

Enhanced Custody Transfer and Status Reporting for Delay Tolerant Space Networks

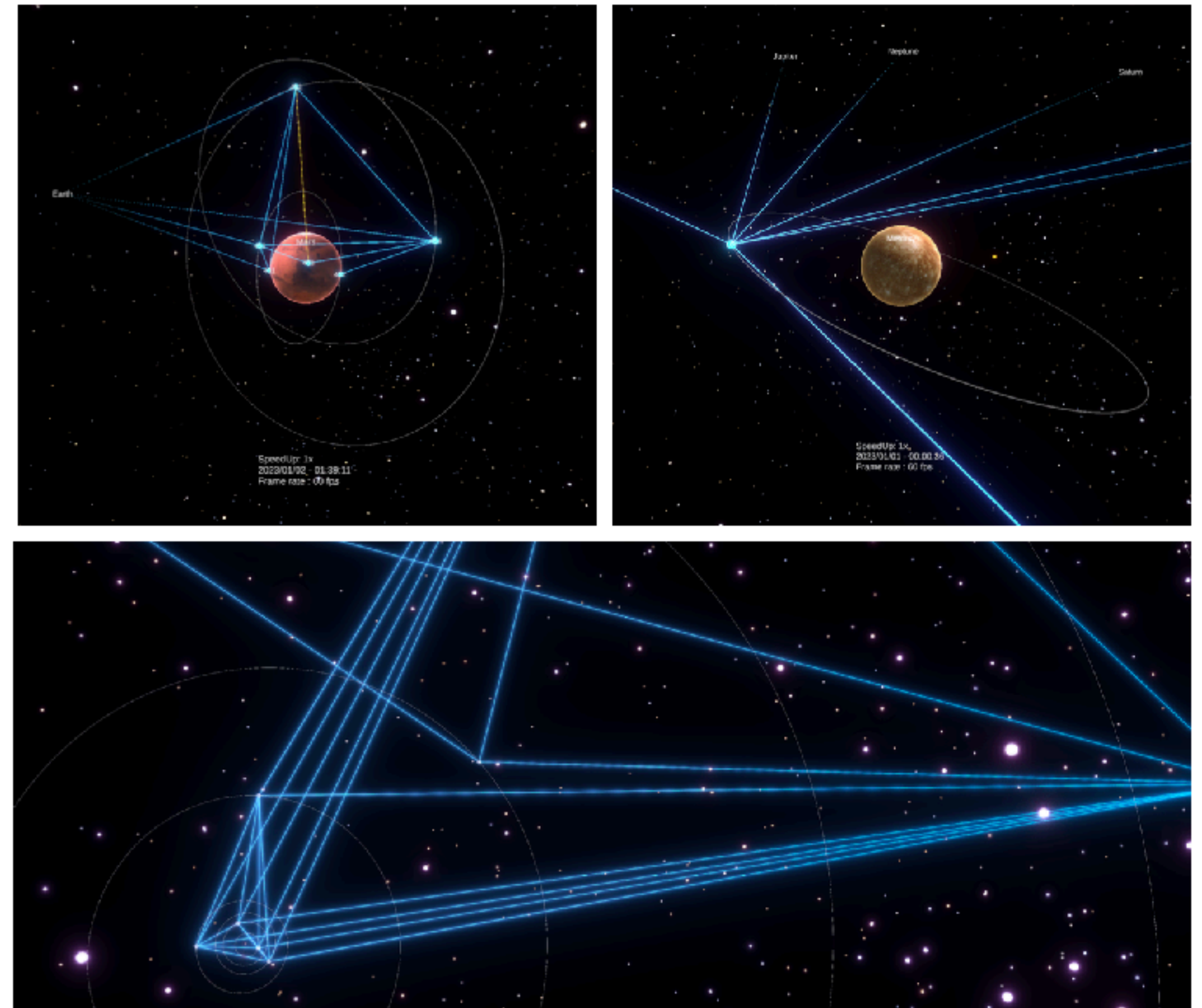
Alice Le Bihan, Felix Flentge, Juan Fraire

18/10/2024

The Solar System Internet

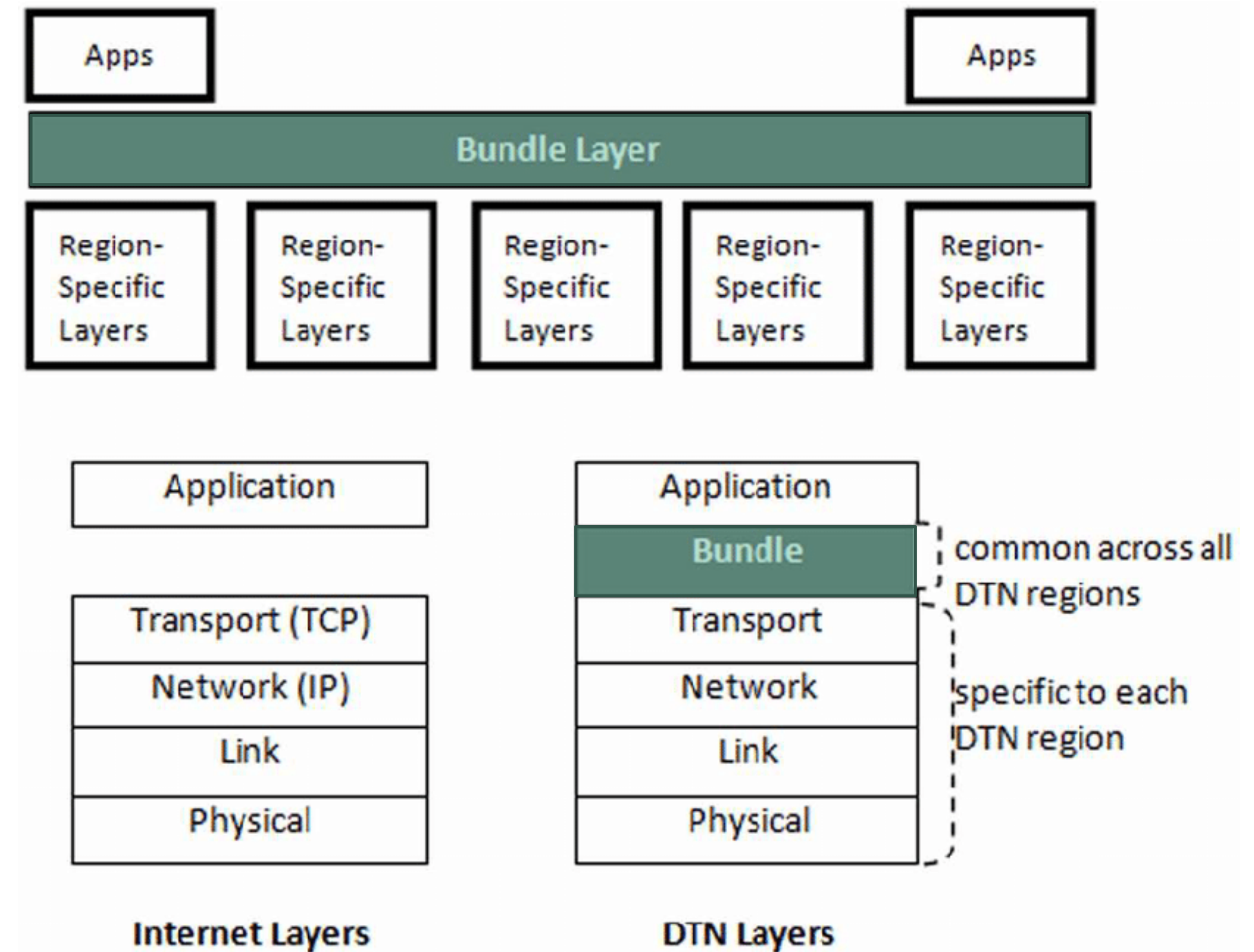
Could communicating with distant spacecrafts be as easy as connecting to the internet?

- Moving away from point-to-point communication
- Interconnecting a set of network nodes
- Developing adapted protocols above which standard applications can run



Delay and Disruption Tolerant Networking (DTN)

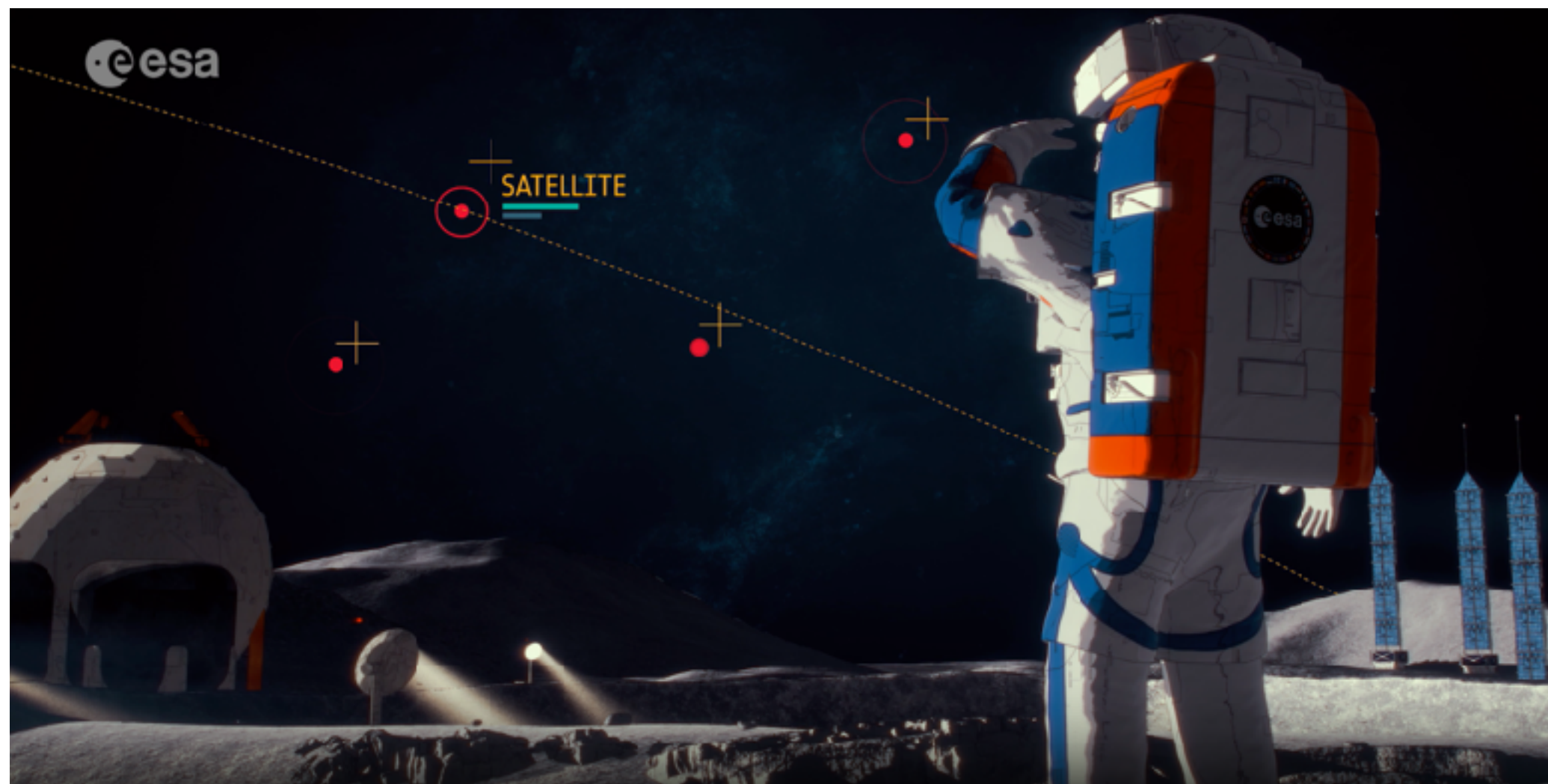
- DTN is the **network architecture** proposed to overcome the issues of **latency** and **intermittent connectivity** in deep space links
- The protocol running on nodes in a Delay Tolerant Network is the **Bundle Protocol (BP)**
- The Protocol Data Unit of BP is a Bundle
- BP uses a store and forward mechanism



