Future Vision: Intelligent Networks for Autonomous Ground and Aerial Vehicles

Jie Rockey Luo

ECE, Colorado State Univ., Fort Collins

In collaboration with CU Boulder, Worcester Polytech

Building on preliminary results of the NSF SWIFT project

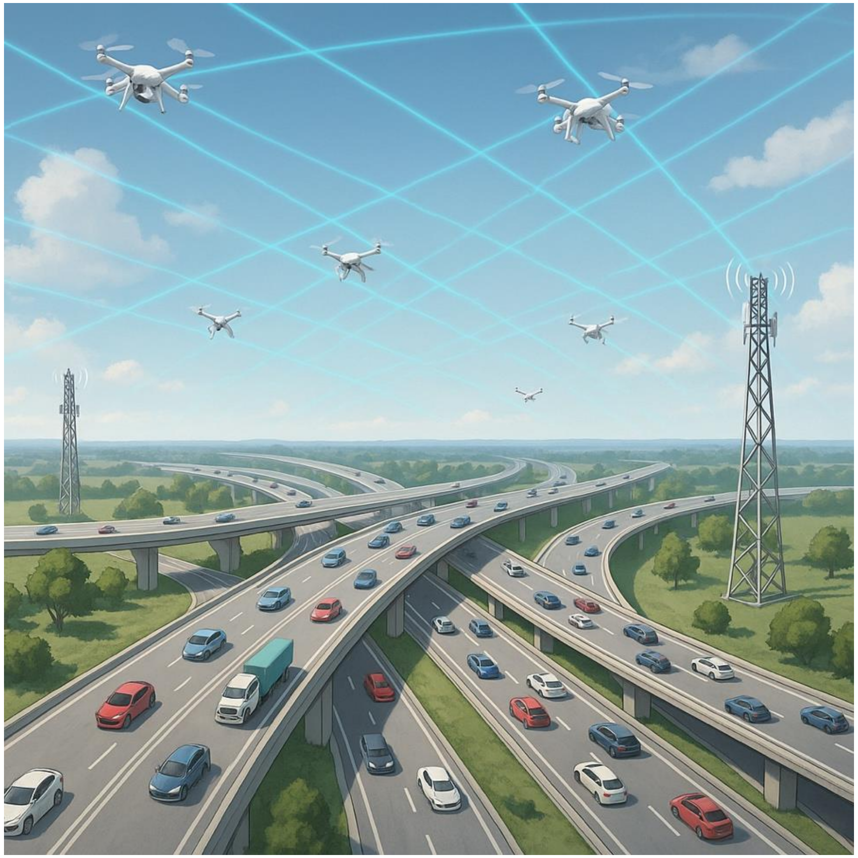
Networks for Ground & Aerial Vehicles

Key Characteristics

- Fully automated vehicles and drones
- Ground highway & Aerial corridors
- Massive heterogeneous traffic demand
- Limited critical safety-related traffic
- Patchy infrastructure support

Technical Challenges

- Ensure continuous signal coverage
- Guarantee QoS for critical data
- Support ultra-high data rates when infrastructure permits



