Mobility Management Schemes with Fast Handover in Integrated Wi-Fi and WiMAX networks

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ABSTRACT

The seamless internetworking among multiple heterogeneous networks is in demand to provide "always-on" connectivity services with QoS provision quality, anywhere, at any time. The hybrid networks of Wi-Fi and WiMAX networks can provide high data rate and enhanced multimedia services. In this paper, we discuss some handover issues and propose network architectures between Wi-Fi and WiMAX networks, a concept model of protocol stack and a two-tier mobility management scheme. Although this paper does not deal with detailed handover and QoS algorithms, We concentrate on mobility management mechanisms and investigate network architecture for supporting mobility management.

Index Terms- *mobility management, seamless handover, cross-layer communication, heterogeneous wireless networks*

1: INTRODUCTION

Recent research has intensively focus on the next generation wireless networks that will meet the increasing demand for services with higher data rate and enhanced multimedia applications. Instead of developing an all new network, the next generation wireless networks strive to seamlessly integrate existed multiple heterogeneous networks and make modification of protocol and signaling schemes as few as possible.

Based on the IEEE 802.11[1] standard, many companies and families can connect to the internet in a limited range only with an access point (AP), which has accelerated the Wi-Fi network development. As a step toward providing Quality of Service (QoS) support in a Wi-Fi network, the 802.11 Working Group developed the IEEE 802.11e[2] standard provided differentiation mechanisms at the medium access control (MAC) layer. A number of studies has evaluated the 802.11e standard by both analytical evaluation and simulation, and have demonstrated the usefulness of the proposed mechanisms in the 802.11e [3].

The 802.16 standard [4] specifies the MAC and Physical (PHY) layers of fixed broadband wireless access systems. Similar to the IEEE 802.11, the MAC layer is structured to support multiple physical layer specification to give the standard flexibility. The principal mechanism of 802.16 for providing QoS is to associate packets with a service flow. Uplink and downlink QOS is provided for each flow. The bandwidth allocation and request mechanism are implemented using unsolicited bandwidth grants, polling, and contention procedures. The IEEE 802.16 has created the 802.16e task group to explore how to modify the 802.16 so that it supports mobility [5].

Although the 802.11e and the 802.16e enhance the current access mechanisms, there are a number of challenges that must be addressed to enable compressive QoS and mobility support. The limited coverage range of Wi-Fi networks makes it difficult to meet the need of the next generation wireless network that provides "always-on" connectivity services anywhere, at any time. WiMAX networks can provide high speed internet access in a wide area, but there are energy saving issues for Mobile Subscriber Stations (MSS) and quality issues in some indoor area. Thus, the integration of Wi-Fi and WiMAX networks can combine their best features to provide ubiquitous access while mediating weakness of both networks. One major challenge in seamless integration of Wi-Fi and WiMAX networks is the design of a reliable, robust, and efficient internetworking architecture.

We assume the mobile terminals in our proposed network support IEEE 802.11e and 802.16e dual interface. We consider this integrated network as a two-tier system, and survey previous mobility management schemes for the integration of 3G and WLAN networks. There are different QoS and mobility issues in a network layer and a MAC layer, and seamless handover should be fast and robust, so we propose a multi-layer network protocol architecture. The rest of paper is organized as follows: Section II describes basic network architecture. Then in Section III, we present a concept model of the wireless network protocol stack. The mobility management schemes and their simulation results are described in section IV and V, respectively. Finally, section VI concludes this paper.

2: Network Architecture

Based on previous research [6] in the integration of 2G/3G cellular networks and Wi-Fi networks, the tight coupling mechanism can connect the Wi-Fi networks with the 3G networks by the same management mechanism. From the view of the 2G/3G network, Wi-Fi networks serve as a 2G/3G Base Station (BS) coverage area. As a result, all the data and signaling traffic, generated in the Wi-Fi networks, are injected into the 2G/3G cellular networks. On the contrary, the loose coupling mechanism separates the data path for the Wi-Fi and 2G/3G networks. A Wi-Fi gateway connects to the internet and all data traffic is transmitted into the IP backbone network, instead of into the 2G/3G core network, while signaling traffic may optionally go through either the 2G/3G networks or through core internet.

