Aziala-net: Deploying a Scalable Multi-hop Wireless Testbed Platform for Research Purposes

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ABSTRACT

Aziala-net is a flexible and scalable experimental testbed for wireless multi-hop networks based on simple off-the-shelf hardware that is able to adapt to various research purposes. It is composed of more than 50 Asus wireless routers that have been adapted to either work as fixed base station or as mobile nodes. After describing the technical details of Aziala-net, we illustrate the potential of the testbed by showing two samples of works that are currently under study in the testbed. The first example focus on the use of the IEEE 802.11 MAC layer protocol for multi-hop networks and the stability problem that it faces in the case of wireless mesh networks. The second example focus on epidemic forwarding protocols and their performance in a real testbed deployment.

Categories and Subject Descriptors

B.8.2 [**Hardware**]: Performance and Reliability—*Performance Analysis and Design Aids*

General Terms

Design, Measurement

Keywords

Testbed, multi-hop, wireless

1. INTRODUCTION

The rapid technology developments seen by mobile communication devices are revolutionizing the society and its needs. A couple of decades ago, the goal was to deliver a certain level of communication possibilities mostly through a fixed infrastructure. Later on, with the more intense development of wireless technologies, users got used to a certain level of mobility with an access point deserving wirelessly a given area depending on factors such as transmission power and topology. This technological improvement gave birth to new mobile services such as mobile video streaming, online gaming and inter-device communication. The demand existing nowadays shows the limitation of the architecture based on single-hop communication to deliver ubiquitous broadband connectivity in a cost-effective manner. To overcome the cost of deploying fiber, the next-generation wireless networks, such as Wireless Mesh Networks (WMNs) and Mobile Ad-hoc Networks (MANETs), are based on a multi-hop architecture.

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However, despite the exiting promises of multi-hop networks, the need for a decentralized architecture brings various challenges as far as throughput, delay and fairness are concerned [6] and our understanding of the exact phenomena occurring in the network is still in its infancy. It is thus crucial to develop a solid experimental testbed platform to validate analytical models and simulation results before any large scale deployment of a commercial solution.

Toward this goal, we designed and deployed Aziala-net that is an indoor multi-hop testbed based on small and low-cost wireless devices already available. Due to the importance of the problem, similar efforts to deploy wireless testbed exist with for example the MIT Roofnet [1] and the MagNets project [7] that are two testbed that aim at providing broadband access to real users. Roofnet is a fixed indoor testbed that can work on similar hardware than our testbed and MagNets is an outdoor testbed. Our testbed differs in the sense that we do not aim at delivering a service to real users, but we focus on deploying a purely experimental testbed with a high level of freedom and flexibility for research purposes. We present the technical details of our testbed in Section 2.The incentive to deploy a highly adaptable testbed comes from the two different research projects that motivated the creation of Aziala-net.

The first project focuses on the challenges related to the Medium Access Control (MAC) layer of Wireless Mesh Networks. Mesh networks are based on both: (i) a standard access part connecting to the end users and (ii) a backbone part that forwards the traffic through multiple wireless hops in the network from the access part to a wired access point connected to the Internet. The most widely used MAC protocol for the backbone of mesh networks is IEEE 802.11 that was initially designed for single-hop traffic. Unfortunately, the lack of synchronization between the nodes composing the multiple hops of the network harms the end-to-end performances. Section 3.1 discusses some of the problems we illustrated experimentally with unmodified IEEE 802.11 and presents the different parameters that could be monitored and modified in our testbed.

The second project focuses on the field of epidemic forwarding protocols. Epidemic-style forwarding has been proposed as an approach to achieve system-wide dissemination of messages. With epidemic-style forwarding, the destination of a packet is an entire network, nodes within a few hops away from the source, nodes within a geographical area, or only one node where the epidemic-style forwarding is used to replace or assist routing protocols in Disruption Tolerant ad-hoc Networks (DTNs) or highly mobile networks. It evolves similarly to an infectious disease. An infected node (that has a message) encounters new nodes and may decide to infect them, i.e. to pass them the message. In this paper, we consider Self Limiting Epidemic Forwarding (SLEF). SLEF requires

Figure 1: Illustration of the hardware used in our experimental testbed: Asus WL-500gP routers with an Atheros-based wireless card and a possible battery-based power supply.

specific configuration of the wireless card. Through implementing SLEF we prove the flexibility of our testbed. Furthermore, in order to evaluate the performance of SLEF, we show in Section 3.2 a measurement design where nodes are distributed over twelve buildings at the EPFL campus.

