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Hybrid Mesh Networking for Distributed Operations

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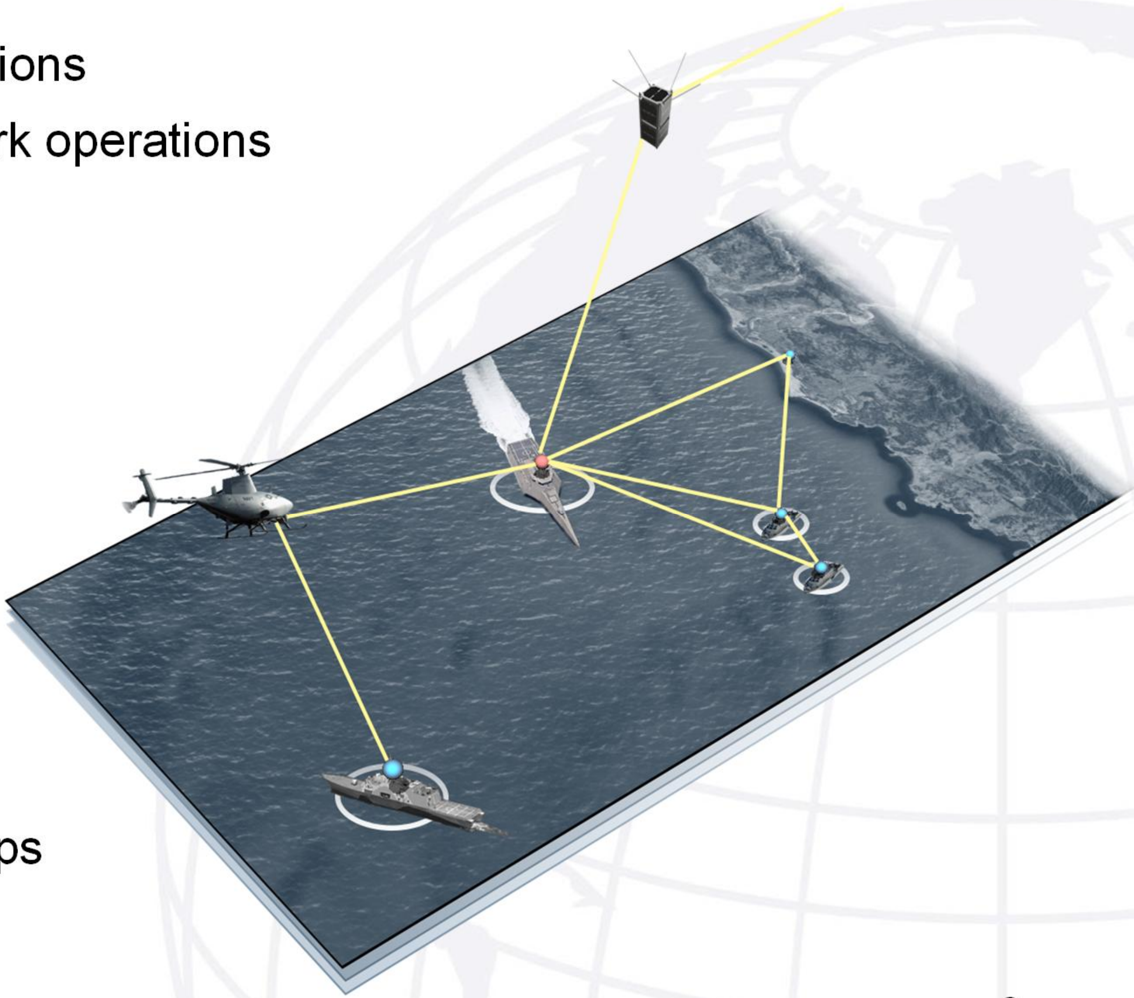
CENTER FOR NETWORK CENETIX INNOVATION AND EXPERIMENTATION

LITTORAL OPERATIONS CENTER
LOC

Overview

- Distributed Operations
  - Motivation
  - Dispersed littoral operations
  - Distributed mesh network operations
- Mesh Networking
  - Network topologies
  - Fundamentals
  - Technologies
- Field Experimentation
  - NMIOTC Crete 2015
  - SF Bay 2015
- Tactical Implications
  - Enhancing distributed ops



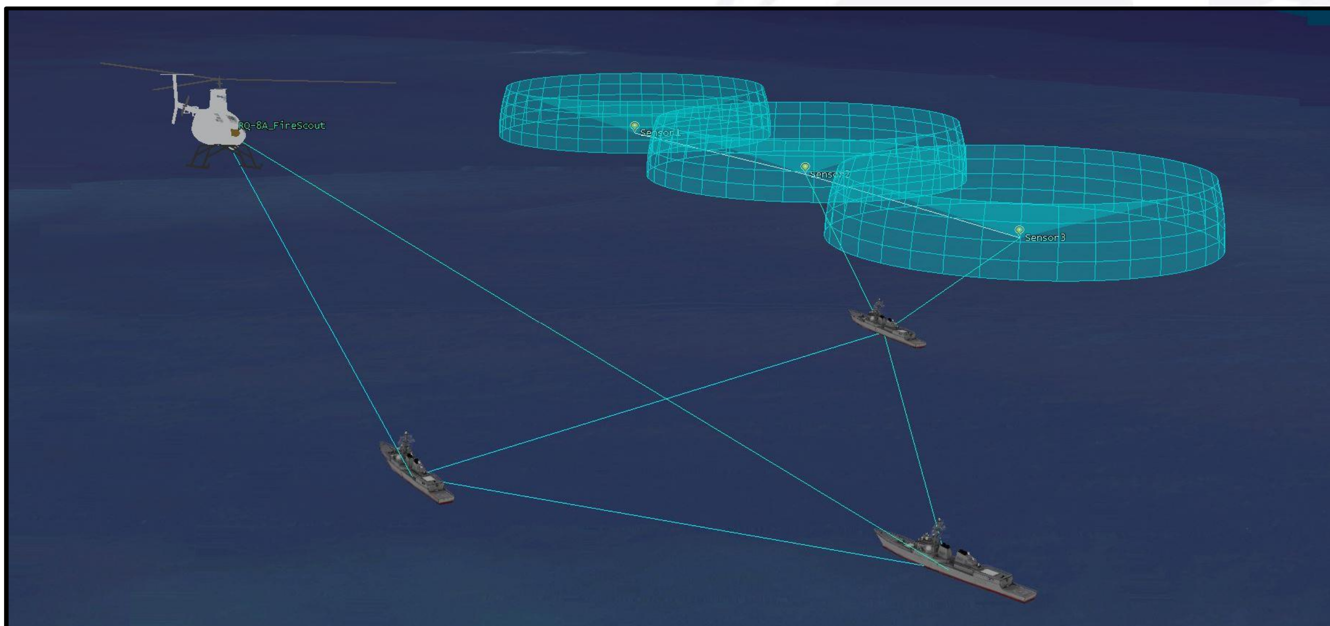
Motivation: Distributed Operations

- Give operational commanders options to employ naval forces in any anti-access/area-denial (A2/AD) environment.
  - Improve offensive capabilities
  - Develop new CONOPs, doctrine and tactics
  - Seek out innovative methods for employing forces

