

# AdHoc Mobile Mesh: A Public Safety Field Trial

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# PacketHop

- Provides Mobile AdHoc Mesh Networking Software for Commercial Off-The-Shelf Hardware Products.
- Founded in February 2003, based upon 30 years of packet radio networking research at SRI, funded by DARPA/DoD.

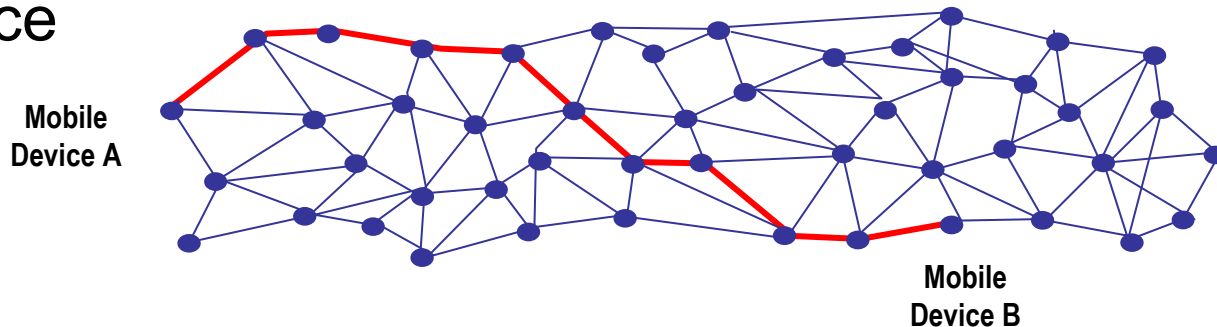
# PacketHop Lineage

- **SRI International: 30 Years of Technology Innovation**
  - **1960s:** First Internet Message Sent (ARPANET – precursor to Internet)
  - **1970s:** First Mobile Internet Session; Invention of TCP Protocol on Wireless Networks
  - **1980s:** Multimedia Electronic Mail System; Intrusion Detection Software
  - **1990s:** DARPA Global Mobile Information Systems (GloMo)
  - **2000s:** Internet Chameleon; Mobile Mesh Networking Solutions
- **Proven Technology: \$50M SRI R&D Trials**
  - DARPA Packet Radio program
  - US Army CECOM
  - US Navy ONR
  - DARPA SUO/SAS
  - US Marine Corps



# Mobile Ad Hoc Networks (MANET)

- Self-organizing and self healing – No fixed infrastructure
- Mobile multi-hop networks
  - Scalable and reliable
  - Can be used for range extension of WLANs
- Principal differences from fixed Internet
  - Accommodates frequent joining and leaving of nodes
  - Efficiently updates the topological changes with minimal overhead
  - Routing techniques appropriate for mobile environment
- Needs tailored technologies to support network and resource management, addressing, security, and quality of service

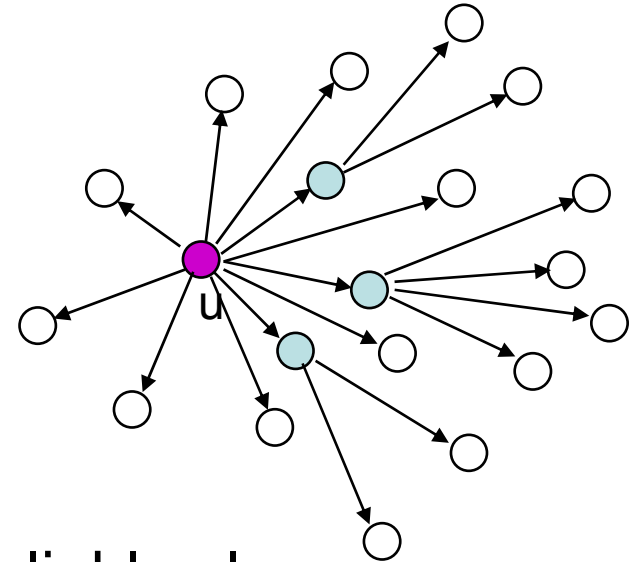


# Proactive vs. On-Demand MANET protocols

- Proactive Protocols
  - Set up routes continuously based on update information on changing link states
  - Highly scalable and adaptive
- On-Demand (or Reactive) Protocols
  - Search for a route for destination whenever a source needs to send a packet
  - Useful for small size networks, low mobility, and sparse traffic
- IETF MANET Working Group is planning to recommend “Experimental RFCs (Request for Comments)” for four protocols
  - Proactive protocols
    - Topology Broadcast with Reverse Path Forwarding (TBRPF)
    - Optimized Link State Routing (OLSR)
  - On-Demand Protocols
    - Ad Hoc on-Demand Distance Vector (AODV) Routing
    - Dynamic Source Routing (DSR)

# PacketHop Ad Hoc Network Protocols

- Based on SRI's 3<sup>rd</sup> Generation protocols:
  - TBRPF = Topology Broadcast based on Reverse Path Forwarding
- Has three principal functions
  - A neighbor discovery mechanism for initialization and subsequent dynamic departure and joining of nodes
  - An efficient topology update distribution methodology
  - A routing mechanism
- Each link-state update is broadcast reliably along the min-hop path tree rooted at the source of the update - each update is sent along a single path to each node achieving a dramatic reduction in control traffic
- Reduces update overhead dramatically (80% reduction compared to flooding In a network of 20 nodes)



# TBRPF Modules

- **Neighbor discovery**

- Performs the detection of new and lost neighbors using 'Hello' messages
- Uses differential Hello messages that report only changes in neighbor states
- Utilizes Hello count for reliable detection of acquisition or loss of neighbors
- Hello intervals can be periodic or aperiodic
- Link layer indication of loss of neighbors can be used to speed up detection

- **Topology discovery**

- Provides sufficient link-state information to each node to allow the selection of shortest paths and alternate paths to each destination
  - Partial topology, full topology, mixed mode
- Each node reports, in periodic and differential updates, its reportable subgraph
- Allows link metrics to be included in topology updates
- supports multiple interfaces

