Interference Mitigation Scheme for 4G Wireless Communication Network

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***Abstract*—In recent years, several radio access technologies (RATs) with different types of base stations (BSs) have been considered to improve system performance in wireless communication networks. In this heterogeneous network (Het-NW), it is very important for operators to integrate many different kinds of BSs together in order to further reduce the deployment expense and maintenance cost. As a result, this paper considers the basic interference problems on control channels in heterogeneous networks, and proposes an efficient method to mitigate interferences for control channels.**

***Keywords*— Heterogeneous Networks, Closed Subscriber Group, Femtocell, Interference Mitigation, Control Channel**

1. INTRODUCTION

With a growing interest among operators to deploy efficient broadband access networks, many advanced base stations, such as femto advanced base stations (femto ABS) or home eNodeBs, have been proposed to improve the system coverage and to provide a better user throughput especially for mobile users accessing wireless networks in their houses or offices [1][2]. A femto ABS is a wireless base station with lower transmission power, and may operate in a licensed spectrum to serve a specific group of users [3][4]. The femto ABS may therefore provide wireless coverage in an area that overlaps with the coverage area of a macro ABS.

A femto ABS may be installed into the wireless network as a plug-and-play product. When a femto ABS is initially installed, it can detect its surroundings and try to self-configure and self-organize its network connections to optimize the system performance. The self-configuration may include operating frequency determination, interference control, and so on. In general, femto ABSs can be classified into two types. One is closed-access femto ABSs, in which only allows registered and authorized mobile stations (MS) to access, and the other one is open-access femto ABS, which allows any MS to access even though the MS is not in the white list.

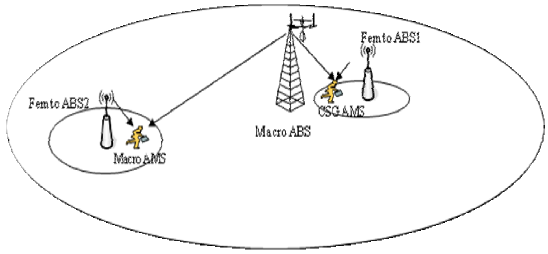

Fig. 1. an example of co-channel interference

As mentioned, a femto ABS can use the same spectrum as its overlapping macro ABS so as to fully utilize the spectrum resource. However, that would introduce huge co-channel interference in some cases [5][6]. An example is illustrated in Fig. 1, where a macro ABS provides a coverage area that extends over a relatively-wide area. Two femto ABSs (i.e., femto ABS 1 and femto ABS 2 in the figure) may locate within the coverage area of the macro ABS, and each of femto ABSs has its own respective smaller coverage area. When the location of a femto ABS is close to the location of the macro ABS (e.g., femto ABS 1), the transmission power of the macro ABS may interfere with the femto ABS. Thus, for example, the AMS, which is served by the femto ABS 1, may receive signals with a relatively-strong downlink power from the macro ABS, and these signals may interfere with the downlink signals transmitted by the femto ABS 1 that is serving CSG AMSs.

Another potential interference scenario may be created when an AMS, which is not allowed to be served by the femto ABS 2 because it is not a

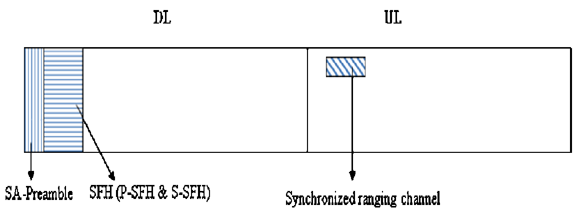

Fig. 2. An example of frame structure

member of the CSG of the femto ABS 2 enters into the coverage area of a femto ABS that is relatively far away from the macro ABS (e.g., the femto ABS 2 in Fig. 1). Because the macro AMS is within the coverage area of the femto ABS 2, but is not allowed to access the network via the femto ABS 2, the transmission power of the femto ABS 2 would interfere with the downlink signalling from the macro ABS such that data transmission from macro ABS can not be decoded by the macro AMS. As the deployment of femto ABSs becomes more and more popular, this interference problem would happen much more frequently.

Fig. 2 shows a conventional frame structure to further explain typical operation of wireless equipments. The conventional frame structure includes an SA-preamble and a super frame header (SFH), followed by a downlink (DL) frame and an uplink (UL) frame. In general, an AMS would attempt to find a synchronization signal or channel (e.g., the SA-preamble in Fig. 2) for downlink synchronization when it powers on. After achieving DL synchronization, the AMS is enabled to receive system information (including a primary SFH (P-SFH) and secondary SFH (S-SFH)), which is carried in the control channel. After successful decoding the system information, the AMS would get system information for a corresponding ABS and proceed to network entry procedures, such as UL synchronization through a ranging channel, authorization and registration, capability negotiation.

