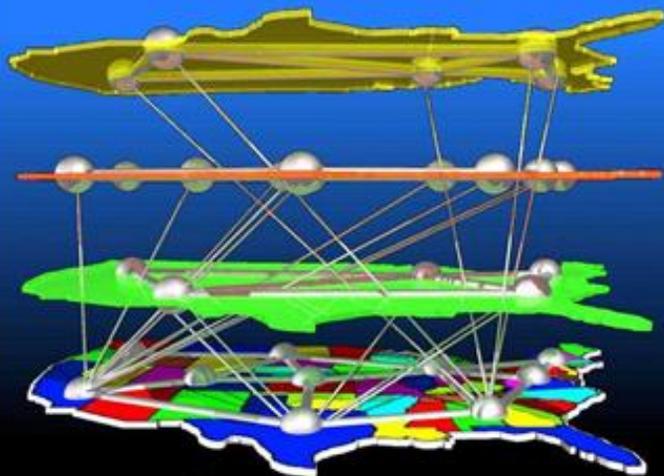


Supporting the information technology industry with measurements, standards, and research...

*Providing the networking industry with the  
best in test and measurement research*

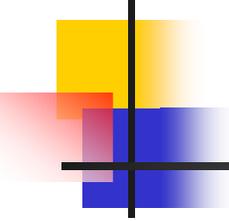


**A**dvanced  
**N**etwork  
**T**echnologies  
**D**ivision

<http://w3.antd.nist.gov/>

ANTD Contacts: <http://www.antd.nist.gov/>

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# General Guiding Themes

## **Mission:**

*Provide the networking industry with the best in test and measurement research.*

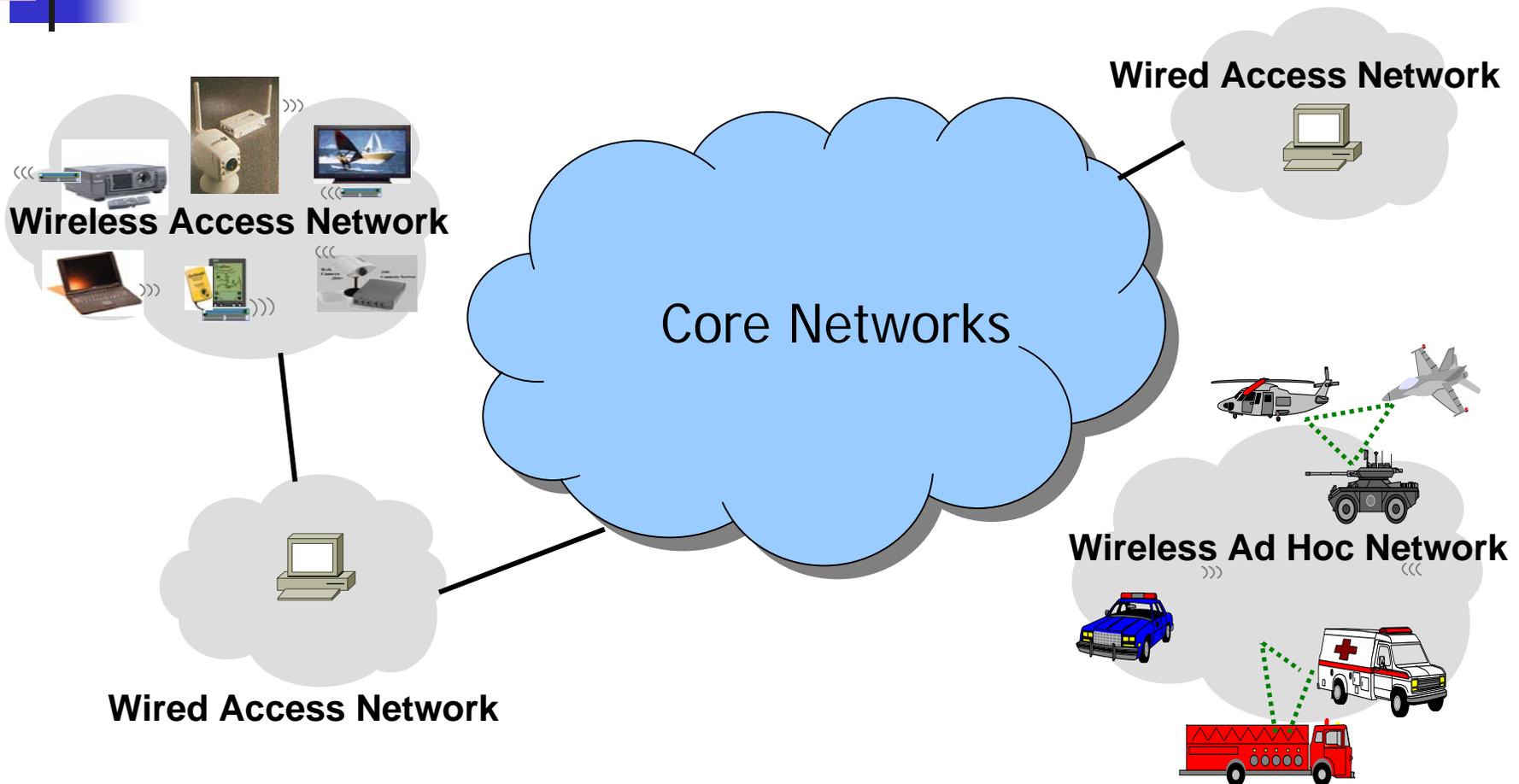
## **Goals:**

- **To improve the quality of emerging networking specifications and standards.**
- **To improve the quality of networking products based on public specifications.**

