Improvement of the LTE handover algorithms in terms of quality of service

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ABSTRACT

With the emergence of new possibilities and user requirements in the field of mobile technology, long term evolution (LTE) is the most popular as it offers high-speed service. LTE is a 4G wireless network developed by the 3rd generation partnership project (3GPP). The implementation of LTE is strongly affected by the quality of service (QoS) when transfer management is the main issue. Handover management allows communication to be maintained when switching from one base station to another. In this paper, we explain that there are several types of transfers that are not efficient in terms of quality of services such as throughput, signal-to-interference-plus-noise ratio (SINR), and latency. For this purpose, we thought of creating a new algorithm on the A1 and A3 events and the reference signal received quality (RSRQ). Our algorithm is effective compared to other already available algorithms using the NS3 network simulator.

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1. INTRODUCTION

Long term evolution (LTE) is a mobile communication standard proposed by 3GPP [1]. It provides fast speeds for real-time traffic with a wide range. In theory, LTE can attain speeds of 50 Mb/s Uplink (Ul) and 100 Mb/s Downlinks (Dl) [2]. To achieve high data rates, LTE applies orthogonal frequency division multiple access (OFDMA) on the downlink and single-carrier frequency division multiple access (SC-FDMA) on the uplink and meets the delay requirements of real-time traffic [3]. To have a good QoS at the LTE level, it is crucial to ensure it at the handover level.

Handover is a procedure that allows users to move freely within a network without interrupting conversation or data transfer [4]. In LTE mobility management is distributed, and eNodeBs decide to handover autonomously without intervention from other equipment: mobility management entity (MME) and serving gateway (SGW) [5]. The information necessary for the handover is communicated between the eNodeBs via an X2 interface [6]. The MME and SGW obtain a notification with a handover message after the new connection has been established from the UE to the new eNodeB [7].

The LTE is a hard handover [4] (handover of the S1 and X2 interfaces). The implementation of hard handover minimizes the complexity of the LTE network architecture. However, hard handover can introduce inefficient LTE performance (i.e., increased number of handovers, reduced system throughput, and increased system latency). Consequently, an efficient handover algorithm can maximize system throughput while reducing the number of handovers and system delays.

Transfer algorithms are used to make transfer decisions. A handoff is triggered if several conditions specified by the handoff algorithm are achieved. Due to the mobility of users, the conditions of the handover algorithm may change over time. Hence, it is required to determine optimization parameters to provide the efficiency and reliability of the handover algorithm.

In the remainder of the paper, the thoughts are organized as follows: section 2 introduces the work related to LTE handover algorithms. In section 3, we present a new handover algorithm. This section shows the architecture of the LTE EPC module. Then the proposal of the A1-A3-RSRQ algorithm. The simulation parameters and the result comparison are detailed at the end of this section. In the conclusion, section 4 summarizes this work.

2. RELATED WORK

This part describes various types of LTE handover algorithms. The construction of the handover algorithm is based on a variety of factors (received reference signal power (RSRP), reference signal received quality (RSRQ), signal-to-interference-plus-noise ratio (SINR), handover margin (HOM), time to trigger (TTT), and the events). These parameters are not always reliable for achieving good mobility.

RSRP is a measure of cell-specific signal power that serves as an input for resection and cell handoff decisions. For a given cell, RSRP takes the form of the average power (in watts) of the resource elements (REs) that transport cell-specific reference signals (RSS) in the bandwidth in question [8]. RSRQ is a measurement of cell-specific signal quality. This measurement is used to evaluate the signal quality of various candidate cells. It is similar to the RSRP measurement [8]. SINR is the received signal level ratio and the sum of interference and noise [8]. HOM, also known as hysteresis margin, is the primary parameter that controls the handover algorithm between two eNBs. The handover process starts if the link quality of another cell is better than the current link quality. The difference in link quality is called the hysteresis value.

TTT is a period the UE waits after the handover condition is satisfied [9]. Thus, the TTS hysteresis delays the handover concerning time, not concerning RSRP. Table 1 describes the different events that trigger the handover.

