Custodial Multicast in Delay Tolerant Networks

Susan Symington
Robert Durst
Keith Scott

susan@mitre.org, durst@mitre.org, kscott@mitre.org
Support for Multicast in DTN

- Basic DTN message delivery service is unacknowledged and is not guaranteed.
- The Bundle Protocol supports unacknowledged delivery to singleton and multicast endpoints.
- The Bundle Protocol supports custodial delivery of bundles sent to singleton endpoints.
- Support for custodial delivery of bundles sent to multicast endpoints is not defined.
- Internet Draft (Symington, Durst, Scott)
  - Defines extensions to the Bundle Protocol to support custodial transfer of bundles sent to multicast endpoints.
How Custodial Unicast Works

- Bundles may have a “custody transfer requested” bit set.
- A DTN node that receives a bundle with this bit set may:
  - Take custody of the bundle by sending a custody transfer success signal to the previous custodian and starting a retransmission timer
  - Forward the bundle without taking custody, or
  - Send a custody transfer failure signal to the previous custodian, indicating that the bundle can neither be forwarded nor stored

- A custodian should store the bundle in persistent storage until custody is transferred or the bundle is delivered
- A custodian may retransmit the bundle in response to a failed custody signal or retransmission timer timeout
- When bundles are unicast, there is only one copy of each bundle for a custodian to keep track of
How Multicast Complicates Custodial Delivery

- Any node (custodial or non-custodial) may be a branching point for the bundle.
- Custodians are not aware of downstream branching points or how many times a bundle is copied at any downstream branching point.

The custodian of a bundle is responsible not only for the copy(ies) of the bundle that it forwards, but for all copies of that bundle that may be created at other nodes downstream, until a new custodian takes over or the copy is delivered.

Need a mechanism to enable a custodian to determine when all downstream copies have either been delivered or have been taken custody of.
Custodial Multicast Objectives

• Increase the likelihood that the bundle will be delivered to its destination endpoint before expiration
  - to as many nodes as possible in its destination endpoint

• Reduce the cost of bundle retransmissions
  - Want the cost (in terms of the routing metric in use) of re-forwarding from the custodian to be less than the cost of re-forwarding from the source and (ideally) previous custodians

• Enable delivery to late-registering nodes*
  - Custodians can deliver bundles to nodes whose registration request hadn’t yet propagated sufficiently to be grafted onto the distribution tree when the bundle was originally sent

*This objective is not addressed by the mechanisms presented
Bundle Protocol Extensions for Supporting Custodial Multicast (Overview)

- X stores the bundle and starts a retransmission timer. X must receive two custody signals before it can delete the bundle.

  - Proxy custodian Y does not store a copy of the bundle, but inserts its own EID in the bundle’s custodian field. It expects to receive two custody signals.
  - If Y receives two Success signals, it sends a single custody success signal to X.
  - If Y receives one or more custody Failure signals, it sends these (possibly aggregated) to X.
  - If X’s timer times out or X receives a custody Failure signal, X retransmits the saved bundle.
  - Y should retransmit on only those branches for which it did not receive a Success signal (copy IDs are useful)
How custodians know when they can delete a bundle

- When a custodian receives a “succeeded” custody signal for a copy of the bundle that it forwards, this indicates that all copies downstream of that copy have been either delivered or taken custody of.

- When a custodian receives a “succeeded” custody signal for every copy of the bundle that it branched, it may delete the bundle from storage.

- Until a custodian receives a “succeeded” custody signal for every copy it branched, it must assume that there is at least one downstream copy that has neither been delivered nor taken custody of.
Efficient Re-forwarding

• When a proxy custodian receives a “failed” custody signal, it must generate a replacement “failed” custody signal and insert a Proxy EID extension block into this bundle (if there is not one in there already) that identifies the source of the original “failed” custody signal.

• When a custodian receives a “failed” custody signal, it retransmits a copy of the bundle referred to by the “failed” signal, perhaps encapsulated in a unicast bundle sent to the “failed” custody signal’s source.
When a custodian’s retransmission timer expires, it retransmits a copy of the bundle associated with that timer to the next-hop node(s) associated with that timer.

Ideally, it retransmits only to those next-hop nodes from which it has not received a successful custody signal.

If a custodian marks the copies of a given bundle that it delivers or forwards individually, then when a custody signal is received, the receiving custodian can determine not only which bundle, but which copy of the bundle (e.g. which next-hop node), it refers to.

The EID that a custodian inserts into the bundle’s custodian field can differ for each copy forwarded so as to act as a copy discriminator.
Custodial Multicast Extensions are Optional

- Not all nodes in the delivery tree must implement the optional custodial multicast extensions
- Non-custodial-multicast-capable nodes can deliver custodial multicast bundles
- Non-custodial-multicast-capable nodes can forward custodial multicast bundles to a single next hop
- Only custodial multicast capable nodes may be custodians and branching points
- The multicast routing protocols must enforce the restriction that only custodial-multicast-capable nodes may be branching points
DTN Multicast Open Issues

- Accommodating nodes that register late or whose registration requests are delayed (W. Zhao, M. Ammar, E. Zegura)

- Multicast routing protocols are not yet defined for DTN
  - Multicast routing protocols for supporting custodial multicast must meet certain requirements
    - Must operate over trees rather than meshes
    - Only custodial-multicast-capable nodes may be branching points
    - If convergence-layer multicast is used, the forwarding node must know the number of next-hop receivers

- Security protection for multicast bundles
Backup slides
Forwarding Failures

- As mentioned earlier, there may be a delay between when a node registers and when that registration propagates to graft that node onto the distribution tree.
  - As a result, custodians may need to re-forward bundles to “late-joining” nodes.
- Analogously, there may be a delay between when a node de-registers and when that de-registration propagates to prune that node from the distribution tree.
  - A custodian could forward a multicast bundle that arrives at a downstream node with “no known route to destination”.
  - This should generate a “success” custody signal because there are no remaining downstream copies of the bundle that need to be either delivered or taken custody of.
Assumptions and Design Principles

1. Branching point nodes are not required to be custodians

2. Branching point nodes are required to maintain state for each custodially-transferred bundle that they branch (even if they are not custodians)
   - Must keep track of the delivery/custody status of each of the copies that it creates and report this to the nearest upstream custodian or branching point node

3. DTN multicast routing protocols must enforce certain restrictions when supporting custodial delivery
   - Only custodial-multicast-capable (CMC) nodes may be branching points
   - Routing protocols must operate over trees rather than meshes
4. Convergence Layer Multicast may be used, with some restrictions

- The node that is forwarding using convergence layer multicast must be CMC (because this node is a branching point), and
- The forwarding node must know the number of next-hop nodes the bundle is expected to reach via that convergence layer

5. Bandwidth conservation is given priority over robustness of delivery by default, but local policy may override this

- Custodians and branching nodes do not forward bundles to next-hop nodes from which successful custody signals for those bundle have already been received