TO-GO: TOpology-assist Geo-Opportunistic Routing in Urban Vehicular Grids

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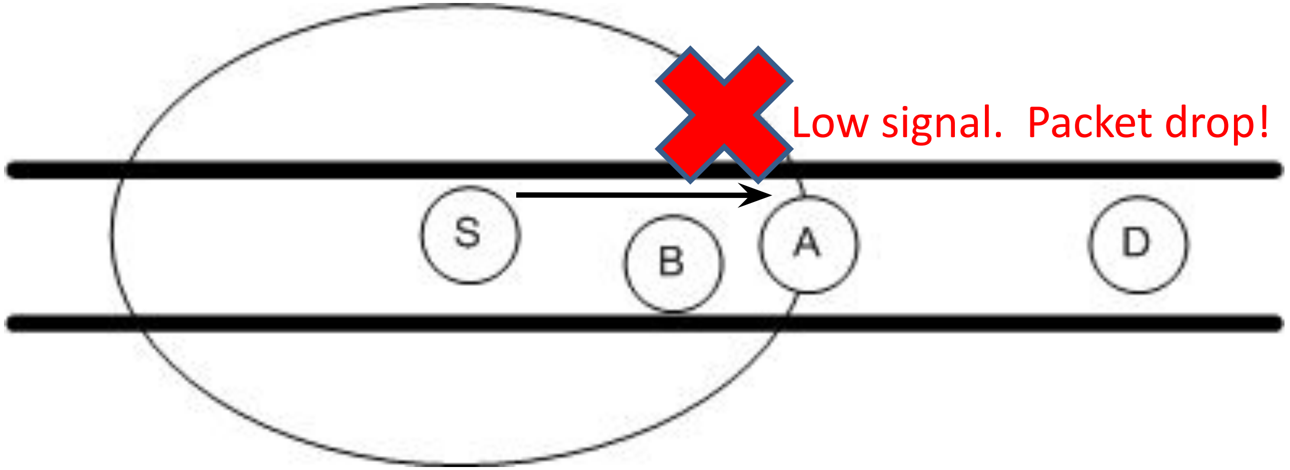
Possible Routing Solutions in VANET

- Proactive (table-driven) => Not too scalable
  - DSDV
  - OLSR
- Reactive (on-demand) ⇒ Long route establishment, susceptible to route breaks
  - AODV
  - DSR
- Geographic => Scalable, yet robust to route breaks, but…
  - GPSR, GPCR, GOAFR+…

