NATIONAL COMMUNICATIONS SYSTEM

Route Diversity Project (RDP)
Mobile Communication Systems, Inc. -
Emergency Communications Solutions
Evaluation Results Report

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EXECUTIVE SUMMARY

This document presents the results from an evaluation of Mobile Communications Systems' (MCS) Emergency Communications Solutions (ECS). The National Communications System (NCS) conducted the evaluation as part of the Route Diversity Project (RDP), which seeks to evaluate and improve the resiliency of Federal agencies' communications networks through methodologies, tools, and evaluations of new communication services and technologies. The evaluation was conducted from March 26 to April 6, 2007 in Houston, TX.

Purpose and Objectives

The NCS evaluated the ECS as a quickly deployable back-up communications services for national security and emergency preparedness (NS/EP) incidents, Emergency Support Function (ESF) #2 incidents, and use as a service to provide route diversity in the local network for Federal agencies. As part of the assessment, the NCS conducted tests to determine:

- Speed and ease of solution deployment
- Availability of satellite link
- Performance and throughput of satellite link
- Effectiveness in supporting voice and data applications such as email and file transfer (i.e., those applications most likely to be used in an emergency situation)

Emergency Communications Solutions Background

The ECS is a vehicle-based command and control solution that includes three key features:

- Satellite: Provides a backhaul transport from any location to the world through a teleport located in Houston. This evaluation used a truck that was deployed with satellite capabilities and a satellite link provisioned for 1 Mbps downlink/1 Mbps uplink.
- Wireless mobile: Offered through a wireless access point for wireless LAN connectivity.
- Radio: Supported through four radios for emergency communications and the Pan Tilt Zoom (PTZ) IP camera for remote monitoring and surveillance.

Results and Conclusions

Key results from the evaluation include:

- The solution can support up to 30 users using e-mail, web services, and voice over IP (VoIP) phones.

- The setup and configuration of the satellite dish and equipment were quick and straight forward[1].
- Link performance (throughput) was satisfactory.
- Applications performed satisfactorily, including FTP, web, email, and using multiple applications (web and email) concurrently.
- Radio communications were clear within a three miles radius of the radio mast.

The NCS also identified several factors that should be considered when deploying the solution:

- The transportation of the command-and-control vehicle with the satellite dish may take a few days to deliver to the emergency site.
- Radio communications have a limit of 3 miles on a flat terrain.

Overall, the MCS satellite solution is ideal for supporting a small field office or a single building in support of ESF#2 or NS/EP, or in recovering from loss of primary communications at a Federal agency.

[1] It is expected that MCS will install the equipment for the agencies.

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1. INTRODUCTION

This document presents the results from an evaluation of Mobile Communications Systems' (MCS) Emergency Communications Solutions (ECS). The National Communications System (NCS) conducted the evaluation as part of the Route Diversity Project (RDP), which seeks to evaluate and improve the resiliency of Federal agencies' communications networks through methodologies, tools, and evaluations of new communication services and technologies. The RDP has conducted several technology evaluations in the past on other technologies including wireless broadband and free space optics. For more information, please visit the RDP website at http://ncs.gov/rdp.

1.1 PURPOSE

The purpose of this evaluation is to determine if ECS is viable as:

- A quickly deployable back-up communications services for national security and emergency preparedness (NS/EP) and Emergency Support Function (ESF) #2 incidents, and
- A solution for creating route diversity at Federal agencies

1.2 OBJECTIVES

The NCS set several objectives to evaluate ECS and assess its viability:

- Observe how quickly and easily the satellite dish and equipment can be setup,
- Determine availability of satellite link,
- Evaluate performance and throughput, and
- Determine how effectively the ECS can support voice and data applications such as email and file transfer (i.e., applications likely to be used in an emergency situation).

1.3 SERVICE INFORMATION

MCS products and services consist of fly-away kits, vehicle-based satellite solutions, and the ECS, a vehicle-based emergency command-and-control solution, which was selected by the NCS for this evaluation. The ECS setup, as shown in Figure 1, provides three types of emergency communications services: satellite, wireless, and radio.

1.3.1 Satellite

The satellite solution provides a backhaul transport from a location to the world through a teleport (satellite hub facility) located in Houston. It is based on geosynchronous satellite technology[2] that has a capability of up to 5 Mbps downlink and 2 Mbps uplink. It can also be

[2] MCS leases satellite bandwidth from satellite operators.

provisioned for 1 Mbps downlink/1 Mbps uplink or 4 Mbps downlink/2 Mbps downlink. A typical configuration of 4 Mbps downlink/2 Mbps uplink supports 24 voice ports and 100 or more data (Internet) ports. During the testing, the satellite link was configured for 1 Mbps downlink/1 Mbps uplink.

1.3.2 Wireless Mobile

The wireless mobile solution is offered through a wireless access point for wireless local area network (LAN) connectivity. The wireless solution is an alternative to wireline connectivity in creating a local access network backhauled by the satellite link..

1.3.3 Radio

The radio solution is supported through four radios for emergency communications and the Pan Tilt Zoom (PTZ) Internet Protocol (IP) camera for remote monitoring and surveillance. The radio communications equipment supports VHF and UHF radios, trunking scanner, emergency lighting, and siren control. The surveillance camera allows assessing damage at the disaster site from remote locations. About 20 different remote web users can view from this camera. In addition, MCS provides Voice over IP (VoIP) and Radio over IP (RoIP) capabilities.

1.3.4 Emergency Communications Solution Setup

MCS provides the the ECS and the associated communications electronics on a Ford Excursion that contains the following: a custom center console housing a Global Positioning System (GPS) navigation system integrated with NOAA for real-time Doppler radar, an emergency siren and lighting package, two PC workstations, a laptop, printer, copier, scanner, fax, and DVD/VCR unit. The 1.2 meter satellite dish mounted on top of the truck can auto acquire satellite in five minutes to send and receive satellite signal. The back of the vehicle contains two custom racks with computer equipment, routers, a satellite modem, wireless access point, 24 phone lines, 48 internet ports, video conferencing, radio interoperability, real time Doppler radar and an independent/redundant power system.

The teleport in Houston consists of several satellite dishes of different sizes to transmit information from satellite to PSTN and vice versa. The teleport is used for tracking and monitoring of information as well as maintaining correct altitude in a satellite’s orbital slot. The teleport consists of several routers, satellite modems, network management and monitoring systems, VPNs, and PSTN access via fiber. The teleport monitors not only satellites, but also their own facility.

Figure 1 provides a diagram of the ECS setup, including the connection between the vehicle and the teleport.

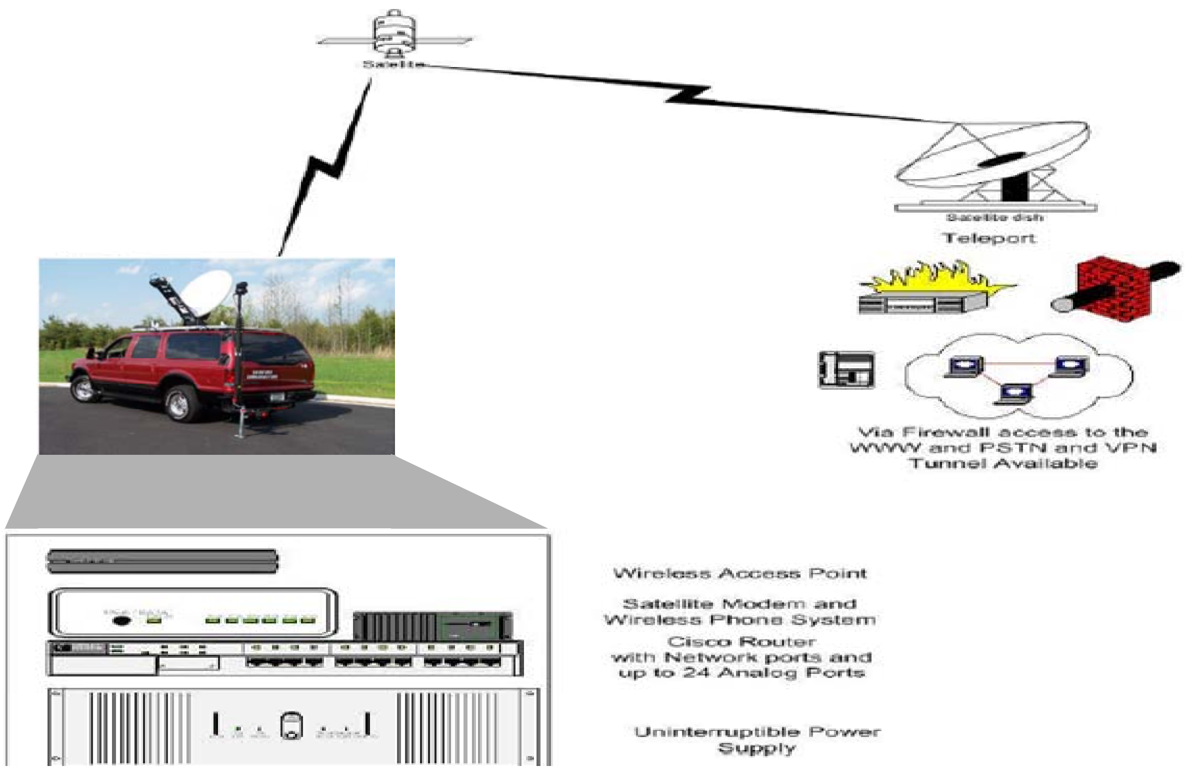

Figure 1 – Emergency Communications Solution Setup

2. EVALUATION DETAILS

The following sections describe how the NCS and MCS configured the ECS for testing, the tests performed, and environmental constraints.

2.1 EVALUATION CONFIGURATION

The NCS evaluated the ECS by using a test configuration provided by MCS. The testing equipment was placed at two locations both next to the teleport at 11140 Aerospace Avenue, Houston, TX 77034. The very small aperture terminal (VSAT) satellite dish (on the vehicle), network equipment, Ixia chassis (#1), testing laptop, and Cisco switch were set up at Site 1. The IXIA chassis (#1), the laptop, and the dish were interconnected through the Cisco switch. The second IXIA chassis (#2) for looping test data through the satellite link, public switched telephone network (PSTN), and Internet were set up at Site 2.

The test configuration is depicted below in Figure 2 and a detailed description of the test equipment and software is in Appendix D.

