11TH INTERNATIONAL COMMAND AND CONTROL RESEARCH TECHNOLOGY SYMPOSIUM

Coalition Command And Control In The Networked Era

Experiment Future Might 05 (Technology) – A Study Into The Effects of Low Cost Broadband Networks And Collaborative Tools For Net-Centric Operations in The Field

Topic:

C2 Experimentation

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ABSTRACT

Network-Centric Warfare (NCW) was defined as a revolutionary concept for military forces to fight distributed, yet integrated by exploiting the power of networks to self-synchronize entities in the battlefield. It is a vision. The question is when and how can military forces transform to be more effective with the NCW concept? The possibility to realize NCW is here today, with technologies at our very doorstep! Today's COTS (commercial off-the-shelf) technologies possess the functionality to support the information and knowledge needs of the military. Text messaging, voice over IP (VoIP), portals and collaboration tools, for instance video conferencing, are relatively mature and widely used in the commercial practice. Broadband communications such as WIFI and WIMAX are also likely to be more favoured over traditional radios to support high bandwidth information demands.

In November 2005, the SAF Centre for Military Experimentation (SCME) conducted Experiment Future Might 05 (Technology) in Shoalwater Bay, Queensland, Australia. The intent of the experiment was to demonstrate the potential of using state-of-the-art C2 collaboration tools to facilitate dynamic planning for both the Air and Land forces, enabled by a COTS network environment that was both adaptive and high bandwidth. The COTS network environment was deployed using several 802.11 Radios, hoisted high in the air by balloons, capable of providing a coverage area of about 20 km by 20 km at the exercise training area.

This paper will look into how knowledge is acquired rapidly over several adaptive environments i.e. static, vehicle-on-the-move, dismounted and onboard helicopters through the process of self situation awareness, assessment and distributed collaborative planning. It will also discuss the effects of the underlying broadband communications network that can significantly affect performance of the collaboration tools over a tactical air-land operational environment.

INTRODUCTION

The Integrated Knowledge-Based Command and Control or IKC2 is a Singapore's Armed Forces (SAF) strategy towards NCW [1]. It assumes the principle of using knowledge as a commodity to force multiply our force. This means it is the people themselves within the SAF that will make IKC2 realisable, for knowledge is a commodity that can only be achieved through shared mental models or real-time collaboration.

Coupled with technology's obsolescence cycle, perhaps 2 to 3 years, as opposed to the average 7 to 10 years cycle in the earlier generation, it is evident that the approach to buying expensive and robust technology for communications and even software will not position us towards the goals of IKC2. The strategy is to apply creative ideas and clever technologies to meet operational challenges of the future and that would allow for quick renewal in pace of today's or tomorrow's technology.

Experiment Future Might 05 (Technology) is an experimental concept that suggests the employment of low cost COTS technology with a bandwidth capability of 100 times more than the current military communication system, in exploring the tenets of IKC2's evolving concept of see first, understand and decide faster and better, thus giving rise to smarter and self-synchronized warriors.

THE VALUE OF BROADBAND COMMUNICATIONS

Why is commercial broadband communications important for the 3G SAF? New generation military radios such as the combat net radios are able to achieve 115 kbps in year 2005 [2] while traditional military data radio systems that the SAF operates currently are at less than 10 kbps. Trends over the last 10 to 20 years showed that military radios can cost 10 times more than commercial IEEE standards of WIFI and WIMAX, yet have bandwidth that is 100 times less. See Figure 1. In other words, we argue that military radios are increasingly more expensive with the minimal increment in data bandwidth, which would not advance our knowledge any much further than required for the future generation of the SAF.

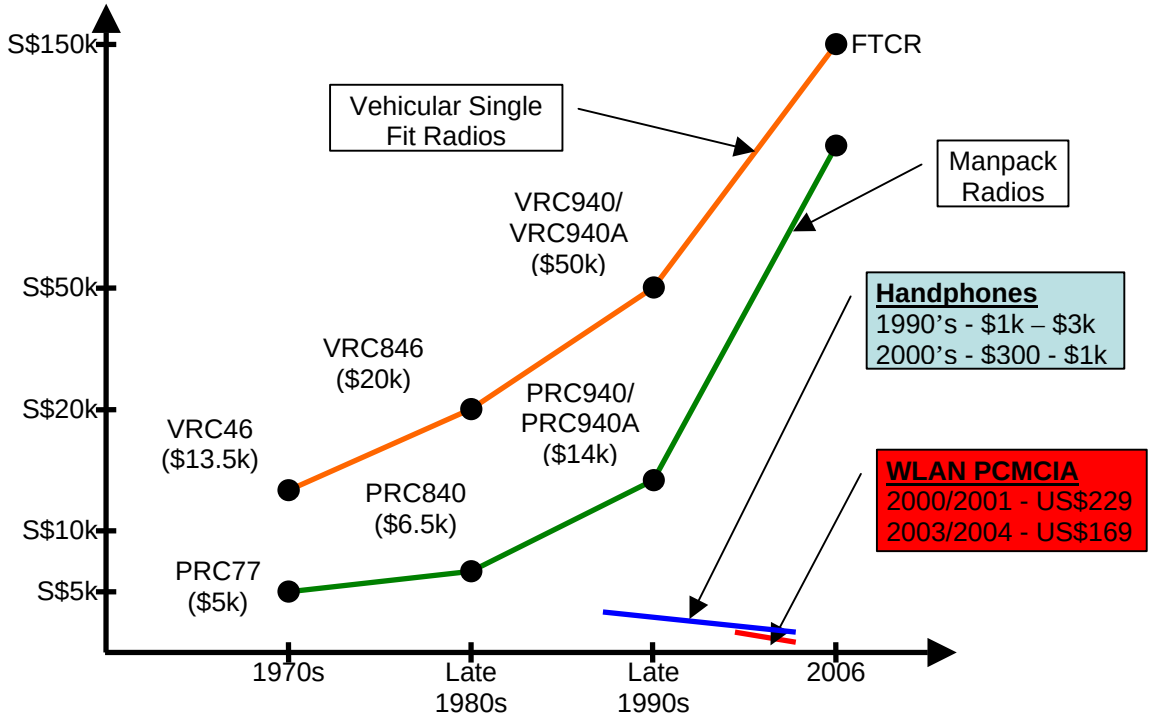


Figure 1: Cost Of Military Radios Versus COTS

Given greater bandwidth, we witnessed that knowledge is achieved far more quickly through video and picture feeds as evident in Operation Iraqi Freedom [3]. The ability to own high bandwidth communications also give rise to potentially more innovative C2 software to be used on the network by the Command Team in gaining knowledge across the 3 domains of Air Force, Army and Navy Services. These include real-time simulation feeds of predicted actions, collaborative planning on graphical interfaces, on-line video and picture mosaic, on-line immersion and agent-based computing methods that increase awareness of logic and situation on the battlefield.

