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MIH/SDN-Based Vertical Handover Approach for 5G Mobile Networks

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Mobile communication systems are witnessing an ongoing-increase in connected devices and new types of services. This considerable increase has led to an exponential augmentation in mobile data traffic volume. Ultra-densification is a key solution aimed at satisfying the emerging requirements in next-generation 5G networks. However, the deployment of a high number of small cells and mobile nodes on the 5G networks poses challenges for the mobility management, including frequent, unnecessary and ping-pong handovers, with additional problems related to increased delay and total failure of the handover process. In this article, a novel optimized vertical handover approach is proposed to find the optimal network to connect with a good quality of service. This approach cooperates Media Independent Handover and Software-Defined Networking for seamless vertical handover. Simulation results validate the efficiency of our proposal.

Keywords: 5G networks, ultra dense networks, media independent handover, software defined networking, fast handover

1. INTRODUCTION

The rapid growth in smart devices and the ongoing increase user demands for seamless multimedia services are pressing towards the future generation of mobile communication system, Fifth Generation (5G). This next generation mobile technology is expected to reach market around 2020 [1]. 5G mobile systems are characterized by networks having different coverage ranges such as macro-cell, small-cell and atto-cell [2], and diverse technologies interacting with varied type of entities. Such diversity forms a new type of networks, the so called heterogeneous networks (HetNets), including *e.g.*, 4G [3, 4] and 5G [5] base stations, wireless-fidelity (Wi-Fi) Access Point (AP), Device-to-Device (D2D) communications *etc*. However, the deployment of a large number of small cells and mobile nodes on the HetNets increase the handover count, which blow up the network congestion, during the process of obtaining network conditions for all the scanned Point of Attachment (PoAs) individually. In addition, mobility related signaling overhead, increased handover delay and failures are other observed problems in 5G networks. To address the above-mentioned challenges, the proposed handover approach adopts Software Defined Networking (SDN) [6], which maintains a global network visibility and Media Independent Handover (MIH) [7] for seamless connection to different RATs (Radio Access Technology). In order to optimize the network selection phase, handover decision based on multiple-parameter is widely utilized. However, to make the

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handover decision phase at Mobile Node (MN) more efficient and suitable for mobility states, the traditional measurements tend to combine with the states of MN and network. The SDN has global network view so that most of the network features are supplied via SDN. However, some specific information such link-layer measurements, triggers and access rights to different networks can be obtained via MIH framework. Utilizing these features improve the efficiency of the handover decision, reduce the handover failure ratio and handover delay.

The main contributions of this article can be listed as follows: (i) Proposal of a handover architecture that integrates MIH and SDN to enhance the vertical handover procedure. The enhanced architecture contains new components for seamless vertical handover. (ii) Proposal an optimized vertical handover process. In the handover process, the network selection process is divided into two stages, which are pre-selection and network selection. The pre-selection eliminates the non-potential candidate networks dependent on the mobility profile of the MN. The network selection process is based on multiple parameters. Finally, (iii) Performance evaluation using simulation of the proposed approach.

The remainder of this article is organized as follows. In section 2, we present the most relevant related works. In section 3, we present the MIH/SDN-based vertical handover approach. In section 4, we describe the performance evaluation and the simulation results. In Section 5, we conclude the article and present our future direction.