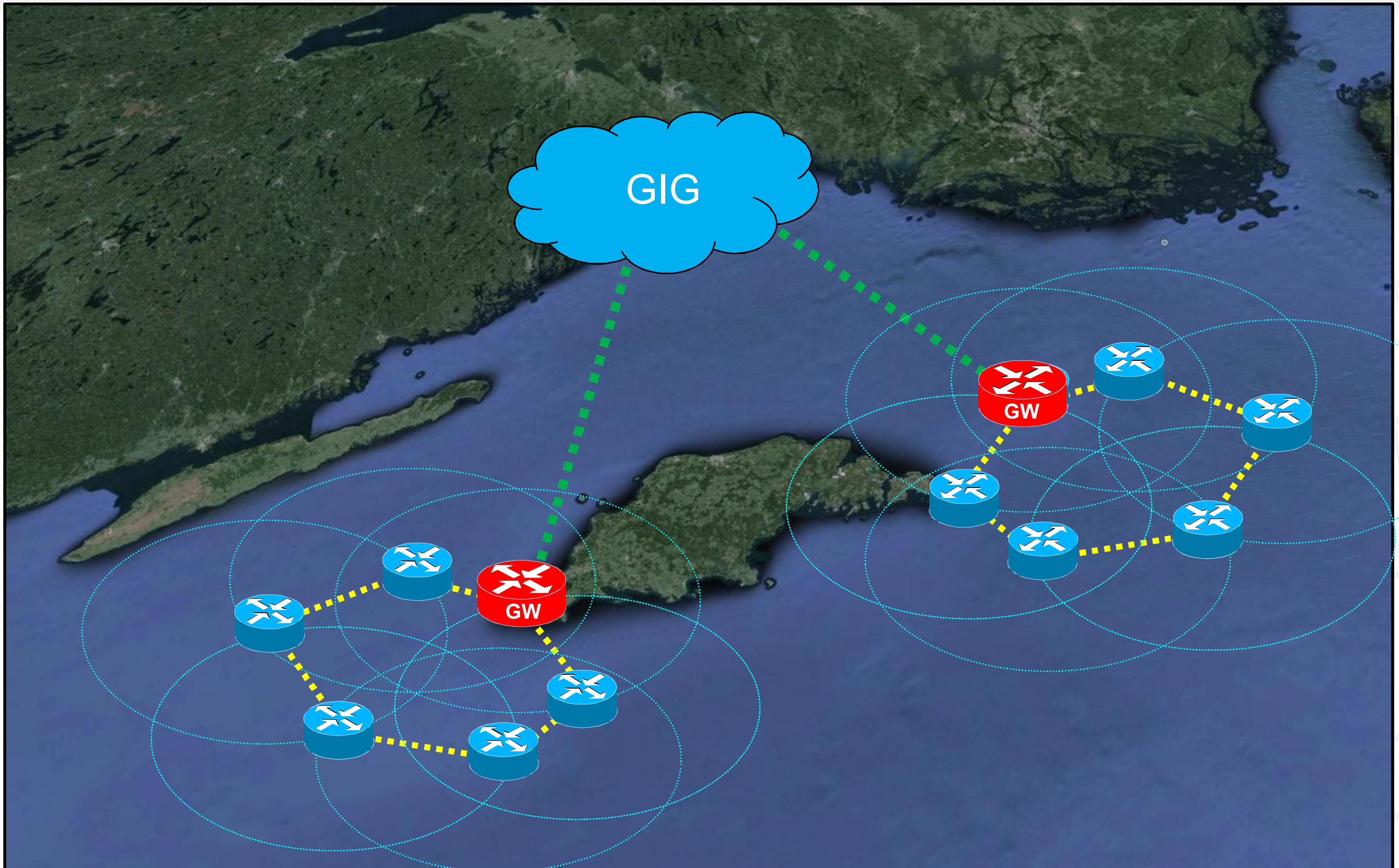
Distributed operations are a complex operating model requiring innovative approaches to Command and Control (C2).

Distributed Littoral Operations

- Littorals are among the most challenging and complex environments for disaggregated or dispersed operations
  - Inherently joint/combined
  - Congested RF spectrum
  - Diverse terrain features
  - Dense commercial and maritime traffic

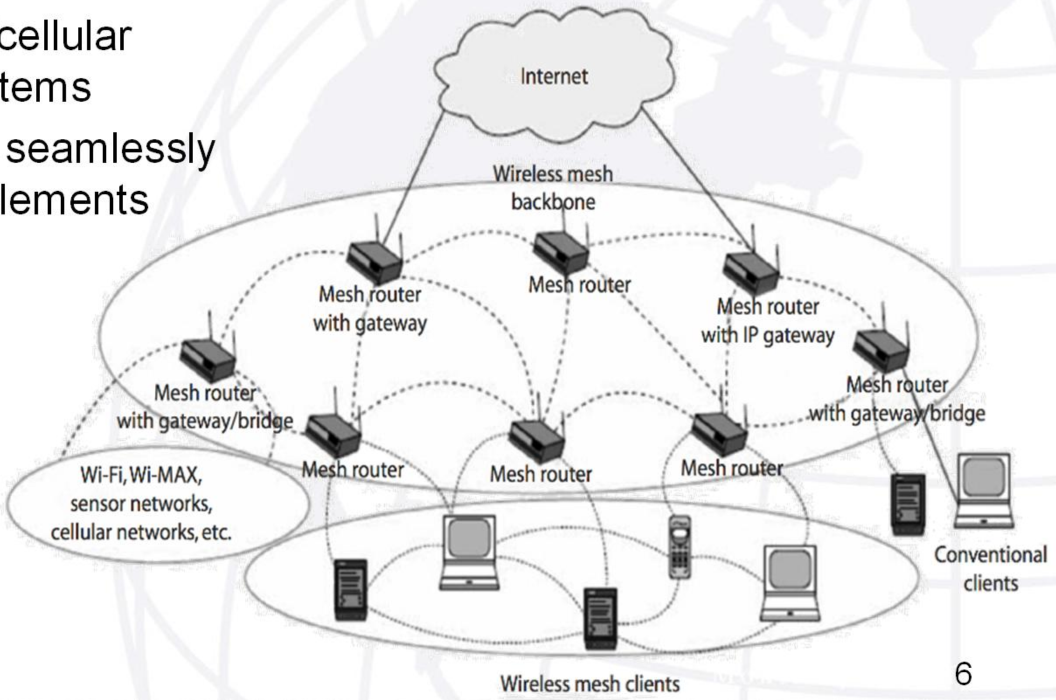


Distributed Mesh Network Operations

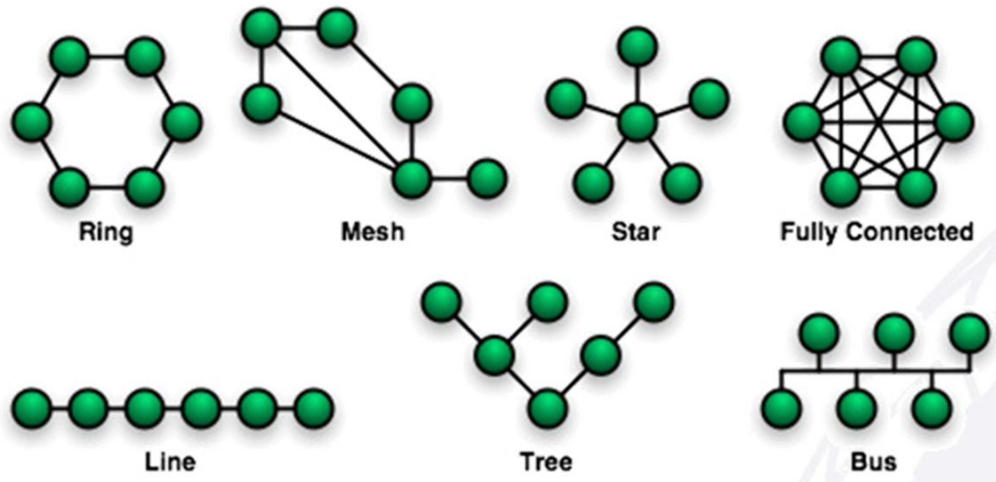


Hybrid Mesh Networks

- Highly mobile, high-bandwidth data, video and voice communications
- Self-forming, self-healing, scalable peer-to-peer networks
- Connectivity across disparate networks
- Leverage existing infrastructure to enable reachback
  - GIG access through shore 4G/cellular networks or legacy satcom systems
  - Mesh-network-over-IP WAN to seamlessly connect distributed operating elements across geographic areas