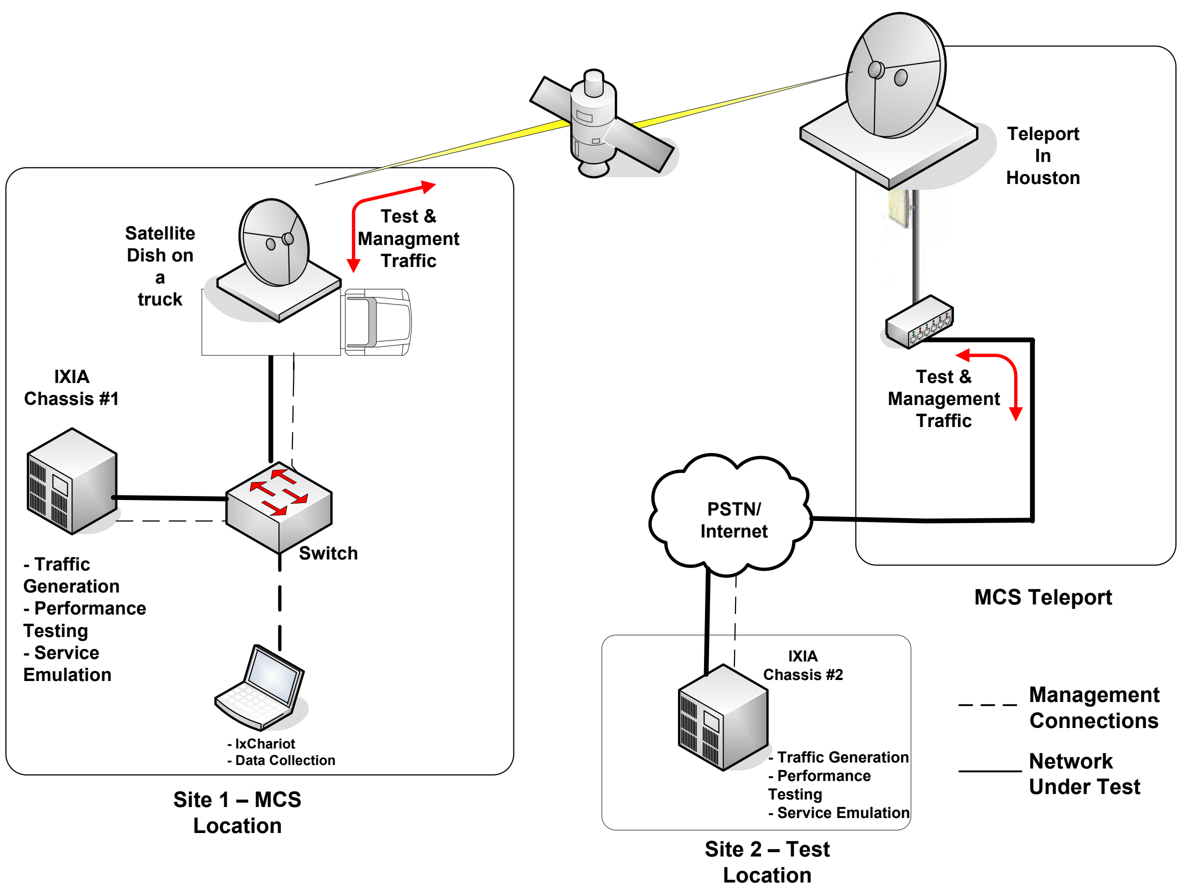

Figure 2 – MCS Evaluation Configuration

The test laptop controlled tests, as well as collected test results. The NCS managed each Ixia chassis using VNC remote desktop software. Test traffic was generated and received in batch mode (ensuring that simultaneous transmission of management traffic and test data on the satellite link during testing was avoided). Ixia equipment at both locations received traffic that traversed across the satellite link.

2.2 EVALUATION TESTS PERFORMED

The NCS evaluated ECS services by conducting performance and applications emulation testing, evaluating the radio communications solution and the PTZ IP camera operation, and observing installation set up. This section describes each test performed. For greater detail about the tests performed and the results of those tests, see Appendices B and C.

2.2.1 Satellite Installation Observations

During the set up, MCS gave a demonstration of how quickly and easily the ECS can be installed during a mock disaster scenario. The NCS made observations on the ease of setup and configuration of the system.

2.2.2 Satellite Basic Capabilities

The NCS evaluated the satellite solution for basic voice, data, and video capabilities to determine whether they were functioning adequately. MCS can packaged the ECS with one of two versions of a satellite service, Time Division Multiple Access (TDMA) or Single Channel Per Carrier (SCPC). The NCS primarily conducted its evaluation using the iDirect/TDMA[3] configuration; TDMA is the default ECS configuration. The TDMA service was configured with a 1 Mbps symmetrical link, while the SCPC was configured with a 512kbps symmetrical link. The NCS performed the throughput evaluation test using the SCPC configuration[4] in addition to TDMA configuration.

The NCS generated several voice calls from plain old telephone service (POTS) and observed call setup time and latency in communications[5], evaluating voice priority over data. In addition, the NCS evaluated access to a contractor's corporate network, as emergency responders may need to access their own agencies' enterprise network for emergency information using a virtual private network (VPN)[6].

The NCS initially planned to test he video capability in a streaming video evaluation; however, streaming video was not evaluated for reasons explained in Section 2.3.

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[3] The iDirect/TDMA configuration allows sharing the bandwidth among other subscribers with Quality of Service (QoS).

[4] The SCPC configuration provides a dedicated bandwidth without QoS.

[5] Generally, satellite communications have delay of about 500 msec.

[6] Emergency responders are going to access their enterprise networks to perform their mission critical functions. This test emulates accessing the enterprise network using VPN.

2.2.3 Satellite Link Availability

The NCS evaluated satellite link availability as it is very important that the satellite service is available during NS/EP incidents. Link availability was monitored by obtaining appropriate documentation during the evaluation period from MCS.

2.2.4 Performance Evaluation

The NCS conducted a performance evaluation to determine the throughput[7] of the satellite link. Performance evaluation measured data transmission quality across the satellite link in the downstream direction, the upstream direction, and in both directions simultaneously. The performance evaluation provided information on collisions, throughput, and frame transmission errors to determine the performance.

2.2.5 IxChariot Throughput Test

The NCS used IxChariot to determine the throughput performance of applications using Transmission Control Protocol/Internet Protocol (TCP/IP). IxChariot simulates applications that use protocols at all layers of the protocol stack, providing a more comprehensive evaluation including impact on performance due to TCP features such as error detection, windowing, sequencing, and retransmissions not provided by IxExplorer. The throughput tests were performed for TDMA and SCPC configurations.

2.2.6 Applications Evaluation

The purpose of the applications evaluation was to provide an assessment of the transmission quality and performance characteristics for various applications across the MCS link. The IxChariot test tool was used to configure, emulate, and collect statistics on the following service applications[8]:

- File Transfer Protocol (FTP)
- E-mail
- Web (HTTP)
- Voice over Internet Protocol (VoIP)
- Multiple applications (e-mail and web being tested simultaneously)

2.2.7 Radio Solutions Evaluation

MCS provided radio communications and a surveillance camera that may be useful during emergency situations. The radio capabilities allow emergency responders to be in touch with each other in the emergency area. The NCS tested the emergency radio communication capability for basic call set up and communication from different locations within a 5 miles

[7] The throughput is the fastest rate at which the count of test frames transmitted by the device under test is equal to the number of test frames sent to it by the test equipment.

[8] The streaming media test was not performed due to a configuration issue mentioned in Section 2.3.

radius of the truck, as shown in Figure 3. The NCS also tested the communications between hand-held devices and a dispatch center in Montana.

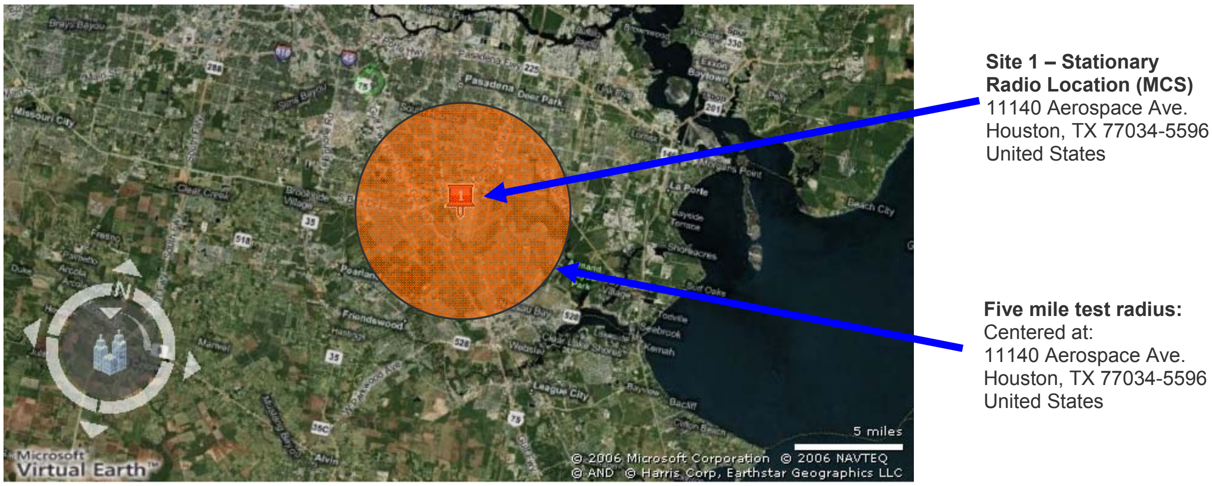

Figure 3 – Radio Test

The surveillance camera allows assessing damage at the disaster site from remote locations. The basic monitoring and operation of the surveillance camera from different remote web users were evaluated.

2.3 EVALUATION ENVIRONMENT CONSTRAINTS

During the evaluation of the MCS service there was one testing constraint that impacted testing. A configuration issue between the Ixia testing equipment and the MCS system prevented tests using RTP with traffic flowing from Site 1 to Site 2 (upstream) from returning test results. Unfortunately, this issue was unresolved during the period of testing. The full-duplex and upstream VoIP tests and streaming media tests could not be performed for this evaluation since they required traffic flows in both directions simultaneously. However, the NCS validated that bidirectional phone conversations could be carried out using the VoIP phones.

3. RESULTS

The following subsections document the results of evaluation tests described in Section 2.2. For greater detail about the results of these evaluation tests, see Appendices B and C.

3.1 INSTALLATION OBSERVATION

MCS demonstrated a mock disaster scenario. The scenario involved emergency personnel driving in the emergency command-and-control vehicle (belonging to the MCS), receiving instructions to install emergency communications by setting up the satellite dish, phones and data connectivity for the laptops. The set-up was completed by a two-man MCS team within 25 minutes. Even though the tent was set up ahead of time, all phones and data capabilities were installed after the satellite dish was operational.