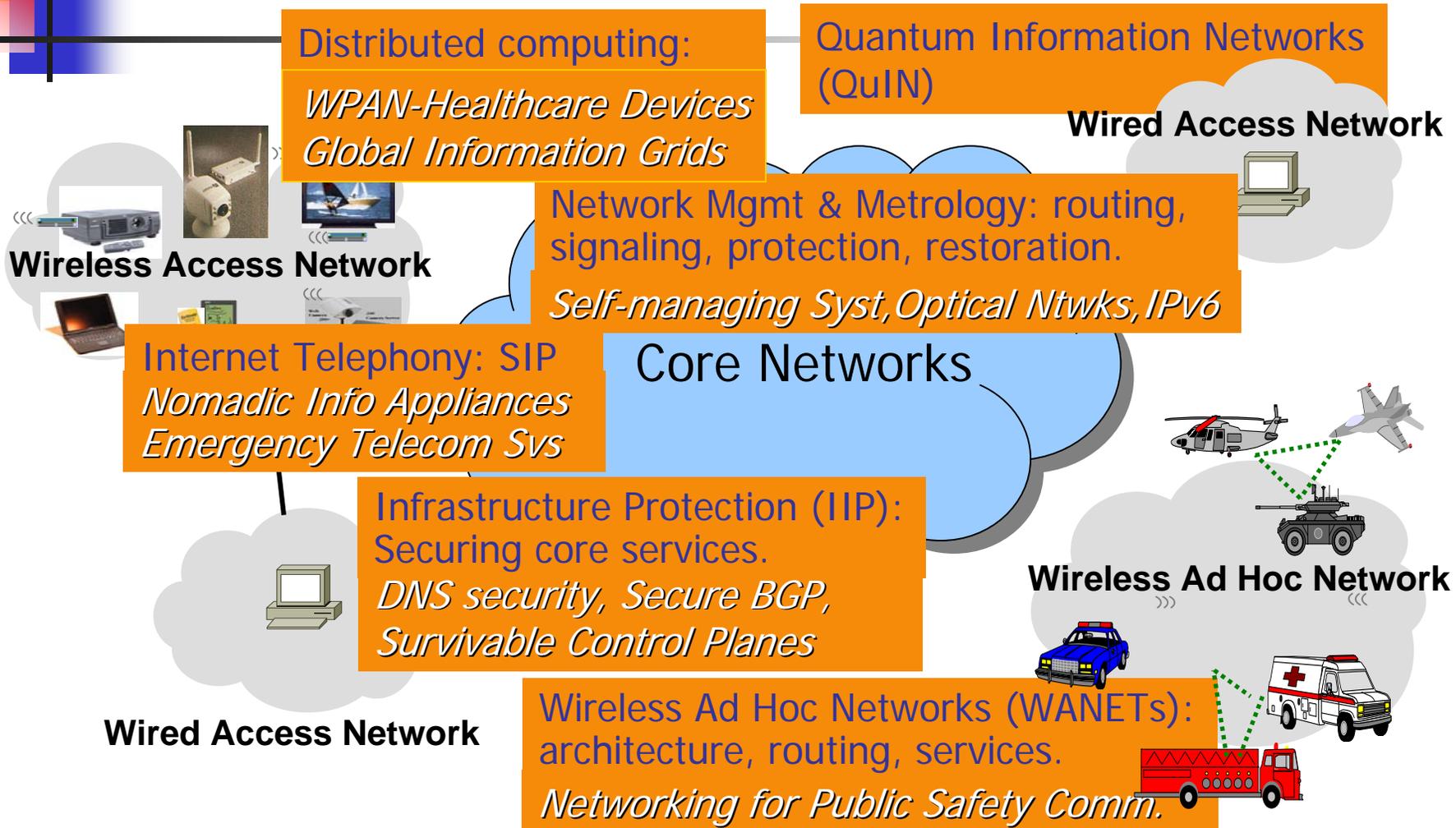
## **Core Technical Contributions:**

- **Models and analyses from specifications to assess consistency, completeness, precision, and performance characteristics**
- **Prototypes and empirical studies from specifications to determine feasibility**
- **Test and measurement tools, techniques, metrics, and data to assess conformance, interoperability, and performance**

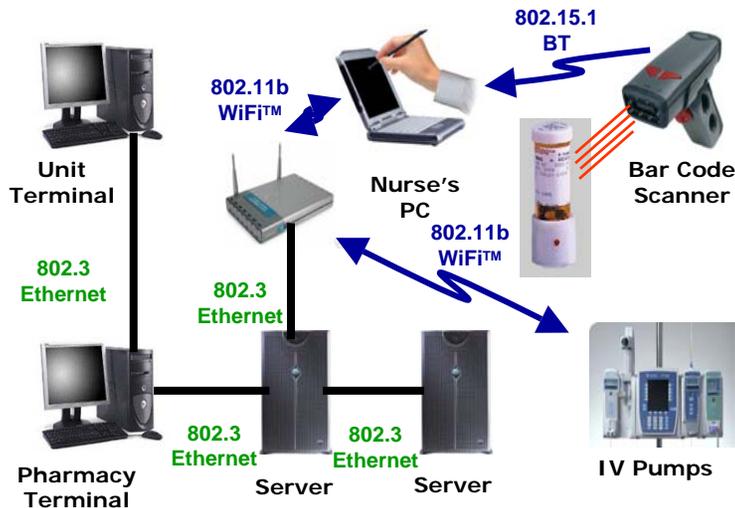
# ANTD Research Areas & Projects



# ANTD Research Areas & Projects



# Healthcare, Wireless Technologies, and You



picture by Rickey Hampton, Partners Healthcare

## Goals

Assist in the development of a universal and interoperable wireless interface for medical equipments and contribute to the IEEE 1073 standardization effort.

## Technical Approach

Investigate what wireless technologies can be used for medical applications and how well they perform in a healthcare/hospital environment:

- Evaluate the performance of existing and emerging IEEE 802 wireless technologies and their suitability to a hospital/healthcare environment.
- Study scalability, interference, and performance trade-off issues and the need to support tens of communicating devices in a patient's hospital room.

