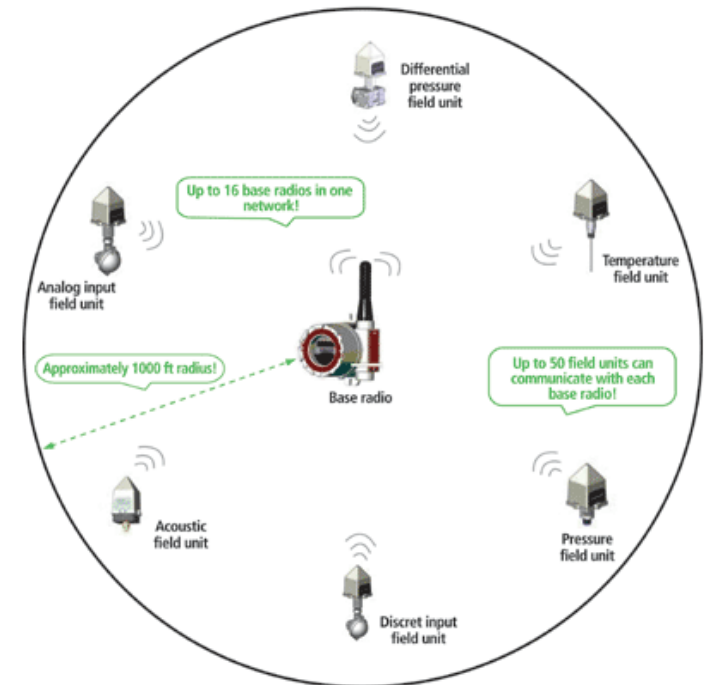


Algorithms for Wireless Sensor Networks

Presenters

- Vaibhav Mittal
- Sumeet Bajaj

Wireless sensor network



Prof. Jie Gao

State University of New York at Stony Brook

Virtual Ring Routing: Network Routing Inspired by DHTs

[Matthew Caesar, Miguel Castro¹, Edmund B. Nightingale³, Greg O'Shea¹, Antony Rowstron¹

¹ Microsoft Research ² University of California Berkeley

³ University of Michigan Cambridge, UK Berkeley, USA Ann Arbor, USA

mcastro,gregos,antr@microsoft.com mccaesar@cs.berkeley.edu
enightin@eecs.umich.edu]

Virtual Ring Routing (VRR)

- new network routing protocol implemented directly on top of the link layer
- Provides both traditional point-to-point network routing and DHT routing to the node responsible for a hash table key
- Never floods the network and uses only location independent identifiers to route.
- Nodes organized into a virtual ring ordered by their identifiers
- Each node maintains a small number of routing paths to its neighbors in the ring.
- VRR uses these routing tables to route packets between any pair of nodes in the network

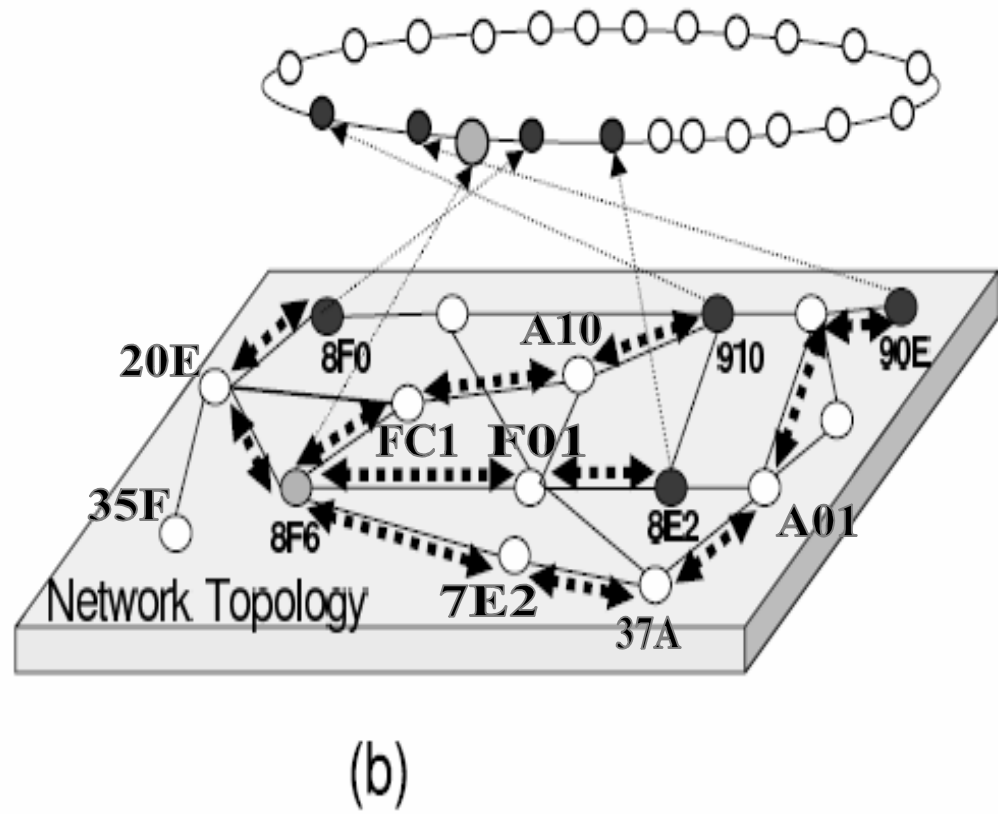
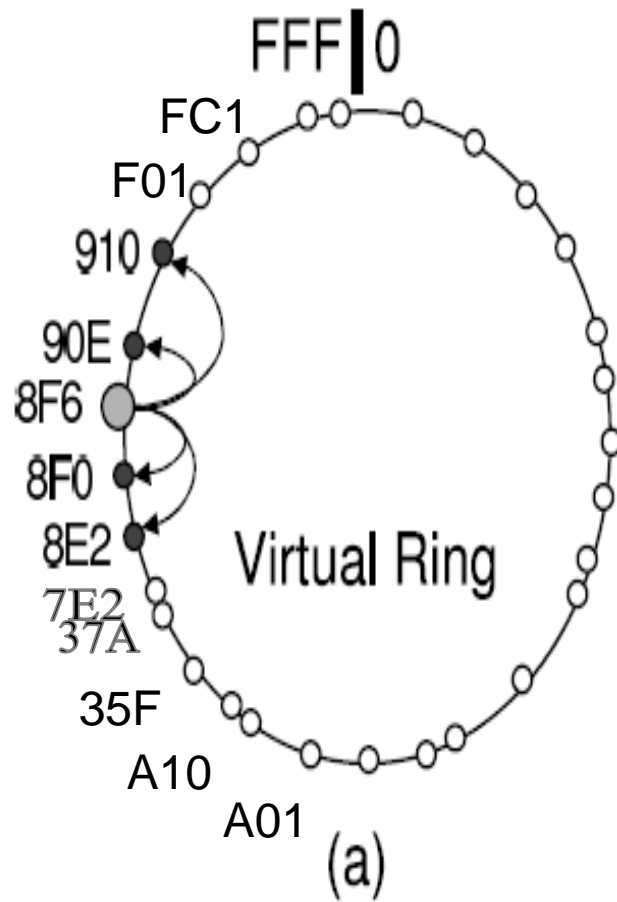
OVERVIEW

- VRR uses random unsigned integers to identify nodes, and organizes the nodes into a virtual ring in order of increasing identifier
- Node identifiers are fixed, unique and location independent and can be generated in different ways.
- for example, an identifier could be the 160-bit SHA-1 hash of a node's public key to facilitate secure communication or a randomly selected 32-bit integer to provide backwards compatibility with IPv4 addresses

OVERVIEW(contd...)

