Endpoint Naming for Space Delay / Disruption Tolerant Networking

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Overview

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- Delay/Disruption Tolerant Networking (DTN) background
- IP and Interplanetary Internet Naming/Addressing Comparison
- DTN Naming and Addressing
- Space vs. Terrestrial DTN Naming
- CBHE Conformant Naming
- Node and Service Number Assignment
- DTN Internetworking Examples
- Conclusions

Disruption Tolerant Networking Background

- DTN Bundle Protocol provides an internetwork layer that conveys data in an internetwork data unit, called a *bundle*
- Bundle Protocol does not assume continuous connectivity and specifically allows for in-network data storage
- BP can support a multitude of different endpoint naming schemes
  - All adhere to a standard endpoint name identification pattern
- Little work done on how routing will work when source and destination endpoints are identified by names expressed in different schemes
  - even the exact use of the default ‘dtn’ scheme is not fully standardized
- This presentation: Endpoint naming developed for space internetworking domain
  - meeting the needs of the space community
  - enabling the network to scale up to large numbers of nodes
  - preserving interoperability with an emerging terrestrial DTN infrastructure

Comparison of IP and DTN Naming

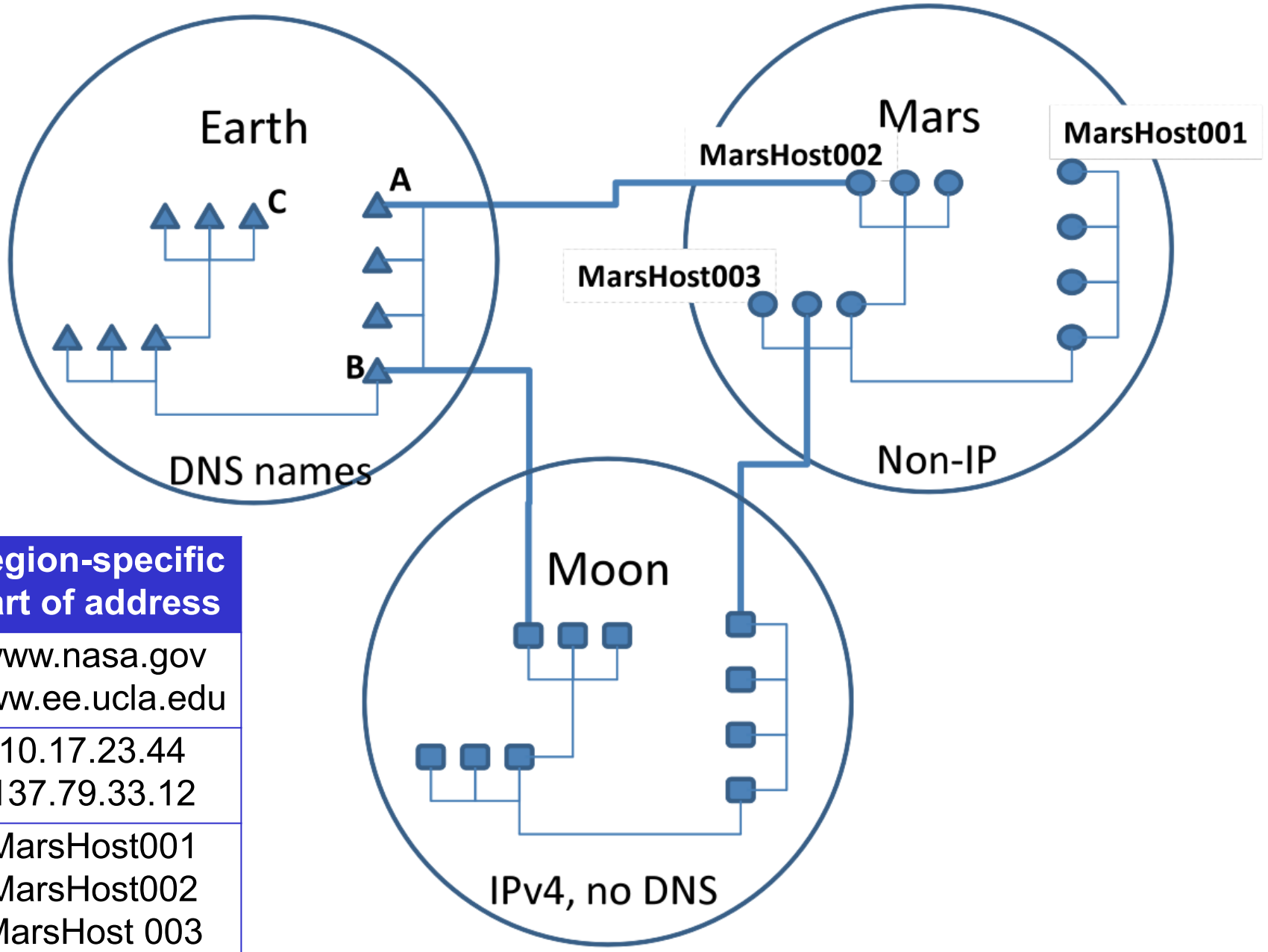
Internet Naming and Addressing

- IP uses address
  - address is different from a *name*: address has “topological significance”
  - names such as www.nasa.gov must be resolved to addresses before communication can begin
- IP routing efficiency improved by IP address aggregation, assigning addresses with a common prefix to nodes residing in a common subnet

Interplanetary Internet Naming and Addressing

- Original design was on two-level hierarchical endpoint identification. Endpoint ID tuple consisted of a *region* and a *region-specific-part*.
  - Regions were intended to be topologically significant and useful for coarse-grained routing
  - E.g., ‘Earth’, ‘Mars’, and ‘Moon’ might be useful regions
  - region-specific-parts might not have topological significance
  - DNS and IP addressing might be used within region