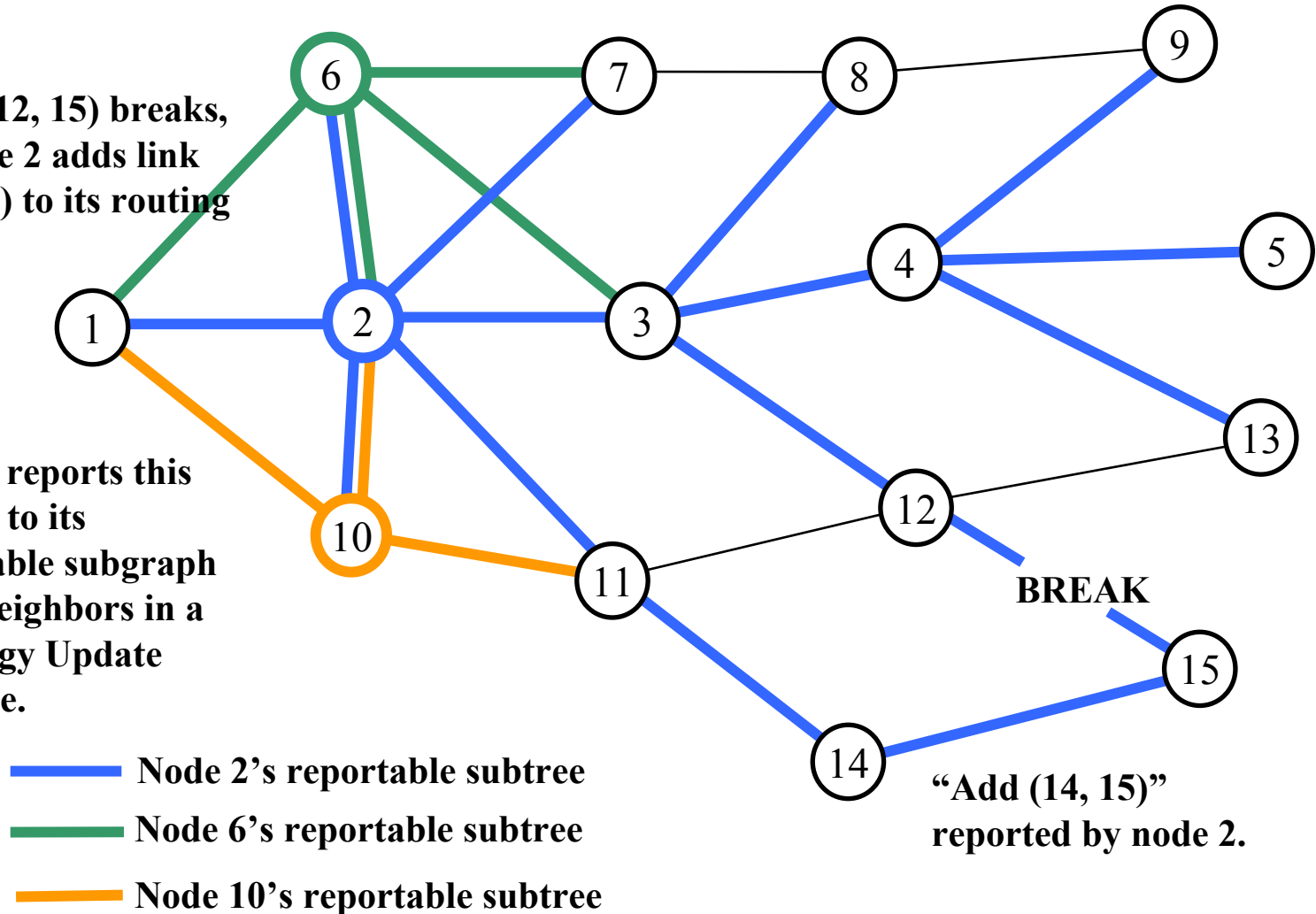
- **Packet routing**

- Forwards packets based on topology information - minimum hops
  - Link metrics can be used for other routing criteria - QoS routing

# Example illustrating TBRPF (minimum topology)

Link (12, 15) breaks,  
so node 2 adds link  
(14, 15) to its routing  
graph.

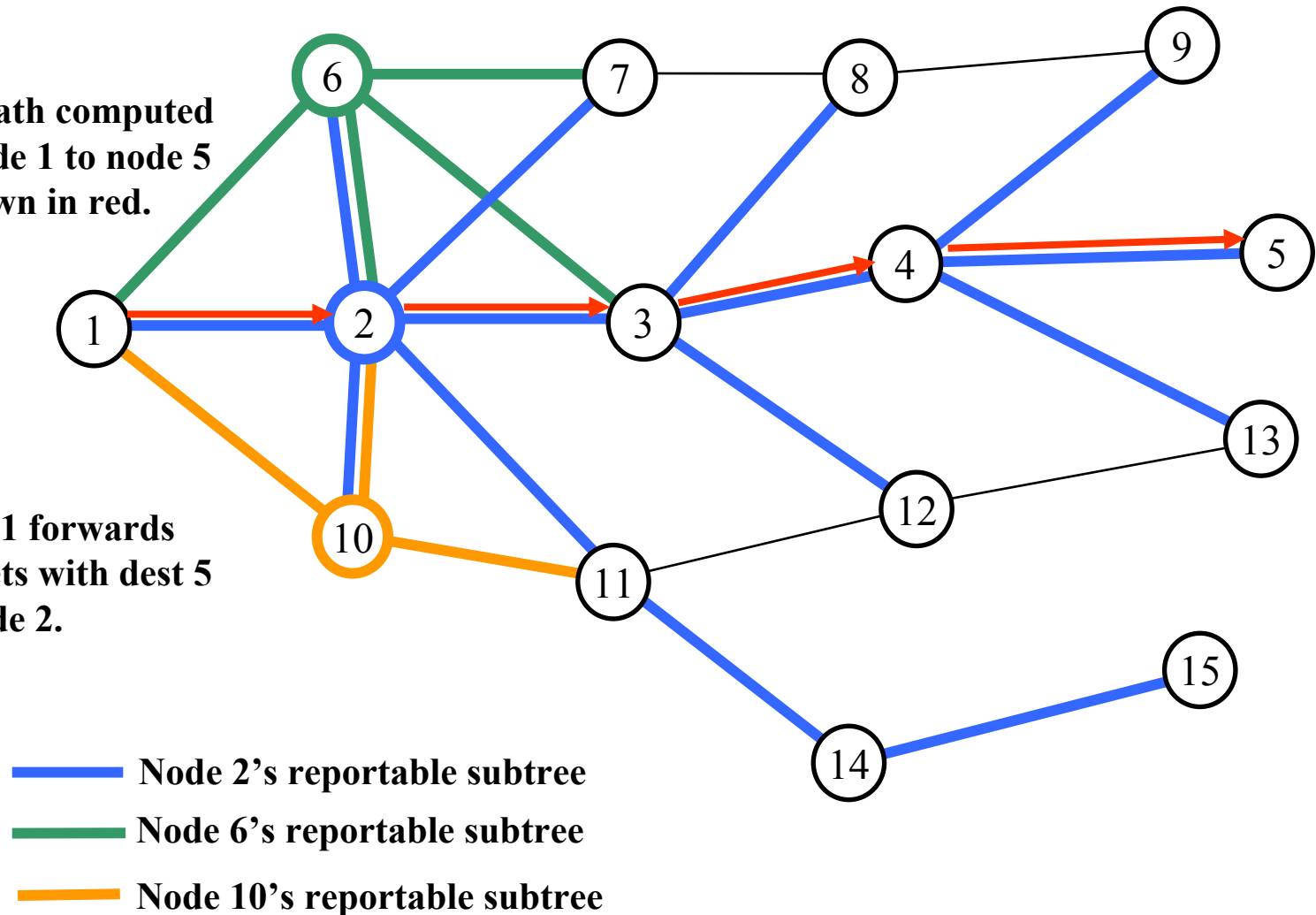
Node 2 reports this  
change to its  
reportable subgraph  
to all neighbors in a  
Topology Update  
message.



