出國報告（出國類別：國際會議）

在疊蓋式巨型/毫微型蜂巢網路中以位置為基礎的重新轉向連結建立的效能分析

服務機關：國立高雄師範大學
姓名職稱：曾秀松副教授
派赴國家：日本
出國期間：7/22/2014-7/26/2014
報告日期：7/24/2014

摘要

參加國際會議並發表學術論文，論文題目為「在疊蓋式巨型/毫微型蜂巢網路中以位置為基礎的重新轉向連結建立的效能分析」。主要探討內容如下。毫微微細胞網路提供行動用戶低成本和高頻寬的網路存取方式。毫微微細胞可嵌入巨細胞內形成階層式網路。當行動用戶進入巨細胞下的毫微微細胞時，用戶可連向其所在位置的毫微微基地台。然而，目前無線位置估測方法提供的位置都有誤差，導致用戶做出不適當的連線要求，進而降低系統效能。在此論文報告中，我們建立一個模型可依據位置估測的平均誤差、誤差機率分佈及估算的用戶位置判別用戶連結正確毫微微細胞的機率，並依此模型評估不同位置估測方法對用戶與系統效能的影響。

一、目的

出國參加第四屆國際工程與應用科學會議(The 4th International Conference on Engineering and Applied Science, ICEAS 2014)，並發表會議論文，在疊蓋式巨型/毫微型蜂巢網路中以位置為基礎的重新轉向連結建立的效能分析(Performance Analysis of Position-Based Redirection Connection Establishment in Overlaid Macro/Femtocellular Networks)。

二、過程:

7/21 從高雄搭乘高鐵至桃園住宿一晚，趕搭 7/22 中華航空早班的班機至日本北海道。ICEAS 的會場在日本北海道最熱鬧的城市札幌(Sapporo)的 Renaissance 飯店。今年 ICEAS 的議程共有三天。在會議舉辦中，除了發表自己的論文，也觀摩跟自己相關領域作者研究成果和目前研究發展近況，也進一步看看其他領域作者研究的最新發展。會議結束後，搭乘 7/26 的華航班機回台灣。

二、 與會心得及建議:

A. 藉由許多與會不同學者發表的論文，瞭解了目前各個工程領域的研究最新進展。

B. 對於其他各國學者發表論文的展示方式，有不同的認識。

C. 主辦單位舉辦國際會議的經驗不錯，選擇治安良好的地區開會，沒有安全上的顧慮。此外會議舉辦的飯店，從報到、會議報告場所、中餐、中場休息、餐飲供應等都安排不錯，可作為舉辦國際會議的借鏡。然而，可能由於會場人數眾多，無線網路品質時好時壞，經常斷線，使得在會議過程中要紀錄整理資料很困擾。

D. 會議的舉辦地點生活機能還不錯，只是日本物價高，生活費昂貴，在住宿生活花費上要注意。

E. 建議辦理國際會議時可參考該會議，選擇適當的地點舉行，可提高會議參加人數。

F. 除了專門領域的國際會議之外，跨不同領域的國際會議亦值得參加。

三、 發表國際會議論文內容簡介

毫微微基地台可安裝於室內，例如:居家、辦公室或是一些室內公共區域。毫微微細胞基地台透過室內寬頻網路、閘道，與行動核心網路連結。由於目前室內低成本高寬頻技術的成熟,行動用戶透過毫微微基地台連線上網成本會低於直接透過巨型細胞基地台上網。再者，行動用戶大部分的資料傳輸地點是在室內環境，因此低成本的毫微微基地台連線方式是一個滿足行動用戶高頻寬要求的可行性解決方案。

