WARFIGHTER'S INTERNET – THE STUDY

Robert J. Reid
Naval Undersea Warfare Center

ABSTRACT

A "Warfighter's Internet" recognizes that next-generation warfare will take place in an information-rich environment, with highly mobile forces who are dependent on beyond line-of-sight (BLOS) communications. Connectivity is required to provide them information, surveillance, and reconnaissance (ISR) products, command and control (C2) messages, logistics support, and fire support. This technology also has direct application to the Test and Evaluation (T&E) community by providing the geographical extension of the range boundary via mobile BLOS communications.

INTRODUCTION

Warfare in the 21st century will be fought in an increasingly information-rich environment. The application of detailed information about the battlefield (location, composition, and maneuvers of enemy and friendly forces) will greatly increase the effectiveness of U.S. forces. To change data into information, sensor data and battlefield reports must flow to analysis centers for processing and then to users in a form they can easily digest and apply. The increased knowledge provided will allow U.S. decision-making to occur more rapidly than that of the enemy and our forces can immediately take the advantage in the battlefield. Through these mechanisms, information becomes a force multiplier that maximizes the effectiveness of deployed troops. To accomplish all of this, information must be delivered to the battlefield from anywhere on the globe. Battlefield users require communications systems to deliver information that reaches all force levels throughout the theater. Furthermore, the communications system must provide for information transfer from the forward warfighters and data relay from sensors to commanders and planning centers to complete the information feedback loop. In short, all combatants and their command and support elements must be connected in a secure, robust, global grid of communications.

However, the "global grid" available today is less than perfect, particularly in the forward areas of the tactical theater. Much of the communications infrastructure currently in the field is heavy, large, and not portable enough to keep up with rapidly maneuvering forces. Its arrival in a rapidly developing tactical theater is dependent on scarce air and sealift capability. Shortfalls have occurred in many recent deployments of U.S. forces overseas. In Operation
Desert Storm, the flanking maneuver by U.S. armored forces was accomplished with only minimal (and vulnerable) communications links because the theater Mobile Subscriber Equipment (MSE) communications system could not keep up with the armor. In Haiti, U.S. forces landing in Port-au-Prince had only limited ultra-high frequency (UHF) Satcom connectivity with forces landing in the north because of intervening terrain, since heavy super-high frequency (SHF) Satcom equipment did not land until sometime later.

What is needed is a new communications capability that is lightweight, rapidly deployed, and requires minimal logistic support in the theater. The new capability must be able to provide communications connectivity to isolated forces that are on the move (true mobility). The concept relies on airborne nodes within line-of-sight of theater forces, each other, and command and support centers (some of which are reached through connectivity to the world-wide Defense Information Simulation Network (DISN)). These airborne nodes, connected by crosslinks into a Warfighter's Internet, provide continuous, robust connectivity to forward theater forces for two-way data, voice, and multimedia traffic. They extend the global networking services utilized pre-deployment into the tactical theater, allowing users to operate as they are accustomed in the continental U.S. (CONUS). This technology can also be applied to other noncombatant users, such as the T&E and Training communities. The operational need as scenarios is discussed below.

**OPERATIONAL NEED AND CONCEPT**

Contingency operations as envisioned in the 21st century will be quite different from those in the past. They are likely to be comprised of smaller units, rapidly deployed, and at long range from their support services. Different deployment tactics may be used, such as small unit operations (SUO) in which teams of 10 to 20 soldiers are deeply deployed to determine enemy movements and then call in massive indirect fire rather than engaging the enemy directly. Special Operations Forces (SOF) operate in a similar manner, although traditionally they have only their own resources for support, and rely on stealth and surprise for success. The SUO depends on long-range communications (BLOS) for success. However, heavy communications infrastructure is inconsistent with their light armament and deployment methods. Simple line-of-sight radios to reach an airborne communication node, which in turn is able to relay messages to and from Theater and/or CONUS command and support services, provide the effective connectivity these forces need. Through this Warfighter's Internet can flow needed command and control traffic, ISR products, and requests for medical, logistic, and fire support services. Most of this traffic is (bursty) computer data, but it also includes continuous-rate voice and video.

Amphibious assault is another scenario that can benefit from an airborne communications network and is typical of early-entry situations with limited support infrastructure. Future amphibious assaults will likely be carried out with fleet resources over the horizon from the
beach head or landing zone to protect ships from cruise missiles. Troops arriving from landing craft and helicopters will not be able to carry heavy communications infrastructure. The Warfighter's Internet can provide the over-the-horizon connectivity while requiring only small, lightweight line-of-sight radios.

