A Review of Handover Schemes in Overlaid Macro-femto Cellular Networks

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Abstract: In today's scenario, large number of disparate wireless technologies account for heterogeneity of the access environment. For seamless mobility in such networks the handover plays an important role. In cellular a network, which is an integral part of heterogeneous environment, coverage and subsequently QoS (Quality of Service) are the main issues. Femtocells have emerged as the most promising solution by improving coverage and the Quality of Service to users on one hand and by offloading the macrocells and thus benefitting the service providers on the other hand. Femtocells are the small, low power base stations deployed inside the homes or buildings to provide better coverage in those regions and to increase the capacity of the networks. This paper presents works on the handover management between macrocells and overlaid femtocells. In this direction, the different handover techniques are reviewed for improved throughput, energy efficiency, reduction in unnecessary handovers, network load balancing, interference management and network security. The study demonstrates that more number of objectives achieved leads to better QoS.

Keywords: Femtocells, handover, Quality of Service(QoS), throughput, energy efficiency, network load balancing.

1. Introduction

The wireless revolution today is having a profound impact on the way people work and live. More people all over the world are having a mobile phone than having a PC. The mobile wireless handheld devices have overtaken the wired computers as dominant internet access throughout the world. With the introduction of new and varied mobile devices like smartphones, tablets every now and then in the market, their efficient use requires a serious thought as these devices now a days are not used for voice only but data services are equally important. With the wireless revolution new wireless technologies are also taking shape. A fast research and development has lead to the emergence of Bluetooth, IEEE 802.11 wireless LAN and satellite networks [1]. This growing demand to access communication services that too with mobility has lead to an accelerated technological development towards integration of various types of access technologies. Such a mix of radio technologies and cell types working together seamlessly is called a heterogeneous network. A Heterogeneous Network (HetNet) is based on the coordinated radio network with integrated Wi-Fi, advanced traffic management and high-performance backhaul. As the user moves, he chooses the best access technology which provides the best data speed, high quality and which supports mobility also. Mobility Management is one of the important issues of Heterogeneous Networks. It is the set of tasks required to supervise the mobile user terminal in a wireless network to check that it is always connected to the network even when moving [2]. Mobility management has several aspects like maintaining Quality of Service, Handover management, Location management and power management etc. A wireless network supports mobility and provides QoS through handover management. It is the process of transferring an ongoing call from one cell to another. Handover process faces several challenges like maintaining the QoS across different systems, deciding the correct handover time, the correct handover decision, packet losses, latency, signaling traffic overhead, security and increased system loads [3].

Out of many existing heterogeneous network, one is femto-macrocell integrated network. A femto cellular network is the technology to meet the demands of ever increasing wireless capacity [4] [5]. Existing networks do not have the flexibility to adapt to changes in demand. Moreover much of the traffic is generated indoors and the existing networks suffer from the problem of poor indoor coverage. Various ways of overcoming this challenge are installation of more sites and consequently more base stations, deploying signal boosters or installing more relay stations, add more spectrums to the network to improve the spectral efficiency or reuse the existing spectrum. Undoubtedly, this leads to a reduction in the above cited problems but the overhead in acquiring the permission and cost of installation is also significantly high. Small cells such as microcell, picocell and femtocell can be deployed to enhance the coverage in specific locations and to improve voice and data capacity. The microcells and picocells cannot be deployed inside the house by the user as their base stations are big enough and specific standards are required for installation which can be fulfilled by operator only. Therefore, over a past few years, Femtocells
have evolved as a new small cell technology to improve
the indoor cellular coverage. A femtocell is a low power,
low cost, and user-deployed cellular base station (BSs)
with a small coverage range e.g. 30–40 m. A large number
of femtocells are deployed in the coverage area of
macrocells. The mobile industry is now flooded with
femtocells as they provide a good solution to the various
problems suffered by macrocellular networks. As most of
the calls are made indoors and the signal from the
macrocell base station deteriorates very quickly as it
reaches indoors and due to the interference in the cell, the
true 3G service is available to end users only if there is
a good quality signal indoors and the number of users per
cell is limited [6]. The femtocell technology helps to
offload the traffic from macrocell. In other words,
Femtocell is a low cost solution and easy to install which at
the same time provides significant coverage indoors and
offload macrocells [7].

