Performance Evaluation of Service and Power Based Handover Algorithm in Multi Radio Access Technologies

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Abstract- Deployment of new radio technologies in the mobile world has been gaining momentum to satisfy the customers and applications appetite for improved spectral efficiency and higher data rates. LTE (Long Term Evolution) and LTE Advanced with an enhanced air interface and optimized packet data architecture (an all IP network) that envisioned to provide enhanced data rates, reduced latency and cost efficient operations has been standardized by 3GPP. The deployment of LTE with the existing legacy cellular system such as UMTS in the same cell sites has proven to enhance the network resources available to the operators. Such deployment brings to the forefront many challenges such as mobility. Mobility is one of the cellular networks and 3GPP standard requirements to provide anywhere anytime services. The diversity of the services and the availability at the moment of several radio access networks such as legacy 3G and LTE coupled with user mobility makes the management of the handover process rather complex. In this paper, we propose a multi service handover algorithm to optimize the available network resources and power in multi radio environment (3G and LTE) based on service requests and user profile.

Keywords- LTE, MIMO, Algorithms, Handover, MultiRadio

I. INTRODUCTION

Mobile communications is going through a rapid transformation that has not seen before. The wide spread deployment of LTE in the same cell site as of UTRAN brought to the forefront several technical research challenges such as handover among others. 3GPP standards have these multiple radio technologies connected via signaling and data interfaces as depicted in Figure 1. Multi-access network planning and radio resource management are essential aspects in the multi-radio/multi-access technology deployment, which are further complicated by the requirements to support diverse traffic classes and services standardized by 3GPP community [1].

Mobility of users while maintaining service connectivity for voice and data services at all times is an essential and core part of cellular networks. For data transmission a reliable connection should be maintained when the user is moving from one coverage area to another.

Providing service continuity is one of most serious and vital issues for mobile network operators. Drop calls have severe impact on customer perception of the service and operator service. There are two types of handover, horizontal and vertical. Horizontal handover is the process of providing service continuity while handing the service to cells of the same technology, in other words the target cell is of the same radio type of the source cell.

Vertical handover is the process of handing the service to a target cell that is of different type than the source cell. Handover is maintaining service continuity to user sessions while moving from one coverage area to another associated with different base station or Node B. Service continuity is applicable only to any service that can be maintained by the target domain. Mobility is controlled by E-UTRAN in connected mode while in idle mode the UE is responsible for cell-selection or reselection. Enabling seamless handover especially vertical handover is a challenge for the operators. The decision to move the service within the same technology or to a different technology seamlessly while maintaining QoS is becoming increasingly complicated. The diverse of services and the power consumption when several network entities are involved further complicate service continuity issues and handover management. In this paper, we are proposing energy aware handover algorithm to enable service continuity for horizontal and vertical handover based on service requests.

The paper is organized as follows, in Section II, literature review and in Section III a description of the Radio Access Technologies and traffic classes is presented. While in section IV, the designed handover algorithm is illustrated and section V describes the simulation environment, and cell deployment are defined and Section VI presents partial simulation results. Finally Section VII concludes the papers and provides some hints for future research.
II. LITERATURE REVIEW

The design of LTE architecture is simplified to become a more efficient all-IP system and optimized for packet traffic. For example Radio Network Controller (RNC) used in early 3G releases for Radio Resource Management (RRM) functions, is removed and its intelligence is moved to the Evolved Node B (eNodeB). Another considerable difference to legacy cellular systems is that there is no circuit switched domain in LTE architecture. The core network is solely all-IP, and therefore control data and user data as well as voice are all transferred on top of packet switched IP-protocol. Therefore, a fundamental change to the handover architecture and implementation has been introduced when compared to the legacy 3GPP technologies. UMTS has a radio network controlling element (Radio Network Controller) which possesses the necessary intelligence and signaling capabilities to handle the handover. LTE handover architecture as depicted in Figure 2.

