國立交通大學

資訊管理研究所

碩士論文

一個基於即時交通資訊與使用者行為的蜂巢式網路頻道分配機制

A Channel Allocation Mechanism Using Real-time Traffic Information and User Behavior for Cellular Networks

研 究 生：雷 哲 豪

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摘要

在蜂巢式網路(cellular networks)中，當基地台缺乏可用的頻道可供連線時，通話中的手機(或稱行動台(Mobile Station, MS)從另一個細胞移動至這個細胞時，將發生換手(handover)程序失敗,(造成通話阻斷(Call Block))。故將使得手機用戶滿意度的下降和電信業者的損失。故在蜂巢式網路中，頻道分配是很重要的資源管理議題。因此，本論文中利用在國道上之車輛探測設備(Vehicle Detector, VD)取得即時交通資訊(包含有交通流量、車速)，並考量使用者的通話行為(包含有通話間隔時間、通話時間)，依此資訊預測行動網路端通話頻道數的使用狀況，進行頻道動態分配機制之設計。在通話阻斷率的實驗中，模擬一般情況和交通事故兩種情境，在一般情況下所提出的機制較傳統的靜態式頻道分配機制少 3.37%通話阻斷率，而在交通事故情境下則可減少 30.23%。本研究之頻道分配機制可有效且即時因交通狀況而做動態分配。

關鍵字：個人通訊、蜂巢式網路、通話失敗、通話阻斷、頻道分配

A Channel Allocation Mechanism Using Real-time Traffic Information and User Behavior for Cellular Networks

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Abstract

In cellular networks, when the *Base Station* (BS) has no the extra available channels, the handover procedure of communicating *Mobile Station* (MS) will be failed. As a result, it caused to call blocking which will decrease the customer satisfaction and result in financial loss. Therefore, the channel allocation for call block avoidance is an important issue of resource management in cellular networks. In this paper, we propose a mechanism which considers the real-time traffic information (e.g., traffic flow and vehicle speed) and the user behaviors (e.g., call inter-arrival time and call holding time) to analyze the adaptable amount of communication calls in the specific cell for channel allocation. In conducting the experiments of *Call Block Probabilities* (CBP), we simulate two cases by the situations of the whole day and traffic accident. The simulation results show that the CBP proposed by our scheme in the case of the whole day can decrease 3.37% CBP, compared to that of SCA scheme. Moreover, the CBP proposed by our scheme in the case of traffic accident can decrease 30.23% CBP, compared to that of SCA scheme. Therefore, our proposed mechanism is more effective that can decrease the number of CBP.

Keyword: Personal communication systems, Cellular Network, Call drop, Call block, Channel allocation.

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Outline

FIGURE INDEX

TABLE INDEX

Chapter 1 Introduction

In recent years, as the rise of the economics growth and information technology advance which already improve the quality of *Personal Communication Systems* (PCS). Moreover, people pay more attention to the quality of service in cellular system. As the number of *Mobile Stations* (MS) rise, how to provide the high quality of service in cellular networks has been became a big challenge. The cellular system is composed of cells. A cell is the specific coverage of the *Base Station* (BS) and it overlaps the coverage of neighboring cell. BS are fixed and interconnected through a fixed network usually are wired network. The structure of cellular network is the connective coverage of the cell. Moreover, every cell only has limited channel to provide communicating service. In cellular system, *Global System for Mobile Communications* (GSM) and *Universal Mobile Telecommunications System* (UMTS) are well-known system in this domain [2][20]. GSM is the second generation cellular system and UMTS is the third generation cellular system. They can decide whether to accept the call or to not depend on the available number of the channels. When a MS wants to communicate with another user, it must first obtain a free channel provided by BS. If the BS has no free channel, the call will be failed. So, in this issue, how many the number of channel for handover in BSs which is reserved is an important issue of cellular system. The number of limited channel which be provided by BS and everyone almost has at least one cellphone in the moment, so the channel of BS are easy to be fully occupying.

When the channel of BS be fully occupying, the MSs will encounter the situation of call drop or call block [5]. If the MS wants to communicate with another MS, it must request a free channel from the BS. If a channel is free, it is assigned to the MS. If the BS has no free channel to allocate to the MS, the BS will block the MS which is requesting call. If the communicating call moves from the old cell to the new cell, it has to request the new cell for a free channel. If the new cell has no free channel, the call drop occurs. The call block causes more loss than the call drop because it stops the ongoing call. We can solve the problem through reserving channels for handover in BS but how many channels of the BS to reserve is a big issue.

Therefore, there are many researches working on the quality of cellular telephone system improvement. A number of studies have suggested the method to allocate the number of channels in BSs to reserve. There can be classified two categories [10][16][18], static allocation mechanism [16] and dynamic channel allocation mechanism. Many dynamic allocation mechanism have been proposed [7][14][18] and many static allocation mechanism also have been proposed. However, the static allocation mechanisms are unsuitable in dynamic environments.

This paper will provide a *Dynamic Channel Allocation* (DCA) mechanism. We consider the traffic information to analyze the communication behaviors and propose a method to design the DCA mechanism in personal communication system. The communication behaviors of MSs and the MS movement are employed to estimate the status of channel using in cells. Moreover, a better method which decides how many channels them have to reserve is also proposed in this context. Therefore, we can use our mechanism to dynamically adjust the number of channel reserved in each BS according to the variation of traffic information. Simulation results show our proposed mechanism which is better than SCA mechanism based on CBP that the *Call Block Probability* (CBP) by using the DCA mechanism is lower than by *Static Channel Allocation* (SCA) mechanism. In cellular systems, the CBP is an important factor for measuring the quality of service [4][6][15].

Chapter 2 Related Work

In this chapter, we will introduce some concept of PCS which is related to our paper. In order to design our dynamic channel mechanism, we have to use some knowledge about PCS, including GSM, UMTS and the channel allocation mechanism in PCS in the past.

2.1 Cellular Network Architecture

The rapid growth in the demand for PCS has led the industry into intense research and development efforts towards a new generation of cellular systems. Nowadays, people can't live without cellular systems. The MS can perform the communication via the cellular system when the specific cell has a free channel. In this part, we will introduce two major systems in present cellular system. They are GSM and UMTS.

2.1.1. Global System for Mobile Communications

The GSM is a digital wireless network specified by standardization committees from major European telecommunications operators and manufactures. Through the standard, all mobile users worldwide can use a common set of compatible services. Figure 1 illustrates the architecture of GSM [11][12][20]. The network system of GSM at least includes three sections: a MS (Figure 1 (a)), Base Station Subsystem (BSS, Figure 1 (b)), Network and Switch Subsystem (NSS, Figure 1 (c)). Moreover, it has to build the standard communication interface between any two components in GSM to transmit information and control command. Through the standard interface let the component in GSM can communicate with each other and complete the capability of communication. BSS consists of the Base Transceiver Station (BTS, Figure 1 (d)) and the Base Station Controller (BSC, Figure 1 (e)). NSS consists of the Mobile Switching Center (MSC, Figure 1 (f)), Visitor Location Register (VLR, Figure 1 (g)) and Home Location Register (HLR, Figure 1 (h)). The work of BTS is listening the order from BSC to communicate with the MS via the radio interface while the BSC communicates with the MSC via the A interface (Figure 1 (i)). MSC is a special switch that executes the capability of circuit switch and is responsible for recording to the billing system. HLR is responsible for recoding the information of user subscribed our system, including what service user subscribed and the location of MS. VLR is responsible for recording the information of user inside its domain, including the state and location of user.

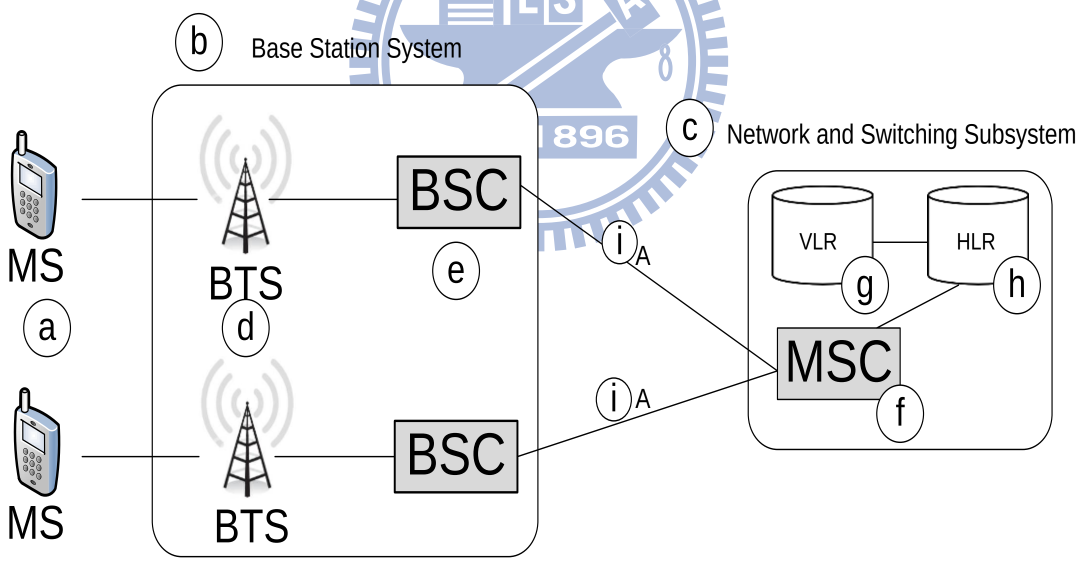

Figure 1 The GSM network architecture

2.1.2. Universal Mobile Telecommunications System

In early 2000, because existing GSM data transmission service was too expensive, only a small portion of GSM subscribers used data service. In order to offer better mobile service, GSM operators proposed the *General Packet Radio Service* (GPRS), which reuse the architecture of GSM to provide end-to-end packet-switched services. In GPRS, the existing nodes such as BSS, MSC, VLR and HLR are upgraded to improve the efficiency of packet data transmission.

The UMTS is the third generation (3G) and is the standard of mobile communication system. UMTS has the feature which is compatible with existing GSM/GPRS, so it is considered as the best cellular system in mobile communication system. Figure 2 illustrates the architecture of the UMTS *Circuit-Switched* (CS) service domain [11][12][20]. The network system of UMTS includes User Equipment (UE, Figure 2 (a)), UMTS Terrestrial Radio Access Network (UTRAN, Figure 2 (b)). Moreover, it has to build the standard communication interface between any two components in UMTS to transmit information and control command. Through the standard, all mobile users worldwide can use a common set of compatible services. URTAN consists of Node B (Figure 2 (d)) and Radio Network Controller (RNC, Figure 2 (e)). UE is equal to user end equipment such as MS. Node B is responsible for capability of physical layer, including controlling information of spread spectrum and modulation. RNC is responsible for radio resource management and the capability to connect to MSC via the interface of *IuCS* (Figure 2 (a)). In general, any coverage of Node B is called *Cell*. HLR is responsible for recoding the information of user subscribed our system, including what service user subscribed and the location of MS.

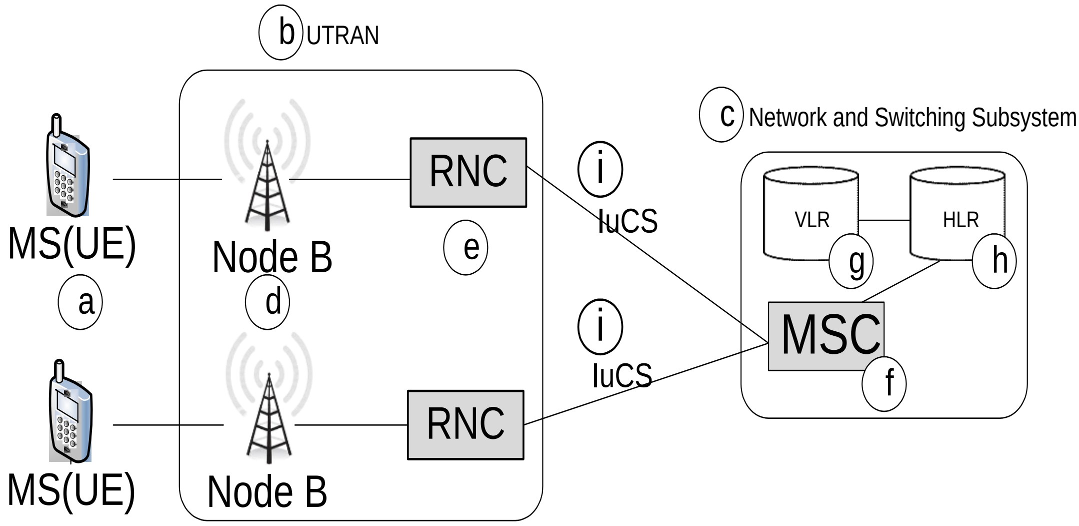

Figure 2 The UMTS network architecture

2.2 Channel Allocation Mechanisms

In cellular networks, when MS wants to communicate with another MS, it must get a free channel provided from BS to server it. So, if the BS has a free channel, the connection between two MSs will be built successfully, otherwise the connection of communication is failed. So, how to allocate the suitable number of channels for communication is a critical issue. In this section, we will introduce two type of channel allocation mechanisms which are traditional SCA mechanism and the DCA mechanism respectively.

