ABSTRACT

This paper defines and develops a future technical network architecture to support mobile multimedia communications on the future Army tactical battlefield, from Corps rear areas to the foxhole. The paper first addresses the technical need and utility of multimedia communications in the battlefield, and then presents a future architecture to support those emerging requirements. The architecture focuses on two specific technical problems, i.e., (1) the need for high bandwidth (> T1) mobile transmission for dispersed network nodes, and (2) the dynamic network capabilities of a multi-tiered, integrated terrestrial, UAV, space-borne network environment.

The architecture supports both multi-access and point-to-point transmissions switching technologies, (including IPv4-v6, N-ISDN, ATM), and proposed enhancements to commercial protocols to provide additional survivability and mobility. Specific enhancements to the commercial protocols include: (1) support for integrated terrestrial, UAV and space-borne access and control protocols, (2) reliable multicast protocols for networks of mixed or integrated switching networks, dynamic addressing and reconstitution protocols and, (3) efficient wireless transport protocols. Future efforts will also incorporate selected capabilities from the GloMo program, which is addressing the next generation of communication systems.

1.0 INTRODUCTION

In the future, battlefield commanders will have a need to conduct Video Teleconferencing (VTC), see actual terrain representation with friendly and enemy force location (3-D representation) and transmit voice and data in order to conduct distributed battle planning. This information must be delivered in real time and while the force is moving on the battlefield particularly at the lower echelons. This paper focuses on providing the transmission facilities and system architecture capable of supporting mobile multi-media from Corps down to Brigade and Battalion Tactical Operations Centers (TOC’s).

Since 1995, CECOM(1) has been investigating and developing a system that can be used to augment existing battlefield communication systems so they can meet the mobile, multi-media battlefield requirements of the future, where special emphasis has been given to the use of commercial off-the-shelf (COTS) products. The focus of this paper is a discussion of the modification to COTS products needed to meet the special problems posed by battlefield dynamics, the military environment and achieving compatibility with legacy systems. The development has had two primary thrusts:

The first thrust is the development of a High Capacity Trunk Radio (HCTR) and Phased Array Antenna (PAA), under development at the Harris Corporation that is capable of supporting on-the-move wide band communication (< 45 Mb/s) over terrestrial, satellite and unmanned aerial vehicle (UAV).

The second thrust is the investigation and development of a mobile base station concept called the Radio Access Point (RAP) that is under development at AT&T Corporation. The RAP is capable of linking and augmenting the lower echelon current IP based Tactical Internet (TI) and providing direct TOC access with an upper echelon transportable backbone (Mobile Subscriber Equipment) employing Asynchronous Transfer Mode (ATM) trunk side switching.

This paper is presented in six sections. Section 2.0 summarizes the proposed operational requirements and the implied technical requirements. Section 3.0 contains a summary of the progress in developing a mobile multi-media system and describes a
series of subsystems that can collectively or independently provide enhancements to the military communication systems of today.

Section 4.0 contains planned tests and exercises that will employ the RAP technology. Improving the operational capability of Command, Control, Communications and Intelligence (C3I) systems will be demonstrated as well as meeting technical performance goals.

Section 5.0 describes potential enhancements to the system that will be part of an advanced technical demonstration called Universal Transactions starting in the year 2000. Conclusions are presented in the last section.

2.0 STATEMENT OF OPERATIONAL REQUIREMENTS AND DERIVED TECHNICAL REQUIREMENTS

The operational need for the design and development of an integrated voice, data, and video information system has been evident since the mid 80's and heightened by the operations in Desert Storm. Most of the current operationally deployed communication systems such as the Mobile Subscriber Equipment (MSE), Single Channel Ground and Air Radio System (SINCGARS), the IP based TI, and data only Enhanced Position Location and Reporting System (EPLRS), handle segregated traffic (by type). Coupled with manual intensive pre-planning operations, they severely limit the flexibility and responsiveness required by current (and future) highly mobile military operations. Additionally, the requirement for near real time video in the form of video teleconferencing (VTC), as currently handled only by the MSE, requires manual patching or the use of an ATM multiplexing modification.

