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A Survey on Technical Challenges in Femtocell Networks

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Abstract: The phenomenon of improving the indoor coverage and enhancing network capacity to provide high data rate services in a cost effective manner is a major challenge to the next generation wireless communication. To overcome this challenge, the transmitters and receivers may be made closer to each other as per the traditional approach. But this may lead to installing several base stations. Hence, the home base stations, commonly called as femtocells, have to be used over a macrocell. Since the femtocells share the same spectrum, the interference mitigation among neighbouring femtocells and among femtocells and macrocell will be the major challenges in wireless networks. Hence, the aim of this survey is to analyze the technical challenges in designing femtocell networks such as access modes, handover, mobility management, self organization, security, timing and synchronization and interference management.

Keywords: Femtocell, technical challenges, interference management, survey, wireless networks.

I. INTRODUCTION

According to recent surveys [1], in future, 50% of phone calls and 70% of data services will be indoor communication. So, macrocell coverage is not suitable for indoor customers who need large service demands. Hence, a new method has to be designed to provide high data rates and Quality of Service (QoS) [2].

One such solution which improves the indoor coverage is Femtocell Access Points (FAPs) [3]. The FAPs are the low power base stations which improve indoor coverage where it is less or unavailable [2]. Already 2.3 million femtocells were installed globally and that will be definitely reaching 50 million by the end of 2014 [4]. As the result, by 2015, femtocells are expected to overcome 60% of global data traffic [38][5]. Now-a-days, different types of femtocells have been developed to handle various air interface technologies, services, standards and access control strategies [6][7].

The interference among the femtocells cannot be handled using network planning techniques, because the number and position of the FAPs are unknown. To overcome this issue [2], the available spectrum can be divided into subchannels and then into orthogonal subcarriers. The OFDMA femtocells can develop the channel variations in both frequency domain as well as time domain to reduce interference because OFDMA acts as a multi-access technique which distributes orthogonal subchannels to different users. The interference among the femtocells is the main limitation in the two-layered networks.

II. HISTORY OF FEMTOCELLS

In 1999, Bell labs first invented the concept of femtocells and home base station. In 2000, the Alcatel brought it to the market [8]. The Alcatel proved it through a plane Old Telephone System (POTS) line but it was not economically feasible. In 2002, [8] Motorola announced 3G home base station and became famous in 2005.

In 2006, many companies started to trial it. By July 2007, a not-for-profit membership organization named Femto Forum (FF) was formed which aimed to promote the standardization of femtocells [9]. When the 3rd Generation Partnership Project (3GPP) release 8 was introduced with the Home Node B (HNB) and Home eNode B (H(e)NB) [10], the femtocells become predominant. In future, femtocells may be included in Long Term Evolution (LTE) networks too.

A. Femtocell specifications

Femtocells acts as small low powered based stations. The femtocells can be installed similar to that of a Wireless Fidelity (WiFi) router [11]. The 3G femtocell High Speed Packet Access (HSPA) and WiFi specifications [12] are listed in the Table 1.

TABLE 1 FEMTOCELL HSPA AND WIFI SPECIFICATIONS

Specifications	3G Femtocell (HSPA)	Wi-Fi
Data Rates (Mbps)	7.2 to 14.4	11 and 54
Operational frequency (GHz)	1.9 to 2.6	2.4 to 5
Power (mW)	10 to 100	100 to 200
Range (m)	10 to 30	100 to 200
Services	Primarily Voice and Data	

Femtocells are standardized as Home Node B (HNB) in WCDMA systems and Home eNode B (H(e)NB) in LTE systems. The most significant femtocell function is Closed Subscriber Group (CSG). The (H(e)NB) can be used in homes and small offices because it provides the access only to the registered User Equipments (UEs) [12]. This access mode can be developed to hybrid access mode which is described in section 3.

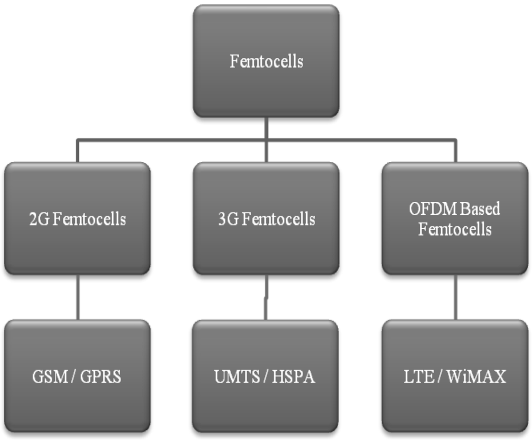

Fig.1 Types of Femtocells Based on Technology Used

The femtocells can be classified into various types on the basis of users' need. The main types of femtocells [12] are shown in Fig. 1.

