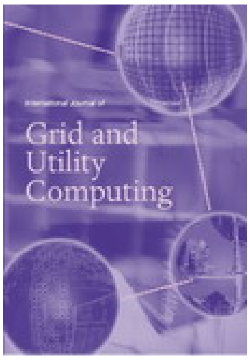

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A fuzzy-based system for handover in 5G wireless networks considering different network slicing constraints: a comparison study of two implemented models

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Abstract: In this paper, we present a fuzzy-based system for handover in 5G wireless networks considering different network slicing constraints. We implement two Fuzzy-based Handover Models (FBHM): FBHM1 and FBHM2. We evaluate the proposed models by simulations. The FBHM1 considers three input parameters: Slice Delay (SD), Slice Bandwidth (SB), Slice Stability (SS) and the output parameter is Handover Decision (HD). In FBHM2, we consider Slice Load (SL) as a new parameter. From simulation results, we found that the HD value increases as the SD and SL values increase, but the HD value decreases when SB and SS values increase for both models. The simulation results show that the FBHM2 is more complex than FBHM1 but performs better HD since four parameters are considered when making handover decision.

Keywords: 5G wireless networks; SDN; network slicing; fuzzy logic; handover.

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1 Introduction

Due to the massive increase in mobile and smart device usage, 5th generation (5G) wireless networks are facing an enormous challenging to handle wireless data traffic. The primary objectives of 5G are to increase network capacity, reduce costs, increase energy efficiency, enhance internet speed and improve Quality-of-Service (QoS) (Andrews et al., 2014; Eze et al., 2018; Hossain and Hasan, 2015; Chekired et al., 2019).

To meet QoS requirements, three separate usage scenarios are utilised. The enhanced Mobile Broadband (eMBB) offers good accessibility to services and multimedia data connected to human needs, which enhances the quality of the user experience in a dynamic way. While enabling a large number of smart devices, the massive Machine Type Communication (mMTC) considers a long time utilisation. By effectively lowering latency and enhancing dependability, Ultra-Reliable & Low Latency Communications (URLLC) can support working operation in real-time by guarantying QoS. These scenarios can be used in transportation, virtual surgeries and automating of industrial processes (Akpakwu et al., 2018).

These three 5G usage scenarios are unable to meet all the technological requirements for beyond 5G and 6G. Thus, three new enhanced scenarios are proposed. The Ubiquitous Mobile Broadband (uMBB) is an extraordinary improvement in network throughput and capability for hot areas and pervasive intelligence, upgraded onboard communications and universal connection. Massive Ultra-reliable & Low-latency Communication (mULC) mixed the URLLC and mMTC features. This can make utilising large-scale actuators and sensors in vertical industries. Applications demanding both URLLC's feature and extremely high transmission rates are supported by Ultra-reliable and Low-latency Broadband Communication (ULBC) (Jiang et al., 2021).

A new technique called Network Slicing (NS) utilises Software-Defined Networking (SDN) and Network Function Virtualisation (NFV) to provide several types of services over the same physical infrastructure for satisfying users QoS expectations (Zhang et al., 2017). A bundle of network resources designed to fulfil the service's demands is known as a slice. By splitting a network infrastructure into several logical networks, it is feasible to provide individualised and on-demand application in a network with constrained resources. So, users of 5G wireless networks will get better QoS compared with 4G because various slices with different priorities can fulfil different users' demands (Zhang et al., 2017; Jiang et al., 2016; Kim et al., 2018; Omnes et al., 2015).

Many research groups have been focused on developing technologies suitable for 5G wireless networks (Hossain and Hasan, 2015). Using SDN and NFV for corporate, administrative, and technological networks, including extremely massive computing services, is one example. Furthermore, SDN and the mobile handover approach are employed to minimise processing latency. Moreover, the QoS is enhanced by integrating Fuzzy Logic (FL) into SDN controllers (Yao et al., 2018; Lee and Yoo, 2017; Moravejosharieh et al., 2018; Prados-Garzon et al., 2016).

The handover procedure in 5G wireless networks is critical for managing mobility and has the potential to impact the performance of network. There are numerous handover scenarios that could happen, which makes it challenging to provide stable and dependable connections (Sun et al., 2020; Saad et al., 2021). In a network environment with several slices, user mobility should be handled not just across multiple base stations or multiple radio access technologies but also between multiple slices. Inter-slice handover is an unique type handover that considers slice service types instead of focusing on the User Equipment (UE)'s physical mobility while making handovers (Sajjad et al., 2022). Thus, a handover decision should consider NS constraints in order to meet user requirements.

In this paper, we present a fuzzy-based system for handover in 5G wireless networks considering different NS constraints. We implement two Fuzzy-Based Handover Models (FBHM): FBHM1 and FBHM2. In FBHM1, Slice Delay (SD), Slice Bandwidth (SB) and Slice Stability (SS) are three input parameters and Handover Decision is the output parameter (HD). Slice Load (SL) is considered a new parameter for FBHM2, thus FBHM2 has four input parameters.

The rest of the paper is structured as follows. In Section 2 is described SDN. In Section 3, we introduce FL. In Section 4, we present the proposed Fuzzy-based system and its implemented models. In Section 5, we discuss simulation results. Finally, conclusions and future work are given in Section 6.

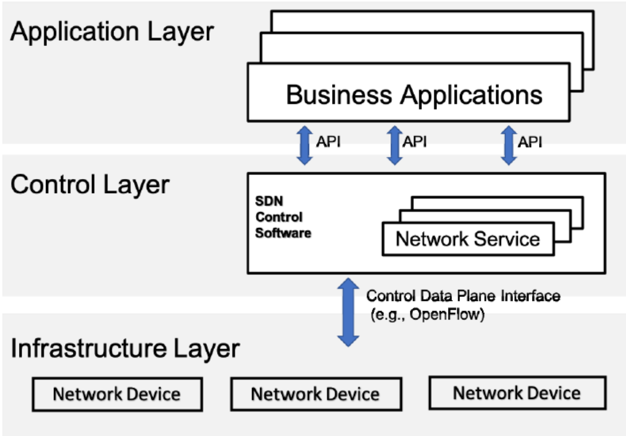
2 Software-defined networking (SDN)

The SDN and NFV approaches can significantly enhance the scalability, flexibility, cost and power usage of mobile networks (Dhruvik et al., 2021). The SDN is a networking technology that manages network traffic by interacting with the underlying physical infrastructure through software-based controllers or Application Programming Interfaces (APIs) (Li et al., 2012; Mousa et al., 2016; Mahmoodi, 2015; Barakabitze et al., 2020).

