Distributed Dataset Synchronization in Mobile Ad Hoc Networks over NDN

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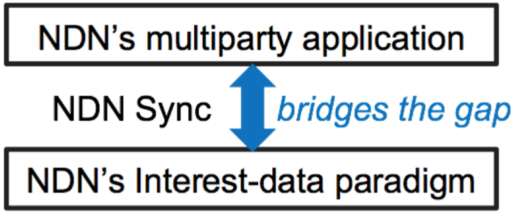
What is Sync

- Distributed applications require synchronized state
  - chatroom messaging
  - collaborative editing
  - routing protocol
- Key Idea
  - Reconcile *set difference* for a dataset shared among multiple parties
  - Each party has a local *state (view)* of *shared dataset*
  - Goal: All parties share the same *state* of the *shared dataset*

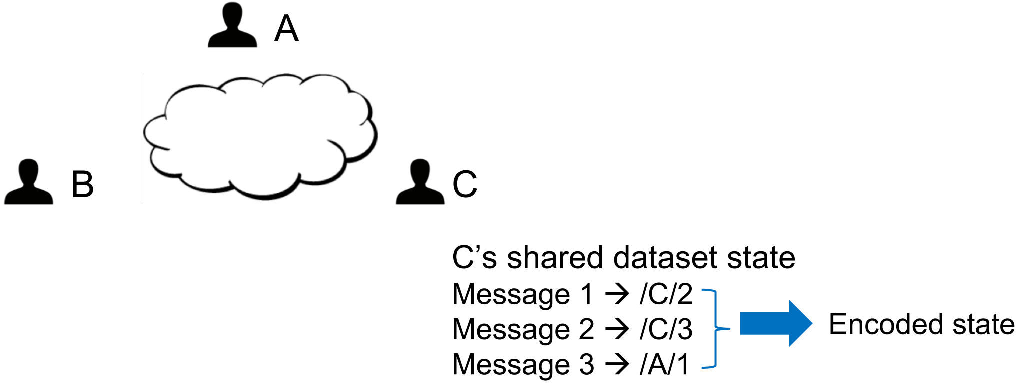
Sync in NDN

- NDN Sync
  - A way to implement data oriented multiparty communication protocol
- Multiparty *communication* ➡ *synchronization* of shared dataset
  - Define application-specific *data units* as items in a *shared dataset*
  - Synchronize *namespace* of data units
- Sync provides synchronization as a service to NDN applications
  - Keeps application up-to-date about newest dataset state
  - Individual applications fetches content based on need



Basic Functions of NDN Sync (Chatroom Example)

- State Representation
  - Namespace design
    - *how to name the chat messages*
  - State encoding
    - *how to encode each user's shared dataset state*



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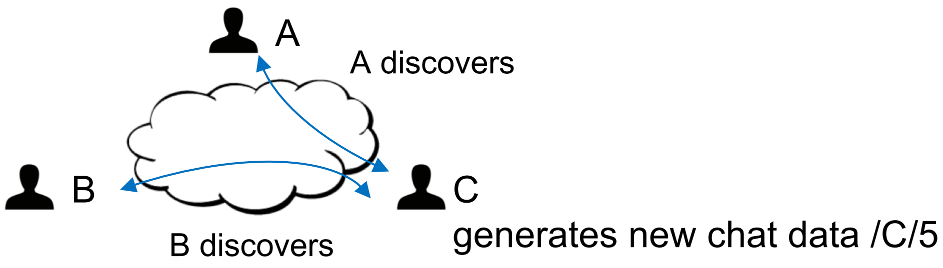

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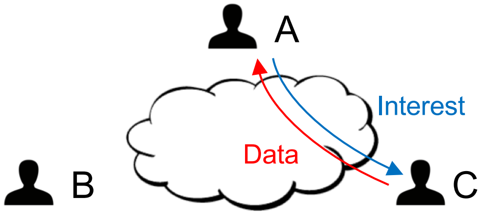
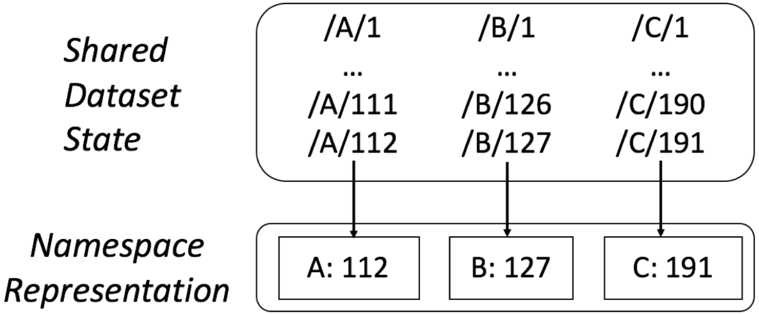
  - *identify the difference in dataset state between nodes*
- Fetching missing data
  - *Receiver-driven data delivery reliability*