毫微微基地台可設置於巨型細胞網路裡低品質信號區域或是低傳輸速率區域。藉由此種階層式巨型細胞/毫微微細胞網路架構，行動用戶可得到低成本高頻寬的傳輸。從行動

用戶的觀點而言，行動用戶會希望連線時可透過毫微微基地台。由於行動用戶未連線時，會執行位置更新程序，以讓網路系統知道目前行動用戶位於行動網路的哪個服務區。所以從系統管理者的角度而言，當行動用戶未連線時應該停留在巨型細胞系統，這是因為可減少系統執行位置更新程序的次數和相關交換訊息的數量。基於以上理由，行動用戶未連線時應該待在巨型細胞，只有在有連線要求時，才將行動用戶導向其所在位置的毫微微基地台。

依據上個段落的想法，我們在之前的文獻提出一個重新導向的連線建立程序，此程序與目前現存的 3GPP 連線建立程序相容。此程序引導發出連線要求的行動用轉向至毫微微基地台並建立連線。由於將行動用戶要求從巨型細胞轉向至毫微微細胞時面臨兩個問題，第一、系統必須擁有一個巨型細胞有哪些毫微微細胞的對應表，第二、要求轉向應該轉向至哪一個毫微微基地台。文獻中描述了第一個問題的相關對應表，並且對第二個問題提出了兩個毫微微基地台的選擇策略，隨機選擇與位置導向選擇。其中隨機選擇策略概念是行動用戶從覆蓋它的巨型細胞下之毫微微基地台群，隨機挑選一個毫微微基地台並進行連線，若失敗，則從剩下的毫微微基地台群繼續挑選直到連線成功或挑完為止。位置導向選擇策略的概念是使用無線位置定位方法，估測目前行動用戶位置，再利用目前行動用戶位置挑選適當的基地台。很明顯，位置導向選擇策略的系統效能(連線建立成功機率、連線建立時間延遲)會優於隨機選擇策略。在評估位置導向選擇策略效能時，文獻中僅使用一個機率值代表系統使用無線定位技術正確判定行動用戶在毫微微基地台的機率，至於此機率如何獲得則無說明。

目前無線位置定位方法估測出來的位置都有誤差，而其誤差的表示方式包含了平均誤差距離以及誤差距離的機率分佈。我們建立一個模型將不同平均誤差距離和機率分佈的無線定位方法轉換至一個行動用戶轉向至正確毫微微基地台的機率值。藉由此模型，我們可以進一步比較不同無線定位方法在重新導向連線建立程序的連線建立成功機率與連線建立時間延遲。

四、 發表之國際會議論文原文 ICEAS-3052

Performance Analysis of Position-Based Redirection Connection Establishment in Overlaid Macro/Femtocellular Networks

Show-Shiow Tzeng
Dept. of Optoelectronics and Communication Engineering, National Kaohsiung Normal Univ., Kaohsiung,82446 Taiwan
E-mail: sstzeng@nknucc.nknu.edu.tw

Ying-Jen Lin
Dept. of Mathematics, National Kaohsiung Normal Univ., Kaohsiung, 82446 Taiwan
E-mail: yjlin@nknu.edu.tw

Yu-Ching Hsu
Information and Comms. Research Lab. Industrial Technology Research Institute
Hsinchu 30043, Taiwan
E-mail: yuching@itri.org
The corresponding author: Show-Shiow Tzeng

Abstract

Overlaid macro/femto-cellular networks can enhance network capacity and extend network coverage. In such an overlaid network, a UE (User Equipment) in an idle mode should stay in a macrocell for lower cost of mobility management and should be redirected to its accessible femtocell when the UE requests an RRC (Radio Resource Control) connection setup and thus transiting to a connected mode. Previous literature proposes a position-based femtocell selection mechanism in macrocells to decide whether to redirect the requesting UE to an accessible femtocell by reusing the redirection mechanism in an RRC connection setup procedure. However, the important parameters, accuracy and precision, of positioning systems are not discussed in the proposed femtocell selection method. This paper develops an analysis to include the accuracy and precision to evaluate the performances of the position-based femtocell selection method. Numerical results show that the position-based method produces better performances at higher accuracy and yields similar performances at different precision.

