Pervasive Systems

Ioannis Chatzigiannakis

Sapienza University of Rome
Department of Computer, Control, and Management Engineering (DIAG)

Lecture 7:
DTN Bundle Protocol

Delay and Disruption Tolerant Networking (DTN)

- DTN overcome problems associated with
  1. Intermittent connectivity,
  2. Long or variable delays,
  3. Assymetric data rates,
  4. High error rates.
- DTN uses the Store and Forward Message Switching.
- Ressembles mechanisms invented in the ancient times: Pony-Express, Postal systems.

Store and Forward Message Switching

- Individual messages are grouped in Bundles.
- Bundles (of messages) are moved from a storage place of one node, to a storage place of another node (switch interaction).
- Store-and-forwarding methods are also used in todays voicemail and email systems.
  - these systems are not node-to-node relays (as shown above) but rather star relays.
  - both the source and destination independently contact a central storage device at the center of the links.

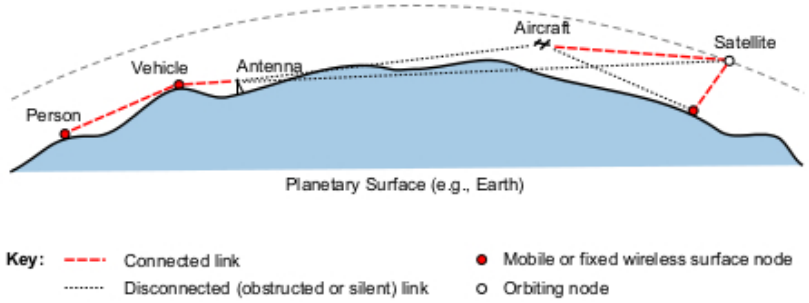
The need for Persistent Storage

DTN routers need persistent storage for their queues for one or more of the following reasons:

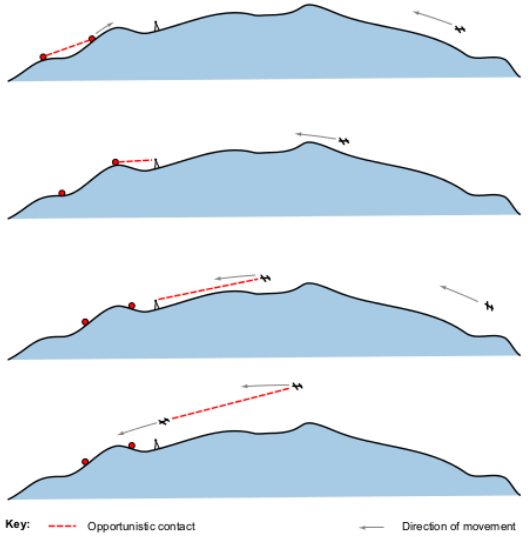
1. A communication link to the next hop may not be available for a long time.
2. One node in a communicating pair may send or receive data much faster or more reliably than the other node.
3. A message, once transmitted, may need to be retransmitted if an error occurs at an upstream (toward the destination) node, or if an upstream node declines acceptance of a forwarded message.

Opportunistic Contacts

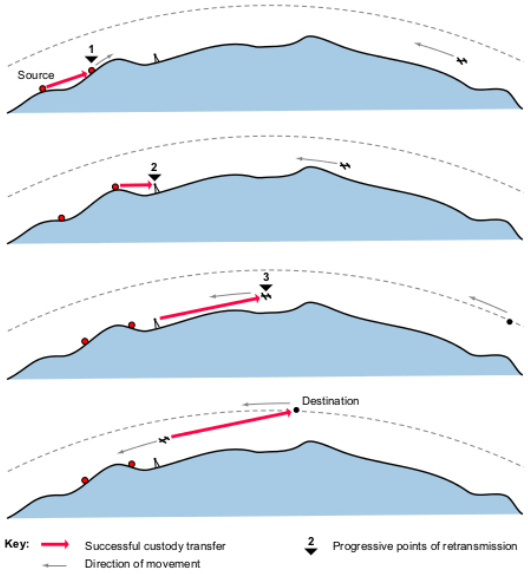
- Network nodes may need to communicate during opportunistic contacts.
- Sender and Receiver make contact at an unscheduled time.



