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A centralized architecture for autonomic quality of experience oriented handover in dense networks

A Centralized Architecture for Autonomic Quality of Experience Oriented Handover in Dense Networks

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Abstract— This paper presents an Optimised Handover (HO) Algorithm for Dense Wireless Local Area Networks (WLANs) based on a novel architecture of Software Defined Wireless Network (SDWN). The work has been designed to be effective in large network environments with a high density of Access Points (APs) and stations, which increase the chances of the Ping-Pong HO effect. Specifically, it considers Quality of Experience (QoE) by applying an optimised HO algorithm for WLANs, which relies on Fuzzy Logic Control Theory (FLCT) combined with Adaptive Hysteresis Values (AHVs). SDWN allows to monitor and manage the networks and to autonomously programme the APs through a centralized controller. The paper includes also a detailed performance analysis of the algorithm developed in an SDWN-based simulator implemented through OPNET. Specifically, our algorithm achieved promising performance results compared to the state of the art in terms of QoE, throughput, delay and reduction of the ping-pong HO effect.

Keywords— : Handover, Hysteresis, QoS, QoE, SDWN, Fuzzy Logic, Wi-Fi,

I. INTRODUCTION

Nowadays, Wi-Fi has become almost ubiquitous, allowing wireless Mobile Nodes (MNs) to experience online services connecting to different cells while moving [1]. Moreover, smartphones and tablets have become increasingly widespread due to their ease of use and low cost. High-density wireless networks are areas that provide services to hundreds or even thousands of wireless devices in a limited area relying on IEEE 802.11 technology or others such as Long-Term Evolution (LTE). For instance, high density wireless indoor and outdoor networks include stadiums, airports, train stations, exhibition halls, shopping malls and e-learning environments like universities [2]. These numerous networks have resulted in a heterogeneous wireless environment, where the devices are able to connect to various wireless networking providers through the traditional network infrastructures [3].

However, IEEE 802.11 standards have not been designed to guarantee MNs' high performances in the above-mentioned dense deployments. In fact, 802.11 standards lack solutions that guarantee high-performance services and seamless mobility in these networks [4]. Note that, although IEEE 802.11 standards have undoubtedly improved from the first generations, for instance providing up to 2 Mbps bandwidth in case of 802.11b and even up to 1.3 Gbps in case of IEEE 802.11ac [5], allowing High Definition (HD) video streaming, still MNs in IEEE 802.11 networks not automatically execute the handover (HO) procedure to change the point of access to the network while the user is moving. This approach is not able to guarantee proper Quality of Experience (QoE). QoE can be defined as an overall measurement of the network system performance, which depends on the perceived acceptability of service from the user's point of view. In this context, many papers can be found in the state of the art addressing the problem of HO[6]. However, these works use to allow the MNs to decide when to execute the HO. Hence, these approaches are limited because MNs are not able to detect the best available Access Point (APs) regarding bandwidth or other Quality of Service (QoS) requirements. Moreover, when MNs make the decision, they cannot help provide a fair distribution of the load among the APs [7]. Therefore, solutions for HO to improve the state of the art are still a hot topic under investigation [8].

Software-Defined Wireless Networking (SDWN), is a promising concept where a control and data plane are separated from each other, which is enabling a centralised programmable network. SDWN could offer several features and advantages over traditional hardware-centric networks, and this will lead to decrease cost, promising better QoE and QoS [9], [10]. In this context, the main goal of this work is the design and the development of a novel SDWN-based architecture that supports handover (HO), which addresses QoE and QoS requirements of the MNs. This solution relies on Fuzzy Logic Control Theory (FLCT) and Adaptive Hysteresis Values (AHV) implemented in the SDWN controller, able to measure the performance, manage a set of APs and provide the autonomic connection of the MNs to the most efficient AP in terms of QoE thanks to its overall view of all the WLAN.

The paper is structured as follows: Section 2 describes the state of the art and our contributions. In Section 3 we discuss the proposed design architecture, while Section 4 will explain the proposed HO algorithm. Section 5 will discuss the evaluation of the results. Finally, Section 6, will illustrate the conclusions.

II. State of the Art and Contributions

A. Handover Mechanism

The HO is the process of switching the users from one AP to other, or among different service providers. In general, the HO can be split into the following phase steps: firstly, the information congregation of the HO phase, secondly, the decision making of the HO phase, and finally the execution phase. The HO information congregation or we can call it Information Gathering also, is based on the collection of the environmental information used to decide if the HO is needed and the possible initialization. All the collected information allows to provide the most efficient HO decision identifying the best-connected network. The HO Decision step aims to address user satisfaction through the computation of the most opportune access network during a HO decision. This is step is challenging, in fact, many works can be found in the literature review and it is classified in static and dynamic strategies. Static solutions focus on the MN profile, while dynamic solutions rely on a received signal where the MN on movement. The Execution step aims to seamlessly consent the change of channel and network based on the input received by the HO Decision step, and possible before the current connection of the MN is terminated[11].