2.2.1 Static Channel Allocation

The mechanism of channel allocation in PCS adopts the *Static Channel Allocation* (SCA) mechanism. In the scenarios, when the channels are allocated, the BS only can use these channels to provide the service of communication. In this case, there have a definite relation between the channels and the cells that can be used at any time. The obvious disadvantage of using SCA mechanism can be explained using an example. Imagine two adjacent cells with their allocated channels. If at any time, one of the cells which all the channels are occupied, and another new call requested a free channel in this cell. This call will be blocked even if the adjacent cell has a free channel at this moment. The situation will result in the customer satisfaction and economic loss.

Channel reuse is an essential feature of cellular system. However, the discussion of directional cell sites explained the economic incentive for minimizing the ratio of σ, the parameter of σ can be expressed as a ratio the physical distance between the center of cells (*D*) divided by the radius (*R*) of cell. The co-channel reuse ratio has an impact on both the communication quality and the ender customer capacity of the system [8]. Because the co-channel ratio actually has impact on the communication quality, the ratio will decide the number of channels in each channel sets. The ratio also can limit the communication capacity of cell by deciding the number of channel in each channel sets. In the SCA mechanism, when the number of channels (*N*) is assigned to each cell, the number of channels (*N*) is a fixed number and permanently allocated to each cells [19]. When the number of channel is decided, the BS only can use these channels to provide service of communication. In generally, the number of channel (*N*) in each cell can be expressed as formula (1) [9][10][14].

$$N = \left(\frac{1}{3}\right)\sigma 2 \qquad (1)$$

Here we define σ as D/R, where D is the physical distance between the two cell centers and the R is the radius of the cell. Therefore, the number of N only can be integer value. For example, N is 3, 4… or etc.

In SCA mechanism, because the number of channels in each cell is permanent, the solution is suitable for the stable situation of traffic information. The CBP will increase with the traffic flow increases.

2.2.2 Dynamic Channel Allocation

The SCA mechanism can't achieve high efficiency of channel using with the variation of traffic in cellular networks. In order to overcome this problem, *Dynamic Channel Allocation* (DCA) mechanism in recent year has been studied widely. In contrast to SCA mechanism, the DCA mechanism has no fixed relationship with each cell and channel [9]. All channels are in the central pool. When any cell has a new call arrival, it will allocate one free channel to that cell [3][10][17]. After the call complete, the channel will be return to the central pool.

In DCA, a channel can be used in any cell provided that the signal interference constraints are satisfied. Generally, more channels can be assigned to the cells required channel by central pool. The main idea of DCA mechanism that minimizes the cost to select and use the candidate channels provided that the interference constraints are satisfied. The selections of cost functions are designed with the different schemes. The factors when we design the function including the usage frequency of the candidate channel, the reuse distance, channel occupancy distribution under current traffic conditions, and radio channel measurements of individual MSs of the average CBP of the system [18]. In this part, DCA mechanism can dynamically allocate free channel to the cell required channel depending on the variation of traffic information. Therefore, the DCA mechanism is suitable for dynamical environment. We design the mechanism for channel allocation based on the DCA scheme in PCS. Finally, depending on the type of control, the DCA mechanism can be divided into centralized and distributed mechanism [10].

2.2.2.1 Centralized DCA Mechanism

In the centralized DCA mechanism, the channels in cell are allocated by the central pool in PCS for temporary use and the channel return to the central pool when used over. The difference between these mechanisms is the specific cost functions adopt for selection the candidate channel for allocation. Generally, the factors of cost functions are *First Available* (FA) and *Locally Optimized Dynamic Assignment* (LODA). In the centralized DCA mechanism, the FA is the simplest strategy to select the candidate channel for using. In FA, the first available channel within the reuse distance σ selected during the channel search which assigned to the cell. In LODA, the selected cost function is based on the future blocking probability in the adjacent of the cell where a call is initiated.

2.2.2.2 Distributed DCA Mechanism

As the growth of economic and the demand of the quality of service in PCS, the DCA mechanisms have been studied in recent years. Several simulation results and analysis have shown that the centralized DCA mechanism can provide near optimum channel allocation, but it will causes to the immensely management cost in the central control. Therefore, the distributed DCA mechanism is proposed. The difference between the centralized DCA mechanism and the distributed DCA mechanism is the distributed DCA mechanism doesn't has the central pool for channel control. The proposed distributed DCA mechanism uses either local information with regard to the current available channels in the cells vicinity () or signal strength measurements [10]. The channel is allocated to a call by the base station in the *Cell Based*. The difference with the centralized approach is that each BS keeps the information of present available channels in its adjacent cells. Through the exchange of status information between BS, the channel information is updated. Through the immense exchange of status information between BS, the *Cell Based* mechanism provides near optimum channel allocation, especially under heavy traffic load.

Chapter 3 Channel Allocation Mechanism in Cellular Networks

In this paper, we will analyze the relation of communication behaviors of MSs and the status of traffic. Moreover, we can use this traffic information to provide a method which can help the cellular telephone system to decide the number of channels which can be reserved. Therefore, before we introduce the mechanism, we will introduce what communication behavior we use. We use four factors of communication behaviors separately in *Call Arrival* (CA), *handover* (HO) in, *handover* (HO) out, *Call Departure* (CD). The subsections of this chapter are structured as follows. In subsection 3.1, we define the call block problem in cellular networks. In subsection 3.2, we design and propose a new channel allocation mechanism based on traffic information and user behaviors. In subsection 3.3, we discuss the expected benefits and limitation of our proposed mechanism. Table 1 shows the notation we use in our proposed mechanism.

Table 1. Notations

Parameter	Description
t (hr)	The call inter arrival time
$1/\lambda$ (hr)	The expected value of t
τ (hr)	The call holding time
$1/\mu$ (hr)	The expected value of τ
l_i (km)	The distance of road segment covered by the cell
V_i(km/hr)	The average speed of the car
F_i	The car flow in the scenario of call arrival
C_i	The amount of communicating call on the road segment covered by the specific cell
A_i	The amount of call arrivals on the road segment covered by the specific cell i
x	The time difference traveled from the first call arrival location to entering the specific cell
I_i	The amount of handover in on the road segment covered by the specific cell
O_i	The amount of handover out on the road segment covered by the specific cell
O_i^A	The amount of handover out derived from call arrival
O_i^I	The amount of handover out derived from handover in
D_i	The amount of call departure from cellular network
D_i^A	The amount of call departure derived from call arrival
D_i^I	The amount of call departure derived from handover in

3.1. Design issue

In the previous work, the PCS applies the SCA mechanism to manage the channel allocation in the cellular networks. The SCA mechanism assigns a fixed number of channels in specific cell for handover, even if the situation in this specific cell has been changed. Therefore, the CBP is higher by using SAC mechanism in the dynamic environment.

In this reasoning, we design the channel allocation mechanism which can dynamically allocate the number of channels in the specific cell depending on the variation of traffic information in this cell. In our proposed mechanism, we will analyze the relation of communication behaviors of MSs and the status of traffic information. We consider the traffic information including traffic flow and vehicle speed in each cell. We can dynamically adjust the number of channels according to the situation of traffic information in each cell. In our proposed mechanism, we assume that one MS per one car moving along the road and the architecture is single-tier cellular networks.

3.2. Channel Allocation Mechanism

In this section, we will introduce the channel allocation mechanism which we proposed in this paper. Figure 3 shows that the architecture of our proposed mechanism. The goal in our proposed mechanism is to find the number of communicating calls (C_i) which is derived from four factors, including the number of *Call Arrival* (A_i), the number of *Handover In* (I_i), the number of *Handover Out* (O_i), and the number of *Call Department* (D_i). Moreover, we can use the formula (2) to estimate the amount of communicating call (C_i) for Cell$_i$. The following, we will discuss the four factors respectively.

$$C_i = A_i + I_i - O_i - D_i \tag{2}$$

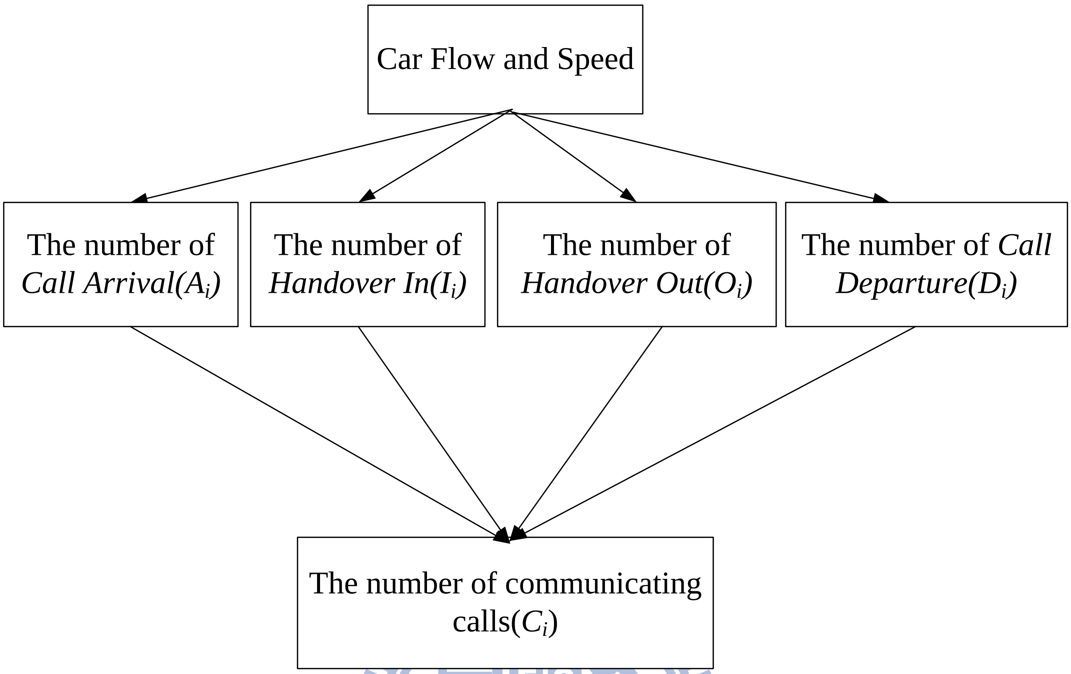

Figure 3 The architecture of our proposed mechanism

3.2.1. The number of *Call Arrival* (A_i)

In GSM and UMTS, the service area provided by a lot of BSs and Node Bs with each providing coverage in its vicinity, respectively. The BSC and RNC (Figure 4 (b)) in GSM and UMTS are responsible for the network environment control. When call arrival at the coverage area of the cell, BSC or RNC order the cell to provide a free channel to the MS (Figure 1 (a)) and the MS will be connected by the cell if the cell has a free channel. Figure 4 shows the scenario diagram for vehicle movement and call arrivals on the road. The MS in a car moving along the road performs the first call set-up at time t_0 (in Figure 4 and Figure 5) and enters the specific cell coverage at time t_1 (in Figure 4 and Figure 5). The MS performs the second call set-up at time t_2 (in Figure 4 and Figure 5) before leaving the specific cell coverage at time t_3 (in Figure 4 and Figure 5). The scenario for the cell is called ***Call Arrival***.