- Late binding
  - accommodates node mobility with high delivery latency
  - Endpoint ID can signify e.g. role (“current mission operations officer”) or attribute (“all rovers within R meters of location XYZ”)

Interplanetary Internet Naming Example



Region	Region-specific part of address
Earth	www.nasa.gov www.ee.ucla.edu
Moon	10.17.23.44 137.79.33.12
Mars	MarsHost001 MarsHost002 MarsHost 003

DTN Naming and Addressing

- DTN naming/addressing is generalization of original Interplanetary Internet design
- DTN Endpoint Identifiers (EIDs) are Universal Resource Identifiers (URIs)
  - Form: *scheme_name*:*scheme_specific_part*
- Neither scheme name nor scheme-specific-part is required to have topological significance
- scheme-specific-part may have topological significance, may be a name, or may be an expression which must be evaluated into a name or address
- 'dtn' scheme, DTN2 reference: dtn://*machineID*/*appID* where
  - ***machineID*** is ASCII string that identifies computer
  - ***appID*** is ASCII string that identifies application using the DTN protocol stack identified by the *machineID*

Example DTN Scheme EIDs

- **dtn://myMachine/dtn_recv**
- **dtn://everyoneWithin100MetersOfMe**
  [Local personal area communications]
- **dtn://rover3.mars.sol/other**
  [Note: while rover3.mars.sol is formatted as a DNS name, it is just a string to the dtn scheme]
- **dtn://allMarsOrbiters/cmdApp**
- **dtn://allSpacecraftInCruise/otherApp**
  [An example of a destination EID whose membership might change with time]
- **dtn://128.29.23.37/dtncpd**
  [Note: in this context, 128.29.23.37 is ***not*** an IP address, it's just a string]
- Note: *connotations* (e.g., allMarsOrbiters) are meaningless without a routing protocol that supports them

Routing Table Example

Destination	Next Hop
dtn://myMachine/*	Link1
dtn://*_yellow_*/*	Link2
dtn://*/*	Link3
dtn://lat35.*lon-74.*	Link2
otherScheme:*	Link6

- Illustrates use of globbing in DTN2 reference implementation semantics that allows for wildcard characters
- ‘dtn://lat35.*lon-74.*’: all machines bounded by 1 degree latitude and longitude
- otherScheme:*’: routes all bundles that use the naming/addressing scheme ‘otherScheme’ out Link6

