Power-Aware Ad Hoc Routing

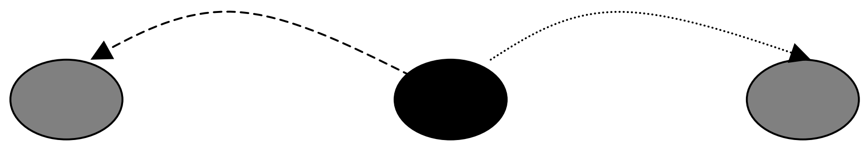
Mobicom98 paper “Power-Aware Routing in Ad Hoc Networks” by Singh, Woo, and Raghavendra

Presentation by – Harkirat Singh

Motivation

- Conservation of power and power-aware routing must take into consideration
- Low Power Hardware
  - energy efficient displays
  - CPU's with *active* and *doze* mode
  - low-power I/O devices
- Energy-efficient algorithms
- 40-70% saving in energy using PAMAS
- Other factors
  - average battery life in *idle* cellular phone – one day
  - DEC Roamabout 5.76 W *transmission*, 2.88 W *receive*, 0.35 W *idle*

Listening Problem



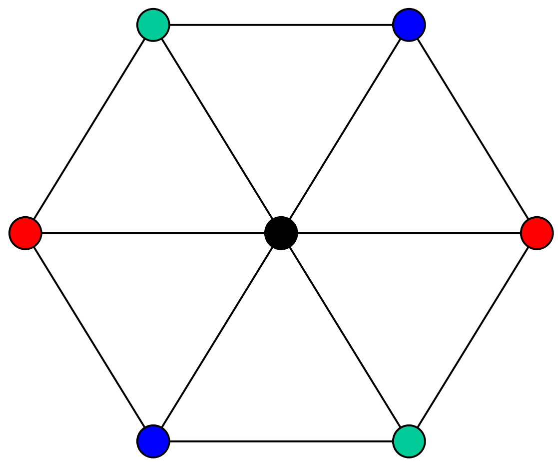
B A C

A transmits to B

A's transmission is overheard by C

The Problem

- Shortest-hop rotes (green, blue, red) all use middle (black) node's resources. It's battery will die early.
- Fairness issue
- Routing packets through lightly loaded nodes also helps in energy expended in contention.



Goal:

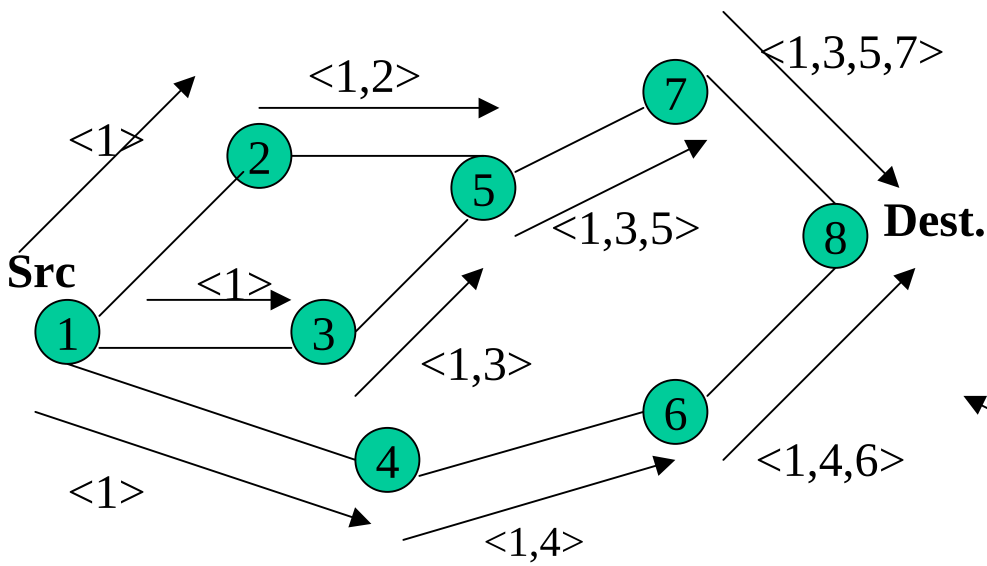
- Reduce the energy consumption of whole communication system
- Increase lifetime of nodes/network until partition