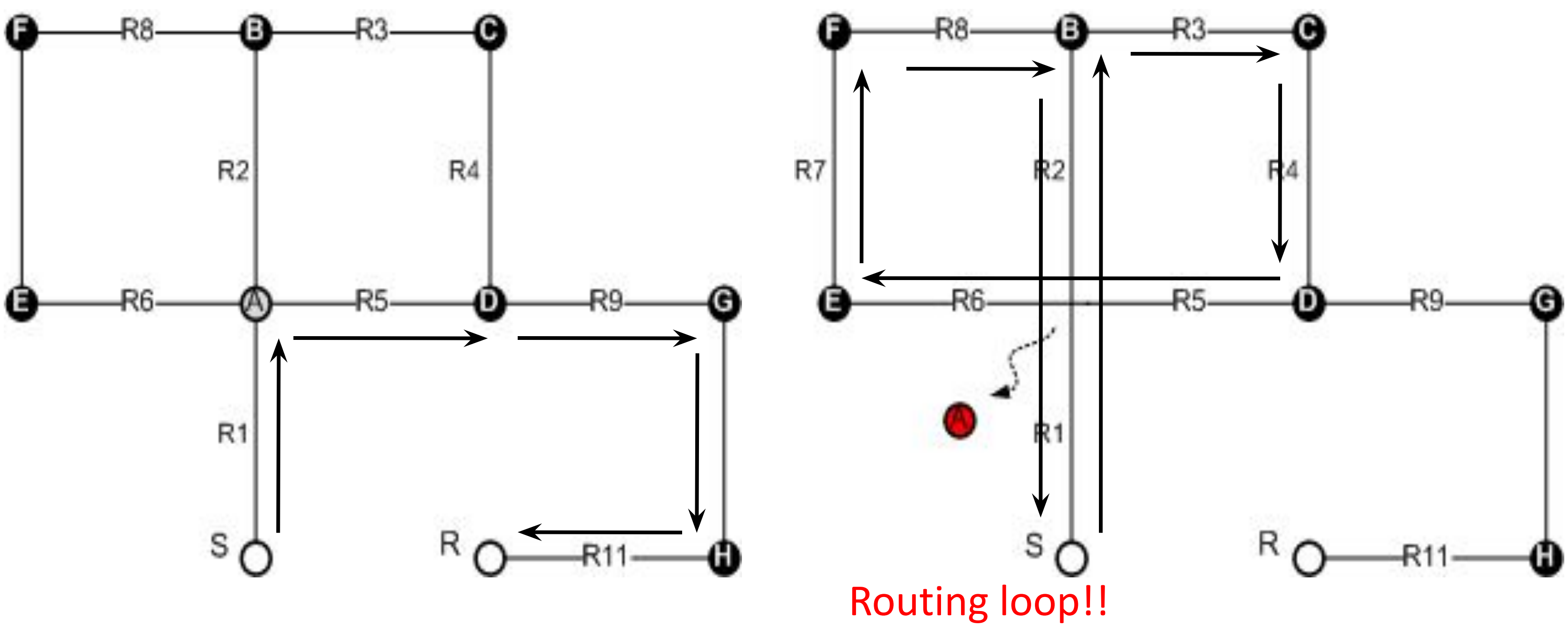
Geographic Routing: Greedy Mode

- Forward to node making biggest progress
- Drawback: Furthest node often fails to receive because of high error rate

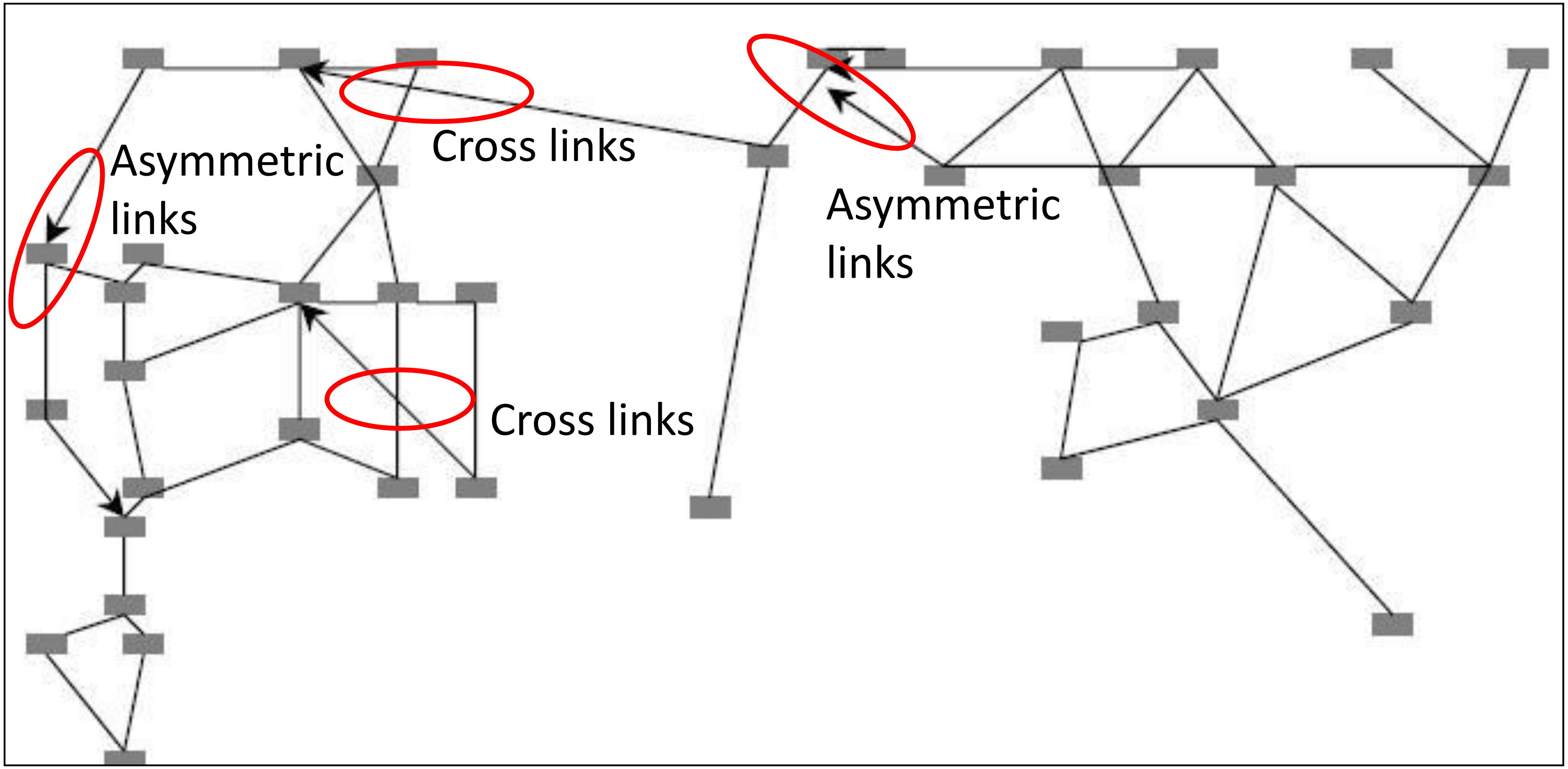


Geographic Routing: Recovery Mode

- Route along faces of a planar graph to avoid loops
- Drawback: Irregular radio range can't produce a perfect planar graph



