



# **MIMO for Tactical Communications: Promise & Issues**

## **MNM Workshop**

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# ARL / ARO MIMO 6.1

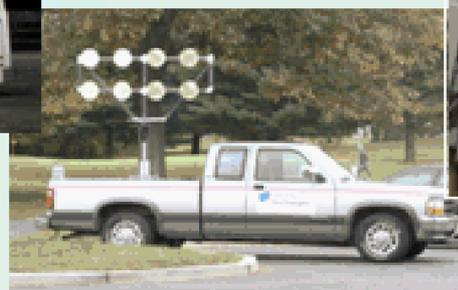


- **Collaborative Technology Alliance in Communications & Networks**

Industry: General Dynamics, Georgia Tech Research Institute, Telcordia Technologies

Academia: Georgia Tech, Morgan State, UCal Riverside, U Del, U Md, U Minn, Princeton

[www.arl.army.mil/main/researchopportunities/alliances/index.cfm](http://www.arl.army.mil/main/researchopportunities/alliances/index.cfm)



- **MURI: Space-Time Processing for Tactical Mobile Ad Hoc Networks**

UCSD et al, <http://zeidler.ucsd.edu/~muri/pages/index.php>

- **ARL, ARO PI's**

- **International Technology Alliance (ITA: US / UK)**



# Keys to PHY Performance

- **Viterbi Algorithm**

VA provides max-likelihood sequence estimation in reasonable complexity

- **Equalization**

Handles severe ISI

- **Turbo (iterative) Decoding**

Provides near max-likelihood decoding in reasonable complexity. Turbo-principle couples synch and equalization with decoder for mutual gain.

- **MIMO**

Overcomes fading via spatial diversity. Multiplies spectral efficiency. Enables network capacity increase.