- Each node maintains a virtual neighbor set (or vset) of cardinality r containing the node identifiers of the $r/2$ closest neighbors clockwise in the virtual ring and the $r/2$ closest neighbors counter clockwise.
- Each node also maintains a physical neighbor set (or pset) with the identifiers of nodes that it can communicate
- A node only adds a neighbor to the pset if the quality of the links to and from that neighbor is above a threshold.
- VRR sets up and maintains routing paths called vset-paths between a node and each of its virtual neighbors.

Virtual Ring & Network Topology



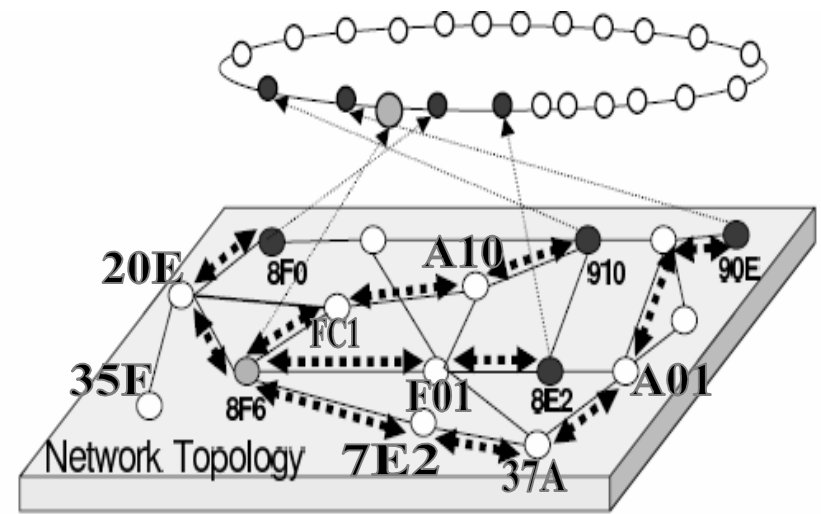
V-SET PATHS

- V-set paths are
 - multi-hop in most cases.
 - bidirectional because membership in the vset is symmetrical i.e (if node x is in the vset of node y then node y is in the vset of x).
- vset-paths can be used to route packets between any pair of nodes.
- VRR routes messages sent to numerical keys to the node whose identifier is numerically closest to the key from among all the endpoints in their routing table.

Forwarding

- Each node maintains a routing table with information about the vset-paths to its virtual neighbors and other vset-paths that are routed through the node
- Each entry contains the identifiers of the two endpoints of the path, the identifier of the physical neighbor to be used as the next hop towards each endpoint, and a vset-path identifier.
- The first endpoint identifier in an entry is always the identifier of the node that initiated the vset-path setup.

endpoint _A	endpoint _B	next _A	next _B	path id
8F0	8F6	20E	null	03
8E2	8F6	F01	null	2F
8F6	90E	null	7E2	1E
910	8F6	F01	null	2F
35F	37A	20E	7E2	12
A01	A10	F01	FC1	F0
8F6	20E	null	20E	FF
8F6	F01	null	F01	FF
8F6	7E2	null	7E2	FF
8F6	FC1	null	FC1	FF



- The first four entries are for the vset-paths from the node to its four virtual ring neighbors.
- Since node 8F6 is an endpoint in these paths, the identifier of the next hop towards the node is null.
- The 5th and 6th entries in the table are for two vset-paths that are routed through node 8F6. VRR maintains the invariant that the next_A and next_B fields in a node's routing table entries are in the pset of the node.
- The last four entries are one-hop paths to physical neighbors

VRR Forwarding Algorithm

- VRR picks the node with the identifier closest to the destination from the routing table and forwards the message towards that node.
- The packet is delivered to the node with the identifier closest to the destination in the network

NextHop(rt, dst)

 endpoint := closest id to dst from Endpoints(rt)

if (endpoint == me)

 return null

return next hop towards endpoint in rt

- the next hop to reach endpoint is retrieved from the routing table and the packet is sent to that node.

Node joining

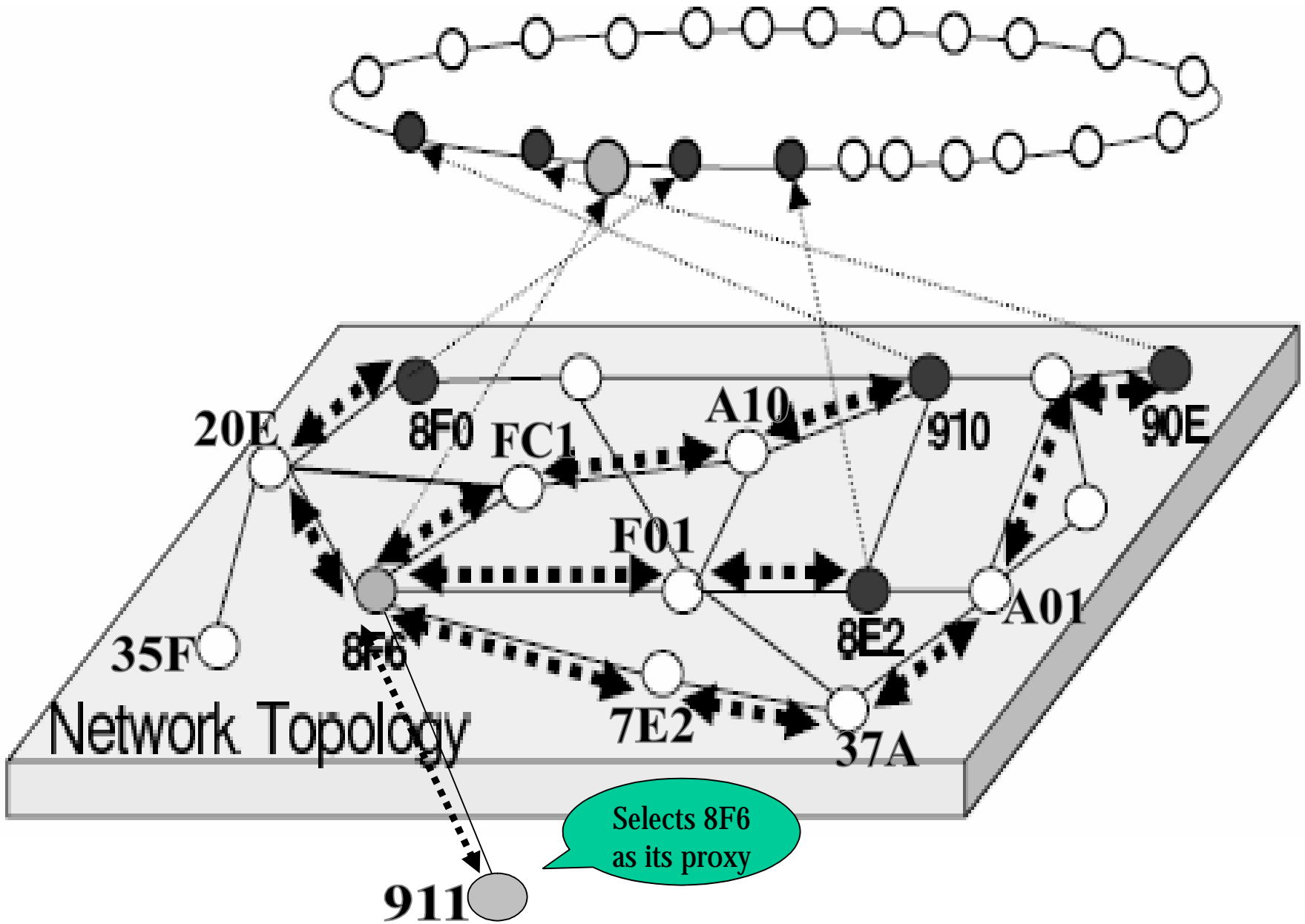
- When a node joins the VRR network, it initializes its pset and vset and sets up vset-paths to its virtual neighbors.
- The joining node starts by looking for physical neighbors that are already active in the network and, therefore, can be used as proxies to route messages to others
- It finds a proxy by sending and listening to hello messages that VRR nodes broadcast to physical neighbors periodically, These messages are also used to initialize the pset of the joining node
- After finding a proxy, the joining node sends a setup req message to its own identifier x without flooding the network, through the proxy.
- This message is routed using the forwarding algorithm to the node whose identifier, y , is closest to x .

