Weak State Routing for Large Scale Dynamic Networks

Utku Günay Acer, Shivkumar Kalyanaraman, Alhussein A. Abouzeid

Rensselaer Polytechnic Institute
Department of Electrical, Computer & Systems Engineering

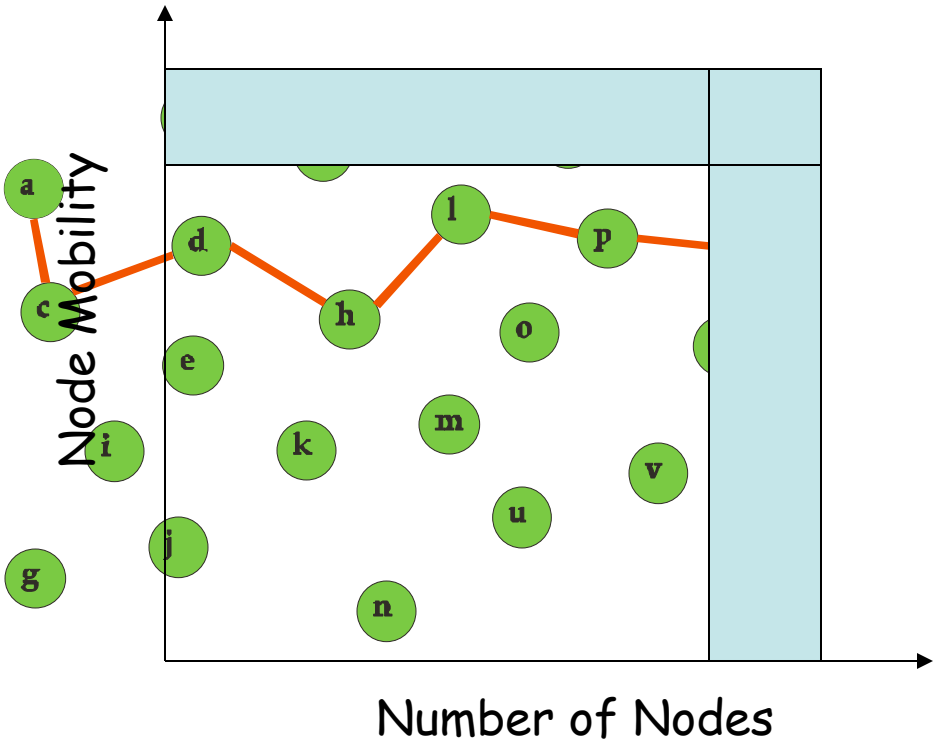
- Which area should we **NOT** be working on in MOBICOM anymore?

- Ans: Routing !

- Victor Bahl, Mobicom 2007 panel

Routing in Large-scale Dynamic Networks

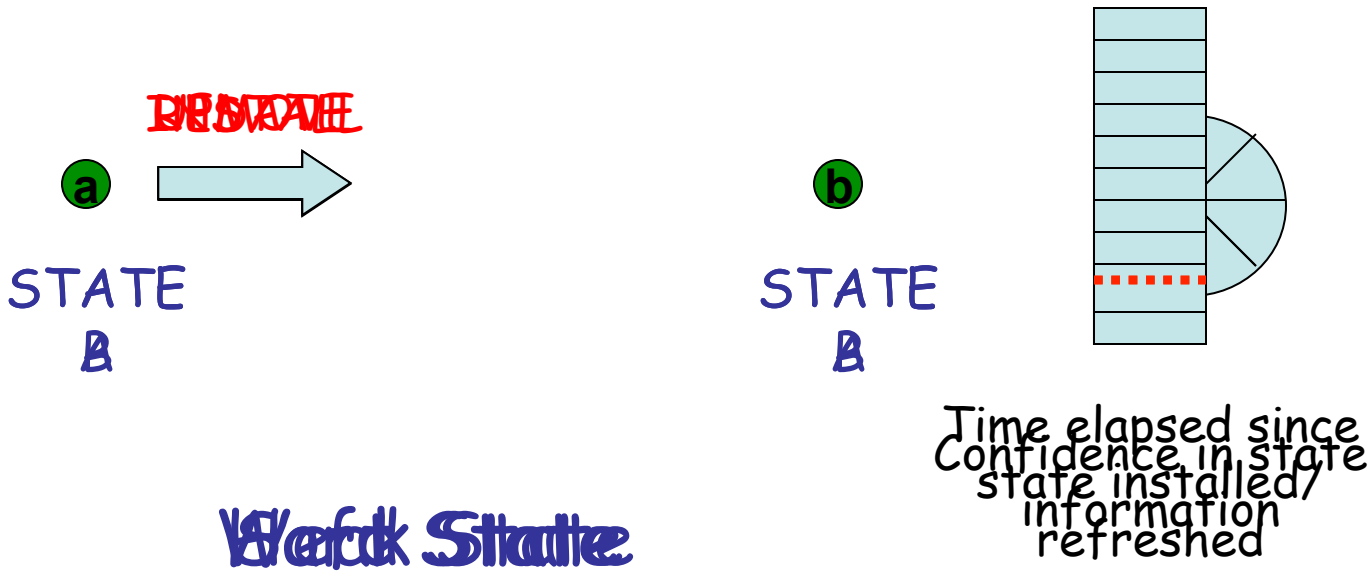
- Routing table entries: "state" = indirections from persistent names (ID) to locators
- Due to dynamism, such indirections break
- Problematic on two dimensions
  - ☑ Dynamism/mobility => frequent update of state
  - ☑ Dynamism + large scale => very high overhead, hard to maintain structure
- We propose constructing routing table indirections using <u>probabilistic and more stable state</u>: *WEAK STATE*



A new class of State

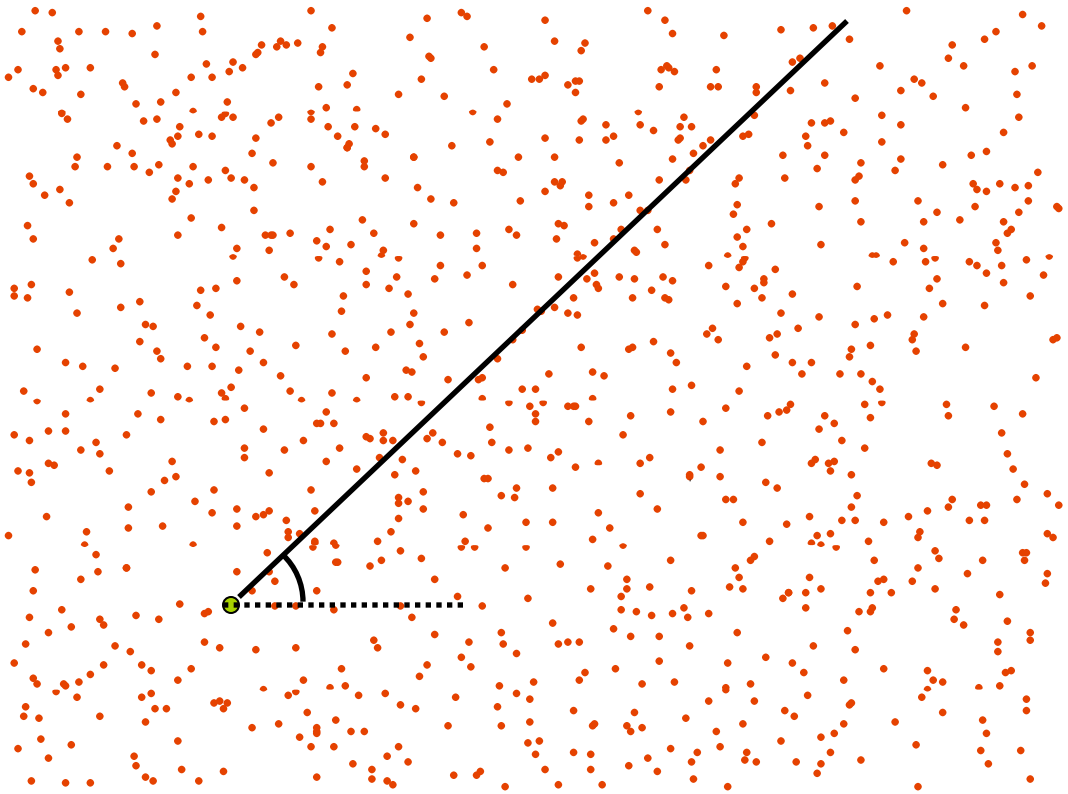
- Strong State
  - ☑ Deterministic
  - ☑ Requires control traffic to refresh
  - ☑ Rapidly invalidated in dynamic environments
- Weak State
  - ☑ Probabilistic hints
  - ☑ Updated locally
  - ☑ Exhibits persistence

