SAQ-2HN: A Novel SDN-Based Architecture for the Management of Quality of Service in Homogeneous and Heterogeneous Wireless Networks

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Summary
Quality of service (QoS) is a major concern for most network administrators. However, QoS requires an implementation of policies, which are often static. This approach is not flexible with the diversity of user services and their varying needs in terms of network resources.
The Software Defined Network (SDN) approach addresses this issue, by bringing to the classical networks the intelligence of the dynamic and intelligent readjustment of the QoS in order to respect the service level agreement.
In this paper we propose an extensible SDN architecture for the intelligent, dynamic and adaptive management of QoS in a heterogeneous or homogeneous wireless network.
The results of the simulation of our architecture show its effectiveness in various applications (Web-based and real-time) compared to traditional solutions.

Key words:
SDN, QoS, Handover, Heterogeneous Networks, Homogeneous Networks, Wireless, WiMAX, WiFi.

1. Introduction

No one can deny that mobile networks are increasingly used for the routing of user data. According to statistics made in the Kingdom of Morocco by The National Telecommunications Regulatory Agency (ANRT) [1]:

- ✓ The equipment of individuals (12-65 years) with a mobile phone (94.4% in 2015) shows a slight stagnation (94.1% in 2014).
- ✓ Meanwhile, the number of people equipped with a Smartphone displays a significant increase from 38.2% in 2014 to 54.7% in 2015.
- ✓ Regarding the equipment of households with computers, it's established at 54.8% in 2015 and shows an increase of more than two points compared to 2014.
- ✓ In terms of households' equipment with Internet, the rate is 66.5%, recording an evolution of more than sixteen points compared to 2014. This growth is due to the mobile technology.
- ✓ Fixed telephony continues to decline in 2015. Hence, the proportion of households equipped with fixed telephony decreased by about two points from 24.1% in 2014 to 22.3% in 2015.

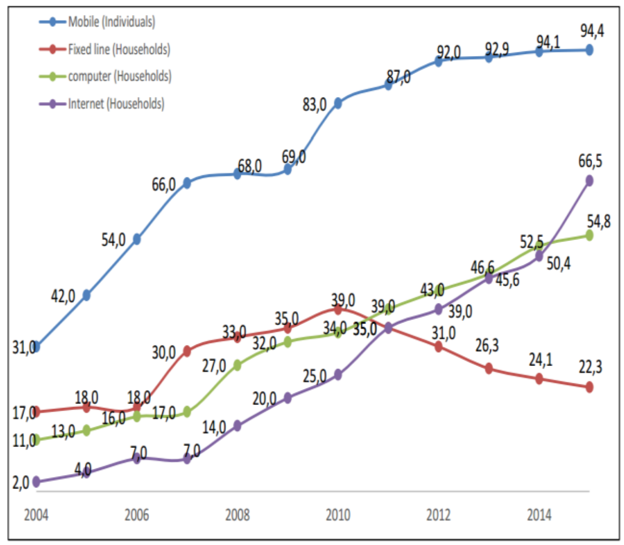

Fig.1 Evolution in % of individuals and households' ICT equipment (2004-2015) (% of individuals aged 12-65 years/ % of households in areas connected to the electric grid)

These mobile networks are currently an active research area, given the limitations they represent mostly in terms of quality of service [2]. Users carry nowadays different types of flows (Real Time, Web-Based, Transactional, etc.) across heterogeneous networks. This constitutes a real problem concerning:

(i) User satisfaction (Quality of Experience - QoE).
(ii) The management of network resources that are often restricted.
(iii) Scalability [3], because the increasing demand for bandwidth and the diversity of flows can lead to saturation of the entire network.

The Software Defined Network "SDN" [4] and Network Function Virtualization "NFV" [5] technologies respond to these three challenges by providing flexibility in the management and the configuration of such networks. These two technologies guarantee a very high efficiency

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of wireless networks and extend the field of innovation thanks to their modularity.
Indeed, SDN is a new approach to deploying and managing network architectures (Wired or wireless) in which the management plan, control plan and data plan are separated. The goal is to make the data layer's devices transparent to the administrator, so that the latter can act through a unified console on the overall system.
With the SDN approach, a user can operate multiple network infrastructures, according to which responds the most to the SLA Service Level Agreement [6]. This data control is ensured by a software entity called controller.
QoS management in heterogeneous or homogeneous networks is generally difficult to ensure, for several reasons:

1) QoS mechanisms change from one access network to another.
2) The resource reservation should be done at each point of attachment.
3) Scalability is a problem if user profiles change periodically from one domain to another, or the number of intermediate equipment increases.