Table 1. The description of the events [10]

Events	Description
A1	The serving cell is better than the threshold.
A2	The serving cell becomes smaller than the threshold.
A3	A neighboring cell is one offset better than the serving cell.
A4	Neighbor offset is better than the threshold.

After describing the different parameters of LTE handover, we will cite the solutions proposed in the literature:

Zheng and Wigard [11] proposed an integrator handover. The main concept of this algorithm is to integrate the RSRP differences between the source cell and the target cell. The performance of the integrator algorithm is compared with the traditional hard handover algorithm in the LTE system. The simulation results show that the integrator algorithm has a similar performance as the hard handover algorithm based on the analysis of the number of handovers and SINR before and after the evaluation of SINR after the Handover evaluations at different UE speeds.

Anas *et al.* [12] improved the hard handover by adding Received RSS. This improvement is based on RSS with a TTT window. This algorithm reduces the average handover number by increasing TTT window size while decreasing the uplink average SINR.

Lin *et al.* [13] proposed a hard handover algorithm with a medium RSRP constraint, which is a hard handover with a well-known handover constraint in various UE speed scenarios. This handover guarantees high throughput and can maintain a lower system delay (integrator, hard handover, RSS).

The A2-A4-RSRQ algorithm uses the RSRQ measurements from the A2 and A4 events, as illustrated in Figure 1. The A2 event (RSRQ service cells become below threshold) indicates that the UE is receiving a bad signal quality and can benefit from a handoff. Event A4 (RSRQ of the neighboring cell becomes better than a threshold) is deployed to find neighbor cells and take the RSRQ of each connected UE into account, which is stored internally by the algorithm. The algorithm configures the A4 event with a low threshold by default so that the trigger condition (handoff) is always true [14].