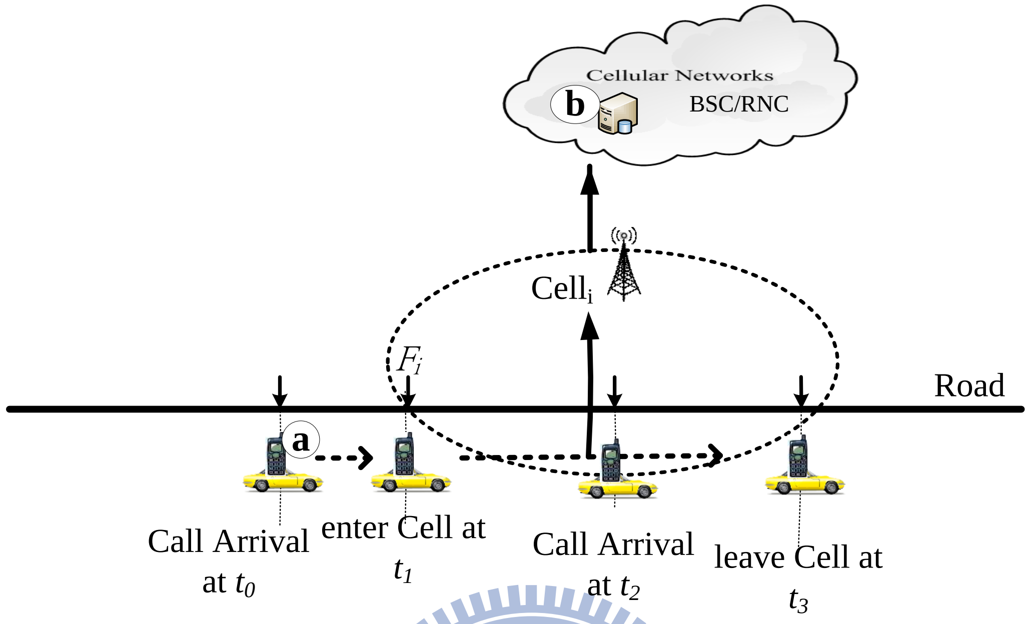

Figure 4. The scenario diagram for vehicle movement and call arrivals on the road segment covered by the specific cell

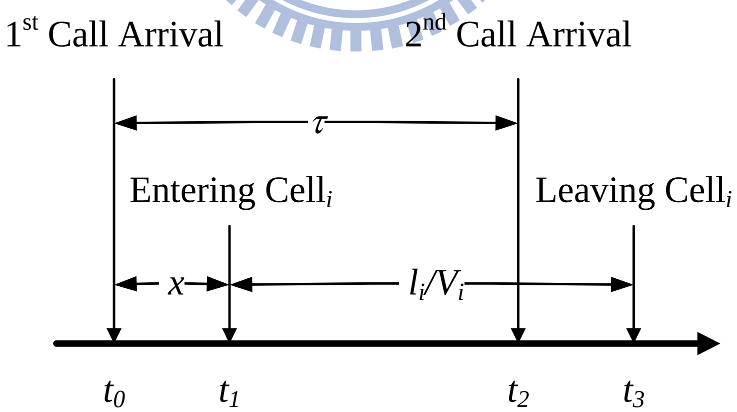

Figure 5. The timing diagram for call arrivals on the segment covered by the specific Cell$_i$

In this paper, we assume that the call inter-arrival time (t) is exponentially distributed with the mean $1/\lambda$ [1] to generate the call arrival. Because the distance of the cell coverage is l_i and the speed of the car is V_i, the time which the car moves from one side to the other side is l_i/V_i. This approach considers the MS which has twice call arrivals, the time entering the cell and leaving the cell to estimate the probability of call arrival. We can get the amount (A_i) of call arrivals on the road segment through traffic flow (F_i) multiply by the probability of call arrival. It can be expressed as formula (3).

$$
\begin{aligned}
A_i &= F_i \times \Pr(t_1 < t_2 < t_3) \\
&= F_i \times \int_{x=0}^{\infty} \Pr\left(x < t < x + \frac{l_i}{v} \right) dx \\
&= F_i \times \int_{x=0}^{\infty} \int_{t=x}^{x+\frac{l_i}{v}} f(t) dt dx \\
&= F_i \times \int_{x=0}^{\infty} \int_{t=x}^{x+\frac{l_i}{v}} \lambda e^{-\lambda t} dt dx \\
&= F_i \times \int_{x=0}^{\infty} -e^{-\lambda t} \Big|_{t=x}^{x+\frac{l_i}{v}} dx \\
&= F_i \times \int_{x=0}^{\infty} e^{-\lambda x} - e^{-\lambda\left(x+\frac{l_i}{v}\right)} dx \\
&= F_i \times \left(1 - e^{-\frac{\lambda l_i}{v}}\right) \int_{x=0}^{\infty} e^{-\lambda x} dx \\
&= F_i \times \left(1 - e^{-\frac{\lambda l_i}{v}}\right) \left(- \frac{e^{-\lambda x}}{\lambda} \Big|_{x=0}^{\infty} \right) \\
&= F_i \times \frac{1 - e^{-\frac{\lambda l_i}{v}}}{\lambda}
\end{aligned}
\tag{3}
$$

3.2.2. The number of *Handover In* (I_i)

When a communicating MS in the car moves from the coverage area of source cell to the coverage area of the target cell, the channel source cell provide will be released and the target cell will provide a channel to the MS if the target cell has a free channel. The process is called handover.

There is a road covered by a set of cells and a communicating MS (Figure 6 (a)) in car on the road. Figure 6 illustrates the scenario of handover in. The MS ((a) in Figure 6) in car performs the call set-up at time t_0 (in Figure 6 and Figure 7) and goes into the handover zone of coverage of the Cell (i-1) and Cell i at t_1 (in Figure 6 and Figure 7) and the BSC or RNC will order the Cell i to allocate a free channel to the MS. In the moment, if the Cell i has a free channel, the connection between the MS and the Cell i will be connected successfully. The process is called ***handover in*** for Cell i.

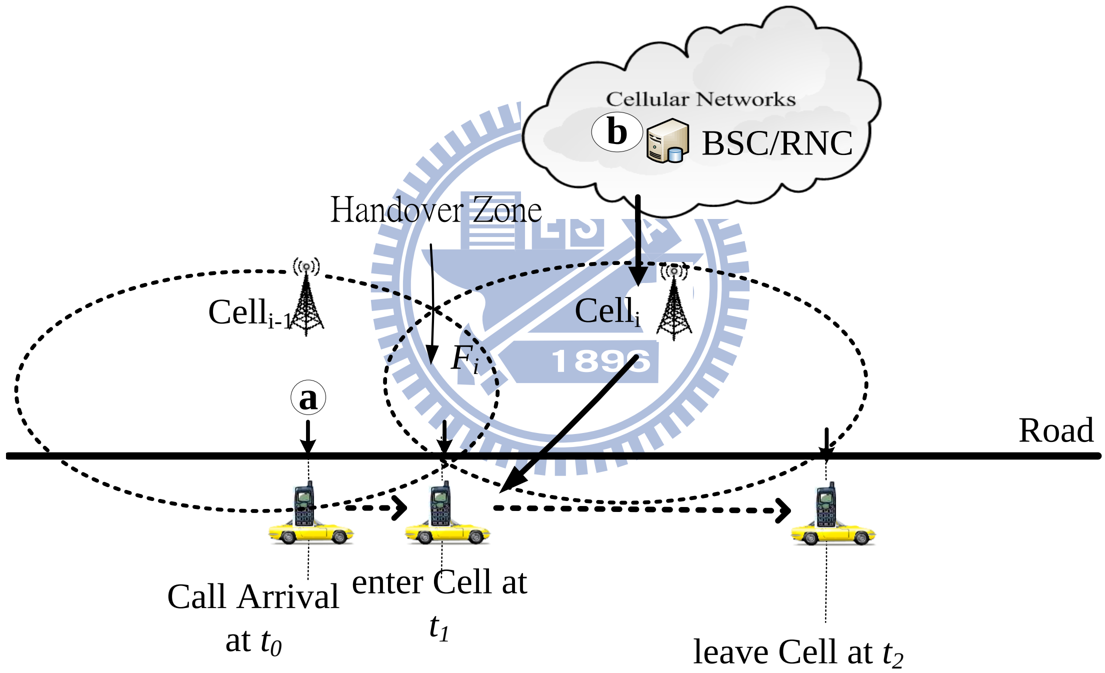

Figure 6. The space diagram for traffic Handover In scenario from cellular network

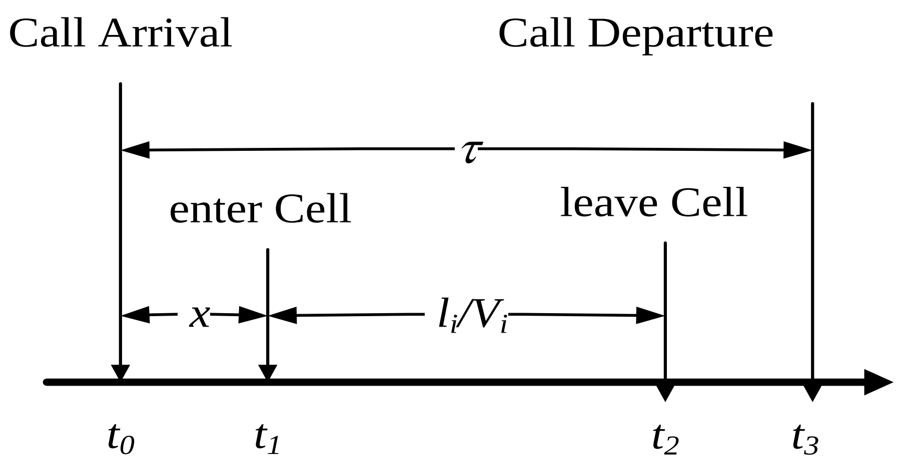

Figure 7. The timing diagram for Handover In scenario from cellular network

In this paper, we assume that the call holding time (τ) is exponentially distributed with the mean $1/\mu$ [1] to generate the handover in. Because the distance of the cell coverage is l_i and the speed of the car is V_i, the time which the MS holding the call is τ. The variable x is the time difference traveled from the first call arrival location to entering the specific cell. The travel time l_i/V_i is the time difference between t_1 and t_2 which the car in the Cell i. This approach considers the call holding time (τ) should be larger than x. The variable F_i is the car flow. The amount (I_i) of handover in on the road segment covered by the specific cell can be expressed as formula (4).

$$
\begin{aligned}
H_I &= F_i \times \Pr(\tau > x) \\
&= F_i \times \int_{x=0}^{\infty} \Pr(\tau > x) dx \\
&= F_i \times \int_{x=0}^{\infty} \int_{\tau=x}^{\infty} g(\tau) d\tau dx \\
&= F_i \times \int_{x=0}^{\infty} \int_{\tau=x}^{\infty} \mu e^{-\mu\tau} d\tau dx \\
&= F_i \times \int_{x=0}^{\infty} - e^{-\mu\tau} \Big|_{\tau=x}^{\infty} dx \\
&= F_i \times \int_{x=0}^{\infty} e^{-\mu x} dx \\
&= F_i \times \left(- \frac{e^{-\mu x}}{\mu} \Bigg|_{x=0}^{\infty} \right) \\
&= \frac{F_i}{\mu}
\end{aligned}
\tag{4}
$$

3.2.3. The number of *Handover Out* (O_i)

In this section, the scenario we want to introduce is Handover Out. The MS (Figure 4 (a)) in car moving the road perform the first call set-up at time t_0 (Figure 4 and Figure 5) and enters the handover zone at time t_1 . At the time t_1, the BSC/RNC (Figure 4 (b)) will order the Cell (*i*-1) release the connected channel between Cell (*i*-1) and the MS and order the Cell *i* to allocate a free channel to server the MS. The MS in car leaves the coverage of cell *i* at time t_3 (Figure 4 and Figure 5) and departure the call at t_4 (Figure 8) out of the coverage of the Cell *i*. The process is called **Handover Out** for specific Cell *i*.