Of relevance to radios is the Mobile Ad-hoc Network or MANET for the battlefield. If the national telecommunications would not fail in time of chaos like 911, perhaps there may not be a need for an independently owned MANET system. The employment of the military MANET is to quickly set-up the communications infrastructure independently as well as to extend the range of the Area of Operation (AO) easily, without prior infrastructure set-ups by the addition or relocation of node/s to the network.

The SAF Centre for Military Experimentation (SCME), together with Defence Science and Technology Agency (DSTA) in Singapore, developed 2 exploratory Low Cost Data Network (LCDN) programs essentially looking at COTS technologies to test new infrastructure for the SAF communications.

The first program was the 802.16a WIMAX. This LCDN was experimented successfully during Experiment Future Might 04 in Australia, October 2004 [4]. The purpose of the experiment was to investigate the following hypothesis: Given good collaborative C2 applications over a broadband network like WIMAX, we could physically disperse the

Cells of a Brigade Command Post (CP) across the theatre of operations so that they remain highly survivable without airborne detection and that the Command Team would be equally effective in information and knowledge sharing. The program achieved a good 6 Mbps throughput constantly for information and knowledge sharing to take place. With 802.16e on the way to the market, probably this year, it would be interesting to experiment this standard for the military, which boasts of allowing broadband communications amongst users traveling at speed exceeding 100 km/h [5].

The second program was the 802.11b/g WIFI in 2005. Unlike the former, this program had both broadband and MANET capabilities, although the bandwidth is a fraction smaller than the 802.16a. The aim of this program is to adopt COTS wireless networking standards that is to be fixed on unmanned and manned airborne platforms, allowing a physical transmission of 1 to 2 Mbps. This second program was featured in Experiment Future Might 05 (Technology), which will be discussed in subsequent sections.

TECHNOLOGIES TO ACQUIRE KNOWLEDGE QUICKLY

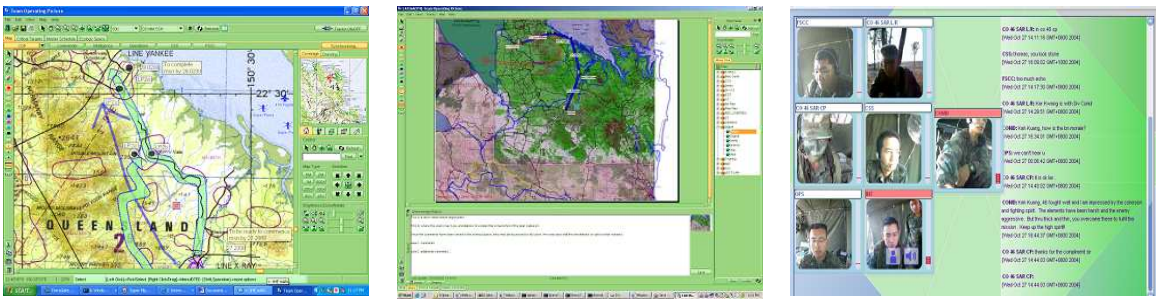
The technology of the future for the SAF is fundamentally allowing every soldier an on-line, on-time access to information that would enable them to know, understand, visualize and discuss mental models across all commands and forces at any time, and hopefully at any place.

When we had the second generation of C2 system, the web technology was probably the biggest selling point for users to use the system. We have since improved upon the web to include how we can allow users to customize their own window views, not unlike those in Yahoo or MSN Web Portal, and incorporated chat on-line. We noticed that older generation of users and very senior Commanders were able to browse the web and have also used chat tools for on-line collaboration, as they were both easy and fun to use.

Given the experience of chat tools for military C2 systems, we believed that new ideas in collaboration technologies would be the next generation of useful tool for military users, especially for the Command Team to quickly achieve shared awareness and mental models. Collaboration technologies [6] are particularly prominent in the commercial world as industries recognize the significance and demand in collaborative software platform as it promotes multi-party collaboration and sharing, be it within company or between companies, in a common environment. From instant messaging, sharing files, web browsing or a virtual sketchpad, there is no special training necessary for the end users yet allowing for greater interweaving of processes.

SCME, together with DSTA, developed MissionMate in 2004. It is also known as the Command and Control Knowledge System or CCKS [7]. It created great excitement about what such collaboration could do for the Command Team. The collaborative environment comprises the Team Operational Picture (PowerMap), a collaborative information archival tool (PowerMind) and communication tools like video-conferencing and text-chat (PowerVC), which facilitate the co-ordination and collaboration amongst

team members whether they being physically co-located or distributed, thereby allowing them to draw on the relevant system-level knowledge and expand their individual awareness to support the activities that they perform. See Figure 2.



PowerMap **PowerMind** **PowerVC**

Figure 2: Collaborative Environment Comprising PowerMap, PowerMind And PowerVC

A MissionMate light version was created this year called ForceMate, which aims to work under a relatively smaller bandwidth than WIMAX. ForceMate is customized mainly for the tactical CP that requires to work under several environments (static, armor-on-the-move, dismounted, on-the-move in helicopters). While MissionMate is likely to be employed at the operational CP level such as the Division with a 3-screen display, the strength of ForceMate is to be a Tactical Digital Assistant (TDA), one that is almost similar to the everyday man in the streets with his PDA but bigger in display and for used in the tactical environment. Thus, ForceMate is the first version of the SAF tomorrow's TDA that allows Tactical Commanders to carry everywhere with it, enabled by broadband communications, Global Positioning System (GPS) and collaborative technologies from MissionMate. With a smaller screen size (that of a tablet PC), the intuitiveness in Man Machine Interface (MMI) becomes the focal in its development approach with features such as Blue Force management, Red Force pictures, Collaborative Mission Planner and Video Visualizer that allow for dynamic update of information exchange among the forces. The Common Operational Picture (COP) was customized to provide One-Touch, One-Glance on the screen, consequently enabling resultant situational understanding in any environment.

The 2 CCKS (MissionMate and ForceMate) were both fielded for Experiment Future Might 05 (Technology).

EXPERIMENT FUTURE MIGHT 05 (TECHNOLOGY) - AN OVERVIEW

Experiment Future Might 05 (Technology) was set in a realistic, operational environment at Shoal Water Bay Training Area (SWBTA), Queensland, Australia. The terrain was cluttered with thinly vegetated trees, over an area of 20 by 20 km[1] for LCDN, SHELIDON [8] and MACEN [9] technology experiments.