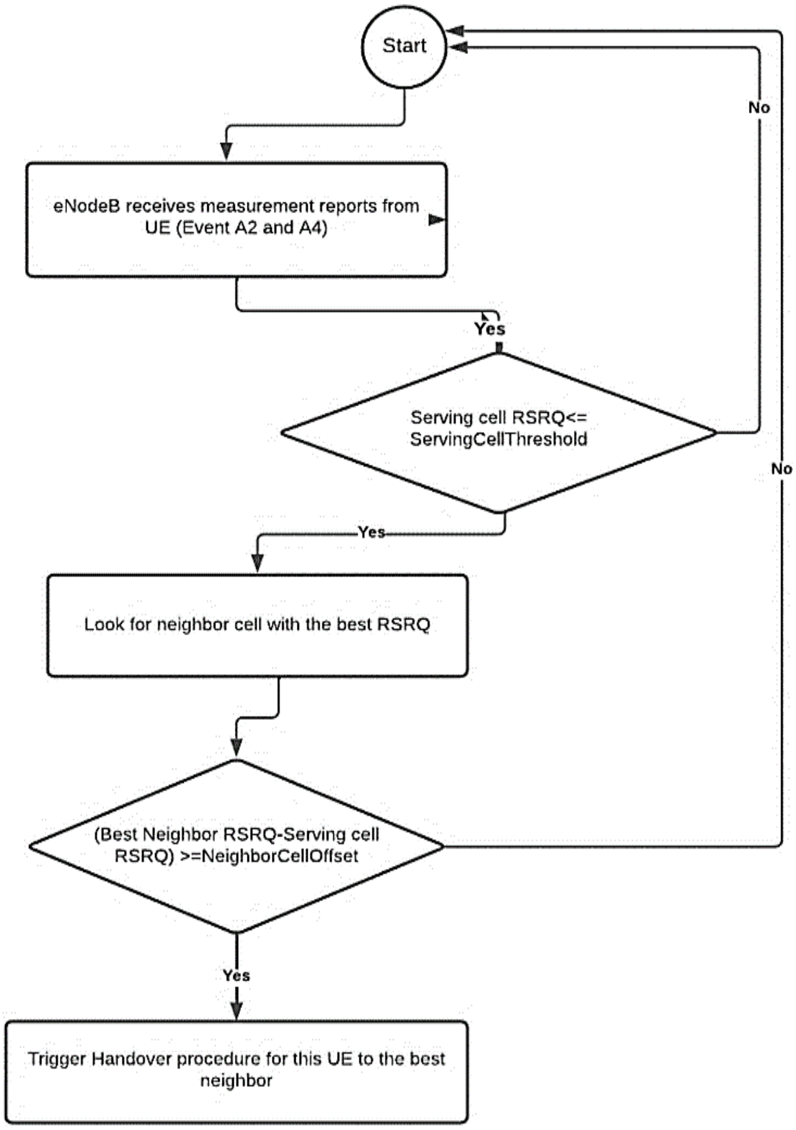

Figure 1. A2-A4-RSRQ algorithm handover [15]

The second A3-RSRP algorithm is known as the traditional power balance algorithm (PBGT) [12]. The objective is to achieve the optimal received reference signal power (RSRP) at each UE node, as illustrated in Figure 2. To achieve this goal, a handover is performed when a best cell (i.e., with higher RSRP) is detected and event A3 (neighboring RSRP cells become better than the RSRP service cells) is selected. The transfer of the UE to the better cell in the measurement report is triggered. A3-RSRP algorithm depends on the hysteresis and triggering time parameters of the UE configuration [16]. The hysteresis delays the transfer of the RSRP. The trigger time delays the transfer in time. Katti *et al.* [17] propose a hybrid handover is the association of A2-A4-RSRQ and A3-RSRP. This combination reduces the number of handovers and increases the throughput.

The A2-A4-RSRQ and A3-RSRP handover algorithms implemented into NS3 are not good at preventing unnecessary handovers such as ping-pong handovers that can produce a poor quality of service channel. In this context, the authors thought of adding the A1 event to the existing algorithms. This new algorithm reduced the number of ping-pong transfers and increased the throughput [18].

In our project, we have to develop a new algorithm for handover for the new generations. For this purpose, our paper proposes a new algorithm based on A1, A3, and RSRQ. We will also compare the performance of this new algorithm with existing algorithms.

Figure 2. A3-RSRP algorithm handover [15]

3. PROPOSED NEW HANDOVER ALGORITHM

In this section, we describe the LTE EPC architecture and the steps of the handover algorithm. Then, the handover algorithm proposition. Finally, a description of the parameters of the simulation and a comparison of results.

3.1. Architecture of LTE EPC module

Figure 3 represents the architecture of the LTE EPC simulation model used in NS3. The LTE EPC model mainly consists of two components, the LTE model and the EPC model [19]. Both models contain a number of protocols.

LTE model: the LTE module contains the LTE radio protocol like radio resource control (RRC), packet data convergence protocol (PDCP), radio link control (RLC), media access control layer (MAC), and physical layer (PHY). These elements still reside within the UE Node and the enhanced base station node (eNB). The LTE model in NS3 has sufficient classes and functions to enable the conception and evaluation of radio resource management (RRM), QoS that assists programming, inter-symbol interference (ISI) access, and spectrum access.

EPC Model: this model contains the interfaces, entities, and protocols. These protocols and entities reside in the SGW, PGW (packet data network gateway), MME, and partially in the eNodeB. The EPC model helps to provide end-to-end IP connectivity and simulate the required topology. It also allows multiple UEs to the Internet via a radio access network (RAN) with multiple eNBs (advanced base station nodes) connected to the single SGW/PGW node. It includes IPV4 support for packet data networks. SGW and PGW are both deployed in a single node [20].

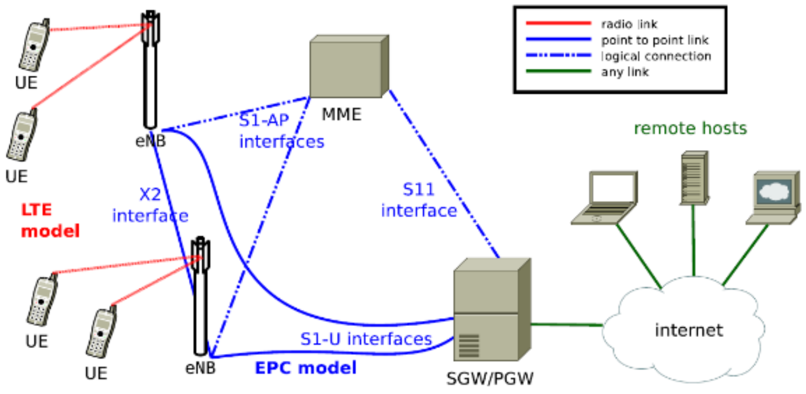

Figure 3. Overview of LTE EPC model [19]