2. RELATED WORK

Recently, there are different approaches in the literature which tried to solve the handover management problem in 5G mobile communication systems. We present the latest ones. Bilen *et al.* [8] presented a 5G network architecture based on SDN. In this architecture, the authors defined a mobility management and admission control modules in the SDN controller (SDNC). The first module calculates the eNBs transition probabilities while the second module estimates the eNBs available resources. The two obtained probabilities for each eNB are multiplied to get a selection probability. The eNB which has the highest selection probability will be chosen as target network. The simulation results presented that the proposed architecture reduced the handover delay and failures. However, this approach still has several limits. The proposed handover process is based on a lot of arithmetic computations, which increase the handover latency. In addition, in this approach, the proposed eNB selection engine does not consider the network and user states in handover decision algorithm. Tartarini *et al.* [9] proposed a software-defined handover solution. They proposed to use the SDNC for managing handover in heterogeneous cloud radio access networks. The handover mecanism uses context information of MN's gathered by SDNC to perform a handover decision. However, in this work, the proposed handover decision strategy doesn't consider the MN preference and the traffic load of networks which are relevant decision factors. Wang *et al.* [10] introduced an SDN-based architecture for future networks. The main characteristics of the proposed architecture are as follows: (i) virtual RATs design employing interface sets and controlled by an SDNC is introduced; (ii) the proposed SDNC is able to predict a user's movement path. Experimental results demonstrated that the proposed architecture reduces handover latency compared to traditional scheme. However, in this work, the authors don't provide details of their proposed handover scheme. Mansouri *et al.* [11] proposed a cross layer architecture based on MIH framework. In this architecture, they introduced vertical handover (VHO) engine for handover making decision between the network layer and the MIH layer. However, the handover decision strategy does not consider the network conditions such as the traffic load of networks which is an important decision factor. In addition, the handover decision algorithm handles many parameters that involve lots of arithmetic calculations. A high computational effort increases the response time. Gharsallah *et al.* [12] proposed a novel VHO framework for the specific purpose of selecting the optimal network to connect. This framework is based on an extension of MIH frame- work with new Vertical Handover Management Layer (VHML) for seamless VHO. This additional layer was introduced between the MIHF layer and the upper layer. The VHML is responsible for VHO management. VHML is composed of two main functional entities: Multi-layer Sniffer (MLS) and Multi-criteria Selection Module (MSM), which are responsible for context gathering and intelligent handover decision-making.

Table 1. Synthesis of relevant works.

Ref.	Key Descriptions	Strengths	Drawbacks
[8], 2017	SDN-based mobility and available resource estimation strategy.	Minimize the handover delay / failures.	Lot of arithmetic calculations and does not consider network conditions
[9], 2017	Handover solution based on SDN for heterogeneous cloud radio access networks.	Improve the throughput. Reduce the handover percentage failure.	VHO decision does not consider user preference, network conditions such as traffic load.
[10], 2017	SDN-based architecture for future networks.	Reduce handover latency.	Details of handover mechanism are absent.
[11], 2017	Cross layer architecture based on the MIH framework and new different modules.	Reduce both new and handover call blocking probability. Reduce packet loss rate.	Handover decision algorithm sets many parameters that involve lots of arithmetic calculations.
[12], 2017	Enhanced MIH-based framework for network selection in future wireless networks.	Reduce handover blocking probability. Reduce packet loss rate.	Handover delay is not considered.
[13, 14], 2017	VHO decision-making schemes.	Decrease the number of handovers.	High signaling overhead. Handover complexity.
[15], 2018	VHO and resource allocation management approach.	Reduce handover failure. Ensure a good level of the fairness index.	Handover decision strategy doesn't consider the user context. Long handover delay.
[16], 2018	Enhanced RRM mechanism using MIH and Proxy Mobile IPv6 (PMIPv6) policies	Reduce handover delay. Reduce packet loss.	Increased signaling. Additional decision parameters are required to ensure better QoS.
[17], 2017	Enhanced MIH approach	Ensure energy saving during a handover.	HO decision and network selection are absent

In addition, the authors proposed a novel network selection algorithm, based on multi-parameter such as user velocity, battery status, bandwidth, delay, packets loss rate, *etc*. Simulation results demonstrated that the proposed network selection algorithm reduces handover blocking probability and packet loss rate. However, handover delay is not considered in this works. Goudarzi *et al.* [13] dealt with seamless mobility problem in heterogeneous vehicular networks. They proposed an algorithm for VHO decision-making able to choose the best access network. This algorithm uses two major approaches namely the Bio-geographical Based Optimization (BBO)and the Markov chain. The proposed algorithm uses the IEEE 802.21 standard to acquire several handover information. It was proved via the simulation that this algorithm is able to select the best network candidate accurately. The same authors proposed in [14] a network selection scheme based on Markov Decision Process (MDP) framework. The problem is formulated as a Markov decision process which is merged with Genetic Algorithm (GA). The GA algorithm is used to find the current and future optimal wireless network. Simulation results indicate that using the proposed algorithm can decrease the number of unnecessary handovers. However, these works are characterized by high signaling overhead and complexity.

Table 2. Vertical handover evaluation metrics.