[1] This equates to half the size of Singapore.

The technology experimental design consisted of several hoisted balloons (a total of 3) in the air at an altitude of 60 m Above Mean Sea Level (AMSL). The LCDN radio onboard each balloon or the Aerial Communications Node (ACN) formed the broadband communications backbone for the technology trials spanning over a distance of about 20 km.

For the technology tests as well as operational experiments, 2 helicopters, a static CP and 8 armored vehicles were fitted with CCKS that ride on the LCDN. Experiment Future Might 05 (Technology) is an exploratory study into the effects of broadband communications and collaboration tools for the Command Team and forces to acquire knowledge rapidly through the process of self situation awareness, assessment and collaborative planning for dynamic decision-making over an air-land environment.

EXPERIMENT OBJECTIVES

The intents of Experiment Future Might 05 (Technology) were to demonstrate the ad-hoc networking capability of the LCDN radios, the performance of the air-to-air, air-to-ground communications link in terms of throughput and range as well as evaluating the features and functionalities of ForceMate, the optimum loading of ForceMate clients on the LCDN network during SHELIDON and MACEN technology trials over a period of 7 days.

The key difference as compared to Experiment Future Might 04, is to explore how CCKS (MissionMate and ForceMate) with LCDN (MANET capability on WIFI) is able to provide knowledge rapidly to a team working over several adaptive environments i.e. static, vehicle-on-the-move, dismounted and onboard helicopters. Furthermore, MissionMate was linked to receive Unmanned Aerial Vehicle (UAV) information, as well as air tracks from the Divisional Air Tactical Centre Radar System, thus providing the CP with a rich integrated situation awareness picture consisting of real-time UAV video and synchronized position location, aircraft tracks as well as both helicopter and Armor Blue Force tracks that are equipped with ForceMates.

EXPERIMENT DESIGN

The technology field set-up comprised a static CP and a group of mobile nodes such as Armor vehicles and helicopters operating within the LCDN communications coverage. A detailed map study of SWBTA was first carried out in Singapore to identify potential LCDN deployment sites prior to the actual ground recce. A total of 4 sites were shortlisted and assessed to be suitable for the conduct of LCDN technical trials as well as the experimental runs for both SHELIDON and MACEN. See Figure 3. Balloon deployment was not necessary at site 1 as it was already on high ground with good Line-Of-Sight (LOS) with the balloon at site 2.

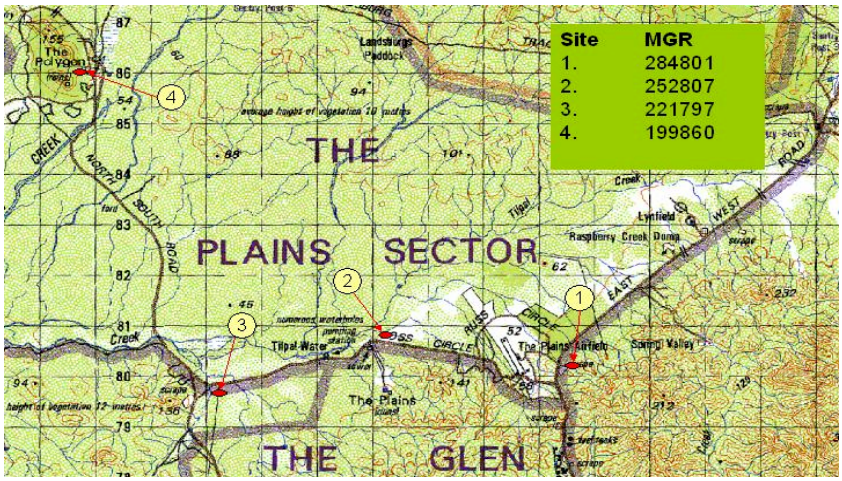


Figure 3: Location Of Deployment Sites

An illustration of the communications payload configuration onboard the tethered balloon in providing the air-to-air and air-to-ground linkages is as in Figure 4. Figures 5 and 6 depict the C4 system configuration at the distributed mobile clients i.e. 2 Super Pumas (SPs) and 8 armored vehicles (Bionix and Bronco) for connectivity among the on-board and/or dismounted warfighters respectively.

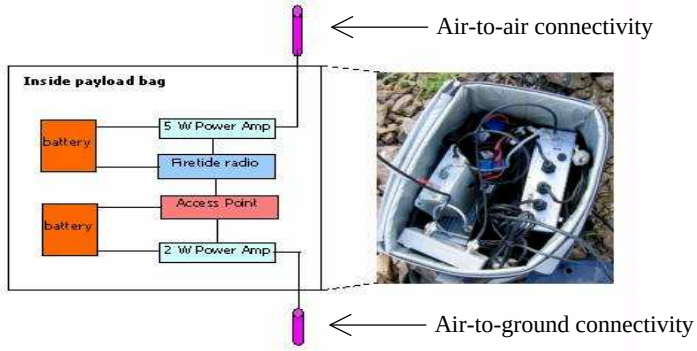


Figure 4: Communications Payload Configuration Onboard Balloon

Figure 5: System Configuration Onboard SP

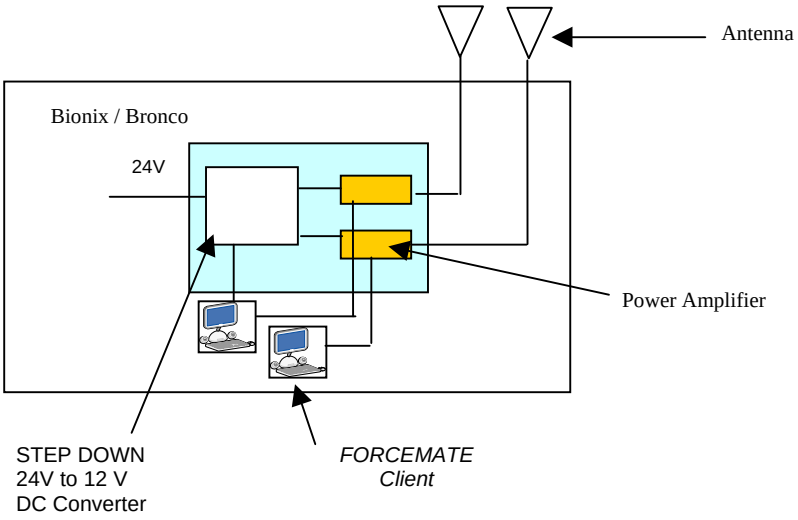


Figure 6: System Configuration Within Armored Vehicle

SHELIDON Technology Trial

The flight profile for SHELIDON technology trial was similar to that of the operational SHELIDON experiment. Two SPs, three tethered balloons, seven ForceMates and three ForceMate notebook servers (based on a central server concept) were deployed. To enable better performance through distributed load balancing, the server load was split into ForceMate System domain and Multimedia-based applications such as Chat and UAV video feed. The focus areas of the technology trial were to demonstrate the ad-hoc networking performance of the LCDN radios, network performance of the air-to-air communications link between the SP and tethered balloon, followed by evaluating the features of ForceMate application and loading of ForceMate on the network.

