Lab # 3: WiFi Systems and Networks

Preparation

1. What is WiFi? Give a brief but clear description.
2. What are the frequencies allocated for WiFi systems? How many channels are there? What is the bandwidth of each channel?
3. What is the maximum transmit power of a WiFi router? What power is typically transmitted?
4. What is the minimum SNR required for reliable WiFi system operation?
5. What is the maximum distance for a WiFi system? Support your answer with a simple link budget calculation.
6. Download and install on your notebook computer or tablet software for analyzing a WiFi network. For Windows-based systems, we recommend "Acrylic WiFi" and for Android-based systems, we recommend "WiFi Analyzer". Similar software is also available for Mac-based systems (in fact, modern Mac OS already has a WiFi scanner – you can find a description of how to use it using Google). Practice using it before coming to the lab. Find out how many WiFi devices are available in your home or on the campus, what are their frequencies and powers as received by your device.
7. Download and install on your tablet software to measure Internet access speed. For Windows and Mac-based notebook computers, you can use this speed test web site,

   http://www.speedtest.net/

   For tablets, find and install similar software.

Laboratory

In this Lab, we will measure the basic parameters (power, frequency) of WiFi transmitter and study how they vary in space and time.

If you use your own device (e.g. a computer or tablet), please make sure that the battery is **fully charged** before the lab begins.

Part I:

1. Start WiFi Analyzer (or its equivalent). Determine how many WiFi networks are available, what are their frequencies and powers.

2. Find the strongest WiFi router, record its name and MAC address. Look around and find its location. Measure its signal power at a distance of about 1 m if the router's location permits or as close as you can safely approach it otherwise. Do the same at 2-3 and 5-10 meters, every time ensuring that line-of-sight (LOS) is not obstructed (by some objects or people, e.g. other students moving around). Sketch the environment, indicate the router and your locations. **Important note**: at each distance you take measurements, measure at least 5-10 points and take the average value

of those measurements to compensate for temporal signal level fluctuations. Disregard particularly low power levels (e.g. 10 dB and more below the peak level). As an alternative, evaluate the peak power level (over a significant interval of time, e.g. 1-2 minutes) at each distance. Change the orientation of your device to find the best one (largest power) to take the measurements. Make sure that the LOS is not obstructed during the observations by other students. Do no locate your device close to a wall as this may produce significant reflection. Plot the received (and averaged) power as a function of distance. Based on these measurements, estimate the path loss exponent. The distance from each reference point to the router will be measured by the TA.

3. Now measure the signal power at a location where there is no LOS, take a note of (approximate) distance to the router and compare to the signal power at this distance but when LOS is present. Make conclusions on the impact of LOS.

4. Assuming that the transmit power is 20 dBm, find the propagation path loss in steps 1 and 2. Compare it with free space, 2-ray and indoor (such as ITU) models. Make conclusions.

5. Find out the noise power of your WiFi receiver and the SNR values corresponding to your measurements in steps 1 and 2 (hint: assume that the bandwidth is 20 MHz and the Rx noise figure is 6 dB).

6. Now, walk around a floor and make a number of measurements at different locations (making sketch of the floor plan and recoding router's and your locations). Analyze your measurements and make some conclusions.

7. Go to your original location and record the signal power over an interval of time (WiFi Analyzer and Acrylic WiFi have tools to do that). Does it stay the same or varies? Explain.

8. Measure Internet access speed at this location. How long would it take to download a typical HD movie at this speed?

9. If you are to install a new WiFi router, what frequency would you use at your current location? Why?

<u>Note:</u> at all stages, it is critical that you are measuring the signal power produced by the same WiFi router as identified via its MAC address (network name maybe not enough). Taking several measurements at about the same distance from the router and averaging them out is also essential to compensate for signal fluctuations.

Part II:

More accurate path loss measurements are done with <u>RF Explore Signal Generator</u> (a transmitter, Tx) and <u>Spectrum Analyzer</u> (a receiver, Rx) as follows.

1. Use an Rx to make sure that no WiFi routers create excessive interference at 2450 MHz (if this is not the case, new frequency has to be selected, which is interference-free). Turn on the Tx, it should be in "RF Generator" mode all the time (default setting – do not change it). Set up Tx frequency = 2450 MHz and power = 0 dBm (or the nearest you can get, e.g. 0.2 dBm). Enable RF power. This 1st step is done by the TA as there is one Tx unit to be used as a Tx by all groups.

2. Turn on the Rx. It has to be in the "spectrum analyzer" mode (default setting – do not change it) all the time. If necessary, make proper settings for X and Y axis to see clearly a peak at 2450 MHz. Top and bottom points of the Y axis has to be set at -20 and -90 dBm respectively. "Calculator" has to be set at "normal" (default setting – do not change it).

3. Place the Tx and Rx next to each other (side-by-side) so that the antennas are parallel and as close as possible to each other. Find the path loss in this (near-field) setting by taking the difference of Tx and Rx powers (effectively assuming unit-gain antennas). This is the minimum path loss possible for this particular configuration. Now, rotate the Rx with respect to Tx so that antennas are perpendicular to each other. How does this affect the path loss? Find an orientation that provides the smallest path loss.

4. Now place the Rx at d=1m from the Tx and measure the path loss. Move the Rx around a bit, keeping approximately the same distance, and find the point where the Rx power is largest. You may also need to move the Rx a bit up and down while observing the changes in Rx power, as well as tilting a bit Rx unit with respect to Tx one (so that the antennas are not parallel to each other anymore). The objective is to find the largest Rx power at d=1m and to determine the path loss based on this also indicating the values of fluctuations you observed while moving and tilting the Rx around. At all steps, make sure that there is clear line-of-sight (LOS) and 1st Fresnel zone is not obstructed. To see the impact of polarization, rotate the Rx to make its antenna being orthogonal to that of the Tx (without changing the distance) and observe the difference.

5. Now place the Rx at d=2, 3, 5 and 10 m and repeat step 4.

6. Compare the measured path loss with that in free space as well as the ITU indoor model (see Lecture 4) by plotting the theoretical path loss vs. distance for appropriate distance interval and also plotting the measured points on this graph. For the ITU model, you have to find the path loss exponent that fits best the measured results. What is its value? Any difference to the free space path loss exponent? Why? You may also use 2-ray model for comparison.

7. Now make some measurements with obstructed LOS and compare it to clear LOS results. For this, walk out of the lab and make measurements when the door is open (so that there is LOS) and then closed (no LOS); compare the results. You may use some obstructions in the lab room (furniture, other students). Now walk all the way to the back wall of the room (largest distance to the Tx), measure the path loss at that point (with LOS) and compare it with no LOS measurements (e.g. closed door). In which case the path loss is larger: blocked LOS at shorter distance (closed door) or larger distance with LOS present (at back wall)?

After completing the measurements, turn the Rx and Tx off.

You report has to provide not only the measurement results, but also a clear comparison with the theoretical models (i.e. free-space, 2-ray and the ITU indoor model).

References:

1. https://en.wikipedia.org/wiki/Wi-Fi
2. https://en.wikipedia.org/wiki/IEEE_802.11

3. www.google.ca
4. E. Perahia, R. Stacey, Next Generation Wireless LANs, Cambridge University Press, 2013 (pdf available via uOttawa library).
5. RF Explorer® Signal Generator: User Manual, available at http://j3.rf-explorer.com/downloads
6. RF Explorer Spectrum Analyzer:User Manual, available at http://j3.rf-explorer.com/downloads