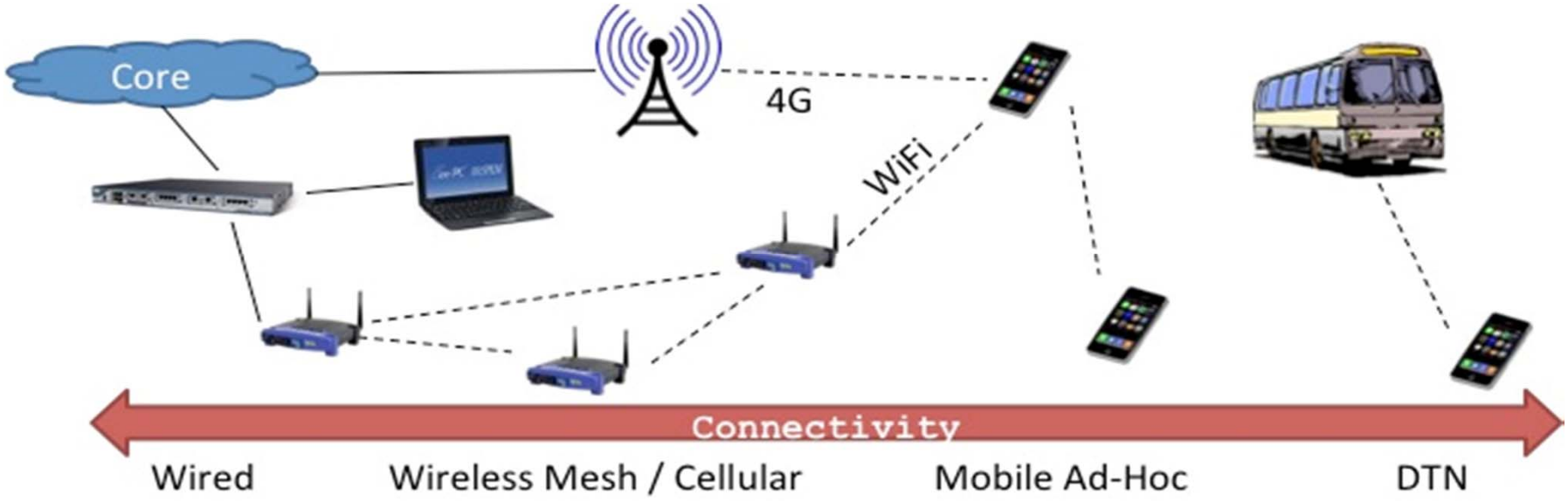
GSTAR: Storage Aware Routing Protocol for Efficient and Robust Services

Nehal Somani, Abhishek Chanda, Samuel Nelson, Dipankar Raychaudhuri

WINLAB
Rutgers University

Routing in MobilityFirst: Objectives

- Efficient and robust support of mobility services in the core Internet
- Unified approach for handling all the challenges associated with mobile devices and associated applications
- Capable of achieving high performance across a wide range of wireless and wired networks



Routing in MobilityFirst: Approach

- Challenges associated with mobility are not addressed by current local-scale routing protocols.

- Some solutions have been proposed by:
  - Delay Tolerant Networking (DTN) Community –
    - Uses message replication and hop-by-hop transport
    - Not sufficient in highly connected environments
  - Ad-hoc/MANET Community –
    - Not sufficient in highly disconnected environments

Merging MANET and DTN

Generalized Storage Aware Routing (GSTAR)

- Proactive link-state protocol with DTN capabilities for use in MobilityFirst networks
- Unifies techniques from MANET and DTN protocols
- Handles mobility related challenges at network layer using:
  - Exposed path quality information
  - Exposed connectivity patterns
  - Directly accessible in-network storage

