An Experimental Study of VoIP Performance in Wireless Mesh Networks Using Different Mobility Approaches

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Abstract — Performance evaluation and analysis of different VoIP over WLAN mobility schemes is essential in order to meet adequate QoS levels in VoWLAN deployments. This paper presents a study of real time voice communication QoS in terms of delay, jitter, throughput and packet loss between three different Wireless Mesh Network mobility schemes in a crowded 802.11 environment. We also discuss the feasibility of implementing Wireless Mesh Networks for VoIP in the presence of other 802.11 data-only networks. Other researches can also use our QoS measurements as guidelines for other mobility schemes performance tests.

Keywords — VoIP performance, wireless mesh networks, QoS.

I. INTRODUCTION

Nowadays, real time voice communications have gained a special interest in 802.11 Networks. However, care must be taken when deploying Voice over WLAN as it should provide good QoS and Network Capacity to the final user in order to meet today’s end-user needs.

While most currently available handoff schemes relay on vendor-specific 802.11 infrastructure mode implementations, there are no vendor-specific Wireless Mesh mobility solutions that support seamless, real time communications, even though there are currently VoWLAN over Wireless Mesh Networks being developed by Strix Systems and Cisco.

Moreover, most VoIP and other real time communications networks are designed to work along with data-only WLANs. In such situations, new network implementations would implicate in the installation of new infrastructure, as well as different channel architecture assignment and probably the deployment of a controller-based vendor-specific roaming solution for the network.

In such situations, wireless mesh networks solutions can mitigate the excess of infrastructure equipment while maintaining an acceptable QoS, as well as giving enough capacity for real time communications such as VoWLAN.

Solutions such as SMesh [1] provide a fast handoff scheme whereas other Wireless Mesh implementations such as Roofnet [2] provide a high throughput scheme but standard infrastructure mobility. Other solution schemes such as LCMIM [3] offer gARP broadcasting combined with a custom implementation of the AODV protocol to provide fast handoffs.

While each solution offer their own unique testing results, we consider important to test the same schemes under similar conditions in order to offer a different perspective of their performance.

This paper presents an experimental study of the impact, in terms of QoS, of Voice over WLAN communication between three different Wireless Mesh Networks mobility schemes along with the presence of existing 802.11 data-only networks.

II. RELATED WORK

There are currently many solutions [1], [3], [4] [5] that solve handoff issues in real time communications in Wireless Mesh Networks. Each solution offers a different fast handoff approaches in wireless mesh networks while maintaining acceptable levels of QoS.

There are also several studies on Wireless Mesh Communications related to different applications and topics. [6] discusses the deployment of different handoff approaches for public safety disaster recovery networks. [7] presents an experimental study of Multimedia traffic performance in mesh networks. [8] investigates several methods to improve voice quality, as well as to study the performance of VoIP in Wireless Mesh Networks.

III. CONSIDERED SCHEMES

We have considered three schemes for our tests: SMesh [1], Meraki/Roofnet [2] and a customized version of LCMIM [3], which from this point will be referred to as SVGB (Single Virtual-default Gateway gARP Broadcasting). This scheme is based on LCMIM [3], a Light-Weight Client Mobility Approach for Infrastructure Mesh Networks. Mobility is possible via mesh node gARP broadcasting. We did not use LCMIM’s modification of the AODV protocol. Instead, we set default routes on each router that pointed to a single mesh gateway. We programmed WRT54GL, installed with the OpenWRT [11] open source firmware, to broadcast gARP packets every 1.5 seconds, advertising their MAC address and thus updating the client’s ARP cache. We also configured the router to not answer to any ARP requests, so that the interface dedicated to route packets and communicate with other routers should not be asked by the clients at any time.

Table 1 presents a summarized comparison between the three schemes tested in our study.

IV. TEST BED

First, we determined that the least crowded channel was channel 11. We used this channel on each of our tested networks. Fig. 1 shows the network topology used on every test with each considered solution, as well as the path that is followed through the experiments, from point A to point B.

We also conducted tests on our University’s WiFi 802.11 network. From this point, we will refer to this network to as ESPOL. We only ran VoIP call tests over this network, as our goal is to provide a point of comparison between mesh networking and 802.11 infrastructure networks in terms of VoIP performance.