Opportunistic Contacts: An Example

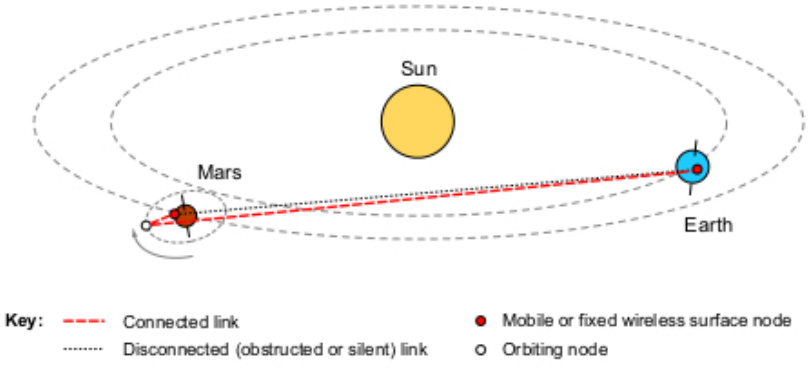


Opportunistic Contacts: An Example

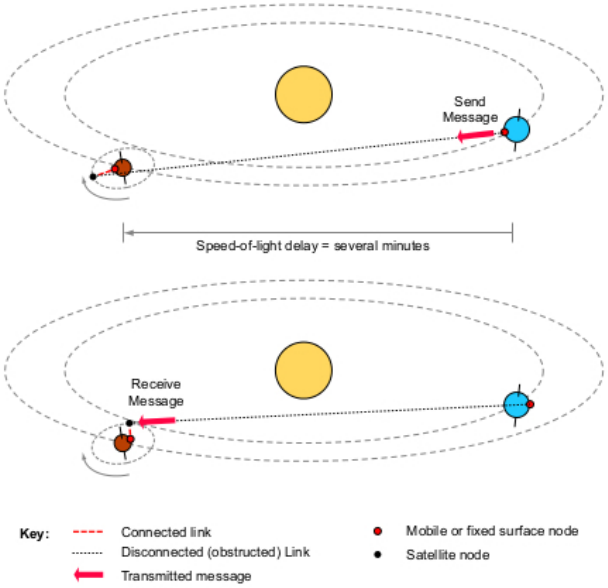


Scheduled Contacts

- In many scenarios we can predict (or receive) times schedules of nodes future positions.
- We can arrange future communications sessions.
- Time synchronization between nodes is of crucial importance.