The SDN structure is shown in Figure 1. It has three layers and two interfaces. The data plane or infrastructure layer is the lowest layer. The forwarding components of the network, such as routers, load balancers and switches, are provided by the Infrastructure Layer, which takes instructions from the SDN controller. The Southbound Interfaces enable communication and interactivity between the Control Plane (Control Layer) and the Data Plane (Infrastructure Layer), which enables the controller to build up rules for the forwarding plane. The Control Layer upon receiving requirements or instructions from the Application Layer manages the Data Plane and transmits various regulations and procedures to the Infrastructure Layer through Southbound Interfaces. Network programming is accomplished through the Northbound Interfaces, which connect the Application Layer with the Control Layer. Application Layer collects information from the controller to build a comprehensive network overview and makes decisions.

By using SDN, the management system can be adaptable for different traffic congestion situations, enabling users to instantly govern and allocate resources effectively across the control plane. It is faster and simpler for mobility management between various radio access technologies. There are several research works utilising SDN in wireless environments. For example in Rizkallah and Akkari (2018), the handover procedure can be performed easily and the delay can be shorten. In Nguyen-Duc and Kamioka (2015) and Dhruvik et al. (2021), the SDN reduces the possibility of losing the connection to the controller and the delay from the controller to the devices with ensures QoS to the UEs during the handover processing.

Figure 1 Structure of SDN (see online version for colours)



3 Outline of fuzzy logic

For expressing human reasoning, a logic based on the two values such as True and False is insufficient. Fuzzy Logic (FL) describes human reasoning by using the entire range between 0 (False) and 1 (Truth) (Jantze, 1998; Mendel, 1995; Wulandari et al., 2018). The FL can process both linguistic information and numerical information simultaneously. Boolean logic is capable of handling assertions that may or may not be true, but FL is capable of handling more than that by dealing with intermediate truth-value. For example, if we use Boolean logic to describe the slice delay, there are only two linguistic values low (0) or high (1). While by FL we can describe by more than two linguistic values such as very low, low, medium, high, very high and so on, which are between 0 and 1 as shown in Figure 2.

Figure 2 Boolean logic and FL (see online version for colours)

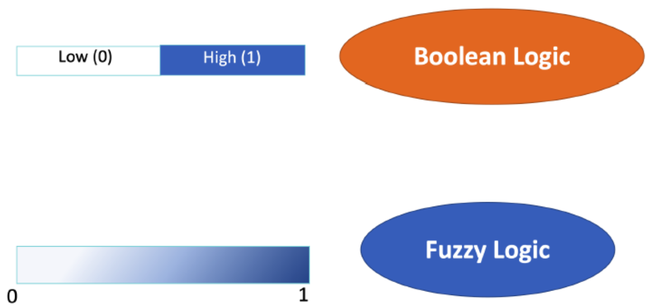


Figure 3 shows the operation of the fuzzy controller. The Fuzzification is the operation of transforming the crisp input to a linguistic variable. The Fuzzy Processing consists of Rules and Inference Engine. Rules can be given by a professional in the field or may be generated from numerical data. The Rules are written as a series of IF-THEN statements in engineering cases. The Inference Engine evaluates all rules and give the fuzzy output. The Defuzzifier converts the fuzzy output that was obtained from the fuzzy inference engine back into crisp value (Lee, 1990). There are various defuzzification techniques such as The Centroid Method, The Centre of Are (COA) Method and Tsukamoto's Defuzzification Method.

3.1 Fuzzy sets

A fuzzy set, which basically consists of the classical set and without a distinct boundary, can include objects that have only a partial degree of membership in the value range from 0 to 1. For instance, a membership number between 0 and 1 can be used to describe the degree of coldness.

3.2 Membership function

The membership function defines how to map each point in the crisp inputs with a degree of membership between 0 and 1 to create a graph as shown in Figure 4. It can characterise fuzziness to represent the degree of truth in FL as shown in Figure 4(a). Usually, more than one membership function can be used to describe a single input variable. To represent a single input variable, i.e., a three-level fuzzy system with the fuzzy sets 'Low', 'Medium' and 'High' is preferable.

In Figure 4(b), the features of trapezoidal membership function consist of three components.

- *Core* is the region of universe which have the membership function as 1 and can be written as $\mu_A(z) = 1$.
- *Support* is the region of universe characterised by nonzero membership and has the elements whose membership is greater than zero. This can be written as $\mu_A(z) > 0$.
- *Boundary* is the region of universe when membership values are between 0 and 1. This can be written as $0 < \mu_A(z) < 1$.

Figure 3 Operation of a fuzzy controller (see online version for colours)