The satellite dish was simple to set-up and most of the operation was automatic. Within the first 3 minutes of the set-up, the auto-acquire capability had positioned the satellite to send and receive a satellite signal. During the next 7 minutes, four wireless IP phones were configured, tested and ready to use. In the next 15 minutes, an additional 19 wired phones had been set-up and tested. Also during this time, data connection (both wired and wireless) and a line for fax were established and tested. Total communications were established within 30 minutes from receiving instructions.

It should be noted, however, that the truck with satellite dish was at the location. During the actual disaster scenario, the truck or trailer with satellite and equipment has to be transported to the emergency site. The transportation time for the truck or trailer should be considered for emergency planning. In addition, the satellite service needs to be leased from MCS in advance for this operation to be performed.

3.2 SATELLITE BASIC CAPABILITIES

The NCS generated several voice calls from plain old telephones at Site 1 to the PSTN (e.g. NCS office phones). When placing voice calls using the phones provided by MCS the call quality was good and calls sounded clear. There was a noticeable delay during the initial call setup, but this is an expected behavior of satellite communications. During the calls, the delay seemed similar to a cellular phone service and for the most part was unnoticeable. However, some latency existed during communications, especially right after a pause in the conversation. Three calls were placed simultaneously to different users, and the call quality was not impaired or affected by the other conversations.

MCS set up highest priority for voice calls. The NCS evaluated this priority by saturating the bandwidth with data transmission and then initiating voice calls. The voice calls went through even when the satellite link was fully loaded with data transmission.

In addition, the Booz Allen Hamilton corporate network was accessed from Site 1 using a laptop. Email, corporate websites (iShare and RDP), and public Internet were accessed to assess basic data capabilities using the Booz Allen Hamilton VPN[9] tunnel. The data access was slow, but there was no issue in accessing this network.

3.3 Satellite Link Availability

During the course of testing, MCS' satellite link was stable and no major issues were observed with link availability. However, the link went down 3 times while trying to run the FTP full-duplex test, each time coming back within 4-8 minutes. The test involved filling the link with a 3 MB file in the upstream and downstream directions simultaneously. Overloading the link also blocked the management traffic. When the network management system did not see the management traffic (responses), it shut down the satellite link[10]. MCS/teleport engineers resolved this issue by giving test management traffic a higher priority over other data on the link. This solution was acceptable because the test management traffic involves only small ping requests and responses, which did not adversely affect test results.

The NCS was also able to observe the effect of adverse weather conditions on link availability when a storm occurred for about 2 hours on one of the test days[11]. The Carrier-to-Noise (C/N) ratio[12], power levels and link status information were obtained from the teleport to analyze the effects of the storm on the link availability. The NCS observed that for a period of 18 minutes, the C/N ratios went as low as 4.28 dB and as high as 9.61 dB as compared to the normal range of 8 to 12 dB. The lower C/N ratio indicates poor quality of reception and lower communications accuracy and reliability; however, the link was available during the entire storm period.

3.4 Performance

The NCS completed the performance evaluation using IXChariot for both iDirect/TDMA and SCPC configurations. For iDirect/TDMA, the NCS verified that the downstream and upstream throughput rates were in line with the rates as specified by MCS. The NCS measured slightly higher uplink and downlink speeds than rated speeds. The rated (MCS specified) link speeds were 1 Mbps downstream and 0.965 Mbps upstream. When measuring throughput utilizing the entire protocol stack and forwarding traffic in one direction only, the average throughputs measured were 1.342 Mbps downstream (134% of 1 Mbps) and 1.121 Mbps upstream (116% of 1 Mbps). This test only used the maximum frame size of 1518 bytes when sending data. Transmitting traffic in both directions simultaneously resulted in the throughput falling significantly. The total throughput measured for both upstream and downstream was found to be only about 74% of the total (1.46 Mbps measured against 1.965 Mbps rated) available bandwidth.

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9 Emergency responders may access their enterprise networks to perform mission critical functions. This test emulates accessing the enterprise network using VPN.

10 The network management system is designed is to shut down the link when it does see traffic.

11 All tests were suspended during the period of the storm due to dangerous environment conditions.

12 A C/N ratio is a measure of the received carrier strength relative to the strength of the received noise. High C/N ratios provide better quality of reception. A C/N ratio that falls between 8 and 12dB is considered good (12 being the best). For the power levels, -30 dBm is considered to be the highest level attainable. The -30 dBm power level assumes a perfect sky condition.

A possible cause for the reduction in bandwidth is the TCP handshaking behavior. When using TCP, synchronization and acknowledgment signals are sent in both directions to verify that data sent was received correctly. When transmitting traffic at the maximum rate in both directions simultaneously (full-duplex), these acknowledgements are delayed in both directions resulting in lower throughput.

For SCPC configuration, NCS tested a single direction mode only. The link was set to 512 kbps for both downstream and upstream, but results showed that the link did not perform as high as it was rated. The results were 434 and 435 kbps, respectively, for upstream and downstream throughput values, measuring at nearly 84-85% of the rated link speed. A summary of throughput evaluation is provided below in Table 1.

Test	Mode	Direction	Rated Link Speed (Mbps)	Throughput (Mbps)
IxChariot iDirect/TDMA Throughput	Single-Direction	Upstream	0.965	1.121
		Downstream	1.000	1.342
	Full Duplex	Upstream	0.965	0.594
		Downstream	1.000	0.866
IxChariot SCPC Throughput	Single-Direction	Upstream	0.512	0.434
		Downstream		0.435

Table 1 – Throughput Evaluation Results

3.5 APPLICATIONS

The results of applications evaluation are documented for the following applications.

- File Transfer Protocol (FTP)
- E-mail
- Web (HTTP)
- Voice over Internet Protocol (VoIP)
- Multiple applications (e-mail and Web were tested simultaneously)

3.5.1 File Transfer Protocol (FTP)

The FTP test evaluated transferring a 3MB test data file across the MCS link. The test transferred the 3 MB file in the upstream and downstream direction independently, then in both directions simultaneously (full-duplex).

The results of average response time when run in each direction independently and in full-duplex are shown in Table 2. The measured response times for single direction upstream and downstream were nearly equal. The same is true for the response times for full-duplex FTP in both the upstream and downstream directions. Larger response times (146-156%) for the full-duplex FTP transmissions were measured, which may be due to acknowledgment signals being sent in both directions as mentioned in Section 3.4.

Direction	Mode	Size (MB)	Response Time (Sec)
Upstream	Single Direction	3.00	24.71
	Full Duplex	3.00	38.61
Downstream	Single Direction	3.00	25.18
	Full Duplex	3.00	36.79

Table 2 – FTP Average Response Time

3.5.2 Email

The e-mail service test evaluated data transfer using SMTP and POP3 protocols. Two email sizes were selected to emulate large and small emails: 35 kB and 1 MB.

The results of the e-mail test demonstrated that SMTP and POP3 e-mail applications can be used on the satellite link. Table 3 summarizes the measured response times for the POP3 and SMTP transmissions for the two email sizes in the upstream and downstream directions. Larger response times were expected and measured for the 1 MB when compared to response times for the 35 kB email due to more time needed for transmission across the link that was of a fixed size.

Direction	Protocol	Size (kB)	Response Time (sec)
Upstream	POP3	35	5.247
		1000	11.745
	SMTP	35	4.93
		1000	11.436
Downstream	POP3	35	4.717
		1000	10.394
	SMTP	35	4.509
		1000	10.192

Table 3 – Email Average Response Times

As indicated above, most results are close to 10 seconds even with large size (1 MB) file. Considering the inherent nature of satellite communications delay, the email response time is satisfactory.

3.5.3 Web (HTTP)

The test emulated the transfer of web pages consisting of both text and graphics in the upstream and the downstream directions, sending a page sized at 235 kB. The test was run 50 consecutive times to get a large sample of data. The average response times for each 235 kB file sent in the upstream and downstream directions were 3.633 and 3.359 seconds, respectively. This behavior was expected given the fact that satellite transmissions have an inherent round trip latency of approximately 0.5 seconds. The average response time is shown in Table 4.

Direction	Size (kB)	Response Time (sec)
Upstream	230	3.633
Downstream	230	3.359

Table 4 – HTTP Average Response Times

3.5.4 Voice over IP (VoIP)

The VoIP test evaluated the G.729 codec both quantitatively and qualitatively. The results of the quantitative G.729 voice emulation test in the downstream direction demonstrated that the link can support between 50 - 55 users simultaneously because as the number of users reached 60, the calls began to experience data loss of 4%. When testing the G.729 codec utilizing the telephones provided by MCS, the call quality sounded clear and the delay did not hinder voice conversations. Three simultaneous calls were placed and there was no noticeable interference to any of the calls.

3.5.5 Multiple applications (Web and email)

The multiple applications test emulated users performing the two common data transactions of using email and web browsing (HTTP). The test began by emulating only one user using HTTP and email applications simultaneously. The test then increased the number of concurrent users sending traffic to 10, then 20, 30, 35, 40, and concluded with 45 users. File sizes were 35 kB for POP3/SMTP and 235 kB for HTTP web pages.

The multiple applications test results indicate that the link can support up to 30 users using HTTP and email applications simultaneously for the traffic profile used by NCS. NCS set a limit of 60 seconds for the maximum response allowable by any of the applications, due to the delays associated with using a satellite services. Response times exceed accepted levels if more than 35 users used the ECS service as indicated in Table 5. Response times peaked at 110.76 seconds for HTTP at 45 users. Response times for POP3 peaked at 32 seconds for 45 users. For SMTP, response times also peaked at 28.20 seconds for 40 users. Based on the above data, the NCS determined that 30 users can be effectively supported since the response time is below 51 seconds. Overall, the HTTP response time was the limiting factor because larger delays in these transactions are most noticeable by users. The email response times seen at the peaks would not have a large impact on the user's experience, since delays in email transactions are not as obvious to end users. A larger number of users could be supported by the link if the traffic profile of each user had less activity and required less bandwidth than the profile used for this testing. Information on the traffic profile can be found in Appendix C.

Number of Users	Protocol	Response Time (sec)
1	HTTP	3.25
	POP3	5.13
	SMTP	4.97
10	HTTP	8.05
	POP3	6.57
	SMTP	7.88
20	HTTP	25.90
	POP3	15.22
	SMTP	18.22
30	HTTP	50.10
	POP3	13.85
	SMTP	20.81
35	HTTP	69.99
	POP3	21.14
	SMTP	31.75
40	HTTP	96.80
	POP3	28.20
	SMTP	10.66
45	HTTP	110.76
	POP3	14.06
	SMTP	32.56

Table 5 – Multiple Applications Average Response Times

3.6 RADIO SOLUTIONS EVALUATION

The radio solutions evaluation was performed for UHF radio and video surveillance capabilities.