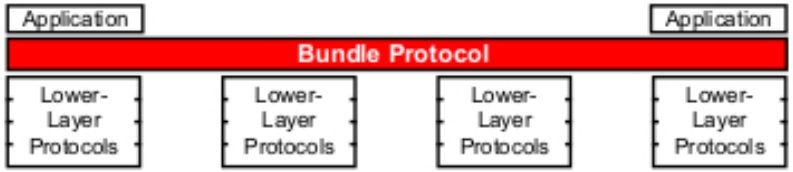


Scheduled Contacts: An Example

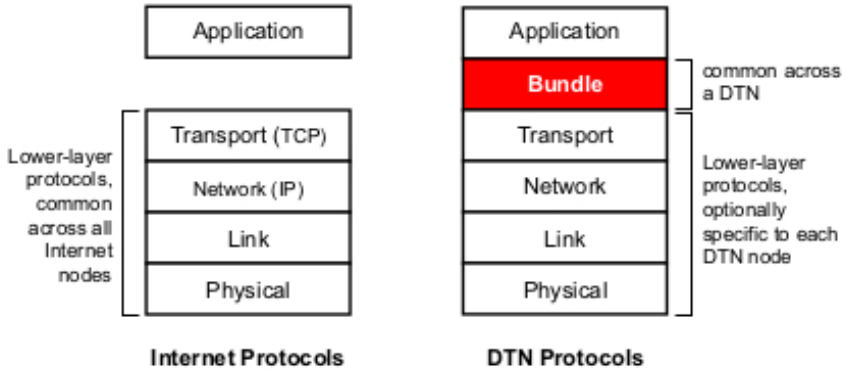


Main Concepts of Bundle Protocol

- Implements store-and-forward message switching.
- Overlays a new transmission protocol (the bundle protocol) on top of the lower layers (e.g., the Internet protocols).
- Ties together the lower layers so that application programs can communicate across the same or different sets of lower-lower layers under conditions that involve long network delays or disruptions



IP stack vs DTN stack

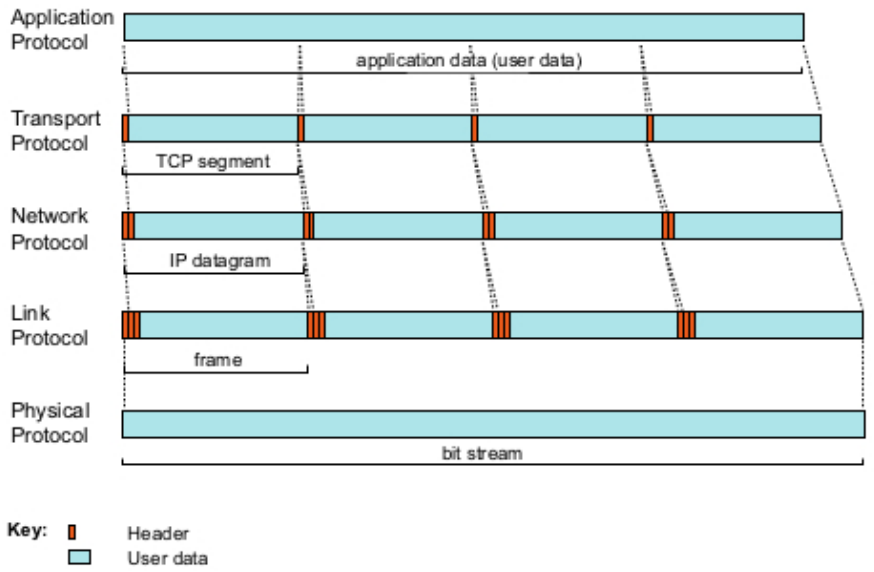


Bundles

Bundles consist of three things:

1. a bundle header consisting of one or more DTN blocks inserted by the bundle-protocol agent,
2. a source-applications user data, including control information provided by the source application for the destination application that describes how to process, store, dispose of, and otherwise handle the user data, and
3. an optional bundle trailer, consisting of zero or more DTN blocks, inserted by the bundle-protocol agent (not shown in the figure below). Like application-program user data, bundles can be arbitrarily long.