In general, there are three types of HO strategies: Hard, Soft and finally the Smart HO. In this first hard HOs strategies, the connection will break-before-make with the source (i.e., the AP), as a result, the MNs will first break the connection with current AP before making the new connection to the selected AP [12]. This approach results in latency and packet loss and, therefore, is not efficient for live-streaming or online gaming and other applications in real-time. The second strategy is the soft HOs, where is the connection will be make-before-break down, enables MNs to launch a new link to the selected AP before the break of connection with the current AP. In this strategy, the MNs will be able to experience better service and without any interruption on the connection [13]. The final strategy is the smart HO, this strategy allows the MNs to HO seamlessly between deferent APs without breaking the connections using smart algorithms to select the best possible connection from candidate APs even if the APs from different provider source [14].

B. Handover Decision Schemes Strategies

Mobility management is crucial in a wireless environment. In this context, HO strategies enable to maintain the connection of the MNs in movement, by switching them from a cell to another. This section illustrates a literature review of HO decision approaches. The most common HO strategies are based on RSS. In this category of HO, the MN simply compares the RSS of two or more available networks before deciding which one provides the best signal strength [15].

In Multiple Attributes Decisions (MAD) strategies, a selection is made through a limited number of candidate networks, depending on several criteria such as Multiple Attributes and Multiple Objectives. Works presented in [16] classify MAD strategies into four categories as follows: 1) Grey Relational Analysis (GRA), which allows the grade to nominee APs, and the highest rank from the list is selected as the best nominee network; 2) Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), which also lists a nominee APs, while the decision algorithm decides on choosing the closest AP to the ideal solution avoiding the poorest case solution; 3) Analytic Hierarchy Process (AHP), which breaks down the problem of the selection into a number of sub-problems, where each one is assigned to a weight value. Breaking down the problems provides more accuracy in terms of the HO decision that is based on the highest QoS satisfying the user requirements; and 4) Simple Additive Weighting (SAW), which computes the weight of a set of attributes, in order to sum up to the overall score. All the candidates APs will be ranked according to their scours, then the top AP at the rank will be selected.

In terms of AP selection strategies, a combination of GRA and AHP techniques can be considered to find a trade-off between network conditions, service application and user preferences [17]. In detail, there are three logical function processes within these techniques. The first one starts by collecting data, then, the second process elaborates such data, and finally, the third ones make a decision based on the obtained data. In these works, the results claimed that the combination of these techniques can work efficiently in UMTS and WLAN systems.

C. Software-Defined Wireless Networking

SDWN is a modern concept that adds programmability to the network management and support decoupling between both data and control plane, in another word, the controller will get the power to rule and manage the network in a single entity. The SDWN controller has the ability to monitor, control and program data plane and implements several networking rules and policies through the so-called southbound Application Programming Interface (API). OpenFlow protocol is a well know example of southbound API [18].

SDWN is an interesting solution to address the problem of seamless HO, through its capabilities such as improved scalability, reduced network complexity, and fine-grained network control. One of the most important capabilities of SDWN is the functionality of the measurement that allows to flexibly monitor and manage the whole network and which can be also used in the HO process during the Information Gathering step [19].

An author in [20] illustrates a flexible and extendable SDWN monitoring framework, which offers sophisticated per-flow statistics and measurements of the centralized network that supports the HO information-gathering phase. Those flows statistics will increase awareness of the controller for each flow in QoS or QoE [21].

In [9], the author proposes a framework for integrating different heterogeneous wireless networks based on network slicing and utilizing the SDN paradigm in a wireless environment. In this proposed solution, the framework uses the Virtual Network Function (VNF) to facilitate the functionality of each network slicing controlled by the SDN controller.

Moreover, virtualization relies on a shared hypervisor layer deployed on shared physical infrastructure. Ensuring the isolation of each virtualized system is essential in order to prevent information leakage and unauthorized access in hosted environments [22].

D. Paper Contributions

As we have mentioned in the introduction, the literature review presents a number of different approaches that aim to address the HO problem. On the other hand, these strategies do not consider the application's requirements of the wireless users, because of their lack of intelligence, especially considering the tremendous growth of smartphone and the growth of data consumption. Furthermore, the analysis of our literature review demonstrates that these works address the HO problem only in wireless networks developed in small areas where a few MNs can connect. However, wireless networks are nowadays more complex due to the growing number of WLAN uses and data consumption.

Hence, our work is aiming to present a novel architecture based on SDWN in a large scale of the network, which supports the HO autonomously and seamlessly, taking into account the QoE requests of all the MNs. In detail, with respect to previous publications [6]-[30], we propose a scalable network SDWN-based architecture in which the controller is able to program and manage the APs in order to provide efficient HO solutions based on QoE and QoS requirements, and maintaining the change of the point of access to the network invisible to the MNs. Moreover, in the proposed architecture an FLCT-based HO algorithm is implemented in order to reduce the number of redundant HO. Note that we have proposed and assessed a preliminary version of this work in [23]. The summarising of the contributions of this paper as follows:

- Extending SDWN architecture we presented in [23] by adding a new agent for each AP that has a capability to synchronise the control event with the HO controller.
- Proposing a HO algorithm that considers the dynamic AHV to optimize the number of required HO.
- Extending the performance analysis through the inclusion of 1) further APs in order to represent an enormous and dense environment, and 2) a new performance metric.