Node joining(contd...)

- Node y is one of the immediate virtual neighbors of the joining node in the virtual ring and it knows the identities of the other virtual neighbors of x .
- Node y replies with a setup message and also adds x to its vset.
- This message sets up the vset-path between node y and the joining node by updating the routing tables of the nodes it visits.
- The joining node adds y to its vset when it receives the message.
- The setup message also includes y 's vset.
- The joining node uses the received vset to initialize its own; it sends setup req messages to the identifiers of its other virtual neighbors.

Node joining(contd...)

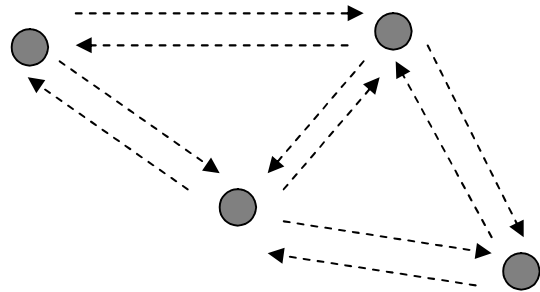
- The joining node adds these neighbors to its vset when it receives setup messages from them.
- This completes all routing state initialization and the node becomes active
- There are two additional message types:
 - setup fail messages: sent in reply to setup req messages indicating refusal to setup a vset-path to the source,
 - Teardown messages: used to remove entries for vset-paths from the routing tables along the path.
- A node replies to a setup req message from x with setup fail when it does not add x to its vset.
- VRR aborts a vset-path setup by calling TearDownPath to remove all entries for the path from the routing tables of all nodes that may have been visited by the setup message.



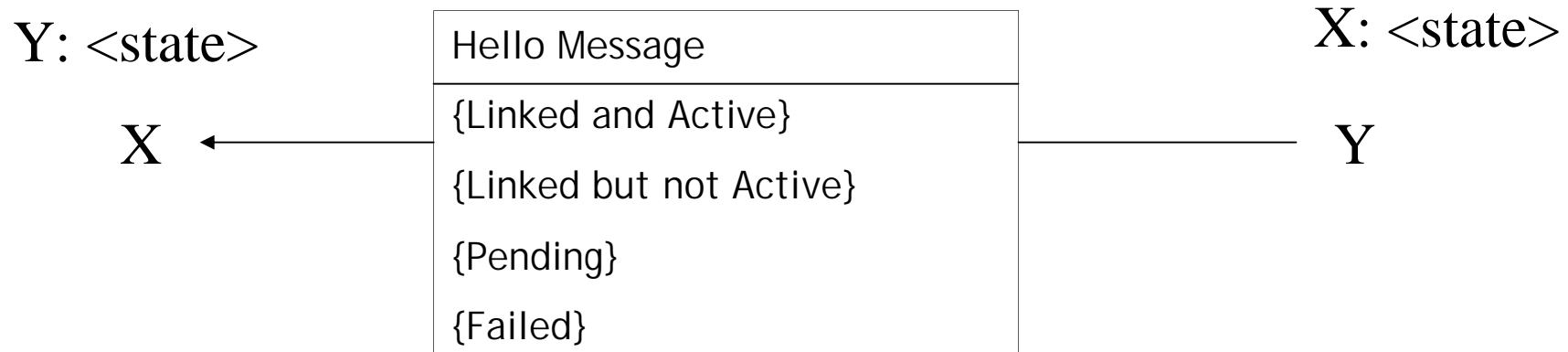
Failure Detection

Each Node ...

