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An Optimized Handover Algorithm for LTE-A Femtocell Networks

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Abstract: A femtocell is a low power mobile base station that can be used in a home or office providing the same services as a traditional base station. Femtocells were introduced in order to improve the indoor coverage and also the capacity of users. Implementation of femtocells in existing cellular network form a cross-tier network. Due to this cross-tier network, the conventional handover techniques cannot be applied for the mobility management.

It offers a large number of handovers due to its low power and small coverage area which degrades the performance of the network in terms of throughput. To improve the performance, several and over algorithms were presented that used only a single criterion for handover. In this paper, a handover algorithm is proposed based on multiple steps. A handover is triggered only when all these steps and criteria are satisfied. The algorithm is simulated in LTE-*Sim* and the results demonstrate that the performance of the network is improved. Hand-In scenario is considered for simulation as this is the most complex handover scenario of femtocells.

Keywords: Femtocell; Cross-Tier Network; Mobility Management.

I. INTRODUCTION

There is a dramatic shift of mobile data users over the last few years and it is still increasing day by day. In order to cope with such increased number of users, there is an immense need of high speed network because the existing network cannot support such a huge number of users. New network topologies are required that can efficiently accommodate the mobile users(Andrews, *et al.,*2012.). A study revealed that 66% of voice and 90% of data traffic is indoor, the researchers are trying to offload the data traffic from macro-cells which will provide relief to both operator and users.

There exist different approaches to tackle this challenging issue of huge number of users and indoor coverage. These include improvement in the formats of transmitting signals and bringing the transmitter and receiver close to each other. Both of these approaches were costly for the operators and hence discarded. Another approach is to introduce small cells within the coverage area of macro-cells. Femtocell is one of the small cells that is best solution for offloading the traffic from macro-cell and also for improving indoor network coverage. Its deployment is also economical for the operators.

Femtocells are low power base stations that are also termed as Home eNodeB or Femtocell Access Point (FAP). Their coverage area ranges from 10 to 30m with power of 100mW and advantage of having no need operators for its installation as these are plug and of play devices (Robust (2019)).Femtocell technology can easily be integrated into an existing mobile network. The following figure shows how femtocells can be deployed in a building to improve indoor mobile coverage with an existing mobile base station.

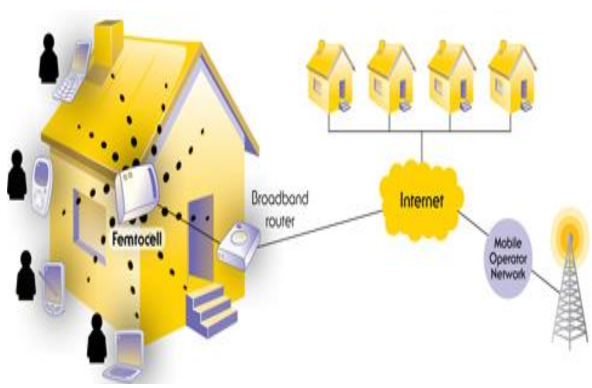

Fig. 1.Femtocell deployment inside building.

As these FAP are integrated within the existing network, there should be management of mobility for the user from coverage area of macro-cell to the area of femtocells. The existing handover algorithms cannot satisfy the mobility of users because this a two-tier network consisting of macro-cell and femtocells. We have proposed a handover algorithm for such a two-tier network.

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2. BACKGROUND

The First generation (1st G) mobile networks that were introduced in the 1980s, were analogue and capable of delivering only voice services. However, in 1990s, second generation (2G) mobile networks were introduced. 2G mobile networks were designed to be digital and provided data services in addition to SMS messages beyond voice services. Global System for Mobile (GSM) became most successful mobile network standard. In the latter half of 1990s, cell Phone usages rose enormously as well as demand for Internet also encountered huge surge. To support the services of data in the mobile networks, GPRS was initiated and for provision of better data services for the users, third generation (3G) mobile networks were introduced in late 90s. 3G, with remarkable data rate improvements over the 2G mobile networks were acknowledged all over the world. In the beginning on 21st century, cellular telephony observed outburst of data usages with the growing number of multimedia services on the Internet. To cope up with this growth on the mobile networks, fourth generation (4G) mobile networks came into inception.

Furthermore, LTE, introduced in 2008, is a 4G network standard. It has provided enhanced capacity and data rate over the previous standards and iscurrently used worldwide. Also, to provide good services at par to the growing number of users and handle the increasing data, LTE standard is constantly rejuvenated. LTE-Advanced, a major update over LTE, was introduced back in 2011.

