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Victim macro UE detection procedure based on network assistance in LTE-femtocell networks

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Abstract: In long term evolution (LTE), home evolved node B (HeNB) has been introduced to improve indoor channel quality and take over indoor traffic from macro eNB (MeNB) at a low cost. As MeNB and HeNB share radio resources to obtain high capacity, victim macro user equipments (VMUEs) may exist due to severe interference from HeNB. For efficiently coordinating interference to the VMUEs, the HeNB should exactly perceive presence and absence of its neighboring VMUEs. In this paper, we propose a VMUE detection procedure based on network assistance in LTE-femtocell networks. By using the proposed detection procedure, HeNB can appropriately perform interference coordination (IC) as detection results of VMUE. Performance evaluations show the throughput of MUEs can be improved by combining the proposed procedure and IC.

Keywords: cross-tier interference, femtocell, network-assisted approach, victim MUE detection

Classification: Wireless communication hardware

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1 Introduction

In long term evolution (LTE), femtocell base station termed home evolved node B (HeNB) was introduced to support high rate data services to indoor user equipments (UEs) with low power, capital expenditure, and operating expenditure. HeNB can enhance the entire system capacity by off-loading indoor traffic treated by the macrocell base station, termed Macro eNB (MeNB) in LTE [1]. Moreover, as femtocells fully share the entire system frequency band with the macrocell, we can efficiently use radio resources with a limited frequency band [2]. However, due to reuse of radio resources between macrocell and femtocell, macro UEs[1] attached to MeNB experience co-channel interference from their nearby HeNB(s).

Research on mitigating co-channel interference between macrocell and femtocell has been performed [2, 3]. In order to relieve interference to VMUE with minimal performance degradation of femtocell, HeNB may dynamically adjust its transmission power by considering the existence of VMUE [3]. In the research, the HeNB finds the optimal transmission power based on the existence of VMUEs and the channel condition of home UEs (HUEs). However, the research does not consider the VMUE detection method for the power control schemes, while the research mainly focused on transmission power control schemes of HeNB. Thus, research on VMUE detection schemes should be conducted prior to interference coordination schemes.

For VMUE detection of HeNB, self detection and network-assisted detection approaches have been introduced [4, 5, 6, 7]. In self detection ap-

[1]The macro UEs are called victim MUEs (VMUEs).

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proach, HeNB perceives existence of VMUE by observing interference over thermal noise (IoT) or strength of uplink reference signal (ULRS) received from the VMUE [4, 5]. VMUE detection based on the IoT has lower detection accuracy than that base on the ULRS [5]. Besides, time period or frequency band where all MUEs do not transmit their signals is required to measure thermal noise [8]. In order to detect VMUE using the ULRS, HeNB should know information on base sequence, cyclic shift, and hopping pattern in advance [9]. In addition, for tracing the hopping ULRSs, HeNB should be synchronized with VMUE in both frequency and time domain. In network-assisted detection approach, serving MeNB detects the VMUE based on channel information reported from the MUEs, and then informs it to an HeNB dominantly interfering the VMUE via backhaul networks [6, 7]. Thus, HeNB using network-assisted detection can detect VMUE without measuring radio signals transmitted from VMUE. Unfortunately, the network-assisted detection method in [6, 7] does not reveal detailed message flows and interactions between VMUE, MeNB, and HeNB.

In this paper, we propose a network-assisted VMUE detection procedure in LTE-femtocell networks. The proposed procedure consists of two procedures, one to detect the VMUE entering into the dead zone [2] and the other to detect the VMUE leaving the dead zone. The proposed procedure includes detailed message flows and interactions between VMUE, MeNB, and HeNB. By evaluating performance of a simple transmission power adjustment scheme with the proposed procedure, we show that the proposed procedure can be usefully utilized to coordinate the co-channel interference from HeNB to VMUE.

2 Proposed VMUE detection procedure

In LTE networks with femtocells, as an MUE approaches to an HeNB, its channel condition worsens due to interference from HeNB. If the MUE is not a member of a closed subscriber group (CSG) of the HeNB, it becomes a VMUE by the HeNB. To minimize performance degradation of the VMUE, the HeNB should perceive the presence of the VMUE and perform interference coordination (IC). Conversely, if the VMUE moves far from the HeNB, the HeNB should perform IC to improve performance of its serving HUEs. In this section, we propose VMUE detection procedure with two sub-procedures, VMUE presence and absence notification sub-procedures, for appropriate IC operation of HeNB, as shown in Fig. 1.

Each MUE periodically reports the reference signal power received from its serving MeNB and dominant interfering MeNB/HeNB to the MeNB. If the reference signal received power (RSRP) from the serving MeNB becomes smaller than that from the dominant interfering HeNB, the MeNB starts the VMUE presence notification procedure by sending a radio resource control (RRC) reconfiguration message (Step 1). On receiving the RRC reconfiguration message, the MUE searches CSG ID of the dominant interfering HeNB

[2]The dead zone means the area where MUE suffers severe interference by HeNB.