Keyword: Connection establishment, redirecting, femtocell, macrocell, overlaid cellular networks.

1. Introduction

Overlaid macro/femto-cellular networks can enhance network capacity and extend network coverage. Macrocell is in the coverage of a base station equipped with high-power transceivers. Femtocell [1] is the service area in the coverage of a low-power indoor base station, called femto access point (Femto-AP); the transmission power of a Femto-AP is similar to that of an access point in wireless local area networks. As shown in Fig. 1, a Femto-AP, which is mostly installed in a home, office or public environment, connects with mobile core networks via indoor broadband access (e.g. Digital Subscriber Line), IP networks and a gateway (called Femto-GW). The hierarchical architecture of macrocellular networks with femtocells not only provides UEs with broadband transmission in a cost-effective manner, but also reduces the overall power consumption of cellular networks [2, 3, 4].

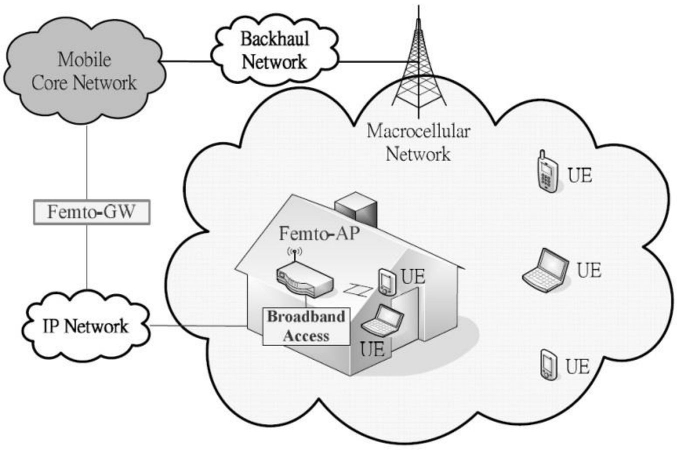

Figure 1: Architecture of macrocellular networks with Femto-APs.

In such an overlaid network, a UE in an idle mode should stay in a macrocell for lower cost of mobility management and should be redirected to its accessible femtocell when the UE requests an RRC connection setup and thus transiting to a connected mode [4]. This redirection concept will achieve 1) higher utilization of the broadband backhaul of the femtocell and thus lowering communication cost, 2) lower overhead of mobility management by idle-mode UEs camping on macrocells, and 3) lower power consumption by avoiding the blindly measurement for handover preparation in a connected mode. To realize the concept, a position-based selection policy in macrocells is proposed to decide whether to redirect the requesting UE to an accessible femtocell by reusing the redirection mechanism in an RRC connection setup procedure [4]. However, the important parameters, accuracy and precision, of positioning systems are not discussed in the proposed femtocell selection method. This paper develops an analysis to include the accuracy and precision to evaluate the performances of the position-based femtocell selection method. Numerical results show that the position-based method produces better performances at higher accuracy and yields similar performances at different precision.

The rest of this paper is organized as follows. Section 2 describes and analyzes the position-based redirection connection establishment scheme. Subsequently, numerical results are described in Section 3. Finally, some concluding remarks are presented in Section 4.

2. Analysis of Position-Based Redirection Connection Establishment

In the position-based scheme [4], the precise location information of both Femto-AP and UE could be obtained by using wireless positioning techniques. When the position information of UEs is available to a radio network controller (RNC), the RNC could precisely determine whether to redirect a UE into a Femto-AP or directly connects with a macrocell. However, it is possible that the position information is inaccurate. If a UE in femtocell is mistaken in a macrocell, the UE will be connected to a macrocell at its first attempt. If a UE merely in a macrocell is mistaken in a femtocell, the UE is failed to connect with a Femto-AP at its first attempt but successfully connects with the macrocell at its second attempt.

