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Frame Replication and Elimination for Reliability (FRER) in Time-Sensitive Networks

OMNeT++ Community Summit 2021

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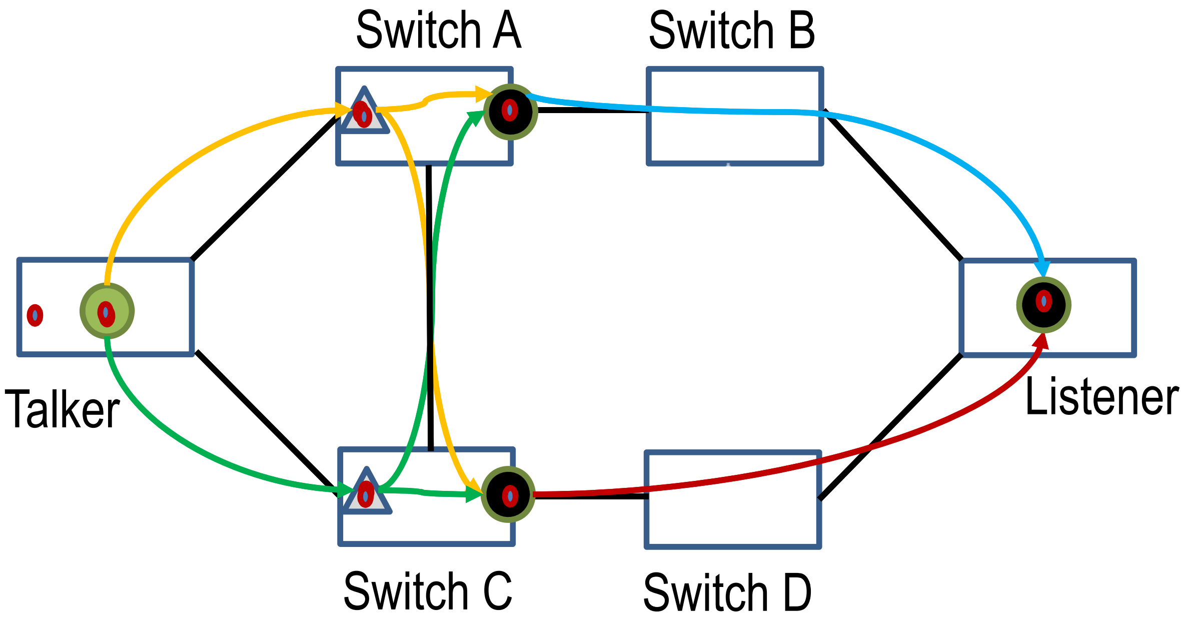
Motivation

- Some applications require very reliable frame delivery
- Critical data must reach at destination
- Retransmissions would cause non-acceptable delay