Delay and Disruption Tolerant Networking (DTN)

DTN and BP:

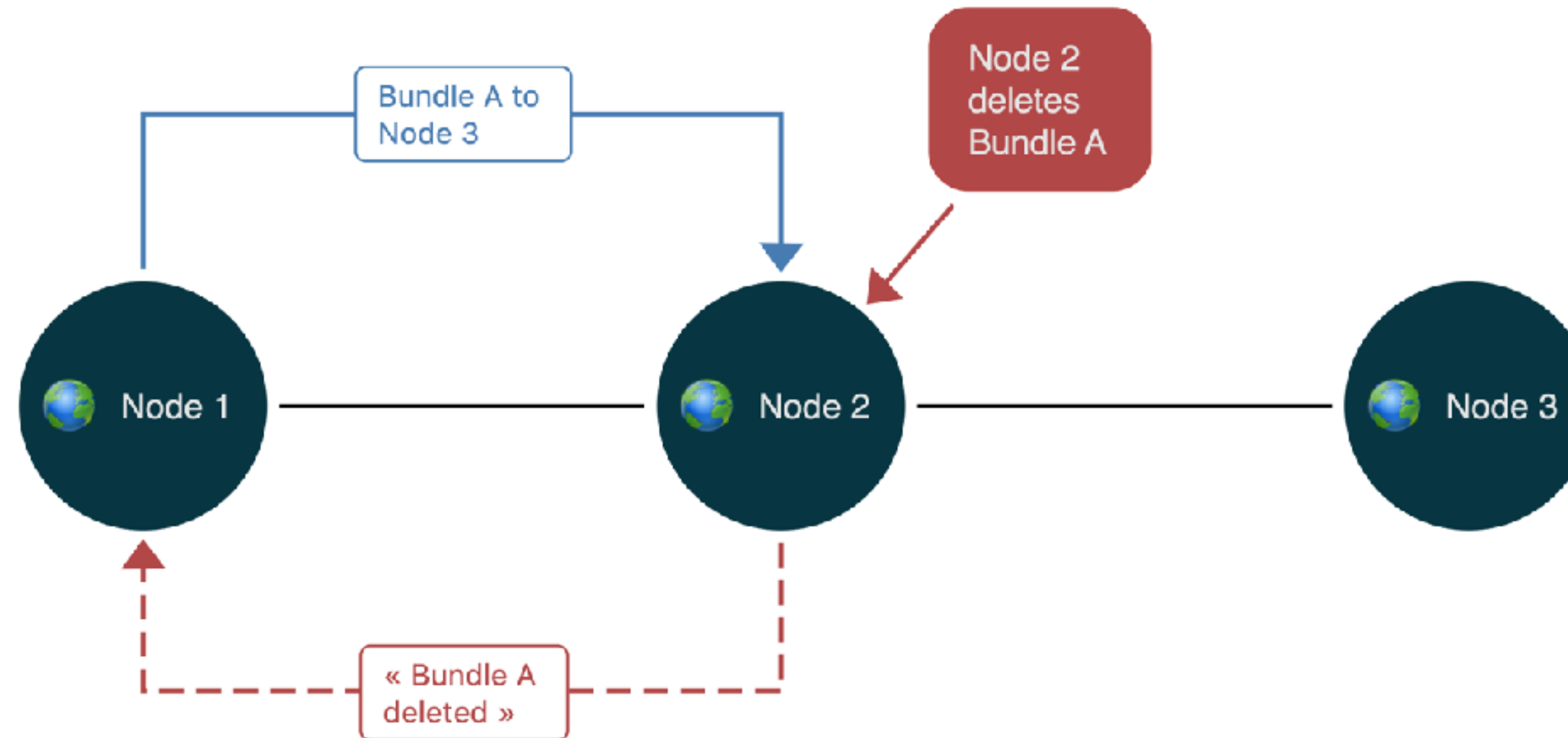
- are considered for **Moon** [1], **Mars** and **Earth-observation** scenarios



- The BP implementation at ESA is called **ESA BP**

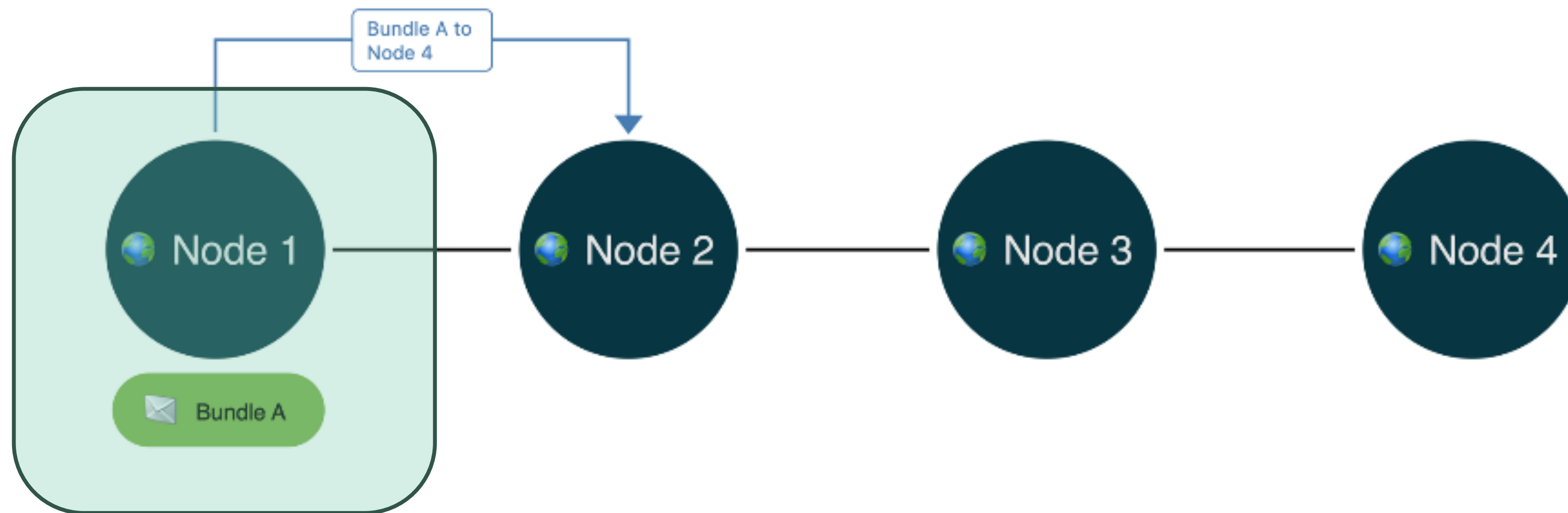
Bundle Status Reporting

Reporting mechanism to give information on the **status of a bundle** in the network



Custody Transfer

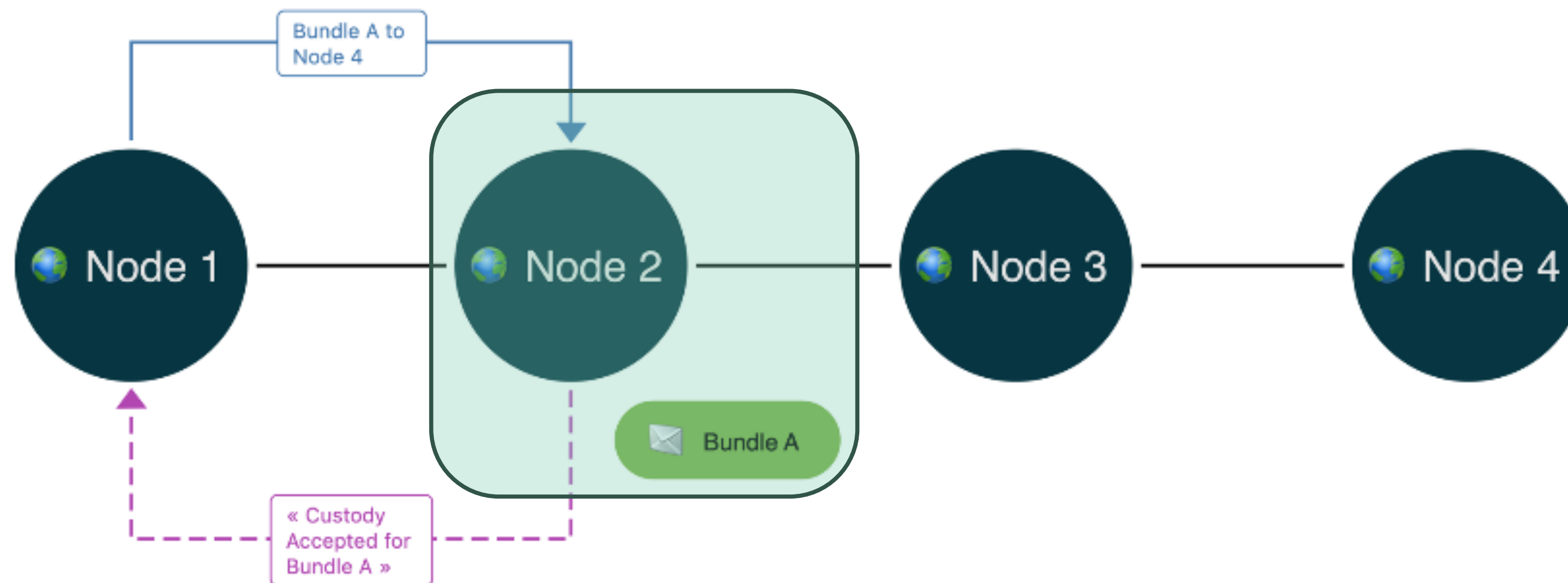
Custody Transfer moves the **retransmission responsibility** of a bundle to subsequent nodes in the network



 Current custodian

Custody Transfer

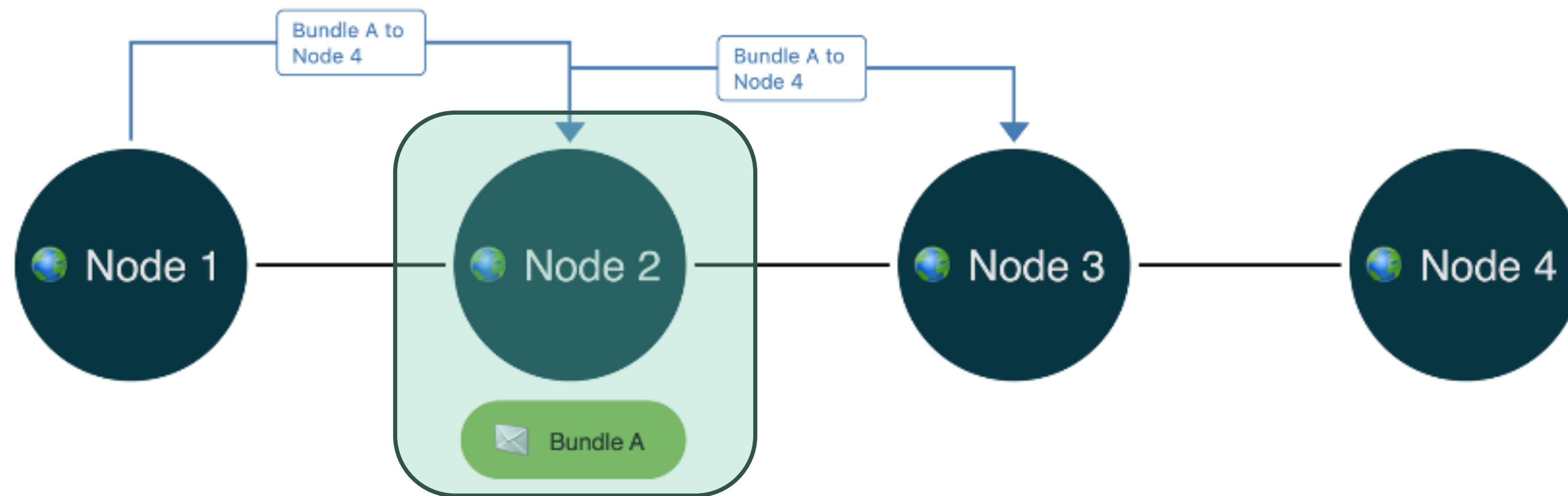
Custody Transfer moves the **retransmission responsibility** of a bundle to subsequent nodes in the network