Brief overview of Routing Protocols

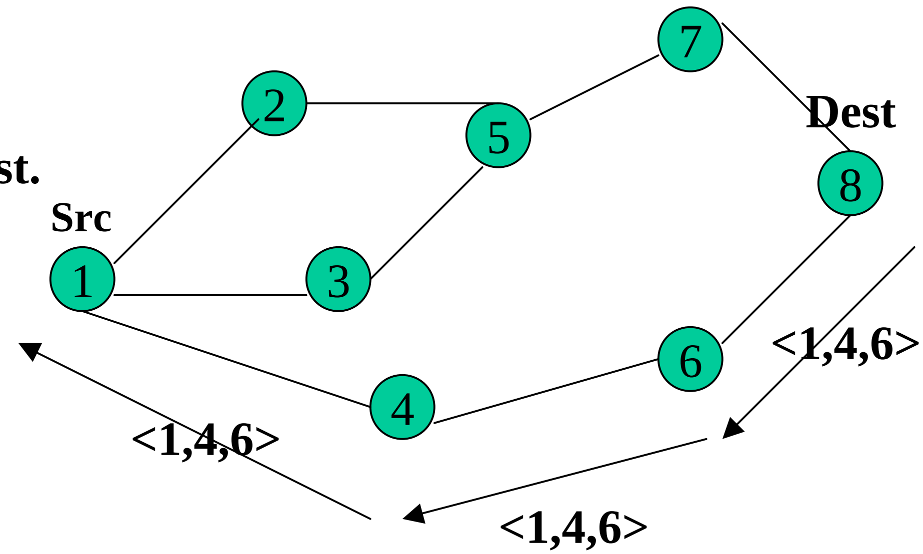
- On-Demand Routing protocols
  - no up-to-date routes are maintained
  - Routes are created as an when basis:
    call passive convergence.
- Table-Driven Routing protocols
  - Each node maintains a table containing routing
    information to every other node in network:
    call active convergence.

Dynamic source Routing

- Source-routed on-demand routing protocol



Route Discover – Route Record



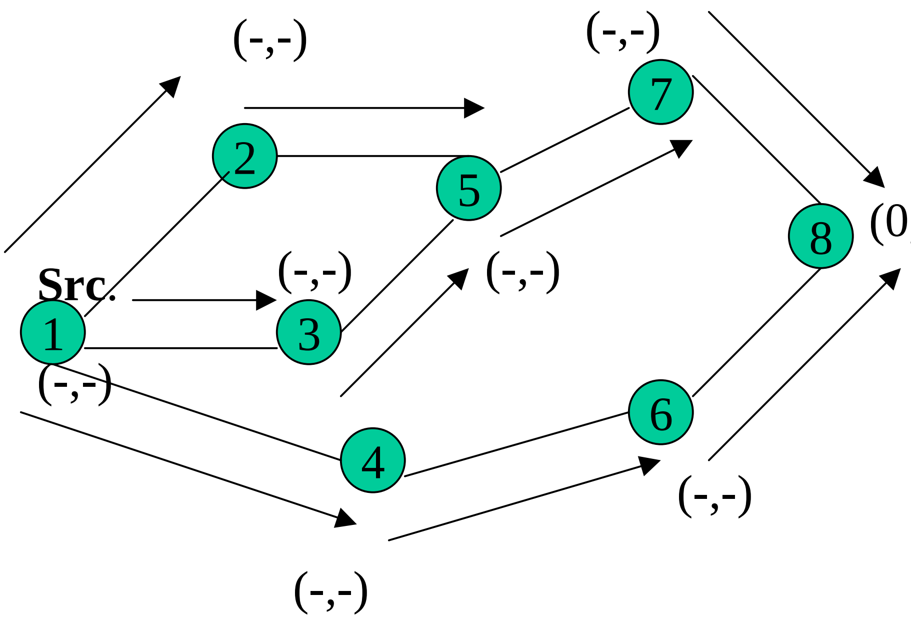
Propogation of Route Reply with Route Record