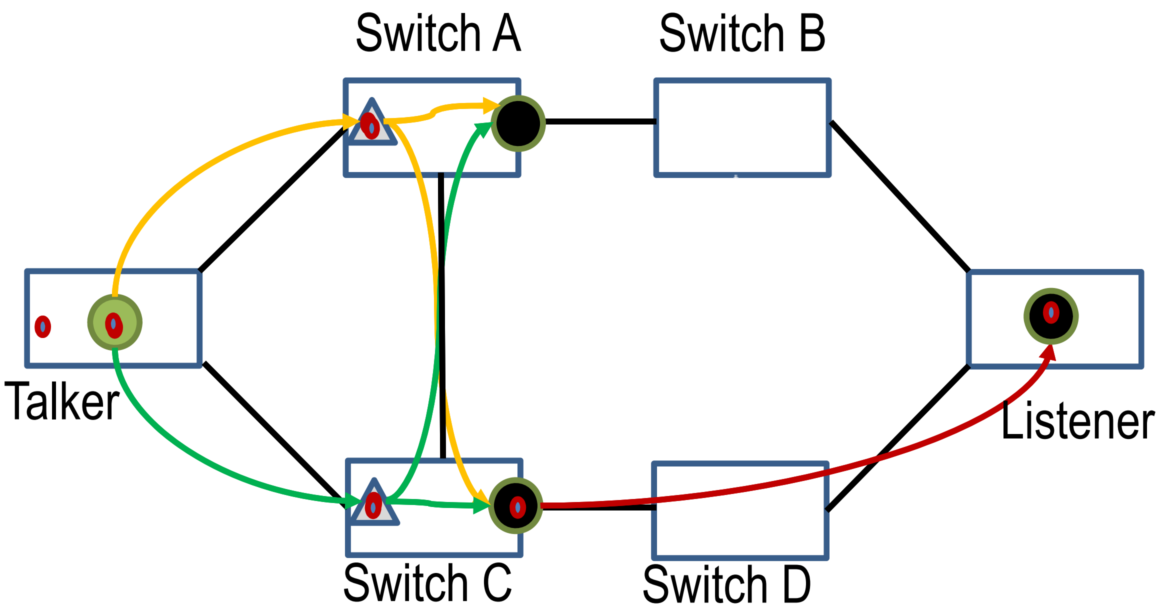
Problem statement

- How to ensure reliable communication in Ethernet networks?