Hard, Soft and Weak State



Weak State is natural generalization of soft state

Random Directional Walks

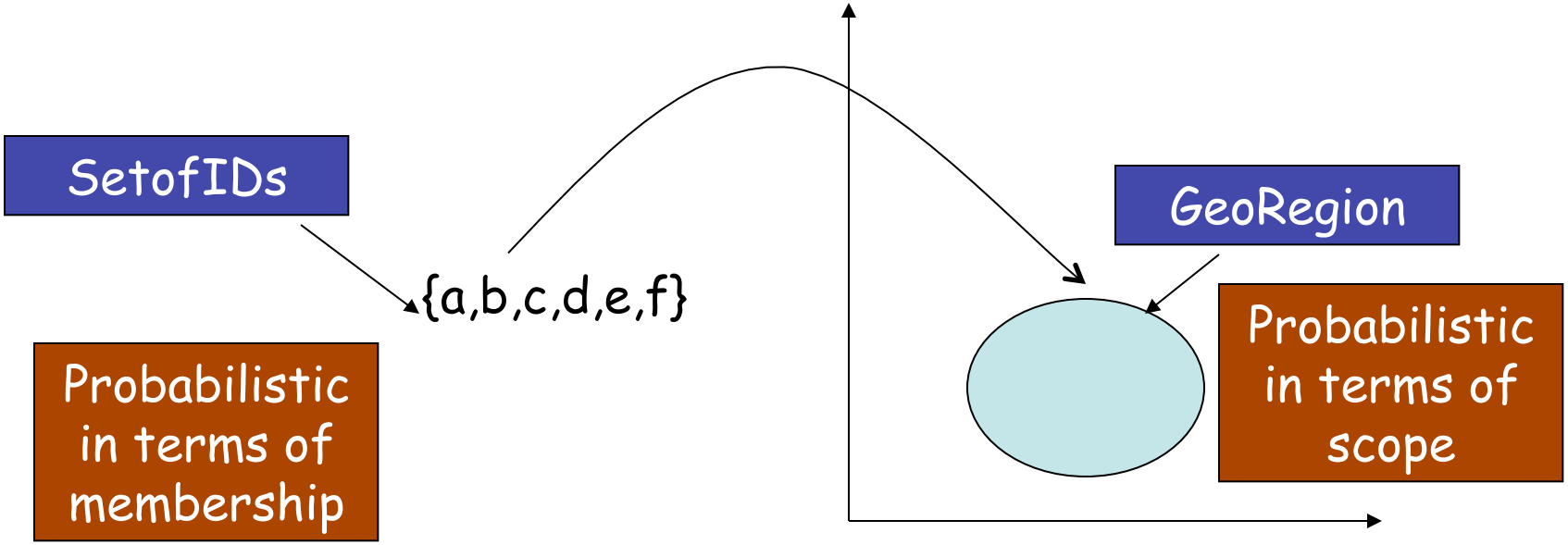


- Both used to announce location information ("put") and forward packets ("get")

Outline

- Our Weak State Realization
- Disseminating Information and Forwarding Packets
- Simulation Results
- Discussion & Conclusion

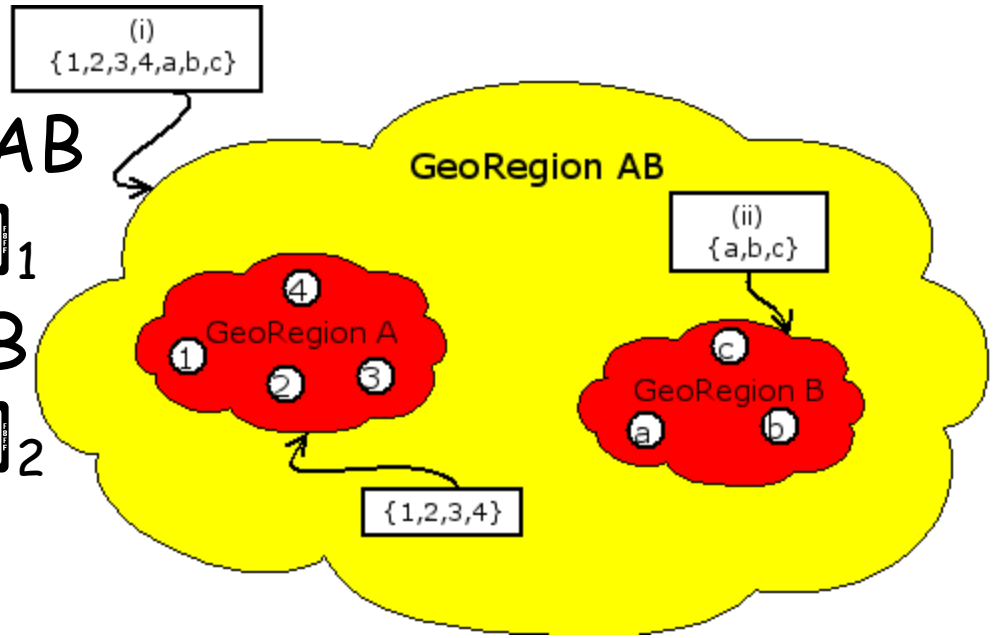
An Instance of Weak State



- The uncertainty in the mappings is captured by locally weakening/decaying the state
- Other realizations are possible
  - ☑ Prophet, EDBF etc…

Example: Weak State

- Consider a node a
- Where is node a?
  - ☑ (i): It is in region AB with probability $\mathbb{W}_1$
  - ☑ (ii) It is in region B with probability $\mathbb{W}_2$ ($\mathbb{W}_1 \leq \mathbb{W}_2$)

