**Purpose**

Prototypes for static and dynamic free-space optical communication (FSOC) systems will be created. The static system will primarily satisfy the high bitrate requirement and the dynamic system will primarily satisfy the over the horizon requirement. All other requirements will be satisfied in both systems.

**Objectives**

To determine the success of each system, the latency and throughput will be measured during various trials. The tests will be performed through two virtual machines, running Ubuntu 20.04. Various cores will be carried out for the throughput tests and various throughput setups will be used to help identify the root cause of bottlenecks.

The latency and throughput tests include unidirectional and bidirectional in both the control and experimental setups. The ping command will be used to perform latency tests, while Ipeff3 will be used to perform throughput tests. Python 3.8 will be used to analyze the data gathered during experiments.

**Procedure**

Static System Testing:

1. Connect ethernet to USB-C converters to USB-C ports on laptop.
2. Create two virtual machines registered to each port.
3. Create shared folders on each virtual machine to store data from test trials.
4. As a control, directly connect an ethernet CAT-8 cable to each port.
5. From virtual machine 1 (VM1), ping virtual machine 2 (VM2) to run several latency tests on the control system and store data to shared folder.
6. Run bidirectional latency tests by storing output of the ping command on control system and store data to shared folder.
7. Repeat control latency tests, pinging VM1 from VM2, and store onto shared folder.
8. Run throughput tests on one core using Iperf from VM1 to VM2 and store results to shared folder.
9. Repeat one core throughput tests, going from VM2 to VM1.
10. Run one core bidirectional throughput tests on control system.
11. Run bidirectional tests on both VM1 and VM2 simultaneously to increase traffic congestion.
12. Repeat all throughput tests with three cores and store data on shared folders.
13. Disconnect one end of the ethernet cable and connect it to one of the media converters.
14. Repeat this setup with the other port.
15. Connect the SFPs to their respective ports on the media converters.
16. For the experimental fiber setup, directly connect an LC duplex fiber between the two SFPs and power the media converters.
17. Repeat steps 5 through 12 for the fiber experimental setup.
18. Disconnect LC duplex fiber from one SFP and connect second LC fiber to SFP.
19. Tape open ends of LC fibers onto its respective media converter
20. Set lenses in lens holders and place each lens 10 cm away from the media converter.
21. Adjust set up of beams for collimation and align transmitting beams to receivers. Note the size of each beam and check for fiber light on media converters to ensure data is transmitting and receiving properly through the FSOC system.
22. Repeat steps 5 through 12 for the static FSOC system

Dynamic System Testing:

1. The setup will be placed in the FSOC configuration as detailed in steps 18 through 21 with a scanner system placed immediately after the lens of each endpoint.
2. The scanner will be calibrated by placing it at the distance from the lens at which the beam divergence is minimum.
3. The ability to connect with the scanner reflecting the beam will be confirmed.
4. The power loss of the scanner will be found by comparing the relative strength at an equal distance of the setup with the scanner and without the scanner.
5. The throughput and latency tests detailed in steps 5 through 12 be repeated for the dynamic system.
6. The dynamic system will be placed into a container to allow for easier movement
7. The system throughput and latency will be tested as detailed in steps 5 through 8 again inside the container. The values from this test will be used as the maximum rated throughput and latency of the system.
8. Both endpoints of the system will be connected to a different Raspberry Pi 2B+ (RPi).
9. The system will be tested again as detailed in steps 5 through 12 with both the scanner and RPi in use.
10. One dynamic FSOC and corresponding RPi will be placed on a movable mount.
11. The endpoint mounted on a movable mount will be moved in a predetermined random path at increasing velocities. The maximum speed at which the system can maintain connectivity will be measured.
12. Both endpoints will be placed on a movable mount with its corresponding RPi.
13. The test from step 9 will be repeated with both endpoints moving.
14. The final dynamic system will be tested as detailed in steps 5 through 12.

**Test Specimen**

The test will be performed on 5 separate setups. The static fiber system will be used to benchmark the maximum possible throughput and latency of the system’s components and identify bottlenecks. The static free space system without the scanner will be used to find issues introduced into the system from free space communication. The static free space system with the scanner will be used to test the maximum realizable throughput and latency of the final system. This setup will be repeated using the RPi as a test system to find the effects of the RPi on the throughput and latency. The dynamic free space system will be used to test the ability of the system to track moving endpoints and to determine the maximum relative velocity of the two endpoints while maintaining connectivity.

**Expected Results**

The throughput results from the static system are expected to be approximately 1Gbps and about 300Mbps for the dynamic system. The difference in expected throughput is due to the use of the RPi, which has significantly lower throughput than larger, more powerful personal computers. The latency of the dynamic system is expected to be less than that of the static system due in part to the decreased processing power of the RPi and the increased packet loss from lag time in tracking the device.