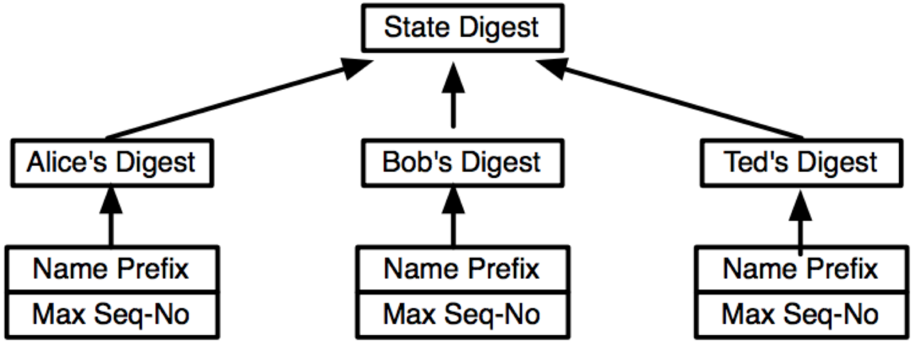
State Representation (Namespace Design)

- Sequential Naming
  - Data name: unique producer prefix + sequence number
  - Dataset namespace: set of [producer prefix + latest data sequence number]
  - Sequential naming provides efficient namespace representation



State Encoding approach-1: State Digest

- State Digest
  - compress knowledge of dataset into crypto digest
  - hashes each producer’s name prefix and latest sequence number
  - compare state digest to detect state inconsistency

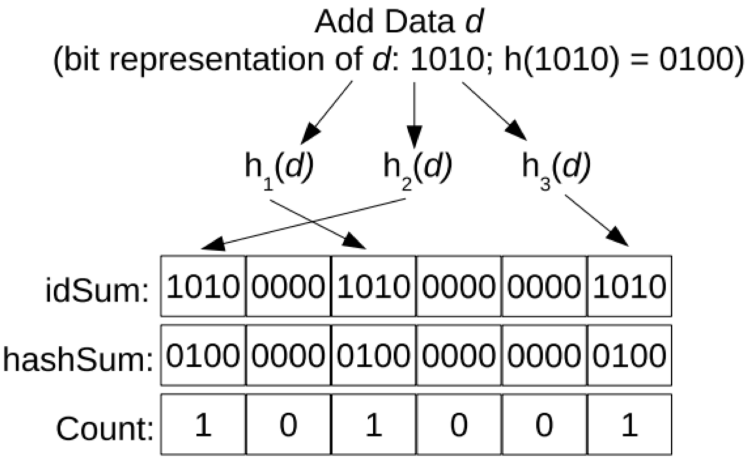


hash of each [producer prefix + latest seq no]

Example of State Digest

State Encoding approach-2: Invertible Bloom Filter

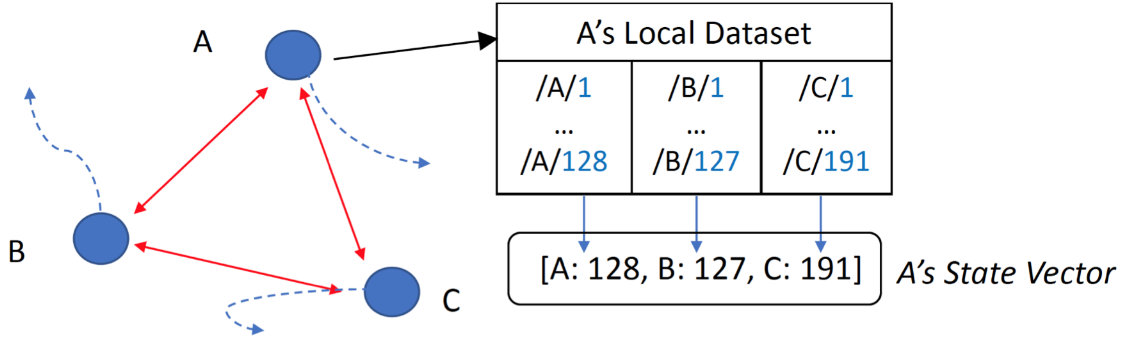
- Invertible Bloom Filter (IBF)
  - Inserts hashes of each [stream prefix+latest seq no] into cells in IBF
  - IBF supports subtraction operation to identify state difference (IBF1-IBF2)



