Notes on avxWifi 9-21-18

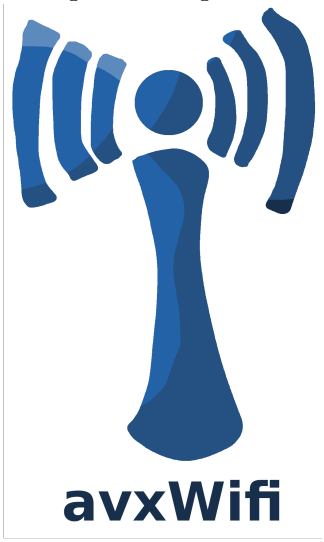
Supplies

- Raspberry Pi Zero W, https://www.adafruit.com/product/3400
- Micro USB-B to USB-A Connector,
  - I think this is the one I'm using, https://www.adafruit.com/product/2910
- microSD Card
  - I'm using a 64GB card. You don't need one this big, but I wouldn't go below 16GB.
- Power supply for the RPi Zero W , https://www.adafruit.com/product/1995
- USB Hub
  - I'm using a powered one. Maybe I should switch to an unpowered one?
  - https://www.newegg.com/Product/Product.aspx?Item=N82E16817801107
- HDMI mini cable
  - or a regular HDMI cable and an adapter to mini HDMI.
  - You want HDMI mini, not micro.
- Amazon Basics Wifi adapter with detachable antenna
  - https://www.amazon.com/AmazonBasics-Wi-Fi-11N-USB-Adapter/dp/B071Y6Y83W
- Small piece of coax cable
  - I found this in my lab...
- Coax connector
  - Digikey part number CONSMA007-R58-ND
  - Male cable end crimp RG58
- USB keyboard and Mouse
- HDMI monitor
- Custom PCB
- Soldering iron and small amount of solder.
- 4 pin header, digikey part number 609-2670-ND. This part is optional, it is for the impedance matching circuit near the antenna.

Intro

According to https://motherboard.vice.com/en_us/article/kz3xyz/detroit-mesh-network , 40% of Detroit residents lack internet access. We're solving this with Raspberry Pi Zero W access points and custom made directional antennas. These notes are very rough.

Our github page is at: https://github.com/amitofsk/avxWifi



Set up the Raspberry Pi Zero W

I'm using Raspbian Stretch, Linux 4.14.52.

Update the OS... Not sure if all of these steps are needed...

```
sudo apt-get upgrade
sudo apt-get dist-upgrade
sudo apt-get clean
sudo apt-get update
sudo apt-get install vim
```

Antenna Driver

I'm using an Amazon Basics brand wifi adapter with a detachable antenna. When I bought this adapter. I didn't realize that the antenna could just unscrew. I was even more pleasantly surprised to find the mating connector lying around my lab.
The problem with this adapater, though, is that Raspbian doesn't recognize it. I looked in dmesg, and it said the adapter was Realtek, serial number 70F11C0531F8, idvendor=0dba, idProduct=818b. According to https://www.raspberrypi.org/forums/viewtopic.php?t=103989

, the chip in it requires the RTL8192EU driver, and this driver is available online. I downloaded and installed it, and it worked fine! Make sure the antenna is plugged in during the install process.

```
sudo wget http://fars-robotics.net/install-wifi -O /usr/bin/install-wifi
sudo chmod +x /usr/bin/install-wifi
sudo install-wifi -h
sudo install-wifi
```

Rasperry Pi Zero W as an Access Point

The general strategy is to follow the tutorial on the Adafruit page. https://learn.adafruit.com/setting-up-a-raspberry-pi-as-a-wifi-access-point/install-software However, you need to make some additional changes to config files even beyond what is discussed in that tutorial. The post from 9-11-16 at
https://www.raspberrypi.org/forums/viewtopic.php?t=139866 was also useful.

The Adafruit tutorial assumes you have a wired network connection eth0 and are setting up a wireless access point through wlan0. In our case, we have two wireless connections. The internal wifi device, wlan0, will be the access point we are setting up for our local network. The external wifi adapter, wlan1, will connect to the established network (my router). When following the Adafruit tutorial, we'll replace eth0 by wlan1.

Following the adafruit page, we have to alter the following seven config files.

