A Software-Defined Networking Solution for Rural Connectivity

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***Abstract*—Universal access is crucial for the development of any society, as no part of the world should be without the benefit of information and communication technology (ICT) services today. The International Telecommunications Union, the United Nations agency for telecommunication development, notes that the major barrier to the deployment and dissemination of ICT networks and services is hardware cost. To overcome this problem, a combination of Software-Defined Networking and access point (WiFi and wire) architecture is investigated in this paper. Voice and video conference call services are considered with particular attention to the problem of jitter. The impact of the traffic level is evaluated based on the occupied bandwidth. The various tests performed on the considered equipment show that the proposed solution could be cost-effectively deployed to reach rural and underserved communities, thereby enhancing social and economic development**.

Keywords—OpenFlow; Quality of Service (QoS); rural connectivity; Software-Defined Networking (SDN); universal and service access; Voice over Internet Protocol (VoIP); WiFi

I. Introduction

In recent years, Africa has seen considerable development in access to information and communication technologies (ICTs), particularly in the field of telephony with 3G, CDMA, VSAT, WiMax, and 4G. However, this technological advancement has not occurred in a uniform manner in most countries [1]; rather, urban localities are clearly favored over rural areas. This tendency occurs because in rural localities, none of the technologies mentioned above are economically viable for a telecommunication operator due to the high required capital and operating expenditures (CAPEX and OPEX), the low population density, and the low income of rural settings. Even if a rural area may have some ICT availability, the cost of access to services remains exorbitant for most of the population.

Innovative solutions responsive to local needs must fulfill three dimensions of universal access and service: availability, accessibility, and affordability. These solutions must also have low CAPEX/OPEX and must guarantee a very good Quality of Service (QoS). QoS is one of the main challenges of today's networks and can be measured and assessed by Key Performance Indicators (KPIs) such as bandwidth, latency, jitter, and packet loss [2].

In this article, we demonstrate how Software-Defined Networking (SDN) technology and WiFi combined with Voice over Internet Protocol (VoIP) can provide the most viable and optimal solutions for isolated areas that are candidates for the deployment of universal access networks. We examine the QoS aspect by testing for jitter in both WiFi and wired solutions.

The remainder of the paper is structured as follows. Section II describes the technical background and advantages of SDN; section III presents a proposed approach to combining WiFi and SDN architecture for low-cost deployment; section IV describes a test case; section V concludes the paper.

II. TECHNICAL BACKGROUND AND ADVANTAGES

A. SDN and WiFi description

The Open Networking Foundation (ONF) has presented an SDN architecture as shown in Fig. 1, dividing it into three main layers [3],[4]. The application layer is at the top of the architecture. It consists of software that uses SDN communication services and interfaces with the control layer via the northbound Application Programming Interface (API) [4]. The control layer is responsible for configuring the switch and routes. The data plane transmits packets according to the decision of the control plane through control messages and APIs such as OpenFlow. Network elements (such as switches and routers) capable of switching and packet transmission reside in the infrastructure layer.

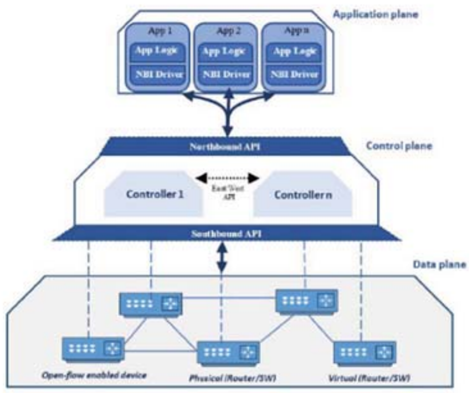

Fig. 1. Architechture of an SDN [5]

WiFi belongs to the IEEE 802.11 standard; the new IEEE 802.11n standard is operating in 2.4GHz or 5GHz band.

B. *SDN and WiFi benefits for rural connectivity*

SDN offers advantages and opportunities for CAPEX and OPEX reduction [6],[7]. Both are important for enable a technology to be a reliable candidate for rural connectivity.

