General

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| Student Wi-Fi Network Experiment Project |
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## Map of Adastral Park



Figure 1 Adastral Park Map

# Your Research Tasks

## 

**TASK: UWB Experimental Testing**

The team that you will be working with throughout the 2-week period of the work experience is the Wireless Research team which specializes in the next generation of Wi-Fi and predominately the next rollout of BT’s ‘Smart Hub 4’.

The project itself will primarily be focusing on the testing and debugging of different configurations and scripts which can test different variables in the Smart Hub 4 Router. The results from these tests can then be manipulated and visualised using different styles of graphs.

Some of the skills you will learn throughout the 2 weeks include, learning syntax and using WSL (a subsystem of Linux), Python, the physical setup of the test and aspects of shell scripting.

**PLEASE NOTE: Throughout the placement I advise you take notes (e.g. a journal each day) detailing your learning, steps taken, and any command used. This will help you document your research for your final poster/presentation.**

Useful Links:

[How does ultra-wideband work? (samsung.com)](https://insights.samsung.com/2021/08/25/what-is-ultra-wideband-and-how-does-it-work-3/)

[Plot types — Matplotlib 3.9.1 documentation](https://matplotlib.org/stable/plot_types/index)

[Intro to Data Analysis / Visualization with Python, Matplotlib and Pandas | Matplotlib Tutorial (youtube.com)](https://www.youtube.com/watch?v=a9UrKTVEeZA)

[Python Pandas Tutorial (Part 1): Getting Started with Data Analysis - Installation and Loading Data (youtube.com)](https://www.youtube.com/watch?v=ZyhVh-qRZPA&list=PL-osiE80TeTsWmV9i9c58mdDCSskIFdDS)

## Report, Presentation and Poster

Throughout your work experience, you will be completing a report and poster task, provided by Nuffield. As well as this, you will be preparing a PowerPoint presentation to show your peers what you have been up to on your placement.

**Your Investigation:** Exploring the pros and cons of the UWB system, compare it to already existing Wi-Fi networks and gain an understanding of the development process, cataloguing issues, and their fixes where and when they happened. Some of the key points to think about are:

* Results from the data output visualization. Making notation on what the fluctuations mean and show an overall understanding of what you have learned.
* Making note of any issues you had during the project as well as how you managed to overcome them.
* What you learnt and how it could help you in the future?

Feel free to reach out to your supervisor throughout the process with help on any of the tasks. You will also be able to have a session with your supervisor on how to deliver presentations confidently and professionally if you would like one.

# Useful Links and Resources

2.1 Python Libraries

**matplotlib.pyplot:**

**What is matplotlib.pyplot?**

Matplotlib is a popular Python library which can be used to create static and animated visualizations in Python. Matplotlib has a sub-module called ‘.pyplot’, the pyplot library is another collection of commands and functions which specialise in the creation of graphs and charts. Some examples of charts which can be plotted include:

* Line graphs
* Scatter graphs
* Pie charts
* Box plots

This is a simple example of how matplotlib.pyplot should be used to plot a graph:



Import the matplotlib.pyplot library into the Python Jupyter Notebook:



Making some X and Y values which will be plotted onto the X and Y axis in the line graph:



The function plt.plot will plot the values in the brackets (x, y) into a line graph, plt.show() will show the graph:

A line graph with numbers

Description automatically generated

The final output will look like this, the maximum value on the X axis is 9 as seen in the X values list, the same can be seen on the Y axis as 11 is the highest value within the Y values list.

Matplotlib.pyplot has many different customization options and can be combined with other Python functions to make complex graphs to visualize data outputs.

This will be used a lot in the visualization process of the data file outputs taken from the data tests.

**pandas:**

**What is pandas?**

Pandas is a powerful and versatile data manipulation and analysis library used in Python. It provides functions needed to work with data seamlessly, this could be in file format (.csv, .txt, .config etc) and in string format. By using pandas, individual data sets (i.e. columns and rows) can be used to compare data in the scenario that the data is stored in a table format. Data frames can also be made using pandas to create new spreadsheets using a variety of different data. Some more examples of how pandas can be used include:

* Data Cleaning and Preparation
* Data Analysis and Data Transformation (i.e. into a data frame)
* Data Visualization

Here is an example of how pandas could be used to create a data frame to visualise data in a file:



Import the pandas library into the Python Jupyter Notebook:



Give the data frame (df) a file to visualise, ‘pd’ will use a function from the library to ‘.read\_csv’ the .csv file we have defined in the brackets. In this case the file I want to read is students.csv:



To show the output from the .read\_csv function, we need to print the output from the defined data frame (df):

A black background with white text

Description automatically generated

The output will look something like this, the row number is listed on the left (row and column numbers will always start at 0) and the names of the students listed on the right.

Pandas allows for much more in-depth analysis into data frames, the library supports functions such as mode, median and range variables, working out averages and much more.