Technical Characteristics

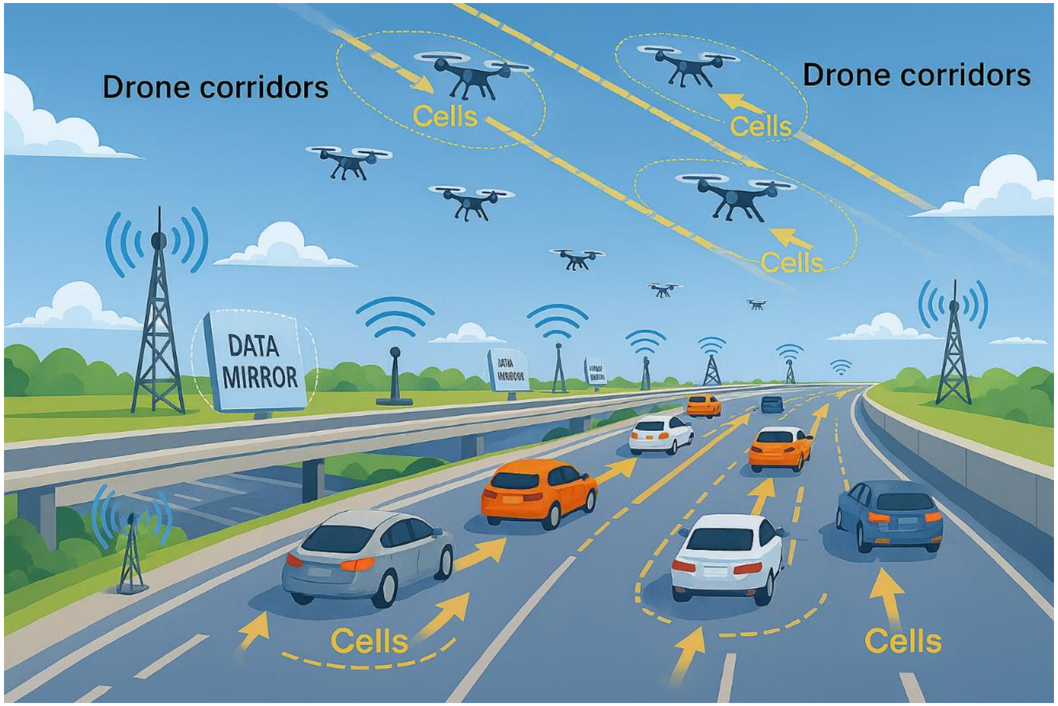
- Scheduled long-message transmissions
- Random short-message transmissions
- Predictable mobility patterns
- Incomplete infrastructure support

- Highly dynamic traffic, channel, and infrastructure conditions
- Primary-secondary structure enforced in random access for bursty short messages

Key Proposals

For both long & short messages

- Deploy massive "**data mirrors**" (reflective surfaces) to expand signal coverage
- Create a rolling "**cell carpet**" that moves with vehicle traffic to reduce handoff disruptions



- Channel tracking & prediction
- Beam & reflection optimization
- Correlating vehicle mobility with communication traffic patterns

For bursty short messages

- Enable "**flexible multi-packet reception**" in random access to boost efficiency
- Establish a "**hierarchical primary-secondary structure**" in random access to guarantee QoS for critical data

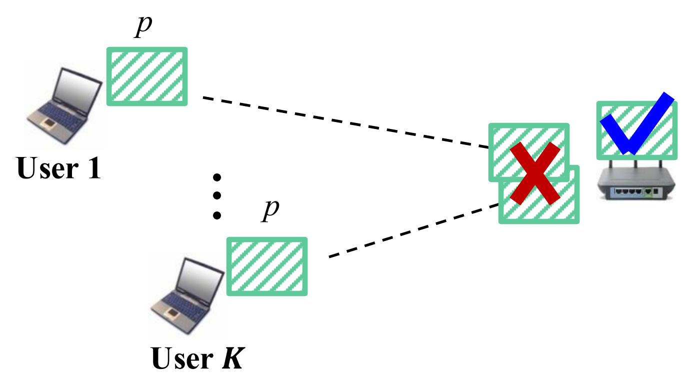
- Smooth navigation through multiple coding options
- Enforcing hierarchy without explicit user coordination
- AI-assisted channel/traffic prediction for robust optimization

Flexible MPR + Hierarchical Structure

Current Random Access Adaptation

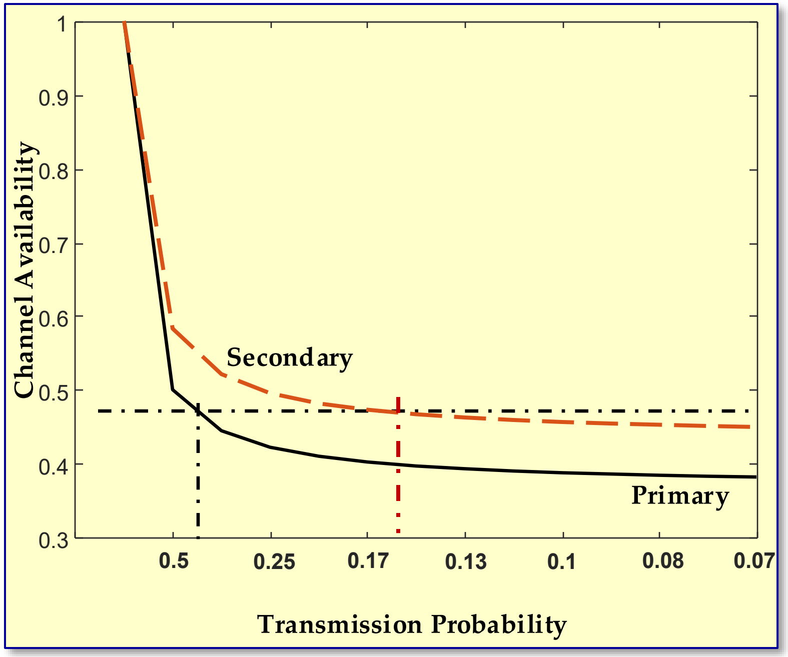
Success/collision ⟶ Channel availability
Transmission probability ⟵