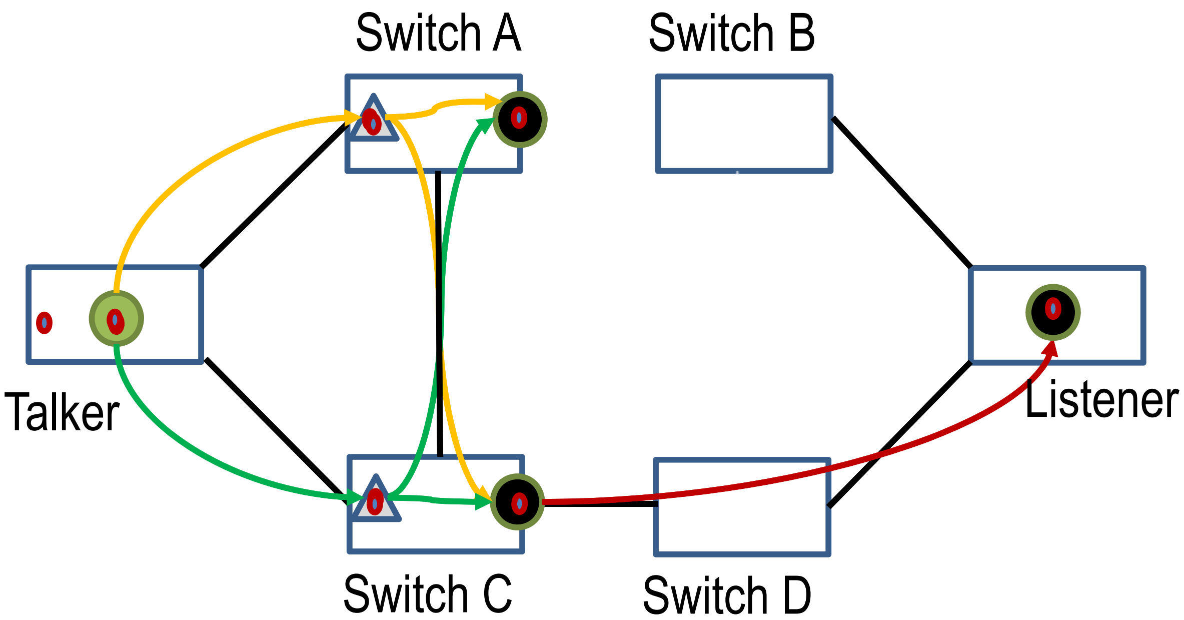
Possible failures

- Packet loss



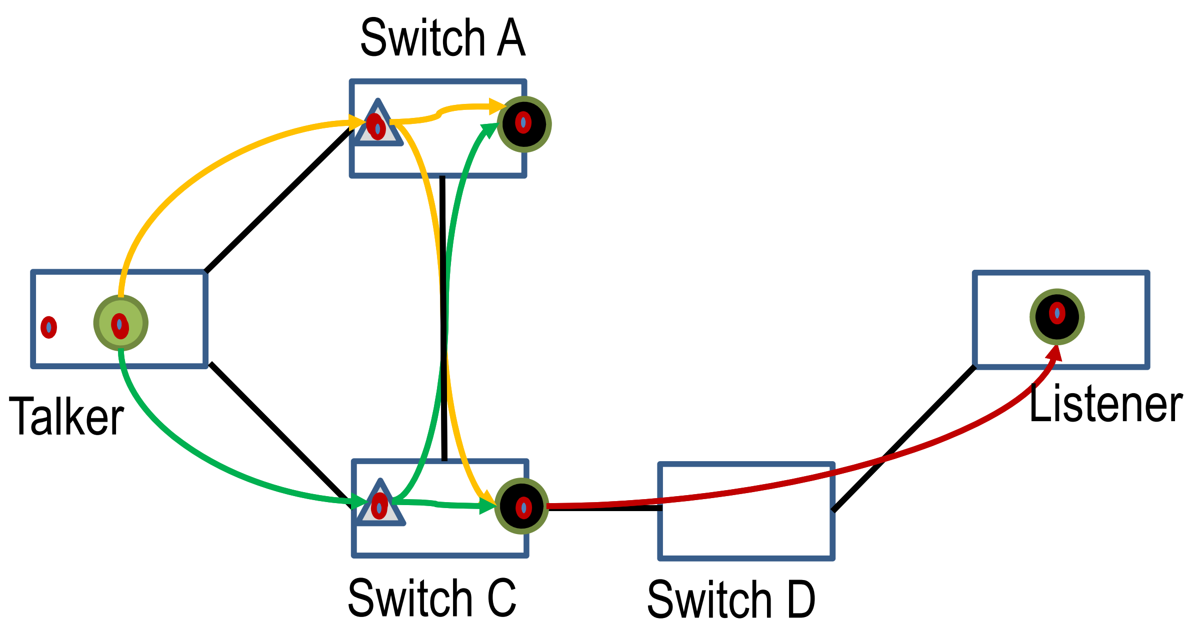
Possible failures

- Packet loss
- Failing link



Possible failures

- Packet loss
- Failing link
- Failing bridge



Supplements to the FRER standard

- Unaddressed aspects in the FRER standard
  - Which traffic to replicate?
  - How many times to replicate the traffic?
  - What happens in the case of a permanent error?

Which traffic to replicate?

- Video
- Voice
- Internetwork control
- Network control

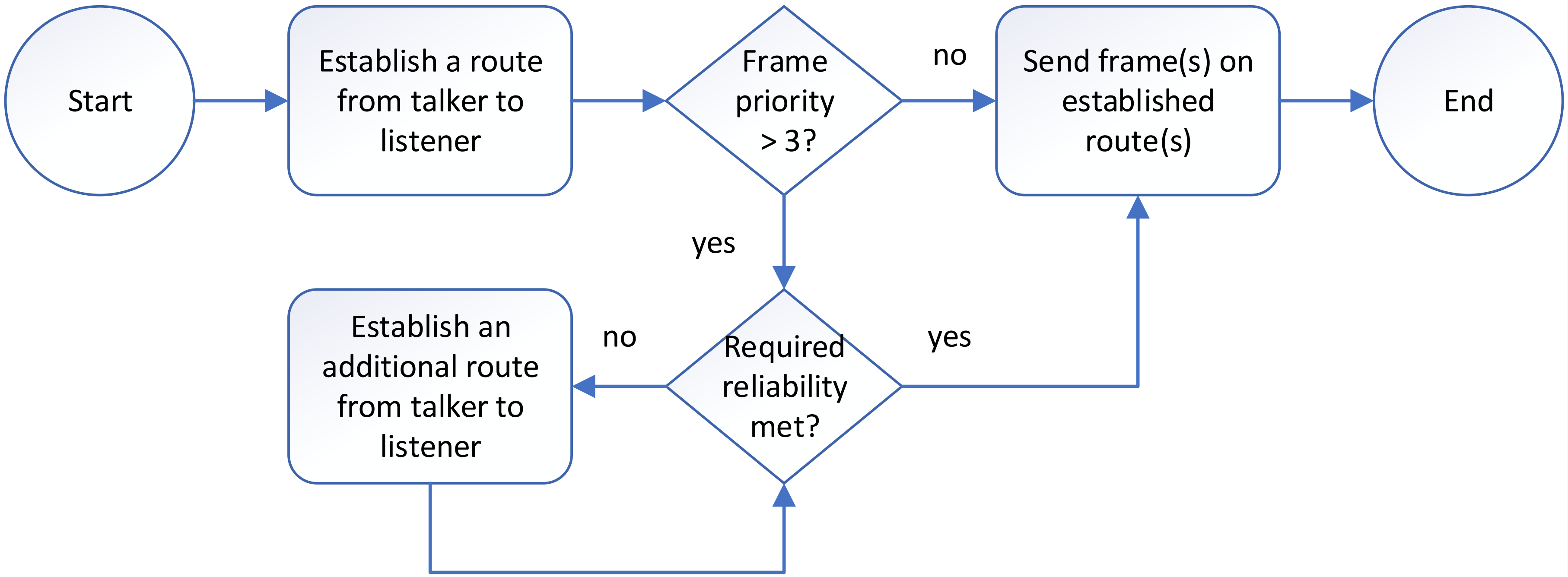
Priority	Traffic Types
0	Background
1	Best Effort
2	Excellent Effort
3	Critical Application
4	Video, <100ms
5	Voice, <10ms
6	Internetwork Control
7	Network Control

Which traffic to replicate?