Network Topologies



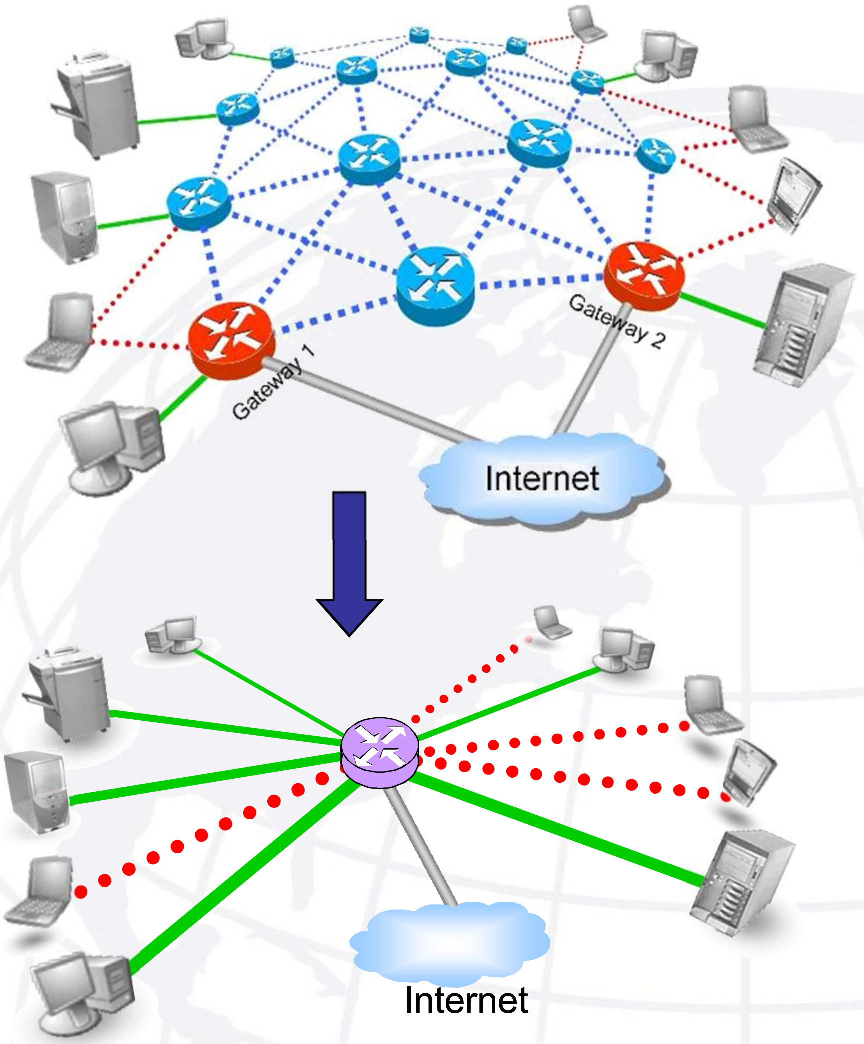
Full mesh: each node is directly connected to all other nodes.

Partial mesh: not all nodes are directly connected.

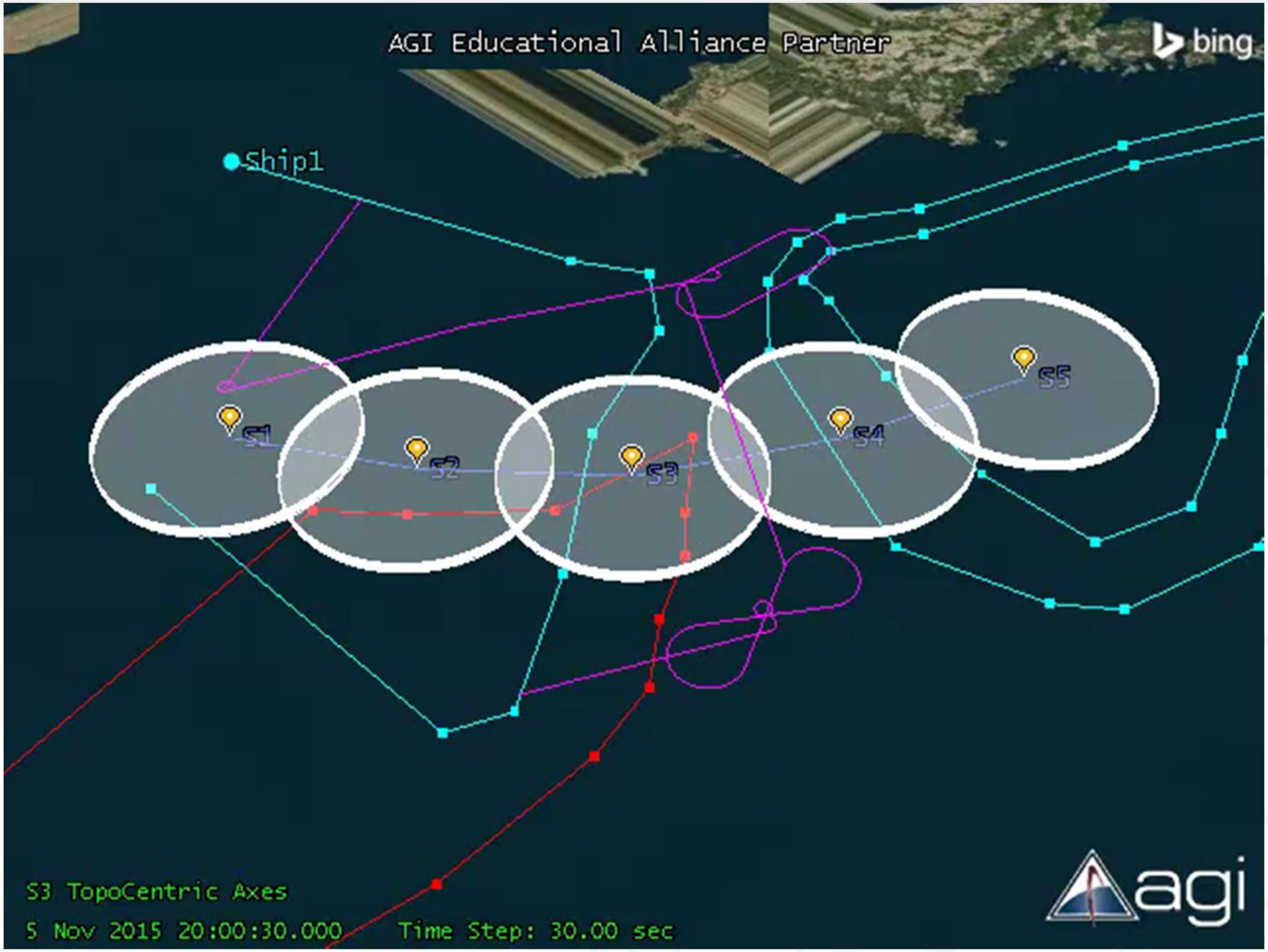
Wireless Mesh Network (WMN) are multi-hop peer-to-peer wireless network in which ***nodes connect with redundant interconnections*** and cooperate with one another to route packets.

Layer 2 Connectivity

- The entire wireless mesh cloud becomes one (giant) ethernet switch
  - Perfect for short-term and opportunistic/delay-tolerant networks



Mesh Network Modeling



Technologies - Wave Relay

Man Portable Units (Quad Radio & MPU4)

Peer-to-Peer MANET

- Proprietary Wave Relay Layer 2 Routing
- Simultaneously support voice, video streaming, IP data, PLI

WR Frequency Range	WR Output Power
907-922 MHz	27dBm/500mW
2312-2507 MHz	28dBm/600mW
2412-2462 MHz	28dBm/600mW
5180-5320, 5500-5700, 5745-5825 MHz	28dBm/600mW
2312-2507 MHz	33dBm/2W*
1352-1387 MHz	27dBm/500mW
4400-4800 MHz	25dBm/320mW
4800-4985 MHz	26dBm/400mW

NETWORKING

- Seamless layer 2 network connectivity.
- Industry leading Wave Relay® MANET routing.
- 802.11a/b/g AP compatible with MANET.
- Integrated serial-to-Ethernet capability.
- Cursor-on Target.
- Wave Relay® over IP (WRoIP)
- Dynamic Link Exchange Protocol (DLEP) Certified.
- IPV4 and IPV6 compatible.
- Integrated DHCP server.
- Advanced multicast algorithm.

SECURITY

- Integrated hardware cryptographic accelerator.
- FIPS 140-2 (Up to level 2).
- Utilizes all Suite B algorithms.
- Anti-tamper mechanisms.
- AES-CTR-256 with SHA-512 HMAC.
- Over the air re-keying.

ANDROID(TM)

- Multicast Video, position locator and chat in a Android application.
- Supports commercial/custom phones and tablets.
- Provides power through USB tether.