# Example illustrating TBRPF (minimum topology)

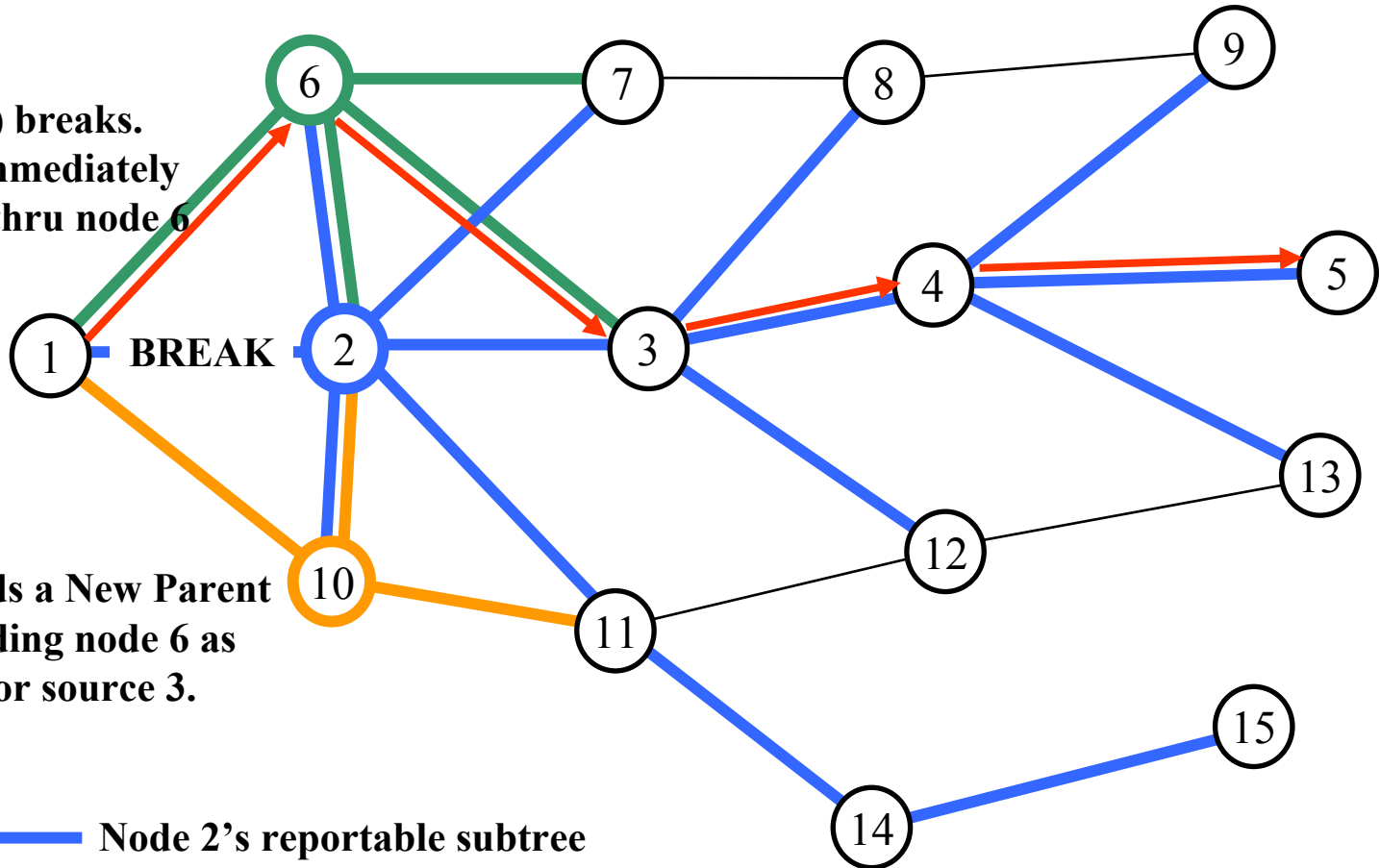
The path computed by node 1 to node 5 is shown in red.

Node 1 forwards packets with dest 5 to node 2.



# Example illustrating TBRPF (minimum topology)

Link (1,2) breaks.  
Node 1 immediately  
reroutes thru node 6

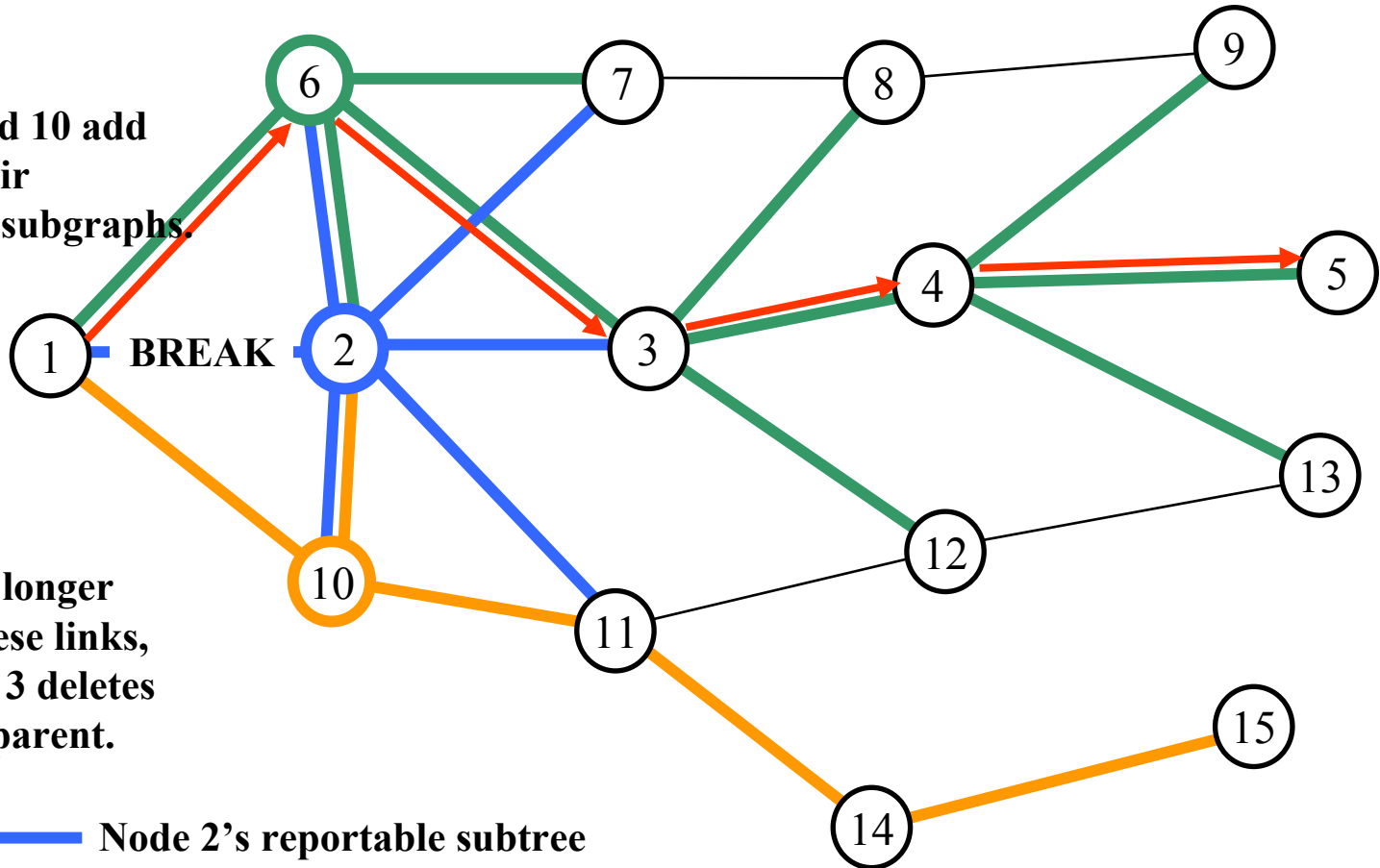


and sends a New Parent  
msg, adding node 6 as  
parent for source 3.

