Towards a Collaborative Distributed Ground Station for Small CubeSat Teams

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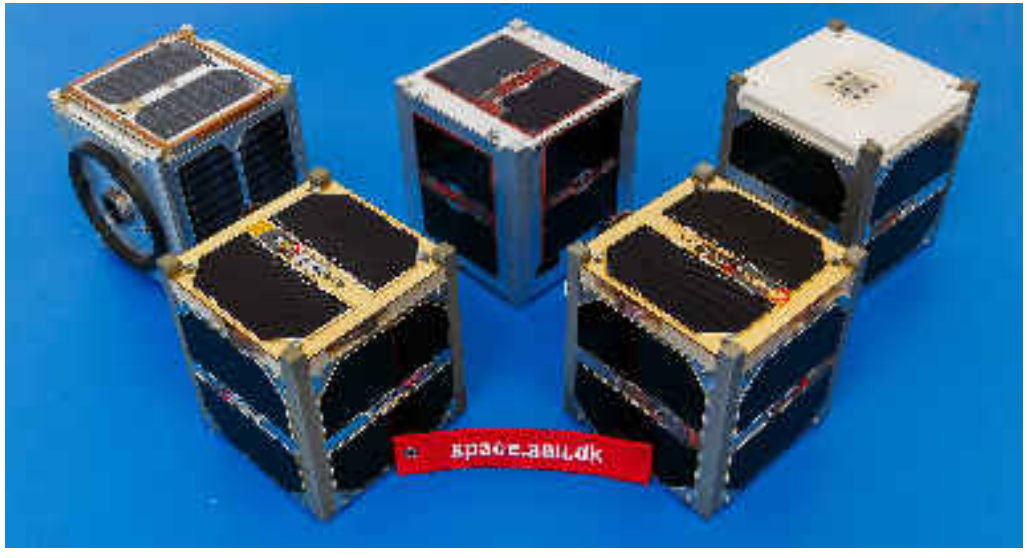
Disposition

Motivation
Overall requirements
Decentralized coordination
Receiving from multiple ground stations
Implementation
Simulation results
Conclusions
Experience from AAUSAT5
Acknowledgements

AAU Student Space

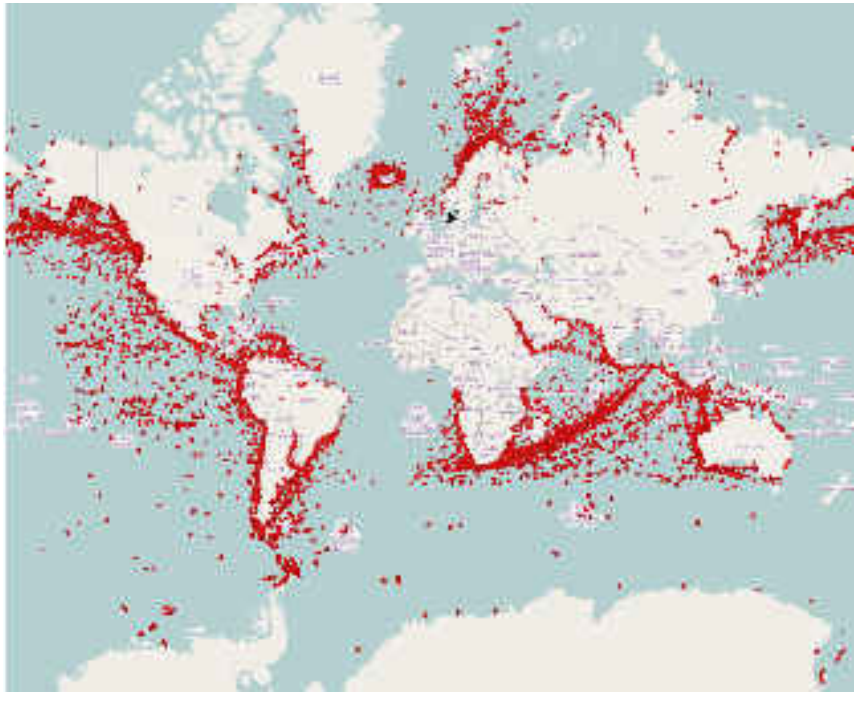
- AAU CubeSat - 2003
- AAUSAT-II - 2008
- AAUSAT3 - 2013
- AAUSAT5 - 2015
- AAUSAT4 - 2016



