Tactical Wireless Research &
Challenges

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.
Stanford University
AHPCRC
Sensors, Communications & Imaging

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Agenda

Internal Research Program
Collaborative Programs
Communications and Networks CTA
Network & Information Sciences ITA
Research Challenges
Summary
Vision

Self-configuring wireless network technologies that enable secure, scalable, energy-efficient, and survivable tactical networks

Research Areas

• Network Analysis, Modeling & Design for MANETs
• Signal Processing for Communications
• Intrusion Detection for MANETs
• Sensor Communications
• Laser Communications
• Network Scalability and Behavior Modeling
  ⚫ Scalability analysis of routing protocols with directional antennas and PHY-layer constraints

• Component-Based Routing
  ⚫ Networking that adapts its protocol components to perform better in varying operating conditions
  ⚫ Component-based performance modeling and analysis

• Intrusion Detection for MANETs
  ⚫ Intrusion detection and localization for network infrastructure protocols
  ⚫ Dynamic intrusion detection hierarchy of cooperative intrusion detection components

• Secure Network Emulation and Performance Analysis
  ⚫ Realistically emulate MANETs
  ⚫ Performance analysis of intrusion detection algorithms and networking protocols
**Vision:** Enable a fully-mobile, agile, situation-aware, and survivable lightweight force with internetted C⁴I systems

**Impact and Relevance:**
- Enables the Soldier to operate while on-the-move with a highly mobile network infrastructure, and
- Under severe bandwidth and energy constraints
- Provides the soldier with jam-resistant comms in noisy hostile environments
- Enables dynamic spectrum, resource, and network management
- Provides efficient security services that protect wireless MANETs without reliance on strategic services

**Technical Areas:**
- Survivable Wireless Mobile Networks
- Signal Processing for Secure Comms and Networking
- Tactical Information Protection

*TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.*
ACADEMIA
1. Carnegie Mellon University
2. City College of New York
3. Cornell
4. Georgia Tech
5. Princeton
6. Morgan State University
7. Stanford
8. Texas A&M
9. University of California - Davis
10. University of California - Riverside
11. University of Delaware
12. University of Maryland
13. University of Michigan
14. University of Minnesota
15. University of Washington

INDUSTRY
16. Telcordia Technologies (LEAD)
17. SPARTA
18. BBN Technologies
19. General Dynamics

Blue = full Consortium members,
Black = non-member participants
Survivable Wireless Mobile Networks

**FY06-07**
- Developed Controlled Dissemination Filter technology
- Developed MONOPATI network configuration toolset
- Characterized link lifetimes based on mobility
- Developed POMDP approach to optimal transmission scheduling

**FY08-09**
- Domain auto-configuration with social networking
- Component-based routing analysis and design
- Network modeling; capacity and scalability analysis techniques
- Dynamic and survivable network resource control for multicast flows

**Objective:** Develop networking capabilities to enable Army’s Vision of information dominance
Overall Plans

- Form advanced structures that improve key aspects of the underlying network.
- Develop a formal, versatile and efficient framework for diverse networks
  - Physical and logical network
  - Social, knowledge & resource networks
- Dynamically adapt structures as the mission, network and requirements evolve

Social Networking Extensions

- Task assignment for efficient resource utilization and robust real time organizational adaptation.
- Dynamic network analysis based on real data collected from military installations
- Structures’ optimality vs. adaptability

Intrusion Detection Extensions

- Requirements for efficient and Byzantine attack-resistant network structures

Objective: Design of a common, versatile, formal and algorithmic framework for efficient network configuration and assessment
Objective: Signal processing foundations for advanced communications for tactical MANETs & sensor networks

FY08-09
- MACs for MIMO, multi-packet reception and spectral agility
- Cross-layer design of MANETs and sensor networks
- UV and UWB communications
- Adaptive Cognitive MIMO Testbed experimentation

FY06-07
- Turbo-MIMO algorithms and adaptive coding schemes for low-complexity spectrally efficient comms
- Developed & tested efficient OFDM channel estimation, and synch algorithms
- Error-exponent characterization of distributed inference in sensor nets
**Tactical Information Protection**

**FY06-07**
- Distributed cooperative detection and localization of in-band wormhole attacks in MANETS
- Byzantine-resistant routing attack detection
- Efficient group key management
- Threat models for cross-domain information flows