Through the introduction about call arrival and handover in above the subsection, we can get the probability of handover out derive from call arrival and handover in. We will introduce the probability of handover out based on call arrival and handover in respectively. Firstly, the Figure 8 which reference the Figure 4 illustrates the scenario of handover out derived from call arrival. The MS in car enters the coverage of the Cell *i* at time t_1 (Figure 4 and Figure 8) and perform the call set-up at time t_2 (Figure 4 and Figure 8). In Figure 8, the variable

l_i is the distance of road segment covered by the cell, variable V_i is the speed of the car, the variable τ [1] is the call holding time, variable x is the time difference traveled from the first call arrival location to entering the specific Cell i. For the purpose of the scenario of handover out derive from the call arrival in Cell i, the τ must be larger than $(l_i/V_i - x)$. The variable F_i is the traffic flow. The amount (O_i^A) of handover out on the road segment from call arrival covered by the specific cell can be expressed as formula (5). Secondly, the Figure 9 which reference the Figure 6 illustrates the scenario of handover out derived from handover in. We will introduce the probability of handover out derived from handover in. The MS in car performs the call set-up at time t_0 (Figure 6 and Figure 9) and enters the Cell i at time t_1 (Figure 6 and Figure 9). The communicating MS in car leave Cell i at time t_2 and call departure in another cell at t_3 (Figure 6 and Figure 9). The variable x is the time difference traveled from the first call arrival location to entering the specific Cell i. The variable l_i is the distance of the cell coverage. The variable V_i is the speed of the car. The value of l_i/V_i is the time which the car in Cell i. The variable τ is call holding time. For the purpose of the scenario of handover out derive from the handover in in Cell i, the τ must be larger than $(x+l_i/V_i)$. The variable F_i is the car flow. The amount (O_i^I) of handover out on the road segment derived from handover in covered by the specific cell can be expressed as formula (6).Therefore, the amount of handover out is the formula (7).

$$O_i^A = F_i \times \int_{x=0}^{\infty} \Pr\left(\tau > \frac{l_i}{V_i} x \right) dx$$

$$= F_i \times \int_{x=0}^{\frac{li}{Vi}} \int_{\tau=\frac{li}{Vi}-x}^{\infty} \mu e^{-\mu\tau} d\tau dx \qquad (5)$$

$$= F_i * \frac{1-e^{-\mu\frac{li}{Vi}}}{\mu}$$

$$O_i^I = F_i \times \int_{x=0}^{\infty} \Pr\left(\tau > x + \frac{l_i}{V_i} \right) dx$$

$$= F_i \times \int_{x=0}^{\infty} \int_{\tau=x+\frac{li}{Vi}}^{\infty} \mu e^{-\mu\tau} d\tau dx \qquad (6)$$

$$= F_i * \frac{e^{-\mu\frac{li}{Vi}}}{\mu}$$

$$O_i = O_i^A + O_i^I$$

$$= F_i * \frac{1}{\mu}$$

$$= I_i \qquad (7)$$

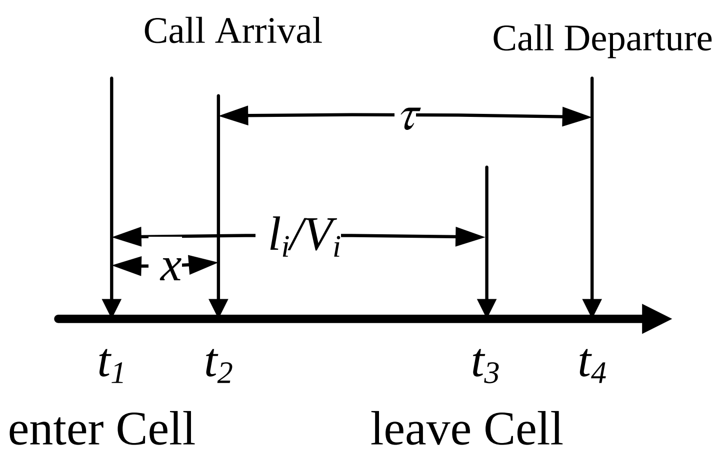

Figure 8. The timing diagram for Handover out scenario derived from call arrival from cellular network

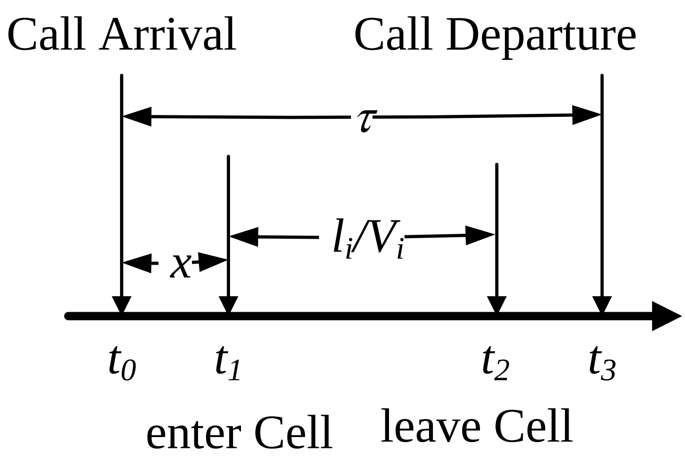

Figure 9 The timing diagram for Handover out scenario derived from Handover in in cellular networks

3.2.4. The number of *Call Departure* (D_i)

In this section, the scenario we want to introduce is call departure. The MS in car enters the coverage of the Cell *i* at time t_0 (Figure 10 and Figure 11) and performs the call set-up at time t_1 (Figure 10 and Figure 11). The MS will perform the call departure at t_2 (Figure 10 and Figure 11). The scenario is called ***Call Departure*** for Cell *i*.

Through the introduction of call arrival (in subsection 2.1) and handover in (in subsection 2.2), we know that we can get the probability of call departure derived from call arrival and handover in. We will introduce the probability of call departure derived from call arrival and handover in respectively. Firstly, the Figure 10 and Figure 11 illustrate the scenario of the call departure derived from call arrival. The MS in car enters the coverage of Cell *i* at time t_0 (Figure 10 and Figure 11) and performs the call set-up at time t_1 (Figure 10 and Figure 11). Then, the MS in car perform the call departure at time t_2 (Figure 10 and Figure 11). The variable (D_i^A) is the number of call departure on the road segment derived from call arrival covered by the specific cell. The process is called call departure derived from call arrival. Secondly, the Figure 12 and Figure 13 illustrated the scenario of call departure derived from handover in. The MS (Figure 12 (a)) in car performs the call set-up at time t_0 (Figure 12 and Figure 13) and enters the coverage of the Cell i at time t_1 (Figure 12 and Figure 13). Then, the MS (Figure 12 (a)) in car perform the call departure at time t_2 (Figure 12 and Figure 13). The variable (D_i^I) is the number of call departure on the road segment derived from handover in covered by the specific cell. Therefore, the amount of call departure is the formula (8). The scenario is called call departure derived from handover in for Cell_i. In this paper, we know the formula(9) and through the formula(7) which let us understand that I_i is equal to O_i. Because I_i is equal to O_i, A_i is equal to D_i. So, we can get the formula (10) by the information from above section.

$$D_i = D_i^A + D_i^I \tag{8}$$

$$A_i + I_i = D_i + O_i \tag{9}$$

$$A_i = D_i = F_i \times \frac{1 - e^{-\frac{\lambda l_i}{V_i}}}{\lambda} \tag{10}$$

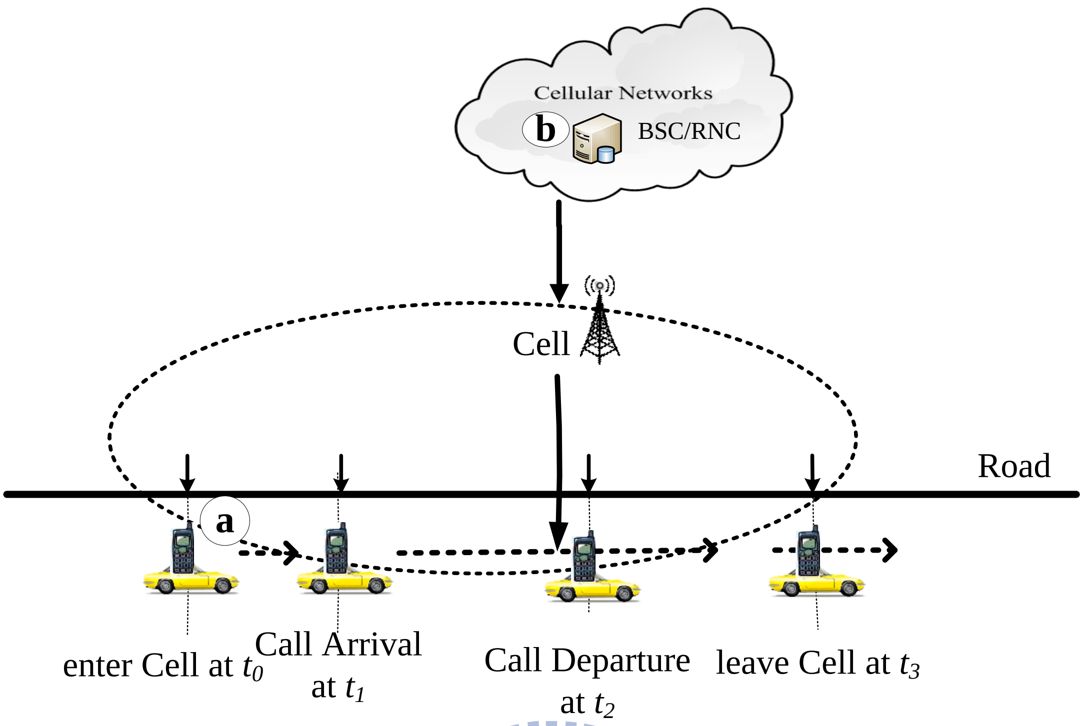

Figure 10. The scenario diagram for vehicle movement and call departure on the road

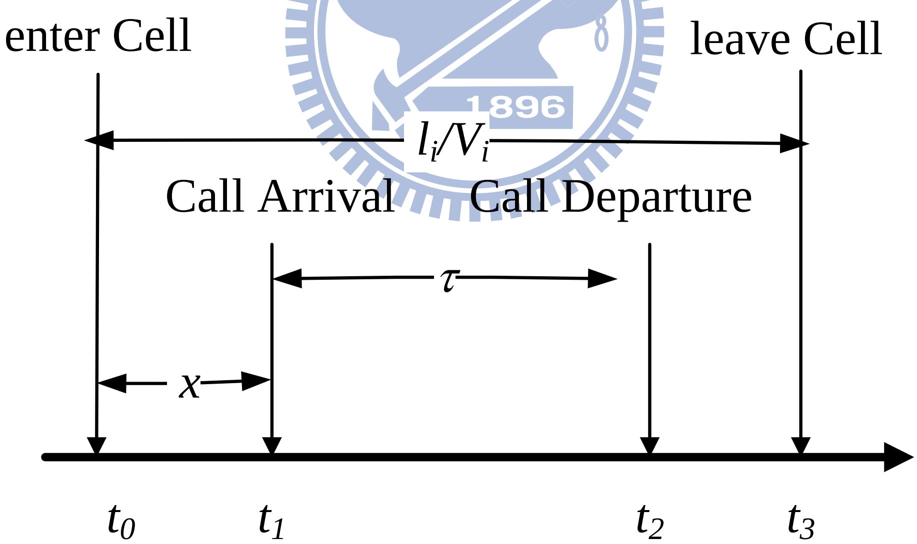

Figure 11. The timing diagram for call departure derived from call arrival in cellular networks

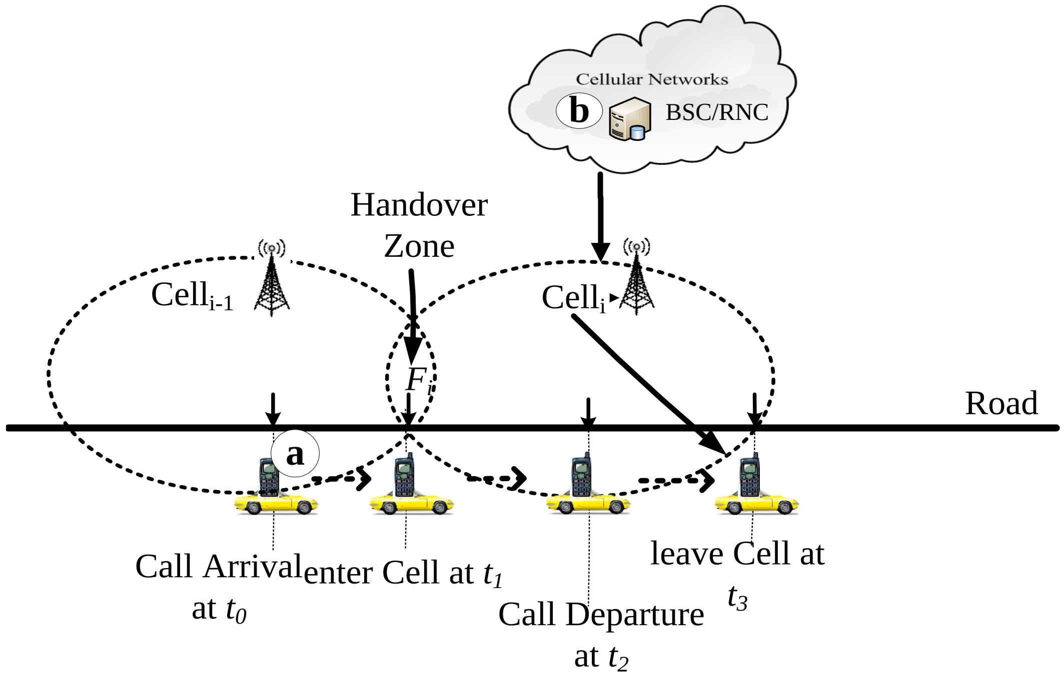

Figure 12. The space diagram for traffic call departure scenario derived from handover in from cellular networks