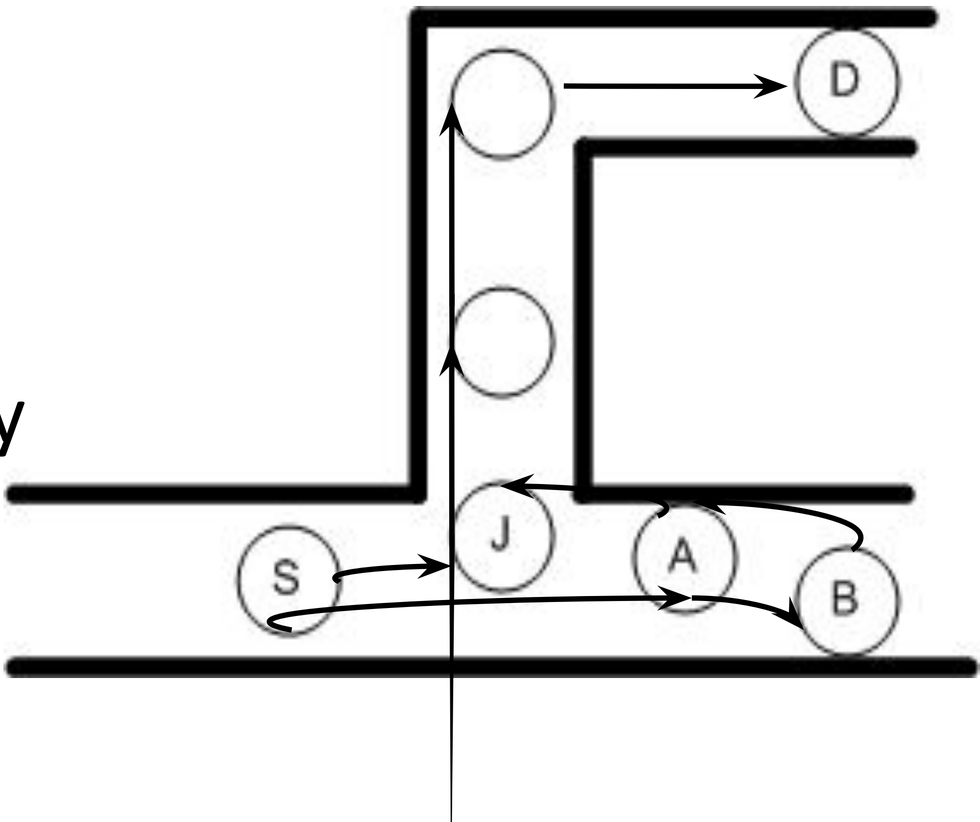
Cross Links in Real Office Suite



Kim et al. Geographic routing made practical. NSDI 2005

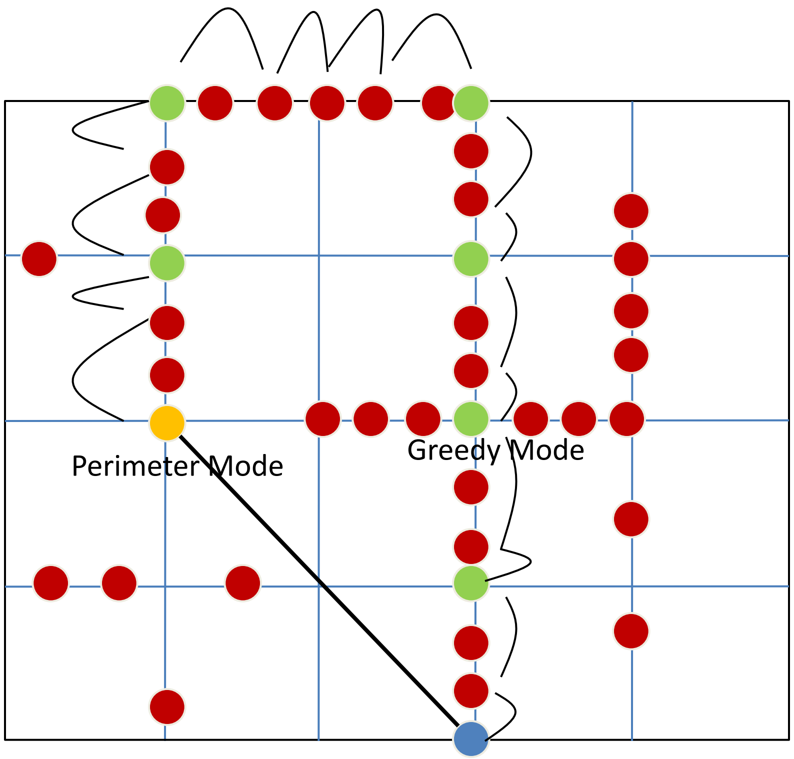
GPCR

- Eliminate planarization by routing along roads
- Roads naturally formed a "planar" graph
- *Greedily* forward until junctions so as not to miss best route to the destination
- Drawback: Inefficiency in routing as packets always stop @ junction nodes