![Figure 2 Handover Architecture](image)

Resource scheduling is also influenced to a great extent by the considered modulation and coding schemes (MCS) and the HARQ protocol. However, we only consider MCS in this paper. In theory, it is possible that each subcarrier of 15 KHz can have different modulation. However, this would be too inefficient and impractical. Therefore, the modulation is assumed to be fixed for each resource block [8].

The eNodeB is an important element in Mobility Management (MM), since it is responsible for deciding on whether a handover is required. The decisions are made based on the measurements sent by the UE. The eNodeB is also responsible for implementing the handover. The Mobility Management Entity (MME) connects to the eNodeBs in its service area via the S1-MME interface. The MME is the main signaling component in the network, and can be considered as the center of intelligence and control. MME is the control plane that manages the mobility and tracking the user equipment at the location area in connected idle mode and with cell location in connected mode.

The S-GW functions as a mobility anchor in internetworking with UMTS systems. When a UE moves to the service area of a new eNodeB or NodeB, the MME instructs the S-GW to switch the user plane path towards the new eNodeB as illustrated in Figure 2. The same S-GW still serves the new eNodeB. However, if the new eNodeB is in the service area of another S-GW, a new S-GW must be chosen by the MME. If the UE mobility is to an area covered with UMTS then the S-GW and the SGSN are signaled by MME to initiate handover procedure and if successful then the path is established via S-GW who is the anchor of mobility if both networks are under the same operator management otherwise the P-GW will be the mobility anchor.

Handover can be classified into two operations, first, inter-system operation where the handover will be to a different access technology as the case when the UE is moving from a cell in UTRAN to an LTE cell or LTE cell to UTRAN cell. In this case the handover is hard handover and the UE is involved in the operation, second, intra-system handover where the operation will be to the same radio access technology. In this case the UE is moving from UTRAN cell to another UTRAN cell or when moving from LTE cell to another LTE cell [3].

In [15-16] the standard outlines the service requirements for handover. If handover is due to UE movement then there should be no measurable impact on the quality of service. The standard does not imply that all handover should achieve this ideal requirement, but this should be achieved based on the UE speed not exceeding the standard requirements and that the UE stays within a single UTRAN coverage area. In case of the handover to a cell of different radio conditions and the quality of service for streaming cannot be maintained then the quality of service might be modified to a lower quality to maintain the continuity of the session. Handover can also be due to a different radio access technology (RAT) is better suited to service the session. This makes it possible for the core network to recommend to the access network to handover the UE to another RAT. Considerations must be given to cell capacity especially when multimedia sessions are involved. As the target cell might not be able to support all the bearers, handover to another cell should not be precluded. The UE should have access rights to any cell that the handover needs to take place. If the UE does not have access rights then the handover should be prevented.

In [4], the authors divided the process of handover into three stages, first, the vertical handover information gathering which is based on the perception of the signal strength, path loss, signal to noise ratio and customer preference. Traditional handover is based on the radio signal strength received by the UE. If the signal strength reaches a certain threshold then the handover takes place. The standards have defined measurement reporting criteria in the measurement control message. UTRAN notifies the UE which events should trigger the reporting events. The UTRAN can use the reporting events to evaluate if a handover is needed [5, 6]. The UTRAN can choose the reporting events to be triggered by the UE. These events are carried on the monitored primary common pilot channel (CPICH) of the cell specified. The measurements include path loss measurements. The events are numbered 3A, 3B, 3C and 3D. Second, the handover decision stage such as
radio link transfer where the authors distinguish between intra cell where the call stays in the same cell and would require a different channel assignment and an inter cell where the cell is changed all together and a new radio link is need to be assigned in new cell (horizontal handover). The handover decision might also be in changing cellular system that is available during the information gathering stage. In such case the handover when changing networks is referred to as vertical handover. Third, Handover execution phase where channel assignment which constitutes the allocation of radio resources to the handover session as well as selecting the network from the gathered information in the first and second phase.

