Army Transformation: Wireless Network Support to Horizontal Fusion

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1 ABSTRACT:

Quantum Leap is a phased, multi-faceted experiment, with different agencies taking the lead in different programs, to test network-centric warfare operations. Army Research Laboratory (ARL) is a key participant in the Horizontal Fusion program which facilitates the flow of specific, relevant and timely information from strategic information sources to the user based on pre-established criteria. The goal of Horizontal Fusion is to get the information into the hands of the designated user as quickly as possible, without going through the traditional process of processing and analyzing collected data. ARL is also responsible for the Warriors Edge program which consists of sending and receiving data from robots that follow and support ground soldiers. In order for these devices to communicate with the ground soldiers, and for the soldiers to communicate with each other using various devices, a robust communications network is essential. Since army radios are currently not sufficient for the volume of data transferred between all of the nodes, the ARL networking team turned to commercial off-the-shelf 802.11x wireless technology in order to ensure the overall success of the program. With this equipment, a wireless network is established with the necessary bandwidth, range and separation of data to ensure that all of the many assets are able to effectively communicate in order to accomplish the Quantum Leap mission.

2. Introduction.

In order for the soldier of the future to be more lethal and effective in combat, they must have the most advanced and technologically capable systems. The Warrior's Edge project outfits the future soldier with a voice over Internet Protocol (IP), digital movie camera, heads up digital display, digital compass, a GPS with gyro a capability that allows tracking even after the loss of

the satellite signal and a laser range finder. In order to manage all of this equipment, the Warrior's Edge soldier has two laptop PCs (see Figure 1).