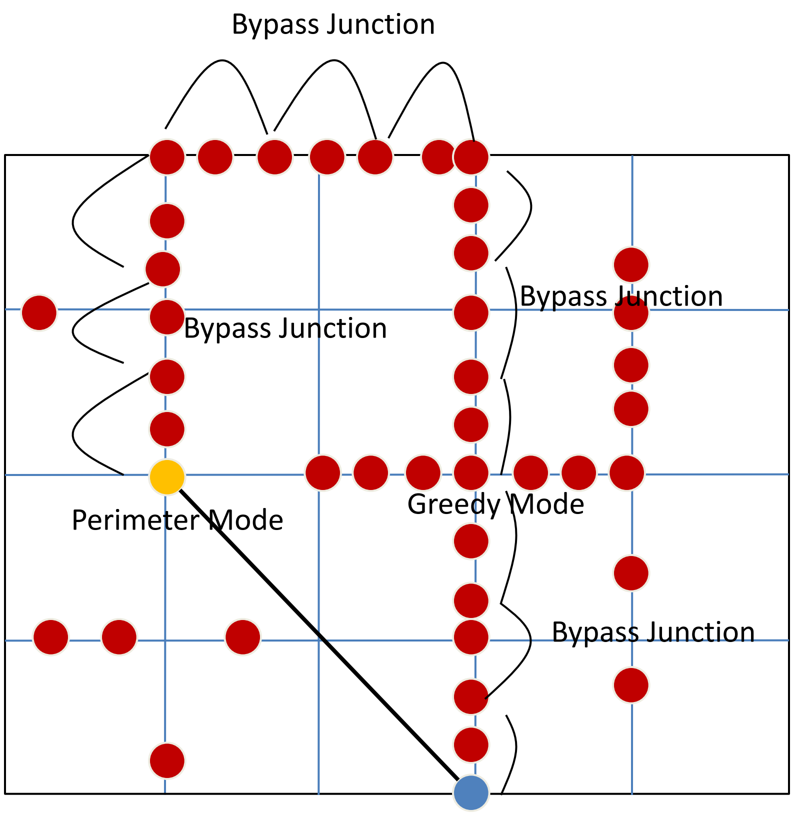


GPCR Inefficiency

GPCR Routing



Total Hops: 16



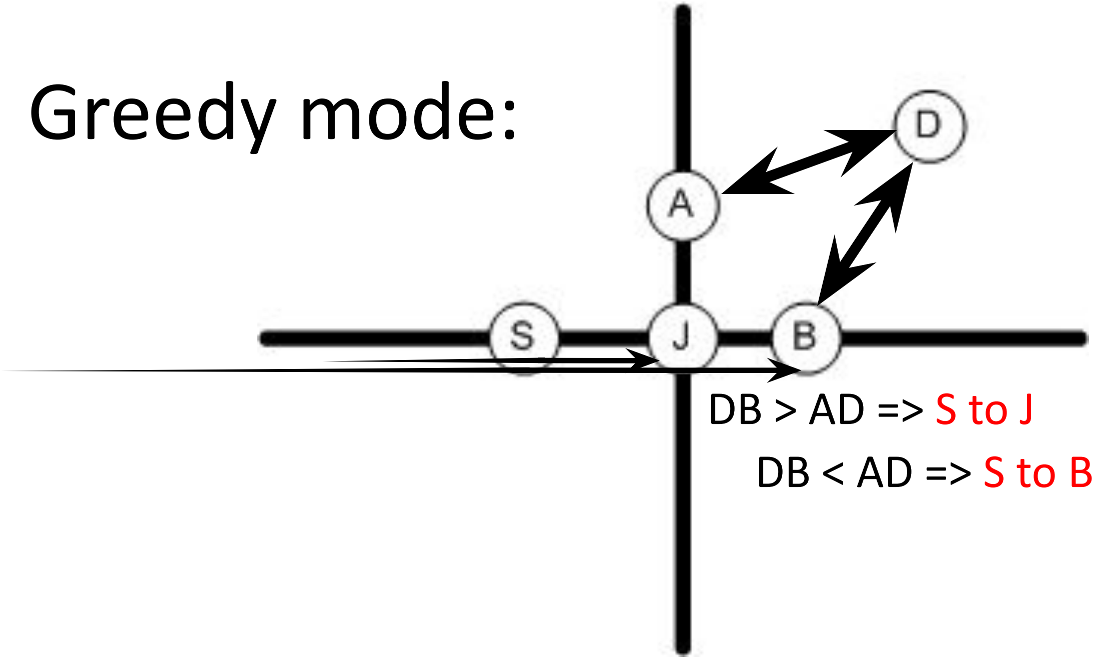
Total Hops: 12 (+25%)

