Interplanetary Overlay Network

An Implementation of the DTN Bundle Protocol

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Background

- Reference implementation for the DTN Bundle Protocol (BP) is DTN2, maintained at UC Berkeley.
  - Designed as a research vehicle.
  - Widely used, well supported.
- Most DTN researchers are investigating terrestrial applications, for which DTN2 works very well.
- Space flight applications impose different constraints, motivating development of an alternative BP implementation for use in space flight missions.
- Interplanetary Overlay Network (ION) is a space flight implementation of BP, developed at NASA's Jet Propulsion Laboratory.

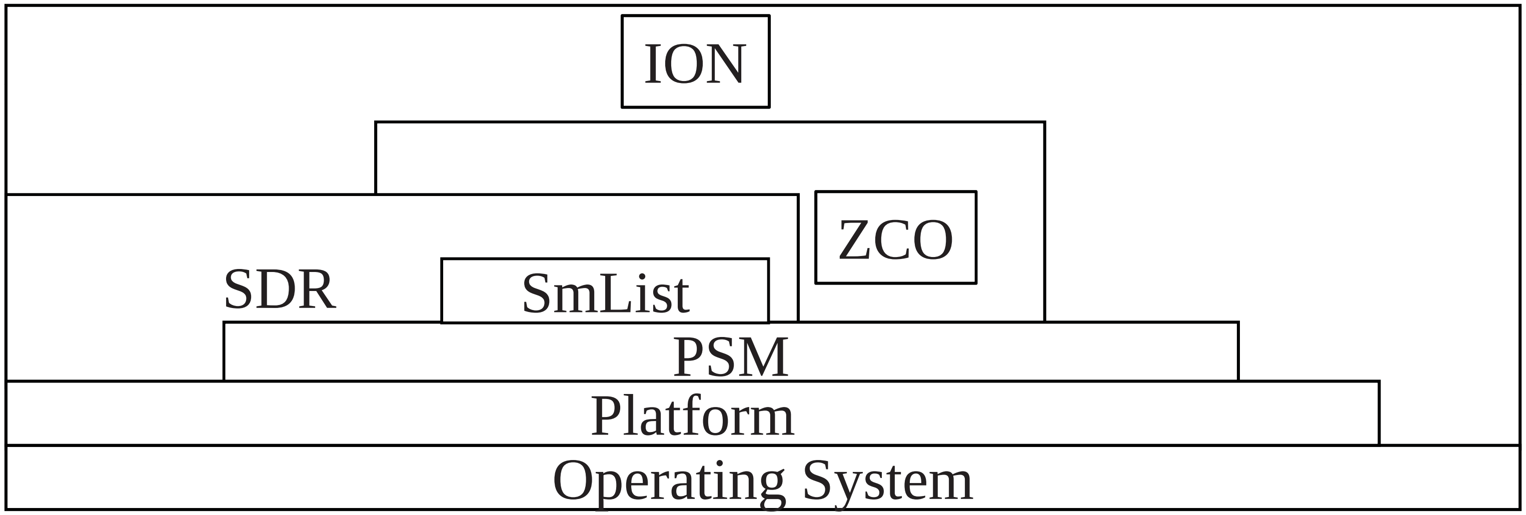
Constraints on a Flight Implementation

- Link constraints
  - All communications are wireless, generally slow, asymmetric.
    - From spacecraft to ground: 256 Kbps to 6 Mbps.
    - From ground to spacecraft: 1 to 2 Kbps.
  - Links are very expensive, virtually always oversubscribed.
  - Fine-grained transmission, small bundle payloads.
    - Immediate delivery of partial data is often OK.
- Processor constraints
  - Flight processors typically run real-time operating systems (VxWorks®, RTEMS™) lacking protected memory models.
  - Robustness is paramount. No *malloc* and *free* or standard *new* and *delete*; must not crash other flight software.
  - Processing efficiency is important:
    - Slow (radiation-hardened) processors.
    - Relatively slow non-volatile storage: flash memory.

ION's Divergence From DTN2

Design Element	DTN2	ION	Rationale
Language	C++	C	Processing efficiency, memory management visibility.
Memory management	*new*, *delete*	PSM	No dynamic system memory management permitted.
Non-volatile storage management	Berkeley DB, RDBMS (MySQL)	SDR persistent objects	Processing efficiency, footprint.
Locus of processing	**dtnd** daemon process, separate routing engine	highly distributed: forwarders, ducts, applications, and admin tools	Robustness (module simplicity, incremental upgrade; prevent head-of-line blocking); simplify flow control.
Locus of node state (e.g., queues)	private memory of **dtnd** daemon	shared memory	Support distributed functionality, limit impact of demand spikes.
Application Programming Interface	remote procedure calls to **dtnd**	shared library functions act on shared memory	Support real-time operations: prevent blocking, support deterministic execution.
Endpoint IDs in bundle's primary block	only ASCII URIs in dictionary	supports CBHE	Bandwidth efficiency.

