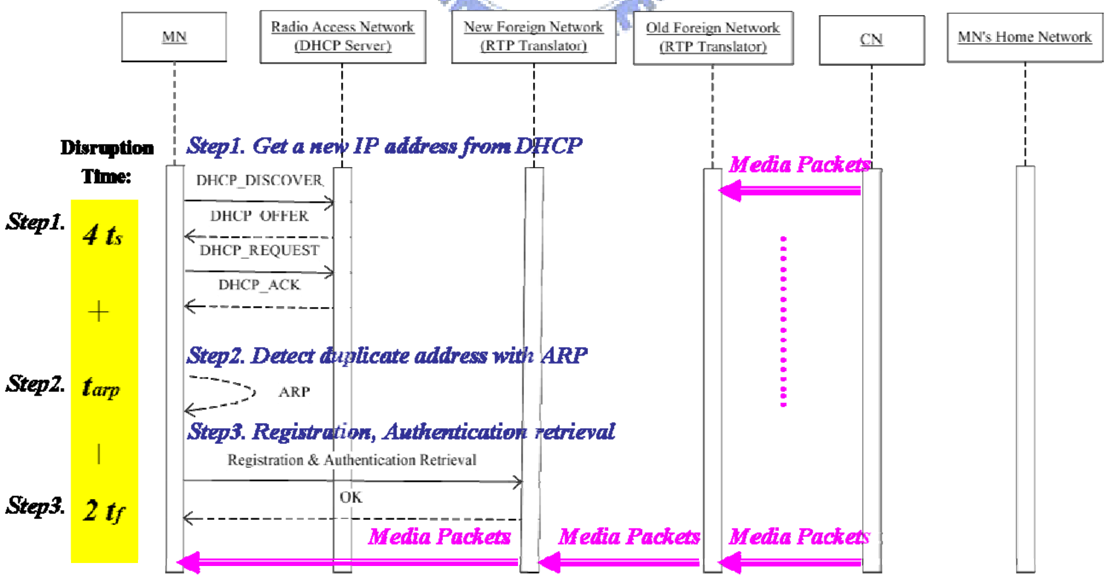

Figure 5.6：Operation Sequence: SIP with STAMP & Shadow Registration

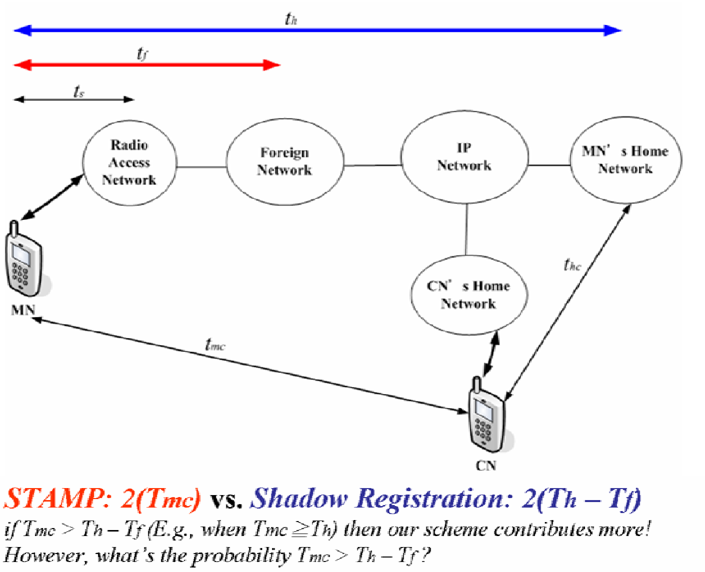

Figure 5.7 : Contribution Comparison of STAMP vs. Shadow Registration

5.2 Evaluation of Problem2. Home Registrar Failure Restoration

For original HRFR Problem, some locations are updated until the user makes any Inter-domain mobility; STAMP restores the location information actively as soon as possible instead. Comparatively speaking, STAMP shortens the interval and probability of call failures, evidently improving the service availability.

5.3 Evaluation of Problem3. Pre-Call Mobility

In regard to PCM Problem, STAMP reduces the interval of service unavailability by ***2(th −tf)***. The procedure is as the following: (1) the call requests are intercepted at the old domain and then forwarded to the predicted domain according to STAMP once the In-bound Router knows the absence of the mobile user; (2) the call request starts being received by the mobile user once the authentication is retrieved, according to the sequence operation diagrams depicted in Figure 5.8 and Figure 5.9.