Similar events are standardized for LTE, The events announced in reporting configurations work in a similar fashion than in UMTS. After receiving the configuration, the UE monitors the measurements and sending a report if any of the triggers configured by the events is satisfied. Six events have been standardized, A1-A5 may be used for horizontal handover and B1and B2 is used for vertical handover measurements [7].

In [8], the authors presented a general architecture for the integration at the UMTS radio access level, also known as very tight coupling with emphasis on vertical handover to provide seamless session continuity. Many vertical handover algorithms are presented between UMTS, WLAN, IEEE 802.16e and DVB-H in different combination. They concluded that integration at the radio access layer of UMTS may be beneficial for 4G networks. The above research is focused between wireless systems and cellular systems, mainly UMTS and WLAN including its evolutions (WiMAX). Context aware mobility management architecture system was presented in [9]. The authors claim that this system can provide seamless handover based on cross layer information gathering. The architecture has four functional entities, context gathering, intelligent handover decision-making, accurate handover triggering, and post-handoff management. The authors did not test/simulate the architecture for performance evaluations. But it is our belief that the more entities involved in the handover process the more time consuming the process is which is a critical factor for real time services such as VoIP and gaming services. One other important issue arises, since we are trying to reduce power consumption by UE’s and base stations; we need to minimize the number of entities involved.

III. TECHNOLOGIES AND TRAFFIC CLASSES

UMTS networks or legacy 3G has two links, one to the circuit switched side through Mobile and Switching centre (MSC) and one to the packet switched side through serving GPRS Service Node (SGSN). Radio resources and capacity in MSC are different from SGSN due to the nature of the services and traffic classes that both entities are handling. Legacy voice call is the main service that is provided by UMTS as the target signal-to-noise ratio (Eb/Nt) determines the quality of service and offered through virtual circuits. Services and required signal to noise ratio are described in 3GPP standards [1, 5, and 6]. WCDMA cell capacity can be derived from determining the relationship between the target (Eb/Nt), the requested data rate (Rb) and the cell load. In the uplink, the pole capacity described in [1, 5 and 6] is depicted in equation 1;

\[ N_{pole} = \frac{(W/Rb)/((Eb/Nt)\gamma*(1+\alpha))}{(1)} \]

Where \(W\) is the spreading bandwidth of 3.84 Mega chip, \(Rb\) is the service bit rate, \((Eb/Nt)\) is the energy per bit to the total noise spectrum density, \(\nu\) is the activity factor, for data it is one and for voice the value is normally between .5-.65 and \(\alpha\) is the interference factor which represents own/other cell interference.

Each user admitted to the cell will add a percentage of the load which is calculated based on resources consumed and noise added [6]. In 3G, two services are to be admitted if capacity permits, voice calls and streaming service. Streaming can be VoIP, streaming video.

Long Term Evolution (LTE) networks are based on Orthogonal Frequency Division Multiple Access (OFDMA) technology. LTE is envisioned to support data rates up to 300Mbps and up to 1 Gbps in theory through the utilization of MIMO antenna system as reported by our previous studies [11]. However, the radio resources as in RBs and cell power as well as deployment scenario have a major influence on cells throughput. The effective downlink peak data rate is one half of the values reported in Table 1 [6].

<table>
<thead>
<tr>
<th>Modulation and coding</th>
<th>MIMO usage</th>
<th>5MHz/25RB</th>
<th>10MHz/50RB</th>
<th>15MHz/75RB</th>
<th>20MHz/100RB</th>
</tr>
</thead>
<tbody>
<tr>
<td>QPSK</td>
<td>Single stream</td>
<td>4</td>
<td>8.0</td>
<td>11.8</td>
<td>15.8</td>
</tr>
<tr>
<td>16QAM</td>
<td>Single stream</td>
<td>7.7</td>
<td>15.3</td>
<td>22.9</td>
<td>30.6</td>
</tr>
<tr>
<td>64QAM</td>
<td>Single stream</td>
<td>18.3</td>
<td>36.7</td>
<td>55.1</td>
<td>75.4</td>
</tr>
<tr>
<td>64QAM 2x2 MIMO</td>
<td></td>
<td>36.7</td>
<td>73.7</td>
<td>110.1</td>
<td>149.8</td>
</tr>
</tbody>
</table>