 Current custodian

Custody Transfer

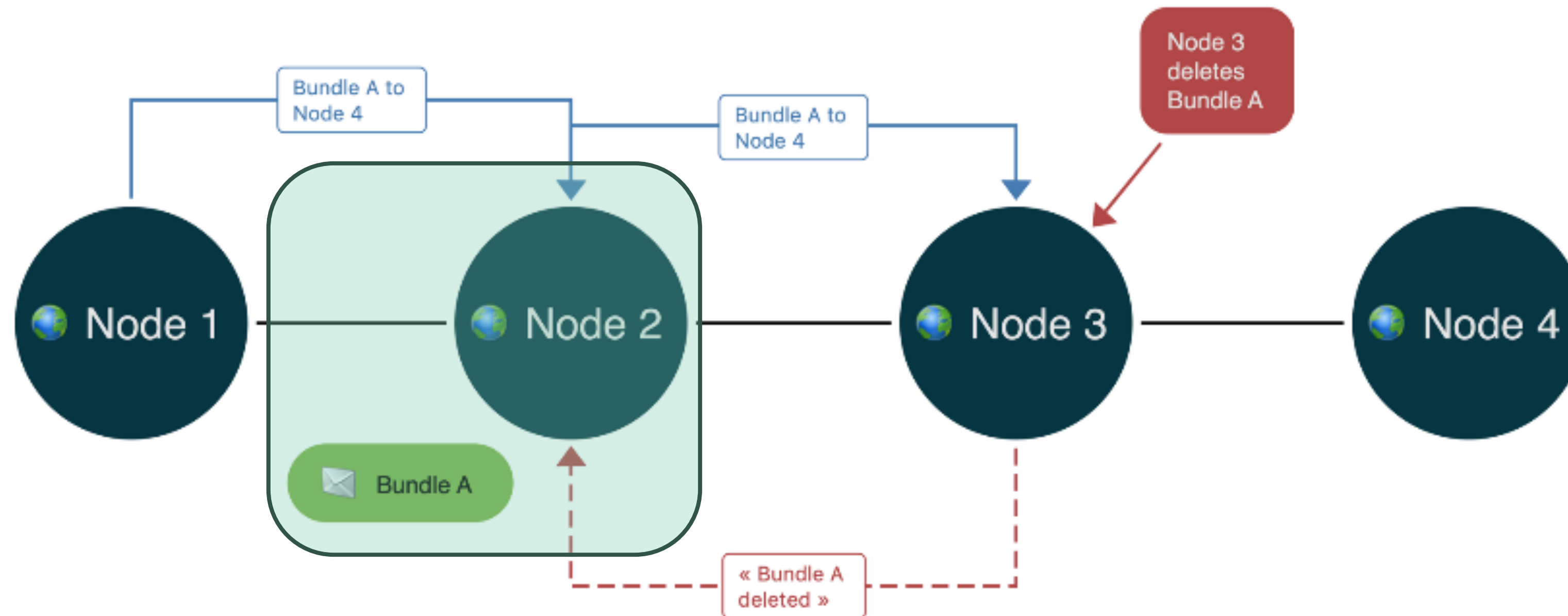
Custody Transfer moves the **retransmission responsibility** of a bundle to subsequent nodes in the network



 Current custodian

Custody Transfer

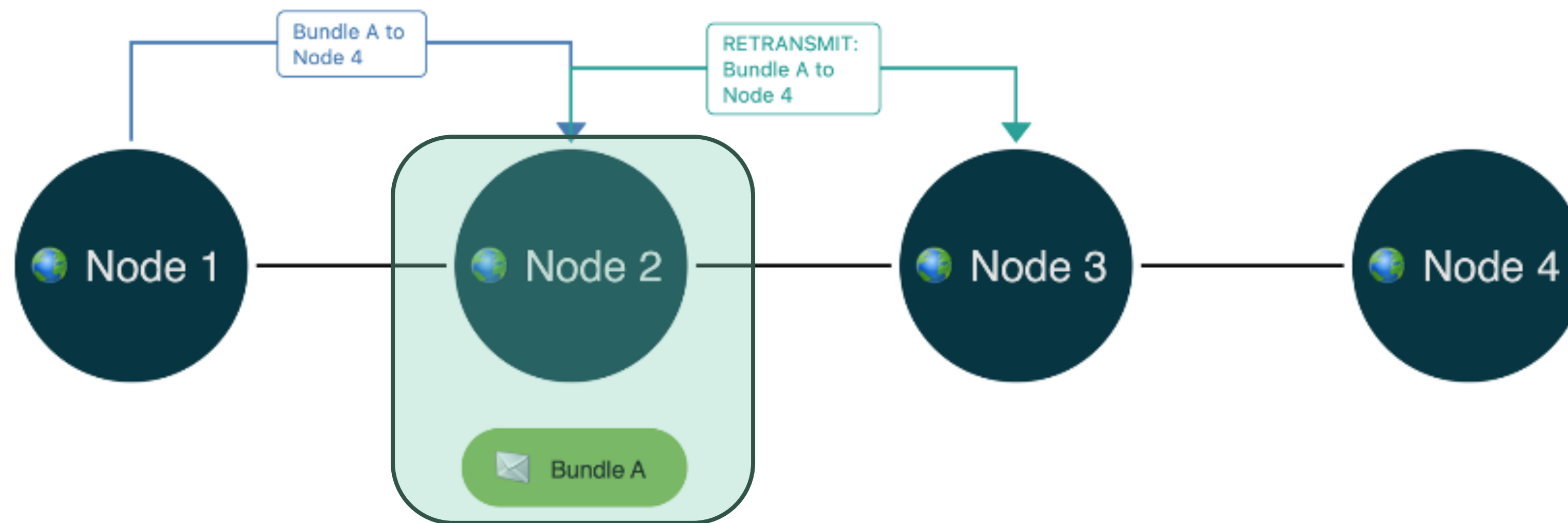
Custody Transfer moves the **retransmission responsibility** of a bundle to subsequent nodes in the network



 Current custodian

Custody Transfer

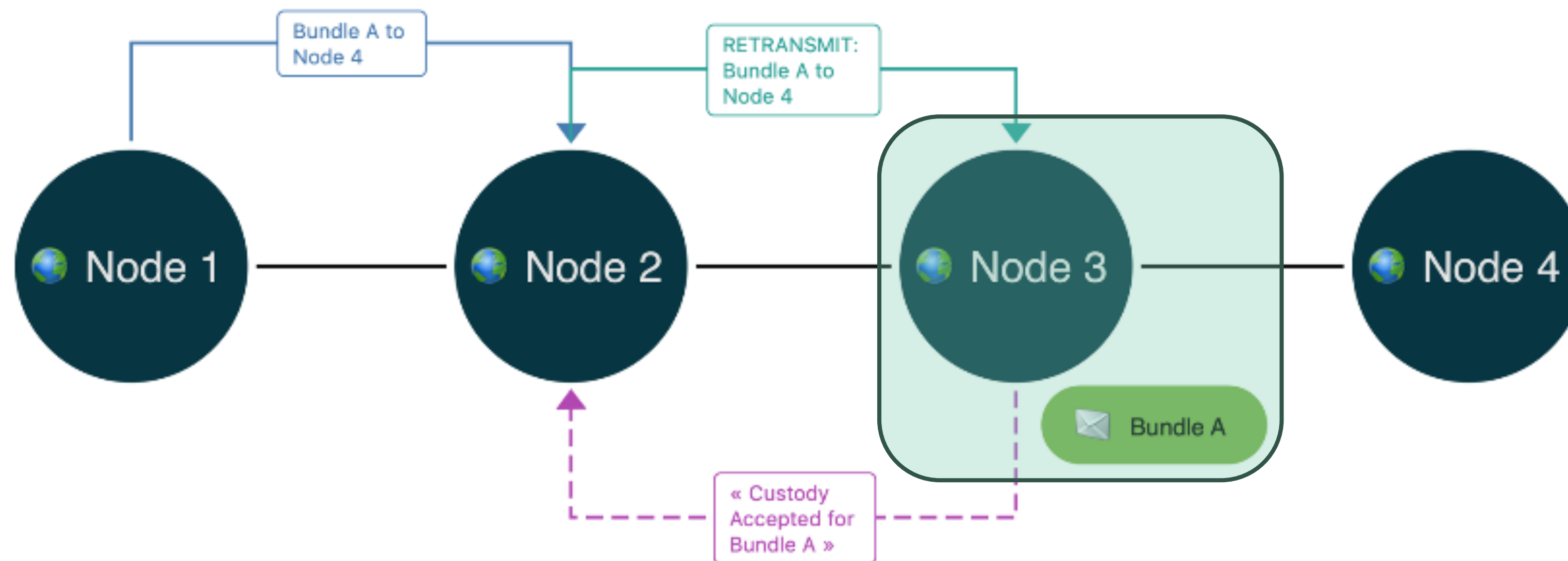
Custody Transfer moves the **retransmission responsibility** of a bundle to subsequent nodes in the network



 Current custodian

Custody Transfer

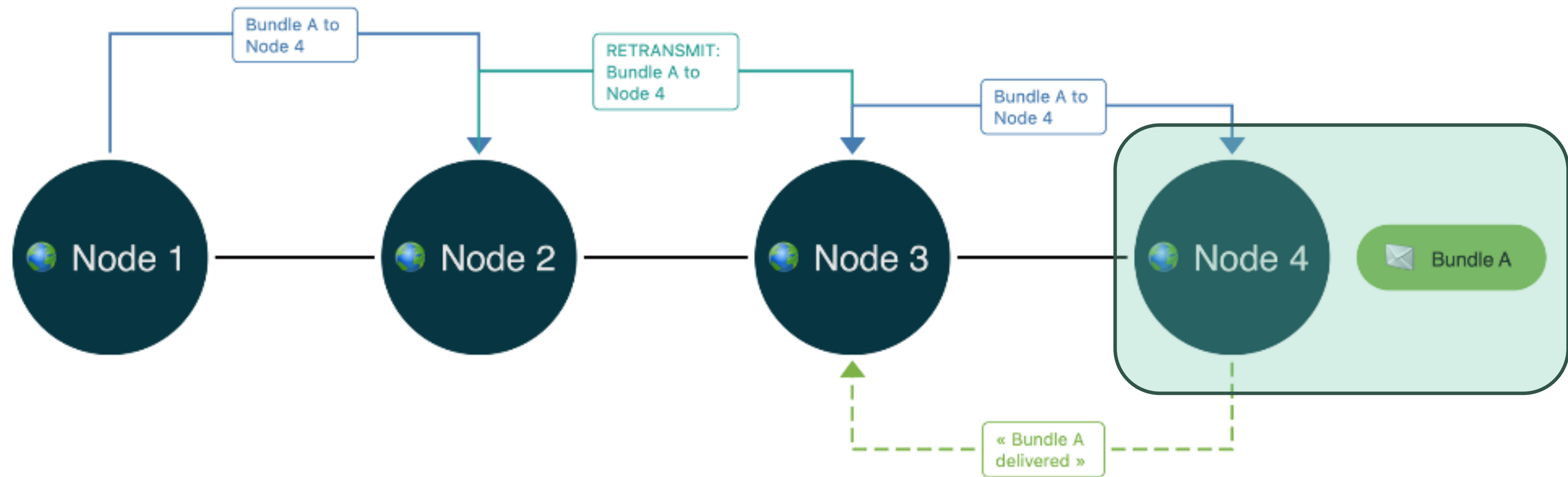
Custody Transfer moves the **retransmission responsibility** of a bundle to subsequent nodes in the network