Temporally-Ordered Routing Algorithm (TORA)

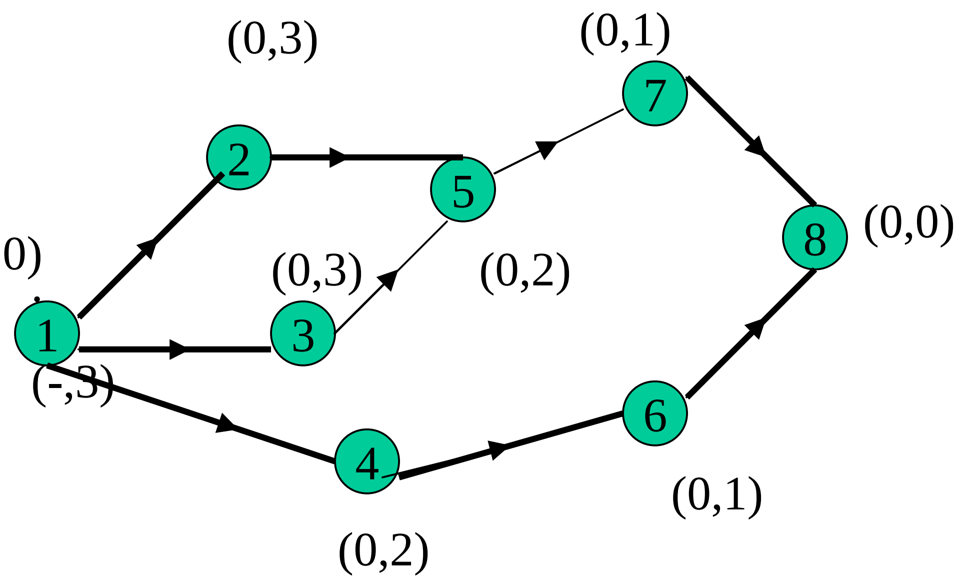
- Assign each node a "height" heuristic value based on various attributes
- A node with higher height called upstream and a node with lower height called downstream
- Route creation is done using QRY and UPD packets, results in DAG.
- In case of node failure, TORA floods a CLR (clear) packet.

TORA – Route creation

- Height of destination assigned to 0 and all other set to NULL(i.e. undefined)
- Src broadcast a QRY packet with Dest id in it.



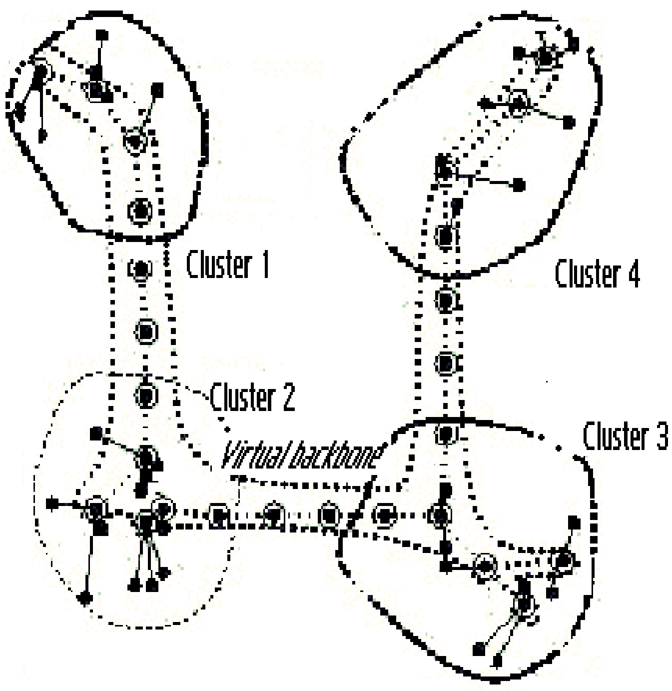
Propogation of QRY packet



UPD pkt – height updates

Spine routing Algorithm (SRA)