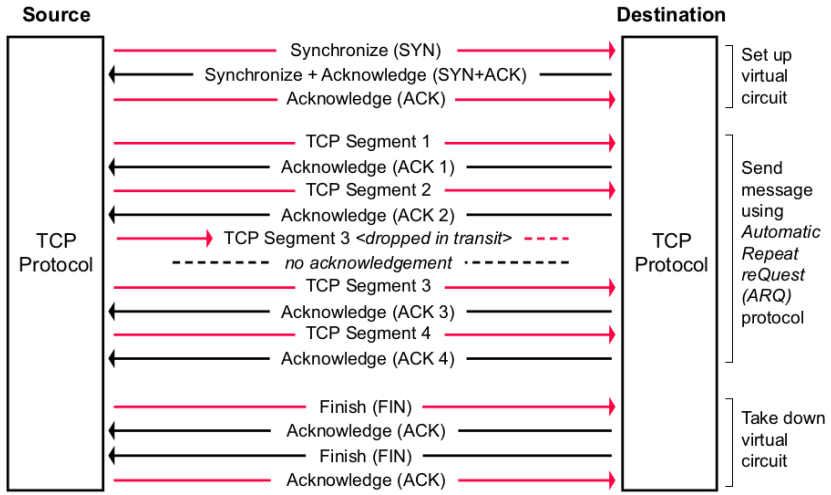
Bundles Encapsulation



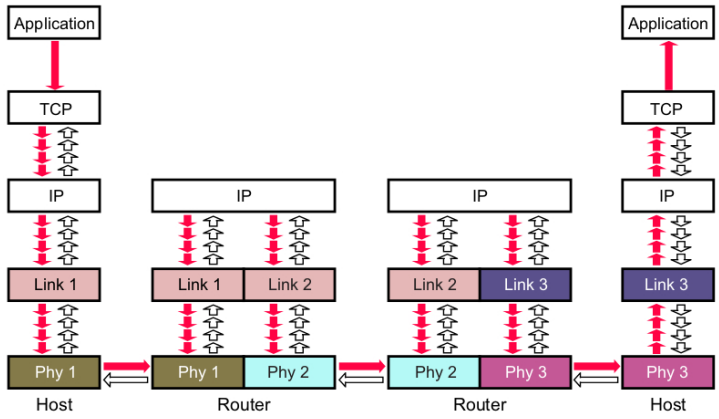
Todays Internet – Conversational Protocols

- TCP protocol is said to be conversational (interactive).
- A complete one-way message involves many source-to-destination signaling round-trips:
  1. Set Up: A three-way "Hello" handshake.
  2. Segment Transfer and Acknowledgement: Each TCP segment (or a few segments) sent by the source is acknowledged by the destination.
  3. Take Down: A four-way "Goodbye" handshake.

Conversation Example

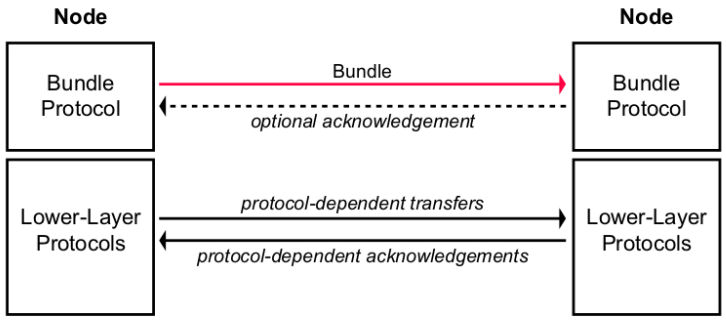


Conversation Example



A Non Conversational Protocol

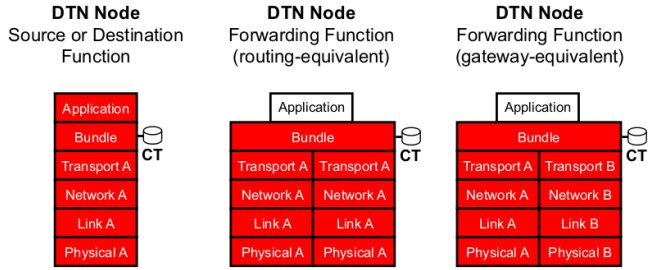
- DTN nodes communicate using simple sessions with minimal or no round-trips.
- Acknowledgements are optional.
- The Lower-layer protocols may be conversational (e.g., like TCP).