3.6.1 Radio Evaluation

The NCS evaluated UHF[13] (two-way) radio coverage using two of MCS' hand-held radio devices. The NCS performed the evaluation in a suburban area of Houston with almost flat terrain (no high rise buildings). The distance between the two radio hand-held devices was measured by a GPS navigational system in a vehicle. The evaluation was first conducted at a distance of 1 mile and then in increments of a mile until the communication was lost. The result of radio testing is shown in Figure 4.

[13] The VHF and interoperability between VHF and UHF were not tested due to non-availability of equipment.

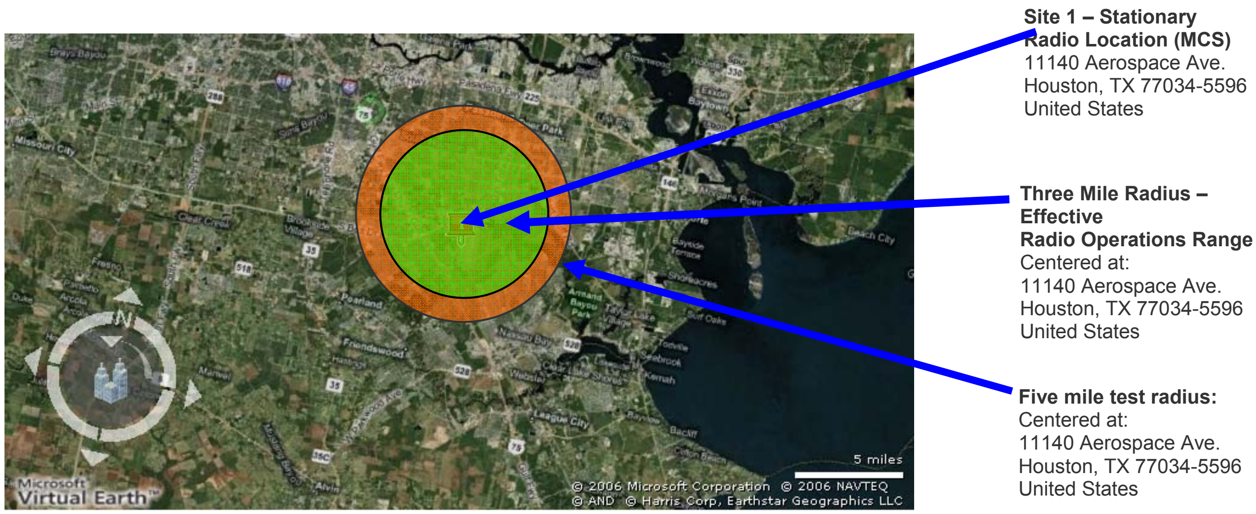

Figure 4 – Radio Test Results

For up to 2 miles, the NCS established communication between the radios and observed very good and clear sound quality. At a distance of 3 miles, the NCS established communication, but with degraded sound quality and noticeable static noise. At a distance of 4 miles, the NCS was unable to establish communication. In order to determine the exact point of failure distance, the radio tests were performed at 3.4, 3.6 and 3.9 miles. For each of these tests, communication was re-established and maintained. However, beyond a distance of 3 miles, static noise increased with the increased distance. Therefore, the NCS concludes that the radios can be used reliably up a distances of 3 miles on a flat terrain.

3.6.2 Surveillance Camera Evaluation

The surveillance camera capability allows remote access and viewing for up to 20 users. For this evaluation, the surveillance camera was mounted on a mast attached to the MCS truck with the satellite dish. The surveillance camera can be configured for remote user control or viewing. Both configurations were tested.

The NCS remotely accessed the surveillance camera from over the Internet. One user logged in with control access and was able to move the camera in different directions and zoom in and read the license plate on a parked car about 300 feet from the camera. The second user, who was simultaneously logged on to the camera, was able to view only. Both users rated the video resolution and frame rate as subjective "good". On the subjective scale of 1-5, with 5 being the highest, the video quality was given a 3.75 rating (note that this is only two persons' opinion and not a scientific survey).

4. CONCLUSION

Based on this evaluation, the NCS believes that MCS solutions can fulfill communications needs in an ESF# 2 or NS/EP incident and a Federal agency's route diversity needs by providing phones, radio, and Internet. In addition, the evaluation validated MCS's claim that their solution can be deployed in about half an hour provided the satellite truck or trailer is available at site. This solution is available in the U.S.A. as well as Iraq.

Overall, the solution offers capabilities, including a satellite link for voice and data, radio communications, and video surveillance. Results from testing verified the functional capabilities and operation of these capabilities. Specifically, major findings from testing include:

- Link performance i.e., throughput, is satisfactory.
- Applications (FTP, web, email, and multiple applications (web and email) work as expected, but with the normal delays associated with the satellite link (the VoIP and streaming media application were partially evaluated because of router configuration IXIA testing equipment issues).
- Actual telephone conversations using the VoIP service are possible.
- The radio communication is clear within three miles radius of the radio mast. Beyond thee miles, the noise level increases with the distance.
- The video surveillance capability can be helpful to get hands-on view of the devastated area. A user from McLean, VA was able to control the video camera in addition to users in Houston and McLean being able to view the video from the camera.
- The evaluated solution can support up to 30 users with reasonably good quality of voice and data.

When deploying the ECS, there are several factors that should be considered. The most notable is that when planning for emergency communications using these solutions, a few days should be allowed for satellite truck/trailer transportation time. Also, delay is inherent in satellite communications and as such, there is a delay during the setup and pause of a call of about 500 msec. Lastly, radio communications may be limited to less than 3 miles depending on the terrain in the deployment area.

In conclusion, MCS' ECS solution is suitable for relief efforts where telecommunication infrastructure is severely damaged. These solutions provide a viable alternative that is mobile and quickly deployable during a National Security/Emergency Preparedness (NS/EP) incident, thus helping NCS fulfill its ESF#2 responsibilities.

APPENDIX A – ACRONYMS

C/N	Carrier-to-Noise
CPE	Customer Premise Equipment
CRC	Cyclic Redundancy Check
ECS	Emergency Communications Solutions
FSO	Free Space Optics
FTP	File Transfer Protocol
GPS	Global Positioning System
GUI	Graphical User Interface
HTTP	HyperText Transfer Protocol
IP	Internet Protocol
LAN	Local Area Network
Mbps	Megabits per second
MCS	Mobile Communications Systems
MOS	Mean Opinion Score
NCS	National Communications System
NOC	Network Operation Center
NS/EP	National Security/Emergency Preparedness
POTS	Plain Old Telephone Service
PSTN	Public Switched Telephone Network
QoS	Quality of Service
RDP	Route Diversity Project
RFC	Request For Comments
RTP	Real-Time Transport Protocol
SCPC	Single Channel Per Carrier
SPX	Sequenced Packet Exchange
TCP	Transmission Control Protocol
TDMA	Time Division Multiple Access
UDP	User Datagram Protocol
VNC	Virtual Network Computing
VoIP	Voice over IP
VPN	Virtual Private Network

APPENDIX B - PERFORMANCE TESTING DETAILS

IxChariot Throughput Test

The IxChariot throughput test was used to determine the throughput performance that a typical application using TCP/IP will experience. The IxChariot simulates services that use protocols at all layers of the protocol stack. It also provides a more comprehensive evaluation, including impact on performance due to TCP's features such as error detection, windowing, sequencing, and retransmissions. The IxChariot test measures throughput using only the maximum frame size of 1518 bytes.

IxChariot Throughput Evaluation (iDirect/TDMA)

The evaluation was carried out in two parts. The first part involved sending a 3MB file in both the upstream and downstream directions at different times. The test was run 20 consecutive times in each direction. The second part involved sending a 3MB file in the upstream and downstream direction simultaneously (full-duplex). This test was also run 20 consecutive times.

The link was configured for 1 Mbps symmetrical and the results showed an average of 1.121 Mbps in the upstream direction and an average of 1.342 Mbps in the downstream direction. MCS's network performs TCP acceleration, a technique in which the header of the first packet received is retained. Headers of subsequent packets are dropped and the retained header is used with each new packet. This technique speeds up traffic and may also be a contributing factor to the higher than expected throughput averages.

When traffic was transferred in both directions simultaneously (full- duplex), the upstream and downstream throughputs were significantly reduced. In the full-duplex test, the average upstream throughput was 0.594 Mbps and in the downstream direction was 0.866 Mbps. A possible cause for the reduction in bandwidth is the TCP control congestion behavior. When using TCP, synchronization and acknowledgment signals are sent in both directions to verify that data sent was received correctly. When transmitting traffic at the maximum rate in both directions simultaneously (Full-Duplex), these acknowledgements are delayed in both directions resulting in lower throughput. The average upstream, downstream, and the combined upstream and downstream for the single direction and full-duplex tests side by side is shown in Figure 5.

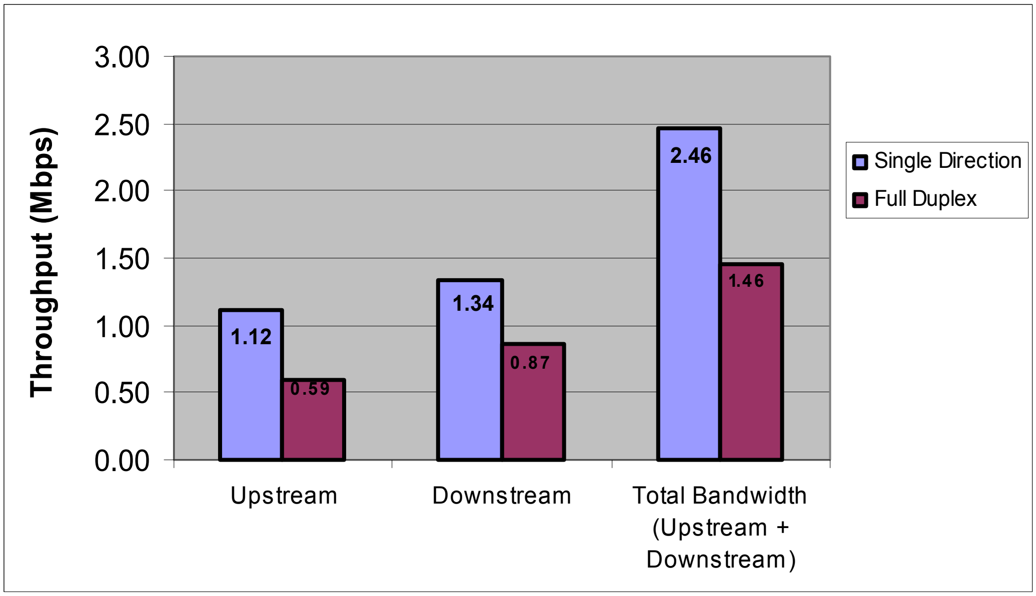

Figure 5 – IxChariot Average Throughput Results (TDMA/iDirect)

IxChariot Throughput Evaluation (SCPC)

The satellite link performance was also measured using SCPC modem using IxChariot. The evaluation involved sending a 1MB file in both the upstream and downstream directions at different times. The test was run 20 consecutive times in each direction.