- Node 2's reportable subtree
- Node 6's reportable subtree
- Node 10's reportable subtree

# Example illustrating TBRPF (minimum topology)

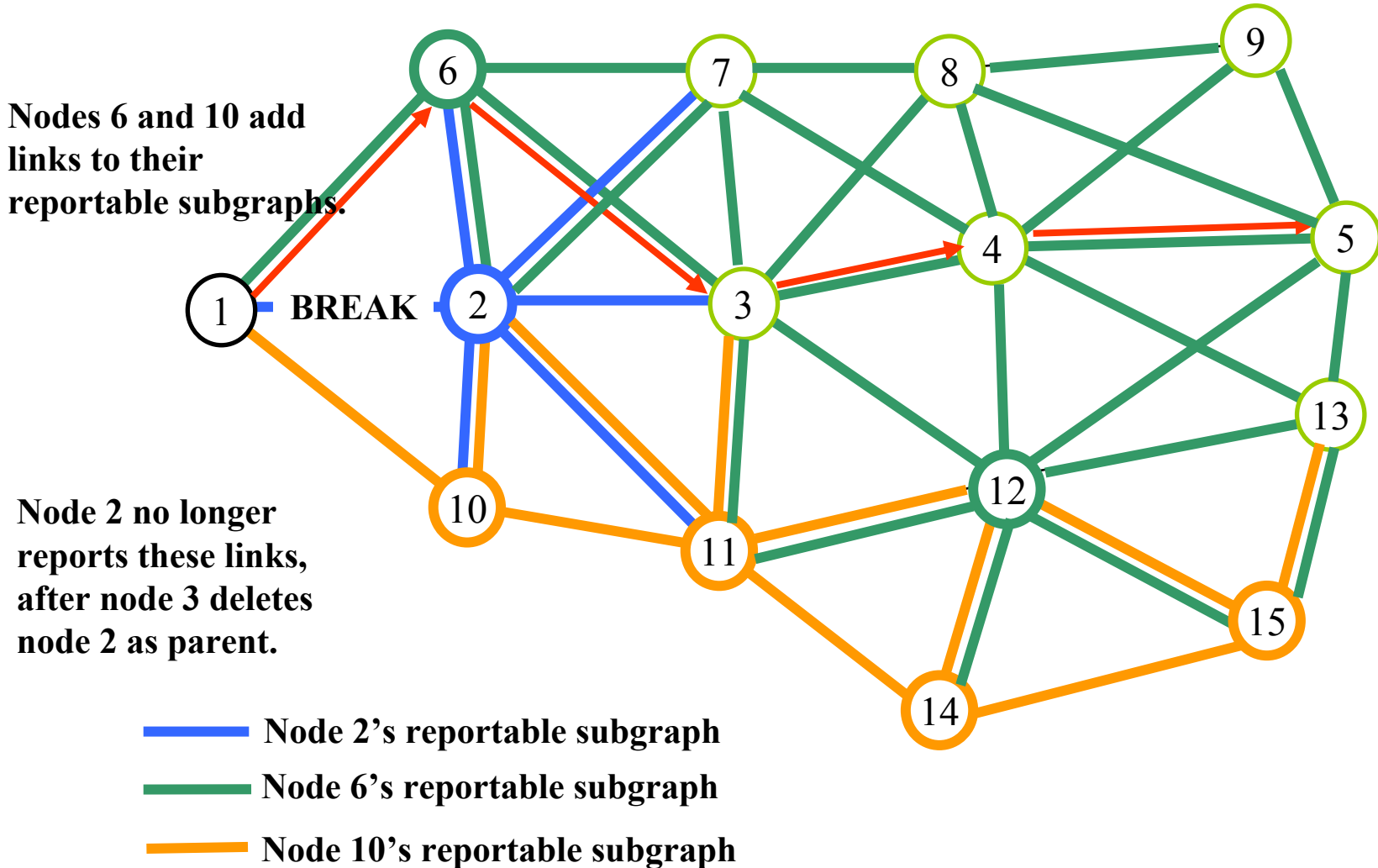
**Nodes 6 and 10 add links to their reportable subgraphs.**



**Node 2 no longer reports these links, after node 3 deletes node 2 as parent.**

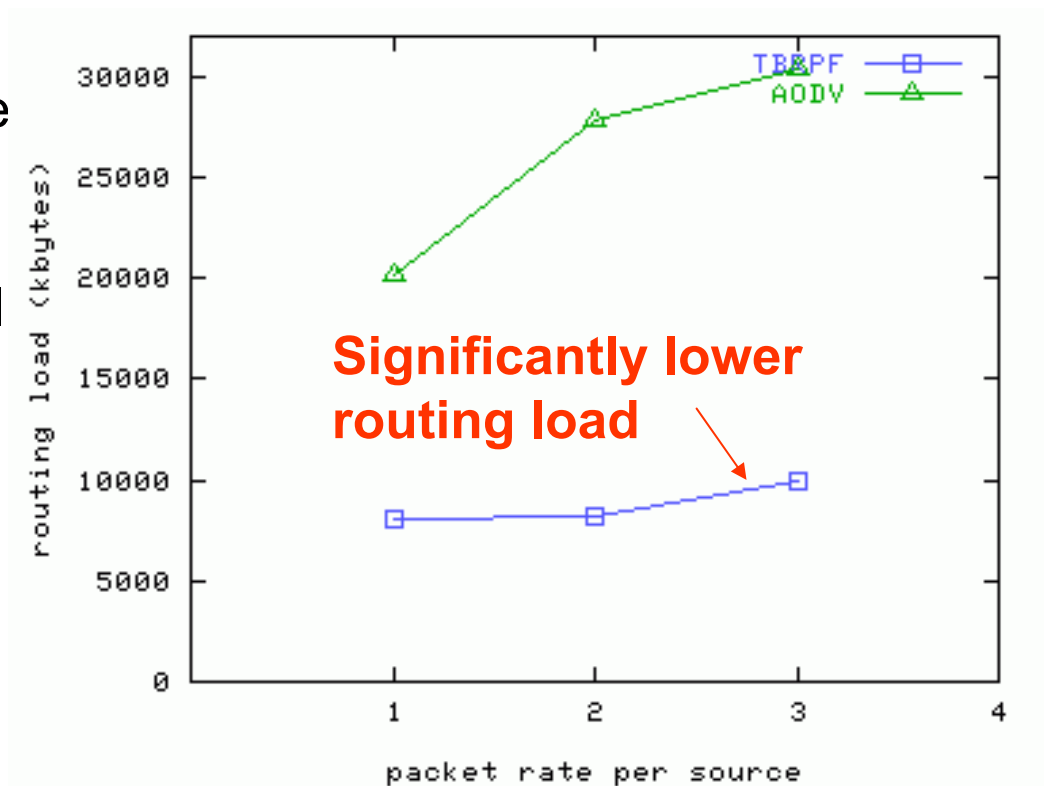
- Node 2's reportable subtree
- Node 6's reportable subtree
- Node 10's reportable subtree

# Example illustrating TBRPF (full topology)



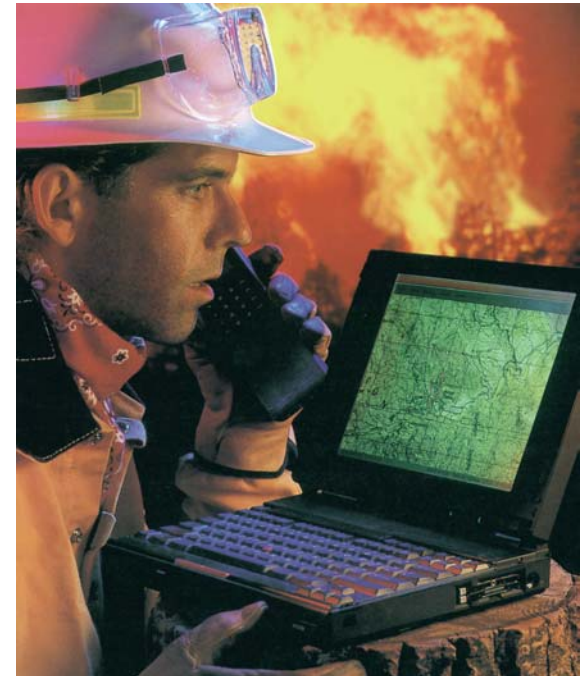
# Comparison of proactive TBRPF and reactive AODV

- Scenario:
  - 802.11b MAC
  - 100 mobile nodes
  - 40 simultaneous source nodes
  - 1500x300m area
  - Random mobility model with max speed of 45 mph (72 km/hr)
- Lower overhead allows:
  - Greater scalability
  - Increased mobility
  - Higher throughput
  - Faster convergence