Ref.	Evaluation Metrics			
	VHO delay	VHO blocking rate	Throughput	Packet Loss
[8], 2017	Better delay than Conventional LTE.	Better VHO failure than LTE handover scheme.	Not provided.	Not provided.
[9], 2017	Not provided.	Better VHO blocking rate than UserCentric handover.	Better Throughput than UserCentric handover.	Not provided.
[10], 2017	Lower delay.	Not provided.	Not provided.	Not provided.
[11], 2017	Not provided.	VHO blocking rate is not important.	Not provided.	Lower packet loss rate.
[12], 2017	Not provided.	Lower VHO blocking rate.	Not provided.	Better packet loss rate.
[13], 2017	Better delay than TOPSIS, GRA and NEMO.	Better VHO Blocking rate than TOPSIS and GRA.	Better Throughput than TOPSIS and GRA.	Lower packet loss rate than TOPSIS, GRA.
[15], 2018	Lower delay.	Better VHO Blocking rate.	Not provided.	Not provided.
[16], 2018	Lower delay.	Not provided.	Not provided.	Lower packet loss rate.
[17], 2017	Not provided.	Not provided.	Not provided.	Better packet loss rate.

A new solution that involves resource allocation and VHO process based on MIH was proposed in [15]. In this solution, new elements are added in the core network to enhance the VHO procedure and to support the resource management process in wireless networks. Simulation results indicated that this approach can optimize the VHO process and enhance the overall network performance, such as the fairness index and call blocking rate, *etc*. The handover decision strategy does not consider the users' preferences. In addition, executing this scheme takes a long time, which causes many handover latency.

Omheni *et al.* in [16], proposed an enhanced Radio Resource Management (RRM) protocol using MIH policies. They deployed MIH to ameliorate the management of network resources. Simulation results indicated that the proposed approach can reduce handover delay and packet loss. However, additional decision parameters are required to ensure better QoS. Hocine *et al.* in [17], dealt with the problem of energy saving VHO in 5G networks. The proposed model is based on MIH framework including modifications in order to make MIH more collaborative in energy saving. However, in this work the study of mobility management aspects is absent such as handover decision and best network selection. Table 1 presents a resume of relevant works and Table 2 provides a comparison of the above described VHO mechanisms.

3. MIH/SDN-BASED VERTICAL HANDOVER APPROACH

First, it should be noted that this work is an extension of our previous research work published in [12]. The benefit in this work is the use of SDN to optimize the vertical handover procedure in 5G ultra-dense networks. The SDN is required to enable obtaining network conditions, thus improving the efficiency of the handover decision-making and accordingly minimizing the handover failure ratio and handover delay. In the remainder of this section, we detail the proposed MIH/SDN-based vertical handover architecture and the optimized handover procedure.

3.1 MIH/SDN-Based Vertical Handover Architecture

The proposed software-defined vertical handover architecture is based on MIH and SDN to optimize vertical handover in 5G networks. In addition, this architecture involves new component for the management of the handover. Fig. 1 shows the proposed architecture, which consists of four units.

1. MIH-enabled multi-mode mobile node with the extension Handover Management Module (HMM) for handover decision-making and network selection. HMM is introduced between the MIH layer and the upper layer in the protocol stack of the MN. The HMM interacts with its MIHF to get link layers' measurements such as Radio Signal Strength (RSS) and Signal-to-Interference-plus-Noise Ratio (SINR). In addition, HMM interacts with upper layers to get information on application requirements and user preferences. To get updated neighbor network conditions such as load level and available bandwidth, the HMM interacts with the SDN controller through MIHF. Based on collected information, HMM determines in advance the need for the handover and chooses the best access network among heterogeneous networks, leading to

the success of the handover process.

2. The Information Server (IS) providing static information about RATs like MAC address, location and service provider's name.
3. The SDN controller with MIHF extension: Conventional handover mechanism, do not deploy SDN, and therefore the MN requires to interact with all available PoAs to obtain network conditions. However, it spends more energy, bandwidth, and also needs a lot of time for handover. Thus, the deployment of SDN minimizes the delay and complexity in the handover procedure. The SDN controller can interact with different network entities via OpenFlow switches, and it retains an overall view of the network. So, it offers a centralized control to PoAs. Instead of interacting with all available PoAs, the MNs in SDN-based handover architecture gets the required information of available PoAs on SDN controller. Therefore, the SDN contributes to perform efficient handover without delay. In the proposed architecture, the MIHF extension operates like a middleware between network entities to carry handover related messages between them. So, MN can exchange MIH messages with the SDN controller via MIHF.
4. The openFlow switches associate diverse types of PoAs to the SDN controller. OpenFlow switches are responsible for the data forwarding. They consist of one or more flow tables. A flow entry consists of the source address, destination address, session id, port number, time, *etc*. [18]. An OpenFlow updates its flow tables based on instructions provided via an OpenFlow protocol from the SDN controller.