Implementation Layers



ION	Interplanetary Overlay Network libraries and daemons
ZCO	zero-copy objects capability: minimize data copying up and down the stack
SDR	Spacecraft Data Recorder: persistent object database in shared memory, using PSM and SMList
SmList	linked lists in shared memory using PSM
PSM	Personal Space Management: memory management within a pre-allocated memory partition
Platform	common access to O.S.: shared memory, system time, IPC mechanisms
Operating System	POSIX thread spawn/destroy, file system, time

Compressed Bundle Header Encoding

- For a CBHE-conformant scheme, every endpoint ID is
  scheme_name:*element_nbr*.*service_nbr*
  - 65,535 schemes supported. Up to 16,777,215 elements (i.e., nodes) per scheme. Up to 65,535 services per scheme.
  - Service ~= "demux token" or IP protocol number. All administrative bundles are service number zero.
- CBHE limits primary bundle header length to 34 bytes.
  - Dictionary not needed, so it's omitted.

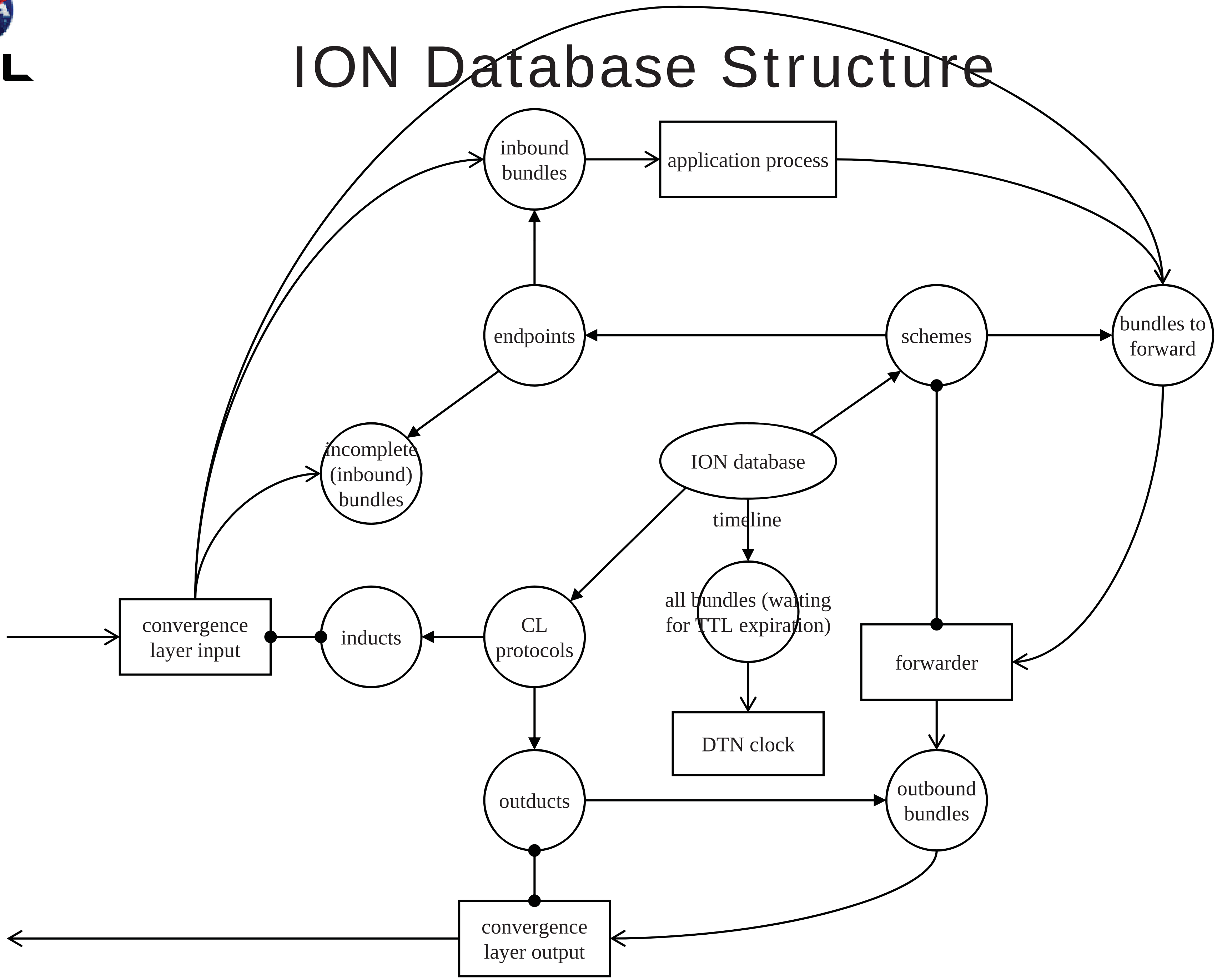
Non-CBHE

Destination offsets		Source offsets		Report-to offsets		Custodian offsets	
Scheme	SSP	Scheme	SSP	Scheme	SSP	Scheme	SSP