- Video
- Voice
- Internetwork control
- Network control

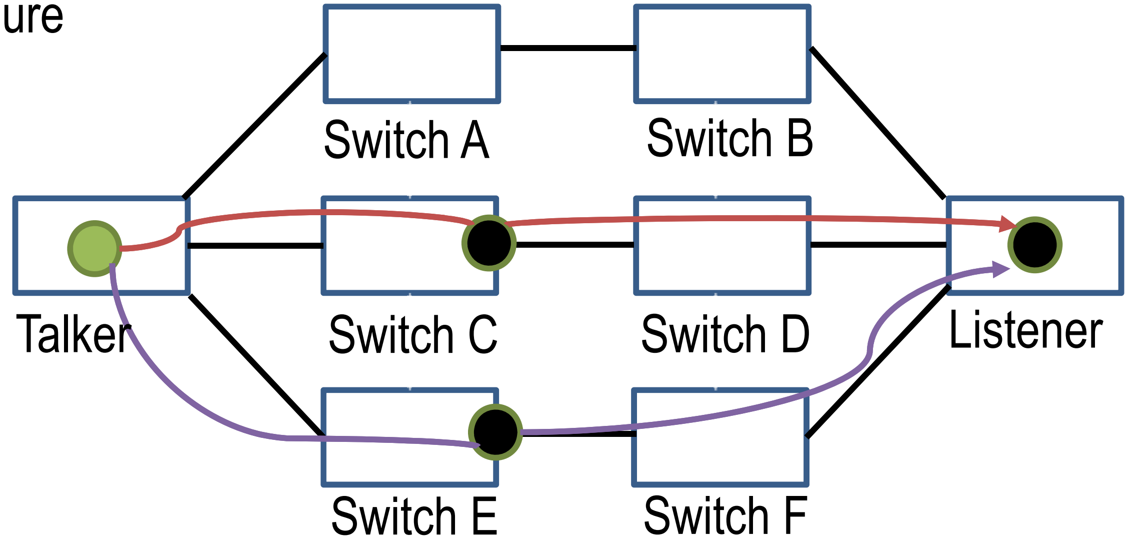
Priority	Traffic Types	Reliability [%]
0	Background	
1	Best Effort	
2	Excellent Effort	
3	Critical Application	
4	Video, <100ms	99
5	Voice, <10ms	99.9
6	Internetwork Control	99.99
7	Network Control	99.999

How many times to duplicate the traffic?