By adopting the SDN approach, we propose by this work a new architecture of the intelligent and adaptive management of the quality of service in a homogeneous and heterogeneous network. This model is called Smart Adaptive QoS for Heterogeneous and Homogeneous Networks (SAQ-2HN).
The rest of the paper is organized as follows: in the second section we will present recent related works. In the third section we propose the architecture of SAQ-2HN model. The operation of the model and its flexibility will be treated respectively through the fourth and the fifth section. The evaluation of the model will be presented in the sixth section. Finally we will conclude.

2. Related Works

SDN technology [7-9] has emerged recently thanks to its many services such as network virtualization (NFV) [10-11], self-management of architectures, and separation of plans (management, control and data), which provides much more flexibility and scalability to modern networks.
This technology has been applied for a long time on wired networks [12-13]. However, most recently, researchers have published many works by adapting the SDN technology in wireless networks Software Defined Wireless Network "SDWN" [14-16].
Our contribution is in the context of the adaptation of the SDN technology for the management of the QoS in the heterogeneous or homogeneous wireless networks. Some work has been published in this context. The work [17] proposes a solution which allows to manage the QoS in a heterogeneous wireless network. However, this work does not deal with the constraint of mobility, in other words, the QoS adaptation will be performed when the client is associated with an attachment point.
The work [18] proposes a solution to change the routing plan in a flexible and automatic manner to meet QoS needs of multimedia applications. However, this work does not deal with the management of the QoS policies for multimedia streams.
Taking into account our comments on previous work, we propose a SDWN architecture for managing quality of service and mobility intelligently and dynamically.
This model is named SAQ-2HN acronym for Smart Adaptive QoS for Heterogeneous and Homogeneous Networks.

3. Architecture of SAQ-2HN Model

We propose by this work the SAQ-2HN architecture for dynamic and intelligent management of the quality of service in heterogeneous and homogeneous wireless networks.
The various modules of the SAQ-2HN model are defined in Fig.2.

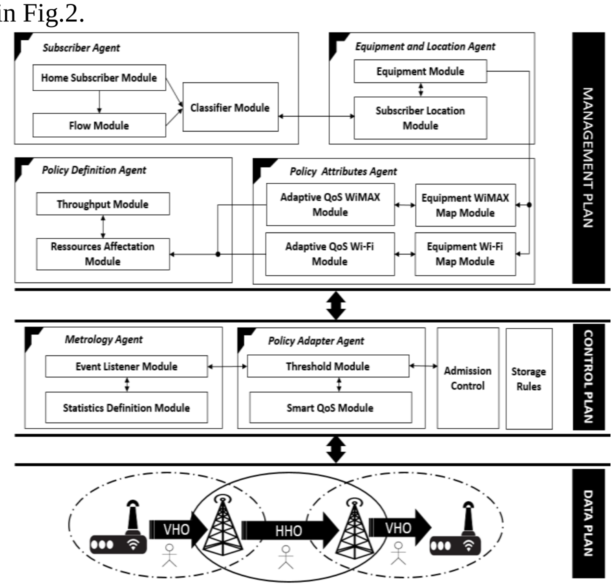

Fig.2. Architecture of SAQ-2HN model

The SAQ-2HN model consists of three plans: The data, control and management plan.

3.1 Management Plan

The management plan is composed of four agents: (i) Subscriber Agent, (iii) Policy Definition Agent, and (iv) Policy Attributes Agent.

A) Subscriber Agent

This Agent maintains a table of mobile users' identities, their roles, and network traffic and performs correspondence between applications and beneficiary users. This agent consists of three modules:

- Subscriber Module:

This module registers users after the authentication phase. The protocol diameter is chosen for this task.
A user is identified by its MAC address. The Subscriber module allows static and dynamic records.
Fig. 3. shows an extract of records from the Subscriber module after authentication.

ID	TYPE	USERNAME	ROLE	MAC
1	S	Azzedine	Administrator	MAC 1
2	S	Jamila	Professor	MAC 2
3	S	Mohamed	Professor	MAC 3
4	D	Ayoub	Researcher	MAC 4

Fig. 3 Subscriber Module example.

These records can be static Type = S or dynamic Type = D.

- Flow Module:

Flow Module, maintains a table of information about the flows used in the network classified by categories. This module is configured by standardized applications, it can be customized manually (for example: ENSET-CITRIX = TCP port 2017).

- Classifier Module:

This module allows to assign a DSCP code for each Subscriber-flow pair (Fig.4)

ID	Match	Subscriber_ID	Flow	Code
1	ALL	1	ENSET-Citrix	Excellent Effort
2	ANY	2	VOIP	Interactive Voice

Fig. 4 Subscriber Classifier example.

Subscriber_ID is the primary key of the Subscriber table. This module allows a preliminary classification of users-traffic according to DSCP codes. Each class is characterized by an ID, which will be useful for the application of the QoS policy depending on the intermediate equipment.