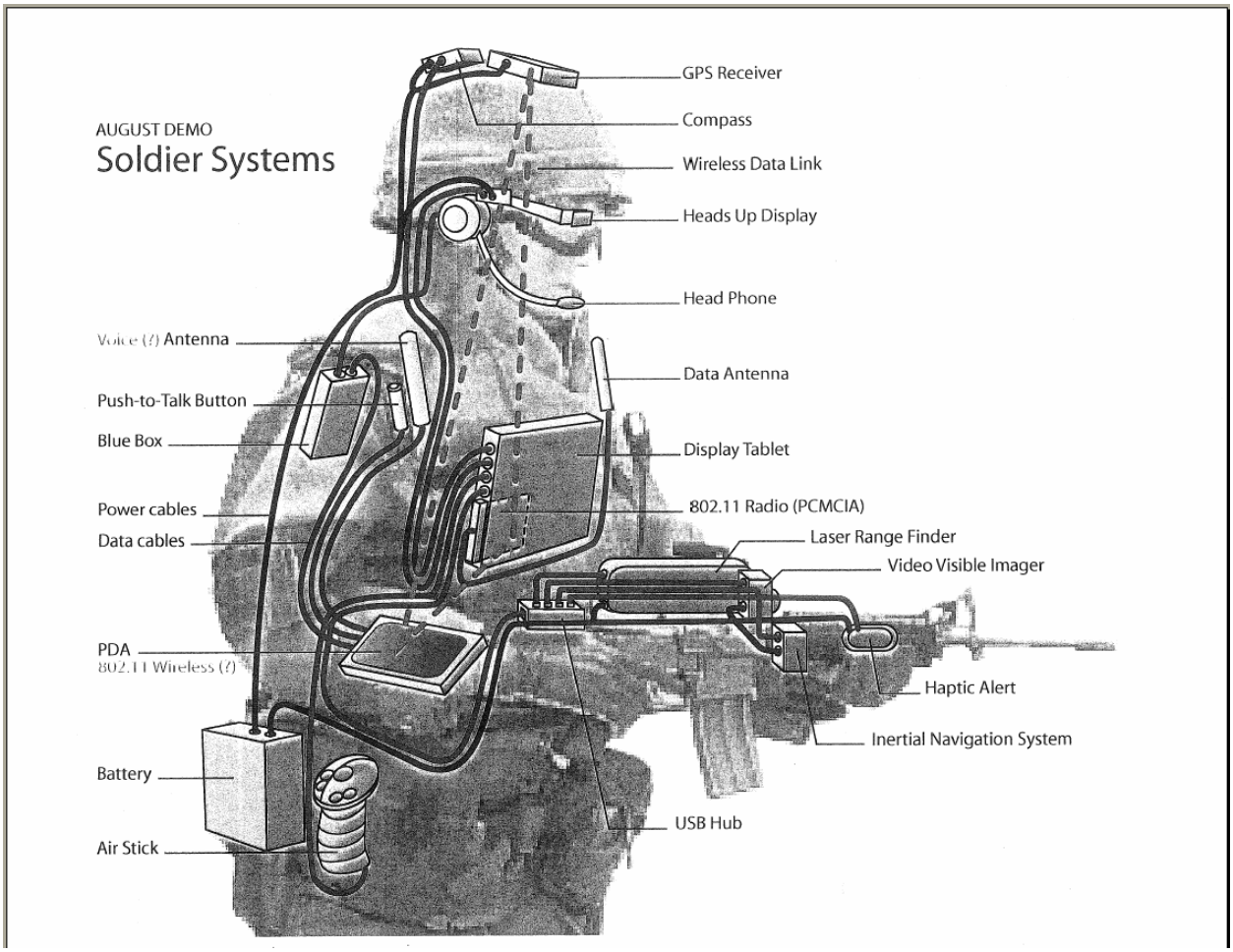

Figure 1. Warrior's Edge Soldier Systems

However, none of this would be relevant, if the soldier could not talk to their equipment, or to other systems. This is where Horizontal Fusion comes in. Horizontal Fusion is a program which facilitates the flow of specific, relevant and timely information from the collateral space to the user, based on pre-established criteria. The goal of Horizontal Fusion is to get the information into the hands of the designated user as quickly as possible, without going through the traditional technique of processing and analyzing collected data. None of this would be possible, however, without the means to communicate. Not only does a soldier have to be able to communicate with their own equipment, but also with other assets. More importantly, this is done while on the move and in real time. Current Army inventory radios are not capable of facilitating the necessary connectivity.

With commercial off the shelf equipment, we are able to establish the necessary network for the soldier of the future to communicate effectively using current wireless technology. With a combination of 802.11a, 802.11b and 802.11g networks, we established a wide area of connectivity in which the soldier was able to shoot, move and communicate efficiently and effectively.

The main challenge was to find a high speed network that provided the required channels at necessary ranges with sufficient bandwidth.

3 Research

3.1 Looking for the right combination.

At the time 802.11a protocol, was new to the wireless mainstream and 802.11b was well entrenched in the market. In fact, the McKenna Military Operations and Urban Training (MOUT) site at Fort Benning Georgia, where the test was conducted, already had a reasonably effective wireless network established with 802.11b equipment. However, we did not feel that the existing wireless network would be robust enough to successfully support the Quantum Leap One experiment. Although 802.11b has the necessary range, it only has three non-overlapping channels (channels 1, 6 and 11) and limited bandwidth. (It can only transmit a maximum of 11 mbps, which stands for a million bits of data transmitted per second). One advantage that 802.11b has over 802.11a, since it operates at the 2.4 GHz (gigahertz) Industrial Scientific Medical (ISM) band, is that the signal travels farther and propagates further through objects. 802.11b uses Direct Sequence Spread Spectrum (DSSS) as the physical layer technique.

The following information represents the ranges and throughputs for a generic, unobstructed 802.11b wireless Access Point (AP). In an outdoor environment:

Distance from AP	Bandwidth
500 meters	1 Mbps
400 meters	2 Mbps
350 meters	5.5 Mbps
250 meters	11 Mbps

Table 1: 802.11b wireless throughput at different ranges outdoors

The following information represents the ranges and throughputs for a generic, unobstructed 802.11b wireless Access Point (AP). In an indoor environment:

Distance from AP	Bandwidth
150 meters	1 Mbps
120 meters	2 Mbps
80 meters	5.5 Mbps
50 meters	11 Mbps

Table 2: 802.11b wireless throughput at different ranges indoors

Even though the ranges are sufficient for the experiment, with the limited bandwidth, there would be no way to push the video and other feeds without flooding and overwhelming the network. So we turned our attention to an 802.11a network to augment the existing 802.11b network. (At this point it is worthwhile to note that the 802.11g had not been approved for use and there were significant problems with interoperability. Subsequently, it became available and we fully integrated it into our network).

As stated earlier, 802.11a does not have the long ranges that 802.11b has. The ranges for 802.11a are as follows.

Distance from AP outdoors	Bandwidth	Distance from AP indoors	Bandwidth
360 meters	6 MBps	90 meters	6 Mbps
30 meters	54 Mbps	18 meters	2 Mbps

Table 3: 802.11a wireless throughput at different ranges indoors and outdoors

Although the ranges are not as great as 802.11b, the bandwidth is considerably more robust. Additionally, where 802.11b only has three non-overlapping channels, 802.11a has eight utilizing 300 MHz of bandwidth in the 5 GHz Unlicensed National Information Infrastructure (U-NII) band, which uses Orthogonal Frequency Division Multiplexing (OFDM). OFDM is an encoding scheme that provides greater data rates and more channels. The eight channels are found in the low to middle partition of this band.

