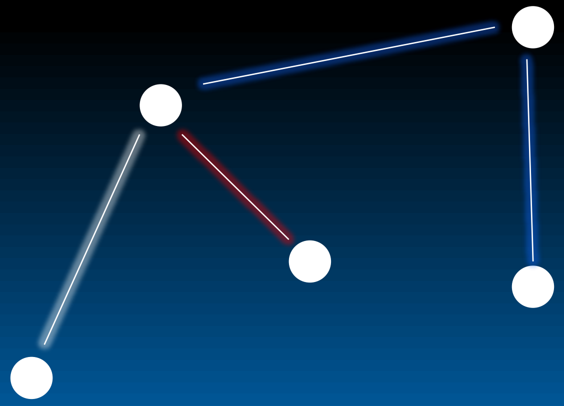
Service Provider Agnostic Adaptive Coding and Modulation System Design

41st International Communications Satellite Systems Conference, Seattle, WA
September 27, 2024

Matthew Hilts*, Adam Gannon*, Ethan Schweinsberg*, Shadi Zogheib*
*NASA Glenn Research Center, Cleveland, OH, United States

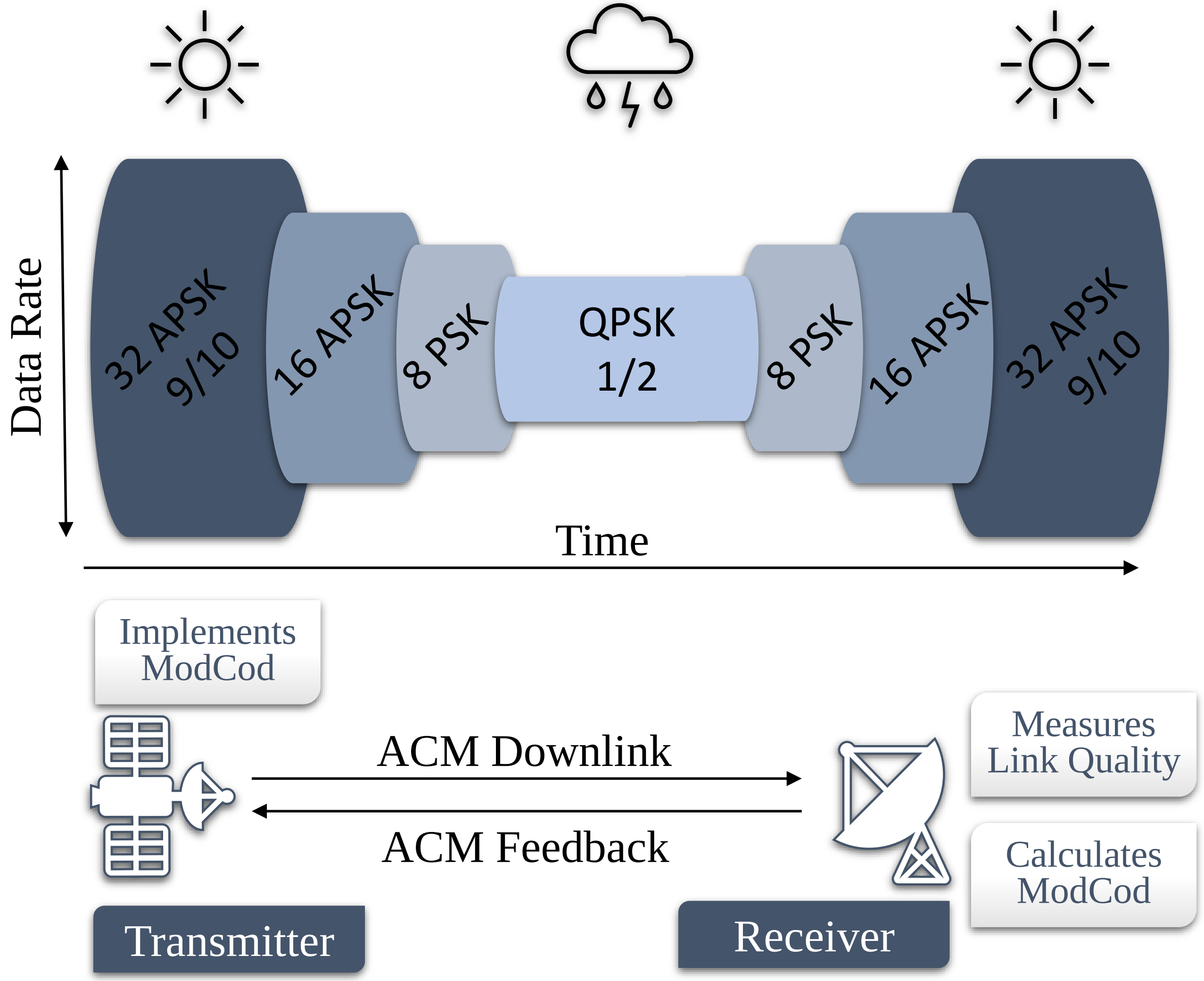


Overview

- Introduction to ACM
- Motivation
- Our ACM System Design
- The Cognitive Ground Testbed
- Testing and Results
- Conclusion