B) Equipment and location Agent

This agent defines all the managed equipment (BSS, AP ...) as well as the current attachment equipment and the next attachment equipment for each user defined in the Subscriber module.
This agent consists of two modules:

- Equipment Module:

This module maps the intermediary equipment of the network. (BSS, Access point, routers, etc.)
The devices must be populated manually by the administrator, as they can be detected dynamically via the SNMP V3 protocol. This module is very important, it allows to identify the types of QoS policies to apply. Fig. 5. illustrates an example of its entries.

ID	Public IP	Name	Capability	Location
1	196.200.172.10	AP-GI	Access Point	ENSET
2	192.200.100.1	ANY	WIMAX	PRESIDENCE1
3	192.200.100.1	BS-AP-FS	Access Point + WiMax	PRESIDENCE2

Fig. 5 Equipment Module example

- Subscriber Location Module:

A user can be mobile, he can switch from a WiFi network to a WiMax network and vice versa. Detect its exact position allows to define the adapted QoS policy to its context.
The Subscriber Location module detects the current position of each subscriber. This detection can be (i) active: by consulting the ARP cache periodically of the intermediate equipment. Or (ii) passive: The attachment point sends an alert via the diameter or RADIUS protocols.
As, the distance between a user and its point of attachment can be determined. Our architecture can predict the next point of attachment and configure this node as soon as possible to ensure continuity of a user's QoS.
Fig. 6. shows subscriber location entries.

ID	ID_USER	ID_EQUIPMENT	DISTANCE	NEXT EQUIPMENT
1	1	1	80 m	2

Fig. 6 Subscriber Location Module example

Note that ID_USER and ID_Equipment are the primary keys of the Subscriber Module and Equipment Module tables. Next Equipment, is based on standardized selection algorithms (RSS, BW, Loss Rate, etc.).

C) Policy Definition Agent

This agent allows to define the different attributes of the QoS policies for each domain, detailed below.
This agent consists of two modules.

- Throughput Module:

Before proceeding to the final phase, it is necessary to detect the Uplink and Downlink throughput of each equipment defined in the module "Equipment Module". The TTCP script can be used for this task. The domain administrator can specify these values manually.
This module is indispensable in the architecture proposed, because the allocation of the bandwidths must be made

according to the existing resources. Without excess or waste.

Fig.7. illustrates an example of the module records:

ID	ID_EQUIPMENT	Downlink	UPlink
1	1	30 M	50 M
2	3	10 Mb	14 M

Fig. 7 Throughput Module example

ID_Equipment is a foreign key associated with the primary key of the Equipment Module.

- Resources affectation Module:

After (i) authenticating and authorizing subscribers, (ii) detecting their active flows and customizing new flows, (iii) detecting attachment points, and detecting their capabilities. The resources affectation module allows to associate for each class of the module a determined bandwidth.

This module allows also to adapt the QoS policies according to: (i) Intermediate equipment, (ii) traffic class, (iii) suitable QoS category in case of WiMax, and the size of contention window in case of Wi-Fi.

- ✓ Concerning the appropriate QoS WiMax category (see module: adaptive WiMax QoS)
- ✓ Concerning the appropriate QoS WiFi category (see module: adaptive WiFi QoS)

The basic entries for this module are shown in Fig.8:

ID	Classifier_ID	Location_ID	Current Equipment	NEXT EQUIPMENT
1	1	1	1	2

Fig. 8 Resources affectation Module example

The QoS policy to be applied for each entry in the figure below is therefore related to the information of each class (Subscriber, Traffic, and DSCP), Current location and next attachment point.

A QoS policy example is illustrated in Fig. 9:

ID	TECH	Current Policy_ID	TECH	NEXT Policy_ID	Assigned BW
1	2	1	1	1	300Kbps

Fig. 9 QoS Policy example

It should be noted that with the architecture of this module, policies are defined by domain. The same subscriber may benefit from different priorities from one domain to another.

D) Policy Attributes Agent

This agent is the last gateway to generate an appropriate and exploitable QoS policy for a specific attachment point. It consists of four modules:

- Adaptive QoS WiMAX Module:

This module provides a definition of the different classes of WiMAX services and membership criteria. These correspondences can be customized by the administrator for each BS device.

Fig.10. Shows an example of module entries.

ID	User_ID	TECH	Title	Codes
1	1	1	UGS	AF44; FF; Excellent Effort; Interactive Voice
2	2	1	nrtps	Background

Fig. 10 Adaptive QoS WiMAX Module example

An administrator can define different categories and their associated codes. The User_ID field determines the user affected by this category.

The field TECH (means Technology) will be set to value 1 for WiMax policy and 2 for Wi-Fi policy.

The field is very important to simplify the search on the policy to apply. Example: without this field, it is necessary to detect the number of the current equipment, to determine its type then to look for the policy having ID 1. With this field the system will recognize that the policy 1 belongs to domain 1, so it looks directly into WiMAX.

