Prediction Aware Multipath Scheduling in Satellite–Terrestrial Integrated Networks for Real-Time Applications

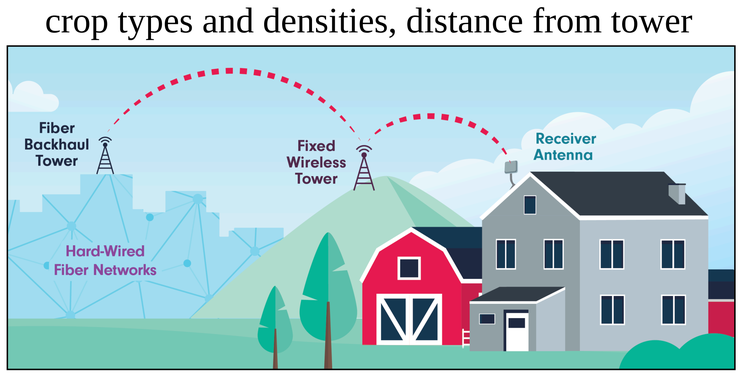
Evan Gossling, Jalal Jalali, Daji Qiao, Hongwei Zhang, Naveen Rajanikantha†

Iowa State University, †Collins Aerospace (evang@iastate.edu)

Real-Time and Rural Challenges

Wireless networks are required for rural regions
- Lower cost than fiber
- Connects ground and air vehicles

However wireless can be unreliable
- Highly dynamic and variable links
- Connection quality subject to weather, terrain, crop types and densities, distance from tower



Satellite links extend connectivity
- Covers oceans, polar regions, and remote terrain

However satellite links are inherently challenging
- High, variable propagation delay and frequent handovers
- Frequent network reconfiguration and high impact loss

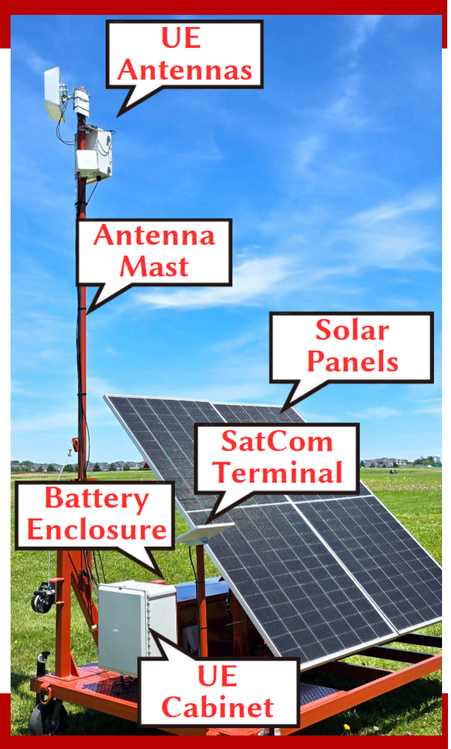
Combining 5G with NTN enables seamless coverage
- Multipath allows failover and throughput aggregation
- Extends reach where single links fall short

However multipath integration is difficult
- Asymmetric latency/bandwidth across paths
- Path switching causes reordering, jitter, and throughput swings
- How to steer traffic across heterogeneous STIN without hurting QoS?

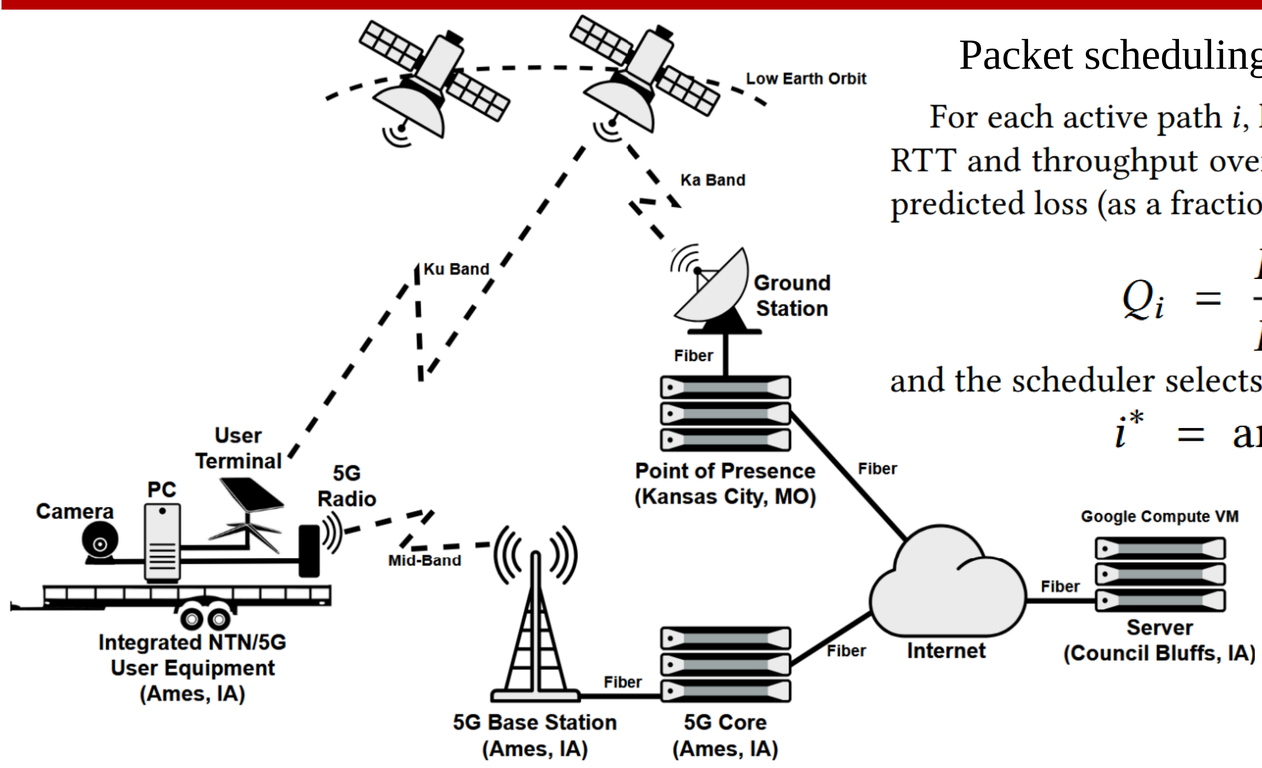
Default multipath scheduler:

