Heraklion *MESH*: An Experimental Metropolitan Multi-Radio Mesh Network*

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ABSTRACT

We present the design and initial experience from an experimental metropolitan multi-radio mesh network that covers an area of approximately 60 Km^2 in the city of Heraklion, Crete. The network consists of 14 nodes, among which six are core nodes with up to four 802.11a wireless interfaces each, and one wireless interface for management and monitoring. The distance between core nodes varies from 1 to 5 Km. Finally, the wireless mesh network contains two gateways that connect it to a fixed network.

Categories and Subject Descriptors: C.2.1 [Computer-Communication Networks]: Network Architecture and Design–*wireless communication*

General Terms: Design, Experimentation.

Keywords: metropolitan test-bed, multi-radio, mesh.

1. INTRODUCTION

Wireless multi-radio multi-channel mesh networks have the potential to provide ubiquitous and ultra high-speed broadband access in urban and rural areas, to both fixed and mobile users, with low operation and management costs. To investigate issues related to the management and performance of a multi-radio mesh network in an actual metropolitan environment, we have deployed an experimental multi-radio mesh network covering an area of approximately 60 Km^2 in the city of Heraklion, Crete, Greece. Our longer term objective is to use the mesh network as a metropolitan scale test-bed to investigate the performance of a multi-radio mesh network built from commodity components in 1 to 5 Km city links, to evaluate channel assignment procedures for efficiently utilizing the wireless spectrum, to investigate MAC and network layer mechanisms for supporting performance guarantees, and to evaluate routing metrics for multi-radio, multi-channel, multi-rate mesh networks.

Other mesh and/or long-distance 802.11 networks include the 802.11b-based Digital Gangetic Plains rural area test-bed with $1-23$ Km links [3], the WiLDNet network with $50-100$ Km links [4], the Roofnet network which considers single-radio mesh nodes [1], the Quail Ridge wireless mesh network [6], and other city-wide mesh networks[1].

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2. MULTI-RADIO MESH NODE

Each multi-radio mesh node consists of a mini-ITX board (EPIA SP 13000, 1.3 GHz C3 CPU, 512 MB DDR400 memory) and a 40 GB 2.5" HDD. A four slot mini PCI to PCI adapter (MikroTik RouterBOARD 14) holds four 802.11a/g mini PCI adapters (NL-5354 MP PLUS Aries 2, Atheros-based High Power Super A/G dual Band 802.11a/b/g). The mini-ITX runs Gentoo 2006 i686 Linux (2.6.18 kernel) with the MadWiFi driver version 0.9.2. Finally, the nodes run OLSR daemon version 0.4.10 (by olsr.org), which implements the Optimized Link State Routing (OLSR) protocol.

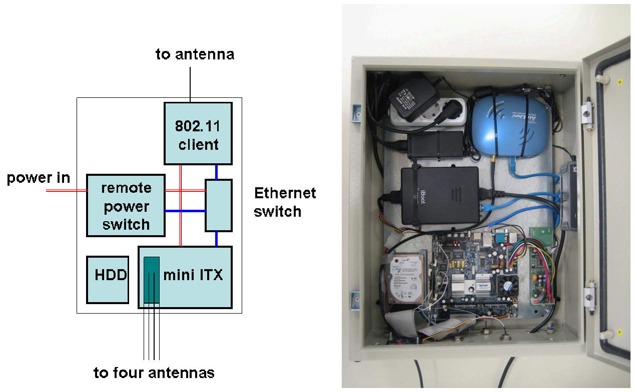
One of our design requirements was to allow remote management, monitoring, and recovery of the mesh nodes, even in situations when a mesh node's mini-ITX board crashes or its wireless interfaces are down. To address this requirement we added to each mesh node an additional 802.11a client, Figure 1, which connects to a management and monitoring network that operates in parallel to the experimental mesh network. Additionally, to enable remote recovery of the mesh node's mini-ITX board we added an intelligent remote power switch (Dataprobe iBoot), Figure 1; this allows the power to be switched off and on through a web interface, but also supports timed power reboot based on the results from the power switch pinging other devices (the mini-ITX board or some remote device).

3. MULTI-RADIO MESH NETWORK

The metropolitan mesh network covers an area of approximately 60 Km^2 and currently contains 14 nodes, Figure 2, among which six are core mesh nodes, whose design was discussed in the previous section. The distance and antennas used for the links between core mesh nodes[2] are shown in Table 1. Each wireless interface is assigned a static IP address, and the OLSR protocol is used for routing traffic in the network. The mesh test-bed is connected to a fixed network through two nodes (FORTH and UoC).