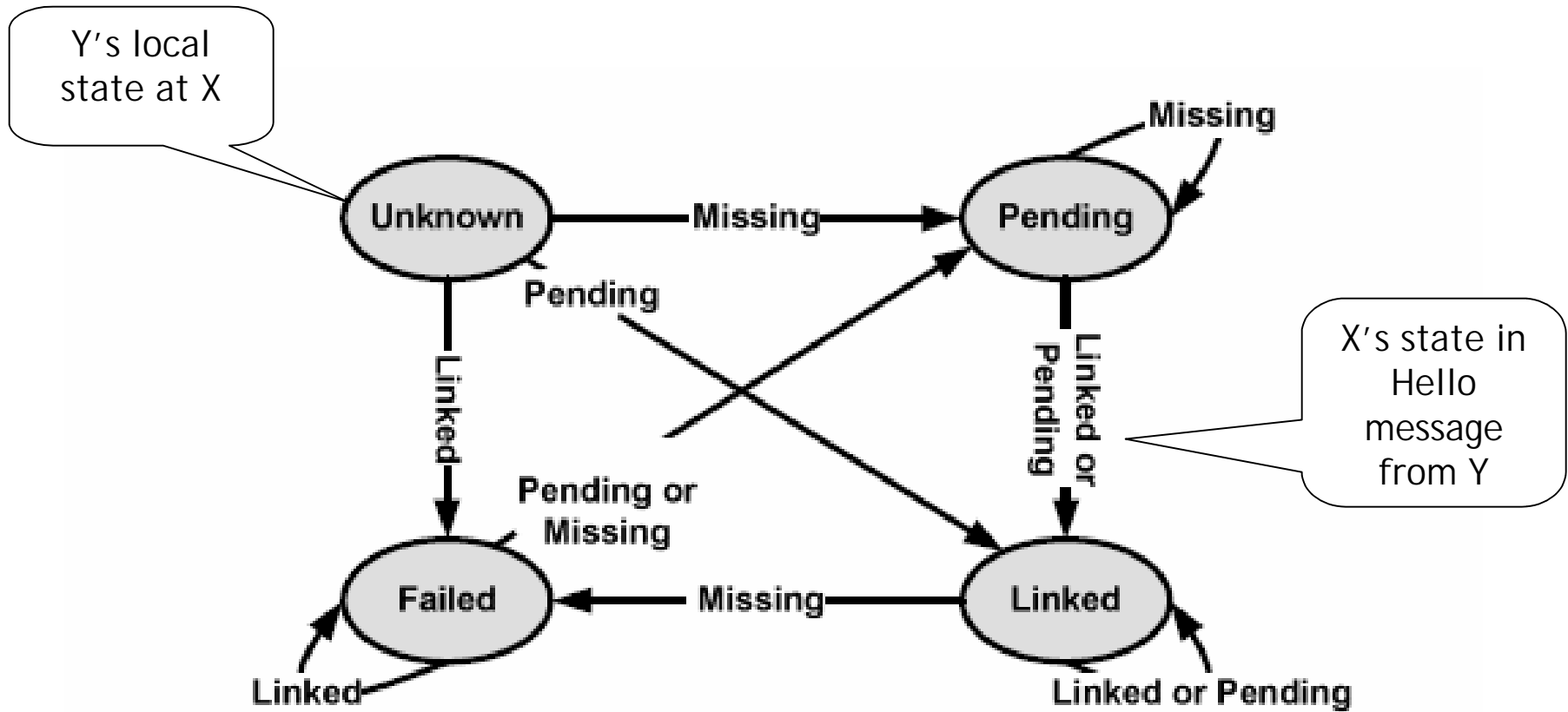
- Detects failures using only direct communication between physical neighbors
- Broadcast hello messages every T_h seconds



- Maintains state for each neighbor {Linked, Pending, Failed, Unknown}
- considers pset as the set of nodes in the Linked state



Failure Detection



State Diagram at node X

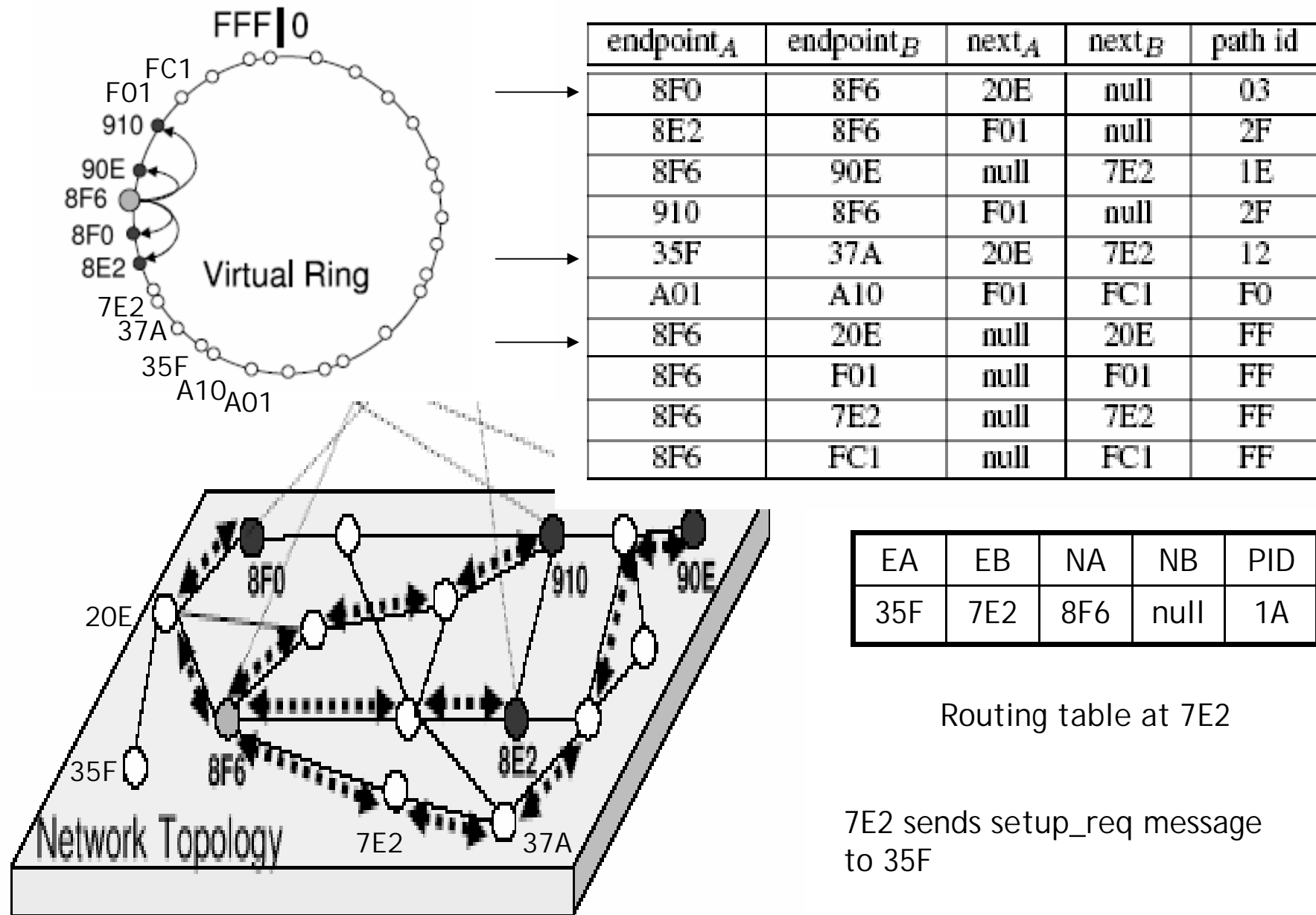
Failure Detection

Additional Rules

- Hello message is an indication of whether a node is active or not
- Whenever a 'Linked & Active' node is found a physical neighbor path is inserted in the routing table
- A node is marked 'Failed' if no Hello message is received for kT_h seconds
- Two-hop paths determined from these rules are also recorded

Also uses per-hop acknowledgements and retransmissions for all messages other than Hellos for detecting node failures

