Mesh your Senses: Multimedia Applications over WiFi-based Wireless Mesh Networks

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I. Motivation

WING is an experimental multi–radio WMN testbed designed and built exploiting commodity hardware and open–source software components. WING implements a flexible and scalable WMN architecture capable of supporting next-generation Internet services with a particular focus on multimedia applications. The WING project aims at providing an open–platform on top of which innovative solution can be implemented and tested in a realistic environment. WING's design has be driven by our previous work on the state-of-the-art solutions for engineering a WMN testbed [1] by applying the observed guidelines to a real-world scenario. All the developed software has been released under a BSD License and is made fully available to the research community[1].

Currently, the testbed consist of 10 nodes deployed at CREATE-NET premises and implementing a two-tiers architecture. Other well-known IEEE 802.11-based WMNs include Roofnet [2], Hyacinth [3], Microsoft's MCL [4], and Meraki [5]. We establish the uniqueness of our mesh solution in that it is capable of achieving both service differentiation and performance isolation in IEEE 802.11-based WMNs. While not providing strict QoS performance bounds, the proposed scheme aims at enhancing the perceived quality of experience by combining opportunistic scheduling and packet aggregation and by implementing a DiffServ-like architecture in order to provide traffic prioritization.

The aim of this demonstration is to show that by combining opportunistic scheduling with traffic aggregation it is possible to efficiently support data, video and VoIP services over a multi-hop wireless access network, namely the WING wireless mesh networking platform. Furthermore, we will demonstrate the testbed's self-healing and self-configuration functionalities made possible by a modular gateway design capable of switching among several uplink technologies (Ethernet, WiFi, and cellular) according to their availability and without disrupting the network operation.

This work was partially supported by the Italian Ministry of Scientific Research (MIUR) within the framework of the WING project (grant number RBIN04M292).

[1]On line resources available at http://www.wing-project.org/

II. The WING Platform

A. Mesh nodes

The WING testbed consist of 10 nodes deployed in a typical single-floor office environment and implementing a two-tiers architecture. Mesh routers build and maintain the multi-hop wireless back–haul and provide end-users with a standard 802.11 Access Point. Internet connectivity is delivered by dedicated mesh gateways equipped with an high bandwidth wired connection to the Internet backbone. An optional third–tier providing Internet connectivity by means of a Point–to–Multipoint wireless technology (WiFi or cellular) is also supported.

Each mesh node is equipped with either a PCEngines ALIX 2C2 (500MHz CPU, 256MB of RAM) processor board or a PCEngines WRAP 1E (233MHz CPU, 128MB of RAM) processor board. Operating system and application are stored on a 1Gb Compact Flash card. Connectivity is provided by 2 Ethernet channels, 2 miniPCI slots and one serial port. Each miniPCI slot holds a Mikrotik R52 WiFi IEEE 802.11a/b/g card based on the Atheros AR2412 chipset: one interface builds and maintains the multi-hop wireless backhaul, while the other can be configured either in *Master* mode, providing end-users' with a standard IEEE 802.11 Access Point (AP), or in *Client* mode, allowing the mesh node to exploit an existing IEEE 802.11 AP as uplink to the Internet. Single interface setups are also supported, however, in this case the device acts as a pure relay node. Dual and single NIC nodes can coexists in the same network. One of the PCEngines ALIX boards is also equipped with a Huawei E169 cellular modem.

B. Routing

The WING testbed is built on top of the Roofnet platform. Roofnet is an experimental WMN developed by the MIT. The Roofnet architecture is described in detail in [2]. Roofnet routes packets using a DSR-like routing protocol called *SrcRR* exploiting the Estimated Transmission Time (ETT) as routing metric [4] and optimized for network scalability and throughput rather than for supporting mobility. The default Roofnet implementation has been extended with additional modules responsible for link scheduling and traffic aggregation. These enhancements are described in details in [6], [7], [8]. For readers' convenience, a brief overview of their main features are provided in the next sections.