- Nodes are assigned to cluster
- Clusters are joined together by a virtual backbone.
- Reduce the complexity of maintaining routes



Ad Hoc Routing Protocols and Usual Metrics

Protocol	Metrics	Message Overhead	Convergence	Protocol Type	Summary
DSR	Shortest Path	High	Passive	Source Routing	Route discovery, Snooping
DSDV	Shortest Path	High	Active	Distance Vector	Routing table exchange
DARPA	Shortest Path, Link Quality	High	Active	Distance Vector	Routing table exchange, Snooping
WRP	Shortest Path	High	Active	Distance Vector	Routing table exchanges
SSA	Location Stability, Link Quality	Moderate	Passive	Source Routing	Route Discovery
TORA	Shortest Path	Moderate	Passive	Link Reversal	Route update packets
SRA	Message and Time overhead	Moderate	Active	Hierarchical, Spine	Route discovery within cluster, Spine routing

Contribution ??

- New Metrics
- *Minimize* energy consumed per packet
- *Maximize* time to network partition
- *Minimize* variance in node power levels
- *Minimize* cost per packet
- *Minimize* maximum Node cost

Minimize Energy consumed/packet

- Energy consumed for a packet j during traversal over nodes $n_1 .. n_k$

$$e_j = \sum_{i=1}^{K-1} T(n_i, n_{i+1})$$

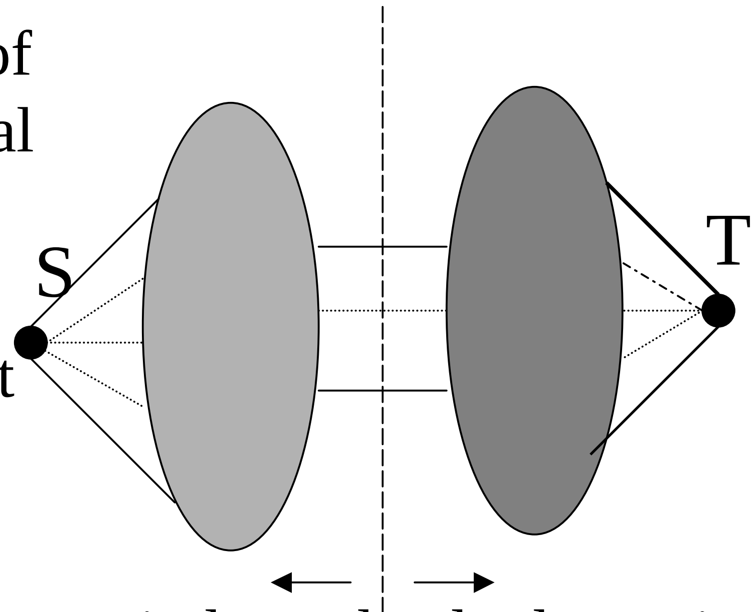
where T(a,b) denote the energy consumed per packet over one hop from a to b

Goal : Minimize e_j $\forall$ packets j

- Light loads same as shortest hop (assumes only variation in energy per hop is due to contention)
- Tend to routes around congested areas (inc. hop count).
- Drawback : nodes with widely differing energy consumption

Maximize Time to Network Partition

- Maximum-flow-min-cut theorem gives a minimal set of nodes (the cut-set) the removal of which will cause network partition.
- Load balancing among cut-set nodes to ensure equal power drain.



- Since nodes in different partitions independently determine routes, it's hard to achieve global balancing while keeping low delay
- Can not decide optimal path without knowledge of packet

➢Minimize variance in node power levels

- All nodes are equally important
- Join Shortest Queue (JSQ)
- RR if packets of same length

➢ Minimize Cost / Packet

- Goal : Maximize life of all the nodes in the network
- Nodes with depleted energy reserve should not lie on many paths

Minimize Cost/Packet cont.

