Indian Journal of Science and Technology, *Vol 8(34), DOI: 10.17485/ijst/2015/v8i34/87459, December 2015*
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Ubiquitous Learning System using Femto Technology

Young C. Park*

Division of Information and Communication Engineering, Baekseok University, Republic of Korea; ycpark@bu.ac.kr

Abstract

Users or learners want ubiquitous connectivity independent of devices and locations. Femto technology seems to be a good candidate for the open mobile alliance that can potentially play a much broader role by enabling a new class of multimedia and ubiquitous learning. The femtocells operate in the licensed spectrum and provide flexible and scalable end-to-end connectivity. In this paper, we present a femto technology for ubiquitous learning (u-learning) system. We consider the scenario that femtocells and macrocells are being operated in campus area and study the link budget of femtocells.

Keywords: Component, Budget, Digital Subscriber Line (DSL), Femto Technology, Link Introduction, Ubiquitous Learning (U-Learning)

1. Introduction

Recently Table PCs could be considered a ground-breaking technology as the leading mobile device for supporting ubiquitous learning (u-learning). Mobile technologies continue to evolve and there is an exponential growth of traffic volumes last decade. The worldwide consumption of data is going to be far more than what is being consumed now. Andrews et al. forecasted in their paper that more than one billion people may access the Internet by use of a mobile device such as smart phone in 2015[1]. By 2016 about 71% of network traffic will be video traffic and smartphones will count over 100 million with a monthly bandwidth consumption of over 1 GB. Such enormous consumption exceeds the capacity of 4G/WiMax/LTE (long term evolution)[2]. Network developers or operators are requested to support this increasingly heavy traffic at higher bandwidth in the near future. Cisco systems analyzes the growth of IP (Internet protocol) worldwide networks yearly and estimated that global mobile data traffic reached 4.2 exabytes per month at the end of 2015 and by 2019, and it is expected to grow to 24.3 exabytes (EB) per month which is about 6 times increase over 2015. Analysis from Cisco shows mobile data traffic continues to grow at a Compound Annual Growth Rate (CAGR) of 57% from 2014 to 2019. And it is reported that the smartphones and the tablets will continue to generate data traffic exponentially and Wi-Fi and Femtocells will carry some of the brunt. Video streaming will be the major driver of data traffic.

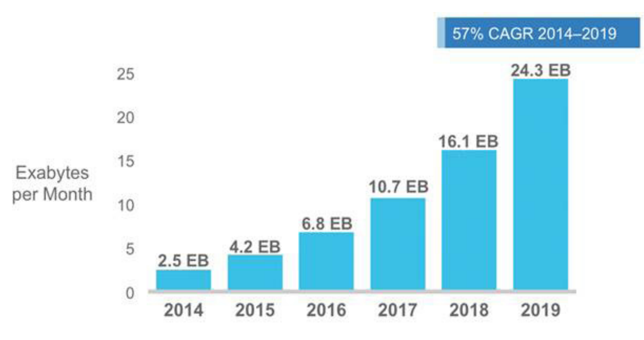

Figure 1. Cisco Forecasts 24.3 Exabytes per Month of Mobile Data Traffic by 2019. Source: Cisco VNI Mobile, 2015.

South Korea which leads the world in terms of LTE-A (Long Term Evolution Advanced) technology currently

*Author for correspondence

has the third highest rate of smartphone adoption globally and has invested a lot of money to develop B4G (Beyond Fourth Generation). The government had launched 'Giga-KOREA Project' which develops Giga bit per second (Gbps) data capacity by 2020, almost forty times faster the current data speed. This project also includes the IT (Information Technology) ecosystem such as green networks and devices, and new network topologies and multimedia[4]. Korea's leading companies, SK Telecom and Korea Telecom as well as Samsung and LG, are now developing fifth generation (5G) technology that will be 1,000 times faster than 4G LTE. The core technologies for 5G are Cloud virtualized Radio Access Network (Cloud vRAN), massive Multiple-Input Multiple-Output (mMIMO), Radio Access Network (RAN), Network Function Virtualization (NFV), Software Defined Networking (SDN), millimeter Wave (mm-Wave) frequency, highly directional beamforming antennas, and cognitive Femtocell technology.