## Accomplishments

- Produced theoretical service data rates which may be used as IEEE 802.15.4 standard reference.
- Extended the WPAN coexistence evaluation and modeling platform to include low-rate WPAN models and healthcare scenarios.
- Produced presentations and tutorials on the IEEE 802.15.4 wireless technology and its possible usage in medical environments.
- Completed 2 conference papers and 1 journal article.

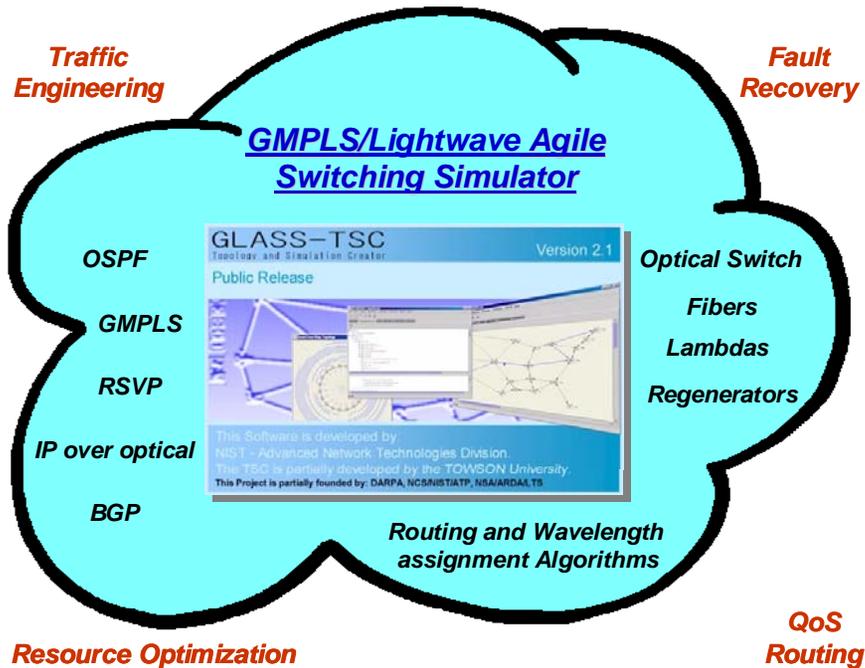
## Impact

- Expedited the IEEE 1073 standards activities and the development of guidelines for wireless medical device communications.

## Future Plans

- To continue to expand and refine coexistence evaluation and modeling platform and release it to the public via the NIST web site.
- To supply IEEE 1073 with reference data for supporting the creation of a guidelines document for wireless technology for medical device communications.
- To evaluate reliability issues when using various wireless technologies for medical device communications.
- To publish future results in conference and journal papers.

# Agile Switching Infrastructures



## Goals

To work with industry and government customers to accelerate the development and deployment of integrated, agile switching infrastructures. Main foci: (1) integrated control planes for optical switched internets and (2) dynamic control algorithms for traffic engineering and for fault tolerance.

## Technical Approach

- Employ GLASS simulation environment to evaluate routing, signaling, and recovery protocols proposed by standards development organizations.
- Design and evaluate dynamic control algorithms for integrated MPLS / WDM networks.
- Extend GLASS to enable evaluation of physical layer technologies and assess how these might effect emerging IP/WDM management schemes.

## Recent Accomplishments

- Supported the IETF's protection and restoration design team with GLASS simulations and performance results.
- Extended the GMPLS/Lightwave Agile Switching Simulator (GLASS) with models of optical regenerators and shared path recovery schemes.
- Published results in conference and journal articles.

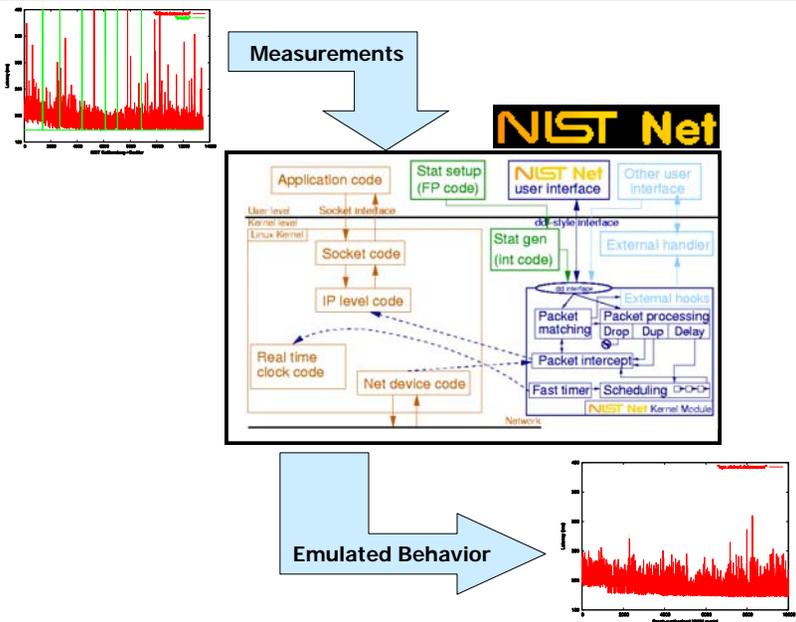
## Impact

- Enhancements to optical control plane standards developed at the IETF.
- Guidelines and performance trade-off studies to benefit end-users, network planners and Internet service providers.

## Future Plans

- Extend GLASS by developing the capability to simulate networks with optical burst and optical packet switching.
- Develop theoretical and simulation models to evaluate protocols for next generation optical technologies.
- Extend design and analysis work to other applications, such as storage area networks.
- Support development of high-speed networks for scientific collaboration involving large data sets and real-time interactions.

# Network Metrology, Modeling and Management



## Goals

- To assist the development of new techniques for measuring, modeling and managing networks.