# MANETs for Public Safety

- Requirement for infrastructure-less communications
  - Rapidly set up and deployed
- Local and distributed Command and Control
  - Situational Awareness
  - People and asset tracking & management
- Multi-hop to avoid building obstructions and line of sight challenges
  - Highly mobile users
  - Interoperable IP-based
  - Greater efficiencies in spectrum utilization
- Highly reliable
  - Redundant packet routes
  - No single point of failure
- Low costs due to leverage of off-the-shelf computing and networking equipment



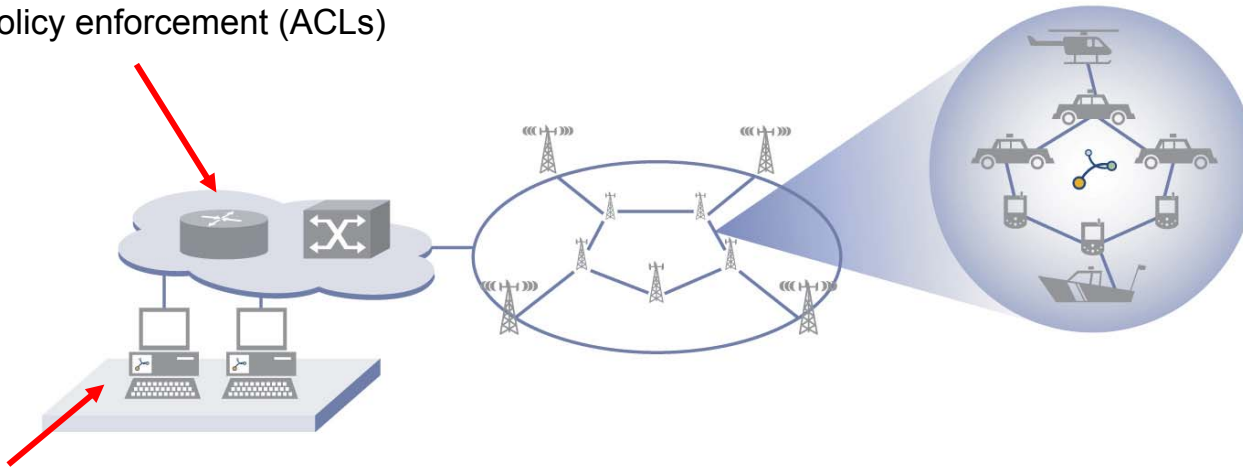
# PacketHop Mobile Mesh Software

## PacketHop Network Controller

- High performance, secure network appliance
- Interfaces mobile mesh networks to existing networks
- Provides roaming, security and quality of services among any IP network
- Connectivity between multiple mobile mesh networks
- Network policy enforcement (ACLs)

## PacketHop Network and Gateway Devices

- Self-forming autonomous networks
- Easily installed on Windows-based devices
- Mesh routing, roaming, security, QoS
- Multi-interface mobile mesh gateway



## PacketHop Mobile Mesh Manager

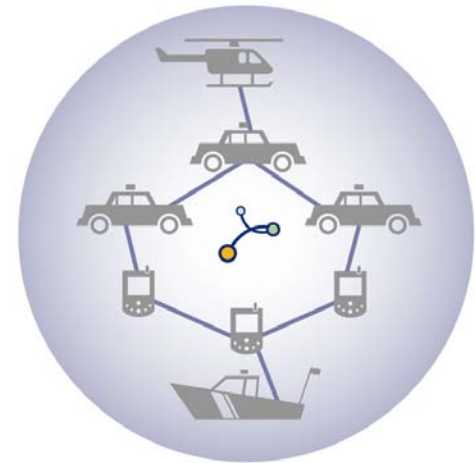
- Subscriber management and provisioning
- Centralized and/or distributed operation
- Real-time network visualization and control
- Mesh network troubleshooting
- Network policy management

## PacketHop Application Components

- Optimized for dynamic mobile mesh networks
- Peer-to-peer operation over any network
- Instant, secure, and reliable multimedia communications
- Automatic logging and accounting
- Easily installed on Windows-based devices

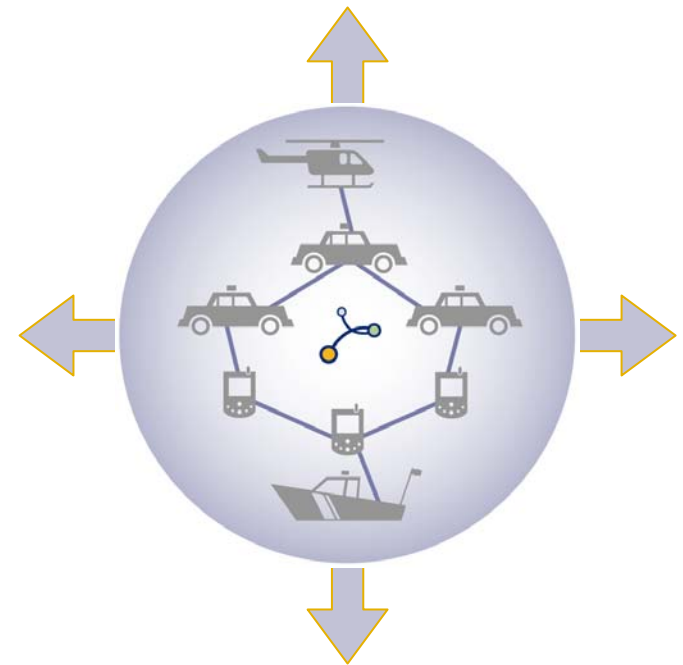
# Network Client

- Mobile Mesh Routing on one 802.11 interface
  - Address management
  - Subnet Roaming
  - “Drive-by” delivery
  - Infrastructure OR ad hoc connectivity
- Mobile Mesh QoS
  - Routing metrics
  - Prioritization
  - Queuing
  - Multicast
- Session persistence (PacketHop enabled apps)
- Network management client
- PocketPC and Windows XP



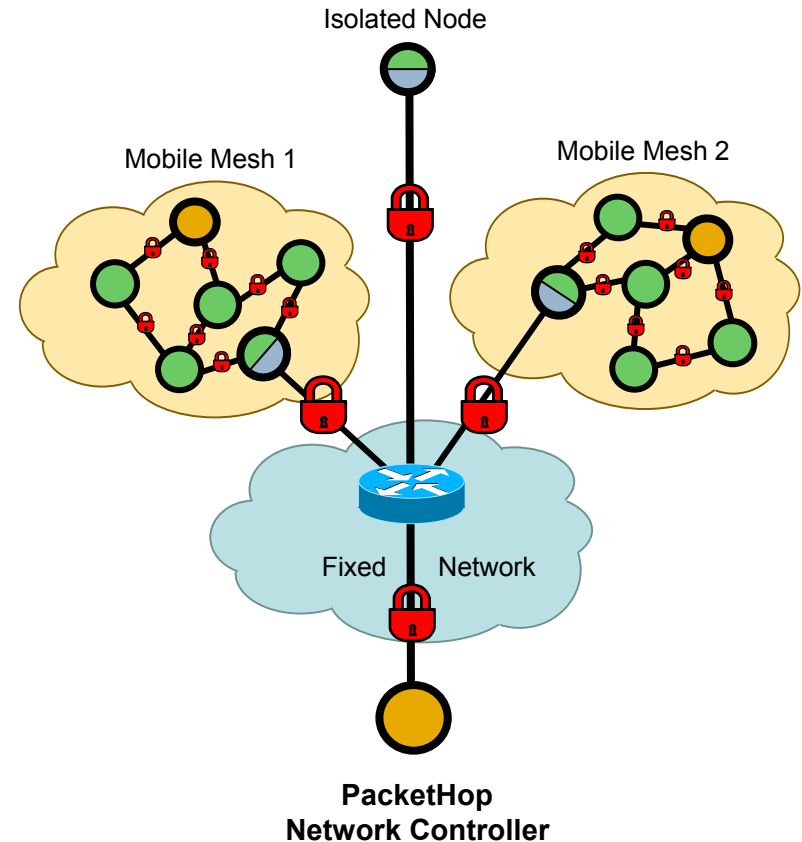
# Gateway Client

- **All PacketHop Network Client features *plus***
- **Multi-network roaming**
  - 2.5G cellular networks
  - Satellite
  - Wired LAN or WAN
- **Infrastructure to ad hoc gateway**
  - Multiple logical and physical interfaces
  - Routing, QoS, security
  - Infrastructure (AP) emulation
- **Secure public network connection**
  - Firewall, NAT, VPN
- **Reliable logging support**
- **Windows XP devices**