The performance metrics considered in the position-based scheme are mean connection delay and femtocell connection probability. The mean connection delay D_p is defined as the average time which starts from the time a UE sends a connection request until the time instant the UE completes its connection. The femtocell connection probability p_f^c is the probability that a UE successfully connects with a Femto-AP under the condition that the UE is in the coverage of the Femto-AP. As shown in [4], the mean connection delay D_p and the femtocell connection probability p_f^c are as follows:

$$D_p = [p_f(1 - p_f^e) + p_f p_f^e + p_m(1 - p_m^e)](t_r + t_h) + p_m p_m^e (t_r + t_o + t_h), \quad (1)$$

$$p_f^c = 1 - p_f^e, \quad (2)$$

where p_f is the probability that a UE is in a femtocell, p_m is the probability that a UE is in a macrocell but is not covered by femtocells, p_f^e denotes the probability that a UE is in a femtocell but is mistaken out of the coverage of the femtocell due to inaccurate position information, and p_m^e denotes the probability that a UE is merely in the coverage of a macrocell but is mistaken in a femtocell. t_r, t_o, and t_h respectively denote the time a UE sends a connection request and receives a reply, the time a UE sends a connection request in a radio band but suffers a time-out, and the time to complete a three-way handshaking.

Inaccurate position information affects p_f^e and p_m^e. In most positioning techniques, two metrics, accuracy and precision [5] are introduced to quantify the correct degree of position information. The former, accuracy, is the mean Euclidean distance between the true position and the estimated position. The smaller mean distance error is, the higher accuracy is. The latter, precision, is the cumulative probability function of the distance error, which demonstrates the distribution of the distance error. For easy representation, probability density function and probability mass function are used herein instead of cumulative probability function. Different positioning systems have different accuracy and precision, which reveals different p_f^e and p_m^e. In the following, we will introduce how to obtain the p_f^e and p_m^e of the system with a given set of accuracy and precision, which then will be further explained by an example.

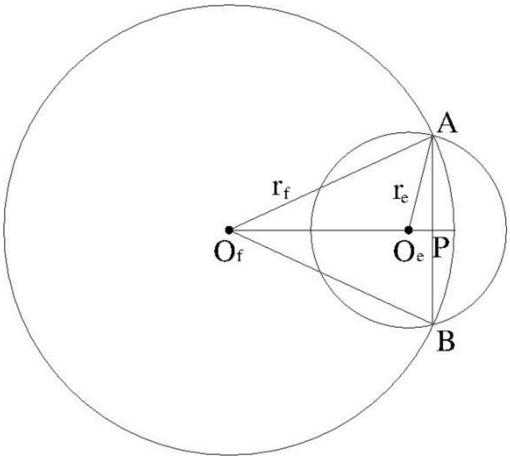

Figure 7: Relation between a femtocell and the position of a UE.

Fig. 7 shows the relation between a femtocell and the position of a UE, assuming that the accuracy of the positioning technique herein is r_e. In the figure, O_f is the position of Femto-AP and r_f is the radius of the coverage of the Femto-AP. In the coverage of the Femto-AP, a UE can establish a connection with the Femto-AP. O_e is the true position of a UE and r_e is the difference between the true position and the estimated position of the UE. Usually the estimated position may be distributed away from the true position in any direction; that is, the UE may be mistaken on the circle which is centered at O_e. From Fig. 7, we obtain that points A and B are the intersection of circles O_f and O_e. Point P is the intersection of the line segment $\overline{AB}$ and the extension of the line segment $\overline{O_f O_e}$. Since $\Delta AO_f B$ and $\Delta AO_e B$ both are isosceles triangles, P is the midpoint of the line segment $\overline{AB}$, right triangles $\Delta AO_f P$ and $\Delta BO_f P$ are congruent (i.e., Rt $\Delta AO_f P \cong$ Rt $\Delta BO_f P$), and right triangles $\Delta AO_e P$ and $\Delta BO_e P$ are congruent (i.e., Rt $\Delta AO_e P \cong$ Rt $\Delta BO_e P$). In Fig. 7, the arc $\widehat{AB}$ of the circle O_e, which lies outside of the big circle O_f, can be used to calculate the probability p_f^e; that is, the probability p_f^e is equal to the ratio of the arc $\widehat{AB}$ to the circumference $2\pi r_e$. In order to compute the arc $\widehat{AB}$, we would like to derive the angle AO_eP. Suppose the angle $AO_fP=\theta$, the angle $AO_eP=\varphi$ and $\overline{O_fO_e}=x$, we can use the position information of the femtocell and the UE to derive the θ as follows.