Example of IBF

State Encoding approach-3: State Vector

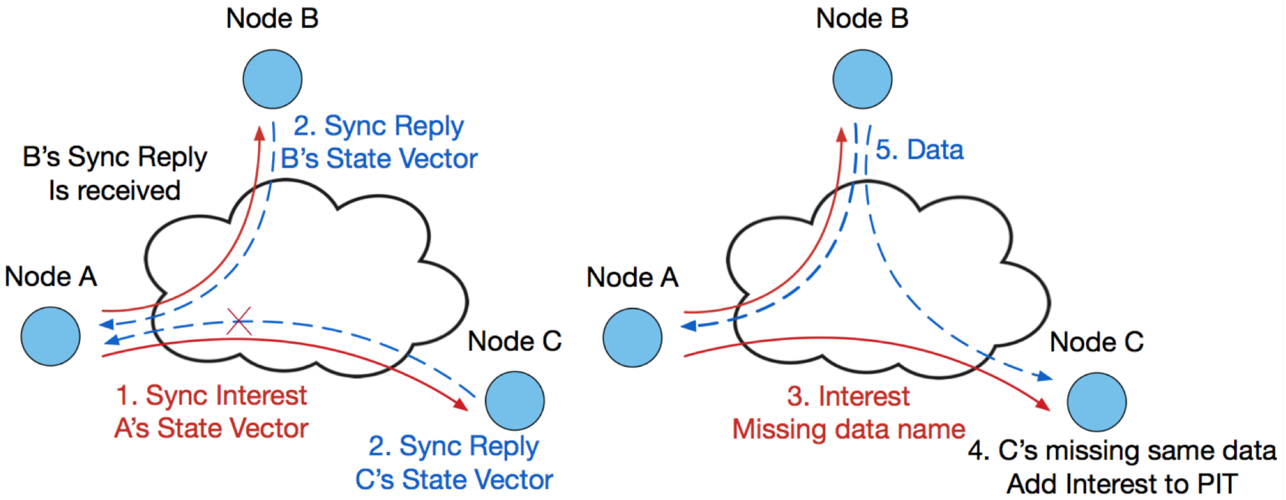
- State Vector directly lists the [producer prefix : latest seq no] in a version vector
- Nodes can compare State Vector directly to resolve any state mismatch
- Do not have assumption on underlined connectivity



State Vector Example

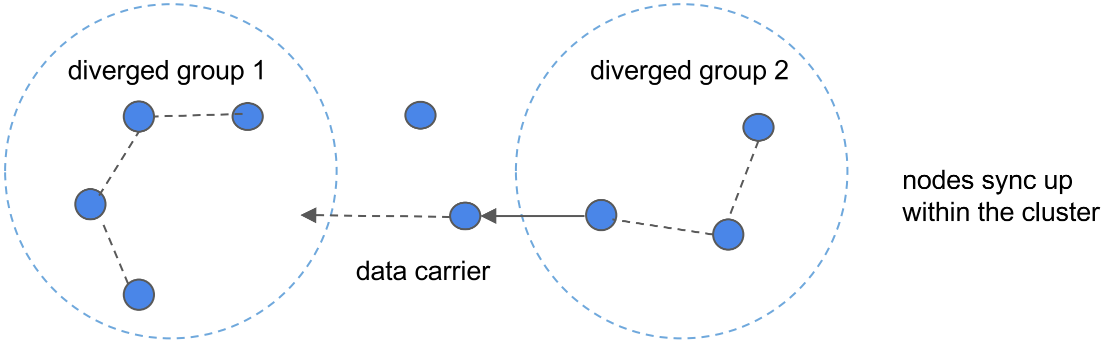
State Change Detection

- Sync Interest
  - Contains sender’s encoded state
  - Periodically multicasted to advertise sender’s state and detect state change
  - Receiving nodes can identify state difference though encoded state comparison
- Sync Reply
  - Contains updated data names or sender’s state vector



MANET Challenge 1

- Intermittent connectivity with mobility
  - Connectivity may be lost quickly
- State divergence is the norm
  - Network partitioned into different clusters
  - Nodes accumulate different state updates