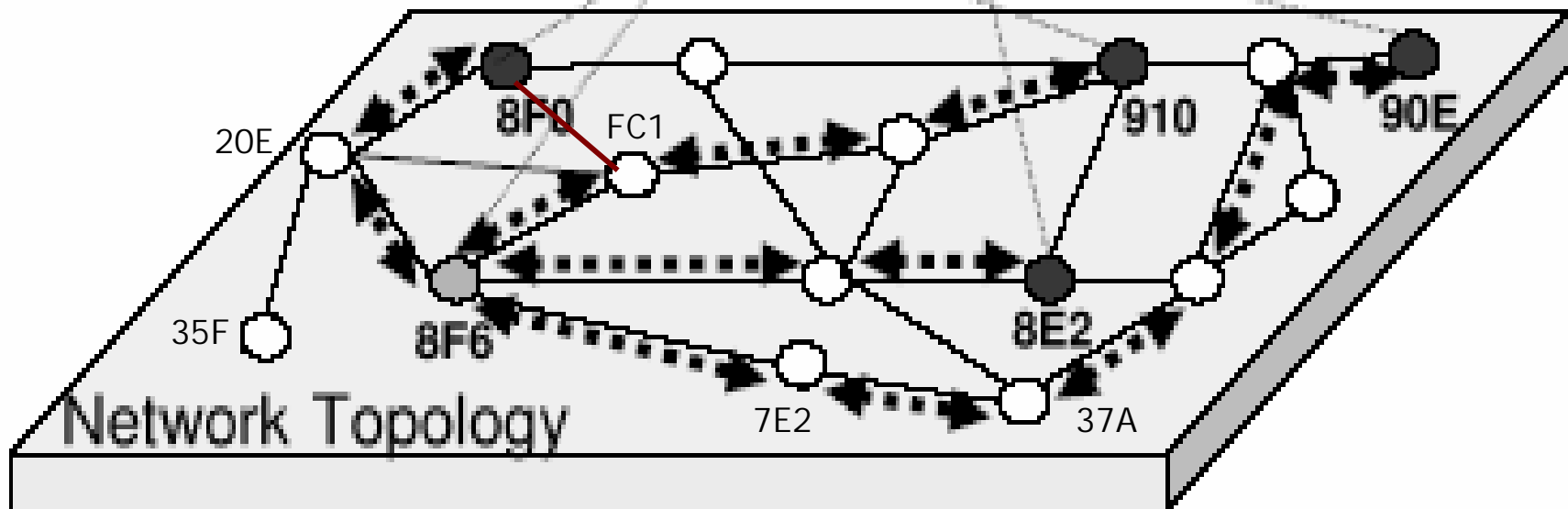
Failure Repair



Local vset-path Repair

EndpointA	EndpointB	NextA	NextNextA	NextB	PID
8F0	8F6	20E	8F0	Null	03
35F	37A	20E	35F	7E2	12
8F6	20E	null	null	20E	FF
8F6	FC1	null	8F0	FC1	FF

EndpointA	EndpointB	NextA	NextNextA	NextB	PID
8F0	8F6	FC1	8F0	Null	03
35F	37A	20E		7E2	12



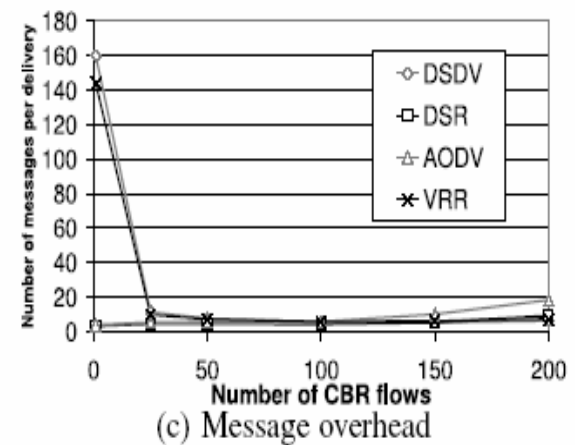
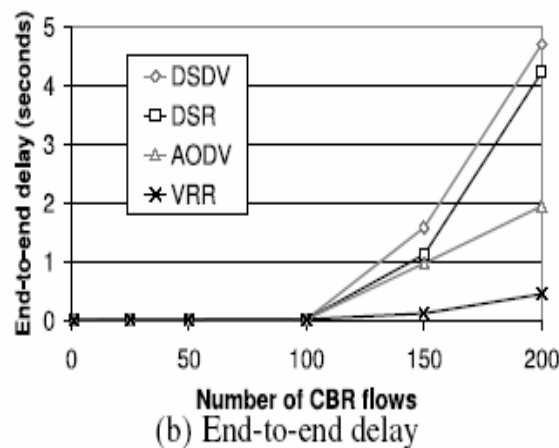
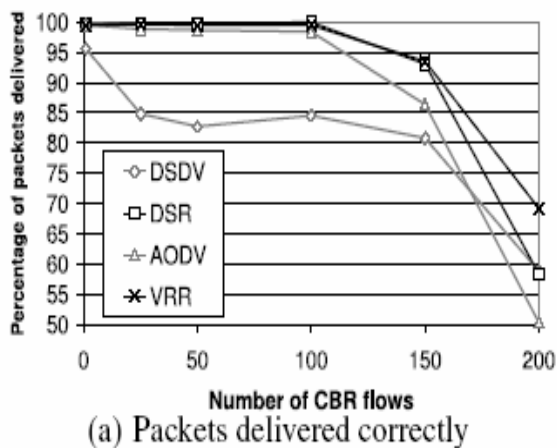
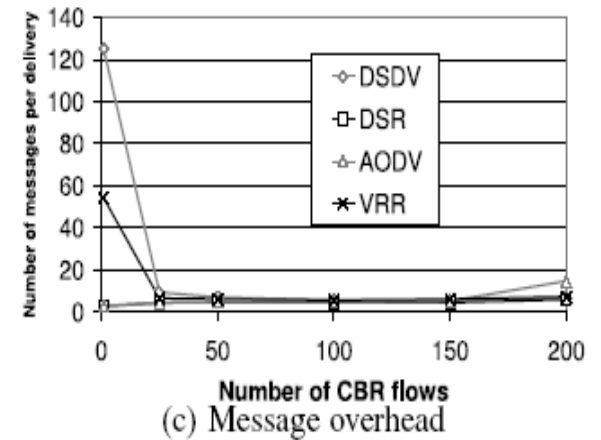
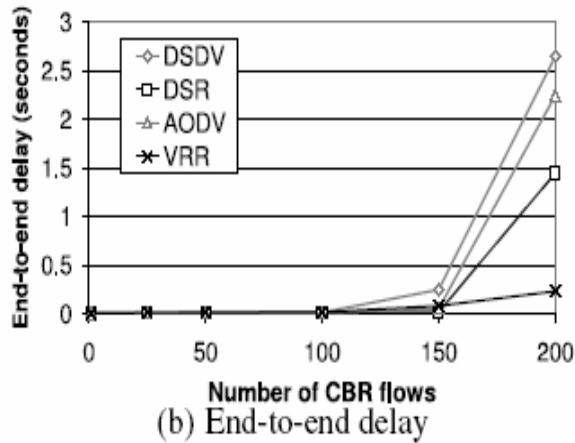
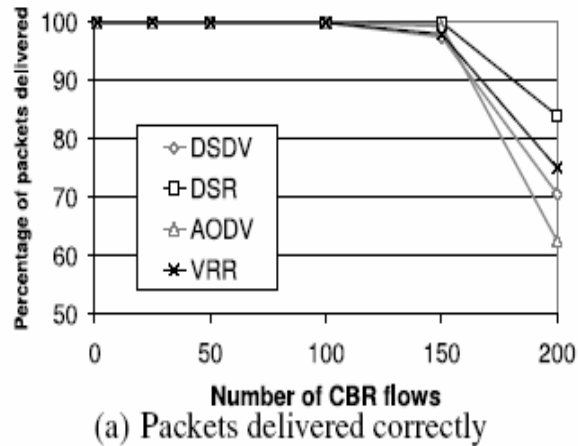
Evaluation