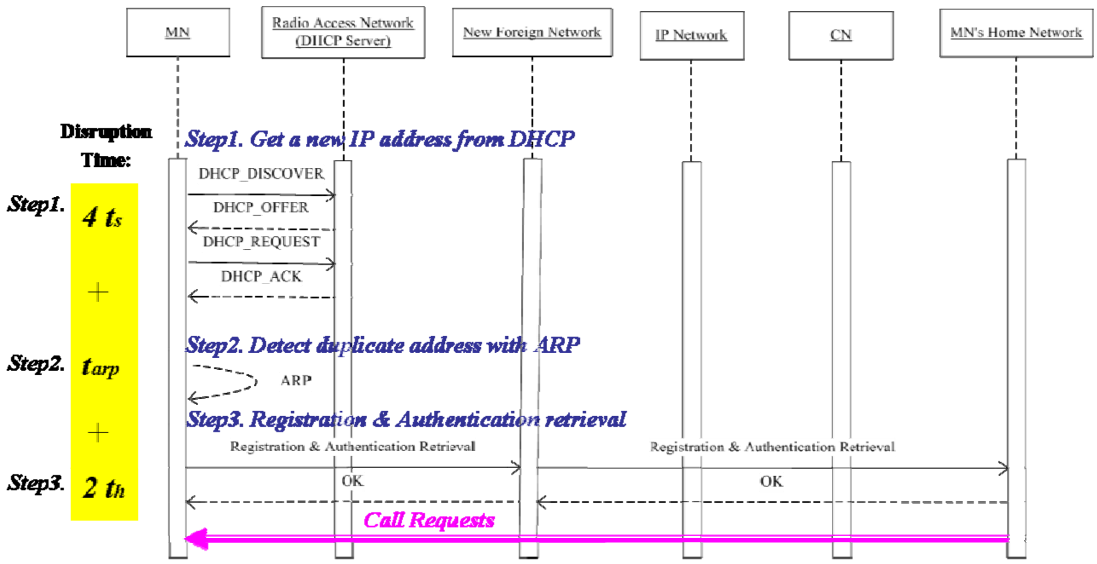

Figure 5.8：Operation Sequence: Original SIP registration

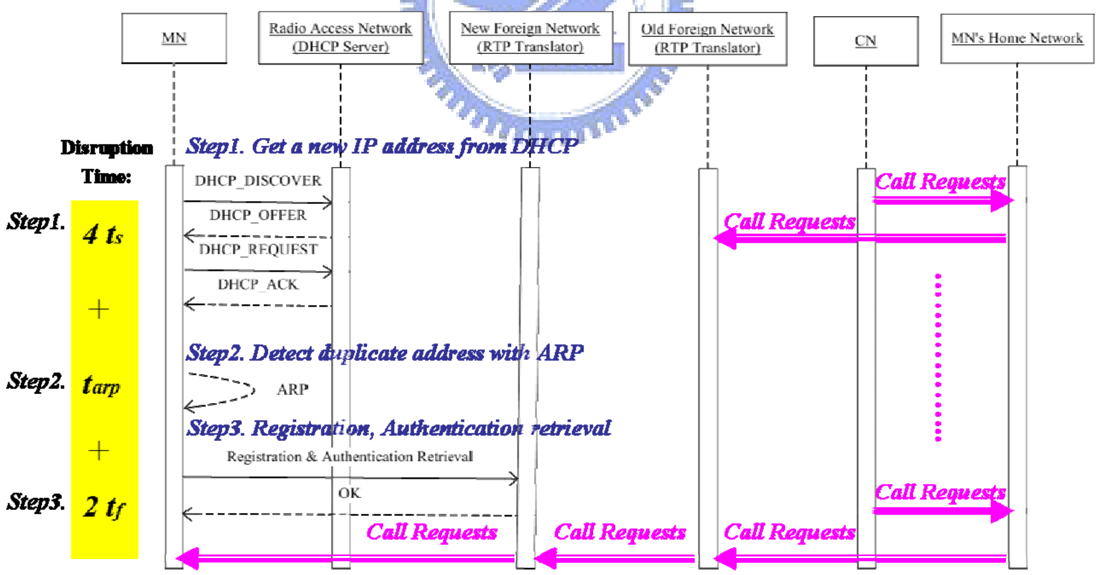

Figure 5.9：Operation Sequence: SIP registration under STAMP

Chapter 6.
Conclusion

As the mobile communication technologies become widespread and prevalent, a vast majority of portable devices providing a series of comprehensive real time applications grow rapidly. As a result, seamless terminal mobility plays a significant role in the quality of most mobile services. In this thesis, we focus on the SIP terminal mobility issues via Mid-Call Mobility, Home Registrar Failure Restoration, and Pre-Call Mobility Problems. We devise a mobility approach, STAMP, to solve all of the three problems in an adaptive manner. Considering both AAA functionality and RTP Translator, firstly we analyze and compare the Inter-domain handoff disruption time of Shadow Registration versus STAMP for MCM Problem. The fact that STAMP shows less disruption time than Shadow Registration proves that STAMP is not only fast but smooth handoff scheme itself. Moreover, STAMP could even enhance Shadow Registration more efficiently with the knowledge of moving patterns. Then, for HRFR and PCM Problem, STAMP reveals shorter interval of service unavailability; especially for PCM Problem, the contribution of STAMP increases when the mobile user happens to be far away from the home network. In brief, STAMP contributes to service continuity as well as service availability.

Future Work

We have already evaluated STAMP on the MCM, HRFR, and PCM Problems in a mathematical manner, based on the analysis model presented in [7]. Moreover, experiments are under progress. The simulation results are expected to prove the contribution of STAMP in a statistical way.

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