Communicating on the Move: Mobile Ad-Hoc Networks

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Mobile Ad-Hoc Networks (MANET) is wireless networking that continually re-organizes itself in response to its environment without benefit of a pre-existing infrastructure. A MANET is comprised of a set of mobile participants who must communicate, collaborate, and interact in order to complete an assigned mission. The challenges of MANET are to provide wireless, high-capacity, secure, and networked connectivity. Participants must communicate using bandwidth limited wireless links, with potential intermittent connectivity, as compared to stable wired links and infrastructure. MANET is a key enabler for achieving the goals of net-centric operations and warfare, provides the right information at the right place at the right time, and shortens the kill chain by extending the Global Information Grid (GIG) to the tactical edge.

The Internet is dominated by wired network technologies in which dedicated devices perform the task of forwarding data from source to sink. Wireless attachments to the network are handled through fixed access points that convert wireless data to wired data and vice versa. The GIG expands on the Internet architecture with the addition of airborne wireless, as well as space-based components in its transport layer. Both networks employ the Internet Protocol (IP) suite.

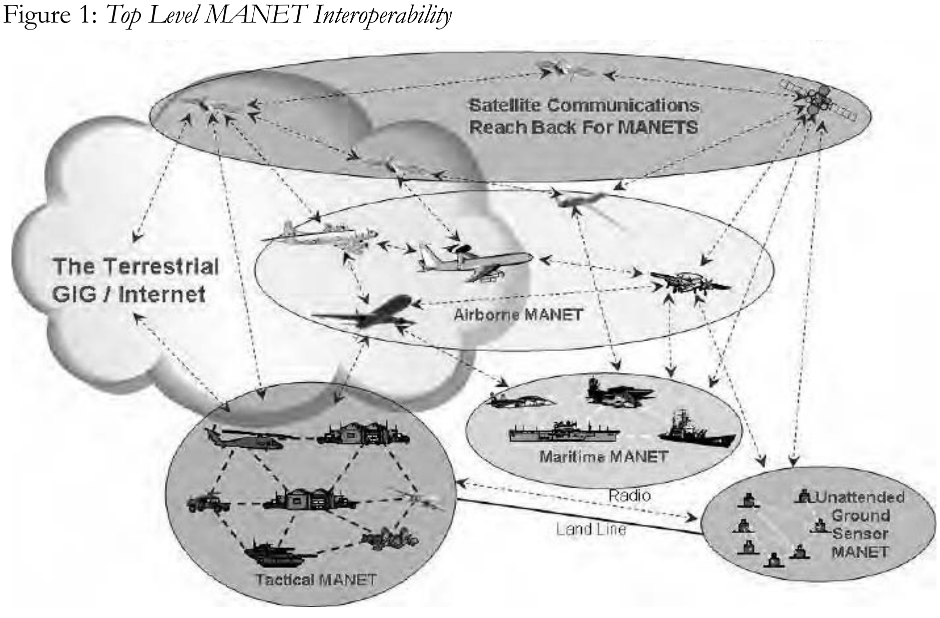
Military MANET must accommodate a diverse mix of deployed units, platforms, and systems with critical communications needs, often in adverse environments. At times, operation may be autonomous or connections may be through the space or wired networks, but the expectations are that networking services will continue without interruption. The entire network or portions of it may be mobile and subject to outages or losses inherent in a military environment. Therefore in a MANET, every node must be capable of forwarding data packets destined for other nodes. Forwarding decisions must be made independently by every node based on some combination of function, sensed network connectivity, and previously shared routing information.

MANETs are found in several major developmental military communications programs; the most visible of which are the Army's Future Combat System, the Army's Warfighter Information Network – Tactical (WIN-T), the Joint Tactical Radio System (JTRS) and space borne Transformational Communications which includes the Transformational Satellite Communications System and Mobile User Objective System programs.