DTN Node Roles

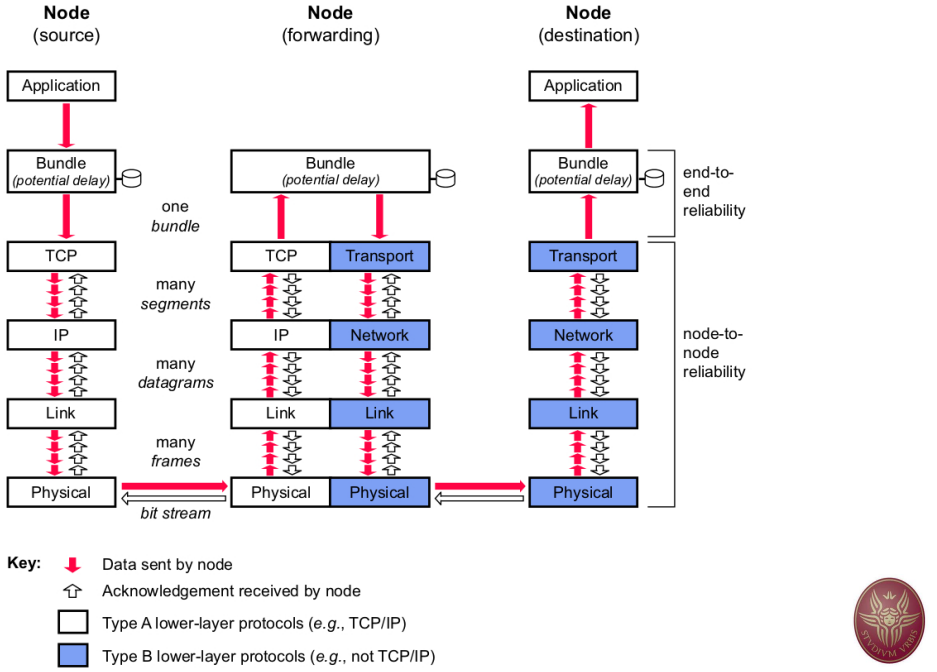
At any moment, a given node may act as a source, destination, or forwarder of bundles:

- Source or Destination Function
- Forwarding Function
  1. Routing-Equivalent Forwarding – implement same lower layer protocols.
  2. Gateway-Equivalent Forwarding – implement multiple stacks of lower layer protocols.



Delay Isolation via Transport-Protocol Termination

- TCP protocol provides end-to-end (source-to-destination) reliability by retransmitting any segment that is not acknowledged
- The network, link, and physical protocols provide other types of data-integrity services.
- The bundle protocol relies on these lower-layer protocols to insure the reliability of communication.
- However, all DTN nodes terminate lower-layer transport protocols.
- Problem: The bundle protocol agents thus act as surrogates for end-to-end sources and destinations.
- Opportunity: Conversational lower-layer protocols are isolated by the bundle protocol from long delays elsewhere in the end-to-end path.

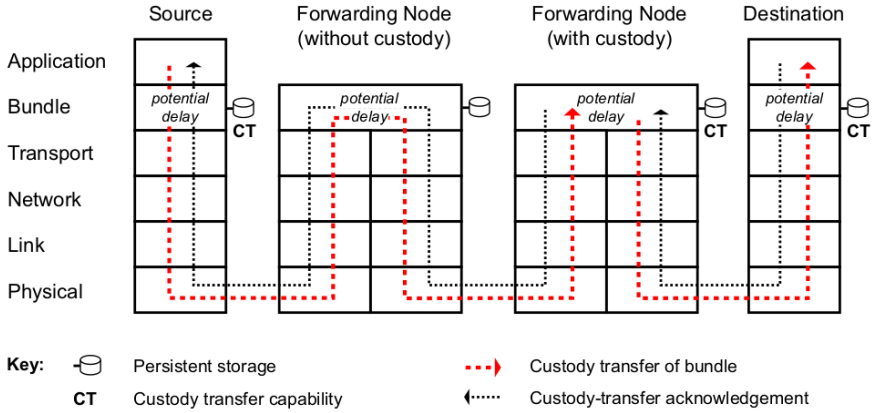


Custody Transfers

- How to support node-to-node retransmission of lost or corrupt data ?
  - No single transport protocol typically operates end-to-end across a DTN.
  - End-to-end reliability can only be implemented at the bundle layer.
- Support node-to-node retransmission by means of custody transfers.
  - Custody transfers enhance end-to-end reliability,
  - but they do not guarantee it.
- Such transfers are arranged between successive nodes.
  - Not all successive nodes need to be custodian.
  - If the next successive node accepts custody, it returns an acknowledgment to the sender.