TO-GO Contributions

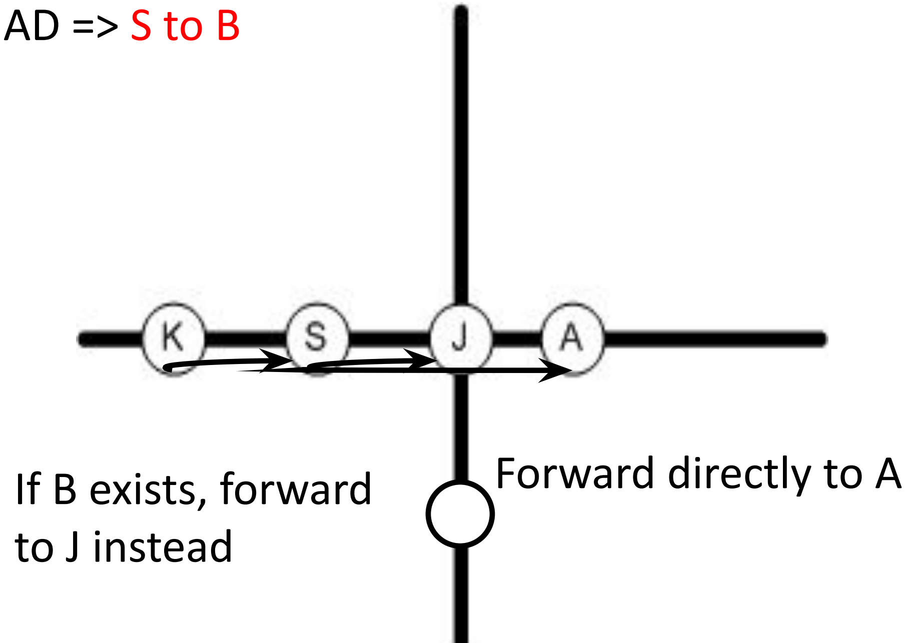
- Opportunistic forwarding to improve packet delivery in greedy and recovery forwarding
  - Broadcast to a set of nodes
  - Forwarding set construction
  - Priority scheduling
- Junction look-ahead – Bypassing junction whenever it can

Junction Look-ahead

- Greedy mode:



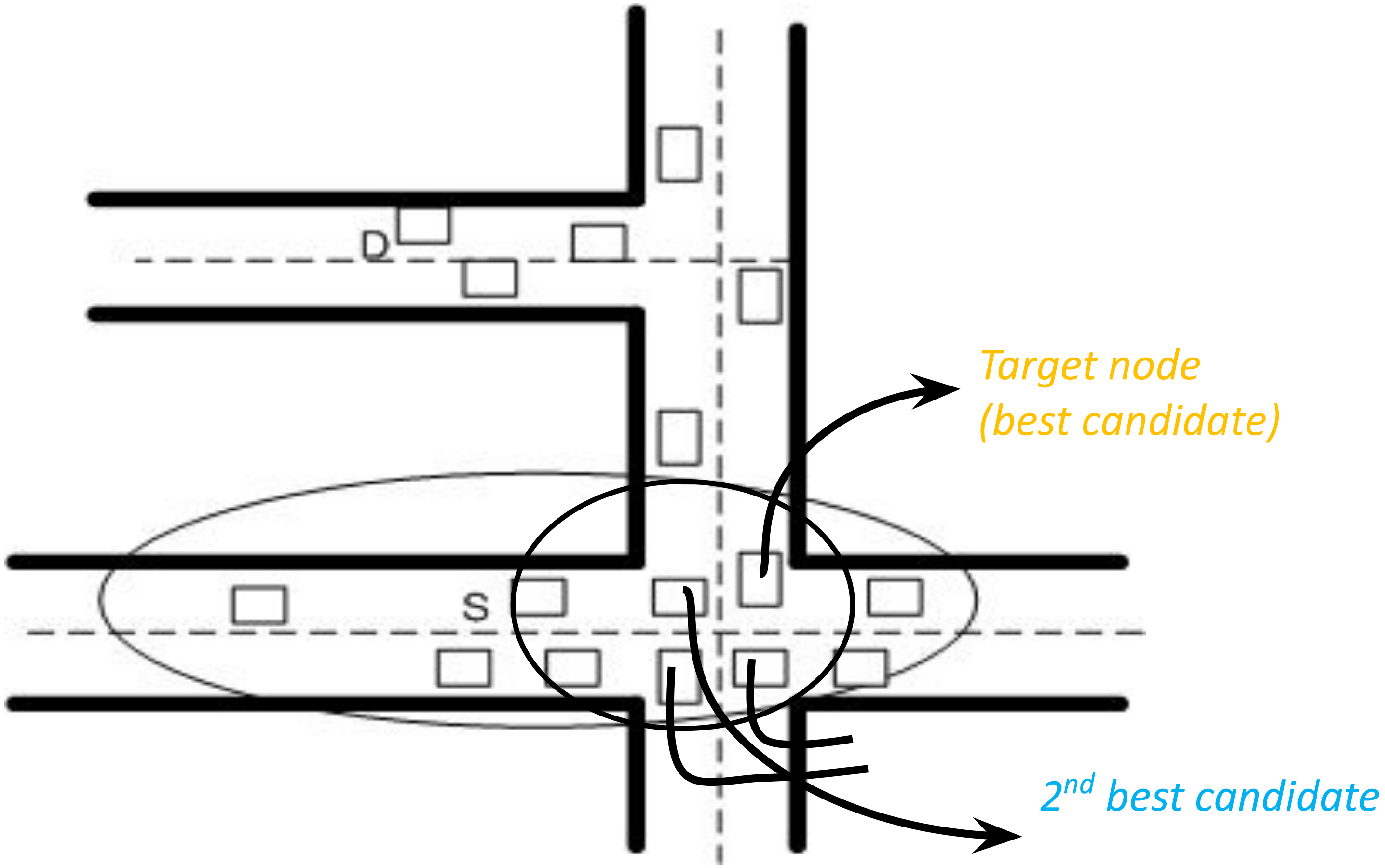
- Recovery mode:



TO-GO Opportunistic Forwarding

- Node forwards to a set of nodes
- Construct a set between the current node and the *target* node
  - Nodes in a set can hear each other and contend the channel
  - Node closest to the destination wins the contention and is chosen to be the next forwarding node (priority scheduling)
  - Equivalent to finding a clique, NP-hard!

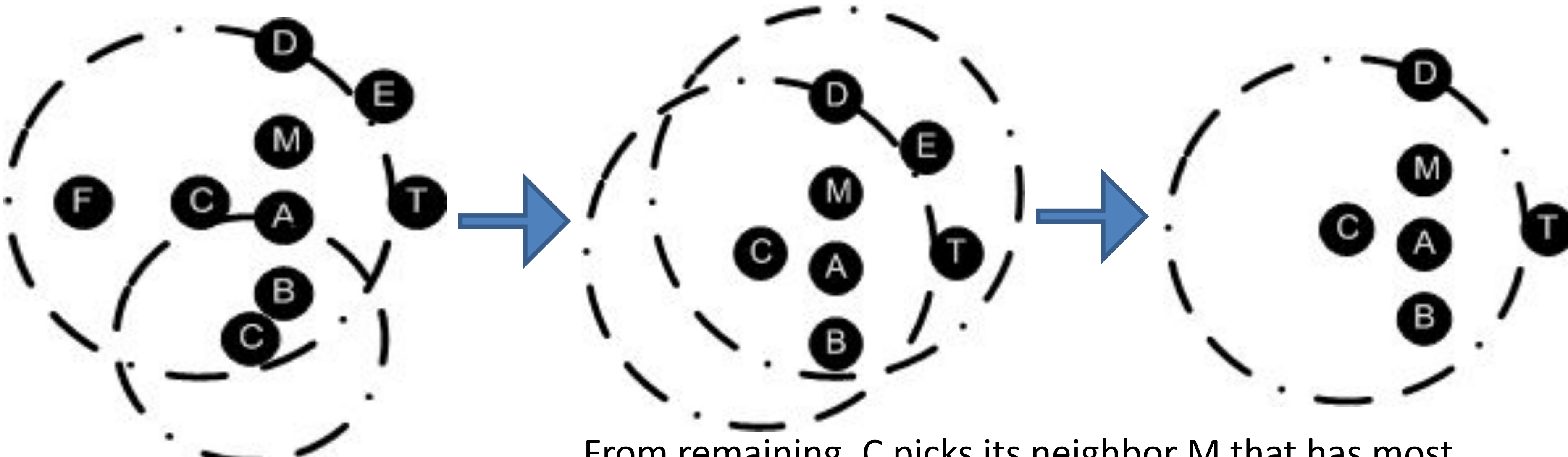
Demo Opportunistic Routing in TO-GO



Finding such a set is NP-hard!