Because the IEEE 802.16e may compete with 3G and B3G cellular networks, we propose a two-tier network that uses the 802.16e as an overlay cell and the 802.11e as a underlay cell cluster. We can use the algorithms of internetworking and mobility management based on these previous proposed architectures [12], then, internetworking architecture will have the benefit of the previous architectures, also increase system capacity, performance and coverage. A two-tier network is illustrated in Fig. 1, where each WiMAX cell overlays a few Wi-Fi cells. In such an architecture, a group of cells (Wi-Fi or WiMAX) called a cluster is governed by a virtual Base Station Control (BSC).

When roaming from WiMAX networks to Wi-Fi networks, it is not reasonable to initialize handover too soon when Wi-Fi is available because both WiMAX and Wi-Fi networks can provide high bandwidth and good performance. The information of received signal strength level from physical layer and available bandwidth of network layer are common parameters to determine when to initialize handover. The proposed scheme can choose the best Wi-Fi access point (AP) to provide higher bandwidth and reduce the unnecessary handover probability due to the signal strength dropping down [11]. There are qualitative analysis in refs.[9],[10],[13] showing that the effects of MIPv6 and FMIPv6. From the analysis, it is evident that link-layer triggers are required to aid the IP handover preparation and execution, and cross-layer information exchange can speed up the handover procedure. Because of the requirement of fast handover, we propose using cross-layer concept in handover layer to holistically consider many parameters of PHY, MAC, and network layers. In the simulation analysis, we will use residential time, WiMAX-cell capacity, blocking and dropping probability as overflow thresholds to improve the performance of the integrated network.

3: The wireless network protocol stack

It is widely accepted that the next generation heterogeneous networks will be all IP-based. Thus, we propose a concept model of the integrated network architecture in Fig.2. Beginning from the bottom layers, there are three main 802.11 physical layers – 802.11b, 802.11g, 802.11n. The maximum data rates of 802.11b, 802.11g, 80211n are 11, 54, 250Mbps, respectively. The cost of the 802.11b is dropped rapidly, even close to the devices of wireless personal area networks (WPAN). The IEEE 802.16 defines several physical layers, and vendors are left free to whatever they need. The maximum data rates of 802.16, and 802.16e are 134, 30Mbps, respectively.

An 802.11e QoS framework defines a hybrid coordination function (HCF), which multiplexes between two medium access modes: a distributed channel access (EDCA), and a centralized scheme called HCF controlled channel access (HCCA). Both access schemes enhance or extend functionality of the original access schemes, distributed coordination function (DCF) and point coordination function (PCF) , specified in the 802.11a/b/g.[7] The MAC layer of the 802.16 is connection-oriented. The MAC layer includes convergence sub-layer (CS), common part sub-layer (CPS) and security sub-layer. The CS handles higher-layer protocol placed above the MAC. The CPS handles channel access, connection establishment and maintenance.

To maintain uninterrupted user connections during handovers across different networks, the IEEE 802.21[8] defines a common media independent handover (MIH) function between Layer 2 and Layer 3 of the OSI network stack, which enables mobility across heterogeneous networks. By allowing client devices and networks to work cooperatively during these network transitions, the IEEE 802.21 provides mechanisms for optimizing handovers across Wi-Fi, WiMAX and cellular radios that will dramatically enhance the user's mobile experience.

Fast Mobile IPv6 protocol [15] and its related drafts are proposed to support fast handover in all IP networks. The enhancements offered by Fast MIPv6 operation toward seamless handover support are strongly dependent on the timely availability of handoff-related information. A non-exhaustive list of generic link-layer triggers used for this purpose, as identified by the IEEE 802.21[8].

Management entities, spanning the entire layered architecture, consist of all necessary functions for provisioning, maintenance, operation and administration of this integrated network. Besides, management entities communicate with the servers with functions of QoS policy, mobility decision and profiles storage.

Applying a two-tier network architecture to a more realistic scenario involving a mobile node's mobility management across hybrid Wi-Fi and WiMAX wireless networks, we propose Wi-Fi networks being in the micro-cell area, WiMAX being in the Macro-cell area and consider these QOS metrics as the PHY/MAC trigger through IEEE 802.21 to make Mobile IP fast handover. The IEEE 802.21 also provides a unified framework to help MIP nodes to across the internetworking environment. We propose to making unified layer 2 abstractions in the IEEE 802.21 to support layer 3 fast handover. Then the interaction between 802.11e / 802.16e and Fast Mobile IP is presented with the primitives proposed by IEEE 802.21 for the close interaction between layer 2 and layer 3. We will combine the IEEE 802.11 and 802.16e trigger-assisted proactive fast MIPv6 handover scenario from refs. [9], [14] to provide session continuity during handover. The IEEE 802.16e and 802.11e trigger-assisted proactive fast MIPv6 handover scenario is illustrated in Fig. 3.