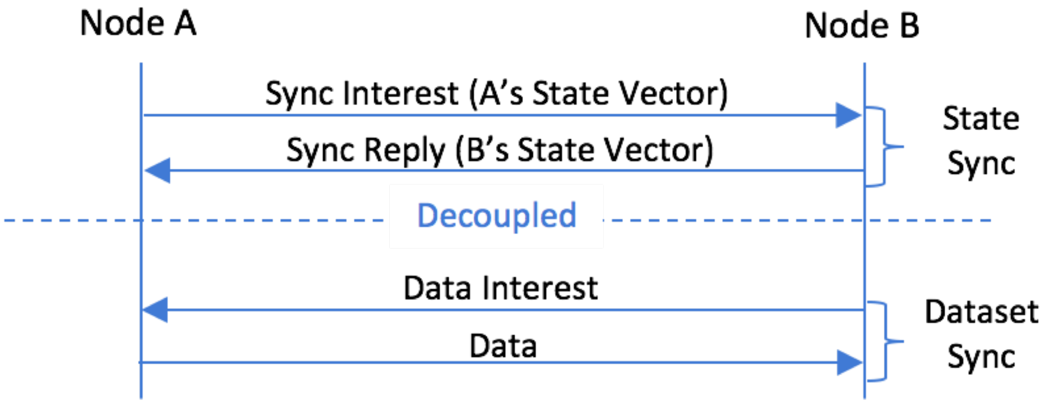


Reconcile State Divergence

- State digest
  - node fetches complete dataset state information
- IBF
  - can deduce difference in dataset namespace (IBF1-IBF2)
  - IBF size limits the amount of state difference which can be recovered (False Positive of IBF)
    - In case of large state divergence only part of the state difference can be decoded
- State Vector
  - Directly expresses dataset state
  - Can resolve any degree of state divergence

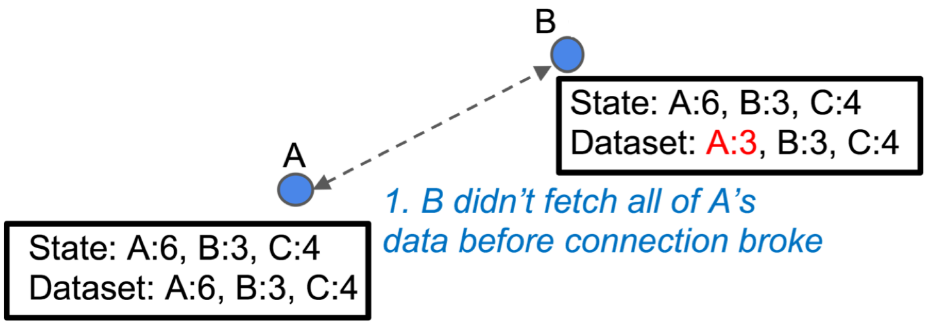
MANET Challenge 2

- Decoupling state and dataset synchronization
  - Sync provides synchronization as a service to NDN applications
    - State Sync: synchronize knowledge about the latest dataset
    - Dataset Sync: application decides which data to fetch



MANET Challenge 2 (Cont)

- Decoupling state and dataset synchronization causes excessive transmission
  - State and dataset mismatch caused by intermittent connectivity
  - Results in nodes continuously fetching none existent data
  - Mismatched state gets propagated further in the network



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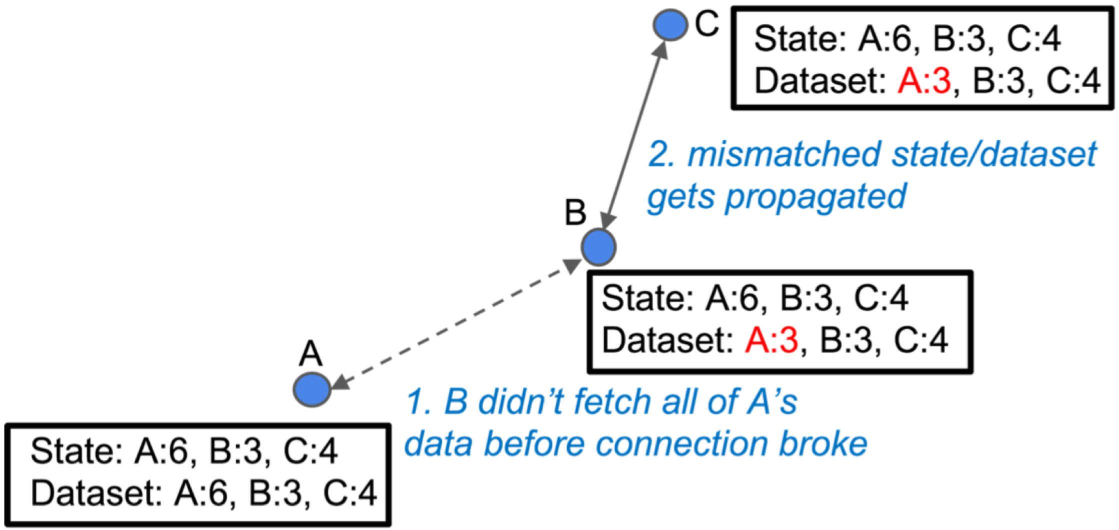