Background for the project

Experience from AAUSAT3

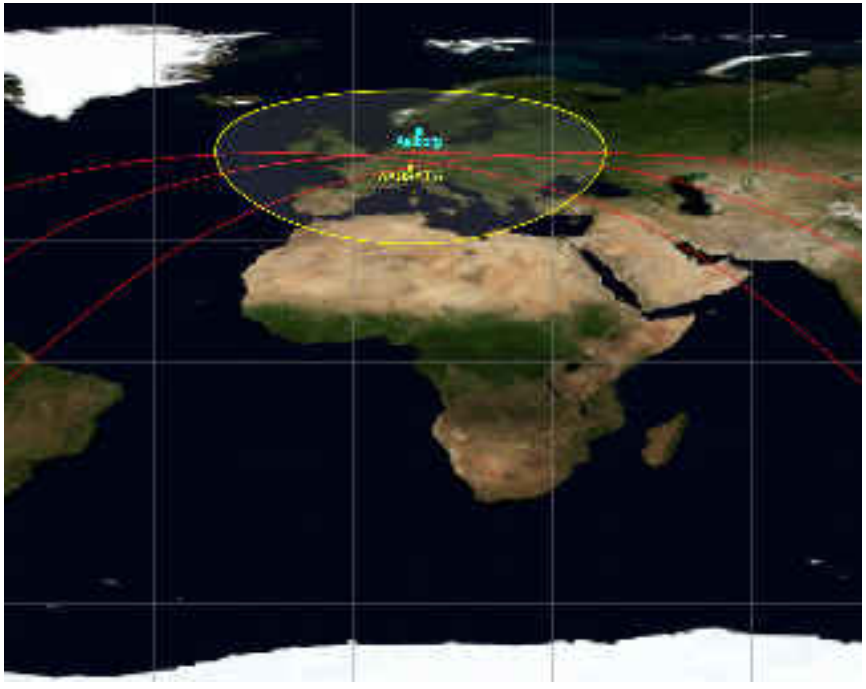
- More payload data was produced that we were able to download



Background for the project

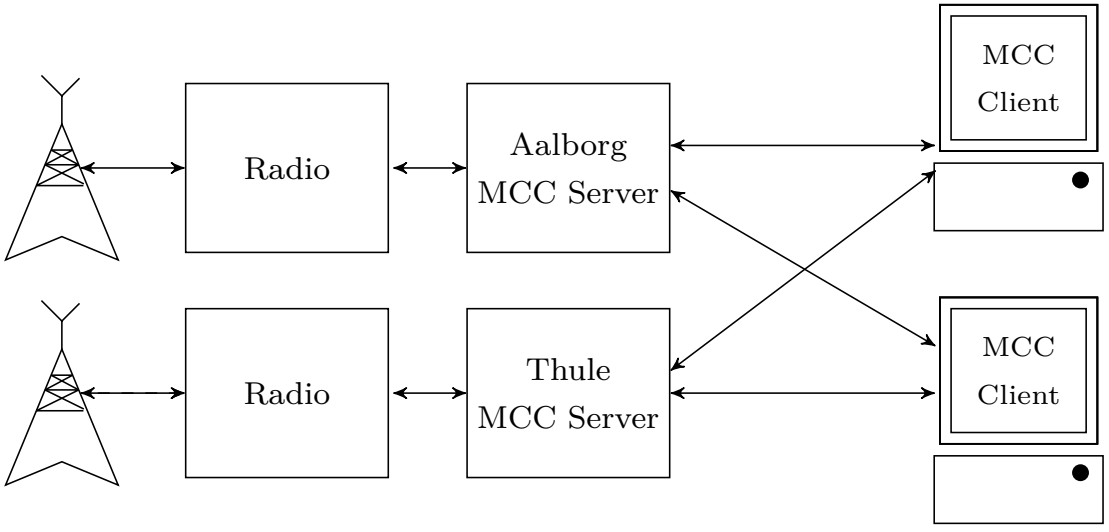
AAUSAT5

- AAUSAT5 was ejected into ISS orbit
- 52° inclination
- Aalborg is located at +57° latitude, resulting in short passes