III. PROPOSED SDWN ARCHITECTURE DESIGN

Fig. 1 illustrates the proposed solution, which contains application layer, control layer, and infrastructure layer. This proposed architecture will enable the programmability to manage the data plan and HOs in unlicensed frequency. The controller will implement our HO algorithm to manage all the flow and *n* APs and trigger the HO where it's required. The proposed architecture is supported via the following components shown in Fig. 1:

- **The Control Layer:** It consists of the controller elements, which includes the monitoring manager and HO manager. The main functions of the controller are measuring the statistics of all the flows and AP in real-time. This accuracy of the statistics will lead the controller to manage the whole network effectively in terms of packet forwarding or HO through which the controller will guarantee the best AP connectivity to the MNs. Examples of the collected data from the flows and APs are delay, jitter, bandwidth, SINR.

- **The Information Central Base (ICB):** All the measured and gathered information data via the controller will be stored in the ICB. This will include also the QoE requirements and network performance. The ICB play an important part in terms of tracking the currently connected MNs.
- **Application Layer:** It consists of all the applications implemented on the top of the SDWN. In details, such applications have the ability to access both lower layers (Control layer and Infrastructure one) in order to manage the whole network functionalities. The proposed HO algorithm is one of this application. Our HO strategy is based on FLCT which allows calculating the following components: association function, association degrees, and Fuzzy Handover Decision. Specifically, the algorithm firstly obtains a set of information monitored in real-time from the monitoring manager, named association values. Each of these values is then mapped to a number included in the range between completely true which is 1 and completely false which is 0 giving the respective association function [19]. All these association functions are the association degree for a certain candidate AP. Then, the FHOD (Fuzzy Handover Decision) is a score, which is utilized for each AP when the proposed HO strategy is executed. Finally, AHV values are considered in order to avoid redundant HOs. In detail, AHV is the margin provided for maintaining the minimum difference between the QoE received from the current AP and the candidate AP, and calculated in real-time, associated with the difference between the minimum and maximum QoE in an overlapped area. All the details of these elements, how they are computed and then, employed will be explained in the following section.
- **Infrastructure layer:** It contains all the physical components such as routers, MNs and switches, all managed by the controller. For instance, they respond to orders such as forwarding packets. Moreover, it provides control with live monitoring by gathering network status from the agents. For example, as illustrated in Fig.1, there will be an agent for each AP that has a capability to synchronise the management of events with the HO controller. In our architecture, the agents sent to the controller all the possible elements used in the implemented algorithms, such as AP coverage area, AP available bandwidth and AP load.

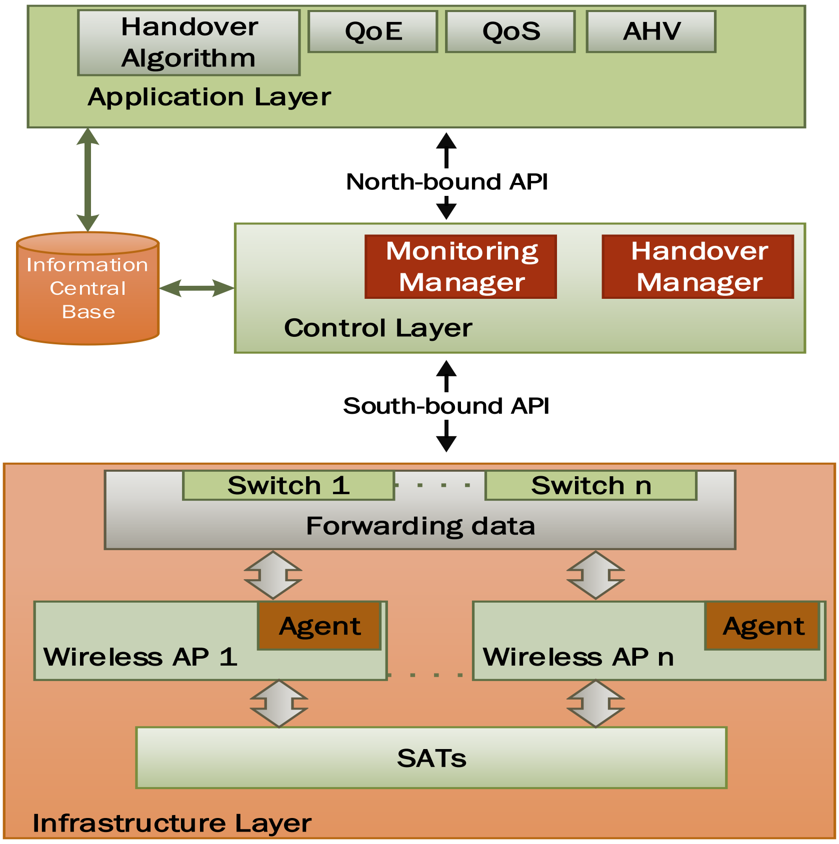

Fig. 1. SDWN Architecture for QoE-Aware HO

IV. Handover Approach based on FLCT

The first step of the proposed algorithm is the definition of the input parameters provided in the Fuzzy algorithm. In detail, the association values measured in the algorithm are delay, SINR, jitter and bandwidth. In subsection 4.3 we will describe an appropriate combination of such parameters will enable us to satisfy the requirements of both QoS and QoE through the HO process.

A. FLCT Association Functions

In order to execute the FLCT-based HO algorithm, we first need to convert the association values from their original status to the association function. In another word, the association function for a fuzzy set A on the universe of discourse X is defined as $\mu A{:}X \rightarrow [0,1]$. In this sub-section, we deliver an explanation of this conversion. Specifically, Fig.2 observe examples of the association functions for SINR, BW, Jitter and Delay.