For each active path i, let R_i be live measuerd RTT, then the scheduler selects:

$$i^* = \arg\min_i R_i$$



Intelligent STIN with Integrated Modeling Solution



Packet scheduling with integrated modeling:

For each active path i, let $\hat{R}_i$ and $\hat{B}_i$ denote the mean predicted RTT and throughput over the forecast horizon, and $\hat{\ell}_i$ the mean predicted loss (as a fraction). The path quality score is

$$Q_i = \frac{\hat{R}_i}{\hat{B}_i}\left(1+\hat{\ell}_i\right)^2,$$

and the scheduler selects

$$i^* = \arg\min_i Q_i.$$

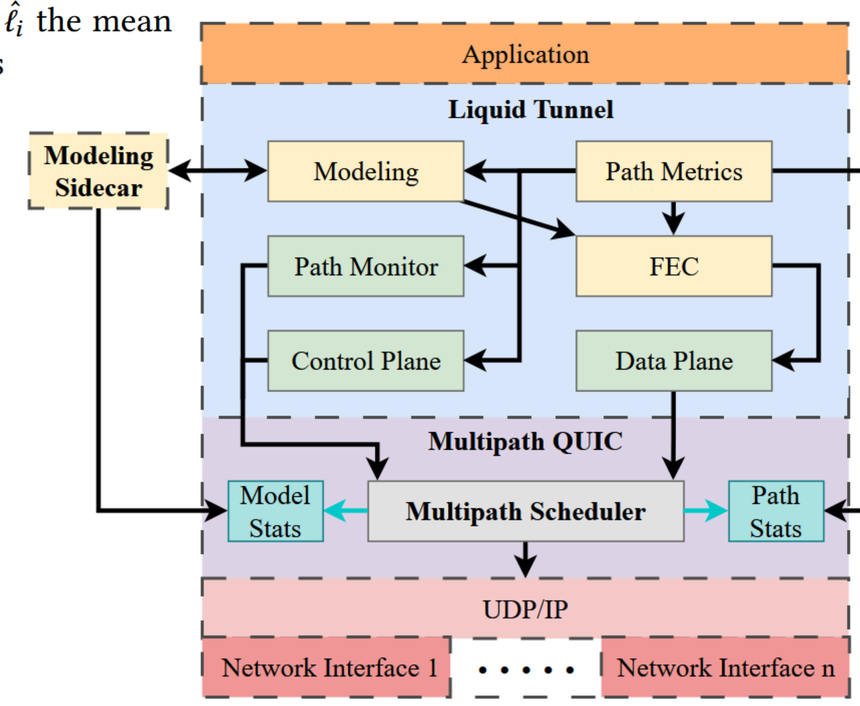


Figure 2: The real-world deployment setup of the STIN.

Real-Time Video Streaming Application Results

Table 1: Comparison of single path Starlink and 5G compared against multipath with default minimum RTT scheduling algorithm and predictive minimum RTT.

Trial	FPS	Packet Loss (%)	Frame Loss/s	Packet Disp. (μs)	Total Packet Loss	Total Frame Loss
(SP) Starlink	13.1	42.7	14.1	304.6	72,988	522
(SP) 5G	18.1	27.5	11.3	266.4	61,558	418
(MP) minRTT	23.8	11.3	3.9	262.1	19,093	145
(MP) Pre-minRTT	24.0	5.6	2.0	246.0	9,654	74