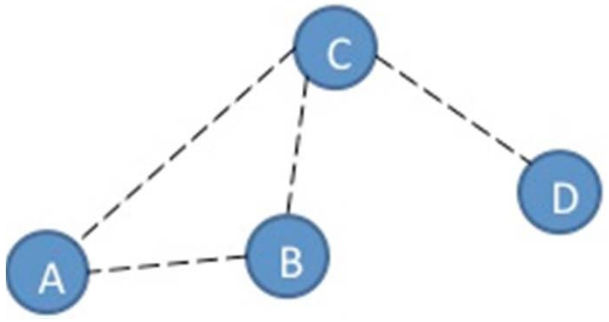
GSTAR: An Overview

- Intra-partition Graph
  - Contains fine-grained, time sensitive information about the links
  - Uses Expected Transmission Time (ETT) as a measure of link quality
- Inter-partition Graph
  - Contains coarse-grained, time insensitive information about the connection probabilities
  - Based on Average Availability (AA) of nodes in the network
- Routing decisions are made on a set of data packets called *chunks*.

Intra-partition Graph: Control Messages

- Link Probe (LP)
  - Enables a node to know about the ETT of current one-hop neighbors
  - Used to compute short term expected transmission time (SETT) and long term expected transmission time (LETT)

- Flooded Link State Advertisement (F-LSA)
  - Contains SETT and LETT for all one-hop neighbors
  - Periodically flooded and re-transmitted by every node



D sees:

IP_A <-> IP_C (fair/fair)

IP_A <-> IP_B (good/fair)

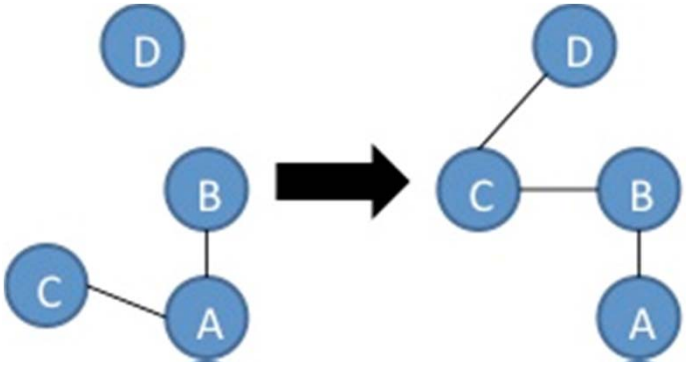
IP_B <-> IP_C (fair/bad)

IP_B <-> IP_C (good/good)

IP_C<-> IP_D (fair/fair)

Inter-partition Graph: Control Messages

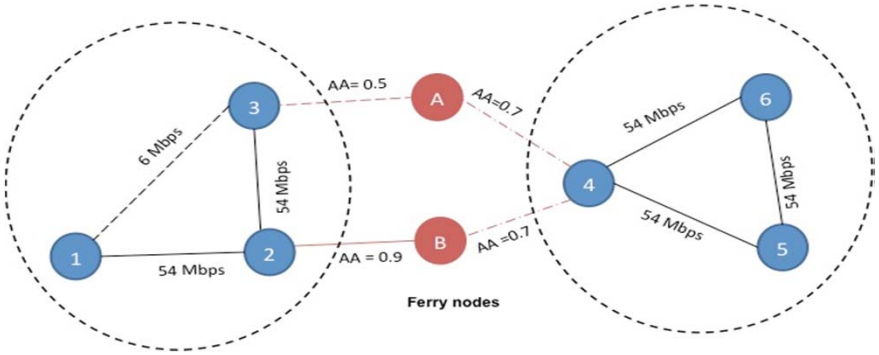
- Link Probe (LP)
  - Used to compute Average Availability (AA) as: $AA = \frac{on}{on + off}$
  - "on" time: active connection and "off" time: disconnection
- Disseminated Link State Advertisement (D-LSA)
  - Contains AA for all nodes in the complete network
  - Epidemically disseminated and carried in-definitely by every node



D sees:
A <-> C (1/2)
A <-> B (1)
B <-> C (1/2)
C <-> D (1/2)

Intra-partition Forwarding Table

- Computed using any shortest path algorithm like Djikstra's with SETT as link weights
- Contains only *end-to-end routes* with the corresponding SETT and LETT



