RESEARCH ARTICLE OPEN ACCESS

The Effects of Interferenceon the Transmission and Coverage in High Buildings

Saleh HabibHusain
Public Authority for Applied Education & TrainingTransmission Department, Higher Institute of Telecommunication & Navigation, Kuwait

ABSTRACT
Wireless communication is one of the most rapidly developing technologies in recent time, with wonderful services and products emerging together. These developments present huge challenges for communication engineers, as the demand for increased wireless capacity grow fast. Re-using the limited available spectrum will results a critical issue that affects the system performance, which is co-channel interference. This issue will limits the uplink coverage and capacity of the wireless system. It is needed to come up with such method of interference cancellation. We will investigate the transmission in multiple floors building by deploying femtocell based distributed antenna that connected at each entire floor, the signal will be processed by jointing all femto base stations for all cells in the building. We will try to introduce a solution to the arising problem of co-channel interference from frequency reuse, by measuring and analyzing the gain when deploying interference cancellation at each base station.

Keywords – Co-channel interference, Distributed antenna system,Femtocell, Frequency reuse, Interference cancellation.

I. INTRODUCTION

As the demand for increased wireless capacity grow fast. Of course, there are many difficulties in the dynamics of underplaying work and the nature of the physical medium wireless communications that presents many challenges to designers. The dominant technical issue in the wireless communications is that of multipath-induced fading, namely the random fluctuations in the channel gain that rise due to scattering of transmitted signals from intervening objects between the transmitter and the receiver. Multipath scattering is therefore commonly seen as weakness to wireless communication. However, it can now therefore commonly seen as providing opportunity to improve the capacity add reliability of such systems [1].

A technique of using multiple transmitters and receivers antennas in wireless system is known as (MIMO) multiple-input/output has rapidly gained in popularity due to its powerful performance-enhancing capabilities. MIMO technology offers a number of benefits that help meet the challenges posed by both the weakness in the wireless channel as well as resource perform. The influence of MIMO is realized by exploiting the spatial dimension (providing by the multiple antennas at the transmitter and the receiver).

Multi-path is the arrival to the transmitted signal at an intended receiver through differing angles and/or differing time delays and/or differing frequency shift due to the scattering of electromagnetic waves in the environment. Consequently, the received signal power oscillates in space through the random superposition of the influencing multi-path components. The random oscillation andfluctuation in signal level, known as fading, can severely affect the quality and reliability of wireless communication. In addition, the constraints posed by limited power and frequency bandwidth make the task of designing high data rate, high reliability wireless communication systems extremely challenging [2].Using macro-cell system at indoor wireless data service within the high office buildings, is not enough solution to meet increasing demands where a higher data rate and higher quality transmission is required at these buildings and other indoor propagation environments.This system can only provide degraded low services or provide no coverage at all. Depending on construction materials used in these structures, floors and walls inside the building and outside terrain, it becomes a challenge to provide reliable signal levels [3].

It is needed to improve the capacity by introducing a higher frequency reuse and smaller cell size due to the limited available spectrumin indoor wireless communication systems. However, interference from co-channel floors within the building will become dominant and it will limit the performance of the system. Different techniques are available to improve the performance of indoor wireless communications. Therefore, to achieve this goal, a centralized antenna systems(CASs) are used. However, the CAS technique is limited to small buildings.

So, a new idea has become as alternative strategy trying to reduce the overall transmit power using distributed antenna systems (DASs), which employ multiple remote antenna units (RAUs) that connected to each base station. DASs have a better in-building coverage due to its enormous improvement, power efficiency and higher data rate. It also has the ability to increases the spectral efficiency without using the extra frequency bandwidth through all RAUs since they are typically connected to the base station via wires setup such as optical fibers.