To meet this new and evolving communications need, US Army CECOM is investigating how and where the commercial integrated network technologies of the Internet, N-ISDN, and ATM may be exploited. The commercial world has long recognized the advantages and efficiencies of an integrated network (i.e., voice, data, and video) reaching back to the early 80’s with the CCITT studies that led to the N-ISDN. More recently, the commercial world focus on much higher bandwidth to individual subscribers coupled with the requirement to support higher trunk speed, has lead to the development of the ATM networking and switching capabilities. The Internet world, with the advent of the World Wide Web (WWW) point and click technologies, has provided an unprecedented access to computer based information, including data from video and audio files. Additionally the recent Internet activity in the MBONE(2) effort has shown the feasibility of limited broadcast video over pre-allocated packet subnets.

Given the budgetary limitations in the DOD as well as the desire to provide direct interoperability with the commercial world, the DOD has made a conscience decision to exploit and utilize commercial telecommunications technology wherever and whenever possible. While commercial networking typically consists of a fixed backbone infrastructure supporting both fixed, and mobile subscribers, the military requirements for continuous mobility requires that the supporting backbone itself must move along with the fighting units as they advance or change geographic position. The requirement for this On-The-Move (OTM) communication is a direct result of the fluid nature of modern warfare as well as a well understood desire to survive. Although the military maxim of “Shoot, Move, and Communicate” has been well established over the years, its importance has been heightened by the increasing tempo of modern and future warfare.

In the last several years at military test beds such as the Central Test Support Facility (CTSF) at Fort Hood, Texas and others, the advantages of video teleconferencing (VTC) have been explored. While the advantage of face-to-face meetings has been in use since the first general issued an “officer call” sounded by trumpets on the ancient battlefield, the requirement to physically relocate to a meeting place requires both time and resources that are in short supply in the fast moving battlefield of the next century, as well as providing a very lucrative target for the enemy. The application of video teleconferencing provides a modern solution to the problem. Although most VTC have been applied to the higher echelons at Brigade, Division, and Corps, it seems appropriate, although not without technical difficulty to apply the lessons learned at the upper echelons to the lower, more forward units.

In addition to classic VTC, there is an emerging requirement at all military echelons to provide the capability to send and receive imagery. While bandwidth compression technology continues to make impressive advances, the ability to fully integrate the imagery, typically associated with surveillance and targeting, with more traditional voice and computer data is recognized as a mandatory requirement on the tactical battlefield.

The tactical Army is just starting to exploit the “point and click” technology of the WWW and support packet Internet in military Command and Control (C2) systems. The point and click method of access to distributed C2 information, coupled with the appropriate access control and security measures, clearly seems to be the wave of the future.

In order to support the C2 paradigm shift, tactical systems will require increases in bandwidth for the battlefield. In
addition to the subscriber user requirements for telecommunication services, one must consider the tactical operational environment. In addition to on-the-move communication, the requirement for communication network survivability (i.e., providing the desired level of service to its subscriber population while sustaining battle damage) is both obvious and well known. The network must provide operation with multiple dispersed controlling nodes, and provide continuous operation during the heat of battle (i.e., switching points and transmission links being destroyed or jammed) with minimal interruption of service to the subscribers or users. In addition, an operational doctrine is emerging that requires military operations that are more dispersed than conventionally indicated, where the dispersed units may have to communicate and coordinate action over territory that is not under their control, or is inaccessible due to nuclear, biological, or chemical warfare operations. As a result, a wireless multi-hop integrated multi-tiered architecture is envisioned. (See figure 1.)

![Figure 1. WIN Transport](image)

Thus the dominating technical requirements for the next generation of military communication networks are clear:

1. Integration of all traffic types including voice, IP data, VTC and imagery video in a common network fabric.
2. Survivable operation in hostile, fluid, battlefield environment.
3. Directly supporting communication on-the-move for all subscribers while the “backbone” itself is moving.
4. Fully secure and providing levels of access consistent with military requirements.
5. Autonomous operation with a minimum of human planning and operation.