$$\left(r_f\cos\theta - x\right)^2 = r_e^2 - \left(r_f\sin\theta\right)^2$$

$$\Rightarrow \theta = \cos^{-1}\frac{r_f^2 + x^2 - r_e^2}{2r_f x} \qquad (2)$$

Then, we can use the θ and the position information to further derive the φ as follows.

$$r_e\cos\varphi = r_f\cos\theta - x$$

$$\Rightarrow \varphi = \cos^{-1}\frac{r_f^2 - x^2 - r_e^2}{2r_e x} \qquad (3)$$

Let $f(x)$ denote the probability density function of x. Let $f(r)$ denote the probability density function of the distance error r. Then, we can write down the probability p_f^e as follows.

$$p_f^e = \frac{1}{p_f}\int_x \int_r f(x)f(r)\frac{\widehat{AB}}{2\pi r_e}drdx$$

$$= \frac{1}{p_f}\int_x \int_r f(x)f(r)\frac{\varphi}{\pi}drdx \qquad \text{as UE in femtocell } (0\le x\le r_f). \qquad (4)$$

Similarly, the probability p_m^e can be written as follows.

$$p_m^e = \frac{1}{p_m}\int_x \int_r f(x)f(r)\left(1 - \frac{\widehat{AB}}{2\pi r_e}\right)drdx$$

$$= \frac{1}{p_m}\int_x \int_r f(x)f(r)\left(1 - \frac{\varphi}{\pi}\right)drdx \qquad \text{as UE merely in macrocell } (x>r_f). \qquad (5)$$

Equations (4) and (5) describe how to calculate p_f^e and p_m^e in concept, but the equations may be not solved due to the double integral of triangular functions. However, in most situations, it is reasonable to assume that *f(x)* is uniform distribution. Furthermore, from the engineering of viewpoint, the probability density function *f(r)* could be reduced to discrete probability mass function *p(r)* recording a set of the probabilities of different distance errors which can be achieved by collecting a large number of measurements of distance errors. According the above simplification, the probabilities p_f^e and p_m^e are written as follows:

$$p_f^e = \frac{1}{p_f} \sum\nolimits_r p(r) \int_x \frac{1}{x} \frac{\varphi}{\pi} dx \quad (6)$$

$$p_m^e = \frac{1}{p_m} \sum\nolimits_r p(r) \int_x \frac{1}{x} (1 - \frac{\varphi}{\pi}) dx \quad (7)$$

In the following, given r_f and r_e, we would like to derive the probabilities p_f^e and p_m^e, assuming that a UE is uniformly distributed in the coverage of a macrocell. Although a UE within and near the boundary of a macrocell is possibly mistaken out of the macrocell, we neglect this situation, which is reasonable because the radius of the macrocell is usually far greater than the distance error (i.e. $r_f \gg r_e$) and the probability of the situation is very small. We also assume that the distance error r_e is less than r_f, which is usually reasonable because the employed wireless positioning techniques [5] could satisfy the requirement of small distance error. According to the value of *x*, we consider four cases in Table 1.

Table 1. The probabilities of the four cases.