It is very useful to analyze the potential benefits of DAS for indoor communication with the idea of implementing an in-building downlink communication system and the capacity. However, the indoor environment is characterized by complex radio propagation affected by a number of factors which include the walls, floors, partition, floor plan, building layout and possible nearby buildings in close neighborhood, as mentioned before. If the same frequency channel is reused in adjacent floors of the building, the multipath which generated bytransmission and reflections within the building may increase the level of co-channel interference. Therefore, to analyze and design multi-floor in-building wireless system with acceptable performance, it is necessary to develop a propagation channel model which accounts for inter-floor interference caused by the effect of the building structure and its terrain [4].

To enhance the coverage of dead spots in high buildings, and further reduce the interference from co-channel floors,a suggested technique creates the advantages of both the DAS and the signal attenuation caused by the floors and the walls. Taking in consideration the major advantage of a distributed antenna system (DAS) deployment is the much lower path loss between the user terminal and the remote antenna unit when compared to the path loss of the conventional macro-cell [5].

II. THEORETICAL BACKGROUND

The gains of the performance that are expected from the use of MIMO technology can be indicated by the plotting in Figure 1. It shows the data rate versus the receiver signal-to-noise ratio (SNR) in a 100 KHz channel for an M × M (where, M is the transmit antennas and M is receive antennas) and fading link with M = 1, 2, and4. The channel response is assumed constant over the bandwidth of interest for this simple example. Assuming a target receive SNR of 25 decibels (dB), a conventional single-input single-output (i.e., M = 1) system can deliver a data rate of 0.7 Mbps. With M = 2 and 4 we can realize data rates of 1.4 Mbps and 2.8 Mbps respectively. This increase in data rate is realized for no additional power or bandwidth expense compared to the single-input single-output system. In principle, the single-input single-output system can achieve the data rate of 2.8 Mbps with a receive SNR of 25 dB if the bandwidth is increased to 400 KHz, or alternatively, with a bandwidth of 100 KHz if the receive SNR is increased to 88 dB. The result presented in this example is based on optimal transceiver design. In practice, the modulation and impairments-constrained data rate delivered will be less but accepted at the general trend.

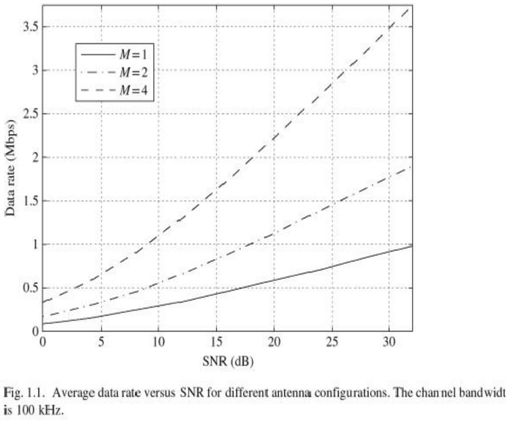

Fig.1: Average data rate versus SNR for different antennas configurations. The channel bandwidth is 100 KHz.

A brieffundamentals about some of the terms that involved into the research will be introduced.

2.1. Interference

In telecommunication, anything mightdisrupts, modifies, or alters a message as it travels along a channel between a source and a receiver. Typically the term refers to the addition of an unwanted signal to the useful signal.Wireless signal interference model specifies how a number of signals interact when they are received by the sameradio. Co-channel interference is crosstalk from two different radio transmitters using the same frequency. There can be several causes of co-channel radio interference.The co-channel interference arises in the cellular mobile networks owing to this phenomenon of frequency reuse. Thus, besides the intended signal from within the cell, signals at the same frequencies (co-channel signals) arrive at the receiver from the undesired transmitters located (far away) in some other cells and lead to drop in receiver performance.Interference in wireless networks results from multiple users sharing time and frequency resources. Interference can be mitigated in MIMO systems by exploiting the spatial dimension in order to increase the separation between users. For example, in the presence of interference, array gain increase the tolerance to noise as well as the interference power, hence improving the signal-to-noise-pulse-interference ratio (SINR). Additionally, the spatial dimension may be leveraged for the purpose to interference avoidance. Such as directing signal energy towards the intended user and minimizing interference to other users [6].