- **2G femtocells:** The function of 2G femtocells are based on the Global System for Mobile communication (GSM). Even though the development of 2G femtocells is low cost and gives good quality voice, they were not a great success and also General Packet Radio Service (GPRS) does not support high data rates [12].
- **3G femtocells:** The 3G femtocells are based on Universal Mobile Telecommunication System (UMTS) called UMTS Terrestrial Radio Access (UTRA). The 3G femtocells provides better power allocation and higher data rates compared to that of 2G femtocells [13].
- **OFDM based femtocells:** These femtocells come under Worldwide Interoperability for Microwave Access (WiMAX) and LTE air interfaces. These femtocells are more famous and will be considered as the predominant indoor technology in near future [14][15][16][17][18][19].

B. Merits of femtocells

- Better signal quality due to closeness between transmitter and receiver.
- It saves power & energy consumption and also reduces the electromagnetic interference.
- More users can access the same set of radio resources and coding techniques [2].
- Reduces the overall network cost.

C. Cost Benefits

- A macrocell costs about $1000/month and additional electricity and backhaul costs [3]. This cost may increase with respect to the data traffic. This can be reduced by involving femtocells in the network, which may brings down the cost from $60,000/year/macrocell to just $200/year/femtocell [20].

III.TECHNICAL CHALLENGES IN FEMTOCELLS

A. Access Modes

There are three access modes of the femtocell as shown in the Fig. 2.

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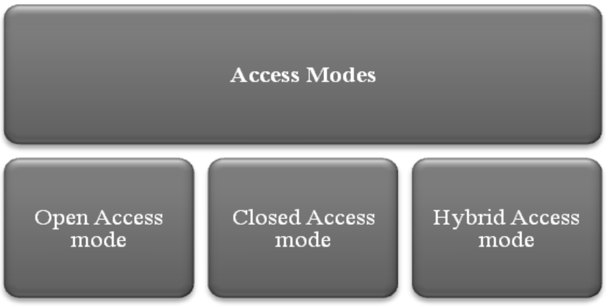

Fig. 2 Three Access Modes of the Femtocell

- **Open access modes:** All users can access in this mode. This is not applicable for home users. Since unknown users can utilize the resource of femtocells, this can be used at airports, shopping malls and universities for the sake of good coverage [21].
- **Closed access modes:** Here the usage is restricted to specified users since the owner decides the user who deserves to use the femtocell. It is referred as Closed Subscriber Group (CSG) by 3GPP [12]. The only disadvantage is that the users near femtocell shall experience high signal level, which would cause interference even though they are not subscribed to that particular femtocell.
- **Hybrid access modes:** In this approach, there are two set of users. The first among them is the authorized femtocell users and the next is the guest or new user whose entry should be requested by the owner. Increase in outside users directly affects the performance of authorized femtocell users.

B. Mobility Management

Normally femtocells are designed for indoor users and there is no much importance for mobility management. In case of dense deployment of femtocells, handover and continuous tracking of neighbor cells would be great challenge. A mobility management scheme [22] with intermediate node to control the mobility is employed at those circumstances.

C. Handover

The foremost thing in handover is the access mode which is being used. This handover is very large in open access but of less importance in closed and hybrid access modes. A hand over mechanism between macrocell and femtocell in case of LTE based networks which take Quality of Services (QoS) and speed of UE into account is presented in [23]. Another handover algorithm [24] takes Received Signal Strength (RSS) and velocity of UE handover into account. Handover procedures for UMTS based networks is of presented [25][26] by reducing signal overhead and number of handovers in femtocells. Fig. 3. Shows different handover schemes [27].