Technologies - TrellisWare

TW-225 CheetahNet Mini

Infrastructure-less MANET

- Dynamic Network Architecture at MAC layer and above
- Barrage Network Relay
- Simultaneously support voice, video streaming, IP data, PLI

PHYSICAL

- **Size (w/o Accessories):** 4.0' x 2.5' x 0.9'
- **Weight (w/o Accessories):** 10 oz
- **Environmental:** MIL-STD 810G, 2 Meter Immersion
- **Power In/Out:** External Power Supply, 6-18 V DC
- **Battery Run Time:** > 10 Hours
- **Data Interfaces:** Ethernet (RJ-45), USB mini A/B

NETWORK

- **Transmit Power:** 2 Watt
- **Operating Frequencies:** 1775-1815 MHz, 2200-2250 MHz
- **Network Throughput:** Up to 8 Mbps
- **Encryption Security:** AES-256
- **Range:** (26 miles per hop) x (8 hops) = 208 miles network wide
- **PTT Voice Channels:** Up to 12 channels
- **Occupied Bandwidth:** 4-20 MHz
- **Data Handling:** IPv6 or IPv4

TrellisWare® TECHNOLOGIES

Technologies - Harris

Highband Networking Radio (HNRv2)

ATH or OTM mesh networking

- Dynamic Network Architecture at MAC layer and above
- 802.11g OFDM physical layer
- Black or colorless ad-hoc network backbone
- ATO

HNRv2 Capability and Implementation

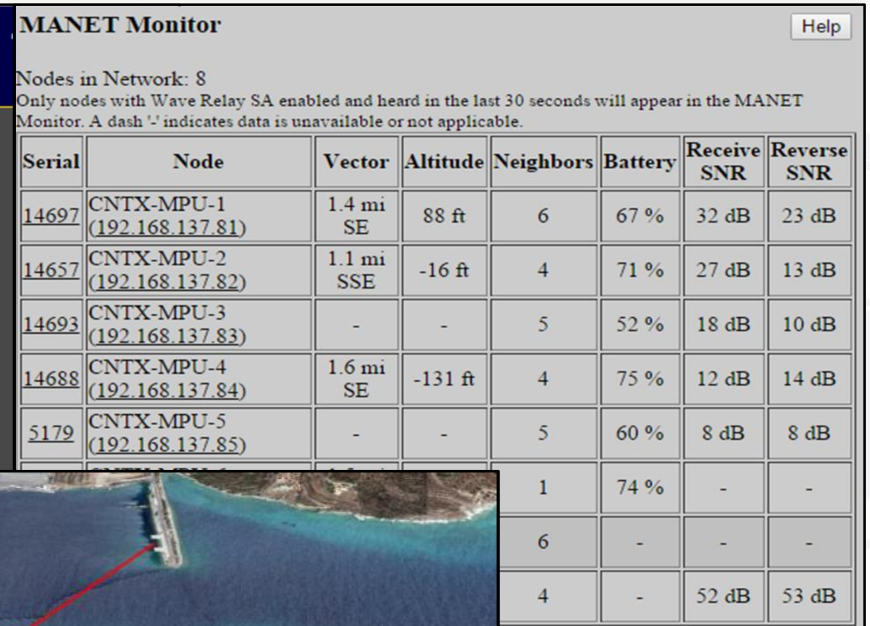
Performance Parameter	Capability
Radio (BPU) SWaP	½ ATR form factor (4.9"x8.5"x14.2") 14 lbs +20 to +33 Vdc 180 W
Highband RF Unit (HRFU) SWaP	20" x 20" x 15" 60 lbs +20 to +33 Vdc 90 W
Current Band	C-band (4.5 to 4.99 GHz)
Occupied Bandwidth	22 MHz
RF Coverage	Full hemispherical
Tiers	Air and ground
Operational Modes	Warm-up Silent Watch; MANET operation
Network Modes	Point-to-Point; MANET; Managed Topology
Network Size	Easily supports battalion-size network configurations
Router	Internal to BPU, MANET IOS OSPF or EIGRP router protocols PPPoE OSPF.v3 interfaces
AES TRANSEC Cover	AES 256 bit; AES FIPS 197 certified FIPS 140-2 Level 2 certified
Modem	TDD/TDMA OFDM
Modulations	BPSK, QPSK, 16 QAM, 64 QAM with ½ and ¾ rate coding
Data rate adaptation	8 burst rates from 6 to 54 Mbps
Range	Ranges up to 30 km
Environmental	
Sheltered Equipment	+20°F to 110°F (extended temp option available)
Antenna	−35°F to 120°F (includes full solar loading)
Antenna Electronics	−35°F to 120°F (includes full solar loading)
Reliability: MTBF	>6500 hrs (based on actual performance)

TrellisWare® TECHNOLOGIES

Recent NPS Research

- CENETIX
  - WMD-ISR
  - MIO and SSE operations
- Crete 2015
  - MIO/CWMD SA sharing in littorals
- SF Bay 2015
  - CWMD SA sharing and C2 in littorals
  - Mesh network management decision support

NMIOTC Crete 2015



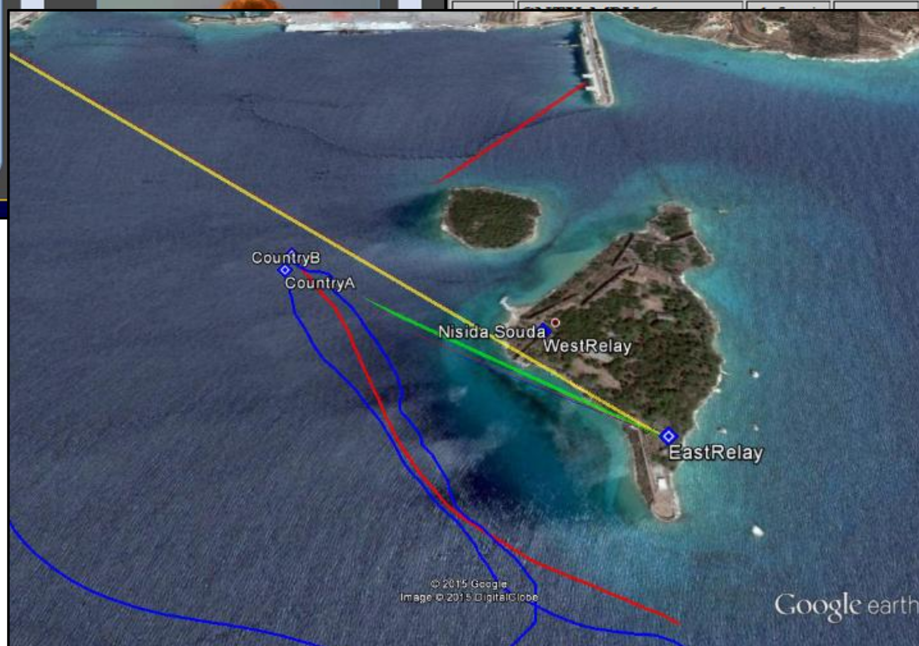
MANET Monitor

Help

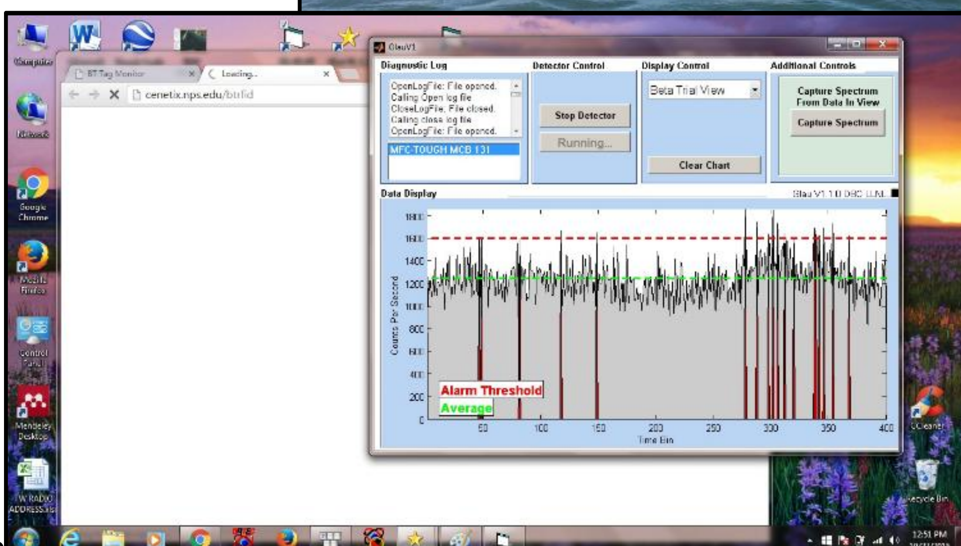
Nodes in Network: 8

Only nodes with Wave Relay SA enabled and heard in the last 30 seconds will appear in the MANET Monitor. A dash '-' indicates data is unavailable or not applicable.