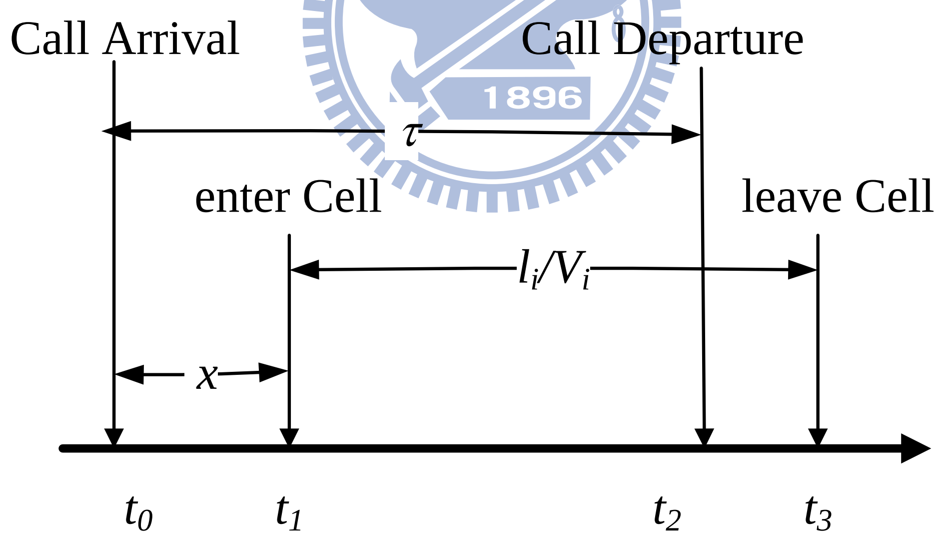

Figure 13. The timing diagram for call departure derived from handover in in cellular networks

3.3. Discussions

Our proposed mechanism can estimate the number of communicating calls and handover events according to the real-time traffic information (e.g., traffic flow and vehicle speed) for channel allocation. This mechanism will dynamically predict and allocate the number of channel in each cell for handover when the traffic condition is changed. Therefore, this channel allocation mechanism can be adaptable in dynamic environment. However, the limitations of this mechanism include: (1) it doesn’t be adopted when there are multiple MSs in one car and (2) it can’t be adopted in the multi-tier cellular networks.

Chapter 4 Numerical and Simulation Analysis

In this chapter, we will introduce the experiment environments. We use the real traffic information derived from VD and the random number generator to simulate the communication behaviors on the road. By the output of the simulation, we can get the information of the vehicle movements and the MS communication behaviors. Through the above information, we analyze it and compare the results between our proposed mechanism and the traditional SCA mechanism. The subsection of this chapter is structured as follows. In subsection 4.1, we investigate the effects of traffic information on the handover and call arrival. In subsection 4.2, we introduce the construct of simulation designation. In subsection 4.2.1, we introduce the experiment environments. In subsection 4.2.2, we introduce the simulation case design and performance metrics. In subsection 4.3, we analyze the simulation results and analysis. In subsection 4.4, we discuss the results derived from the simulation.

4.1 Numerical Analysis

This section investigates the communication behaviors of handovers and call arrivals by our model through numeric analysis. The following input parameters are considered as follows.

- The variable l_i is the distance of the road segment covered by the cell i
- the variable V_i which is the average speed of car
- the variable F_i which is the car flow
- the call inter-arrival time t (hr) has exponential distribution with mean $1/\lambda$.
- the call holding time τ (hr) has exponential distribution with mean $1/\mu$

The variable A_i is the count of call arrival per hour. The variable O_i is the count of handover out per hour. The variable I_i is the amount of handover in. The variable D_i is the amount of call department per hour. In this paper, we investigate the effects of traffic information on the A_i and O_i as followed. The effects of the input parameters are investigated as follows:

Effects of F_i on the A_i and O_i: Figure 14 plots A_i and O_i against F, which indicates that A_i and O_i increase as the amounts of car flow (F) increases. This phenomenon is explained as follows. When the amounts of car flow become more per hour, more A_i and O_i in the coverage of the cell is observed. Though the Figure 14, we can know that if we want to study the issue of the handover, the factor of car flow (F_i) which is important for us.

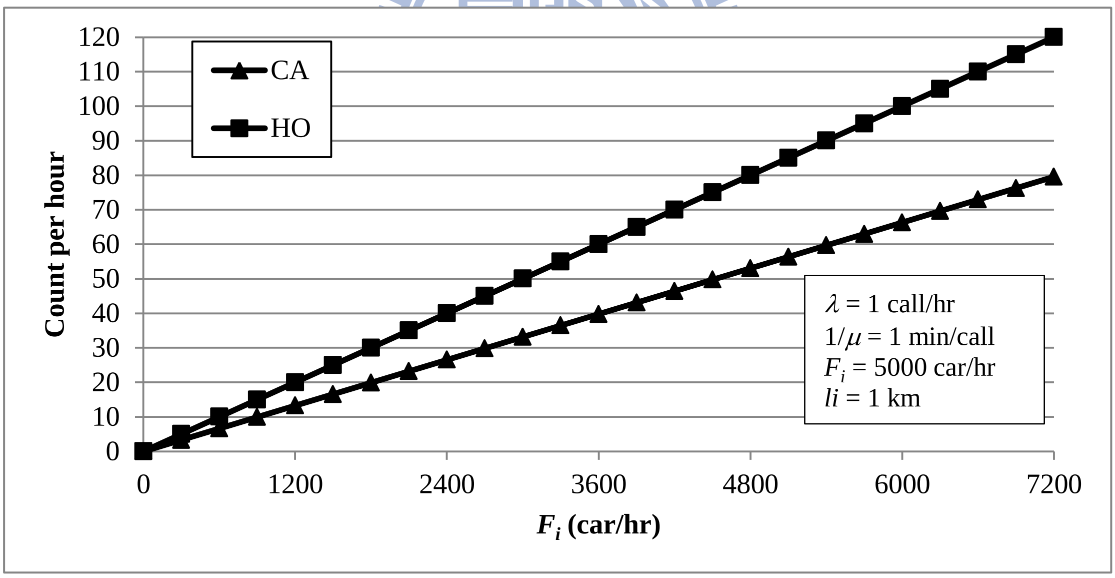

Figure 14. Effect of f on the A_i and O_i

Effects of V_i on the A_i and O_i: Figure 15 plots A_i and O_i against V_i, which indicated that A_i decreases and O_i is unchanged as the average speed of car (V) increases. This phenomenon is explained as follows. When the speed of the car becomes higher, the amounts of the call arrival become more less. In the other way, no matter how the speed of the car changes, the influence of the speed of car on O_i is invalid. Though the Figure 15, we can know that when we want to study the issue of the handover, the factor of the average speed of car (***V**_i*) which is not important for us.

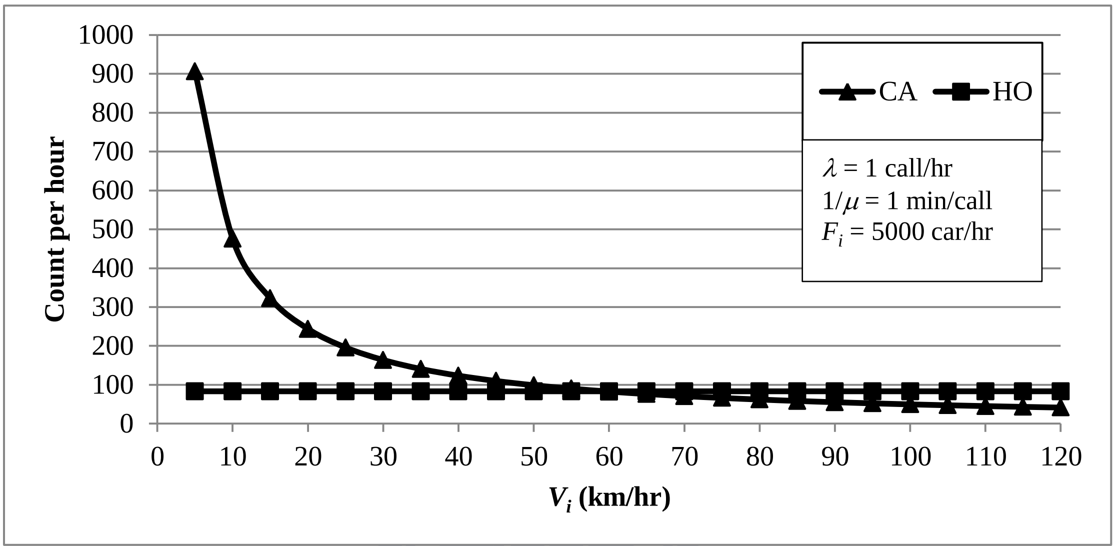

Figure 15. Effect of Vi on the A_i and O_i

Effects of λ on the A_i and O_i: Figure 16 plots A_i and O_i against λ which indicates that A_i and O_i are unchanged as λ increases. This phenomenon is explained as follows. When the call arrival rate (λ) become more, the influence of call arrival rate (λ) on A_i and HO_C are invalid. Though the Figure 16, we can know that when we want to study the issue of handover, the factor of call arrival rate (λ) is not important for us.

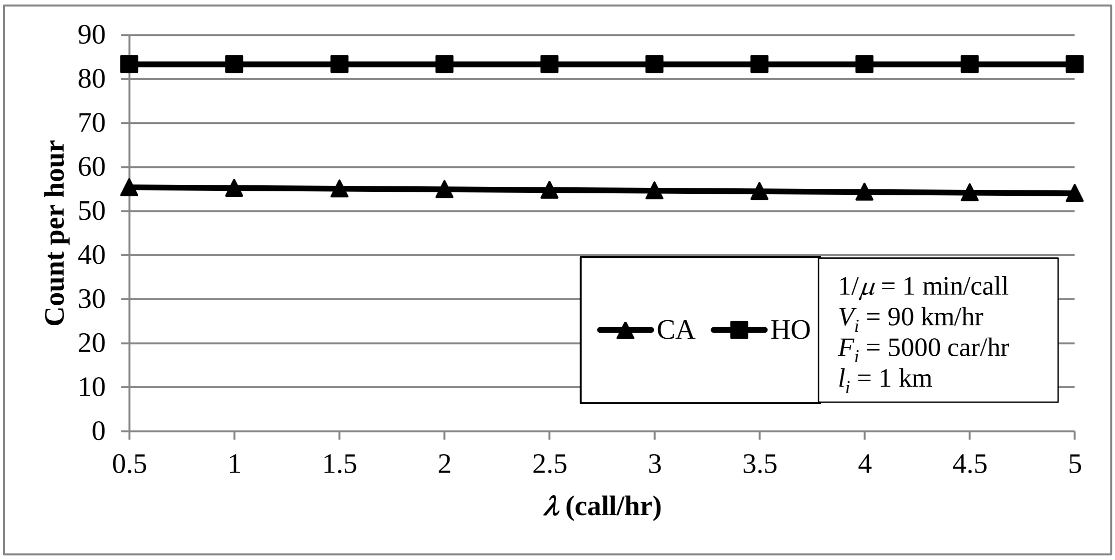

Figure 16. Effect of λ on the A_i and O_i

Effects of μ on the A_i and O_i: Figure 17 plots A_i and O_i against μ, which indicates that A_i is unchanged and O_i increases as call holding time (μ) increases. This phenomenon is explained as follows. When the call holding time (μ) becomes more, the amounts of handover become higher. In the other way, no matter how the call holding time (μ) changes, the influence of the call holding time (μ) on O_i is invalid. Though the Figure 17, we can know that when we want to study the issue of handover, the factor of the call holding time (μ) which is important for us.