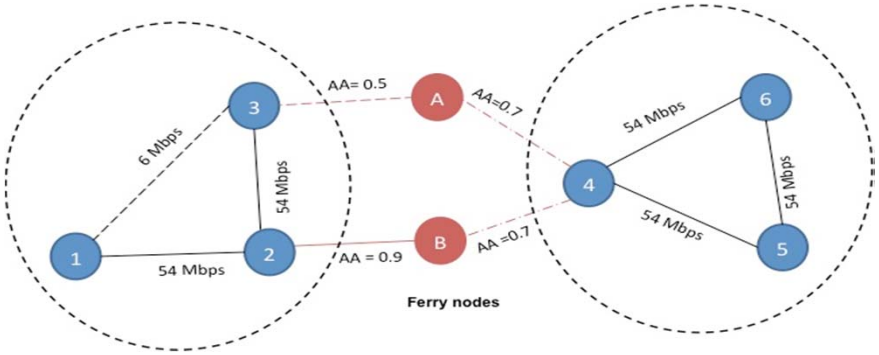
Intra-partition table at Node 1

Dest	Next Hop	ST Path	LT Path	Hops
2	2	13332	13332	1
3	2	66666	66666	2

ST Path – SETT Sum and LT Path – LETT Sum

Inter-partition Forwarding Table

- Computed using any shortest path algorithm like Djikstra's with link weights as: (1-AA+0.01)
- Contains *highly probable routes* to all nodes in the network



Intra-partition table at Node 1

Dest	Next Hop	AA	Dest	Next Hop	AA
2	2	0.01	4	2	0.43
3	3	0.01	5	2	0.44
A	3	0.52	6	2	0.44
B	2	0.12			

Transmission of Data

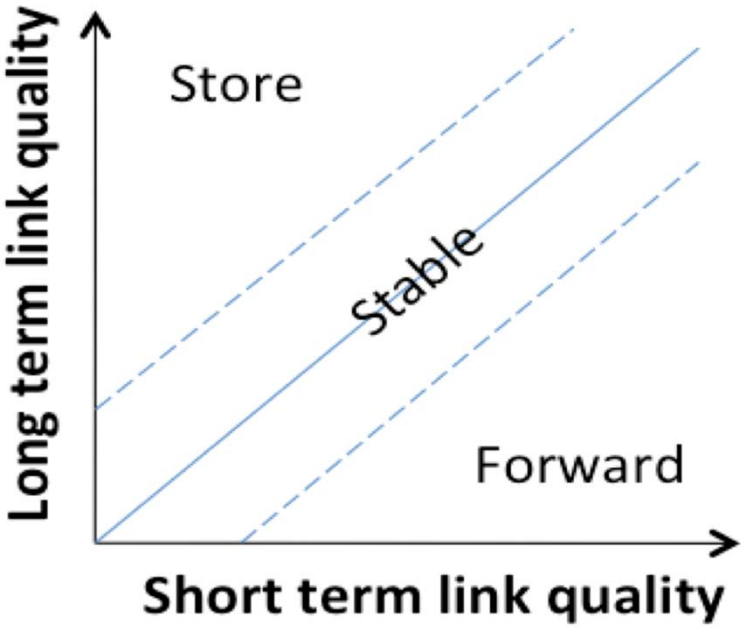
- A node first checks its intra-partition table for an end-to-end route to the destination.

- if (SETT > 1.1*LETT)