The average flying speed of the SP was between 70 to 100 knots while the altitude of the SP's flight was capped between 200 and 300 feet Above Mean Sea Level (AMSL), close to the tethered balloon's altitude. Banking of the SP was maintained within 20 degrees to minimise link outages as severe banking affects the stability of the communications link. For consistency, the 5 W power amplifier was placed on the left side of the SP while the 2 W power amplifier was placed on the right side.

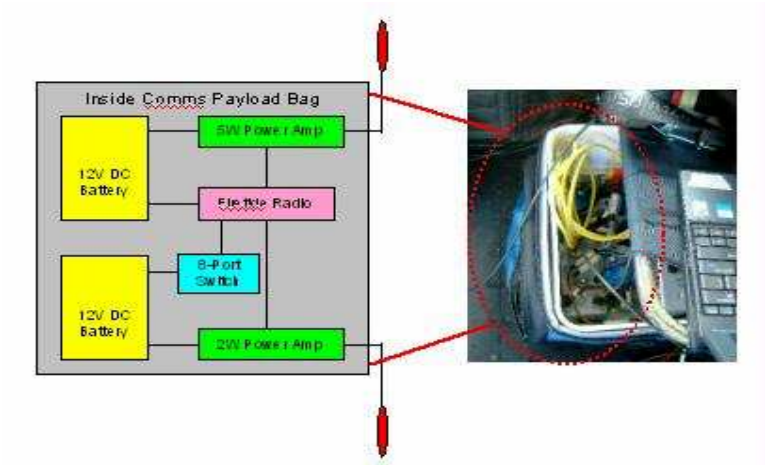


Figure 7: Communications Payload Configuration in SP

Continuous pings were used to monitor the link connectivity among the network entities while Iperf software was used to measure the network throughput. LCDN Vypress chat was also launched to enable text chat functionality for co-ordination among the nodes. Upon link stability, the ForceMate application was launched. Features such as the Blue Force Tracking (BFT) capability, chat and video streaming used for collaboration between the Heliborne Planning Team (HPT) and the Jump Seat pilots (in both SPs) were assessed.

MACEN Technology Trial

The route profile for MACEN technology trial was similar to that of the operational MACEN experiment i.e. along site 2 - site 3 route. Six armored vehicles, two tethered balloons, twelve ForceMates and two ForceMate notebook servers were deployed. The focus areas of the technology trial were to demonstrate the network performance for armor-on-the-move, assessing the features of ForceMate application and loading of ForceMate on the network.

The LCDN system installed in the Bronco and Bionix armored vehicles enabled communications connectivity among the clients. It consisted of a ForceMate client terminal connected to an external magnetic antenna mounted on the exterior of the vehicle. This allowed the client terminals in the armored vehicle to link up with the Access Point (AP) on the tethered balloon. 2 W power amplifiers were also used to increase the signal strength and communications range. The system set-up is as shown in Figure 8.

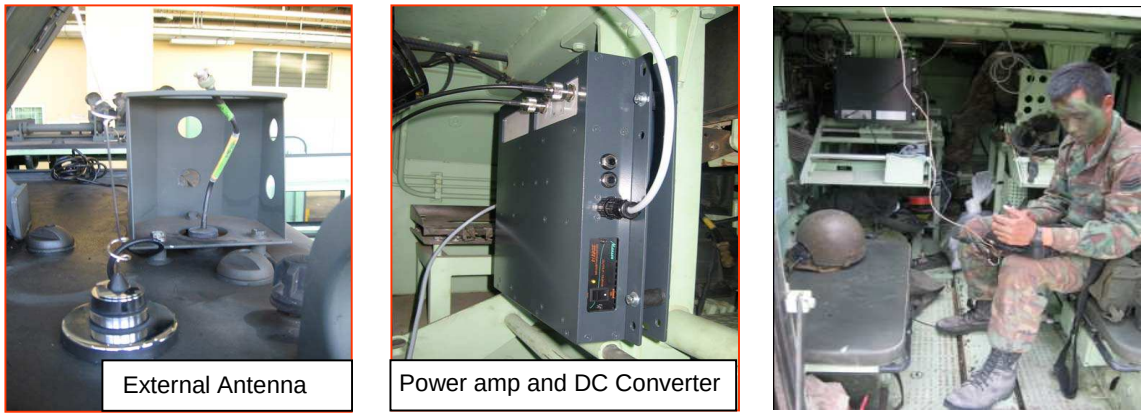


Figure 8: System Setup Within Armored Vehicle

During the trial, the armored vehicles traveled at an average speed of 35 km/h along the track between the balloon deployment sites 2 to 3. Continuous pings were used to monitor the link connectivity among the network entities while Iperf software was used to measure the network throughput at various ranges from the balloon. LCDN Vypress chat was also launched to enable text chat functionality for co-ordination among the nodes. Upon link stability, the ForceMate application was launched. Applications such as BFT capability, chat and video streaming used for collaboration between the CP and the mobile units were assessed.

RESULTS OF LCDN, SHELIDON, MACEN TECHNOLOGY TRIALS

LCDN Technical Trial

Air-to-Air Communications Link

Tethered balloons with the communications payload onboard were set up at sites 2, 3 and 4 where Figure 9 illustrates a typical deployment. Figure 10 shows the deployment at site 1 that was on high ground, with the communications payload set up and the antenna secured to the tripod.

Figure 9: Balloon Deployment At Site 3

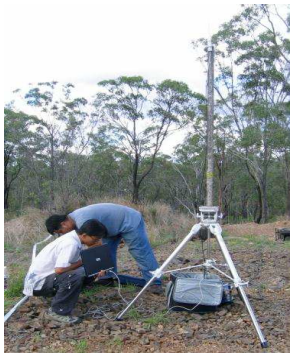


Figure 10: Deployment At Site 1

The network connectivity of the four deployed nodes is shown in Figure 11. As the 3 hoisted balloons at sites 2, 3 and 4 were in LOS of each other, a fully meshed i.e. 1-hop network was formed. However, the radio node at site 1 was only within the LOS of the tethered balloons at site 2 and 4. Nevertheless, it was able to connect to the node at site 3 via a 2-hop link through the intermediate nodes at sites 2 and 4. This link was established automatically with the ad-hoc routing features of the LCDN radios.

