Consultative Committee for Space Data Systems

RESEARCH AND DEVELOPMENT FOR SPACE DATA SYSTEM STANDARDS

Next Generation Space Internet (NGSI)— Supporting Spacecraft IP Mobility

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PREFACE

This document is a draft CCSDS Experimental Specification. Its Experimental status indicates that it is part of a research or development effort based on prospective requirements, and as such it is not considered a Standards Track document. Experimental Recommendations are intended to demonstrate technical feasibility in anticipation of a 'hard' requirement that has not yet emerged. Experimental work may be rapidly transferred onto the Standards Track should a hard requirement emerge in the future.

FOREWORD

This Experimental Specification describes the role of Internet Protocol (IP) Mobility Support within the proposed Next Generation Space Internet (NGSI) architecture.

Through the process of normal evolution, it is expected that expansion, deletion, or modification to this Experimental Specification may occur. This Experimental Specification is therefore subject to CCSDS document management and change control procedures which are defined in the *Procedures Manual for the Consultative Committee for Space Data Systems*. Current versions of CCSDS documents are maintained at the CCSDS Web site:

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1 INTRODUCTION

1.1 PURPOSE

The purpose of this Experimental Specification is to define the role of Internet Protocol (IP) Mobility Support within the proposed Next Generation Space Internet (NGSI) architecture. IP Mobility Support (reference [1]), commonly referred to as MobileIP, was designed to permit mobile agents to move randomly while still receiving datagrams at a fixed address. Since MobileIP cannot predict the movement of mobile nodes, the protocol specifies several mechanisms to associate a mobile node with a mobility agent (i.e., a home or foreign agent).

Spacecraft, however, do not move randomly. Contacts between spacecraft and ground stations are scheduled, with a priori agreement of established state. If we think of the spacecraft as a mobile node, the ground station as a foreign agent, and the control center as a home agent, then MobileIP is directly applicable to this environment. Moreover, since the contacts are planned, the mechanisms to associate a mobile node with a locally attached mobility agent are no longer necessary. Eliminating these exchanges will free space link resources during the contact period.

1.2 SCOPE

NASA's Advanced Information Systems Technology (AIST) Program is developing capabilities to support the concept of providing practical, secure, high performance access to orbiting spacecraft while communicating through multiple geographically-distributed ground stations. In particular, a spacecraft in this program may have multiple, even hundreds, of IP addresses on board. Performing all of the required exchanges to enable proper MobileIP routing will consume a significant amount of link resources. Modifying the protocol to take advantage of the particulars of this environment will directly support the AIST task.

1.3 REFERENCES

The following documents are referenced in this Experimental Specification. At the time of publication, the editions indicated were valid. All documents are subject to revision, and users of this Experimental Specification are encouraged to investigate the possibility of applying the most recent editions of the documents indicated below. The CCSDS Secretariat maintains a register of currently valid CCSDS Recommendations.

[1] Perkins, C. *IP Mobility Support*. RFC 2002, October 1996.

[2] Jet Propulsion Laboratory, *Task Plan for Next Generation Space Internet Communications Service to the Advanced Information Systems Technology (AIST) Program*, June 2000.

[3] Solomon, J. D. *Mobile IP, The Internet Unplugged.* Prentice Hall PTR. Upper Saddle River, New Jersey, 1998.

[4] Noles, J., et al. *Next Generation Space Internet*, Earth Science Technology Conference, College Park, MD, August 28-30, 2001.

[5] *Next Generation Space Internet (NGSI)—End-to-End Security for Space Mission Communications*. Experimental Specification for Space Data System Standards, CCSDS 733.5-O-1. Experimental Specification. Issue 1. Washington, D.C.: CCSDS, April 2003.

2 OVERVIEW

MobileIP specifies protocol enhancements for the transparent routing of IP datagrams to mobile nodes in the Internet. A mobile node is known by a fixed home address, and other nodes wishing to reach the mobile node use that address. If the mobile node is away from its home, a care-of address is associated with it that provides information as to its current point of attachment to the Internet. The mobile node registers this care-of address with its home agent, who tunnels datagrams destined for the mobile agent to this care-of address. The preferred method of acquiring a care-of address is through foreign agents, where the foreign agent acts as the endpoint of the tunnel, decapsulates received datagrams, and delivers them to the mobile node. This method is preferred since it allows many mobile nodes to share the same care-of address. The other method is ‘co-located care-of addresses’, where the mobile node itself acts as its own foreign agent, associating a care-of address with one of its own network interfaces and terminating the endpoint of the tunnel. This document deals with the foreign agent care-of address mode only.