4: Mobility Management Scheme

A simple solution to mobility management would be the use of Mobile IPv6 but with move detection optimizations [13]. These optimizations include triggers from the link layer. Our mobility management scheme is based on Fig.3 to find suitable "Link Parameters" such as signal strength, velocity of mobile nodes, relative delay, service level prediction, etc. It is evident that such cross layer optimization can reduce handover latency to an acceptable range. The residential time threshold in our proposed handover scheme can be specified in "Link Parameters Change" trigger defined in the 802.21, and Link handoff triggers are analogous to the handover decision procedure in our proposed scheme.

An abstract representation of the network in which call-level QoS parameters, namely call blocking and dropping probabilities are considered. We focus on the suitable mobility management schemes of our two-tier network at first. The speed-sensitive cell selection is defined to direct the mobile hosts to the appropriate cell layer according to their speeds to improve the system performance in terms of blocking and dropping probabilities [12]. The arrival and departure cases regarding mobile hosts in a two-tier cellular network are illustrated in Figure 4. There includes three types of arrival hosts in the Wi-Fi cell in terms of from neighbor Wi-Fi cells, overlaid WiMAX cell and initial session itself.

The scheme used by most cellular telephone companies is location-based. A user generated in micro cell (or macro cell) is served by micro cell BS (or macro cell BS), respectively. In the overlay region, the user is served by micro cell BS if there is no enough capacity in macro cell. The original mobility management scheme of a two-tier cellular network is illustrated in Fig 5. The process in our proposed scheme is illustrated in Figure 6. According to the arrival cases, if a filtered mobile host arrives in the Wi-Fi cell including from neighboring WiMAX cells and overlaid WiMAX cell, the scheme keeps the previous state. When a non-filtered mobile host arrives in the Wi-Fi cell including from overlaid WiMAX cell and initial session itself, and if the residential time is longer than the residential time threshold and if the WiMAX cell has enough capacity, then it will be overflowed into the WiMAX cell to reduce the handoff probability. Otherwise, it will be assigned to the Wi-Fi cell, accordingly. The overflow threshold is presented to avoid too many overflows occurred to reduce the blocking and dropping probabilities. When a non-filtered mobile host arrives in the Wi-Fi cell and the blocking and dropping probabilities of the WiMAX cell are less than the overflow threshold, it will be overflowed into the WiMAX cell. Otherwise, it will be assigned to the Wi-Fi cell, accordingly.

Because the dropping of a handoff call is more unacceptable than the blocking of a new call, we add a handoff protection mechanism in scheme II that made reserves two free guard channels for handoff usage in advance.

5: Numerical Results

5.1: The simulation model

The simulation model is a two-tier cellular network that each WiMAX cell overlays 7 Wi-Fi cells as shown in Fig.2, and some assumptions involved in this model are stated below.

There are three speed types of mobile hosts in terms of fast, middle and slow following Poisson distribution with average speeds of 40 km/hr, 20 km/hr and 5 km/hr, respectively.

The cell radius of WiMAX cell and Wi-Fi cell are 3000m and 500m, respectively.

The number of fast type mobile hosts is 5% of the total hosts, middle type mobile hosts occupy 15% and slow hosts occupy 80%.

There are three schemes that will be investigated to evaluate the system performance in this paper

Scheme O: The original scheme is described in Fig. 5.

Scheme I: The proposed scheme is described in Fig. 6.

Scheme II: A handoff protection mechanism is added to the scheme I where two free guard channels are reserved for handoff usage in advance.