- Comparison with DSR, AODV, DSDV
- 802.11b wireless network at 11Mbps
- The VRR implementation supports local repair optimization

Evaluation Metrics

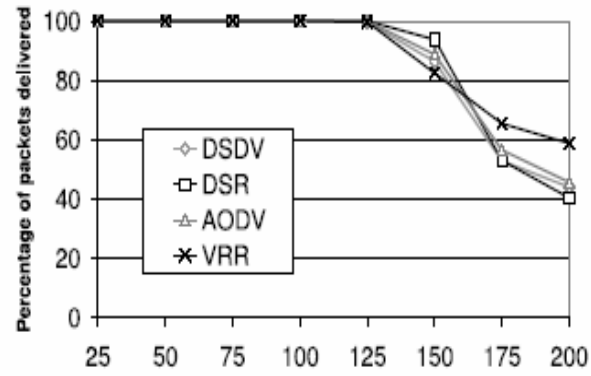
1. Fraction of packets delivered correctly
2. end to end delay
3. Messages per correct delivery

Performance with increased traffic load

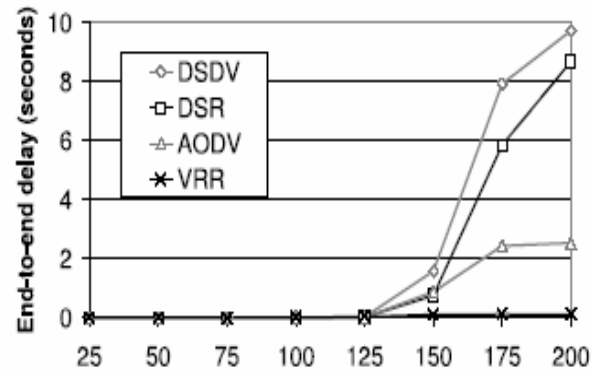


Number of nodes = 100

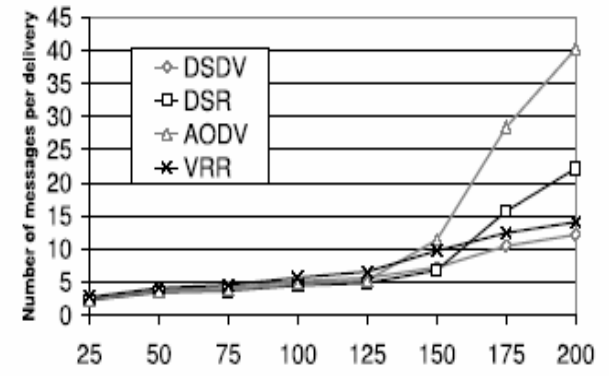
Performance with increasing network size



