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Fast game-based handoff mechanism with load balancing for LTE/LTE-A heterogeneous networks☆

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ABSTRACT

Due to the development of femtocell technologies, indoor LTE/LTE-A signal quality can be significantly improved. However, since femtocells and macrocell are deployed into a coexisted heterogeneous network, handoff from macrocell to femtocell turns out to be one of the major design issues to achieve better user experience provided by femtocells. In general, the macrocell user equipment (MUE) selects a handoff target femtocell base station (FBS) in the handoff procedure solely based on the received signal strength indicator (RSSI), signal to interference plus noise ratio (SINR), or signal to noise ratio (SNR). Although this approach is very simple and easy to implement, it can result in load imbalance among FBSs. Hence, this paper proposes a novel game-based handoff mechanism that combines the modified Dutch Auction (MDA) and stochastic election process (SEP) to jointly take the uplink and downlink signal qualities and load balance of the handoff candidate FBSs into consideration when selecting handoff target FBS. Besides, in order to speed up the execution of the handoff mechanism and reduce the percentage of handoff failures, the Fast SEP and Go Back *B* are further developed, respectively. Simulation results confirm that the proposed MDA+Fast SEP+Go Back *B* handoff mechanism provides better load balance, faster handoff and higher percentage of successful handoffs.

1. Introduction

In recent years, due to the advancement of the fourth generation (4 G) mobile communication technologies, the major services of mobile communication systems provided to the mobile users have been shifted from voice calls to mobile multimedia applications. Although the demands for mobile high-speed data transmission are greatly increased, wireless access technologies to satisfy such requirements still face many challenges (Yeh et al., 2008). The 4 G mobile communication technologies are required to provide higher transmission rate and throughput, better quality-of-service (QoS), and lower transmission delay. To achieve a high transmission rate, the transmission technology adopted by the 4 G Long Term Evolution/Long Term Evolution-Advanced (LTE/LTE-A) is the orthogonal frequency division multiplexing (OFDM) which has been recognized as one of the transmission technologies to provide high spectrum utilization. Although the performance of 4 G LTE/LTE-A mobile communication systems in the outdoor environment is promising, it suffers serious degradation in the indoor environment due to the attenuation of signal strength caused by shadowing effect.

Femtocell technologies have been selected as one of the feasible solutions to the issue mentioned above. A femtocell consists of a low-cost, low-power, and user-deployed base station called Femtocell Base Station (FBS) or Home eNodeB (HeNB) and all the associated User Equipments (UEs) called Femtocell UEs (FUEs). On the contrary, a macrocell consists of a high-cost, high-power, and operator-deployed base station called Macrocell Base Station (MBS) or eNodeB (eNB) and all the associated UEs call Macrocell UEs (MUEs). As illustrated in Fig. 1, in a macro-femto heterogeneous network, femtocells are deployed within the coverage area of the macrocell and are connected to the backhaul network through a broadband router. In some implementations, the functionalities of the broadband router are integrated into the FBS. Although femtocell brings many advantages to the operators, e.g., extending the mobile network coverage, offloading the traffic of MBS, increasing the spectrum utilization, and reducing the capital expenditures (CAPEX) and operating expenses (*OPEX*), the issues listed below still need to be further examined:

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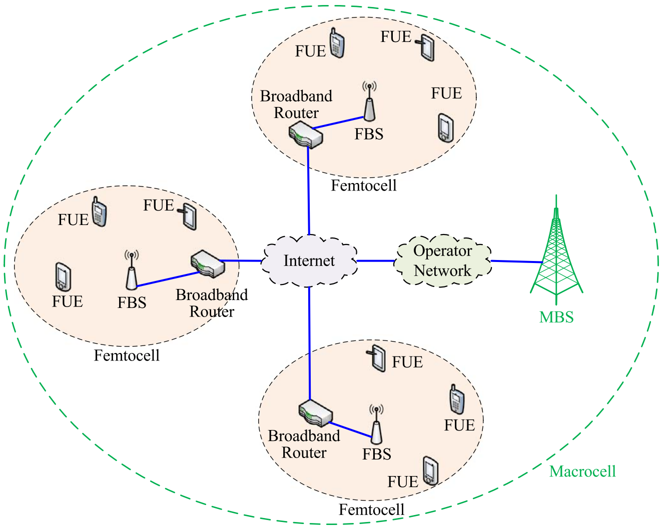

Fig. 1. The architecture of macro-femto coexisted heterogeneous network.

