Communications Link Modeling and Simulation

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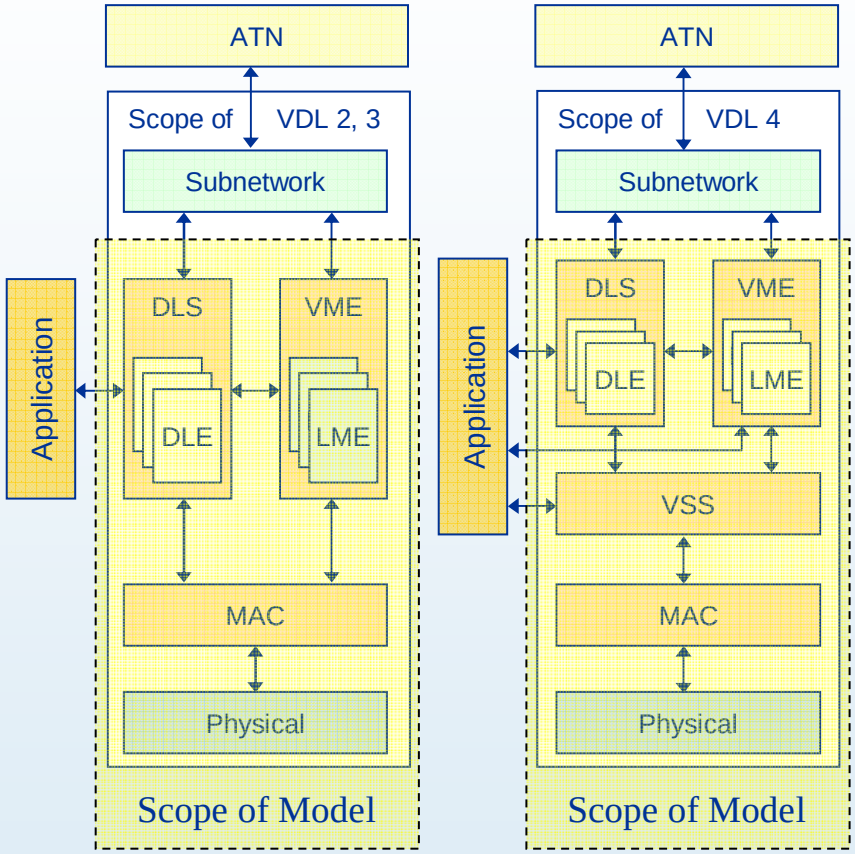
Overview

