

Technology **Today**

HIGHLIGHTING RAYTHEON'S TECHNOLOGY

2008 ISSUE 3

Raytheon's Net-Centric Communications

Building a Foundation for Innovative Solutions



Raytheon

Customer Success Is Our Mission

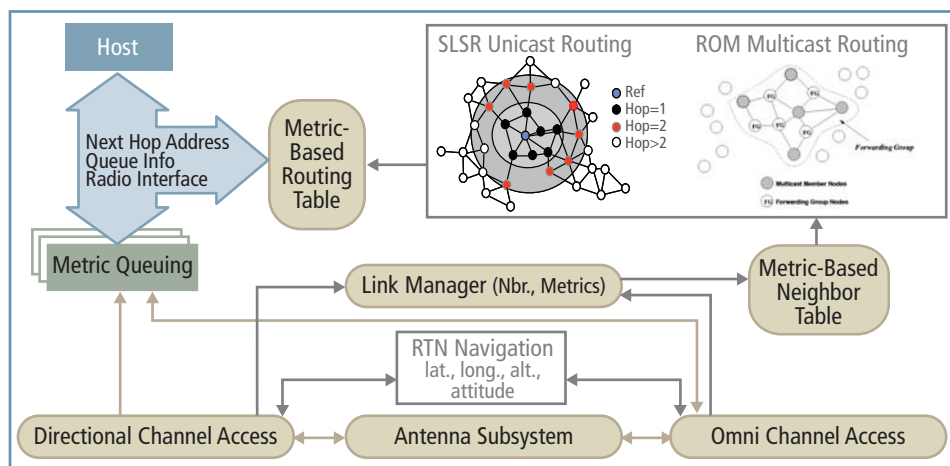
Mobile Ad-hoc Networking (MANET)

Next-generation wireless, mobile, net-centric research provides tactical, secure, self-forming, ad-hoc networks

Raytheon has developed a novel approach to mobile ad-hoc networking (MANET) — one that is applicable to many environments. The basic technology has been developed through experience in science and technology efforts spanning the last 20 years. Raytheon participated in DARPA efforts on packet radio in the 1980s; global mobile networks in the early 1990s; Airborne Communications Node and Small Unit Operations Situation Awareness System in the late 1990s; the DARPA Future Combat System Communications in the 2000s and the AMRDEC NetFires Communications in the early 2000s. Added to these experiences are Raytheon's development activities and field experience with the Enhanced Position Location Reporting System (EPLRS) radio technologies during the past 20 years.

Through these experiences, Raytheon has developed a complement of MANET technologies, collectively referred to as RAYMANET, that create a broadband tactical IP-based mobile backbone to enable net-centric warfare. An instantiation of this system seamlessly interconnected multiple heterogeneous networked radio systems during the DARPA NetCentric (NC) demonstration at Ft. Benning, Ga., in January 2006. This system served as the high availability terrestrial backbone link between dismount units that were otherwise beyond communications range. Real-time tactical voice, video, and situation awareness data were reliably delivered over the network to support the planning and execution of a simulated tactical mission with all radio network operation conducted by active-duty U.S. military personnel. Each NC node operated as a vehicular or airborne relay mobile ad-hoc router for the terrestrial backbone tactical network and a host system node.

The RAYMANET technology suite redefines each functional component in the traditional data link radio to create a network paradigm. This technology suite adapts to each individual user's communication path with-



out user intervention. Failed physical layer paths are overcome through cooperation in signal coding, channel-access scheduling, and routing decisions to maintain robust end-to-end delivery. The system provides both high-data-rate and long-range communications by autonomously adapting each link in the ad-hoc network topology to deliver the maximum possible throughput under dynamically changing link conditions. Prioritized delivery of time-sensitive and high-value traffic is achieved through novel quality-of-service (QoS) mechanisms implemented in both the media access control (MAC) and network layers to ensure that the most important traffic is delivered during periods of network congestion. The reliable autonomous adaptation of the networked radio allows warfighters to focus on external events during tactical maneuvers without having to worry about communications connectivity.

The RAYMANET technology suite is implemented to accommodate new advances and has been continually updated throughout the past eight years of development. Key features of the technology suite are its MAC and network layers. The MAC layer manages access to the physical RF resource. Most MAC layers are designed for fairly static resource assignments. The RAYMANET MAC layer has incorporated dynamic resource assignment protocols and adaptive algo-

rithms to dynamically schedule time-slot transmissions and receptions and enable ad-hoc connectivity. The MAC protocols include node activation multiple access for omnidirectional antenna implementations, and receiver oriented multiple access for directional antenna implementations. The MAC algorithms include an adaptive data-rate algorithm and a segmentation and reassembly algorithm. These algorithms automatically maintain the highest supportable reliable data rates to all neighbor nodes. In addition, QoS is implemented to maintain the users' desire for data delivery, and may be configured to support priority, weighted round robin, or hybrid queuing.