- $c_j = \sum_{i=1}^{k-1} f_i(x_i)$, where

  $f_i(x_i)$ denotes the node cost of node i (node's reluctance to forward packet)

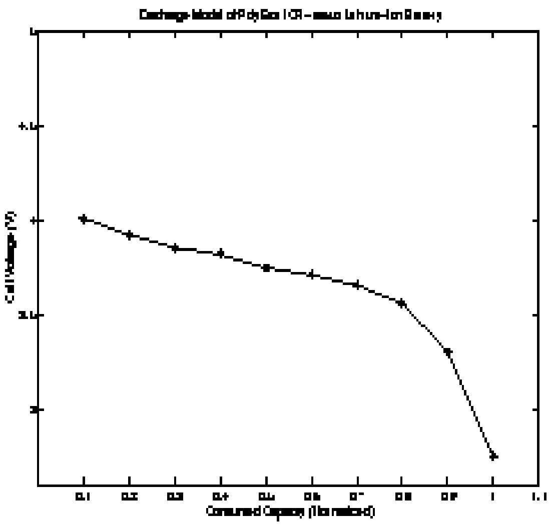
  x_i could be the energy consumed by node so far

  c_j represents the cost of sending packet j from node n_1 to n_k via intermediate nodes $n_2 .. n_{k-1}$

  f_i could reflect battery life remaining

- Goal : Minimize c_j, $\forall$ packets j

Cost Function



Lithium ion discharge curve

$$f_i(z_i) = \frac{1}{(Z_i - 2.8)}$$

Where z_i denotes measured voltage

f_i ensures that shortest-hop routing
Will be used when network is new

But as node approaches near end
Of the lifetime, carefully route
packets to ensure longevity of
these nodes

Benefits

- It is possible to incorporate the battery characteristics directly into the routing protocol
- Reduce variation in node cost and increase time to network partition
- Effects of network congestion are incorporated

➢Minimize Maximum Node Cost

- Goal is to minimize maximum node cost after routing N packets to their destinations or after T seconds

Overview of PAMAS

This work assumes a MAC layer solution in which nodes power off when can not transmit

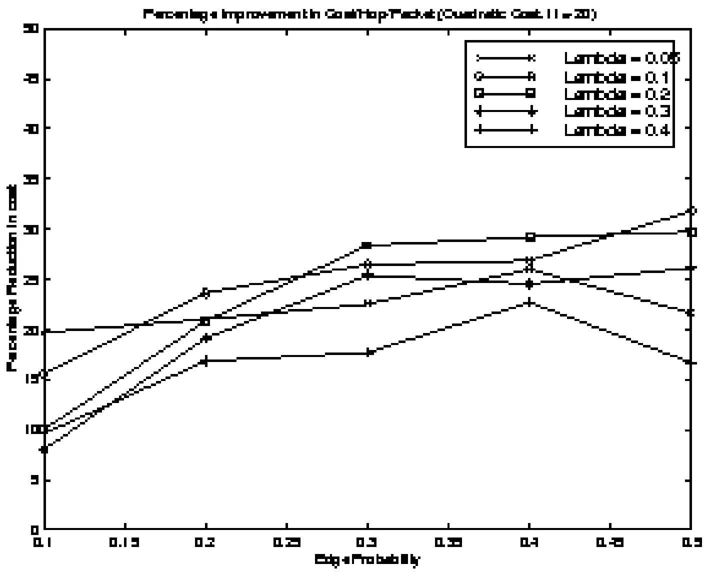
- Assumes separate signalling channel for RTS/CTS exchange
- RTS/CTS contain info about length of packet
- Other nodes in neighborhood can predict how long to turn off (no power wasted in listening)
- Delays and throughput remain unchanged
- Related work : (pagers) base transmits beacons and minislot with ID of nodes with message waiting