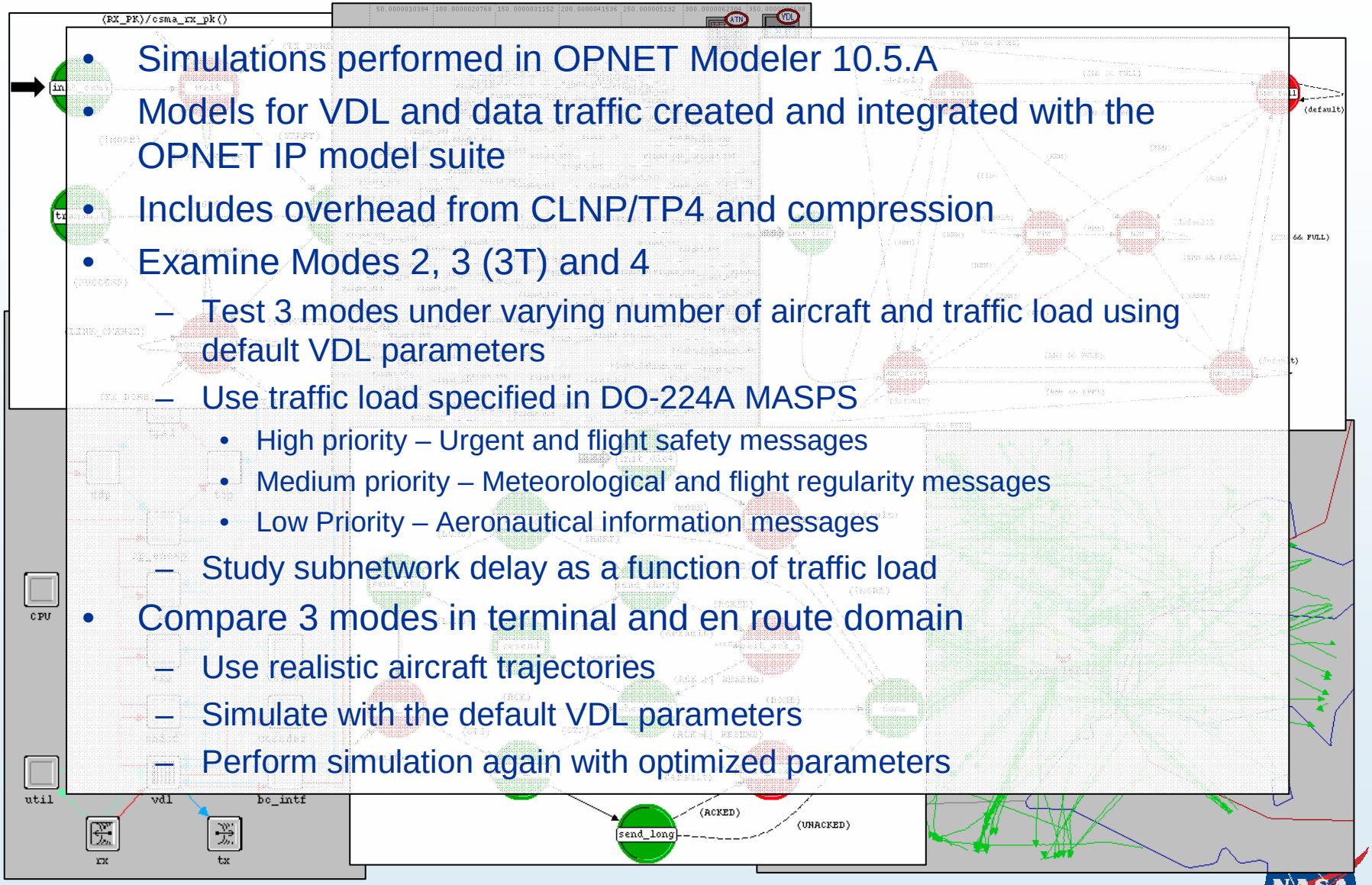
- VDL
  - VDL will provide datalink services for the future. Determine the modes performance.
  - Review the model of VDL Modes 2, 3, and 4. Discuss the simulation for a general scenario and specifically in the terminal domain. Examine the results.
- 802.16
  - 802.16 has been identified as a candidate link for the airport surface. Evaluate its performance.
  - Examine the 802.16 protocol capabilities. Discuss the modeling of 802.16 in OPNET and describe a scenario for its use on the airport surface.

VDL Model

- VDL standards specify subnetwork, datalink, and physical layers
- Model includes physical and data link sublayers
  - MAC
  - DLS
  - VME
- Each mode has separate models for MAC and DLS
  - Mode 2: CSMA / AVLC
  - Mode 3: TDMA / ACL
  - Mode 4: STDMA / NSCOP



VDL Simulation



- Simulations performed in OPNET Modeler 10.5.A
- Models for VDL and data traffic created and integrated with the OPNET IP model suite
- Includes overhead from CLNP/TP4 and compression
- Examine Modes 2, 3 (3T) and 4
  - Test 3 modes under varying number of aircraft and traffic load using default VDL parameters
  - Use traffic load specified in DO-224A MASPS
    - High priority – Urgent and flight safety messages
    - Medium priority – Meteorological and flight regularity messages
    - Low Priority – Aeronautical information messages
  - Study subnetwork delay as a function of traffic load
- Compare 3 modes in terminal and en route domain
  - Use realistic aircraft trajectories
  - Simulate with the default VDL parameters
  - Perform simulation again with optimized parameters