TABLE 1, TRAFFIC SERVICES

<table>
<thead>
<tr>
<th>Traffic Class</th>
<th>Sub Class</th>
<th>File Size</th>
<th>Data Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voice</td>
<td>Voice call</td>
<td>16Kbps</td>
<td></td>
</tr>
<tr>
<td>Streaming real-time</td>
<td>VoIP</td>
<td>16Kbps</td>
<td></td>
</tr>
<tr>
<td>Streaming Non real-time</td>
<td>Video Str.</td>
<td>2.5 Mega Bytes</td>
<td>144Kbps</td>
</tr>
<tr>
<td>Streaming Non real-time</td>
<td>MTV</td>
<td>384Kbps</td>
<td></td>
</tr>
<tr>
<td>Streaming Non real-time</td>
<td>NRT1</td>
<td>512Kbps</td>
<td></td>
</tr>
<tr>
<td>Streaming Non real-time</td>
<td>NRT2</td>
<td>1024Kbps</td>
<td></td>
</tr>
</tbody>
</table>

The LTE system that is realized for this paper comprises of 50 PRB each of 12 subcarriers in accordance with LTE standards. Power allocation first [6, 11] algorithm over the...
total PRBs is utilized while resources are scheduled dynamically.

In Table 2, a list of the traffic classes and services that we are considering in this performance study as per the standards. We have also shown a file size of 2.5MBytes for NRT and for video streaming as well.

IV. HANDOVER ALGORITHM

Handover is maintaining service continuity while mobile station is moving from one node coverage area to another coverage area associated with different base station or node.

Figure 3 First Stage Handover Algorithm

In general it is always preferable that the UE is not involved in mobility management in order to save power consumption and make the UE battery last longer. The core network mobility management has the capability and information to fulfill the requirements of the mobility without heavy involvement from the UE.

Enabling seamless handover especially vertical handover is a challenge for the operators. The decision to move the service within the same technology or to a different technology seamlessly while maintaining QoS is becoming increasingly complicated. The main reason is the existence of different RATs in the same cell site. In addition to the radio resources, the diverse services as presented in the standards [1] offered to customers further complicate service continuity issues.

Moving a call/session from one system to another (Vertical Handover) requires more processing power because several networking entities will be involved as opposed to transferring a call/session within the same system. This is the reason why our proposal is giving priority to horizontal handover. The initial handover decision is based on cell coverage and path loss calculations as depicted in Figure 3. Each cell has an average cell distance that it covers depending on the environment. If the subscriber falls outside these two parameters this causes the initiation of the handover process. The call/session will be tried on target cells that are of the same type as the serving cell (intra system/Horizontal) if the target cell has enough capacity.

If this fails then the call/session is transferred to a cell of different type than the serving cell (inter system/Vertical) if there is enough capacity, otherwise the call/session is dropped as depicted in Figure 4.

Figure 4 Second and Third Stage Handover Algorithm

Several scenarios will be presented and analyzed in the future to enable service continuity based on a complete algorithm for horizontal and vertical handover.

V. SIMULATION ENVIRONMENT

The simulation was carried out using a customized version of the Discrete Event simulator as described in [12] and as depicted in Fig. 5, with an extension to evaluate vertical handover and service time for broadband services...
under power constraint. The considered simulation environment is dense urban.

The path loss model used is COST-Hata [5, and 6] model for dense urban environment.

Several traffic services are offered as depicted in table II. The users have the same mobility of 50km/h. The simulation scenario is assuming dense urban environment with LTE cell deployment in the same cell site of legacy WCDMA cells and coverage area of 500 m.

