Self-healing Adaptive Network Technologies for IVHM

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Quick Background

- What is IVHM?
  - Integrated Vehicle Health Management
  - Communication system and components used to generate, transmit, and combine information to form parameters on the health of various systems
- What do we constitute for the health of a system?
  - Information regarding the ability for each device, function, or system to perform within expectations.

Self-healing Adaptive Networks?

- Tolerate faults within the architecture
- Quickly detect problems and correct communication disruptions
- Make adjustments in an automated fashion
- Allow for different types of physical communication
  - Current IVHM systems rely only on wired communication

Goals

- Enable the use of wireless communications
  - Sensors in remote areas or harsh environments (ie: Engines)
  - Decrease cost and mass associated with wires
- Easier to scale and extend IVHM network
  - Increase the quantity of sensors
  - Increase robustness in communication paths

Goals (cont.)

- Help reduce maintenance and repair expenses
  - Monitoring of areas that could only be done by manual inspection previously
  - Ability to add sensors more easily
    - Add to trouble areas that are discovered after using the aircraft for some time
    - Can avoid the need to route wires

Requirements

- Size and Power
  - Some area have severe space constraints
  - Some sensors may need to rely on battery power
- Scale
  - Large number of sensors in a subsystem
  - Need to operate efficiently
- Timeliness
  - Sensitivity of periodic measurements should not suffer when compared to current methods

Comparison to Sensor Networks

- Some key differences
  - Most sensor-net architectures deal with nodes that move, drop, or arrive at some non-negligible rate
  - Sensors on an aircraft will be relatively fixed in location
    - May move modestly if on a movable part (ie: landing gear)
    - Additions would happen in a controlled environment
    - Drops would be due mostly to faults
- So we need to “route around” the potential faults when they happen...

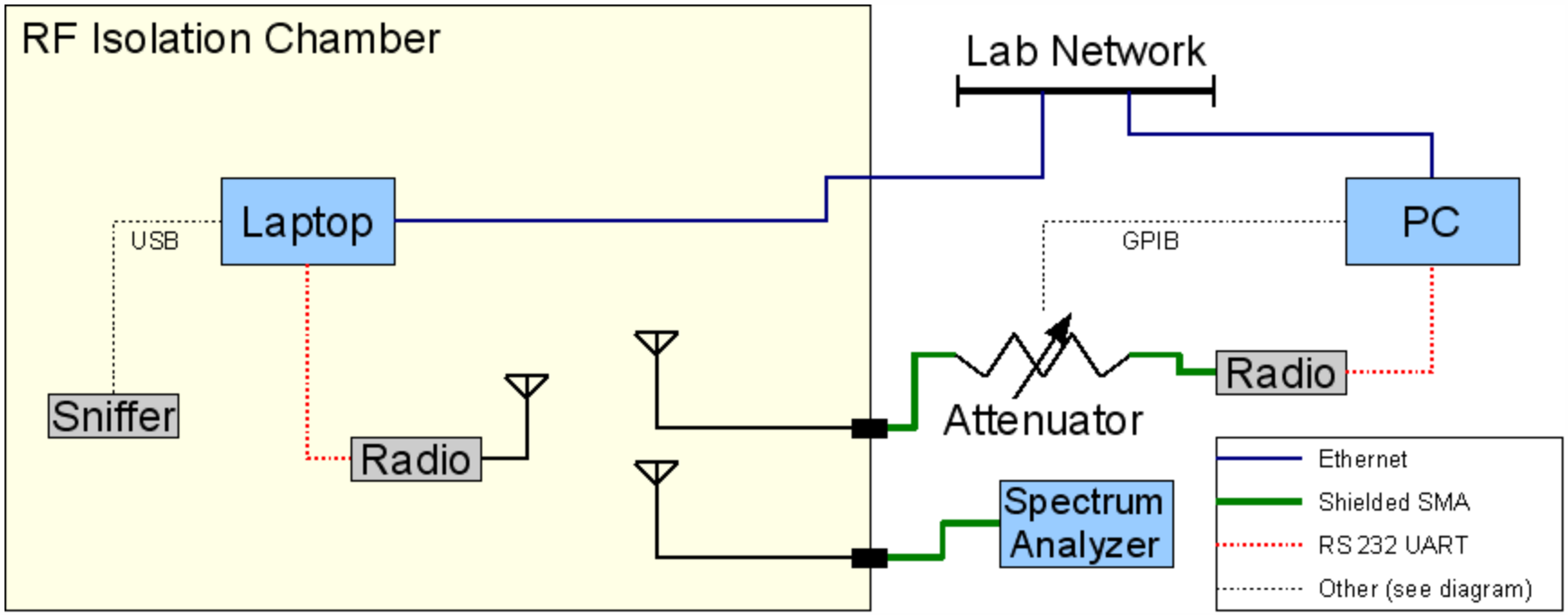
Comparison to Terrestrial Networks

- So this sensor-net would be better treated as a typical terrestrial network?
  - Use OSPF or IS-IS for routing?
- Hang on though...
  - Sensor-nets are constrained; Wireless communications
  - Significant overhead and “chattiness” of typical routing protocols wouldn't work well here

