Internet Routing in Space: Prospects and Challenges of the IRIS JCTD

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Abstract— Recent technological advances coupled with the collaboration between government and industry will soon make it possible to include IP routers and IP modems on board a commercial geostationary communications satellite. The Internet Protocol Routing in Space (IRIS) Joint Capability Technology Demonstration (JCTD) will introduce a new network capability that is aimed at enhancing military network-centric operations through information access, collaboration and dissemination. This paper describes the IRIS vision and strategy, and the specific goals of the JCTD. It describes the network architecture and technology development aspects for deploying a combined router and modem function as part of a hosted payload within a commercial transponded satellite.

1. INTRODUCTION

A new communications architecture that will extend the Internet into space, and potentially, can be the next generation of global Service Oriented Architecture, is evolving from collaboration between the United States Department of Defense (DoD) and commercial industry. The Internet Protocol Routing in Space (IRIS) Joint Capability Technology Demonstration (JCTD) is sponsored by the U.S. Strategic Command (USSTRATCOM). General J.E. Cartwright, the USSTRATCOM Commander, has said this is his number one technology demonstration for Fiscal Year 2007. The aim of the IRIS JCTD is to accelerate network-centric capabilities in space by placing an Internet Protocol (IP) router payload on board a commercial geostationary communications satellite.

Satellites with on-board processing and regenerative capabilities have been successfully deployed in recent years [1, 2, 3]. Although some of these satellites provide a packet-switching function, an IP router as a communications network node in space has not been implemented. The foundation of IRIS has its roots in many years of teamwork and experimentation between the DoD and the private sector. The U.S. Army Space and Missile Defense Command's (SMDC) Future Warfare Center along with the Air Force Space Command's Space Battle Lab and NASA's Glenn Research Center collaborated with an industry consortium on the Cisco Router in Low Earth Orbit (CLEO) initiative [4]. The CLEO initiative resulted in placing a router on board a small remote sensing satellite for test, evaluation and demonstration in 2003, which is still in use for experimentation today. The IRIS JCTD will allow the further development of Concepts of Operation and Tactics, Techniques and Procedures for this new network-centric capability with a router on board a geostationary communications satellite. Experimental results may indicate that this could well be the next generation satellite communications networking capability. A Military Utility Assessment (MUA) conducted during the JCTD will evaluate the benefit to the military of this internet node in space. If the MUA results are successful, the U.S. Army, Air Force, Navy, Marine and Coast Guard forces could leverage this capability to enhance military network-centric operations.

2. IRIS VISION AND STRATEGY

The IRIS vision is to extend the IP capabilities of current terrestrial networks into space by providing IP capabilities on board space-based assets and interconnecting them with cross-links. This extension

would allow the integration of land, sea, air and space network assets and provide any-to-any connectivity. The use of IP technologies will leverage open standards that will allow a faster integration of today's disparate systems.

The strategy for commercial satellite companies is to collaborate to provide the space version of the terrestrial service providers and establish agreements that would allow cross-traffic flows. Services may be provided to the government and commercial customers over this new infrastructure that expands network reach and connectivity. The IRIS JCTD constitutes the first step toward this vision. While the IRIS payload will not have any inter-satellite links, it will provide the basis upon which subsequent capability spirals will be built to increase the payload's performance and capabilities.

From the DoD standpoint, the IRIS JCTD provides the opportunity to collaborate with industry to examine, demonstrate and assess the utility of space-based routing and processing in support of Joint, Interagency, Intergovernmental and Multinational (JIIM) users. The IRIS JCTD will also provide a demonstration of a capabilities-based approach through the rapid deployment of space systems using commercial processes, schedules and space qualified technology.

The IRIS JCTD aims to provide an on-orbit demonstration of the feasibility of a space-based IP routing communications system. The JCTD is further intended to demonstrate the feasibility of providing a quick reaction response to a government requirement by applying best commercial practices to realize the desired capability with an experimental package flown aboard a convenient commercial host spacecraft.

3. JCTD GOALS

The IRIS JCTD will serve as an operational testbed for Policy-Based Network Management and Concept of Operations (CONOPS) development, and exploration of Network Operations (NetOps) and Situational Awareness (SA) concepts, and the capability to conduct IP packet routing in space. Moreover, the JCTD will explore and incorporate the decision support processes and procedures to determine how best to leverage the IRIS capability to satisfy user needs. The specific IRIS JCTD goals are as follows:

- Demonstrate the capability to collaborate with industry in leveraging the commercial acquisition processes to provide near-term, space-based IP routing network capability.
- Gain knowledge on how to manage space-based IP networks, while demonstrating the capability that space-based networking brings to the Warfighter.
- Demonstrate the capability to conduct on-board IP packet routing communications from a geostationary orbit satellite.