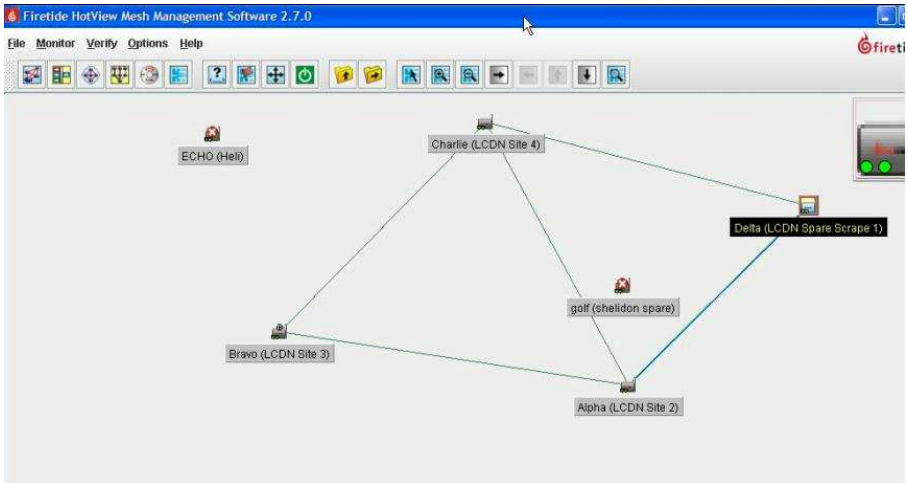


Figure 11: Network Topology Of Sites 1, 2, 3 & 4

Both 802.11b (Direct Sequence Spread Spectrum or DSSS) and 802.11g (Orthogonal Frequency Division Multiplexing or OFDM) modes of operation of the LCDN radios were used during the trial. The Iperf software was used to measure the network throughput between each of the air-to-air links. Table 1 summarises the average throughput results obtained.

Table 1: Air-to-Air Throughput Measurements

Between balloon site	**Range (km)**	**Throughput (Mbps) (OFDM)**	**Throughput (Mbps) (DSSS)**
1 & 2 (1 hop)	3.2	6.0	1.1
2 & 3 (1 hop)	3.3	5.2	0.4
3 & 4 (1 hop)	6.7	0.13	0.15
2 & 4 (1 hop)	7.5	0.1	0.1
1 & 3 (2 hops via site 2)	6.3	1.6	0.5

As the OFDM mode of operation can support higher data modulation scheme, the throughput achieved was therefore much higher as compared to the DSSS mode of operation. Generally, a stable link was observed among all established links. However,

during days with strong abrupt wind conditions, the tethered balloon will start to sway, occasionally being pushed by the strong wind to below the tree canopy level and hence affected the stability of the communications link.

Furthermore, it was noted that the performance of the LCDN radios suffered a significant drop in throughput (reduced to orders of 100 kbps) for range beyond 4km. This phenomenon was peculiar to the deployed COTS radios as link budget calculations showed otherwise. Follow-ups with the Original Equipment Manufacture (OEM) are in the midst to identify the cause and to determine ways in mitigating the deteriorated performance.

Air-to-Ground Communications Link

The air-to-ground link was served by the AP on the tethered balloon that provided connectivity to ground wireless client terminals. A vehicular wireless client terminal as in Figure 12 was used to measure the network performance along the tracks.

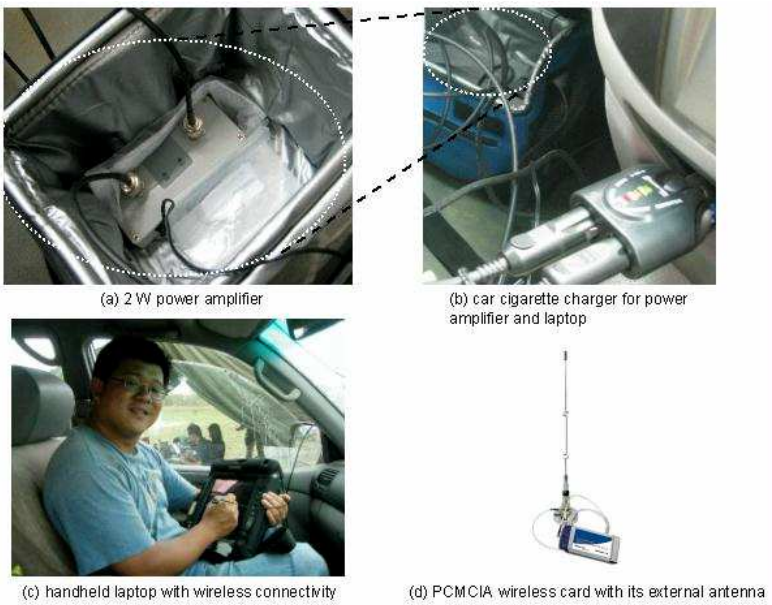


Figure 12: System Configuration Of Vehicular Wireless Client Terminal

Figure 13 shows the ground communications coverage area around the balloon sites where stable link connectivity was achieved with the use of an omni-directional antenna on the AP. The two circles depict the coverage area of 1.5km and 2km around the balloon site respectively. Depending on the availability of LOS from the vehicular wireless client terminal to the balloon along the road track, a throughput of about 1 to 5 Mbps was achieved within the first 1.5km radius around the balloon site. For the next 500m, the network throughput started to fall below 1 Mbps. Thereafter, the link became intermittent or loss eventually. However, when the vehicular client terminal entered the coverage area of another balloon site, the link was automatically re-established.

