



# On The Recovery Performance of Single- and Multipath OLSR in Wireless Multi-Hop Networks

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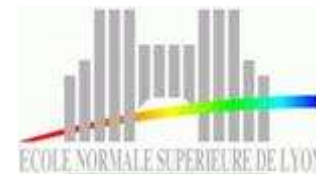
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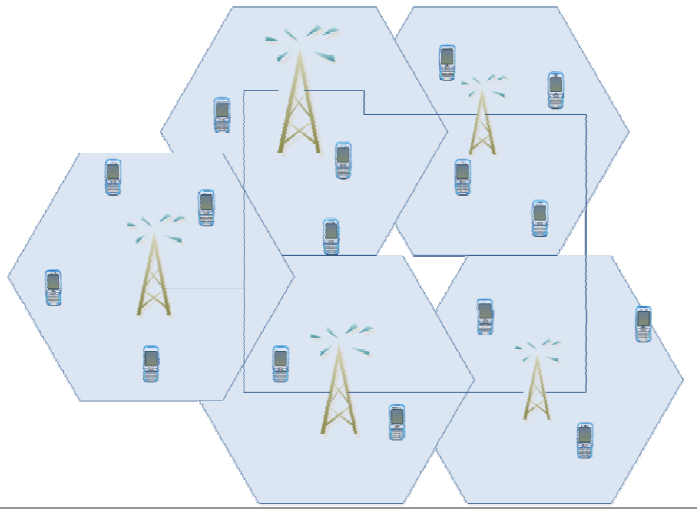
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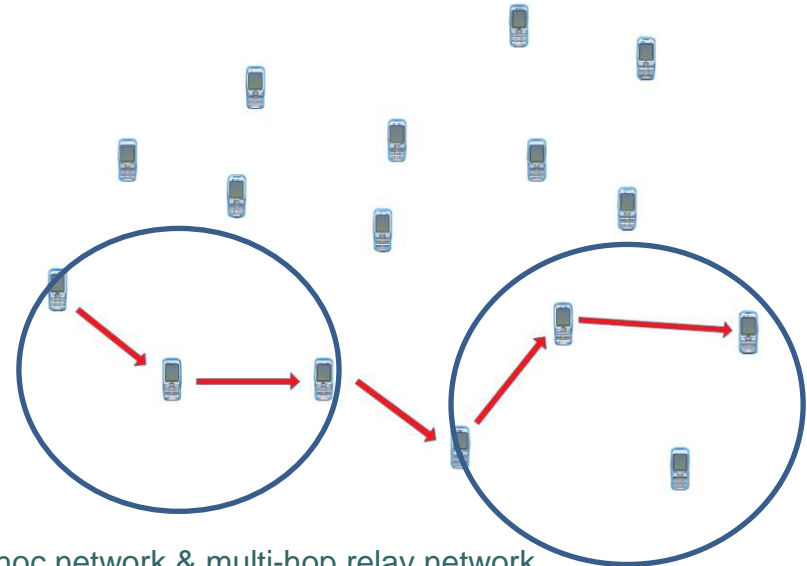
# Wireless multi-hop communication ...



•Cell phone with access point and base station.

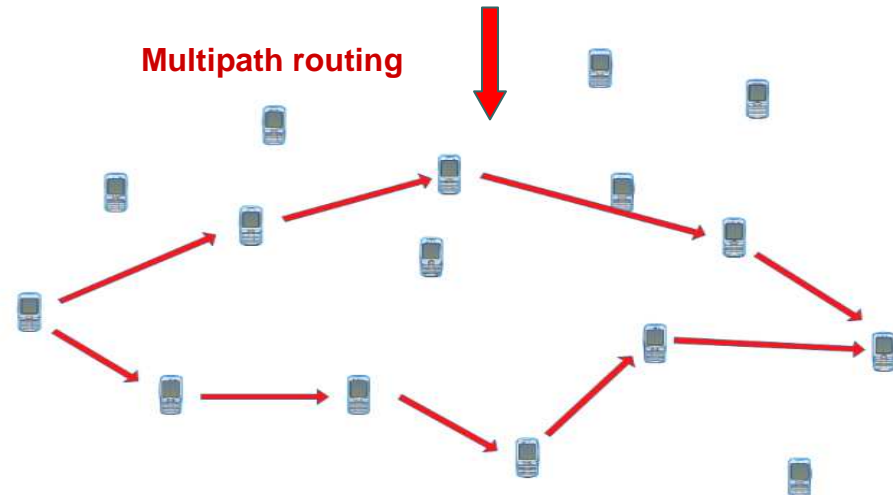


Without infrastructure



- Ad hoc network & multi-hop relay network
- Applications: Military and disaster recovery

**Multipath routing**



**To provide a reliable and efficient routing protocol for self-organized networks.**



# Outline

- State of the Art
- Multipath Optimized Link State Routing
- Analyse of long recovery delays in dual-chain topologies
- Design of efficient recovery schemes
- Conclusion & Future work



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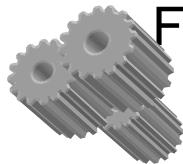
# Routing protocol for ad hoc networks

