International Journal on Advanced Science Engineering Information Technology

Vol.10 (2020) No. 4
ISSN: 2088-5334

Efficient Handover Approach in 5G Mobile Networks

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***Abstract*— Femtocell technology has improved cellular coverage and capacity allowing the provision of rich and interactive communication services in current mobile networks. However, this technology suffers from several drawbacks including; increased interference and packet loss, frequent handovers, and high energy consumption. This paper presents a new handover management approach to overcome performance limitations linked to handover taking place at dense femtocell environments. RSSI of Base Station (BS), mobile user's movement direction, and BS available capacity are factors used in this work to improve handover decision while sustaining perceived network performance. In addition, in order to reduce the complexity and delay of handover process, the proposed approach has redefined handover major phases including; preparation, decision and execution phases. A densely deployed simulated environment representing heterogeneous 4G and 5G architecture was implemented to evaluate the proposed approach. The simulation environment consists of three paths, each path represents a different network and mobility condition including BS distribution, obstacles, UE movement direction and distance. Results confirmed that the proposed handover approach reported an improved performance in terms of handover delay and number of unnecessary handovers. The average number of handovers occurred during all simulation scenarios was 3, also the average handover delay achieved was (55.15 ms). The number of handovers were decreased 30% and handover delay was reduced more than 10 ms comparing to conventional handover approaches such RSS-based. Hence, an improved adoption of handover management into femotocell environment.**

***Keywords*— 5G; femtocell; RSSI; handover; QoS.**

I. INTRODUCTION

The fifth generation (5G) of mobile technologies has been developed to satisfy increased demands on high data rates and accommodate Quality of Service (QoS) challenges encountered by previous mobile generations. 5G cellular technology is designed to provide high bandwidth and supports very high transmission speed, and aims at preventing penetration loss through building walls by separating outdoor and indoor environments. This is achieved by Distributed Antenna System (DAS) and massive Multiple-Input and Multiple-Output (MIMO) techniques where hundreds of distributed antenna arrays are installed. In 5G architecture, multiple networks corresponding to different technologies will share a common infrastructure implementing macrocells, picocells and femtocells that overlap among themselves by a picocell [1].

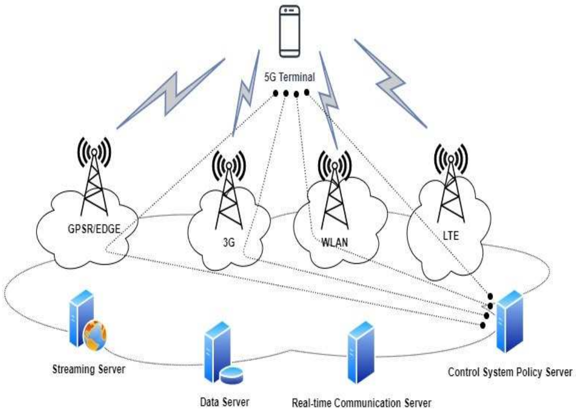

Fig.1 Functional architecture for 5G mobile networks [2].

The system architecture of 5G is entirely based on IP model, and comprises main mobile terminal and a number of independent Radio Access Network (RAN) technologies, see Fig 1.

Each of those radio technologies is treated as an IP link for the outside internet world, more likely to the cloud. Currently, one of the most challenging issues in mobile communications is the smooth integration of small-sized cells into the predominant macro-cellular network layout. Femtocell was deployed to solve these problems with low cost, power saving capability and easy installation [3]. However, the small range of femtocell's coverage, allows simple users' motion to exit a femtocell or reach the border of macrocell which requires a handover. Maintaining service and connectivity when moving from one cell's coverage to another is a challenge; even if both cells are related to the same network technology or not. Therefore, the need for effective handover management approach has become imperative for fast and seamless handover while maintaining network QoS [4].

The introduction of femtocell technology in cellular networks has enhanced cellular coverage and capacity allowing the provision of rich and interactive communication services. However, the expense of these advantages are; increased interference, high packet loss, repetitive handovers, increased handover delay and failures, and high energy consumption [1]. Such problems will expand in high-speed User Equipment (UE) scenarios and in indoor environments. Hence, advanced handover management techniques are required to be able to fulfill femtocell deficiencies, minimize unnecessary handovers and prevent service degradation accompanied with handovers [5].