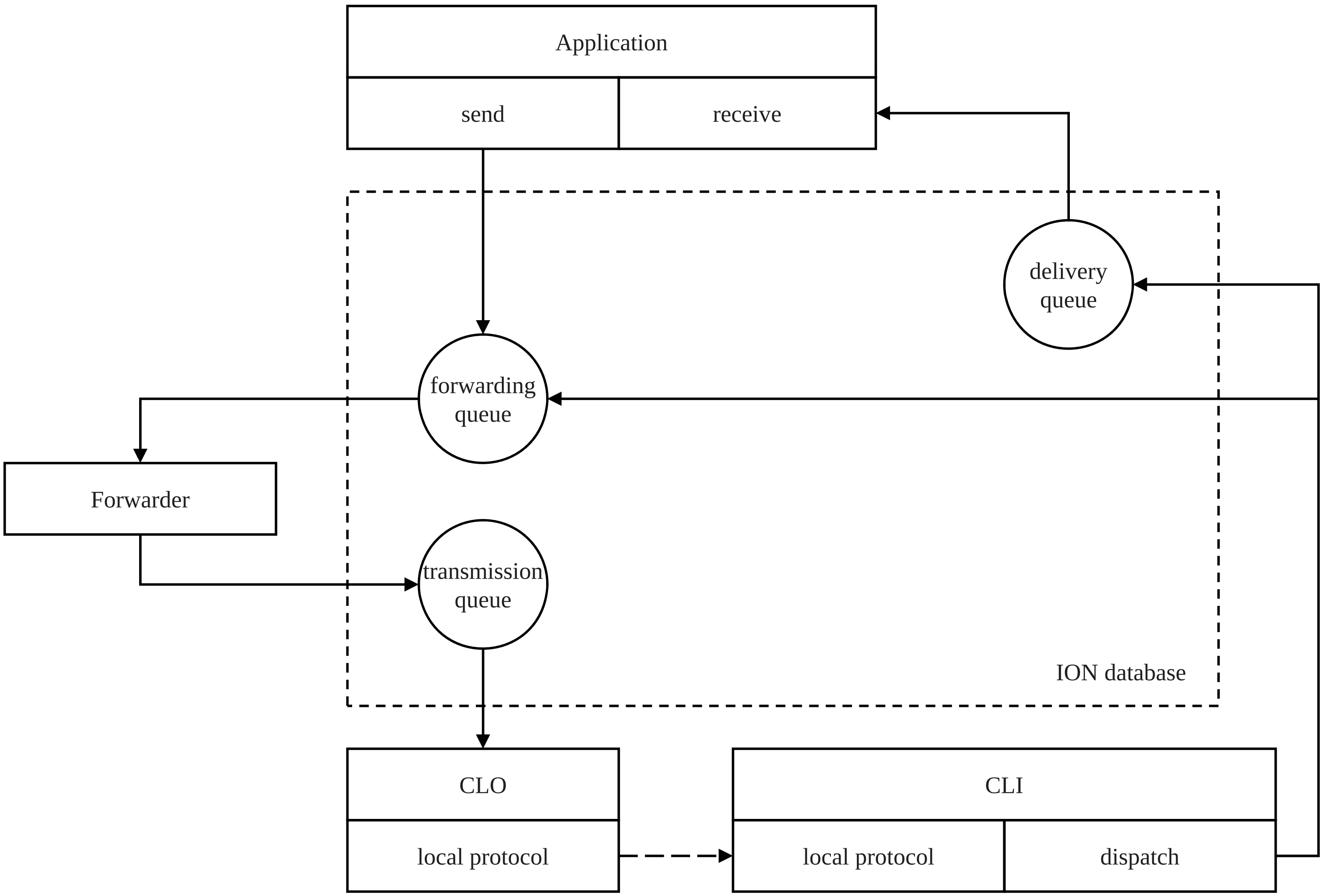
CBHE

Common Scheme number	Destination Element number	Source Element number	Report-to Element number	Custodian Element number	Service Number for source & destination