Mobile technologies have enabled ubiquitous services including u-learning which takes place anytime and anywhere through the internet and mobile devices. In recent years, there has been a rapid change from m-learning to u-learning and adaptive learning which uses computers and software as interactive teaching devices. In u-learning system, learners can interact with the environment by capturing multimedia information in different contexts and create new learning situations. Ubiquitous computing using Information and Communication Technology (ICT) utilizes a variety of intelligent digital devices and thus changes the paradigm of education [5].

Femtocell technology can be a potential solution to support the high demand of data traffic due to the propagation of Internet enabled multimedia services, maintained mobility, enlarged mobile broadband capacity, and prolonged handset battery-life performance in the next decade. Recently the ABI Research forecasts Femtocell business represents a tremendous market opportunity since it reaches up to $4.3 billion market revenue in 2019[6]. Femtocell, also known as 'Home NodeB'(HNB), is a small size, low power, inexpensive indoor based cellular station which carries a variety of mobile device such as 3G Wibro, W-CDMA and 4G LTE-A, by means of standard TS (technical specification) document series. Femtocell is normally installed by user and connected to its own wired connection and it provides seamless communication, high-quality coverage across a small footprint, better Signal-To-Interference-Noise Ratio (SINR), and increasing area spectral efficiency. Therefore it is called 'win-win' strategy that brings benefits to both cellular users as well as network providers[7]. Unlike cellular macro-cells, Femtocell is reliable since it enables soft handoff between the main cellular network and the home network. Unlike the Wi-Fi, Femtocell customers do not need to concern about dropped calls as they roam in and out of femtocell coverage. When the signal received from the Femtocell is strong enough, the mobile device may be switched to its femtocell to support Quality of Service (QoS). Currently Wi-Fi networks use the unlicensed 2.4 GHz ISM (Industrial, Scientific, Medical) band for IEEE 802.11b and 802.11g wireless devices, and the 5 GHz UNII (Unlicensed National Information Infrastructure) band for IEEE 802.11a devices. When the devices are operated by the macro-cell, there will be a chance that Femtocell devices may experience an adjacent channel interferences, co-tier and cross-tier interference. In case of dense Femtocell deployment, it is not ease for a femtocell to keep track of its neighbors for handover and mobility management and handover research is now being carried out these days.

4G LTE has become the fastest-growing mobile technology since it has several advantages or characteristics such as All-IP (Internet Protocol) based data network, higher bandwidth and speeds to deliver more data, seamless soft handover and smooth streaming data service for the user. But it has several limitations or challenges such as relatively high latency to approximately 10 milliseconds, narrow wireless operating coverage, and high battery usage. To meet ongoing traffic growth in high density and Heterogeneous Network (HetNet) service using dual connectivity to link the macro and small cell, improved operating area with in-band support, millimeter wave (mm-wave) wireless connections with new spectrum bands above 20 GHz on small cells and low end-to-end service latency of less than 1 millisecond, next generation 5G network is necessary. Also, 5G is required to be operated in bands similar to existing LTE and WLAN networks in frequencies below 2 GHz[8]. It is expected that high band carriers of 5G will be based on Universal Filtered-Orthogonal Frequency-Division Multiplexing (UF-OFDM). Recently ITU-R (International Telecommunication Union – Radio communication sector) is now establishing International Mobile Telecommunications (IMT) for 2020 year and beyond which will enable wireless communication to match the speed and reliability and is studying the network standardization requirements of 5G network for next generation mobile broadband society. 5G devices will use a low band carrier from either a LTE/WLAN macro cell, if available, or small cell for primary service which offers more capacity. When small cells are deployed, we can expect high-capacity hotspots, most economic and scalable way of networking and high end users' QoE (Quality of Experience)[9].

In this paper we study to work out the u-learning services that can be delivered to a Femto terminal when it is on the edge of the Femtocell in campus. We study the design of a Femtocell network for u-learning environment and the link budget of Femtocells.

