InterPlaNetary Internet

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Acknowledgments

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Historical Conceptual Framework

• Early requirements:
  – pt-pt links, time-slotted access to spacecraft instruments
• Packetized channels (link protocols)
  – Flexible multiplexing, improved error handling
• Simple radio and link level relays
  – DSN to orbiter to lander to rover
• Each communication requirement is a distinct case
  – DSN establishes link to remote target and is scheduled as a series of pt-pt encounters
Conceptual Trends

- Longer mission lifetimes
  - Return to radio-isotopic power
  - Fission reactor power?
- Increasing number of concurrent missions
- Increasing use of sensor *networks*
  - Tandem sensor systems (interferometers)
  - Self-organizing sensor networks on ground communicating among themselves and linking to landers and orbiters by radio
- Increasing use of orbiting communication assets
- Potential for store-and-forward, packet relay operation
Internet Concepts

- Devices have names and addresses
- Inter-device communication is really inter-process communication (exchanges between running programs)
- Layered protocols, IP core, routing
- Any device can theoretically talk to any over via IP
- Common standards lead to interoperability
- Rich connectivity leads to resilience
- Dedicated links vs episodic links
- Optical communication increases capacity
Critical Notions

- Not all parts of a rich communication architecture need always be engaged
  - e.g. note TCP/IP on Ethernet – no routers!
  - Early arguments about specializing TCP/IP on Ethernet
- “Networking” is increasingly valuable as population of communicating devices/systems increases
- Re-use of communication resources by subsequent missions only works well with standardization
- Network is “accreted” mission-by-mission as assets are flown containing advanced protocol capability
- Potential for persistent links with multiple antennas
International space standards are developed within the Consultative Committee for Space Data Systems (CCSDS) • 34 space agencies
The Consultative Committee for Space Data Systems (CCSDS) is an international voluntary consensus organization of space agencies and industrial associates interested in mutually developing standard data handling techniques to support space research, including space science and applications.

**Member Agencies**
- Agenzia Spaziale Italiana (ASI)/Italy
- British National Space Centre (BNSC)/United Kingdom
- Canadian Space Agency (CSA)/Canada
- Central Research Institute of Machine Building (TsNIIMash)/Russian Federation
- Centre National d'Etudes Spatiales (CNES)/France
- Deutsche Forschungsanstalt für Luft- und Raumfahrt e.V. (DLR)/Germany
- European Space Agency (ESA)/Europe
- Instituto Nacional de Pesquisas Espaciais (INPE)/Brazil
- National Aeronautics and Space Administration (NASA HQ)/USA
- National Space Development Agency of Japan (NASDA)/Japan

**Observer Agencies**
- Australian Space Office (ASO)/Australia
- Austrian Space Agency (ASA)/Austria
- Belgian Science Policy Office (SPO)/Belgium
- Centro Tecnico Aeroespacial (CTA)/Brazil
- Chinese Academy of Space Technology (CAST)/China
- Communications Research Laboratory (CRL)/Japan
- Danish Space Research Institute (DSRI)/Denmark
- European Organization for the Exploitation of Meteorological Satellites (EUMETSAT)/Europe
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- Hellenic National Space Committee (HNSC)/Greece
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- Ministry of Communications (MOC)/Israel
- National Oceanic & Atmospheric Administration (NOAA)/USA
- National Space Program Office (NSPO)/Taiwan
- Swedish Space Corporation (SSC)/Sweden
- United States Geological Survey (USGS)/USA

http://www.ccsds.org

Initial focus: space/ground data link protocols

Recent focus: space networking

http://www.scps.org

Clay Frost, MSNBC
245 missions, and counting
Deploy standard internets in low latency remote environments (e.g., on other planets)

The three building blocks of the IPN Architecture

1. Support dialog across a network of Internets
2. Connect distributed internets via an interplanetary backbone
3. The Basic IPN Concept: construct a “Network of Internets”
Space exploration becomes fully Internet-based.

Missions log-on to the "Interplanetary Internet Service Provider" to communicate.

Remote internets are deployed in short delay space environments.

An interplanetary backbone network evolves.
The IPN is a “network of internets”

Operations driven by power, weight, volume

Long propagation delays

High value data, finite buffers

Transaction sizes are small compared to bandwidth-delay product

Backbone contact periods:
- short relative to delay
- possibly one-way
- possibly separated by days, weeks
- cannot guarantee an end-to-end path

Transaction sizes are small compared to bandwidth-delay product
"Delay Tolerant Networking" - reliable communications in highly stressed environments

Delay can be introduced by, e.g.,
- Propagation
- Intermittent connectivity
- Lack of resources (power, buffers)
- Simplex or asymmetric channels
The **Internet** is a connected, chatty 'network of networks' based on a wired backbone with negligible delay and errors (with untethered “edges” emerging)

The **InterPlaNetary Internet** is a disconnected, store-and-forward 'network of Internets' based on a wireless backbone with huge delays and error prone links
Some of the Hard Problems

- Time synchronization/scheduling
- Antenna pointing (note optical)
- Routing
- Flow Control
- Error handling, retransmission, reassembly
- Persistent communication over operation system reboots
- Mobile robot control in high delay/uncertainty cases
- Naming conventions (DNS doesn’t work: tuples!)
- Mobile spacecraft with multiple “named” processes
Current Space/Ground Communications Protocol Stack

- Space Applications
- Space Networking
- Space Link
- Space Channel Coding
- Space Wireless Frequency and Modulation
Deploy standard internets in low latency remote environments (e.g., on other planets)

Support dialog across a network of Internets

The Basic IPN Concept: construct a “Network of Internets”

Connect distributed internets via an interplanetary backbone

The IPN is a “network of internets”

So how does all of this relate to the Interplanetary Internet?

We need a general way to communicate in a disconnected, long-delay environment
IP: the “Thin Waist” of the Earth's Internet

Internet: a Network of Connected Sub-Networks
Bundles: A Store and Forward Overlay

The "Thin Waist" of the Interplanetary Internet

Network of internets spanning dissimilar environments
IPN Architecture (Internet Draft 1) May 2001

DTN Architecture (Internet Draft 2) July 2002

First Draft Bundle Protocol Specification September 2002

Bundle Specification

Specifications
Code base

Bundle Prototyping

1st. Rough Code August 2000
2nd. Prototype Code May 2002
3rd. Prototype Code July 2002

CFDP-over-Bundles Experiment.
Bundle Service Layering

- e2e Applications (e.g., Bundle FTP, CFDP, Bundle NTP)
- Bundle API
- Bundle Segmentation & Reassembly
  - Custody Transfer Bundle
  - End-end Reliability Bundle
  - Authentication Bundle
  - Encryption Bundle
  - TBD Services Bundle
- Bundle Routing
  - Convergence Layer (specific adapters that map Bundles to underlying transmission services)
  - LTP
  - TCP
  - UDP
- IP

CCSDS Long-haul Link
CCSDS Proximity Link
SONET
Ethernet
DTN Core Engineering
- DTN Architecture
- DTN Design Documents
- Reference Implementation
- Configuration Control

DTN Standardization
- DTNRG
- CCSDS

IPN - Public Outreach
- Sensor Webs
- Tactical Military

IPN - Implementation

DTN User Communities

DTN Open Source
- Reference Implementation
- Configuration Control

DTN Technical Outreach

Technical Volunteers
The 5 year Scenario: 
fully automated end to end space mission data transfer
Mars Network
Gateway to the Mars Frontier

Next Generation Internet (NGI) Initiative
The Interplanetary Internet
For more information......

... http://www.ipnsig.org