Pandas is a very versatile library and is definitely worth learning as its use cases within the data analysis portion of the project are very valuable.

**numpy:**

**What is numpy?**

Numpy is a library used in Python which specializes in working with numbers and calculations effectively. It has many use cases in the data analysis process and can work with large amounts of numerical data. Other use cases for numpy include:

* Data Analysis
* Machine Learning
* Image Processing
* Gaming and Graphics
* Audio Processing

Here is an example of how numpy can be used to calculate numerical values in Python:



Import numpy library into the python Jupyter Notebook:



Import or make a series of arrays in this example to be calculated together, with numpy’s syntax this should be much simpler and more readable compared to the standard Python syntax:



Give the result function a definition, calculate the arrays together using their respective names. Finally print the result of the calculation:



The result will be printed into the terminal and will display the calculation between the 2 arrays and will have concatenated them into a single array.

This format of calculating strings and arrays can be expanded upon to great complex algorithms which can automatically calculate and check values.

For reference, if this same calculation was to be done without using numpy:

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Description automatically generated

The array/list variables are similar however, when it comes to calculating the 2 together it becomes much more complicated to read.

2.2 Introduction to WSL (Windows Subsystem for Linux)

**WSL Syntax:**

**SSH Syntax and what are its use cases?**

Throughout your time working on this project, you will be using a form of Linux to control the tests which we will be conducting. The commands will have different parameters to test different aspects of the throughput, UDP, ping and iperf tests.

SSH is used to connect to a remote server to test speeds between the host and ‘client’ servers. As an example:



Here the syntax is typed into the WSL terminal, the ‘ssh’ is the protocol to connect to a remote system (server), the ‘wifi@’ is defining what connection it will be using (in this case wifi) and the ‘@’ symbol will determine what IP address we want the test to be ran on, in this case it is ‘192.168.1.212’ which is a server we will be testing on.

Once this command is run, the following message will appear:



NUCF7 Password: **abc1defF7**

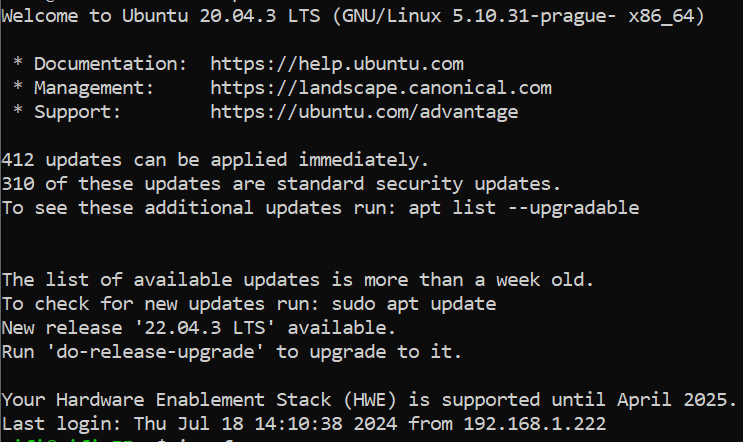
NUCFE Password: **abc1defFE**

The connecting device will prompt for a password to conduct the tests, the devices you will be using to conduct the tests are called NUC’s. NUC’s are miniature Linux computers which have their own individual IP addresses which will allow you to make a small-scale server to client setup. The setup will look like this:

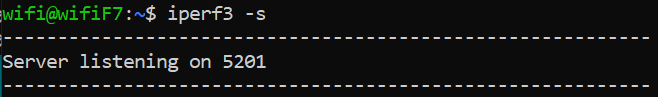


The test setup will use 2 NUCs, the new prototype BT Smart Hub 4 Wi-Fi router and new prototype BT Smart Hub 4 Wi-Fi extender. The connections between the NUCs and the router/extender will be hard wired using ethernet. The router will also be hard wired to the laptop you will be using to be able to send the ssh requests over the network. The speed test will be tested from the router to the extender using 2.4Ghz, 5Ghz and 6Ghz bandwidths to test the most effective bandwidth for a particular distance and network traffic/noise.

After the password is accepted by the NUC the following text will be displayed:



To be able to start the test server the following command must be input into the terminal:



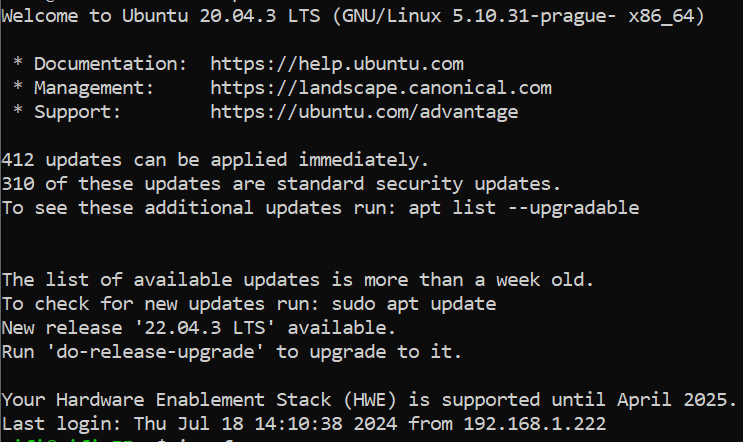
Here the syntax is typed into the WSL terminal after the password is accepted. The command ‘iperf3’ is a WSL extension which allows for customized throughout, UDP and ping tests to be run over a network. The ‘-s’ portion of the command states that we want this IP address to act as the server. Once the command has been run, the ‘Server listening’ text will appear which confirms that the server is ready to accept client tests.

