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Future Army Bandwidth Needs and Capabilities

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Summary

Across the services, there is an increasing demand for communications capacity. For the U.S. Army, this is a result of the Army's transition to a new force structure that will be knowledge-based[1] and network-centric.[2] Since bandwidth facilitates communications capacity, bandwidth has become increasingly critical. To the user, high bandwidth is useful because it supports increased capacity, high-volume data exchange, short delays, and high assurance of connectivity. New technologies, commercial and military, will continue to increase available bandwidth and hence the communications capacity available to users. Based on specified requirements and proposed technologies and architectures for the future force, the capacity of communications systems planned to support the new force structure will continue to fall short of the required demand.

With unlimited spectrum and unlimited budget, the Army could resolve its bandwidth issues. But these are unrealistic assumptions. Certainly, demand reduction can help close the gap between the requirements and availability of network capacity. However, it is not clear how much demand reduction is possible while retaining the information dominance that is critical for the future force. Demand reduction will need to be coupled with technology investments (e.g., satellites, UAVs, directional antennas, more radios). A number of

[1] Casper et al. (1996).

[2] Cebrowski and Garstka (1998).

technologies and concepts are being developed to enhance spectral efficiency, thus allowing the Army to make the best use of the available spectrum. Gaps between the supply and demand of capacity, both now and in the future, will have to be addressed by constantly reassessing demand for capacity and developing technologies that increase the supply.

It is important to note that bandwidth is not the only issue with regard to networked communication. Among the other critical issues are communications-on-the-move (not widely possible in Operation Iraqi Freedom) and interoperability. The Joint Tactical Radio System will be required to address these two issues.

Although the Army can take advantage of commercially developed technologies, the Army's operational situation differs fundamentally from that of industry. Currently, the Army differs from commercial industry in its approach to user and communications infrastructure mobility, information assurance (i.e., secure communication), and interoperability. It is not clear that the commercial world will be the source of all of the technology solutions. Department of Defense (DoD) funded initiatives are likely to be critical to the development of the key technologies.

Recent RAND Arroyo Center research analyzed how the Army uses bandwidth. As a result, this report describes a number of specific steps that can be taken to address the gap. They are listed below in order of priority, where priority is assigned to the steps that are likely to lead to the largest gains, based on our assessment.

Reassess Information Demands and Needs

The Army must perform experiments to understand what drives "real-world" information demands. There exists only a scant amount of data on the details of real-world demands and there has been little analysis of the necessity and the value of proposed information flows at each of the various echelons. Furthermore, the Army must reassess the necessity of these information requests. More experimentation is

needed to test how various information demands contribute to mission success.

Change Application Structure

Applications determine the volume and timing of a large part of information flow. Adjusting applications demands, such as by compression, can decrease bandwidth requirements by orders of magnitude. Minimizing the need to transmit raw sensor data will be beneficial, especially if local fusion is feasible. However, explicit performance assessments must be conducted to maintain quality with respect to data fusion and compression.

Manage Operational Demands to Meet Needs

Information traffic patterns exhibit differing needs for different priority users. Changing information needs require a dynamic network management approach to prioritize and smooth flow through the network. This has already been explicitly recommended in an Operation Iraqi Freedom after action report.[3]

Increase Efficiency of Network Routing

Army communications are increasingly network based and must be addressed from a network perspective. The Army Communications-Electronics Command (CECOM), the Defense Advanced Research Projects Agency (DARPA), and commercial industry are attempting to increase capacity through more efficient routing through networks.

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[3] Shaaber, Hedberg, and Wesson (2003) call for the "ability to manage bandwidth usage dynamically at the discretion of the commander [to allocate bandwidth] commensurate with operational priorities."

These techniques take advantage of knowledge of the network state to improve routing efficiency.

Increase Capacities of Links

Both CECOM and DARPA (e.g., in their FCS Communications and Next-Generation Communications programs) are working to increase link capacities by using higher frequencies and directional antennas. Theoretical assessments by Yi, Pei, and Kalyanaraman (2003) show that the capacity-multiplying effect of directional antennas over today's nondirectional (omnidirectional) antennas could be as high as one to two orders of magnitude, depending on the technology used. These are better results than what has been seen in simulation of various types of directional systems. Clearly, the opportunity for improvement exists, and more development is needed to fully realize the benefits of this concept. If directional antenna systems can be developed to their full potential, they could help ameliorate the inherent capacity limitations of large numbers of radios sharing a frequency channel.

Today's fixed, limited frequency allocation of available spectrum creates a hard limit on the amount of capacity, especially for ground vehicles on the move. Commercial demands in the United States, Europe, and elsewhere are squeezing the available spectrum for use by the U.S. military and its allies.[4] By one estimate, there may be as little as 55 MHz available[5] today for the Army; this could translate into 50 to 100 Mbps capacity for a given area of operation, at best. (Such

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[4] Quoting: "high-tech companies are lobbying to block the recent DOD proposal [to open up the 5,150 to 5,720] megahertz band to accommodate the burgeoning industry." *Inside the Pentagon*, "DoD Battles Industry on Spectrum Wanted for Wireless Networking," December 2002.

[5] This is when given only the JTRS threshold operating frequencies, which are between 2 Mhz and 2 Ghz, when considering availability for the Future Combat Systems (FCS) communication network. U.S. Army, "FCS WNW Spectrum Requirement" white paper, December 6, 2002.

limited spectrum access in CONUS also prohibits the "train as you fight" notion.) The lower end of this range may not be sufficient to accommodate one brigade-sized unit's situational awareness needs.[6]

Spectral reuse is key to achieving as much capacity as possible. Directional antennas facilitate reuse even with fixed frequency/spectral allocations. Fully dynamic spectrum management could facilitate even greater reuse of the spectrum by obviating the need for static channel/frequency assignments. DARPA is developing technologies to enable dynamic access to radio frequency spectrum. This is an important technology concept that needs to continue development.

Overall Assessment and Recommendations

Bandwidth is a limited resource that needs to be managed. New technologies will greatly increase capacity, but unchecked user demands will probably keep pace and exceed available capacities. No single technique will solve the problem. There are no silver bullets.

The challenge is to meet the right users' needs at the right time. To achieve this, it is recommended the Army do the following. First, bandwidth needs to be treated as an operational resource to be allocated by commanders and staffs. Second, the Army should continue to pursue all technologies that could provide benefit. Technology development should be synchronized through a single cognizant agency for efficiency and coordination. This includes not only communications systems but also systems-of-systems to reduce demands and create an overall information architecture. Third, the Army should develop and refine assessment tools; better assessment tools are needed to make complex tradeoffs. Last, the Army needs to make a partner of DoD to avoid unnecessary redirection and to take advantage of DoD-wide capabilities. This is especially important with respect to the

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[6] Assuming an average situational awareness (SA) data rate of 64 kilobits per second per vehicle/node and a 1,000+ node brigade.

DoD efforts to maintain and perhaps acquire new spectral allocations.