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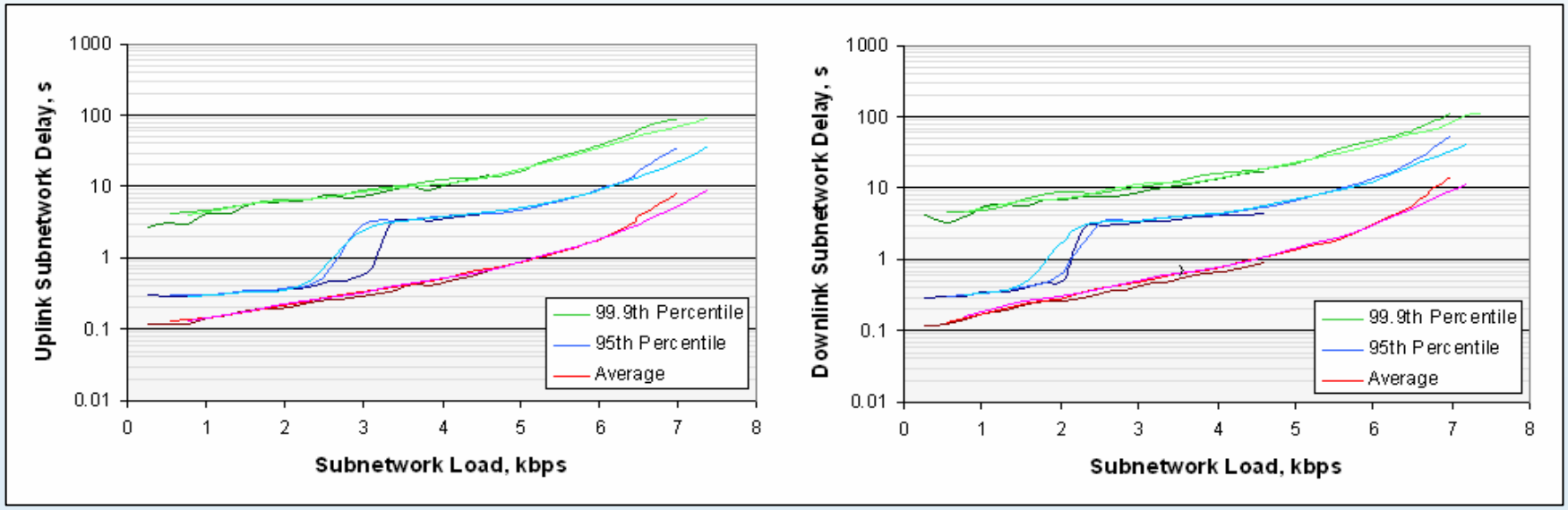
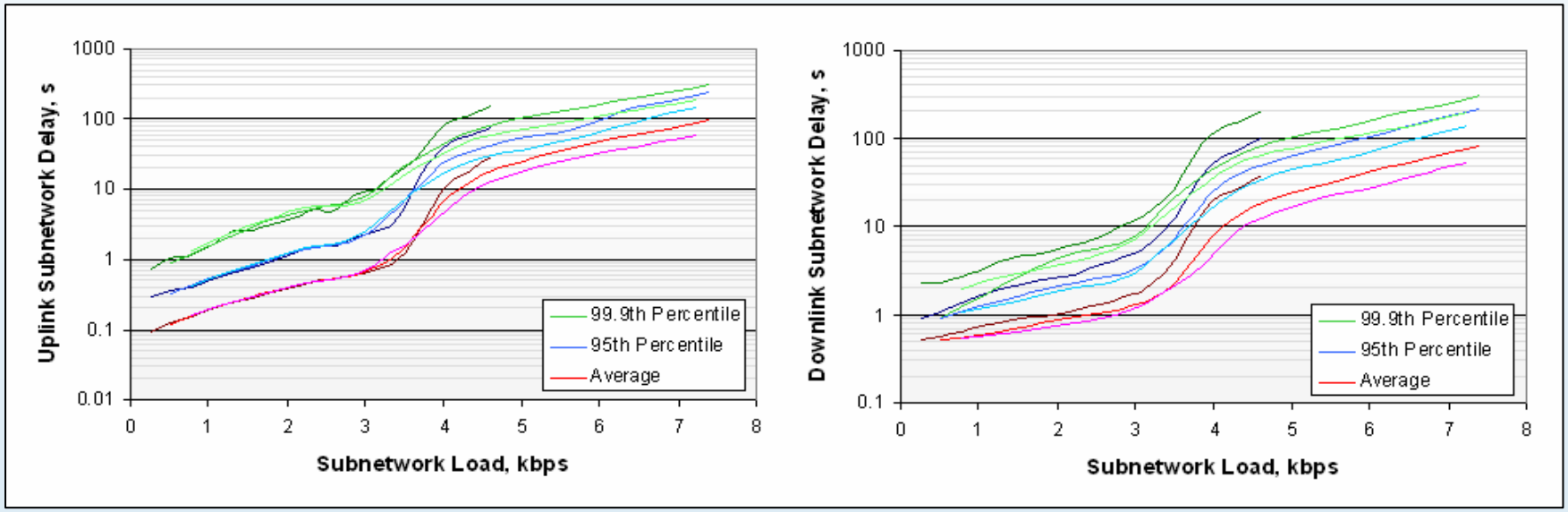
Mode 2