## Technical Approach

- Work with research community to integrate advanced network models and available measurement data into practical tools for network research and development.
- Devise new approaches to the modeling emergent behaviors in large scale networks.
- Explore new generation of network processors technology to prototype and evaluate emerging architectures for packet metrology in very high speed networks.
- Work with industry to define extensions to emerging network management frameworks so as to enable next generation autonomic systems.

## Accomplishments and Impact

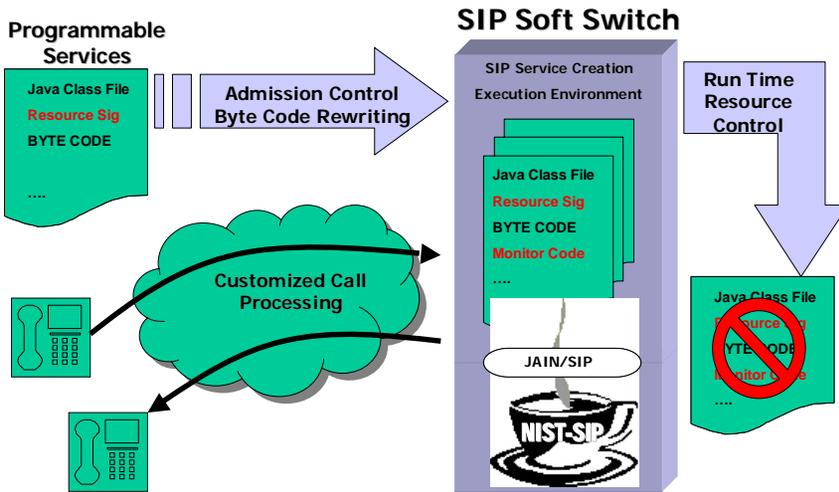
- Publish 3 research papers/chapters on fundamental techniques for analysis / detection of macroscopic emergent behaviors in large scale networks.
- Integrated into NISTNet multi-fractal wavelet models and tools to parameterize them from public measurement data. Published 2 research papers on these extensions and new work on modeling microscopic behaviors of high speed networks. Developed extensive calibration framework and data for network emulation tool.
- Devised untrained learning algorithms for detection of anomalous traffic flows.
- Evaluated semantic translation and mapping requirements for DTMF CIM management information models.

## Future Plans

- Conduct basic research to develop a modeling and analysis framework for emergent behaviors in complex systems.
- Design and evaluate extensions to CIM/WEBM management frameworks necessary to support next generation self managing systems.
- Prototype and evaluate algorithms and architectures for high speed packet metrology based upon network processor technologies.

# Internet Telephony & SIP Signaling

## Programmable Active Services for SIP (PASS)



## Accomplishments

- Co-designed (with Sun MS) new JAIN/SIP 1.2 specification (JSR 32) for Java SIP platforms.
- Developed NIST-SIP 1.2 reference implementations and test tools. Integrated NIST-SIP J2ME (JSR-180) port in Distributed First Responder Testbed. Developed embeddable (browsers, EJB, SLEE) NIST-SIP stack.
- Conducted simulation analysis of SIP in WANets and published research papers on proposed mechanisms to improve the hand-off performance for mobile users. Released NS SIP / MANet simulation framework.
- Designed and prototyped security and resource control framework for programmable active services for SIP. Incorporating PASS techniques into JAIN Service Logic Execution Environment (SLEE, JSR 240) security framework. PASS publication submitted.

## Goals

- Design, evaluation and standardization of technologies to expand the capabilities and scope of applicability of emerging Internet Telephony standards.
- To foster technologies for programmable signaling services in devices ranging from wireless handhelds to carrier class switches.

## Technical Approach

- Design and development of architectures and standards for programmable SIP platforms and services (JAIN SIP, PASS, embeddable SIP).
- Research and measurement of SIP signaling in wireless ad-hoc networks.
- Test and evaluation of scalable presence and content distribution mechanisms to enable location / context / content aware call control.

## Impact

- Continued to lead the development of industry standard software architecture and API's for Java based SIP services.
- Developed and released new NIST-SIP research platforms widely used through out the research and development community. NIST-SIP adopted as kick-off project in Java.net community. [downloaded by 2600 unique orgs since Jan 2003, 800 members on mailing list]
- Published new approaches to SIP integration in WANets.

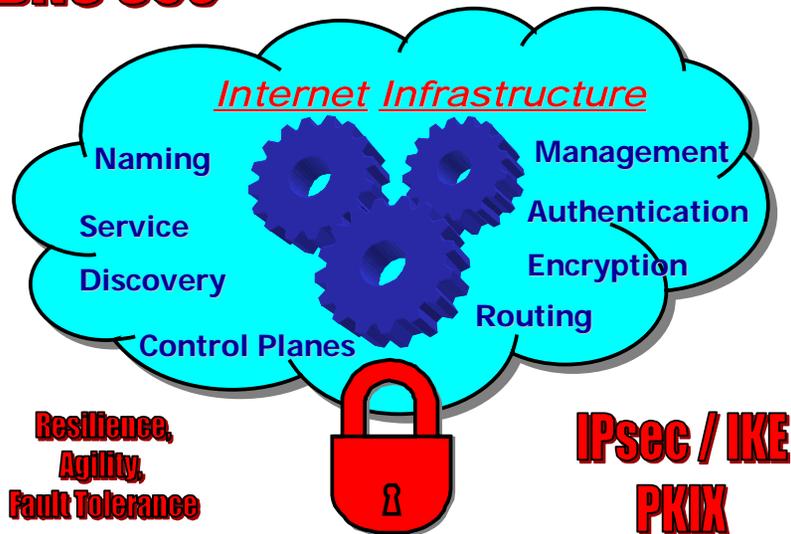
## Future Plans

- Continue to research and develop new approaches to scalable presence, content distribution and context aware communications
- Design & evaluate SIP extensions for emergency communications.
- Incorporate PASS technologies into standardized security frameworks for JAIN service creation environments.