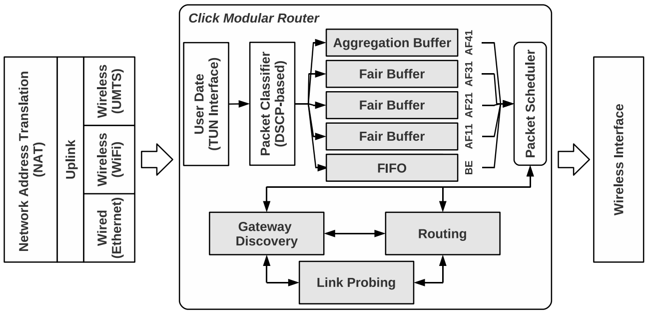

Fig. 1: Architecture of the traffic differentiation scheme implemented in the WING testbed.

C. *Software Architecture*

OpenWRT [9] has been selected as operative system for our testbed. OpenWRT provides an automated system to download the source code (both kernel and the user–space tools) and compile it to work on any supported platform. Moreover, it is characterized by a small memory and disk footprint making it suitable for a wide rage of networking devices. Notwithstanding the fact that the PCEngines processor boards are based on the x86 architecture and then they do not require cross-compilation, we decided to use OpenWRT in order to abstract ourself from the underlying hardware architecture making the WING wireless mesh networking toolkit platform agnostic. The overall node architecture is sketched in Fig. 1.

WING nodes can automatically detect if they are relays or gateways. The node auto–configures itself as gateway if an IP address can be obtained using DHCP over one of its uplinks. At the present moment three different uplinks are supported:

- *Wired*. The first Ethernet interface available on the node, typically the *eth0* device.
- *Wireless (WiFi)*. In dual radio setups, the second WiFi interface can be configured in *Client* mode allowing the node to exploit an existing IEEE 802.11 AP as uplink to the Internet.
- *Wireless (Cellular)*. If a cellular modem is available, the mesh node can exploit an UMTS/GPRS network as uplink to the Internet. The cellular modem must be equipped with a SIM cardholder (i.e, Huawei E169, Sierra 881, etc.) and an active SIM card must be inserted.

At any moment only one uplink can be active in a given node, however multiple gateways can exploit different uplink technologies. A finite state machine has been implemented in order to dynamically select the best uplink technology without disrupting the network operation.

D. *Traffic prioritization*

The WING testbed implements a traffic prioritization scheme based on the DiffServ [10] framework in order to allow classification and differentiated treatment. Network traffic entering a mesh router is classified by DSCP code and then fed to a suitable queue. Traffic differentiating is provided by means of an Deficit Weighted Round Robin (DWRR) scheduler which pulls packets from buffers, according to some input weights (see Table I).

TABLE I: PHBs supported by the DiffServ module

DSCP	PHB	Weights	Queuing	Traffic Type
0	Default	1	ADRR	*Best Effort*
0x0A	AF11	2	ADRR	*Low Priority*
0x12	AF21	4	ADRR	*Medium Priority*
0x1A	AF31	8	ADRR	*Streaming (UDP)*
0x22	AF41	8	ADRR w/ A–MSDU	*Real-time (UDP)*

Each buffer maintains a pool of queues and an hash table that associates the MAC destination addresses with one of those queues. Incoming MAC frames are first classified according to their destination address and then fed to the corresponding queue. If such a queue does not yet exist, it is created dynamically by the scheduler. Unused queues are moved from the hash table to the pool, this is done in order to alleviate the need for repeated memory allocation as neighbors come and go. Within each buffer two different link scheduling policies are supported by the system:

- *Airtime Deficit Round Robin (ADRR)*. Aims at providing intra-cell *airtime* fairness. ADRR enhances the Deficit Round Robin (DRR) discipline by taking into account the channel quality which in time prevents a node affected by high packet loss from monopolizing the wireless channels thus lowering the performance of the whole system.
- *ADRR with Frame aggreagation*. Aims at reducing the MAC service time by concatenating several MAC Service Data Units (MSDUs) to form the data payload of a large Aggregated–MSDU (A–MSDU). Such packet aggregation scheme leverages the channel probing functionalities of mesh routers in order to compute the optimal saturation burst length.