# Security

- **Wireless Infrastructure**
  - WEP
  - WPA
  - 802.1x
- **Terrestrial infrastructure**
  - IPSec VPN
  - IPSec and SSL VPN
- **Robust mesh security**
  - Peer-to-peer xEAP
  - Peer-to-peer key distribution
  - AES, 3DES, DES encryption
  - Consistency checking

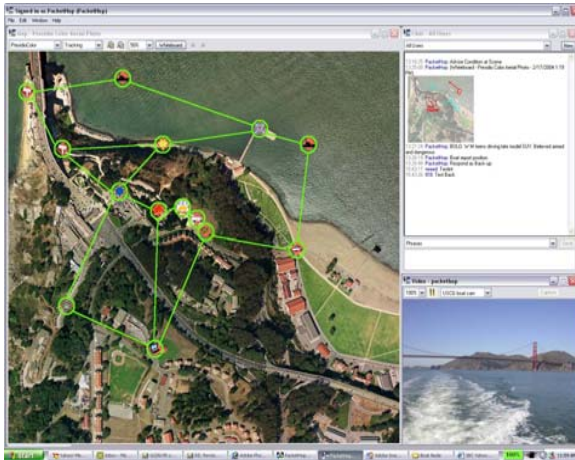


# Quality of Service

- Multiple simultaneous routing paths
- Re-routing in 10's of milliseconds
- Multiple routing metrics
  - Hop count
  - Path bandwidth and latency
  - Node memory, battery, etc.
- Multicast over mesh
- Configurable priority queues
- Low latency voice (future 802.11e)
- WRED and WFQ
- Traffic marking & VLAN tagging
- Inter-node interference mitigation

# Modular Application Components

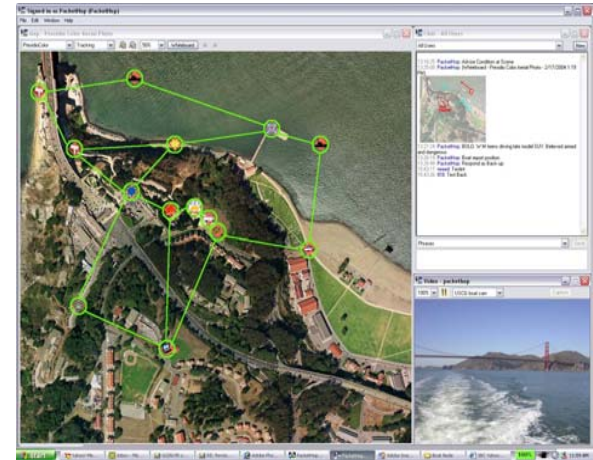
**Messaging**



**Video**



**Mapping**

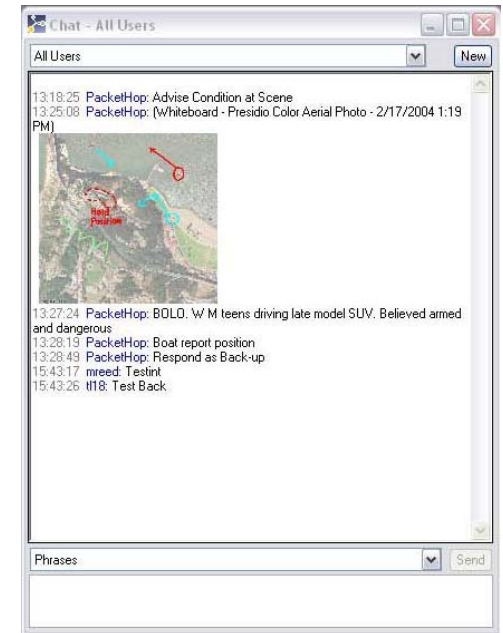


**Voice**

- Optimized for dynamic mobile mesh networks
- Peer-to-peer operation over any network
- Instant, secure, and reliable multimedia communications
- Automatic logging and accounting
- Easily installed on Windows-based devices

# Messaging

- Text chat with talk groups
  - One-to-one
  - One-to-many
  - Many-to-many
- Embedded object support
  - Images and whiteboards
  - Sound/voice files
  - Web links
  - Documents
- Pop-up alerts
- Message history retrieval
- Predefined phrases and text completion
- Message logging and receipt verification
- With other components
  - **Whiteboard tear-sheets**
  - **Interactive whiteboard**
  - Click user icon to send
  - Click to BOLO video frame



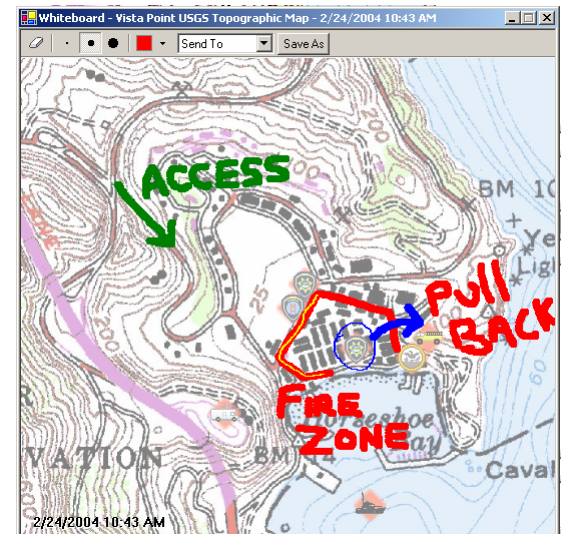
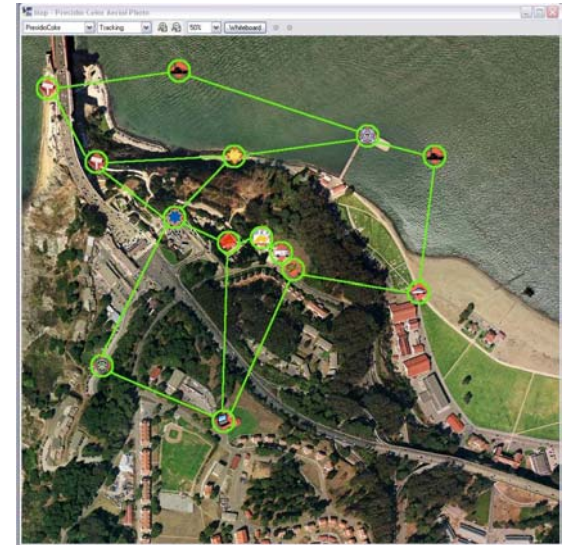
# Video

- Video encoder and decoder
- Selectable frame rates, CODECs
- Multicast and video QoS (priority)
- Click to pause
- Instant replay (local buffer)
- Pan, tilt, zoom controls
- With other components
  - Click camera to select video source
  - Click to BOLO video frame



# Mapping

- Layered geo-referenced map viewing
- Automatic map downloading
- Multi-user location tracking
- Active icons
- Map annotation
- Map object find
- Motion alarms
- Full logging
- Interactive whiteboard
- With other components:
  - **Whiteboard tear-sheets**
  - Click user icon to chat
  - Click user icon to call
  - Click camera icon to open video