# Internet Infrastructure Protection

**DNS Sec**

**BGP Sec**



## Goals

- Improve the performance, scalability, interoperability of Internet security services.
- Expedite the development and adoption of protection mechanisms for core Internet naming and routing infrastructure services.
- Research and develop techniques to exploit emerging programmable data planes to improve the survivability of Internet infrastructures.

## Technical Approach

- Foster IETF/OIF specifications for network layer security and key management technologies. Develop reference implementations, test systems and simulation frameworks to evaluate behavior and performance.
- Contribute to the design, specification, testing and measurement of DNS and BGP security technologies. Work with other agencies to foster adoption and deployment.
- Research approaches to incorporate control plane security mechanisms and DDOS mitigation techniques in emerging network processor based protocol architectures.

## Accomplishments and Impact

### Leading the development of key standards:

- Lead IETF editorship of (5) core DNSSEC specifications.
- Lead IETF editorship of (3) AES/IPsec specifications.

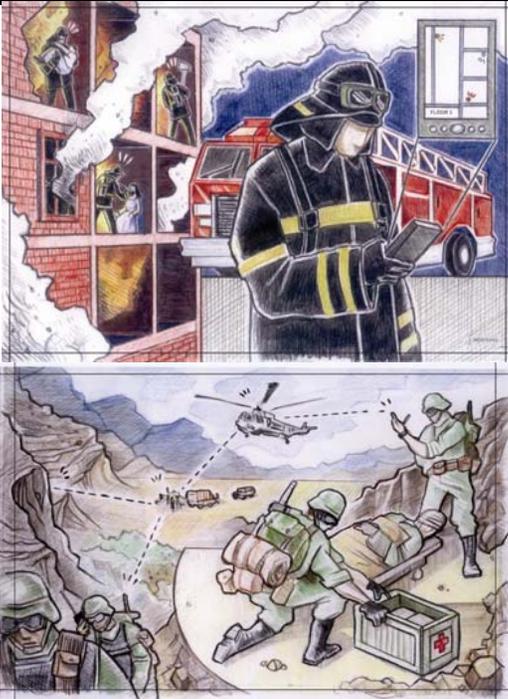
### Tools and analysis to expedite industry adoption:

- Released NIST IPsec/IKE Simulation Tool and published characterizations of IPsec/IKE VPNs.
- Developed reference implementation and evaluation of OIF UNI protection profile based upon IPsec/IKE.

## Future Plans

- Develop test and measurement framework, tools and reference data sets for emerging DNSSEC implementations and pilot deployments.
- Design and standardize "last mile" interface between application and secure DNS infrastructure.
- Evaluate the BGP threat models and mitigation techniques.
- Develop a simulation and modeling framework to characterize the threat of large-scale attacks on BGP routing and to compare the effectiveness of proposed mitigation techniques.
- Research extensions to the architectures and protocols for Forwarding and Control Element Separation (ForCES) to enable control plane resource protection and improved survivability / security.

# Communication and Networking Technologies for Public Safety



## Goals

To facilitate the development, standardization, and deployment of modern communications, networking, and indoor localization technologies for public safety operations.

## Technical Approach

- Turn NIST into premier national laboratory for testing and evaluation of various communications and networking technologies for public safety.
- Disseminate test and evaluation results to standardization organizations and government agencies responsible for public safety.
- Study interoperability of public safety communication technologies and develop mechanisms to improve interoperability.
- Organize workshops to jumpstart standardization for indoor localization.

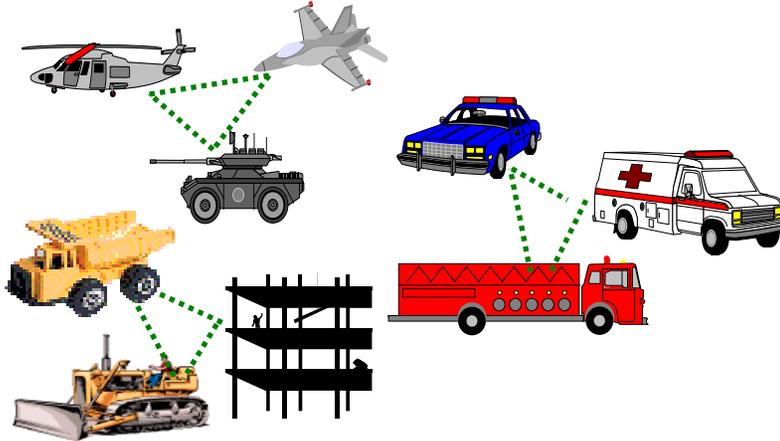
## Accomplishments & Impact

- Developed Distributed Testbed for First Responders (DTFR) in collaboration with BFR and MEL integrating various technologies from 3 NIST labs.
- DTFR was demonstrated and very well received to a large number of times to fire/police chiefs, industry, and other government agencies.
- Released prototype research software developed for DTFR on ANTD web site.
- Developed the document "System Reference Model" for Project MESA.

## Future Plans

- Develop guide on public safety applications of wireless technology for users and practitioners in that field.
- Actively participate in Project MESA and NPSTC standardization meetings.
- Develop methodology and evaluate performance of indoor localization techniques.
- Evaluate performance of emerging commercial indoor localization products.
- Design, prototype, and evaluate novel techniques and protocols to improve performance of DTFR.

# Wireless Ad Hoc Networks



## Goals

To facilitate the development of technology and standards for wireless ad hoc networks (WANETs).

## Technical Approach

- Develop metrics and measure performance of various WANET protocols to facilitate standardization.
- Study MAC layer performance and QoS provision in WANETs.
- Develop simulation models of popular WANET protocols.
- Develop WANET hardware test bed based on WLAN technology to complement analytical and simulation work.
- Study collaborative signal processing and communication and networking aspects of smart sensor networks.