In general, it may not be possible to exploit simultaneously all the benefits described above due to conflicting demands on the spatial degrees of freedom. However, using some combination of the benefits across a wireless network will result in improved capacity, coverage, and reliability.

2.2.Femtocell &Macrocell

A femtocell is a small cellular base station, typically designed for use in a home or small business (1-10 meters). It connects to the service provider's network via broadband; current designs typically support 2 to 4 active mobile phones in a residential setting, and 8 to 16 active mobile phones in enterprise settings. A femtocell allows service providers to extend service coverage indoors, especially where access would otherwise be limited or unavailable [7].

A macro-cell is a cell in a mobile phone network that provides radio coverage served by a power cellular base station, it describes the widest range of cell sizes. Generally, macro-cells provide coverage (highway areas)larger than micro-cell (100-1000 meter). The antenna for macro-cells are mounted on ground base masts, rooftops and other existing structures, at a height that provides a clear view over the surrounding buildings and terrain. Macro-cell base stations have power outputs of typically tens of watts.Over a smaller cell area, a micro-cell is used in a densely populated urban area. Currently the smallest area ofcoverage can be implemented with a femtocell; used in homes or small offices.

The research project is to use distributed antennas wireless communication system in-building would be represented in the next section.

III. PROJECT WORK AND RESEARCH

The project is focused on implementing in-building wireless system using distributed antennas in a single multi-story building, which is represented of 7 floors of 300 cm height and rectangular shaped, each floor is mounted and equipped with multiple RAUs (about 3) that are separated by equal distance (L)as shown in Figure-2. The distant between the user and the floor is 1 meter; the horizontal distant between a user and its target RAU is 3 meters. All RAUs are connected to a central unit (CU), and each floor and its adjacent floor should use a different frequency. The system should have 7 users including 6 interferers and only one desired user. The penetration loss is assumed to be 13 dB per floor, and for the penetration loss of about 10 to 15 dB for concrete floors. The path loss exponent is assumed to have amount of 2.The distance between the reference and the adjacent building is assumed to be 10 meters.

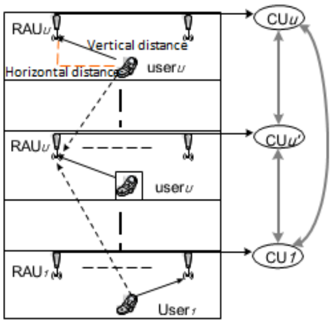

Fig. 2: A femtocell distributed antenna system for a high building

The reflection coefficient at the adjacent building surface and the transmission coefficient through two set of glass windows reduce the received power by 18 dB.When employing interference cancellation mechanism at the CUs in which the co-channel signals from several users, received at neighboring CUs are communicated to neighboring CUs and are separated through shared processing. This would provide solution to interference problem. RAUs located at different floors in the building receive uplink signals from different users and locally performs RF processing. The signals are then expected and guided to the neighboring CU as shown in Fig.2 for shared processing. The CU jointly detects and decodes the received signals, does interference cancellation and makes available at its output the transmitted data from each user.

IV. EVALUATION AND DISCUSSION

Referring to the building structure that shown in Fig.2 with geometry as follows: the inter floor spacing to be equal to 3 meters, the horizontal distance between a user and its target RAU is 3 meters and the vertical distance between the user target RAU is 2 meters. Hence, the distance between a user and its target RAU equals $\sqrt{2^2+3^2}$= 3.6 meters. Formulas (1), (2) and (3) are numerically evaluated in the uplink scenario for BPSK modulation, and to calculate the average BER for the performance of the femtocell based

DAS for the cases with and without interference cancellation.

The floor attenuation factor λ_{uv} increases as the number of floors increases. According to the measurement results in different building environments, the attenuation factor takes value from (2) to (4.5). The attenuation factor in the simulation is given by $\lambda_{uv} = \log_2[2.(|u-v|+2)]$.The absolute value of |u-v| denotes the number of floors between user *u* and RAU*v*.The sum of the variance from all co-channel floors in the building is given by:

$$\sigma(v') = \sum_{u \neq v}^{U} P_s \, (d_{u,v'})^{-2\lambda_{u,v'}} \quad (1)$$

Where $d_{u,v'}$is the distance between desired RAUv' and its interfering user (u ≠ v').