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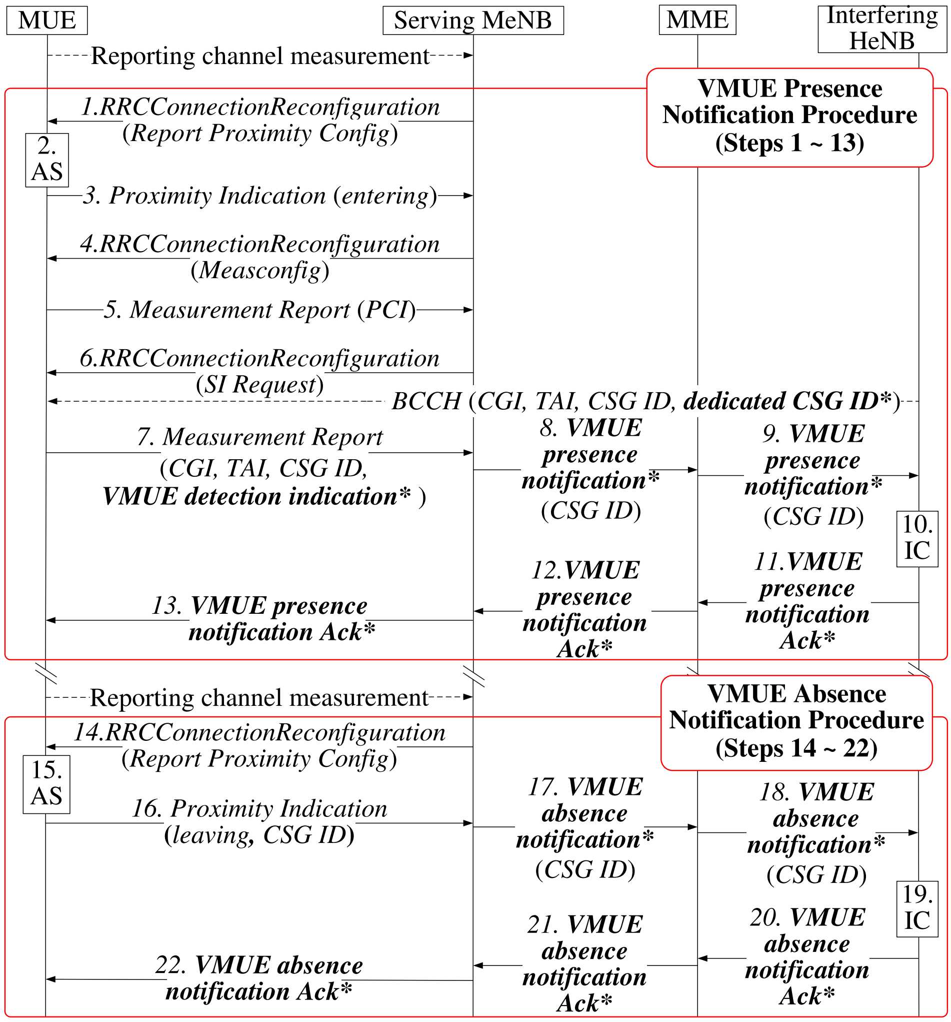

Note 1: messages and information elements marked with '*' are newly defined for the proposed procedure
Note 2: AS(autonomous search), IC (interference coordination for VMUE)

Fig. 1. Message flow in VMUE presence and absence notification procedures

and determines if it can attach to the dominant interfering HeNB (Step 2). If the MUE is not a member of CSG of the interfering HeNB, it realizes itself as a VMUE and then notifies its presence to the MeNB by sending a proximity indication message with 'entering' type (Step 3). To identify the interfering HeNB, the MeNB obtains physical cell identifier (PCI) of the HeNB from the VMUE (Steps 4 to 5). The MeNB instructs the VMUE to acquire system information (SI), including cell global identifier (CGI) of the HeNB, from the periodically broadcasted SI [3] (Step 6). After obtaining SI of the interfering HeNB, the VMUE sends a measurement report message with SI obtained and the VMUE detection indication to the MeNB (Step 7). The serving MeNB sends a VMUE presence notification message to the interfering HeNB via the mobility management entity (MME) (Steps 8 to 9). On receiving the VMUE presence notification message, the HeNB may perform IC to mitigate

[3]Since multi HeNBs may have same PCI due to a limited number of PCIs, it is necessary that the MeNB should know CGI to exactly discriminate the dominant interfering HeNB from HeNBs with same PCI [10].

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the interference to the VMUE (Step 10). Then, it acknowledges the VMUE presence notification to the VMUE through networks (Steps 11 to 13).

When the MeNB perceives that RSRP from the serving MeNB becomes larger than that from the HeNB dominantly interfering to the VMUE, it starts the VMUE absence notification sub-procedure by sending the RRC configuration message to the VMUE (Step 14). The VMUE performs the autonomous search function to find CSG ID of the dominant interfering HeNB (Step 15). If the VMUE cannot find CSG ID of the HeNB, it sends the proximity indication message with 'leaving' type to the MeNB (Step 16). On receiving the proximity indication message, the MeNB notifies the absence of VMUE to the corresponding HeNB by forwarding the VMUE absence notification message via networks (Steps 17 to 18). Upon receiving the VMUE absence notification message, the HeNB perceives the absence of VMUE and performs IC to maximize the performance of its serving HUEs (Step 19). Then, it acknowledges the VMUE absence notification to the VMUE through networks (Steps 20 to 22).