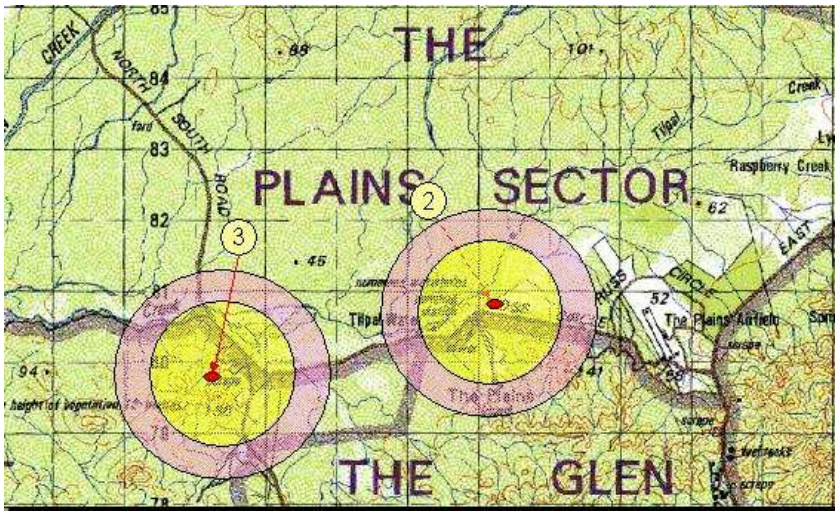


Figure 13: Ground Coverage Around Site 2 And Site 3

The throughput performance for a 3-hop transmission from a wireless client at site 3 to another wireless client at site 2 was measured. An average throughput of 2.8 Mbps was obtained for the 3-hop transmission.

Applications such as text chat and video conferencing were also tested on the vehicular wireless client terminals. The COTS Vypress text chat used on all the client terminals achieved a very reliable and high message success rate due to its distributed architecture whereby no server was required. As such, it was used heavily for trial co-ordination at all the deployment sites. For video conferencing, the Microsoft Portrait software was used. A good quality and smooth video transmission (image size of 176 x 144, frame rate of 15fps) was observed.

In addition, an IP camera was fielded to provide video surveillance. Any of the wireless client terminals on the LCDN network were able to login to the IP camera and viewed the real-time video stream captured. An UDP-based transmission was used for the connection. Thus, it was not necessary for the wireless client terminals to perform a re-login to the IP camera upon any link breakage. The video transmission will resume automatically after the recovery of the link connectivity. The IP camera uses MPEG-4 compression and at a video bandwidth of less than 200 kbps. A good video quality was observed during the trial.

SHELIDON Technology Trial

Prior to the operational experimentation runs, a SHELIDON technology trial was conducted to assess the MANET capability of LCDN radios, to demonstrate the air-to-air communications link between the SP and tethered balloon as well as an evaluation of the functionalities of ForceMate application.

The network connectivity for the two aircrafts and three tethered balloons is shown in Figure 14. All the nodes are fully meshed and within 1-hop connectivity to each other. Figure 15 shows the connectivity of the SP (Foxtrot) via a 2-hop link to the tethered

balloon. As the SP (Foxtrot) started to fly further away from the balloon at site 3, the link became unstable at around 9km and broke thereafter. However, it was still able to link to the balloon at site 3 via a 2-hop link through the first aircraft (Echo) stationed at 7km. The air-to-air communications link performance between the SP (Foxtrot) and balloon at site 3 for a 1-hop link is as represented in Figure 16.

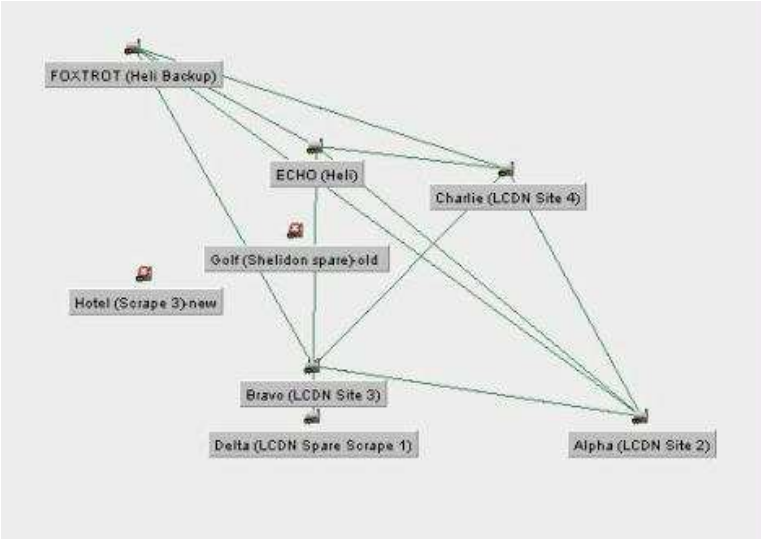


Figure 14: Fully Mesh Network For 2 SPs And 3 Balloon Sites

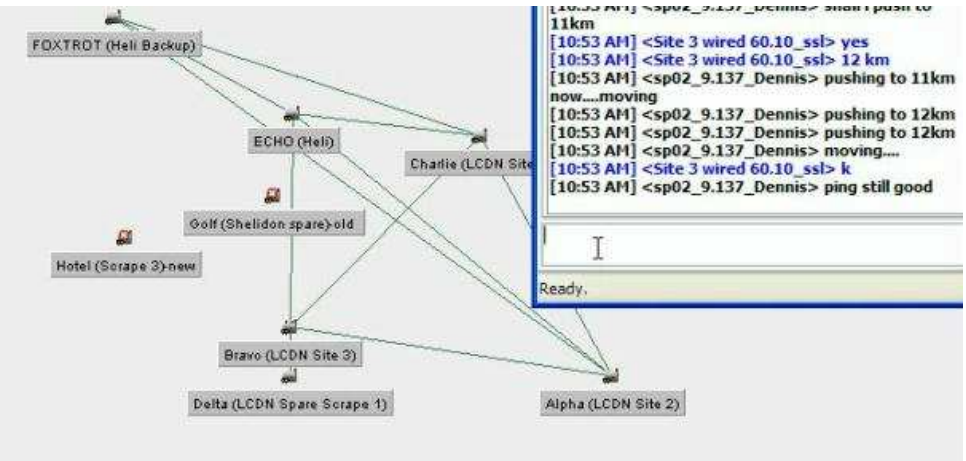


Figure 15: 2-hop From SP (Foxtrot) To Balloon At Site 3

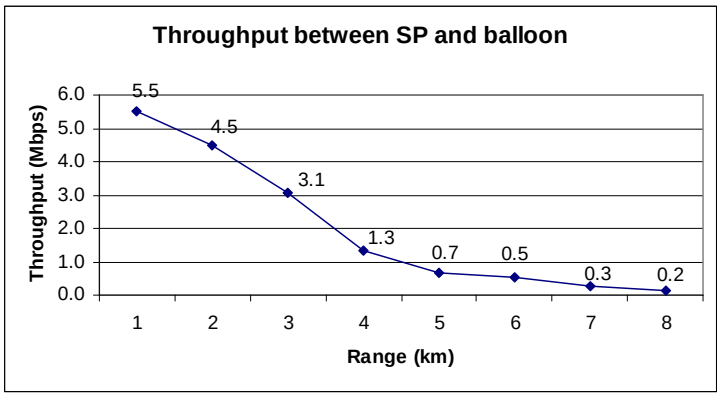


Figure 16: Throughput Performance Between SP And Balloon

The 2-hop link range and throughput performance was also carried out. Echo hovered at the 7km location away from one of the balloons while Foxtrot positioned itself behind Echo at the 9km location. The 2-hop throughput from Foxtrot to the tethered balloon was about 0.1 Mbps when Echo was 4km away from Foxtrot. The link of Foxtrot became intermittent beyond 4km away from Echo[2].