The previous setup

Two ground stations, one in Aalborg (Denmark) and one in Thule (Greenland)



Overall requirements

Scalability

- Long term goal of including radio amateurs

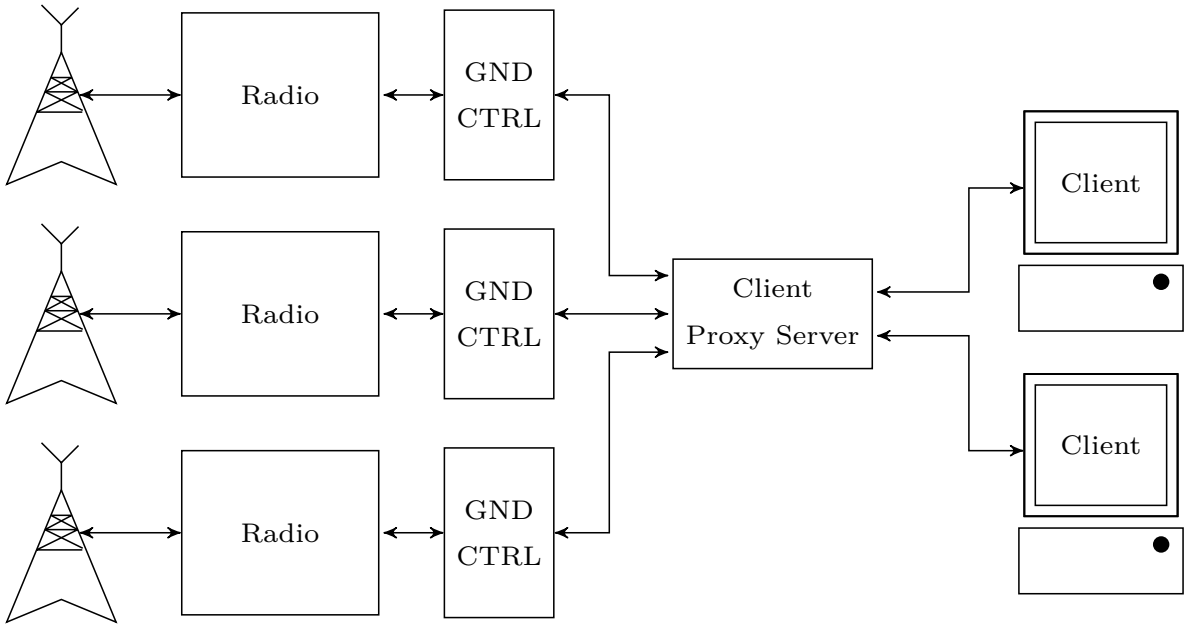
Decentralized and fault-tolerant coordination