Space vs. Terrestrial DTN Naming

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Issue	Space DTN Environment	Terrestrial DTN Environment
Capability / Power of Naming	Limited (at least for the short term): need to address ‘applications’ on ‘hosts’	Researchers looking at everything from ‘IP-like’ to content-based addressing to sensor network queries
Scalability	To 1000s of nodes spread across 10s of agencies	To millions of nodes spread across thousands of administrative entities
Mobility	Limited, planned	Common, unscheduled

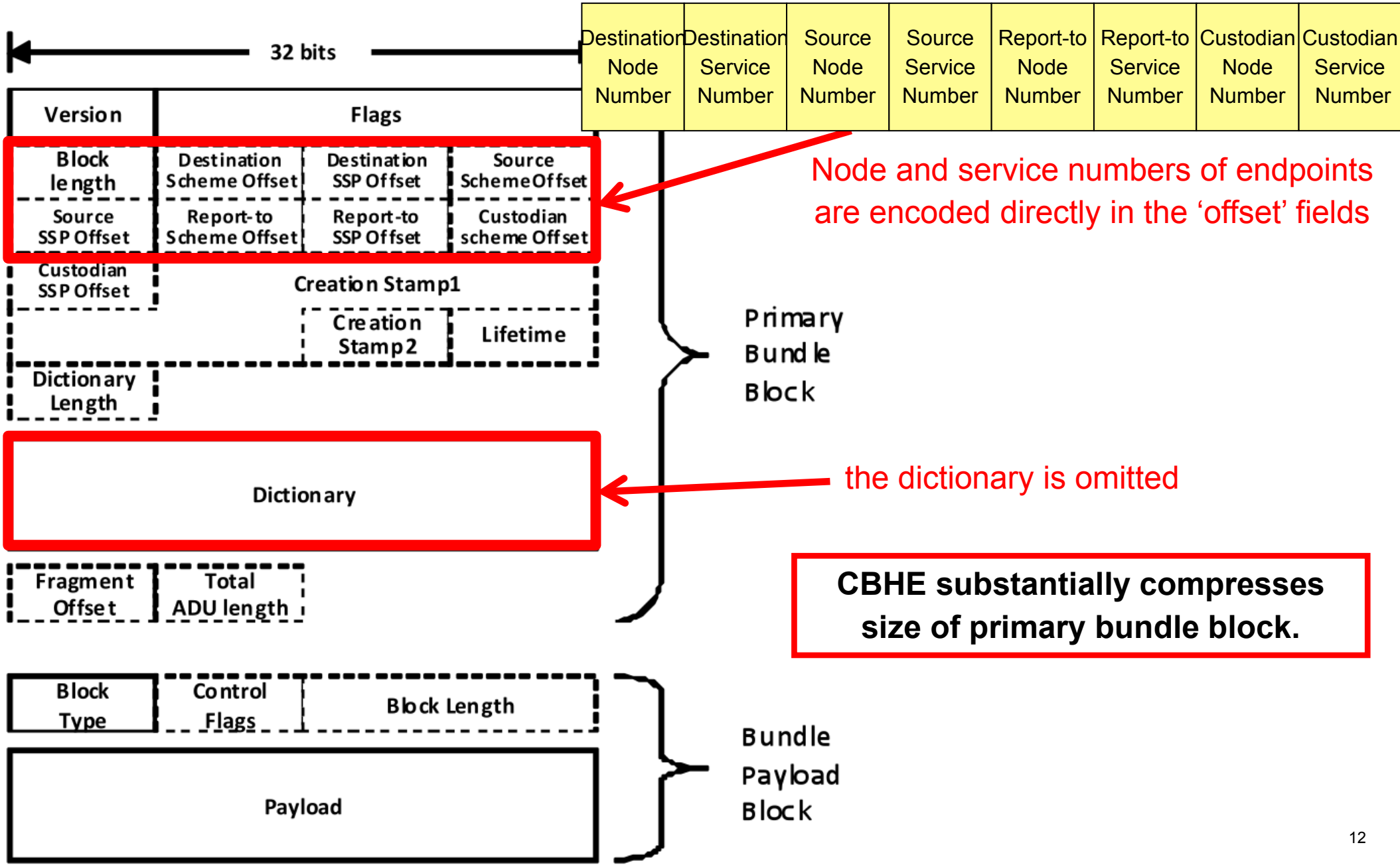
CBHE-Conformant Naming

