Fuzzy Logic-Based Handover in 3GPP LTE Network

Parul Datta and Sakshi Kaushal

Abstract In today's world, people use Internet services and access applications on their mobile phones anywhere in the world. Wireless communication networks such as Third Generation Partnership Project's (3GPP's) Long Term Evolution (LTE) assist people to access Internet on their mobiles at high speed and in a seamless manner. When mobile devices move from a network from time to time, they need to be handed off to another network in order to provide users with same quality of service (QoS). In this paper, a FL-based handover scheme in LTE network is presented by considering parameters like received signal strength (RSS), data rate, and network coverage area. The handover scheme is implemented through simulation in NS-2. The results show improved packet delivery ratio (PDR) and decreased packet loss.

Keywords LTE · Fuzzy logic · Handover · RSS · PDR

1 Introduction

Wireless telecommunications networks are implemented to provide high-speed Internet access on mobile devices. For this purpose, many new technologies like Third Generation Partnership Project (3GPP) Long Term Evolution (LTE) were developed. Wireless network technologies are required to effectively exchange images and live video streams. LTE provides users with an all-IP solution at anytime and anywhere basis for data and voice traffic. Fourth-generation systems have two candidate systems: WiMAX and LTE [1]. LTE network architecture has two parts: E-UTRAN and EPC. Communications between the mobile nodes and the evolved

P. Datta (✉) · S. Kaushal
Computer Science and Engineering Department, UIET Panjab University, Chandigarh, India
e-mail: paruldatta14@gmail.com

S. Kaushal
e-mail: sakshi@pu.ac.in

D. Mandal et al. (eds.), *Intelligent Computing and Applications*,
Advances in Intelligent Systems and Computing 343,
DOI 10.1007/978-81-322-2268-2_23

packet core (EPC) are handled by evolved universal terrestrial radio access network (E-UTRAN) [2]. E-UTRAN has only one component, i.e., evolved node B (eNB). The mobile nodes are controlled by eNB. The base station communicating with a mobile node will become its serving eNB. The EPC network has the following components: The Home Subscriber Server (HSS) is a central database containing information about subscribers of network operator. A default router for the user equipment (UE) and for communication with the outside world using SGi interface is packet data network gateway (P-GW). The data are forwarded between E-UTRAN and P-GW by serving gateway (S-GW). The high-level operations of managing mobiles and their sessions are controlled by mobility management entity (MME).

When an ongoing call or data session is transferred from one channel to another, it is known as handover. There is a possibility of handover in any technology [3]. The desirable features in handover process are as follows: It should be fast enough, low latency, QoS should be minimally affected, additional signaling during handover should be minimized, etc. Also, there are several handover performance metrics which should be considered for successful handover mechanism: handover call blocking probability, rate of handover, probability of unnecessary handover, etc. During handover, certain characteristics of a network like quality of service (QoS), throughput, performance of network, cost, and handover latency should be considered so as to satisfy user. Call dropping and latency should be minimized. Considering user needs, call termination, interference in signal, and several other handover failure reasons should be avoided as much as possible. In order to avoid handover failure, handover should be prioritized, i.e., different methods should be incorporated to handle and manage handover requests. Prioritization will avoid abrupt termination of ongoing calls.

The paper is organized as follows: Section 2 gives a brief insight into literature review. Section 3 gives FL-based handover algorithm. Section 4 presents the simulation analysis and results, and Sect. 5 concludes the paper.

2 Related Work

So far, a large number of researchers have discussed the handover issues by considering different QoS parameters. Some have considered received signal strength (RSS) and velocity of mobile terminal, while others considered RSS, data rate, network coverage area, etc., for effective handover management in LTE networks. Some of the schemes are discussed below.

LTE network has become the network technology choice for 4G deployments around the world. LTE's vision of wireless access has resulted in a comprehensive transition toward packet-switched only system as LTE represented significant shift from legacy mobile systems to all-IP network. LTE's all-IP architecture enables seamless delivery of applications and services. Authors in [4] have presented LTE specifications. Release 99 defined original dual-domain UMTS system supporting both circuit-switched voice services and packet-switched access. Release 4 was the circuit-switched architecture which was bearer-independent. Release 5 through 7 increased the efficiency and improved data rates. Release 8 marked the start of transition to 4G technologies. Release 9 offered enhancements to LTE which included home evolved node base stations (eNBs) for improved residential coverage. Release 10 defined LTE-Advanced (LTE-A) which includes operational efficiencies by supporting self-optimizing, self-healing capabilities. Also, various LTE QoS Class Identities are discussed. Class identity represents QoS features a bearer offers. Network operators preconfigure class identity characteristics in each eNB. Each data path in LTE is assigned a set of QoS criteria. For users requiring different services, additional bearer paths are added. To harvest the benefits of LTE, network operators face many challenges such as migration strategies from legacy 2G/3G networks and deployment of IP networks to deliver low latency in order to support real-time QoS. Deploying LTE to meet such challenges will lead to improved network performance and overall cost savings across the network. LTE introduced IP-based architecture, with radio resource management and mobility management, where handover decisions are made by eNBs [5]. During intra-system handover, UEs are not connected to the system for some time. This is the time, i.e., detach time, when user traffic is being forwarded from source eNB to target eNB. Length of this time and some extra delay may lead a decrease in QoS. The traffic is prioritized based on the service: handover control messages having highest priority, VoIP messages having second highest priority, and data traffic having least priority. A strict priority scheduler was implemented in routers which follows the prioritization scheme. The priority scheme and alternative hierarchical scheduling architecture improved the performance of the system in terms of data rate, latency, and cost.