- Reactive routing (on-demand routing)
  - Dynamic Source Routing (DSR)
  - Ad hoc On-Demand Distance Vector Routing (AODV)
- Proactive routing (table-driven routing)
  - Dynamic Destination Sequenced Distance Vector Routing (DSDV)
  - Optimized Link State Routing (OLSR)
- Hybrid routing
- Multipath Routing



# Reactive routing recovery

- Route discovery
- Route maintenance
  - Relays on sending a unicast Route ERROR control messages to the nodes that need to be aware of the changes of topology.
  - ☺ This is faster than proactive schemes and generates less overhead.
  - ☹ re-discovery phase to rebuild the broken routes
  - ☹ -> induce overhead and longer packet delays



Fast local recovery scheme : Initiating a new re-discovery only if there is no route found by the node before the link failure.

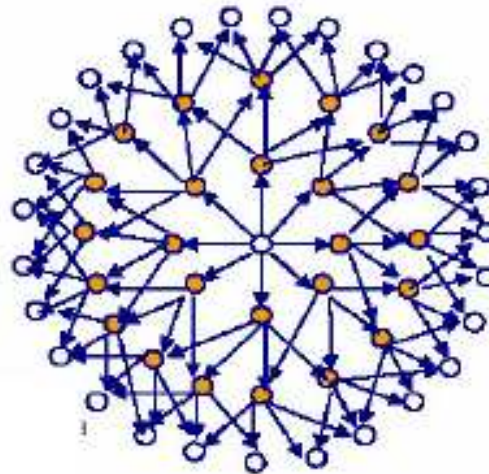


# Proactive routing

- Optimized Link State Routing (OLSR)
  - Based on periodic routing messages (HELLO & TC)
  - Table driven
  - Each node can obtain the whole network topology
  - Optimized flooding with Multi-Point Relay (MPR)

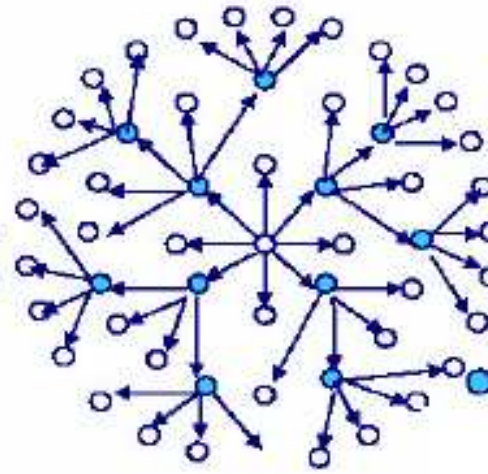
24 retransmissions to diffuse a message up to 3 hops.

● Retransmission node



11 retransmissions to diffuse a message up to 3 hops.

● MPR node retransmission



- Remote nodes are aware of link loss when they receive a control message carrying the relevant information
- ⊗ Topology changes because of the dynamic nature of multihop networks
- ⊗ periodic messages incurred delays



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# Objectives and components of a multi-path solution

- **Objectives**
  - Fault tolerance
  - Load balancing
  - Resource aggregation
- **Components**
  - Path discovery : finding multiple paths between a source and a destination node. Multi-path routing protocols can attempt to find node disjoint or link disjoint.
  - Route maintenance
  - The traffic allocation : how the data is distributed amongst the paths.
- **Examples**
  - Ad hoc On-Demand Multipath Distance Vector Routing (AOMDV)
    - Based on AODV
  - Split Multipath Routing (SMR)
    - Based on DSR



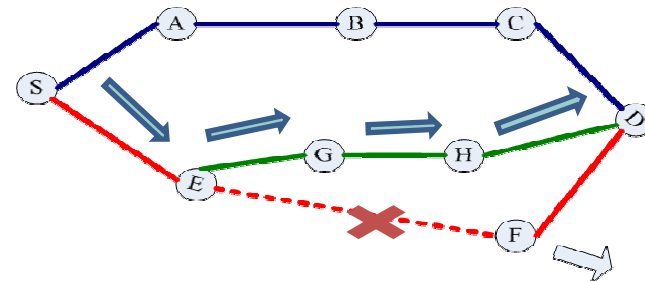
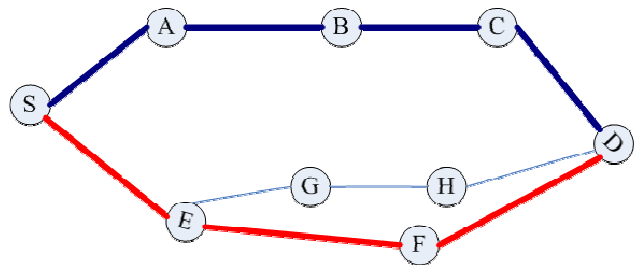
# Multipath OLSR

- Topology sensing : based on OLSR
  - Link Sensing HELLO
  - Neighbor Detection
  - Topology Discovery TC
- Route computation
  - Multipath Dijkstra
  - Source routing
- Route recovery
- Loop detection



# Route Recovery

- The problems of source routing
  - Topology information in the source node is out of date
  - Changes of topology during data transmission
- Route recovery
  - At the intermediate node, before forwarding the packet to the next hop, check if the next hop is in the neighbor set
  - If the next hop in the source route is not the neighbor anymore, recompute the route