- Subnetwork delay requirement (from MASPS):
  - 3.5 seconds 95th percentile
- Collisions and subsequent retransmission delay limit capacity
- Maximum capacity: 3.3 kbps



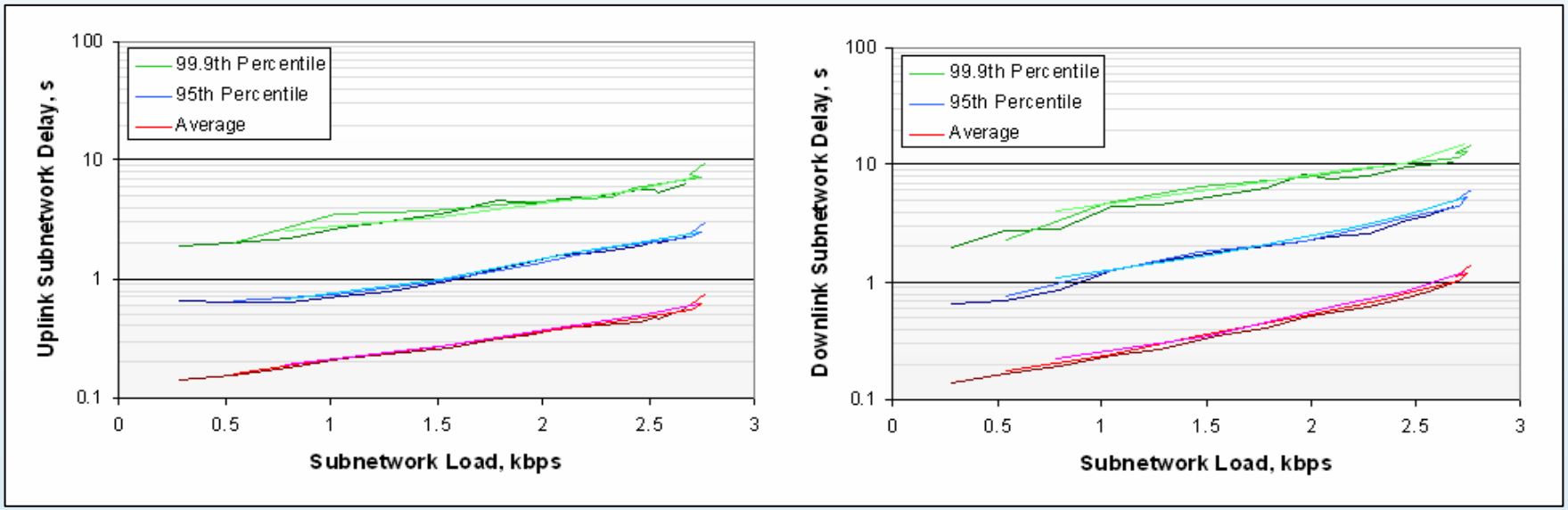
Mode 3

- Subnetwork delay requirements for high priority messages:
  - 1 second 95th percentile
  - 5 seconds 99.9th percentile
- Reservation request mechanism for aircraft has difficulty meeting 95th percentile 1-second delay
- Maximum capacity: 0.5 kbps