The transfer algorithm runs at the source of the eNodeB. It is assigned to make transfer decisions automatically. It communicates with an RRC instance of the eNodeB via the SAP transfer control interface [21]. The interface of the transfer algorithm contains the different steps:
- AddUeMeasReportConfigForHandover (handover algorithm --> eNodeB RRC): Used by the handover algorithm to request measurement reports from the eNodeB RRC entity, passing through the required reporting configuration. This configuration will be used on all future attached UEs.
- ReportUeMeas (eNodeB RRC --> handover algorithm): In this step, the UE can send measurement reports to the eNodeB using UE measurements previously configured in AddUeMeasReportConfigForHandover. The eNodeB RRC entity employs the ReportUeMeas interface to pass these measurement reports to the handover algorithm.
- TriggerHandover (handover algorithm --> eNodeB RRC): The handover algorithm can announce a transfer after evaluating the measurement reports. This procedure is employed to communicate this decision to the eNodeB RRC entity that will start the transfer procedure.

3.2. Proposed algorithm

The objective of proposing a new handover algorithm is to evolve the metrics like throughput, SINR, and response time in the LTE module for 4G networks. The proposed handover algorithm focuses on two events A1 and A3, and the RSRQ value. The A1-A3-RSRQ algorithm is based on measurements of RSRQ of A1 and A3 events as shown in Figure 4. Event A1 (service becomes Improvement of the LTE handover algorithms in terms of quality of service 7 better than the threshold) indicates that ServingCellRSRQ is above the threshold. If the condition is verified it will look for the neighbor cell that has the best RSRQ. After it passes the condition of event A3 (neighbor becomes better than PCell). If it succeeds it will trigger the handover.

In the LTE module, there are two algorithms: A3-RSRP and A2-A4-RSRQ. We introduce a new transfer algorithm to enhance the management of transfers in the LTE module. We will compare them with A2-A4-RSRQ and A3-RSRP.

3.3. Simulation results

3.3.1. Work environment

NS3 [22] is an open-source platform for network simulation. It is useful in network research. It implements several modules such as LTE and WIFI. The use of NS3 consists in executing the handover algorithms in the LTE module.

3.3.2. Specification parameters

Different parameters have to be taken into consideration when executing the handover (handover compaign). These parameters are assigned default values at runtime. Table 2 describes the parameter configuration for (the handover compaign) [23].

Table 2. The parameter configuration for (handover compaign) [23]

Parameter name	Description
SimTime	Simulation duration
NBlocks	Disabling apartment buildings and femtocells
NMacroEnbSites	Number of macrocell sites (each site has 3 cells)
NMacroEnbSitesX	The macrocell sites will be positioned in a 2-3-2 formation
InterSiteDistance	500 m distance between adjacent macrocell sites
MacroEnbTxPowerDbm	46 dBm Tx power for each microcell
EpcDl	Enable full-buffer DL traffic
Epc	Enable EPC mode
EpcUl	Enable full-buffer UL traffic
UseUdp	Disable UDP traffic and enable TCP instead
MacroUeDensity	Indicates the number of UEs (translates to 48 UEs in our simulation)
OutdoorUeMinSpeed	Minimum UE movement speed in m/s (60 km)
OutdoorMaxSpeed	Maximum UE movement speed in m/s (60 km)
MacroEnbBandwidth	5 MHz Dl and Ul bandwidth
GenerateRem	(Optional) For plotting the Radio Environment Map