Key steps required for operation of the protocol are as follows:

a) Agent Discovery comprises the method by which a mobile node is made aware of mobility agents (i.e., foreign or home agents). This may be through explicit Agent Advertisements, in which mobility agents announce their presence. Optionally, a mobile node may solicit such a message through locally attached mobility agents.

b) The mobile node receiving these advertisements determines whether it is attached to its home or a foreign network.

c) If attached to its home network, the mobile node operates without mobility services. If returning home after being on a foreign network, the mobile node deregisters with its home agent via exchange of Registration Request and Registration Reply messages.

d) When a mobile node determines it’s on a foreign network, it associates itself with a foreign agent and obtains a care-of address.

e) This new care-of address is then registered with the home agent through exchange of Registration Request and Registration Reply messages (via the foreign agent).

f) Datagrams destined for the mobile node are sent to the home address, intercepted by the home agent, tunneled to the foreign agent, decapsulated for the foreign agent and delivered to the mobile node.

g) Datagrams sent from the mobile node are generally delivered using standard IP.

Figure 2-1 illustrates these key steps.

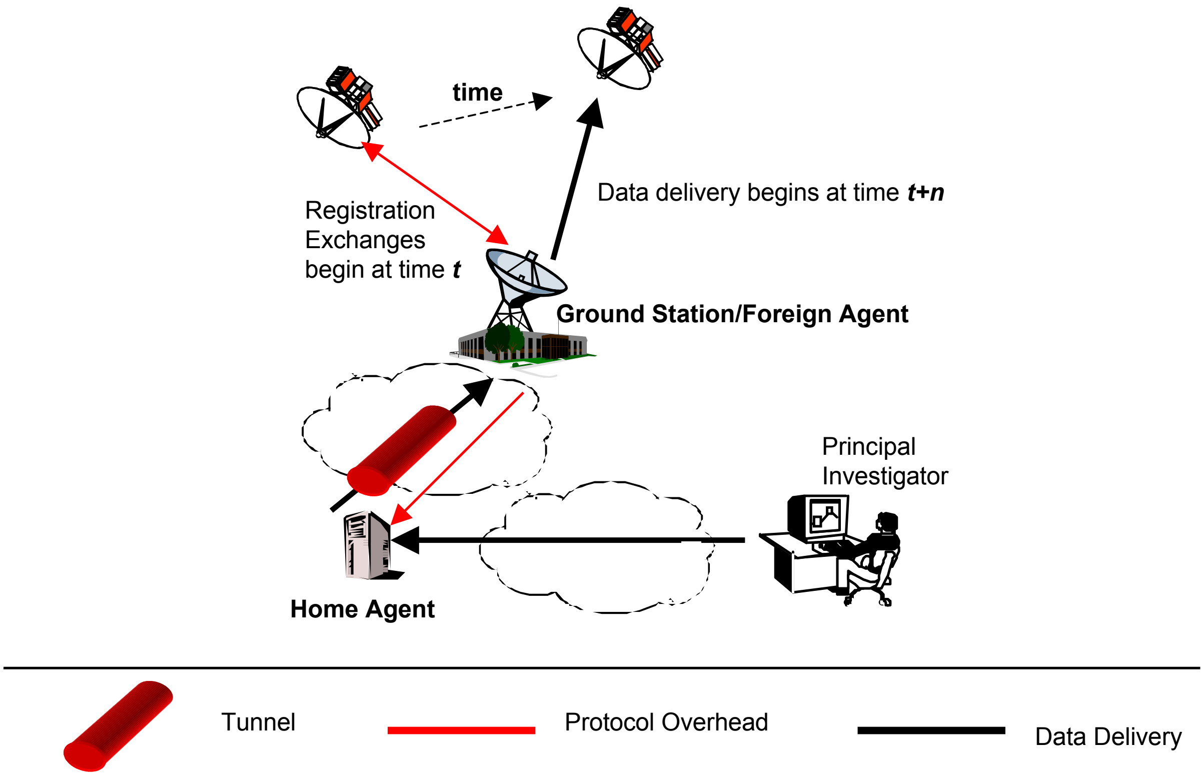

Figure 2-1: Standard IP

3 MODIFICATIONS TO MobileIP

NOTE – This section will examine each of the seven major steps required for operation of the protocol, discussing in general the modifications required for the AIST environment.

3.1 AGENT DISCOVERY

MobileIP is assumed in all of the ground stations. Since contact between the spacecraft and ground stations is pre-scheduled, spacecraft running MobileIP may take for granted that ground stations are mobility agents. Therefore, Agent Advertisements and solicitation of Agent Advertisements are not required.