Initial Study and Environment

- Desire to build an environment to evaluate current solutions and test new ideas
  - In example, ZigBee radio devices
- Accurate time keeping
- Isolate sources, limit noise
  - Controlled disruptions
- Gather some metrics on the behavior and performance of the devices

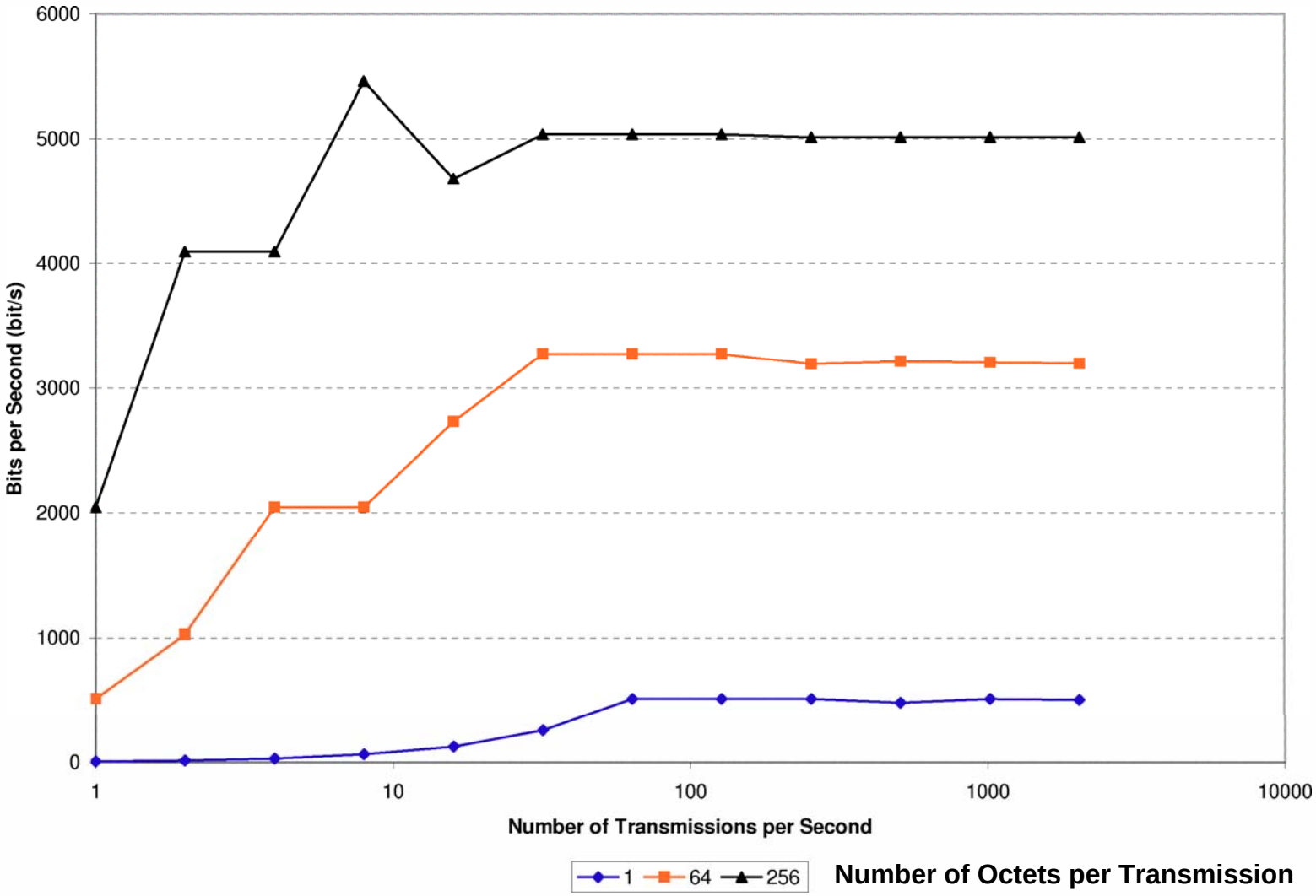
Test Environment



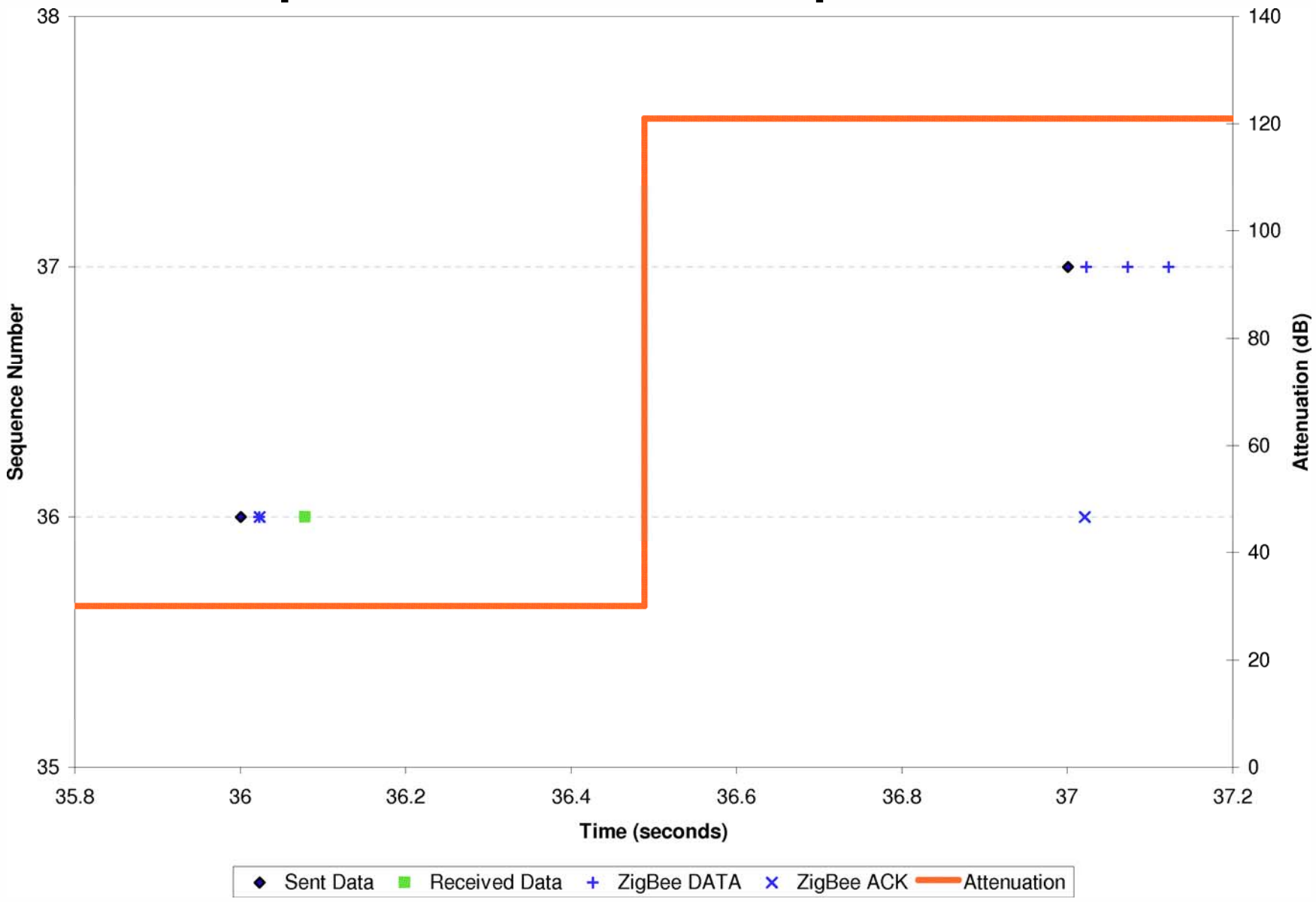
Observations

- Performance test comparing message size and frequency of messages
  - Better performance with larger messages
  - Smaller messages are “expensive”
- Avoiding all disruptions is not tractable
  - How quickly can we recover?
  - May be able to minimize losses by leveraging behavioral characteristics

ZigBee Radio Performance Transmission Sizes vs Frequency



Disruptions and Response Time



Architectural Concepts

- Piggyback the messages needed to maintain the network on data packets
  - Reduces the number of messages (and ideally the duty cycle as well)
  - Increases the size of messages
  - Help save power, increase performance
  - Leverage periodic transmissions, send independent messages if necessary

Architectural Concepts (cont.)

- Tune routing protocols to leverage data transmission behavior
  - Make repairs quickly, limit number of losses
- Develop or leverage a framing layer that can benefit from deterministic sending patterns
- Potential triggers between layers when a device detects abnormality

Conclusions

- Aircraft sensor networks are rather structured
  - Typical sensor network solutions may not be the best approach
- Reduce the number of messages which need to be sent
- Leverage sending patterns to minimize disruptions

Thank You