Finally, Section 4 concludes the paper by summarizing the advantages of Aziala-net and discussing the future work that we plan to study in the testbed.

2. EXPERIMENTAL TESTBED

Our testbed is composed of more than 50 wireless routers that are equipped with an omni-directional antenna. We chose the Asus WL-500gP v1 as wireless router due to its compatibility with our firmware and the availability of multiple USB ports. As depicted in Figure 1, we modified the routers by changing the mini-PCI WiFi card to an NMP-8602 Atheros card in order to benefit from the flexibility of the open-source MadWifi driver [3]. Our routers operate then on 802.11b/g, but the existence of a mini-PCI WiFi card that is separated from the motherboard give us the flexibility to extend our testbed to other MAC layer protocols in the future, by only replacing the wireless card (we note that this possibility is not available in the version v2 of the Asus-WL500gP router). We also included mobility to some of our devices by equipping them with a 6 V battery. In order to meet the high amperage required to support the wireless interface, we used an A506/10 battery. Furthermore, as the Asus requires an input voltage of 4.5 V, we added two inductances to the cabling connecting the battery to the router.

Each router runs the version *Kamikaze 7.07* of the OpenWRT firmware [2] with a modified version of the MadWifi driver. The modification we perform on the driver are threefold: (i) we unlock the modification of the MAC layer parameters (i.e., CW_{min}, CW_{max},...) for Best Effort traffic via the *iwpriv* command; (ii) we use part of the methodology presented in [9] to continuously monitor the MAC layer buffer of the different nodes. More specifically, each node includes the information about its buffer queue length into a packet before forwarding it. Therefore, each node can continuously monitor the buffer evolution of its previous hop by using a simple sniffer routine such as *tcpdump*; (iii) we coded three new functions to the *wlanconfig* command in order to access the instantaneous buffer queue occupancy and to access and modify the maximal MAC queue length (usually locked to 50 packets). The combination of OpenWRT and MadWifi provides access to multiple parameters useful for research purposes. Furthermore, additional packages can easily be developed and added in the embedded software of the firmware in order to test new protocols. Indeed, we showed the flexibility of such a software architecture by implementing packages, which have been deployed and evaluated on the testbed, for both protocols improving the performance of 802.11 in multi-hop mode and epidemic forwarding protocols.

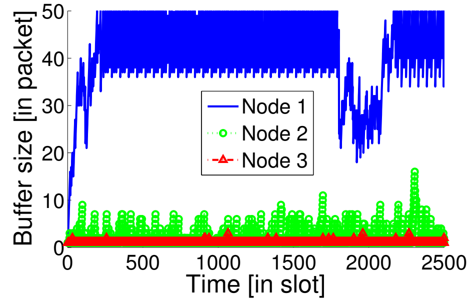

Figure 2: Illustration of the logs of the experimental testbed showing buffer instability of 802.11-based multi-hop networks, where node 0 is the source and node 4 is the final destination.

3. SAMPLE OF EXPERIMENTAL STUDIES

3.1 Investigating 802.11 MAC layer properties

One of the important projects currently under study on the Aziala-net testbed is the understanding of the performances of IEEE 802.11 on a multi-hop wireless mesh network. The ad-hoc mode of IEEE 802.11 is the most commonly used protocol for multi-hop networks and it is a completely decentralized protocol. Indeed, each node that has a packet to transmit senses the wireless channel to decide whether it is idle or busy. In the case the channel is idle, the node directly transmits the packet. In the opposite case, the node waits for the channel to be idle again and then enters a *backoff process*, where a counter is decremented at each idle slot. Finally, when the counter reaches zero, the node starts its transmission. The motivation for the backoff process is to avoid collisions that happen when two nodes transmit simultaneously. Such a mechanism appears to perform reasonably well for single-hop communications, where all nodes hear each other.