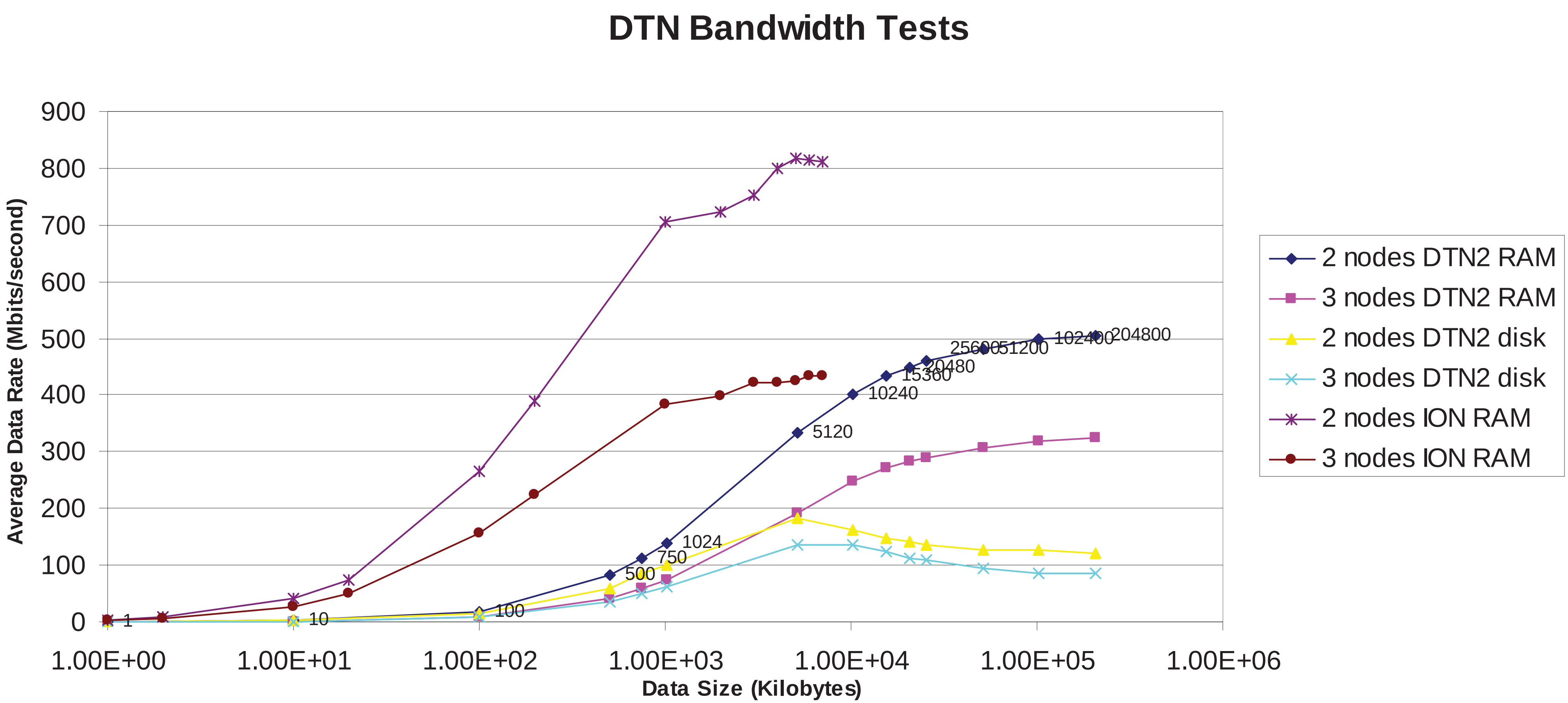
ION Database Structure



Processing Flow



Performance



ION flight software footprint: about 708 kilobytes including SDR database management system.

Evaluation Copies Distributed To Date

- NASA
  - Goddard Space Flight Center
  - Marshall Space Flight Center
  - Ames Research Center
  - Glenn Research Center
  - Johnson Space Center
  - Constellation project
- Other US
  - Johns Hopkins University Applied Physics Laboratory
  - Cal Poly San Luis Obispo
  - Ohio University
  - MITRE Corporation
  - Interface & Control Systems
- ESA (European Space Agency)
- CNES (French national space agency)

Status of ION

- Conforms to version 4 of the BP specification (August 2006). Upgrade to version 5 (December 2006) is in progress.
- Implements custody transfer, status reports, delivery options, priority, reassembly from fragments, flow control, congestion control.
- Tested in Red Hat Linux 8+, Fedora Core 3+, on 32-bit and 64-bit processors. Also in VxWorks 5.4 on PowerPC 750.
- Interoperability with DTN2 (and other Bundle Protocol implementations: C# .Net, Symbian) demonstrated at IETF in San Diego, November 2006.

Summary

- ION is an implementation of the Delay-Tolerant Networking Bundle Protocol that is designed for use in spacecraft flight software.
- Testing to date suggests that it will be suitable for this purpose.
- Development and evaluation are continuing.

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