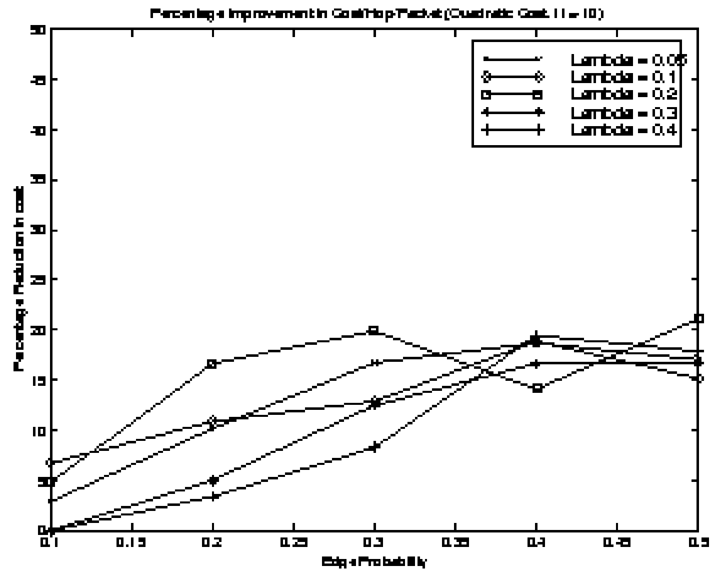
  Other turn off. Reservation in 802.11(scheduling and reservation better than contention).

Simulation and results

- Compared the performance of shortest-hop routing with shortest-cost routing in terms of :
  - End-to-end packet delay
  - Average cost/packet
  - Average maximum node cost (after 300 sec)
- Used 16-node mesh topology and 10 and 20 node random graph
- Each simulation ran for 20 times, computed the mean and standard deviation for each of the three aforesaid metrics

% reduction in average cost in random network

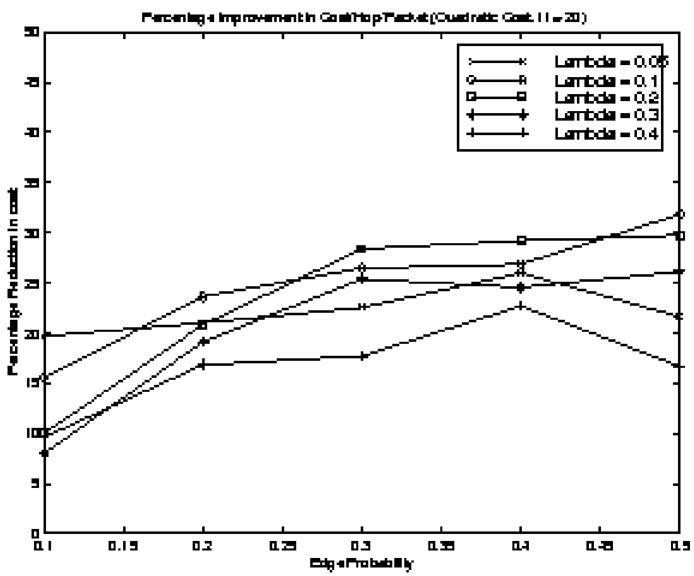




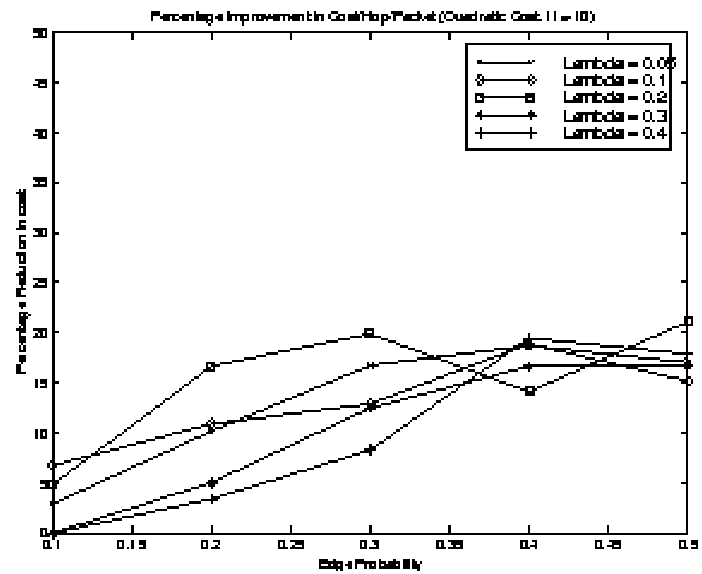
20-node random network 10-node random network

