Femtocell Handover Technology with TAP-Based Technique: A Review

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Femtocells are the new emerging technology of heterogeneous networks, which are used to improve the signal strength of the networks at homes or indoor. These femtocell devices are operated by Internet or broadband connection to provide good quality of signal strength at homes or indoor where it is difficult to get direct signals or good quality signals from the macro cells. The ranges of these femtocell devices are around a few meters, which are very small. Long-Term Evolution (LTE) is purely based on hard handover, which follows the standard handover technology. Due to the small range of femtocell devices, frequent numbers of handovers occur. So conventional handover schemes generate more delay during handovers, which is not suitable for femtocell networks. In this paper, we discuss the temporary area network handover technique and compare the temporary area-based technique with standard handover technique and prefetch-based techniques.

Keywords: Heterogeneous networks, LTE macrocell, Femtocell, Handover, Handover latency

Introduction

Long-Term Evolution (LTE) is based on purely hard handover (Dampage and Wavegedara, 2013). LTE follows the conventional handover process for its handover (Rath and Panwar, 2012). Handover occurs when user equipment moves from one cell to another cell. Nowadays, there is requirement of fast handover procedure for femtocells because the size of the femtocells is around 10 to 50 meters. The conventional handover procedure is not suitable for femtocell networks because the size of femtocell is very small, which generates frequent number of handovers (Rath and Panwar, 2012). The conventional scheme of handover is originally defined for macrocell, which generates higher latency during handovers between femto and femto, and femto and macro cells (Dampage and Wavegedara, 2013). Macrocell is denoted by eNodeB, where e is enhanced; and femtocell is denoted by HeNodeB, where h is home. There is no direct path between femto and femto, and femto and

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macrocell, so handover is the main technical problem of heterogeneous networks (Chandrasekhar and Andrews, 2008).

Femtocell technology is a new emerging technology which performs the low cost and low power consuming operation (Shrivastava and Merchant, 2013). Research on wireless shows that more than 50% voice calls and more than 70% data traffic are generated indoor (Liu *et al*., 2014). Femtocell can go on switch-off mode when there is no load. It is power-saving and energy-efficient technology (Kim and Lee, 2010). Data rate requirements are increasing day-by-day and are expected to rise exponentially in the near future (Cho *et al*., 2014). Heterogeneous network is the best option for providing higher data rates (Rose *et al*., 2011). So femtocell technology will be a valuable technology in the near future. There are many issues related to integrating of femtocell with macrocell as interferences, handover and some modifications of architecture are required (Wu, 2011). The handover is the main challenge (Badri *et al*., 2013).

In this paper, we mainly focus on handovers in heterogeneous networks with femtocells and discuss the temporary area-based techniques of handover in which the researcher used the device-to-device discovery technique (Dampage and Wavegedara, 2013). In this technique, the user equipment can directly send the handover command to nearby femtocell through target user equipment. In this, the user equipment sends the handover command to the target user equipment with source id. So it reduces the Internet delay one time. In this paper, the authors have considered minimum Internet delay as 10 ms and on comparing this scheme with others, it shows lower latency during handover (Dampage and Wavegedara, 2013). Temporary area network is a network of devices which can be connected by device-to-device discovery technique, so that all nearby devices form a temporary area network. These nearby devices are called the Temporary Area Partners (TAP). If, in rare conditions, there is no device present in temporary area network, then handover will be performed in normal way as standard process.

The rest of the paper is organized as follows: First, the paper presents a literature review. Then it explains low latency and energy-efficient forward handover scheme for LTE-femtocell networks. Next, it compares different handover schemes. Finally, the paper ends with the conclusion.