Heterogenous Networks:

LTE-Advanced brought many improvements over the LTE. One of the many improvements is the introduction of heterogeneous networks. It gives best ever spectral efficacy of cellular networks that is almost equivalent to its theoretical limits, and to improve network capacity, network topology can be altered at will. Traditionally, cellular networks are homogeneous networks which comprises of macro-cells. In such type of networks, to improve network capacity and coverage, low power micro-cell, picocell, femtocells and relay stations could be deployed within the coverage of high power macro-cells and are termed as heterogeneous networks(Salman,*et al.*,2014).

A. *LTE FemtoCell Architecture*

LTE femtocell architecture consists of elements and the interfaces to support the architecture signaling. Femtocell architecture basically consists of the following two basic elements:

1. Home Node B (HNB)
2. Home Node B Management System (HMS)

There are three interfaces in the femtocell architecture to link the elements of the architecture.

1. Home Node B Gateway (HNB-GW)
2. Security Gateway (SeGW)
3. LuH

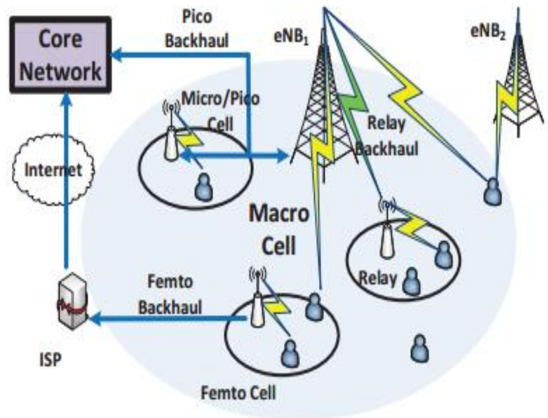

Fig. 2. The Architecture of LTE-A Heterogeneous System.

B. *Handover Scenarios*

In femtocell network, there are three types of handover scenarios, i.e., Hand-In, Hand-Out and Inter-Femto handovers. These categories are according to the movement of users in the two-tier networks. Like in theHand-In scenario, users are moving from the coverage area of macro-cell to the coverage area of femtocells, e.g., a building where there are multiple femtocell installed (Yusof, *et al.*,2013). Therefore, the UE is going to face too many femtocells and it would be difficult for the UE to which femtocell it should be switched smoothly. This is the complex scenario of all the scenarios as UE will face multiple femtocells. In the Hand-Out scenario, the UE is moving out of the femtocell area into the macro-cell area. It is a normal scenario as UE will face only a single microcell. There is not much scanning involved in the selection of suitable target cell. The third one is similar to the Hand-In handovers as the UE will face too many femtocells for handover.

Handovers are necessary for moving from the coverage area of one to another cell while using the services of a network. This will also affect the network performance when a user is moving in such a two-tier network. In Hand-In scenario, there are multiple femtocells for a UE and as we know that these are low power and short-range base stations so there will be increased number of handovers which will degrade the performance of the network. For such a situation, several handover algorithms were presented that used a specific criterion for handover execution. In the following section, these algorithms are discussed and our proposed algorithm is presented.

Existing Algorithms

A. Received Signal Strength based Algorithms:

In this category of algorithm, a margin is set which act as a threshold, named as Hysteresis HO Margin (HHM).The main focus is on the reduction of handovers and to avoid the effect of ping-pong. It focuses on the comparison between the Reference signal Received Strength (RSS) of serving and target cell (Moon, and Cho,2009)

B. Speed based Algorithm

This algorithm was introduced to decrease the un wanted handovers which takes place due to the entry of high speed users. In such algorithms, a threshold value of speed is used for the triggering of handover. Whenever this threshold value is exceeded, hand over is triggered by the serving cell (Ulvan, *et al.*, 2014).

C. Cost-function based algorithms

This type of algorithm has too many parameters for the triggering of handover whose aim is to improve the mobility among femtocells. In this algorithm, cost-function of serving cell is compared with the hysteresis result. This was introduced in (Xu, *et al.*,2010) for different stats of user consisting of user speed, data traffic and SINR. The basic criterion states that cost-function must exceed 0.

D. Interference-aware Algorithms

In this algorithm, the number of handovers are reduced in two-tier network by the usage of different parameters like RSRQ, RSRP, RSQ and interference. Through these parameters, the status of interference is assessed. Handover is triggered after the satisfaction of interference with threshold of hysteresis (Becvar and Mach, 2010).

E. Multistep Algorithm:

In this handover algorithm, multiple decision criteria were used for executing handover. These are signal power, capacity of femtocell and CSG group. Once all these are satisfied, the handover is executed and, in this way, the number of handovers were decreased(Khan, *et al.*,2017). The block diagram is given below.