Serial	Node	Vector	Altitude	Neighbors	Battery	Receive SNR	Reverse SNR
14697	CNTX-MPU-1 (192.168.137.81)	1.4 mi SE	88 ft	6	67 %	32 dB	23 dB
14657	CNTX-MPU-2 (192.168.137.82)	1.1 mi SSE	-16 ft	4	71 %	27 dB	13 dB
14693	CNTX-MPU-3 (192.168.137.83)	-	-	5	52 %	18 dB	10 dB
14688	CNTX-MPU-4 (192.168.137.84)	1.6 mi SE	-131 ft	4	75 %	12 dB	14 dB
5179	CNTX-MPU-5 (192.168.137.85)	-	-	5	60 %	8 dB	8 dB
				1	74 %	-	-
				6	-	-	-
				4	-	52 dB	53 dB



SF Bay 2015


Diagnostic Log
Detector Control
Display Control
Additional Controls
Stop Detector
Running...
Beta Trial View
Clear Chart
Capture Spectrum From Data In View
Capture Spectrum
MFC-TOUGH MCB 131
Data Display
Counts Per Second
Time Bin
Alarm Threshold
Average

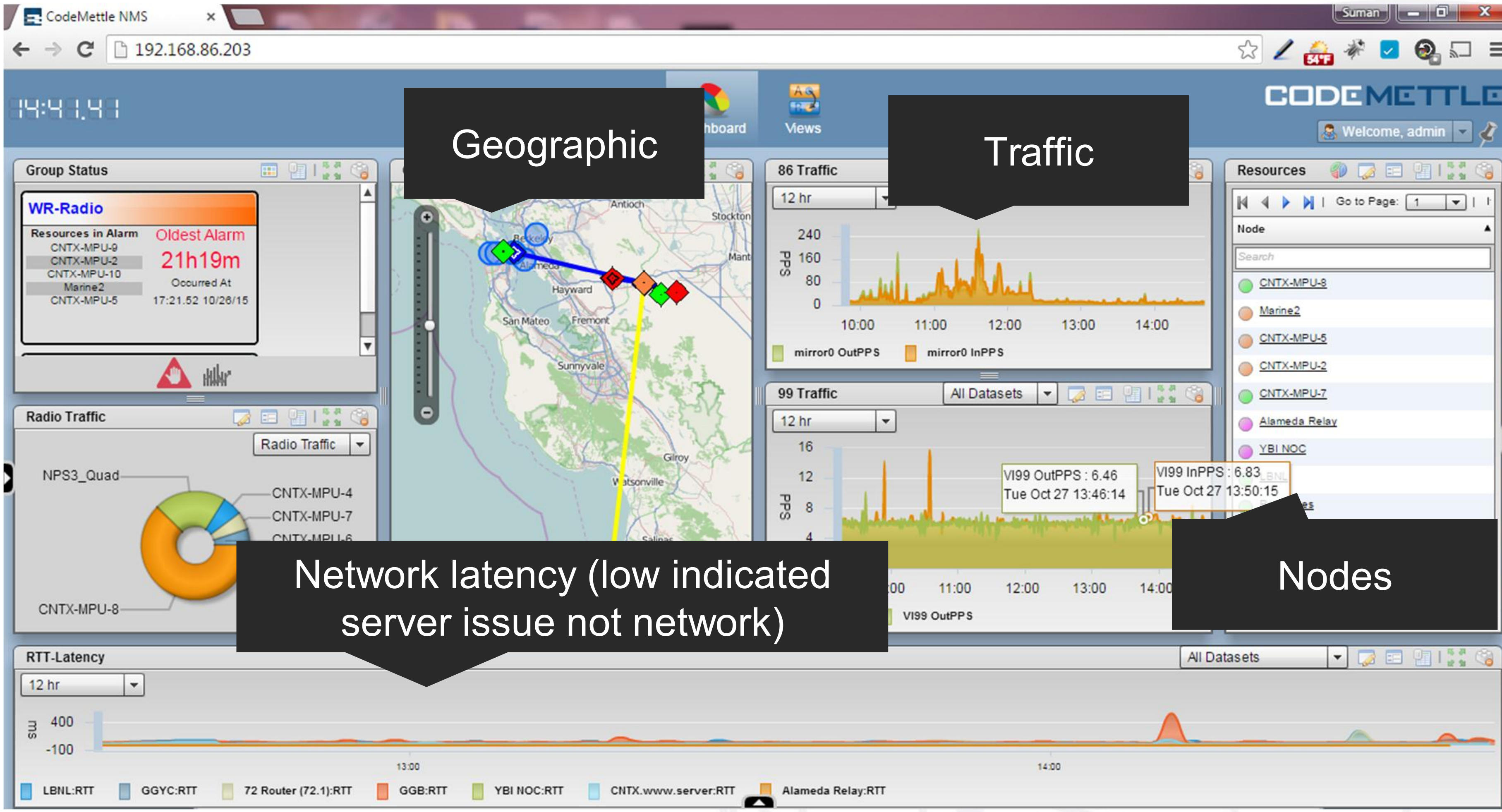

Vstream-Tx
Refresh
Stream ID: ROV
Streaming server IP: cenetix.nps.edu
Fps: 10
BW: 200 (Kbps)
Qlty: 90
08:44:02

SF Bay 2015 - CodeMettle

- CodeMettle Network Service Orchestrator
  - Unified network management dashboard
- Experiment support
  - Centralized awareness and management
    - Geo-Positioning
    - IP traffic performance
    - Visualize dynamic tactical mesh topologies
  - High-level results
    - Detect tactical network failure in real time
    - Analyze application failure to hardware vs network
  - Post-experiment
    - Provide historical experiment events for research