 Current custodian

Custody Transfer

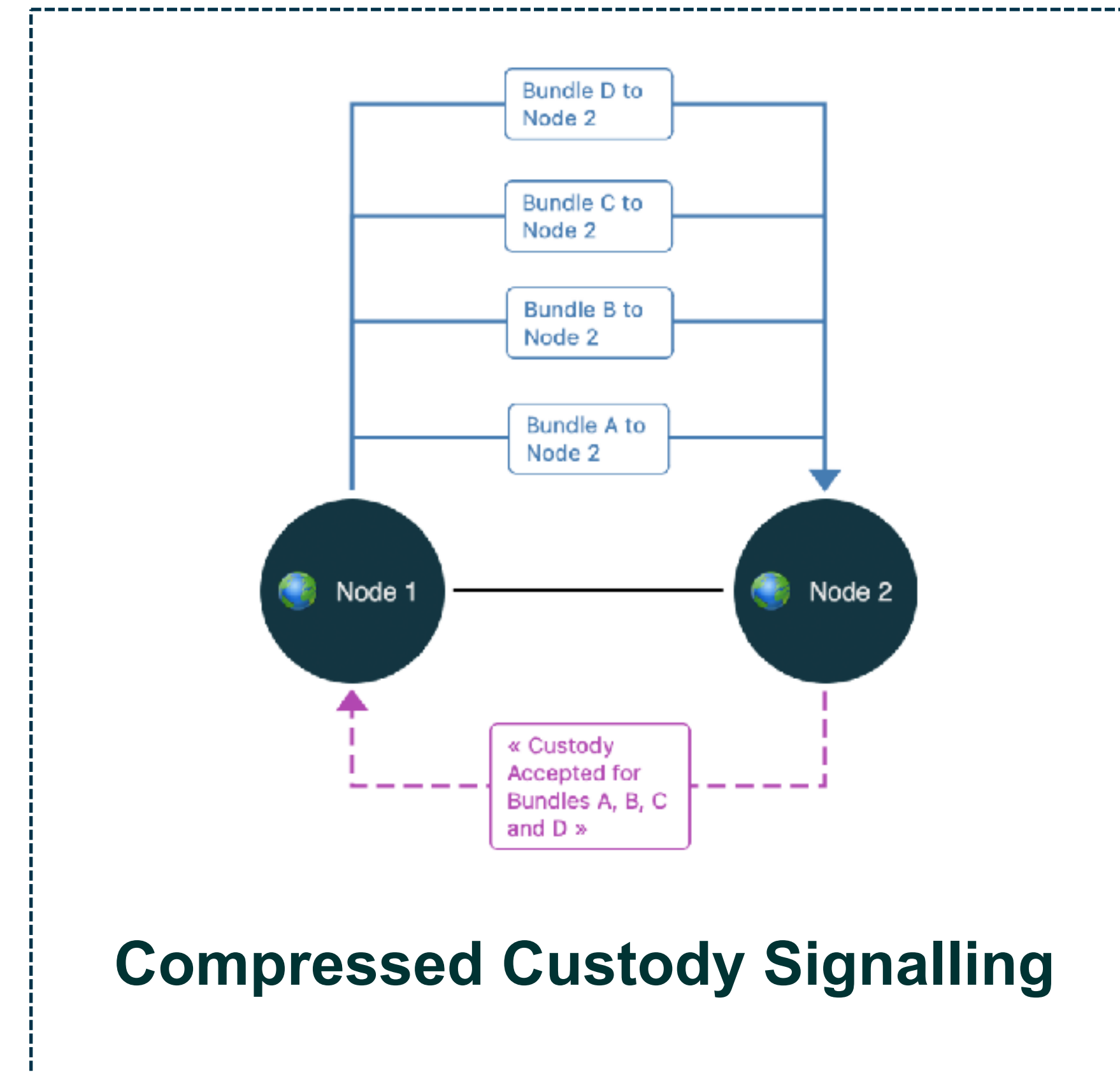
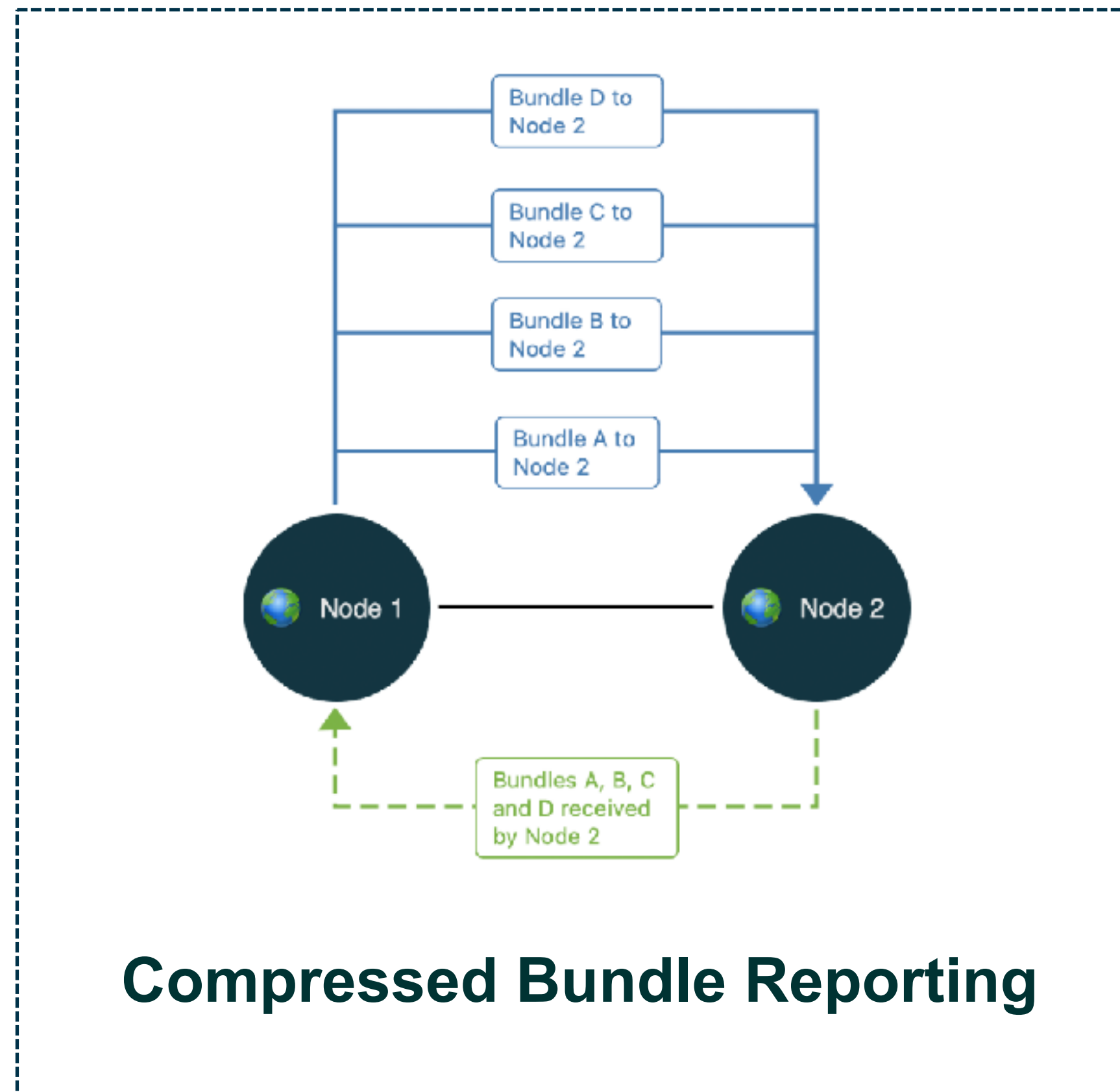
Custody Transfer moves the **retransmission responsibility** of a bundle to subsequent nodes in the network



 Current custodian

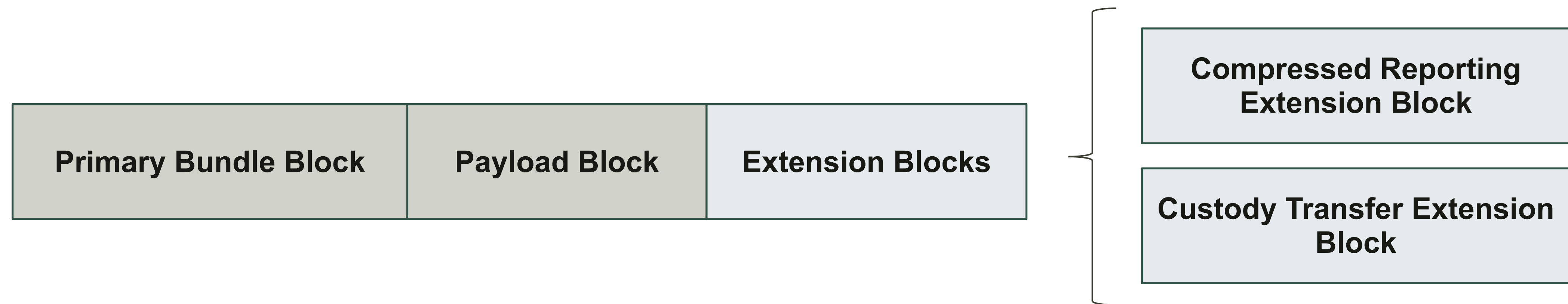
Toward more efficiency

Because both mechanisms are quite **inefficient** (one Administrative Record is sent per bundle to report on), new protocol extensions were introduced:



Extension Blocks and Administrative Records

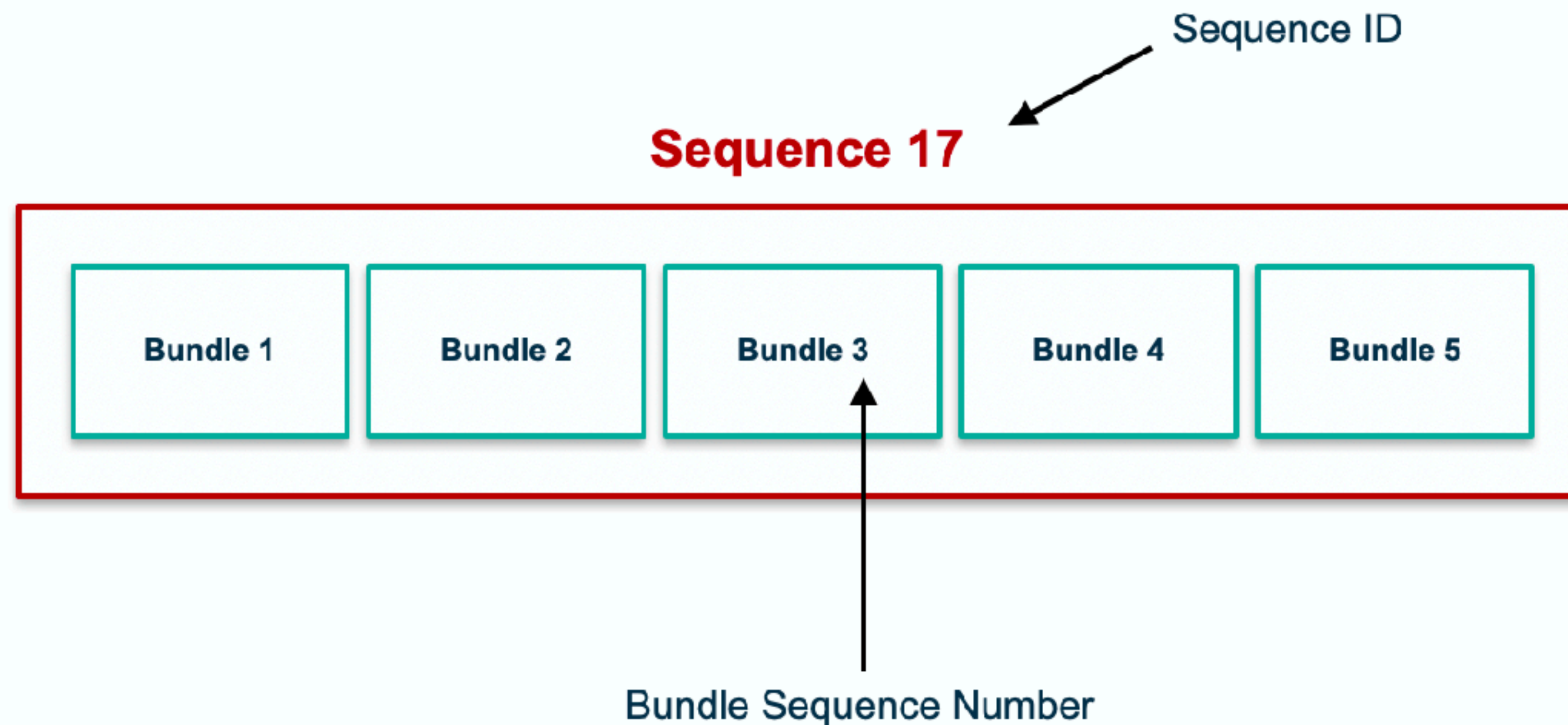
- A Bundle is composed of a sequence of two or more **blocks**
- Two new **extension blocks** were defined for CBR and CCS:



- **Administrative Records** (special Application Data Units of BP) carry protocol-related information
- Two new ones were also defined: Compressed Reporting Signal and Compressed Custody Signal

Bundle Sequence Numbers and IDs

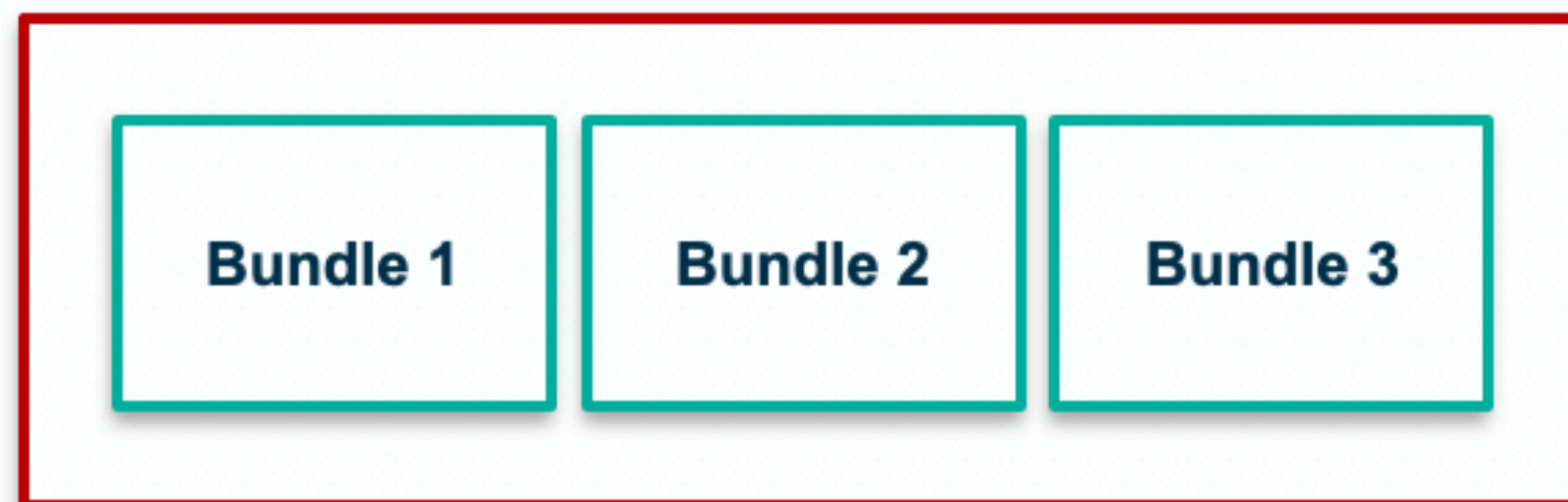
- Each bundle with CCS or CBR requested gets put in a sequence identified by a **Sequence ID**
- The bundle gets a **Bundle Sequence Number** inside its sequence
- The Bundle Sequence Numbers are generated by **Bundle Sequence Counters**



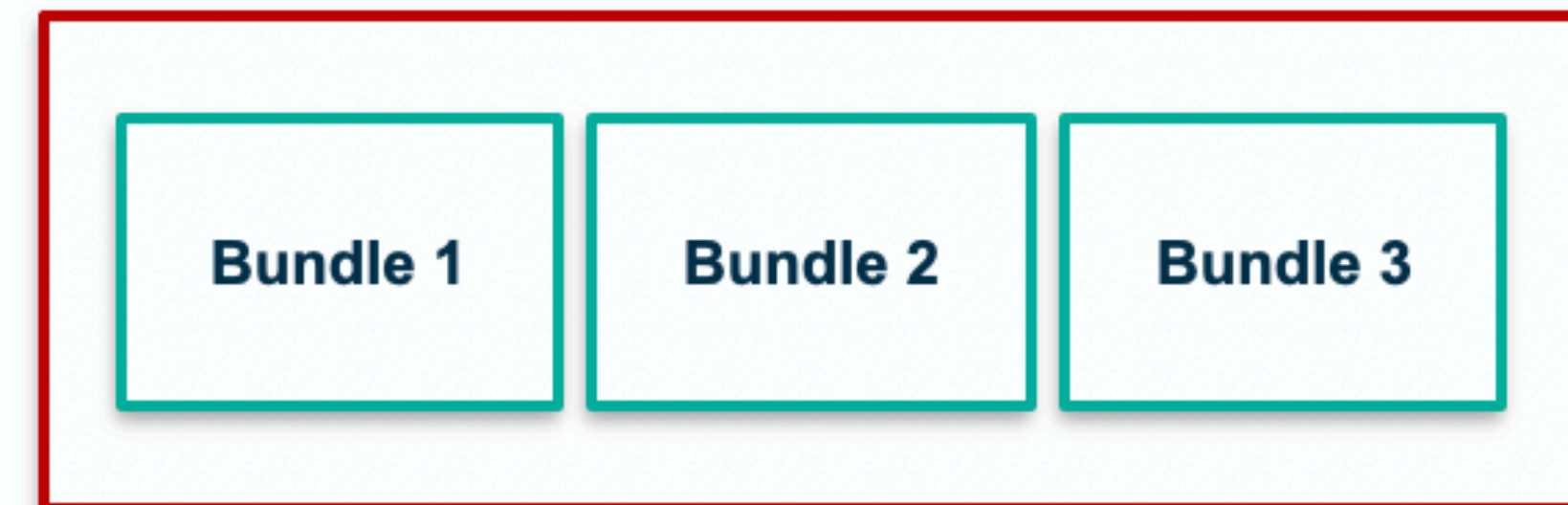
Bundle Sequence Numbers and IDs

- This gives a lot of **flexibility** (one sequence per client, one sequence per next hop, etc)
- The most common case is **one sequence per destination node** (sequence ID = 0)
 - => A Bundle Sequence Counter is mapped either to a Bundle Sequence ID (if $\neq 0$) or to a destination node

Sequence 0, destination endpoint 2.1



Sequence 0, destination endpoint 8.9



Uniquely identifying a bundle

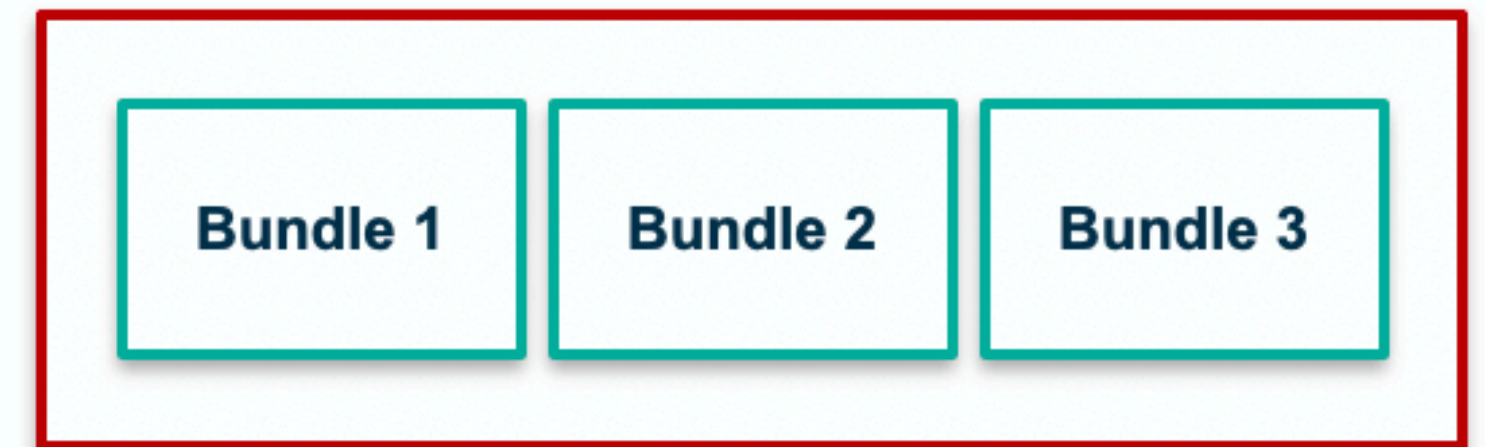
To uniquely identify a bundle with a **Bundle Sequence ID $\neq 0$** :

- Bundle Sequence Number
- Bundle Sequence ID
- Block Source Administrative Endpoint ID

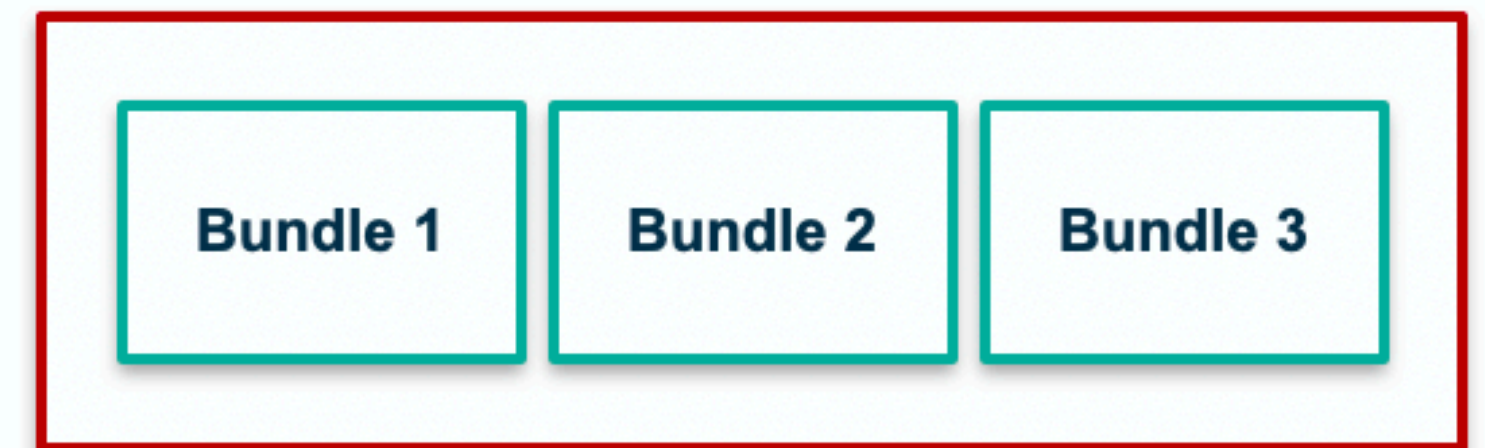
To uniquely identify a bundle with a **Bundle Sequence ID = 0**:

- Bundle Sequence Number
- Block Source Administrative Endpoint ID
- Bundle Destination Endpoint ID