# Voice

PacketHop 1.0	PacketHop 2.0	Future
Voice messaging Half duplex Record and send Message logging	LMR voice emulation Half duplex Low latency Talk groups Wireless voice QoS Call logging	Telephone emulation Full duplex Low latency PSTN signaling VoIP gateway integration Video conferencing

- Added functionality with other components
  - Click user icon to call
  - Voice mail
  - Video conferencing

# Golden Gate Safety Network

- **GGSN Mission**

- Develop a regional public safety communications plan and explore new communications systems that will enable multi-agency, interoperable communications to support day-to-day incidents as well as large-scale emergencies

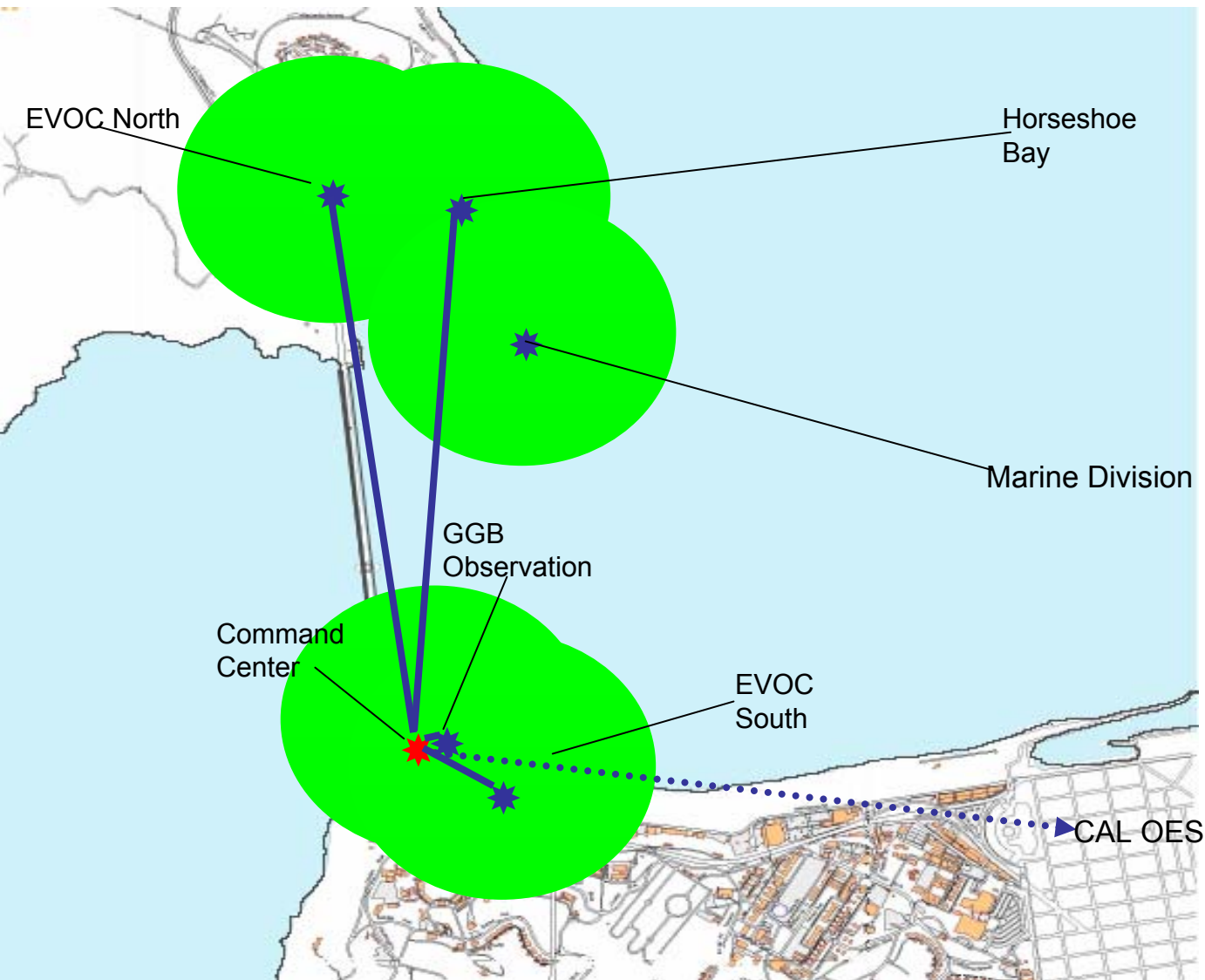
- **GGSN Interoperable Communications Exercise**

- Timing: February 12, 2004
- Place: Golden Gate National Recreation Areas, San Francisco Presidio, Marin & Alameda Counties, California's Emergency Operations Center in Sacramento

- **GGSN Participants**

- California Governor's Office of Emergency Services, California Highway Patrol, the Federal Bureau of Investigations, Marin County Office of Emergency Services, Marin County Sheriffs Department, National Park Service, Presidio Fire Department, San Francisco Emergency Communications Division\*, San Francisco Fire and Police Departments, U.S. Coast Guard and U.S. Park Police