SF Bay 2015 - CodeMettle

CENETIX Backbone: Node health, traffic and quality



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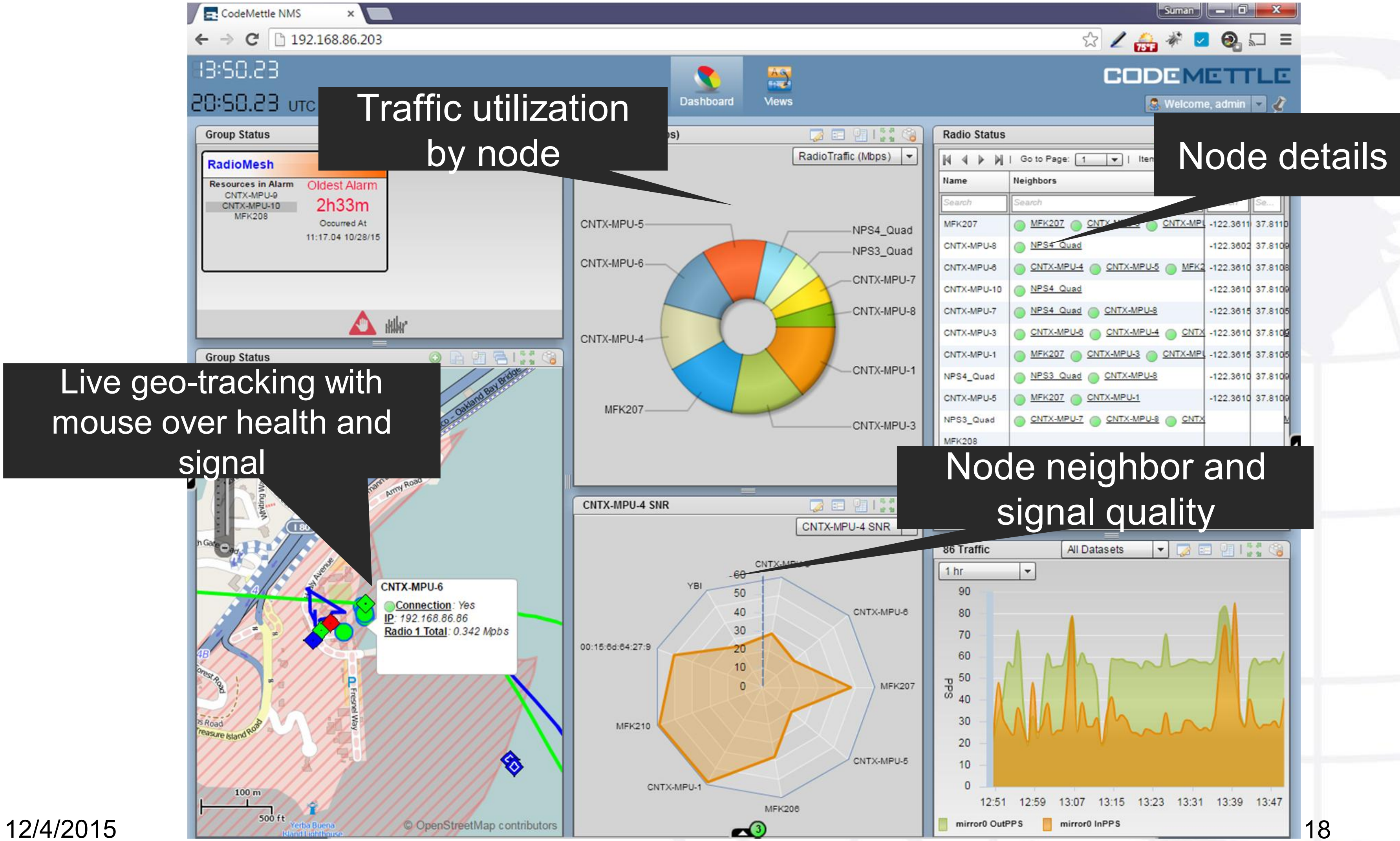
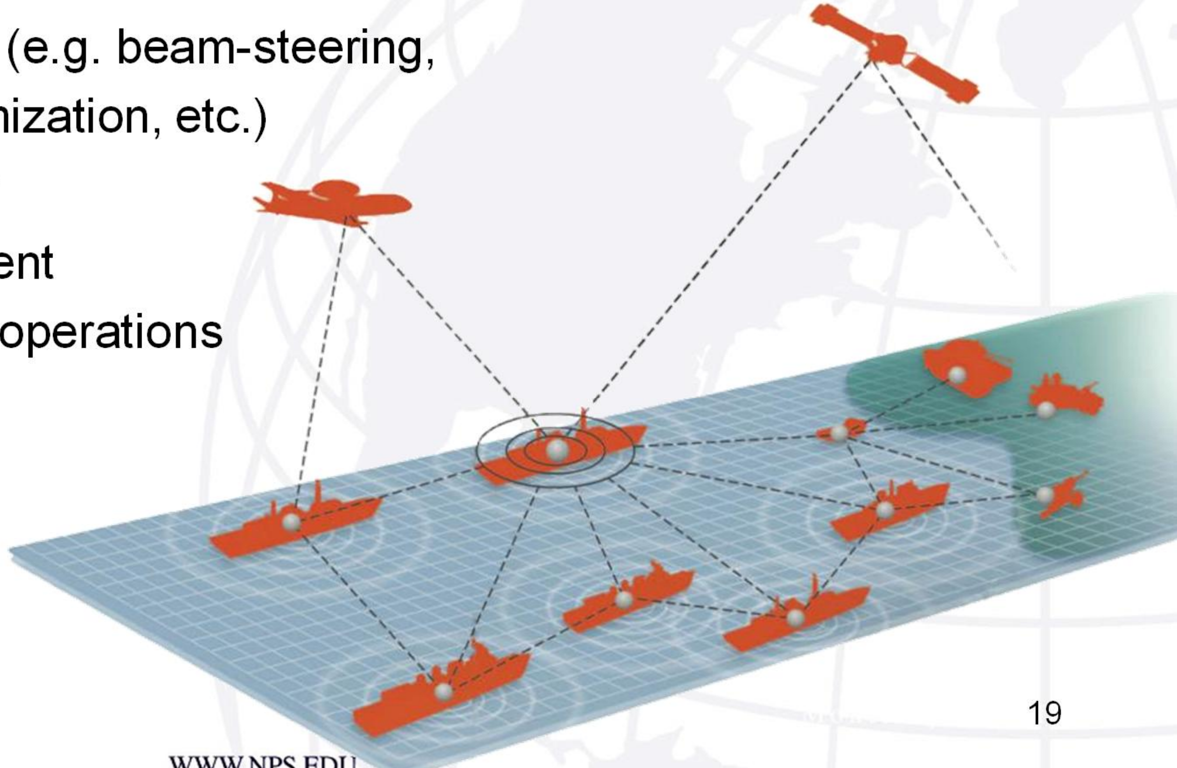
Tactical Mesh: Geo-Position, IP traffic, Radio quality



Enhancing Distributed Littoral Operations

- Rapid deployability
- Quick adaptation to dynamic environment
- Tactical-level resilient connectivity for localized battlespace awareness
- Lower probability of interception/detection
  - Directional antennas
  - “Smart” physical layer (e.g. beam-steering, transmit power optimization, etc.)
- Improve interoperability
  - Ship-to-shore movement
  - Surface Action Group operations
  - Allies and partners



Enhancing Distributed Littoral Operations (cont)

- Strengthen mesh using deployable sensor networks and unmanned systems (UxVs)
- Improve UxV C2 ecosystem
  - Robust control and data links
  - Expand network with UxV nodes
- Reduce reliance on overhead assets
  - Soft GPS trilateration in denied environments
- Flexibility to integrate legacy and next-generation networking concepts (e.g. optronics, projectile-based networks, cubesat, etc.)

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Questions

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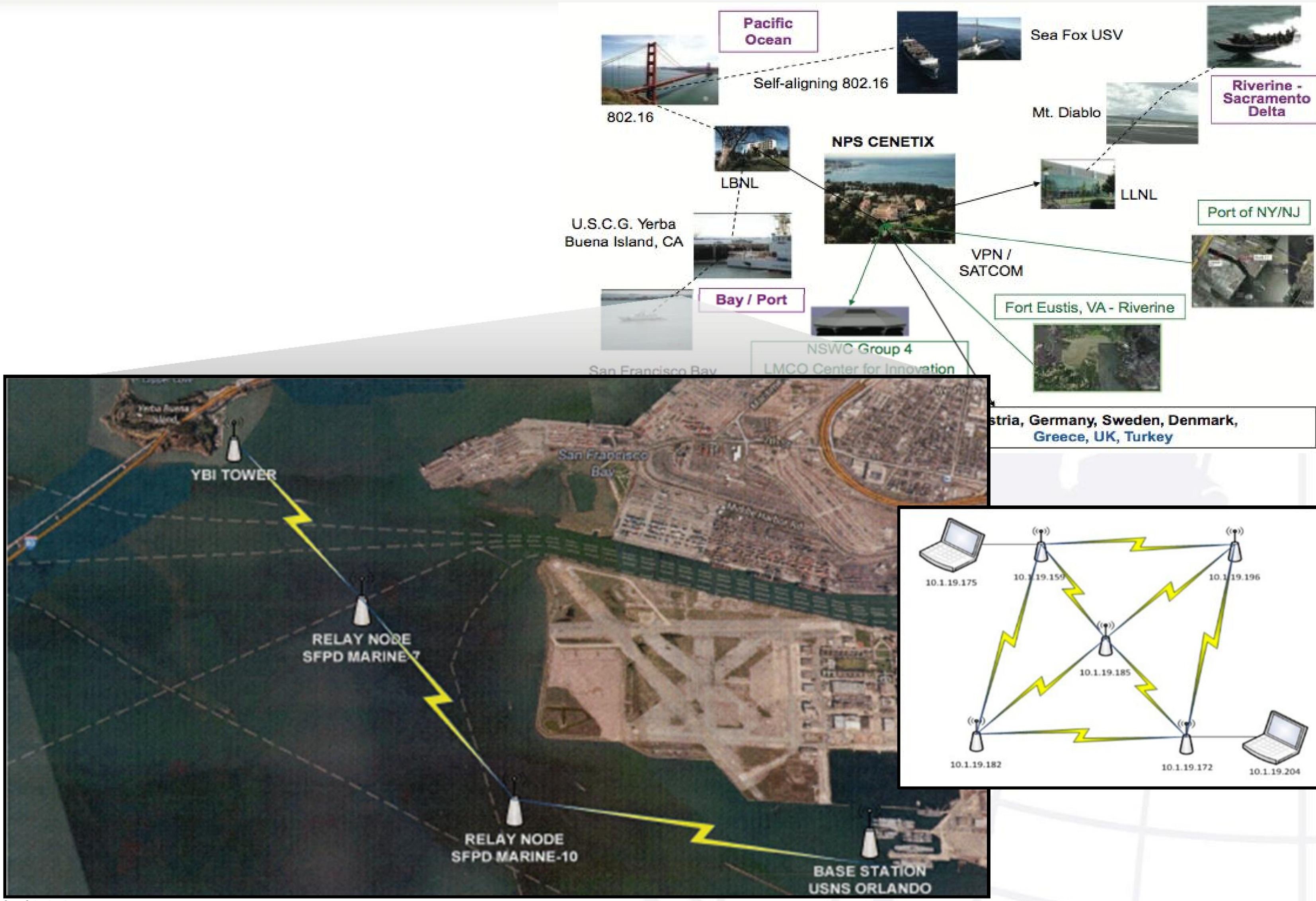
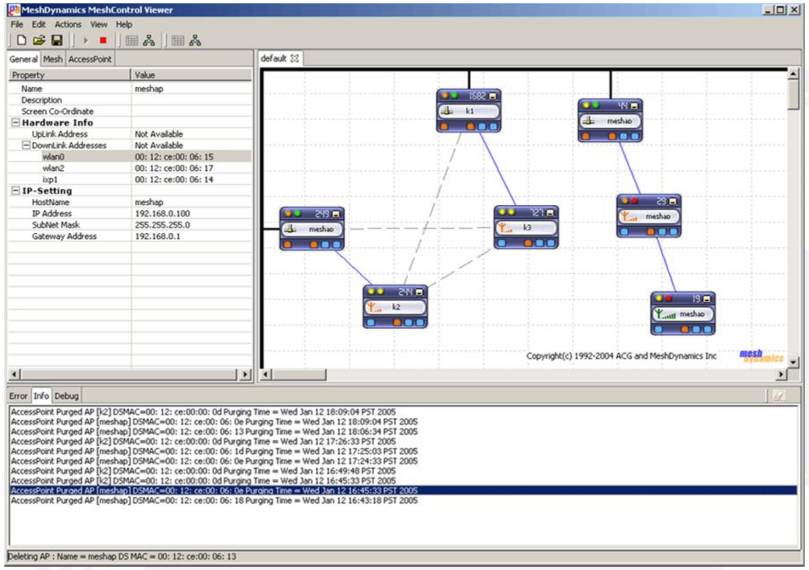
Backup Slides