Sequence 17

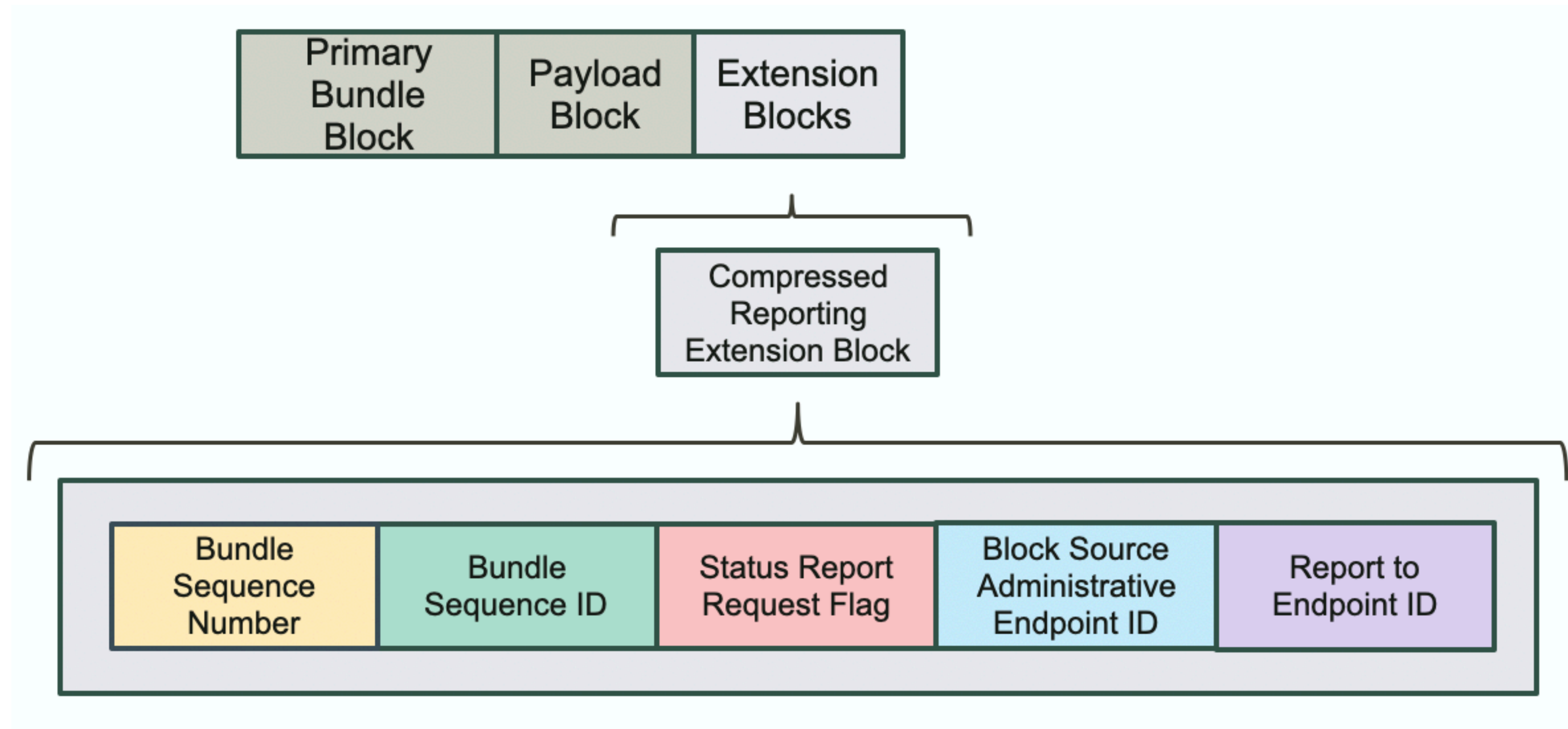


Sequence 0, destination endpoint 3.1



Compressed Reporting Extension Block

- Added by the node requesting reports, unchanged by subsequent nodes



Compressed Reporting Signal

A Compressed Reporting Signal is a CBOR Map:

- **Status report reason** (key)
 - 0: Reception report
 - 1: Forwarding report
 - 2: Delivery report
 - 3: Deletion report
- **Bundle Sequence Collection** (value)

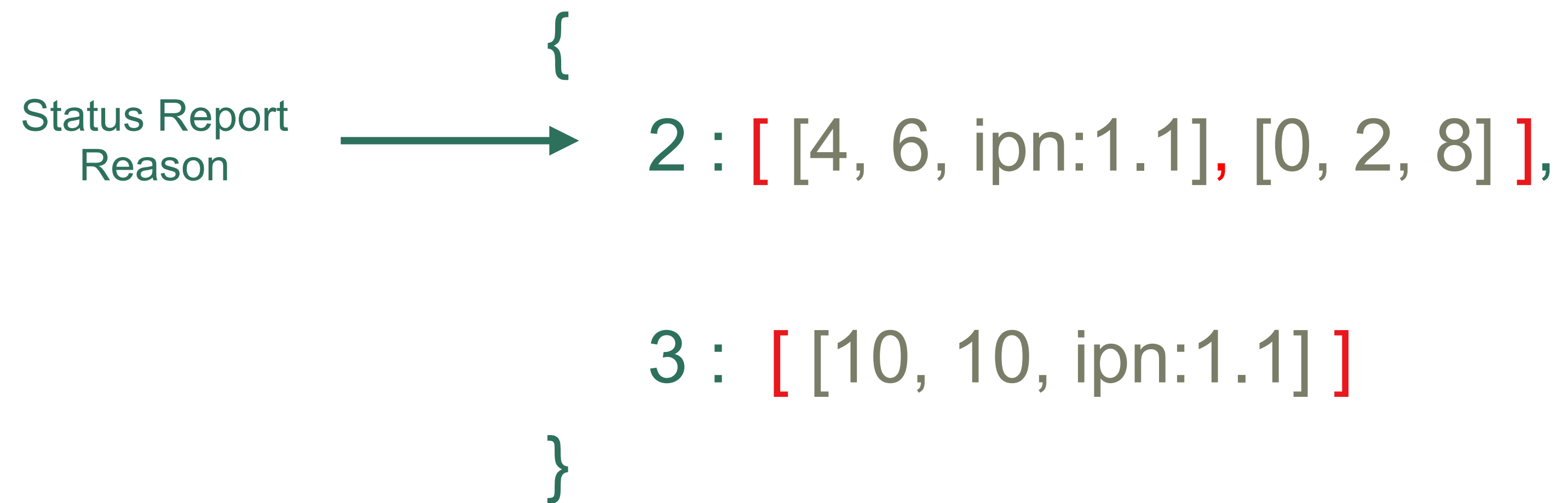
```
{  
  2 : [ [4, 6, ipn:1.1], [0, 2, 8] ],  
  3 : [ [10, 10, ipn:1.1] ]  
}
```

They are sent based on a **bundle threshold** or a **time threshold**

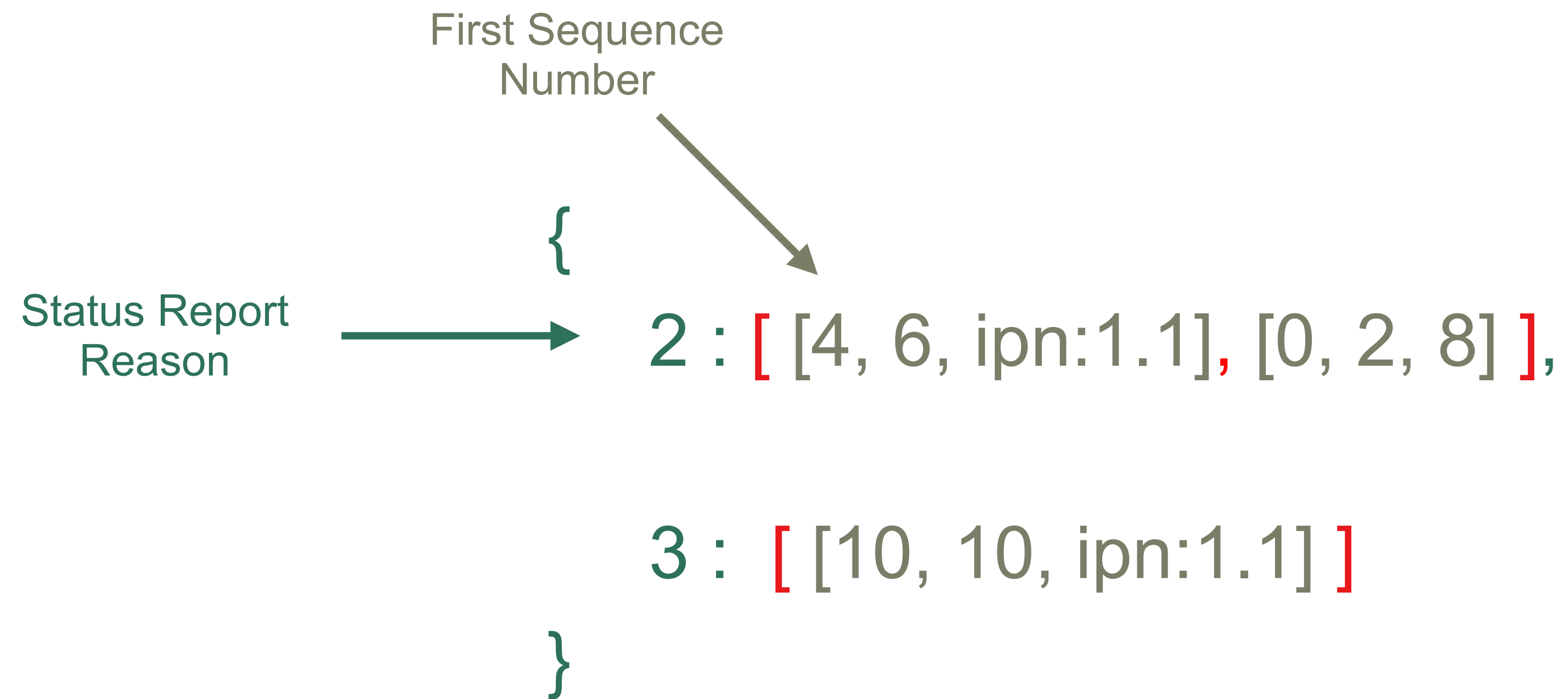
Compressed Reporting Signal

```
{  
  2 : [ [4, 6, ipn:1.1], [0, 2, 8] ],  
  
  3 : [ [10, 10, ipn:1.1] ]  
}
```