The received SINR after interference cancellation can now be derived as follows:

$$\bar{y} = \frac{E[{}_{u'}^{2}]}{\sum_{u \neq v'}^{U} Ps.(d_{u,v'})^{-2\lambda u,v} .\ 4Pe(u) + P_e\ (u) + \sigma_\eta^2} \quad (2)$$

The BER of PSK as a function of the SINR of this system is expressed as:

$$P_e = \frac{1}{2}\left(1- \sqrt{\frac{\frac{E[{}_{u'}^{2}]}{\sum_{u \neq v'}^{U} Ps.(d_{u,v'})^{-2\lambda u,v} .\ 4Pe(u) + P_e\ (u) + \sigma_\eta^2}}{1+\frac{E[{}_{u'}^{2}]}{\sum_{u \neq v'}^{U} Ps.(d_{u,v'})^{-2\lambda u,v} .\ 4Pe(u) + P_e\ (u) + \sigma_\eta^2}}}\right) \quad (3)$$

Note that formula (3) considers all interferers in the building and since all the detected estimates are exchanged among all the cooperating CUs, both diversity and array gain are obtained.

Figure 3 shows the compared performance of the systems in the two cases. First, when CUs corporate and does interference cancellation. Second, the system without and cooperation on interference cancellation. This figure shows an improvement in performance when interference cancellation (IC) is applied resulting in a larger SINR, particularly when the SNR is above 20 dB. The remarkable gains are observed when compared with a system without any interference. It is obvious that the smaller the power of the interferer, the lower the BER is. The curves tend to converge to the no interference case when SNR is below 20 dB.

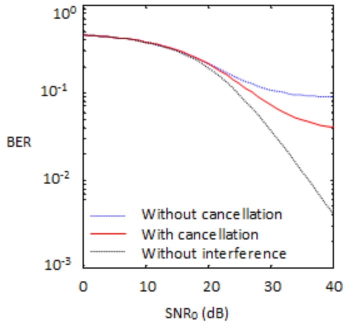

Fig. 3: Effect of the ratio of transmit power to the noise on BER

With the two scenarios for the different building geometries, figure 4 shows the evaluated results with floor attenuation factor between the user u and RAUv equal to $\log_2[2.(|u-v|+2)]$ and $\lambda_{u,v} = \log_2[2.(|u-v|+3)]$ indicated as small and large group respectively. The figure shows that the two groups illustrate similar trends when Interference Cancellation (IC) is applied, however, the group with the smaller floor attenuation factor tends to show better performance as a result of a reduced path loss and the BER decreases, this is even more pronounced at higher SNR i.e. above 20 dB.

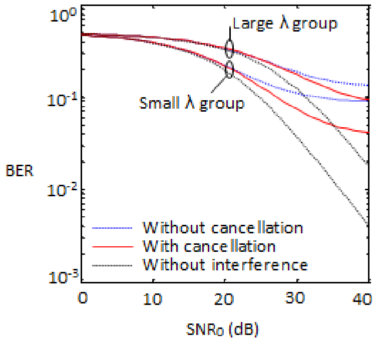

Fig 4: Effect of the attenuation factor on BER

The effect of increasing the number of floors in the building can be physically interpreted as increasing the number of CUs or users with the same frequency. Figure 5 shows the effect in BER value for buildings with different number of floors. It can be seen that there is a large improvement in the performance with increasing SNR, when IC is employed in the lower number of floors building. This is because the interference from the strongest interferers is reduced. However, as the number of the interferers increases the achievable gain becomes lower as a result on theincreasing in the estimation error and the increasing in the distance between the user and the referenced RAU as the number of floors increases. The shown curves in fig.5 tend to converge when SNR is below the amount of 20 dB. It is better to do interference cancellation and reuse the frequency within 3 tiers of floors of this building. The performance parameters are noticed when CUs cooperate to do interference cancellation when compared with the non-cooperating system.