Example: K user collision channel
channel availability = $(1\text{-}p)^{1/(K\text{-}1)}$
transmission probability $p = 1/K$



Primary-Secondary Structure

Primary: baseline (standard) curve
Secondary: raised curve, protect primary QoS

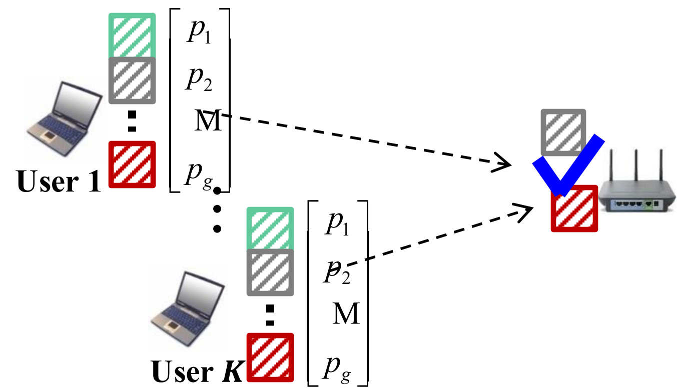


Flexible MPR & Hierarchical Structure

Current Random Access Adaptation

Success/collision ⟶ Channel availability
Transmission probability ⟵

K user collision channel,
channel availability = $(1-p)^{1/(K-1)}$
transmission probability $p = 1/K$

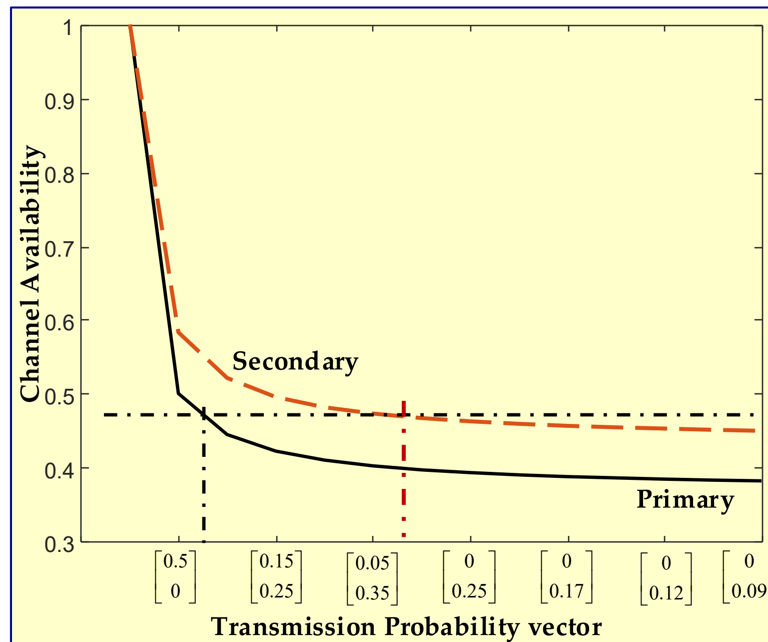


Primary-Secondary Structure

Primary user: standard curve
Secondary user: raised curve

Flexible Multi-packet Reception (MPR)

- Multiple coding options per user
- Channel availability ⟶ Probability **vector**



- Achieve **4-8x throughput** over 802.11 DCF
- Guarantee QoS for critical short-message traffic (including scheduling control)