**FY08-09**
- Distributed dynamic trust management
- Efficient group key management
- Dynamic intrusion detection hierarchies

**Objective:** Automated detection of vulnerabilities and efficient security services to prevent attacks, without compromising agility
Enhancing distributed, secure, and flexible decision-making to improve coalition operations

**Network Theory**
- Theoretical Foundations for Design of Wireless and Sensor Networks
- Interoperability of Wireless Networks and Systems
- Biologically-Inspired Self-Organization in Networks

**Sensor Information Processing and Delivery**
- Quality of Information of Sensor Data
- Task-Oriented Deployment of Sensor Data Infrastructures
- Complexity Management of Sensor Data Infrastructures

**Security Across a System-of-Systems**
- Policy Based Security Management
- Energy Efficient Security Architectures and Infrastructures
- Trust and Risk Management in Dynamic Coalition Environments

**Distributed Coalition Planning and Decision-Making**
- Mission Adaptive Collaborations
- Command Process Transformation and Analysis
- Shared Situational Awareness/Semantic Battlespace Infosphere

**Technology Driven. Warfighter Focused.**
ITA Team Overview

ACADEMIA
1. Carnegie Mellon University
2. City University of New York
3. Columbia University
4. Pennsylvania State University
5. Rensselaer Polytechnic Institute
6. University of California Los Angeles
7. University of Maryland
8. University of Massachusetts

INDUSTRY
9. BBN Solutions LLC
10. The Boeing Corporation
11. Honeywell Aerospace Electronic Systems
12. IBM Research
13. Klein Associates

ACADEMIA
1. Cranfield University, Royal Military College of Science, Shrivenham
2. Imperial College, London
3. Royal Holloway University of London
4. University of Aberdeen
5. University of Cambridge
6. University of Southampton
7. University of York

INDUSTRY
8. IBM UK
9. LogicalCMG
10. Roke Manor Research Ltd.
11. Systems Engineering & Assessment Ltd.
Fundamental underpinnings for adaptive networking to support complex system-of-systems and ad hoc coalition teams

- **Theoretical foundations for design of wireless and sensor networks** (Towsley, U. Mass)
- **Interoperability of wireless networks and systems** (Hancock, RMR/Lee IBM-US)
- **Biologically-Inspired self-organization in networks** (Lio Cambridge/Pappas IBM-US)

**FY08-09 Objectives**

- Mathematical models of interoperation to enable design of coalition networks
- Analysis of community patterns in biological networks and their applications to wireless systems.
- Models analyzing MANETs and performance of protocols
Theoretical Foundations

• Determine fundamental limits of wireless networks
  – *dynamically* changing environment
    • mobility, varying channel conditions, intermittent nodes
  – *new* technologies (e.g., MIMO, network coding)
  – *application* metrics (capacity, delay, sensing quality)
  – *energy*, *bandwidth*, *computation* constraints

• Develop frameworks and algorithms for resource allocation
  – account for *dynamic/uncertain* conditions
  – *application* metrics
  – *Joint* MAC, scheduling & routing

• Conditions for Connectivity
  – *Cooperation* models
Sensor information processing and delivery from distributed multi-modal sensor systems within adaptive sensor networks

- Quality of Information of sensor data  
  (Bisdikian, IBM-US)
- Task-oriented deployment of sensor data infrastructure  (La Porta, Penn State)
- Complexity management of sensor data infrastructure  (Szymanski, RPI)

FY08-09 Objectives

- Quality of information representations to facilitate fusion at multiple levels
- Adaptive data infrastructures based on mission requirements and sensor-mission matching algorithms
- Information overload reduction techniques for military sensor networks
Research Challenges

- Inadequate models of network behavior
- Lack of analytic methods and heuristics to understand impact of network design options and trade-offs
- Limitations of large-scale discrete-time, event-driven simulations
  - High fidelity modeling from PHY to APL
  - Very large parameter space
- Lack of large-scale network emulation capability
- Techniques to analyze and visualize large quantities of network data

Objective: Develop capabilities to assess and analyze mobile ad hoc network designs for large networks, such as WIN-T and FCS.
``Model, design, analyze, predict, and control the behavior of secure (tactical) communications, sensing, and command-and-control (or decision-making) networks.’’

Understand the interactions between these complex networked system-of-systems

Lead to Network Designs with predictable performance

Need HPC Support to Achieve
Questions