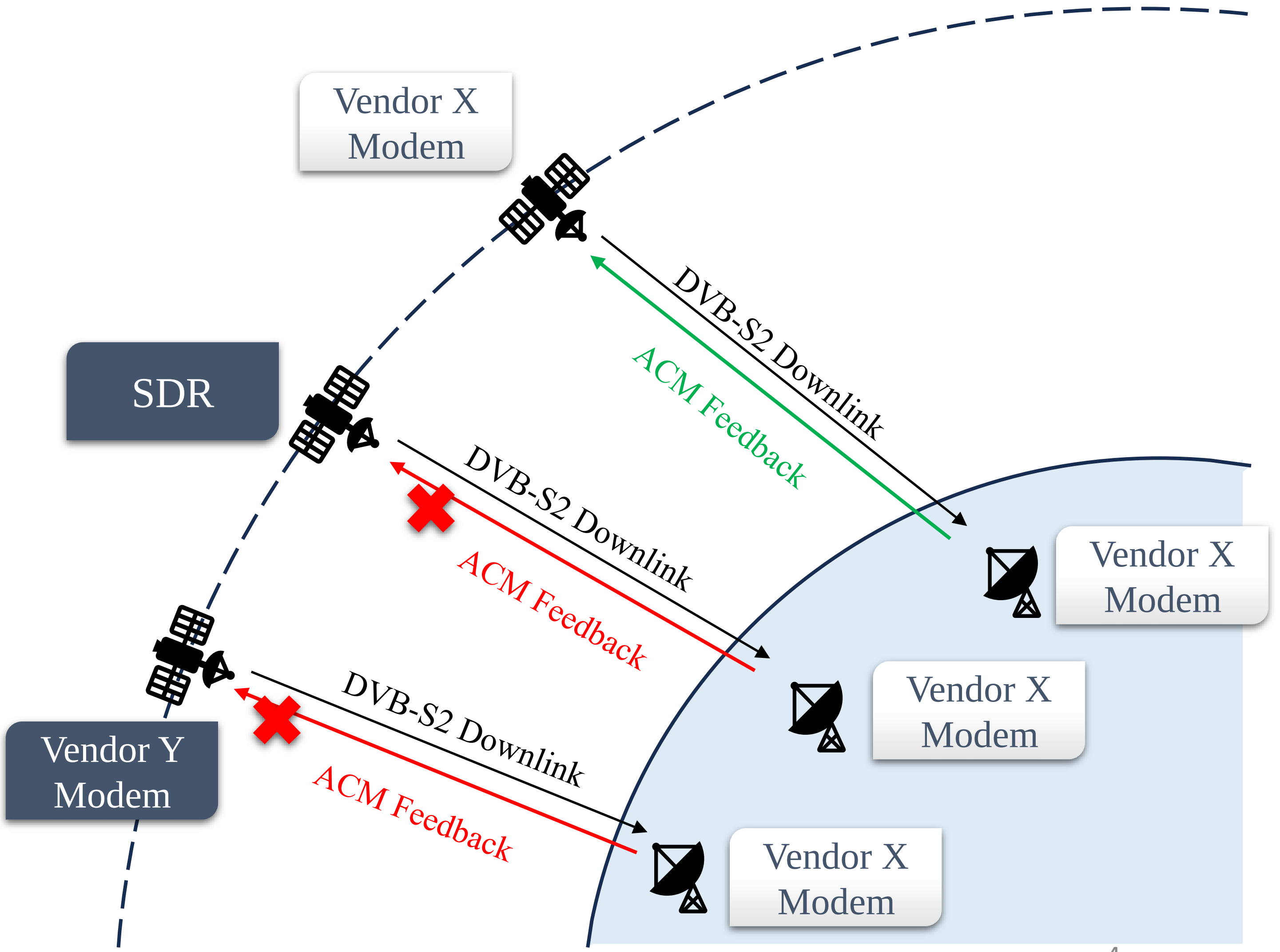
Adaptive Coding and Modulation

- ACM allows user to trade data throughput for link robustness
- ACM is a closed loop method, requires feedback from RX to TX
- DVB-S2 allows TX to unilaterally change ModCod frame-by-frame
- DVB-S2 does not specify feedback method, left to modem vendors