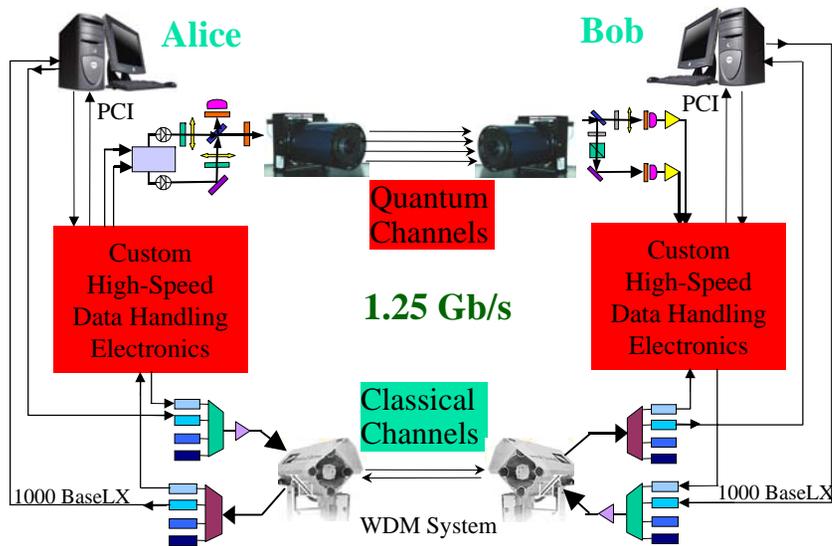
## Accomplishments & Impact

- Published 3 journal and 7 conference papers.
- AODV implementation was adopted and used in emerging products by a number of companies (Nova Engineering, Ascentry Technologies, Intel).
- Further expanded popular knowledge bases on performance analysis and simulation of WANETs.
- Supported IEEE 802.15 standardization activities.

## Future Plans

- Investigate cross-layer protocol optimization issues, such as use of AODV routing information in video encoding and use of physical layer information and link quality in routing.
- Develop fast, realistic simulation models of large WANETs.
- Investigate scalability of WANETs.
- Evaluate performance of security mechanisms for DSRC standard for vehicle safety communications.
- Evaluate applicability and effectiveness of smart antenna techniques in WANETs.

# Quantum Communications Testbed



## GOAL

Design & Implement a Record Breaking High-Speed Free-Space Quantum Key Distribution Communication Testbed and conduct related research in Quantum Networks and Protocols.

## Technical Approach

- Prototype quantum key distribution protocols and evaluate their performance in QuIN testbed.
- Research techniques to improve the performance of quantum key distribution protocols.
- Characterize the performance limitations of an optical quantum communication link.

## Accomplishments and Impact

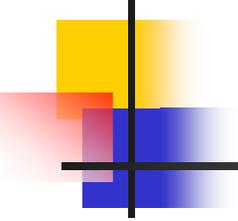
- Completed integration of the lasers, optics, electronics, and software into an operational QKD system with an effect key exchange rate of 1Mbit/sec.
- Established a new record in the speed of quantum key distribution.

## Collaborators

- DARPA, BBN
- NIST Physics, Electronics & Engineering Laboratories.
- ITL Computer Security, Math Science Divisions

## Future Plans

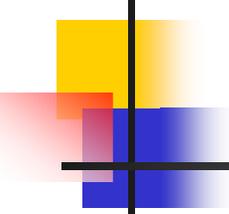
- Complete testbed system integration
- Tune & Enhance Quantum Sources & Detectors
- Tune & Enhance Optics
- Tune & Enhance Data Handling Boards
- Integrate sifting into hardware
- Implement Demonstration QKD Application
- Design a Companion Fiber QKD Testbed
- Investigate Integration into Std Security Protocols
- Investigate Classical Channel Authentication
- Investigate Methodology for Statistical Evaluation



# Additional Material

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- Publications - FY 2004 (October 2003 - 2004)
- Tools for Industry

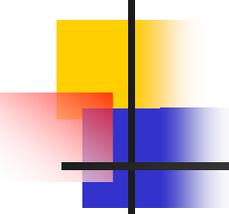


# Papers

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## Networking for Pervasive Computing

- N. Golmie, "Bluetooth Dynamic Scheduling and Interference Mitigation," ACM Mobile Networks, MONET Vol. 9, No. 1, February 2004.
- K. Mills, S. Rose, S. Quiroigico, M. Britton, and C. Tan, "An Autonomic Failure-Detection Algorithm", Proceedings of the 4th International Workshop on Software Performance (WoSP 2004), January 14-16, 2004, San Francisco, California, ACM Press, p. 79.
- N. Golmie, N. Chevrollier, and O. Rebala, "Bluetooth and WLAN Coexistence: Challenges and Solutions," IEEE Wireless Communications Magazine, Vol. 10, No. 6, December 2003.
- N. Golmie, R. E. Van Dyck, A. Soltanian, A. Tonnerre, and O. Rebala, "Interference Evaluation of Bluetooth and IEEE 802.11b Systems," in ACM Wireless Networks 2003, Vol. 9, pp. 202-211.
- N. Golmie, O. Rebala, "Bluetooth Adaptive Techniques to Mitigate Interference," Proceedings of IEEE GLOBECOM 2003, December 5-10, San Francisco, CA.
- N. Golmie, N. Chevrollier, O. Rebala, "Bluetooth and WLAN Coexistence: Challenges and Solutions," IEEE Wireless Communications Magazine, December 2003.
- N. Golmie, N. Chevrollier, and O. Rebala, "Bluetooth Adaptive Frequency Hopping and Scheduling," in the Proceedings of Military Communications, MILCOM 2003, Boston, MA, October 12-16, 2003.