Bundle Custodian

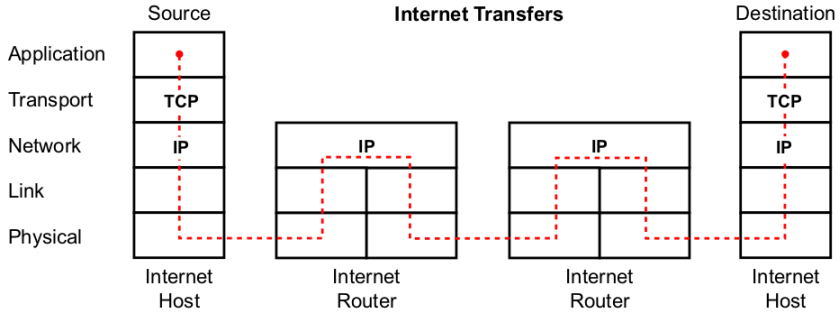
- A bundle custodian must store a bundle until either
  1. Another node accepts custody, or
  2. Expiration of the bundles time-to-live.



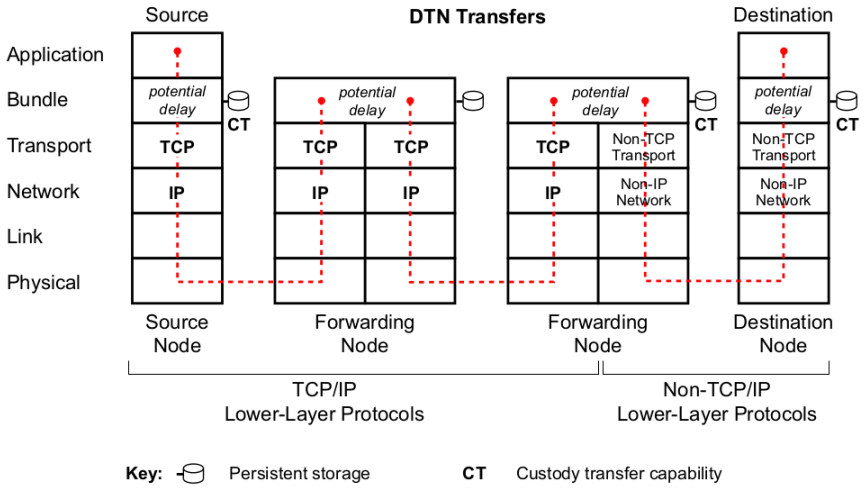
Internet routing vs DTN routing

- On the Internet, the TCP and IP protocols are used throughout the network.
  - TCP operates at the end points of a path.
  - TCP manages reliable end-to-end delivery of TCP segments.
  - IP operates at all nodes on the path.
  - IP routes IP datagrams.
- In a DTN, all nodes implement both the bundle protocol and a lower-layer protocols.
  - Nodes that forward bundles can implement either the same or different lower-layer protocols on either side of the forwarding.
  - Nodes functions are comparable to Internet routers or gateways, respectively.