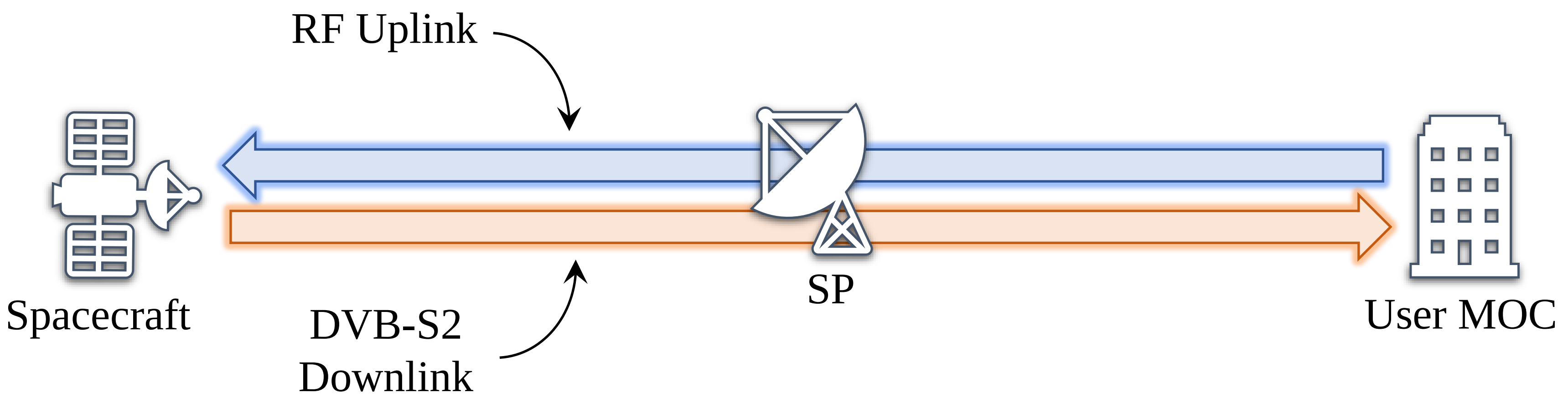


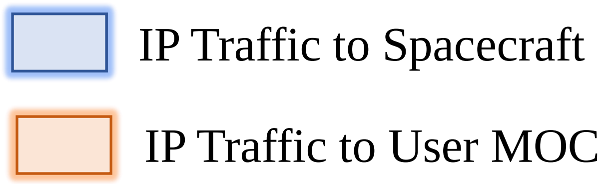
Motivation

- DVB-S2 modem vendors implement unique or proprietary ACM feedback methods
- Communications service providers (SPs) use these modems to service spacecraft
- Impractical to integrate a closed-source feedback method on SDR
- Some vendors design for terrestrial use only (maritime, aviation)