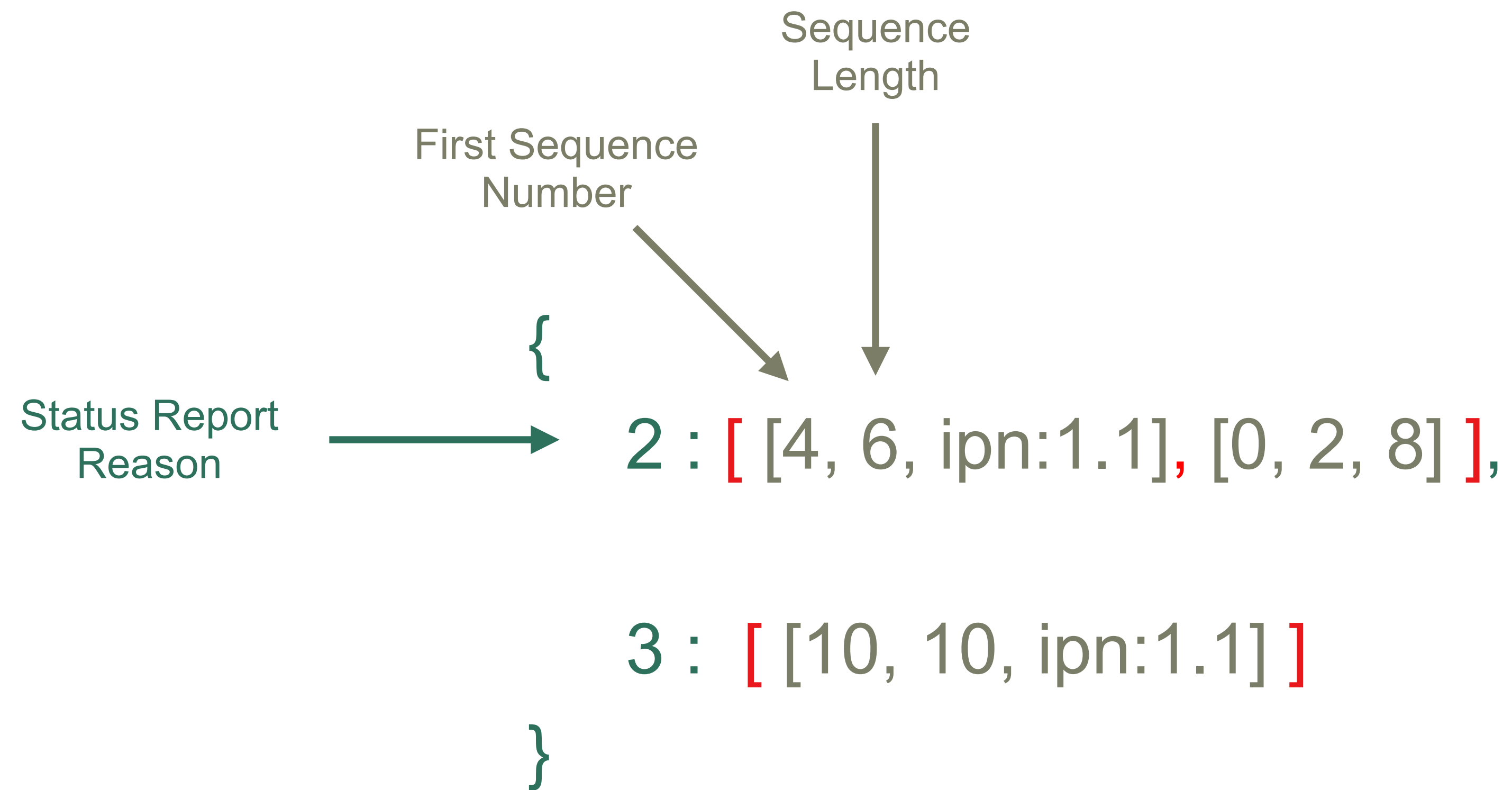
Compressed Reporting Signal



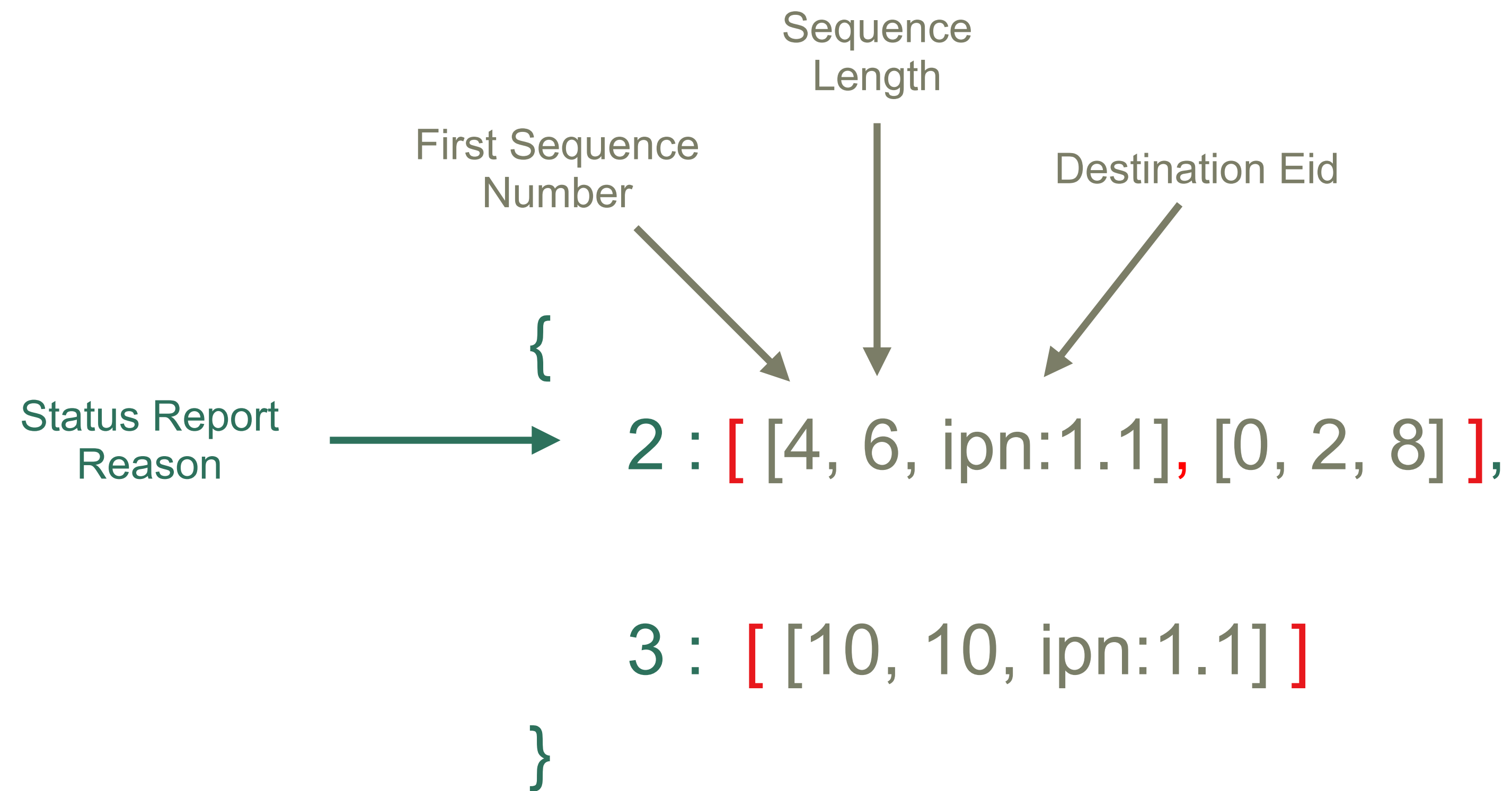
Compressed Reporting Signal



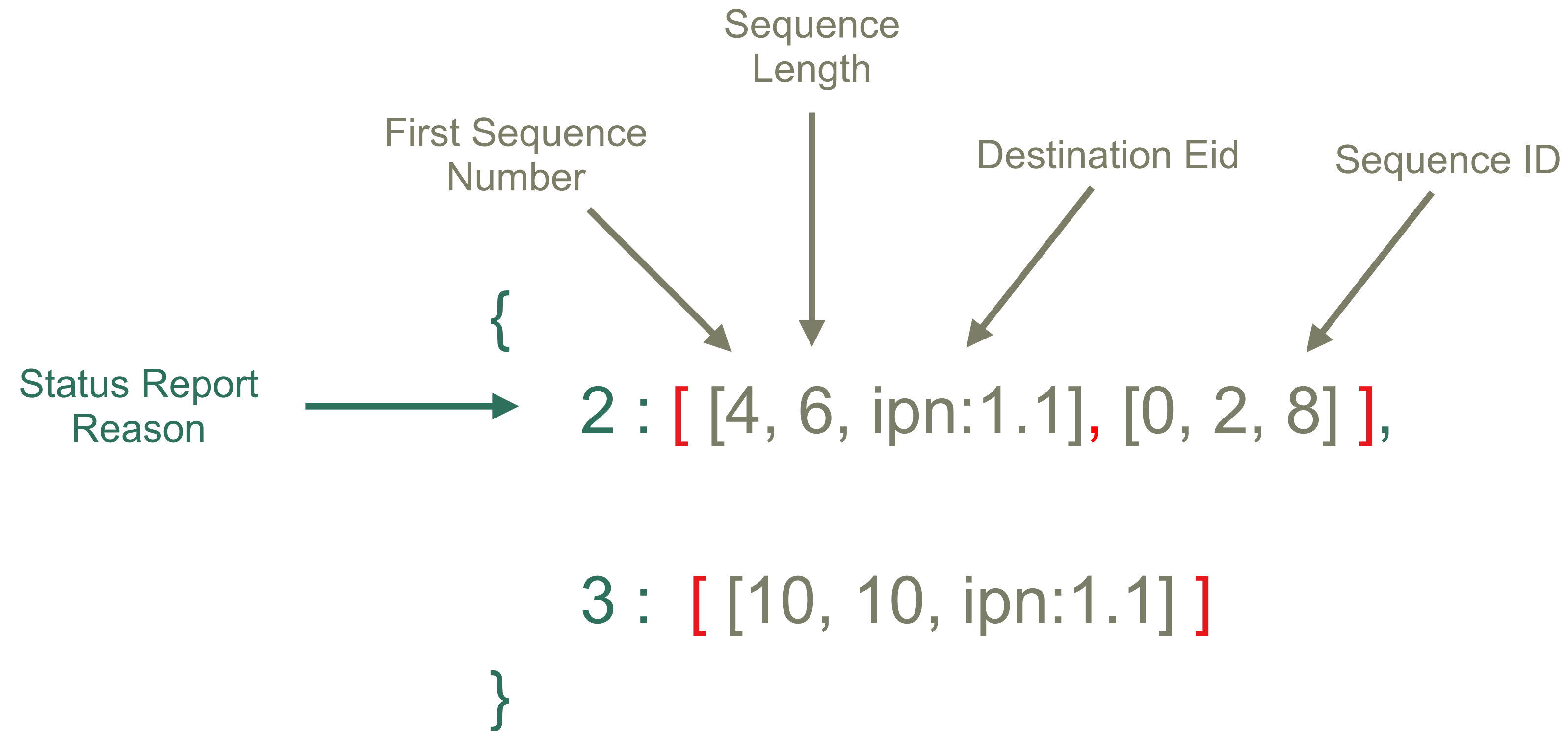
Compressed Reporting Signal



Compressed Reporting Signal

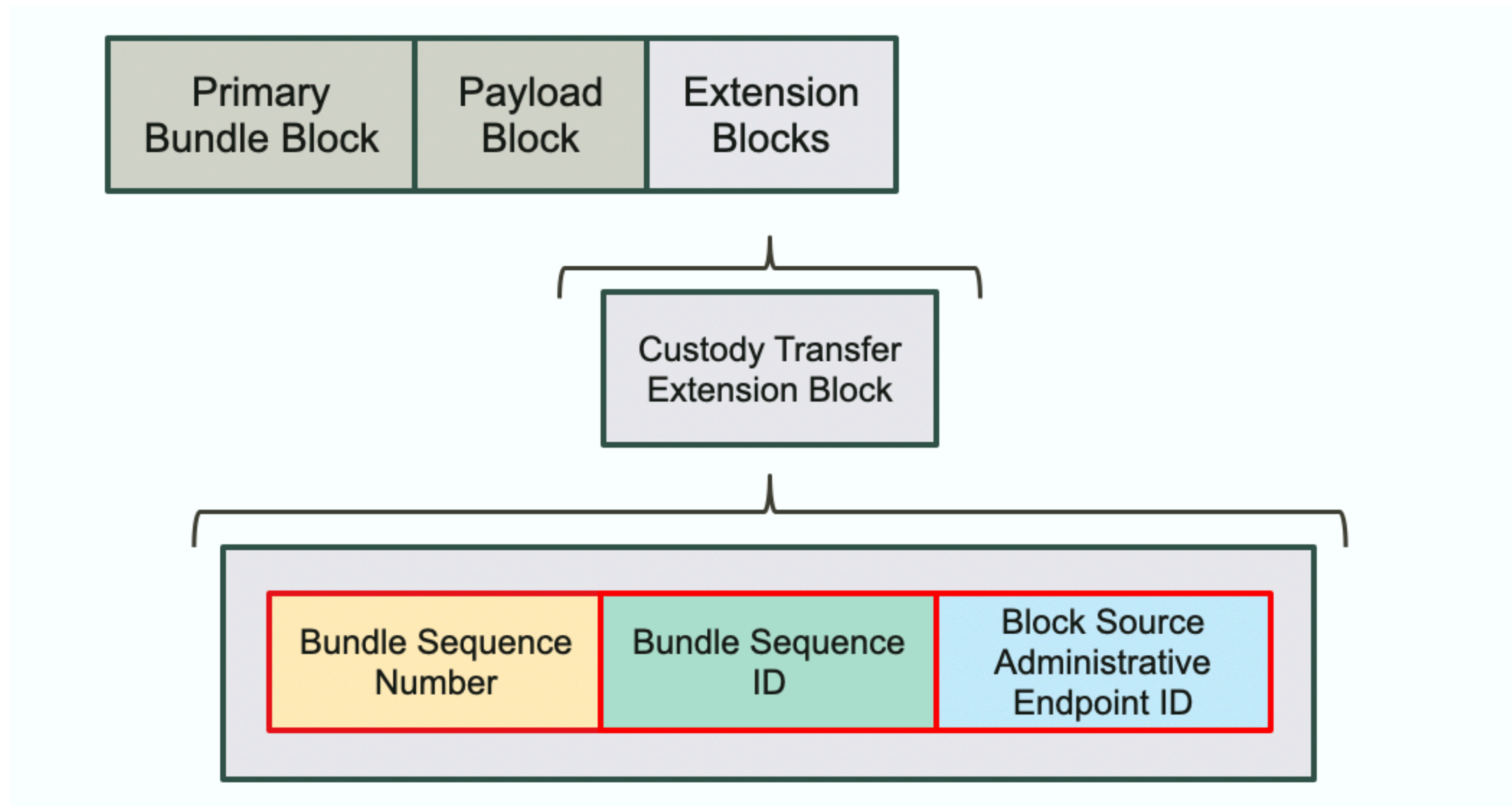


Compressed Reporting Signal



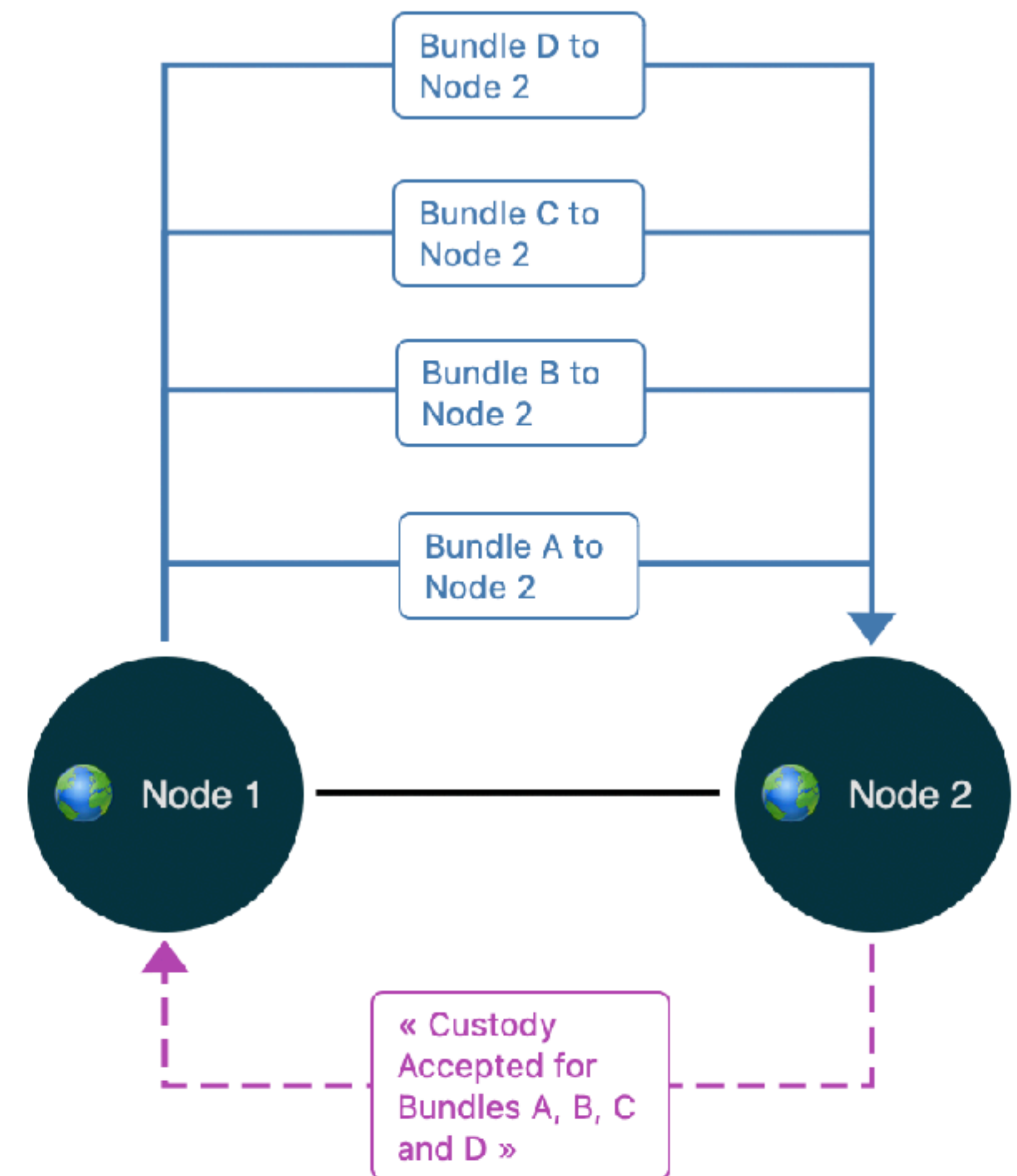
Custody Transfer Extension Block

- Added by the node requesting custody, replaced by subsequent custodians



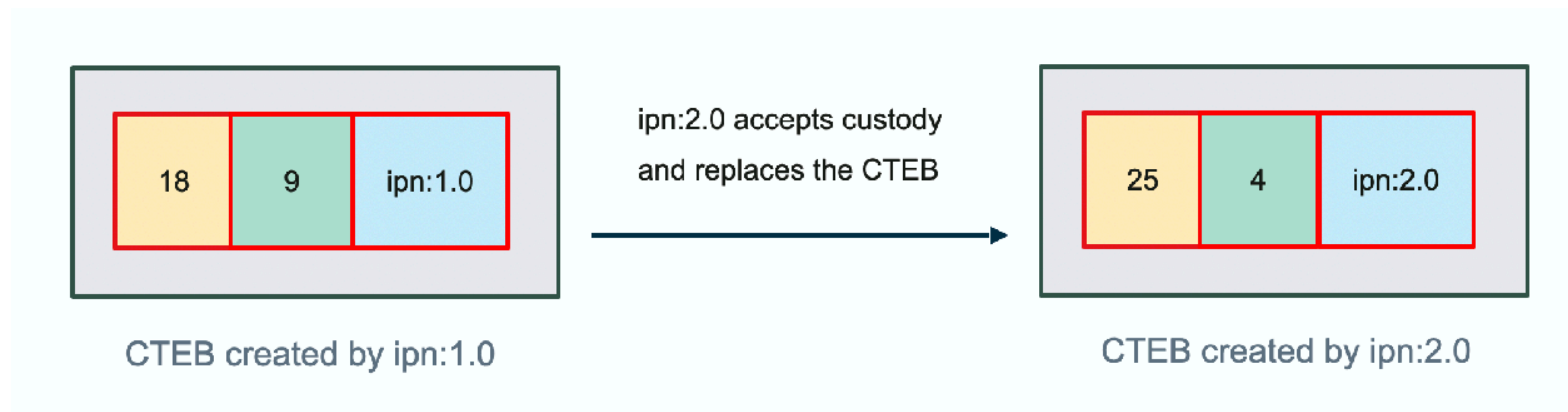
Evaluating custody

- **Accepted custody**: **forward** the bundle and **save it** in its persistent memory until another node takes custody
- **Refused custody**: either **drop** the bundle or **forward** it
- After evaluating custody: send a Compressed Custody Signal to the **current custodian** with the decision
- Custodian waits for the CCS for a certain amount of time before **retransmitting** the bundle



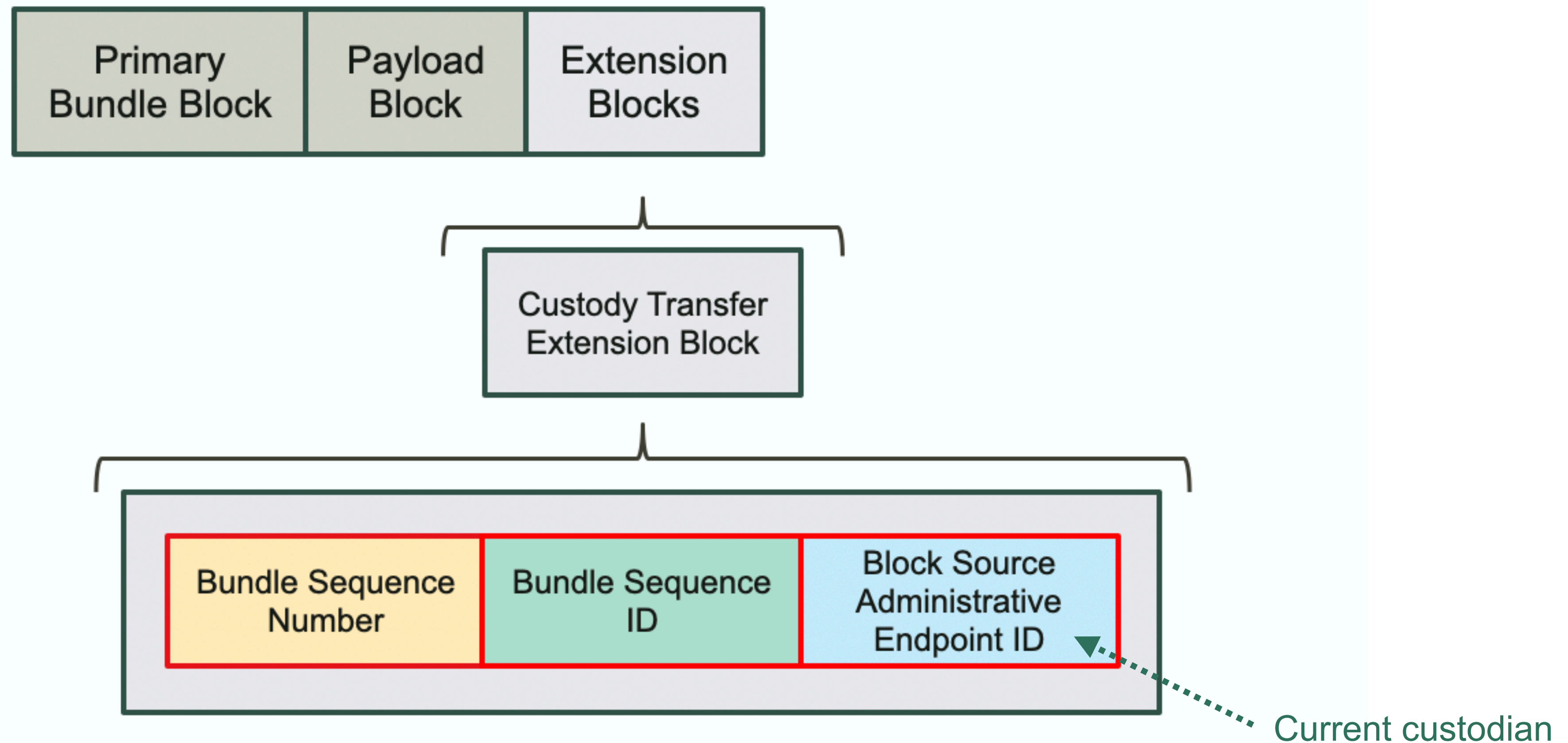
Evaluating custody

- A node evaluates custody for a bundle based on:
 - **resources** (storage, available routes, etc)
 - **policies**
- When accepting custody for a bundle, the node must **replace the CTEB**:



Custody Transfer Extension Block

- Added by the node requesting custody, replaced by subsequent custodians