6. Operation over widely dispersed geographic areas, where intervening territory may be owned by the enemy or inaccessible due to nuclear, biological, chemical activities or actions.

The related transmission facilities will need to include the following:

1. Wide band radio HCTR (~45 Mb/s) capable of operating on-the-move.
2. Multiple-narrow-beam phased array tracking antenna to assure connectivity while on the move.
3. Relaying via an (UAV) and/or satellite to assure operation at extended ranges.

### 3.0 RESULTS OF RAP PROGRAM

The purpose of this section is to document the progress made in this program. (3, 5)

#### 3.1 Network Design

The Radio Access Point (RAP) assumes two classes of users: (1) the War Fighters who want to communicate with each other; and, (2) the Signal Corps personnel who are responsible for operating the nodes and network. The architecture of the RAP takes both of these users into consideration. It supports the needs of the War Fighter (who are assumed to be at a Tactical Operations Center [TOC] in close proximity to a RAP) with a multitude of services such as audio and video teleconferencing services; IP data services such as e-mail, access to the tactical internet; white boarding, etc. It also address the needs of the Signal Corps by automating the Operation, Administration, and Maintenance (OA&M) of the node(s) and the network.

The high level RAP node architecture (See figure 2) makes use of standards-based protocols and services where possible. PBXS that provide augmented Integrated Services Digital Network (ISDN) capabilities, Internet Protocol (IP) Routers that provide data services, and Asynchronous Transfer Mode (ATM) Switches that switch merged streams of voice and data traffic are key commercial products used in the architecture. FASTLANE provides encryption of the standards-based ATM cells (data portion). An ATM Multiplexer, imbedded in the switch, maintains Red/Black separation, as well as potentially providing additional error correction coding to improve reliability of communications between nodes in a noisy radio environment. As described in Section 4.2, HCTR provides communication at 1.5 Mbps (standard T1), 8 Mbps, and 45 Mbps (standard DS3) on the move using its PAA (5).

The architecture also accommodates interfaces for legacy systems such as the Tactical Internet (i.e., SINCGARS SIP, EPLRS, etc.). The Nodal control and Network control segments of the RAP architecture are also standards based. In order to
maintain red/black separation, the architecture accommodates a red nodal controller and a black nodal controller. Each controller uses a standard network management product. The interface between the red nodal controller and the devices it is controlling is either Simple Network Management Protocol (SNMP)-v1 or an RS232 interface (the craft port on the PBX). The interface between the black nodal controller and the devices it is controlling is also SNMP- v1. In the case of the black controller interface to the devices it is controlling, Management Information Base (MIB) interfaces are being defined and developed between the controller and a non-commercial HCTR, and its phased array antennas. The intent is to identify and standardize the information between the radio/antenna combination and the black nodal controller in order to automate the determination of frequencies and location information to establish and maintain communications with other RAP nodes. In cases where the terrestrial line of sight connectivity cannot be maintained between two RAPs, the black network controllers of these RAPs automatically provides information to their PAA's to point to an UAV to maintain connectivity. Version 1 of the black controller software accommodates the Joint War Fighter Interoperability Demonstration 99 (JWID99) scenario consisting of three nodes (See section 4). Version 2 of the software will accommodate connectivity of up to eight RAPs within a Brigade by implementing a Robust Network Design Algorithm (RNDA)(6). Version 2 of the software will also include a Graphical User Interface (GUI) for both the Red and Black controllers, an automated initialization procedure, as well as control of the network of RAPs.

3.2 HCTR and PAA Design

A critical element of this program is the development of a HCTR capable of supporting wideband transmission while on-the-move. In order to meet range requirements, it is necessary to provide adequate antenna gain (narrow beam width) and maintain connectivity at all times. The resolution of this problem led to the use of a phased array with beam tracking antennas, using UAV's for range extension, and employing the military SHF spectral region (6GHz—8GHz).

The HCTR consists of the vehicle mounted radio transceiver, phased array assembly and the PAA control assembly which is interfaced to the network portion of the RAP (See Figure 2 for a detailed RAP node diagram).