The MCS used in the downlink have three levels of modulations, QPSK, 16QAM and 64QAM where each signalling element carries 2 bits, 4bits and 6bits respectively. MCS values in this paper are based on [10].

The customers locations follows a uniform distribution, customers arrival to the system following Poisson process with inter arrival rate of $1/\lambda$, where $\lambda = 5$ as shown in Fig. 6.

The deployment is for 90% coverage of 2kmX2km, with 7 nodes of WCDMA and 7 nodes of LTE. The investigated scenario is depicted in Table III below:

<table>
<thead>
<tr>
<th>Scenario 1</th>
<th>Percentage</th>
<th>UE Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Distribution</td>
<td>Voice 75%</td>
<td>75% 3G</td>
</tr>
<tr>
<td>Streaming 25%</td>
<td>VOIP 12.5%</td>
<td>25% LTE</td>
</tr>
<tr>
<td>Video Stream</td>
<td>7.5%</td>
<td></td>
</tr>
<tr>
<td>Mobile TV</td>
<td>5%</td>
<td></td>
</tr>
<tr>
<td>Scenario 2</td>
<td>Voice 85%</td>
<td>85% 3G</td>
</tr>
<tr>
<td>Streaming 15%</td>
<td>VOIP 7.5%</td>
<td>15% LTE</td>
</tr>
<tr>
<td>Video Stream</td>
<td>4.5%</td>
<td></td>
</tr>
<tr>
<td>Mobile TV</td>
<td>3%</td>
<td></td>
</tr>
<tr>
<td>Scenario 3</td>
<td>Voice 65%</td>
<td>65% 3G</td>
</tr>
<tr>
<td>Streaming 35%</td>
<td>VOIP 17.5%</td>
<td>35% LTE</td>
</tr>
<tr>
<td>Video Stream</td>
<td>10.5%</td>
<td></td>
</tr>
<tr>
<td>Mobile TV</td>
<td>7%</td>
<td></td>
</tr>
</tbody>
</table>

VI. PARTIAL SIMULATION AND EVALUATION

The above handover algorithm is proposed to minimize the handover failure rate and enhance call retention. A partial study on the above algorithm was conducted as described below.

This scenario was carried out to illustrate the performance of LTE technology and gauge the Algorithm behaviour. One LTE was deployed with cell throughput at 50Mbps. Only one NRT service was modelled for this scenario where the user requested service of 1024Kbps is considered (as specified in table I). The user is assumed to have a file size .625MB (5*10^6 bits) for download. The system will consider blocking in the case where it cannot deliver the 1024Kbps service. The service holding time depends on the available users in the system and is outputted by the simulator.

User throughput is illustrated in Figure 7 below. It is clear from the above figure that the average user data rate is decreased as the number of user increase in the system. When the system is saturated, the user minimum data rate was holding at approximately 1024Kbps.

When the user average service time was considered as illustrated in Figure 8. It is clear that as the number of users increases in the system; the service time increases as well. This demonstrates that in shared all-IP networks the average service time is inversely proportional to the user bit rate. This is because the system bandwidth is shared among all the users of the system equally.
Such way of abstracting the all IP network and confine LTE technology to delivering a certain amount of bandwidth without any considerations to resource allocation management does not provide a real sense for the technology and the complications of resource allocation.

VII. CONCLUSION

The proposed multi criterion handover algorithm is essential to provide service continuity which leads to enhanced blocking probability of the system. The initial results show that a balance between handover blocking probability and system blocking can be achieved. The results also show that the operators will have a better utilization of their new deployed technologies, if they speed up the replacement of the existing user equipment with technology advanced UEs. It has also been showed that the traffic distribution can impact the system blocking probability. A complete handover algorithm has been presented, several factors influence the decision making process as the user mobility, user equipment capabilities, power consumption and user service.

For future work we will present a complete study of the algorithm as proposed in this paper as well as suggest any enhancements on the algorithm. The link between resource allocation and services as well as user throughput shall be the focus of our next research.

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