The SCPC link was configured for 512 kbps symmetrical but the results showed an average of 434 kbps in the upstream direction and an average of 435 kbps in the downstream direction, which measured at 84-85% of the rated value. The average upstream and downstream results are shown in Figure 6.

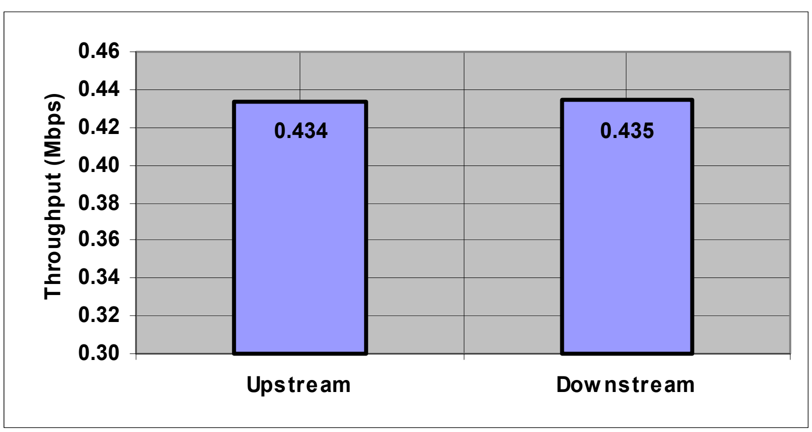

Figure 6 – IxChariot Average Throughput Results (SCPC)

APPENDIX C – APPLICATIONS EVALUATION

The purpose of this testing is to provide an assessment of the transmission quality for various applications across the MCS link. The IxChariot test tool was used to configure and emulate various applications and collect statistics for the tests described in the sections below.

FTP

This test evaluated the performance of FTP applications on the link. IxChariot emulated FTP transactions between one FTP server and a single FTP client by emulating all required traffic flows of a FTP application. The traffic flows consisted of logging into the server, selecting a file, and transferring a 3 MB file. The FTP Test transferred the 3 MB file in the upstream and downstream direction independently, then in both directions simultaneously (full-duplex). For each run, the test performed the FTP transfers five times to get a sample of the performance over multiple runs. Table 6 shows the location of the FTP server and FTP client for each test.

Direction	Endpoint 1 (Site 1)	Endpoint 2 (Site 2)
Upstream	FTP Server	FTP Client
Downstream	FTP Client	FTP Server

Table 6 – FTP Configurations

Test Results

The results of the FTP service test validated the throughput rates already measured across the link by the previous tests. The average throughput results and response times of the test when run in each direction independently and in full-duplex are shown in Figure 7 and Figure 8.

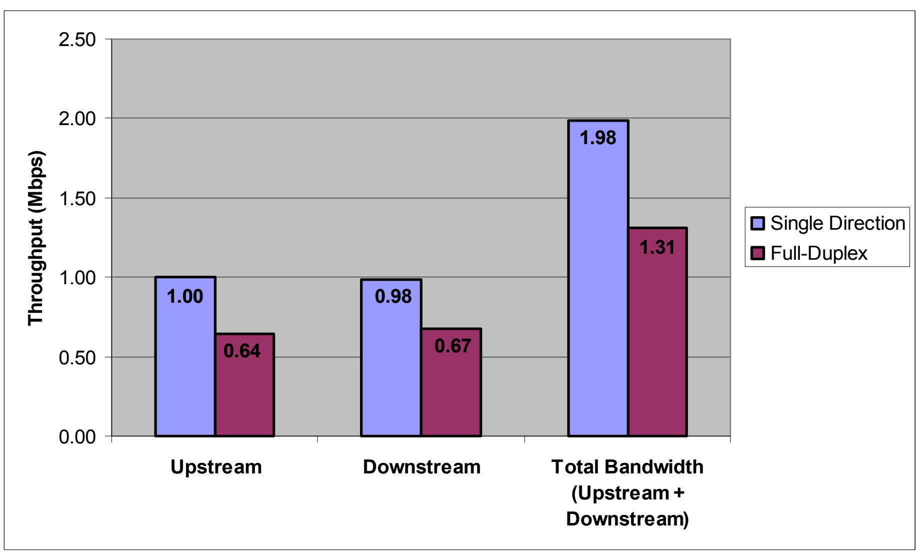

Figure 7 – FTP Average Throughput

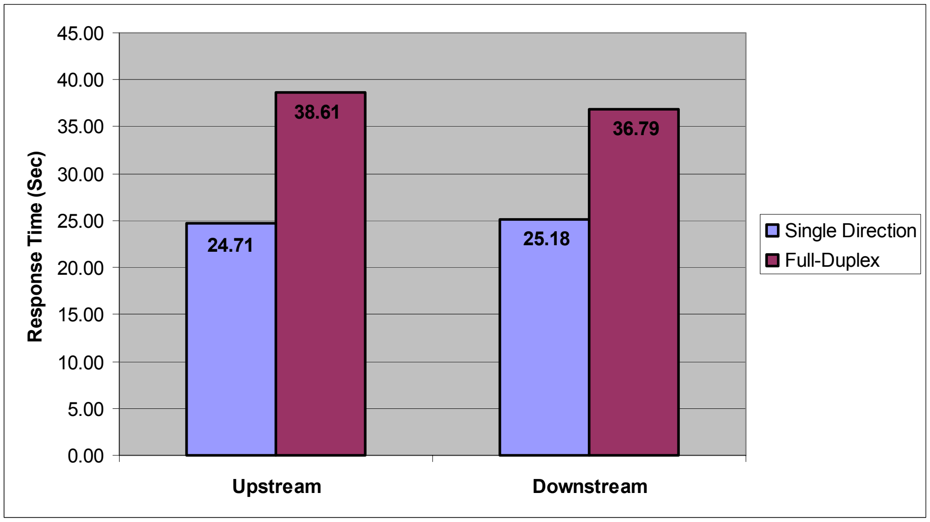

Figure 8 – FTP Average Response Time

Results showed an average throughput of 1Mbps in the upstream direction and an average of 0.98 Mbps in the downstream direction. When traffic was transferred in full duplex, there was a significant reduction in the throughput rates. In the full-duplex test, the average upstream throughput was 0.64 Mbps and 0.67 Mbps in the downstream direction. As with the previous IxChariot throughput test, a possible cause for the reduction in bandwidth is the TCP congestion control behavior. When using TCP, synchronization and acknowledgment signals are sent in both directions to verify that data sent was received correctly. When transmitting traffic at the maximum rate in both directions simultaneously (full-Duplex), these acknowledgements are delayed in both directions resulting in lower throughput.

E-mail

The e-mail service test evaluated how email transactions would perform across the link using two standard email transfer protocols: SMTP and POP3. The test emulated all traffic flows generated by each of the protocols for the sending and receiving of emails. In order to simulate large and small emails, two email sizes were selected: 35 kB and 1 MB.

Test Results

The results of the email application test demonstrate that email application using SMTP and POP3 can be used on the link. The throughput and response times of the email transactions for each of the file sizes in each direction are shown in Figure 9 and Figure 10. Both the smaller emails of 35 kB and the larger emails of 1 MB experienced equivalent respective average throughput and response time measurements in both directions. The throughput and response time measurements climbed significantly for the 1MB transmission when compared to the 35 kB transmission. This is expected due to the magnitude of difference between the transmission sizes.

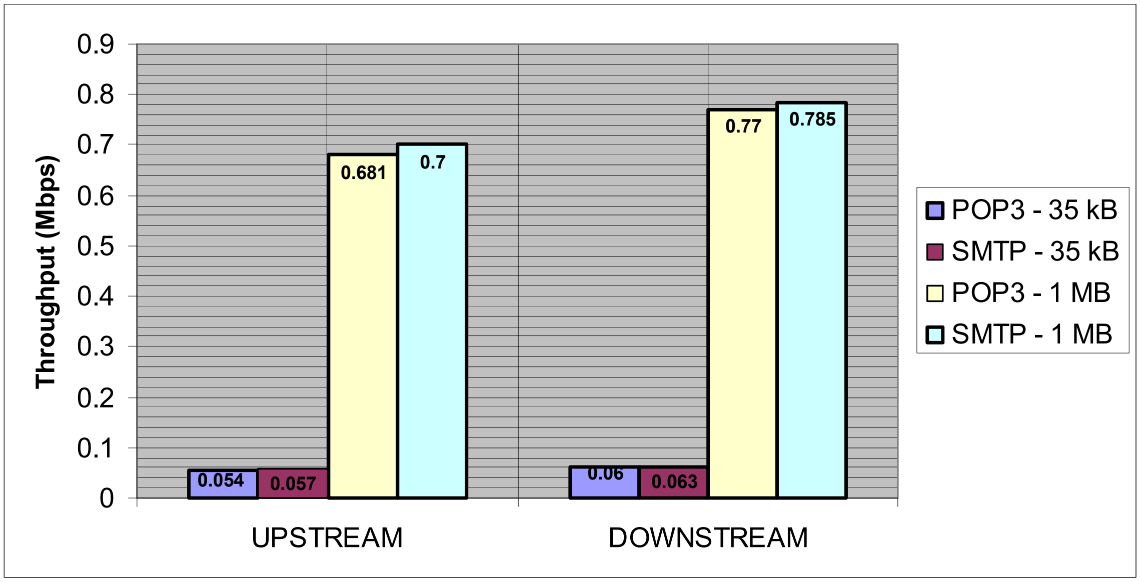

Figure 9 – E-mail Average Throughput

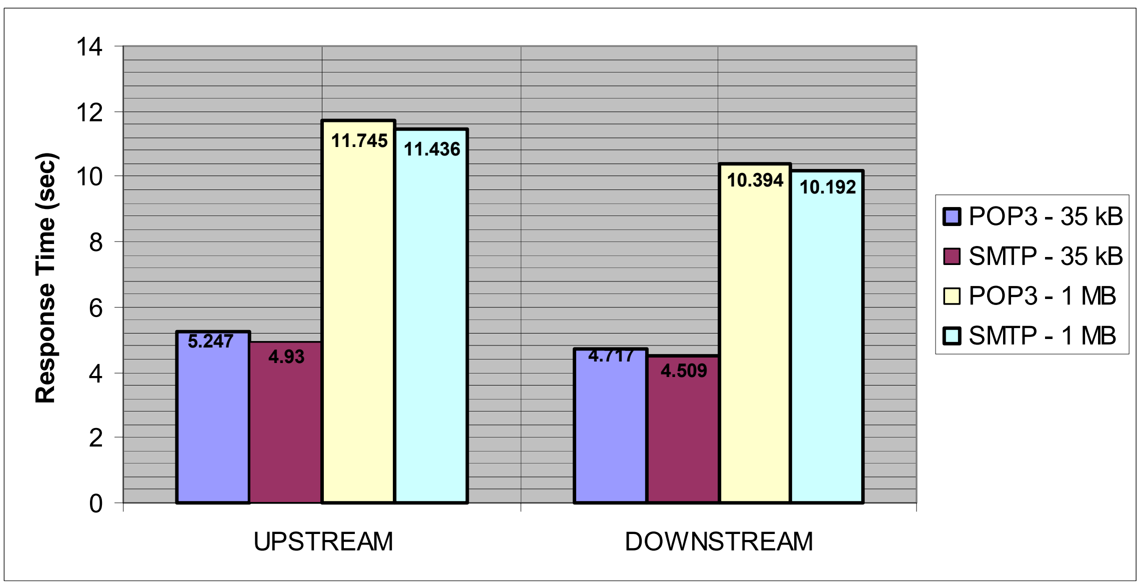

Figure 10 – E-mail Average Response time

Web (HTTP)

The HTTP test emulated transactions between an HTTP server on one side of the link (Site 1) and an HTTP client on the other side of the link (Site 2). The test emulated the transfer of web pages consisting of both text and graphics in the upstream and the downstream directions. The size of the page sent was Kbytes. The test was run 50 consecutive times to get a large sample of data.