Internet routing



DTN routing

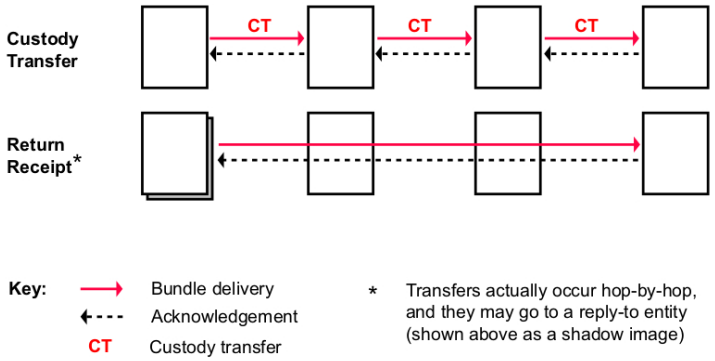


Classes of Bundle Service

The bundle protocol provides six classes of service for a bundle:

- Custody Transfer: Delegation of retransmission responsibility by one node to another accepting node, so that the first node can recover its retransmission resources. The accepting node returns a custodial-acceptance acknowledgement to the previous custodian.
- Return Receipt: Confirmation by the destination to the source, or its reply-to entity, that the bundle has been received by the destination application. Reception by the source, or its reply-to entity, of the return receipt provides end-to-end assurance of delivery.
- Priority of Delivery: Bulk, Normal, or Expedited.
- Time-to-Live

Classes of Bundle Service



Endpoint IDs

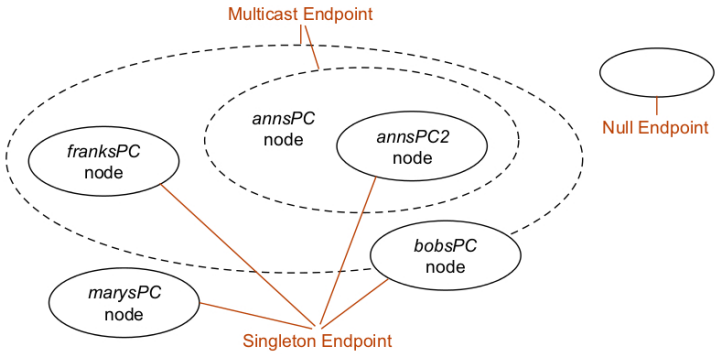
- A bundle endpoint is a set of zero or more nodes that all identify themselves by the same endpoint ID.
- Common case: only one node has a given endpoint ID – called a singleton endpoint.
- Source nodes are always singleton endpoints or null (anonymous source) endpoints.
- Destination nodes may or may not be singleton endpoints.
- Endpoints may also be multicast (multiple destination nodes with the same endpoint ID) or null (no nodes).
- Endpoints may contain multiple nodes.
- Nodes may be members of multiple endpoints.

Endpoint IDs

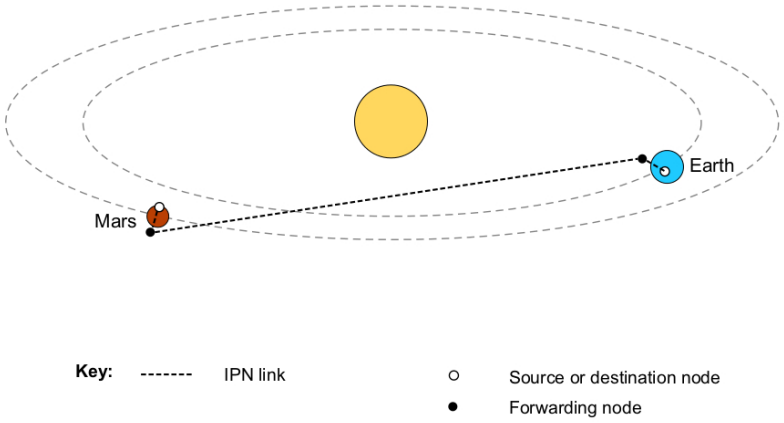
- An endpoint ID is a uniform resource identifier (URI) text string using the syntax:
  `<scheme_name>:<scheme-specific_part>`
- the scheme name is either `dtn` or `ipn`.
- The scheme-specific part comes in two flavors:
  1. Application-specific, used to identify a source or destination node, or
  2. Administrative, used when forwarding bundles from node to node.