- Adaptive QoS Wi-Fi Module:

This module allows to define the duration of contention window for each class of the traffic, by default the HCF mode is applied.

The parameters on which we can act are: the class of service and the maximum and minimum contention window durations.

Fig. 11. Shows an example of the module's records.

ID	User_ID	Category	Codes	CW_Min	CW_Max
1	1	Background	BE, Excellent Effort	Value 1	Value 2
2	1	Voice	AF 41	Value 2	Value 4

Fig. 11 Adaptive QoS Wi-Fi Module example

- Equipment WiMAX Map Module:

This module allows to assign a policy to a base station. Fig. 12. Illustrates an example of mapping.

ID	ID_Equipment	ID_WiMAX Policy	Date
1	2	1	10/02/2017 17:22:10
2	2	2	10/02/2017 17:40:30
3	2	3	10/02/2017 17:52:40

Fig. 12 Equipment WiMAX Map Module example

- Equipment Wi-Fi Map Module:

This module allows to assign a policy to an access point. Fig. 13. illustrates an example of mapping.

ID	ID _Equipment	ID_WIFI Policy	Date
1	1	1	10/02/2017 17:22:17
2	1	2	10/02/2017 17:30:30
3	2	5	10/02/2017 17:32:20

Fig. 13 Equipment Wi-Fi Map Module example

3.2 Control Plan

The control plan consists of two agents: (i) Metrology Agent, and (ii) Policy Adapter Agent.

A) Metrology Agent

This agent as its name indicates, performs an active and passive metrology to (i) Collect reports on the performance of the network and its transported applications and (ii) Detect new subscriber connections.
This agent consists of two modules:

- Event Listener Module:

As soon as the first policies are delivered, an active measurement of application performances is required in order to deduce the effectiveness of the QoS policy.
This module performs a metrology, it just collects the statistics defined by the next module.

- Statistics Definition Module:

This module is responsible for defining the statistics to be collected. These statistics may be related to the network or applications.
This module provides a list of evaluation criteria. The administrator then specifies the important criteria. I.e., in case of a conference activity, the administrator can collect the delay, jitter and loss rate criteria.
Fig. 14. illustrates an example of module entries:

ID	Category_ID	Parameter	Frequency	Equipment_ID
1	3	Voice jitter	1s	1
2	3	Voice loss	2s	1
3	3	TCP Delay	3s	1
4	1	Number of users	2s	2
5	1	Network Queue	3s	2

Fig. 14 Equipment Wi-Fi Map Module example

B) Policy Adapter Agent

This agent plays the role of the regulator of the QoS policy. It compares the statistics of data collected by the Metrology agent with a base of recommended thresholds. If a threshold is exceeded, the module adjusts the QoS policy dynamically to meet the requirements of the trigger flow. This adaptation can only be carried out by validation of the admission control.
This agent consists of two modules.

- Threshold Module:

This module performs two tasks:

1. Define standardized thresholds for each application;
2. Compare obtained statistics by the module "Event listener" with this database. If a threshold is exceeded, processing will be triggered. This treatment will be detailed by the next module.

This database is defined as follows (Fig.15):

ID	ID_Equipment	Criteria_ID	Value Excess	operand
1	1	1	50%	>=
2	1	2	1%	=
3	2	3	5%	=

Fig. 15 Threshold Module example

- Smart QoS Module:

Once a threshold is triggered. A performance problem is therefore posed. However, even with QoS mechanisms implemented, SLA is not respected.
This module will allocate additional bandwidths to certain services temporarily, and remove these resources once the network is in critical condition or applications of higher priority users need additional bandwidth.
The model proposed by Ayoub BAHNASSE [19-20] can be adopted because it exactly meets our requirements. Except that we just have to act on contention windows for WIFI networks.

3.2 Data Plan

This plan accommodates all intermediate equipment (attachment points). These equipment can be of different technology, for example: BSS, AP, Radio Antenna, etc.
This plan receives the policies delivered by the control plan, and sends traps when detecting the connection of new users to trigger the QoS management process.
All agents' data are stored periodically in a database.