Test Results

The average response time for each 235 kB file sent in the upstream and downstream directions were 3.633 and 3.359 seconds respectively.   It is a common known fact that satellite transmissions have an inherent round trip latency of approximately 0.5 seconds which may cause for the high response times. Upstream and downstream transmissions for HTTP traffic exhibited near equivalent performance with slightly greater performance in the upstream direction. The average throughputs and response times are shown in Figure 11 and Figure 12 respectively.

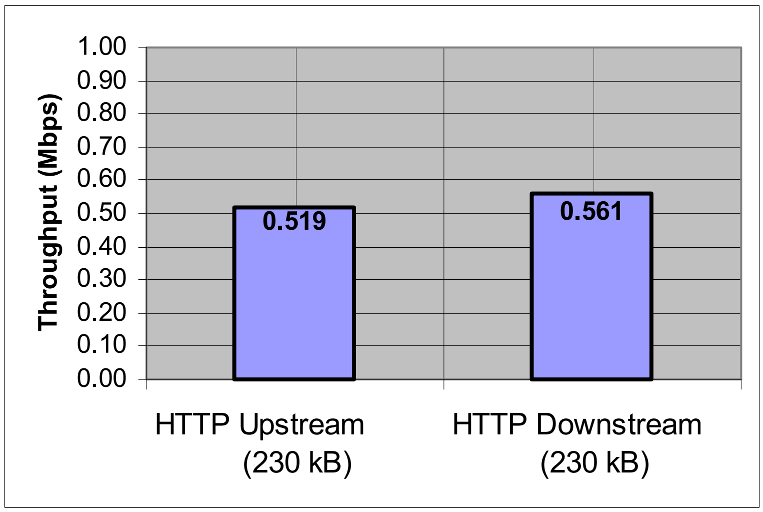

Figure 11 – HTTP Average Throughput

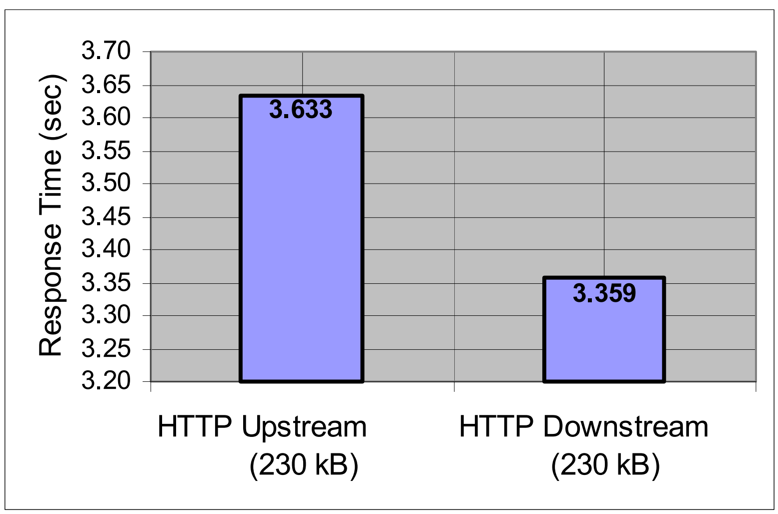

Figure 12 – HTTP - Average Response Time

VoIP Testing

The VoIP test was used to observe the quality of VoIP calls across the link and to determine the maximum number of simultaneous VoIP calls that could be supported while maintaining good call quality. Two VoIP codec (G.729 and G.711u) were originally selected for this evaluation but only downstream G.729 packet transmission was tested. This was due to configuration issues between the Ixia testing equipment and the MCS network that prevented tests using RTP with traffic flowing in the upstream direction from returning test results. The overall VoIP performance was rated both quantitatively and qualitatively. IxChariot has the capability to evaluate VoIP performance quantitatively using MOS (Mean Opinion Score) based on the E-Model (refer to Appendix E). However, the large latency inherent in satellite systems renders the E-Model invalid for this testing. Therefore, NCS chose to rate the calls using the network performance metrics that go into computing the MOS: jitter, latency, and data loss. The qualitative testing was performed by utilizing the VoIP phones provided by MCS to place actual phone calls to team members located in Virginia and Atlanta. The phones were standard POTS phones but were connected to a Cisco router that digitally converted the voice using the G.729 codec.

Test Results

The results of the G.729 voice emulation in the downstream direction demonstrated that the link can support between 50 - 55 users simultaneously. As the number of users reached 55 and above, the calls began to suffer from increased dropped packets and a significant rise in the one way delay. The cause of this was the satellite link congestion, as more calls were placed on the link the amount of bandwidth consumed also increased as shown in Figure 13.

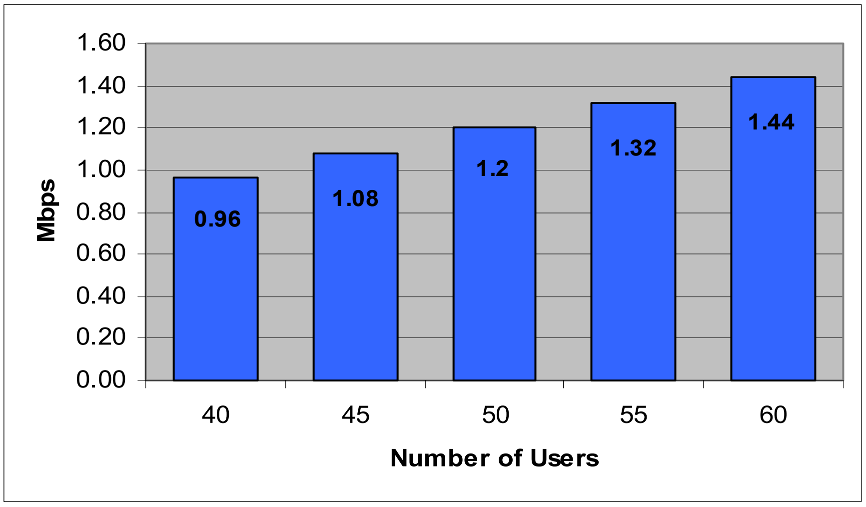

Figure 13 – G.729 Total Throughput (Header + Payload)

The increase in the percentage of lost bytes as the number of users increased is charted in Figure 14. Between 50 and 55 users the percentage of bytes lost increased from .02% to .11% which in either case is not significant, but at 60 users the percentage of bytes lost increased to around 3.84%. The G.729 codec requires a loss of less than 1% to prevent audible errors within the calls.

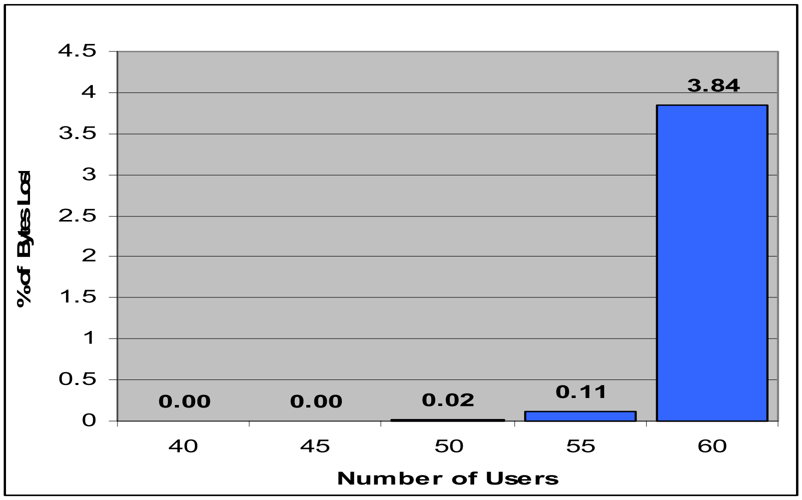

Figure 14 – G.729 Data Loss (Average)

Satellite services have an inherently large one-way delay due to the distances the signals have to travel to reach the satellite in space and then back down to earth on the receiving end. As shown in Figure 15, the one-way delay increased as the number of users increased. As mentioned earlier, this can be attributed to congestion on the link. The one-way delay numbers seemed to spike at 55 users and lower slightly at 60 users. This behavior was unexpected and may have been caused by outside interferences. Another run of the test for 55 users most likely would have given delay numbers more inline, given the trend for each of the other sets of users.

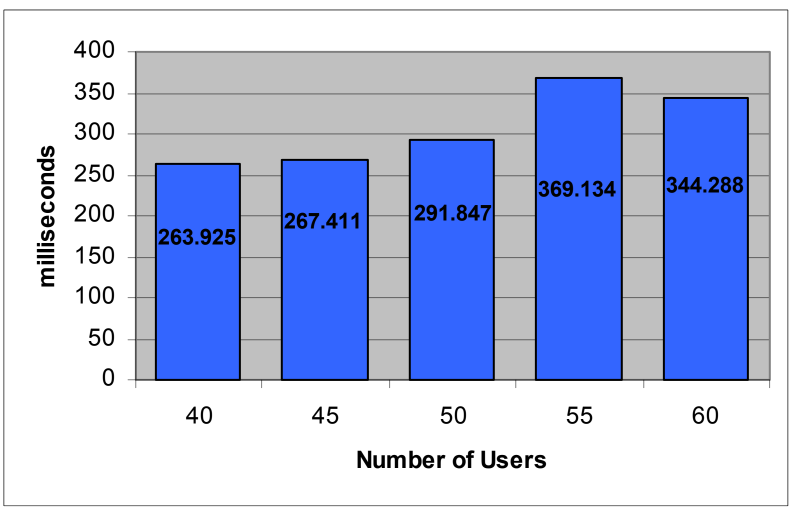

Figure 15 – G.729 Downstream One-Way Delay (Average)

The RFC 1889 jitter measurements calculates a mean statistical deviance of the packets inter-arrival times during the tests. The amount of RFC 1889 Jitter remained below 7ms for each set of users as shown in Figure 16. Overall jitter was not an issue on the network for each set of users.