3 Performance evaluation

To show usefulness of the proposed VMUE detection procedure, we consider that HeNB performs IC as receipt of the VMUE presence or absence notification message. Normally, HeNB maintains its transmission power at $23\,dBm$. If the HeNB receives the VMUE presence notification message (Step 10 in Fig. 1), it reduces its transmission power to $3\,dBm$ and maintains this, until that it receives the VMUE absence notification message. Upon receiving the VMUE absence notification message (Step 19 in Fig. 1), it restores its transmission power as $23\,dBm$. For performance evaluation, we consider a cellular network consisting of 19 macrocells, each of $500\,m$ radius and femtocells with $10\,m$ radii uniformly distributed in the cellular network. Other system parameters, such as transmission power, carrier frequency, and system bandwidth, are referred to in [11] and [12]. WINNER II models referred to in [13] are considered as pathloss models. In addition, we consider that transmission delay between MUE and MeNB is $1\,ms$ and delay between MeNB and HeNB is in $[0\,sec, 4\,sec]$.

Fig. 2 shows average throughputs of macrocell and femtocell as varying the number of HeNBs, when the delay between MeNB and HeNB is $1\,sec$. As the number of HeNBs increases, both throughputs of macrocell and femtocell decrease due to increasing co-channel interference from HeNBs. On detecting VMUE, HeNB reduces its transmission power. Thus, interference from the interfering HeNB to VMUE is mitigated, while received signal strength of HUE is decreased. Enabling PC improves macrocell throughput, while it decreases femtocell throughput compared to those of the disabling PC.

When 300 HeNBs are deployed in a macrocell, Fig. 3 shows average throughput as varying delay between MeNB and HeNB. As the delay between MeNB and HeNB increases, throughputs of both macrocell and femtocell decrease, because the HeNB does not coordinate interference until it receives

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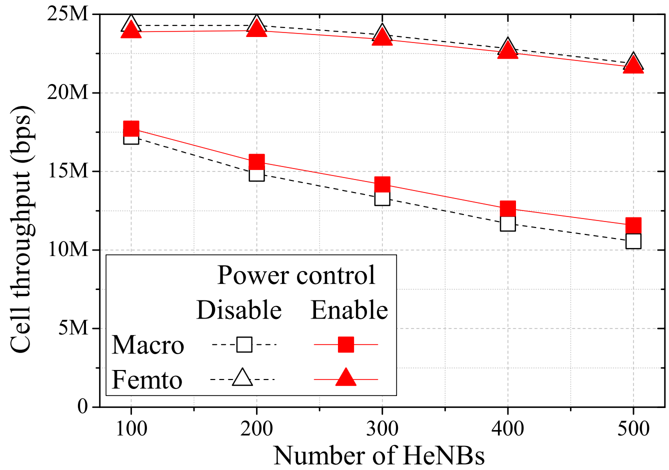

Fig. 2. Average throughputs of macrocell and femtocell according to the number of HeNBs

the VMUE presence or absence notification message. That is, even though VMUE suffers from interference, the interfering HeNB does not reduce its transmission power until it receives the VMUE presence notification message. In addition, the HeNB maintains the reduced transmission power until it receives the VMUE absence notification message, although HeNB does not interfere with VMUE.

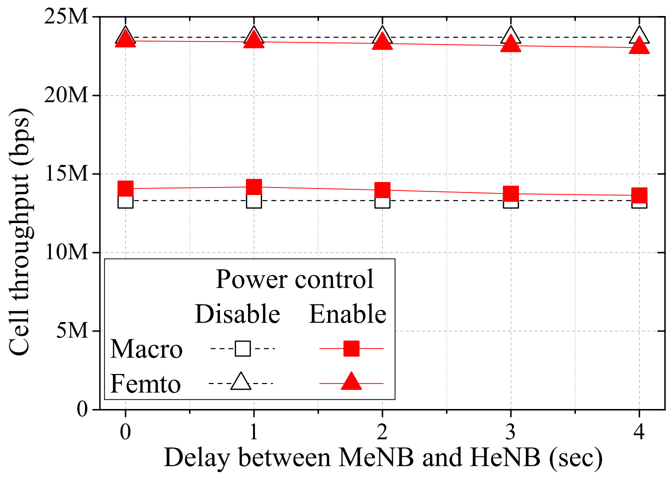

Fig. 3. Average throughputs of macrocell and femtocell according to delay between MeNB and HeNB

4 Conclusion

In this paper, we proposed the VMUE detection procedure, consisting of VMUE presence and VMUE absence notification sub-procedures. Performance evaluation showed the proposed procedure can help HeNB mitigate interference for its VMUE. Throughput of LTE-femtocell networks depends on time difference between the MeNB and HeNB perceiving VMUE. For further study, research on IC algorithms tightly coupled with the proposed VMUE detection procedure is required to improve performance of MUE and HUE.

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