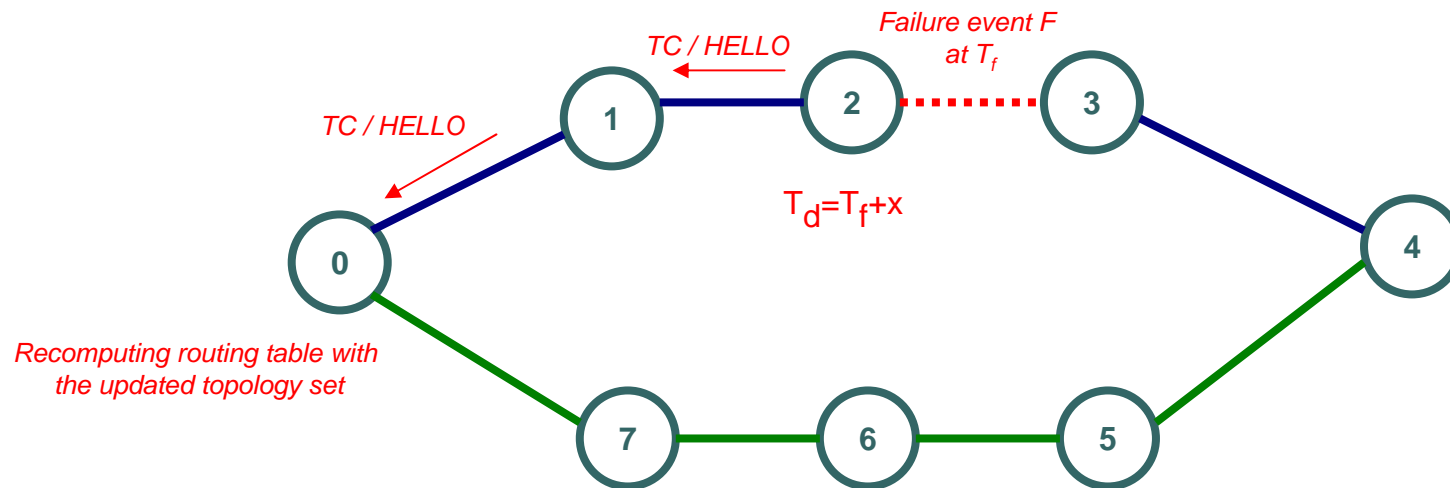
- Loop detection is based on source route
  - Link Layer Notification (LLN)
    - Information from MAC layer to notify the link break
  - Route Recovery + LLN
    - Loops in the network



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# Source reactivity time when facing a route failure