[1]e.g., Mad City Broadband in Wisconsin - www.madcitybroadband.com, Berlin RoofNet - http://sarwiki.informatik.hu-berlin.de/BerlinRoofNet

[2]Two core mesh nodes are under deployment, and are not shown in Table 1.



(a) Component layout (b) Actual node

Figure 1: Multi-radio mesh node.

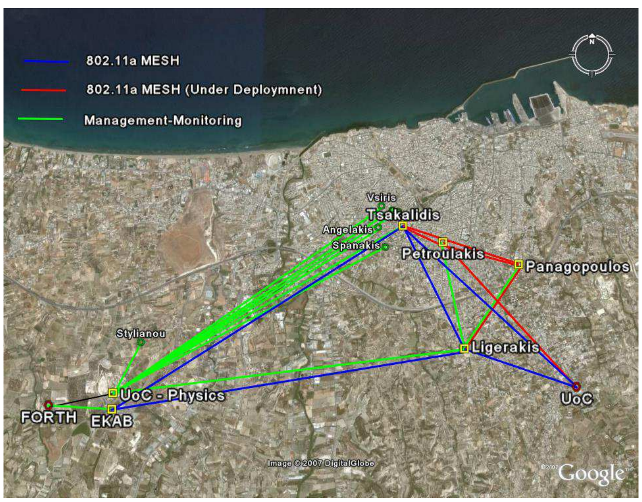


Figure 2: Heraklion MESH.

4. INITIAL PERFORMANCE AND MONITORING RESULTS

We first investigated, in a laboratory setting, the mesh node hardware's ability to support the maximum transmission rate available in IEEE 802.11a and if we have cross-talk among the four interfaces in a mesh node. We considered a scenario with two flows entering two wireless interfaces of a mesh node and exiting through the other two interfaces, and performed two experiments: in the first, the two ingoing interfaces and the two outgoing interfaces where assigned neighboring channels, while in the second the interfaces where assigned channels with a one channel separation (i.e., leaving one unused channel between the assigned channels). The throughput achieved by the two flows is shown in Figure 3, and indicates that there is significant interference between neighboring channels. On the other hand, when there is a one channel separation the throughput achieved

Table 1: Links between core mesh nodes

Link	Distance (Km)	Antennas
Ekab-Lygerakis	5.0	29 dBi grid - 21 dBi panel
Ekab-Tsakalidis	4.9	29 dBi grid - 21 dBi panel
Lygeraki-Tsakalidis	2.0	21 dBi - 19 dBi panel
UoC-Lygerakis	1.6	21 dBi - 21 dBi panel
UoC-Tsakalidis	3.3	21 dBi - 19 dBi panel

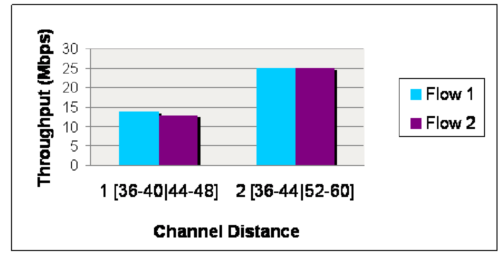


Figure 3: Throughput for different channel assignments. Single mesh node in a laboratory setting.

by each flow (approximately 25 Mbps) is close to the theoretic maximum if we consider all the overheads, hence there is no significant interference with a one channel separation; we are currently investigating the interference with long distance links, since their is also power leakage between channels with a higher separation [2], the magnitude of which is very small hence does not influence the performance of short distance links. Finally, unlike [5], our results do not show crosstalk among the four mini PCI wireless adapters.

Table 2 shows typical values we have observed for the signal-to-noise ratio (SNR) and transmission rate of the core links in an interval of 12 hours. These results show that the links are asymmetric and the link quality varies. Moreover, the variation of the link quality is different for different links.

We have developed a set of scripts that continuously monitor important performance metrics for all links between core nodes, and make them available through a web server[3] using the RRDTool. The metrics include the signal-to-noise ratio (SNR), transmission rate, MAC and physical layer errors, two-way delay, and throughput.

5. REFERENCES

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[3]See http://www.ics.forth.gr/HMESH

Table 2: Link SNR and transmission rate

Link	SNR min,max,avg	Rate min,max,avg (Mbps)
Ekab-Tsakalidis	18,29,21	6,54,24
Tsakalidis-Ekab	13,23,18	6,48,24
Lygerakis-Tsakalidis	13,18,15	6,18,7
Tsakalidis-Lygerakis	14,26,19	6,36,8
Lygerakis-UoC	13,19,17	12,54,44
UoC-Lygerakis	22,28,25	12,54,45
Tsakalidis-UoC	20,25,22	12,24,18
UoC-Tsakalidis	20,29,22	12,36,24