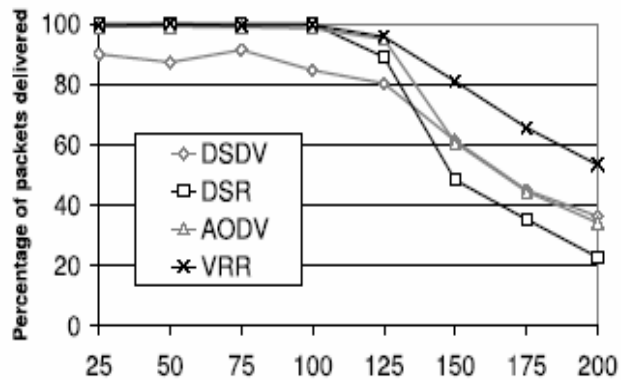
(a) Packets delivered correctly



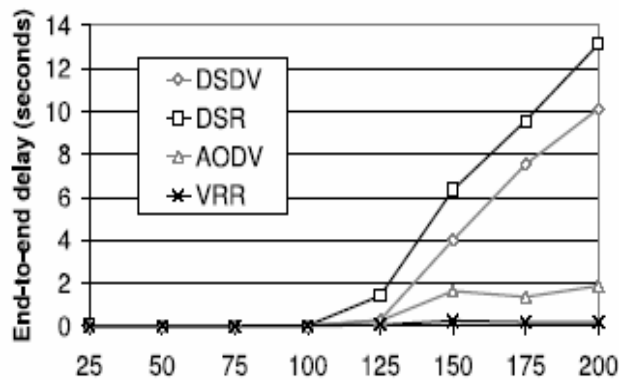
(b) End-to-end delay



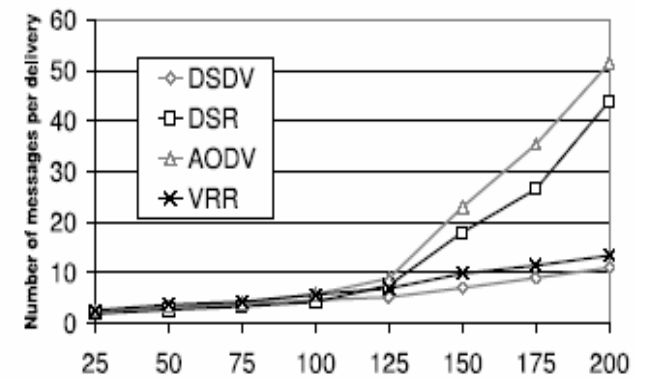
(c) Message overhead



(a) Packets delivered correctly

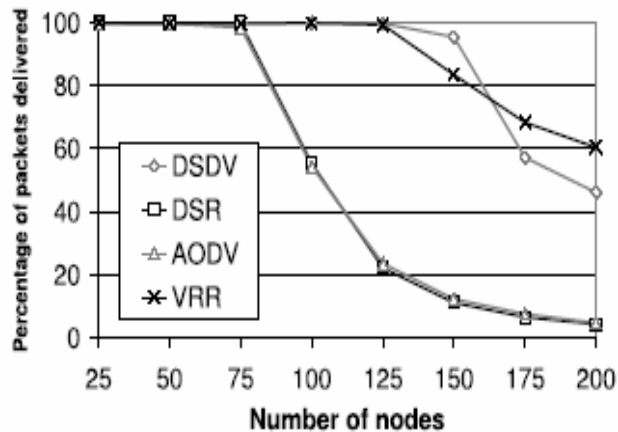


(b) End-to-end delay

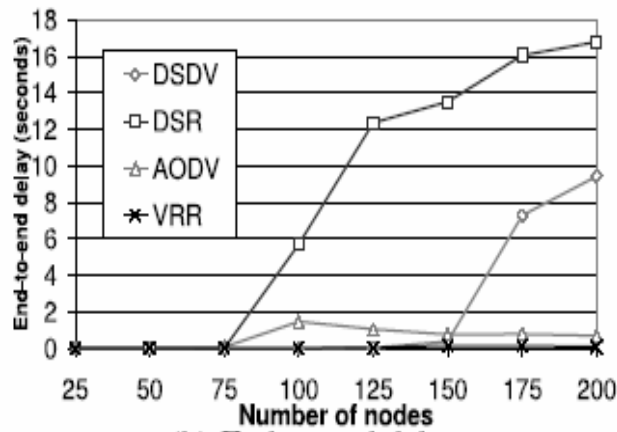


(c) Message overhead

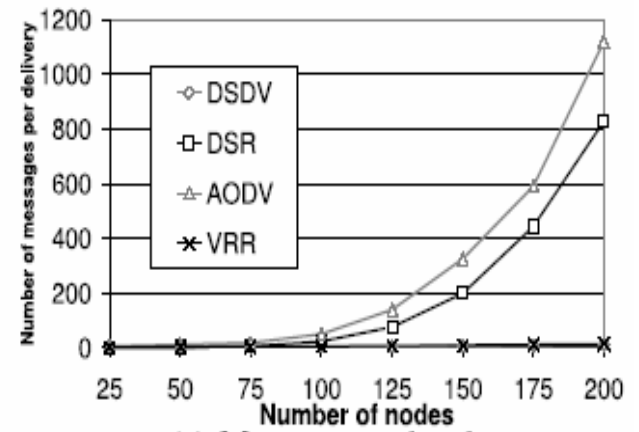
Performance with short-lived flows



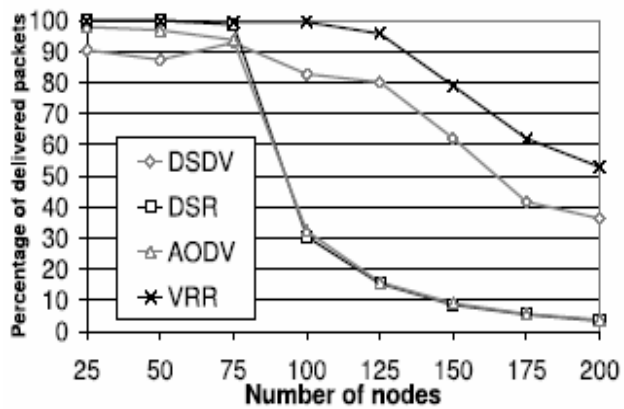
(a) Packets delivered correctly



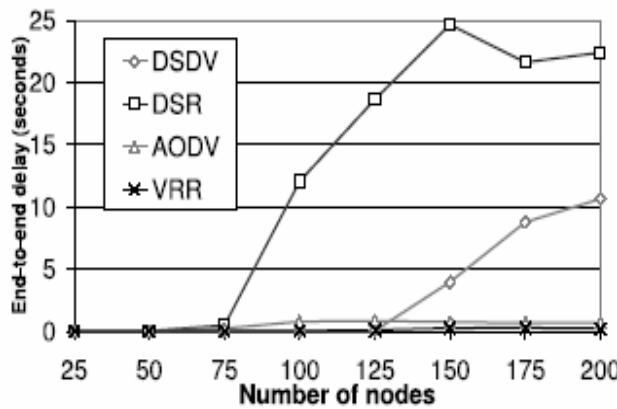
(b) End-to-end delay



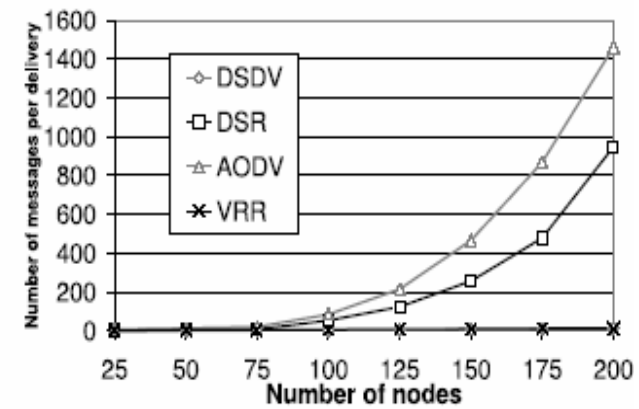
(c) Message overhead



(a) Packets delivered correctly

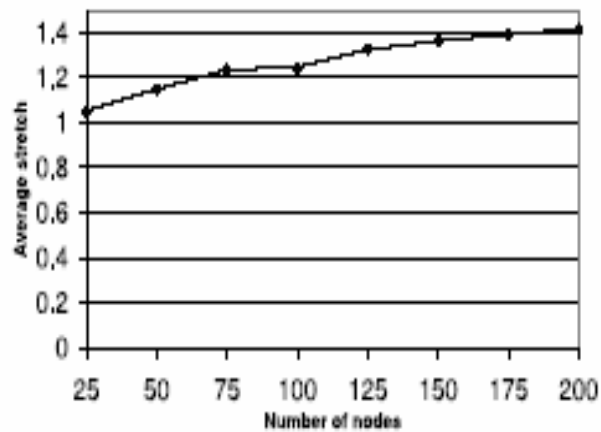


(b) End-to-end delay

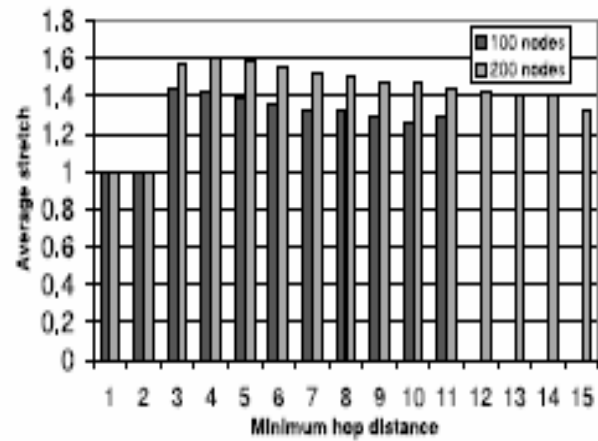


(c) Message overhead

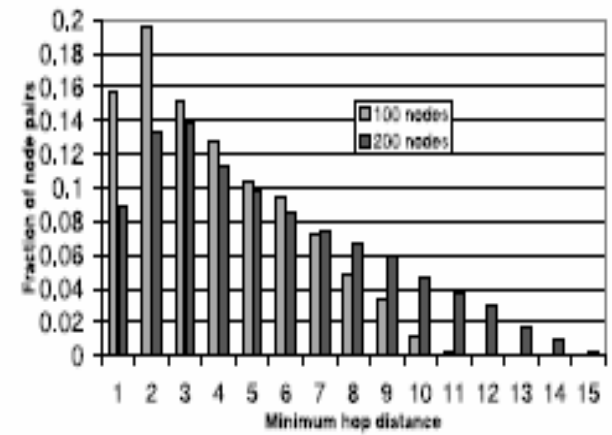
Stretch



(a) Average stretch

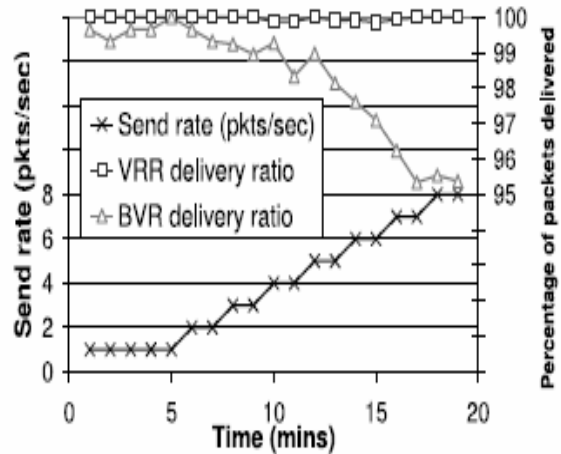


(b) Average stretch per minimum distance

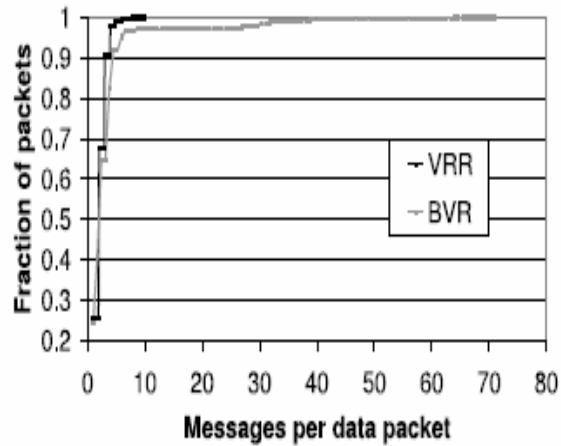