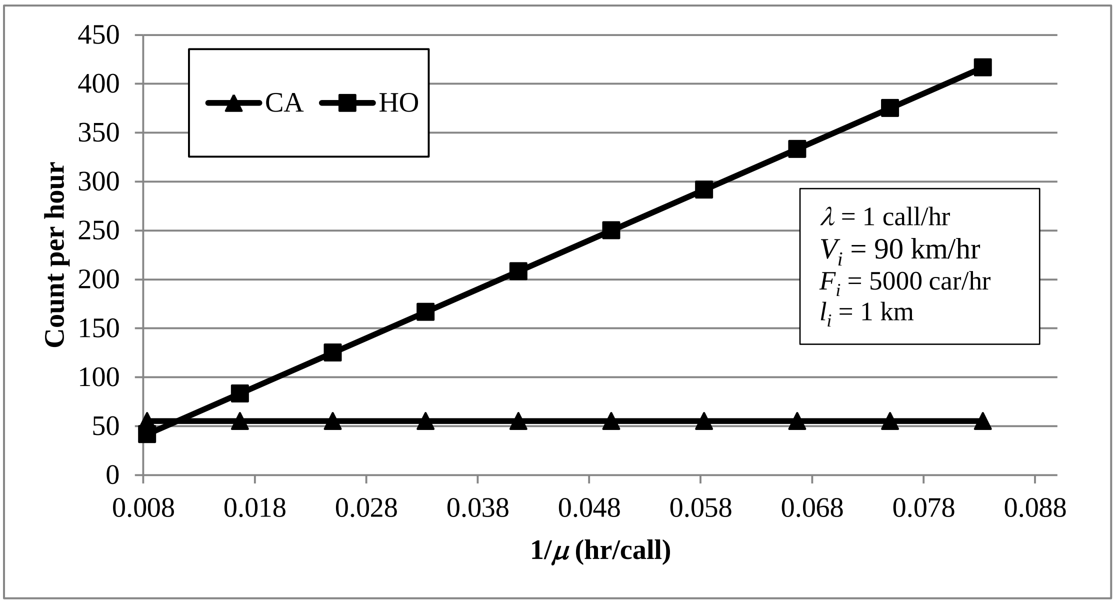

Figure 17. Effect of μ on the A_i and O_i

4.2 Simulation Design

In this section, we introduce the architecture of our simulation consists of the environment of simulation, simulation case design, performance metrics, simulation results and comparison our proposed mechanism with traditional SCA mechanism. The subsection of this chapter is structured as follows. The subsection 4.2.1 shows the simulation environments including road conditions, the traffic information (e.g., traffic flow and vehicle speed) and MS communication behaviors. In subsection 4.2.2 shows that the simulation case design and performance metrics.

4.1.1 Simulation Environments

In this section, we design trace-driven experiments to investigate the traffic information estimations from cellular networks data. As shown in Figure 18, this approach consists of the vehicle movement trace generation, MS communication trace generation, and the combined trace generation of the two behaviors described below.

In this paper, the vehicle movement and MS communication trace files are obtained from the traffic simulator as well as real measurements of a highway in Taiwan. The inputs of trace generator include the road conditions (e.g., the length of the road, the number of lanes, the locations of handover points, and traffic flow), the vehicle movement behaviors (e.g., the desired speeds, the car following model and lane-changing model), and MS communication behaviors (e.g., the call holding time and call inter-arrival time). We assume that one MS per one car moving along the road. The output is a trace file which records the vehicle's ID, desired speed, its locations, its call arrival time, and its call departure time. This trace file is then used to drive the mobility management simulator to estimate the real-time traffic information which includes speed, and traffic flow.

Therefore, we simulate the highway scenario by VISSIM and assign the position of each cells and the position of the handover. The vehicle movement and MS communication traces are generated by a traffic simulation program VISSIM. We consider highway scenario which is characterized by the Wiedemann "psycho-physical" car-following model and lane changing model [13]. For MS communication behaviors, we generate the random numbers of call holding time and call inter-arrival time for each MS in car. The call holding time is exponentially distributed with the mean $1/\mu$ and the call inter-arrival time is exponentially distributed with the mean $1/\lambda$ [1]. Figure 18 illustrates the architecture of the simulation. Figure 19 shows the position of handover and DCP.

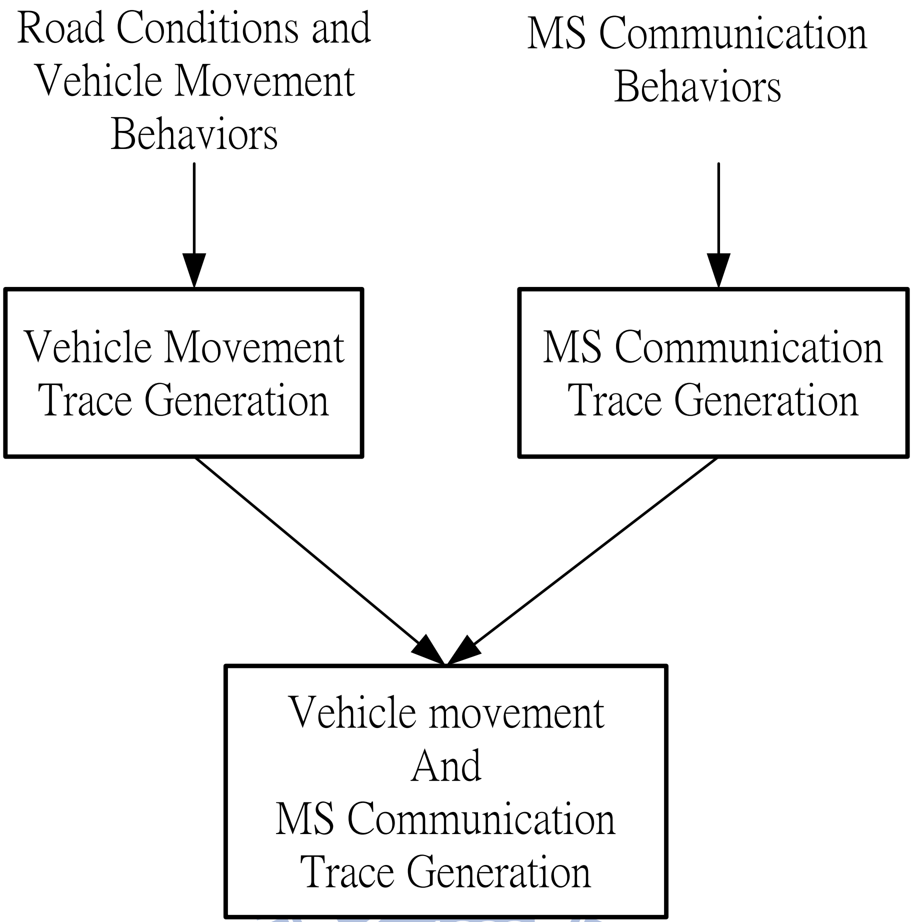

Figure 18. The architecture of simulation

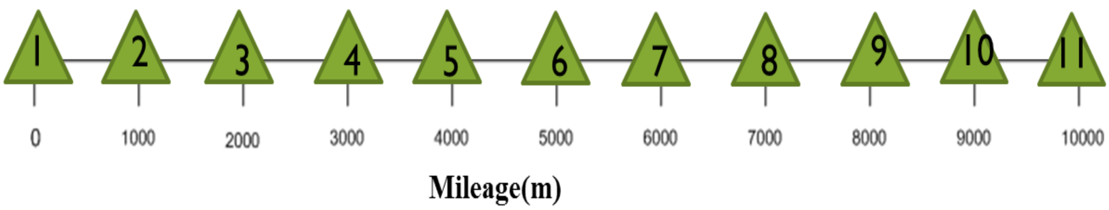

Figure 19. The position of handover and DCP

4.1.2 Simulation Case Design and Performance Metrics

In the simulation, we design two cases of simulations which are the whole day simulation and the traffic accident simulation respectively. Case 1 is the whole day simulation. We can obtain the peak and off-peak of traffic flow from this case.

Through the variation of car flow, we analyze the channel of cell using and handover occurrence. Case 2 is the traffic accident situation. We simulate the vehicle movement and handover behaviors before and after traffic accident. In case 2, we can analyze the surging number of traffic flow and discuss the number of channel using and the number of handover occurrence.

4.1.3.1 Normal Case

In case 1, the traffic information is obtained from the actual VDs which are built on the 42 KM milepost on National Freeway No.1 on 2008/07/31. We use the real traffic information to simulate the vehicle movement and MS communication behaviors. Figure 19 shows the environment of simulation. We assign the length of a 3-lane highway is 10 km. There are 11 handover points and 10 cells distributed on the road from 0 km to 10 km, and the coverage of a cell is 1 km. Moreover, we assume that there are 11 *Data Collection Points* (DCPs) which are built in the same locations with handover points. Those DCPs can record the time which car passes. It means that the coverage area of $Cell_1$ is the area between the first DCP_1 and the second DCP_2. In this case, we can obtain the traffic information in the whole day and analyze the CBP during traffic peak hours and traffic off-peak hours.

4.1.3.2 Emergency Case

In case 2, we design a traffic accident to simulate the MS communication behaviors and handover events in the situation of road congestion. We can observe the number of channels using in cellular system during traffic occurred and removed. Figure 20 shows the environment of simulation. We assign the length of a 3-lane highway is 10 km. There are 11 handover points and 10 cells distributed on the road from 0 km to 10 km, and the coverage of a cell is 1 km. Moreover, we assume that there are 11 DCP which are built in the same locations with handover points. Those

DCPs can record the time which car passes. It means that the coverage area of $Cell_1$ is the area between the first DCP_1 and the second DCP_2. In each simulation run, up to 5,000 vehicles are injected in the road during 1 simulated hour, where the desired speed of a vehicle is uniformly randomly selected between 85-120 km/hr. The totally simulation time is 1.5 hours. We simulate a traffic accident at the location of 5.05 km between simulation time 15^{th} minute and 45^{th} minute. The accident has impact on the range is two lane and the mileage is between 5.05 km and 5.35 km between simulation time 15^{th} minute and 45^{th} minute. When cars go through this section, the average speed of car is dropped to 4-6 km/hr. Until to simulation time 45^{th} minute, the traffic accident is removed and the traffic congestion state comes to normal state.

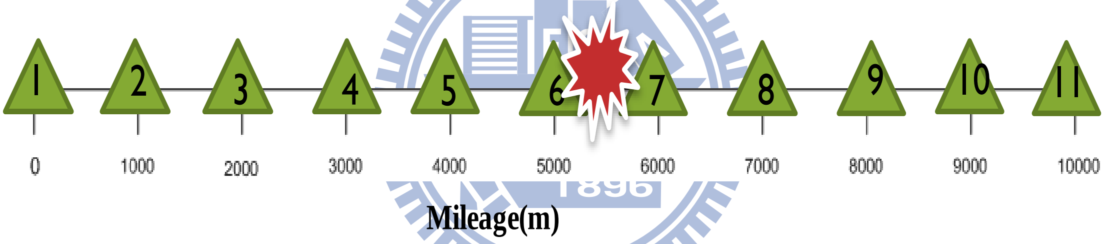

Figure 20. The position of handover and the position of car accident

4.1.3.3 Performance Metrics

In cellular system, the CBP is an important performance metrics for measuring the quality of service. The CBP is denoted as the following formula (11). The number of call block (B_i) divided by the number of the handover (I_i). The probability represents what the fraction of the number of handover that are blocked.

$$\mathrm{CBP} = \frac{B_i}{I_i} \tag{11}$$

4.3 Simulation Results and Analysis

In this section, we introduce the simulation results and analysis. In the simulations, we analyze two cases which are the whole day and the traffic accident simulations. So, we separately analyze the results derived from both cases. In subsection 4.3.1, we analyze the result derived from the case 1. In subsection 4.3.2, we analyze the result derived from the case 2. In subsection 4.3.3, we analyze the results which are the comparison between SCA mechanism and proposed mechanism.

4.2.1 Normal Case

In the whole day simulation, we can simulate the traffic information (e.g., traffic flow and vehicle speed) in $Cell_6$ in the whole day. Figure 21 and Figure 22 show the results of the simulation. In experiments, we analyze the relation of traffic flow and the number of channel using in each cell. We observe the CBP in $Cell_6$ during the traffic peak hour (i.e., 8 AM) and the traffic off-peak hour (i.e., 4 AM). In Figure 21, we can discover that the minimum number of traffic flow is off-peak at 4 AM because the time is deep in the light in Taiwan. Figure 22 shows the number of handover in $Cell_6$ in the whole day. In this situation, the number of the handover events in $Cell_6$ is lower with the lower traffic flow. When the time going to morning, we can discover that the maximum number of the traffic flow at 8 AM is peak in the whole day. The number of the handover events in $Cell_6$ is higher with the higher traffic flow during traffic peak hour. Moreover, depending on above subsection 4.1 the effects of F_i on A_i and I_i, the simulation results also can prove that the number of handover increase with the number of car flow increases in case 1. According to the simulation results, our proposed mechanism can dynamically allocate the channels to use the source of channels effectively.