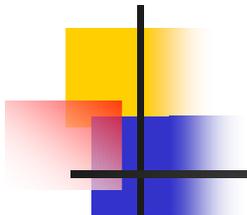


# Papers

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## WPAN in Healthcare Environment

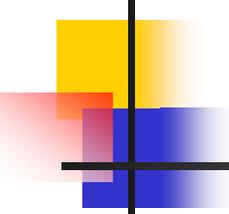
- N. Golmie, D. Cypher, O. Rebala, "Performance Analysis of Low Rate Wireless Technologies for Medical Applications," to appear in the *Proceedings of IEEE Globecom 2004 - Wireless Communications, Networks, and Systems* held November 29 - December 3, 2004.
- N. Golmie, D. Cypher, O. Rebala, "Performance Analysis of Low Rate Wireless Technologies for Medical Applications," to appear in *Computer and Communication's special issue on WPANs*.
- N. Golmie, D. Cypher, O. Rebala, "Performance Evaluation of Low Rate WPANs for Sensors and Medical Applications," to appear in the *Proceedings of Military Communications Conference (MILCOM 2004)* held October 31 - November 3, 2004.



# Papers

## Agile Switching and Optical Networks

- S. Lee, K. Sriram, H.S. Kim, and J.S. Song, "Contention-Based Limited Deflection Routing Protocol in Optical Burst-Switched Networks", accepted for publication in the *IEEE J. Selected Areas in Commun.*, special issue on Optical Communication and Networking (2004).
- K. Sriram, D. Griffith, R. Su, and N. Golmie, "Static Vs. Dynamic Regenerator Assignment in Optical Switches: Models and Cost Trade-offs," accepted for presentation at *The 2004 IEEE Workshop on High Performance Switching and Routing* (HPSR 2004), April 2004, Phoenix, AZ, pp. 151-155.
- D. Griffith, K. Sriram, S. Lee, and N. Golmie, "Restorability versus Efficiency in  $(1:1)^n$  Protection Schemes for Optical Networks," accepted for presentation at *ICC 2004* Optical Networking Symposium.
- S. Lee, K. Sriram, H. Kim, and J. Song, "Contention-Based Limited Deflection Routing in OBS Networks", the *Proc. of the IEEE Globecom 2003*, San Francisco, December 2003.
- K. Sriram, D. Griffith, S. Lee, and N. Golmie, "Optical Burst Switching: Benefits and Challenges," First International Workshop on \ Optical Burst Switching (WOBS), in conjunction with OptiComm 2003, Dallas, TX, 16 October 2003.
- K. Sriram, D. Griffith, S. Lee, and N. Golmie, "Backup Resource Pooling in  $(M:N)^n$  Fault Recovery Schemes in GMPLS Optical Networks," in *Proceedings of SPIE* Vol. 5285 OptiComm 2003: Optical Networking and Communications, edited by Arun K. Somani, Zhensheng Zhang, (SPIE, Bellingham, WA, 2003), pp. 185-196.
- D. Griffith, R. Rouil, S. Klink, and K. Sriram, "An Analysis of Path Recovery Schemes in GMPLS Optical Networks with Various Levels of Pre-Provisioning," in *Proceedings of SPIE* Vol. 5285 OptiComm 2003: Optical Networking and Communications, edited by Arun K. Somani, Zhensheng Zhang, (SPIE, Bellingham, WA, 2003), pp. 197-208

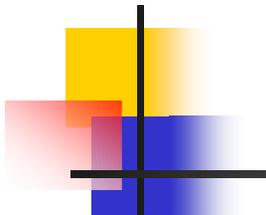


# Papers

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## **Network Metrology, Modeling, and Management**

- J. Yuan and K. Mills, "Macroscopic Dynamics in Large-Scale Data Networks", chapter in upcoming book *Complex Dynamics in Communication Networks*, edited by Ljupco Kocarev and Gábor Vattay, to be published by Springer, in press.
- V. Marbukh and R. E. Van Dyck, "On aggregate utility maximization by greedy ASs competing to provide Internet services," submitted to IEEE Globecom 2004, Dallas, Tx, Nov.-Dec., 2004.
- Mark Carson, Darrin Santay (2004). "Micro-time-scale Network Measurements and Harmonic Effects," in *Passive and Active Network Measurement, Proceedings of the 5th International Workshop, PAM 2004, LNCS 3015*, Springer Verlag, Berlin.
- V. Marbukh, "On aggregate Utility Maximization Based Network Management: Challenges and Possible Approaches," *IEEE International Communications Conference (ICC 2004)*, Paris, France, 2004.
- S. Kumar and V. Marbukh, "On Route Exploration Capabilities of Multi-Path Routing in Variable Topology Ad hoc Networks," *IEEE Instrumentation and Measurement Technology Conference, (IMTC 2004)*, Como, Italy, May 2004.
- V. Marbukh, "Towards Flexible Service Level Agreements," *Proc. Conf. on Information Sciences and Systems*, Princeton University, March, 2004.
- V. Marbukh, "Towards Market Approach to Providing Survivable Services," *Proc. Conf. on Information Sciences and Systems*, Princeton University, March, 2004.
- N. Chevrollier and R. E. Van Dyck, "Packet filtering for aggregate-based congestion control," *Proc. Conf. on Information Sciences and Systems*, Princeton, NJ, March 2004.
- V. Marbukh and R. E. Van Dyck, "On competition between greedy autonomous systems in providing Internet services: emergent behavior and stability," *Proc. Conf. on Information Sciences and Systems*, Princeton, NJ, March 2004.

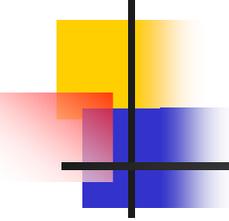


# Papers

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## Wireless

- C. Gentile and L. Klein-Berndt, "Robust Location using System Dynamics and Motion Constraints," to appear in the *Proc. IEEE Conf. on Communications*, June 2004.
- Byung-Jae Kwak, Nah-Oak Song and L. E. Miller, "On the Scalability of Ad Hoc Networks: a traffic analysis at the center of a network," *Proc. WCNC 2004*, Atlanta, 21-25 March 2004.
- D. J. Shyy, H. Gharavi, and K. Ban, "System Design Tradeoff for Supporting Soft Handoff in 3G cdma2000 Networks," *Proc. WNCG Wireless Networking Symposium*, Austin, Texas, 22-24 October 2003.
- H. Gharavi and K. Ban, "Cross-layer Feedback Control for Video Communications via Mobile Ad-hoc Networks," *Proc IEEE 2003 Fall VTC*, October 2003.