4. NETWORK ARCHITECTURE

The elements of the IRIS network architecture include the IRIS payload on board Intelsat-14, the satellite beams connected to the RF IRIS channels, the user's terminals that can operate with the IRIS payload, and the satellite control and network operations systems.

The IRIS payload will connect to 1 C-band and 2 Ku-band satellite beams providing coverage of territories in Europe, Africa, the Caribbean and the Americas. Network interconnectivity between users will be accomplished by the IRIS router using IP (layer 3) packet routing. This feature allows, for example, a user within a Ku-band East beam coverage to communicate directly and instantly with another user within the coverage of a C-band beam or a Ku-band West beam. Authorized users that have properly configured IRIS-compatible IP modems will simply need to establish a connection with the IRIS payload and then they can potentially interconnect, via IP, with any other IRIS JIIM user, with other government networks, or with the Global Information Grid (GIG). The IRIS network architecture is shown in Figure 1.

The Global Information Grid (GIG) is an information-sharing network with multiple levels of security for use by the DoD and possibly other elements of the national security community. Because of these security levels, any proposed GIG-integrated solution will include design, integration, and testing governed by DoD information assurance policy. The resulting integrated IRIS capability will provide net-centric connectivity capabilities and enable DoD users to connect to Defense Information System Network (DISN) services, either directly or through satellite teleport entry sites.

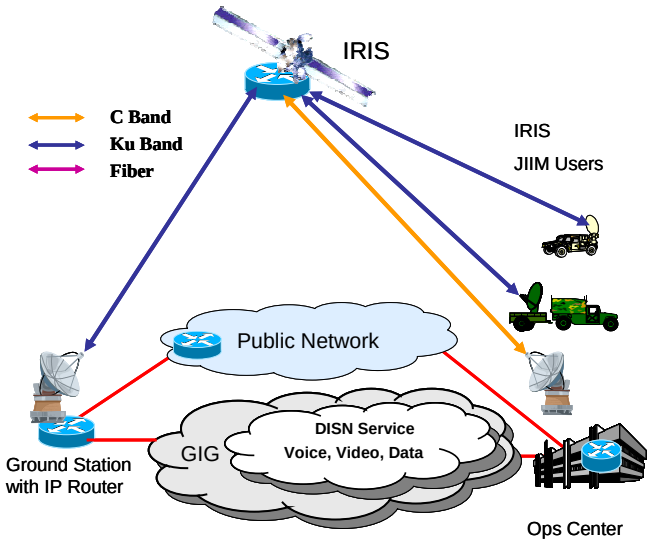

Figure 1 - *IRIS Network Architecture*

One goal of the demonstration will be to assess the ability of IRIS to connect DISN services to the user in the field. Voice, video and data capabilities over IP will be assessed via interconnection to the Defense Switched Network (DSN). The architecture will allow the deployed user to connect to the broader information enterprise and the capabilities provided by the GIG. The IRIS IP-based network architecture will be evaluated for its ability to provide benefits such as integrated network management, end-to-end information dissemination processes and security management.

Another goal of the JCTD is to assess converged IP services over a network-centric and transformational communications framework. The JCTD will provide an opportunity to evaluate how IRIS could implement a Policy Based Enterprise Management (PBEM) system and its ability to support Quality of Service (QoS). The JCTD will include test scenarios and use cases that will address QoS capabilities. Moreover, security considerations for the IRIS network will be considered.

5. TECHNOLOGY DEVELOPMENT

Several key components comprise the IRIS architecture. These include the satellite system, the IRIS payload, and the ground segment.

5.1 Satellite system

The IRIS payload will be hosted on Intelsat-14 satellite located at 45° West longitude. Intelsat-14 is scheduled for launch in the second quarter of 2009. Three 36 MHz transponders on three different beams will be interconnected with the IRIS payload: one C-band transponder of the America West-Hemi beam, one Ku-band transponder of the Europe/Africa beam, and one Ku-band transponder of the Caribbean and South America beam. Figure 2 provides a high-level view of the IRIS payload architecture.