Literature Review

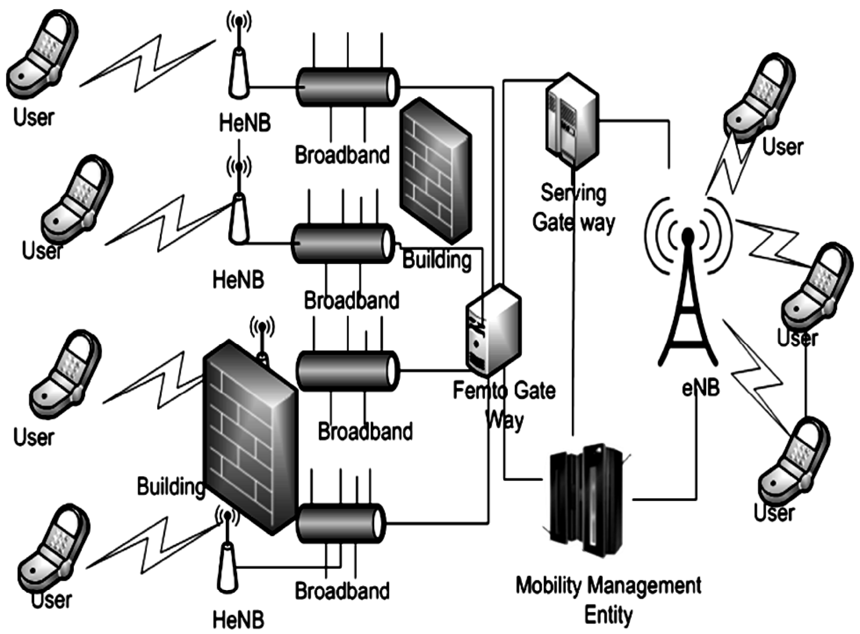
More focus on the femtocell network technology is required because only a little work has been done so far to improve this technology. Especially, the handover section is less touched by the researchers. More research can help in reducing the handover latency of femtocell networks, which is an emerging technology.

Conventional Procedure of Handover

Architecture of Femtocell Networks

Figure 1 shows the architecture of the femtocell network. Femtocell is not directly connected to mobile core network. It is connected to mobile core network through Internet or broadband connection. On the other hand, there is a direct connection between mobile core network and macro cells (Barrie, 2012). It is the basic difference between the femtocell and macrocell connection with mobile core network.

Figure 1: Connections of LTE Networks with Femtocell

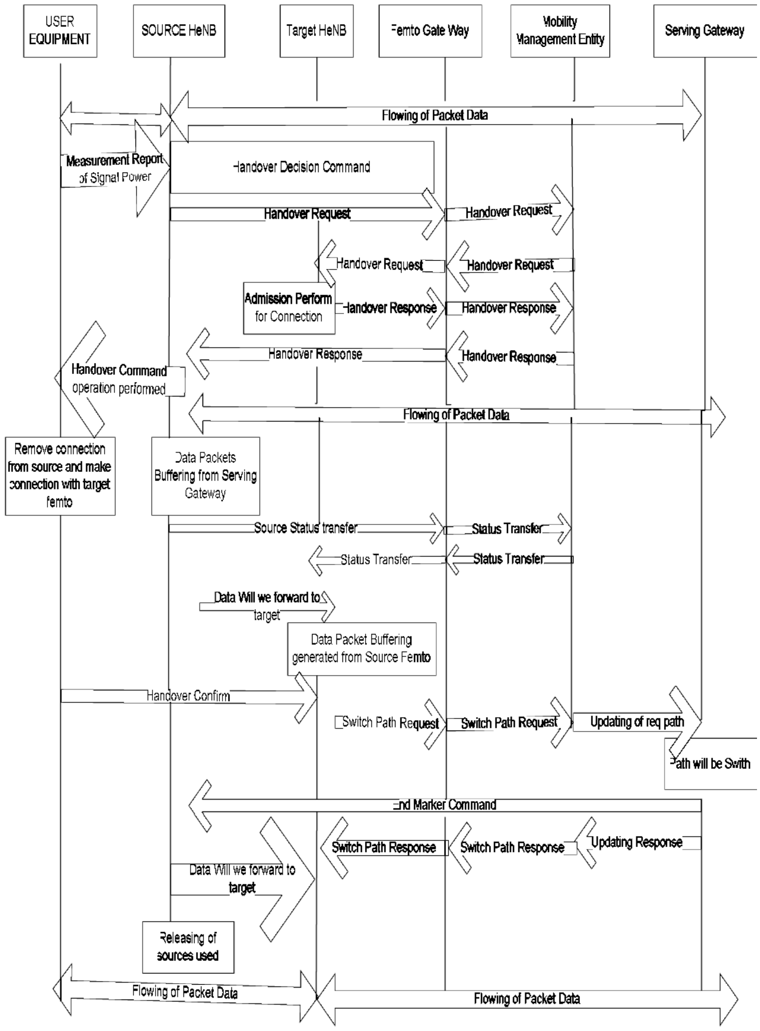


Serving gateway provides routing and forwarding functionality among the macrocell, femtocell and packet data network (Acakpovi *et al*., 2013). It supports routing of data. Femtocells and macro cells are connected to the mobile core network by serving gateway which behaves like a mediator for signaling control (Lee and Lin, 2010). Mobility management provides the correct serving gateway to the user equipment. Mobility Management Entity (MME) also authenticates the users.