4. Operation of the SAQ-2HN model

After discussing the architecture of the SAQ-2HN model. We will present the functioning of its agents. (see Fig. 16).
(**Bloc 1**) defines the set of parameters of different modules (subscriber, flow and classifier).
These parameters can be detected dynamically by DIAMETER and SMMP protocols, or else specified statically (**Bloc 2**). For modularity measures and to make our model open to other technologies. The administrator can add other attributes for subscribers (ISIM, for cellular users ...) and other characteristics for the flows (**Bloc 3**).
After inserting the subscribers in the database and determining the classes of service. An essential phase must be approached, it is the detection of the location of the subscriber and its current point of attachment. (**Bloc 4**) ensures this phase. However, the detection of intermediate

equipment in the network can be performed manually by the administrator or SNMP Trap of location (OID: 1.3.6.1.2.1.1.6 of the MIB version 2 table). (**Bloc 5**)
For scalability measurements new equipment can be customized in (**Bloc 6**).
After completing the second phase, the declaration of the Qos attributes is required (**Block 7**). Through this phase, the administrator mentions all the Wimax Qos categories to be applied UGS <-> EF ,rTPS <-> AF33 , nrTPS <-> AF11, BE <-> BE) or WiFi contention window duration to apply (Voice --> Cwmin=t : Cwmax=t' , Video --> Cwmin=t' :Cwmax=t'',…). These attributes can be performed statically or dynamically if the system detects that the configuration of administrator is not optimal (**Bloc 8**).
For scalability measures, other technologies attributes can be added through (**Bloc 9**) (UMTS: Conversationnal class, streaming class, interactive class, Background class).
From the fourth phase, all the preliminary data to implement a Qos policy are gathered. However, before assigning bandwidths to users, it is necessary to know their natures and apply the attributes defined in **(Bloc7).** (**Bloc 10**) Can detect throughputs, apply attributes and assign bandwidths. This assignment can be dynamic, i.e. the allocated bandwidth can increase or decrease over time (**Bloc 11)**.
Our model is scalable, other QoS parameters related to other technologies can be defined (**Bloc 12**). (UMTS : Guaranted Bit Rate, maximum Bit Rate , max SDU Size…).
As mentioned earlier, our model is adaptive, it means that QoS policies will be dynamically varied according to the state of the network, the quality of the communication and current position of the subscriber. (**Bloc 13**) measures these parameters according to the services declared in the policy (**Bloc 10**).
The measurement parameters are specified according to the applications (intrinsic) or according to the choice of the administrator (dynamic) (**Bloc 14**).
To ensure scalability, (**Bloc 15**) authorizes the application of the model in several types of network.
From phase 5, we can say that point of attachment can offer the "Subscriber" a requested QoS level. However, in some cases a user requires a lot of bandwidth, and that the channel is free. In this case allocating additional bandwidth may be tolerable. (**Bloc 16**) allows this task of allocating and releasing resources, as soon as a malfunction is produced. However, we added other QosS management criteria in relation to WiFi networks such as the duration of contention window (**Bloc 18**).
Adapt or release resources can be performed according to thresholds, as soon as a threshold is triggered the procedure is executed, the thresholds are defined in (**Bloc 17**)

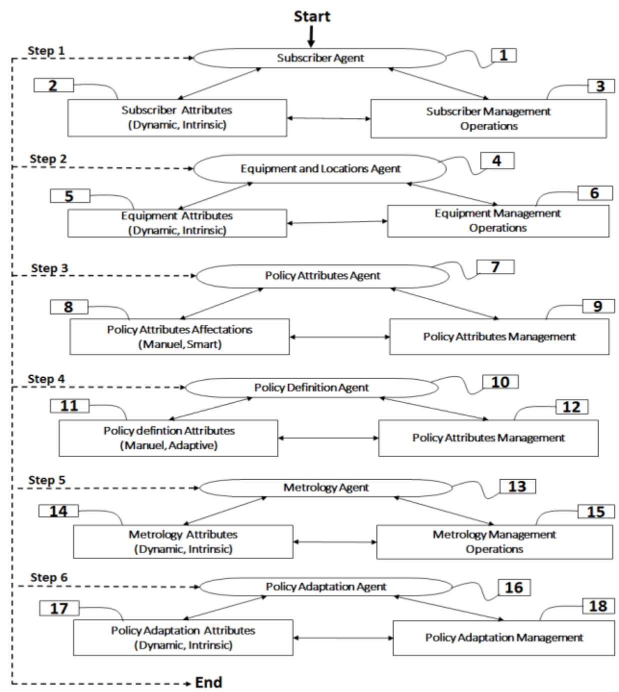

Fig. 16 Operation of SAQ-2HN Model

5. Flexibility of SAQ-2HN model

The proposed model provides flexibility in terms of (i) resource adaptation, (ii) release of allocated resources, and (iii) QoS guarantee in the case of handover (Horizontal and Vertical).
Flexibility is shown through Fig.17.

5.1 Resources adaptation

This process is represented in the first sequence. After user authentication, the current attachment point "CH" acronym of "Current Hop", sends an information to the Agent indicating the identity of the Subscriber. The latter detects the user's profile (Network type and flow) and requests the appropriate QoS policy from the Controller. The Controller carries out an admission control to decide on this policy and delivers the appropriate resources to the Subscriber profile.
The agent converts the Controller's response into a QoS policy adapted to the CH equipment. CH will acknowledge receipt of this policy.