MANET Capabilities/Challenges

The challenges of implementing effective MANETs are exacerbated in the military environment. MANETs must be developed to accommodate numerous and diverse missions ranging from formations of soldiers to high-speed aircraft communications. Some of the resulting challenges of particular significance in the military environment include the following:

Figure 1: *Top Level MANET Interoperability*



- **Interoperability.** To be interoperable, DoD MANETs must be developed within a consistent, integrated architecture, with defined hierarchal relationships, network structures, and GIG attachment points. The DoD is developing this interoperable architecture with various DoD level and service/agency efforts defining the net-centric architecture and interfaces. At lower network layers, channel access methods, operating frequencies, and security techniques must all be compatible or no link can be established. At mid-layer machine to machine authentication, routing/addressing and networking services must work together to implement the IP suite. At the highest networking layers, message formats and applications must all be compatible to provide the user a comprehensible output. Figure 1 illustrates the highest levels of interoperability and hints at the complexity of the problem.
- **Mobility Support.** The mobility aspect of MANETs has significant ramifications. At the physical layer, motion places an additional burden on the radio receivers in the form of Doppler shifts, signal outages due to body shading or terrain, range and multi-path; all contributing to link instability. Since nodes are free to move randomly, MANET is differentiated from wireless ad hoc networking by a heightened sensitivity to time.
- **Discovery.** In ad-hoc networks, nodes do not have a priori knowledge of the network around them. A node (optionally) announces its presence and listens to broadcast announcements from its neighbors. This activity is generally termed *neighbor discovery*. The process of neighbor discovery must be continuous (at some predeter-

mined rate) in order to maintain current knowledge.

- **Network Management.** Many areas fall within the realm of network management including IP configuration, security, spectrum, monitoring, and reconfiguration upon loss of nodes. Minimal configuration and quick deployment make ad hoc networks desirable for those in direct military conflict. There must be coordination among nodes to accomplish network management, while the ad-hoc nature of MANETs makes this coordination more difficult. MANET network management schemes must also be interoperable with higher level planning and network management layers.
- **Routing/Scalability.** If we add the advantage of a flawlessly interoperable communications infrastructure, how big a MANET is reasonable? It is well established that radio frequency spectrum available to MANET is limited, directly affecting information transfer capacities. At a minimum, MANET must perform neighbor discovery and collect extended neighborhood awareness information to maintain a local picture of network topology. Topology sustains routing. The amount of network traffic required to maintain topology varies with each MANET approach and the needed overhead increases as the number of nodes increase. Changes in the (MANET) network trigger additional topology maintenance traffic, consuming capacity. Based on field testing and limited modeling and simulation, current estimates of the size of a MANET network generally fall into the 10 to 200 node range. These numbers are based on early field data collected during Defense Advancement Research Projects Agency, Army, and Air Force experimentation augmented by a large body of modeling and simulation.
- **Security.** Security is a matter of life and death in combat and sets the military apart in many respects from the commercial world. Elements needed for security consume information capacity and add both design and operational complexity and cost. For example, the basic question of exposure. For a node to be discovered it must broadcast. Therefore it can be located, tracked, and potentially compromised. Covertness is achieved through low observable transmission techniques or by ceasing to transmit altogether, both of which have adverse affects on MANET network awareness. On the other hand, when a node is actively transmitting and receiving, authentication and data encryption are required at a minimum, impacting overhead loading.
- **Layered Interaction.** Each layer of the protocol stack plays an important part in the overall communications process for a MANET. An effective MANET solution addresses all layers of the protocol stack; single mechanisms at particular layers can mitigate particular technical issues but not the general MANET problem space. Interaction among network layers in MANETs improves overall functionality.

Outlook

The development of DoD MANETs present significant challenges and much development effort remains, however solid progress is being made. The JTRS and WIN-T programs have demonstrated increasing capabilities with early versions of their networking waveforms. The Office of the Assistant Secretary of Defense (Networks and Information Integration) (OASD [NII]) DoD Chief Information Officer continues to refine guidance and direction to provide a cohesive basis for an interoperable architecture. This process will be a continuing one as DoD capitalizes on emerging technology to improve on current solutions.◆

About the Authors

Robert F. Dillingham is a member of the senior technical staff at SRA International, Inc., and has more than 28 years of research, development, test, and evaluation experience in navigation, guidance and control, command and control, communications, and software simulation/hardware emulation. He has extensive experience in the design, specification, implementation, and operation of laboratory and test facilities with specific expertise in the areas of global positioning software (GPS), real-time systems, networking and embedded applications. Dillingham provides review and comment on behalf of JTRS10 on the series of documents in process by the JTRS Joint Program Executive Office, and the Joint Network Enterprise Services working group, which is defining common network and enterprise management services. Prior to SRA, he was a civilian employee of the Navy, where he was the lead systems designer for the Navy GPS Central Engineering Activity, and systems engineer for the first GPS satellite signal generator. Dillingham has a bachelors degree in electronics engineering from Lehigh University.

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