Handover Procedure

Figure 2 shows the standard handover procedure which was originally designed for handover between macro cells. This procedure is not suitable for femtocells because in femtocell, frequent numbers of handovers are possible, which generate more latency during handover (Rath and Panwar, 2012).

Figure 2: Standard Handover Procedure



At every particular time interval, the user equipment measures the strength of all channels which is present at that time and will send this measurement report to femtocell or macrocell to which it is connected (Rath *et al*., 2010). Now the handover procedure is started if measurement report shows that the other base station is providing best signal power (Ahmed and Kim, 2014).

Prefetch-Based Handover Technology

The new scheme of prefetch-based fast handover scheme was developed to reduce latency during handovers between femtocells. In this handover process, some part of legacy handover process is modified by modifying the architecture of network.

The scheme uses the concept of proximity and associable region. Prefetch-based fast handover process is divided into two subprocesses: proximity add and release process (prefetch process) and fast handover process. This process reduces the delay or latency during handover up to some extent (Rath and Panwar, 2012). In the first part of the handover process, the region cell area is divided into two subparts: associable region and proximity region (Rath and Panwar, 2012). When the user equipment starts to move towards proximity region, the near cells start the copy of the data of user equipment. When the user reaches the cell boundary, the handover process starts. So some work has been done before handover because higher layer data has been copied by target femtocells. So it saves valuable time and data will not be lost during handover. By sending switch marker command, the upper layer data will be forwarded by target femtocell to user equipment. Figure 3 shows the concept of proximity and associable region.

Figure 3: Associable and Proximity Region

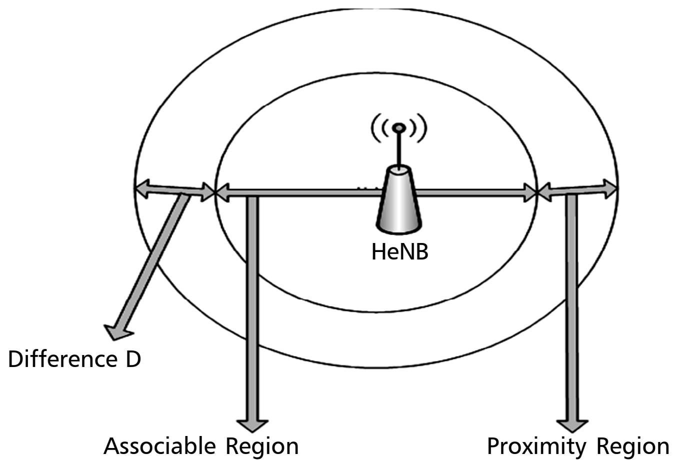
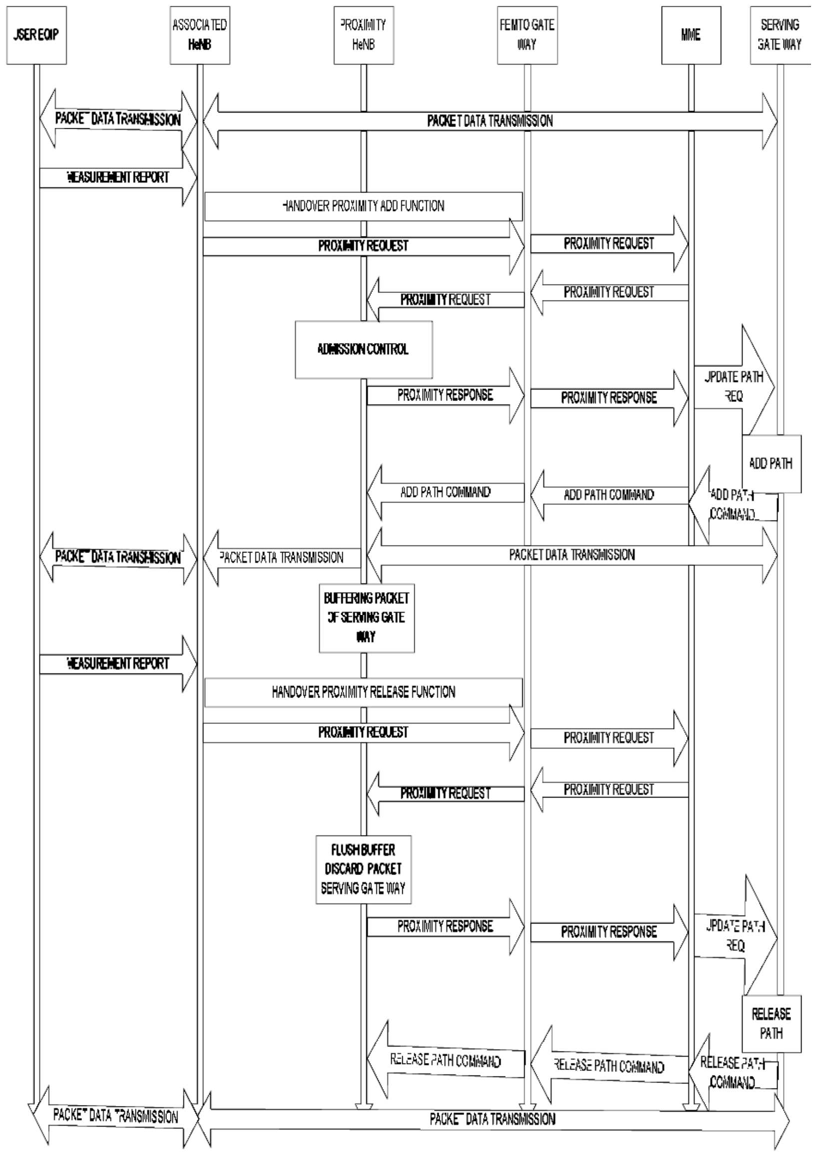