  store the chunk

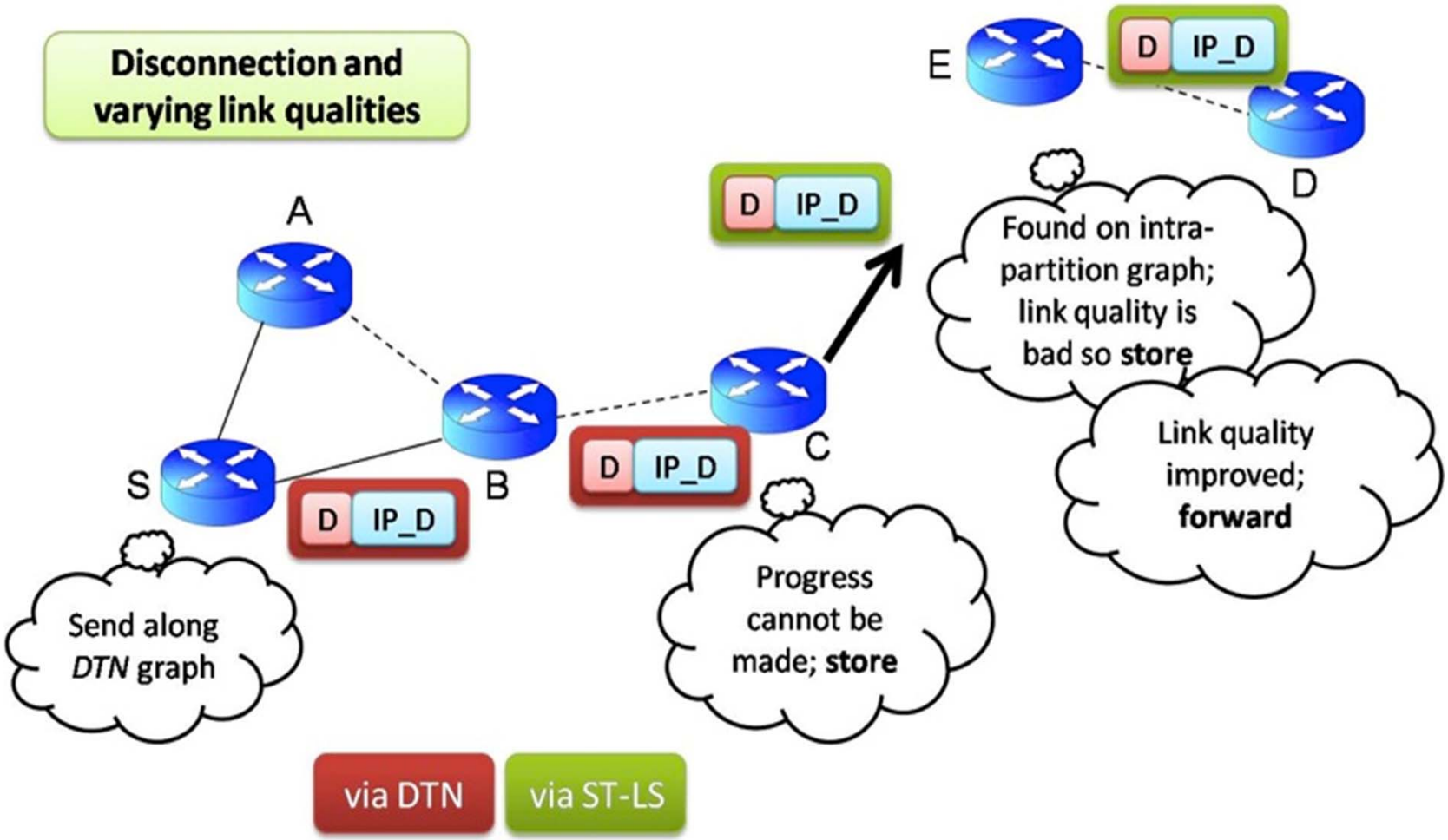
  else

  forward



- If no route exists in the intra-partition table, the node switches to DTN mode and checks the inter-partition graph.