- Spectrum allocation (Mahmoud and Güvenc, 2009; Lopez-Perez et al., 2009): Since femtocell is operated in the licensed band, allocating the limited licensed spectrum to femtocells and macrocells turns out to be one of the important factors to maximize the performance of the macro-femto heterogeneous network. In general, the limited licensed spectrum can be allocated using dedicated channel, co-channel, or hybrid channel approach. In the dedicated channel allocation approach, the entire licensed spectrum W is divided into two independent sub-bands, W_M and W_F, which are allocated to macrocell and femtocells, respectively. The advantage of this approach is the avoidance of interference between femtocells and macrocell. But, this approach does not utilize the limited licensed spectrum efficiently. In the co-channel allocation approach, femtocells and macrocell share the entire limited licensed spectrum. Since femtocells and macrocell are operated in the same spectrum, the spectrum utilization is greatly improved. However, the interference between them needs to be carefully managed. By combining the concepts of dedicated and co-channel allocation approaches, in the hybrid channel allocation approach, the entire licensed spectrum W is divided into two independent sub-bands, W_M and W_H. Similar to the dedicated channel allocation approach, the band W_M can only be used by macrocell. However, the band W_H is shared by macrocell and femtocell.
- Access control (Xia et al., 2010; Tsai et al., 2010; Bai et al., 2009): Since FBS can be deployed by end users or operators, access to the resources of FBS can be configured as closed subscriber group (CSG), open subscriber group (OSG), or hybrid subscriber group (HSG). In CSG, the resources of FBS can only be accessed by authorized FUEs. On the contrary, in OSG, all resources of FBS are opened for public access. As the combination of CSG and OSG, only part of resources of FBS is opened to the public.
- Interference management: As stated in (3GPP TSG-RAN WG1 #59 R1-094775), the interference scenarios in a macro-femto heterogeneous network can be classified into co-tier interference and cross-tier interference. Co-tier interference is the interference between femtocells and cross-tier interference is the interference between femtocells and macrocell. There are two typical scenarios for co-tier interference: interference from the uplink of FUE to FBSs and interference from the downlink of FBS to FUEs served by other FBSs. As to the cross-tier interference, there are four typical scenarios: interference from the uplink of FUE to MBS, interference from the downlink of MBS to the FUE, interference from the downlink of FBS to MUE, and interference from the uplink of MUE to FBS. Detailed descriptions for the six interference scenarios can be found in (Zhao and Kaiser, 2016).
- Handoff mechanism (Tseng et al., 2016; Tseng et al., 2013; Hasan et al., 2009): In general, handoff in the macro-femto heterogeneous network can be classified into horizontal handoff and vertical handoff. Four different types of handoff can be observed in the macro-femto heterogeneous network: macro-to-macro, femto-to-femto, femto-to-macro, and macro-to-femto. The first two types are horizontal handoff, while the last two are vertical handoff. Consider the scenario when an MUE served by MBS1 moves toward to a neighboring MBS2. As the MUE arrives at the boundary of MBS1 and MBS2, a macro-to-macro handoff mechanism is initiated to support the MUE to be handed over to MBS2. Then, the MUE keeps moving and enters a building located inside the coverage of MBS2. Due to the poor signal quality from MBS2, the MUE makes a vertical handoff from MBS2 to FBS1 installed on the first floor of the building. After that, as the MUE moves to the second floor, a femto-to-femto handoff mechanism is invoked to help the MUE connect to FBS2 installed in the second floor.

The application scenario considered in this paper is shown in Fig. 2. In this scenario, all the femtocells are configured in OSG mode so that an MUE can connect to any FBS whenever necessary. For example, when an MUE goes into a shopping mall in which FBSs are deployed,

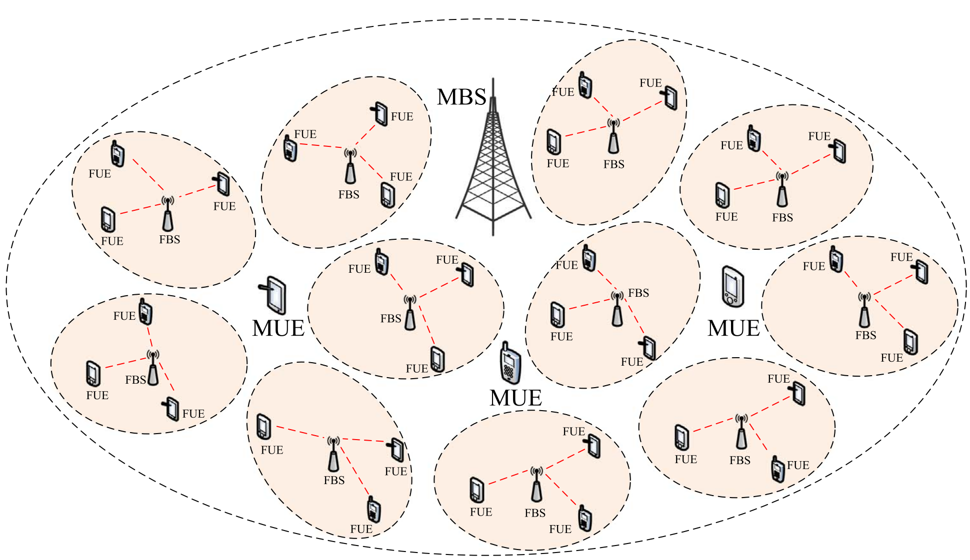

Fig. 2. The application scenario under consideration.