Channel	Frequency
36	5.18 GHz
40	5.2 GHz
44	5.22 GHz
48	5.24 GHz
52	5.26 GHz
56	5.28 GHz
60	5.30 GHz
64	5.32 GHz

Table 4: Available channels and frequencies for 802.11a

Having multiple channels allowed us to place more access points without overlapping and running the risk of jamming the channel, which happens when two access points are too close together on the same channel. Having two networks also allowed us to divide the assets among the different networks to maximize their ability to communicate effectively.

A last benefit of 802.11a came towards the end of our research when we discovered that one of the vendors we were working with produced an access point which operated in all three band divisions, providing five more channels in the high band between 5.725 and 5.825 GHz. The new channels available are:

Channel	Frequency
149	5.745 GHz
153	5.765 GHz
157	5.785 GHz
161	5.805 GHz
165	5.825 GHz

Table 5: Available channels and frequencies in the high band of 802.11a

3.2 Gathering the necessary tools

Now we had a good idea of what we wanted and the general equipment that we needed to establish the network the only thing left to do was to find it. Since we were on such a short timeline, we weren't able to build the equipment, so we turned to Commercial Off the Shelf (COTS) equipment. Early on, one of the problems we faced was the incompatibility of amplifiers. We had amplifiers that would work with the 802.11a access points in the High GHz range (approx. 5.8 GHz), but no access points were available in that range. We had numerous access points in the lower 802.11a GHz range, but did not have any amplifiers available. Additionally, since the FCC had restrictions on the power output that commercial vendors could produce for their amplifiers, there were none commercially available that would suit our purposes. After failing to push the amplifier industry to support our requirements, in accordance with our timeline, we discovered an 802.11a AP that operated in all three frequency bands. Thus, our problem was solved.

Initial tests with the access points were positive, but there where some incompatibilities with the wireless cards that we were using, that also covered all three bands in 802.11a. This problem was solved when we obtained the new cards with the new chip set that fully supported the upper five channels.

During this time, 802.11g received approval and numerous vendors began offering the newest 802.11 protocol. Since 802.11g operated at the 2.4 GHz range, it had the same three non-overlapping channels as 802.11b, but was much faster. Because it uses the same Orthogonal Frequency Division Multiplexing as 802.11a, it has the same speeds as 802.11a with the greater distances found with 802.11b.

After considering the requirements for Warrior's Edge, we settled on the following for the wireless network. To provide the necessary coverage, we used the Netgear 802.11a/b Access Points for the soldiers, who are equipped with Netgear a/b/g cards. We established a dedicated 802.11g for the MULE to communicate with Space and Naval Warfare Systems Command (SPAWARS) without being overwhelmed with data from the rest of the traffic being passed. The three robots have been equipped with a Netgear 802.11g bridge that will allow them to pass video and other traffic on the higher speed network.

4 Re-wirelessing the MOUT site

All that was left to do was to emplace all of our equipment, in conjunction with the existing network, to ensure connectivity at the critical points of the exercise. Over a six week period we emplaced the various pieces of network equipment and tested it for range and throughput as required for each phase of the exercise. Figure 2 below represents what the MOUT site looked like, with the yellow circles representing the existing access points.

Figure 2. 802.11b wireless access points at the McKenna MOUT site.

Figure 3 depicts how all the assets involved, communicated and passed data to any other asset on the network. The only dedicated line is from the MULE to the trailer where the information is passed from the exercise to SPAWARS in Charleston, South Carolina.