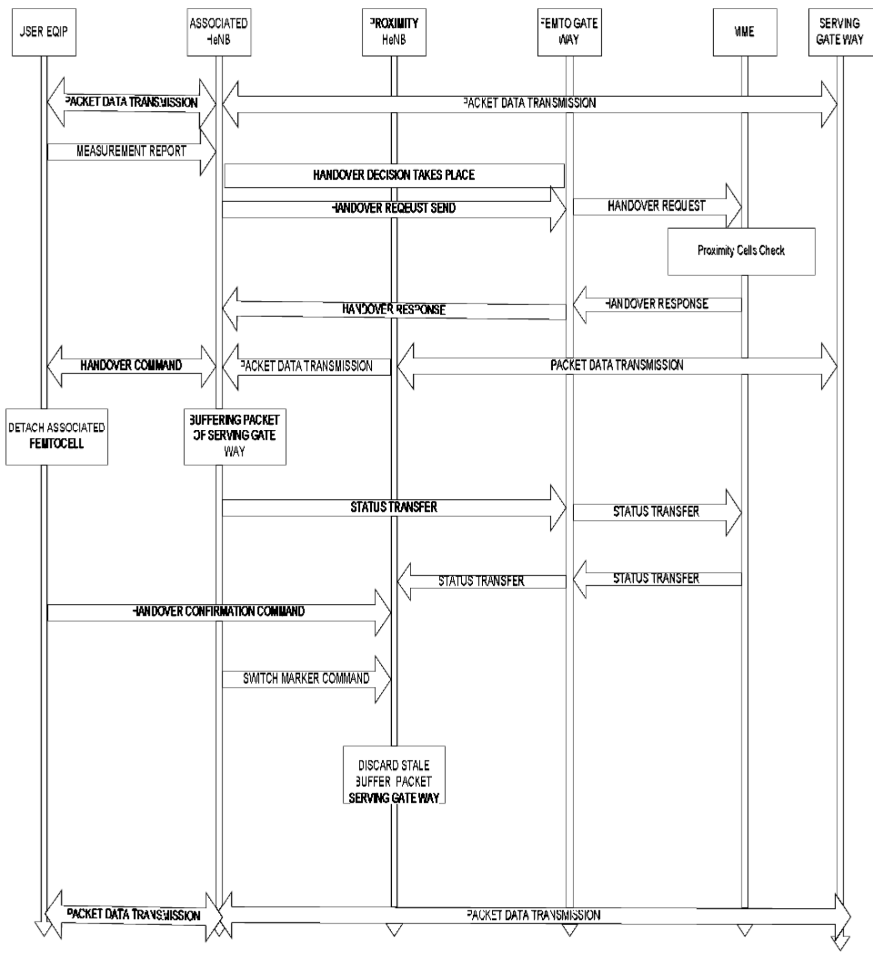
Figure 4 shows the prefetch process. Prefetch process is done before handover; when the user moves towards the proximity region, the signal power level decreases, so this process is initiated. In this, the user equipment sends the measurement report to the associated femtocell. Then source femtocell sends the handover proximity add function to the MME. MME adds extra paths with serving gateway to nearby femtocells. So these nearby femtocells buffer the replica of packet data. In this way, some of the tasks will be already done before handover. So this scheme saves precious time during handover. If the device moves towards the associable region, then handover proximity release function generates and it releases the extra path which is connected to serving gateway. So the proximity femtocells flush their buffer. This is the first part of prefetch-based process. Figure 5 shows the next part which is called fast handover process.