- Compressed Bundle Header Encoding (CBHE) method reduces bundle protocol (BP) overhead
- scheme-specific part of CBHE-conformant scheme has structure *node_number.service_number*
  - *node_number* and *service_number* are nonnegative integers
- 'ipn' scheme is CBHE conformant. Examples EIDs:
  - ipn:0.0
  - ipn:631.0
  - ipn:233.11
- Unlike IP, node numbers uniquely identify communicating entities, and have no topological significance
- Service number is a demultiplexing token, to identify a particular application on a DTN node (~UDP port number)

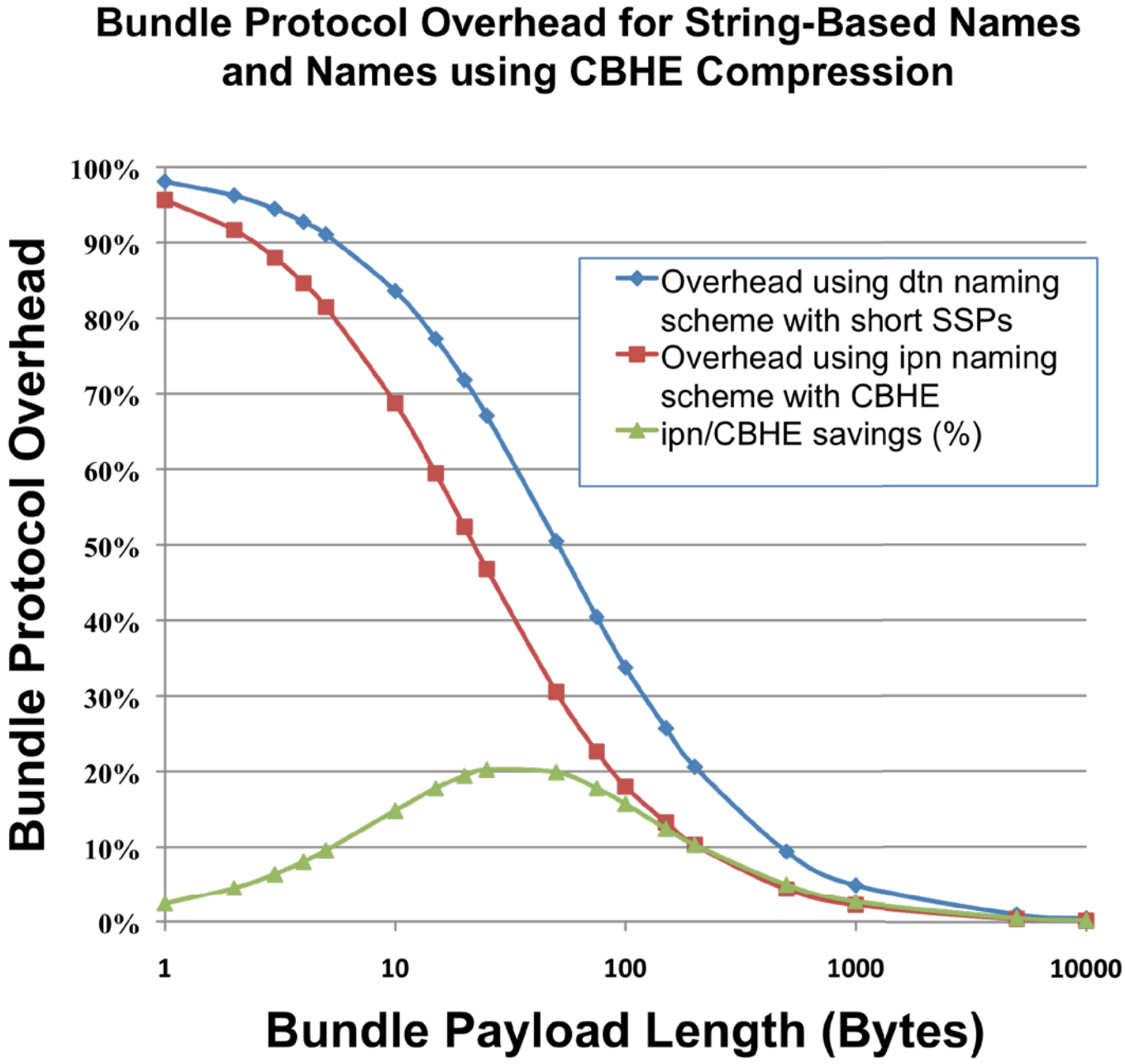
CBHE-Conformant Naming (cont'd)