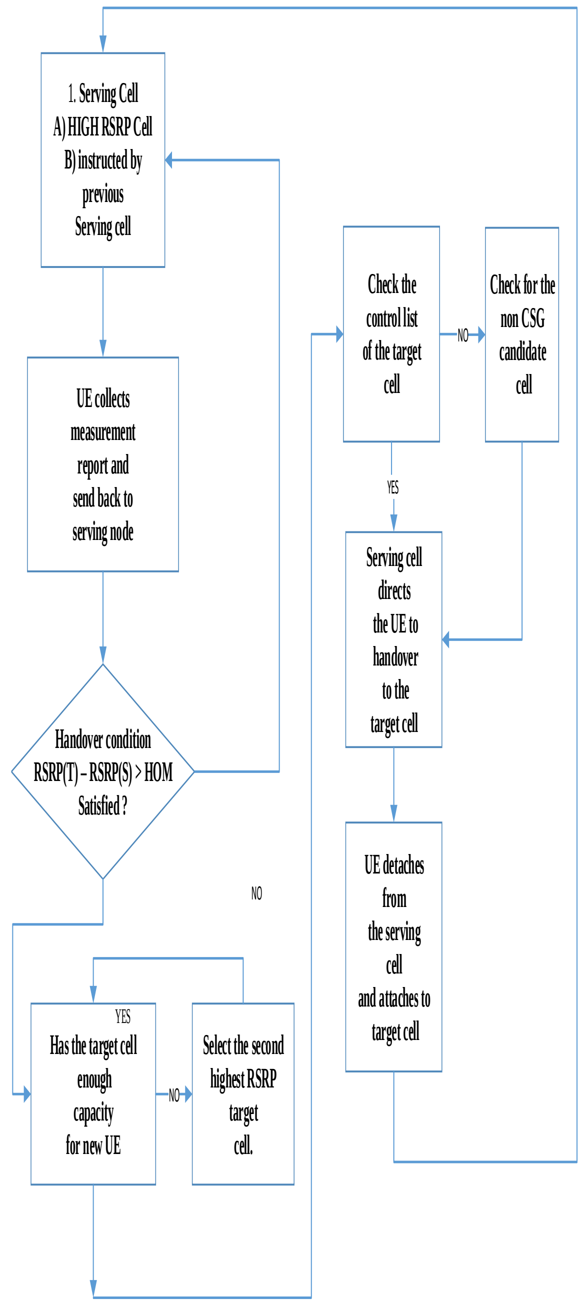

Fig. 3: Block diagram of Multistep Algorithm.

Proposed Algorithm

In the previous section, different handover algorithms were discussed along with a multistep algorithm. Here, we present an algorithm in order to improve the performance of the system. The Proposed algorithm is shown below in the form of a block diagram.

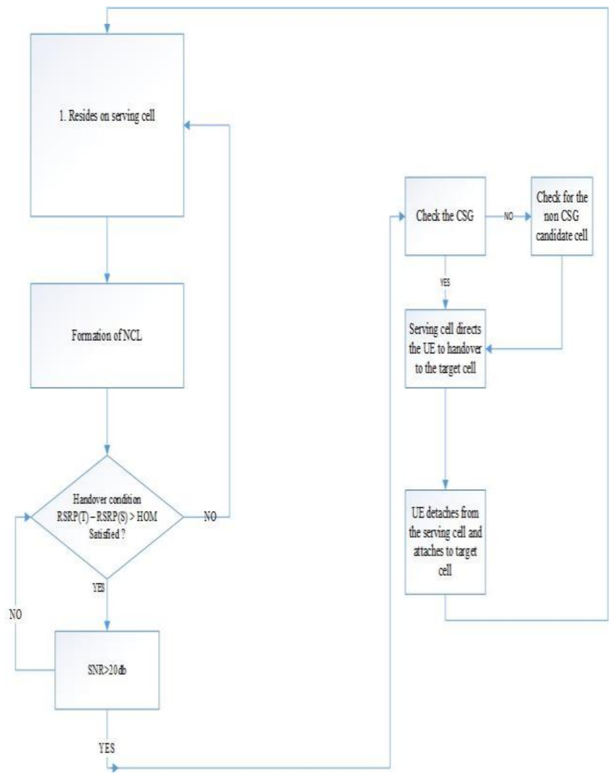

Fig. 4: Proposed Algorithm Block Diagram.