Figure 4: Prefetch Process



In fast handover process, the user equipment sends the measurement report to the source femtocell. Source femtocell takes the handover decision. It sends the handover request to the MME. Proximity check process is used by MME to ensure that the target femtocell has performed proximity add process then MME sends the handover response to the source femtocell. So MME sends the handover response to the source femtocell. Source femtocell sends the handover command to the user equipment. Now the user equipment detaches from source user equipment and is

Figure 5: Fast Handover Process



ready to attach itself to target femtocell. Now the source femtocell buffers packets which are received from serving gateway and sends the status transfer message to the target femtocell, followed with switch marker. Switch marker discards the already received packets. Now the handover is confirmed between target femtocell and the user equipment. This is called fast handover process due to switch marker command.

TAP-Based Forward Handover Scheme

The temporary area network technology was next developed to overcome latency during handovers. This handover scheme uses the device-to-device discovery and connection technology by which the devices make TAP, in which the already connected devices make the TAP with those devices which want to perform the handover. So this scheme depends on networks of user equipment, which are nearer to user equipment and which are served by femtocell. These devices can communicate with each other directly by device-to-device communication links. This type of network topology of devices is called TAP (Dampage and Wavegedara, 2013). In this scheme, at least the user equipment has already been connected with femto or target macro cells. So any other user equipment, which wants to handover with femto cell or macrocell, sends the direct SOS message to target user equipment through device-to-device communication links. Then target user equipment sends the connection reestablish command to the associate femto or macro cells with the id of source user equipment. So it saves the precious time of sending handover command through Internet. In this scheme, handover command is send by device-to-device discovery process, so it saves Internet delay during handover.

Figure 6 shows the creation of temporary area network, in which source user equipment wants to handover with macrocell. So the source user equipment sends the SOS message to the target user equipment by device-to-device direct communication links. Now the target UE sends the connection reestablishment command to associated macrocell with source id. So it saves valuable time of sending handover command directly.