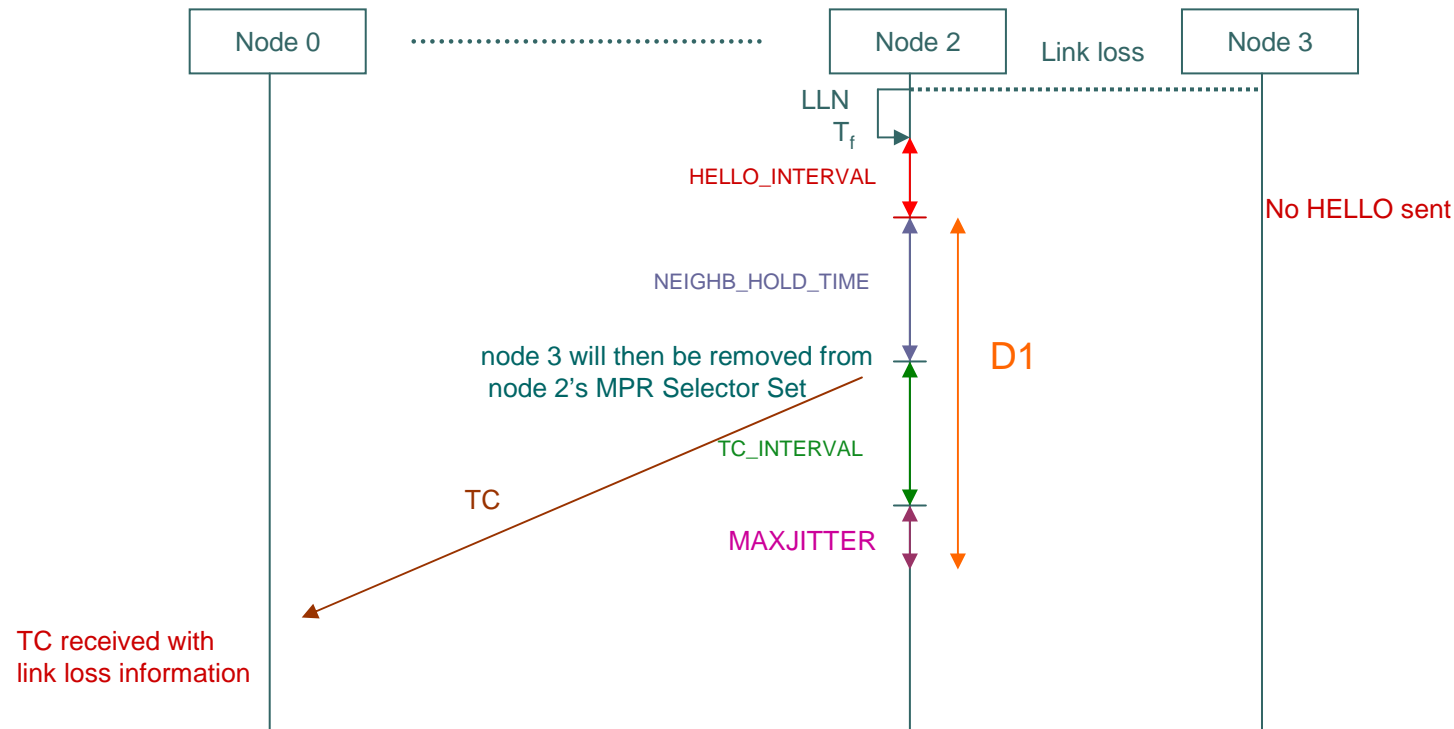
•Latency :  $\Delta = |T_r - T_d|$

where  $T_d$  = the time when a first data packet is dropped.

$T_r$  = the time when the source node has recomputed its routing table taking into account the topological effects of the link failure event.

# Analysis of long recovery delays in dual-chain topologies (1/2)

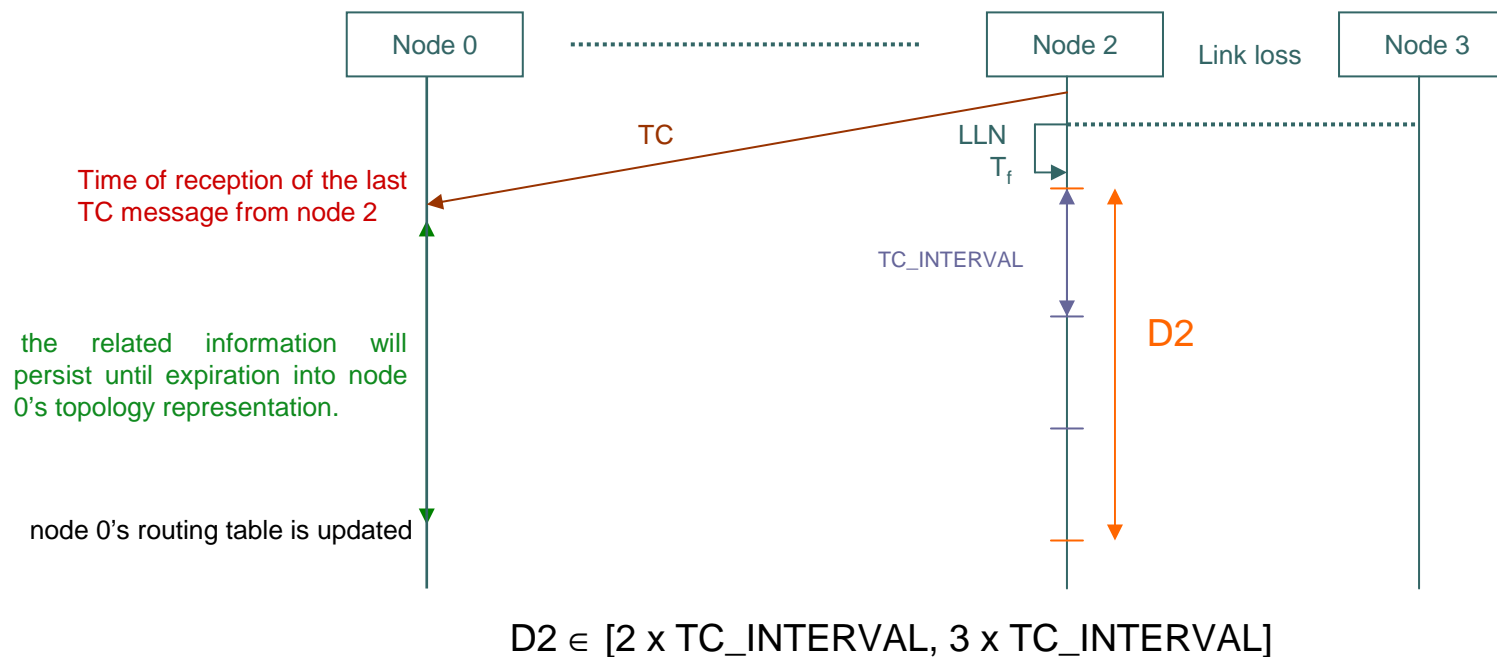
- Node 2 sends a TC message taking into account the link loss



$$D1 \in [\text{NEIGHB\_HOLD\_TIME} - \text{HELLO\_INTERVAL}, \text{NEIGHB\_HOLD\_TIME} + \text{TC\_INTERVAL} + \text{MAXJITTER}]$$

# Analysis of long recovery delays in dual-chain topologies (2/2)

- Expiration of outdated topology information into node 0's Local Topology Set



$D1 \in [4 \text{ s}, 11.5 \text{ s}]$  and  $D2 \in [10 \text{ s}, 15 \text{ s}]$   
 Those estimations show that in this topological context,  $\Delta$  is significant. On a practical level, it is unacceptable for delay constrained applications.