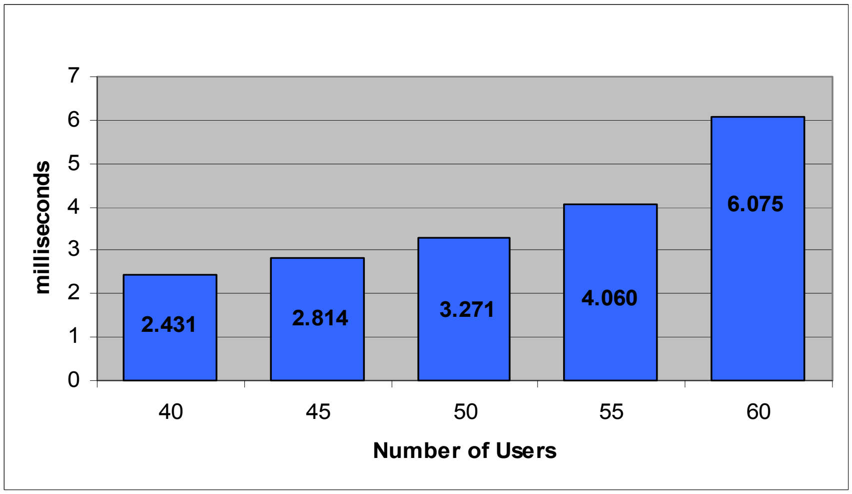

Figure 16 – G.729 Downstream RFC 1889 Jitter

Multiple Applications Testing

The multiple applications test emulated users performing the two common data transactions of using email and web browsing (HTTP) in a typical NCS scenario. In a typical scenario, users are connected to the CPE behind a switch with the majority of the traffic composed of users receiving HTTP traffic downstream (in the user direction), users receiving email traffic in the downstream direction, and users sending outbound email traffic in the upstream directions. The test began by emulating only one user using HTTP and email applications simultaneously. The test then increased the number of concurrent users sending traffic according to this profile to 10, then 20, 30, 35, 40, and concluded with 45 users. The test used a normal distribution to emulate users randomly sending and receiving emails and browsing web pages. This was done to make this traffic profile more realistic.

Test Results

The results of the multiple applications test are summarized in Figure 17 and Figure 18. Due to the significant size differential of the HTTP traffic when compared to that of the email traffic, HTTP throughput drops significantly as number of users climbs from a single user to 10 users. Throughput begins to level off between 20 and 30 users. The response time remains under an acceptable 60 seconds for each service up to 30 users. In each case the downloading of the 235 kB web pages had the largest response time which was expected due to its larger respective size in comparison to the 35 kB emails for POP3/SMTP.

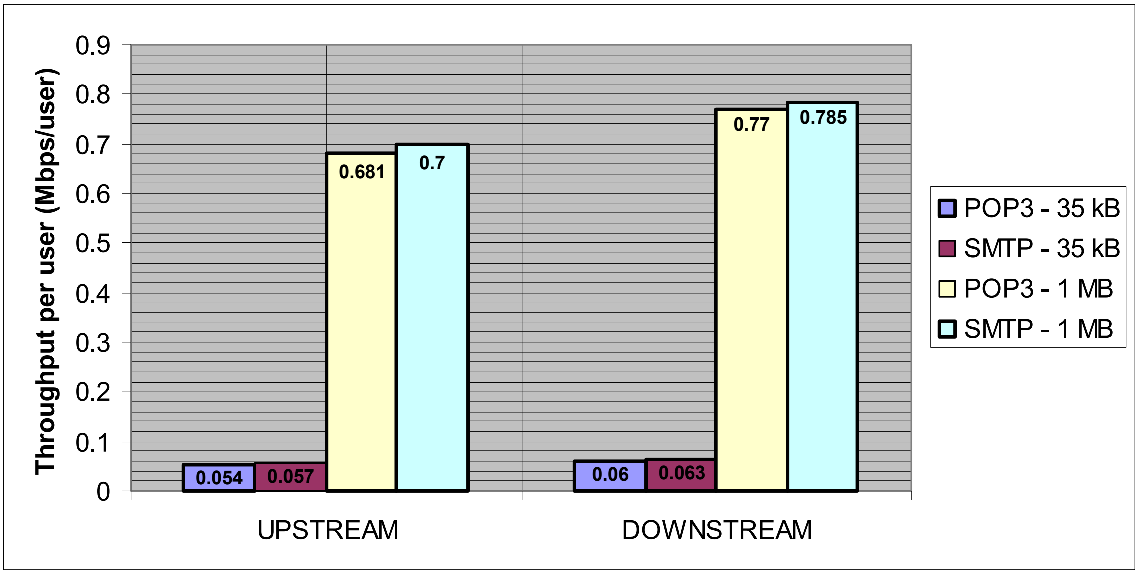

Figure 17 – Multiple Applications Test – Average Throughput

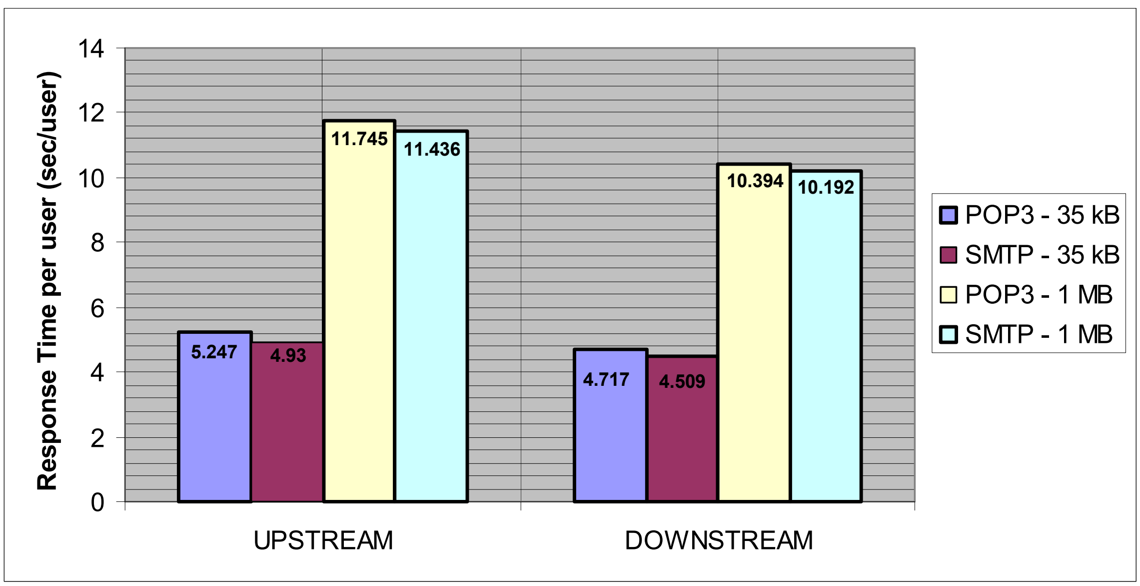

Figure 18 – Multiple Applications Test - Average Response Time

When considering the simultaneous transmission of the various protocols and their potentially variant payload sizes in real-world scenarios, 30-35 users seems to be a reasonable cutoff for the given MCS link when factoring in end-user convenience and any possible server time-out settings that may be set to a value of greater than one minute.

APPENDIX D - TEST EQUIPMENT DETAILS

Ixia hardware and software generate stateful and stateless traffic flows across the link and capture results for performance evaluation. The Ixia Ethernet modules provide wire-speed traffic generation and analysis, upper layer protocol emulation running simultaneously with wire-speed packet generation, and capture various performance data statistics on layer 2 – Data Link and Layer 3 – Network Routing. The IxChariot software is a traffic pattern analysis and decision support tool emulating real world application data. It offers thorough application assessment and device testing by emulating hundreds of protocols across network endpoints and providing upper layer session emulation. The integration of Ixia hardware and IxChariot software provides the ability to simultaneously transmit stateless and stateful traffic sessions and measure performance across all layers of the protocol stack. Additional tools and software are used to monitor and collect data for further analysis and correlation as described below.

IXIA Hardware and Software
Ixia's scalable test solutions generate, capture, characterize, and emulate network and application traffic, establishing definitive performance metrics of the applications. Ixia's integrated hardware / software platforms can generate and analyze Layer 2 and 3 network traffic, while simultaneously testing Layer 4 through 7 application traffic. The Wireless Broadband links will be evaluated using the IXIA 400T chassis, Gigabit Ethernet Load Modules, IxExplorer software, and IxChariot application test software.

Ixia 400T Chassis
The Ixia series of chassis deliver comprehensive solutions for high performance, multi-port traffic generation and analysis. The Ixia chassis share a highly scalable architecture that support daisy-chaining of multiple chassis' for timing synchronization. Each chassis supports Packet over SONET, 10 Gigabit Ethernet, Gigabit Ethernet, 10/100 Ethernet, and ATM interfaces. The integrated PC, running Windows 2000, is used for configuration and statistics gathering and is able to generate and analyze traffic synchronously over multiple ports simultaneously.

Ethernet Load Modules
Ixia's family of Ethernet load modules offers wire-speed Layer 2 and 3 traffic generation and analysis, scalable routing protocol emulation, and Layer 4 through Layer 7 session emulation. Every port on the load module contains a powerful RISC processor running the Linux operating system and a full TCP/IP stack. This architecture gives flexibility when testing systems or devices that require upper layer protocol emulation running simultaneously with wire-speed packet generation. Traffic is generated in real-time by logic implemented on each IXIA port. The packet streams transmit engine allows generation of up to 256 unique streams on each port. Within each stream, millions of packets can be configured with completely customizable characteristics for every packet header field. Customizable payload contents can also be defined. Frame size can be fixed, vary according to a pattern, or be randomly assigned across a weighted range.