5.2: Numerical Results

Fig. 7 presents the decrement of accessing times in the network. It shows that the decrement increases with increasing high residential time threshold due to the fact that fast mobiles are served preferably by WiMax cells. Due to the overflow admission control adopted in Scheme I, the decrement increases slowly for high residential time threshold. Compared with Scheme I, reduced access times in Scheme II will smaller than Scheme I due to that more guard channels are reserved for handoff calls. Fig. 8 shows the average number of handoff experienced by mobile hosts. It decreases as residential time threshold increases. The reason is that mobile hosts are more often served by WiMax cells. Fig. 9~Fig.12 presents blocking and dropping probabilities versus residential time thresholds. The system includes 7 Wi-Fi cells and a WiMAX cell overlays these 7 Wi-Fi cells. We can see that the scheme I and II performs better than the original scheme generally. Due to the handoff call protection mechanism, the dropping probability is smaller than the blocking probability in Scheme II. Due to fast mobile hosts are easily overflowed into WiMAX cell, thus blocking and dropping probabilities are higher in WiMAX cell than in Wi-Fi cell. The blocking probability increases with the increasing of residential time threshold. In addition, it increases slowly with high residential time threshold. The amount of overflow is presented in Fig. 13. The amount of overflow in Scheme II is smaller than that in Scheme I. The difference among three schemes increases with the increasing residential time thresholds.

6: CONCLUSIONS

In this paper, we proposed a two-tier network architecture between Wi-Fi and WiMAX networks with seamless handover and proposed a concept model of protocol stack. Although this paper does not deal with detailed handover and QoS algorithms, we concentrate on mobility management mechanisms and investigate network architecture for supporting mobility management. Our future works will involve other performance evaluation by comparing more parameters such as handover latency, packet loss, cost, throughput etc. through discussing more PHY and MAC characteristics.

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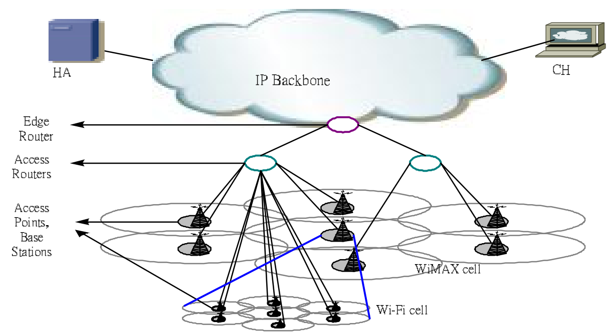

Fig. 1 network architecture

<table>
<tr><td colspan="2">Higher Layers</td><td rowspan="5">Management Entities</td></tr>
<tr><td colspan="2">Network Layer
(Mobile IPv6)</td></tr>
<tr><td colspan="2">Handover Layer
(802.21)</td></tr>
<tr><td>MAC - 802.11 e</td><td>MAC - 802.16-2005</td></tr>
<tr><td>PHY- 802.11 b/g/n</td><td>PHY - 802.16 -2005</td></tr>
</table>