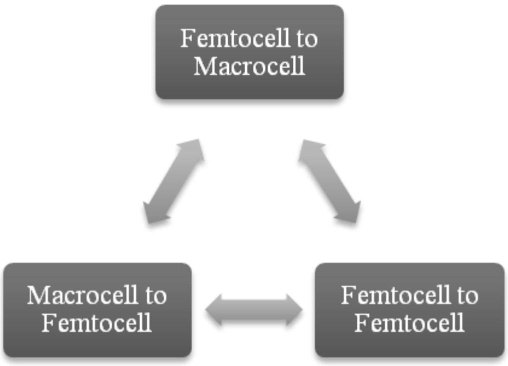

Fig. 3 Different Handover Schemes

D. Self Organization

The femtocells have the tendency to be turned on and off at anytime. Hence they need to be intelligent to automatically integrate in a radio access network [28] and to self configure and optimize. It mainly comprises of [12],

- **Self configuration:** It plays a vital role when addition of new cell sites or removal of network features is done. Also the femtocell needs to configure itself whenever it is moved to a new location on when it is rebooted.
- **Self Optimization:** In femtocells, the optimization phase needs to check whether all network parameters like transmit power, physical resources, access modes and handover control are tuned to a particular allowed level.
- **Self Healing:** Resolving the problem occurred to a most possible extent there by adjusting the settings accordingly.

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E. Security

Security is a key challenging parameter for femtocells. The femtocell networks have to be prevented from security risks and from hackers, since all the private information of the subscriber is available. This is more evident in open access mode [29].

In case of closed access mode, the femtocells are at the danger of Denial of Service (DoS) attacks and it is necessary to prevent unwanted users to access the femtocell network [30].

Internet protocol security (IPSec) provides security to the link for this purpose, which provides a link between FAP and operator core network. This is also achieved by secured gateway i.e., data travel via security tunnel [31].Threats like man-in-middle attack and compromising subscriber access list have been postulated [30]. These threats are not treated efficiently till date.

F. Timing and Synchronization

In wireless communication, internal clock generated by crystal oscillator is used to align packets between transmitter and receiver and also for frequency arrangement. The error in timing and synchronization yields to Inter Symbol Interference (ISI) in OFDM system [32].

The FAPs use Asymmetric Digital Subscriber Line (ADSL) to utilize the clock for synchronization. Precision Time Protocol (PTP) [33] is introduced to avoid synchronization errors and to synchronize independent clock. An enhanced synchronization algorithm [34] is proposed for this purpose. The location of femtocell can be predicted by the use of GPS receiver in case of emergencies or to share local news and information. The only disadvantage is that GPS signal suffers attenuation. The remedy is to use television receiver built in femtocells [35].

Frame synchronization [36] uses adjacent Base stations for synchronization and the neighbouring femtocells preamble signal [37] is used to align femtocell frames.

G. Interference Management

This is one of the most important challenges faced due to dense deployment of femtocells. The two- tier architecture enables to separates the interference into two main types as shown in Fig. 4.

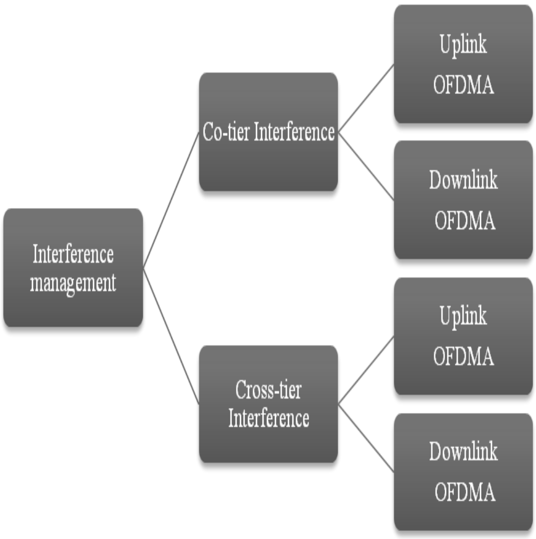

Fig. 4 Types of Interference Management

- **Co-tier interference :** The co-tier interference arises among network elements that belong to the same tier in the network. In case of a femtocell network, co-tier interference occurs between adjoining femtocells [6]. For example, a femtocell UE (aggressor) causes uplink co-tier interference to the adjoining femtocell base stations (victims). On the other hand, a femtocell base station acts as a resource of downlink co-tier interference to the neighbouring femtocell UEs. In OFDMA systems, the co-tier uplink or downlink interference occurs only when the aggressor and the victim use the same sub-channels. Consequently, efficient allocation of sub-channels is required in OFDMA-based femtocell networks to diminish co-tier interference.
- **Cross-tier interference:** The cross-tier interference arises among network elements that belong to the different tiers of the network, i.e., interference between femtocells and macrocells [6].Femtocell UEs and macrocell UEs act as a resource of uplink cross-tier interference to the serving macrocell base station and the in close proximity femtocells, respectively. Similarly the serving macrocell base station and femtocells cause downlink cross-tier

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interference to the femtocell UEs and in close proximity macrocell UEs, respectively. In OFDMA-based femtocell networks, cross-tier uplink or downlink interference arises only when the same sub-channels are used by the aggressor and the victim.