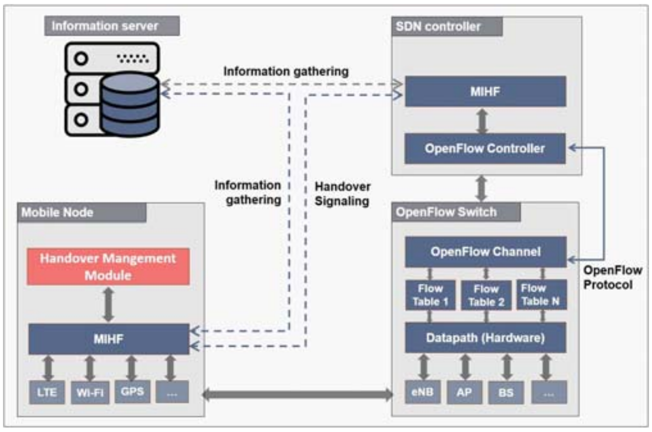

Fig. 1. MIH/SDN-based vertical handover architecture.

3.2 Optimized Vertical Handover Procedure

The proposed vertical handover procedure is presented in Fig. 2. Firstly, the MN is connected to its serving PoA, monitors in continuous the link status. When the link quality cross a certain threshold, the link layer signals a Link Going Down (1) event to the MIHF in the MN. The MIHF then passes this notification to the Handover Management Module (HMM) in the MN. HMM decides the handover to the best network or a network better than the current one.

Therefore, the MN starts to search for available candidate RATs. MN performs active scanning, and queries the SDN and the IS information about surrounding RATs through an MIH Get Information.request (3) message. SDN and IS reply an MIH Get Information.response (4). Then the MN signals the SDN to query the PoA candidates resources availability via MIH MN HO Candidate Query.request message (5). The SDN asks candidate networks on resources availability via OFPT STATUS REQUEST (6) message and then, passes the results to the MN using MIH MN HO Candidate Query.response message (8). In the next step, the HMM engine filters out the candidate RATs that are unsuitable with the MN's moving speed and direction. The filtering process can reduce the unnecessary handover calculation and speed up the handover process. Then, the HMM ranks the filtered candidate networks and find the best one. We have introduced cost function model for seamless network selection based on network factors, application requirements and user's preferences.

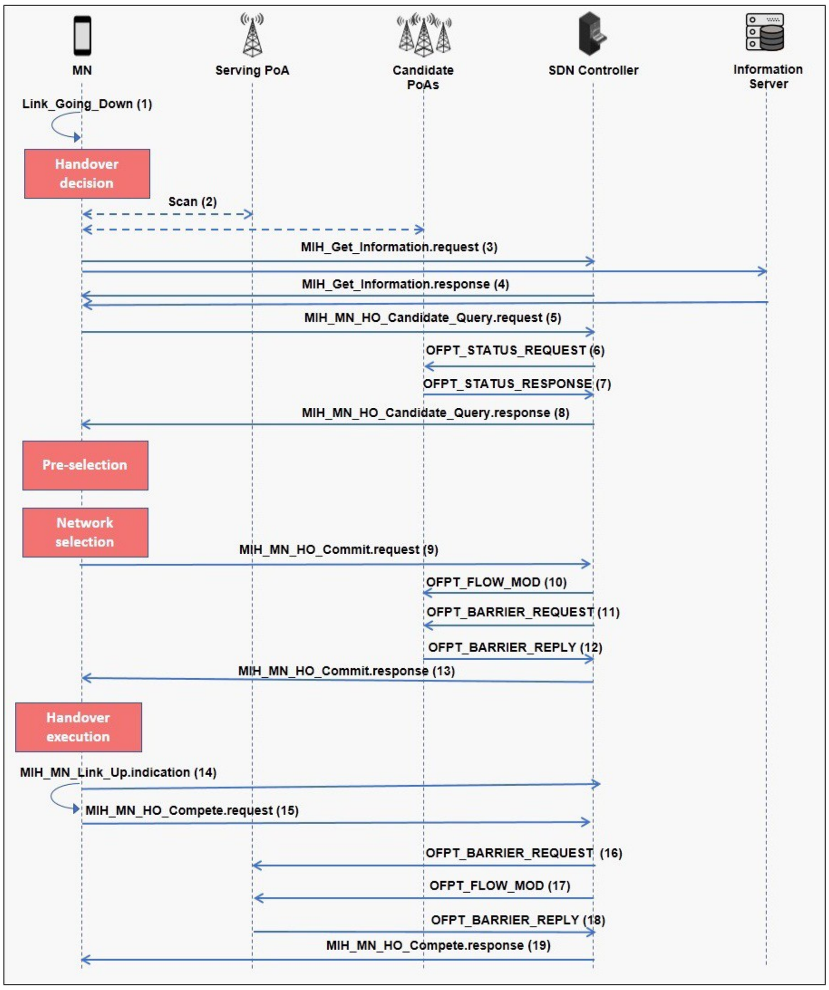

Fig. 2. Proposed vertical handover scenario.

