

Teaching Advanced Networking Concepts Using a Raspberry Pi

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Perspectives on Teaching Advanced Networking Topics

- Using CompTIA's Network+ and Security+ certifications as a model for the Knowledge, Skills and Abilities that a network administrator and technician will need to know there are several great possibilities to teach advanced topics, such as:
 - VPN
 - RADIUS Server
 - Firewall
 - Wireless Access Point
 - Work with less common protocols
 - Such as UDP and real-time packet streaming
 - Simple Electronics and Programming

Issues Encountered in Teaching Advanced Networking Topics

- Two of the biggest issues that schools have in teaching a practical “hands-on” approach to advanced networking topics are:
 - Facilities
 - Many of the labs use combinations of expensive servers, routers, firewalls, workstations, etc
 - In fact ... it could be argued that each student (or group of students) should have their own datacenter to work with
 - Equipment Costs
 - Commercial / Industrial networking hardware (Cisco, Palo Alto), servers (Dell, HP) and storage (EMC, Netapp) is expensive to purchase and maintain

A Solution ...

The Raspberry Pi

- These small computers make an ideal platform for teaching networking concepts
 - Inexpensive ~ \$60 - \$100 each (system cost)
 - Readily available
 - Large user base
 - Zero software cost
 - Quality Open Source software
 - Reasonably powerful
 - Linux based



The Raspberry Pi as a Lab Platform

- The Advantages
 - Use of Open Source Software eliminates licensing issues
 - Easy to leverage existing lab equipment (such as a generic desktop/laptop computers and inexpensive routers/switches/Aps)
 - Costs are low enough to purchase additional hardware providing more students, working in smaller groups to do more labs
- The next slides will show some labs that can be done using the Pi for your labs
 - Sensor Actuator I/O with Automation
 - Zigbee, Z-Wave and WiFi wireless interfacing
 - Presence Detection
 - Surveillance
 - VPN Appliance
 - RADIUS Server

Sensor Actuator I/O Lab

- Home Assistant appliance running on a Raspberry Pi used as a Microcontroller
- An inexpensive temperature/humidity sensor and LED are interfaced via the GPIO connector
- Students add the configurations for the devices by programming the Home Assistant's main configuration file
- Once the devices are functional the students can write simple automations around the devices using IFTTT (if this then that) statements
 - For example:
 - If the temperature is $>x$, turn on the LED, if the temperature is $<y$ turn off the LED

Zigbee, Z-Wave and Wifi Wireless Device Labs

- Home Assistant appliance on a Raspberry Pi used as a Microcontroller
- “Off the shelf “Zigbee, Z-Wave and WiFi devices are paired with Pi
 - Zigbee and WiFi Light Bulbs
 - Z-Wave and WiFi switches
 - Z-Wave and WiFi Motion Sensors
- Students add the configurations for the devices by programming the Home Assistant’s main configuration file
- Once the devices are functional the students can write simple automations around the devices using IFTTT
 - For example:
 - If the time = x then turn on a Zigbee light bulb
 - If the contact sensor = open then turn on a WiFi light bulb to color = red
 - If motion detected = TRUE then turn on WiFi light bulb for 1 second, then turn off for 1 second and repeat 20 times

Presence Detection Lab

- Home Assistant appliance on a Raspberry Pi used as a Microcontroller
- Home Assistant has several ways to determine if a person is “home” (at least if their phone is) using ping, nmap or even communication with a router
- Students add the configurations for the devices by programming the Home Assistant’s main configuration file (config.yaml) adding the configurations for their phones
- ... which will need static IP addresses
- Once they get Home Assistant to detect the presence of the phone the students can add customized icons for each person to display
- The students can write simple automations around who is present
 - For example
 - If student x is home turn on a specific bulb

Video Surveillance Lab

- Home Assistant on a Raspberry Pi as a Microcontroller
- Home Assistant can support a number of security cameras ... including webcams.
 - Note: not all cameras work well and integrate with Home Assistant (“Foscam” seems to be the go-to camera)
- Home Assistant can use cameras as motion detectors, send snapshots and even integrate with 3rd party surveillance platforms (iSpy ... open source video surveillance)
- Students add the configurations for the devices by programming the Home Assistant’s main configuration file adding the configurations for the cameras

VPN Lab

- Only requires:
 - Raspbian on a Raspberry Pi running OpenVPN
 - Both OpenVPN and Raspbian (the Pi's version of Debian) are open source
 - Inexpensive Router/Switch/AP (DLink, Asus, Netgear, etc)
 - A desktop or laptop on “both sides” of the router
- Students install the OpenVPN software on the Pi
 - Then configure an RSA self-signed certificate for encryption and authentication
- The students get invaluable understanding and practice a critical piece of network security while demonstrating that you don't need a complex infrastructure to provide this valuable service.

RADIUS Lab

- Only requires:
 - Raspbian on a Raspberry Pi running FreeRADIUS (and other stuff)
 - Both FreeRADIUS and Raspbian (the Pi's version of Debian) are open source
 - Inexpensive Router/Switch/AP (DLink, Asus, Netgear, etc)
 - A desktop or laptop on “both sides” of the router
- Students install FreeRADIUS and other required service software on the Pi
 - then configure FreeRADIUS authentication
 - then configure the router to forward RADIUS packets to the Pi
 - then configure the computer to connect to the Access Point and authenticate to the RADIUS Server (the Raspberry Pi)
- The students get invaluable understanding and practice a critical piece of network security while demonstrating that you don't need a complex infrastructure to provide this valuable service.
- One note ... this lab can be far more complex than any of the other labs if you wish to teach more advanced functions, such as installing and configuring MySQL for the authentication data base. Consider this option for the lab in a more advanced networking class.

Lab Examples

- Two labs are included with this presentation that have been used in A+, Network+, Security+, Wireless and IoT classes.
 - Setting up VPN's Using a Raspberry Pi
 - Setting up FreeRADIUS Using a Raspberry Pi

Recommended Environment

- Raspberry Pi System
 - Raspberry Pi (labs used a Pi 3 Model B+)
 - Raspberry Pi 7-inch Touchscreen
 - Smart Pi Touch Case
 - 16GB MicroSD Card
 - 2.5amp Raspberry Pi Power Supply
 - Running Raspberry Pi OS Lite “Buster”
- USB Keyboard
- Router/Switch/Access Points
 - Using older Linksys WRT54g devices work great
 - They are inexpensive and easy to get on the used market
 - They run DD-WRT very well
 - DD-WRT is an excellent open source firmware replacement that provides features only found on expensive commercial routers and access points
- (2) Laptop computers



In Conclusion

- Our Business and Industry Leadership Teams are starting to tell us that our students need to have practical skills as opposed to just certifications.
- Advanced networking concepts and technology skills need to be taught using a practical “hands-on” approach rather than simply studying the theory and passing tests.
- But, the cost of commercial and industrial grade equipment can be cost prohibitive to purchase in the quantities needed for students to practice in small teams (typically two students per team)
 - Also, vendors such as Cisco use proprietary configuration tools that are not the same on all manufactures’ products
- To best provide students with a low-cost, vendor-neutral environment, look to using Raspberry Pi’s as the platform of choice.