- Disadvantages:
  - Not user-friendly
  - Need something similar to DNS; expect name update rate need to be slower for space
- Advantages of numeric node identifiers & demux tokens: Allows compression into binary rather than strings
  - Faster processing (integer storage, retrieval, and comparison operations)
  - Compressed header lowers overhead (significant for small bundles)
- Important advantages in the resource-constrained communications environment of space flight missions
- NASA's Space DTN program has adopted the ipn scheme as the mandated minimum capability for endpoint naming

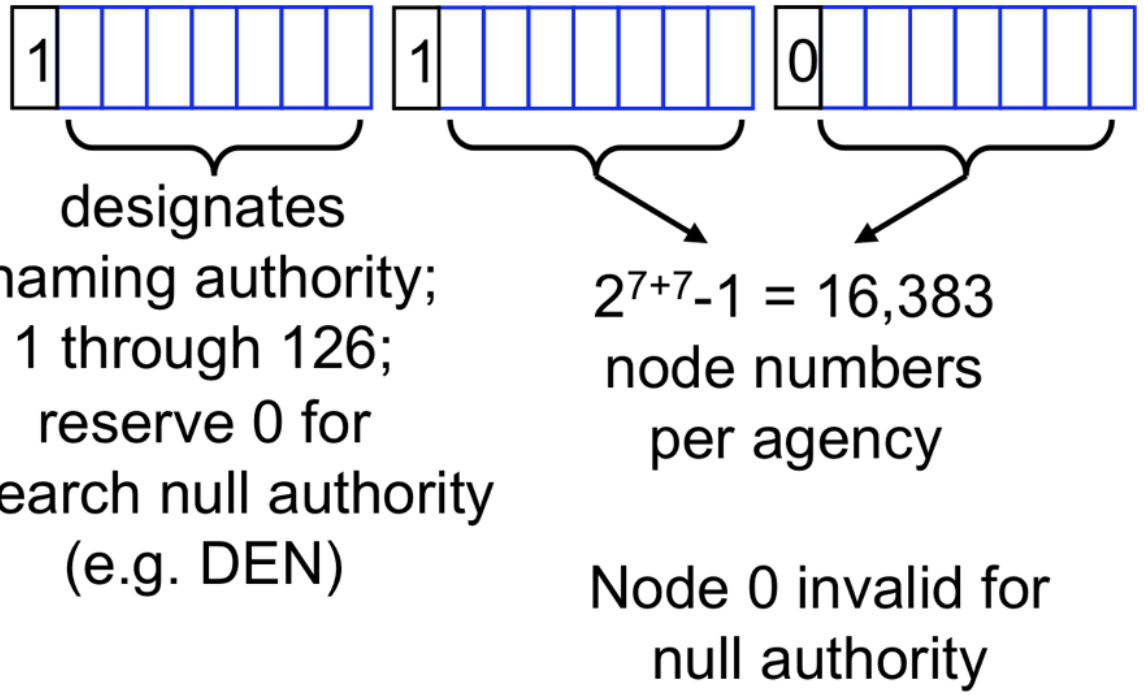
Bundle Protocol Structure and CBHE



BP Overhead Comparison



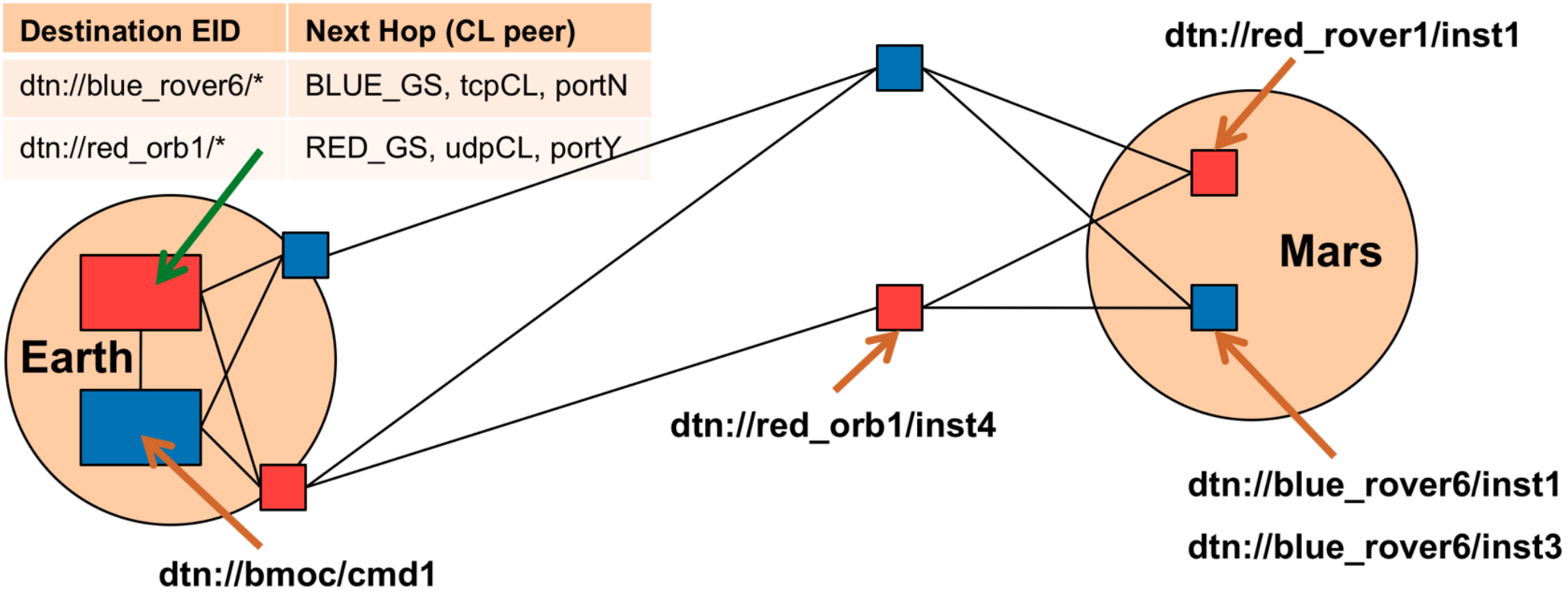
Node and Service Number Assignment



- 3-octet Self-Delimiting Numeric Value (SDNV) proposed for node number and service number assignment
- Consider as special case of 4-octet based structure for extensibility
- Will be managed by CCSDS
  - Space Assigned Numbers Authority (SANA) draft generated

