A network-aware MAC and routing protocol for effective load balancing in ad hoc wireless with directional antenna

S.Roy, D.Saha, T.Ueda, etc.

Mobihoc, 2003

2003. 10. 9

Presented by Yoon, Hye-young

Contents

Introduction

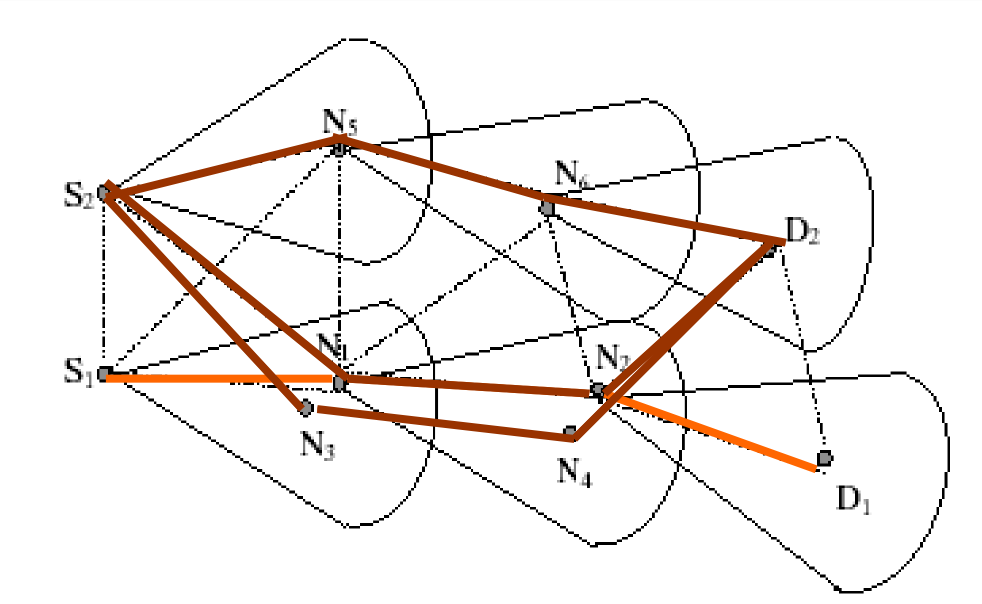
The use of directional antenna in ad hoc wireless networks can largely reduce the radio interference.

→ **"Improve the network performance"**

Lack of centralized control in ad hoc networks makes difficult to set and control the directions of such antenna at each node.

Devise a routing strategy, along with a MAC protocol, that exploits the directional antenna in ad hoc networks!

Route coupling



Path

{S_1, N_1, N_2, D_1}

{S_2, N_1, N_2, D_2}

{S_2, N_3, N_4, D_2}

{S_2, N_5, N_6, D_2}

zone disjoint

two routes are located close enough to interfere with each other during data communication.

routing performance depends on

- The congestion characteristics of nodes
- Pattern of communication in the **neighborhood region**

System description

ESPAR

- Electronically Steerable Passive Array Radiator
- A small, low-cost adaptive antenna
- Continuous tracking is possible with small number of antenna.

Experimental environment

- Ad hoc network consisting of nodes with directional antenna
- Transmission beam width is 45 degree.
- Random way-point model
  - A node randomly chooses a destination point and moves to the target point with a constant speed v.

Network-awareness

Neighbor

- A set of nodes within the omni-directional transmission range

Network-status information

- Neighborhood Link-State Table ($NLST_n$)
  - The maximum strength of radio connection at a particular direction
  - Track the direction of its neighbor
- Neighborhood Active Node List ($NANL_n$)
  - The communication-activity-status of its neighbors
  - Help a node to become neighborhood-communication-aware

Network-awareness

Network-status information (cont'd)

- Active Node List (ANL_n)
  - A list in node n containing all active nodes in the network
- Global Link-State Table ($GLST_n$)
  - The network topology information

Each node broadcasts its ANL at 2 seconds.

- With mobility, it will be 1 seconds.