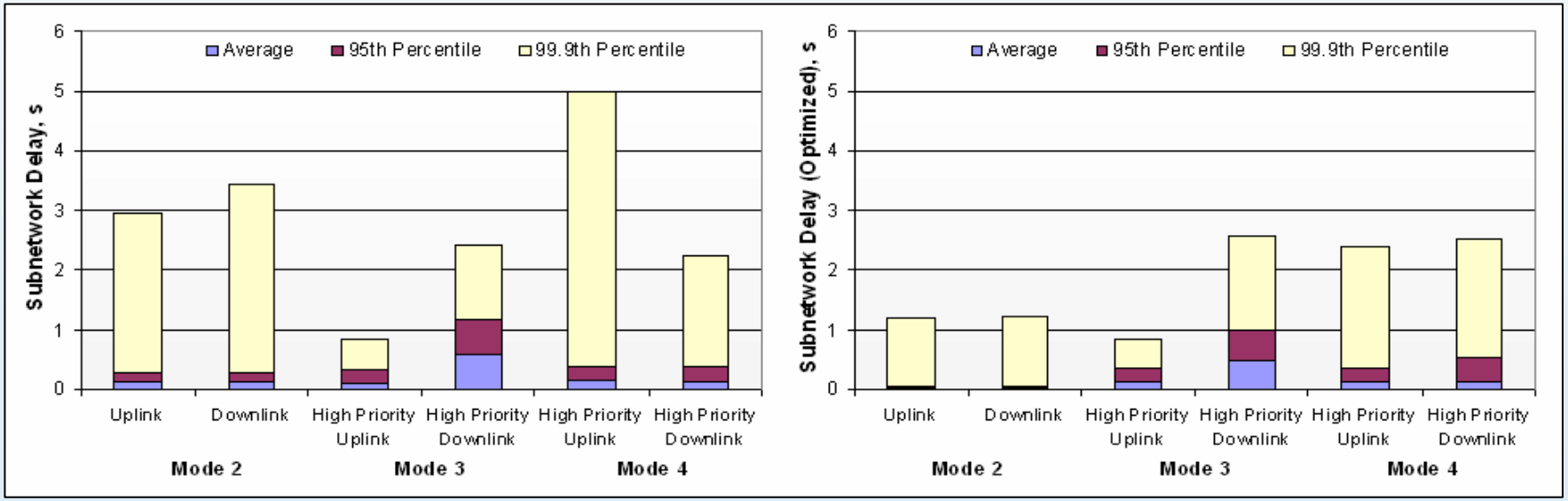
Mode 4

- Subnetwork delay requirements unknown
  - Use same criteria as Mode 3
- Capacity limited because aircraft make too many random-access transmissions
  - Not enough transmissions to piggyback reservations
- Maximum capacity: 0.8 kbps



Terminal Domain

- Explore Mode 2, 3, and 4 in a terminal scenario
- Determine the subnetwork delays
- Examine the delays with optimized parameters
  - Mode 2: Large improvement due to tuning for shorter distance
  - Mode 3: Slight improvement that meets delay requirements
  - Mode 4: Improvement in 99.9th percentile delay



VDL Remarks

- For data, Mode 2 performs well
  - Can handle 0.8 kbps while meeting Mode 3 requirements
    - For all traffic, not just high-priority
    - This while using default (non-optimized) parameters
- Remember that the 3 Modes were created for different purposes
  - Mode 2: Data (AOC)
  - Mode 3: Voice (Primary purpose)
  - Mode 4: Surveillance (ADS-B)
- Full details available in paper:

  "Characteristics and Capacity of VDL Mode 2, 3, and 4 Subnetworks"
  Steven C. Bretmersky, Robert W. Murawski, Vijay K. Konangi,
  AIAA *Journal of Aerospace Computing, Information, and Communication, accepted*

IEEE 802.16

- IEEE 802.16 WirelessMAN Standards
  - 802.16-2004 is the base standard
  - 802.16e adds mobility component
- Metropolitan Area Network (Range ~30 miles)
- Employs a DOCSIS-based MAC protocol
- Has 5 defined physical layer types
  - WirelessMAN-SC
  - WirelessMAN-SCa
  - WirelessMAN-OFDM
  - WirelessMAN-OFDMA
  - WirelessHUMAN
- Identified by the Future Communication Study as a possible data link for the surface domain in C-band

Physical Layer Configurations

IEEE WirelessMAN® 802.16	WirelessMAN-SC	WirelessMAN-SCa	WirelessMAN-OFDM	WirelessMAN-OFDMA	WirelessHUMAN
Frequency	10 – 66 GHz	2 - 11 GHz	2 - 11 GHz	2 - 11 GHz	2 - 11 GHz
Duplexing	TDD FDD	TDD FDD	TDD FDD	TDD FDD	TDD
Automatic Repeat Request (ARQ)		✓	✓	✓	✓
Adaptive Antenna System (AAS)		✓	✓	✓	✓
Spaced Time Coding (STC)		✓	✓	✓	✓
Mobility		✓	✓	✓	
Mesh			✓		✓