Once the ‘iperf3 -s’ command has been run and the server is ready to accept client tests, you need to open a secondary WSL window and run the same ‘ssh wifi@’ command but with the client NUC IP which will be the NUCFE device.

Here is the step-by-step of setting up the client test using the newly opened WSL tab:



Enter the password for the NUCFE:



The same text will be displayed after the password has been accepted:



This command uses the same ‘iperf3’ statement but in this case, we use ‘-c’ to state that we want this specific IP address to act as the client ad to start the test being run from the IP address, which is added to the end of the command (in this case 192.168.1.212 which is the NUCFE).

This command can be modified to change the type of test being run, other parameters which can be changed includes bandwidth throughput, parallel tests, reversed tests etc.

In the scenario that you need help understand what each command means and does, the shortcut to get the help page is **iperf3 -h**. This will open the help page prompt which will list all of the different commands which can be used in the iperf3 tests. An example of a more specific test would be:



‘iperf3 -c’ the client test, ‘192.168.1.178’ the IP the test is connecting to, ‘-u’ is the command to run a UDP test which is a more reliable test to run and returns more parameters, ‘-P’ is the command to run multiple tests in parallel (in this case it will be running 5 tests every second for 10 seconds), ‘-b 2.5g’ is the command to define how much bandwidth you would like to transfer over each test (2.5g refers to 2.5Gbs/s, this command can be adjusted to different parameters i.e. 250m refers to 250Mbs/s).

After these tests are ran, the outputs should be as follows: A screenshot of a computer screen

Description automatically generated

**Interval =** The interval refers to the time each test is ran. In our case we have the test running every second for 10 seconds meaning that we should have 10 test results. However, we are using the ‘-P 5’ command which states we want 5 tests to be run in parallel every second.

**Transfer =** The transfer is the maximum amount of data, which was transferred over that 1 second period, this can vary from the amount of data which was been defined in the ‘-b 2.5g’ command in the iperf3 test. The final row at the bottom of the list of results highlighted in **red** shows the total amount of data transferred over the 1 second period over 5 tests.

**Bitrate =** The bitrate is amount of Mbits/sec Wi-Fi speed is transferred over the 1 second period in this case the 5 parallel tests had a total amount of 912 Mbits/sec.

**Jitter =** Jitter also known as ping is the amount of time is has taken the test to be requested and received.

**Lost/Total Datagrams =** Also referred to as packet loss, packet loss works out the number of packets which had failed to be received. This could be down to network usage as this test was conducted on 2.4Ghz (which is the most popular and used bandwidth) after lunch on a Wednesday in the office which is the most popular time of the day.

2.3 Tutorials and Courses

**Python Libraries:**

[Python Pandas Tutorial (Part 1): Getting Started with Data Analysis - Installation and Loading Data (youtube.com)](https://www.youtube.com/watch?v=ZyhVh-qRZPA&list=PL-osiE80TeTsWmV9i9c58mdDCSskIFdDS&index=1)

[Learn NUMPY in 5 minutes - BEST Python Library! (youtube.com)](https://www.youtube.com/watch?v=xECXZ3tyONo)

[What is Pandas? Why and How to Use Pandas in Python - YouTube](https://www.youtube.com/watch?v=dcqPhpY7tWk)

[Matplotlib Tutorial (Part 1): Creating and Customizing Our First Plots (youtube.com)](https://www.youtube.com/watch?v=UO98lJQ3QGI&list=PL-osiE80TeTvipOqomVEeZ1HRrcEvtZB_)

[Intro to Data Visualization in Python with Matplotlib! (line graph, bar chart, title, labels, size) (youtube.com)](https://www.youtube.com/watch?v=DAQNHzOcO5A) (good introduction to plotting your own graph and some other ways you can customize your graphs)

**WSL Syntax & Testing:**

[iPerf How to Test Bandwidth and Throughput (youtube.com)](https://www.youtube.com/watch?v=Fb4LeAuXd7k)

[Use iperf to diagnose Linux network speed | Top Docs - YouTube](https://www.youtube.com/watch?v=A-mDAB6jzbU&t=182s)

[Network Engineer? You NEED to know iPerf. - YouTube](https://www.youtube.com/watch?v=SjvP8fGJOoY)

Find out more at [bt.com](https://www.bt.com/)

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