2. Related Works

Educators and student are using social media and personal mobile devices in school or in worlplace across time and space. The usage of mobile, personal and wireless devices results a paradigm shift in the nature of building knowledge in education. Jones and Jo studied on the adaptive u-learning and U-Learning Environment (ULE) model using wireless technology[10]. Park studied 5G (or beyond 4G) network using pervasive computing technologies for u-learning to solve the data traffic and wireless spectrum problems[11]. In year 2002, Motorola engineers were developing a new television scheme, they studied a very small Universal Mobile Telecommunications System (UMTS) base station. Chandrasekhar et al.[7] overviewed several technical issues of Femtocell networks, such as interference and mobility management, and network infrastructure.

Claussen and co-authors at Bell Labs carried simulation for Femtocells in a hierarchical topology[12]. Network densification has been studied to increase area spectral efficiency, including the use of heterogeneous infrastructure (macocells, picocells, femtocells, and relays). Heath studied mm-wave cellular systems for 5G heterogeneou network to increase spectral efficiency and to get a high Signal-to-Noise-Ratio (SNR)[13]. The main challenge of interference management of Femtocells and Femtocell standardization are discussed in[14]. Bennis et al. described an overview of the BeFEMTO (Broadband Evolved Femto Networks) project and analized the performance of radio resource management algorithms for the combined macro Femtocell model[15]. Kulkarni et al. proposes some design considerations for femtocell deployment[16]. The premise of deployment, applications and usage patterns, resource allocation, detection of UE (User Equipments) interference and the device interfering with it, and a good plan for negotiating resources to overcome interference are some of the proposed design considerations for femtocells.

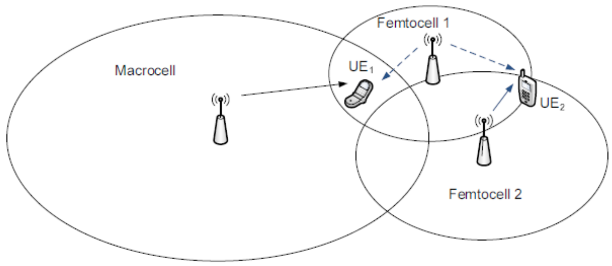

Figure 2. Inter-macro-femtocell and Inter-femtocell interference.

3. Network Design of Femtocell for U-Learning

Femtocell is an emerging technology and this research is largely and essentially conceptual and addresses a coordinated design approach which would be followed by any wireless network planners and designers. We consider the design of a femtocell network for u-learning environment in Baekseok University, Korea. An extensive Wi-Fi network has been installed for Baekseok University since 2013. Table 1 compares several characteristics of Wi-Fi and femtocell technologies[17].

Table 1. Wi-fi v.s. Femtocell features

Paremeters	Wi-Fi	Femtocell
Spectrum	Licensed	Licensed (Operator assigned)
Frequency	2.4 GHz and 5GHz	1.9 GHz ~ 2.6 GHz
Power	100 mW, 200 mW	10 mW, 100 mW
Range	100 m ~ 200 m	20 m ~ 30 m
Backhaul	IP network	IP network
Data rates	11 Mbps and 54 Mbps	7.2 Mbps ~ 14.4 Mbps
Services	Primarily data, and voice	Primarily voice, and data
Cons	Dual-mode handset required	· RF interference with macro-cell · Access point cost

Femtocells should be considered as a viable converging next generation wireless access technology towards 5G u-learning technology. Since it is able to give truly next gen multimedia broadband, i.e. higher bit rates for larger data traffic, QOS specified real-time multi-media streams, better coverage, lower power consumption, higher spectral efficiency, and better interference immunity. The design of a femtocell network as has been proposed for campus environment comprising of 8 Buildings of 10 Floors and 10,000 users with a monthly broadband access demand of 5 GB per user each in an area of 1 square kilometer. Femtocells are small size and indoor based cellular stations that carry any mobile devices using existing Digital Subscriber Line (DSL) or cable broadband lines. When a mobile device arrives at campus in the Femtocell zone, it will switch to communicate with the mobile core network via Femtocell Access Points (FAPs) which provide wireless voice and broadband services to learners. FAPs usually have an output power less than 100 mW. The management of the radio interference between densely deployed small cells and the macro cells is a major concern in campus area.