Internetworking Multiple Schemes: Example 1

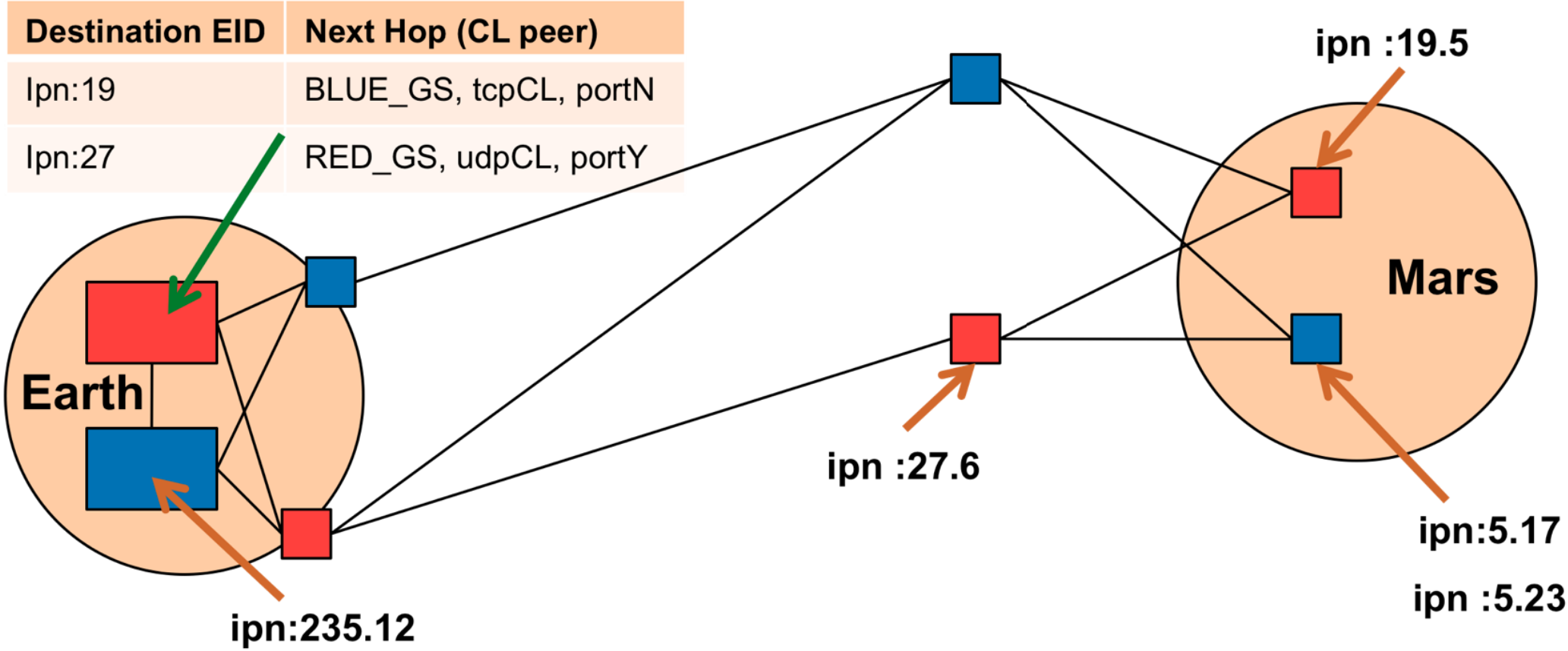
Destination EID	Next Hop (CL peer)
dtn://blue_rover6/*	BLUE_GS, tcpCL, portN
dtn://red_orb1/*	RED_GS, udpCL, portY



Example routing with standard dtn naming

Internetworking Multiple Schemes: Example 2

Destination EID	Next Hop (CL peer)
Ipn:19	BLUE_GS, tcpCL, portN
Ipn:27	RED_GS, udpCL, portY