- Savings are greater in larger networks because larger networks has more routes to choose from
- Saving increases with load as cost differential increases, however, at very heavy loads it becomes constant (contention)

% reduction in maximum node cost



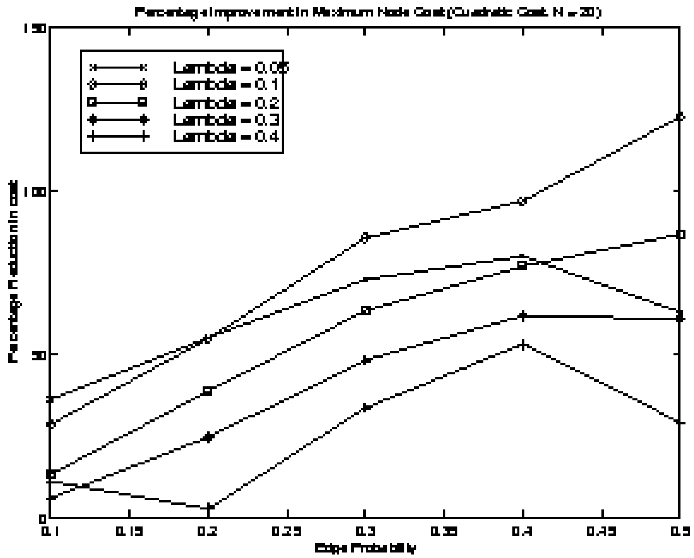
20-node random network



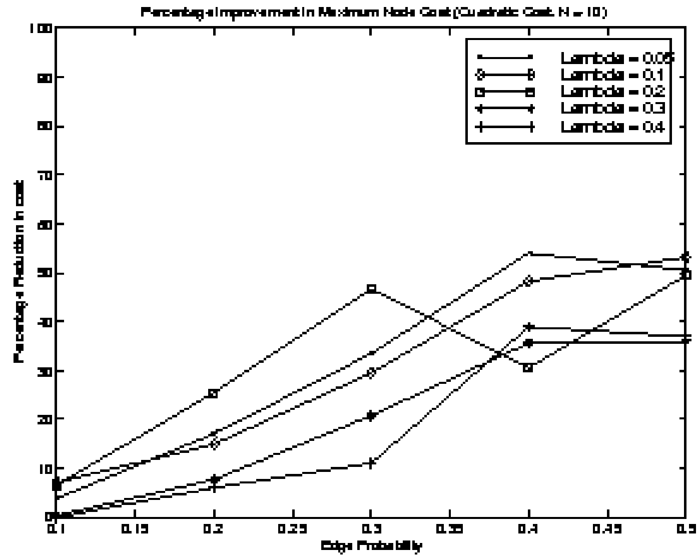
10-node random network

- Saving is more in denser network and increases with λ

% reduction in cost/pkt/hop and max node cost



% improvement in cost/pkt/hop



% improvement in max. Node Cost

Saving in cost/packet increases with load and then decreases
Because as load increases there is increasing difference in node cost between two algos, later on costs are same so no saving

Conclusion

- Larger networks have higher cost saving,
- Cost savings are best at moderate network loads and negligible at low & very high loads,
- Denser networks exhibits more cost saving
- It is easy to incorporate these metrics in existing routing protocols for Ad Hoc Networks