If interference occurs, the interference on data region can be avoided by resource reservation or by other state-of-the-art interference mitigation schemes. However, the location of the control channel is usually fixed, so those schemes can not be applied to reduce the interference on control channels. The control channel includes system information, and an AMS is not able to camp on the ABS without system information. As a result, it is necessary to develop an advanced interference mitigation mechanism for control channels.

The rest of this paper is organized as follows. In Section 2, the background and related research is introduced. In Section 3, the proposed scheme is presented to mitigate the interference on control channels. Finally, conclusion remarks are drawn in Section 4.

2. RELATED WORK

So far, many publications have been proposed to solve interference problems for control channels [7-14]. The main concept of these methods is to separate the resource location of control channels of aggressor base station and victim base station. In general, these methods can be classified into two groups: frequency domain solutions and time domain solutions.

2.1. Frequency Domain Solutions

In frequency domain solutions [7-11], control channels for aggressor and victim base station would be transmitted in different frequency. For example, base stations may transmit their control channels in a restricted channel frequency or in a partial channel frequency. Based on different implementation scenarios, there will have different partition methods.

(a) Carrier aggregation scenarios:

Base station which causes interference could use different carrier with the base station which suffers interference to transmit its control channel.

(b) Non-Carrier aggregation scenarios:

Base station which causes interference could use a partial frequency channel to transmit its control channel. The partial frequency which includes the control channel may sometimes be used to transmit the data by the base station.

Using frequency partition to stagger the control channel may result in some problems. For carrier aggregation scenarios, even though the interference could be mitigated but not all AMSs will have carrier aggregation capability. If base station uses different carrier to carry the control channel, the AMS without supporting carrier aggregation may not successfully receive the control channel. As for non-carrier aggregation scenarios, base stations need to use restricted or partial frequency channel to provide their control channels, but these restricted or partial frequency channel may be used to carry the data. If a base station uses restricted or partial frequency channel to transmit the control channel, these resource region can not be use to carry data at the same time. That would reduce the resource utilization.

2.2. Time Domain Solutions

In time domain solutions [12-14], base stations would shift their control channel by several time units so as to mitigation the interference.

However, if base stations use time shifting method to stagger their control channels, it would cause the frame timing un-synchronized between base stations. Thus, in general, these time domain solutions can not be applied to TDD systems. Furthermore, a more complicated AMS operation may be needed to perform cell measurement.

Based on above discussion, interference on control channels is not completely solved by using either frequency partition method or time shifting solution. Some problems still remain. As a result, this paper proposes a novel control interference mitigation method, which would minimally affect the resource utilization and not affect the normal AMS operation.

3. CONTROL CHANNEL INTERFERENCE MITIGATION SCHEME

The control channel interference may be encountered when an AMS attempts to obtain system information while within the coverage area of both a femtocell and a macrocell. To overcome this interference in the control channel (e.g., the SFH in an IEEE 802.16m system or the physical broadcast channel (PBCH) in the long term evolution (LTE) system), a novel method may employ selective muting control channel within the femtocell. For example, the femto ABS may be enabled to mute its SFH (representative of a control channel herein) in a period of time. Accordingly, the femto ABS can selectively provide its system information through the control channel to prevent interference. The system information can be provided to an AMS dependent upon the state of the AMS. In general, AMS would be classified into one of the following states: an incoming AMS, serving AMS, paging AMS, or an idle mode AMS. Different operations regarding system information transmission may be applied for each of the different states outlined above. Moreover, the selective muting described above can include always muting the SFH and/or event-based muting of the SFH.

3.1. The state of the AMS

The operating state of the AMS includes:

(1) Incoming AMS: An AMS was not in the coverage area of the corresponding femto ABS in preceding moments and then entered the coverage area of the femto ABS.

(2) Serving AMS: An AMS has registered with femto ABS and prepare to transmit/receive date to/from femto ABS

(3) Paging AMS: An AMS states at idle mode and prepares to receive paging message.

(4) Idle mode AMS: An AMS states at idle mode and the AMS does not prepare to receive paging message or perform location update procedure.