These modules provide extensive statistics and logging capabilities depending on the test configuration, including data capture, data integrity, and sequence checking. Each Gigabit port is configured with 8 MB of capture memory, which can store tens of thousands of packets in real-time. The capture buffer can be configured to store packets based on user-defined trigger and filter conditions. To validate performance, the data integrity function allows packet payload contents to be verified with a unique CRC that is independent of the packet CRC. This ensures that the payload is not disturbed as the header fields are changed and transmitted across the network. Sequence numbers can be inserted at a user-defined offset in the payload of each transmitted packet. Upon receipt of the packets through the system or device under test, out-of-sequence errors are reported in real-time at wire-speed rates. Sequence error thresholds can be defined and measured to distinguish between small, big, reversed, and total errors.

IxChariot

The IxChariot software is a traffic pattern analysis and decision support tool emulating real world application data. Incorporating the IxChariot console and performance endpoints, IxChariot offers thorough application assessment and device testing by emulating hundreds of protocols (TCP, UDP, RTP, SPX, IPX, SNA, IP Multicast, etc.) across thousands of network endpoints. IxChariot provides the ability to predict the expected performance characteristics of any application running on wired and wireless networks. Over a hundred pre-programmed scripts are capable of emulating all common enterprise protocols and services including VoIP, Multicast, and IPv6 applications running on thousands of endpoint pairs. The software provides the ability to create sophisticated traffic pattern, throughput, jitter, lost data, QoS, and latency analysis using performance endpoints running on various operating systems.

IxChariot sends stateful traffic, which maintains the context of the session between the sender and receiver in order to provide some service level guarantee, commonly reliable, in-order delivery. IxExplorer transmits stateless traffic, which are packets without context reservation to any related stream of packets/flows/sessions/protocols or applications.

The IXIA test configuration and test results data will be transmitted across a separate out-of-band connection. This out-of-band network connectivity is over the Internet between the two labs. When a single network is used, both management and test traffic travel over the same network, providing additional load to the network elements being tested. The preferred method uses two networks and serves to isolate test traffic from all other traffic.

Cisco Catalyst Switch

The Catalyst 3550 switch is a stackable 10/100 and Gigabit Ethernet switch. The Catalyst switch was used at location Site 1 to build the Local Area Network (LAN) and connect all other devices together via a Fast Ethernet connection. It allows a central point for managing all hardware and gathering test and performance data. The Gigabit Ethernet ports may be used for additional network connectivity for further testing / demonstrations.

Laptop

The IBM ThinkPad T40 laptop operates on the Windows 2000 Operating System (OS). The laptop was used to make network configuration changes, manage various network-monitoring applications, and capture test and performance data as stated in this test plan.

Virtual Network Computing (VNC) Software

Virtual Network Computing (VNC) is remote control software that allows viewing and interacting with one computer (the "server") using a simple program (the "viewer") on another computer anywhere on the Internet or via remote dial connectivity. VNC enables remote management of the laptops at each location for configuration and management of the IXIA endpoints during the evaluation.

APPENDIX E - ADDITIONAL APPLICATION INFORMATION

Voice over IP

VoIP traffic consists of Real-Time Transport Protocol (RTP) streams in each direction. RTP is designed to send data in one direction with no acknowledgement. The header of each RTP datagram contains payload type (which Codec to use), sequence number (helps receiver reassemble data and detect missing or out-of-order datagrams), time stamp (enables receiver to reconstruct the timing of the original data), and source ID (enables receiver to distinguish multiple, simultaneous streams).

Mean Opinion Score Estimation

Several statistics will be collected for VoIP performance. One characteristic unique to VoIP is the mean opinion score (MOS). In most cases, MOS is based on subjective opinions from testing participants. For testing, MOS will be calculated by IXIA using a modified version of the International Telecommunications Union (ITU) G.107 standard E-model equation, which evaluates the quality of a transmission by factoring in the "mouth-to-ear" characteristics of a speech path. Then it calculates an R-value, which correlates directly with the MOS estimate. IXChariot modifies the E-model slightly and uses the factors shown in Table 7 to calculate the R-value and the MOS estimate.

One-Way (Network) Delay	Similar to propagation delay, except the delay factors associated with the network itself are included. IxChariot measures this by synchronizing the end-points' timers and determining delay in a single direction.
End-to-End Delay	Latency measured by adding the following factors: one-way delay, packetization delay, jitter buffer delay, and additional fixed delay. As with one-way delay, end-to-end delay is in a single direction between the end-points, but it extends to the VoIP HW to include all delay factors. One-way delay measures only network delay
Packetization Delay	Delay associated with conversion of the voice signal from analog to digital is factored into the score calculation. It varies according to the Codec type being used.
Jitter Buffer Delay	Delay associated with jitter buffers that work to reduce variability in datagram inter arrival times.
Additional Fixed Delay	Delay factor from a known, constant source of delay. Necessary for accuracy if the test emulates HW associated with a fixed delay factor.
Data Loss	Total number of datagrams lost. When a datagram is lost, you can lose an entire syllable, and the more datagrams lost consecutively, the more that clarity suffers. IxChariot factors in lost data and includes the amount of consecutive datagram loss that was measured.
Jitter Buffer Lost Datagrams	Number of datagrams lost due to jitter buffer overruns and under-runs.

Table 7 - Estimated Mean Opinion Score Components

A MOS of 5 is excellent; a MOS of 1 is unacceptably bad. Table 8 shown below from ITU G.107, summarizes the relationship between the MOS and user satisfaction.

Mean Opinion Score (lower limit)	User Satisfaction
4.34	Very satisfied
4.03	Satisfied
3.60	Some users dissatisfied
3.10	Many users dissatisfied
2.58	Nearly all users dissatisfied

Table 8 – ITU G.107 MOS Scale

Streaming Media

Streaming scripts emulate multimedia applications that send data without acknowledgements. Datagrams are sent in only one direction, from E1 to E2. Of the many IXIA streaming scripts, NetMeeting will be used with the Real-Time Transport Protocol (RTP). When running a streaming script, E2 keeps statistics on lost data and returns this information as part of the results. In addition, when using RTP, E2 records statistics on jitter.

Typical multimedia applications use various packet sizes. End-point multimedia support uses a 12-byte header for RTP. In addition to these headers, the protocol stack adds 8 bytes for the User Datagram Protocol (UDP) and 20 bytes for IP.

APPENDIX F - METRICS DEFINITIONS

Listed below are definitions of the metrics recorded for each of the tests.

Listed below are definitions of the metrics recorded for each of the tests.

FTP, HTTP, Email, and Multiple Applications

Throughput – The average, minimum, and maximum throughput values were recorded for each test.

Response time - the time, in seconds, needed for one transaction to complete.

VoIP

Throughput – The average, minimum, and maximum throughput values were recorded for each test.

One Way Delay (Latency) - Similar to propagation delay, except the delay factors associated with the network itself are included. IxChariot measures this by synchronizing the end-points' timers and determining delay in a single direction.

RFC 1889 Jitter – RFC 1889 jitter (calculated for all RTP pairs) shows mean statistical deviance of packet inter-arrival times over a period of time.

Bytes Lost – The amount of Data expressed in bytes sent by Endpoint 1 that never reached Endpoint 2.

Jitter Buffer Lost Datagrams - Datagrams lost due to jitter buffer overruns, or the number of datagrams that had a delay variation greater than the jitter buffer size, and jitter buffer underruns, datagrams that arrived too quickly while the jitter buffer was still full.

APPENDIX G – REFERENCE DOCUMENTS

IxExplorer Users Guide: General Configuration and Operation, Release 3.70; Ixia, Part No. 909-0002-01, Rev. A, August 2003.

IxChariot Users Guide, Release 5.0; Ixia, Part No. 909-0154, Rev. A, January 2004.

IxChariot Application Scripts, Release 5.0; Ixia, Part No. 909-0157, Rev. A, January 2004.

APPENDIX H - ROUTE DIVERSITY PROJECT BACKGROUND

On September 11, 2001, terrorists struck the World Trade Center in New York City and the Pentagon near Washington, DC. Reports indicated that telecommunication assets near the affected areas were either congested or incapacitated, causing users to experience intermittent or no voice service. The reports of these events generated concern among White House officials that key federal agencies in Washington, DC might lose critical wire line voice and data communications services if the infrastructure was damaged or destroyed.

To highlight the concerns of the White House officials, the National Security Council (NSC) raised the issue of telecommunications resiliency in its meeting of October 5, 2001, stating—

"Key federal agencies may be at risk of losing wire line communications services in certain emergencies where telecommunications infrastructure gets damaged or destroyed."[14]

The NCS, which is responsible for ensuring National Security and Emergency Preparedness (NS/EP) communications in times of network congestion or outage, addressed this concern by investigating the possibility of a route diversity capability for federal agencies. The NCS established the RDP (formerly known as the Backup Dial Tone Project) and took the following steps:

Evaluated the need for a route diversity capability in the Washington, DC area and determined whether such a capability would have been helpful in the New York City and Washington, DC areas on September 11, 2001 (Phase I—RDP).

Evaluated various technical approaches to providing such a capability (Phase II—RDP)

Determined the cost and schedule for deploying chosen technical approaches (Phase III—RDP; ongoing).

During these initial phases, the RDP has proven to be a constructive, valuable program in helping to address the NCS directive. The CRM, which is Phase IV of the RDP, uses lessons learned from the first three phases to provide individual federal agencies with a tool to evaluate and address RDP capabilities.

Methodology of RDP Project

The NCS approached the RDP initiative in the following phases:

- **Phase I: Identify Key Federal Facilities and Perform Generic Analyses—**compiled a comprehensive list of potential vulnerabilities based on generic government facility architectures and a list of technical solutions for addressing these vulnerabilities. This phase was completed in January 2002.

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14 National Security Council Memorandum. Subject: Minutes from October 5, 2001, Meeting on Selected NS/EP Telecommunications Projects (U)

- **Phase II: Narrow the Solutions and Interview Federal Agency Representatives—** refined this list of solutions, relying on interviews with government agencies to enhance the generic architectures with real-world data. This phase was completed in August 2002.

- **Phase III: Conduct Technology Demonstrations—**selected the final technologies for demonstration, determined potential agency test sites, and developed the test demonstrations for evaluation. This phase is ongoing, and includes the demonstration detailed in this report.

- **Phase IV: Develop Route Diversity Methodology—**applies knowledge gained from the first three phases to develop a methodology for assessing route diversity at a single agency location. The methodology highlights areas that may be weak in route diversity in an agency's communications infrastructure. After the weak areas are highlighted, potential mitigation solutions that were identified and evaluated in previous phases can be reviewed for implementation at a specific site. This phase is ongoing.

- **Phase V: Network Resiliency and Emergency Support Functions #2 (ESF #2) Support** - includes developing tools and leveraging previous RDP efforts to assist member agencies in meeting legislative and regulatory requirements pertaining to route diversity and ESF #2 needs. This phase is ongoing.