For the ForceMate clients deployed in the airborne platforms, the mobile terminals were adjustable to become either a tablet or a laptop. With the laptop layout, it facilitated users in the use of textual chat in the ForceMate application. An extra battery for each terminal aided in extending the operating time, stretching it up to a maximum of 6 hours. Tapping power from the aircraft may be considered as an alternative in the event that the battery pack is faulty.

In addition, there is a Bluetooth enabled GPS device, associated with each ForceMate, that was required to capture GPS signalling in providing own Blue Force tracks. However, the sensitivity of the GPS device was doubtful as the number of satellite signals received was only about three to four most of the time. To improve own force tracking mechanism, the Java Messaging System (JMS) template was also tweaked to allow automatic updating of the tracks after a time-out period of one minute. Should the tracked JMS message was stuck; it will be re-sent, hence enhancing the robustness of the system. Further to this, with the air tracks from the ground server cluster, ForceMate was able to provide an integrated air position location picture.

The chat function is especially useful to communicate ideas, actions and passing of fragmented or urgent orders to highlight dangers, targets or even to reroute. The chat also doubles up as a content logger, which can be used for reviews subsequently. Furthermore, the UAV live feed could stream out to the airborne clients whenever required. During the trial, UAV video of size 320 x 240 at one frame per second was hosted. It was noted that at least one ForceMate client in either of the SPs could view the video (200 kbps) even under a limited bandwidth environment.

[2] The tail of Foxtrot was facing Echo when it was flying away from Echo. The tail and head facing of the SP have a weaker RF signal.

A maximum of four ForceMates in the coverage area of the LCDN were able to login to the ground server cluster for effective sharing of plans, images, maps and video via ForceMate collaborative tools. This optimum loading will prevent airborne ForceMate clients in locking up precious server service times and thereby neglecting other users. There should also be a sequential login of clients as the initial data pull-in (approximately 200 kbps) just after login can be quite substantial.

Figure 17: Use Of ForceMate Clients Onboard SPs And At HPT

MACEN Technology Trial

Based on the air-to-ground coverage area of each of the balloon site mapped out during the LCDN technical trial (see Figure 13), the armored brigade was able to plan their route of advance before conducting the operational experimentation runs.

Although the tethered balloon was hoisted to an altitude of 60m with a clear LOS connectivity for the air-to-air communications, the LOS air-to-ground communications was limited due to the relatively dense vegetation in SWBTA. With a lower air platform, the RF signal of the ground client will suffer from more vegetation loss as compared to an air platform deployed at a higher altitude. Hence, with the deployment of an ACN at a much higher altitude, a greater ground coverage area can be achieved.

Depending on the availability of LOS from the vehicular wireless client terminal to the AP on the tethered balloon, the network throughput can vary from 6 Mbps to 1 Mbps within the ground coverage area. The ground throughput performance from site 3 is shown in Figure 18. During the trial, the armored vehicles were travelling at an average speed of 35 km/h. A stable link was observed while the vehicles were on-the-move within the coverage of the AP.

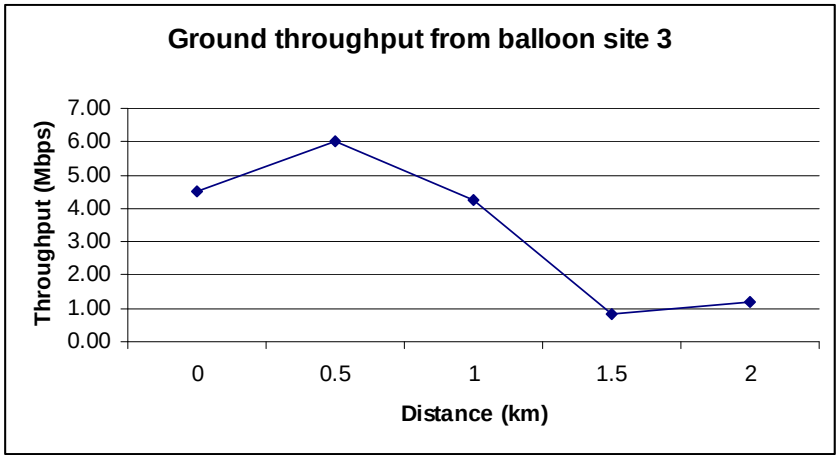


Figure 18: Ground Throughput Performance From Balloon Site 3

The ForceMate terminals for the ground users were tablets that came with an attached stylus, different from the ones used onboard the air platforms. The stylus was to allow users to manage conveniently by means of tapping on the collaborative features while on-the-move. This explains for the creation of large buttons, neatly packed away sliding windows and intuitive colorful icons on the MMI of ForceMate. The lack of a keyboard input device, however, slowed down users substantially when using the chat function though they were able to 'type' with a stylus using the on-screen keyboard.

The tablet came with a built-in GPS device. In enabling own force tracking as well as connectivity to the ground server cluster via the LCDN within the armor vehicle, an external magnetic-based antenna linked to the ForceMate client was mounted on the exterior of the vehicle. The Blue Force picture was constantly updated for the twelve moving nodes thus enabled the commander to track the movement of its forces. Nonetheless, prolonged exposure under the hot weather caused some of the built-in GPS of the ForceMate client terminals malfunctioned during actual experimentation. One other essential feature, particularly for the commander, is the Time Slider. This function allows potential courses of action to be simulated and serve to forward in mission coordination and execution in the best way possible.

As video feed was not critical for the mobile land users, all twelve ForceMates in the 2-radio nodes coverage of the LCDN were able to login to the ground server cluster in sharing plans, images and maps, therefore achieving shared situational awareness.

KEY OBSERVATIONS

Specific observations were noted during the technology trials and were summed up as below.