- No single point of failure

Data-link protocol independent

- Support for multiple protocols, e.g. AX.25 and CSP

The new setup



- Requires coordination
- Allows for multiple receivers

Decentralized coordination

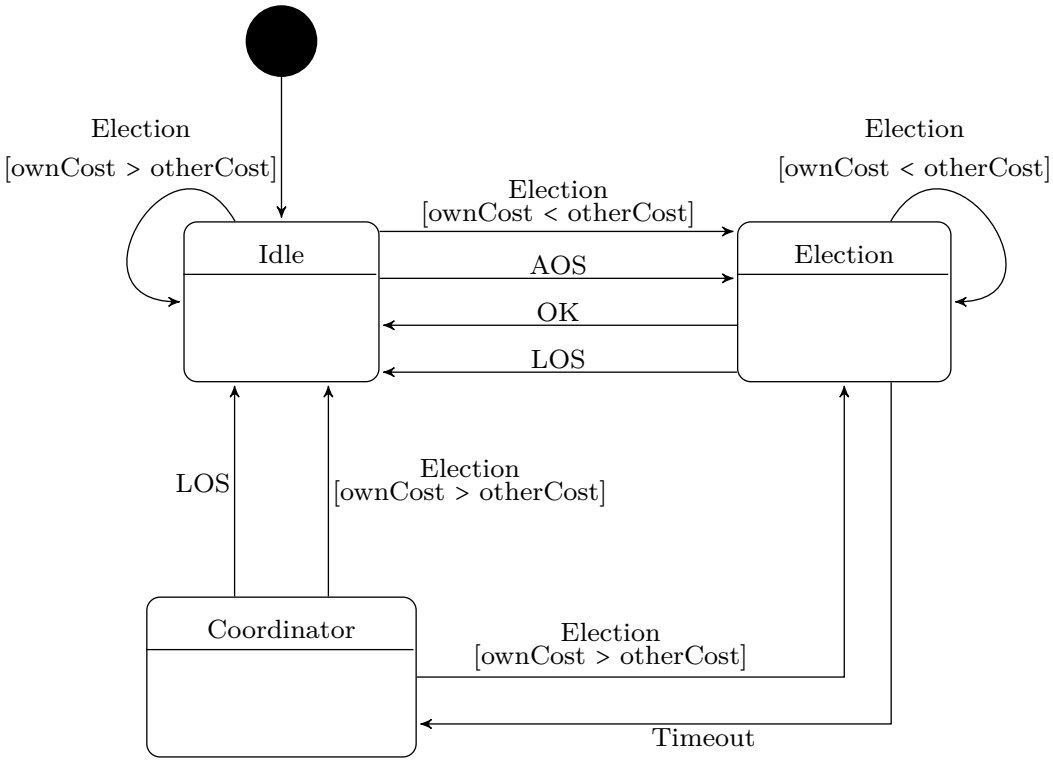
- Must be highly scalable
- Tolerant of sporadic crashes
- Should not introduce high delays

Decentralized coordination

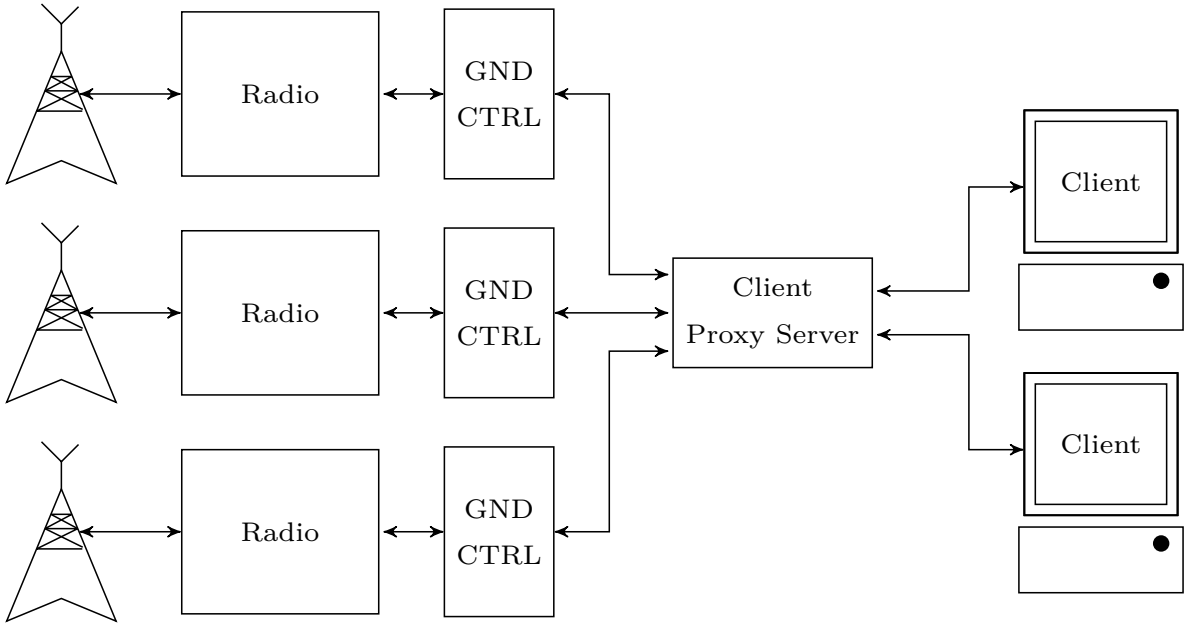
- Must be highly scalable
- Tolerant of sporadic crashes
- Should not introduce high delays
- Can be seen as a distributed leader election
- A modified bully algorithm has been implemented