Even in more conventional force deployments, there will be situations in which some forces have lost line-of-sight connectivity with the rest of the forces, because of either rapid maneuvers or geographical factors such as intervening mountains. The airborne network provides the needed connectivity in this case as well. Figure 1 graphically depicts the Warfighter's Internet supporting military operations.

![Figure 1. Warfighter's Internet Support of Military Operations](image)

Airborne communications assets can also be seen as an overlay to conventional force deployments. Airborne nodes extend existing theater communications systems to highly mobile or separated forces at or beyond the forward line of troops (FLOT). In addition to servicing these isolated forces, the airborne network can provide alternative connectivity to substitute for deployed MSE equipment that is unable to make a node connection because of terrain, enemy action, or equipment failure.

The Warfighter's Internet contributes in several ways to information flow in the battlefield, and is synergistic with other theater communications systems in the process. The obvious use is BLOS connectivity for theater-wide networking with global access. This capability would be utilized by small unit operations for C2, support requests, and for ISR data dissemination and requests. ISR products will normally be delivered to the theater by the Global Broadcast Satellite (GBS) /Battlefield Awareness and Data Dissemination (BADD) system to locations equipped with the standard GBS microwave receive terminal and Warfighter's Associate processing system. But for forward and lightly equipped troops, the essential ISR products can arrive through the Warfighter's Internet. This can be in the form of secondary dissemination of selected BADD information that is multicast through the Warfighter's
Internet, or from special re-broadcast (at a frequency around 1 gigahertz (GHz)) of selected BADD information from the airborne communication nodes (ACNs) to mobile receivers that can operate on the move using omnidirectional antennas as shown in Figure 2.

Airborne nodes used for the Warfighter's Internet include, but are not limited to, ACNs on the Global Hawk high-altitude endurance (HAE) unmanned airborne vehicles (UAVs) flying at 65,000 feet. These ACNs are particularly effective nodes for theater communications because of their altitude (coverage) and endurance. In addition to hosting the Warfighter’s Internet communications equipment, the ACN carries other equipment to service legacy radios in the tactical theater (e.g., the Single-Channel Ground-to-Air Radio System (SINCGARS), Line-of-Sight Ultra-High Frequency (LOS UHF), Extended Position Location Reporting System (EPLRS), and Joint Tactical Information Data System (JTIDS). ACN equipment also includes the T1 rebroadcast of selected BADD traffic and the ability to relay wideband data between MSE node centers or between radio access points (RAPs). Interconnects between the Warfighter’s Internet equipment and other ACN equipment can take place on board the ACN platform. Both the ACN and the Warfighter’s Internet would make use of the communications satellite terminal on board the Global Hawk to provide global reachback connectivity.

Figure 2. Integrated Information Flow in the Battlefield

**NON-COMBAT APPLICATIONS**

Non-combat operations should also be considered. T&E and Training would be supported by technology developed from the Warfighter's Internet concept in support of new testing requirements. Joint Vision 2010 presents a conceptual approach to increasing the effectiveness of future U.S. military forces while being constrained by force reductions and operating in an era of flat military budgets. The basic goals of the U.S. military remain the same as in the past, namely, deterrence of conflict if at all possible, but, when necessary, a power projection that will dominate in all aspects of conflict and achieve decisive victory with minimal U.S. casualties.
T&E activities take place throughout the system acquisition process and continue after actual system deployment. Developmental test and evaluation (DT&E) is usually performed on a small scale to collect engineering data on the performance of the System Under Test (SUT), requiring telemetry that will allow engineering diagnosis of malfunctions. Operational OT&E can be performed on a larger scale, perhaps on the order of a significant training exercise, but the data collected are oriented toward evaluating the accuracy or ability of the SUT to cope with stressing scenarios. Operational tests are usually performed with military personnel operating the SUT.

TEST AND EVALUATION (T&E)

Both DT&E and OT&E can include virtual forces to enhance the scope of the testing, for example, by overloading the SUT with virtual targets or electronic countermeasure (ECM) threats. Continued OT&E after deployment is concerned with T&E of system upgrades, performance against new threats or scenarios, or new employment concepts. Both DT&E and OT&E are expected to take place off-range more frequently in the future, requiring special communication support to couple the virtual entities into the live tests and to collect and analyze data from remote areas. This is where the Warfighter’s Internet appears to be most valuable in T&E.