- Ad-hoc Networking Capability Demonstrated. The LCDN was shown to be able to form dynamically, allowing both SPs to communicate independently and

simultaneously with the ground clients i.e. HPT during SHELIDON technology trial. The communications network was able to adapt and re-configure itself on-the-fly according to the node mobility and changing network topologies.

- Broadband Communications Link with COTS Radios. An average throughput of 5 to 6 Mbps was achieved between 2 nodes of a distance about 3 km apart and about 1.6 Mbps for a 2-hop link for a distance of about 6 km apart. This tremendous leap in throughput is 60 times more than what the current traditional military data radios can offer and at a cost possibly 10 times cheaper.

- Stability of Aerial Platforms and Antennas. The two omni-directional antennas onboard the balloons, which were subjected to wind conditions, had to be relatively stable at the hoisted altitude for a stable Radio Frequency (RF) link to be established. This challenge was compounded by the fact that there was no firmed platform on the balloon for the mounting of antenna. Innovative means were therefore used to secure the antenna in minimizing movement during strong wind conditions. A gimbal may also be employed on the ACN platform for the stabilizing of antenna.

- Labor Intensive Setup for Balloon. The current LCDN setup is too labor intensive. An alternative worth considering is to utilize a mobile platform with the capacity to hoist and bring down the balloon, possibly by means of a mechanical winch, together with the communications payload as well as to transport the necessary logistical items along with it, hence a self-sufficient node. The suggested implementation would create the connectivity and quicker deployment for increasingly important tasks such as Operations Other Than War (OOTW).

- Power of Blue Force Tracking. Real-time and near real-time feeds from multiple C2 applications such as Air Tracks Monitoring System and Blue Force Tracking provided constant monitoring of the battlefield, by means of tracking the combat elements on maps, satellite photos, video feeds from battlefield sensors, following enemy forces through intelligence reports, ground observations, forward scout units or UAVs. By incorporating own force tracking mechanism via GPS track propagation, ForceMate effectively assisted commanders in drastically reducing the need to make constant radio checks to enquire about the status of the mobile units.

- Collaborative Mission Planner. ForceMate offered presentation style briefing that included map, photos and video. Comments can be sketched swiftly while new enemy positions detected can be immediately inserted into the shared workspace available to every mobile ForceMate user in air or on ground. This scalable shared workspace environment provided commanders with the ability to access all CP information and functions anywhere, anytime in the battlefield as the network deployment was based on a central server concept. The synchronized situation picture allowed subordinates to arrive at a better common understanding of the commander's intent, especially during order disseminations such as the need for heliborne forces to be diverted to another flight path upon discovering potential

threats along the primary flight path, by using appropriate planning and collaborative tools.

- Design of ForceMate MMI. The overall objective is to create an intuitive and seamless experience for the typical user on-the-move. Hence, the implementation of ergonomically designed large buttons, neatly packed away sliding windows and instinctive colorful icons were created for rapid ease of maneuvering. The main application display was further being utilized to the full extent, with the addition of compact dockable toolbars encompassing the most salient functionalities on top. A dockable framework was also adopted for users to customize the placing of important sub windows, thereby enhancing user interaction with ForceMate.

DISCUSSION

The vital value ascertained was that high availability of bandwidth from COTS technologies is feasible with CCKS in enabling forces to work distributed. This allowed heterogeneous forces capable of rapidly assimilating shared situational awareness via video, collaboration, chat and Blue Force tracks. During the operational experiments of SHELIDON and MACEN, Blue Force tracks were highlighted as the most important feature in the entire C2 system for situational awareness, followed closely by the need to collaborate. If we would like forces to work distributed or disperse in future, both the BFT and collaborative planner would become critical modules that require a very long Mean Time Before Failure (MTBF) in a wireless network. In this experiment, the robustness of the BFT module was improved by tweaking the JMS template to enable automatic updating of the tracks after a time-out period of one minute.

For heliborne forces operating at distances of more than 70 to 100 km, perhaps in operations such as OOTW and hot-war context, multi-hop environment will be expected. There are several approaches to enhance this connectivity. It is about increasing the efficiency of information transfer to complement MANET. Thus, the design of the C2 applications for MANET has to be adapted for wireless environment where compression techniques may be implemented to ensure as little bandwidth will be taken up. Another key area is the incorporation of Quality of Service (QoS) mechanism such as prioritization of messages, as this can enable the most critical data to flow through the network under difficult link conditions. QoS mechanism in MANET at multiple layers in the protocol stack will also optimise the usage of the wireless network and can help to improve the network performance, in particular for synchronous messaging applications.

BENEFITS

Both LCDN and ForceMate can potentially be viewed to offer expanded advantages as a highly quick-deployable system in a foreign environment for broadband network connectivity in less challenging operational scenarios such as OOTW given its affordability and bandwidth. The ability to overcome traditional communications

limitations through automatic relaying, self-healing and self-forming features of MANET without the reliance on fixed based stations proves to be extremely attractive. The lack in basic communications infrastructure after an unexpected disaster, for instance a tsunami, can be easily surmounted and be provided by the LCDN network in ensuring information networking can be established quickly among the forces, the media, the civilians and the Non-Government Organizations (NGOs).

The SAF helicopters are normally required for OOTW and ForceMate provides the needed situation awareness and collaboration leveraging on LCDN with ground organizations, saving precious time for more critical missions such as evacuations of casualties. In addition, besides notebooks, similar hardware equipped with wireless adaptor can also ride on the LCDN. Media and/or Intelligent reports via the video feed can be sent quickly over the LCDN hence possibly saving time in the process that would be better put to use elsewhere.

THE WAY AHEAD

Experiment Future Might 05 (Technology) embraces and leverages on the latest COTS technologies and collaborative software trends to demonstrate what technology can offer for the 3G SAF. Despite some hiccups in the initial stages of testing with respect to link stability and hardware issues associated with GPS tracks, the technology was tested and demonstrated successfully during operational experiments and VIP visits.

The way ahead will be to evolve the efforts and experiences gained from Experiment Future Might 05 (Technology) to realizing it for possible operations. With proven success in the integral use of wireless broadband technologies and collaborative C2 system in field environment, the next significant step is to delve into the viability of the LCDN and CCKS functioning over a distance in access of 100 km as explained earlier.

Concurrently, it is timely to look into evolving the communications network to one that is capable of self-managing, self-diagnostic its communications needs and configurations such as a dynamic bandwidth management to automatically allocate bandwidths that are critical, effective and optimal for the operational scenario in meeting tomorrow's warfighters' requirements. This is imperative since the network topology and network condition can vary over time knowing the inherent unpredictable nature of the tactical environment.

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