The modified Bully algorithm

- Uses a dynamic cost function, based on elevation and pass duration
- Triggers election on AOS and LOS
- Triggers election periodically during passes

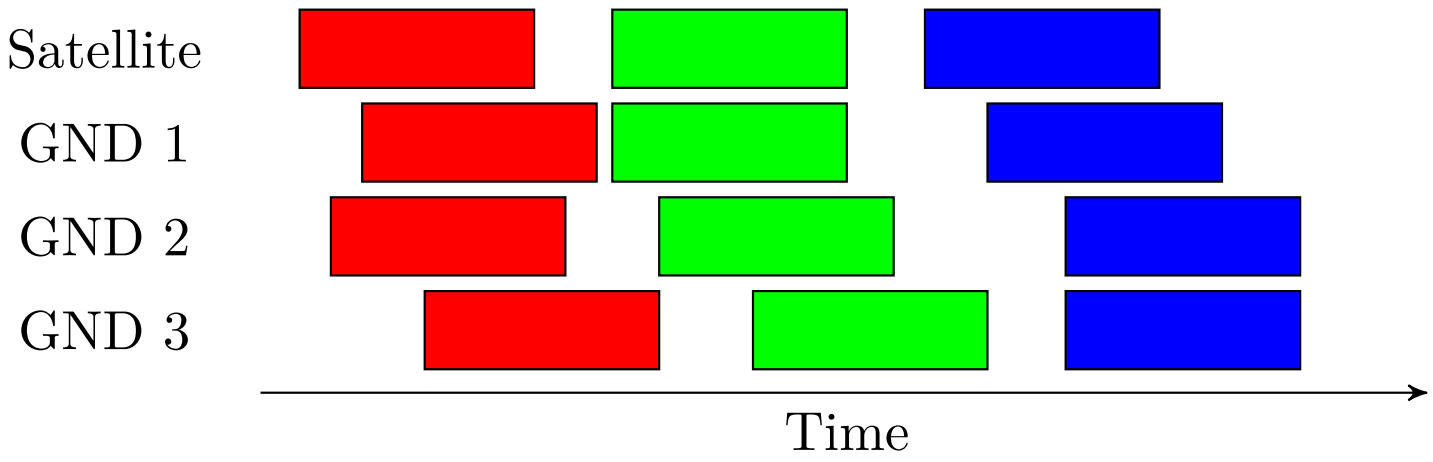