A phased approach of developing and demonstrating the RAP and its HCTR is employed. It involved developing, acquiring and integrating the required interfaces and software, as well as assembling the system hardware. A specification phase was followed by a laboratory demonstration of a mobile RAP. A static RAP field demonstration incorporated a static version of the HCTR. Finally, communication on-the-move will be demonstrated with a proof-of-concept PAA at JWID99, in September 1999 (see section 4) using a mobile RAP and a UAV. Version 1 of the controller is employed as mentioned in section 4.1. A 3 beam version of the PAA linked to multiple UAV's will be examined in a future UT program (see section 5).

While in motion, the RAP backbone link is established via its HCTR, through a PAA. The PAA is located on the roof of sheltered High Mobility Multi-Purpose Wheeled Vehicle (HMMWV) in a horizontal plane. An unfaded bit error rate of less than 10^-8 is maintained to a UAV transponder at altitudes of up to 25K ft. and elevation angle greater than 30 degrees. When stationary, a terrestrial link can be created via a mast mounted self aligning antenna (SAA) system (15 meter mast). A range of 25 km , is achieved with an nonfading bit error rate of less than 10^-8. A rate 2/3 forward error code is utilized. Circular polarization is employed to reduce sensitivity to antenna tilt.

The HCTR operates in the 7.25–8.40 GHz frequency band and uses a dynamic equalizer to compensate for a maximum multipath delay of 300 nanoseconds. Filter notch sweep rates of up to 2 MHz/millisecond are required for OTM operation. The radio is modulated using Quadrature Phase Shift Keying (QPSK) modulation at DS1 through DS3 rates. Radio and antenna status is provided by an on board network management system using an SNMP-v1 agents linked to the RAP controller. The RAP's controller maintains a local situation awareness database to track the position of nodes. This position information is used for initial link acquisition via the PAA while providing OTM connectivity.

3.3 Subsystem Products for Technology Insertion in Legacy Systems

The original objective of this effort was to produce a multimedia capability for military OTM C2 systems by the year 2005. With the introduction of computers at lower echelons and the Force XXI initiative, underway in the Army(6), a greater near term need for mobile multimedia now exists. There currently is a lack of transmission facilities capable of supporting multiplexed multimedia traffic OTM as well as protocols that can cope with the inherent user dynamics and multicast addressing associated with the battlefield. Although the RAP is still evolving as a systems concept, a number of the subsystems that have been created will find near term applications as augmentations to legacy systems. We describe some of these products below.
The HCTR Transceiver-An SHF (6GHz—8GHz) radio capable of supporting data rates up to 15 Mbps on-the-move and 45 Mbps in a stationary mode.

A Self-Aligning mast mounted Antenna (SAA) that can speed the establishment of wideband stationary links and reduce guying requirements to reduce the effects of wind loading.

A new version of a mobile IP protocol for lap top computers that does not rely on classical mobile IP (RFC-2002) tunneling or centralized name server and can cope with extensive host mobility while reducing communication overhead and processing.

Augmentations to commercial ISDN switches that support multimedia services and can find mobile users via a search mechanism (Not commercially available).

Seamless multimedia extension to Brigade and Battalion TOCs linked to the Tactical Internet using commercial ATM backbone switches. This includes seamless addressing, self initialization, congestion control and connection management.

The use of SNMP-v1 protocol and needed agents for network management including switches, radios, antennas and other RAP components for integrated node control.

A PAA for on-the-move linkage between RAPs and a UAV. (Additional effort is required to reduce cost and weight of the PAA).

4.0 PLANNED TESTS

Testing, in preparation for JWID99 will be done in phases. The first phase will be subsystem testing. The communications subsystem will be tested to insure all interfaces are working and that all communications capabilities (e.g., video, voice, data, etc.) within a node are operating properly.