Useful Features

- Adaptive Modulations and FEC
- Quality-of-Service
  - 4 types of service with priority
- Security
  - Secure key exchange, encryption, authentication
- Mobility
- Broadcast and Multicast capabilities
- Payload Header Suppression
- Flexible bandwidth allocations
- High data rates
- Mesh capability

Modulations and FEC

- 802.16 uses multiple modulations and FEC rates to offer best performance for link conditions.
  - Modulation / FEC selection is a tradeoff between robustness and data rate.
  - Options vary slightly based on PHY type.
- WirelessMAN-OFDM modulations:
  - BPSK
  - QPSK
  - 16-QAM
  - 64-QAM
- WirelessMAN-OFDM FEC algorithms
  - Reed-Solomon-Convolutional Code (RS-CC) at rates of 1/2, 2/3, and 3/4
  - Block Turbo Coding (BTC) at rates of 1/2, 3/5, 2/3, 3/4, 4/5, and 5/6 (optional)
  - Convolutional Turbo Codes (CTC) at rates of 1/2, 2/3, and 3/4 (optional)

Quality of Service

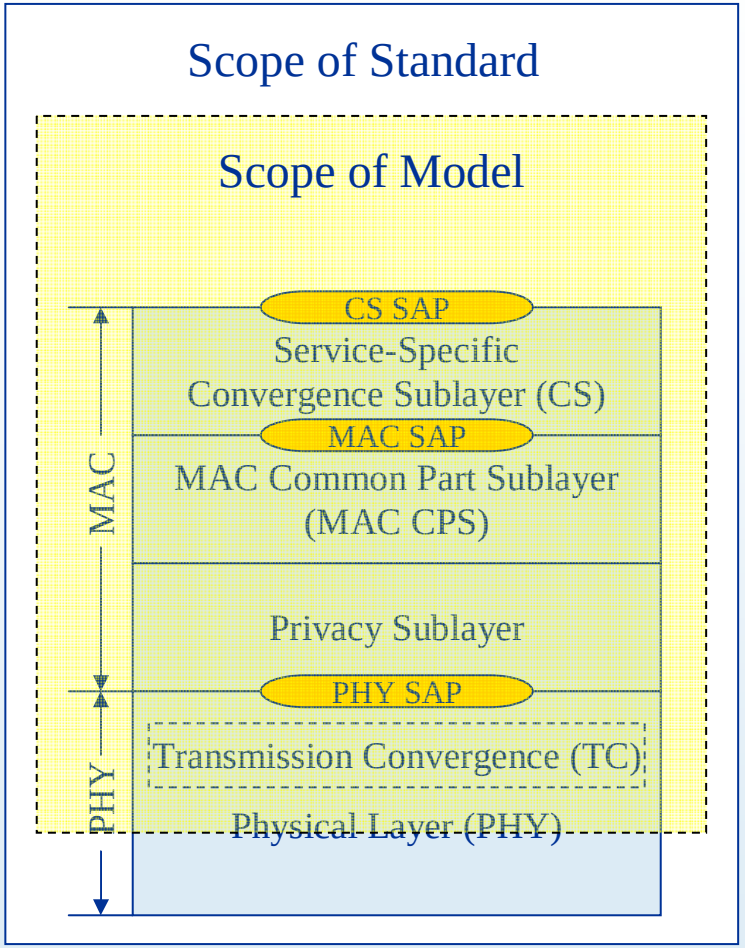
- 802.16 offers four types of services
  - Unsolicited Grant Service
    - Real-time fixed-rate flows
  - Real Time Polled Service
    - Real-time variable rate flows
  - Non-Real Time Polled Service
  - Best Effort Service
- QoS for real-time services
  - Priority (8 levels)
  - Tolerated jitter
  - Maximum tolerated latency
  - Minimum tolerated traffic rate
- 802.16 scheduler is **not standardized**

Privacy / Security

- Key management
  - X.509 digital certificates
  - RSA public key encryption/authentication
  - Optional EAP authentication in 802.16e
  - HMAC with SHA-1 authentication
- Data encryption
  - DES with 56-bit keys
  - AES with 64 and 128 bit keys
- Data authentication
  - AES with 128-bit keys in 802.16e