# Simulation results related to these estimations

- Recovery times measurement

Routing schemes	Latency (s)		
	<i>minimum</i>	<i>mean</i>	<i>maximum</i>
Original OLSR	4.818	10.645	14.545
Original MP-OLSR	11.049	13.214	14.934



- Long latencies induced by both OLSR and MPOLSR between 4 s and 15 s.
- ☹ it is important that the recovery process does not imply unacceptable delays for some networking applications like ToIP or streaming.

Mobility	0
Nodes number	8
Topology area	x=150 m et y =150 m
Simulation time	50 s
(Source, Destination)	(Node 0, Node 4)
CBR traffic	The rate = 100kb/s Packet size = 512 bytes Traffic starts at = 10 s
MAC type	MAC/802.11
Transmission range	60 m
Channel capacity	11Mbps
Routing protocols	OLSR MPOLSR : 2 node-disjoint paths
Failure event at T	In [15 s, 19 s]





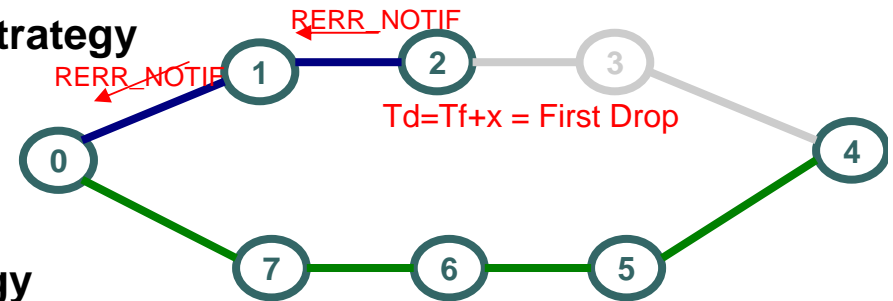
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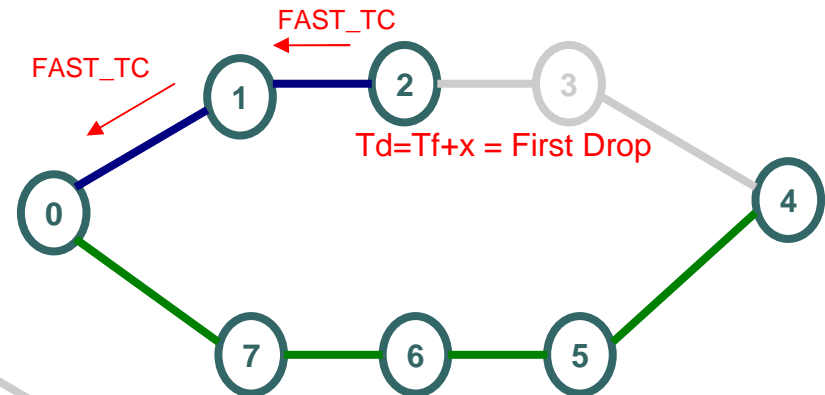
# Design of efficient recovery schemes

- 3 proposed solutions to decrease this latency

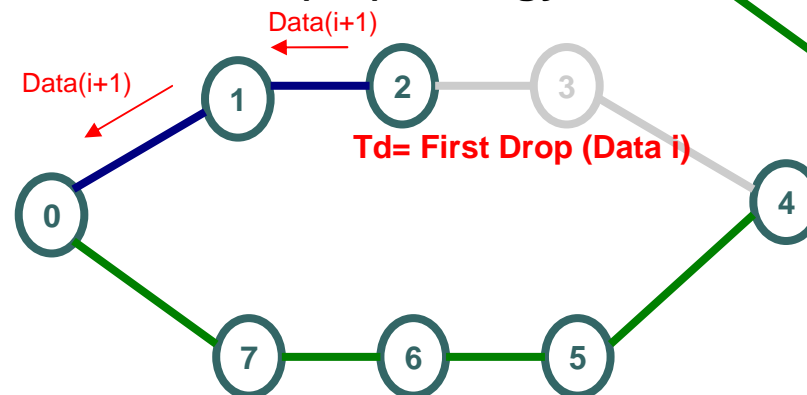
## 1. A Route Error (RE) notification strategy