Receiving from multiple ground stations



- Requires coordination
- Allows for multiple receivers

Frame alignment



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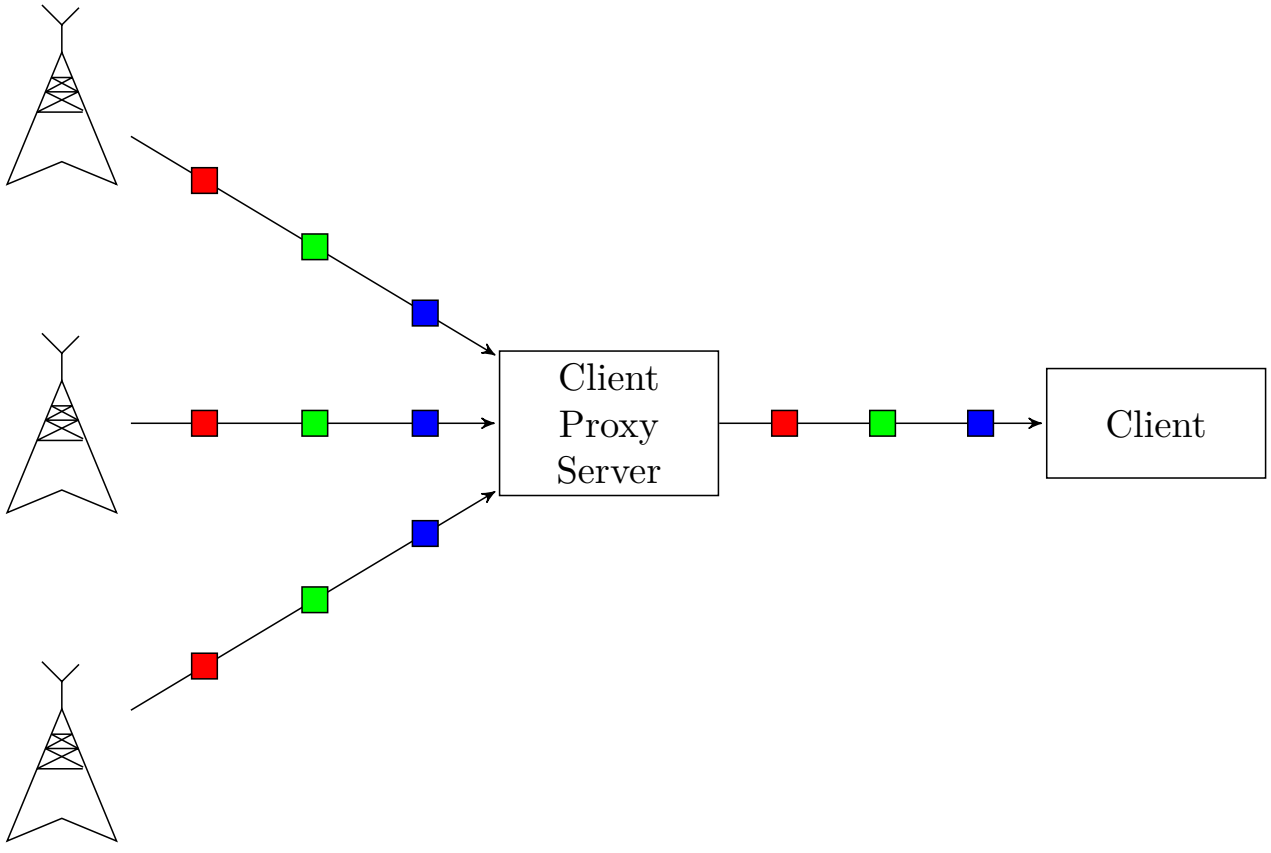
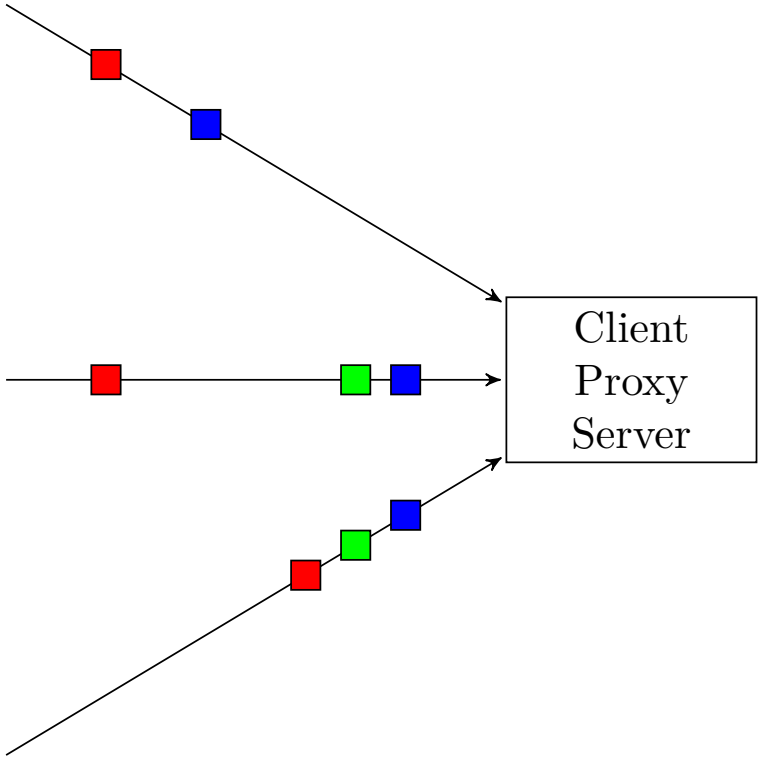