This paper studies the parameters for handover in different
handover algorithms in femtocells and presents their comparison.

1.1 Handovers in Femtocells:

Figure 1 shows an overlaid femtocells deployment over the
macrocell i.e. a smallest unit of cellular network. Handover
in such a network can be performed in the following three
ways [8]:
Hand-In : Hand In takes place when a user moves from
a macrocell to femtocell. It is very complex as the user
chooses the best femtocell out of several options after
considering the neighbouring cells.

Hand-Out : Hand-Out takes place when a user moves from
a femtocell to macrocell. It is simple as compared to Hand
In as the target macrocell is always one.

Femto to femto handover : It takes place as a user moves
out of the boundary of one femtocell and enters into the
boundary of other.

Hand-In and Hand-Out falls under the category of vertical
handover as it involves two different access techniques and
Femto to Femto handover is horizontal handover as two
similar access techniques are used.

The number of handovers increases as the femtocells are
more densely deployed in a macrocell. Moreover, as the
range of a femtocell is very limited, therefore the mobile
device tend to leave coverage area of femtocell very soon
which leads to handover to either a nearby femtocell or the
macrocell. Handover management is one of the most
challenging issues in femto cellular network as in any other
heterogeneous network. A wide range of schemes have
been presented to efficiently handle the handovers [9-14].
The authors have considered a wide range of factors like
Received Signal Strength (RSS), velocity of the user, peak
bandwidth reception, energy efficiency etc. for performing
handover.

2. Literature Survey

A few approaches have been studied for handovers in
macro-femto cellular networks. The mechanisms are based
on different parameters. However, almost all of the
approaches have considered Received Signal Strength
(RSS) as one of the parameters for handover. Various other
parameters such as speed of mobile device, mobility
prediction, available bandwidth etc. are combined to
provide improved Quality of Service (QoS) to the users.

In paper [9], the decision for handover from macrocell to
femtocell is based on the future mobility pattern prediction
scheme to prevent macro femtocell handovers of temporary
femtocell visitors who stay in the femtocell coverage area
for a short period of time thereby reducing the unnecessary
handovers. Each mobile device periodically transmits its
movement history to server. The server collects the
histories and based on the mobility rules, it generates the
mobility pattern. If the received signal strength of the
femtocell is greater than the threshold then before
performing the handover, the mobile device predicts its
next consecutive movements and if the next consecutive
movements are within the coverage area of femtocell for
enough length of time, only then handover is performed.
That is why this handover algorithm is named as Smart.

In [10], the author presents a new handover strategy
between femtocell and macrocell for LTE (Long Term
Evolution) based network. It analyzes the scenarios of
hand-in and hand-out after the handover decision. For
macrocell to femtocell handover, it first checks whether the
user belongs to Closed Subscriber Group (CSG) or not. If
mobile device is a CSG and received signal strength and
velocity are lower than a threshold value and the
application not being a real time application then handover
is performed depending on the availability of bandwidth.
It reduces the unnecessary handovers and eliminates the cross
layer interference.

In paper [11], the authors proposed a handover strategy
based on neighbour cell list. A neighbour cell list is created
together by macro base station and the neighbour femtocell
access points (FAP). The mobile device performs a pre
authentication with all the femtocells included in the list.
The handover decision is taken based on the pre-authentication and the received signal strength from the target femtocell access points. This handover algorithm overcomes the hidden FAP problem and also reduces power loss by decreasing the size of neighbour cell list because of the pre authentication.