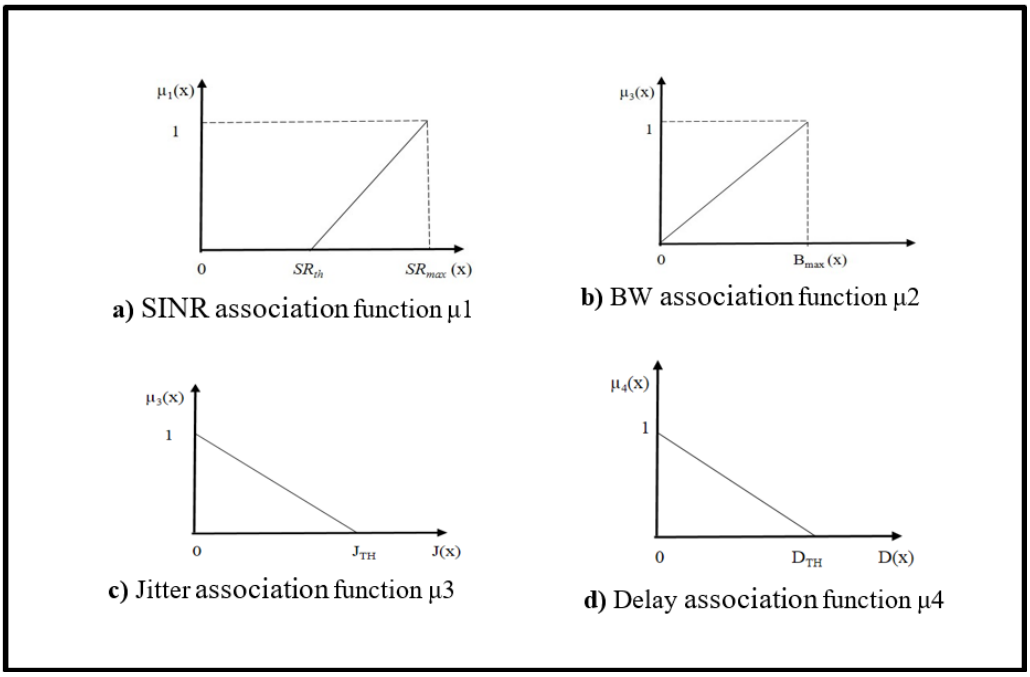

Fig. 2. The association functions

*Association Function for SINR***:** The function of SINR is called $\mu 1$, and its value is calculated in the next tasks. Initially, the controller collects the $SINR$ values through the equation below:

$$SINR = \Upsilon/(I + No) \tag{1}$$

In the equation, Υ represents the total of signal received, while No represents the overall noise and I indicates the interference.

Finally, the $SINR$ association function computed as follows:

$$\mu 1(x) = \begin{cases} 0 & 0 \leq SR(x) \leq SR_{th} \\ \dfrac{SR(x) - SR_{th}}{SR_{max} - SR_{th}} & SR(x) > SR_{th} \end{cases} \tag{2}$$

Here $SR(x)$ is represent the function of the $SINR$ for the candidate AP, SR_{th} represents minimum selected value of the $SINR$ in each simulation, while SR_{max} represents maximum $SINR$ value obtained by an MNs.

*Association Function for Bandwidth***:** it is called $\mu 2$, and is computed as follows:

$$\mu 2(x) = \begin{cases} \dfrac{B(x)}{Bmax} & 0 \leq B(x) \leq Bmax \\ 0 & B(x) > Bmax \end{cases} \tag{3}$$

Here $B(x)$ is the total available BW, *x*, for the candidate AP, and $Bmax$ denotes the maximum volume of BW provided via the candidate AP

Association Function for Jitter: called as a $\mu 3$ and denotes to the level of Jitter *x* for the candidate AP. Below equation 4 will describe the computing of Jitter association function:

$$\mu 3(x) = \begin{cases} 1 - \frac{J(x)}{J_{th}} & 0 \leq J(x) \leq J_{th} \\ 0 & J(x) > J_{th} \end{cases} \quad (4)$$

Jitter *x* here will be represented as $J(x)$, while J_{th} is the minimum value acceptable jitter.

Association Function for the Delay: called as a $\mu 4$ which is denotes to a level of delay *x* for all candidate AP. The following equation will describe the computing of delay association function:

$$\mu 4(x) = \begin{cases} 1 - \frac{D(x)}{D_{th}} & 0 \leq D(x) \leq D_{th} \\ 0 & D(x) > D_{th} \end{cases} \quad (5)$$

Delay *x* here represented by $D(x)$ *x* and D_{th} is the minimum value acceptable.

B. FLCT Association Degrees

Once the calculation of the association functions is finalized, the association degree can be computed. In details, considering n new APs when the algorithm is triggered, the association degrees for such APs can be defined and they are illustrated in Table I.