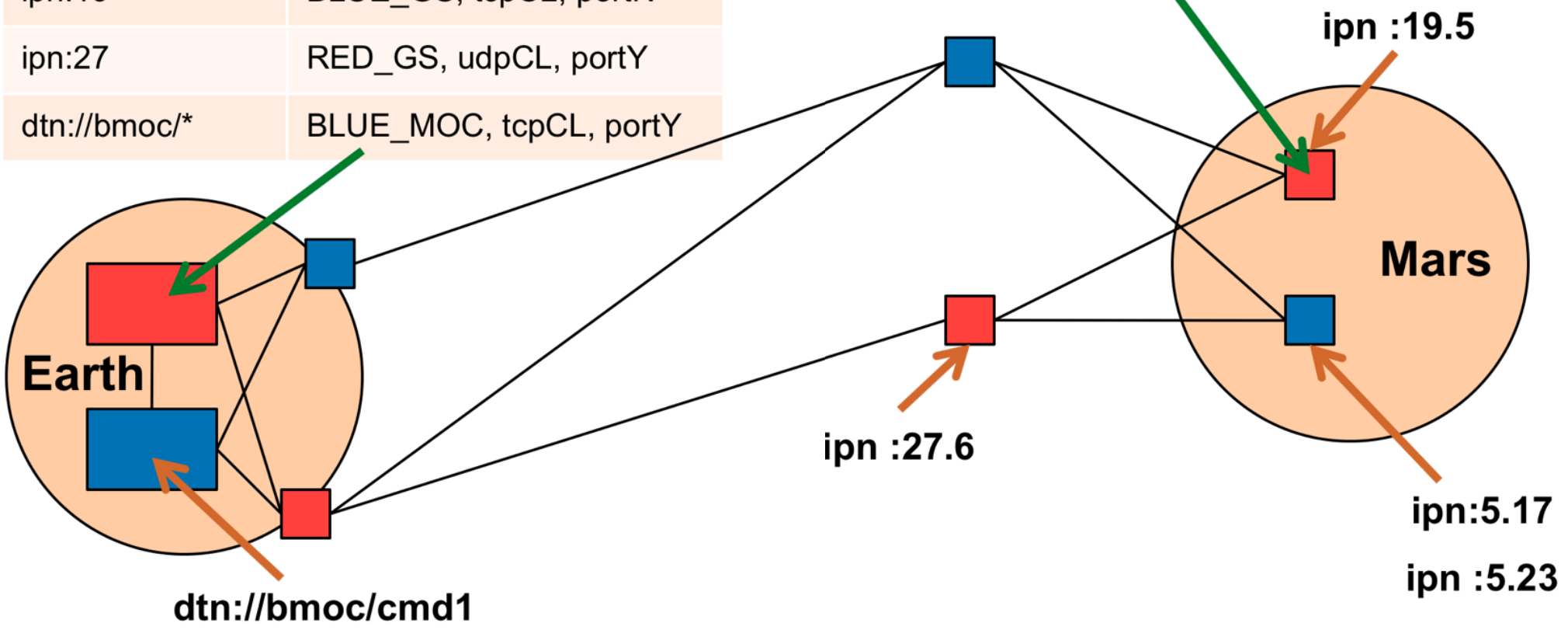


Example routing with ipn naming

Internetworking Multiple Schemes: Example 3

Destination EID	Next Hop (CL peer)
ipn:19	BLUE_GS, tcpCL, portN
ipn:27	RED_GS, udpCL, portY
dtn://bmoc/*	BLUE_MOC, tcpCL, portY

Destination EID	Next Hop (CL peer)
ipn:27	RED_ORB, udpCL, portY
dtn://bmoc/*	BLUE_ORB, tcpCL, portY



Example routing with mix of ipn and standard dtn naming

Conclusions

- Progress in naming Endpoint IDs (EIDs) in Delay/Disruption Tolerant Networking for the space domain has been presented
- Simple “ipn” scheme
  - Will be implemented by all NASA space DTN nodes
  - Provides processing and transmission economy needed in space
  - EIDs are integers *x.y* analogous to host name and port number in IP protocols
- Alternative schemes are not precluded
  - General Bundle Protocol naming interoperation allowed
- Node number assignment strategy presented
  - Bandwidth-efficient, fair
  - Node number assignments may be designated by CCSDS Space Assigned Numbers Authority (SANA)

BACKUP

Disruption Tolerant Networking Background

- Existing TCP/IP Internet service model makes implicit assumptions
  - an end-to-end path exists between a data source and its peer
  - the maximum round-trip time is not excessive
  - the end-to-end packet drop probability is small
- "Challenged networks," in particular space networks, can violate one or more of these assumptions
  - "Opportunistic networks", "intermittently-connected networks", "episodic networks"
- Space networks generally
  - have paths whose links are not contemporaneous due to occultation or unavailable resources because of over-subscribed demand, e.g., Deep Space Network assets
  - have very long light-time propagation delays on links, or long delays due to scheduling of resources
  - form bidirectional communications via two unidirectional links in opposite directions having different data rates
  - can have error rates considerably higher than terrestrial links