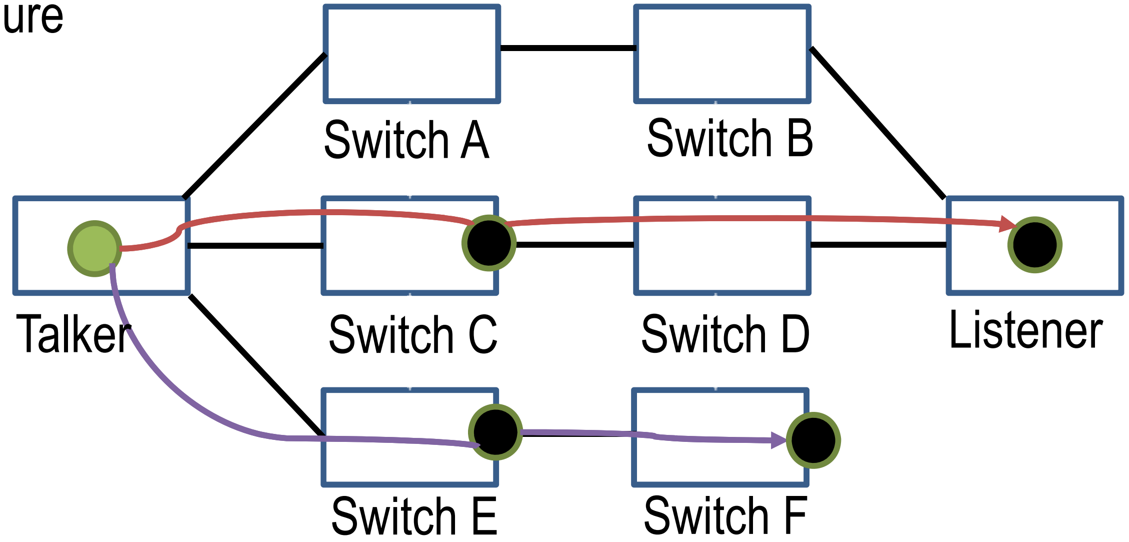
Permanent error model

- Permanent error, e.g., link failure



Permanent error model

- Permanent error, e.g., link failure



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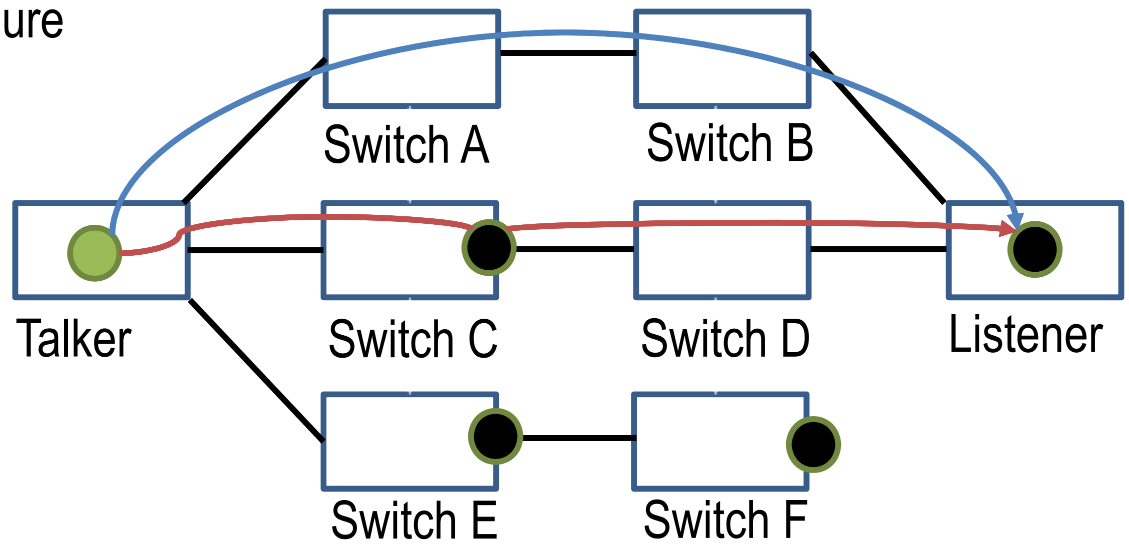
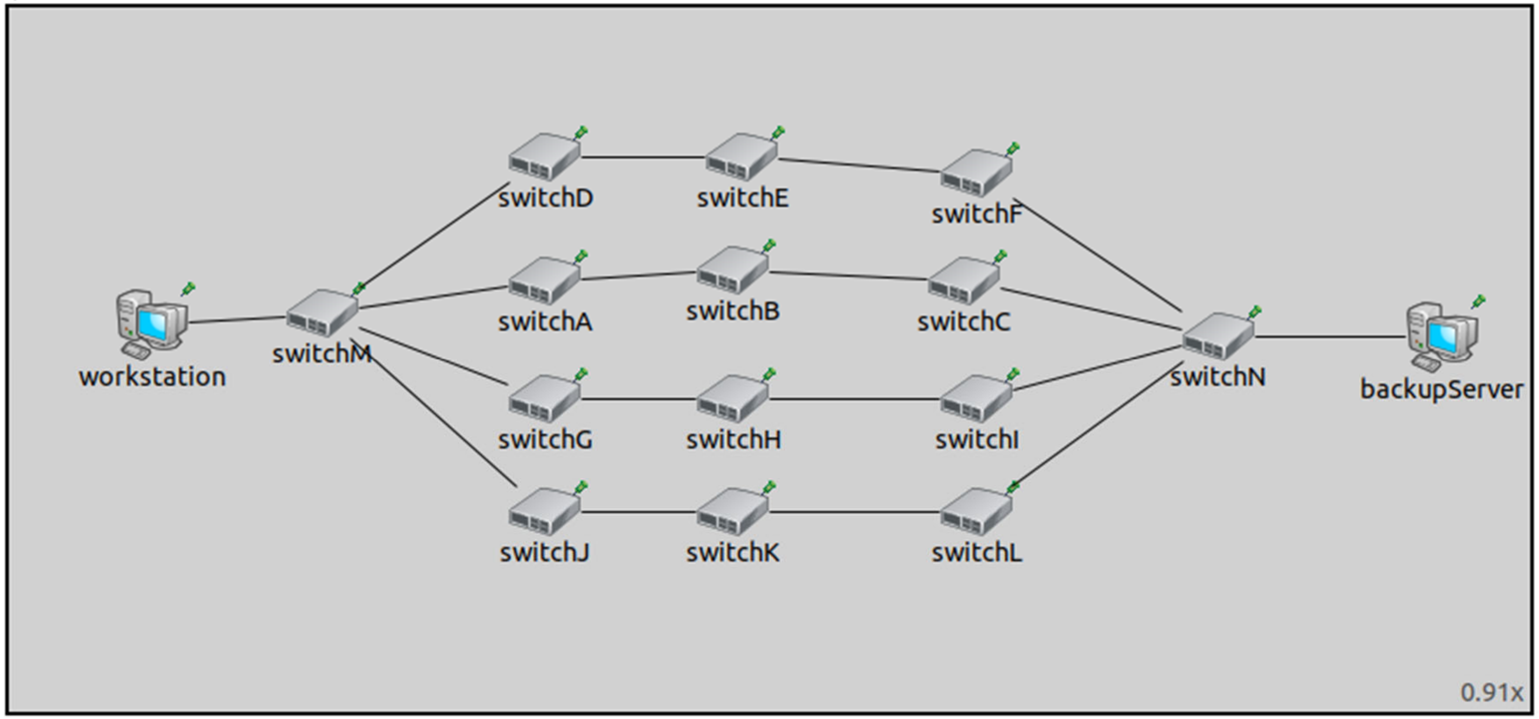
Permanent error model