TABLE I

APS ASSOCIATION

	AP1	AP2	......	APn
SINR	µ1,1(x)	µ1,2(x)	......	µ1,n(x)
BW	µ2,1(x)	µ2,2(x)	......	µ2,n(x)
Jitter	µ3,1(x)	µ3,2(x)	......	µ3,n(x)
Delay	µ4,1(x)	µ4,2(x)	......	µ4,n(x)

Eq. (6) will illustrate the element u_k which is involves every association functions values for a certain AP_k ($1 \leq k \leq n$), that represent via computing the association degree value of AP_k.

$$u_k = \begin{bmatrix} \mu_{1,k}(x) \\ \mu_{2,k}(x) \\ \mu_{3,k}(x) \\ \mu_{4,k}(x) \end{bmatrix} \tag{6}$$

The next step is to compute the weight vector *W* for the association functions as it's described below:

$$W = (W_1, W_2, W_3, W_4) \tag{7}$$

We can rewrite vector *W* as below:

$$W = (w_1, w_2, w_3, w_4) = [\frac{\sigma_1}{\sum_{i=1}^{4} \sigma_i}, \frac{\sigma_2}{\sum_{i=1}^{4} \sigma_i}, \frac{\sigma_3}{\sum_{i=1}^{4} \sigma_i}, \frac{\sigma_4}{\sum_{i=1}^{4} \sigma_i}] \tag{8}$$

As we see from the equation above, we need to compute the standard deviation which is denoted σ_i of value *i* from association functions. The equation below shows the calculation of the standard deviation:

$$\sigma_i = \sqrt{\frac{1}{n-1} \sum_{k=1}^{n} [\mu_{i,k}(x) - \frac{1}{n} \sum_{k=1}^{n} [\mu_{i,k}(x)]^2} \tag{9}$$

Making use of both eq. (6, 7) will now represent the FHOD for AP_k which is shown below:

$$F_k\,(x) \;=\; Wu_k \tag{10}$$

We can then rewrite this equation as below:

$$F_k\,(x) = \; w_1\mu_{1,k}\,(x) + \; w_2\mu_{2,k}\,(x) + w_3\mu_{3,k}\,(x) \; + w_4\mu_{4,k}\,(x) \tag{11}$$

The next step it computes U for each n APs as the association degree matrix:

$$U = \begin{bmatrix} \mu_{1,1}(x) & \mu_{1,2}(x) & \dots & \mu_{1,n}(x) \\ \mu_{2,1}(\mathrm{x}) & \mu_{2,2}(\mathrm{x}) & \dots & \mu_{2,\mathrm{n}}(\mathrm{x}) \\ \mu_{3,1}(\mathrm{x}) & \mu_{3,2}(\mathrm{x}) & \dots & \mu_{3,\mathrm{n}}(\mathrm{x}) \\ \mu_{4,1}(\mathrm{x}) & \mu_{4,1}(\mathrm{x}) & \dots & \mu_{4,1}(\mathrm{x}) \end{bmatrix} \tag{12}$$

The final step is to computes the FHOD values from equations (7)-(12), using $W\ and\ U$ both of the n candidate APs:

$$F = WU \tag{13}$$

C. Adaptive hysteresis value

Nowadays, redundant HOs become challenging especially in a large network environment, such as campuses, airports and business centres. Therefore, new techniques are needed in order to optimize the HO decisions. In [23] we have presented a HO technique based only on QoE, which is efficient in small network areas. Therefore, we introduce a new element in our HO approach to reach the best HO decision through the AH values at the edge of QoE levels.

The QoE level at the current or candidate APs is included in a range of different values because of the movement of the MNs, or the nature of the currently running application. For this reason, we introduce the AHV. It is calculated in real-time, associated with the difference between the minimum and maximum QoE in an overlapped area and is derived as follows [24]:

$$AHV \;=\; max\,\{\,AHV_{\,max} \times (1 - 10^{\frac{QoE_{act} - \,QoE_{min}}{QoE_{min} - QoE_{max}}}\,)^{exp}\,;AHV_{\,min}\} \tag{14}$$

Where, QoE_{act} is the actual QoE at the MN, QoE_{max} and QoE_{min} are maximum and minimum QoE values which could be offered by the APs in the overlapped area, the value of the exponent (exp) is equivalent to 4 and $AHV_{\,min}$ is the lowest possible AHV to set up equal to 0 [25].

The values of QoE (The lowest possible and maximum) also must be measured for the deployment of the AHV. QoE_{min} refers to the minimum QoE level, where the MN is able to receive the service between fair and poor, which is no less than 2.5 according to the Mean Opinion Score (MOS) explained in the next subsection. Therefore, QoE_{min} is set up as a fixed value at this case, which is 2.5 in terms of MOS. The QoE_{max} can be determined by using equation (14).

D. FLCT Optimized HO Algorithm

The FHOD parameters represented by eq. (13) will be taken into account for each AP when our FLCT-based algorithm is triggered. While AHV values represented by Eq. (14) will be taken into consideration for the evaluation of the hysteresis value. In the decision-making phase, the SDWN-based controller triggers our HO algorithm in order to connect a certain MN to the most suitable {AP}_k (1 ≤ k ≤ n) only if it is able to guarantee the following terms:

$$F_k(x) = \max\{F1(x), F2(x), \ldots Fn(x)\} \quad \text{(a)}$$

$$F_j(x) = \max\{F1(x), F2(x), \ldots Fn(x)\} \mid F_j(x) \neq F_k(x) \quad \text{(b)} \qquad (15)$$