Cases	Probability
Case 1: $x \le r_f - r_e$	$p_1 = \frac{1}{\pi r_m^2}\left(n\pi\left(r_f - r_e\right)^2\right)$
Case 2: $r_f - r_e < x \le r_f$	$p_2 = \frac{1}{\pi r_m^2}\left(n\left(\pi r_f^2 - \pi\left(r_f - r_e\right)^2\right)\right)$
Case 3: $r_f < x \le r_f + r_e$	$p_3 = \frac{1}{\pi r_m^2}\left(n\left(\pi\left(r_f + r_e\right)^2 - \pi r_f^2\right)\right)$
Case 4: $x > r_f + r_e$	$p_4 = \frac{1}{\pi r_m^2}\left(n\left(\pi r_m^2 - \pi\left(r_f + r_e\right)^2\right)\right)$

Since a UE is uniformly distributed in a macrocell, the probabilities that the four cases occur are denoted by $p_i, i = 1, 2, 3, 4$, and are in turn listed in Table 1. *n* denotes the number of femtocells in a macrocell. In the first two cases, a UE is truly in a femtocell, in the latter two cases, the UE is in a macrocell. If the first case occurs, it is impossible that a UE is mistaken out of the coverage of the femtocell due to $r_e \le r_f - x$. Therefore, the probability p_f^e is equal to zero. If the second case occurs, the probability that a UE is in the femtocell but is mistaken in the macrocell is equal to $\int_{x=r_f-r_e}^{r_f} \frac{1}{r_e} \frac{\varphi}{\pi} dx$. In summary, the probability p_f is equal to the sum of the probabilities that the first two cases occur. The probability p_f^e is as follows.

$$p_f^e = \frac{p_2 \int_{x=r_f-r_e}^{r_f} \frac{1}{r_e}\frac{\varphi}{\pi} dx}{p_1 + p_2}. \quad (8)$$

If the third case occurs, the probability that a UE is in the macrocell and is identified in the macrocell is equal to $\int_{x=r_f}^{r_f+r_e} \frac{1}{r_e}\frac{\varphi}{\pi} dx$. If the fourth case occurs, it is impossible that a UE is mistaken in the coverage of the femtocell due to $x \geq r_f + r_e$; in such a case, the probability p_m^e is equal to zero. In summary, the probability p_m is equal to the probability that a UE is in the macrocell but is out of the coverage of the femtocell, which is equal to the sum of the probabilities that the latter two cases occur. The probability p_m^e is as follows.

$$p_m^e = \frac{p_3 \left(1 - \int_{x=r_f}^{r_f+r_e} \frac{1}{r_e}\frac{\varphi}{\pi} dx\right)}{p_3 + p_4}. \quad (9)$$

3. Numerical results and discussions

Numerical evaluations are conducted to study the performances of the two femtocell selection policies. The system environment considered herein is a homogeneous cellular system which consists of m macrocells in a hexagonal manner, each of which covers n femtocells which does not overlap with each other. The system parameters used in numerical results are listed in the first two columns in Table 2.

Table 2. Performances at different accuracy and precision.

Accuracy (m.)	Precision	Femtocell connection probability	Mean connection delay (ms.)
(1, 2, 3, 4, 5)	(0.2, 0.2, 0.2, 0.2, 0.2)	0.937	260.4
(2, 4, 6, 8, 10)	(0.2, 0.2, 0.2, 0.2, 0.2)	0.876	260.9
(3, 6, 9, 12, 15)	(0.2, 0.2, 0.2, 0.2, 0.2)	0.818	261.4
(2, 4, 6, 8, 10)	(0.2, 0.2, 0.2, 0.2, 0.2)	0.876	260.9
(2, 4, 6, 8, 10)	(0.1, 0.2, 0.4, 0.2, 0.1)	0.876	260.9
(2, 4, 6, 8, 10)	(0.05, 0.1, 0.7, 0.1, 0.05)	0.876	260.9