Several research work have investigated handover management techniques taking into consideration different factors such network available resources, network density and signal strength. An intensive overview of handover management techniques in 5G new radio (NR) and in long-term evolution (LTE) and was provided in [6]. In addition, an overview of Vertical Handover (VH) techniques in 4G and 5G networks was presented in [3]. Where this study presented a handover approach designed taking into consideration network types and frequency mechanism allowing for seamless integration across networks and enhanced QoS.

Considering Received Signal Strength Indicator (RSSI), in [7] handoff algorithm was presented to compare RSSI value with predefined RSSI threshold and then decides to perform handover or not; this approach have reduced the unnecessary handovers. It is worth mentioning that RSSI indicates the received signal power to UE from either serving or surrounding access points. In the same concern, a handover decision algorithm based on RSSI and speed of user in open access femtocells networks was proposed in [8]. In addition, researchers in [9] used RSSI, user speed, cell radius, distance between user and access point as a parameter to perform seamless handover that reduces unnecessary handovers and packet loss. In [10], Reference Signal Received Power (RSRP) along with user position, movement direction, and network capacity were used to provide handover decision. The basis of this model was to optimize handover process and enhance the performance of femtocell network in LTE by increasing success probability of handover.

An enhanced handover algorithm to reduce both unnecessary handover and the call blocking probability was presented by [11]; taking into consideration a set of network parameter such as; cell capacity, cell radius, bandwidth, number of users, capacity of microcell and user speed. In [12] a handover algorithm was presented based on optimizing the list of the candidate femtocell access points by scanning only the access points that is exist along with the user movement. Authors used linear regression model as a machine learning predictor tool that depends on the user movement history. After optimizing the list of access points, the algorithm selects the access point with best RSSI and high capacity then performs the handover. Mobile position and direction were also investigated by [13], to reduce the unnecessary handover and improving the network reliability. The algorithm was designed to reduce the probability of disconnections by predicting the user's future position using Markov model and then choosing the suitable access point. An additional handover management system which aims to solve the interference problem, reduce noise ratios and optimize handover decision was presented in [14]. This model was known as Hand Over-driven Femtocell Interference Management (HO-FIM).

Several research works have defined techniques used to resolve handover problems in macrocell and femtocell environments. The reported techniques involve using a set of parameters such as RSSI, UE speed, cell load and capacity, number of connections, distance and movement direction. However, reaching desired network QoS while handover is still a challenge especially in dense femtocell and indoor environments due to service interruptions that accompany handover. Also, it is important to consider the operational complexity and overall processing delay of handover management techniques. This paper investigates QoS limitations associated with handover taking place at dense and spars network deplyments. A new handover approach is presented to be adaptive in femtocell networks. The focus was to decrease unnecessary handovers and reduce incurred handover delay without additional complexity or cost. The following section describes the proposed handover approach, and section 3 explains the evaluation study conducted and reports achieved results, and section 4 concludes this work.

II. Materials and Methods

The proposed handover approach adds new set of parameters to be utilized in the handover decision process. This includes; Mobile node direction, Base Station (BS) available capacity, along with BS RSS value. Generally, the RSSI value is computed based on this equation [15]:

$$RSSI_e = -(10.0\,\gamma\ \log_{10}(D) + RSSI_0) \tag{1}$$

Where the:

1. $RSSI_0$: received signal strength at 1 meter distance.

2. D: The distance between the user and the base station.

3. γ: Path loss exponent (average value of 4 for mobile nodes).

In addition to RSS, the distance and direction between UE and BSs are measured. The distance metric considered is the Euclidean distance between two points, which is presented by the following equation [16]:

$$d(p,q) = \sqrt{(q_1 - p_1)^2 + (q_2 - p_2)^2} \qquad (2)$$

Were p = ($p1$, $p2$) and q = ($q1$, $q2$) are two points, and $d(p,q)$ represents the length of the line connecting them.