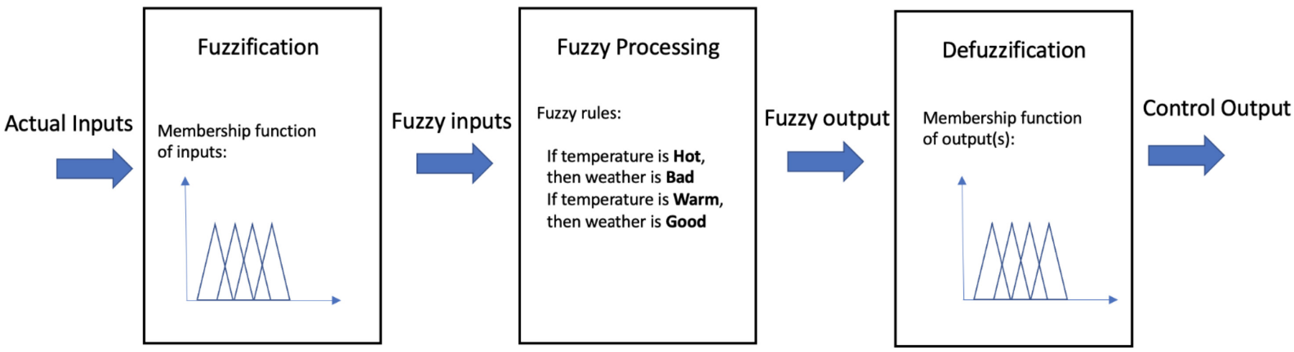
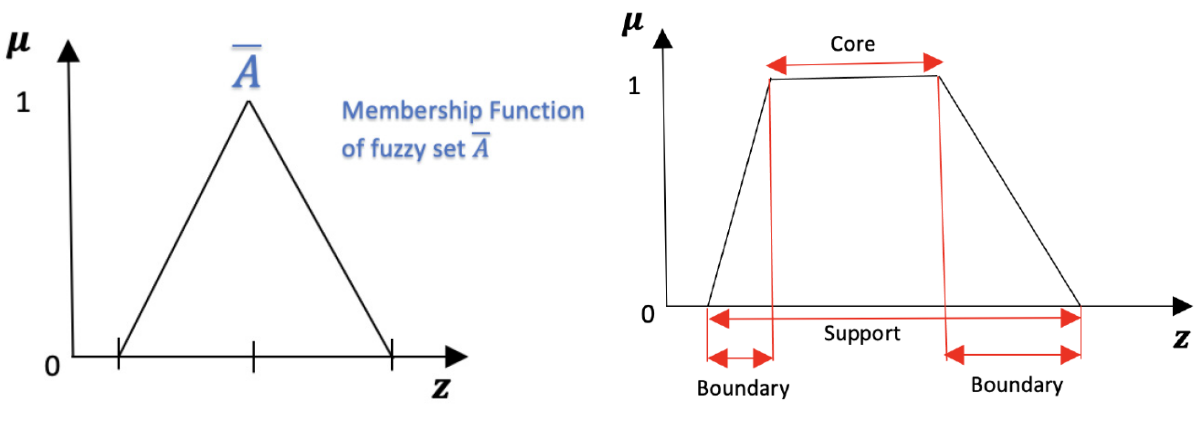


Figure 4 Membership functions (a) Triangular membership function shape (b) Features of trapezoidal membership function (see online version for colours)



(a) (b)

4 Proposed fuzzy-based system

In this section, we present our proposed fuzzy-based system. In Figure 5, we show the overview of our proposed system. The SDN controller will send instructions to each evolve base station (eBS), and these stations can communicate and transfer data to UE. Moreover, a variety of slices with different services are also included in each eBS. The proposed Fuzzy-based system will be implemented in the SDN controller to manage handover process. A communication link between eBS and the 5G core network will be provided by SDN controller.

The proposed system is called Fuzzy-Based Handover System (FBHS) in 5G Wireless Networks. The structure of FBHS is shown in Figure 6. We implement two models: FBHM1 and FBHM2. The FBHM1 considers three input parameters: Slice Delay (SD), Slice Bandwidth (SB), Slice Stability (SS) and the output parameter is Handover Decision (HD). In FBHM2, we consider Slice Load (SL) as a new parameter. The considered parameters are explained in following:

1) *Slice delay (SD)*: High queuing and network delay are produced by the slice delay. As a result, the handover is required to satisfy the QoS.
2) *Slice bandwidth (SB)*: The SB is the available bandwidth of a slice. The possibility of a handover will be lower when SB is higher.
3) *Slice stability (SS)*: The slice with a high level of stability can perform reliable communication. The user will handover to another slice with better stability if the SS is low.
4) *Slice load (SL)*: The high usage of the slice resources by numerous users leads to a heavy load of the slice. In order to receive better QoS, the user will make handover to another slice with a lower load if the SL is high.
5) *Handover decision (HD)*: The HD parameter decides whether or not to carry out the handover process.

Figure 5 Proposed system overview (see online version for colours)

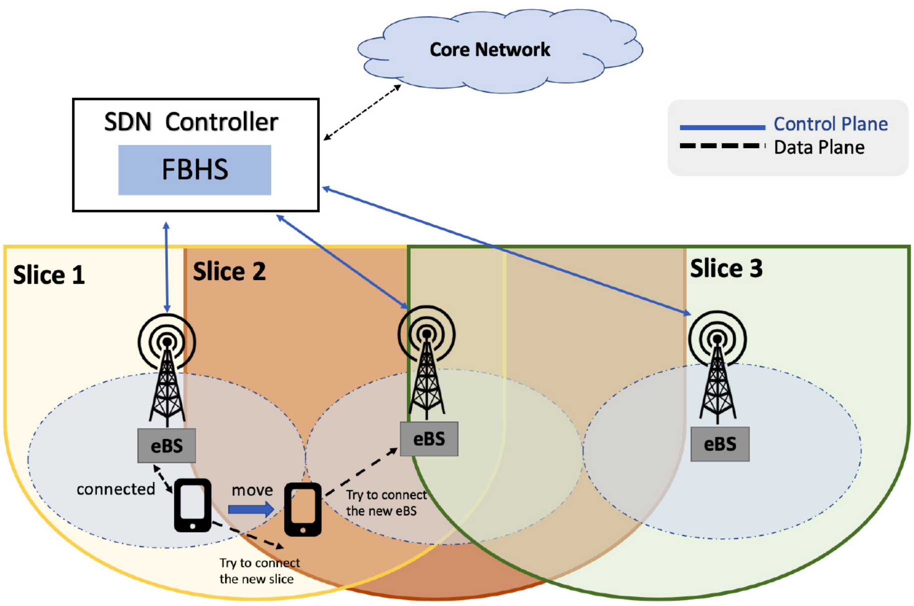


Figure 6 Proposed system structure (see online version for colours)

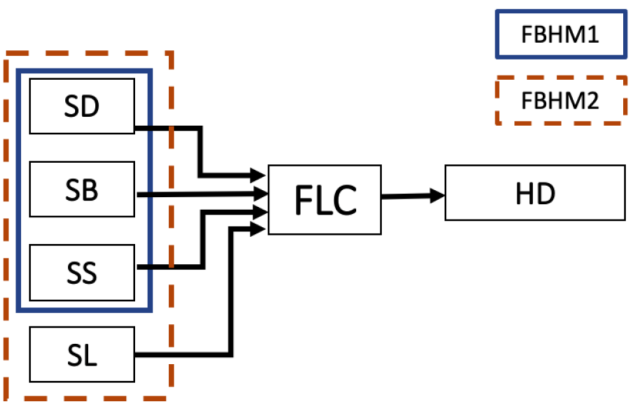


Figure 7 shows the membership functions. In order to easily fuzzify them and be flexible in applying in any scenario, the values for Slice Delay, Bandwidth, Stability and Load are considered between 0 and 100%. So, for example, when we want to use the proposed system in Massive IoT scenario, we can consider the maximum slice delay value 10 ms (100%). But, when applying in Critical Communications, we can consider the maximum slice delay value 1 ms or 5 ms depending on delay sensitivity (Kammoun et al., 2018). We use triangular and trapezoidal membership functions as shown in Figure 8. We explain the design of FLC in following.