# PacketHop GGSN Network



# PacketHop Partnerships

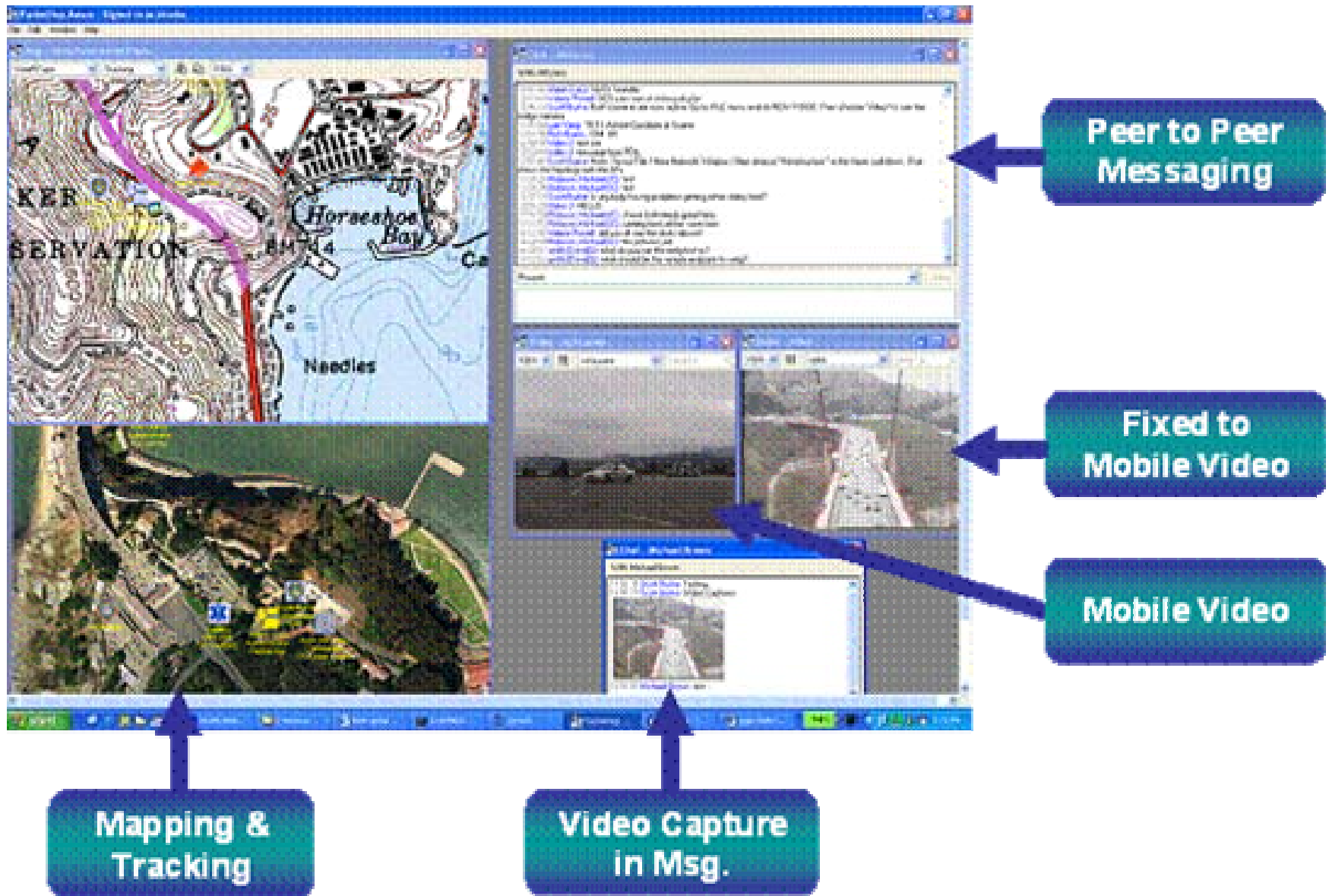
## Infrastructure

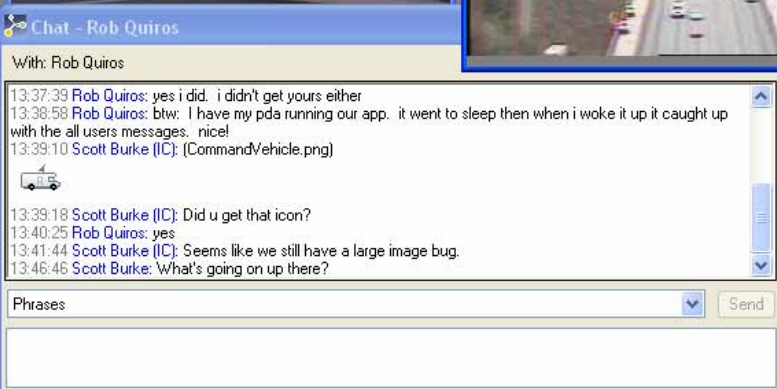
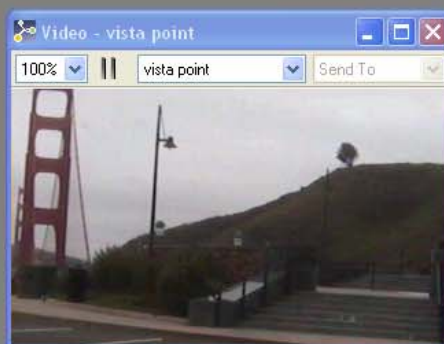
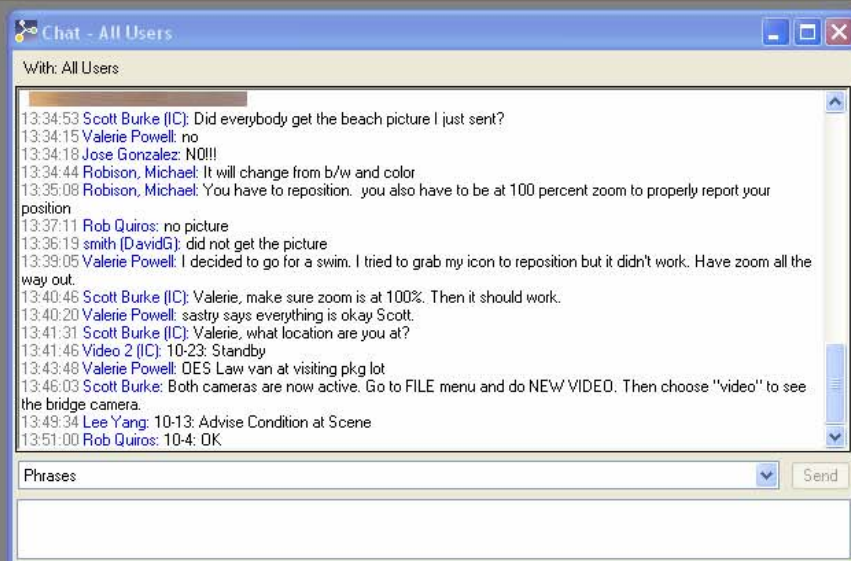


## Devices



# PacketHop Modular Application Components





# GGSN in Operation

**Go to: <http://www.packethop.com/technology/deploy.html>**

# North Side Horseshoe Cove / Vista Point



# South Side Vista Point, Tourist Lot





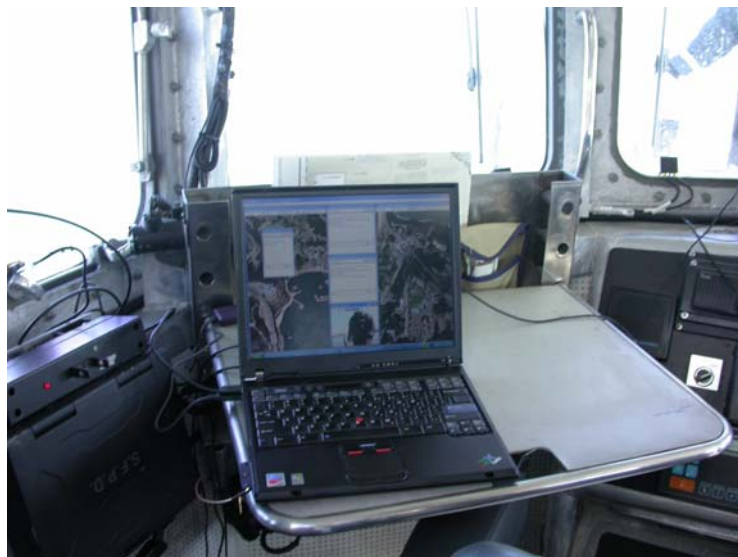








# SFPD / USCG Boat Nodes



# Sacramento Operations Center



# SOC #2



# Last Words . . .

“As demonstrated in a live field exercise, PacketHop was able to achieve mobile broadband connectivity across tough terrain – on land and water – and over mobile, infrastructure-less networks for more than ten multi-jurisdiction agencies. This exercise was unquestionably an important milestone in driving the Golden Gate Safety Network closer to its vision to develop and implement a regional communications system that supports a multi-agency response from local, state and federal first responders for day-to-day operations and incident management.”

***Michael Griffin, Assistant Chief, CA Governor's Office of Emergency Services***

“Stationed at the Emergency Operations Center in Sacramento - over 100 miles from the incident command center in San Francisco - we were able to see the exact location of first responders as they moved, downloading maps, sending messages and sharing video. PacketHop can be an invaluable tool in enabling survivable, remote connectivity, which means we won't have to rely on broadcast news helicopters for on-the-scene updates or follow along by phone/radio. We could source real-time intelligence from the first responders in the field on land, sea or air.”

***George Lowry,***  
*Assistant Chief, Telecommunications Communications Coordinator,*  
*Coastal Region, CA Governor's Office of Emergency Services*

# Last Words . . .

“Mobile mesh networking technology like PacketHop’s allows multiple agencies to instantaneously exchange critical multimedia information while working seamlessly between assorted devices, across differing spectrum channels and in-and-out of networks. For the first time – police, fire, federal agencies, military and other first responders – were able to share rich, mission-critical, real-time intelligence, by leveraging commercial off-the-shelf equipment.”

***Kent F. Paxton,***  
*Special Assistant,*  
*Mayor's Office of Emergency Services and Homeland Security*  
*City and County of San Francisco*

Thank you!

**[www.packethop.com](http://www.packethop.com)**