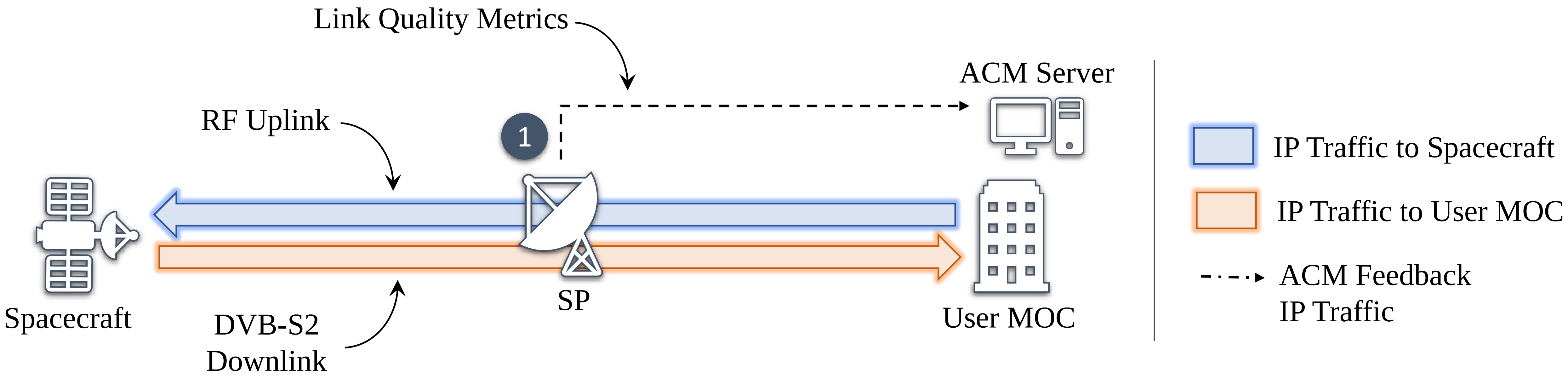
Our ACM System Design





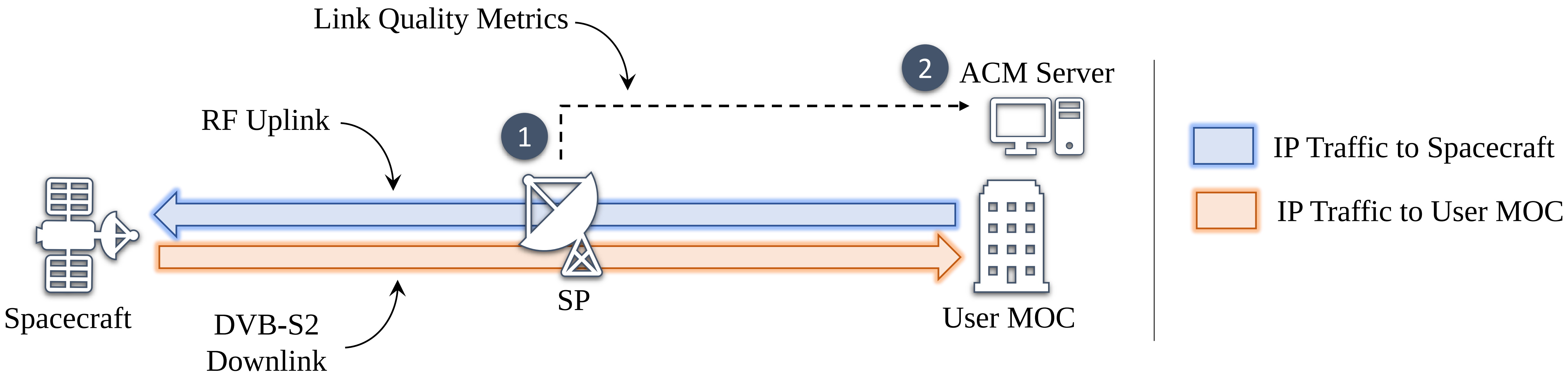
Our ACM System Design

1. User-operated ACM server queries link quality from the SP



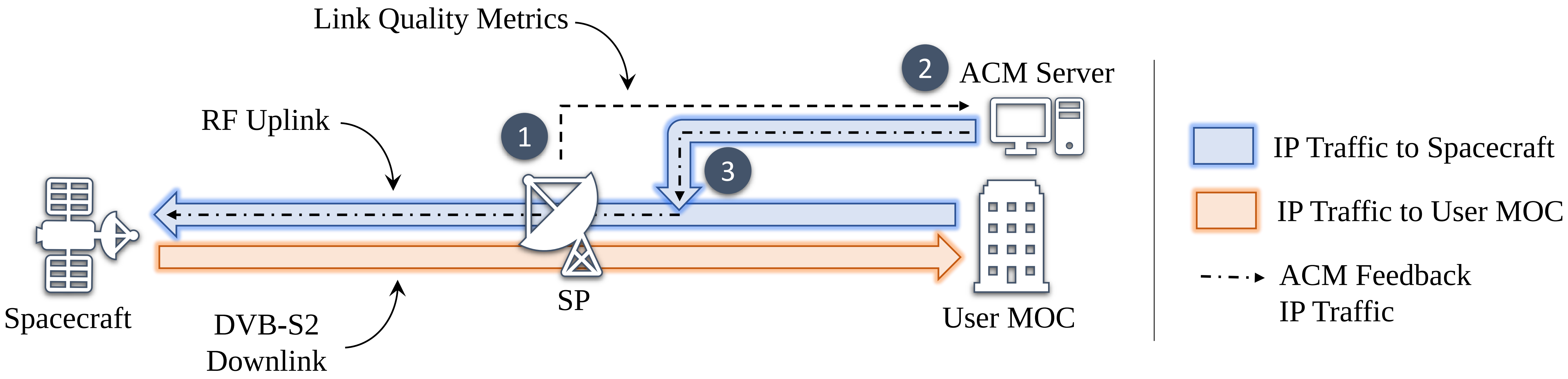
Our ACM System Design

1. User-operated ACM server queries link quality from the SP
2. Optimal DVB-S2 Modcod is selected (factoring in a desired link margin)