## 2. A Fast TC (FTC) message strategy

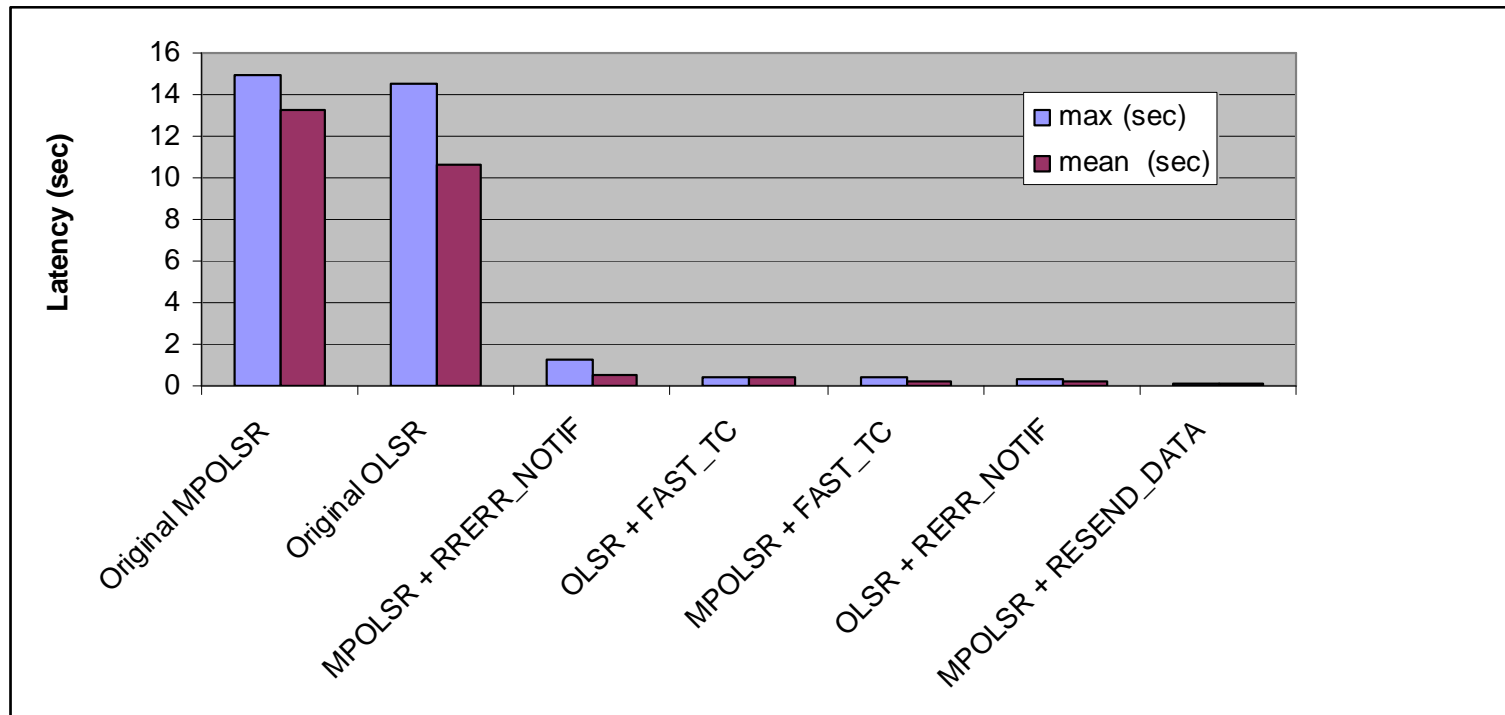


## 3. Data Re-emission (DR) strategy





# Recovery schemes comparison



Impact of the proposed recovery schemes on Latency for single- and Multipath OLSR in dual-chain topology

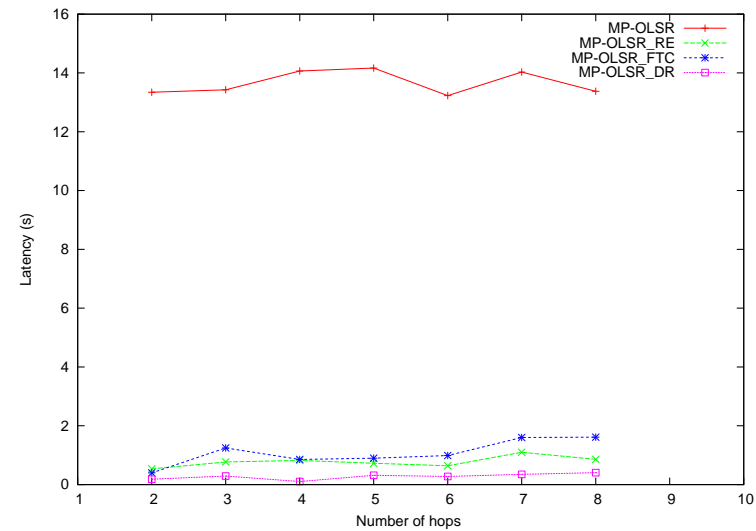
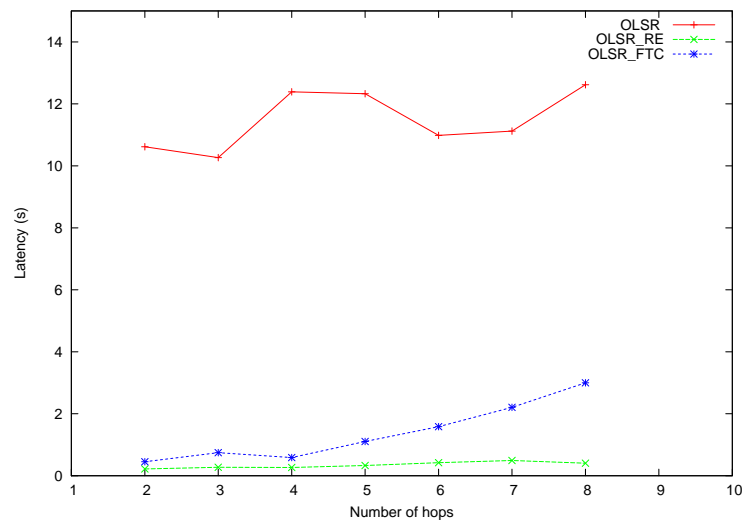