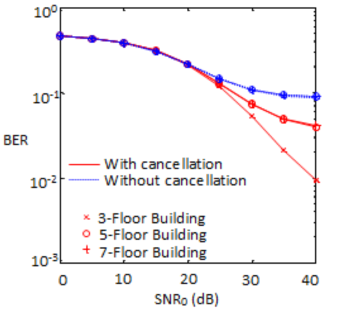

Fig 5: Effect of number of floors in the building on BER

V. CONCLUSION

In this paper, the investigation of the effect of uplink co-channel interference on the transmission and coverage in high buildings has been accomplished. A remarkable result of combining the advantages of the connected femtocell to distributed antenna system and jointly processes at the received signal has come up. It was shown that co-channel operation of users is practical without causing coverage problems as long as interference cancellation is involved at the central units. By analyzing the results, gain performance has reached up to 13 dB, which is better when comparing it with non-cooperating system of BER is more than 10^{-1}. It is also noticed that the same frequency can be reused at 3 tiers of the building without causing low performance.

VI. READING MATERIALS& REFERENCES

[1]. Power coverage and fading characteristics on indoor distributed antenna systems. Xinwei Hu. Yan Zhang; YuanzhiJia; ShidongZho. Aug. 2009 (Paper)
[2]. MIMO technologies in 3GPP LTE and LTE-advanced.J Lee, JK Han, J Zhang - EURASIP Journal on Wireless Communications. 2009 (Paper)
[3]. An overview of the femtocell concept. H Claussen - 2008. Volume 13 Issue 1, March (Paper)
[4]. Distributed antennas for indoor radio communications.Saleh, A.A.M.; AT&T Bell Labs.,Holmdel, NJ ; Rustako, A.J. ; Roman, R.January 2003 (Paper)
[5]. Concepts and challenges of femtocells.H Claussen, LTW Ho, LG Samuel - Bell Labs Technical Journal, 2008 (Paper)
[6]. S. Khattak, G Fettweis, "Distributive iterative detection in interference limited cellular network" VTC, Dublin, spring 2007.
[7]. An overview of the femtocell concept. Claussen, Holger, Bell Labs Technical Journal (Volume13, Issue: 1). 2008
[8]. Digital Communications.Edward A. Lee, David G. Messerschmitt - 2012
[9]. Digital communication over fading channels.Marvin K. Simon, Mohamed-Slim Alouini - 2005
[10]. MIMO wireless communication. EzioBiglieri, Robert Calderbank, A.Constantinides - 2007
[11]. Fundamentals of wireless communications.David Tse, PramodViswanath - 2005
[12]. Coordinated Multi-point Transmission/Reception Techniques for LTE-Advanced.Sawahashi, M. Kishiyama, Y.; Morimoto, A.; Nishikawa, 2010 (Paper)
[13]. On the Way towards Fourth-Generation Mobile: 3GPP LTE and LTE-Advanced.David Martín-Sacristán. EURASIP Journal, March 2009 (Paper)
[14]. LTE Rel. 9 and LTE advanced in 3GPP.T Nakamura - LTE ASIA, 2009 (Paper)
[15]. Capacity of multi-antenna Gaussian channels.N Chiurtu, B Rimoldi, E Telatar - Information Theory, 2001 (Paper)
[16]. Overcoming interference in spatial multiplexing MIMO cellular networks.JG Andrews, W Choi, Wireless Communications networking. 2007 (Paper)
[17]. A novel analytical method for maximum likelihood detection in MIMO multiplexing systems.W Peng, S Ma, TS Ng, J Wang. 2009 (Paper)
[18]. Digital communications, 4th edition. New York: McGrew Hill, 2001.
[19]. Digital communication over fading channels: A unified approach to performance analysis. New York: John Wiley & Sons, 2000.
[20]. A Novel Handover Mechanism between Femtocell and Macrocell for LTE Based Networks. HaijunZhang. 2010.