1) Impact on CAPEX. Among the many factors that can affect CAPEX in a network, the design of SDN favors:

- The use of simpler and less expensive network devices. One can purchase equipment based on the resources available, without having to take interoperability issues into account.
- Network dimensioning. The panoramic view of the entire network provided by the centralized controller promotes efficient management of all network resources with processes such as load balancing.
- WiFi has two key advantages: the equipment cost and the fact that frequencies are exempt from all taxes [1], [9],[10],[11].

2) Impact on OPEX. SDN also impacts several factors that affect OPEX in a network:

- Energy costs. With SDN, the processing unit is centralized at the level of the control plan, which will lead to a decrease in energy consumption.
- Repair and maintenance costs. SDN offers better possibilities for testing, network failure detection, and problem diagnosis procedures. Software problems can be solved remotely.
- Service provisioning costs. The cost of service provisioning in the SDN scenario should be lower due to the automated configuration of network devices, reduced staffing requirements for network tasks through automation, and reduced manual configuration.

SDN and WiFi allow resource sharing, which enable a reduction of 40% of CAPEX and 30% of OPEX [8], [12].

These features of SDN and WiFi make these two technologies very valuable assets that reduce network costs considerably. The next section highlights an initial solution approach using VoIP, followed by an analysis of the results.

III. A VOIP SOLUTION AND JITTER TEST

The OpenFlow protocol is installed or transplanted on the OpenWrt firmware as an application layer [12]. We used the Ryu controller. Ryu and other controllers are software components with well-defined APIs that allow developers to easily create new network management and control applications. Ryu is an interesting controller for this analysis because of its unique process and multi-threaded architecture design, in which new components are connected and executed as a new thread. Once these steps were completed, we installed our VoIP server, Asterisk, to perform video and audio call tests. All the software and programs used are free and open-source, thus enabling maximum reduction of expenditures.

To highlight the performance of SDN technology, we carried out a comparison between our SDN system and the results without SDN integration. Fig. 2 shows a typical architecture for the VoIP environment, with an access point connected to a switch, which is in turn connected to an Asterisk server. In this case, all packet transmission management policies were made locally at each level of TP-LINK. The switch, access points, and TP-LINK WR1043nd routers were all under OpenWrt firmware. All tests were performed locally.

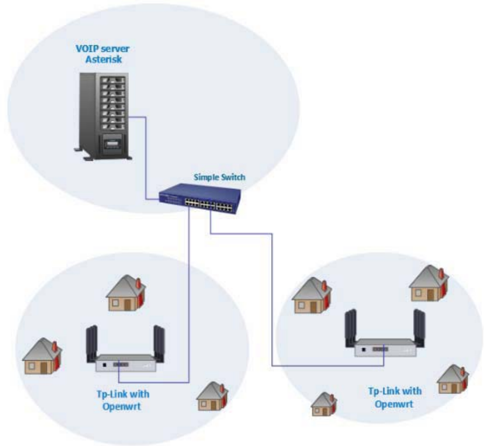

Fig. 2. Simple VoIP architecture

Fig. 3 shows the integration of SDN technology in a traditional architecture. In this experiment. we installed the OpenFlow/OVS protocol as an application on the two TP-LINK routers through the OpenWrt firmware. Switches and access points were controlled by the Ryu controller.

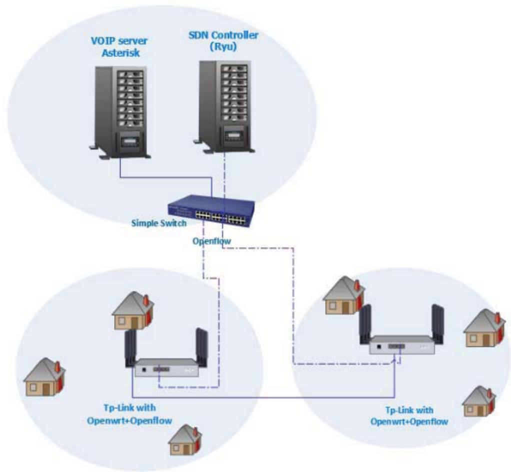

Fig. 3. Architecture with SDN

IV. TEST SCENARIO AND ANALYSIS OF RESULTS

A. *Scenario*

The proposed architecture responds favorably to the challenges of deploying rural connectivity. The implementation plan and the control plan can therefore be centralized in the town. This offers the advantage of optimizing the allocation and reuse of resources. In order to effectively meet the needs of the population, access points can be easily deployed to offer services such as E-learning or other services over wired and wireless networks.