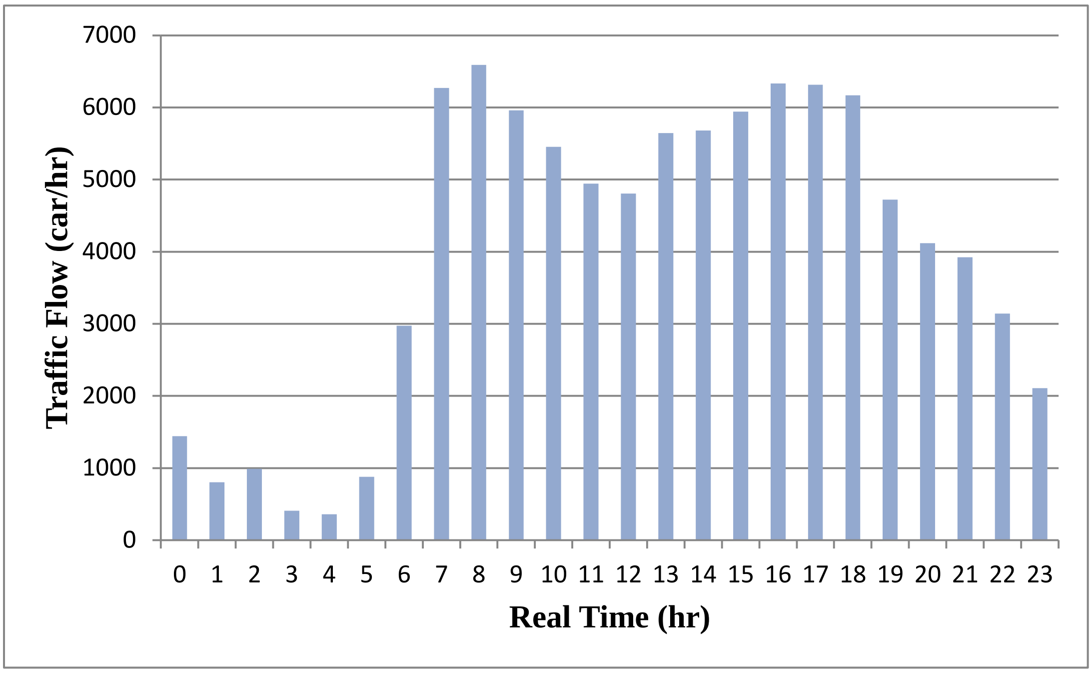

Figure 21. The car flow of whole day in $Cell_6$

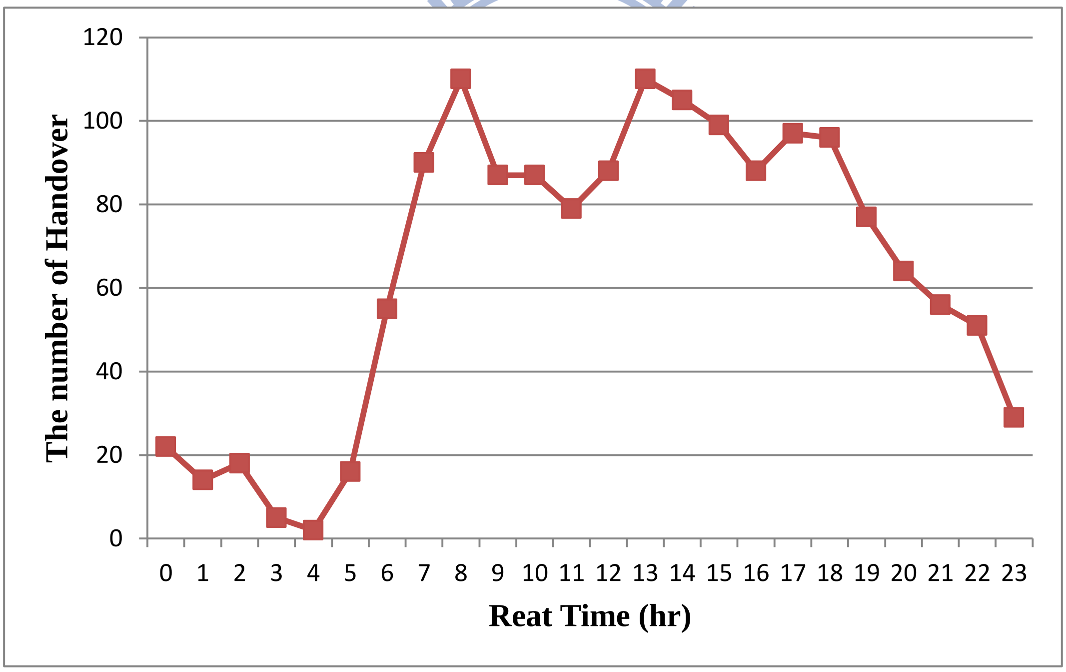

Figure 22. The number of Handover in $Cell_6$

4.2.2 Emergency Case

In the traffic accident simulation, we focus on the positions where front and back the position of traffic accident to observe the relations of the variability of traffic information and the situation of channel of handover using. Figure 23 and Figure 24 show the result of the simulation. At the simulation time 16th minute, due to the traffic accident occur at the mileage of 5.05 km in simulation, resulting in traffic jam occur in $Cell_5$. The cars stop in the $Cell_5$ and they can't go into the $Cell_6$. For $Cell_6$, the number of car flow will drop substantially and the average vehicle speed of car is also drop substantially at the time traffic accident occurred. Due to the traffic accident already is removed at the simulation time 45th minute, the situation of traffic comes to normal state. So, we can discover that the number of traffic flow increases rapidly when the traffic accident removed. In the meanwhile, we will capture another data of $Cell_3$ derived from the simulation. We want to understand both the number of handover of the cell where are on the front and back of the traffic accident.

However, the situation of traffic accident which has impact on the channel for handover uses in cellular system. If we apply the traditional SCA mechanism to support the event of handover in cellular system, it will waste the number of channels during traffic accident or when the traffic accident removed will cause to the situation of Call Block with the number of traffic flow increases rapidly. Figure 25 shows that the number of handover event drop substantially during the traffic accident in $Cell_6$ between the simulation time 16th minute and the 45th minute. The number of handover event increase substantially in $Cell_6$ when the traffic accident removed at the simulation time 46th minute.

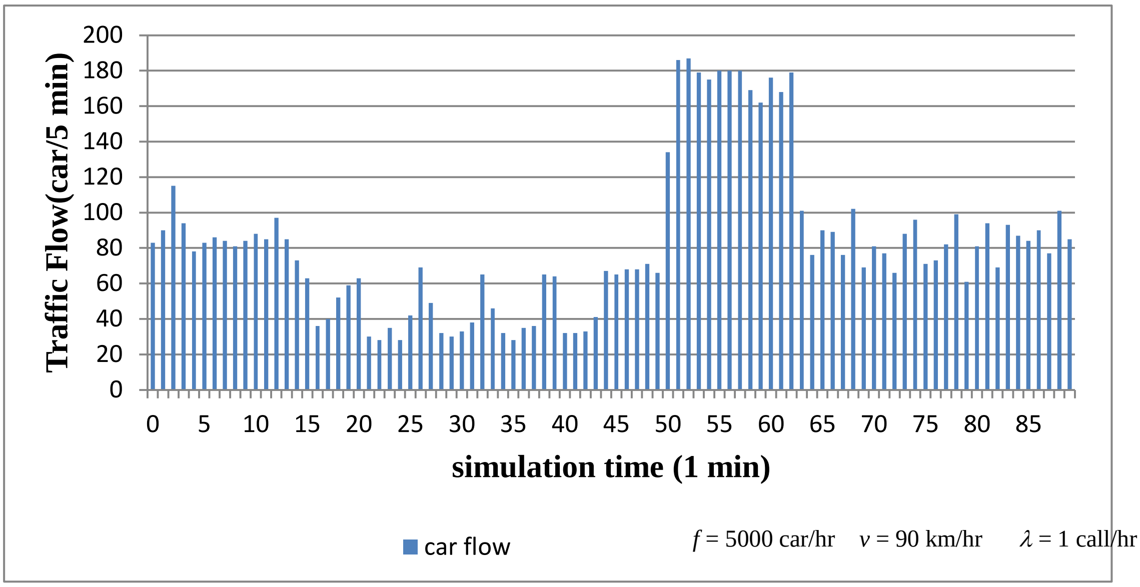

Figure 23. The traffic flow of the Cell$_6$

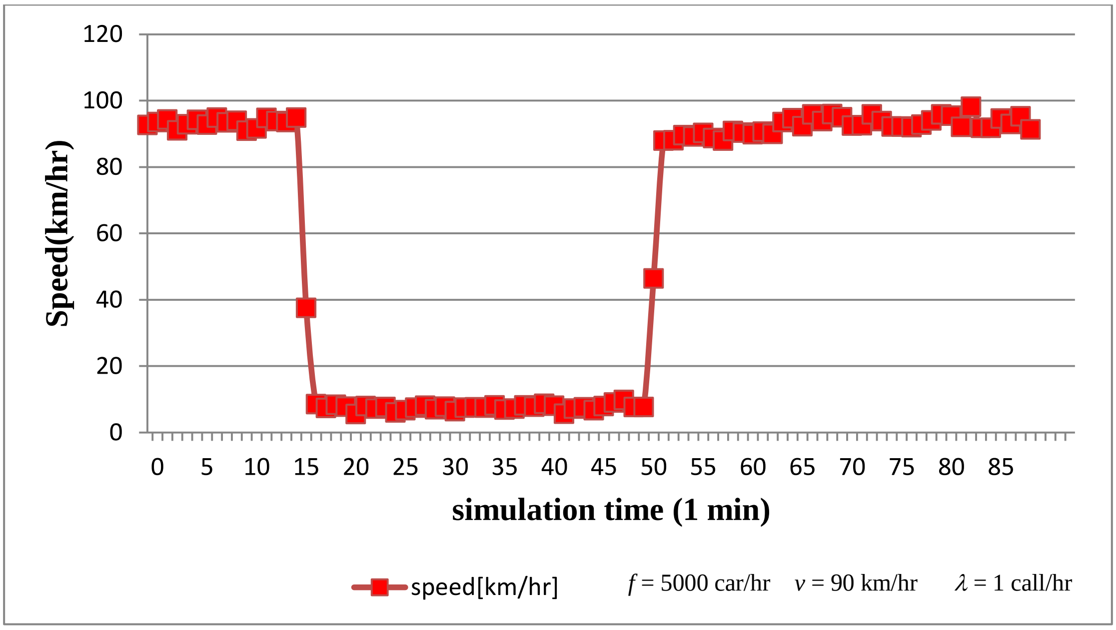

Figure 24. The vehicle speed of the Cell$_6$

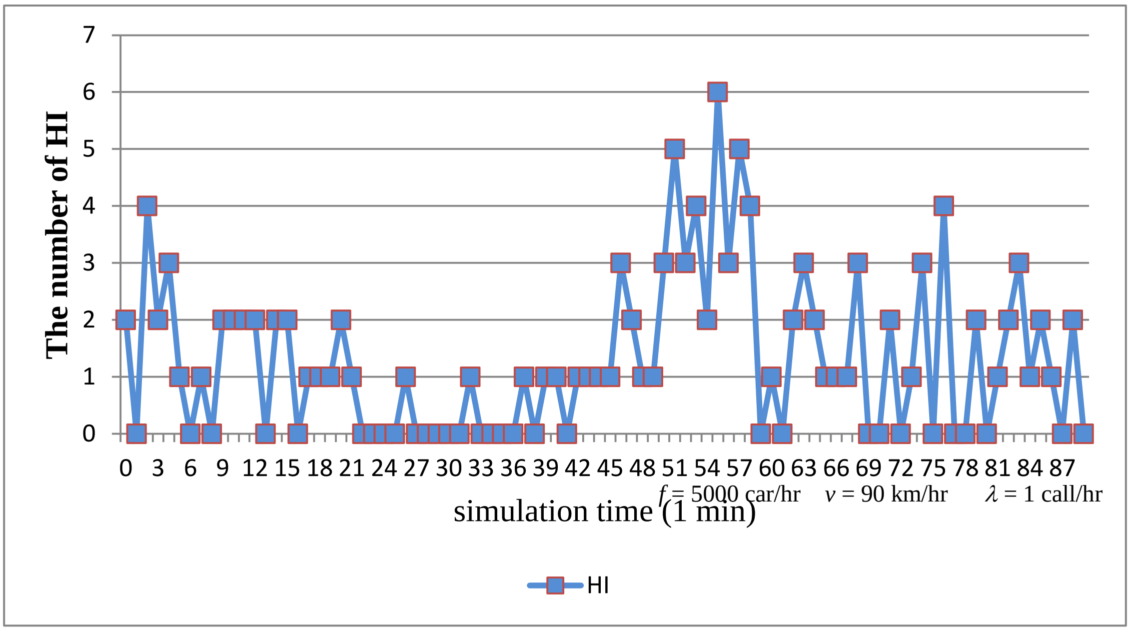

Figure 25. The number of handover in in $Cell_6$

4.2.3 Comparisons between SCA and proposed Mechanism

In this section, we use the number of CBP to compare proposed DCA mechanism with the CBP derived from traditional SCA mechanism under the two cases. The CBP is denoted as the number of the call block divided by the number of handover. In traditional SCA mechanism, it don't consider that specific channel propagation conditions. We have only assumed that depending on the cellular system environment which is allowed to reuse the same channel in cells that the distance is $D = 2R$. Here we define the parameter D and R, where D is the physical distance between the two cell centers equal to 1 km and the R is the radius of the cell equal to 0.5 km. Therefore, if the channel is allocated to Cell i, it cannot be reused in the same cell because of unacceptable co-channel interference. We assume that the signal interference of each cell can't impact on each other in our simulation. Through our proposed DCA mechanism we can dynamically allocate the channel to the cells required channel depending on the variability of traffic information. Due to the feature of dynamic channel allocation, our proposed mechanism can allocate the number of channel for handover better effective than traditional SCA mechanism in cellular system. In traditional SCA mechanism, they only can use the fixed sets of channel to support the handover because the number of channel for handover is assigned to cell is permanently. When the channels of cells are occupied totally, the new call will be dropped or the behavior of handover will fail. Through the formula (1) and the assumption in simulation, the variable D is equal to 1 km and the variable R is equal to 0.5 km. Depending on above value and take it into the formula (1), we can obtain the value of the variable N is equal to 2. So, in traditional SCA mechanism, we assign the number of channels for handover in each cell is equal to 2. Otherwise, in our proposed mechanism, the number of channels for handover in each cell is dynamically adjusted according to the situation of traffic information in each cell. The comparison between SCA mechanism and our proposed mechanism is introduced as following.