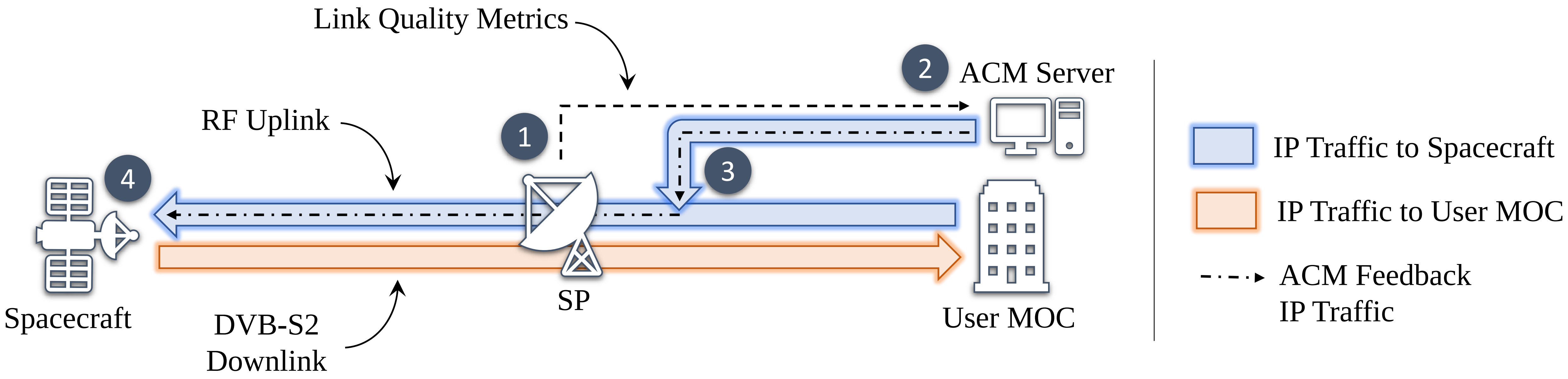
Our ACM System Design

1. User-operated ACM server queries link quality from the SP
2. Optimal DVB-S2 Modcod is selected (factoring in a desired link margin)
3. ACM server sends selected ModCod to spacecraft over SP-handled IP traffic