The input parameters and their term sets are shown in Table 1.

$$T(SD) = Short\,(St), Intermediate\,(It), Long\,(Lg)$$

$$T(SB) = Small\,(Sa), Medium\,(Mu), Big\,(Bi)$$

$$T(SS) = Low\,(Lo), Medium\,(Md), High\,(Hi)$$

$$T(SL) = Small\,(Sl), Intermediate\,(Im), Large\,(Lr)$$

Figure 7 Membership functions (a) slice delay (b) slice bandwidth (c) slice stability (d) slice load (e) handover decision (see online version for colours)

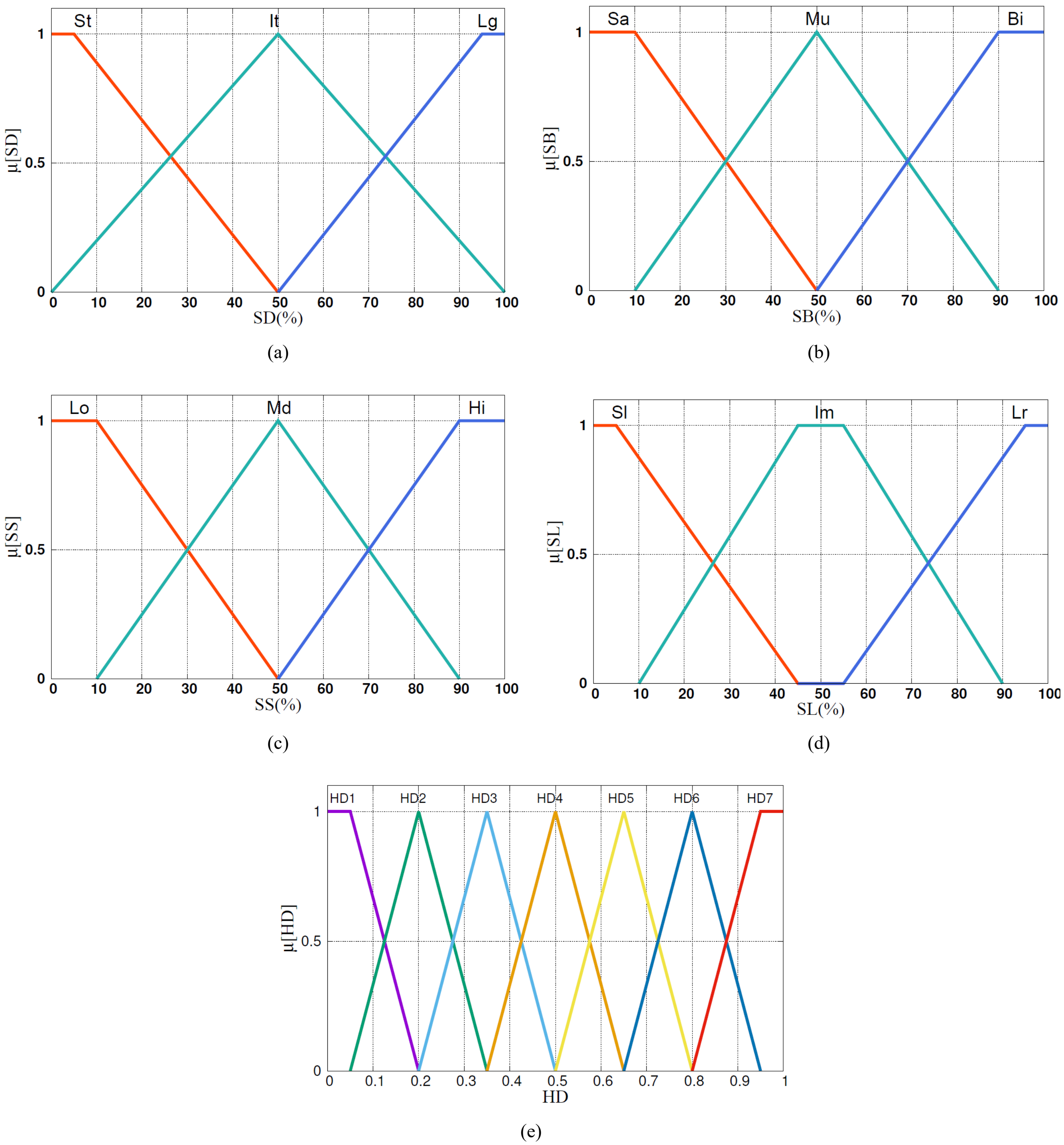


Figure 8 Triangular and trapezoidal membership functions

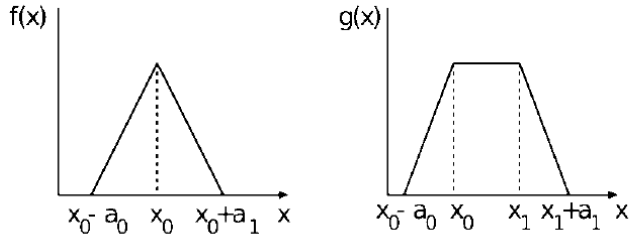


Table 1 Parameter and their term sets for FBHM1 and FBHM2

Parameters	*Term sets*
Slice Delay (SD)	Short (St), Intermediate (It), Long(Lg)
Slice Bandwidth (SB)	Small (Sa), Medium (Mu), Big (Bi)
Slice Stability (SS)	Low (Lo), Medium (Md), High (Hi)
Slice Load (SL)	Small (Sl), Intermediate (Im), Large (Lr)
Handover Decision (HD)	HD1, HD2, HD3, HD4, HD5, HD6, HD7