Fig.2 A concept model of the wireless network protocol stack

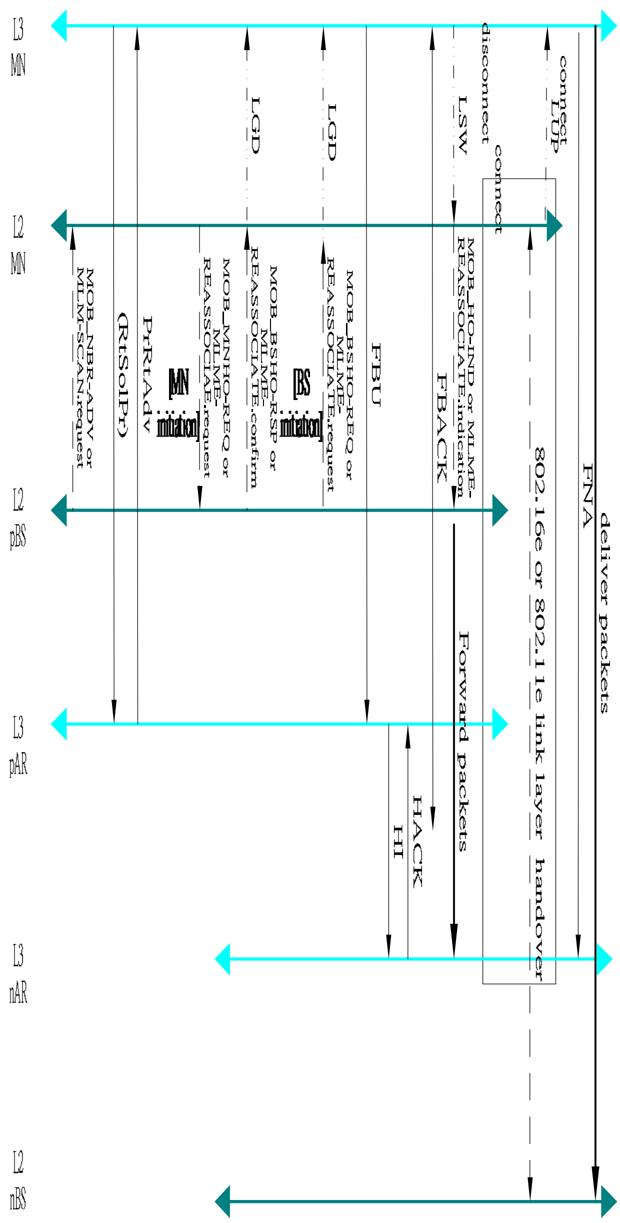

Fig. 3 IEEE 802.16e &802.11e trigger-assisted proactive fast MIPv6 handover scenario