Efficient vertical handover algorithm needs to be designed which maintains network connection and provides acceptable resources to ongoing services is a challenging issue. Handover mechanism has three steps: Initiation is done by measuring RSS and mobile terminal velocity, the decision is taken using FL, and execution is done using Mobile IPv6. In [6], Next Generation Vertical Handover Decision Algorithm (NG-VDA) has been proposed to perform vertical handover between LTE and next generation wireless LAN. Parameters such as bandwidth, signal-to-noise ratio, life of the battery, and load on the network are considered. FL has been used to know most critical parameter for efficient system performance. FL system has three parts: Fuzzifier which converts crisp input into a fuzzy variable, the variables are used in rule base of inference engine and defuzzifier for converting fuzzy variable into a number called Handover Authorization Unit which takes final decision for handover. The proposed algorithm helped in achieving efficient vertical handover.

Reduction in handoff blocking probability is very important in order to improve QoS. Users get more frustrated when an ongoing call is dropped and not when a new call (NC) is denied admission [7]. A connection admission control (CAC) scheme is designed to reduce handoff dropping. Call admission scheme is used to prioritize handoff call (HC) over NC. A resource block is reserved and priority is given to handoff requests in admission. Three types of services are considered: VoIP, video streaming, and data on demand. On arrival of HC and NC calls to an overloaded cell, the NC will await acceptance by storing NCs in specific queues.

For acceptance of HC, a degradation procedure is triggered to degrade number of resource blocks (RBs) allocated to some ongoing calls and to allocate those RBs to HCs. When a call leaves the cell, total available bandwidth is increased. The proposed RB reservation algorithm uses increased or decreased RBs for calls in a cell. This algorithm achieved an improvement over call blocking probability, decreased dropping probability, and better resource utilization.

In [8], the authors have done in-depth comparison of LTE and WiMAX by considering different parameters. The comparison is divided into three parts: throughput comparison of downlink in time division duplexing (TDD); uplink TDD throughput results and LTE throughput in TDD; and frequency division duplexing (FDD) mode to understand LTE throughput in a better way. Performance of LTE is better in downlink and uplink. In [9], the authors have presented comparative study on network architecture and security of LTE and WiMAX networks. A research test bed was developed to gain insights into 4G wireless network in the enterprise, integration challenges, and key research problems. Both WiMAX and LTE have their own specified network architecture. WiMAX has BS, ASN gateway, AAA server, HA server, and some other components. LTE has eNB, S-GW, P-GW, MME, and HSS. In security architecture of WiMAX, authentication process uses either EAP_TTLS or EAP_TLS which uses private certificates and enterprise controlled username and password. In security architecture of LTE, authentication process uses EAP_AKA which requires new ways to integrate enterprise credentials. Authors concluded that both WiMAX and LTE can be deployed by enterprises as both provide high capacity, wide coverage range, QoS mechanisms, and security by using enterprise authentication.

For efficient handover decision making, more intelligent approaches need to be applied to improve the performance results for both the user and the network. The authors in [10] introduced a new adaptive vertical handover decision algorithm in which genetic algorithms are used to optimize fuzzy membership functions. The authors proposed a smart mobile terminal (SMT) to scan the environment for available radio access technologies (RATs). It evaluated the working condition of RATs using its newly developed hybrid fuzzy-genetic algorithm-based vertical handoff algorithm, triggers handoff process, if necessary, and chooses the best access point (AP) to camp on. Genetic algorithms are based on adaptive search techniques based on genetic rules to shape fuzzy membership functions. The proposed algorithm improved the performance by determining whether a handoff is required or not and noticeably reduced the number of handoffs. Managing mobility with seamless handoff and QoS guarantees is vital in 4G wireless networks. Mobility management enables location of roaming terminals to deliver data packets and maintaining connections when moving to new subnet. Current mobility management schemes have many disadvantages such as traffic overhead, high packet loss, high handoff latency, etc. In [11], the authors have proposed efficient handoff protocol for 4G called Handoff Protocol for Integrated Networks. The protocol alleviated service disruption. It also allowed seamless roaming and service continuity across various networks. The results showed improvement in performance as compared to existing schemes in terms of handoff blocking probability.