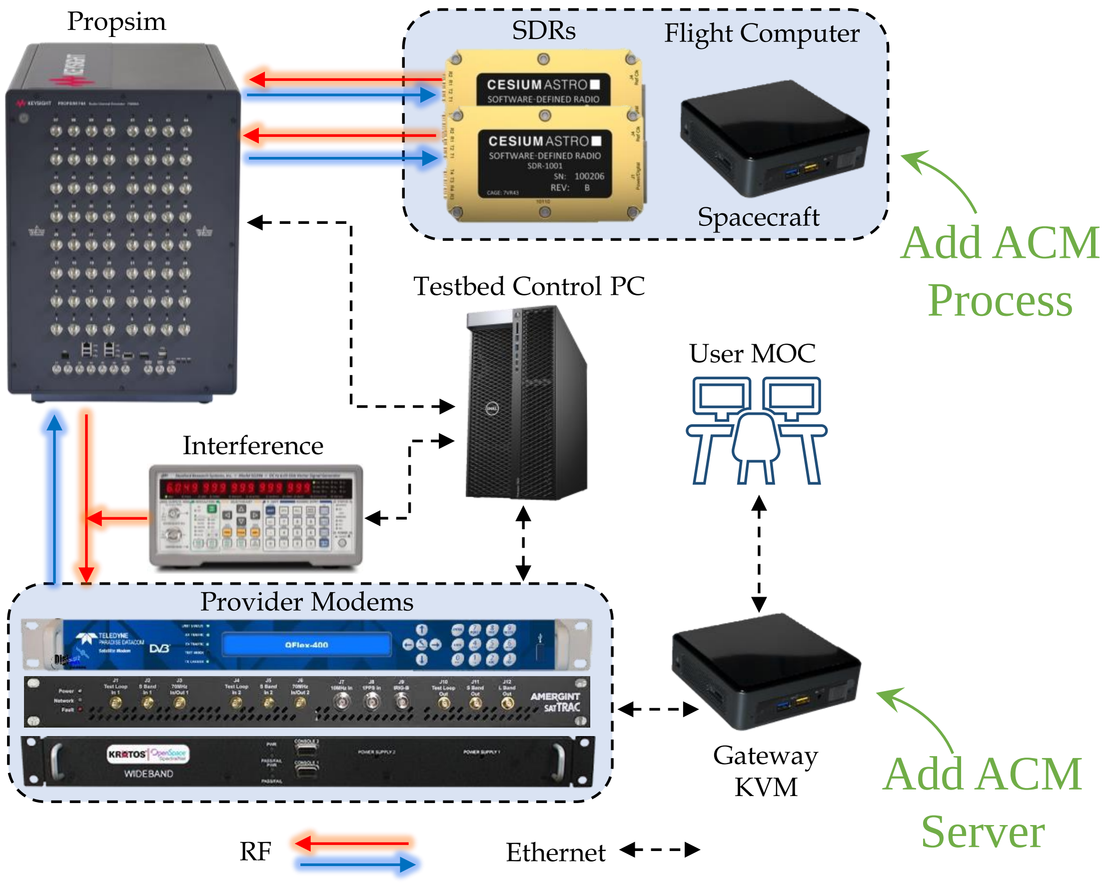
Our ACM System Design

1. User-operated ACM server queries link quality from the SP
2. Optimal DVB-S2 Modcod is selected (factoring in a desired link margin)
3. ACM server sends selected ModCod to spacecraft over SP-handled IP traffic
4. Process on spacecraft receives and implements selected ModCod



Cognitive Ground Testbed

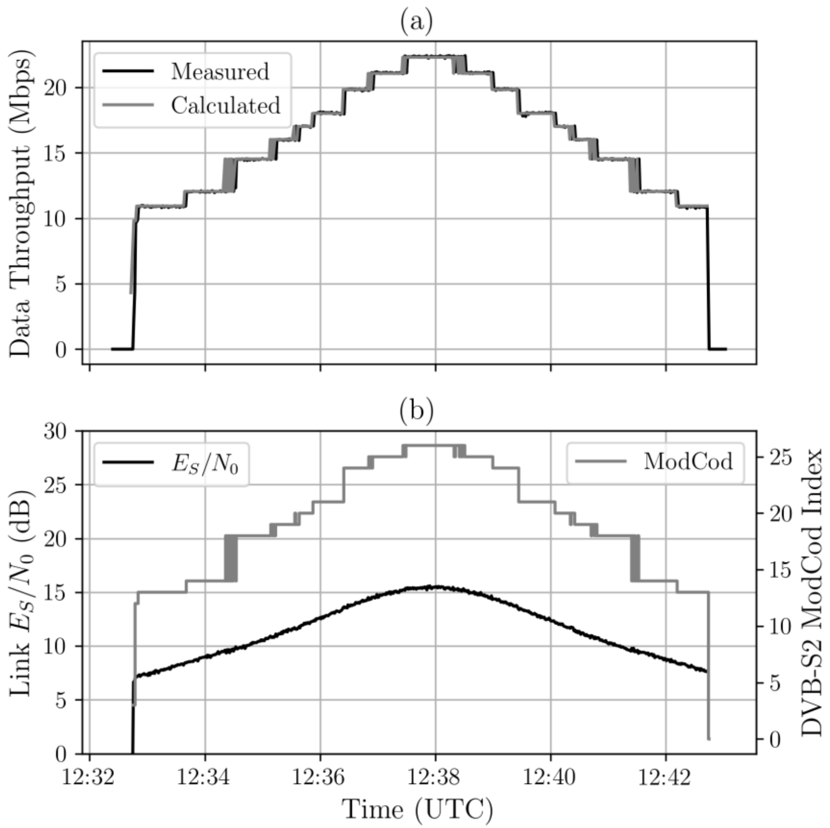
- We test our design on the CGT, a high-fidelity near-Earth communications testbed
- Spacecraft emulation through engineering model SDRs and single-board computers
- RF channel emulation from orbital mechanics simulation, delay, doppler, interference and free space path loss
- Representative modems with provider accurate waveforms



