PROJECT-BASED LEARNING EXAMPLE:

WIRELESS MESH NETWORKS FOR UNDERGRADUATES *

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ABSTRACT

Wireless technology has become a crucial component in communication and networking systems and technology. As the newer wireless technologies have been developed and deployed, the demand for wireless networking professionals from the industry has grown stronger. In response to this demand, we have provided hands-on wireless education for computer science undergraduates. From offering a hands-on wireless course, we notice that our undergraduates are able to move forward through experiencing a real-world wireless project. This paper introduces an example project on wireless mesh networks. How to design, implement, and test a wireless mesh network with off-the-shelf low cost wireless routers have presented. Throughout building a real mesh wireless network, students can be engaged with the topic in a practical manner. We believe that this wireless project significantly enhances student learning with strong motivations.

INTRODUCTION

The newer wireless technologies such as Wireless Gigabit Alliance (WiGig) or 802.11ac, 802.11ad, 802.16 Worldwide Interoperability for Microwave Access (WiMAX), 4G Long Term Evolution (LTE), Near Filed Communication (NFC), and LiFi or Visible Light Communications (VLC) or have been developed and deployed. As

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wireless networks have become a primary mean to access the Internet, there has been a strong demand for wireless networking professionals from the industry. This rising demand for wireless professionals had led most schools and institutes to offer wireless education. However there are a small number of schools providing hands-on wireless education for mostly for graduates but not undergraduate students [1-3].

As one of the leading undergraduate polytechnic institutes, the Computer Science and Networking Department at Wentworth Institute of Technology (WIT), Boston, has developed a hands-on wireless networks course for undergraduate students. Details of teaching methods and example lab assignments for 802.11 wireless networks have been presented in [4]. We believe that the course provides a solid basis for teaching the theory and practice of wireless communication systems with Wi-Fi hands-on lab assignments. Throughout offering the hands-on wireless course, we notice that our undergraduates are able to move forward in the field from an early exposure to a real-world wireless project.

Although many diverse project examples, approaches, and methods have been proposed for computer science and engineering courses, they all agree that incorporating a real-world project into these courses significantly enhance student with strong motivation and learning [5-8]. In response to this movement as well as the increasing demand for wireless networking skills in almost all industries, we present an example project in wireless networks for computer science and networking undergraduate.

In this paper, we will provide an example project on wireless mesh networks. We present how to design, implement, and test a wireless mesh network with off-the-shelf low cost wireless routers.