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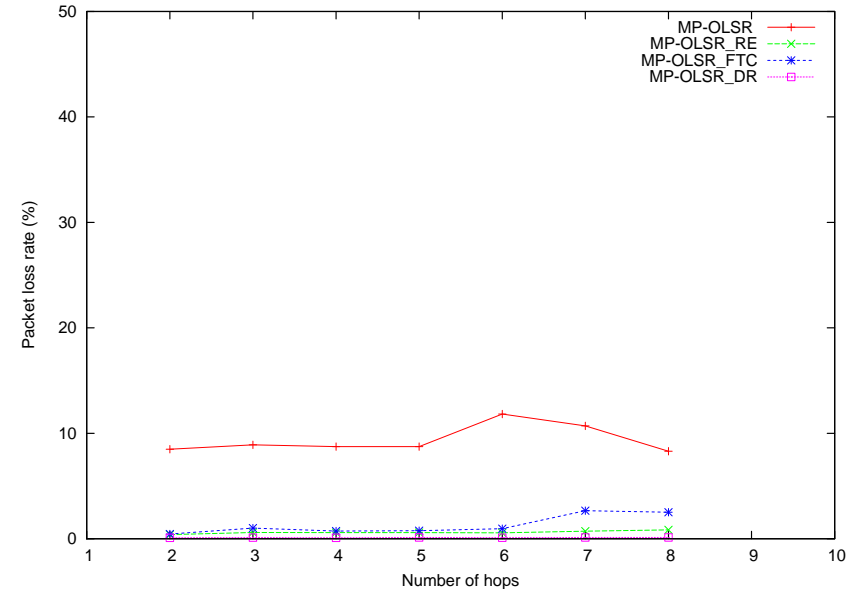
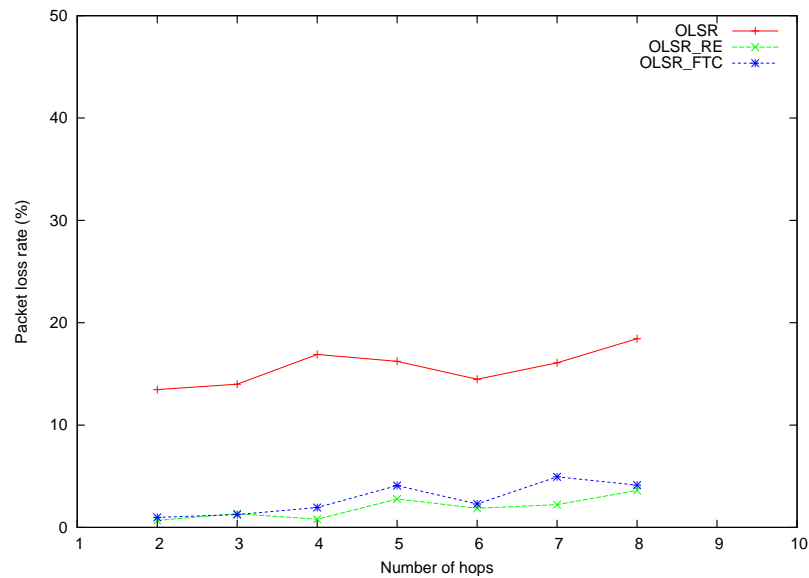
## Average latency with the number of hops to the node that senses the link failure



Average latency with the number of hops to the node that senses the link failure, for OLSR and MP-OLSR, MP-OLSR\_RE, MP-OLSR\_FTC and MP-OLSR\_DR in dual-chain topology with 20 nodes.