The authors in [12] presented a handover strategy for hybrid access mode based on Received Signal Strength Indicator (RSSI), velocity of the UE(user equipment), Signal to Interference level (SINR), capacity bandwidth that one Femtocell can accept, the user type and the duration UE maintains the signal level above the threshold level. If the velocity of a mobile device falls below a threshold value, then six base stations with the highest available RSSI are determined. The base station which can support the bandwidth and having the highest SINR is chosen for handover. If the mobile device is a registered user then handover is performed immediately. Un registered users must stay in the femtocell area for the threshold time interval for the handover to occur. In this way it minimizes the unnecessary handovers.

The authors in [13] proposed a Handover Scenario and Procedure in LTE-based Femtocell Networks. It is based on the mobility prediction to reduce unnecessary and very frequent handovers. If the velocity of a mobile device falls below 10km/h but greater than 5km/h then a mobility prediction is performed to predict the heading position of the mobile device. A pro active handover is then performed for the real time traffic and for non real time traffic reactive handover is performed which reduces the unnecessary handovers by postponing the handover as long as possible until the UE reach the target FAP as the result of mobility prediction. The target FAP is chosen based on signal quality (RSSI/CINR) and QoS.

A handover decision algorithm which helps to conserve the energy of the network and provides for load balancing both at the same time is proposed in [14]. The algorithm is based on two main factors viz. the velocity of mobile station and the service type of the mobile station. The user moving at a speed higher than the threshold and undergoing real time transmission will not undergo any macro/femto handover. Therefore unnecessary handover is eliminated. To overcome the wastage of power in the network, the femto base stations are assumed to remain in low power ‘idle mode’ when no user is present in its coverage.

3. Requirements for Handover in Femtocells

This section explains the various requirements to be kept in mind before performing handover. These are as follows:

(i) Improved throughput: Femtocells are introduced in the existing macrocellular network to improve the user throughput and in turn the overall system throughput by efficiently using the available bandwidth. A femtocell reduces the load on macrocell. But at the same time a mobile device moving in from a macrocell should experience minimum call dropping and call blocking. A good bandwidth allocation ensures lower call blocking and call dropping probabilities and hence an increase in throughput. A handover technique from macrocell to femtocell should always help to increase the user and network throughput. For this reason, the bandwidth should be efficiently distributed among maximum number of users.

(ii) Energy efficiency: Energy efficiency has always been an area of concern as mobile phones lose its battery power rapidly. Both network discovery and activation of interface between networks causes battery drainage. Performing handover further enhances battery consumption. So, unnecessary handovers should be avoided for saving power of the device.

(iii) Reduction in unnecessary handovers: As a femtocell covers only a small area, therefore the mobile device may go out of the coverage of femtocell very soon, if moving at a high speed. In that case large number of handovers only leads to wastage of network resources and thus should be avoided.

(iv) Network load balancing: One of the main limitations which the cellular network is suffering from is very high network load which leads to congestion in the network. The idea of introducing femtocells is to divert data and voice traffic to internet and offload macrocells. A good handover technique would also help in offloading traffic from macrocells.

(v) Interference Management: The overlaid integrated femtocell/macrocell networks offer an efficient way to increase access capacity by improving coverage and quality of service. One of the major technical challenges that femtocell networks are facing is their interference behaviour when they are placed within macrocells. A handover technique should always lead to reduced interference levels among networks.

(vi) Increased Network Security: A femtocell access point is located in customer’s location and accesses the operator’s core network through an IP link. As a result, security threats to operator’s core network increases. The network security deals with the policies to prevent and monitor unauthorized access, misuse and modification of network-accessible resources. Network security features should be included in handover technique to attain the highest levels of integrity, authentication, and confidentiality [15].

4. Comparison of the Existing Handover Techniques

In this section existing handover techniques are compared against the objectives for a vertical handover. Table 1 lists the achievement of objectives by each technique.