Working of GSTAR

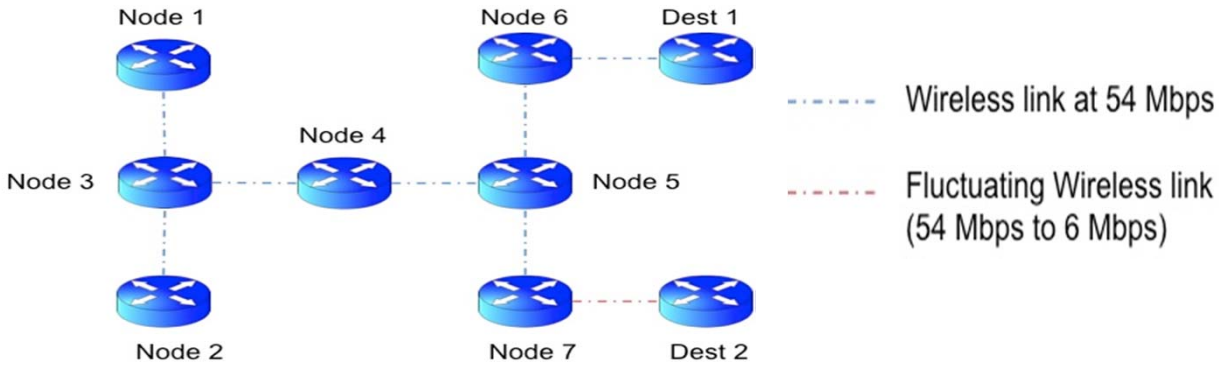


Simulation Model

- NS-3 (Network Simulator 3) based simulation model is developed for evaluation of GSTAR.

- The simulation model consists of:
  - Nodes with storage
  - Hop-by-hop transport
  - Time varying wireless channel
  - Mobile users with possible disconnection

GSTAR vs. Link State in Wireless Network

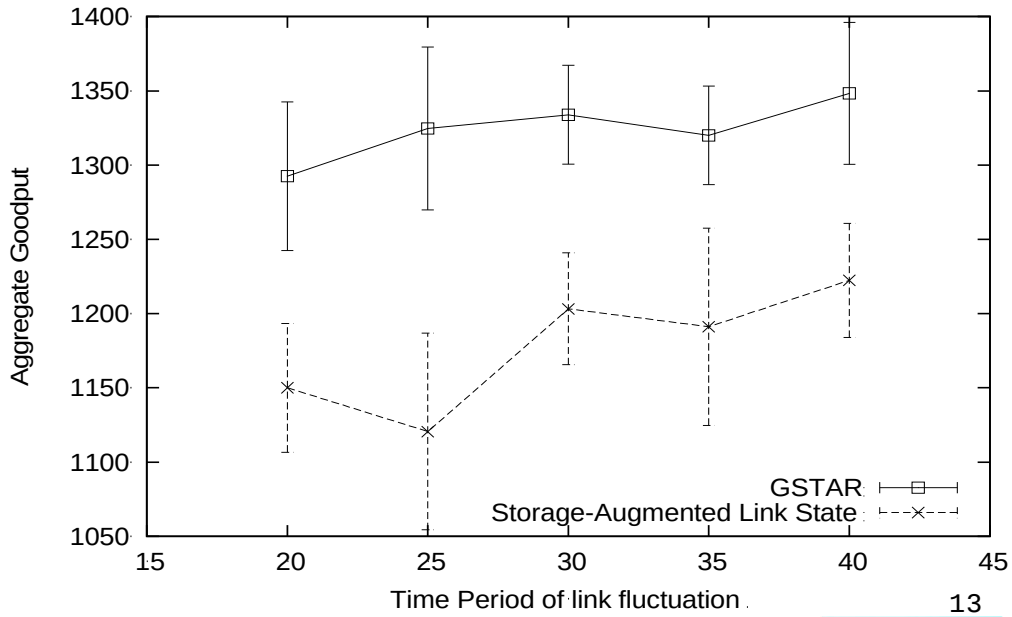


Simulation Parameters

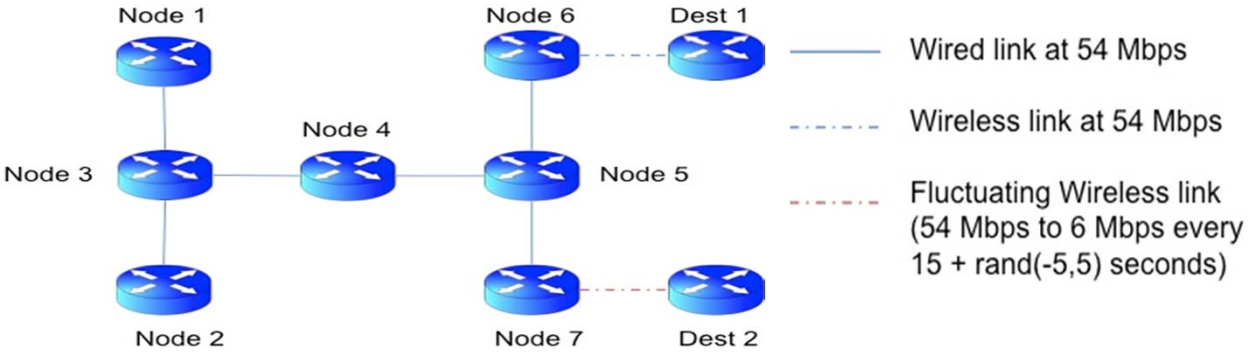
- Flows: Node 1 – Dest 1
  Node 2 – Dest 2
- Chunk Size: 25 packets
- Simulation Time: 90 sec
- Each data point is average of 10 runs

