PROTOTYPE IP SATELLITE NETWORK

Kathy Newtson, EE graduate student
Dr. Stephen Horan, Faculty Advisor
Klipsch School of Electrical and Computer Engineering
New Mexico State University

ABSTRACT

Prototyping an Internet Protocol (IP) compliant architecture will demonstrate a realistic basis for satellite communication design. The prototype IP architecture should prove seamless and secure communications between the satellites and ground stations. Using commercial off the shelf (COTS) equipment, design and development of satellite communications becomes easier and less expensive than developing specialized equipment. IP space applications will improve communications while minimizing development costs.

KEYWORDS

Satellite network, Internet Protocol.

INTRODUCTION

Internet Protocol (IP) has a wide variety of communication tools, and commercial vendors that provide easy interoperability. To keep space system development costs down, to leverage off the existing capabilities, and to access the rapidly-improving technology, we are investigating potential methods to use these components and protocols in satellite communications systems. Additionally, sensor designers are beginning to develop sensors with standard networking interfaces. These techniques can be used for both payload science data and payload health & welfare data. Connecting satellite maintenance and controls with the payload science missions utilizing IP equipment will allow scientists to seamlessly access their experiments while satellite controllers are monitoring health & welfare status and controlling the satellite.

This research project and paper investigates the potential for using Commercial Off the Shelf (COTS) equipment for IP satellite communications. Issues that will be addressed include security, different IP protocols with varying packet sizes/types, and the harsh space environment. The wireless IP network components will be placed in RF shielding boxes so programmable attenuators can be placed in between. The attenuators will then be programmed to simulate the distance between the satellite and the ground station, or another satellite. The attenuation will be maximized when simulating the satellite being out of range from the ground station. The delay will be modeled in a LabView Virtual instrument [5].

After the space environment has been simulated, testing various IP traffic loads will verify that different protocols will operate through the space channel conditions. Encryption and security measures will also be added in order to verify these necessities don't create too much overhead or take up too much bandwidth. Options such as Reed-Solomon encoding improves IP performance over the error-prone channel, and can be verified as well. Testing COTS equipment will validate the IP architecture for potential satellite use.

The main goal of this project has been to develop a prototype IP-compliant architecture that can be used to demonstrate a realistic basis for a satellite design. Included within the main goal is showing that the design can interface with typical ground networks. Plus show that the design is 'secure' and can prevent intentional or accidental access. Lastly, determine if modifications are needed to convert COTS products into satellite communication applications.

One expected outcome of this project is to assist NASA in making the architectural evolution from a legacy switched communication system to a full packet routed system with minimal human intervention. Another outcome is to demonstrate how commercial technology can be readily adapted to fulfilling the space communications needs. Demonstrating that 'test as one operates, operate as one tests' can be applied here as well. Meaning that the prototype will be operated in the lab much like the satellite will be communicating to the ground stations.

THE PROTOTYPE IP NETWORK DESIGN

Ideally the prototype IP network design will support a variety of mission needs. The communication requirements include payload communications with the scientist, and health and welfare communications to a satellite operator. An actual satellite radio system will provide error-correction encoding and similar support to enhance the reliability of the channel. Therefore the prototype IP system will treat the data stream as an unobstructed bit stream, or use a CCSDS-type channel access format into which the IP frames will be inserted [8].

Candidate mission models for the prototype lab setup have been selected for testing purposes. The models chosen have firm data specifications that are accessible. These include: small mission support for small-sat to nano-sat type communications, plus science mission support with advanced cosmic ray composition experiment for space science [4]. Based on communication specifications from candidate missions, the baseline data rate requirements are as follows. The forward data rate of at least 9600 bps, simultaneous return data rate of at least 100,000 bps for science data, and 15,000 bps for housekeeping data so two virtual channels are required.

The services requiring support include Telnet to flight computer and instruments, ftp to flight computer and instruments, and 'finger' service to instruments. The 'finger' service is a pointer to an instrument socket where the socket returns a data file. The data within the files and in the file structure includes science data arranged per the user's format. The housekeeping data is arranged as either real-time (streaming) or file data which is multi-casting. The information in the files may require confidentiality or classified types of security. Security is provided by the COTS equipment

that supports Virtual Private Networking (VPN) capabilities in the routers. The equipment also provides Secure Shell (SSH) login capability.
The block diagram of the prototype IP configuration is illustrated in Figure 1. The satellite addressing template includes the local domain (nmsusat.net), the flight computer (flight.nmsusat.net), and the instruments (instrument_n.nmsusat.net).