III. Demonstration

In this demonstration we would like to show the capability of the WING platform to support multiple traffic flows characterized by different traffic profiles. More specifically we will focus our attention on multimedia applications due to (i) their widespread use (e.g. Skype, YouTube), and (ii) their strict requirements in terms of packet loss and delay. The reference network setup is sketched in Fig. 2. The demonstration will involve the following applications scenario:

- *VoIP*. A set of wireless VoIP Phones (e.g. Nokia N-series) will be used in order to setup multiple voice-only bi-directional communications using the SIP protocol [11]. The desktop *Rome* will act as private branch exchange (PBX) for the network. Asterisk has been selected as PBX for this demo. Conference attendees that owns a SIP-compatible phone will be able to register to the VoIP service and test the voice quality provided by the mesh (no outgoing calls will be allowed). Up to 4 SIP-compatible smartphone will be provided.

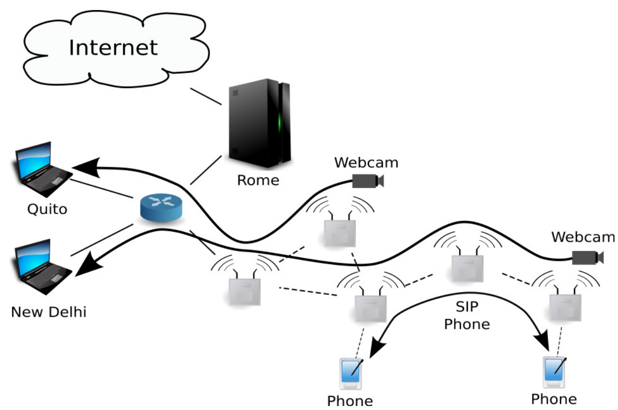

Fig. 2: The two-tiers architecture of the WING testbed.

- *Video streaming*. Two different mesh routers will be equipped with a standard USB webcam (e.g. Logitech Quickcam Sphere AF, Logitech Quickam Pro 9000). The generated video feeds will then be streamed from the mesh routers to either both the *Quito* and the *New Delhi* notebooks through the mesh gateway. VideoLAN [12] will be used as playback application.
- *Best effort*. Conference attendees will be able to exploit the WING platform for their regular Internet browsing and to download files. A sample FTP download will be initiated in order to demonstrate the platform's flow isolation capabilities.

The aforementioned application will be demonstrated with and without the WING platform QoS enhancements. A web-based network monitoring application will be installed in each mesh node in order to display the current network state (e.g. routes, link quality, etc.).

In order demonstrate the self–configuring and self–healing features of the WING platform we will simulate two different kind of failures at the WMN gateway. The following steps will be undertaken:

1) The mesh gateway is connected to the Internet using a wired connection (i.e. Ethernet).
2) Wireless clients associate to the hotspots provided by the mesh nodes and initiate regular browsing sessions.
3) The wired connection is made unavailable by yanking the Ethernet cable from the mesh gateway.
4) The mesh gateway reconfigure itself to use its second wireless interface to exploit an already available IEEE 802.11 AP uplink to the Internet.
5) The IEEE 802.11 AP that is providing the WING network with Internet connectivity is turned off.
6) The mesh gateway reconfigure itself to use the cellular modem to exploit the UMTS network as uplink to the Internet.

During both transitions, existing connections are not teared down, however data session may be delayed and outgoing multimedia connections can experience severe packet–loss.

IV. Conclusions

This demo aims at (i) validating the design choices we have made in conceiving and deploying the WING testbed, and (ii) showing the capability of out software toolkit to properly support heterogeneous multimedia applications. Additionally, the mesh networking toolkit's fault management features will be demonstrated. We hope that our wireless mesh networking toolkit will be considered by both researchers and practitioners as platform of choice to test innovative solutions and to provide end-users with wireless connectivity.

As future work we plan to deploy an outdoor testbed based on the WING platform. Finally, we also intend to extend the software toolkit with a completely distributed network monitoring architecture capable to properly address the peculiarities of the mesh network paradigm.

V. Demonstration Requirements

The demonstration requirements are as follows:

- Equipment (provided by us): Asterisk PBX, 8 ports Ethernet switch, 2 notebooks, up to 6 Mesh routers, 2 web cams, up to 4 Wireless VoIP Phones (e.g. Nokia N-series), 1 IEEE 802.11 AP.
- Space: 10 sqm plus 5 different locations where the mesh nodes can be deployed (e.g. conference rooms, corridors, etc.).
- Time to setup the demonstration: 2 hours.
- Facilities: Wired Internet Access, 5 Power Sockets, 1 table to accommodate the notebooks and 1 mesh router.

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