Each node broadcasts its GLST at 10 seconds.

- With mobility, it will be 5 seconds.

Network-awareness

Table 1. The Structure of ANL

Nodes	n_1	n_2	…	n_N
Recency	R_1	R_2	…	R_N
State	S_1	S_2	…	S_N

Message carrying the higher **recency value** has more current information.

State denotes **active or inactive**.

Table 2. The structure of GLST

Nodes	Recency	Neighbors
n_1	R_1	→ {…………}
n_2	R_2	→ {…………}
…	…	→ {…………}
n_i	R_i	→ {$<n_j,\alpha(n_i,n_j)>$ $<n_k,\alpha(n_i,n_k)>$ ………}
…	…	→ {…………}
n_N	R_N	→ {…………}

n_i is a **neighbor** of n_j

ά: the **transmission beam-angle** at which n_i can best communicate with n_j.

Location tracking

Ad hoc networks with omni-directional antenna

- Lot of nodes in the neighborhood of transmitter & receiver has to sit idle, waiting for the data communication between transmitter & receiver finish.

Directional antenna

- All the neighbors of a source & destination should know the direction of communication.
- They can initiate new communications in other directions, thus preventing interference with on-going data communication.
- Direction tracking incurs a lot of control overhead.

MAC protocol

Receiver-oriented, Rotational Sector Based Directional MAC protocol

- Each node waits in omni-directional-sensing mode while idle.
- When it senses a signal above a threshold, it enters into rotational-sector-receive-mode.
- Node rotates its directional antenna sequentially at 45-degree interval, covering the entire 360-degree space.
- After one full rotation, it decides the best possible direction of receiving the signal.

Request to send /Clear to send

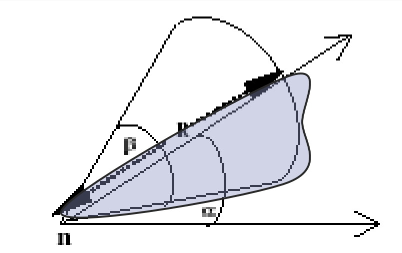
Broadcast control packets

- ANL, GLST, RTS, CTS for medium access control

Routing protocol

Correlation factor

- number of active directional neighbors at transmission zone



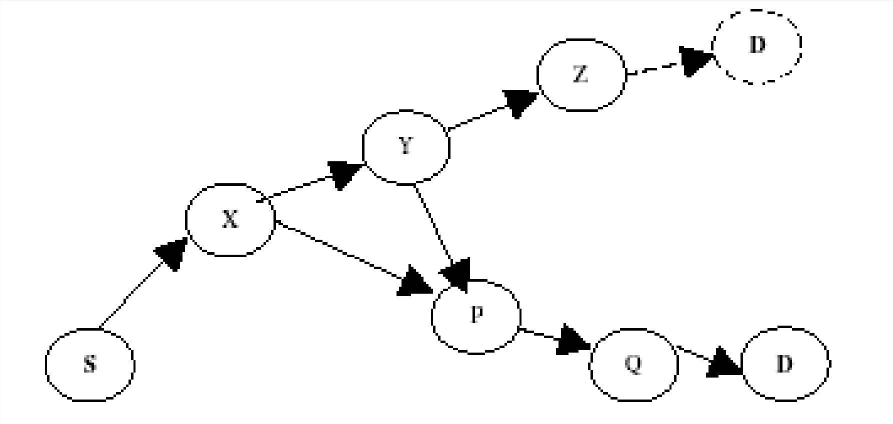
Strategy to choose a suitable path

- Find out all paths between source-destination pair with number of hops less than maximum (6 in this experiment)
- Consult the active node list
- Case 1: The active node list is empty
  - Any one of the minimum hop paths available will be selected.