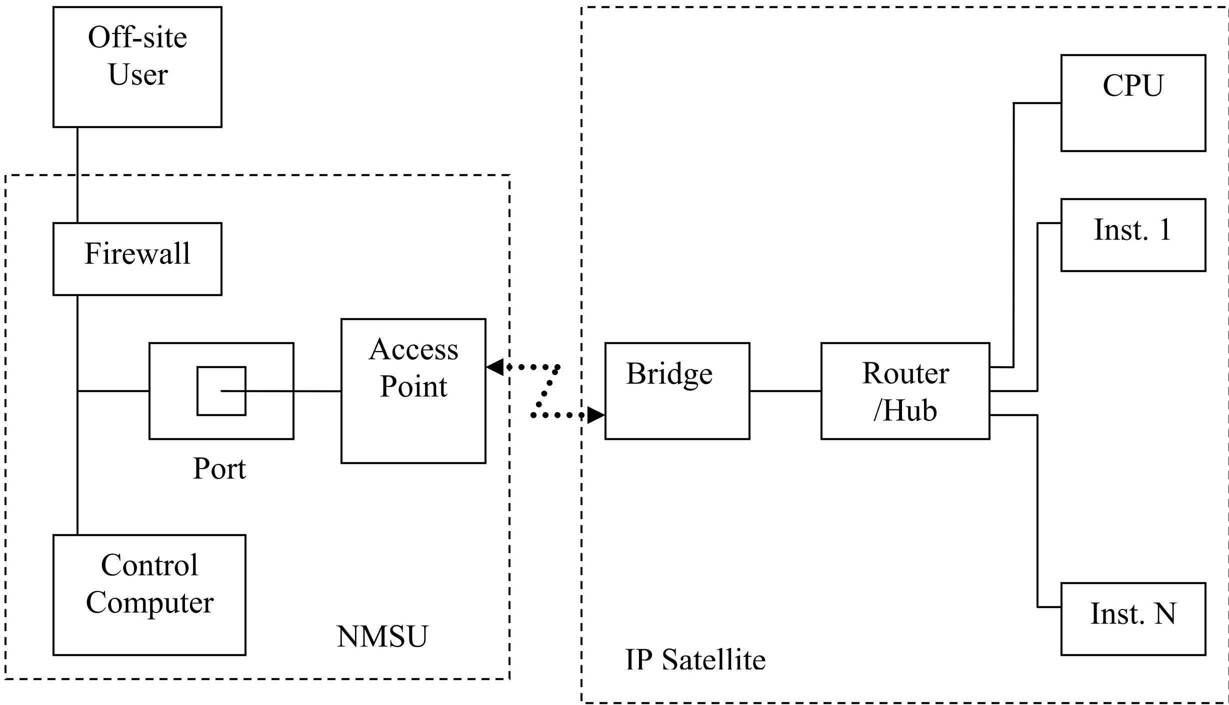

Figure 1 Block diagram of the prototype IP configuration [1]

Accessing IP Satellite includes local ground station access from logical Payload Operations Control Center (POCC) at the Ground station Access Point (GAP). Remote access to IP Satellite is also possible from external POCC connection through the GAP firewall.

The ground segment is labeled NMSU and includes a COTS wireless access point. This access point is connecting through the NMSU networking backbone via the NMSU firewalls. The IP Satellite segment includes a COTS client or bridge. The IP data is passed through Ethernet 802.11b utilizing the COTS network structure. The CPU selected for this project is a Diamond Systems PC/104 Prometheus CPU. This was chosen as the satellite computer for the small size, the built in communications ports, and low power consumption.

The channel will be modeled in Satellite Tool Kit (STK) for acquiring the access timing and link distances between the IP Satellite and a ground station [6]. The estimated gains from the antennas will be taken into consideration. A typical satellite antenna gain is about 10 dB, and the ground station has about 60dB gain. The attenuators will then be programmed to simulate the links changing distance like the satellite would be passing overhead. Using the LabView program [5], delays and channel error scenarios can be simulated [3]. Secure and reliable data transmission in the presence of many channel errors is required. Typical commercial wireless equipment includes VPN's, IP security support, a firewall, protection against denial of service attacks, and address filtering. These features minimize intentional or accidental access to the IP Satellite.