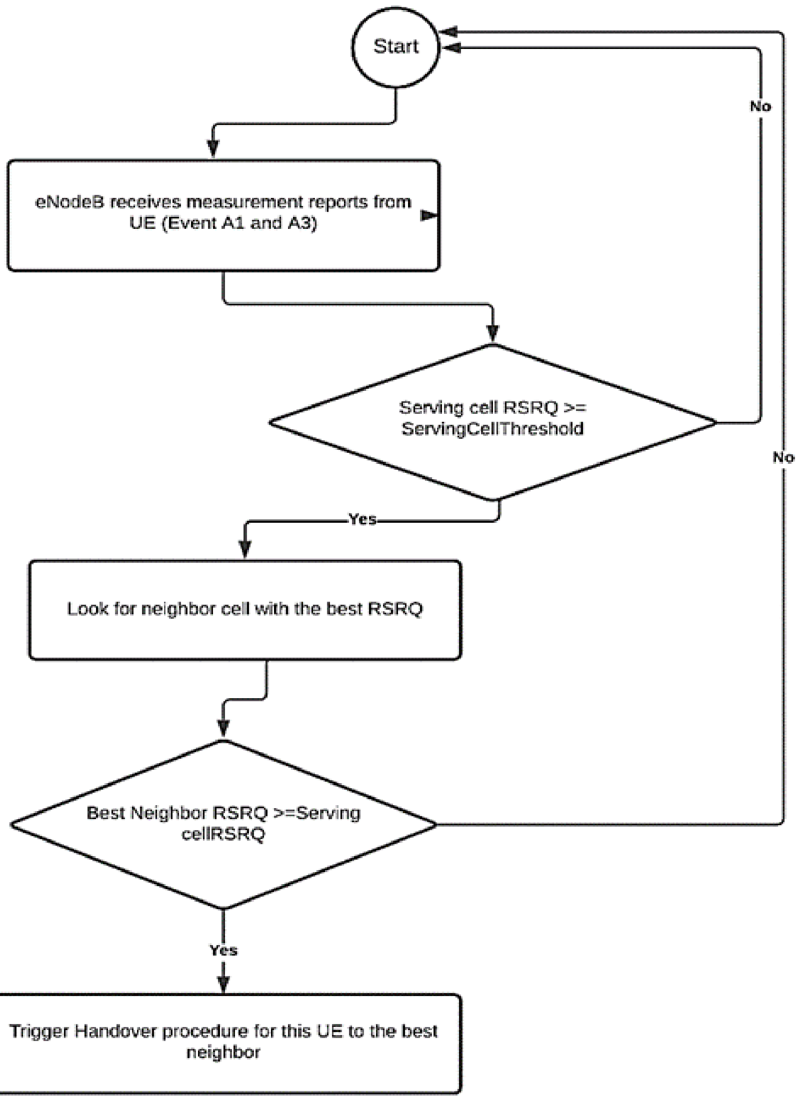

Figure 4. A1-A3-RSRQ algorithm handover

Some parameters such as Lena-dual-stripe are not available. We override the default attributes to the handover compaign. Table 3 indicates the name of the default parameter value in the following handover algorithms A2-A4-RSRQ and A3-RSRP. Additionally, it describes the file names generated during the execution.

Table 3. The default parameter value in the different algorithms [23]

Parameter name	Description
HandoverAlgorithm	A3-RSRP handover algorithm A2-A4-RSRQ handover algorithm
DlRlcOutputFilename	Dl RLC trace output file name
UlRlcOutputFilename	Ul RLC trace output file name
DlRsrpSinrFilename	The output file name of the RSRP/SINR trace for Dl PHY
UlRsrpSinrFilename	The output file name of the RSRP/SINR trace for Ul PHY

3.3.3. Comparison of results

NS3 [24] offers many possibilities for transmitting configuration values in a simulation. In this application, we are using command line arguments. This is mainly achieved by adding the parameters and their values to the waf call at the beginning of each particular simulation. The results obtained are processed at the GNU octave [25] level to derive the necessary information such as throughput, SINR, and latency. To evaluate the importance of the A1-A3-RSRQ algorithm, we have exploited our results using the GNUPLOT [26] for good visibility. The (1) calculation of throughput in the direction Ul and Dl with RxBytes is an output parameter of the RlcOutputFilename. The (2) calculation SINR in Ul and Dl with Sinr is an output parameter of RsrpSinrFilename.