3 Fuzzy Logic-Based Handover Algorithm

A simple way to reach specific conclusion based upon unclear information is defined as fuzzy logic (FL) [12]. FL does not have any crisp limits. Range of FL variables lies between 0 and 1. Rule-based FL incorporates a simple rule-based approach to solve a problem. Fuzzy analysis follows three basic steps: fuzzification of inputs, fuzzy inference, and defuzzification for obtaining crisp output. Syntax of rule-based FL is shown in Eqs. (1) and (2).

$$\text{IF } x \text{ THEN } y \tag{1}$$

$$\text{IF } x \text{ and } y \text{ THEN } z \tag{2}$$

In this study, rule-based FL is considered to take decision whether to do handover or not based on RSS values measured by the UE. Three input parameters are considered, and fuzzy sets are assigned to each of them. Fuzzy set values for RSS, data rate, and network coverage area consists of high, medium, and low. There are three input parameters and three fuzzy sets for each input parameter, respectively. Hence, the maximum possible number of rules in our rule base is the following: $3^3 = 27$.

3.1 Fuzzy Rule Base

Table 1 presents the rules used in this study in which RSS, data rate, and network coverage area are checked for their values, i.e., high or medium or low. Based on the above rules, decision is taken whether to do handover or not. The RSS value indicates that how well the signal is being transmitted by the AP and is reaching the node [13]. On the other hand, RSS does not indicate how well the AP is hearing. RSS depends on a number of factors such as output power of transmitter, sensitivity of receiver, the gain of antennae at both ends of path, path loss, and attenuation of signal as it passes from transmitter to receiver. Sometimes due to low power levels and attenuation of free space, RSS value is expressed as a negative number. The more negative the number, the weaker the signal strength; on the other hand, if the number is closer to zero, then the signal strength is stronger.

The following steps helped in the handover process:

- Initially, UE is connected to a base station known as source base station. When UE experiences low-quality signal, it will measure RSS of source base station, i.e., the base station it is currently connected to and that of the target base station, i.e, the base station it will connect to in future.
- If the RSS of target base station is greater than that of the source base station, UE will handover itself to the target base station.
- RSS is calculated by the formula given below in Eq. (3) [14]:

Table 1 Fuzzy rule base

No.	(IF) RSS (is)	(and IF) data rate (is)	(and IF) network coverage area (is)	(THEN) HO decision (is)
1.	Low	Low	Low	Yes perform HO
2.	Low	Low	High	Probably yes
3.	Low	Medium	High	Probably yes
4.	Low	High	High	Probably yes
5.	Medium	Low	High	Probably no
6.	Medium	Medium	High	Probably no
7.	Medium	High	High	No
8.	High	Low	High	No
9.	High	Medium	High	No
10.	High	High	High	No
11.	Low	Low	Medium	Yes perform HO
12.	Low	Medium	Low	Probably yes
13.	Low	High	Medium	Probably yes
14.	Medium	Low	Low	Yes perform HO
15.	Medium	Medium	Medium	Probably no
16.	Medium	High	Low	Probably yes
17.	High	High	Low	Probably no
18.	High	Low	Medium	No
19.	High	Medium	Low	No
20.	High	High	Medium	No
21.	Low	Medium	Medium	Yes perform HO
22.	Low	High	Low	Yes perform HO
23.	Medium	Low	Medium	Probably yes
24.	Medium	Medium	Low	Probably no
25.	Medium	High	Medium	Yes perform HO
26.	High	Low	Low	Yes perform HO
27.	High	Medium	Medium	Probably no

$$\mathrm{RSS} = \mathrm{Pt} * \mathrm{Gr} * \mathrm{Gt} * \left(\frac{\pi * \pi * d * d}{16}\right) \tag{3}$$

where *Pt* is transmit power, *Gt* is antenna gain of transmitter, *Gr* is antenna gain of receiver, and *d* is the distance $\sqrt{(X_2 - X_1)^2 + (Y_2 - Y_1)^2}$.

Fuzzy handover decision is determined by using the formula [15] given below:

$$\text{Handover Probability} = \frac{\sum Mi * Wi}{\sum Mi} \tag{4}$$

where *Mi* is the membership degree defined as 0.3 for low, 0.5 for medium, and 1 for high and *Wi* is the handover probability weight value as considered from Table 2.