Algorithm1: proposed handover model
1: R: set of application requirements.
2: M: set of mobile nodes.
3: N: set of Neighboring BS.
4: B: set of base station nodes
//Phase 1: preparation phase
5: Continuous scan of RSSI between n and BS
2: CH: select n with highest RSSI.
3: **While** ($BS \in B$)
4: Measure Distance and Direction between n and BS.
6: **If** Distance <= Distance_TH *// Distance threshold.*
7: $BS \in N$
8: **Else** $BS \in B$
9: **End if**
10: **End while**
//Phase 2: Decision Phase
11: Optimal BS = Select BS from N with highest RSSI & capacity.
12: **If** Optimal BS.RSSI ≤ Serving BS.RSSI & Optimal BS.capacity ≥ Serving BS.Capacity
13**: GO TO Phase 3**
14: **Else** GO TO Phase 1.
15: **End If**
//***Phase 3***: ***Handover execution phase.***
16: Attach m to target optimal Bs
End Algorithm

Fig. 2: Proposed Handover Model Pseudocode

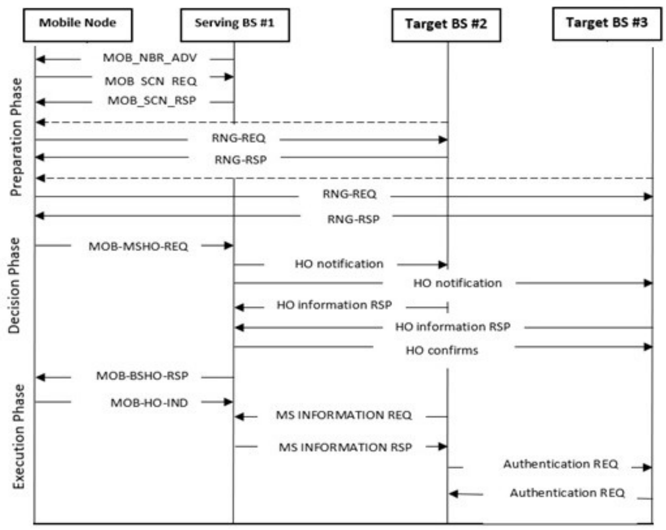

Fig 3. Handover procedures and message exchange.

The proposed handover approach is described in the pseudocode shown in Fig.2. The major three handover phases are redefined. Lines 5 through 10 presents handover preparation phase, which is responsible for continues measurement of RSS values, distance and direction between mobile nodes and BSs. The second is known as handover decision phase, is presented in lines 11 to 15, and is accountable for finding optimal BS and comparing its parameters with serving BS. Lines 15 and 16 presents handover execution phase and is responsible for attaching mobile node to target optimal BS.

The message exchange and procedural steps involved in all three phases are illustrated in Fig. 3. The following table defines request and response messages involved in the handover management procedure [17]:

TABLE I
EXCHANGE MESSAGES ACRONYM DEFINITION

Message Type	Definition
MOB NBR-ADV	Mobile Neighbor Advertisement
MOB SCN-REQ	Mobile Node Scanning Request
MOB SCN-RSP	Mobile Node Scanning Response
RNG-REQ	Ranging Request
RNG-RSP	Ranging Response
MOB MSHO-REQ	Mobile Node Handover Request
MOB BSHO-RSP	Mobile Node Handover Response
MOB-HO-IND	Mobile Node Handover Indication
MS Information REQ	Mobile Node Information Request
MS Information RSP	Mobile Node Information Response
HO Information RSP	Handover Information Response
Authentication REQ	Authentication Request

A. Handover Preparation Phase

The BS periodically transmits neighbour advertisement control message to all mobile nodes. This message is known as (MOB NBR-ADV) and contains BS's MAC address and radio channel. Each mobile node receiving this message recognizes the serving BS and begins the handover handling process. Mobile nodes continuously scan for target BSs and periodically executes channel synchronization and arrangement procedures. A mobile scanning request holding candidate BSs list is broadcasted by mobile nodes to the serving base station, this message is known as (MOB SCN-REQ). The latter allocate a search period to the UE and responses with (MOB SCN-RSP), which is a mobile scanning response. After completing channel synchronization with the target BSs, the mobile node uses several ranging requests messages and ranging response messages, known as (RNG-REQ) and (RNG-RSP) respectively, to exchange parameters, such available capacity and RSS. Afterwards, BSs allocated in the direction of UE will be defined as neighbouring BS [18].