5.2 Resources liberation

After QoS policy delivery, the agent keeps alive the session in order to detect any change of state at the CH level. When a threshold is triggered, the agent determines the trigger profile, if the latter has priority and the

conditions of the network are favorable (the remaining bandwidth is sufficient or the maximum number of users is not reached), then execute the first sequence.
Otherwise, the resources of the lowest priority profiles should be released after an admission control.

5.3 QoS Management during the handover

The first two sequences are running in parallel with the third that manages the QoS during the handover whether vertical or horizontal. Before associating a subscriber with an attachment point "NHE" acronym of "Next Hop Equipment", the Agent inquiries about the network state, then delivers the information to the Controller who decides on the resources to be reserved for that user in the NHE.

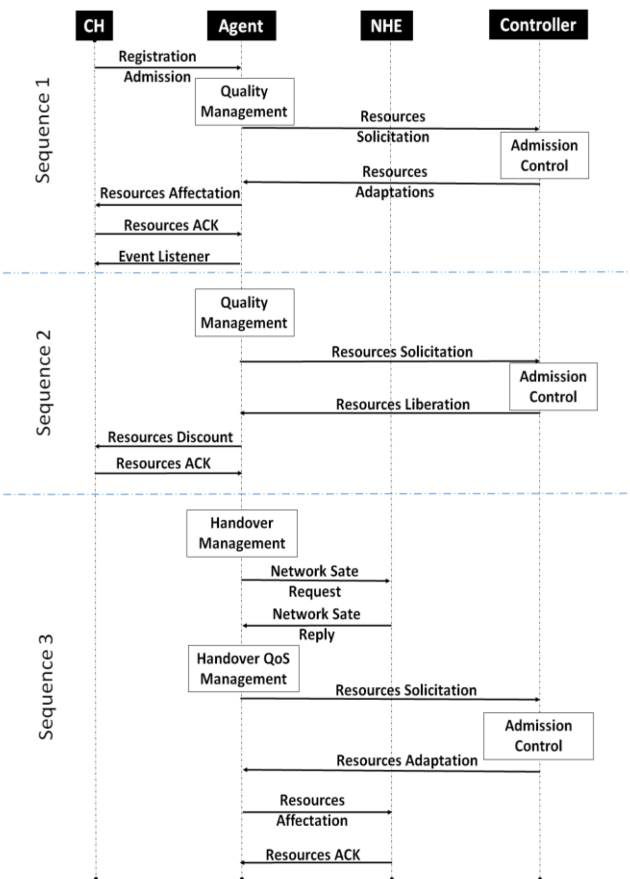

Fig. 17 Flexibiliy of SAQ-2HN Model

6. Evaluation of SAQ-2HN model

6.1 Testbed Topology

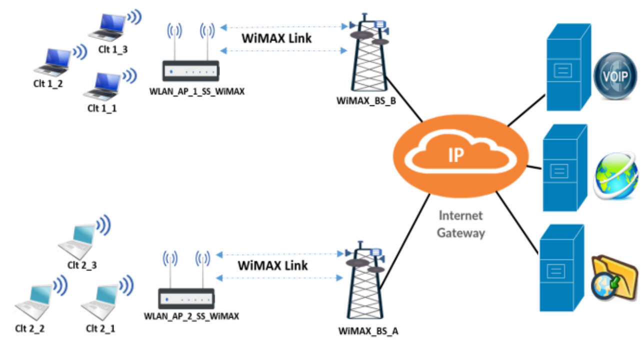

Fig. 18 Testbed Topology

In order to evaluate SAQ-2HN model we realized a scenario, under OPNET Modeler, consistent with Fig. 18.
Various categories of traffic were simulated for the evaluation:

- Bulk application (FTP),
- Real time application (VOIP),
- Web Based Application (HTTP).

The VOIP codec used is G729, the choice of the codec is made thanks to its low consumption of bandwidth (8K) as well as its high MOS score (3.9).
The simulation duration is set to one hour. The E1 links have been assigned to the attachment point's equipment.
To validate the SAQ-2HN model, we created three scenarios:

1. Without quality of service,
2. QoS Enabled
3. Using SAQ-2HN.

The allocation of resources and the affectation of DSCP codes are made according to Table 1.