3.2. Scenario of selective muting SFH method

(1) Always muting SFH

For the always-muting case, the femto ABS is configured to normally mute the SFH and stop muting the SFH in response to receipt of a request from an AMS. Once the femto ABS stops muting the SFH, a timer would be initiated. In response to the femto ABS receiving a response from the AMS to indicate that the receipt of system information is complete, the femto ABS would resume muting of the SFH. Otherwise, if no response indicating completion of receipt of the system information is received, the femto ABS would resume muting when the timer expires.

Based on the different operating states of AMS, we will discuss different system information providing method as follows.

(a) Incoming AMS: For the always-muting case, when a new AMS (e.g., the term “new” referring only to the fact that the AMS was not in the coverage area of the corresponding femto ABS in preceding moments) enters the coverage area of the femto ABS, the new AMS may receive system information via the overlapped macro ABS. Alternatively, the new AMS can request the system information of the femto ABS in response to detecting the presence of an always-muting femto ABS. The presence of an always-muting femto ABS can be indicated by the receipt of a strong preamble from a femto ABS without any SFH at the AMS. Fig.3 illustrates a frame structure for supporting detection of the presence of an always-muting femto ABS as described above. The SA-preamble in Fig. 1 will always be transmitted, but the SFH would not be transmitted except when a request

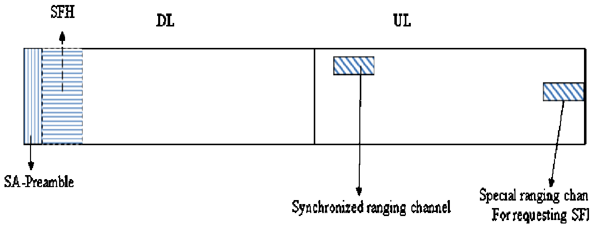

Fig.3. An example of frame structure

for the system information is received (e.g., via a code receiving from a special ranging channel).

The DL frame and the UL frame may then be provided in order with synchronized ranging information being provided in a portion of the UL frame. The UL frame may also include a special ranging channel for enabling the AMS to request the SFH.

(b) Serving AMS: In cases in which it is desirable for the femto ABS to update its system information while the femto ABS is serving an AMS, the femto ABS can notify the AMS by transmitting a unicast message (e.g., AAI_SFH-CMD). Fig.4, which includes A, B and C, shows examples of mechanisms by which the updated system information (e.g., SFH update) can be provided to an on-serving AMS (e.g., an AMS already being served by a femto ABS). Fig. 4-A illustrates an example in which the serving femto ABS simply sends the unicast message (e.g., AAI_SFH-CMD) to the AMS to inform the AMS of the changed system information. Fig. 4-B illustrates an example in which the AMS is in a sleep mode and there is a timing window defining an available interval during which scheduling information would be communicated. The femto ABS would initially communicate a broadcast message and then send the SFH within the available interval. Fig. 4-C illustrates another example in which the on-serving AMS requests system information. The request can come for any reason such as, for example, the AMS losing some portion of the information. As shown in Fig. 4-C, the AMS can send a request for the system information (e.g., via an AAI_SFH-REQ) and the femto ABS would respond with the system information (e.g., via an AAI_SFH-CMD). Furthermore, the AMS would append a change count of its stored information into the request message to help the femto ABS to verify the system information version that is requested.