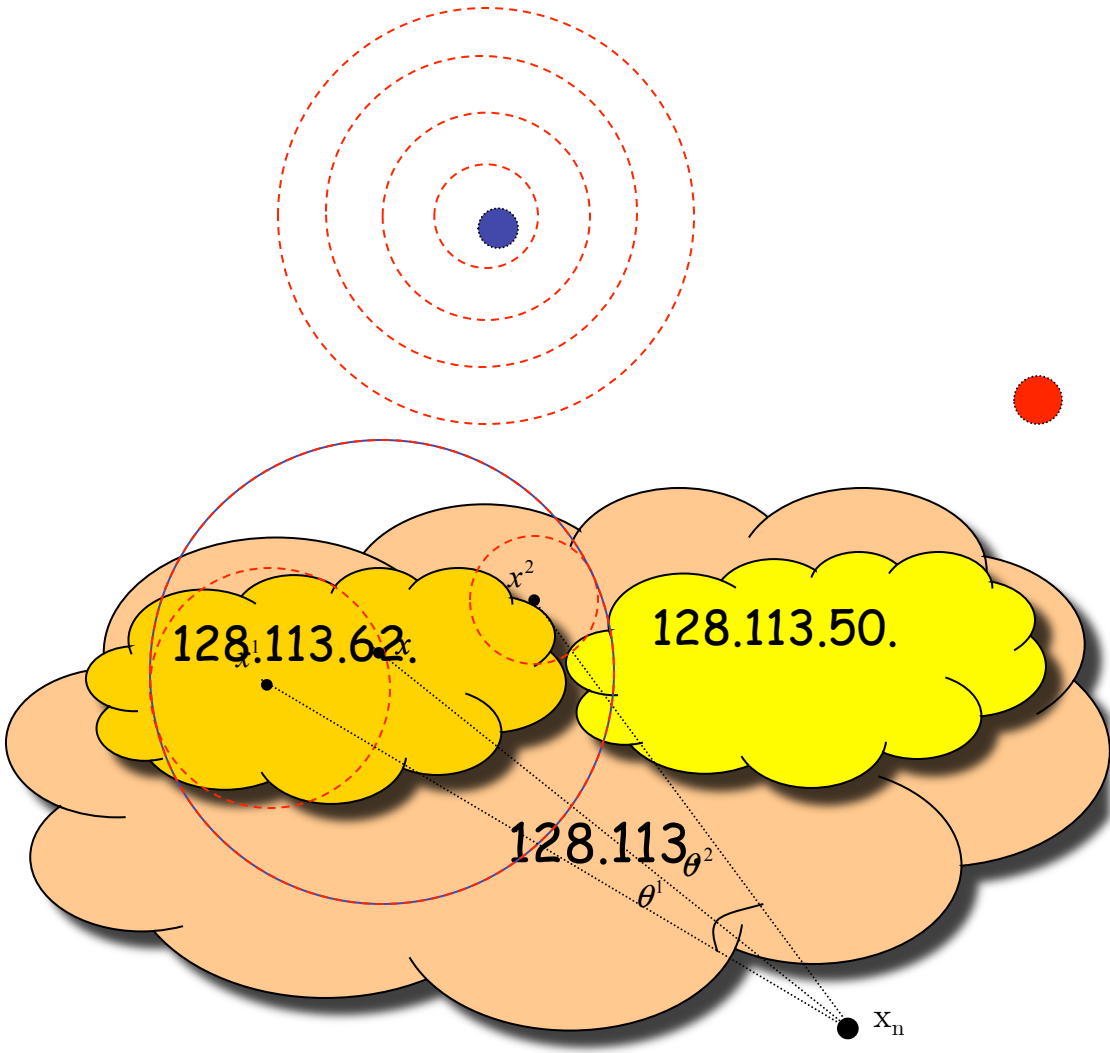


How to "Weaken" State?

Larger Geo-Region

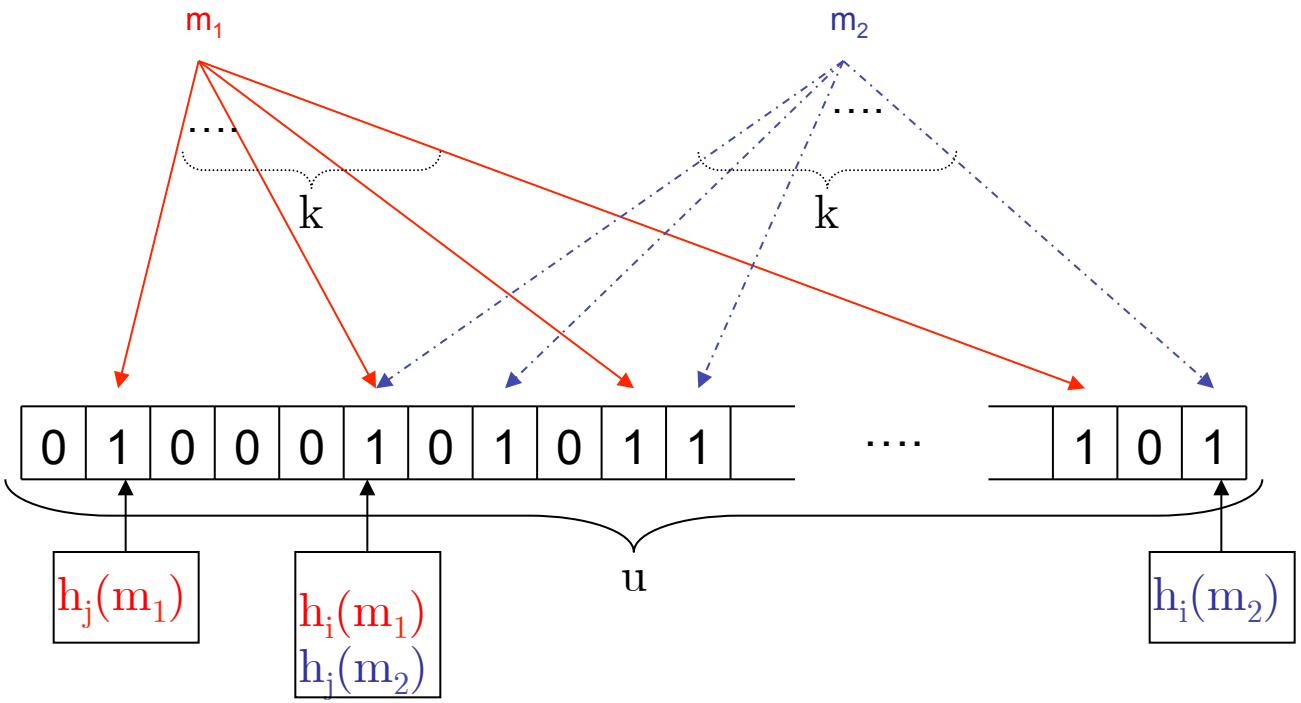
Aggregation

SetofIDs -> GeoRegion



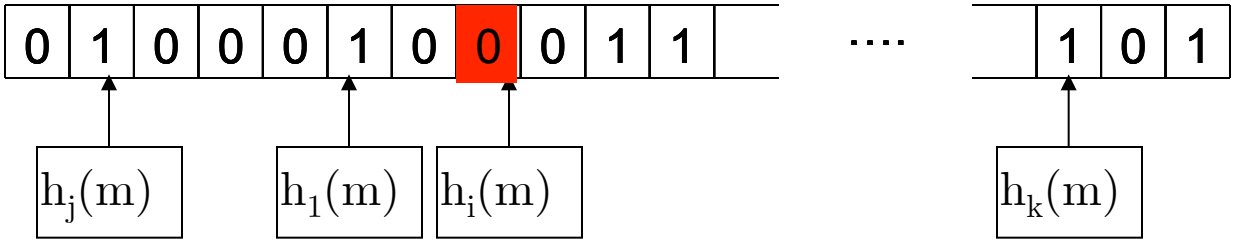
Aggregation: setofIDs

- setofIDs: We use a Bloom filter, denoted by B.