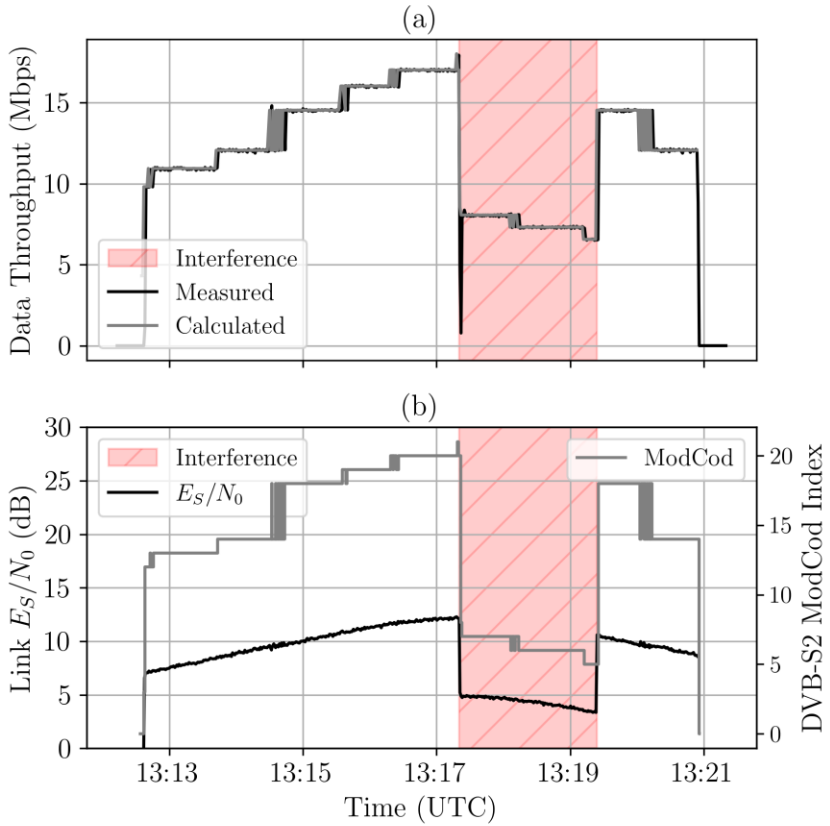
Emulation and Results

- The CGT is configured to emulate two DTE contacts between a LEO spacecraft and a SP
- The ACM server is configured to select ModCods with 3 dB of link margin

1st Contact



2nd Contact

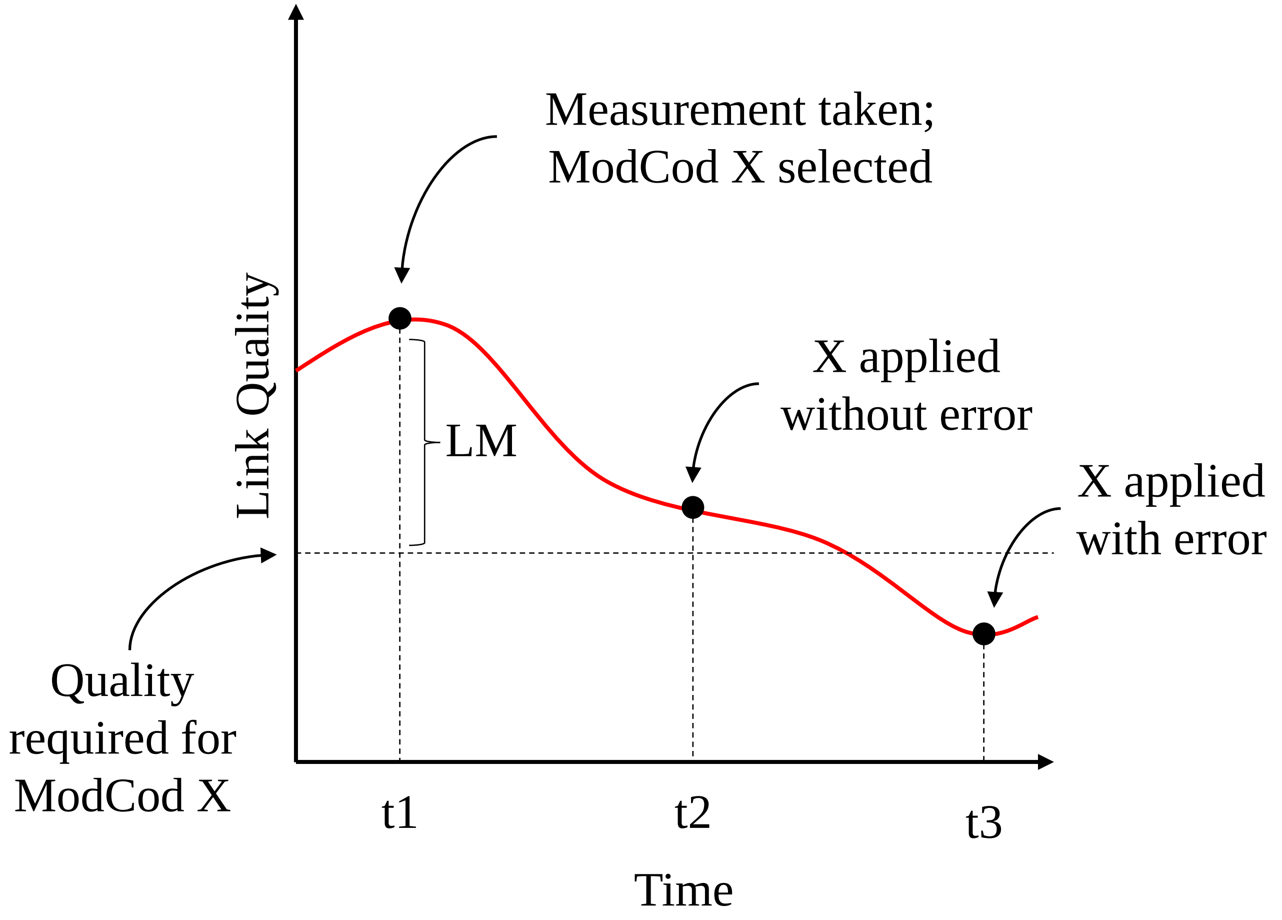


ACM System Performance

- Latency and link margin affect what rate of link quality change an ACM system can handle