The membership function for input parameters are defined as follows:

$$\mu_{St}(SD) = g\left(SD; St_0, St_1, St_{w0}, St_{w1}\right)$$
$$\mu_{It}(SD) = f\left(SD; It_0, It_{w0}, It_{w1}\right)$$
$$\mu_{Lg}(SD) = g\left(SD; Lg_0, Lg_1, Lg_{w0}, Lg_{w1}\right)$$
$$\mu_{Sa}(SB) = g\left(SB; Sa_0, Sa_1, Sa_{w0}, Sa_{w1}\right)$$
$$\mu_{Mu}(SB) = f\left(SB; Mu_0, Mu_{w0}, Mu_{w1}\right)$$
$$\mu_{Bi}(SB) = g\left(SB; Bi_0, Bi_1, Bi_{w0}, Bi_{w1}\right)$$
$$\mu_{Lo}(SS) = g\left(SS; Lo_0, Lo_1, Lo_{w0}, Lo_{w1}\right)$$
$$\mu_{Md}(SS) = f\left(SS; Md_0, Md_{w0}, Md_{w1}\right)$$
$$\mu_{Hi}(SS) = g\left(SS; Hi_0, Hi_1, Hi_{w0}, Hi_{w1}\right)$$
$$\mu_{Sl}(SL) = g\left(SL; Sl_0, Sl_1, Sl_{w0}, Sl_{w1}\right)$$
$$\mu_{Im}(SL) = f\left(SL; Im_0, Im_{w0}, Im_{w1}\right)$$
$$\mu_{Lr}(SL) = g\left(SL; Lr_0, Lr_1, Lr_{w0}, Lr_{w1}\right)$$

The output linguistic parameter is Handover Decision (HD). The term set for HD is defined as follows:

$$HD = \begin{pmatrix} Handover\ Decision\ 1 \\ Handover\ Decision\ 2 \\ Handover\ Decision\ 3 \\ Handover\ Decision\ 4 \\ Handover\ Decision\ 5 \\ Handover\ Decision\ 6 \\ Handover\ Decision\ 7 \end{pmatrix} = \begin{pmatrix} HD1 \\ HD2 \\ HD3 \\ HD4 \\ HD5 \\ HD6 \\ HD7 \end{pmatrix}$$

The membership functions for HD are defined as follows:

$$\mu_{HD1}(HD) = g\left(HD; HD1_0, HD1_1, HD1_{w0}, HD1_{w1}\right)$$
$$\mu_{HD2}(HD) = f\left(HD; HD2_0, HD2_{w0}, HD2_{w1}\right)$$
$$\mu_{HD3}(HD) = f\left(HD; HD3_0, HD3_{w0}, HD3_{w1}\right)$$
$$\mu_{HD4}(HD) = f\left(HD; HD4_0, HD4_{w0}, HD4_{w1}\right)$$
$$\mu_{HD5}(HD) = f\left(HD; HD5_0, HD5_{w0}, HD5_{w1}\right)$$
$$\mu_{HD6}(HD) = f\left(HD; HD6_0, HD6_{w0}, HD6_{w1}\right)$$
$$\mu_{HD7}(HD) = g\left(HD; HD7_0, HD7_1, HD7_{w0}, HD7_{w1}\right)$$

The Fuzzy Rule Base (FRB) for FBHM1 and FBHM2 is shown in Tables 2 and 3, respectively. The FRB is formed by a fuzzy set of dimensions $\left(|T(HD)| = |T(SD)| \times |T(SB)| \times |T(SS)| \times |T(SL)|\right)$, where $|T(X)|$ is the number of terms on $T(X)$. The control rules have the form: IF 'condition' THEN 'control action'. For example, for Rule 50 of FBHM2: 'IF SD is It, SB is Bi, SS is Md and SL is Im, THEN HD is HD3'.

Table 2 Fuzzy rule base for FBHM1

Rule	*SD*	*SB*	*SS*	*HD*
1	St	Sa	Lo	HD5
2	St	Sa	Md	HD4
3	St	Sa	Hi	HD3
4	St	Mu	Lo	HD4
5	St	Mu	Md	HD3
6	St	Mu	Hi	HD2
7	St	Bi	Lo	HD3
8	St	Bi	Md	HD2
9	St	Bi	Hi	HD1
10	It	Sa	Lo	HD6
11	It	Sa	Md	HD5
12	It	Sa	Hi	HD4
13	It	Mu	Lo	HD5
14	It	Mu	Md	HD4
15	It	Mu	Hi	HD3
16	It	Bi	Lo	HD4
17	It	Bi	Md	HD3
18	It	Bi	Hi	HD2
19	Lg	Sa	Lo	HD7
20	Lg	Sa	Md	HD6
21	Lg	Sa	Hi	HD5
22	Lg	Mu	Lo	HD6
23	Lg	Mu	Md	HD5
24	Lg	Mu	Hi	HD4
25	Lg	Bi	Lo	HD5
26	Lg	Bi	Md	HD4
27	Lg	Bi	Hi	HD3