DT&E is involved in the system development process, while OT&E activities can address the effectiveness of systems, doctrine, and operational procedures. In general, however, a test involves one or more test ranges, a range control center (RCC), and (possibly) a virtual battlespace. The virtual battlespace includes remotely located simulation facilities that must be coupled to the players on the live range. The test range has a number of components: live entities operating the equipment or carrying out a particular maneuver; the system under test (SUT); the focus of the test; targets to challenge the SUT; an instrumentation system to locate and determine state of the entities; a telemetry system for gathering data on the SUT operation; a communication infrastructure to collect data, monitor entity positions, and control the test; and a data logging facility to gather and archive data from the test.

T&E SCENARIOS

Currently most T&E activities take place on prepared test ranges with live participants operating the equipment being evaluated. The area required for DT&E may be quite small, depending on the SUT requirements. Testing a new weapon with a 1-kilometer (km) range would require on the order of a few km. However, in medium- and long-range missile tests, two separate ranges are often involved, and communication and coordination between them is complex.
OT&E could resemble a large training exercise, with a large number of personnel organized into Blue (friendly) forces and opposing forces (OPFORS). Tests may involve up to a battalion-size unit, which, together with a battalion-size OPFORS, would require on the order of 1000 square km, with a separation between entities of as much as 100 km. Current test ranges usually provide a communication, control, and instrumentation infrastructure. New types of tests, perhaps involving joint forces for the first time, may require new or augmented communication facilities.

Because of the limited choices in environmental conditions at current test ranges, it is often desirable to conduct certain tests off-range, i.e., at unprepared sites. If a tropical rain-forest environment is needed for T&E of a new soldier radio, present test ranges may not be capable of providing adequate realism. Similarly, systems already deployed on operational platforms are often not able to go to a test range, and a system upgrade might have to be evaluated at an operational military base or even in the open ocean. In the case of off-range T&E, there is one set of communication problems at the test site (i.e., intra-range), and one associated with communication requirements with remote facilities that could be thousands of km away (inter-range).

PARTICIPANTS, TYPES, AND NUMBERS

DT&E involving a single, large SUT might require high-rate telemetry from the SUT (on the order of tens of Mbytes/sec) and perhaps 10 or more remotely controlled targets (each requiring a control link providing a data rate of hundreds of bits/sec). Personnel counts might reach up to 100 people, all of whom should be monitored (position and state or condition) while on the live range. The SUT may be faced with a number of live targets, remotely controlled targets, and virtual targets (simulated entities remotely located, including human-in-the-loop simulators).

At the other extreme, OT&E might involve a battalion-vs-battalion simulated battle, including several tens of tanks, Bradleys, rotary-wing aircraft, and possibly even fixed-wing aircraft. The typical army battalion has 600 to 800 members. Two battalions plus perhaps 100 observer/controllers (O/Cs) on the range to monitor and control the activities, plus other supporting units, could result in nearly 2,000 live entities on the range during such a test. SUT telemetry would still be desired, although lower data rates would suffice, since OT&E requires data sufficient to determine exactly what the SUT did, i.e., how well it performed, but not for diagnosing engineering design problems.
COMMUNICATIONS SERVICES REQUIRED

On a single test range for a simple test on a SUT, the basic types of intra-range message flows can be summarized as follows:

1. Data reporting (position and status) of live entities on the range to the RCC,
2. Control messages to the O/Cs, range safety, remotely controlled devices and platforms, and perhaps to the live players (e.g., "stand by / test on hold" or "break it off"), and
3. SUT telemetry and other special instrumentation sensor data reporting to the RCC.

In the basic case of a single range and a single RCC, all of these message types can be handled most conveniently with a star network topology. This is feasible, for example, if LOS links can be achieved between all players on the range and the antenna tower(s) at the RCC. If LOS cannot be achieved (because of the length of some links or some terrain blockage), then communication relays are necessary, and the topology becomes more complex, as do net management and control.

Data reporting to the RCC could, in general, be satisfied with a connectionless messaging service. Depending on data rates and loading, the latency associated with a wireless network with transmission lengths no longer than 100 km should be on the order of milliseconds, which is more than adequate for this function.

Data reporting by a live player on the range involves sending geolocation and time of measurement (ranging from 64 to 256 bits), and status (8 to 16 bits) in a message to the RCC. The update rate depends on the speed and acceleration of the entity. For example, a tank would probably require no more than one update per second. The more dynamic entities, such as fixed-wing aircraft and missiles, would require up to perhaps 10 to 30 updates per second, while the dismounted players might require only one or two updates per minute. A very rough upper boundary on the position and status reporting message length to the RCC can be taken as 256 bits before error correcting coding. A rate one-half error control coding (ECC) is assumed, so that the total coded message length for this service would be approximately 500 bits in round numbers.