We focus exclusively on the closed user group model in campus. This restricts the pool of allowed students to a small group authorized by the operator of the femtocell in campus. It is concerned primarily with the 900 MHz band in Korea, and the femtocells have been modelled in terms of 10dBm power. We consider a scenario that femtocells and macrocells are being operated in campus area and a terminal is located in a classroom next to the library that is 1 km distance away from a macrocell. In this scenario, the UE on Figure 2 maintains connection with two different base stations, a macro and a femtocell, simultaneously. The macrocell maintains connectivity and mobility using lower frequency bands, while the femtocell provides high throughput data transport using higher frequency bands. The macrocell is operating at 40% load, while the terminal is connected to the femtocell at the edge of its range. The objective of the analysis of this scenario is to work out the services that can be delivered to a femto terminal when it is on the edge of the Femtocell. We study the link budget for the received power from macro node to femtocell terminal. Given the chiprate of 3.84 x 10^6 cps and bitrate of Adaptive Multi-Rate (AMR) voice call of 10.2 kbps, we get carrier to noise ratio E_c/N_o = -17.6 dB at the 10 dBm transmitter power. In order for femto terminal to detect the femtocell and camp on it, E_c/N_o should be greater than -18 dB. It is seen that Femtocell is able to provide voice to the terminal in campus when the Femtocell is located as far as 100 m away. The link budget for the received power from macro node to Femtocell terminal is shown in Table 2. It is seen that voice services of Femtocell are achievable at the edge of coverage in campus.

Table 2. Link Budget for the Received Power from Macro Node to Femtocell Terminal

Parameters	Value
Antenna height of macro node	25 m
Height of femtocell terminal from ground	1.5 m
Path loss	123.5dB
Antenna gain of Femtocell terminal	0 dBi
Received power of Macro node	-78.8 dBm

For evaluating wireless system, the link budget measured in dB is one of the important performance parameters and it provides an 'efficiency index' of closed access Femtocell operation. The link budget is determined by transmit power, transmitting antenna gain, and receiving antenna gain and we can determine the theoretical maximum value or each cell range of base station with it.

Now we study how link budgets vary with user and Femtocell locations in real path loss scenarios. Let D represent distance to macro-cell, D_F distance from grid center to macrocell and $D_{i,j}$, the distance between user j to base station B_i , respectively. We consider that N surrounding co-channel Femtocells $\{B_i\}$, $i = 1, 2, \cdots N$ exist at a distance D_F from the macro-cell B_0, and that they are arranged in area $D^2{}_{grid}$ = 0.25 km^2 with $\sqrt{N}$ Femtocells per dimension. And we consider each Femtocell has R_f meters radio range. Assume that the cellular user 0 is located at a distance $D_{0,0} = D$ from the macrocell B_0 and a reference distance D_{ref} equals 1 meter for all users. For simple calculation, we use the simplified path loss model which has not Rayleigh fading effect according to Goldsmith[18]. Let K_{fi} denote the fixed loss between Femtocell user i to their base station B_i , and letting K_{fo} , the fixed loss between Femtocell user i to a different base station B_j , respectively, and assume $K_{fo} = K_c$. And W is partition loss during indoor-to-outdoor propagation. Then the link budget L is given as

$$L = (K_{fi} R_f^{-\beta} / W^2 K_{f0}) D^{-\alpha} \cdot \left(\sum_{i=1}^{N} D_{0,i}^{-\alpha} D_{i,0}^{-\alpha} \right)^{-1}$$

where α is the indoor path loss exponent and β is the outdoor path loss exponent. Figure 2 shows the

Cumulative Distribution Function (CDF) of the link budget with randomly location femtocells for three cases, (a) $D = D_F = 0.2$, (b) $D = D_F = 0.8$, (c) $D = 0.2$, $D_F = 0.5$. With N = 32 femtocells, case (c) which is located in the center of macrocell grid shows the best link budget. With this simulation results, it is seen that Femtocells are able to reduce transmit power while enlarging the coverage area and capacity of the cellular communication system. Due to their short transmit-receive distance and spectrum reuse in wide ranging coverage, Femtocells can provide great power reduction and better quality communication for 5G u-learning services in the near future.

4. Conclusions

Femtocell technology can be a potential solution to support the high demand of data traffic due to the propagation of Internet enabled multimedia services and several advantages. It also can bridge the dead zones of an inside premise where macro-cell cannot penetrate.

