Hybrid Mesh Networking for Distributed Operations

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Tokyo, Japan

01 December 2015
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).
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
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
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.

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

- **Partial mesh**: not all nodes are directly connected.
Layer 2 Connectivity

- The entire wireless mesh cloud becomes one (giant) ethernet switch
  - Perfect for short-term and opportunistic/delay-tolerant networks
Man Portable Units (Quad Radio & MPU4) Peer-to-Peer MANET

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

<table>
<thead>
<tr>
<th>WR Frequency Range</th>
<th>WR Output Power</th>
</tr>
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<tbody>
<tr>
<td>907-922 MHz</td>
<td>27dBm/500mW</td>
</tr>
<tr>
<td>2312-2507 MHz</td>
<td>28dBm/600mW</td>
</tr>
<tr>
<td>2412-2462 MHz</td>
<td>28dBm/600mW</td>
</tr>
<tr>
<td>2312-2507 MHz</td>
<td>33dBm/2W*</td>
</tr>
<tr>
<td>5180-5320, 5500-5700, 5745-5825 MHz</td>
<td>28dBm/600mW</td>
</tr>
<tr>
<td>2312-2507 MHz</td>
<td>27dBm/500mW</td>
</tr>
<tr>
<td>4400-4800 MHz</td>
<td>25dBm/320mW</td>
</tr>
<tr>
<td>4800-4985 MHz</td>
<td>26dBm/400mW</td>
</tr>
</tbody>
</table>

- 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.

- 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.

ANDROIT(TM)
- Multicast Video, position locator and chat in an Android application.
- Supports commercial/custom phones and tablets.
- Provides power through USB tether.
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
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
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
• 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
CENETIX Backbone: Node health, traffic and quality

Network latency (low indicated server issue not network)
Tactical Mesh: Geo-Position, IP traffic, Radio quality

- Traffic utilization by node
- Node details
- Live geo-tracking with mouse over health and signal
- Node neighbor and signal 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
- 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.)
Questions
Backup Slides
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
Figure 3: Track Plot from Collaborative MIO Experiment
• 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 – 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