Table 3 Fuzzy Rule base for FBHM2

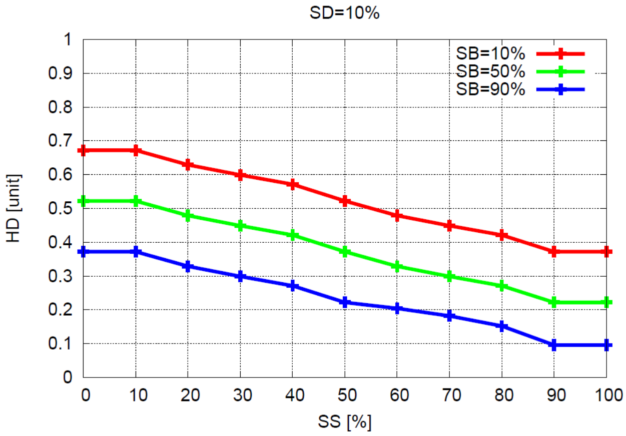
Rule	*SD*	*SB*	*SS*	*SL*	*HD*	*Rule*	*SD*	*SB*	*SS*	*SL*	*HD*
1	St	Sa	Lo	Sl	HD4	41	It	Mu	Md	Im	HD4
2	St	Sa	Lo	Im	HD5	42	It	Mu	Md	Lr	HD5
3	St	Sa	Lo	Lr	HD6	43	It	Mu	Hi	Sl	HD2
4	St	Sa	Md	Sl	HD3	44	It	Mu	Hi	Im	HD3
5	St	Sa	Md	Im	HD4	45	It	Mu	Hi	Lr	HD4
6	St	Sa	Md	Lr	HD5	46	It	Bi	Lo	Sl	HD3
7	St	Sa	Hi	Sl	HD2	47	It	Bi	Lo	Im	HD4
8	St	Sa	Hi	Im	HD3	48	It	Bi	Lo	Lr	HD5
9	St	Sa	Hi	Lr	HD4	49	It	Bi	Md	Sl	HD2
10	St	Mu	Lo	Sl	HD3	50	It	Bi	Md	Im	HD3
11	St	Mu	Lo	Im	HD4	51	It	Bi	Md	Lr	HD4
12	St	Mu	Lo	Lr	HD5	52	It	Bi	Hi	Sl	HD1
13	St	Mu	Md	Sl	HD2	53	It	Bi	Hi	Im	HD2
14	St	Mu	Md	Im	HD3	54	It	Bi	Hi	Lr	HD3
15	St	Mu	Md	Lr	HD4	55	Lg	Sa	Lo	Sl	HD6
16	St	Mu	Hi	Sl	HD1	56	Lg	Sa	Lo	Im	HD7
17	St	Mu	Hi	Im	HD2	57	Lg	Sa	Lo	Lr	HD7
18	St	Mu	Hi	Lr	HD3	58	Lg	Sa	Md	Sl	HD5
19	St	Bi	Lo	Sl	HD2	59	Lg	Sa	Md	Im	HD6
20	St	Bi	Lo	Im	HD3	60	Lg	Sa	Md	Lr	HD7
21	St	Bi	Lo	Lr	HD4	61	Lg	Sa	Hi	Sl	HD4
22	St	Bi	Md	Sl	HD1	62	Lg	Sa	Hi	Im	HD5
23	St	Bi	Md	Im	HD2	63	Lg	Sa	Hi	Lr	HD6
24	St	Bi	Md	Lr	HD3	64	Lg	Mu	Lo	Sl	HD5
25	St	Bi	Hi	Sl	HD1	65	Lg	Mu	Lo	Im	HD6
26	St	Bi	Hi	Im	HD1	66	Lg	Mu	Lo	Lr	HD7
27	St	Bi	Hi	Lr	HD2	67	Lg	Mu	Md	Sl	HD4
28	It	Sa	Lo	Sl	HD5	68	Lg	Mu	Md	Im	HD5
29	It	Sa	Lo	Im	HD6	69	Lg	Mu	Md	Lr	HD6
30	It	Sa	Lo	Lr	HD7	70	Lg	Mu	Hi	Sl	HD3
31	It	Sa	Md	Sl	HD4	71	Lg	Mu	Hi	Im	HD4
32	It	Sa	Md	Im	HD5	72	Lg	Mu	Hi	Lr	HD5
33	It	Sa	Md	Lr	HD6	73	Lg	Bi	Lo	Sl	HD4
34	It	Sa	Hi	Sl	HD3	74	Lg	Bi	Lo	Im	HD5
35	It	Sa	Hi	Im	HD4	75	Lg	Bi	Lo	Lr	HD6
36	It	Sa	Hi	Lr	HD5	76	Lg	Bi	Md	Sl	HD3
37	It	Mu	Lo	Sl	HD4	77	Lg	Bi	Md	Im	HD4
38	It	Mu	Lo	Im	HD5	78	Lg	Bi	Md	Lr	HD5
39	It	Mu	Lo	Lr	HD6	79	Lg	Bi	Hi	Sl	HD2
40	It	Mu	Md	Sl	HD3	80	Lg	Bi	Hi	Im	HD3
						81	Lg	Bi	Hi	Lr	HD4

5 Simulation results

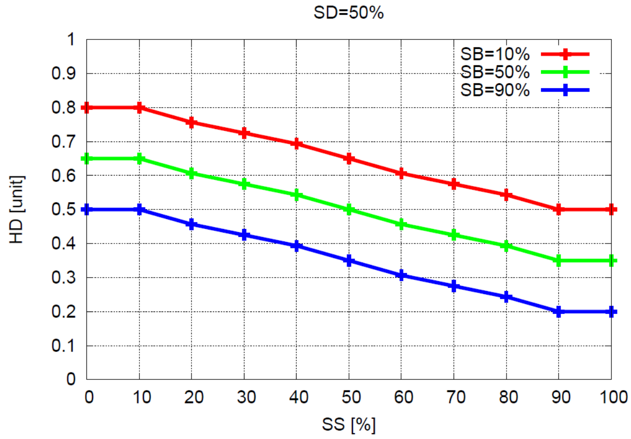
In this section, we present the simulation results. The simulations are performed on a computer running Linux Ubuntu OS with the following specifications: 8 GB of RAM, an i5 (3.2 GHz *xtimes* 4) processor and an SSD (650 GB). For simulations, we used our developed Fuzzy C system (Inaba et al., 2015).

The simulation results for FBHM1 are shown in Figure 9. They show the relation between HD and SS for various SB values while considering SD as a constant parameter. In Figure 9(a), we consider the SD value 10%. For SS 50%, when SB is increased from 10% to 50% and 50% to 90%, the HD decreases by 15%, respectively. This means that the probability of handover to other slices is low when the present slice provides the user with more bandwidth.

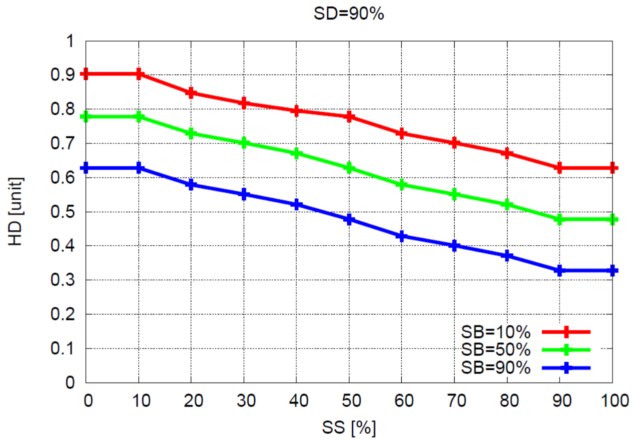
Figure 9 Simulation results of FBHM1 (see online version for colours)