The cost function consists of the following parameters: RSS, SINR, bandwidth (B), delay (D), load (L), cost (C) and security (S). Nonetheless, to define a cost function that take into accounts MN's requirements, we involve another metric which is the application type-based priority (P).

$$x' = N(x) = \begin{cases} \dfrac{\min(x, x_{\max}) - x}{x_{\max} - x_{\min}} \\ \dfrac{x_{\max} - \max(x, x_{\min})}{x_{\max} - x_{\min}} \end{cases} \tag{1}$$

Indeed, we follow the Internet Engineering Task Force (IETF) model that proposed a classification of services into classes depending on their sensibilities to delay as fellows: real-time-intolerant (RTINTLR) applications whose time requirements are strict and have the highest priority, real-time tolerant (RT-TLR) applications are more tolerant to changes in the timeout and non-real time (NRT) applications have the least priority [19]. Once the handover metrics are received by the HMM, it requires to normalize heterogeneous metrics. Handover metrics can be divided into two categories: metric of performance and cost metrics. For metrics of performance, the best utility value is the largest, like bandwidth and security. For cost metrics, the best utility value is the lowest, like load, cost, *etc*. For each metric x calls the function $N(x)$:

x_{max} and x_{min} are the minimum and the maximum exigencies of a metric x in a specific type of application and x is the normalized metric that $0 < x < 1$. Afterward, for each network i it defines the cost function $Q_{(N_i)}$:

$$Q_{ij} = w_{RSS}.RSS_{(i,j)} + w_{SINR}.SINR_{(i,j)} + w_B.B_{(i,j)} + w_D.D_{(i,j)} + w_C.C_{(i,j)} + w_S.S_{(i,j)} + w_P.P_{(i,j)} \tag{2}$$

With: $w_{RSS} + w_{SINR} + w_B + w_D + w_C + w_S + w_P = 1 \qquad 0 \leq Q_{ij} \leq 1$

Where w_{RSS}, w_{SINR}, w_B, w_D, w_C, w_S and w_P are the weighting factors of the RSS, SINR, bandwidth, delay, load, cost, security and the application type-based priority. The weighting factors are tuned according to the user preferences, in a flexible way. The closer Q_{ij} is to 1, the more suitable network i is to application j.

Ones MN determines the target PoA, it requests SDN controller to prepare connection via MIH_MN_HO_Commit.request message, and SDN controller updates the flow table of target PoA using OFPT FLOW MOD (10) message. The MN commits a link switch to the new PoA interface after receiving MIH_MN_HO Commit.response message. Handover execution is performed between the MN and the target RAT. The MN sends a MIH_MN_HO_Complete.request to the SDN controller. On receiving this request, the SDN controller starts to remove the source's PoA flow entries and liberate correspondent resources. Finally, SDN controller returns MIH_MN_HO_Complete.response to notify MN of handover completion.

4. PERFORMANCE EVALUATIONS

In this section, we assess the performance of the proposed MIH/SDN-based vertical handover approach. The performance assessment has been made possible through MAT-

LAB tool. We adopt the conventional used hexagonal cells. The total number of macro cells is 24, and the radius of each is 1 Km. For the smaller cells, the total number equal to 500 APs distributed randomly in the network, and the radius of each varies from 50 to 200 m. MNs are distributed randomly around APs, and they move randomly with a velocity varies from 5 km/h to 140 km/h. We repeat the experiments 30 times, and then plot the average of the runs. Table 3 describes the main parameters that have been used to execute the simulation. To evaluate the performance of the proposed MIH/SDN-based vertical handover approach, we compare it our previous proposed vertical handover mechanism in [12]. This analysis of the system performance is needed to ensure that the novel approach is better than our previous work in [12].

In the simulation, first, we measure the handover delay according to the increase of handover request arrival rate for the proposed and the existing solution. Handover delay is the time it took from the disconnection of the MN from the ancient PoA until the MN correctly receives the first packet from the new PoA. Then, we measure the handover failure ratio according to the variation of handover request arrival rate for the proposed and the existing solutions. Handover failure rate represents the ratio of failure handover number and the total handover number.