Table 1: QoS Parameters used in the simulation

Traffic	Reservation	DSCP
Voice Traffic	Bandwidth 40%	EF
FTP	Bandwidth 25%	AF11
HTTP	Bandwidth 5%	BE

6.2 Obtained Results

A) VOIP Jitter

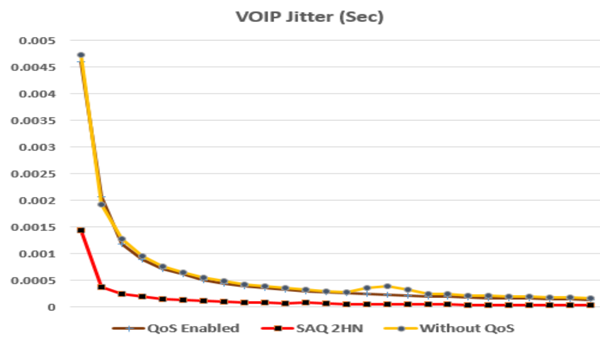

Fig. 18 VOIP Jitter

Jitter is defined as a variation in the delay of received packets. The threshold of the tolerable jitter can be up to 150 ms, beyond this threshold the voice becomes incomprehensible.

Fig.18 illustrates the jitter results, all scenarios offer a tolerable jitter, however our architecture offers even small delays. This can be justified by the fact that thanks to our SAQ-2HN architecture, the bandwidth reserved for VOIP traffic is adjusted dynamically to the needs of subscribers.

B) VOIP End To End Delay

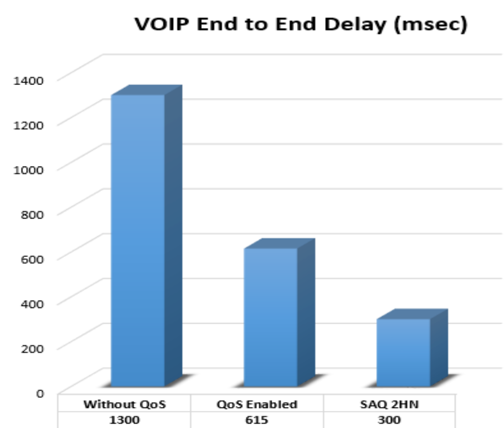

Fig. 19 VOIP End to End Delay

Latency or end to end delay, refers to the time taken for a packet to be transmitted across a network from source to destination. A delay of 300 milliseconds is acceptable.

Fig. 19 illustrates the latency results. It is clearly concluded that in both scenarios without QoS or QoS-Enabled, VOIP is largely unusable as they far exceed acceptable thresholds. While our architecture offers a delay of 300 milliseconds, offering an improvement of 105% compared to traditional QoS architectures.

C) HTTP and FTP Download Response Time

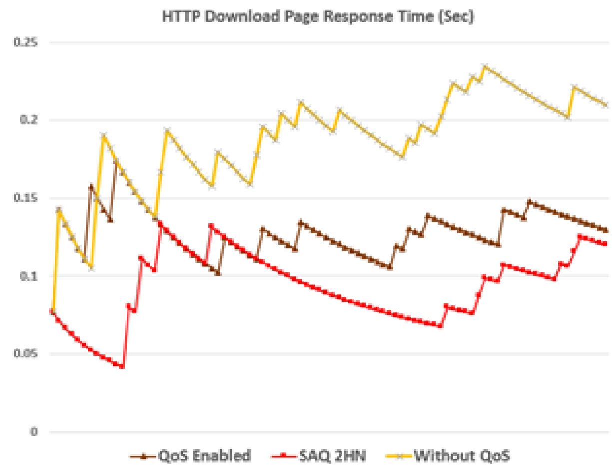

Fig.20. HTTP Download Page Time

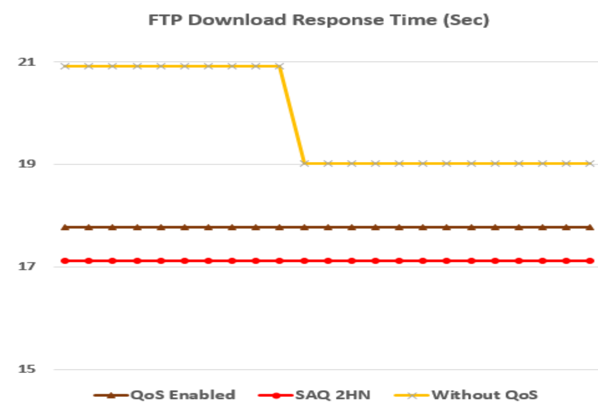

Fig.21. FTP Download Response Time

Fig.20 and Fig.21 represent respectively the delays of http loading page and ftp downloading file. The obtained results confirm the effectiveness of our model compared to the other scenarios.

7. Conclusion

This paper presents a new SAQ-2HN architecture for the management of QoS in a homogeneous and heterogeneous wireless network. The proposed architecture guarantees a dynamic and intelligent management of the QoS policies taking into account subscriber mobility.

The obtained results from the evaluation show the efficiency of the model with various traffic, such as: real-time (VOIP), Web-based (HTTP) and file transfer (FTP).

The proposed architecture does not integrate the security features, as a perspective we will integrate it into the SAQ-2HN architecture.

References

[1] The National Telecommunications Regulatory Agency (ANRT), Information Technology Observatory- Survey on ICT access and usage by households and individuals in Morocco, 2015.