(a) SD=10%



(b) SD=50%

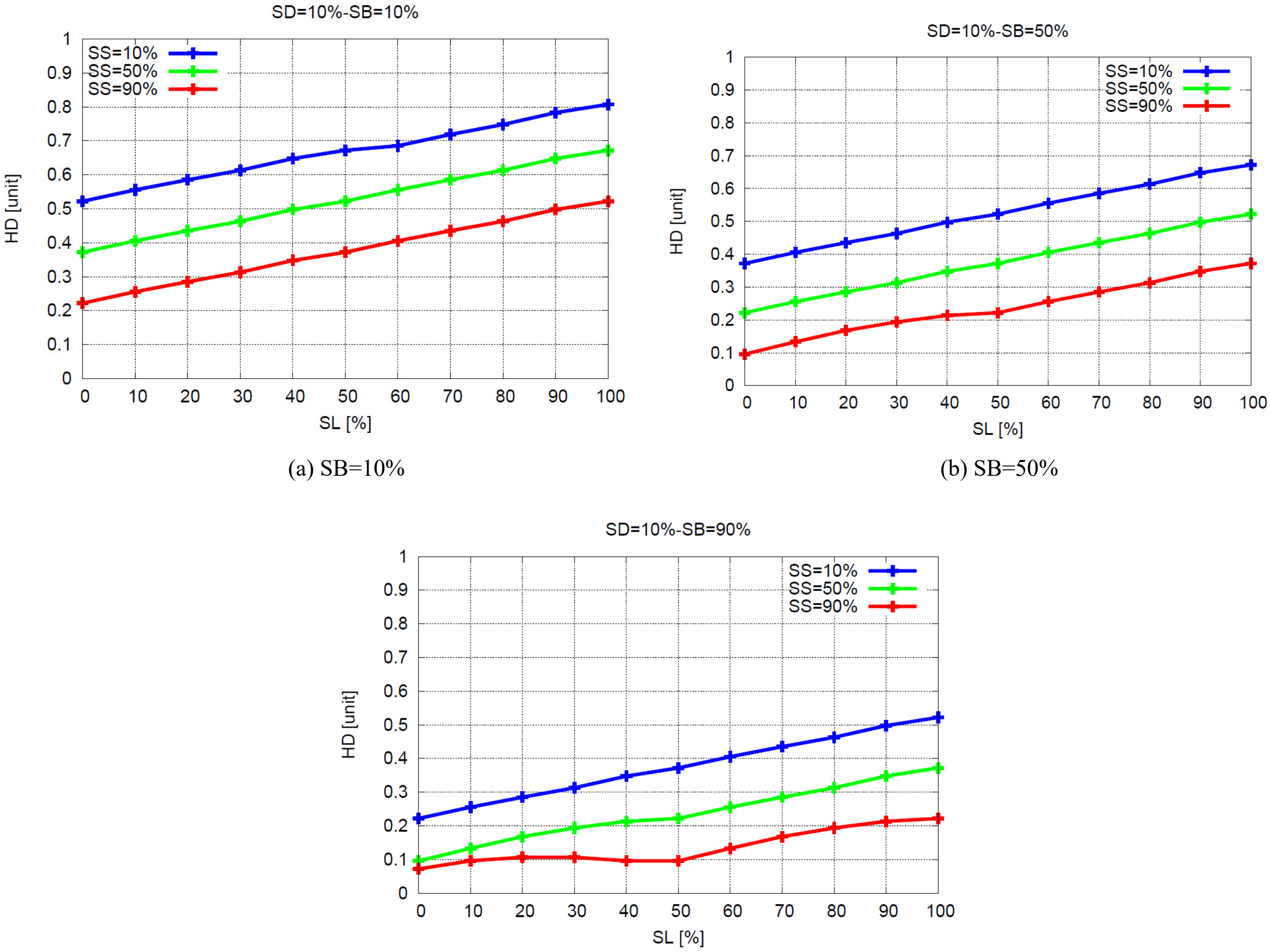


(c) SD=90%

We change the SD value from 10% to 50% to determine how SD has affected HD. We compare Figure 9(a) with Figure 9(b). When both SB and SS values are 50%, the HD increases by 13%. This is because the handover to another slice is required when the present slice delay is higher. In Figure 9(b), when the SS is increased from 20 to 40% and from 40 to 80% for SD 50% and SB 50%, the HD decreases by 6% and 15%, respectively. As can be seen the HD decreases as SS increases. This indicates that the present slice is more stable, and making handover to other slices is unnecessary. We increase the SD value in Figure 9(c) to 90%. When we compare the results with Figures 9(a) and 9(b), we can see that the HD values are increased. All HD values are higher than 0.5 for SB value 10%. Thus, the mobile device will switch to a different slice.

The simulation results for FBHM2 are presented in Figures 10, 11 and 12. We see effect of SL on HD to improve QoS. In Figure 10(a), we consider the SD value 10%. For SB 10% and SS 10%, when SL is increased from 20 to 40% and 40 to 80%, we see that HD is increased by 6% and 10%, respectively. However, when we increased the SB value from 10 to 50% (see Figures 10(a) and 10(b)) and 50 to 90% (see Figures 10(b) and 10(c)), the HD value is deceased by 15% for both cases when the SS value is 10% and the SL value is 50%. This indicates that when the present slice load is high, the possibility of handover to other slices is high. But, when the present slice has greater bandwidth, the possibility of handover to other slices is low. When the present slice can offer high bandwidth and low delay (see Figure 10), the mobile device stay connected to the present slice.

Figure 10 Simulation results for FBHM2 (SD=10%) (see online version for colours)