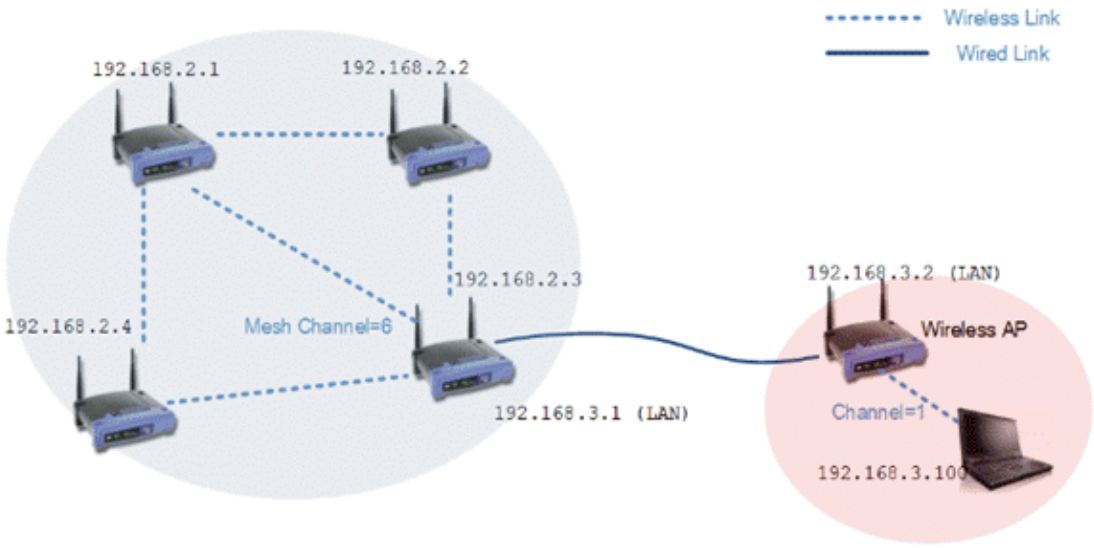

Figure 1. Example layout of a WMN

PROJECT: BUILDING A WIRELESS MESH NETWORK

Students need to design and plan a wireless mesh network through identifying the network map, selecting the network topology type, and allocating wireless channels and IP addresses. According to the network design students can build the wireless mesh network by configuring all the mesh nodes. An example layout of a WMN is shown in Fig. 1. In this example WMN project, Linksys WRT54G series routers and the Freifunk firmware are the main hardware and software requirements.

Mesh Node Settings - System and OLSR

Freifunk firmware is a non-commercial software designed to build a decentralized network. It is based on OpenWRT which is essentially an open source Linux distribution for embedded devices. The idea behind OpenWRT/DD-WRT was to open functionality that was originally unavailable and to provide a Linux framework for customizing your device to do far more than what it was intentionally designed for. Students access the setup page of the WRT54G router through a web browser by typing the address 192.168.1.1 into the address bar. In the setup page, the administration tab provides Firmware Upgrade page. Once the Linksys/DD-WRT firmware has been upgraded to the Freifunk firmware students can start the configuration of the mesh node.

Students start by going into the system tab and entering the initial configuration information. First step is to give each router a host name in the host name field of the

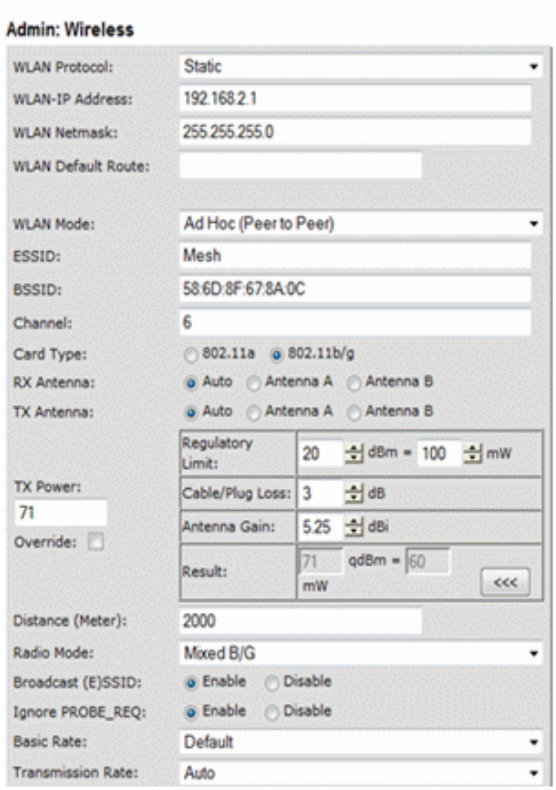

Figure 2. Freifunk Wireless Settings

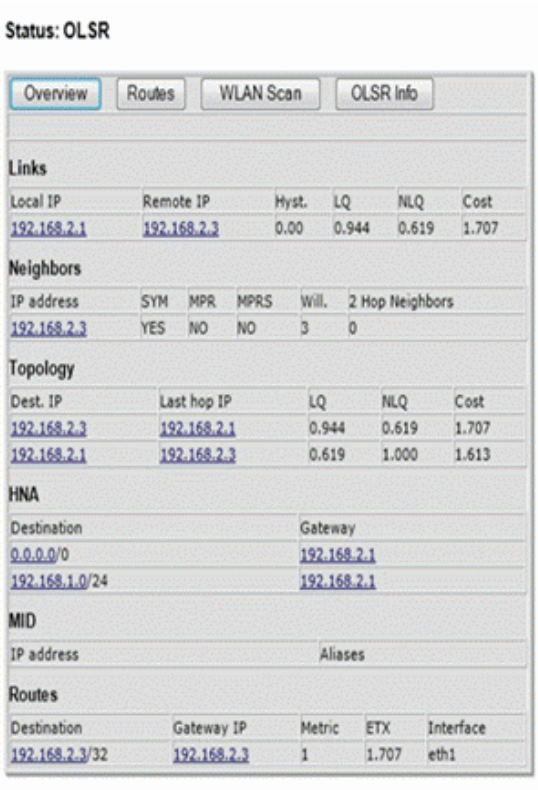

Figure 3. Freifunk Network overview

system setting page. This can be different on each mesh node to eliminate confusion. The default settings of Optimized Link State Routing (OLSR) configuration are sufficient for our purposes and for most networks.