Compressed Custody Signal

A Compressed Custody Signal is a CBOR Map:

- **Disposition Code** (key)
 - Custody Acceptance: a positive CBOR integer:
 - *1: Custody Accepted (no further information)*
 - *2: Custody Accepted (duplicate reception)*
 - *Values above 2: reserved for future use*
 - Custody Refusal: a negative CBOR integer:
 - *-1: Custody Refused (bundle dropped)*
 - *-2: Custody Refused (bundle forwarded)*
 - *Values below -2: reserved for future use*
- **Bundle Sequence Collection** (value)

```
{  
  2 : [ [4, 6, ipn:1.1], [0, 2, 8] ],  
  3 : [ [10, 10, ipn:1.1] ]  
}
```

They are sent based on a **bundle threshold** or a **time threshold**

Conclusion and future works

Two new protocol mechanisms are now functional in ESA BP:

- **Compressed Bundle Reporting** to efficiently report on the status of bundles
- **Compressed Custody Signalling** to efficiently report on the custody transfer operations of bundles

Future works include:

- Testing CBR and CCS with **DTN reference scenarios**
- Using the two mechanisms for **interoperability testing**
- Working on **bundle fragmentation** with Compressed Custody Signalling

Questions?

alice.le-bihan@insa-lyon.fr

juan.fraire@inria.fr

felix.flentge@esa.int

Thank you!

alice.le-bihan@insa-lyon.fr

juan.fraire@inria.fr

felix.flentge@esa.int