We carried out a comparative study using the architectures shown in Fig. 2 and Fig. 3. We made audio calls first and then video calls, both by WiFi and by cable.

The simulation tests proceeded as follows. We performed 90 successive audio calls and 30 video calls with each architecture. Each audio call had a duration of 120 seconds; the video calls lasted 90 seconds. A user was located on either side of the access points, each user was connected and identified on an access point in the case of the tests with WiFi, and the users were connected by cable on either side of the access points.

Since jitter is an important problematic feature of real-time services, we used StarTrinity Session Initiation Protocol (SIP) Tester and Wireshark to conduct the tests and simulations. StarTrinity SIP Tester allows testing and monitoring of the VoIP network, SIP software or hardware. Wireshark is a packet analyzer that retrieves all packets passing through the network and provides very detailed information to analyze them. In our tests, SIP clients shared the same access point. Jitter values were given in milliseconds (ms).

To illustrate the comparative results for the two technologies, Figs. 4 to 7 display results for the voice calls, and Figs. 8 to 11 show results for the video calls.

B. *Results and Analysis*

1) Voice calls (WiFi and cable)

Fig. 4 shows the trend of the curves for the tests carried out with and without SDN integration (in the case of WiFi and voice calls). For both technologies, there are significant variations that do not permit us to draw simple conclusions. However, most points on the WiFi + SDN trend present better jitter results. Variables and peaks are due to radio conditions, temperature, and probably interferences, which are not the primary subject of attention in this article.

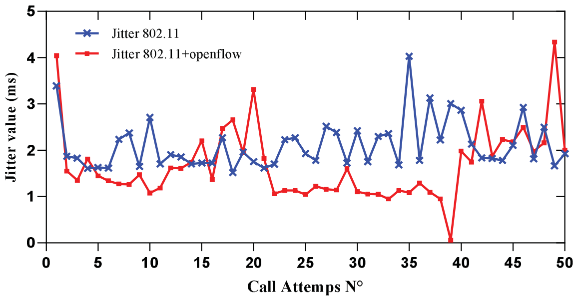

Fig. 4. Jitter trends, 802.11 OpenWrt and 802.11 OpenFlow (in ms)

Fig. 5 shows the overall average for the calls. Here the difference is clearer, as the global jitter of WiFi with SDN is only 1.67 ms, as opposed to 2.10 ms for simple WiFi.

Fig. 6 shows the case of calls made by wired technology. During the 50 calls made, the jitter tendency in the SDN architecture is exceptionally better. In fact, the set of wired call points under OpenFlow is below 0.5 ms, whereas integration without OpenFlow varies between 0.2 and 4.25 ms.

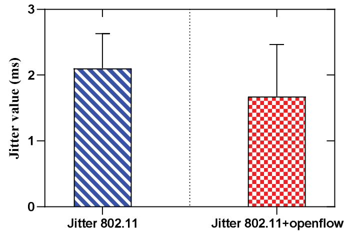

Fig. 5. Average jitter, 802.11 Openwrt and 802.11 OpenFlow (in ms)

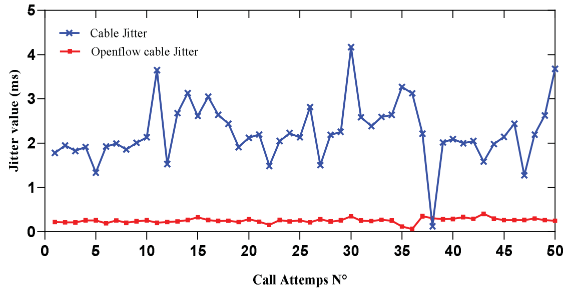

Fig. 6. Jitter trends, cable and cable with OpenFlow (in ms)

Fig. 7 presents the overall average for each architecture. The global jitter for wired calls made with SDN shows a significantly lower (and therefore better) jitter of 0.25 ms, compared to 2.25 ms for wired calls without SDN integration.