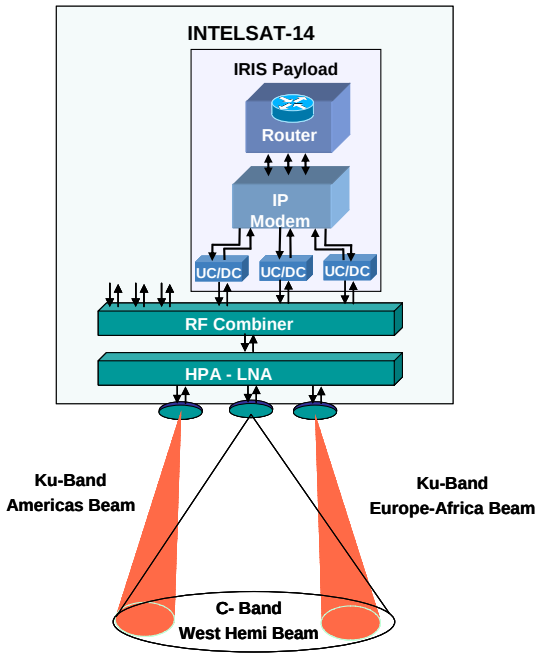

Figure 2 - IRIS Payload Architecture

5.2 Payload

The IRIS payload consists of a core digital section, which includes analog-to-digital converters (ADC), IP modem, IP router protocol processor, digital-to-analog converters (DAC), up-converters to C band and Ku band from 70 MHz, and down-converters to 70 MHz from C band and Ku band. The RF links are connected to a C-band antenna beam and two Ku-band antenna beams.

The IRIS core digital section will be software reconfigurable on orbit, allowing the sub-channel bandwidths to be varied within a transponder channel, and to adapt to a variety of network platform and transmission protocols. Initially, IRIS will support a single IP modem waveform; however, other waveforms may be uploaded in the future.

5.3 Ground segment

The IRIS ground segment will consist of existing operational Ku- and C-band terminals with Commercial-Off-the-Shelf (COTS) modems that match the IRIS payload waveform. IRIS uses the same bands and offers the same satellite performance as typical Intelsat's transponded satellite systems. Because of this, Intelsat standard earth terminals, including maritime mobile terminals, used for the current "bent-pipe" transponders, may be capable of accessing the IRIS payload transparently, if they support the IRIS waveform. IRIS also utilizes the same commercial waveform used in many transponded satellite networks. Rather than communicating with a terrestrial hub or gateway over a transparent "bent-pipe" satellite, terminals can be connected directly to the IRIS payload among each other in a mesh topology. Thus, existing earth terminals may easily adapt to the IRIS system.

5.4 Systems integration and development

IRIS performs the function of an active routing node in space to provide end-to-end broadband managed network services and solutions. Because IRIS is fundamentally a network technology capability, IRIS provides the most advantage when each earth terminal is configured as a network node with membership in both the IRIS space network and local terrestrial networks. One or more IRIS nodes serve to connect multiple nodes on a localized terrestrial network, wired or wireless, to other networks. Mobile users may roam between IRIS nodes, using different IRIS nodes for network connectivity at different times. IRIS uses standard IP layer 3 routing protocols, and thus integrates well with existing networks. The architecture and design will allow flexible IP packet (layer 3) routing, cross-band and cross-beam connectivity within and between coverage areas, and multicast distribution that can be reconfigured on demand.

6. CONCEPT OF OPERATIONS

In order to truly practice network-centric operations and allow the warrior to conduct missions with enhanced IP communications capabilities, the complexity must be removed from the edge of the network and solved by managed services from virtual or coordinated service centers. This IP-based managed satellite service concept was first demonstrated at Ft. Bragg, North Carolina, as part of the Millennium Challenge 2002 (MC02) Demonstration with the SMDC Space Applications Technology Users Research Network (SATURN) experimentation [5]. This concept has since been duplicated by many members of industry in support of current military operations. Figure 3 illustrates the IRIS Global Service Concept.

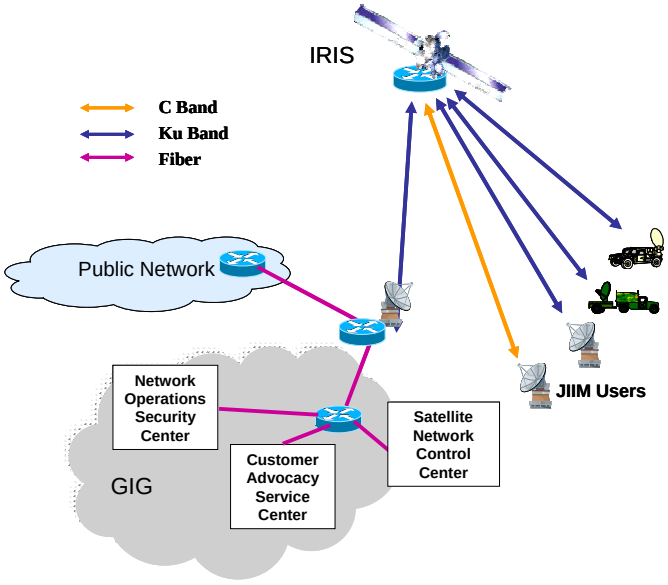

Figure 3 - IRIS Global Service Concept

The IRIS global service concept is based upon service level agreements addressing quality of service in both the IP (layer 3) and satellite (layer 1 and 2) networks. The Department of Defense network management concepts require situational awareness of satellite and terrestrial links, and network status for all DoD customer links. The ability to maintain awareness of network status out to the edge of the DoD customer's network of delivery ensures a capability that provides positive forward control of the quality of service.

