Device-to-Device Communication in the Internet of Things
Providing Development Guidelines for IoT Enthusiasts
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**MOTIVATION**

Smaller and smarter devices permit revolutionary Internet of Things applications, such as wirelessly controlled refrigerators, to evolve. So motivated by:
1. the expected growth in the Internet of Things market Fig 3.,
2. the role of device-to-device (d2d) communication in covering the need-capacity gap resulting from this growth Fig 4. and,
3. the scarcity of practically collected d2d data for IoT developers,

This project aims to provide practical data on the d2d performance of mainstream IoT devices (Fig 1, Fig2) over Wi-Fi and Bluetooth.

**I. D2D over Wi-Fi**

RTT Measurements over UDP/IP

To accurately compare the performance of D2D communication over Wi-Fi between Raspberry-Pi devices and Intel Edison devices, we implemented a two-threaded client that, along with a simple UDP echo server, can calculate average RTT at a given distance. Fig 5 shows the design of the experiment and the graph below shows the results.

Throughput Measurements over TCP/IP

Throughput is the amount of data that can be exchanged in a given time. In this experiment, we used two Intel Edison Devices connected directly over Wi-Fi. We sent files of different sizes multiple times at each given distance and used the average delay to calculate the throughput. The graph below shows the results.

**II. D2D over Bluetooth**

Radio Frequency Communication

The RFCOMM protocol emulates the serial cable line settings and status of a serial port and is used for providing serial data transfer.

RFCOMM’s Reliability issue

RFCOMM’s specification indicates that it should be reliability guarantees similar to TCP’s, however, while sending large files over it, we found out that at least a byte gets corrupted after sending more than 10MBytes of data (Fig 6). It is important to notice that, in an IoT, a single corrupted byte can compromise the entire system.

Throughput Measurements over TCP/BNEP

We used the same methodology for measuring throughput over Wi-Fi, but the Edison devices were connected over TCP/BNEP instead.

**III. APPLICATION: UP & AWAY**

To apply the concepts we’ve learnt in this study, we updated the Up & Away cyber-physical testbed from a centralized version (Fig 7) to a distributed version (Fig 8) by mounting an Intel Edison device on each node then establishing d2d communication between the Edison devices and the Central Node. By doing that, we could move most of the computation from the central node to the UAV Nodes, allowing higher scalability.

**IV. CONCLUSION & FUTURE WORK**

Conclusions
- For Bluetooth, we recommend the use of TCP/RFCOMM for applications that need reliability guarantees over the Intel Edison devices.
- For Wi-Fi, Raspberry-Pi provides a lower RTT than Intel Edison devices.

Future Work
- Study the energy consumption of Bluetooth and Wi-Fi communication
- Overcome the Intel Edison’s low WiFi performance by disabling and/or controlling power saving
- Update the network simulator to support multi-hop data transfer so it can be used to study different Ad Hoc protocols and techniques