MIO-JIFX 2014 BT Experimentation

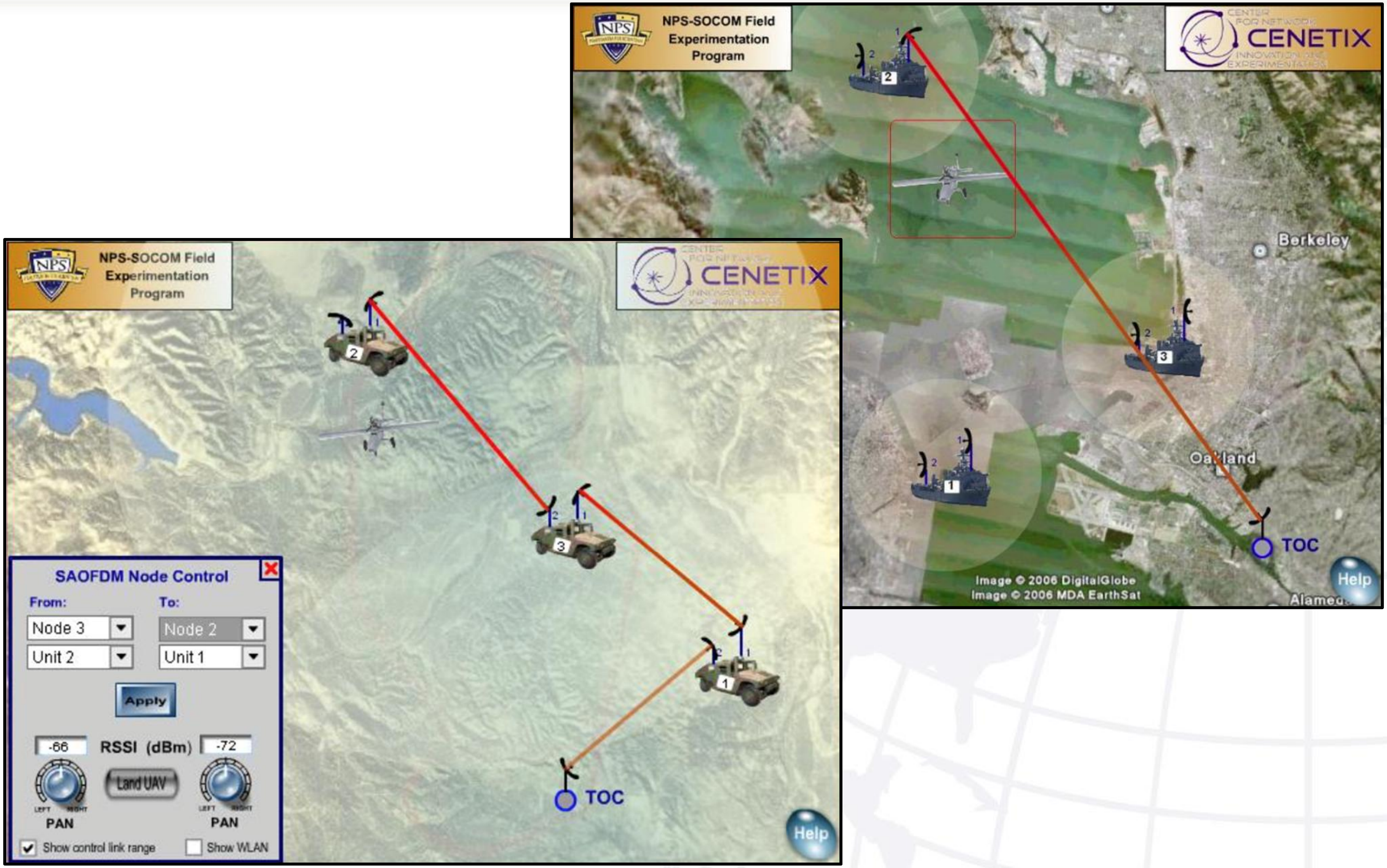


Network Management

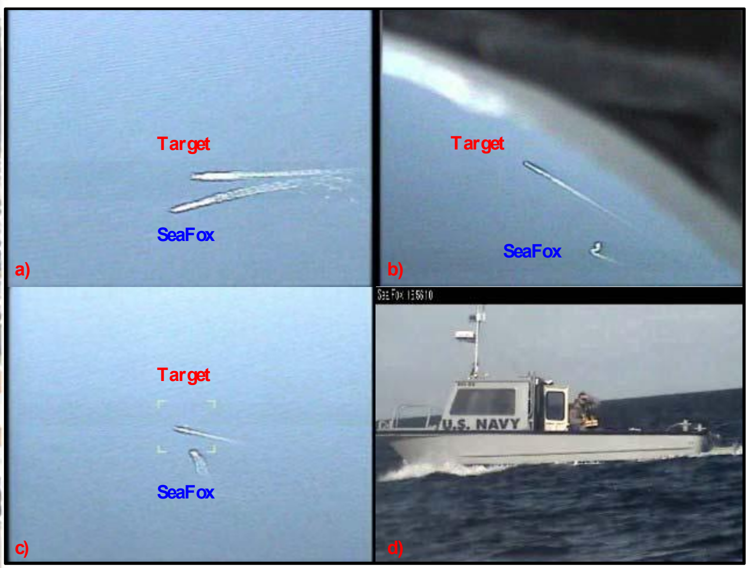
- Monitor the "health" of the network
- Determine when intervention is required
- Detect problems
  - Equipment failures (often hidden by the self-repair feature of the network)
  - Intruders
- Manage the system



Network-on-Target 2006



Bordetsky, A. and Bourakov, E. (2006) Network on Target: Remotely Configured Adaptive Tactical Networks. 11th International Command and Control Research and Technology Symposium (ICCRTS), June 20-22, 2006, San Diego, CA. Naval Postgraduate School.