- LETT: average of past 10 ETTs
- Store-forward decision threshold: 1.1

GSTAR alleviates the effect of congestion in Flow 2 from Flow 1 resulting in better network utilization.



GSTAR vs. Link State in Hybrid Network

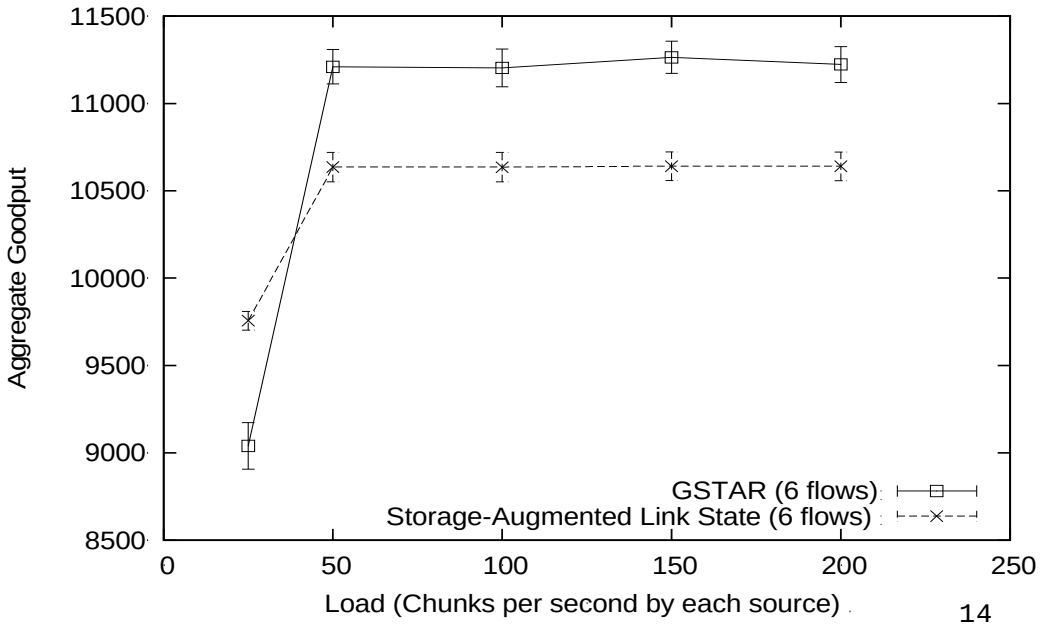


Simulation Parameters

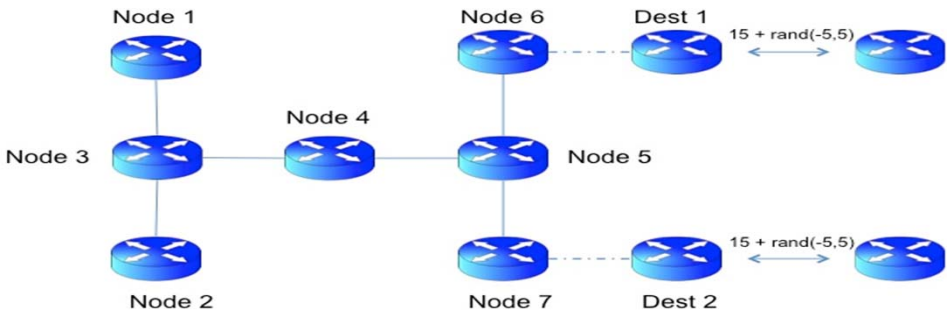
- Flows: 3 flows to Dest 1
  3 flows to Dest 2
- Chunk Size: 10 packets
- Simulation Time: 90 sec
- Each data point is average of 10 runs