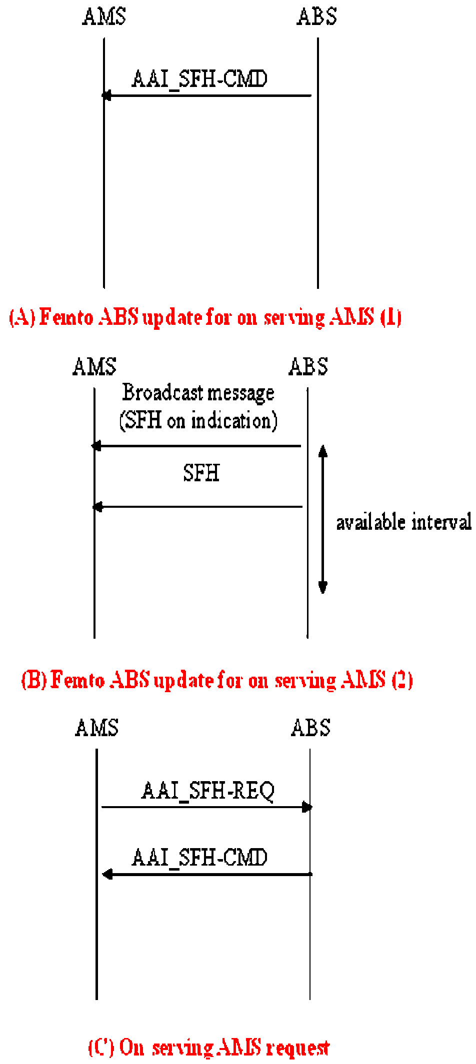

Fig. 4. An example of serving AMS request system information

(c) Paging AMS: For an AMS that is to be paged by an always-muting femto ABS when the femto ABS attempts to update its system information, the femto ABS would notify the on-paging AMS by providing a paging message to recommend that the on-paging AMS wake up. After AMS wake-up, the femto ABS would transmit a unicast message to the AMS to provide the updated system information. Moreover, the on-paging AMS can request updated (or a retransmission) of the system information either by performing a network re-entry and then sending a message as if the AMS had previous system information regarding this femto ABS, or by performing a request mechanism as addressed above for an incoming AMS. Fig. 5 is an example for summarizing those approaches which includes Figs. A, B and C. Fig. 5-A illustrates a femto ABS providing a paging advertisement message (e.g., AAI_PAG-ADV) in

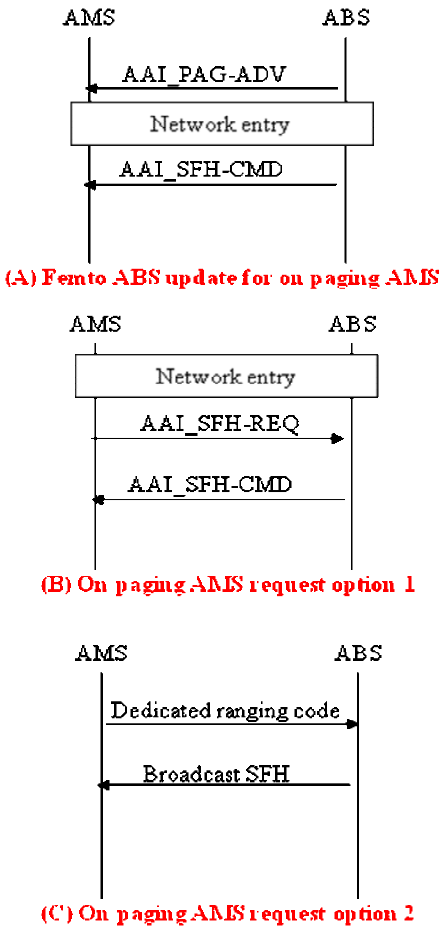

Fig. 5. An example of paging AMS request system information

response to which a network entry is performed followed by the provision of system information to the AMS via a unicast message (e.g., AAI_SFH-CMD). Fig. 5-B illustrates a network entry being performed after which the AMS issues a request for system information via a request message (e.g., AAI_SFH-REQ) in response to which the system information is provided to the AMS via the unicast message (e.g., AAI_SFH-CMD). In Fig. 5-C, a dedicated ranging code is provided to the femto ABS and the femto ABS responds with a broadcast SFH (stop muting SFH) to provide the AMS with the system information.. For network re-entry, the femto ABS would precede the update process in the same manner described above for an incoming AMS. For performing an update request, instead of updating the system information, an on-paging AMS can change the camped cell from a femto ABS to a macro ABS if the AMS does not desire to process the update.

(d) Idle mode AMS: For an idle mode AMS in the coverage area of a femto ABS that

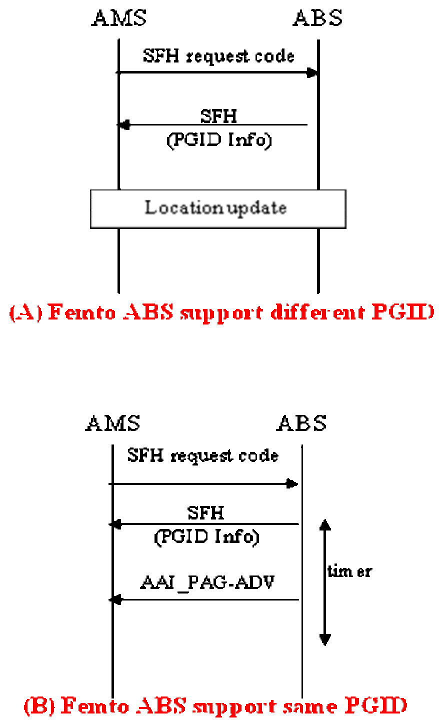

Fig. 6. An example of SFH update for idle mode AMS

practices always-muting the SFH, multiple options are available to the idle mode AMS. In option1, the AMS can be configured to listen for a paging message from the macro ABS even if it finds a stronger SA-preamble but no SFH of a femto ABS (indicating an always-muting femto ABS). In option2, the AMS can be configured to perform a request as described above for a incoming AMS to obtain system information. If the femto ABS supports different PGIDs, then the AMS can perform a location update and the ABS would re-start muting the SFH after network entry procedures are complete. If the femto ABS supports the same PGID, the AMS can inform the femto ABS that it can restart muting the SFH or the femto ABS can restart muting the control channel upon timer expiry.