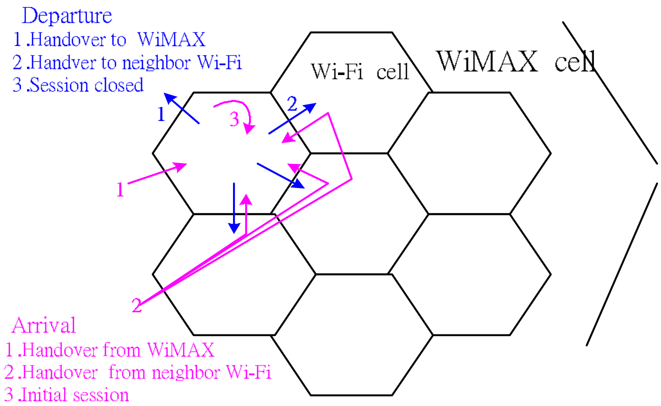

Fig. 4 Arrival and departure cases

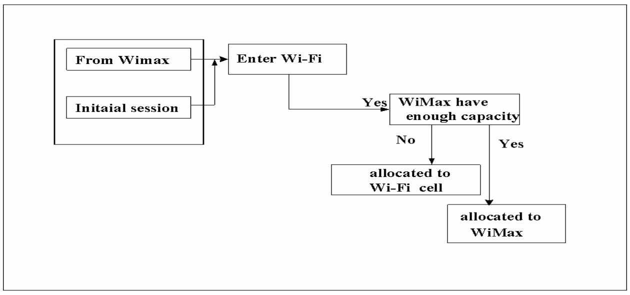

Fig. 5 Original mobility management scheme

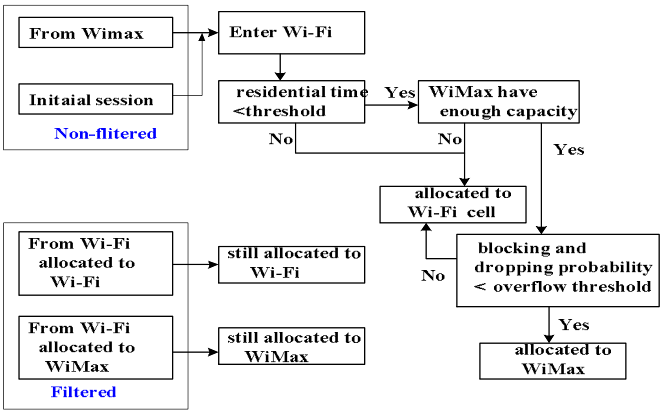

Fig. 6 Proposed mobility management scheme

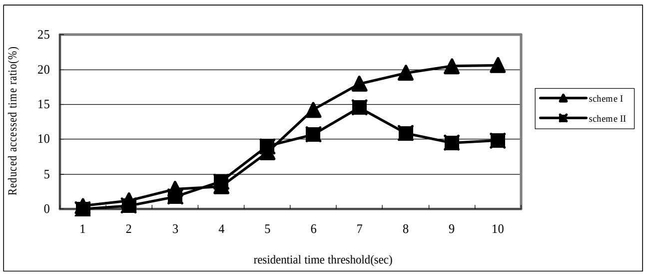

Fig.7.The decrement of accessing times (by percent) in the mobile node

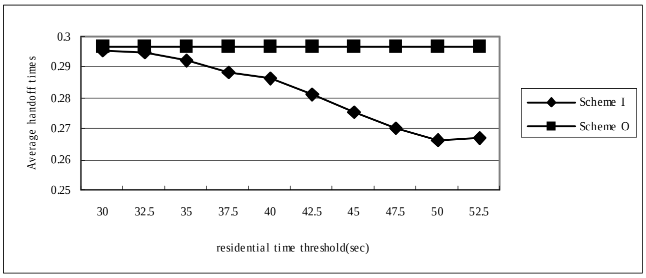

Fig.8. The average handoff times (number) vs. residential time threshold

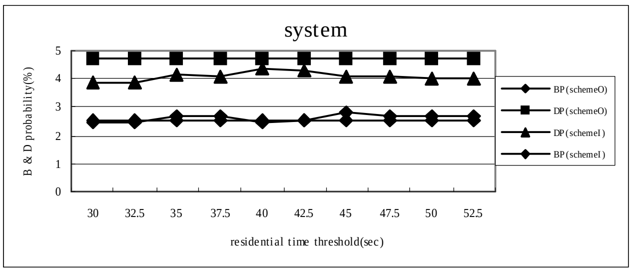

Fig.9 Blocking & Dropping probability in the system with Scheme I and Scheme O

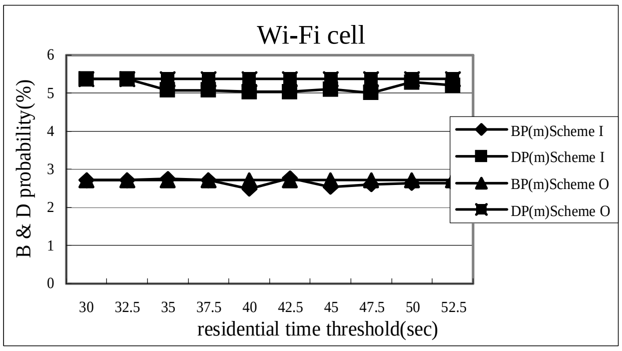

Fig.10 Blocking & Dropping probability in Wi-Fi cell with scheme I and scheme O

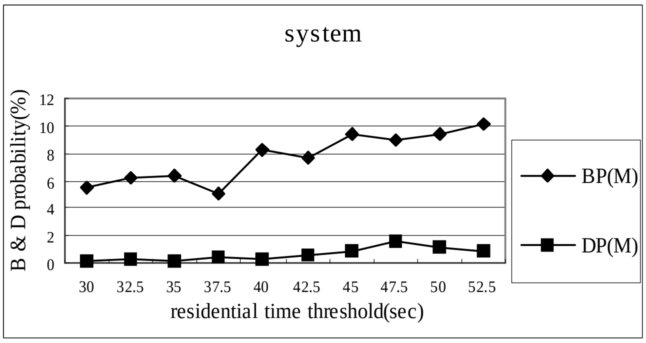

Fig.11 Blocking & Dropping probability in the system with Scheme II

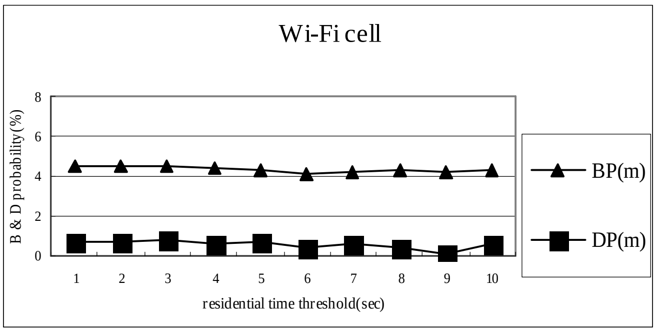

Fig.12 Blocking & Dropping probability in Wi-Fi cell with Scheme II.

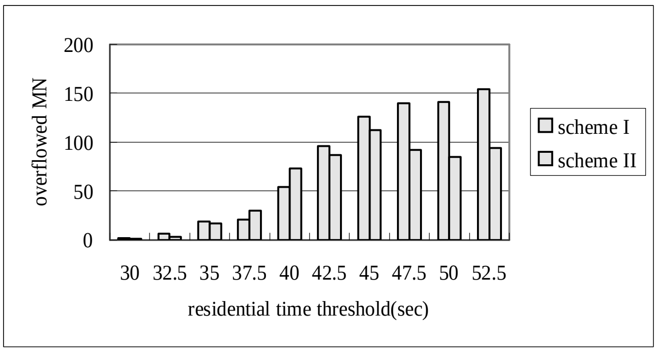

Fig.13. Overflowed MN vs. residential time threshold.