$$F_k\,(x) - F_j(x) \geq F_{TH} \quad \text{(c)}$$

$$F_k > F_c + AHV \quad \text{(d)}$$

where, $F_k(x)$ and $F_j(x)$ are the maximum and the second maximum FHOD values, respectively. Moreover, F_c is the current connected AP. In eq. (15), we achieved (a) and (b) by eq. (11), in which the HO manager will choose the peak scores from the candidate APs available list. The requirement (c) is used in order to prevent HOs that are not needed less than the threshold, by using F_{TH} parameter. Finally, through (d) the controller will calculate the hysterias value which ensures the avoidance of redundant HO. In this work, F_{TH} is chosen in order to provide the lowest value of QoE defined as MOS_{TH} in the paper, which is chosen regarding the MNs case. The MOS is a parameter used to establish the QoE in order to provide a realistic impression of the users in terms of service performance [18]. In detail, the MOS is an arithmetic computation of entire scores given individually and obtained through subjective tests. These scores range from minimum 1 score to maximum 5 score, where 1 means *Bad* and 5 means *Excellent* as illustrated in Table II. Specifically, Table II shows all the characteristics scale from *Bad* scored 1, and it is also representing the *Very Annoying* impairment to *Excellent* scored 5, which also represents the *Imperceptible* impairment.

TABLE II

MOS CORRESPONDING TO THE QUALITY

MOS	Quality	Impairment
5	Excellent	Imperceptible
4	Good	Perceptible
3	Fair	Slightly annoying
2	Poor	Annoying
1	Bad	Very annoying

The next step is to focus on the proposed algorithm implementation. Specifically, every time that a MN *m* using an AP service and receive MOS less than MOS_{TH} because of another MN, which starts using the same AP, the controller runs the proposed algorithm. The controller is in fact able to compute all the MOS values of the connected MNs in order to establish if anyone of them has experienced a decrease of the MOS below the defined threshold due to the connection of the new MN. Therefore, the FLCT-based algorithm is executed in order to connect all the MNs to the candidate AP guaranteeing the conditions defined through equation (15).

Focusing now on the algorithm implemented in the proposed architecture, each time that a generic MN *m* connected to the network experiences a MOS lower than MOS_{TH} due to another MN connecting to the same AP, this is autonomously detected by the network, which triggers the algorithm. Hence, the HO management controller executes the FLC-based algorithm to assign to MN *m* the AP satisfying conditions (a) and (b). Specifically, when the HO algorithm is triggered, the HO management controller computes the FHOD values by using equations (6)-(13) in the FLCT and for the set of candidate APs available for MN *m* achieved from the ICB. Afterwards, the HO management controller will chose for MN *m* the best AP, i.e., the AP satisfying conditions (a) and (b).

V. IMPLEMENTATION AND RESULT

A. *Simulated Algorithm*

Fig.3. illustrates the scenario of the proposed SDWN-based architecture, which has been implemented and assessed using OPNET. We have used OPNET as the deployment of a real network is often costly and requires linking multiple end points with data links. Moreover, note that the use of the simulator has been convenient to validate our solution and achieve preliminary performance results. The results that we have obtained and illustrated in the next sub-section encourage the effort to implement our solution also in real-world scenarios as a part of our future works. In detail, the WLAN following the IEEE 802.11a standard includes 25 APs managed by the Handover management controller and 250 MNs located in the scenario and that try to connect to an AP. The simulation configuration setups are presented in Table III.

We have considered two kinds of applications run by the MNs linked to the WLAN, which are Video Streaming and VoIP, characterized by the traffic features such as resolution, bit rate, codec, respective reachable MOSs shown in following Table IV.

As shown in Fig. 3, in the simulated setup each cell has an AP located in the middle, covering a 500mx500m area. Once the simulation starts, an MN is created uniformly every 5 to 10sec, running VoIP or Video. MNs have been located randomly in the 25 cells covered by the APs. As we will describe in the following sub-section, these session creations triggered our algorithm.

The MOS_{TH} in term (b) equal to 3.1, and that will not decrease the score under the fair level, which for instance is the VoIP codec *G7.11* will be equal approximately 39.68 kbps and the video will be equal approximately to 271.5. Furthermore, to evaluate the results of the proposed HO algorithm, a comparison we make with our previous work based on FLCT [23]. Note that this strategy outperforms the IEEE 802.11a topology and another approach found in the stat of the art.

TABLE III

SIMULATIONS FACTORS AND SETUP

Parameters	Value
MNs speed	3 km/h
Overall AP coverage	500x500
Number APs	25
Number of SATs	250
MAC Type	802.11a
Transmit Power	0.005
Reception Power threshold	-95
AP Bacon interval	0.02sec
AP coverage area	Circular with one cell, R = 25m