TO-GO Set Construction

- Heuristic:
  - Requires two-hop neighbors and Bloom filter (ref. paper)
  - $O(n^2)$, where n is number of C's neighbors



Pick C's neighbors that can hear C & the target node

From remaining, C picks its neighbor M that has most neighbors; add to the set if the rest of neighbors in C are neighbors with M

TO-GO: Priority Scheduling

- Nodes contend based on timer,

$$T = C \times \frac{dist(\text{receiving node, target node})}{dist(\text{sending node, target node})}$$

- Packet duplication possible because of:
  - Nodes' proximity => Similar T, AND
  - Time to suppress > Time T goes off
  - Impose further constraint in set selection:

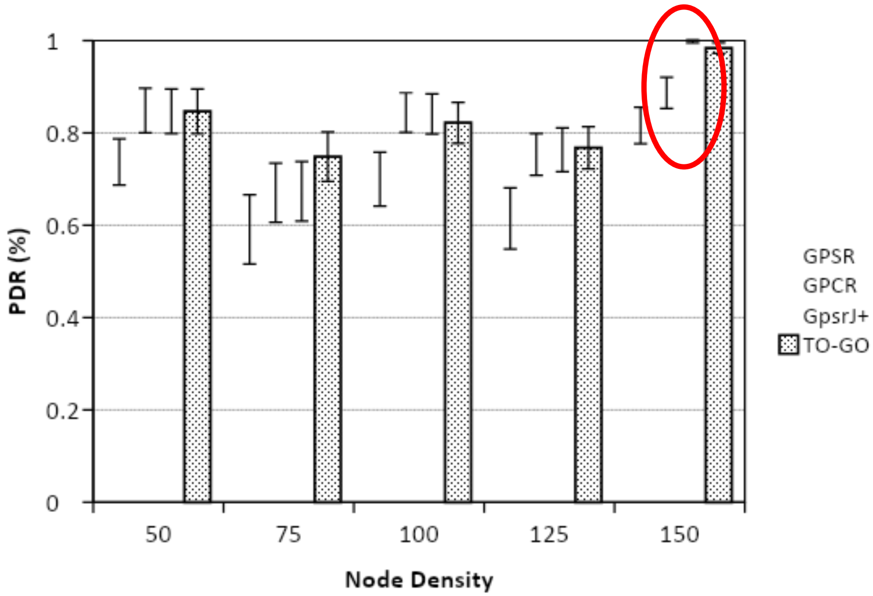
$$|T_{N_k} - T_{N_i}| < \delta$$

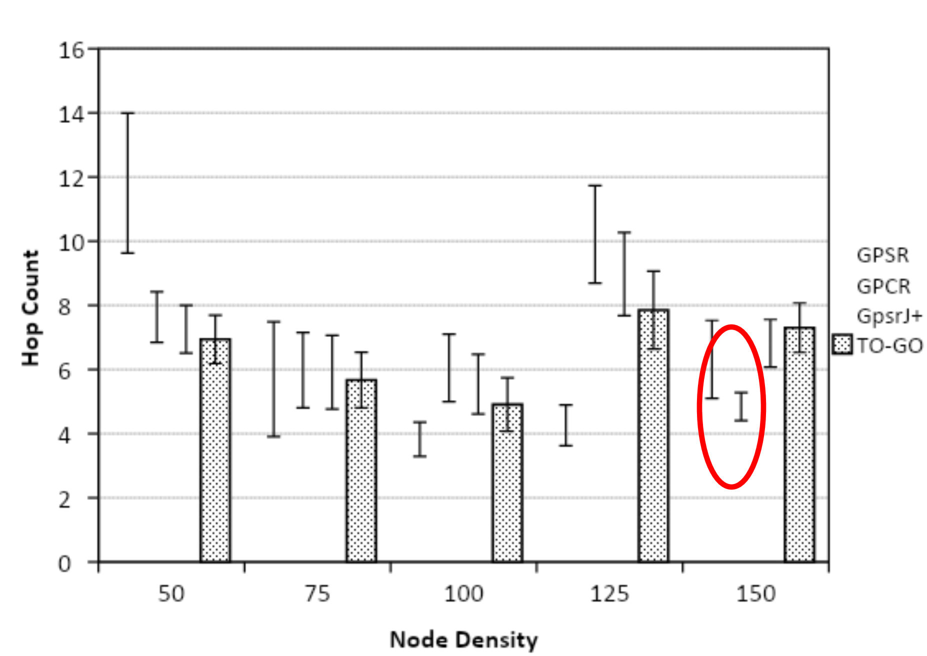
δ is the minimum time interval for suppression, for all nodes N_i in *FS*

TO-GO Evaluation: Set up

- Qualnet 3.95
- 1800m x 300m
- CBR rate: 1460 bytes/sec
- VanetMobisim, vehicular traffic generator
- Avg. vehicle speed, 25 miles/hour
- Inter-road blocking model
- TX range 250m
- Number of nodes 75 to 150
- 20 runs, 95% confidence interval