The proposed algorithm has multiple conditions that needs to be satisfied for the execution of the handover. All these conditions will select a best suitable FAP for handover among a number of FAP. Whenever a macro-cell user enters into a building having multiple FAP, a Neighbor Cell List (NCL) will be created and sent back to the serving cell. UE will compare the signal power of the target cell with that of the serving cell. If the difference of the signal power between the target and the serving cell is greater than a specific threshold value, the first condition is considered to be satisfied. This threshold value is called Handover Margin (HoM). The next step is to check the Signal to Noise (SNR) ratio of the target FAP. If the SNR of a target cell is greater than 20db, the second condition is also satisfied. Finally, the third step will check the CSG group of the selected FAP, i.e., whether the UE is registered in the CSG group of the FAP or not. If it is registered, then all the steps are completed and handover will be executed otherwise it will start searching for another FAP that meets all these criteria. In this way, a best possible FAP will be selected instead of switching between the FAP. Therefore, the number of handovers is decreased and system performance is improved.

In order to simulate the proposed algorithm, LTE-Sim simulator is used which is a system level simulator focused on the features of LTE networks. It has models for both evolved packet system and E-UTRAN, single and multicellular scenarios, transmissions for both uplink and downlink, multiple user's scenarios, user mobility, procedures for handovers and the most important frequency reuse techniques. It also includes different scheduling algorithms like Proportional Fair (PF), Exponential Proportional fair (Ex.PF) and Maximum-Largest Weighted Delay First (M-LWDF). It has support for AMC scheme, Frequency Re-use, CQI feedback and different models at the physical layer. The parameters used for the scenario used are given below.

Table I. Parameters For Proposed Algorithm

Parameter	Value
Total Bandwidth	20MHz
eNB Power	40dBm
Number of Building	1
Apartment Size	10 × 10 m
Number of Apartments	9
Radius of macro-cell	500m
Number of users each FAP	1-8
UE speed	5,15 & 30 km/hr.
Traffic	Infinite Buffer
Active Factor	1

This simulator has built-in scenarios and we have selected Single-Cell-with-Fem to which has a single macro-cell but multiple femtocells. The number of building is one and having a large number of apartments. The scenario for the proposed algorithm is Hand-In in which a UE is entering from a macro-cell into a building that is having a large number of FAP.A building type of 3×3 is used which constitutes 9 apartments, each apartment has a single FAP and the total number of FAP is 9.

3. SIMULATION RESULTS

In order to check the results of our proposed algorithm, two performance matrices are used. These will decide the performance of the system, i.e., how much it has improved with the proposed algorithm. These parameters are:

a) Number of Handovers:

The scenario under consideration is hand-in scenario in which a UE is entering from macro-cell into a building that has FAP. Femtocells are randomly deployed in the small coverage area, a mobile user will undergo too many handovers thus decreasing the performance of the system. In order to check the efficiency of the system, the number of handovers are measured. The results of the proposed system are compared with the existing algorithm.

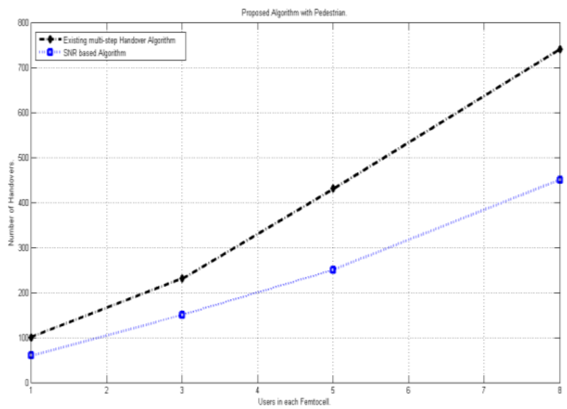

Fig. 5. Number of Handovers while user is pedestrian.

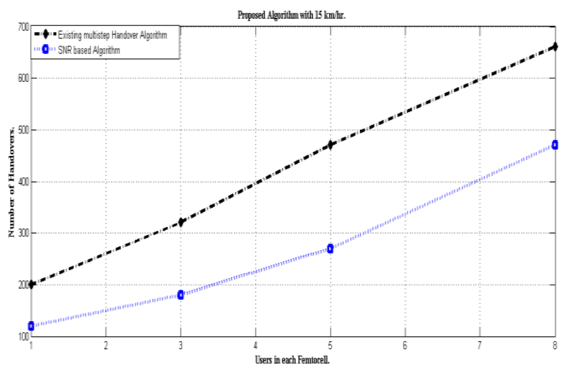

Fig. 6. Number of Handovers with 15 km/h speed of the user.