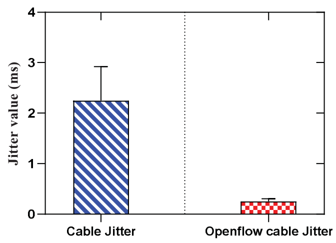

Fig. 7. Average jitter, cable and cable with OpenFlow (in ms)

2) Video calls (WiFi and cable)

Fig. 8 shows the global evolution of all video calls made on WiFi (without and with SDN). As with the voice calls, this figure shows some variations and does not allow us to immediately observe the benefit offered by the SDN architecture relative to the simple architecture.

Fig. 9 shows the overall average for video calls. Calls made with SDN have a relatively low overall jitter compared to those without SDN integration, at 1.67 ms versus 1.75 ms.

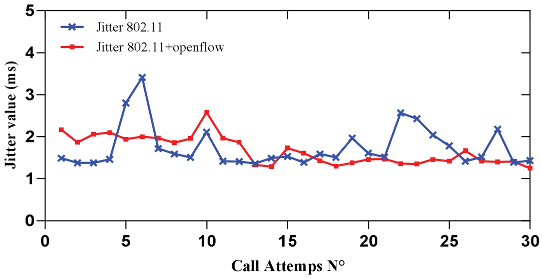

Fig. 8. Mean jitter, 802.11 Openwrt and 802.11 OpenFlow (in ms)

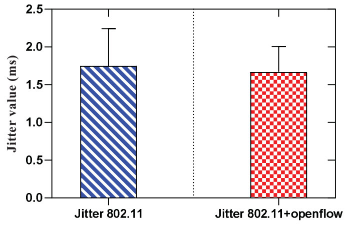

Fig. 9. Average jitter, 802.11 Openwrt and 802.11 OpenFlow (in ms)

Fig. 10 shows the tendencies for the 30 video calls made with and without SDN. Here the difference is quite impressive. The trend for wired tests of access points with OpenFlow is practically between 0 and 1 ms, while without OpenFlow is between 2.5 and 14 ms.

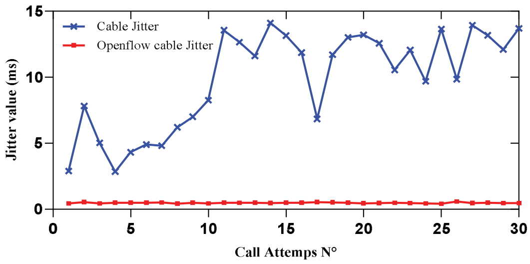

Fig. 10. Jitter trend, cable and cable with OpenFlow (in ms)

Fig. 11 further demonstrates this important gap. The average jitter for wired calls with SDN integration is 20 times better than the average without SDN, at 0.49 ms compared to 9.9 ms.

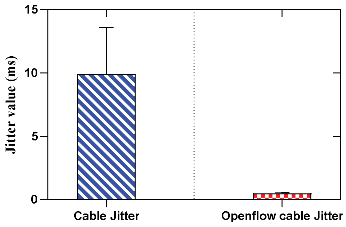

Fig. 11. Average jitter, cable and cable with OpenFlow (in ms)

V. Conclusion and Perspectives

In this article, we have highlighted the advantages of SDN technology–based access points (by WiFi and cable) to efficiently meet the connectivity needs of rural areas while taking into account the requirements of universal access and QoS. A significantly reduced CAPEX and OPEX in a network will allow disadvantaged areas to access the network at a relatively low cost, which is essential for rural populations with limited incomes. The very low-cost SDN environment was have set up can be effectively implemented in rural areas. In comparisons on video and audio calls, the SDN architecture offers a better QoS overall than the one without SDN, although our quality concern in this article was limited to jitter.

In future research, we plan to examine other QoS factors (latency and packet loss) in a more complex environment. We will also discuss how SDN can improve Internet speeds, and we will address the dimensioning aspect between access points, mobility management, and security issues in SDN architecture.

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