Command and Control: Scalable Infrastructure for Dynamic IOT Device Reconfiguration and Management

Introduction:
One of the fundamental tenets of system design advises that effective abstractions allow developers to create more robust systems. Such a philosophy is of particular interest to network programmers, who have long sought to turn complicated and statically configured hardware stacks into general purpose systems that can be modified to handle a wide array of traffic patterns. A wide variety of technologies now exist to help modify network traffic patterns without regard for the underlying hardware. Today, a similar challenge has arisen in the form of Internet of Things (IOT) devices. Currently, no uniform standard exists to connect to and reconfigure IOT devices, and given the major disparities in computational power, hardware, and use cases. In our project, we intend to create a general purpose, scalable system that could, in theory, control large numbers of IOT devices. Technologies do exist for replacing firmware on such devices, but many pieces of hardware are sensitive and cannot be reimaged without significant consequences. This project will explore whether a system can be created that allows network administrators to connect to and reprogram IOT devices without termination of actively running programs.

Proposed Architecture:
I intend to collaborate with Nishant Jain on this project. We will divide our project into two sections: Firstly, we intend to create a network control system to register and interact with new IOT devices. This entails managing the transmission and receipt of data from said devices, as well as building in the ability to establish and terminate connections at scale. The second portion involves creating or implementing a methodology to alter program code running on remote machines in the IOT cloud. When combined, our two components form a centralized platform to
command a large array of IOT devices. For the sake of this project, we will focus specifically on wifi-enabled IOT devices.

The first part of the project, the controller, will require the use of abstractions commonly used in distributed systems (e.g. sharding, replication, etc.) to build a scalable connection management service. We intend to use a node-based design, in which the network controller will be partitioned into a set of controlling nodes that track specific devices in the network’s cloud of IOT machines. Such an architecture will allow us to prevent one machine from being burdened with a large number of connections to devices in the network. We may also replicate controller nodes or investigate the possibility of logging network data in order to provide other distributed systems guarantees as well.

The second part of the project will involve reprogramming devices on the network. Many IOT devices execute infinite loops with conditions that trigger based on sensor inputs. This means that editing the behavior of such devices requires re-imaging or recompiling programs run on said devices, which necessarily requires these devices to be shut down or taken offline. We intend to develop software to update program code during runtime itself, thus removing the need for device downtime. Because compiled binaries may prove to be difficult, if not impossible, to edit in such a manner due to compiler optimizations, so initially we intend to explore altering program execution in an interpreted language such as Python.

By the end of the project, the effectiveness of these two components together will likely illustrate whether a central control platform can be an effective tool to manage the billions of IOT devices that will emerge in coming years.

**Deliverables:**
At the end of term, we will provide the following:

1. Code for a proof-of-concept system that exhibits the ability to connect to an IOT device and edit its running program
2. A report (oral or written) detailing the design of the system in collaboration with Professor Yang, as well as analysis of some test scenarios and performance metrics

**Division of Work:**
The two components of the project in and of themselves provide a logical method to divvy up labor. I intend to focus on the second section of the project, which will study how best to reconfigure devices during runtime. This will require studying existing research on self-modifying code and operating systems. However, I will also help Nishant Jain create and maintain the network controller system used to register IOT devices.

**Timeline:**
- **January 30th-February 10th**
  - Study existing IOT Systems literature and gather background on the topic; acquire any materials we may need
- **February 10th-February 24th**
  - Plan and design our IOT controller system in collaboration with Professor Yang
- **February 24th-April 7th**
  - Implement design using any hardware necessary
- **April 7th-April 21st**
  - Test system and clean up project for presentation; write up report
- **April 21st - May 10th**
  - Miscellaneous work; buffer for unplanned delays