- $Minimum\ guaranteed\ rate = \frac{link\ margin}{latency}$

- Our design is disadvantaged in latency compared to vendor methods



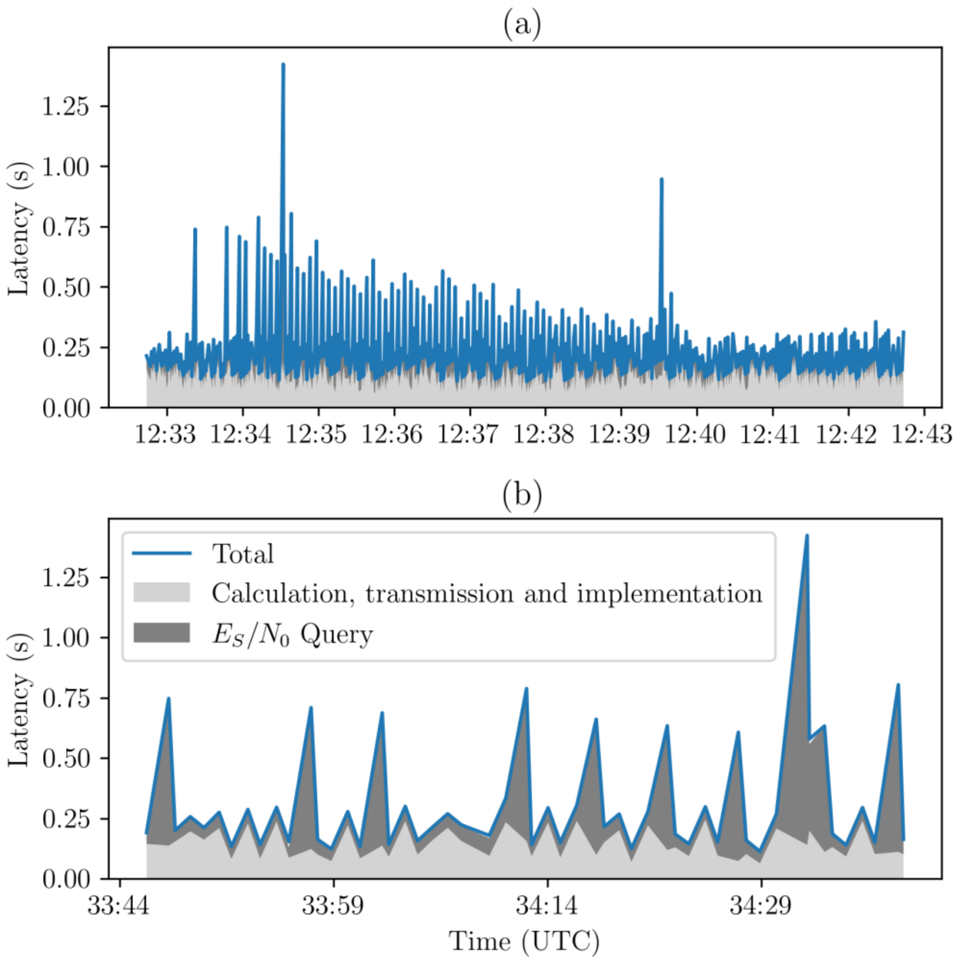
Latency Results

- High variation (due to unoptimized testbed modem) but 2 std deviations is 0.49 seconds

- Thus, with a link margin of 3 dB, our system can handle 6.12 dB/s

- LEO free space path loss slope is on order of 0.1 dB/s

- LEO Ka-Band DTE rain fade slope does not exceed 3 dB/s 99% of the time [1]



[1] Liu, W., Michelson, D.: 'Fade Slope Analysis of Ka-Band Earth-LEO Satellite Links Using a Synthetic Rain Field Model'. IEEE Transactions on Vehicular Technology, 2009, 58, (8), pp 4013-4022

Conclusion

- The benefits of our ACM system design include:
  - No requirement to fly a specific vendor's modem
  - Interoperability between multiple DVB-S2 SPs
  - User control over ModCod selection algorithm (machine learning...)
  - No loss of ACM if DVB-S2 SP switched to a different modem vendor
- Our system does this without:
  - Requiring any hardware to be installed at SP facilities
  - Being too slow to handle typical link quality changes