Figure 6: Temporary Area Network

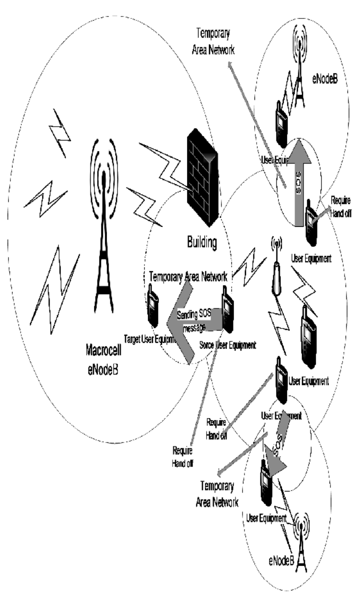
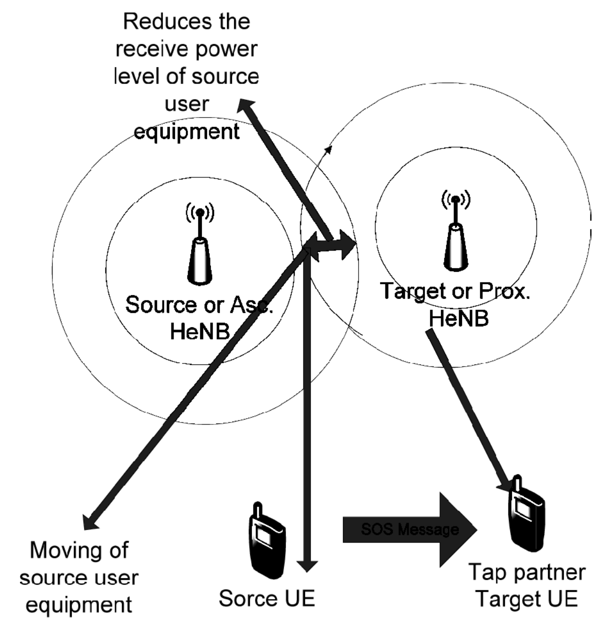


Figure 7 shows the movement of user towards target femtocell. The power level decreases at user equipment when the user equipment moves towards the target femtocell. Now the user equipment sends SOS message to the TAP partner target user equipment. So the handover command will not travel through Internet; it will send directly to target femtocell through target user equipment using device-to-device discovery technique.

Handover Process

Handover process is described in Figure 8. In this process, the user equipment measures the signal strength. This measurement report is sent to source femtocell. If radio link failure occurs, source femtocell takes the handover decision. In this way, the source user equipment sends the SOS message to target user equipment directly through device-to-device discovery technique. SOS message contains the source user

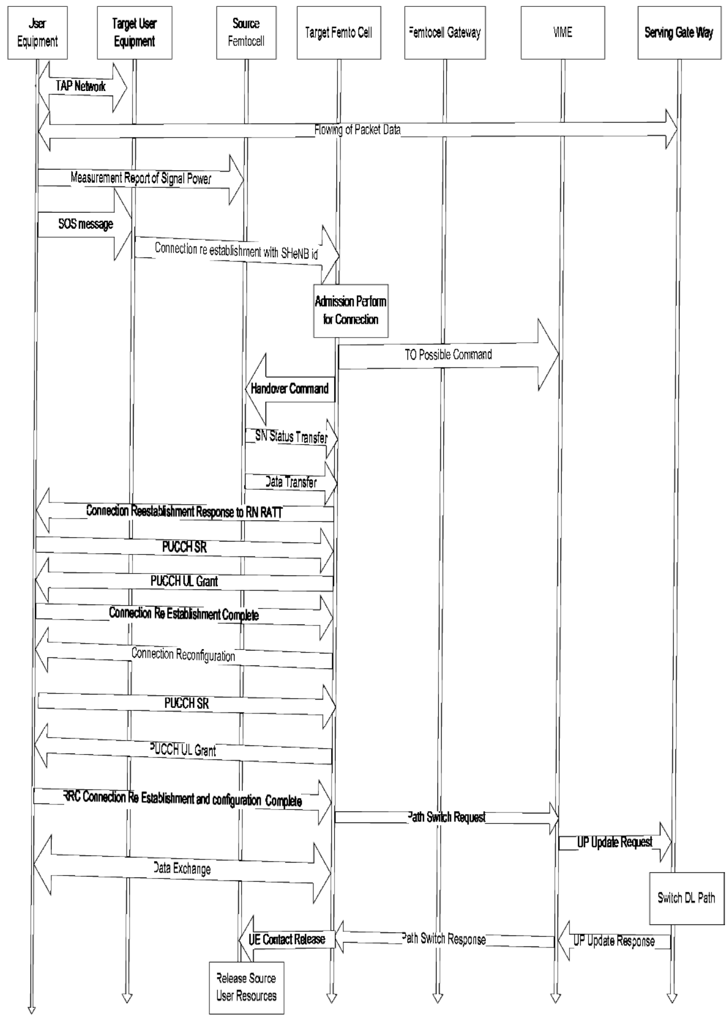
Figure 7: Moving of Source User Toward Target Femtocell



equipment id and source femtocell id (Dampage and Wavegedara, 2013). The direct transfer of handover request to target femtocell saves the Internet delay. Takeover process is performed by target femtocell. This process informs the mobile management entity that target femtocell wants to handover with source user equipment. The following steps show the process of handover (Dampage and Wavegedara, 2013).