We consider the scenario that Femtocells and macro-cells are being operated in campus area and a terminal is located in a classroom next to the library that is 1 km distance away from a macro-cell. We study how link budgets vary with user and Femtocell locations in real path loss scenarios. It is seen that voice services of Femtocell are achievable at the edge of coverage in campus. On the other hand, a macro-cell has a broad coverage area of about 1 km radius and a larger number of users. Femto technology seems to be a good candidate for the open mobile alliance that can potentially play an important role by enabling a new class of multimedia and 5G u-learning technology.

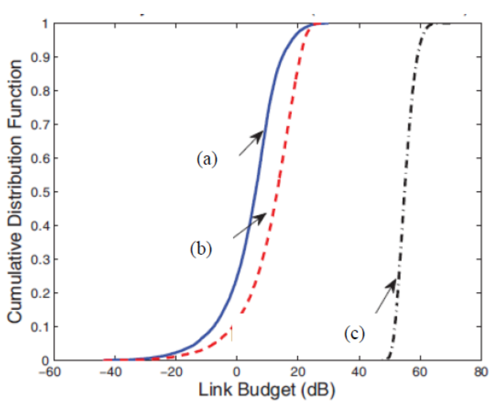

Figure 3. Cumulative distribution function of the link budget.
(a) $D = D_F = 0.2$, (b) $D = D_F = 0.8$, (c) $D = 0.5$, $D_F = 0.5$.

5. References

1. Andrews JG, Claussen H, et al. Femtocells: Past, Present, and Future. IEEE Journal on Selected Areas in Communications. 2012 Apr; 30(3):497–508.
2. Rony MS, Pullin AJ. Design Considerations for 5G Mobile Network. International Journal of Computer Applications. 2013 Jan; 62(10):14–21.
3. Cisco. Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2014–2019. 2015 Feb 3.
4. Lee HW. 4G and B4G R&D activities in Korea, Proc International Mobile Communications Symposium. 2012 Sep; 1–6.
5. Park YC. Femtocell for Ubiquitous Learning System. The 2nd International Conference on Small and Medium Business (ICSMB). 2015 Jan; 2(1). p. 183–4.
6. Gallen C. Consumers Outpaced by Enterprise in the $4B Femtocell Market Says ABI Research, ABI Research. 2014 Mar 27.
7. Chandrasekhar V, Andrews JG, Gatherer A. Femtocell Networks: A Survey. IEEE Communication Magazine. 2008 Sept; 59–67.
8. Rappaport TS, Sun S, et al. Millimeter Wave Mobile Communications for 5G Cellular: It Will Work!. Access, IEEE. 2013 May; 1:335–49.
9. Nokia, Bridging the spectrum gap with 5G. 2013 May 17. Available from: http://networks.nokia.com/news-events/insight-newsletter/articles/bridging-the-spectrum-gap-with-5g
10. Jones V, Jo JH. Ubiquitous learning environment: An adaptive teaching system using ubiquitous technology. ASCILITE 2004 Conference Proceedings; 2004. p. 468–74.
11. Park YC. Pervasive computing and communication technologies for u-learning. Journal of Int’l Education Research, 4th Quarter. 2014; 10(4):265–70.
12. Claussen H. Co-channel operation of macro- and Femto-cells in a hierarchical cell structure. Int’l J Wireless Inform Networks. 2008; 15(3):137–47.
13. Heath RW, Jr. Millimeter Wave Cellular Systems - The Future of 5G. Research in Wireless Communication and Signal Processing. Department of Electrical and Computer Engineering, University of Texas at Austin; 2014 Sep.
14. Zahir T, Arshad K, Nakata A, Moessner K. Interference Management in Femtocells. IEEE Communications Survey and Tutorials. 2013; 15(1):293.
15. Bennis M, Giupponi L, et al. Interference Management in Self-Organized Femtocell Networks: The BeFEMTO approach. 2nd International Conference on Wireless VITAE. 2011. p. 1–6.
16. Kulkarni P, Chin WH, Farnham T. Radio resource management considerations for LTE Femtocells.

SIGCOMM Computer Communication Review. ACM. 2010; 40(1):26–30.

17. Houngninou DK. Femtocell: Indoor Cellular Communication Redefined, WUSTL Technical Report. 2010 Apr.
18. Goldsmith A. Wireless Communications. Cambridge University Press. 2005.