802.16 Model

- 802.16 specification includes MAC and physical layer definitions
- In the near term, the model will concentrate on the protocols
  - MAC Common Part Sublayer
  - Convergence Sublayer
  - Overhead from Privacy Sublayer
  - Overhead from PHY (OFDM)
- Physical channel model will be created later
  - Use inputs from Ohio University Sounding Study
- Coordinate modeling effort with FCS group



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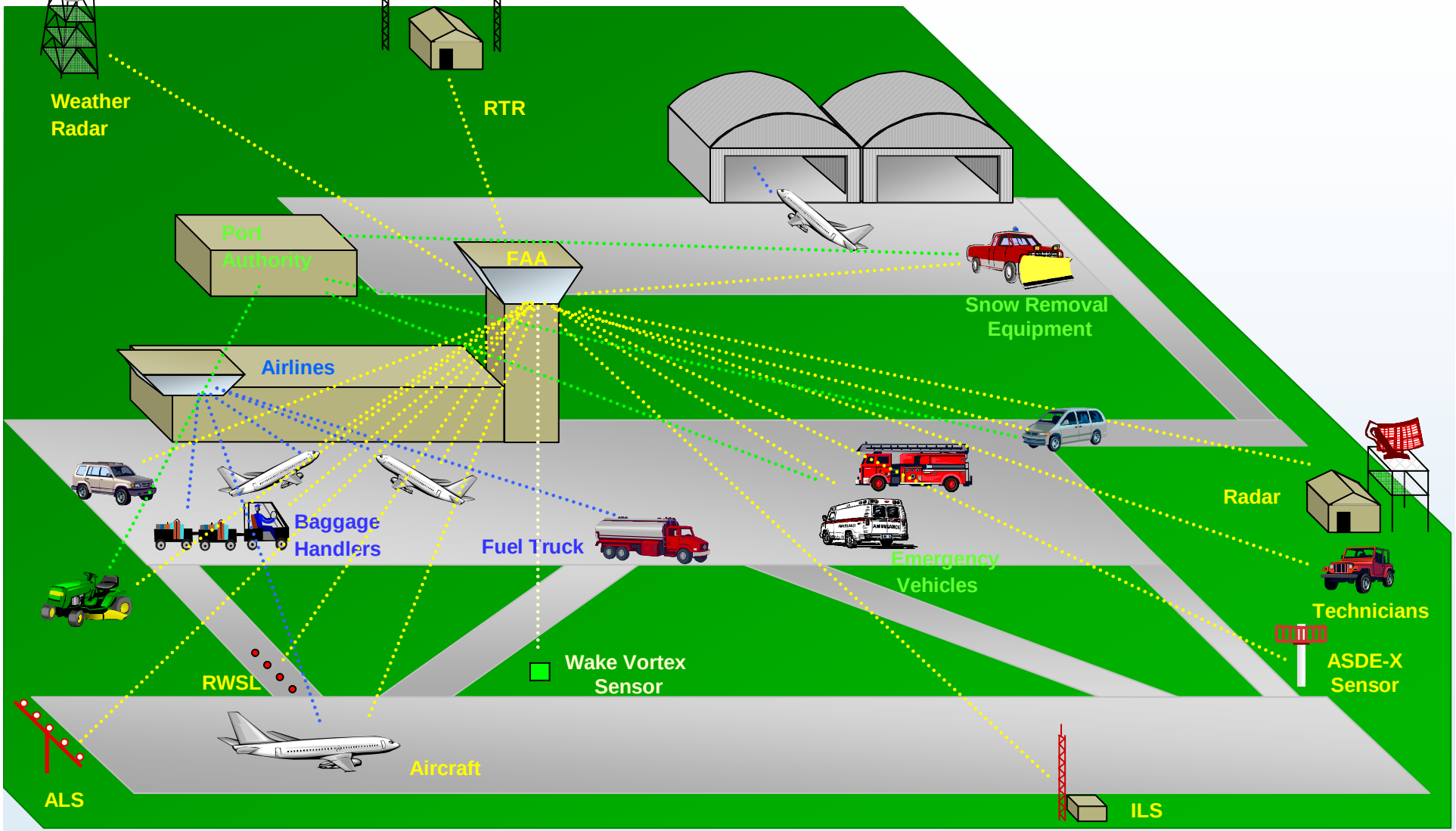
Wireless Surface Scenario



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