The OFDMA – based femtocells use spectrum resources efficiently due to its flexibility in spectrum allocation. In case of an effective interference management scheme, co-tier interference and cross tier interference can be avoided and reduced respectively.

IV. CONCLUSION

The demand for very high speed wireless communications has modified the pattern of cellular networks towards femtocell technology. A femtocell has the ability to provide high quality network access to indoor users at low cost by reducing the burden on the whole network traffic. However, femtocells would face many troubles on crowded employment. This paper has enlightened the key challenges along with the femtocell history, benefits and its technical aspects. Issues like access modes, handover, mobility management, self organization, security, timing and synchronization and interference management are still obstruct the attainable gain of femtocells. If these issues are addressed with novel solutions, femtocell can guarantee higher data rates, better and additional coverage, excellent connectivity, thereby promising better Quality of Service.

REFERENCES

[1] G. Mansfield, "Femtocells in the US Market –Business Drivers and Consumer Propositions," FemtoCells Europe, ATT, London, U.K., June 2008.
[2] Lopez-Perez, D.; Valcarce, A.; de la Roche, G.; Jie Zhang, "OFDMA femtocells: A roadmap on interference avoidance," Communications Magazine, IEEE , vol.47, no.9, pp.41,48, September 2009.
[3] V. Chandrasekhar and J. G. Andrews, "Femtocell Networks: A Survey," IEEE Commun. Mag., vol. 46, no. 9, Sept. 2008, pp. 59–67.
[4] Informa Telecoms & Media, "Femtocell Market Status," Femtoforum whitepaper, 2011.
[5] "Wifi and femtocell integration strategies 2011-2015," Juniper Research Whitepaper, http://www.juniperresearch.com/, Mar. 2011.
[6] Saquib, N.; Hossain, E.; Long Bao Le; Dong In Kim, "Interference management in OFDMA femtocell networks: issues and approaches," Wireless Communications, IEEE , vol.19, no.3, pp.86,95, June 2012.
[7] H. Claussen, "Performance of Macro- and Co-Channel Femtocells in a Hierarchical Cell Structure," IEEE 18th PIMRC 2007, Athens, Greece, Sept. 2007, pp. 1–5.
[8] D. Chambers, "Femtocell history," online available at: http://www.thinkfemtocell.com/FAQs/femtocell-history.html
[9] Femto Forum, http://www.femtoforum.org/femto/.
[10] 3GPP release 8, Online available at: http://www.3gpp.org/Release-8.
[11] D. L. Perez, G. D. la Roche, A. Valcarce, A. Juttner, and J. Zhang,"Interference avoidance and dynamic frequency palnning for WiMAX femtocells networks," 11th IEEE Singapore International Conference on Communication Systems, pp. 1579–1584, 19-21 Nov. 2008.
[12] Zahir, T.; Arshad, K.; Nakata, A.; Moessner, K., "Interference Management in Femtocells," Communications Surveys & Tutorials, IEEE , vol.15, no.1, pp.293,311, First Quarter 2013.
[13] M. Neruda, J. Vrana, and R. Bestak, "Femtocells in 3G mobile networks," 16th International Conference on Systems, Signals and Image Processing, pp. 1–4, 18-20 June. 2009.
[14] D. Williams, "WiMAX femtocells a technology on demand for cable MSOs," in Femtocells Europe, Jun. 2008.
[15] B. Yong, Z. Juejia, and C. Lan, "Hybrid spectrum usage for overlaying LTE macrocell and femtocell," IEEE Global Telecommunications Conference, pp. 1–6, Nov. 30-Dec. 4 2009.
[16] R. Y. Kim, S. K. Jin, and K. Etemad, "WiMAX femtocell: requirements, challenges, and solutions," IEEE Commun. Mag. , vol. 47, no. 9, pp. 84–91, Sept. 2009.
[17] H. Su, L. Kuang, and J. Lu, "Interference avoidance in OFDMA based femtocell network," IEEE Youth Conference on Information, Computing and Telecommunication, pp. 126–129, 20-21 Sept. 2009.
[18] D. Lopez-Perez, A. Ladanyi, A. Juttner, and Z. Jie, "OFDMA femtocells: A self-organizing approach for frequency assignment," IEEE 20th International Symposium on Personal, Indoor and Mobile Radio Communications, pp. 2202–2207, 13-16 Sept. 2009.
[19] D. Lopez-Perez, A. Juttner, and J. Zhang, "Optimisation methods for dynamic frequency planning in ofdma networks," Networks , Budapest, Hungary, Sept. 2008.
[20] Analysys, "Picocells and Femtocells: Will Indoor Base- Stations Transform the Telecoms Industry?" http:// research.analysys.com.
[21] D. López-Pérez et al., "Access Methods to WiMAX Femtocells: A Downlink System-Level Case Study," 11th IEEE ICCS, Guangzhou, China, Nov. 2008, pp. 1657–62.
[22] L. Wang, Z. Yongsheng, and W. Zhenrong, "Mobility management schemes at radio network layer for lte femtocells," IEEE 69th Vehicular Technology Conference, pp. 1–5, 26-29 April. 2009.
[23] Z. Haijun, W. Xiangming, W. Bo, Z. Wei, and S. Yong, "A novel handover mechanism between femtocell and macrocell for lte based networks," Second International Conference on Communication Software and Networks, pp. 228–231, 26-28 Feb. 2010.
[24] S. Wu, X. Zhang, R. Zheng, Z. Yin, Y. Fang, and D. Yang, "Handover study concerning mobility in the two-hierarchy network," IEEE 69th Vehicular Technology Conference, 2009. VTC Spring 2009, pp. 1–5, 26-29 April 2009
[25] M. Z. Chowdhury, R. Won, R. Eunjun, and J. M. Yeong, "Handover between macrocell and femtocell for umts based networks," 11th International Conference on Advanced Communication Technology, vol. 1, pp. 237–241, 15-18 Feb. 2009.
[26] K. Jin-Seok and L. Tae-Jin, "Handover in umts networks with hybrid access femtocells," The 12th International Conference on Advanced Communication Technology, vol. 22, pp. 904–908, 7-10 Feb. 2010.
[27] Mahmud, S. A., et al. "A Survey on Femtocells: Benefits Deployment Models and Proposed Solutions." Journal Of Applied Research And Technology 11 (2013): 733-754.
[28] J. S. Young, G. H. Hae, and K. S. Kwang, "A self organised femtocell for ieee 802.16e system," IEEE Global Telecommunications Conference, pp. 1–5, Nov. 30-Dec. 4 2009.