- LETT: average of past 10 ETTs
- Store-forward decision threshold: 1.1

- **GSTAR provides a gain in aggregate goodput for medium to high offered load.**
- **Cross-over point is the load at which network is fully utilized.**



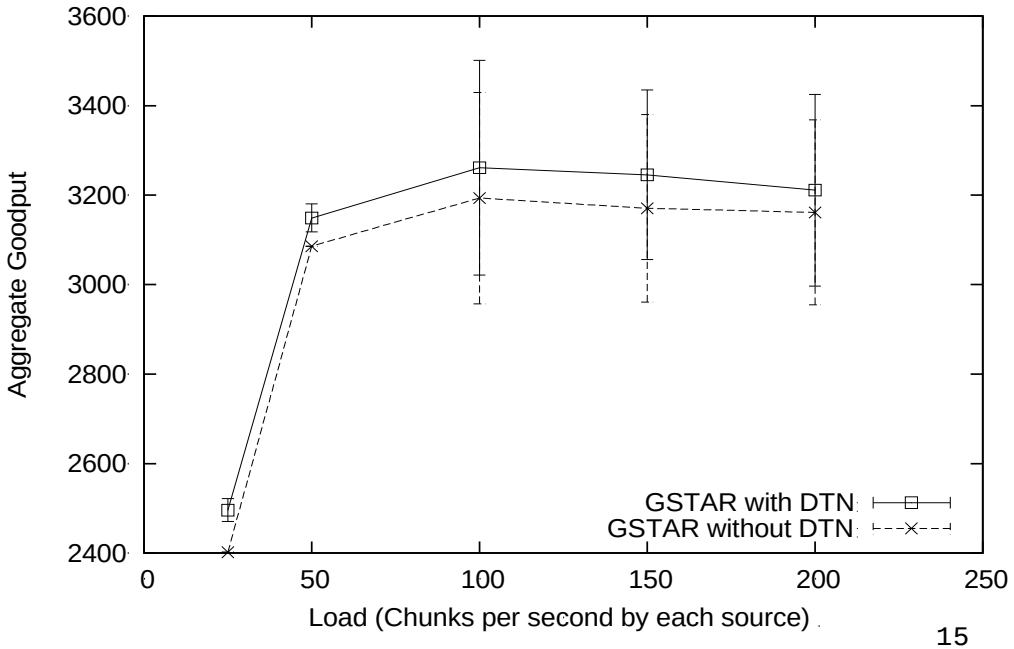
GSTAR w/ DTN vs. GSTAR w/o DTN



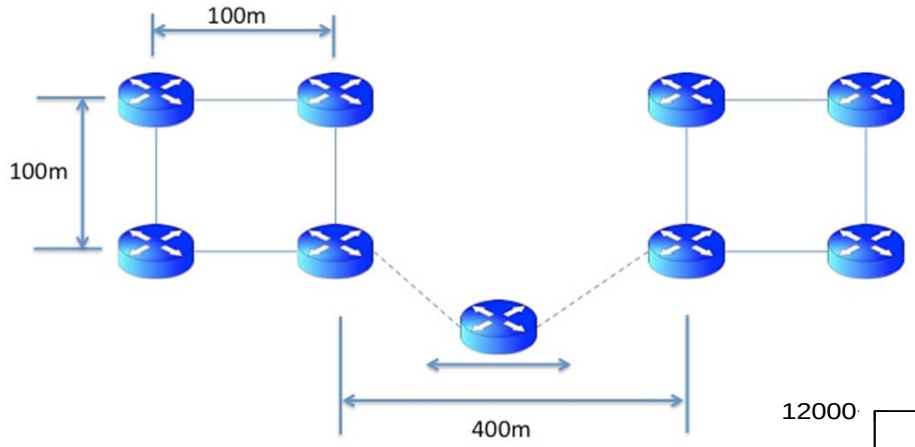
Simulation Parameters

- Flows: Node 1 – Dest 1
  Node 2 – Dest 2
- Chunk Size: 25 packets
- Simulation Time: 90 seconds
- Each data point is average of 10 runs