Table 2 Table for handover probability weight values

Value	Yes	Probably yes	No	Probably no
Weight	1	0.8	0.2	0.4

To determine when handover is required, the handover probability is computed and is used as follows: If handover probability >0.65, then initiate handover otherwise do nothing. In this work, after applying the defuzzification step, handover probability is obtained as:

$$\text{Handover Probability} = \frac{0.3 * 0.8 + 0.5 * 0.8 + 0.3 * 0.8}{0.3 + 0.5 + 0.3} = 0.8$$

As the calculated value of handover probability, i.e. 0.8, is greater than the defined threshold of 0.65, handover will be initiated and UE will connect to target base station with better QoS parameters.

3.2 Algorithm

The algorithm describes handover process in which UE is initially connected to source eNB and is periodically measuring the RSS of source eNB. If UE experiences low RSS, then it will check data rate. If data rate is also low, then network coverage area is checked. If network coverage area is also low, then RSS of target eNB is measured. If RSS of target eNB is greater than that of source eNB, then perform handover. The data rate input parameter is defined from 0 to 55 Mbps. The network coverage area is defined from 0 to 30 km.

Handover Algorithm.

BEGIN
Step 1: UE connected to source eNB
Step 2: UE periodically measures RSS of source eNB
Step 3: If RSS is low go to step 3.1
Else go to step 4
Step 3.1: If data rate is low go to step 3.2
Else go to step 4
Step 3.2: If network coverage area is low then measure RSS of target base stations go to step 3.3
Else go to step 4
Step 3.3: If $RSS_{source\ eNB} < RSS_{target\ eNB}$ then perform handover
Else go to step 4
Step 4: No need of handover
Step 5: UE connects to target eNB
END

4 Simulation Analysis and Results

4.1 Packet Delivery Ratio

Packet delivery ratio (PDR) is the ratio of number of delivered data packets to the destination to the number of packets that have been sent [16]. PDR is calculated by the formula given in Eq. (5). Figure 1 shows graph for PDR versus simulation time.

$$\mathrm{PDR} = \frac{\sum(\text{Number of packets delivered})}{\sum(\text{Number of packets sent})} \tag{5}$$

The simulation trend seen in Fig. 1 for PDR depicts that more packets are reaching the destination after handover; hence, PDR improved by 30 %.

4.2 Packet Loss

Packet loss is the total number of packets dropped during simulation [16]. Packet loss is calculated by the formula given in Eq. (6). Decreased packet loss leads to better performance. Figure 2 shows graph for packet loss versus simulation time.

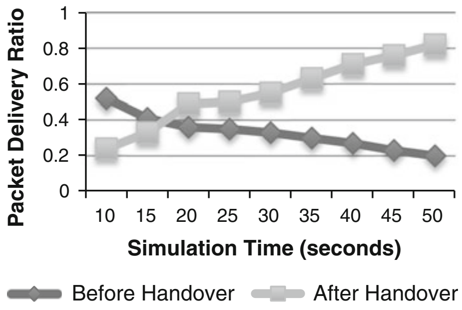

Fig. 1 Graph for packet delivery ratio versus simulation time

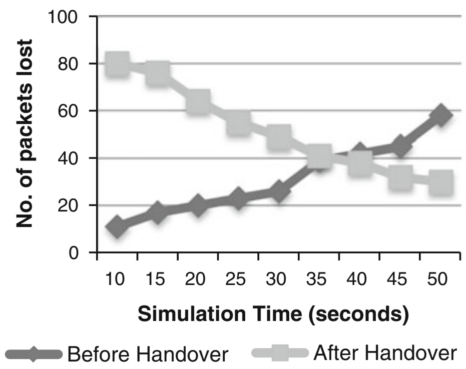

Fig. 2 Graph for packet loss versus simulation time

$$\text{Packet Loss} = \text{Number of packets sent} - \text{Number of packets lost} \quad (6)$$

The simulation trend seen in Fig. 2 for packet loss depicts that number of packets dropped after handover are less in comparison if no handover is performed; hence, packet loss decreased by 33 %.

5 Conclusion

In this paper, certain QoS parameters like PDR and packet loss are improved by performing handover. The simulation results show that PDR increased by 30 % after handover. There is a significant increase in PDR after handover. So, handover in this case is vital as it leads to an increase in PDR and hence, better network performance. The simulation results also show that packet loss decreased by 33 % after handover. Packet loss decreased significantly after UE is connected to target base station. Handover led to decrease in packet loss as reduction in packet loss is considered good for a network to perform better. Future works will focus on using artificial neural networks and genetic algorithms.

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