$$Throughput = sum\,(Ul/DlRxBytes) * 8/1000\,/simTime \quad (1)$$

$$Sinr = 10 * log10\,(mean\,(Ul/DlSinr)) \quad (2)$$

Figures 5, 6, 7, 8, and 9 describe the throughput (Ul and Dl), SINR (Ul and Dl), and, the latency of all algorithms (A1-A3-RSRQ, A3-RSRP, A2-A4-RSRQ). In this subsection, we describe a result-based analysis for these simulation parameters. We used 3 simTime (5,10,20).

Figure 5 shows that the downlink throughput is good for A3-RSRP 10s and A2-A4-RSRQ for the 20s. Figure 6 shows that the uplink throughput is fast at 10s and 20s for the A2-A4-RSRQ algorithm. Hence, at 5s, A3-RSRP is high. Figures 7 and 8 represent the comparison of SINR in Ul and Dl respectively. For Ul SINR, A1-A3-RSRQ performs well in 5s and 10s, but for the 20s it is A3-RSRP. For the Dl SINR, the A1-A3-RSRQ algorithm is efficient in all 3 cases. In Figure 9, we observe that the latency time is reduced for the A1-A3-RSRQ algorithm compared to A3-RSRP and A2-A4-RSRQ. After this simulation, we can say that our new algorithm keeps an important signal quality and has very low latency.

Handover is one of the most fundamental elements in cellular networks. It allows to change the cell without interrupting the conversation or the data transfer, so the response time is essential for handover optimization. For this reason, A1-A3-RSRQ is better than the other two algorithms at reducing response time and increasing SINR.