Decaying/Weakening the setofIDs

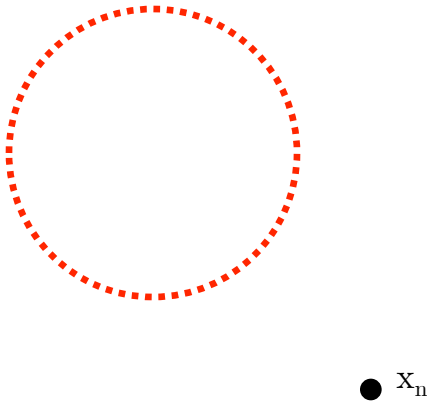
- Randomly reset 1's to 0. Same as EDBF [Kumar et al. Infocom'05]



- Let $W(m) = W_{i=1}^{m} B(h_i(m))$
- Large $W(m) \rightarrow$ fresh mapping
- $W(m)/k$ is a rough measure of $P\{x_m \in A\}$

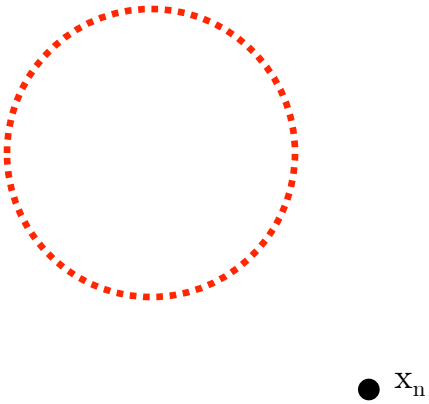
Weakening State (Contd)