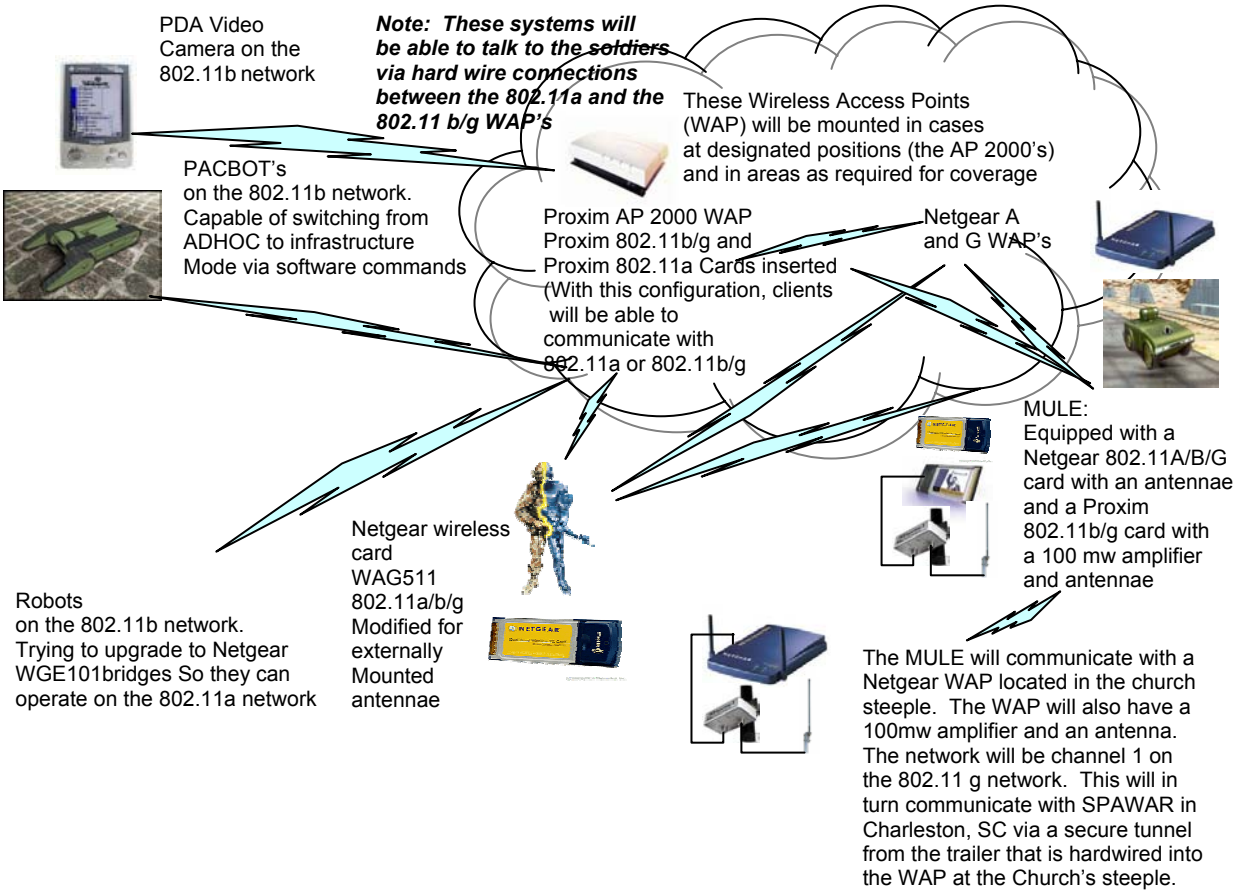

Figure 3. Communications network diagram

When setting up a wireless network, where to locate the access points can be a problem. Of paramount concern, is where to emplace the access points to provide full coverage without jamming each other. Jamming happens when two access points are positioned too close together on the same channel. With 802.11b, because of the greater range and only three non-overlapping channels this can be difficult. However, with 802.11a, since there are 13 channels and more limited range, this is a much simpler problem.

Figure 4 shows the directed graph used to determine the location of the various access points. There are other factors that influence the emplacement of the access points other than channel and range. The amount of solid and semi-solid material intervening between the access points has a dramatic impact on the propagation of the signal. In other words, if there are buildings in between the access points, than we could use the same channel on access points closer together without fear of interference.

