Sound Transit has several commuter train carriages that are shuffled regularly to form a consist (a set of carriages forming a train). Currently, each carriage has 3 information systems that independently upload their data to a back-end using separate cellular connections. In order to track a consist, GPS data from each carriage is used to stitch a consist. There is no consist-wide network which makes broadcasting consist-wide messages cumbersome. Creating a consist-wide dynamically forming (to account for shuffling) network would allow easier message broadcasts and streamline the information flow.

Objectives

- To build a consist-wide network that updates dynamically as carriages are shuffled around.
- Formation of a consist network should require minimal manual input, ideally no human input.
- Adjacent consists (trains on side-by-side rail tracks) should not form connections to each other.
- Ideal end-end throughput speed around 250 Mbps.

Model & Approach

- Wireless connections between neighboring carriages using WiFi.
- Ethernet backbone throughout a single carriage to connect the front and rear ends of a carriage.
- Linksys EA8300 routers equipped with two 5 GHz radios and one 2.4 GHz radio used to implement a node in the network.
- OpenWRT firmware flashed on all routers to improve configurability and flexibility to use a large selection of software packages and tools.
- Notable Packages used:
  - Batctl: suite of tools to configure and monitor mesh network
  - Wpad-mesh-openssl: provides support for WPA encryption needed to encrypt mesh connection
  - Alfred: User space daemon used to create network maps on demand
  - Ttyd: Support for a terminal to the router, forgoing the need to SSH into the router to modify settings or obtain information
- 5 GHz radios are configured in 802.11s mesh mode which only connect to other mesh nodes given matching parameters: mesh name, password, channel
- Received Signal Strength Indicator (RSSI) threshold and radio power tuned to determine when two carriages connect:
  - Sufficient radio power to have good SNR at ~4 ft apart
  - RSSI threshold tuned to allow connection at ~4 ft apart, but not ~20 ft apart
- Wired communication between two routers in the same track car
- Ethertnet backbone across the length of a consist.
- UML Diagram of how a train consist is built and its self-healing capabilities.

Future Work

- We were able to successfully develop a self-healing and intelligent network across multiple consists. Each consist network is a combination of wired connections and wireless hops.
- Currently, our setup uses a daisy-chain of routers linked in a linear fashion with no redundancy.
- In case one of the routers gets damaged or fails, the entire network will get cut off from that point. The next step of this project would be to experiment with a ring network topology to provide some redundancy across the length of a consist.
- Successfully created a local consist-wide network that can be used for local file transfers and broadcasts, as well as provide internet access across all nodes (given one of the nodes is an internet gateway).
- Handshake time (i.e. the time required to establish connection between two carriages) is about 5 seconds.

Results

- End-end throughput of 50 - 190 Mbps tested across 5 nodes, simulating 3 carriages with 2 wired connections and 2 wireless hops.
- Carriages reliably connect to one another by simply coming into close proximity - if the distance between two routers is < 5 ft.
- Any permutation of train carriages can connect and create a unique mesh network at any time upon rebooting (self-healing).
- Automated a script to run on router boot such that a network map of currently connected routers can be generated.
- Handshake time (i.e. the time required to establish connection between two carriages) is about 5 seconds.