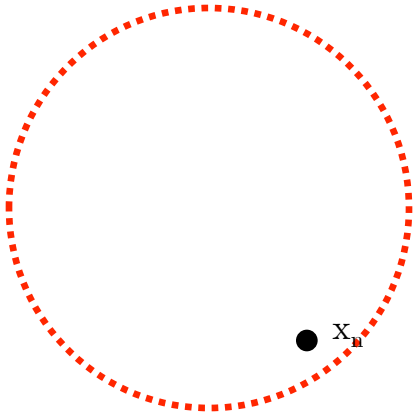
$$|B| \le \frac{u}{2}$$



setofIDs small, time passes:
<u>Decay GeoRegion</u>

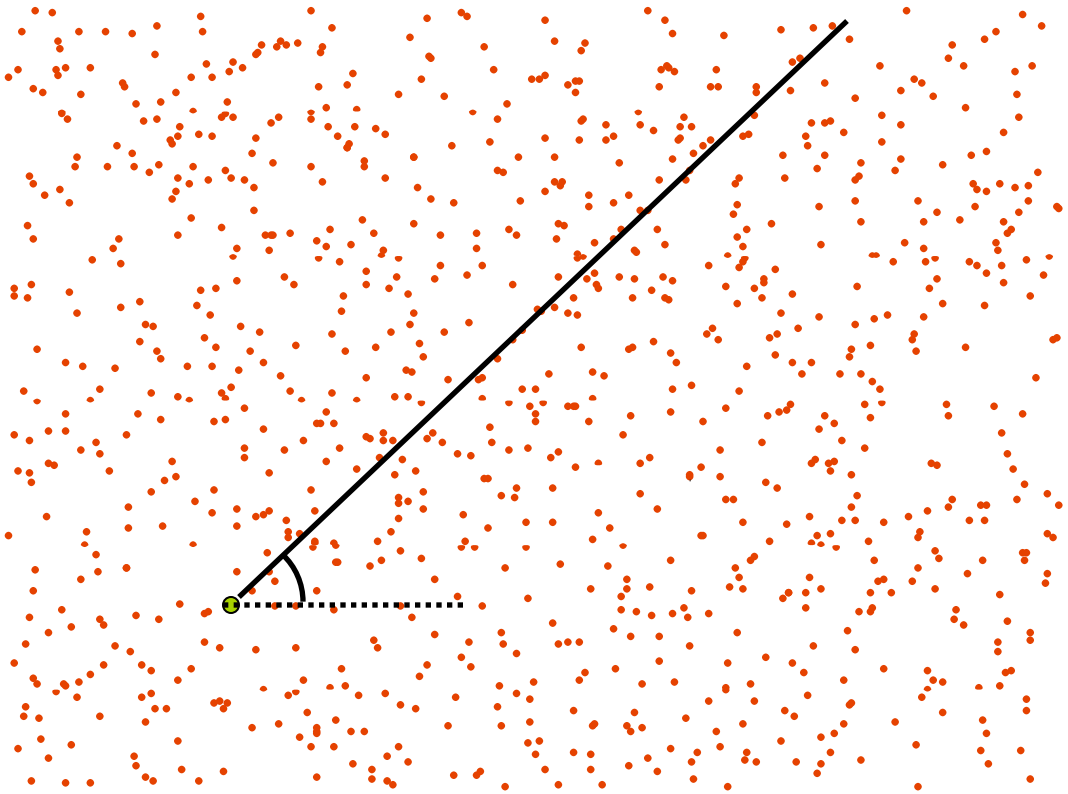
$$|B| \ge \frac{u}{2}$$





Either setofIDs large **<u>OR</u>**
GeoRegion Large =>
<u>Decay SetofIDs</u>

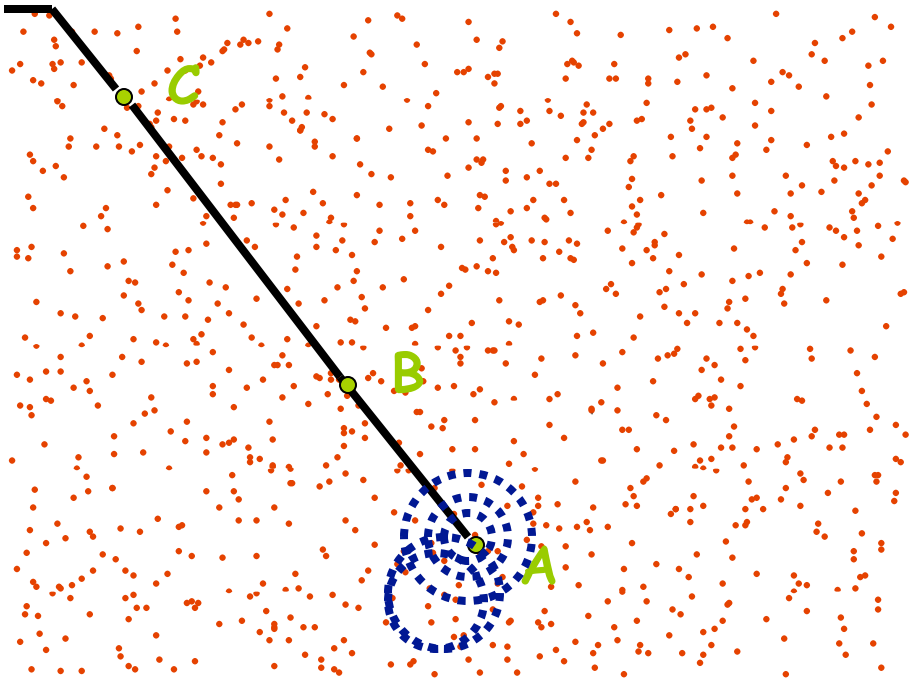
Random Directional Walks



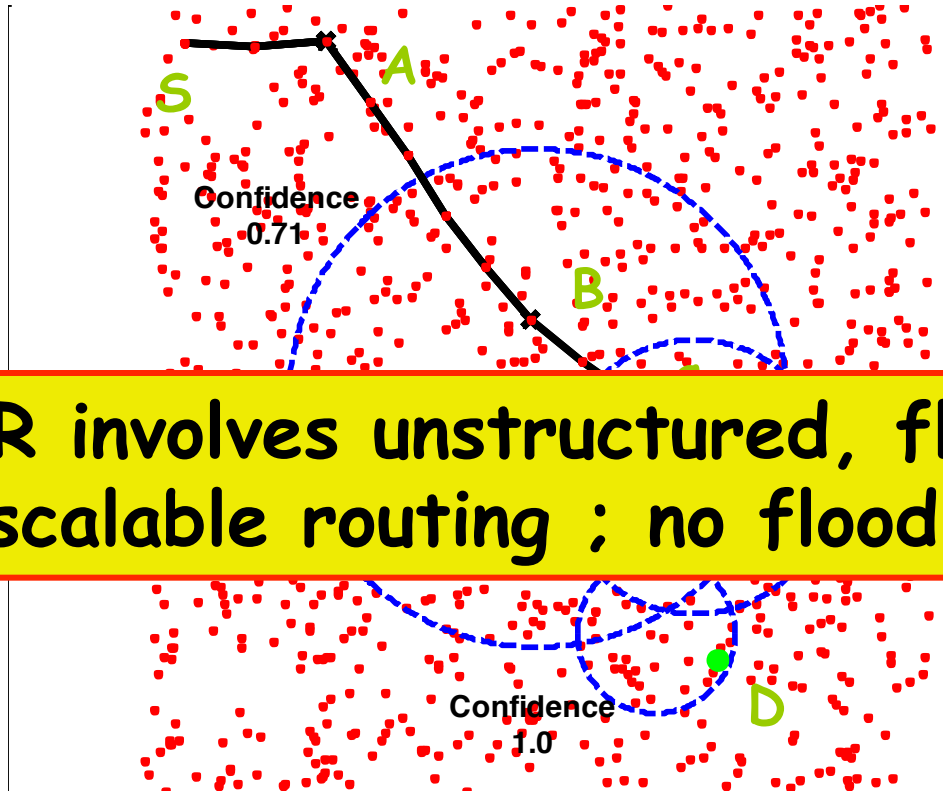
- Both used to announce location information ("put") and forward packets ("get")

Dissemination/Proactive Phase: (put)

- When a node receives a location announcement, it
  - ☑ creates a ID-to-location mapping
  - ☑ aggregates this mapping with previously created mappings if possible



Forwarding Packets (get)



WSR involves unstructured, flat, but scalable routing ; no flooding !

Forwarding decision: similar to longest-prefix-match.
"**strongest semantics match**" to decide how to bias the random walk.

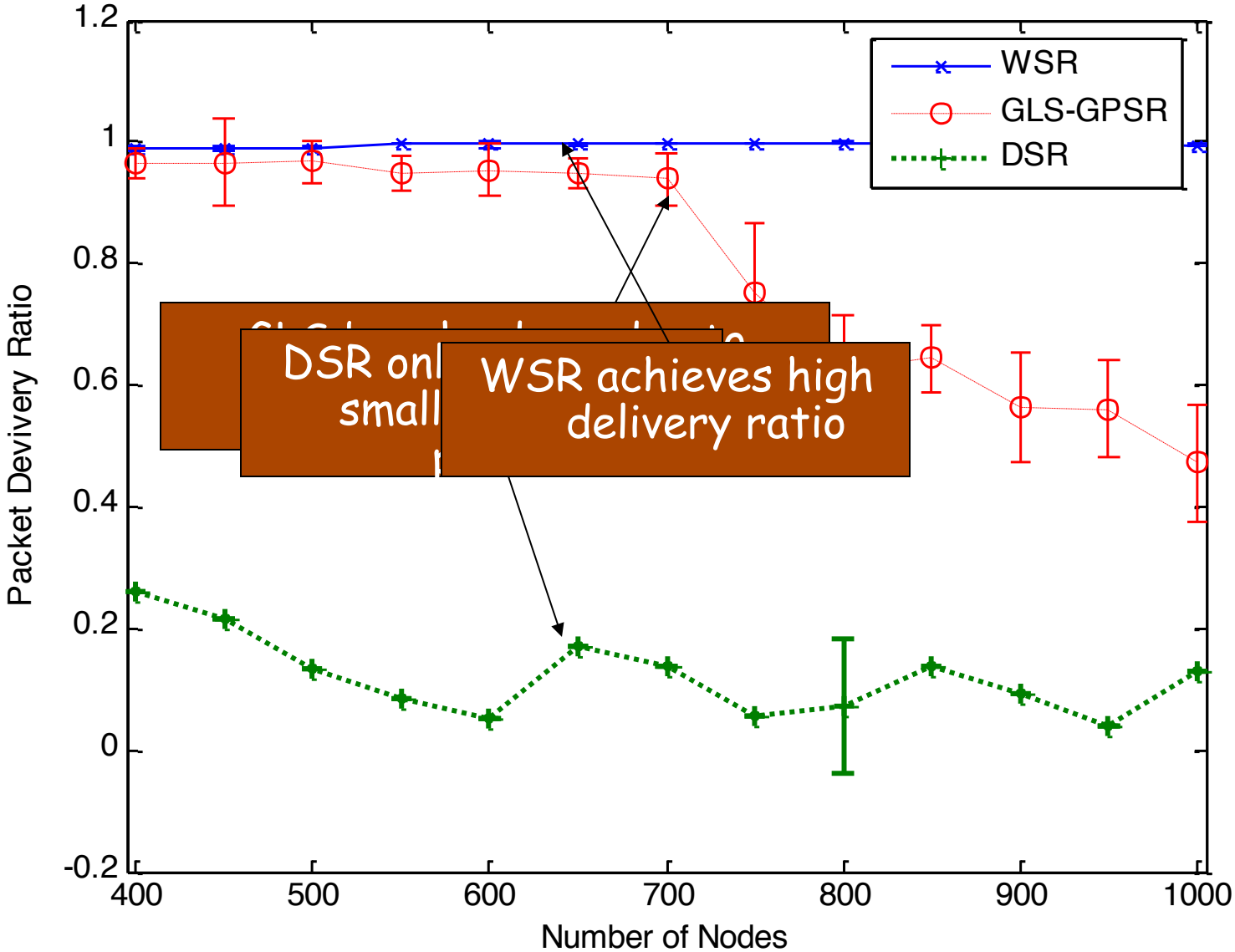
Simulation Objectives

- How does WSR perform?
  - ☑ Large-scale
  - ☑ High Mobility
- Comparisons:
  - ☑ DSR: works well for small scale, high mobility
  - ☑ GLS+GPSR: works well for large scale, low mobility
- Short answer: 98%+ packet delivery despite large scale <u>AND</u> high mobility.
- Tradeoffs: longer path lengths, $\Theta(N^{3/2})$ state overhead