- First source user equipment sends the SOS message to the target user equipment over PUSCH through device-to-device discovery technique.
- Now the target user equipment acknowledges the request over PUSCH through device-to-device discovery technique.
- The target user equipment sends the connection reestablishment message with connection reestablishment cause to the target femtocell with source user equipment id and source femtocell id.
- Now the target femtocell sends the connection reestablishment response to the RA-RNTI of the source user equipment on the downlink shared channel (DL-SCH).
- If the source user equipment does not receive any response within the given period of time, then the source user equipment will check the next nearer TAP partner. So the same process will start again.

Figure 8: TAP-Based Forward Handover Scheme



Comparison of Results

For simulation purpose, MATLAB scenario is used which has flexibility. Delay budget (Table 1) is used with some changes. In the TAP-based scheme, it is observed that the simulation shows lower latency during handover because this technique reduces the signal travelling distance by using the device-to-device discovery process and also reduces the one time Internet delay. Internet delay shows the main effect on delay budget. If the Internet is very slow, it will increase the delay during handovers. The researchers assume that 10 ms is the minimum Internet delay during handover. They also used the device-to-device discovery technology; so they assumed that total delay with transmission and processing is about 4 ms.

Table 1: Delay Budget			
S. No.	**Abbreviation**	**Description**	**Delay Budget**
1.	MH	Transmission from MME to HeNB (Delay Internet) and processing in HeNB (2 ms)	D Internet ms + 2 ms
2.	HM	One way transmission from HeNB to MME (Delay Internet ms) and processing in MME (2 ms)	D internet ms + 2 ms
3.	MN	Transmission from MME to eNB (7 ms) and processing in eNB (2 ms)	9 ms
4.	NM	One way transmission from eNB to MME (7 ms) and processing in MME (2 ms)	9 ms
5.	UN	One way transmission from UE to eNB (2 ms) and processing in eNB (2 ms)	4 ms
6.	RR	Resource reservation in eNB	5 ms
7.	UU	Transmission from UE to UE (2 ms) and processing in UE (2 ms)	4 ms

Source: Dampage and Wavegedara (2013)

We compared the three technologies' delay during handover:

1. Standard handover procedure delay

   Ds1 = HM + MN + RR + NM + MH = 2Dinet ms + 27 ms

2. Prefetch-based fast handover procedure delay (Rath and Panwar, 2012)

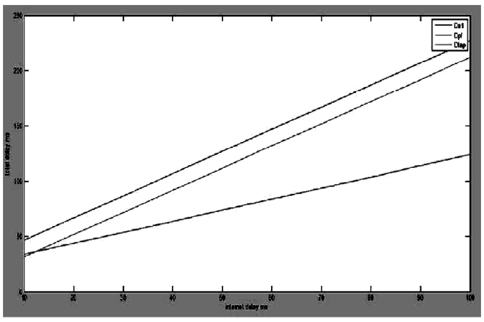
   DPrefetch = HM + 4 + MH + UN = 2Dinet ms + 12 ms

3. Tap-based forward handover procedure delay (Dampage and Wavegedara, 2013)

   Dtap = UU + UN + RR + NM + MH = Dinet ms + 24 ms

Figure 9 shows the simulation results of TAP-based scheme with different schemes. On comparing the above schemes, we found that this scheme reduces the more delay

Figure 9: Simulation Comparison Results



during handover. If the Internet delay is more, then it shows the lower delay during handover.

Conclusion

This paper discusses the different handover schemes for handover between femto and femtocell, and femto and macro cells. In this investigation, we found that standard handover procedure in 3G and LTE network was originally designed for handover between macro cells, which is not suitable for femtocell networks. Based on the comparison of these processes, we found that the temporary area scheme generates the lower latency during handover between femtocells. Finally, we presented the comparison results between different handover schemes, which show that TAP-based scheme is faster than other schemes. This shows lower latency during handover. TAP scheme fails if no temporary area partner is present in TAP. The handover will be performed in normal way. Developing TAP selection algorithm is the focus of our current research. So this TAP-based scheme requires further research.

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