- **Proactive pushing enables destinations to start receiving data as soon as it reconnects.**
- **W/o DTN, the destinations have to wait for there F-LSAs to be received by the sources.**



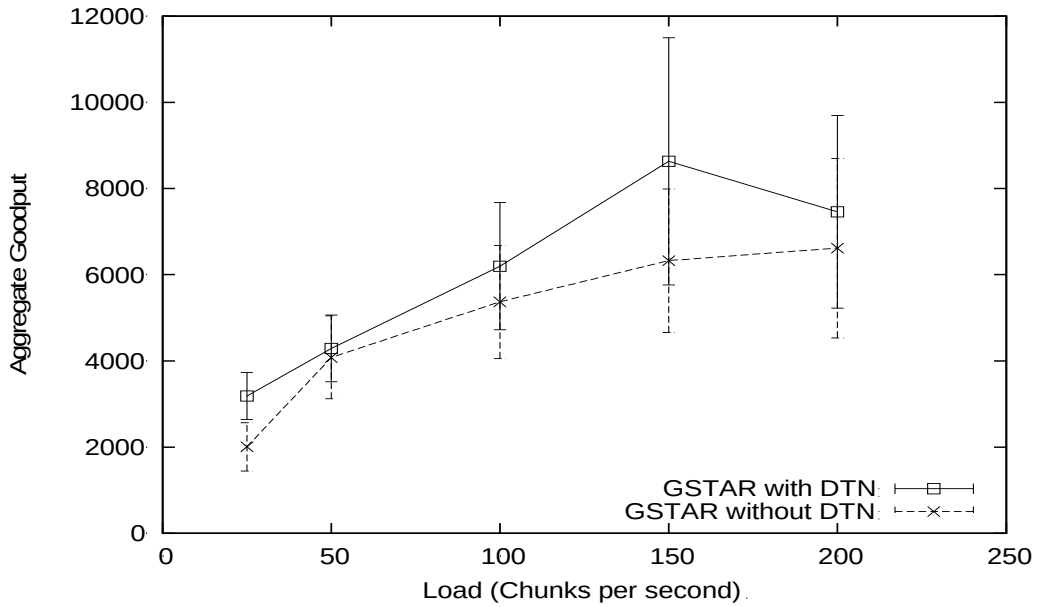
GSTAR vs. Link State with Network Partitions



Simulation Parameters

- Flows: 3
- Chunk Size: 25 packets
- Simulation Time: 120 seconds
- Each data point is average of 10 runs

Proactive pushing enables data to be received across network partitions.



Computation of LETT

1) Exponentially weighted moving average (EWMA)
   - LETT = α . SETT + (1 – α) . LETT
   - α is the weighting factor explored via simulation
   - Works well for periodic links as past information is relevant

2) Simple moving average
   - Giving equal weights to past ETTs
   - Using different amounts of past ETTs is explored via simulation
   - Works well if the link fluctuation period is less than the amount of past history used

Adaptive Store-Forward Decision Threshold

- Static threshold of 1.1 works well
  - With simple on-off model

- Adaptive or dynamic threshold works well
  - For networks where link fluctuation model is unknown
  - Approaches-
    - **Simple Moving Average Filtering**: Average of past *ten* SETT/LETT ratio
    - **Median Filtering**: Median of past *ten* SETT/LETT ratio
    - **Moving Average + Median Filtering**: Perform averaging of past *five* SETT/LETT ratio and then median filtering on *five* such averaged ratio values

Future Work

- Inter-partition Graph
  - Comparing current single copy DTN routing to multiple copy DTN routing mechanisms
  - Comparing GSTAR with existing DTN routing protocols
- Storage Aware Routing Metric
  - The path selection metric should be modified to include SETT, LETT and storage available at each router.
- Effects of finite storage at each router
- Extending GSTAR to support multicast and anycast

Thank you !