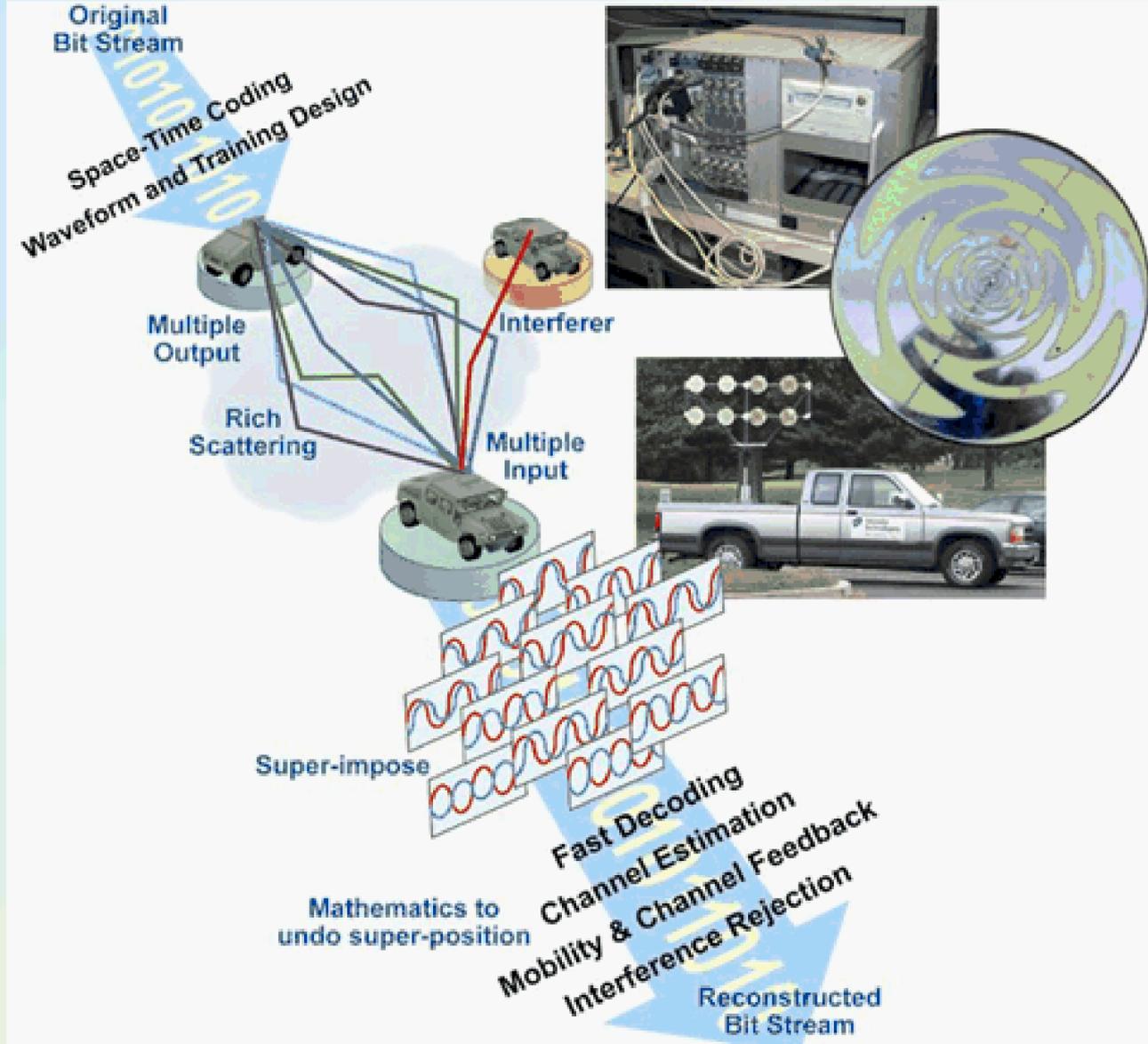
# The Promise of MIMO



- **Spectral efficiency multiplier**
- **Resilience against fading ... *without* power or bandwidth expansion**
  - Diversity, diversity, diversity
- **Network capacity increase with channel state information (CSI) at transmitter**
  - SDMA – interwoven spatial reuse
- **Virtual / cooperative MIMO (network diversity)**
  - Multi-hop, distributed relays
- **Enable degrees-of-freedom tradeoffs**
  - Rate-Diversity, power, MUI / jammer rejection



# Challenges

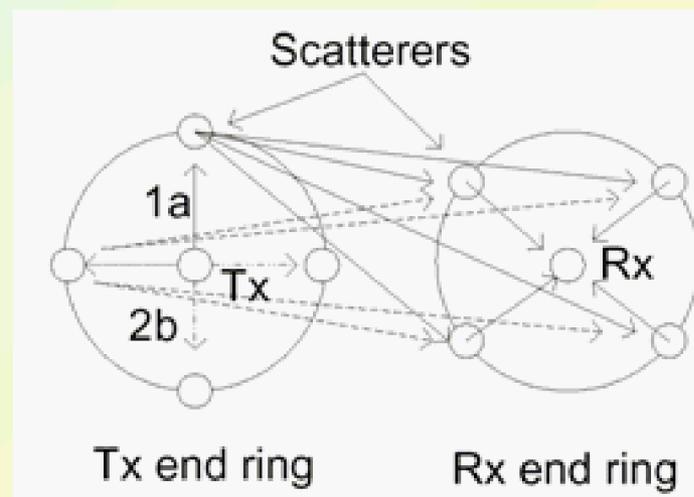




# Challenges – Channel Models



- Fully mobile case (both ends moving)
  - Time-varying models, Doppler
- Triply selective channels (space, time, frequency)
- Spatial coherence
  - e.g., non-iid narrowband channel matrix  $H$
- Temporal coherence
  - Critical for CSI feedback
- Measurements and model validation

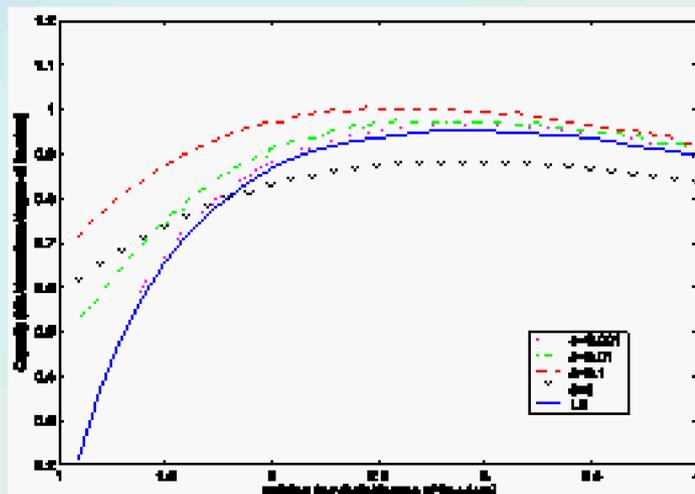




# Challenges - PHY

- Synchronization and channel estimation

Training design: packetized, power allocation



- S-T-F coding and waveform design

Scalability with antennas, and spectrum

- MIMO-OFDM

Pros: highly flexible and adaptable, non-contiguous bandwidth, adaptive spectrum allocation (XG)