- /etc/dhcp/dhcpd.conf
- /etc/default/isc-dhcp-server
- /etc/network/interfaces
- /etc/hostapd/hostapd.conf
- /etc/default/hostapd
- /etc/init.d/hostapd
- /etc/sysctl.conf

My strategy is to copy the original config file so I have a backup I can go back to. If things don't work, you can copy all seven of these original files back into place and reboot.

```
sudo cp /etc/dhcp/dhcpd.conf /etc/dhcpd/dhcpd.conf.orig
sudo cp /etc/default/isc-dhcp-server /etc/default/isc-dhcp-server.orig
sudo cp /etc/network/interfaces /etc/network/interfaces.orig
sudo cp /etc/hostapd/hostapd.conf /etc/hostapd/hostapd.conf.orig
```

```
sudo cp /etc/default/hostapd /etc/default/hostapd.orig
sudo cp /etc/init.d/hostapd /etc/init.d/hostapd.orig
sudo cp /etc/sysctl.conf /etc/sysctl.conf.orig
```

I've attached my new versions of these files. You need to modify the file named interfaces. Replace AAA with the name of the wifi network you will be connecting to, and replace BBB with its password. The file hostapd.conf contains the name of the network you will be setting up. Following the adafruit tutorial, I'm using Pi_AP as the name of the network and Raspberry as the password.

Once you've modified the interfaces file, copy these files into place. I assume here that you are in a directory containing the updated files.

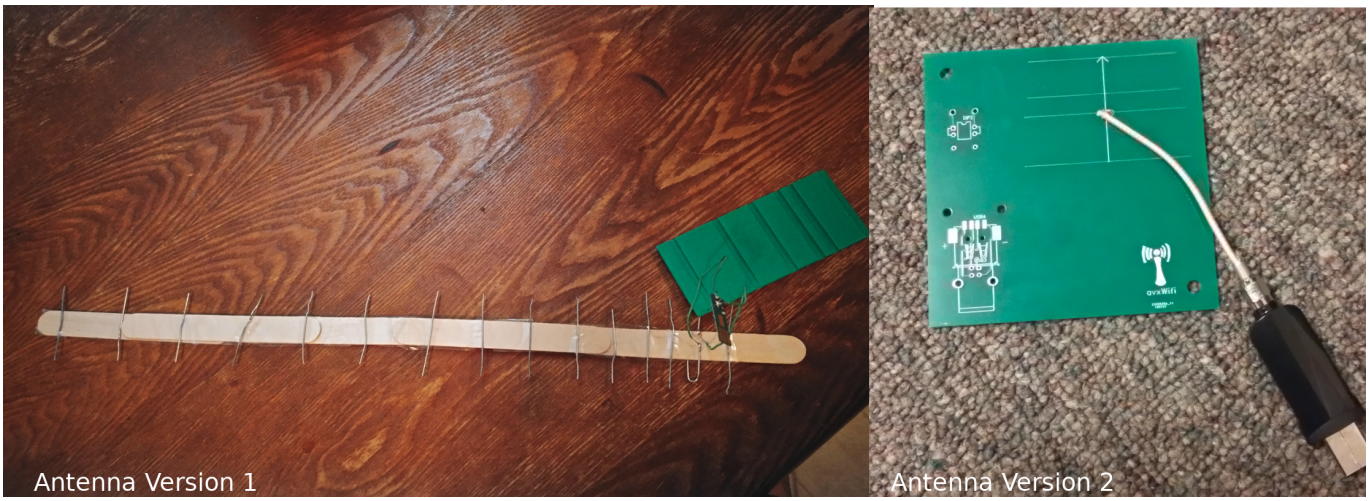
```
sudo cp dhcpd.conf /etc/dhcp/dhcpd.conf
sudo cp isc-dhcp-server /etc/default/isc-dhcp-server
sudo cp interfaces /etc/network/interfaces
sudo cp hostapd.conf /etc/hostapd/hostapd.conf
sudo cp default_hostapd /etc/default/hostapd
sudo cp initd_hostapd /etc/init.d/hostapd
sudo cp sysctl.conf /etc/sysctl.conf
```

Next, continue following along the adafruit instructions. We're replacing eth0 in these instructions with wlan1.

```
sudo ifconfig wlan0 192.168.42.1
sudo sh -c "echo 1 > /proc/sys/net/ipv4/ip_forward"
sudo iptables -t nat -A POSTROUTING -o wlan1 -j MASQUERADE
sudo iptables -A FORWARD -i wlan1-o wlan0 -m state --state RELATED,ESTABLISHED
-j ACCEPT
sudo iptables -A FORWARD -i wlan0 -o wlan1 -j ACCEPT
sudo sh -c "iptables-save > /etc/iptables/rules.v4"
sudo mv /usr/share/dbus-1/system-services/fi.epitest.hostap.WPASupplicant.service
~/
sudo service hostapd start
sudo service isc-dhcp-server start
sudo update-rc.d hostapd enable
sudo update-rc.d isc-dhcp-server enable
```

When you are done, reboot.