Routing protocol

Strategy to choose a suitable path (cont'd)

- Case 2: ANL is not empty. (Some communications are already present.)
  - The source is more than 2 hops away from destination
    - Search for lowest correlation factor path among all possible paths
  - The source is only 2 hops away from destination
    - Search for lowest correlation factor path among all **2 hop paths**



← Adaptive route selection by intermediate node

Performance evaluation

Simulation environment: QualNet 3.1

Table 3. Parameters used in Simulation

Parameters	Value
Area	1000 x 1000 sq. m
Number of nodes	30
Transmission Power	15 dBm
Receiving Threshold	-81.0 dBm
Sensing Threshold	-91.0 dBm
Packet Size	1024 bytes
CBR Packet Arrival Interval	2 ms to 500 ms
Simulation Time	5 minutes
Number of simultaneous communication	8 with a starting time lag of 15 second
ANL Periodicity (T_A)	2 second (static); 1 second (mobile)
GLST Periodicity (T_G)	10 second (static); 5 Second (mobile)

Performance evaluation

Impact of overhead

- In this environment, for only 1.19% of the total time, the medium gets blocked by update traffic and the medium is free for 98.8% of the total time for communication.

- T_a: overhead of ANL periodicity
- T_g: overhead of GLST periodicity

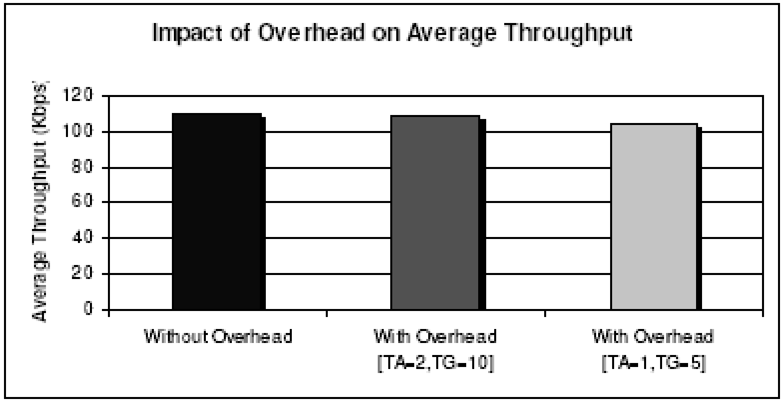


Figure 4(a). Impact of Overhead on Average Throughput

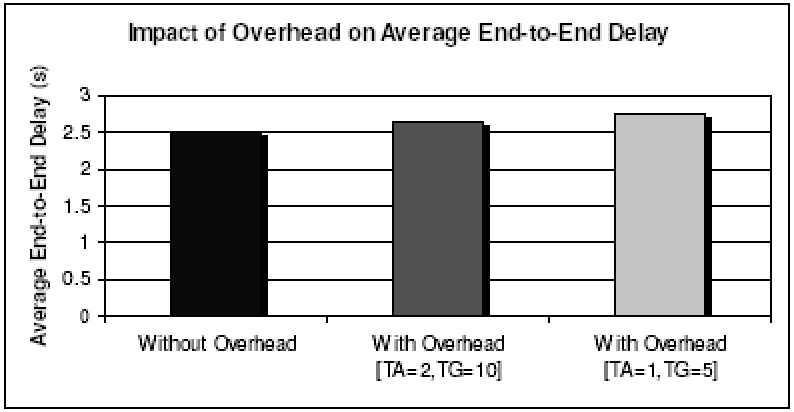


Figure 4(b). Impact of Overhead on Average End-to-End Delay

Performance evaluation

Results and discussions

- Comparison: DSR with IEEE 802.11
- Average throughput
  - 5 times as compared to that of DSR
- Average end-to-end delay
  - 3.5 times less as compared to that of DSR
- Average packet retransmission due to ACK timeout, average packet drops due to retransmission limit
  - Far less as compared to that of DSR
- Cause of improvements
  - The utilization of the medium is increased.
  - Maximal zone-disjoint paths reduce contention among routes.