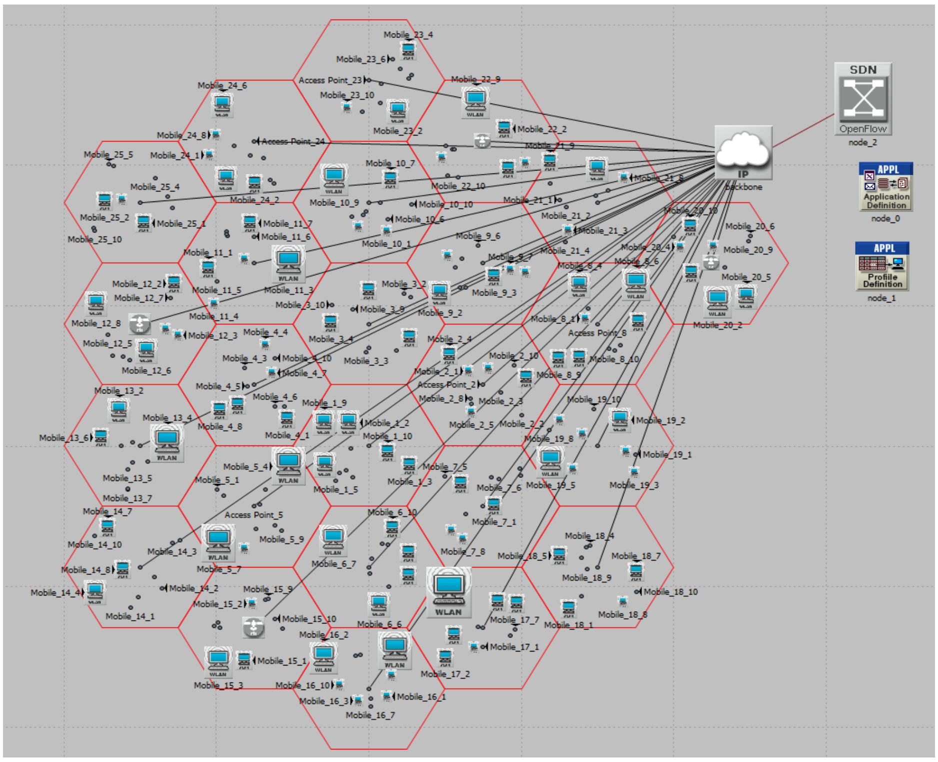

Fig 3. The SDWN-based architecture simulated scenario

TABLE IV

TRAFFIC CHARACTERISTICS

Application Type	codec	Bitrate (kbps)	Resolution (pixels)	MOS
VoIP	G.723	6.3		4.1
	G.726	24		3.8
	G.726	32	525*384	3.5
	G7.11	64		4.1
Video	H.264	438		4.0

B. Simulation Results

We have mentioned, the MNs have been created uniformly each 5 to 10sec in a random location. Approximately, after 150 MNs joined the network, the MOS decreased because of the high load in each AP. Once the MOSs of the affected MNs reached below the MOS_{TH}, the HO algorithm management will be executed via the controller to discover and allocate a better candidate AP for such MNs. The following figures illustrate the performance results of our approach (which is called Optimise AP Selection) compared to the FLCT-based algorithm (which is called FLCT AP Best Selection) in terms of MOS and throughput, as functions of the number of MNs. These figures illustrate the behavior of the performance results from the first MN joining the network, until the last one, which is the 250th. These figures show the improvements obtained corresponding the QoE for the overall network by our algorithm.

In detail, from Fig. 4 we can see how our proposed approach improves the FLCT-based one regard to MOS. For example, after the last MN joined the network, the proposed algorithm reached a MOS value of 2.5, while it is 1.8 in case of the FLCT-based approach. The proposed algorithm maintains the users above the 3.1 MOS. However, the network will be over-congested just after approximately 140 joined flows, therefore, the MOS will keep decreasing with the increase of the flows.

Figure 5 illustrates how our algorithm outperforms the FLCT-based one also in terms of average throughput (i.e., bits received by the MNs per second). Example of that, after the end of the simulation, when 250 flows joined the network, the overall network throughput achieved through the proposed solution is around $2.3\text{x}10^4$ Kbits, while it is approximately $1.5\text{x}10^4$ Kbits for the FLCT-based approach. Specifically, our solution outperforms the state of the art by a gain of 25% in terms of average throughput.

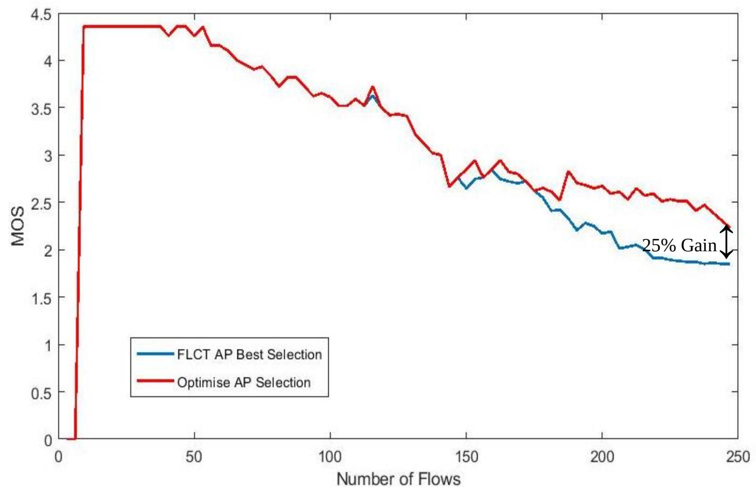

Fig. 4. Overall MOS score as a function of MNs.