Cons: PAPR, (wideband) Doppler sensitivity





# Challenges – Spatial Adaptation

- **Beamforming to spatial filtering: system adaptation**
  - LOS vs NLOS channels
  - Mitigating MUI, jamming
- **Channel state information**
  - Feedback and temporal correlation
  - Partial CSI: quantization, statistical (mean, covariance)
  - SDMA, LPI/LPD
- **Virtual MIMO with distributed nodes**
  - Timing synchronization, carrier offsets
  - Bandwidth expansion



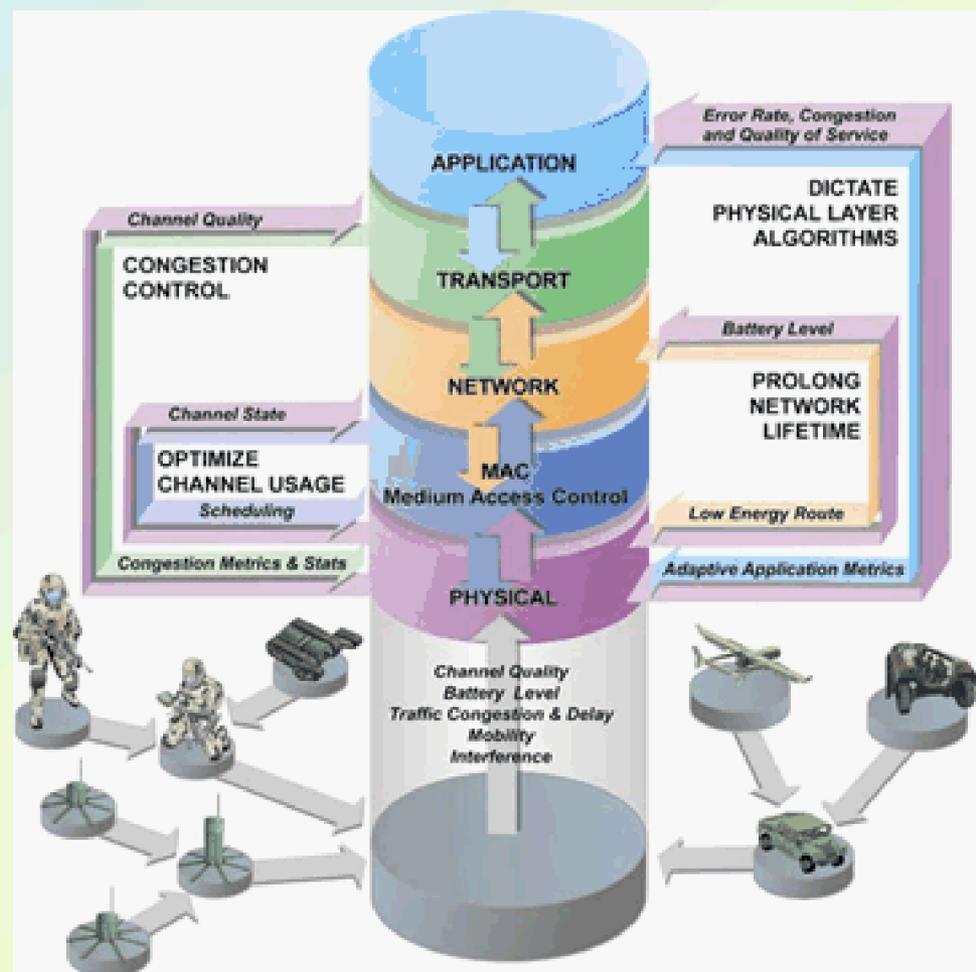
# Challenges – MIMO MAC



- Adaptive resource allocation

Power, rate, # of antennas, # of channels, modulation

- Heterogeneous nodes
- Directionality and neighbor discovery
- Multicast
- Cross-layer design





# The Biggest Challenge - Networking



**Research Goal:** A science of networks that enables us to Design, Analyze, Predict, & Control performance of (tactical) communications networks.

**How is it done now?**

Analysis (limited)

Simulation (OpNet, QualNet, ns2, etc.)

Emulation (with some hardware in the loop)

Small scale (5-50 nodes) field test *with mobility*

Large scale sensor experiments with commercial nodes

**Does not provide**

**\*\* Scaling behavior**

**\*\* Fidelity to PHY/MAC interaction & channel models**

**\*\* Run (faster than) real-time simulations**



**MIMO (and turbo) have significant potential for breakthrough enhancement of tactical mobile networks, but integrated MANET solution still lacking.**