THE PROTOTYPE IP NETWORK RESULTS

Figure 2 shows the lab setup including the programmable RF attenuators and RF isolation boxes. One programmable attenuator can range from 0 to 127 dB and can be installed in series with another attenuator for modeling the RF link. This attenuation range models the effective received power level for a transmission given the quarter watt transmit power.

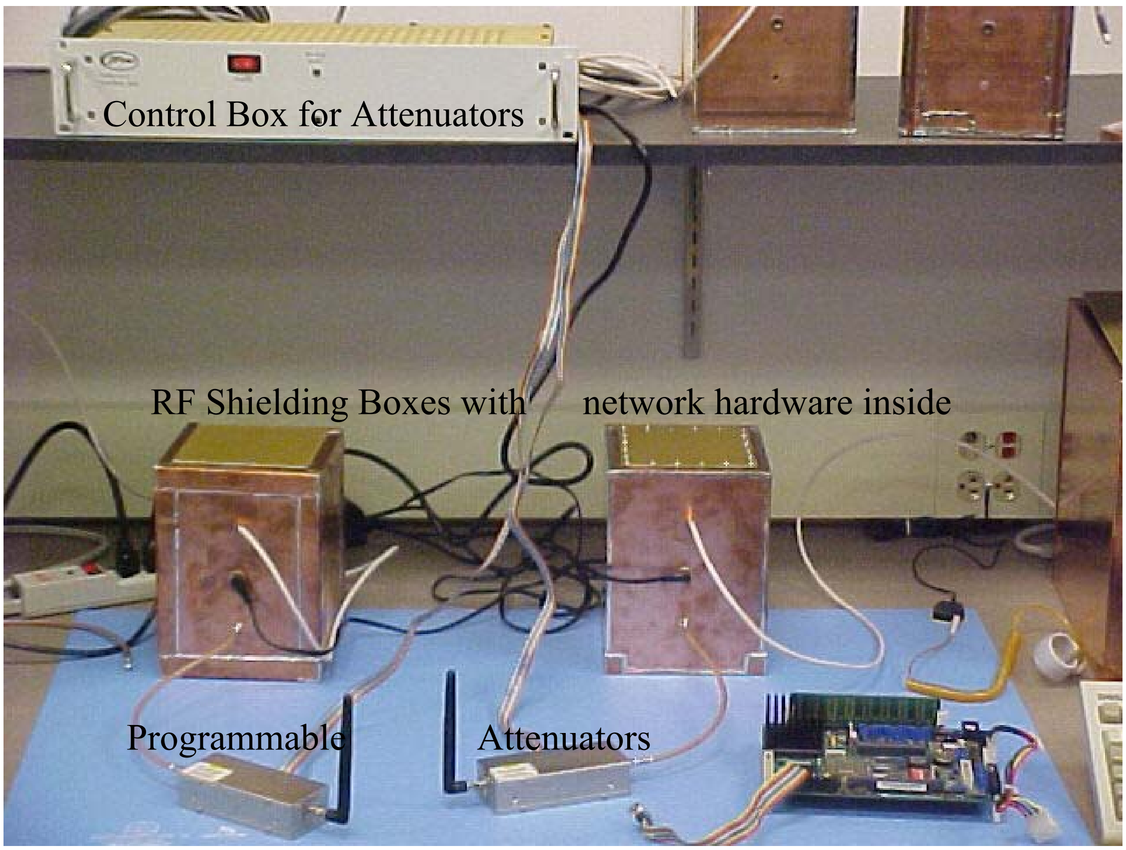

Figure 2 Lab setup with the RF shielding boxes and attenuators [2]

Initial testing included verifying connectivity and socket operation from a local POCC at GAP to the router, the flight computer, and instruments on the IP Satellite. Another test was verifying the connectivity and socket operation from a remote system to the IP Satellite. SSH connections from both POCC configurations are also verified. Operations validated are: transmit "command file" using ftp, transmit "telemetry" data file using ftp, real-time streaming of data, secure access and data transmission, and changing router settings. All the initial results verified the data was transmitted without problems for both the remote and local access.