Table 3. Simulation parameters [19, 20].

Parameters	Values
Number of macro cells	24
Number of small cells	50-500
Number of mobile nodes	125-1250
Mobile nodes distribution	Randomly
Mobility model	Random walk model
Macro cell coverage (m)	1000
Small cell coverage (m)	50-200
Tx power for macro cells (dBm)	46
Tx power for small cells (dBm)	30
Mobile node speed (Km/h)	5-140

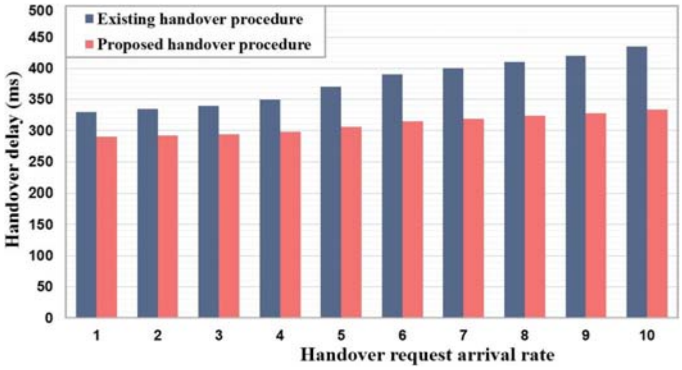

Fig. 3. Comparison of handover delay.

Fig. 3 presents the impact of the handover request arrival rate and the delay occurred following the proposed and our previous handover approaches. We show that, using the previous handover algorithm handover request rate increases so the handover delay gets higher and higher. In addition, we remark that our proposed handover algorithm gets significantly lower delay than our previous handover procedure. By analyzing Fig. 3, we note that MIH/SDN-based vertical handover approach provides a 25% decrease in handover delay compared to the previous handover approach. This best result can be justified by the fact that the utilization of the SDN technology, when the density of networks is significantly important, reduces the complexity of the handover process.

In fact, there is no need to exchange the handover information between several network entities as the SDN controller has a global network visibility. As a result, the MIH/SDN-based vertical handover solution will eliminate many delays required to send messages between diverse entities. Therefore, our approach is believed to provide fast vertical handover in 5G ultra-dense networks. Fig. 4 depicts the handover failure ratios of the proposed and our previous handover mechanism, according to the increase of handover request arrival rate. We observe that when using the previous mechanism, as the handover request rate increases, the handover failure ratios gets higher and higher. This is mainly due to the important number of executed unnecessary handovers. In addition, we remark from this figure, that the MIH/SDN-based vertical handover solution outperforms the previous approach by having less handover failure ratio.

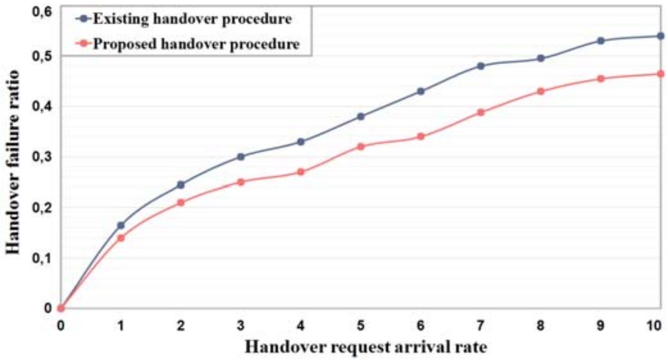

Fig. 4. Comparison of handover failure ratio.

Analyzing Fig. 4, we show that the novel approach registers a decrease of 15% compared to the previous handover mechanism. This enhancement can be justified by the intervention of SDN in our proposed approach. It enables obtaining network conditions in order to perform efficient handover decision. Such decision contributes to the success of the handover process.

5. CONCLUSION

In this work, we deal with the problem of seamless vertical handover in 5G mobile networks. We have proposed an MIH/SDN-based vertical handover approach to optimize the handover in next generation wireless networks. This approach integrates MIH and SDN for seamless handover. Simulation results demonstrated that the proposed solution is capable to select the best network candidate accurately based on the application

QoS needs, MN state and the network conditions provided by MIH and SDN. It significantly minimizes handover delay and failure. As a future work, we plan to move into resource allocation in 5G mobile networks based on SDN and Network Function Virtualization (NFV) technologies.

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