TO-GO Evaluation: Error-Free





- GPCR, GpsrJ+, TO-GO similar in PDR, GPSR always falls behind
- GPCR's hop count lowest @ 150 among all four routing, consistent with low PDR, due to always forwarding to junctions

TO-GO Evaluation: Error-Prone

- Model channel errors based on:

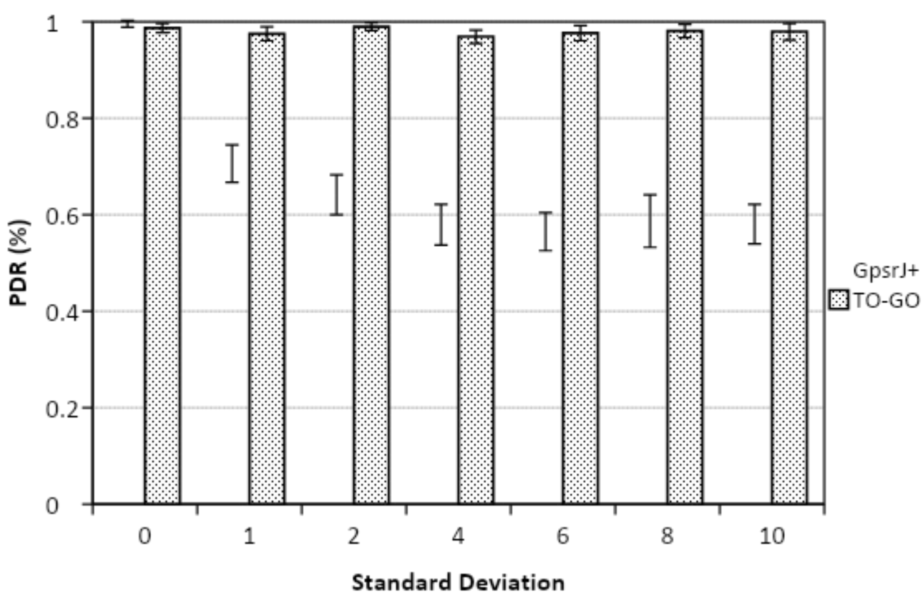
$$PL(d)[dB] = \overline{PL}(d) + X\sigma = \overline{PL}(d_0) + 10n\log(\frac{d}{d_0}) + X\sigma$$

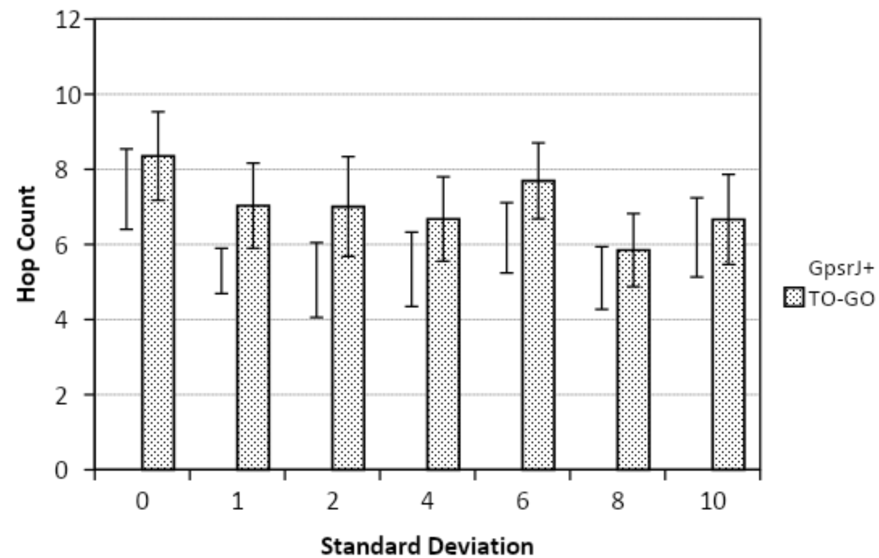
- Solve for d_0,

$$PL(d)[dB] = \overline{PL}(d) + X\sigma = 20\log(\frac{d}{0.025}) + X\sigma$$

- Can calculate *PL*(*d*) for any *d*; if *PL*(*d*) > *PL*(250m), accept; otherwise drop the packet
- Error based on σ; higher σ, higher error

TO-GO Evaluation: Error-Prone





- @ σ = 10, TO-GO's PDR remains @ 98% but GpsrJ+ @ 58%
- Bounded hop count (5.8 & 8.4) show TO-GO's robustness by using neighbors nearby the target to deliver opportunistically

Conclusion

- TO-GO: A geographic opportunistic routing protocol that exploits
  - road-topology information
  - opportunistic packet reception
- Forwarding set and priority scheduling to make sure no packet duplication
- Junction lookahead to reduce hop count