A large-scale test involving two battalions and 100 O/Cs would require an aggregate communication capacity of approximately 35 to 50 kilobytes per second (Kb/s) for the coded data (i.e., including the rate of one-half ECC redundancy). A total of 25 aircraft with update rates of 10 per second would add another 125 Kb/s. The total capacity required for entity reporting to the RCC may be upper bounded by 175 Kb/s.

Another form of monitoring the live range involves the transmission of imagery or video from a number of the O/Cs or fixed camera sites to the RCC. Assuming a 1000 x 1000 pixel
(still) image, 24-bit color, and 10:1 compression, a single image would require the transmission of 2.4 megabytes (Mbytes). A high-speed data service operating at a rate of 120 Kb/s could transmit a single compressed image in 20 seconds (the suggestion of 120 Kb/s is motivated by wireless link considerations). This could provide a maximum of three independent images per minute to the RCC, which is minimal. A large-scale exercise might require 5 to 10 times this image transmission rate. Video would be even more demanding than compressed still images, especially if full-motion TV-resolution video were required. This falls into the SUT telemetry category.

Control messages from the RCC to entities on the range would use both data messages and voice (discussions between the RCC and O/Cs on the range). These messages would be sent almost exclusively to the O/Cs and very rarely to a subset of the players. Compared to the capacity required for entity reporting, the capacity of these control messages is dominated by the number of voice channels simultaneously in use during a test. Assuming that 20% of the O/Cs use voice during a test, and 4.8 Kb/s digitized voice (full duplex), this amounts to a total of 200 Kb/s. Latency requirements are also governed by the voice channel requirements of 100 to 150 msec for acceptable two-way conversations.

Telemetry from the SUT can vary widely, depending on the type of test and the type of SUT. In DT&E, the telemetry would be more demanding than the other services simply because the scale of the test is likely to be smaller and the telemetry is more critical. In OT&E, a large-scale test would involve a large number of players on the range, but less telemetry from the SUT. If we assume that SUT telemetry for DT&E requires 100 times the message length as entity report messages and 100 updates/sec, this implies a telemetry link with a capacity of 5 Mb/s. The telemetry can clearly dominate the communication requirements for T&E. However, the requirement is for connectivity only between the SUT and the RCC. A point-to-point telemetry link would suffice. If a more complex SUT requires significantly higher data rate than the 5-Mb/s estimate, then a separate point-to-point link may well be the cost-effective solution.

In summary, the communication services that would suffice for the T&E problem are low-rate data messaging for monitoring functions, digital voice, and compressed imagery. A high-rate data stream is also required for SUT telemetry and video. A rough estimate of the total communication capacity needed to support T&E activities at a single test range with a single RCC is on the order of 0.5 Mb/s for entity reporting, voice, and limited imagery, plus SUT telemetry which could range from 5 to 10 Mb/s. Connectivity (for the single range and its RCC) can be satisfied by a star network topology with the RCC at the hub or center. That is, there is no strong requirement for independent entity-to-entity communication on the test range. The exception, of course, is the case where an entity may have to be used as a relay between another entity and the RCC.
MULTIPLE RANGE TESTS

In addition to the communications needs of a single test range with its RCC, more than one test range may be involved in certain tests, such as for a medium-range missile, where the launch takes place at one range and the target is located in another. Another example might be the coordination of two tactical units beyond LOS of each other, in which it may be advantageous to have the units on two different ranges.

The second potential of Warfighter’s Internet application in T&E is providing the connectivity between ranges in a multiple range test that would also include a virtual battlespace as one of the nodes. Each node needs to transmit a data stream (that can be as much as 5 to 10 Mb/s) to each of the other nodes participating in the test. A network that could be rapidly deployed anywhere in the world providing coverage over 50 x 50 km areas with a single net entry point would not only be valuable, but could also be critical to future joint-service T&E operations that are likely to involve activities at unprepared sites.

CONCLUSION

The Warfighter's Internet Study conceptualizes an architecture network based on the requirements described in this paper. Detailed network protocol analysis and engineering has been conducted to support the requirements set forth. The hope is that the Defense Advanced Research Project Agency (DARPA) and other military communities will fund some of this technical development in the area of mobile wireless networking because it is required to support warfighting in the 21st century.