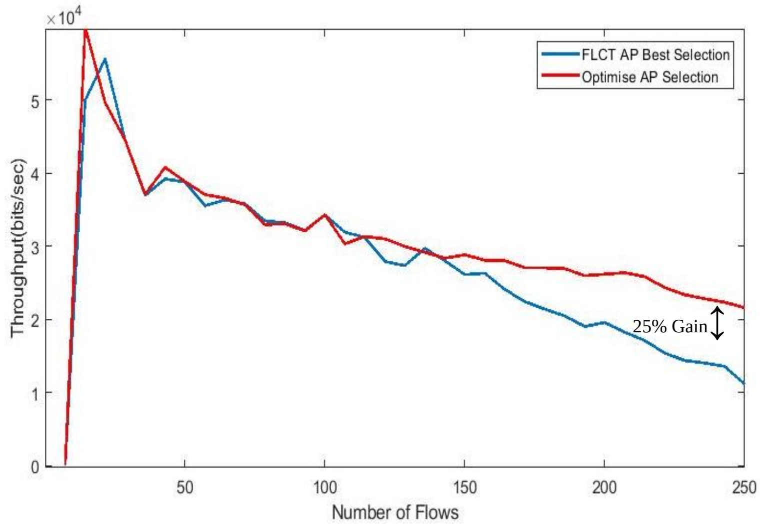

Fig. 5. Overall Throughput

Fig. 6 present the result of the delay from one end (server) to the other end (MN). This figure illustrates a gain of roughly 25% in terms delay reached via applying our proposed solution optimise AP selection compared to the FLCT-based approach.

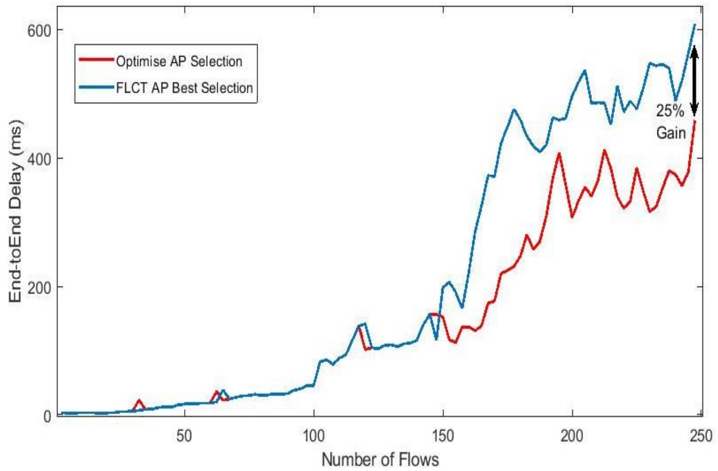

Fig. 6. Delay

Fig. 7. illustrates the overall numbers of HO and the Number of handovers per application (VoIP and Video). As we notice, the proposed algorithm reduces the HO by around 25% compared with FLCT Best AP Selection. The gain of that is reducing the overhead messages which consume about 25% from the overall throughput. From the results illustrated in figures 4, 5, and 6, we can notice that our algorithm outperforms the FLCT AP Best Selection considered in the literature in terms of overall MOS, overall throughput and End-to-End delay. In summary, the proposed solution is able to avoid unnecessary handovers and then, the ping-pong effect. This result has an implication on the reduction of the overhead messages, which in turn allows to improve the performance results by 25% with respect to the state of the art.

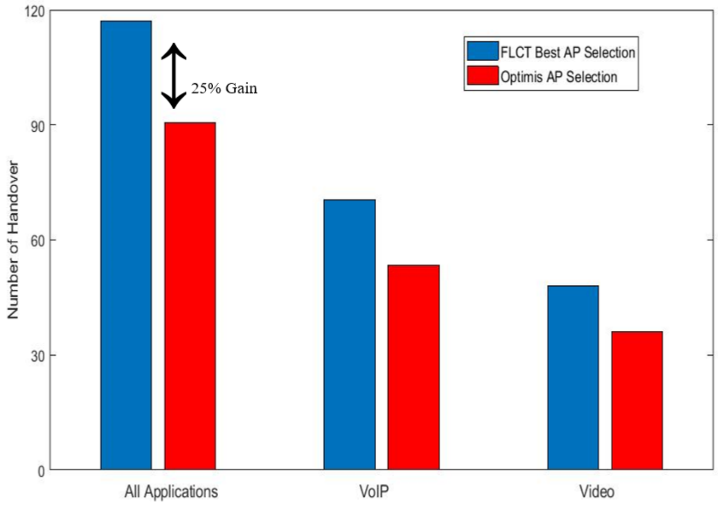

Fig.7. Overall numbers of HO

VI. CONCLUSIONS

Our proposed work was to design a novel network architecture based on SDWN, where the end-users and AP will be involved In HO processes. Considering the awareness of both QoE and QoS and based on FLCT and AHVs. Specifically, this architecture implements an algorithm, which addresses the QoE of the Mobile Nodes (MNs) to guarantee the most suitable AP link, and the AHV to avoid unnecessary handovers. Moreover, we compared our results with another approach found in the state of the art to demonstrate the efficiency of our solution regarding throughput, MOS and delay. For instance, our results have effectively proven that our solution outperforms the state of the art by a gain of 25% in terms of delay. In our future works, we will implement the algorithm also in heterogenous networks including Wi-Fi APs, LTE base stations (eNodeBs) and 5G Base Stations (gNBs). Moreover, we will take into account new algorithms in which the MNs will be classified as high and low priority users.

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