The handover decision is taken based on the pre-authentication and the received signal strength from the target femtocell access points. This handover algorithm overcomes the hidden FAP problem and also reduces power loss by decreasing the size of neighbour cell list because of the pre authentication.
Table 1: Comparison of handover techniques

<table>
<thead>
<tr>
<th>S No</th>
<th>Handover technique</th>
<th>Parameters for handover decision</th>
<th>Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Smart Handover Decision Algorithm using location prediction for hierarchical macro/femto-cell networks [9]</td>
<td>Mobility prediction, RSS, velocity, time for which device stays in femtocell area</td>
<td>Yes(by identifying the time a user spends in femtocell area)</td>
</tr>
<tr>
<td>2</td>
<td>A new handover strategy between femtocell and macrocell for LTE based network [10]</td>
<td>RSS, available bandwidth, velocity, interference level, real/non-real time transmission, user type</td>
<td>Yes(improve handover decision due to more number of parameters for decision)</td>
</tr>
<tr>
<td>3</td>
<td>Handover management in high-dense femtocellular networks [11]</td>
<td>Neighbour cell list, RSS, SINR, available bandwidth</td>
<td>Yes(by creating reduced neighbour cell list)</td>
</tr>
<tr>
<td>4</td>
<td>Performance Analysis of Handover Strategy in Femtocell Network [12]</td>
<td>RSS, velocity, interference level, capacity bandwidth, user type</td>
<td>Yes(by delaying the handover for unregistered users)</td>
</tr>
<tr>
<td>5</td>
<td>Handover Scenario and Procedure in LTE-based Femtocell Networks [13]</td>
<td>RSS, Mobility prediction, velocity, real/non-real time transmission</td>
<td>Yes(by identifying the time a user spends in femtocell area)</td>
</tr>
<tr>
<td>6</td>
<td>Load balancing with reduced unnecessary handoff in energy efficient macro/femto-cell based BWA networks [14]</td>
<td>RSS, velocity, real/non-real time transmission</td>
<td>Yes(better call quality )</td>
</tr>
</tbody>
</table>

Using the requirement parameters listed in section 3, it is found that none of the techniques achieves all the objectives, although maximum number of mechanisms help in the reduction of unnecessary handovers. While
handover techniques at S.No 3 and 6 improve throughput and energy efficiency of the network and also provide for load balancing but they fail to look at another important aspect of interference management. The techniques at S.No. 2, 3 and 4 tend to improve security of the network by pre authentication of the user to access the femtocell network. The techniques at S.No. 1 and 5, although able to achieve only a single objective of reducing unnecessary handovers yet they are using a very efficient scheme of mobility prediction to calculate the time a user device will spend in the femtocell area.

The most important aim of overlaying the macrocellular network with femtocells is to provide enhanced end point service accessibility to users and offloading macrocellular network. All the objectives described above leads to improved QoS in one way or another. The QoS can be taken as a function of all the objectives mentioned in section 3 i.e.

\[ QoS = f(O1, O2, O3, O4, O5, O6) \]

In above equation, if all the objectives are assigned equal weights, then techniques at S.No. 4 and 6 provide the most significant improvement in quality to users. However, different objectives can be assigned different weights based on their priorities and impact on quality.

5. Conclusion:

The femtocells have emerged out as a promising solution to improve the network coverage indoors and to offload the traffic from already overloaded macrocells. Handover is an important area of research in overlaid macro femtocellular networks. In this paper, a few works on the handovers in femtocell overlaid macrocell have been described. The objectives for handover are proposed which include throughput, Energy efficiency, Reduction in unnecessary handovers, Network load balancing, Interference Management, Network security. The comparison of existing handover techniques has been done against the stated objectives. The comparison indicates the need of an efficient handover technique that tries to cover all the objectives. To achieve all the objectives is certainly difficult but more number of objectives achieved leads to improved Quality of Service to user.

References:
[15]. 3GPP TS 33.320 v0.2.0: ”3GPP Security Aspect of Home NodeB and Home eNodeB: Release 9”. 