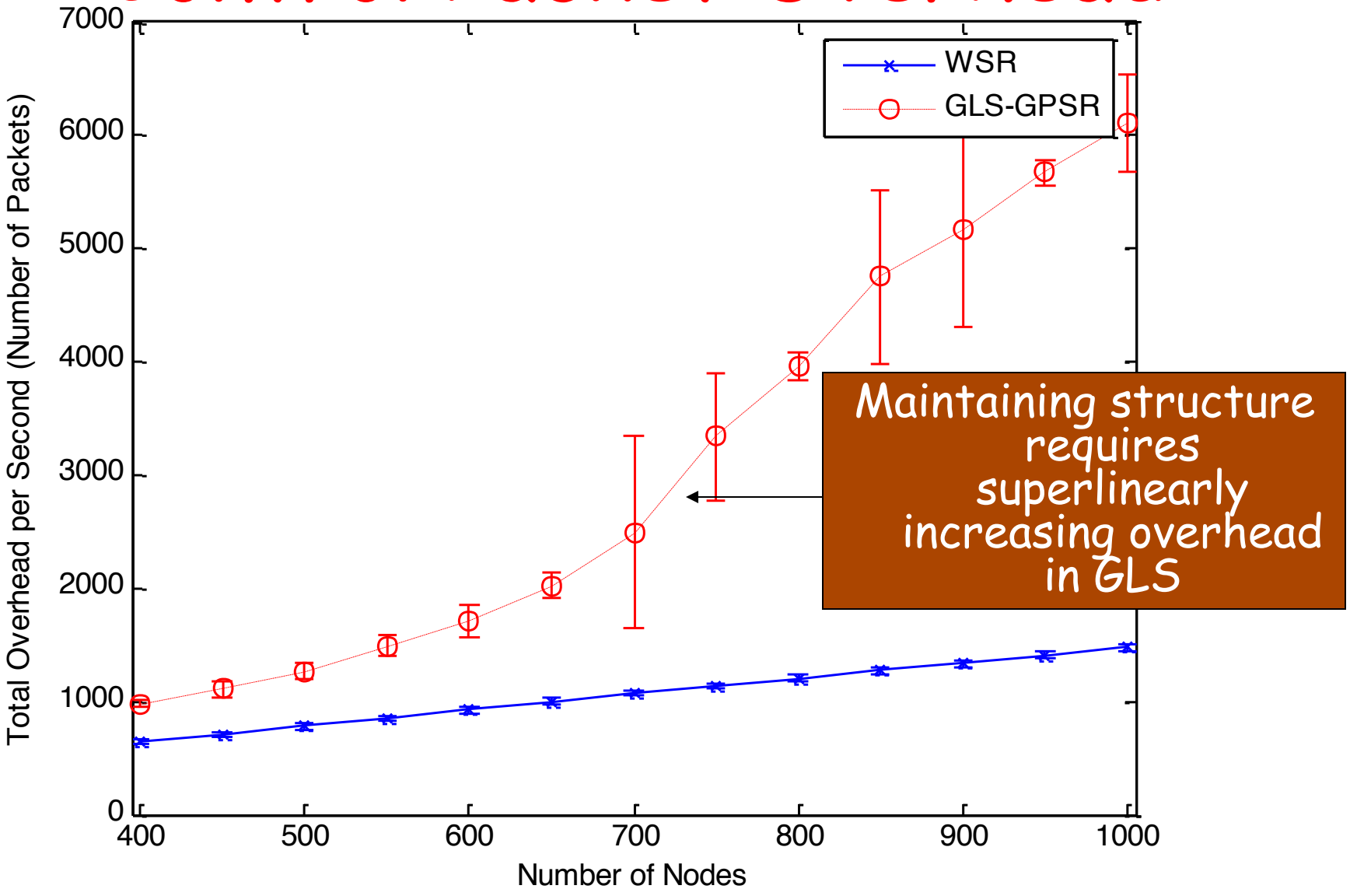
Simulation Setup

- Benchmarks
  - ☑ DSR and GLS-GPSR
- Random waypoint mobility model with v_{min}=5 m/s and v_{max}=10 m/s
  - ☑ WSR is robust against dynamism (please see the paper for details)
- Performance Metrics
  - ☑ Packet delivery ratio
  - ☑ Control packet overhead
  - ☑ Number of states maintained
  - ☑ Normalized path length
  - ☑ End-to-end Delay