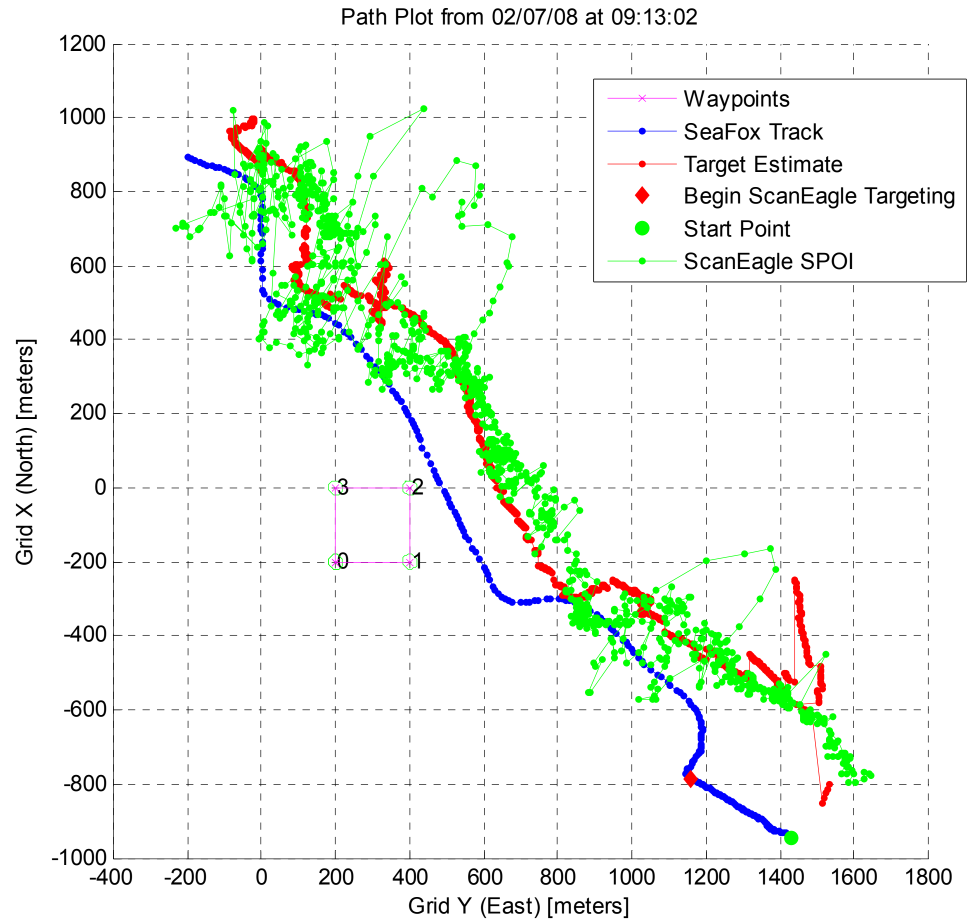
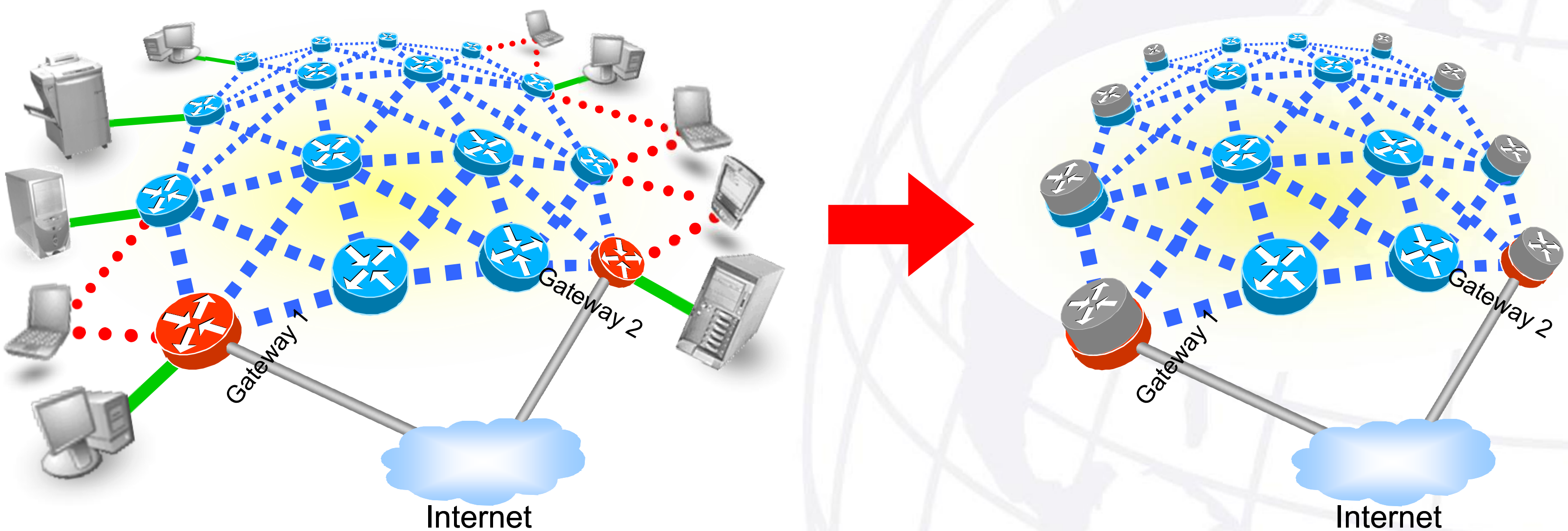


Figure 3: Track Plot from Collaborative MIO Experiment

Center for Autonomous Vehicle Research (2006) Network on Target: Remotely Configured Adaptive Tactical Networks. 11th International Command and Control Research and Technology Symposium (ICCRTS), June 20-22, 2006, San Diego, CA. Naval Postgraduate School.

Abstraction

- Users + routers = nodes
- Nodes have two functions:
  - Generate/terminate traffic
  - Route traffic for other nodes

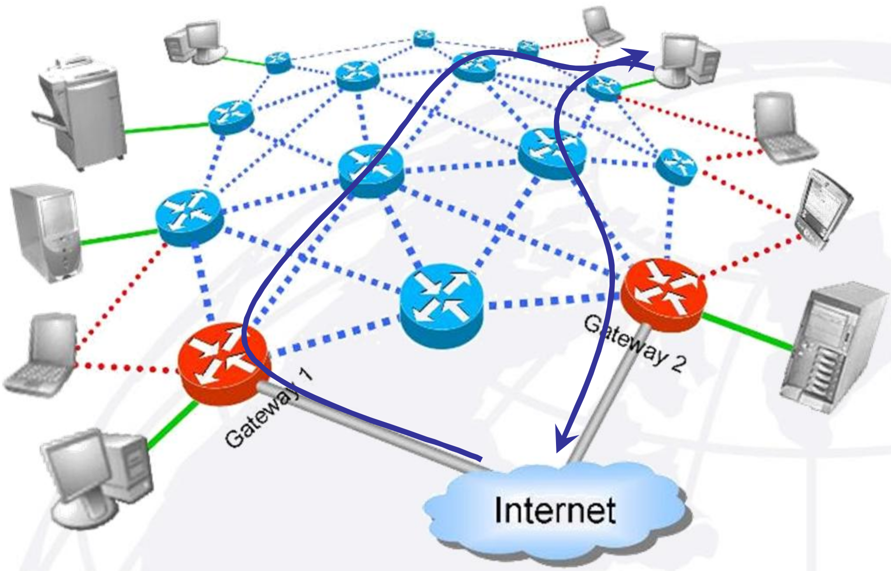


Routing – Cross-Layer Design

- Routing – Physical
  - Link quality feedback is shown often to help in selecting stable, high bandwidth, low error rate routes.
  - Fading signal strength can signal a link about to fail → preemptive route requests.
  - Cross-layer design essential for systems with smart antennas.
- Routing – MAC
  - Feedback on link loads can avoid congested links → enables load balancing.
  - Channel assignment and routing depend on each other.
  - MAC detection of new neighbors and failed routes may significantly improve performance at routing layer.

Routing – Cross-Layer Design (cont)

- Routing – Transport
  - Choosing routes with low error rates may improve TCP throughput.
  - Especially important when multiple routes are used
  - Freezing TCP when a route fails.



- Routing – Application
  - Especially with respect of satisfying QoS constraints