B. Decision Phase

This phase is responsible for determining the need for handover. The handover decision phase is invoked when a mobile node handover request (MOB MSHO-REQ) message or a mobile node handover response (MOB BSHO-RSP) message is received. In this phase, BSs that conform to user's heading direction are defined as neighboring BSs, which are then scanned to find optimal BS having highest RSS and capacity values. If the RSS value of the serving BS is less than RSS value of optimal neighboring BS, the handover execution phase will start.

C. Execution Phase:

During this phase handover is performed attaching mobile nodes to optimal BS, which has highest RSS value, enough capacity, and aligned within mobile nodes's direction. The use of these parameters is expected to minimize the unnecessary handovers numbers and decrease the handover process delay by reducing the scanning time of mobile node to find best optimal BS. As shown in figure 3, during execution phase, a connection is created between UE and target optimal BS, where also negotiation, authentication, and registration are accomplished.

III. Results and Discussion

A new simulation tool was built in this work based on C++ language. In which the proposed handover approach was implemented along with other conventional handover approaches such as RSS based handover as described in [19]. This simulation tool allows the evaluation of both methods considering 4G and 5G environmental settings. An intensive simulation scenario was designed consisting of three different paths, each path implements a different network and mobility condition including BS distribution, obstacles, UE movement direction and distance. The scenario was executed more than 10 times for each path. Results here confirm the impact of involving user direction and available capacity on reducing unnecessary handovers and delay time.

A. Scenario Setup:

The simulation environment implements 4G and 5G dense network. It consists of 1 Macro-cells and (20) Femto-Access Points (FAPs), 12 5G-FAPs and 8 4G-FAPS. As illustrated in figure 4, three different paths are deployed within this environment. Each path implements a different scenario in the concern of cell technology and FAP's density level. User will move along each path with a fixied speed and start recording RSSI, capacity of serving and target access points at seven different locations chosen based on network topology. These measurement points are predifiend and used to define path structure. The proposed approach will utilize measured information to decided either to execute handover or not.

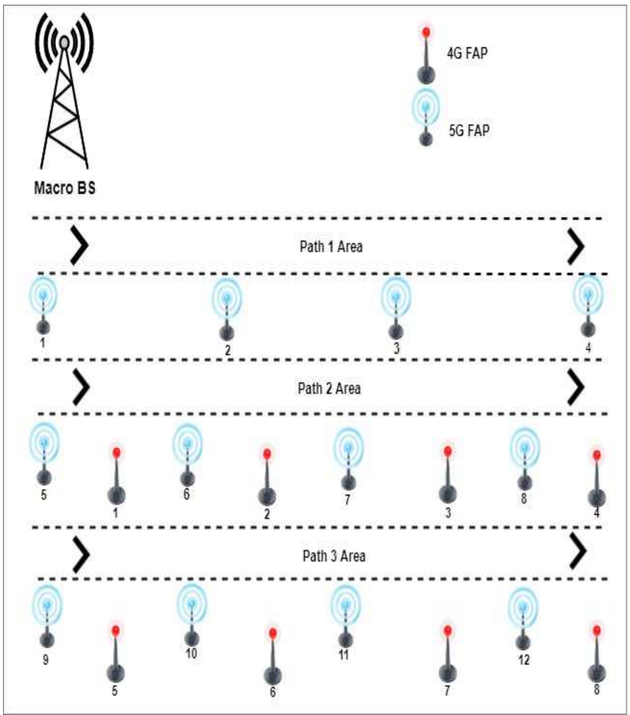

Fig. 4 Simulation Environment

B. Simulation Results

The simulation results were divided into three parts according to different path areas. Both RSS-Based and proposed handover approaches were implemented along each simulated path. Results report RSSI, BS capacity, delay of handover process, and number of handovers occurred at each path. For target BSs; RSSI and capacity values were recorded only if handover process have occurred.

1) Path 1: This path illustrates a spars network environment with a closer connection to the macro BS.