(c) Distribution of minimum distances

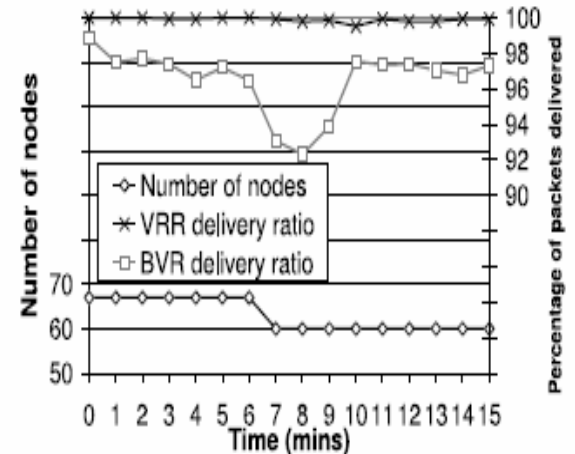
Sensor Network Testbed Results



(a) Delivery rate with varying packet rate

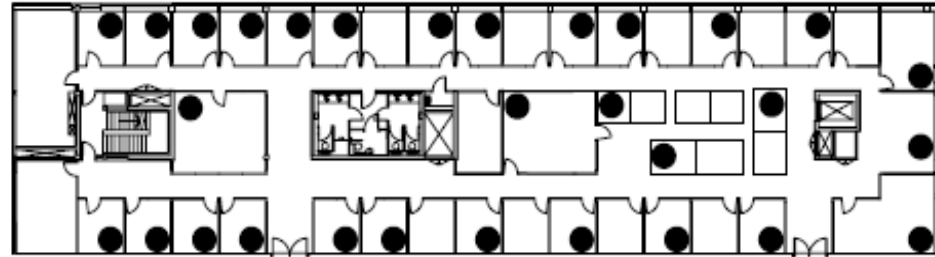


(b) Message overhead per packet

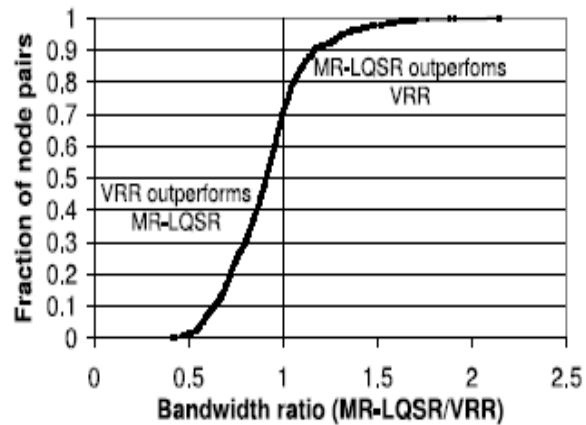


(c) Packet delivery ratio with failures

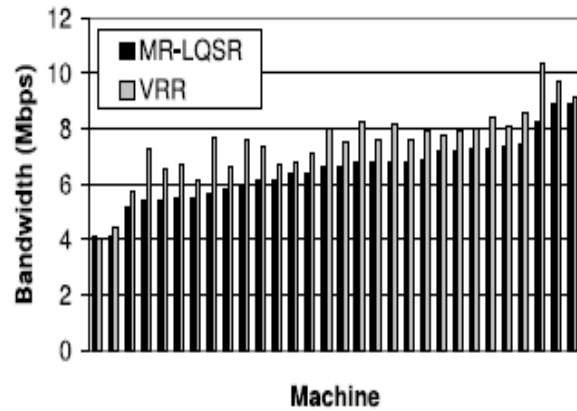
802.11a Testbed Results



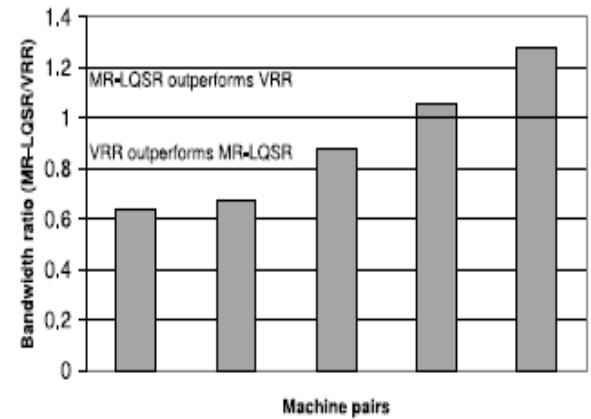
Floor plan of 802.11a PC testbed.



(a) Bandwidth comparison with MR-LQSR.



(b) Bandwidth comparison with MR-LQSR.



(c) Five concurrent flows.

Conclusion

Advantages

- Uses location independent identifiers
- No flooding
- Fault detection & repair can be done locally in many cases
- Can be implemented over any Link layer technology

Drawbacks

- Virtual paths may not always be the shortest paths
- Initial setup might be required to get the system started (since control messages to setup new vset-paths are routed using the existing vset-paths)

Thank You