ISSN (Online) 2278-1021
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International Journal of Advanced Research in Computer and Communication Engineering
ISO 3297:2007 Certified
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[29] S. S. Prasad and R. Baruah, "Femtocell mass deployment: Indian perspective," 3rd International Conference on Anti-counterfeiting, Security, and Identification in Communication, pp. 34–37, 20-22 Aug.2009.
[30] H. Chan, C. Hyoung-Kee, and K. In-Hwan, "Building femtocell more secure with improved proxy signature," IEEE Global Telecommunications Conference, pp. 1–6, Nov. 30-Dec. 4 2009.
[31] T. Chiba and H. Yokota, "Efficient route optimization methods for femtocell-based all ip networks," IEEE International Conference on Wireless and Mobile Computing, Networking and Communications, pp.221–226, 12-14 Oct. 2009.
[32] H. Su, L. Kuang, and J. Lu, "Interference avoidance in OFDMA based femtocell network," IEEE Youth Conference on Information, Computing and Telecommunication, pp. 126–129, 20-21 Sept. 2009.
[33] N. I. of Standards and Technology, Ieee1588 website, http://ieee1588.nist.gov/, 2008.
[34] S. Lee, "An enhanced ieee 1588 time synchronization algorithm for asymmetric communication link using block burst transmission," IEEE Commun. Lett., vol. 12, no. 9, pp. 687–689, Sep. 2008.
[35] "Femtocell synchornisation," by Adrio Communications Ltd. Available online at: www.radio-electronics.com.
[36] T. Wada, N. Saitou, T. Hara, and M. Okada, "Frame synchronization among base stations for tdd systems," 4th International Symposium on Communications, Control and Signal Processing, pp. 1–4, 3-5 Mar. 2010.
[37] J. Yoon, J. Lee, and H. S. Lee, "Multi-hop based network synchronization scheme for femtocell systems," IEEE 20th International Symposium on Personal, Indoor and Mobile Radio Communications, pp. 1–5, Sept. 2009.
[38] A. Kingsly Jabakumar and Dr.P. Ramanathan, "Quality-of-Service Diversity based Sub-channel Allocation (QoS-DSCA) for Femtocells in Cellular Network", International Journal of Printing, Packaging & Allied Sciences, vol. 4, no. 3, pp. 2095-2109, Dec. 2016.

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