Tables 2 and 3 illustrates average results achieved at this path. Table 2 describes the average RSS values being received along the path with reference to predefined measurement points and surrounding BSs. RSS values will vary according to mobile nodes's distance and direction. RSSI is the first factor used by proposed approach for handover decision. The second factor is BS available buffer capacity which is described in table 3. Using the proposed approach, handover have occurred in average three times along path 1, comparing to an average of 6 handovers that took place using RSS-based approach. Looking at RSS and capacity values recorded at tables 2 and 3 respectively, handover have occurred at points (2, 4 and 6) using proposed approach. However, using RSS-based approach, which depends only on RSS values to make the handover decision, handover accoutred at points (1, 3, 4, 5, 6, 7).

During this path, average handover delay achieved by proposed approach was (54.37 ms) compared to an average delay of (66.20 ms) achieved by RSS-based approach. The advancement achieved by proposed handover approach was due to improved decision phase which considers several factors to define optimal target BS. These factors allow the handover decision to be more context adaptive and selected BS will be more efficient and aligned with user movement direction. Also, the redesign of handover phases has reduced overall handover complexity.

TABLE II
PATH1 RSSI SIMULATION RESULTS

Proposed Handover Approach				
Position	**Serving BS ID**	**Serving BS RSS**	**Target BS ID**	**Target BS RSS**
1	Macro AP	-62	-	-
2	Macro AP	-60	5G FAP-1	-55
3	5G FAP-1	-63	-	-
4	5G FAP-1	-74	5G FAP-5	-52
5	5G FAP-5	-61	-	-
6	5G FAP-5	-65	5G FAP-4	-54
7	5G FAP-4	-56	-	-
RSS-based Handover Approach				
Position	**Serving BS ID**	**Serving BS RSS**	**Target BS ID**	**Target BS RSS**
1	Macro AP	-62	5G FAP-1	-56
2	5G FAP-1	-54	-	-
3	5G FAP-1	-63	5G FAP-5	-51
4	5G FAP-5	-61	5G FAP-6	-57

5	5G FAP-6	-62	5G FAP-2	-50
6	5G FAP-2	-59	5G FAP-3	-55
7	5G FAP-3	-64	5G FAP-4	-57

TABLE III
PATH1 BS CAPACITY AND HANDOVER RESULTS

Position	Serving BS Capacity	Target BS Capacity	Handover Occurs
1	-	-	No
2	210	300	Yes
3	-	-	No
4	290	330	Yes
5	-	-	No
6	300	350	Yes
7	-	-	No

2) Path 2: This path implements more density environment with a mixture of 4G and 5G access points.

Tables 4 and 5 illustrates average results achieved at this path. Looking at the difference between RSS values received from serving BSs and target BSs described in table 4, RSS-based approach made at least five handovers at points (2, 3, 4, 5 and 6). However, during this path, proposed approach reported an average of four handovers, mainly at points (3, 4, 5 and 6). This can be clear from table 5 which address the AP available capacity, which is the second factor used to perform handover.

As for handover delay time, average delay time using RSS-based method was (68.05 ms), while average delay time for the proposed approach was (57.50 ms). Hence, the proposed handover approach outperformed RSS-based approach in terms of number of handovers and overall average delay during path 2 simulation. The overall increase of handovers occurrence and handover processing delay at this path is due to network density increase.

TABLE IV
PATH 2 RSSI SIMULATION RESULTS

Proposed Handover Approach				
Position	**Serving BS ID**	**Serving BS RSS**	**Target BS ID**	**Target BS RSS**
1	Macro AP	-65	-	-
2	Macro AP	-65	-	-
3	Macro AP	-67	4G FAP-1	-58
4	4G FAP-1	-69	5G-FAP-2	-69
5	5G-FAP-2	-69	5G-FAP-7	-58
6	5G-FAP-7	-66	5G-FAP-8	-62
7	5G-FAP-8	-52	-	-
RSS-based Handover Approach				
Position	**Serving BS ID**	**Serving BS RSS**	**Target BS ID**	**Target BS RSS**
1	Macro AP	-63	-	-
2	Macro AP	-68	4G FAP-1	-56
3	4G FAP-1	-62	5G-FAP-2	-54
4	5G-FAP-2	-67	5G-FAP-3	-52
5	5G-FAP-3	-58	4G-FAP-3	-55
6	4G-FAP-3	-60	5G-FAP-8	-58
7	5G-FAP-8	-52	-	-

3) Path 3: This path illustrates a densely network environment with more than 16 4G and 5G surrounding APs. This path structure allows a seamless integration between different femtocells.