Receiving from multiple ground stations

- It is unknown how many frames were received
- By estimating the network delay a probabilistic upper bound can be found



Implementation

GND CTRL

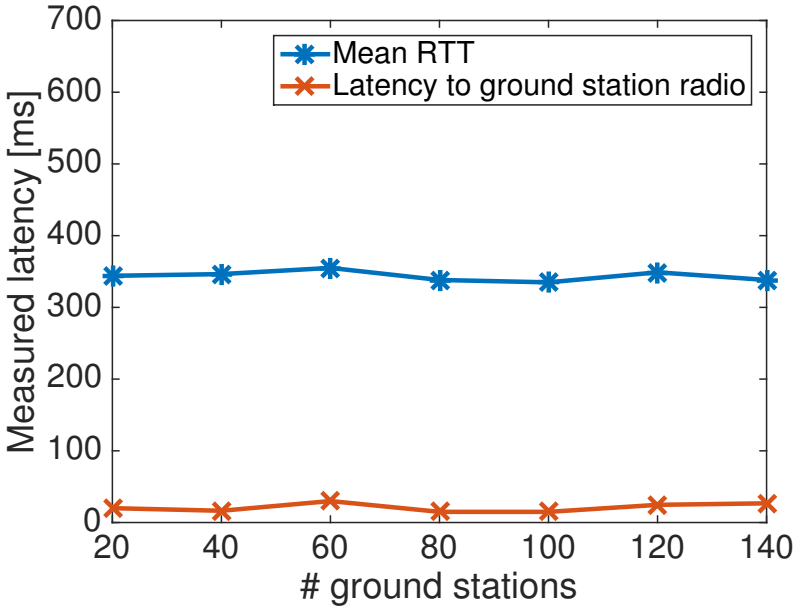
- In Java, with Akka Actors
- Generic radio interface

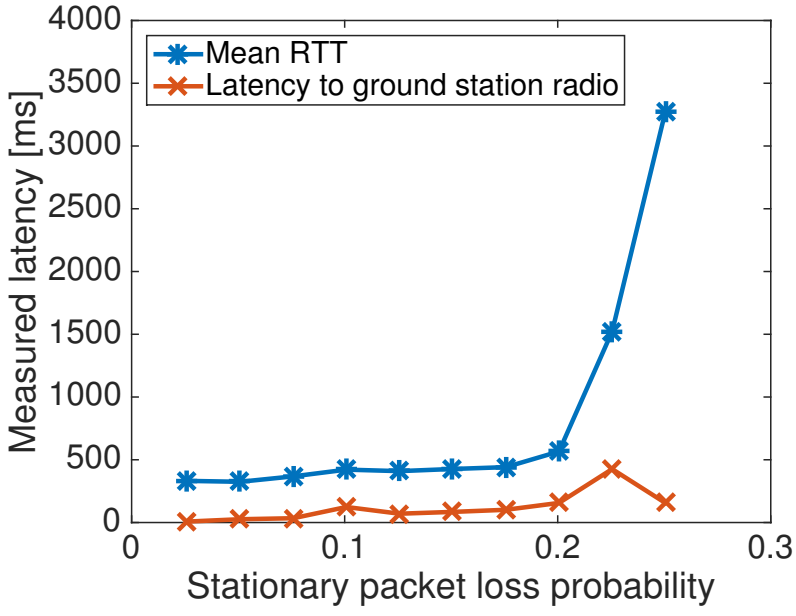
Client Proxy Server

- In Java, with Akka Actors
- MongoDB to keep track of connected ground stations and satellites
- Packet alignment and combining
- RabbitMQ for communication between ground stations and the Client Proxy Server

Simulation results

- Highly scalable
- Tolerant of packet loss and latency





Conclusions

- Highly scalable design
  - Increasing number of nodes does not influence performance
- Tolerant to packet losses
- The decentralized coordination based on a simple model
  - The model could be extended with data from the ground stations
- GNU Radio interface in development

Experience from AAUSAT5

- Running 3 ground stations; AAU, Austria, Germany
- Decentralized coordination functioning
- Weak signals from AAUSAT5; frame alignment and combining not tested
- Still undergoing evaluation

Acknowledgements

Questions?