Mesh Node Settings - Wireless Settings

For the WLAN Protocol field we select Static. Then in the WLAN-IP Address and WLAN Netmask enter the IP address determined in the network diagram. In the example network diagram we assigned 192.168.2.X and set the subnet mask to 255.255.255.0. Students may enter route information into the WLAN Default Route field if their situation calls for it, but for the purposes of our experiment it was left at the default of black.

For the WLAN Mode field we select Ad Hoc (Peer to Peer) as many more nodes will be connecting to this mesh network. Each node in the WMN should have the same Extended Service Set Identification (ESSID - network name), Basic Service Set Identifier (BSSID - a unique address), and operate on the same wireless channel. As shown in Fig. 2, all nodes in WMN have the same ESSID - Mesh and BSSID - 58:6D:8F:67:8A:0C, and channel 6. In the BSSID field, student can enter the MAC address of one of the Linksys nodes. This setting allows rejoining the mesh network should the mesh ever break into two networks in case of a node going down and later coming back up.

Mesh Node Settings - LAN Settings

In the Local Area Network (LAN) section of the admin page select Static for the LAN Protocol field and enter the IP and Subnet Mask determined in the network diagram. In the example network diagram we assigned 192.168.3.1 and 255.255.255.0. Next leave NAT enabled but disable firewall by clicking the check box next to it, turning off the security makes testing the network easier. Note that NAT can be disabled but if it is the two networks, wireless and wired, will not be able to talk to each other, simply the networks become unbridged.

Finishing Up - Creating a hotspot

After the configuration process is complete, students can check the network status through the main page of the router as shown in Fig. 3. The OLSR info option displays a detailed list of all the routes available on the network. The WLAN Scan option lists all other wireless networks that the router detects. It is important to note that if the network is set up correctly, there will only be one entry for the network. It will not list all the wireless nodes in the mesh network.

Students can create a hotspot by linking a wireless access point to a mesh node. As shown in Fig. 1, LAN and wireless settings are required. Just like the above mesh node setting, students upgrade the firmware to the DD-WRT firmware and configure the LAN and wireless settings of the access point.

Students configure wireless settings by going into the Wireless tab and entering the SSID (wireless network name) and wireless channel number. In the example network diagram we assigned channel 1. On the Basic Setup tab of the Setup page LAN and

DHCP information can be configured as shown in Fig 4. By selecting Disabled for Internet Connection Type and DHCP Forwarder for DHCP type, the access point acts as a kind of bridge on the network. Under Router IP, enter the LAN IP address and Subnet Mask determined in the network diagram. In the example network diagram we assigned 192.168.3.2 and 255.255.255.0. For the DHCP server, enter the LAN IP address of the mesh node which the access point has connected.