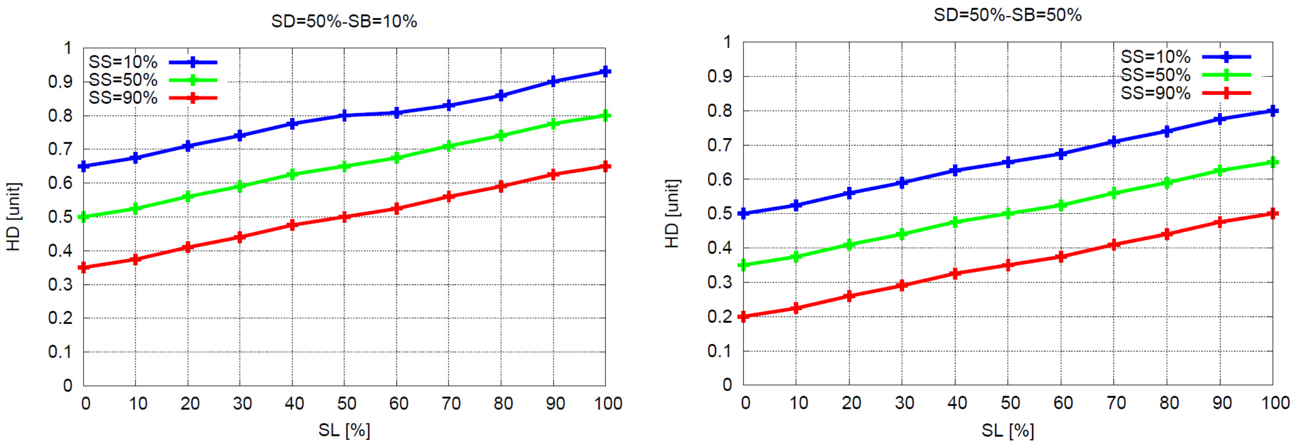


(a) SB=10% (b) SB=50%

(c) SB=90%

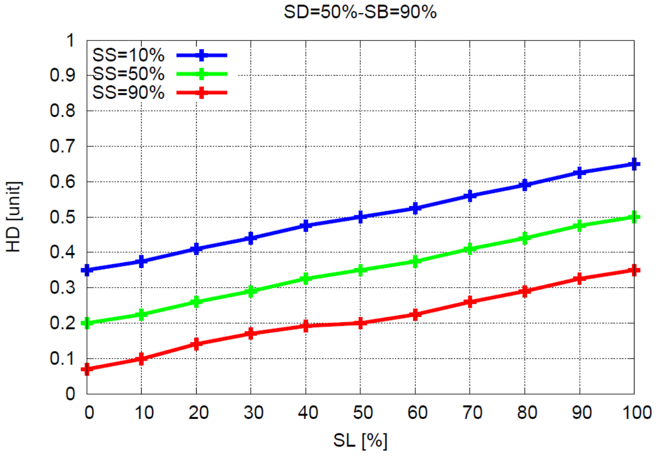
Figure 11 shows the HD for the moderate slice delay considering different parameters. Comparing the results of Figure 11(a) with Figures 11(b) and 11(c), in case when SL is 50%, SS is 50% and we increased the SB value from 10 to 50% and 50 to 90%, the HD value is decreased by 15% for both cases. In Figure 11, we see that all HD values are greater than 0.5 when SS is 10% and 50%. Thus, the mobile device will make a handover to another slice. But, the mobile device connected with the present slice with high bandwidth will not make a handover except the case when the present slice has a higher load and less stability (see Figures 11(b) and 11(c)).

Figure 11 Simulation results for FBHM2 (SD=50%) (see online version for colours)



(a) SB=10% (b) SB=50%

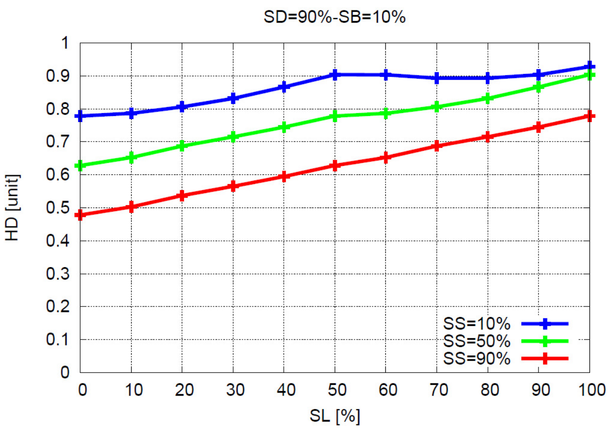
Figure 11 Simulation results for FBHM2 (SD=50%) (see online version for colours) (continued)



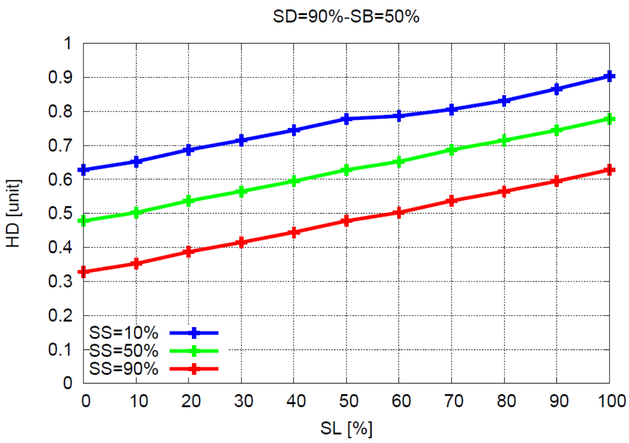
(c) SB=90%

Comparing the results of Figure 12 with other results, we can see that HD values have increased significantly. All HD values are greater than 0.5 for SD 90%, SB 10% and SS values of 10% and 50%. As a result, the mobile device will handover to another slice for better QoS. In Figures 12(b) and 12(c), with the increase of SB, we can see that the possibility of handover will decrease even if the delay is high.

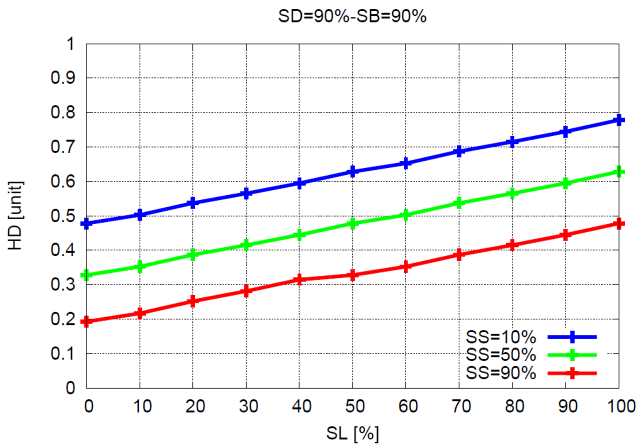
Figure 12 Simulation results for FBHM2 (SD=90%) (see online version for colours)



(a) SB=10%



(b) SB=50%



(c) SB=90%

6 Conclusions and future work

In this paper, we proposed two models of FBHM (FBHM1 and FBHM2), for handover in 5G wireless networks. From the simulation results, we found that four parameters have different effects on HD. The HD value increases when SD and SL values increase, but the HD value decreases when SB and SS values increase. A mobile device connected with a present slice that has high delay, less bandwidth, is non-stable and has high load must be handed over to other slices for better QoS. Comparing both models, we found that FBHM2 is more complex than FBHM1 but performs a better HD since it considers four parameters for making HD.

In future work, we will consider other parameters and perform extensive simulations to evaluate the effectiveness of the proposed system. We also will compare the performance of the proposed system with other systems.

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