Fig. 6, which includes Figs. A and B, illustrates an example of femto ABS support for updating SFH for an idle mode AMS with femto ABS support for a different paging group identifier (PGID) (Fig. 6-A) or for the same PGID (Fig. 6-B). The AMS can be configured to listen for a paging message from the macro ABS even if it finds a stronger SA-preamble but no SFH of a femto ABS (indicating an always-muting femto ABS). Alternatively, the AMS can be configured to perform a request as described above for a new oncoming AMS to obtain system information. If the femto ABS supports different

PGIDs, then the AMS would perform a location update and the ABS would re-start muting the SFH after network entry procedures are complete. If the femto ABS supports the same PGID, the AMS can inform the femto ABS that it can restart muting the SFH or the femto ABS would restart muting the control channel upon timer expiry.

(2) Event-based muting SFH

As indicated above, as an alternative to providing an always-muting SFH femto ABS, event-based muting of the SFH for the femto ABS can be accomplished. Event-based muting can involve muting of the SFH by the femto ABS only when predefined criteria are met and stopping muting of the SFH by the femto ABS only when predefined criteria are met. In general, event-based muting can be initiated when there are AMSs served by a macro ABS and one or more of the AMSs report interference caused by the femto ABS by sending an IM (interference mitigation) request to femto ABS. The femto ABS can otherwise send system information until an AMS reports that it does not suffer strong interference. Generally speaking, after receiving the IM request, the femto ABS would stop providing the system information via its control channel (i.e., mute its SFH). Based on the different operating states of AMS, we discuss different system information providing method as follows.

(a) Incoming AMS: For a new oncoming AMS, the AMS can select the macro ABS as its serving cell and, if the AMS desires a handover to the femto ABS, the macro ABS can reject the handover request until the femto ABS stops muting its SFH. On the other hand, the macro ABS can negotiate with the femto ABS to result in the femto ABS stopping the muting of the SFH. As an alternative, the macro ABS can give the system information of the femto ABS to the AMS during handover preparation.

(b) Serving AMS: The on-serving AMS can receive a system information update via the messaging sequences described above in connection with Fig. 2.

(c) Paging AMS: The on-paging AMS can receive system information update via the messaging sequences same as the procedure like the on-paging AMS in always-muting case.

(d) Idle mode AMS: The idle mode AMS would perform cell selection and receive paging messages from the macro ABS when the femto ABS mutes its SFH.

The decision on whether to begin muting can also be made based on distance. Thus, for example, either or both of initiating and stopping muting can be accomplished based on distance information that would be gathered via any of a plurality of different methods. In some cases, distance may be determined based on RSSI measurements. However, in other instances, Global Positioning System (GPS) distance or another mechanism by which to determine distance may be employed. As such, when the distance between the femto ABS and the AMS suffering interference decreases below a threshold distance, muting can be initiated to reduce interference. However, if the distance increases to above a threshold value, the muting can be stopped.

In either the always-muting or the event-based muting case, the femto ABS may be configured to allow the corresponding allocation to remain empty when the SFH is muted. This may avoid interference with the SFH of the macro ABS, but force un-use of the corresponding resources. Alternatively, the femto ABS can be configured to allocate data regarding allocation when the femto ABS does not provide SFH. When transmitting, the femto ABS would use small power or apply scheduling with location information in order to avoid interference between the data of the femto ABS and the control channel of the macro ABS.

4. CONCLUSIONS

In this paper, selective muting SFH method is proposed to mitigate interference on control channels. Both always-muting SFH Femto ABS and event-muting SFH Femto ABS can let regarding allocation be empty when it mutes its SFH. This scheme can fully avoid the interference with Macro ABS's SFH. Moreover, Femto ABS can allocate data on corresponding resources when it does not provide SFH. When transmitting, Femto ABS can use small power or apply scheduling with location information to avoid the interference between Femto ABS's data and Macro ABS's control channel.

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