Source routing with each packet to be routed carrying in its header the complete, ordered list of nodes through which the packet must pass

Performance evaluation

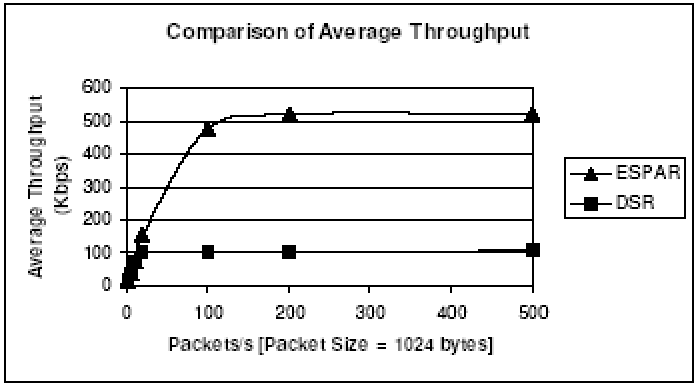


Figure 5(a) Average Throughput: DSR and ESPAR with different packet arrival rate

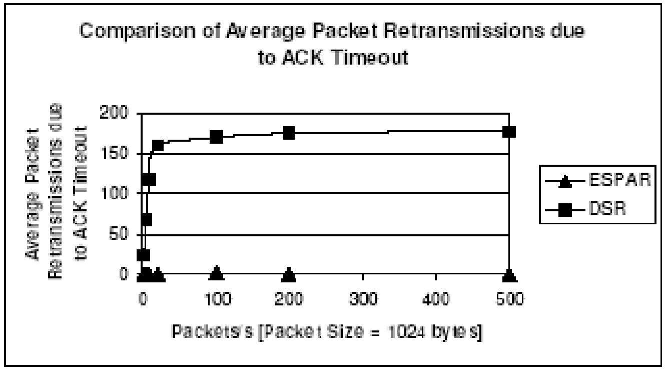


Figure 5(c). Average Packet Retransmission: DSR and ESPAR with different packet arrival rate

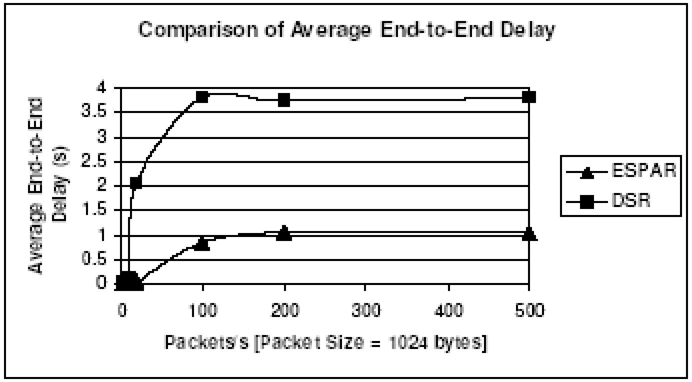


Figure 5(b). Average End-to-End Delay: DSR and ESPAR with different packet arrival rate

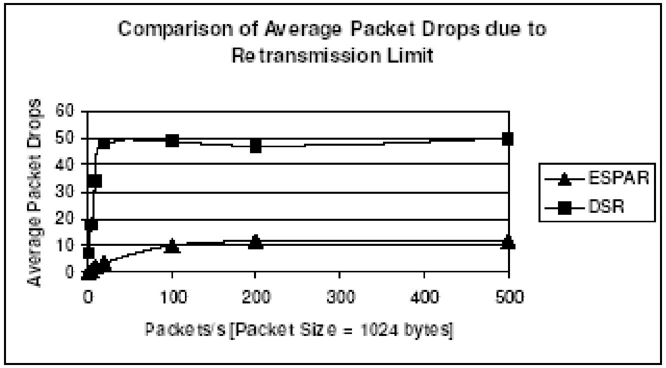


Figure 5(d). Average Packet drops: DSR and ESPAR with different packet arrival rate

Conclusion

Use of directional antenna in ad hoc wireless network can drastically improve system performance.

Maximally zone disjoint routes will be helpful to reduce route coupling.

Future work

- Cope up with high mobility
- Investigate the scalability by increasing the number of nodes in the network (current: 30 nodes)