In case 1, we analyze the situation of channel using during peak hour and off-peak hour. Figure 26 shows that the minimum number of the car flow and the minimum number of handover in $Cell_6$ at 4 am are off-peak. Otherwise, the maximum number of the traffic flow and the maximum number of handover is in $Cell_6$ are peak at 8 AM. Figure 27 shows that the CBP in $Cell_6$ at simulation time 4 AM and 8 AM. According to our assumption of simulation, the number of channels in traditional SCA mechanism is set to 2 and the number of channel in proposed mechanism is dynamically adjusting depending on the situation of traffic information. Through the Figure 27, we can discover that the CBP results derived from our proposed mechanism is 3.37 % less than traditional SCA mechanism. The results indicate that the proposed mechanism is suitable for the normal case in the real life.

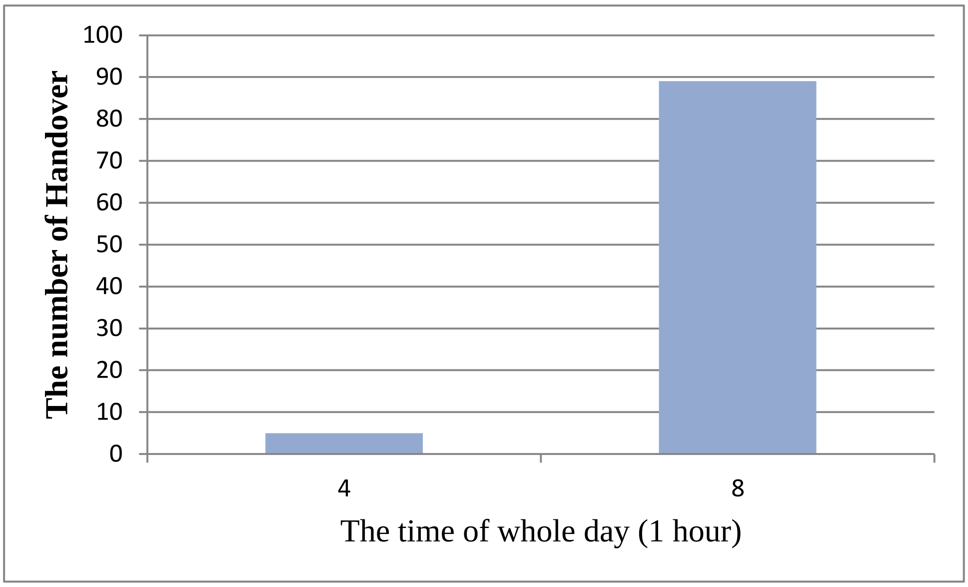

Figure 26. The number of handover at 4 AM and 8 AM in $Cell_6$

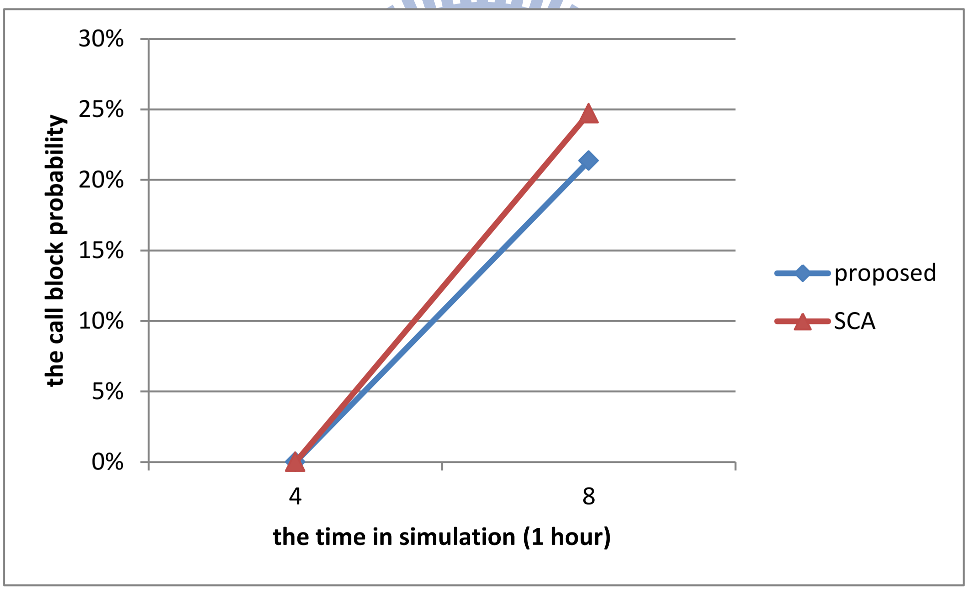

Figure 27. The call block probability in $Cell_6$

In case 2, depending on above mention we know that the traffic accident occurs at the position of 5.05 – 5.35 km between the simulation time 15th minute and 45th minute. So, in this section, we analyze the relations of the situation of traffic information and handover in $Cell_6$. Because the position of $Cell_6$ is at the back of the position of traffic accident, we can analyze the situation of the time when before and after influence on the traffic accident. Through Figure 23 and Figure 25, we can discover that the number of traffic flow in $Cell_6$ decrease rapidly when accident occurred and the number of the handover in $Cell_6$ dramatically increase when accident removed. Depending on the variation of traffic information, we can expect that the number of handover increase dramatically with the number of car flow increase. So, if the cellular system adopts the traditional SCA mechanism, it can’t afford the substantially increasing number of handover and it will result in a lot of number of call block. Figure 28 shows that the CBP by using SCA mechanism and our proposed mechanism. We can observe the situation at the simulation time between 16^{th} minute and 45^{th} minute that the occurrence of traffic accident causes to the car stuck in the coverage of the $Cell_5$ and the number of traffic flow is less in the period in $Cell_6$. In the traffic accident period in $Cell_6$, we discover that the CBP derived from our proposed mechanism and SCA mechanism is little difference because the number of traffic flow and the number of handover are rare. Otherwise, we can observe the simulation time between 46^{th} minute and 60^{th} minute that the number of handover also dramatically increases with the number of the traffic flow dramatically increases when the traffic accident removed. The cellular system which adopts our proposed mechanism can dynamically adjust the number of channel allocating in each cell, it can effectively solve the situation of call block when the number of traffic flow increases. Otherwise, the cellular system adopts the SCA mechanism that it can’t dynamically adjust the number of channel in each cell depending on the variability of the traffic information. So, it will result in a lot of the number of call block due to it can’t provide sufficient number of channel for handover. Through Figure 28, we can discover that the CBP derived from the cellular system adopts our proposed mechanism is 30.23 % less than the CBP derived from the cellular system adopts SCA mechanism. The simulation results show that the fixed number of channels in cell by the SCA mechanism can't suit the situation of the changing traffic flow. Moreover, our mechanism can accurately predict the number of channel which is required for handover. Through our proposed mechanism in this paper, we can use the resource of channel provided in cells more efficiency. Moreover, when the traffic accident removed at approximately 45^{th} minutes, due to the traffic accident removed the larger number of traffic jam originally in $Cell_5$ will go into the $Cell_6$ and they will trigger the event of handover with the number of traffic flow increase. For this reason, if the cellular system adopts traditional SCA mechanism to manage the channel allocation, it will cause the insufficient number of channel for handover which result in the event of call block occurs. On the contrary, if we use our proposed mechanism, we can accurately predict the number of handover depending on the real traffic information to avoid the situation of call block.

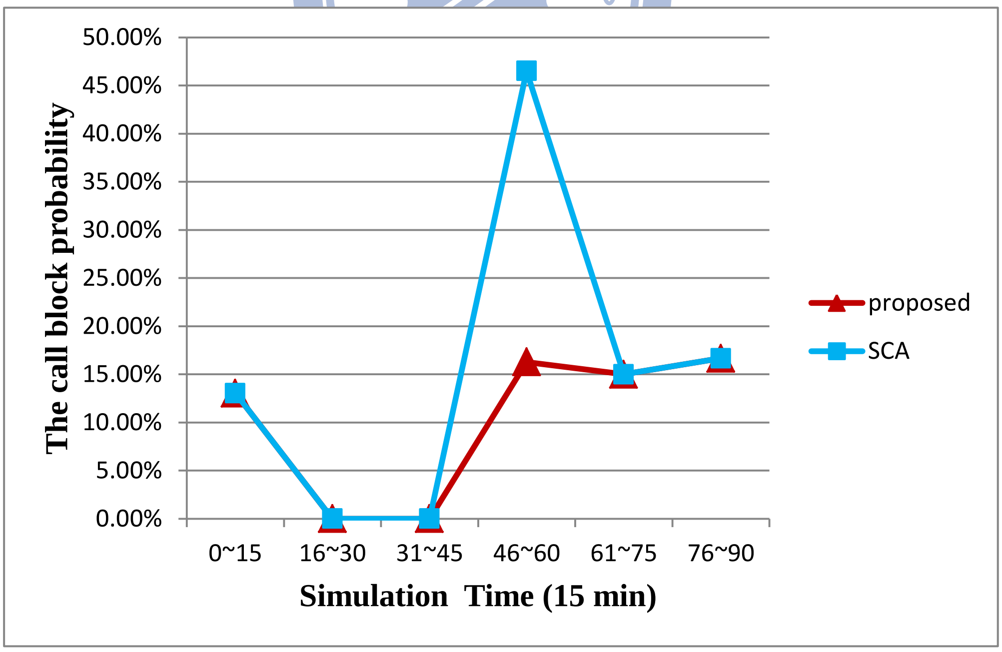

Figure 28. The CBP of using SCA mechanism and proposed mechanism in $Cell_6$

4.4 Discussion

In this section, in our simulation, we design two case to simulate situation of traffic flow and vehicle speed. Through the performance metrics of CBP derived from case 1 and case 2, respectively, we can discover that the CBP of the cellular system adopts our proposed mechanism is always less than the traditional SCA mechanism. So, the simulation results indicate that our proposed mechanism can allocate the number of channel more precise than the SCA mechanism. In this thesis, the maximum number of the CBP in cellular system adopts our proposed mechanism is 30.23 % higher than SCA mechanism.

Chapter 5 Conclusion and Future work

This thesis emphasizes the issues related to the using the resource of channel in cells more efficiency in cellular system. We use the simulation results to prove our proposed mechanism is more effective than the traditional SCA mechanism. This chapter summarizes our studies, and briefly discusses directions of the future work.

5.1. Conclusion

According to our proposed mechanism, we can analyze the communication behaviors and the status of traffic. Moreover, we can adopt the information of traffic flow to solve the problem of channel allocation in cellular networks. Through the simulation results, we obtain the results derived from the whole day simulation and the accident simulation respectively. The results indicate that the CBP derived from the proposed mechanism is less than the SCA mechanism. So, we believe that if the cellular networks adopts our mechanism, it can provide the better quality of service in cellular networks.

5.2. Future Work

In this thesis, the simulation environment we adopt is in the freeway in Taiwan. The coverage of the cells is simpler than the environment in urban and one car only has one MS. In our simulation, the coverage of cell is single layer, so we ignore the inference of signal in the environment of multi layers. In the future, we hope that the simulation environment can change from the freeway to urban and one car can has multiple MSs.

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