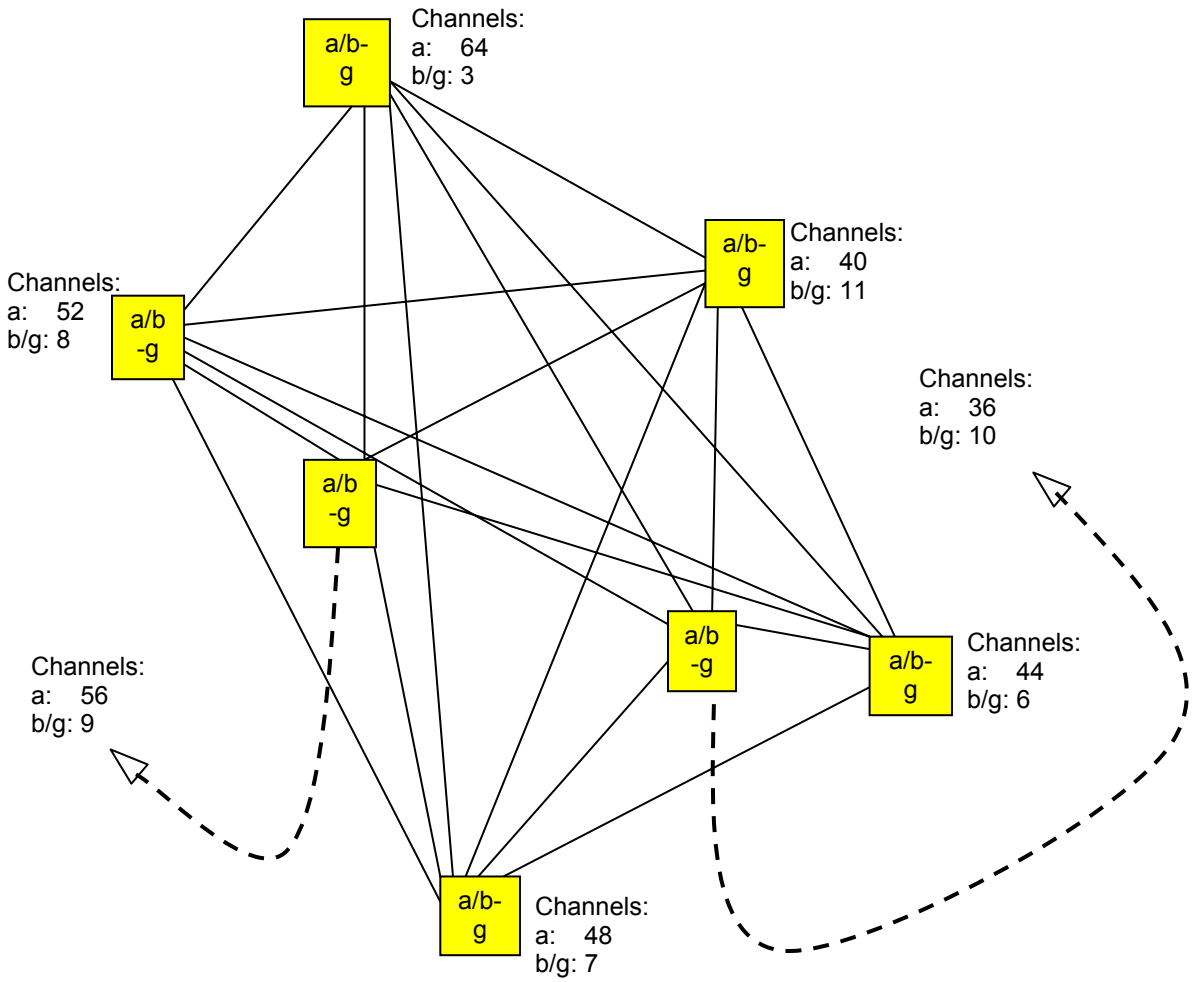

Figure 4. Directed Graph used for the emplacement of access points.

5 Demonstration

As we approached the day of the Warrior's Edge demonstration, we determined that there were a number of areas where the coverage from existing access points was weak, particularly for the 802.11a access points. We added a number of new access points, resulting in the final access

point distribution shown in Figure 5. 802.11a is represented with red, 802.11g is blue and 802.11g to SPAWARS is green.

Figure 5. Overhead photo depicting final wireless coverage.

In this configuration, the entire village had adequate wireless coverage for both 802.11a and 802.11g. The soldiers and robotic vehicles were able to roam freely throughout the village with almost complete signal coverage. However, in some locations in the village, mobile users experienced excessive delays in switching from a weak access point to a stronger one. These delays were observed for both 802.11a and 802.11g, and using equipment from both vendors (Netgear and Proxim). In some cases the switching delay was as long as 20 seconds, during which the mobile user lost all network connectivity. When we reduced the access point density by turning some of them off, the switching time improved greatly, but at the cost of increased areas with weak wireless coverage. Consultation with the equipment vendors revealed that there is a known “convergence problem” with the 802.11 client cards when a card sees more than three access points while switching. They had no solution to this problem. Since we could not resolve the switching delay problem without creating unacceptable weak coverage spots in the village, we modified the delay-sensitive applications being used in the demo to be more tolerant of long disconnected periods.

6 Conclusion

The Warrior's Edge demonstration took place in late August, 2003. With the exception of the switching delays, the wireless network worked well and provided the required network connectivity between the soldier systems, the MULE, and the wired network connection to SPAWAR in Charleston.