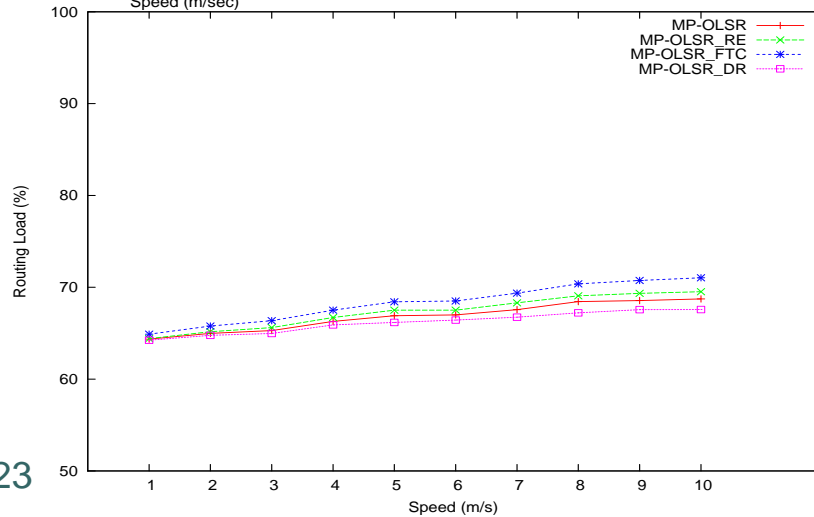
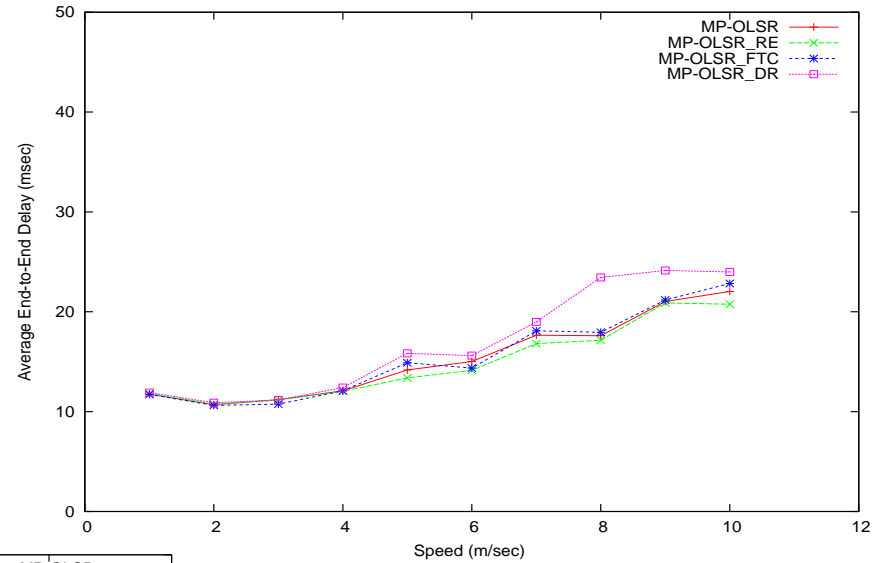
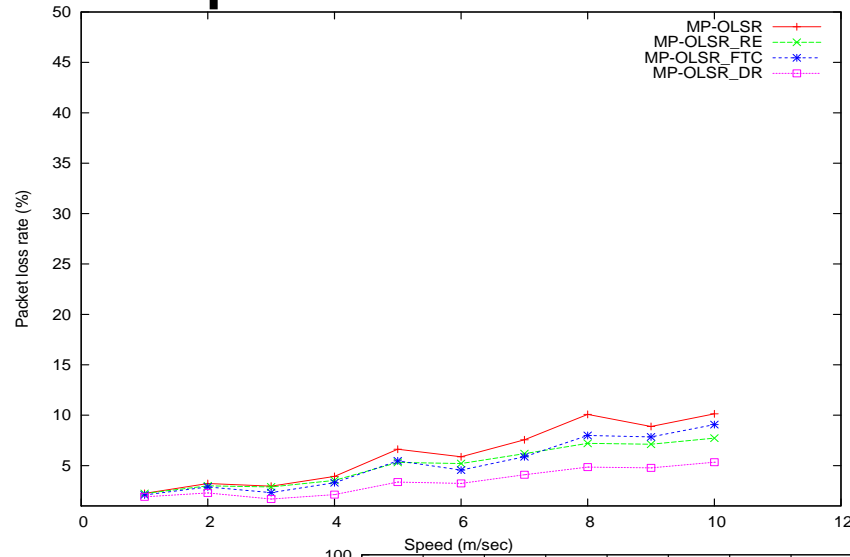


## Packet loss rate with the number of hops to the node that senses the link failure



Packet loss rate with the number of hops to the node that senses the link failure, for OLSR and MP-OLSR, MP-OLSR\_RE , MP-OLSR\_FTC and MP-OLSR\_DR in dual-chain topology with 20 nodes.

# End-to-end delays, Packet loss rate and Routing load with node speed



Nodes number	50
Topology area	1000 m x1000 m
Simulation time	200 s
CBR traffic	10sources emit 10 packets/s Packet size = 512 bytes Traffic starts at = 10 s
Transmission range	250 m
Channel capacity	11Mbps
Routing protocols	MPOLSR : 2 paths



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# Conclusion

- Recovery performance issue with link-state protocols in a multi-hop dual chain-topology network.
  - Analysis of recovery delays consecutive to a link failure of OLSR and MP-OLSR
- 3 adapted schemes to achieve fast recovery
  - FTC : where a TC message is immediately emitted after a link failure detection
  - RE : where the node that detected a link failure sends back a unicast message to the source
  - DR : Specific scheme to MP-OLSR where the same node, in the same situation, re-emits the data packet to the source instead.
- RE is the best scheme for OLSR
  - Improvement of recovery performance in a dual chain-topology network
  - The induced overhead by the extra control messages is limited in a more general topology compared to TC
- DR is the most interesting scheme for MP-OLSR
  - Improvement of both packet loss ratio and routing load in a general topology.



## Future work

- Evaluation of those schemes in other realistic topologies.
- Study of delay issues when re-emitting data packets with MP-OLSR and its DR extension.
- Study of packet-processing mechanisms at a DR source node, when flow-related Quality of Service requirements are known by this source node.