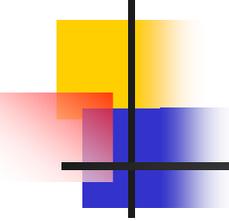


# Papers

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## Quantum Information Networks

- J. Bienfang, A. Gross, A. Mink, J. Hershman, A. Nakassis, X. Tang, R. Lu, D. Su, C. Clark, and C. Williams, "Quantum Key Distribution with 1.25 Gbps Clock Synchronization," to appear in *Optics Express*, 2004
- A. Nakassis, J. Bienfang and C. Williams, "Expeditions Reconciliation For Practical Quantum Key Distribution," to appear in *Proceedings SPIE, Quantum Information and Computation II*, 2004
- C. Williams, X. Tang, M. Heikero, J. Rouzard, R. Lu, A. Goedecke, A. Migdall, A. Mink, A. Nakassis, L. Pibida, J. Wen, E. Hagley, and C. Clark, "A High Speed Quantum Communications Testbed", *Proceedings SPIE, International Symposium of Optical Science and Technology*, July 2002.



# Papers

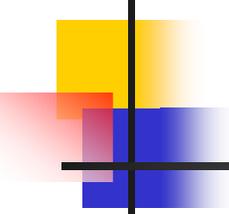
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## Other Topics

Camillo Gentile, Octavia Camps, and Mario Sznaiier, "Segmentation for Robust Tracking in the Presence of Severe Occlusion," *IEEE Trans. on Image Processing*, Vol. 13, No. 2, pp. 166-178, Feb. 2004.

Robert Snelick, Michael Indovina, James Yen and Alan Mink, "Multimodal Biometrics: Design and Testing Issues", *Proc. 5th Intrn'l Conf on Multimodal Interfaces (ICMI'03)*, Vancouver, B.C., Nov. 2003, pp 66-71.

Michael Indovina, Umut Uludag, Robert Snelick, Alan Mink and Anil Jain, "Multimodal Biometrics Authentication Methods: A COTS Approach", *Proc. Workshop Multimodal User Authentication (MMUA'03)*, Santa Barbara, CA, Dec. 2003, pp 99-106.



# Tools for Industry

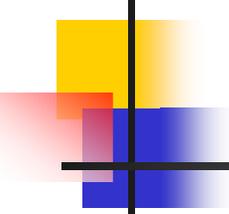
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## **Agile Switching**

*GLASS- GMPLS/Optical Network Simulation Tool* – tool for design and evaluation of dynamic control algorithms for traffic engineering, intrusion detection and fault tolerance in integrated MPLS / optical networks – <http://www.antd.nist.gov/glass/>  
*NIST Switch: MPLS Research Platform* – <http://www.antd.nist.gov/nistswitch/>

## **Networking for Pervasive Computing**

Rapide models for Jini and UPnP (released on request to four research groups).  
SLP, Discrete-Event Simulation Model written in SLX.  
Coexistence models for Bluetooth and WLAN– MAC and PHY layer simulation models to evaluate the impact of interference on the performance of Bluetooth and WLAN networks.  
[http://www.antd.nist.gov/wlan\\_wpan.shtml](http://www.antd.nist.gov/wlan_wpan.shtml)  
Universal Plug-and-Play, Version 1.0, Discrete-Event Simulation Model written in SLX.  
Jini™, Version 1.1, Discrete-Event Simulation Model written in SLX.



# Tools for Industry

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## **Internet Security**

Cerberus/PlutoPlus: - IPsec/IKE reference implementation – August 2001

<http://www.antd.nist.gov/cerberus/>

IPsec-WIT: Web based IPsec/IKE interoperability test system – August 2001

<http://ipsec-wit.antd.nist.gov/>

NIST IKE(v1/v2)/IPsec Simulation Tool: <http://www.antd.nist.gov/niist/>

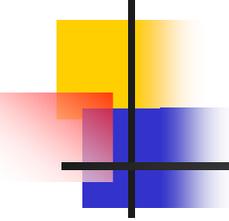
## **Internet Telephony**

*NIST-SIP* – Research platform and reference implementation of a JAIN/SIP/SIP-Lite compliant signaling stack, extensible message parser, scripting environment for call flow generation. <http://www.antd.nist.gov/proj/iptel/>.

*SIP-WIT*: WWW-based SIP interoperability test system <http://sip-wit.antd.nist.gov/>

## **Network Metrology, Modeling and Management**

NIST Network Emulation Tool (NIST Net) – <http://www.antd.nist.gov/nistnet/>



# Tools for Industry

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## **Wireless Ad Hoc Networks**

C++ Software modeling tool for physical layers of Bluetooth and IEEE 802.11 (1 and 11 Mb/s): <http://www.antd.nist.gov/wctg/bluetooth/btint.html>

Kernel Implementation of AODV Ad Hoc routing protocol:  
[http://www.antd.nist.gov/wctg/aodv\\_kernel/](http://www.antd.nist.gov/wctg/aodv_kernel/)

OPNET model for MANET AODV routing protocol:

[http://www.antd.nist.gov/wctg/manet/prd\\_aodvfiles.html](http://www.antd.nist.gov/wctg/manet/prd_aodvfiles.html)

Spreadsheet application for calculation of outdoor propagation loss:

[http://www.antd.nist.gov/wctg/manet/prd\\_propcalc.html](http://www.antd.nist.gov/wctg/manet/prd_propcalc.html)

Spreadsheet application for calculation of link budgets:

[http://www.antd.nist.gov/wctg/manet/prd\\_linkbudgetcalc.html](http://www.antd.nist.gov/wctg/manet/prd_linkbudgetcalc.html)