3.2 DETERMINATION OF HOME OR FOREIGN NETWORK

A spacecraft will know the IP address of any ground station—i.e., mobility agent—it encounters. It may then compare this address to its own home address and determine whether it is on its home network or a foreign network.

3.3 HOME NETWORK DEREGISTRATION

It is unlikely for the foreseeable future that ground stations will operate as home agents. However, in that case, the a priori state in both the mobile node and home agent will trigger an automatic deregistration. Explicit exchanges are no longer required.

3.4 FOREIGN AGENT ASSOCIATION

3.4.1 GROUND STATION

A mobile node running MobileIP shall assume that the ground station will act as its foreign agent. No action is required for this step since the mobile node already has the care-of address for the ground station.

3.4.2 MobileIP IN THE SPACECRAFT

It is likely that not all spacecraft will be running MobileIP. A ground station should not proxy register with a home agent unless it has overt knowledge that MobileIP exists onboard the spacecraft. If no such a priori state is present but a mobile node does exist onboard, it may explicitly register with the ground station, using standard MobileIP Registration services, with Agent Discovery as needed.

3.4.3 REGISTRATION EN MASS REQUEST

A single spacecraft may have multiple IP addresses—and therefore mobile nodes—on board. If the ground station is aware of such addresses, it will proxy register those on the same subnet and to the same home agent with the Registration En Mass function. This is a modified Registration Request containing a mobile node address along with a subnet mask.

A single tunnel between the ground station and home agent is created, and all addresses contained within that subnet range will be routed through the tunnel. Any mobile node address within the range may be used for the Registration En Mass Request.

The foreign agent originates the Registration En Mass Request message on behalf of the mobile nodes for which it is acting as proxy. The format of the Registration En Mass message is similar to that of the standard MobileIP Registration Request, except for the Type flag and the addition of the subnet mask. Figure 3-1 depicts the Registration En Mass Request Universal Datagram Protocol (UDP) header followed by the MobileIP fields.

```
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Type=193     |      Code      |            Lifetime            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                           Home Address                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                            Subnet Mask                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                            Home Agent                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          Care-of Address                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                                   |
+                          Identification                          +
|                                                                   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Extensions ...
+-+-+-+-+-+-+-+-+-

  Type     193 (Registration En Mass Request)
```

Figure 3-1: Registration En Mass Request UDP Header

3.4.4 REGISTRATION EN MASS REPLY

The home agent originates a Registration En Mass Reply message to the foreign agent which initiated the Registration En Mass Request message on behalf of the mobile nodes. The format of the Registration En Mass Reply message is similar to that of the standard MobileIP Reply, except for the Type flag and the addition of the subnet mask. Figure 3-2 depicts the Registration En Mass Reply UDP header followed by the MobileIP fields.

```
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Type=195    |     Code      |           Lifetime            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         Home Address                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          Subnet Mask                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          Home Agent                           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        Care-of Address                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+                        Identification                         +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Extensions ...
+-+-+-+-+-+-+-+-
```

Type 195 (Registration En Mass Reply)

Figure 3-2: Registration En Mass Reply UDP Header

3.5 TUNNELING TO THE MOBILE NODE

Once the care-of address is registered with the home agent, no changes are required for this step.

3.6 SENDING DATAGRAMS

When security gateways are in place at both ends of the MobileIP tunnel, datagrams originating from the spacecraft will be sent via the home agent (i.e., reverse tunneling). This is to ensure that security mechanisms enabled at one end of the tunnel are properly processed at the receiving end. In the absence of tunnel endpoint security, datagrams sourced from the spacecraft may be sent directly from the foreign agent via standard IP (triangle tunneling).

4 CONCLUSIONS

The mobility of spacecraft in relation to ground stations provides a natural setting for MobileIP, where spacecraft are the mobile nodes and ground stations are the foreign agents. However, the limited contact times and scarce bandwidth are impediments to the protocol as currently specified. Modifying MobileIP to take advantage of a priori agreement of state should improve its performance. In addition, such modifications allow for multiple, even hundreds, of IP addresses on a single spacecraft, further supporting the goals of the AIST program.

5 SECURITY CONSIDERATIONS

The tremendous costs involved with implementing and maintaining a space-based network clearly imply the need for security. Moreover, this need becomes paramount when the network is extended to include the Internet (and its own associated security issues [3]). A discussion of security within this context can be found in references [4] and [5].

ANNEX A

ABBREVIATIONS AND ACRONYMS

AIST	Advanced Information Systems Technology
CCSDS	Consultative Committee for Space Data Systems
IETF	Internet Engineering Task Force
IP	Internet Protocol
NGSI	Next Generation Space Internet
PI	Principal Investigator
UDP	Universal Datagram Protocol