Tables 6 and 7 summarizes average results achieved at path 3. As being indicated in table 6, the average number of handovers have increased to 6 using RSS- based approach, because it uses only RSS values differences to decide wither to conduct handover or not. Relaying only on RSS value is considered unreliable and will increase the number of unnecessary handovers.

TABLE V
PATH 2 CAPACITY AND HANDOVER RESULTS

Position	Serving BS Capacity	Target BS Capacity	Handover Occurs
1	-	-	No
2	-	-	No
3	210	315	Yes
4	300	320	Yes
5	320	325	Yes
6	325	330	Yes
7	-	-	No

However, along this path an average of three handovers occurred using the proposed approach. Mainly, these handovers have occurred at measurement locations 1, 3, and 6. At these locations, target BSs have higher available capacity, and target BSs have higher RSSI than serving BSs. In addition, target BSs were at users heading direction and within shorter distance. In terms of average delay both approaches have achieved performance closer to path 2, were average delay experienced by proposed approach was (53.58 ms) comparing to (71.75 ms) achieved by RSS-based approach.

TABLE VI
PATH 3 RSSI SIMULATION RESULTS

Proposed Handover Approach				
Position	**Serving BS ID**	**Serving BS RSS**	**Target BS ID**	**Target BS RSS**
1	5G-FAP-9	-66	4G-FAP-5	-61
2	4G-FAP-5	-63	-	-
3	4G-FAP-5	-77	5G-FAP-11	-59
4	5G-FAP-11	-60	-	-
5	5G-FAP-11	-67	-	-
6	5G-FAP-11	-75	4G-FAP-4	-65
7	4G-FAP-4	-63	-	-
RSS-based Handover Approach				

Position	Serving BS ID	Serving BS RSS	Target BS ID	Target BS RSS
1	5G-FAP-9	-64	4G-FAP-5	-57
2	4G-FAP-5	-59	-	-
3	4G-FAP-5	-72	5G-FAP-11	-59
4	5G-FAP-11	-71	4G-FAP-3	-52
5	4G-FAP-3	-60	5G-FAP-12	-52
6	5G-FAP-12	-59	-	-
7	5G-FAP-12	-66	4G-FAP-4	-62

TABLE VII

PATH 3 CAPACITY AND HANDOVER RESULTS

Position	Serving BS Capacity	Target BS Capacity	Handover Occurs
1	210	-61	Yes
2	-	-	No
3	220	-59	Yes
4	-	-	No
5	-	-	No
6	290	-65	Yes
7	-	-	No

Accordingly, the proposed approach was able to reduce the number of unnecessary handovers. The average number of handovers occurred at densely deployed femtocell environment was 3 comparing to an average of 5 handovers using the conventional RSS-based approach. In addition, using proposed approach, the average delay during all simulation scenarios conducted over all three paths was (55.15 ms) comparing to (68.6 ms) achieved by RSS-based approach. This is due to including user's direction and BS capacity in the target BS selection, allowing handover decision to be context adaptive and more accurate. Reducing the number of handovers and the new structure of handover phases have positively improved the perceived network QoS. In which, handover processing delay was reduced and AP capacity resources were efficiently utilized.

IV. CONCLUSION

This paper investigates performance drawbacks that occurs during handover taking place at dense femtocell environments. A new handover management approach was presented improving the handover decision accuracy. Two new parameters described as user direction, and BS capacity were utilized along with BS RSS to decide wither handover is executed or not. The proposed approach has redefined major handover phases and allowed an improved adoption of handover management into femotocell environment. A new simulation tool was developed using visual C++ programming language presenting dense deployment of 4G and 5G networks and considering all environmental conditions. Comparing to conventional RSS-based handover method, results confirm that the proposed approach reduced number of unnecessary handovers and achieved an improved delay performance. In future work, more performance measures will be considered during simulation also the of machine learning into the handover decision will be investigated.

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