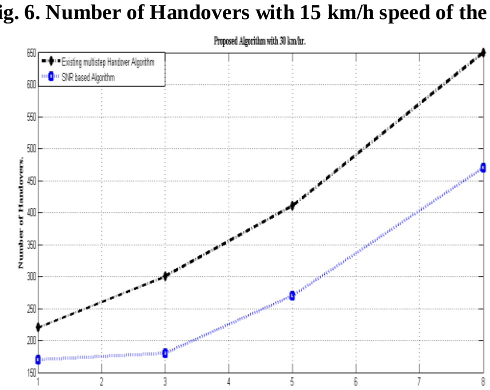

Fig. 7. Number of Handovers with 30 km/h.

The graphs show that the proposed algorithm has decreased the number of handovers as compared to the existing algorithm. This is due to the fact that SNR is considered in this algorithm. SNR is an important factor because there is noise due to the number of femtocells. Another point is that the number of handovers is increased by increasing the speed of the user because of switching between femtocells.

b) Throughput:

In order to check the performance of the system, throughput for VoIP is investigated and compared with the existing algorithm. During the simulations, afixed number of users are considered and each user is getting real time VoIP flow through a source of infinite buffer. In this simulation we have used Proportional Fair PF and Maximum Largest Weighted Delay First (M-LWDF) scheduling algorithms.

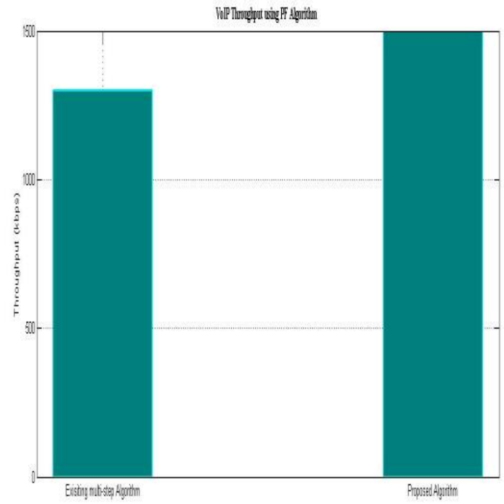

Fig. 8. Average throughput for 3×3 Grid while using PF scheduling Algorithm.

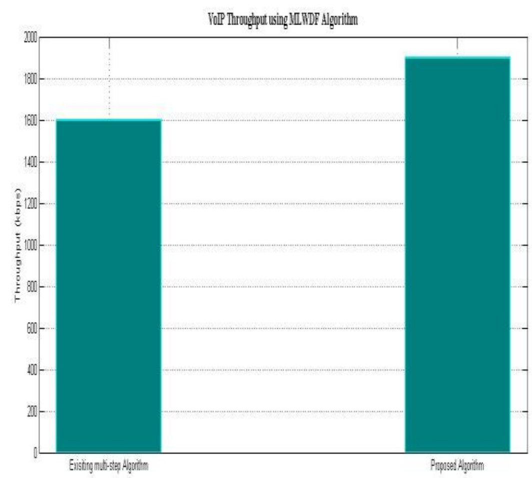

Fig. 9. Average throughput for 3×3 Grid while using MLWDF scheduling Algorithm.

The result of the simulation for PF and MLWDF shows that the proposed algorithm has improved the system performance up to a greater extent as evident from the graphs. This improvement in the throughput for VoIP application is due to the fact that theproposed algorithm has decreased the number of handovers which degrades the system performance. MLWDF has shown much improved results than PF because PF is channel aware scheduling algorithm while MLWDF also consider QoS.

4. CONCLUSION

This paper focused on heterogeneous networks of LTE-A as the number of indoor users are getting increased day by day. Femtocells were introduced to offload the data traffic from the macro-cell and also to improve the indoor coverage. Such combination of macro-cell and femtocell makes a two-tier network where the existing handover algorithms cannot be used for mobility management. Therefore, an improved handover mechanism was presented along with the simulation results. There exist several handover algorithms for femtocells but most of them use single parameter for handover execution. In the proposed algorithm, a multistep handover schemeis presented and simulated in LTE-Sim. The simulations results showed that the number of handovers is decreased and the system performance is improved.

From the results obtained, we can observe that the number of handovers increases as the speed of the user increases. The main reason is that by increasing the speed, the user will be connected with a specific femtocell for a small interval of time. After that interval, handover will occur and the userwill be connected to another femtocell. In this way, the number of handovers increases and degrades the performance of the system. The performance can be improved further by making variation in the Time to Trigger (TTT). As the femtocells are installed in close proximity, there must be interference among them. In future work, interference can also be used as a handover decision criterion for further improvement in the performance.

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