However, the situation is different for multi-hop scenarios, where nodes should ideally cooperate to transmit a packet from a source to a final destination that is multiple hops away. Indeed, we note that in IEEE 802.11 each node takes its transmission decision independently regardless of the traffic matrix or the total achievable throughput of the multi-hop path followed by a packet. Therefore

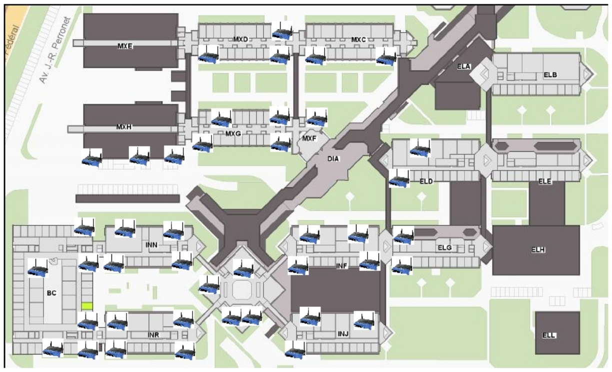

Figure 3: Illustration of a large topology deployment of the Aziala-net testbed on twelve buildings.

some links may be over-utilized (i.e. above the total path capacity) and thus this over-utilization of these links may degrade the performances by having buffer building-up and packet drops. Figure 2 illustrates the problem for a 4-hop linear network. In [4], we investigate this phenomenon in details and model the source of instability of multi-hop networks. The possibility to continuously monitor the buffer evolution and the flexibility to change the MAC parameters in our testbed were of utmost importance to achieve the study and to propose a solution.

3.2 Studying epidemic forwarding protocols

Another project under study focus on epidemic forwarding protocols and more specifically on Self Limiting Epidemic Forwarding protocol (SLEF) that transmits broadcast frames. In order to improve the efficiency and the reliability of 802.11 broadcast, SLEF employs a pseudo-broadcast mechanism [5, 8]. In order to use pseudo-broadcast, the wireless card is configured in promiscuous mode and the RTS/CTS threshold is set to zero so that the RTS/CTS mutual exclusion is used with all unicast transmissions. A node transmits a SLEF frame to the source of the last received SLEF frame (if any) solely in unicast mode to benefit from the MAC acknowledgment (ACK) that reduces the vulnerability to channel errors. On one hand, the neighbors of the source and the destination are inhibited from transmitting due to the RTS/CTS exchange, which avoids collision. On the other hand, the source neighbors receive the frame, as they are configured in promiscuous mode. In addition to setting the promiscuous mode and the RTS/CTS threshold, the pseudo-broadcast requires building SLEF on top of raw sockets. Therefore, SLEF defines its own protocol type. Also, we modified the wireless driver so that SLEF can change the transmission queue length. To evaluate the performance of SLEF, we distributed nodes over twelve building at the EPFL campus (see Fig. 3). Despite the very limited memory of the router (32MB of RAM), we were able to run SLEF experiments with an epidemic buffer size of 10 000 packets without any troubles. Finally, in order to analyze the experiment behavior, large log files (tens of MB) were gathered using USB memory stick. Therefore, our testbed allowed us to evaluate SLEF by monitoring three parameters: the rate, the spread (number of nodes that receive a packet) and the amount of redundancy and we could demonstrate experimentally that SLEF efficiently improves the performance by reducing the amount of redundancy.

4. CONCLUSION AND FUTURE WORK

We presented the technical details of a scalable multi-hop wireless testbed that we deployed at the EPFL campus for research purposes. We briefly presented the flexibility and potential of such an architectural design with two projects currently under study. For future work, we plan to take advantage of other features of the testbed (such as mobility) to extend the results of current projects and investigate new challenges of mobile multi-hop networks.

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