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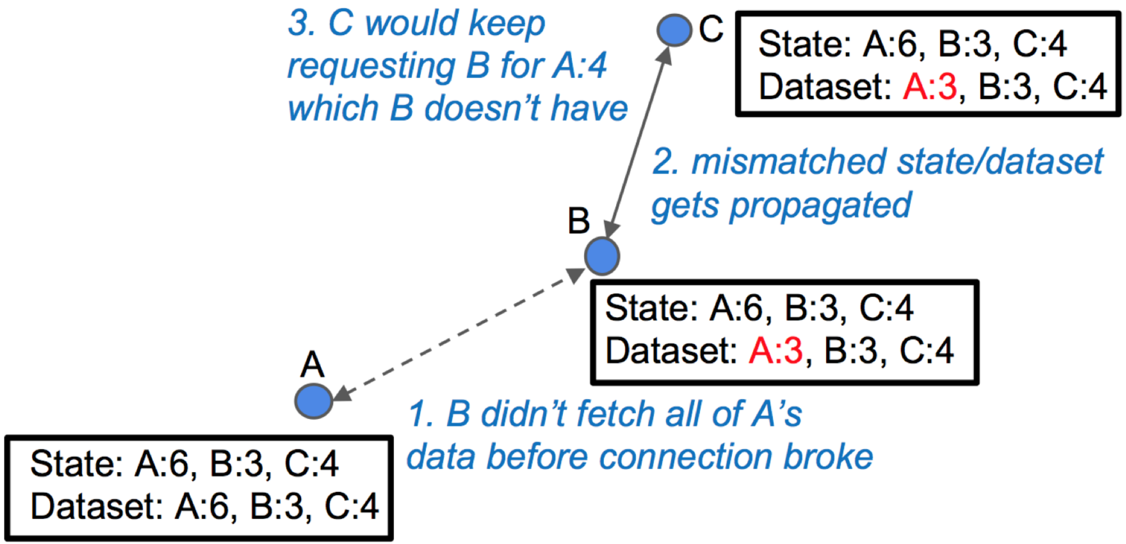
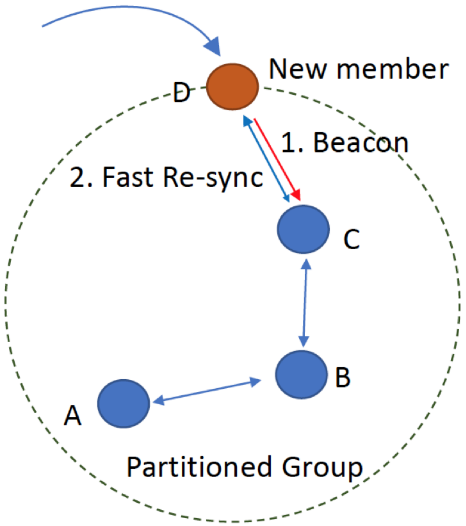


MANET Challenge 3

- State Change Detection
  - Periodic transmission of Sync Interest creates unnecessary overhead in MANET
    - Nodes are unaware of the connectivity of neighbors
    - Nodes do not know if a node with newer state is reachable
    - Sync Interest carries encoded state which is costly to transmit frequently
  - Possible solutions
    - Using lightweight message for state change detection

State Change Detection (Layer 2 Beacons)

- Utilizing Layer 2 beacons (802.11 ad hoc)
  - Encoding state information (digest) into layer 2 frame
  - Detects neighbors with state difference
    - Trigger Sync Interest transmission
  - Issues
    - Requires interface for Network/MAC layer exchange
      - Existing MAC layer design/implementation is unusable by higher layer



Possible Solutions

- Couple state sync with data sync
  - nodes send State Vector based on its actual dataset
  - nodes fetch data pieces in sequence, to support sequential namespace representation
- Increase data availability
  - e.g. deploy distributed repos in the network

Conclusion

- NDN Sync facilitates distributed multiparty applications
- New insight from trying sync in MANET
  - State Vector offers resilient state divergence recovery under adverse conditions
  - Decoupling State and Dataset Sync causes large amount of excessive Interest
  - Simple, old soft-state works: Periodic notification of state offers most resiliency under adverse condition
- Existing MAC layer design/implementation is unusable by higher layer; a redesign may greatly improve the overall network performance

Thank You
Q&A