Making and Using a Custom Antenna



Paperclip antenna

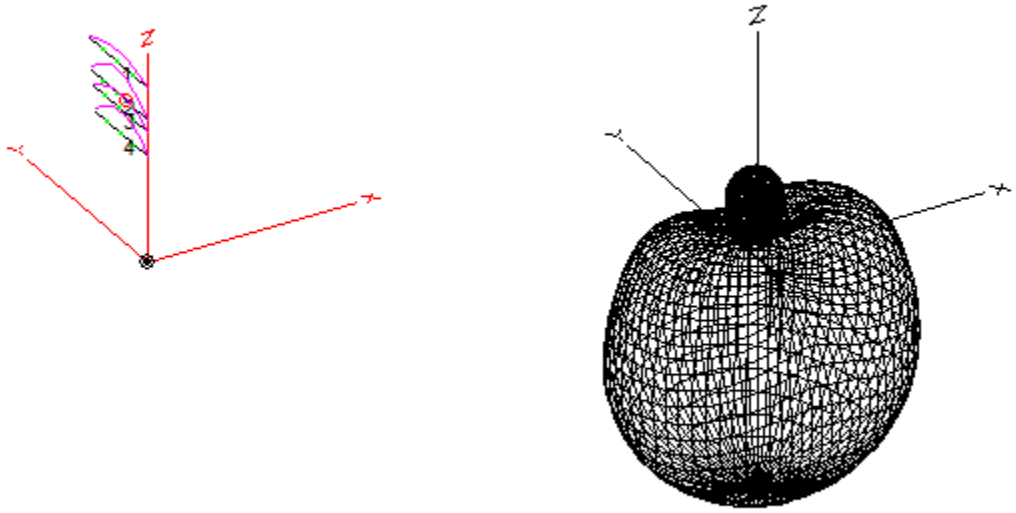
Our first attempt at making a directional antenna was to follow the tutorial at:
https://www.instructables.com/id/Easy-to-Build-WIFI-24GHz-Yagi-Antenna/
Xavier worked on this step at the hackathon. Our antenna is shown in the figure above on the left.

Antenna Template

The difficulty with that design is that it is hard to properly align the antenna elements, and their alignment is important. So, we decided to 3D print a template to make antenna construction easier. Xavier worked on this step at the hackathon too. The antenna template is the green object on the left part of the figure.

Simulation

I decided to simulate a four element Yagi antenna using EZNEC. I used the Demo version of EZNEC available at https://www.eznec.com/ . The antenna is sending a signal to the -z direction (down in the figure), so it is plotted at a weird angle. It assumes that the antenna is communicating with another antenna below it. According to the simulation, this is a very directional antenna.



PCB antenna

Next, I used https://easyeda.com/ to design a custom PCB containing an antenna. The antenna is shown in the right part of the figure above, labeled Antenna Version 2.

The figure below shows the PCB layout. The part in the upper right is the antenna, and the arrow in yellow shows the direction the signal is sent from the antenna. We actually don't need the part in the lower right. At the hackathon, we had to crack open a wifi adapter to connect in our antenna. I included this section since I thought we might need to do the same again to solder in a wifi adapter. However, an antenna can just screw into the amazon basic wifi adapter I bought, so this part is no longer needed. I had some ideas for how to address the impedance matching issue. I included the part in the upper right for that reason, but I haven't tried that out yet.

What is the impedance matching issue? If length of any connecting wires is longer than, or about as long, as the wavelength of the signal involved, those wires act as a transmission line. A wifi signal has frequency 2.4GHz which corresponds to a wavelength of $\lambda = \frac{3 \cdot 10^8}{f} = 12.5$cm. Our connecting wires are a few centimeters long, so this may be an issue. If the connecting wires act as a transmission line, the voltage along the wires is not constant, and it varies along the length of the line. If the impedance of the load is not matched to the impedance of the transmission line, oscillations will develop in the line, and energy will be stored in the line instead of transmitted to or from the antenna. Ideally, the impedance of the antenna should be matched to the impedance of the transmission line. I haven't even tried to address this issue yet.

I haven't had a chance to test this antenna much yet. However, from a very quick test, my PCB antenna appears to be stronger than the internal wifi antenna in the Raspberry Pi but not quite as good as the Amazon antenna that the adapter came with. The PCB antenna is supposed to be directional. From my very quick tests, I couldn't tell if it actually was directional or not.