- `dtn://bobsPC/files` (application-specific)
- `dtn://bobsPC/` (administrative)
- `ipn:81.2` (application-specific)
- `ipn:81.0` (administrative)

Naming Example



A Simple Example



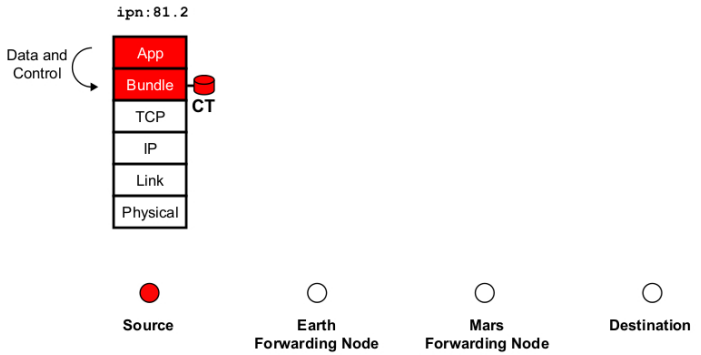
A Simple Example

Node	Endpoint IDs	
Earth Source	`ipn:81.2`	(application-specific ID)
Earth Forwarding	`ipn:81.0` `ipn:49.0`	(administrative ID) (administrative ID)
Mars Forwarding	`ipn:49.0` `ipn:65.0`	(administrative ID) (administrative ID)
Mars Destination	`ipn:65.7`	(application-specific ID)

A Simple Example

Item	Value
Source	`ipn:81.2`
Destination	`ipn:65.7`
Class of service	• Custody transfer • Normal priority • Time-to-live = 36 hours
User Data	Application-specific data, including instructions to the destination application for processing, storage, disposal, and error-handling. User data is not visible to bundle-protocol agents.

A Simple Example



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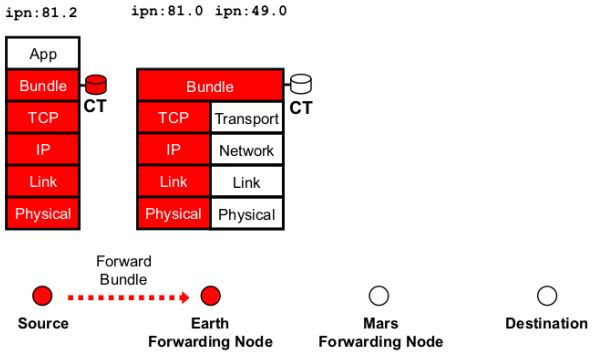

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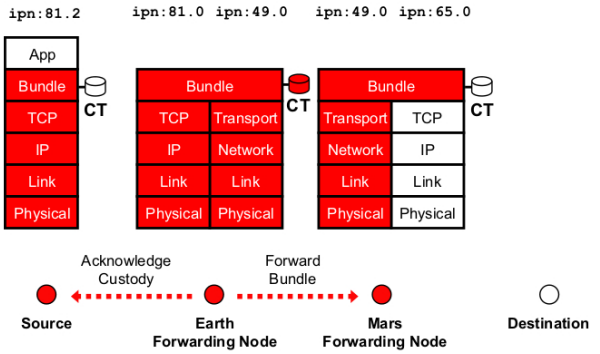

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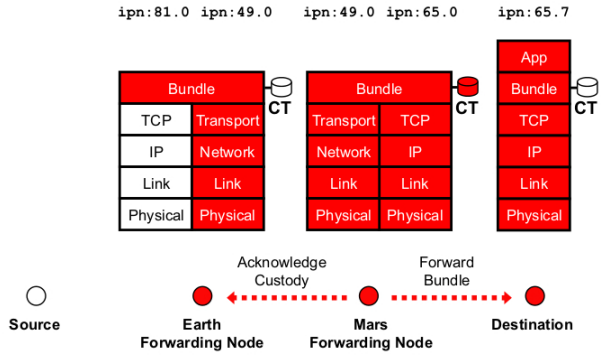

DTN Bundle Protocol
Example

A Simple Example