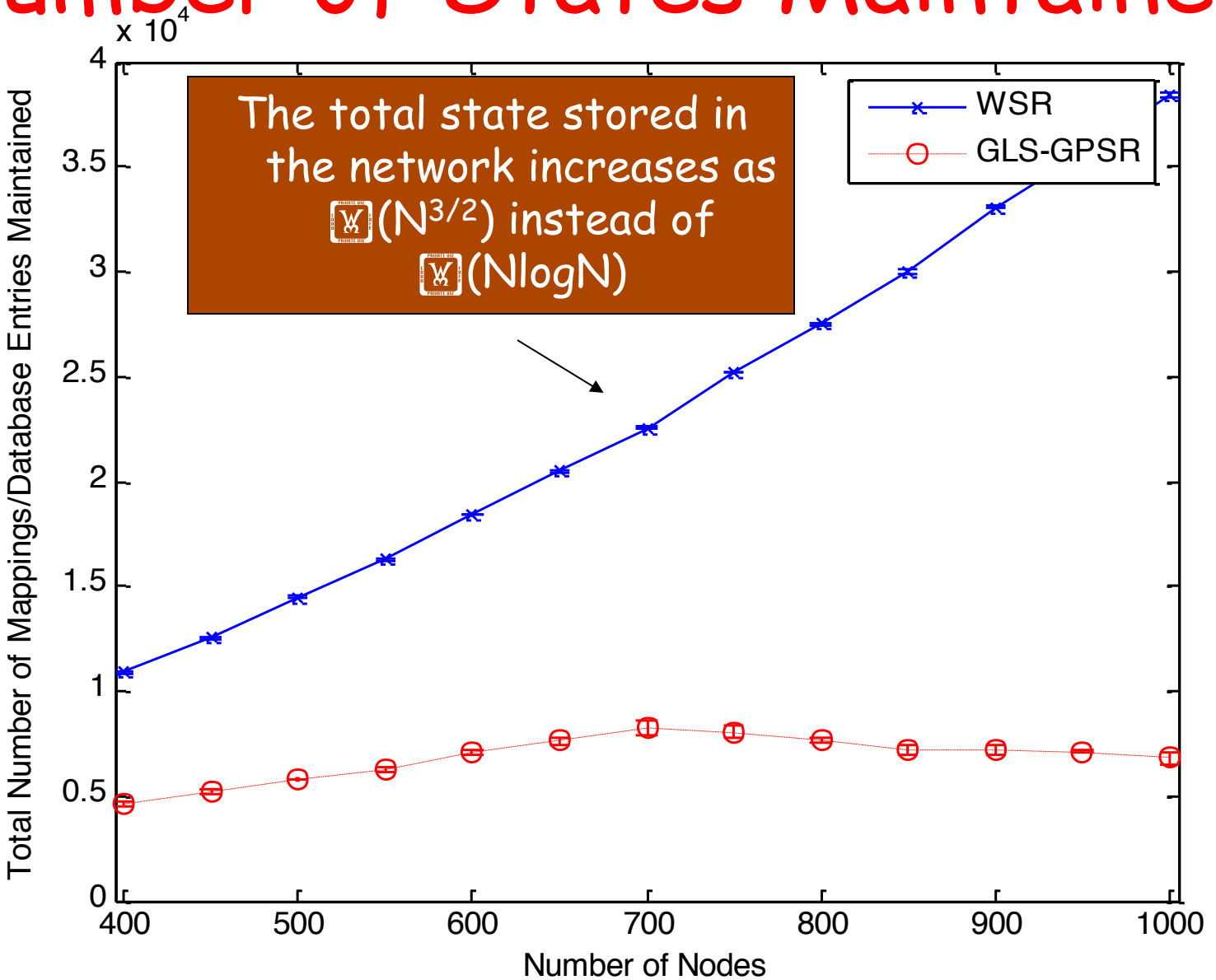
Packet Delivery Ratio



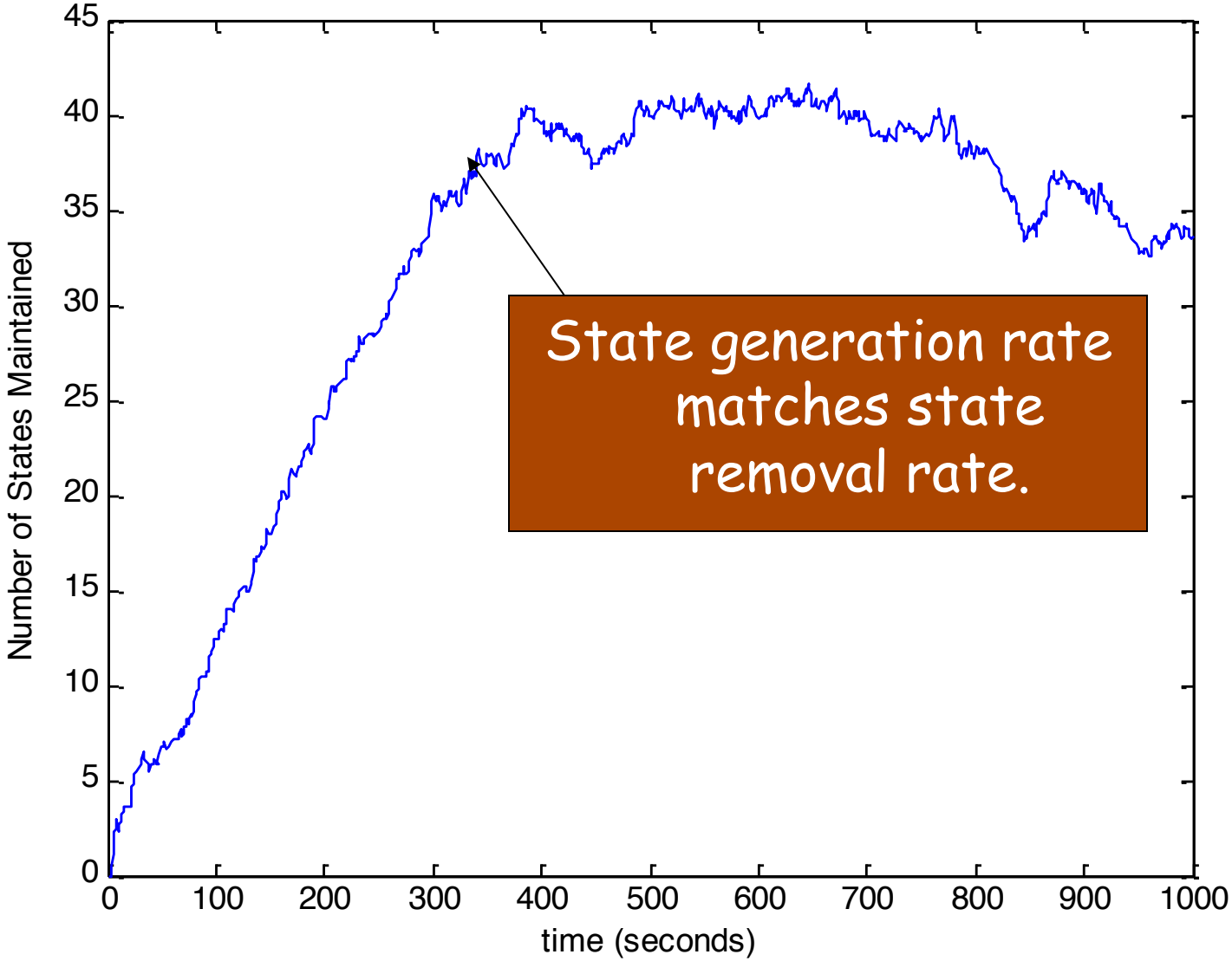
Control Packet Overhead



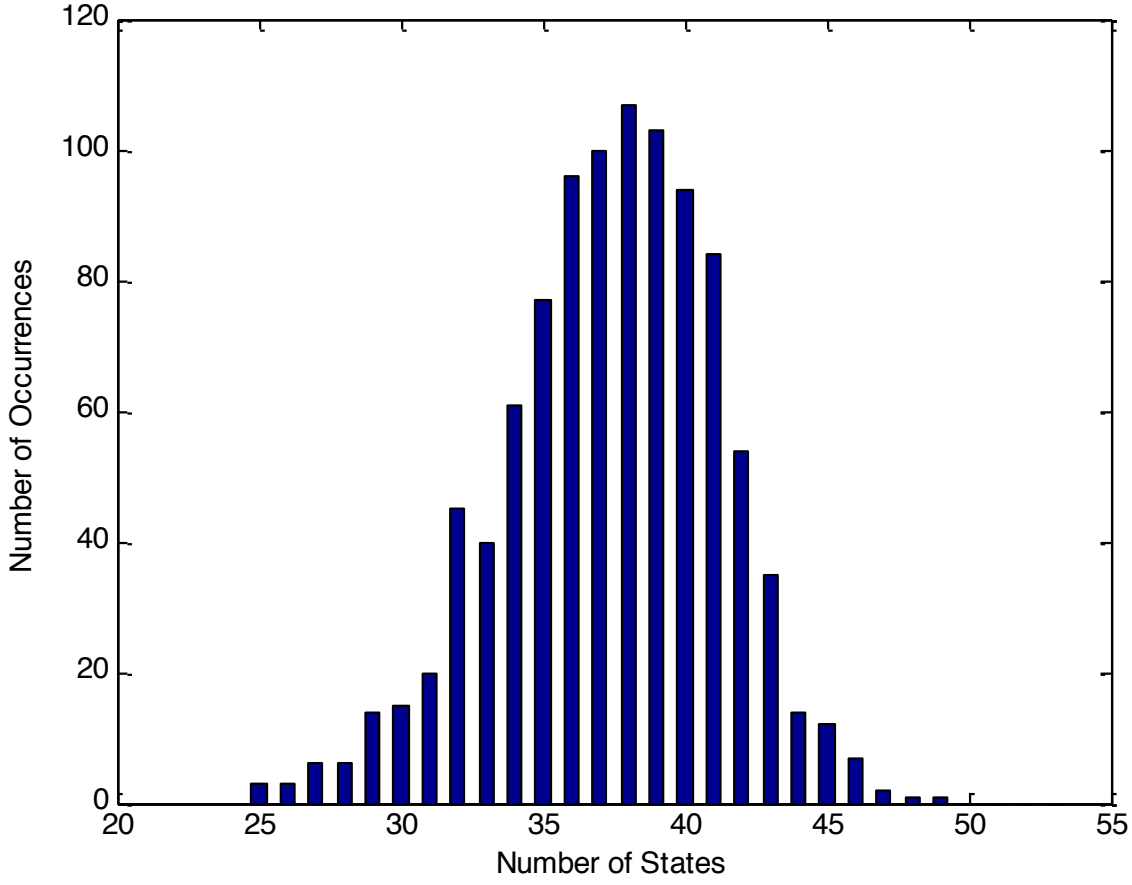
Number of States Maintained



Per-Node State Dynamics

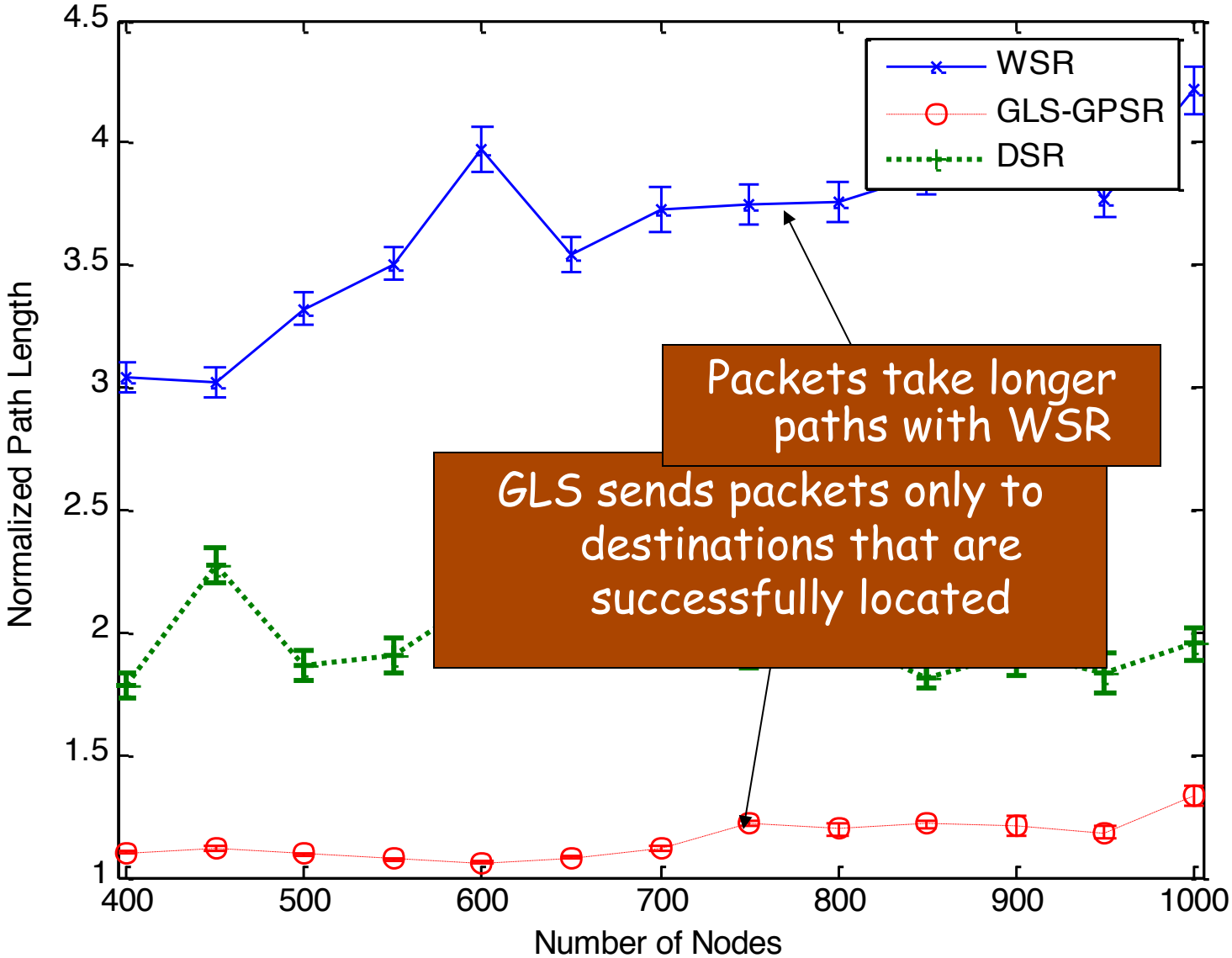


Distribution of Per-Node State in the Network

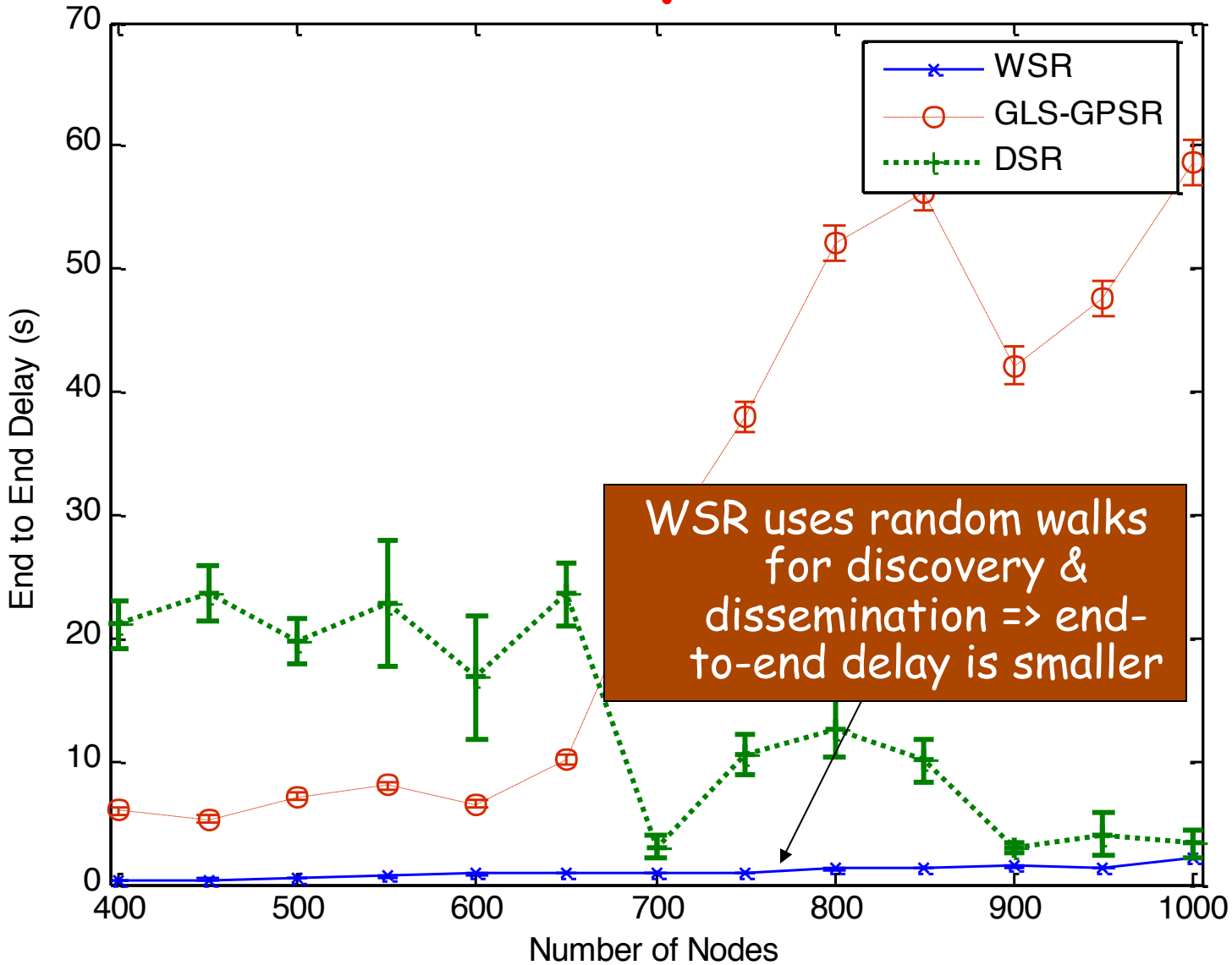


The states are well distributed with a C.o.V 0.101

Normalized Path Length



But, E2E Delay is Lower!



Discussion/Future Work

- Weak State Routing also relates to
  - ☑ DTN routing
  - ☑ Unstructured rare object recall in P2P networks
  - ☑ Distributed Hashing

- Future work:
  - ☑ Such extensions (especially DTNs)
  - ☑ Theoretical analysis

Conclusion

- Weak state is soft, updated locally, probabilistic and captures uncertainty
- Random directional walks both for location advertisement and data forwarding.
- WSR provides scalable routing in large, dynamic MANETs
- WSR achieves high delivery ratio with scalable overhead at the cost of increased path length

Thank you

Questions?