The coverage radii of macrocells and femtocells are 1000 and 30 meters respectively. The number of macrocells, *m*, is seven in our environment; the number of femtocells accessible to UEs in a macrocell, *n*, is equal to seven. The time, t_r, a UE sends a connection request and receives a reply is set to 50 milliseconds. The time, t_o, a UE sends a connection request but suffers a time-out mainly due to frequency tuning time and a time-out period. The frequency tuning time is estimated to 30 milliseconds [6]. The value of the time-out is 1000 milliseconds, which is the default value in [7]. The time t_h to complete a three-way handshaking is set to 80 milliseconds. We consider six combinations of the accuracy and precision of positioning systems, which are shown in Table 2. In the first combination in Table 2, (1, 2, 3, 4, 5) and (0.2, 0.2, 0.2, 0.2, 0.2) mean the error distances *1m, 2m, 3m, 4m,* *5m* with equal probability 0.2. The explanation of the remaining combinations is similar to the first combination. In addition, the first three combinations have different accuracy but have the same precision; the last three combinations have different precision but have the same accuracy.

From Table 2, we can observe the mean connection delay and the femtocell connection probability at the different combinations. The system with the accuracy (1, 2, 3, 4, 5) produces higher femtocell connection probability than that with other accuracy. This is because higher accuracy of positioning leads to that a UE can more accurately connect with a Femto-AP. Besides, the systems with different precisions under the same accuracy produce the same femtocell connection probability. Therefore, the femtocell connection probability is independent of the precision. Furthermore, since the position-based policies at different combination of the accuracy and precision produces significantly low mean connection delay, all of the combinations yields similar mean connection delay.

4. Conclusions

In this paper, the important parameters, accuracy and precision, of positioning systems are discussed in the position based femtocell selection scheme. We develop an analysis to include the accuracy and precision to evaluate the performances, in terms of femtocell connection probability and mean connection delay, of the position-based femtocell selection scheme. Numerical results show that the position-based scheme produces better performances at higher accuracy and yields similar performances at different precision.

Acknowledgments

This research was supported by the National Science Council, Taiwan, under grant NSC 102-2221-E-017-006-.

5. References

[1] V. Chandrasekhar, J. Andrews, and A. Gatherer. Femtocell networks: a survey. *IEEE Communications Magazine*, vol. 46, no. 9, Sep. 2008, pp.59-67.

[2] A. Damnjanovic, J. Montojo, Y. Wei, T. Ji, T. Luo, M. Vajapeyam, T. Yoo, O. Song, and D. Malladi. A survey on 3GPP heterogeneous networks. *IEEE Wireless Communications*, vol. 18, no. 3, pp. 10-21, June 2011.

[3] Y. Li, H. Celebi, M. Daneshmand, C. Wang, W. Zhao. Energy-efficient femtocell networks: challenges and opportunities. *IEEE Wireless Communications,* vol. 20, no. 6, pp. 99-105, Dec. 2013.

[4] Y.-C. Hsu, S.-S. Tzeng, and C.-W. Huang. A study for connection establishment in femtocell network. *IEEE International Conference on Parallel Processing 2011*, pp. 114-118.

[5] H. Liu, H. Darabi, P. Banerjee, and J. Liu. Survey of wireless indoor positioning techniques and systems. *IEEE Transactions on Systems, Man, and Cybernetics, Part C: Applications and Reviews*, vol. 37, no. 6, Nov. 2007.
[6] A. Racz, A. Temesvary, and N. Reider. Handover performance in 3GPP Long Term Evolution (LTE) systems. *Mobile and Wireless Communications Summit, 2007. 16th IST*, pp. 1-5, July 2007.
[7] 3GPP. 3rd Generation Partnership Project; Technical specification group radio access network; Radio resource control (RRC); Protocol specification (Release 12). 3GPP TS 25.331, March 2014.

五、 攜回資料名稱及內容:

A. 會議議程一本
B. 會議論文光碟一張，內含發表文章之全文。
C. 參與會議議程證明