TABLE I. THE THREE CONSIDERED SCHEMES

<table>
<thead>
<tr>
<th>Scheme Specifications</th>
<th>SMesh</th>
<th>Roofnet</th>
<th>SVGB</th>
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<tbody>
<tr>
<td>Main Handoff Method</td>
<td>gARP unicast</td>
<td>None</td>
<td>gARP broadcasting</td>
</tr>
<tr>
<td>Operation Mode</td>
<td>Ad-hoc</td>
<td>Infrastructure</td>
<td>Ad-hoc</td>
</tr>
<tr>
<td>Most relevant feature</td>
<td>Seamless Handoff</td>
<td>High Performance</td>
<td>Light-weight solution</td>
</tr>
<tr>
<td>Routing</td>
<td>Custom, Redundant Multipath</td>
<td>SrcRR Protocol</td>
<td>None, default routes</td>
</tr>
</tbody>
</table>

V. METHODOLOGY

We divided our study in three types of tests. On each test, the same path from point A to point B (showed in Fig. 1) was followed during a 90 second walk. We built a small wired LAN that consisted of a PC and the mesh portal from each considered scheme. The types of tests are presented as follows:

A) VoIP Calls: We deployed a small VoIP wired network consisting of a computer running Asterisk [12] and one IP Phone. In this scenario, the IP Phone made calls to a SIP softphone running on a laptop. By using Wireshark [13], we sniffed the incoming packets from the client’s side perspective. This data was used to calculate jitter and delay.

B) Throughput Tests (TCP): We used iPerf to determine the maximum throughput that one single client could get by sending a continuous TCP stream. In order to meet the highest possible throughput, we set the default TCP window size of 56kb with a buffer length of 2Mb.

C) Packet loss and Duplicated Packets: For these tests, we simulated a VoIP call by programming a Python script that sent 160-byte length UDP packets every 20 ms, thus generating a 64kbps stream. We implemented a Java script that sniffed the incoming packets in order to calculate packet loss. Because of the redundant multipath routing nature of SMesh [14], [15] generating duplicated packets, we also added a sequence number on the data portion of the packet.

VI. NUMERICAL RESULTS AND ANALYSIS

Tests were conducted with similar background noise of approximately -85 dbm. Each network was tested separately, with the common presence of the 802.11 infrastructure WLAN ESPOL.
A. VoIP Call tests

Fig. 2 plots the average delay perceived by the moving client on SMesh, SVGB and Roofnet. As seen in Fig. 4, the average values remain under the 150 ms limit determined by ITU.

Fig. 3 shows the average jitter during the VoIP call tests ran on each of the three considered schemes. The average jitter values were acceptable as they did not exceed the 20 ms limit.

Fig. 4 and 5 respectively plot the average delay and jitter perceived on every network tested in our study, including ESPOL. Both figures show that some average delay and jitter values experimented in ESPOL were above the limits determined by ITU.

Figs. 6, 7, 8 and 9 plot the delay perceived by the moving client for each Wireless Network tested in our study. As seen in the figures, ESPOL presented high latency values, whereas the Wireless Mesh Networks provided lower and more acceptable delay values.

Our VoIP call tests determined that the wireless mesh networks tested in our study provide better delay and jitter values than the ESPOL 802.11 network.

From all the three tested wireless mesh network mobility schemes, SVGB presented the lowest delay and jitter values and Meraki/Roofnet presented the highest and most unstable delay and jitter values.
Figure 6. Delay perceived by the moving client during a 90 second VoIP call over the ESPOL WLAN network.

Figure 7. Delay perceived by the moving client during a 90 second VoIP call over the SMesh network.

Figure 8. Delay perceived by the moving client during a 90 second VoIP call over the Meraki/Roofnet network.

Figure 9. Delay perceived by the moving client during a 90 second VoIP call over the SVGB network.

Figure 10. Roofnet TCP Throughput Test.

Figure 11. SMesh TCP Throughput Test.
B. Throughput Tests

Figs. 10, 11 and 12 respectively plot the perceived throughput for the SMesh, Roofnet and SVGB mobility schemes. As seen in the figures, SMesh presented the most stable performance as opposed to the most unstable throughput presented by SVGB.

C. Packet Loss

Table 2 shows the number of packets sent, packets lost and duplicated packets, as well as the packet loss for each tested mobility scheme. As shown, the lowest packet loss rate was experimented through tests ran on the SMesh network and the highest packet loss rate was experimented during the tests ran on the Meraki/Roofnet network.

<table>
<thead>
<tr>
<th>Test Parameter</th>
<th>Mesh Network</th>
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<tbody>
<tr>
<td></td>
<td>SMesh</td>
<td>Roofnet</td>
<td>SVGB</td>
</tr>
<tr>
<td>Packets Sent</td>
<td>13,617</td>
<td>5,876</td>
<td>12,033</td>
</tr>
<tr>
<td>Packets Lost</td>
<td>18</td>
<td>224</td>
<td>69</td>
</tr>
<tr>
<td>Duplicated Packets</td>
<td>4,488</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>% of Packet Loss</td>
<td>0.13%</td>
<td>3.81%</td>
<td>0.57%</td>
</tr>
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</table>

VII. Conclusions

In this paper, we have presented an experimental study of VoIP over Wireless Mesh Networks with different mobility schemes. Our study determined that the wireless mesh networks presented higher QoS levels compared to a data-only 802.11 infrastructure network. Our study also determined that gARP broadcasting schemes provide the lowest delay values, but more unstable throughput. Seamless handoff solutions with redundant multipath routing, such as SMesh, provide the most stable throughput as well as acceptable QoS values for real time voice communication.

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REFERENCES