Intelsat General and its industry team will develop the details of the IRIS pricing structure and the specifics of the service level agreements, which will include the satellite network and the nodes that will comprise the ground network architecture. The DoD services contracting and usage CONOPS developed during the JCTD is dependent upon the IRIS business plan and the development of a contracting vehicle to influence the processes and procedures for requesting service to enable DoD use of the IRIS network architecture.

The operational manager for the JCTD will develop the CONOPS required by the DoD to leverage the IRIS

capability. Several means to accomplish this are being explored. The current commercial best business practices in areas that address teleports, satellite control, and network operations are being studied. It will be ensured that these CONOPS are in accordance with DOD and DISA doctrine, as well as Network Enterprise Technology Command (NETCOM) policies and procedures.

7. TECHNICAL AND OPERATIONAL CHALLENGES

The IRIS JCTD will examine the potential utility of augmenting JIIM information transport with space-based IP routing and processing. The IRIS JCTD represents a new model for government and industry collaboration. This relationship will allow the United States government to examine, demonstrate, and assess the utility of Intelsat's IRIS capability and potentially transition this capability to United States forces both at home and abroad.

The IRIS JCTD is a three-year program that allows the DoD to collaborate with Intelsat General and its industry team to demonstrate and assess the utility of the IRIS capability. IRIS is designed to support enhanced network services for voice, video and data communications over a common IP network. Additionally, the IRIS JCTD serves as an operational test bed to examine further NetOps, CONOPS, and Tactics, Techniques and Procedures (TTPs), and how space-based routing and processing can serve the JIIM user community.

8. ASSESSMENT PLAN

A primary goal of the IRIS JCTD assessment plan is to evaluate qualitatively and quantitatively the network-centric operations enablers offered by IRIS to the JIIM user community. An important aspect of this strategy will be to assess how the IRIS capability improves the communications and networking capabilities and, in turn, how these capabilities improve the operational effectiveness of JIIM users.

The assessment of IRIS capabilities and military utility will be done through a series of technical tests and operational demonstrations. The CONOPS will describe how IRIS and supporting systems will be used by the JIIM users to achieve the desired capabilities. The assessments will determine how well these capabilities assist with interoperability, network integration, information assurance, and network operations and management. Once the assessment is completed, the conclusions will serve as the basis for developing transition strategies and plans for the IRIS capability.

The capabilities demonstrated by IRIS will be evaluated using the Military Utility Assessment (MUA) methodology that will be described in the Integrated Assessment Plan (IAP). The MUA methodology will utilize an operational-based demonstration driven by mission scenarios that will represent realistic operational conditions using appropriate CONOPS. A set of key Critical Operational Issues (COIs) will be identified, based on stakeholder inputs, in areas such as functionality, operational impact, interoperability and suitability. If these issues are successfully addressed, the IRIS JCTD will be deemed to have had military utility.

9. IMPLEMENTATION SCHEDULE

The overall execution of the JCTD activities and events will last three years (FY-07 through FY-09) and will be conducted in two phases. In Phase 1, the technology development, integration, and pre-production activities will be accomplished using a spiral development process. In Phase 2, the IRIS platform development will take place and will be followed by a series of capability demonstrations using a variety of experiments and limited demonstrations to validate multiple mission support capabilities. Successful IRIS JCTD technologies and capabilities will be transitioned into the formal recommendations.

10. CONCLUSION

The IRIS payload will provide the ability to integrate terrestrial and space communications nodes, through a common network layer protocol and potentially enable U.S. and allied military forces to communicate seamlessly over the Internet. Having an IP network node in space will eliminate the need for routing via a ground-based teleport, thereby dramatically increasing the efficiency, flexibility, and data throughput of satellite links and communication networks. A Military Utility Assessment will be conducted to evaluate the IRIS capability. If the MUA results are positive, the U.S. Army, Air Force, Navy, Marine and Coast Guard forces could leverage this capability to enhance military network-centric operations.

The technical readiness level of the IRIS capability is high, due to the use of proven technology and the legacy of experimentation learned from other programs. However, there are some potential risks in integrating a payload on board a spacecraft on a tight development schedule in order to meet a launch date in 2009.

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