[2] Azeddine KHIAT, Ayoub Bahnasse, Bakkoury Jamila, M. El Khaili. Study, Evaluation and Measurement of 802.11e and 802.16e Quality of Service Mechanisms in the Context of a Vertical Handover Case of Real Time Applications. In: International Journal of Computer Science and Network Security, 02/2017.

[3] Azeddine KHIAT, Ayoub Bahnasse, M. El Khaili, Bakkoury Jamila. Study and Evaluation of Vertical and Horizontal Handover's Scalability Using OPNET Modeler. In: International Journal of Computer Science and Information Security, 11/2016.

[4] BAILEY, Stuart, BANSAL, Deepak, DUNBAR, Linda, et al. SDN Architecture Overview. Open Networking Foundation, Ver, 2013, vol. 1.

[5] MARTINS, Joao, AHMED, Mohamed, RAICIU, Costin, et al. ClickOS and the art of network function virtualization. In : Proceedings of the 11th USENIX Conference on Networked Systems Design and Implementation. USENIX Association, 2014. p. 459-473.

[6] YUANMING, Cao, WENDONG, Wang, XIANGYANG, Gong, et al. Initiator-domain-based SLA negotiation for inter-domain QoS-service provisioning. In: Networking and Services, 2008. ICNS 2008. Fourth International Conference on. IEEE, 2008. p. 165-169.

[7] LI, Chung-Sheng et LIAO, Wanjiun. Software defined networks [Guest Editorial]. IEEE Communications Magazine, 2013, vol. 2, no 51, p. 113.

[8] MONSANTO, Christopher, REICH, Joshua, FOSTER, Nate, et al. Composing Software Defined Networks. In: NSDI. 2013. p. 1-13.

[9] JAMMAL, Manar, SINGH, Taranpreet, SHAMI, Abdallah, et al. Software defined networking: State of the art and research challenges. Computer Networks, 2014, vol. 72, p. 74-98.

[10] MATIAS, Jon, GARAY, Jokin, TOLEDO, Nerea, et al. Toward an SDN-enabled NFV architecture. IEEE Communications Magazine, 2015, vol. 53, no 4, p. 187-193.

[11] HAWILO, Hassan, SHAMI, Abdallah, MIRAHMADI, Maysam, et al. NFV: state of the art, challenges, and implementation in next generation mobile networks (vEPC). IEEE Network, 2014, vol. 28, no 6, p. 18-26.

[12] Velasco, L., Asensio, A., Berral, J., Castro, A., & López, V. (2014). Towards a carrier SDN: An example for elastic inter-datacenter connectivity. Optics express, 22(1), 55-61.

[13] DIXIT, Advait, HAO, Fang, MUKHERJEE, Sarit, et al. Towards an elastic distributed SDN controller. In : ACM SIGCOMM Computer Communication Review. ACM, 2013. p. 7-12.

[14] HU, Honglin, CHEN, Hsiao-Hwa, MUELLER, Peter, et al. Software defined wireless networks (SDWN): Part 1 [Guest Editorial]. IEEE Communications Magazine, 2015, vol. 53, no 11, p. 108-109.

[15] COSTANZO, Salvatore, GALLUCCIO, Laura, MORABITO, Giacomo, et al. Software Defined Wireless Network (SDWN): An evolvable architecture for W-PANs. In : Research and Technologies for Society and Industry Leveraging a better tomorrow (RTSI), 2015 IEEE 1st International Forum on. IEEE, 2015. p. 23-28.

[16] DERAKHSHANI, Mahsa, PARSAEEFARD, Saeedeh, LE-NGOC, Tho, et al. Leveraging Synergy of 5G SDWN and Multi-Layer Resource Management for Network Optimization. arXiv preprint arXiv:1602.09104, 2016.

[17] LU, Zhaoming, LEI, Tao, WEN, Xiangming, et al. SDN Based User-Centric Framework for Heterogeneous Wireless Networks. Mobile Information Systems, 2016, vol. 2016.

[18] TOMOVIC, Slavica, PRASAD, Neeli, et RADUSINOVIC, Igor. SDN control framework for QoS provisioning. In: Telecommunications Forum Telfor (TELFOR), 2014 22nd. IEEE, 2014. p. 111-114.

[19] BAHNASSE, Ayoub et ELKAMOUN, Najib. Policy-based smart adaptive quality of service for network convergence. International Journal of Computer Science and Information Security, 2015, vol. 13, no 3, p. 21.

[20] BAHNASSE, Ayoub et EL KAMOUN, Najib. A Policy Based Management of a Smart Adaptive QoS for the Dynamic and Multipoint Virtual Private Network. International Journal of Control and Automation, 2016, vol. 9, no 5, p. 185-198.

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