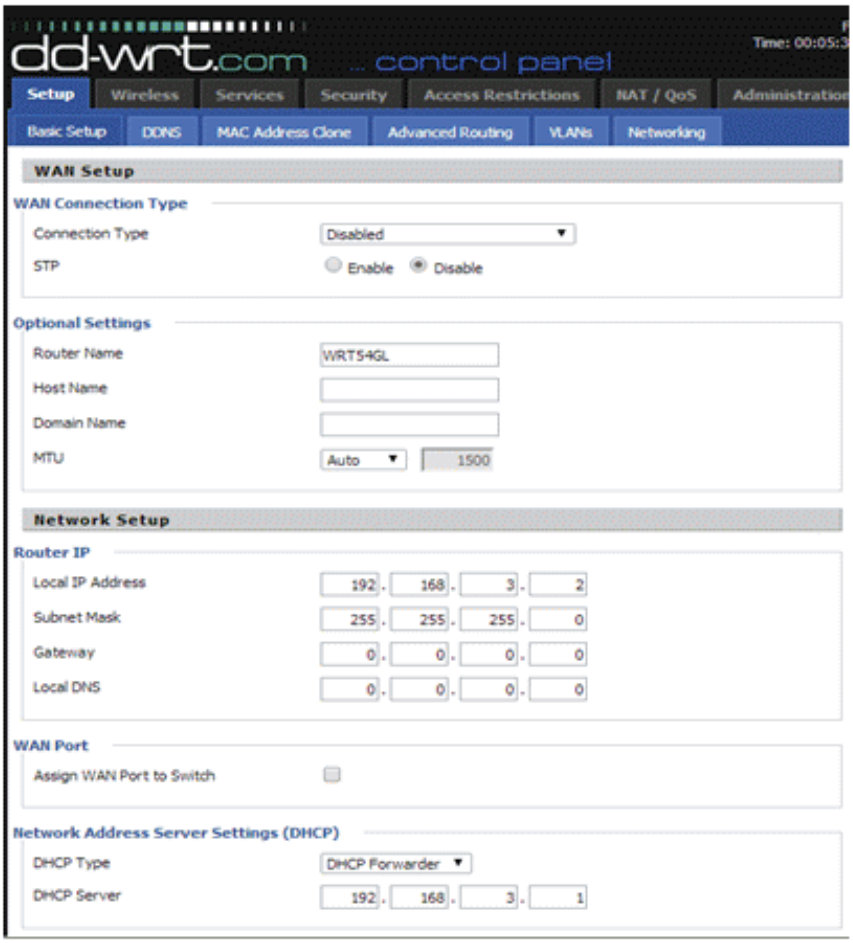

Figure 4. DD-WRT Access Point Setup

Testing WMN Performance

After building a WMN, students can perform many tests on the network to determine its signal strength, stability, speed, and convergence speed. There are several methods and tools to get more detailed wireless information including signal strength of interference and beacons from a wireless router in units of dBm or relative signal strength indication (RSSI). For example, airodump-ng is a wireless packet capturing tool with the intent of using them for aircrack-ng. Through one of the wireless scanning tools, students are able to verify that their wireless network is set up and functioning correctly.

Furthermore students can test and determine the range of each router and whole mesh network.

In order to check the performance of the network, we can consider network throughput which is the rate of successful message delivery over a communication channel or how many bytes-per-sec can be transferred from one node to another. NetStress is a network benchmarking tool used to measure both wired and wireless network throughput. By using NetStress, students can test the stability and convergence of the network. By turning off and then on the mesh nodes (routers), students can check how fast the wireless mesh network would converge while the network was under stress.

Students then can test the file transfer speed by transferring a file. Students install a file server on one of the wireless client node, and then other wireless client nodes can perform the test by downloading it under different network settings i.e. numbers of mesh nodes, mesh node locations, network total traffic, or numbers of clients.

WIRELESS PROJECT EXAMPLES

With the WMN as a backbone network students could use the infrastructure to setup Wi-Fi Protected Access (WPA) and Wi-Fi Protected Access II (WPA2) with FreeRADIUS services for an enterprise secure authenticated network [9]. Student can also setup a wireless Intrusion Detection and Prevention System (IDPS) using Kismet [10] and Snort [11] or implement a captive portal for a wireless hotspot with Wifidog [12] or ChilliSpot [13]. Student can also implement network performance tuning using MadWiFi or discover rouge access point on the network using Karma [14].

Other projects that maybe implemented in interdisciplinary projects by our students would be remote wireless security system or wireless systems connected to sensors controlling appliances in a smart home. Students can also implement wireless health monitoring systems in hospitals as well as at a patient's home [15].

CONCLUSIONS

In this paper we have introduced a wireless project, building a Wireless Mesh Network (WMN), for computer science undergraduate. Students have learned the state of the art in wireless technologies, tools, and applications through the completion of the project. This project starts from designing and planning a wireless mesh network which includes identifying the network map, selecting the network topology type, and allocating wireless channels and IP addresses. By flashing the original Linksys firmware to the Freifunk firmware students configure a mesh node including system, OLSR, wireless, LAN and WAN settings. Through the completion of all tasks, the student learned problem-solving techniques for practical wireless network design such as planning, literature survey, implementing, performance testing, and troubleshooting. Keeping in mind that there is a strong demand for wireless networking professionals, we believe that this project provides an opportunity for students to experience the state of art wireless technologies and eventually excel in their career.

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