For testing the RF shielding and programmable attenuators, the Cisco Aironet equipment was used [7]. Within the Aironet diagnostic directory, RF signal strength and quality can be selected. The results scroll by as shown in Figure 3. The top set of data in Figure 3 has the attenuation at 0 dB and 1dB for the two radios within range. The second set of data has the attenuation set to 40 dB and 80 dB simulating a large distance. Notice that the RF signal strength is lower but the quality of the signal remains relatively high. When the attenuation is maximized, the radios no longer see each other then the radio is no longer in the data set like shown in Figure 3.

RF Signal levels at Client#1 = 0dB (open box) and Client#2 = 1dB

```
Aironet AP4800E V7.22          SIGNAL LEVELS          AP4800E_25979c

UC4800E    0040961531e4 Strength In  ****************************************
                                 Out  ****************************************
                          Quality In  ******************************
                                 Out  ******************************
UC4800E    004096153127 Strength In  ****************************************
                                 Out  ************************************
                          Quality In  *********************************
                                 Out  ******************************
```

RF Signal levels at Client#1 = 40dB and Client#2 = 80dB

```
Aironet AP4800E V7.22          SIGNAL LEVELS          AP4800E_25979c

UC4800E    0040961531e4 Strength In  ****************************
                                 Out  *************************
                          Quality In  ******************************
                                 Out  ****************************
UC4800E    004096153127 Strength In  *******************
                                 Out  **************
                          Quality In  ********************************
                                 Out  ********************************
```

Figure 3 RF Signal strengths for minimal attenuation, top, and more attenuation, bottom

Pictures were sent via UDP/IP, text files were sent via TCP/IP and UDP/IP for verification. As long as there was a radio link the data and pictures transmitted successfully. As soon as the attenuation was increased to the point where the radios no longer registered each other the traffic could no longer be sent. Therefore, while there is a link, IP traffic will reliably get to the destination.

CONCLUSION

Satellites will benefit from incorporating IP architecture for communications. Benefits include allowing scientists to directly access their experiments, at the same time an operator is sending health and welfare commands. Commercial IP equipment allows many levels of security with additional levels readily available. Reliability of the IP transmission is high as long as there is a decodable RF link.

More validation needs to be done for a variety of IP based equipment. Equipment that has been modified with radiation hardened components should also be tested to verify there are no timing issues causing data loss. Prototyping and verifying an IP network on the ground will assure confidence for satellite mission communications.

ACKNOWLEDGEMENTS

This work is supported under NASA grant NAG3-2793 from Glenn Research Center.

REFERENCES

[1] Horan, Stephen, "IP Satellite Preliminary Design Review", Sponsor: NASA Glenn Research Center, Teleconference Feb. 20th, 2003.

[2] Newtson, Kathy, "IP Space Network", Student paper winner for the International Test and Evaluation Association (ITEA) Modeling and Simulation Workshop, Las Cruces, New Mexico, Dec. 9th – 12th, 2002.

[3] Horan, Stephen, and Wang, Ruhai, "Design of a Space Channel Simulator Using Virtual Instrumentation Software", IEEE Transactions on Instrumentation and Measurement, Volume 51, Number 5, October 2002, Page 912.

[4] Stochaj, Steven, Private conversation discussing the advanced cosmic ray composition experiment for space science project.

[5] National Instruments LabVIEW, http://www.ni.com/labview , Copyright 2000 by National Instruments.

[6] Analytical Graphics, Inc. Satellite Tool Kit, http://www.stk.com, Copyright 1989 - 2002 by Analytical Graphics, Inc.

[7] Cisco Aironet 4800 series Access Point and Clients used to test RF signal strength from diagnostics menu, http://www.cisco.com.

[8] Consultative Committee for Space Data Systems, "Telemetry Summary of Concept and Rationale", CCSDS 100.0-G-1 Green Book, NASA, Washington D.C., December 1987

ACRONYMS

CCSDS – Consultative Committee for Space Data Systems
COTS – Commercial Off the Shelf equipment.
dB – Decibels, the unit of measure for attenuation, or sound levels.
GAP – Ground station Access Point
IP – Internet Protocol
NMSU – New Mexico State University
POCC – Payload Operations and Control Center
SSH – Secure Shell method of linking to another computer
TCP/IP - Transmission Control Protocol over IP
UDP/IP - User Datagram Protocol over IP
VPN – Virtual Private Networking