The network layer contains protocols and algorithms that establish and maintain routes between mobile network nodes. The network layer routing functions include unicast, multicast and transit routing path discovery and maintenance. The unicast routing protocols include scoped link state routing (SLSR) and tactical on-demand routing (TOR). SLSR is a proactive protocol and employs multilevel "scoping" to reduce routing update overhead in large networks. TOR is a reactive protocol and employs the maintain routes only to those in active communication to reduce overhead. Routes are found using reverse path forwarding with persistence. Paths are maintained as long as they meet the QoS metrics, otherwise a

new path is chosen from the reverse path maintained in the route discovery packets. The multicast routing protocols include receiver/sender oriented multicast (ROM/SOM) and multicast dissemination protocol (MDP). ROM/SOM applies "on-demand" routing techniques to avoid channel overhead and increase scalability. MDP is a flooding mechanism that does not require path maintenance.

The transit networking capability of the RAYMANET suite exports routes into the standard wired Internet routing protocols to provide a transit capability in support of wireless and wired network integration. Unicast routes discovered in SLSR and TOR are exchanged dynamically with standard Internet unicast routing protocols including routing information protocol and open shortest path first. Multicast routes discovered in ROM/SOM are exchanged dynamically with the standard multicast protocol, protocol-independent multicast and the Internet group multicast protocol.

The RAYMANET technology suite is evolving to support newer applications that require ad-hoc connectivity. In the lower-band spectrum, RAYMANET has been ported into software-defined radios for vehicular and airborne communications that employ dedicated omni-directional antennas. Physical-layer communications are provided through an orthogonal frequency division multiplexed modulation technique that is robust and spectrally efficient. Similar physical-layer techniques have been developed and demonstrated for directional antenna systems as well. However, directional antennas demand significant size, weight and power (SWAP) footprint on mobile platforms. Therefore, for high-frequency systems, we are exploring aperture reuse techniques. Many tactical platforms have high-frequency, directional apertures for radar functions. Resource management protocols are in development that permit reuse of these apertures for ad-hoc communications

without jeopardizing the radar performance. Also, Raytheon is participating with strategic partners to create pulse-based physical layer modulation techniques for even higher capacity MANET systems. This combination of the pulse-based modulation, resource management and RAYMANET technology will enable high-capacity MANET without the SWAP burden of special communication apertures.

In parallel with these advances in MANET technology, Raytheon has been developing the premier tactical data radio network with more than 20,000 EPLRS radios built. EPLRS radios have been deployed to U.S. Army, Marine Corps, Air Force, National Guard and Reserve units, as well as coalition partners. This unique experience has resulted in exceptional insights and capabilities, such as network test beds and field-validated network models. Leveraging the Value Engineering Change Proposal process, we have been able to enhance the radio functionality and reduce its overall cost. Through this process, advanced features of the RAYMANET suite are being incorporated into the existing product lines.

The RAYMANET technology suite provides a springboard into the military goal of network-centric operations. Reliance on pre-planned communications and infrastructure for IP-based communications is inconsistent with tactical communications in the network-centric warfare age. The ad-hoc networking capability enabled by the RAYMANET-based technology suite supports the emerging warfighting concepts for network-centric warfare. Along this path, Raytheon envisions multifunction systems as the next wave of the future.

Multifunction systems will perform communications, sensing and deliver radio frequency effects using the same hardware set to maximize the capability for the warfighter. ●

Timothy Hughes
thughes@raytheon.com

Tim Hughes
Technical Area
Director,
Mobile Ad-hoc
Networking,
NCS



From the telephone and television to CB radios and cell phones, Tim Hughes has always been fascinated by communications.

"I have always wanted to know how and why these systems work," said Hughes.

This passion and interest led Hughes to the University of Scranton in Pennsylvania, where he earned a Bachelor of Science in electrical engineering. He later earned a master's degree in electrical engineering at West Coast University in California.

As the mobile ad-hoc networking (MANET) technical area director for Raytheon Network Centric Systems in Fullerton, Calif., Hughes is focused on developing MANET technology to support opportunistic connectivity for sensors, dismounts, vehicles and airborne instantiations.

Hughes describes it as ubiquitous communications without a reliance on infrastructure. "Our military cannot always rely on the convenience of an infrastructure and are in need of the connectivity which requires a new paradigm to gain the same experience," explained Hughes. "I have made it my career goal to achieve this model for the military user."

The initial solution developed by Hughes' team is being adopted by the Enhanced Position Location Reporting System program. The advancements have been slow, he said, but the field of research is rich. "There are potential breakthroughs occurring each day and our challenge has been to stay at the forefront," said Hughes.

Copyright © 2008 Raytheon Company. All rights reserved.

Approved for public release. Printed in the USA.

Customer Success Is Our Mission is a registered trademark of Raytheon Company.

Raytheon Six Sigma, MathMovesU and NoDoubt are trademarks of Raytheon Company.

MATHCOUNTS and Mathletes are registered trademarks of the MATHCOUNTS Foundation.
Capability Maturity Model, CMM and CMMI are registered in the U.S. Patent and Trademark
Office by Carnegie Mellon University.

Raytheon

Customer Success Is Our Mission