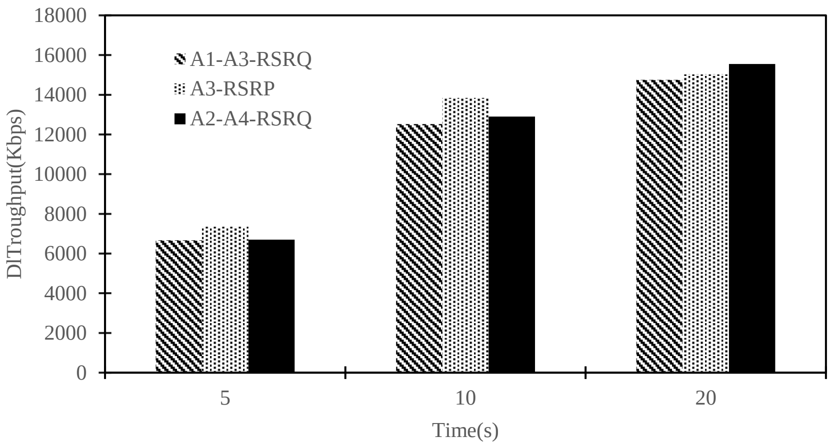

Figure 5. Comparison of DlTroughput

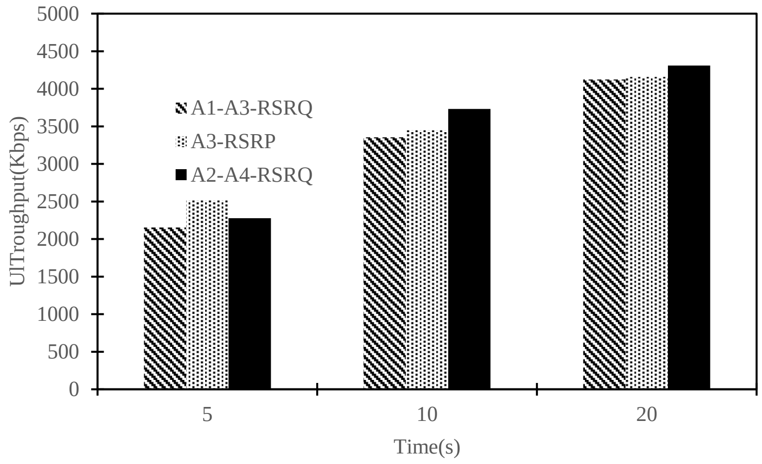

Figure 6. Comparison of UlTroughput

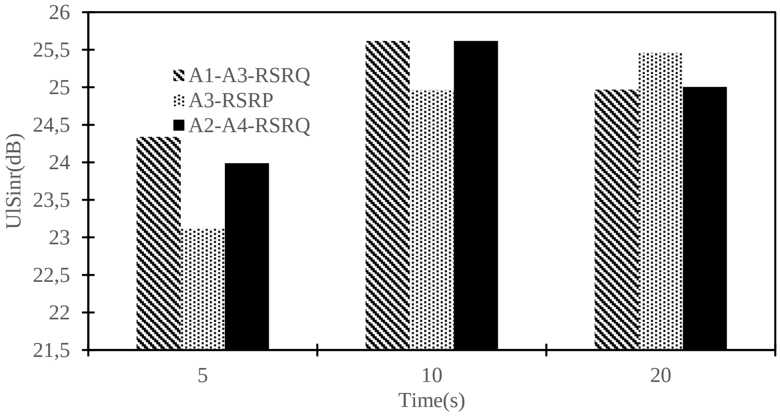

Figure 7. Comparison of UlSinr

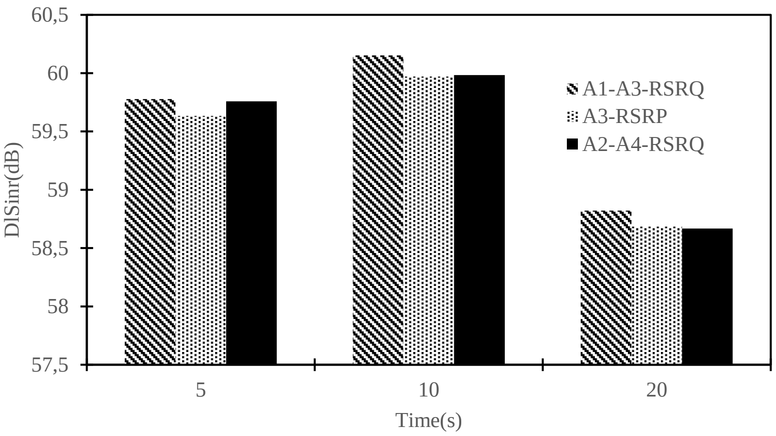

Figure 8. Comparison of DlSinr

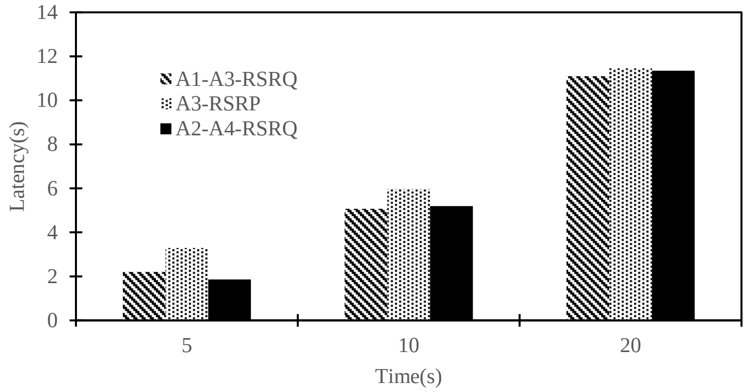

Figure 9. Comparison of latency

4. CONCLUSION

In studying the two existing algorithms: A2-A4-RSRQ and A3-RSRP. A new A1-A3-RSRQ algorithm is proposed with two events A1, A3, and the RSRQ value. We present a model for the use of this new algorithm in the LTE module for handover management. The performance of the algorithms has been studied by simulation in NS3 based on different parameters; throughput, SINR, and latency. The results of the simulation showed that this algorithm is best at latency and signal quality. For our future works, we think to have created a new algorithm for handover at the level of the fifth generation.

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