At the same time, the Radio Frequency (RF) Subsystem will be tested. Commands will be issued to connect frequency/antenna pairs, and the antennas will be pointed to pre-determined locations, and HCTR connectivity established. Measurements will be taken to insure the integrity of the signal. Once this has been completed, an ATM cell generator will be added to the stream, and a loop-back test will be conducted to test ATM cell integrity over a round trip HCTR link through the RAP.

The next stage of testing will be System Testing. The Communications Subsystem and the RF Subsystem will be tested together to insure all components, including nodal control, of a RAP are working together.

The last stage testing will be Network Testing. In this stage, communications between three RAPs will be tested. Interactions via the black controller between the one moving RAP, the other fixed nodes, and the UAV will be thoroughly tested to insure dynamic network communications can be maintained.

The JWID99 is an Air Force led demonstration. The host organization is US CINC Space. US Space Command’s communication thrusts include fusion, cross-ceiling, dissemination, direct down link, common operational picture (COP), global grid, modeling and simulation for space communications, sensor-to-shooter connections, tasking processes (air and space forces) and air and space integration. Since the Digital Integrated System Network (DISN) will employ ATM in its backbone, the COP and sensor information will play a critical role in JWID99. The RAP, with its ATM based technology, is well suited to support this demonstration.

The RAP will be linked to the War Fighters Internet Proof of Concept (WINPOC) facility at the Battle Command Battle Lab at Fort Gordon, Georgia as shown in Figure 3. A mobile RAP will be linked to a mobile representative Brigade TOC. Linkages from a hard wired TOC containing hosts as well as wired ISDN phones will pass traffic from the Brigade TOC to the mobile RAP, and then from the RAP to a 1/4 RAP and into a WINPOC facility. The WINPOC will link traffic into the DISN backbone. The transmission of simulated or real position location of ground forces will be possible. Multimedia transmissions from the Brigade TOC to higher echelons will be supported while the Brigade TOC and RAP are moving.

5.0 PROPOSED ENHANCEMENTS

In order to fully specify the enhancements in the RAP and other products from the DBC ATD, testing/evaluation will assess how well the ATD exit criteria have been met. However, we can discuss some general requirements that are implied by Vision 2010 documentation. Future military and Army After Next systems will depend more heavily on information systems to achieve battlefield supremacy. Communications systems of the future will have to handle more information, be more mobile and rapidly reconfigured, be more widely dispersed, may not have an in-place-tactical-backbone system to link to and may face increased threats on its infrastructure. Many of these requirements are being addressed in the DBC ATD and DARPA sponsored programs (i.e. Global Mobile Communications and Small Unit Operations).
Figure 2: RAP Architecture

Figure 3: JWID'99 Network Configuration
A greater reliance on a space based communication infrastructure is foreseen. A proposed program called Universal Transactions will examine these issues which include:

1. extending the current two beam PAA to a full, concurrent, full duplex, three beam capability to provide maximum survivability;
2. supporting the concept of multiple UAV’s, that have direct cross-link switching capability and can link to ground based RAPs;
3. developing a UAV that contains a RAP;
4. incorporating the results of DAPRA’s Global Mobile (GloMO) Communication as a Local Area Access (LAA) system to a RAP. The program is developing the next generation radio for possible incorporation into future Army Brigade and Below Communications systems;
5. extending the full seamless operation of Army mobile multi-media communications systems from the foxhole up to Joint Services Strategic Echelons.

The Universal Transactions ATD is planned to start in the year 2000.

6.0 CONCLUSIONS

The DBC ATD, including the RAP and related programs, was initiated in 1995 and included a number of challenging technology components. Its objective was to demonstrate mobile multi-media communication to the battlefield using commercial standards-based evolving networking technology. The program has produced a standards-based architecture and initial hardware and software design for a mobile networked system called a RAP. Although the program was targeted at requirements anticipated for the year 2005, the RAP architecture and technology has produced several subsystem products that maybe useful in the next two years to assist in creating a mobile multi-media communication system for the battlefield. These include an HCTR, advanced on-the-move systems, protocol modification to COTS networking products and special network management implementations. Additional work on this system is planned under a follow-on CECOM program called the Universal Transactions ATD.

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