- Permanent error, e.g., link failure
- Establish new route



Implementation

- Example topology: FRER functionality is added to NeSTiNG talker and bridge



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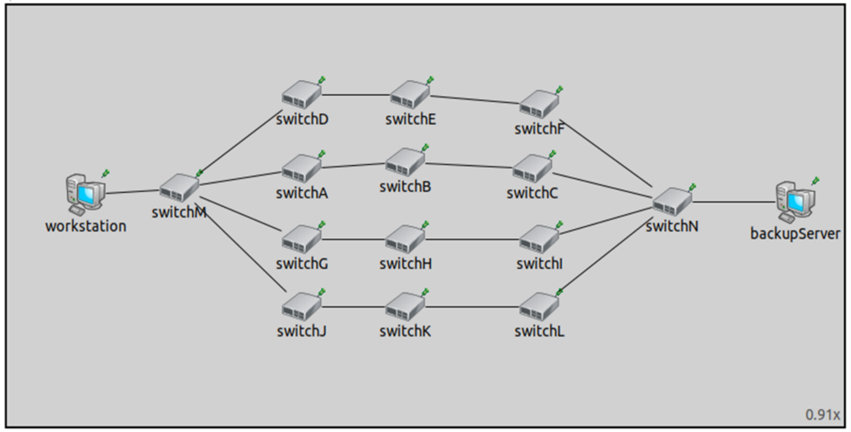
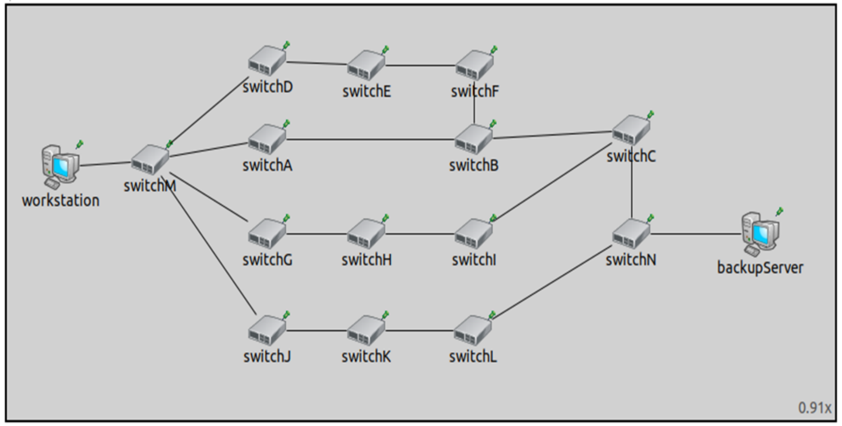
Results: 7 test cases

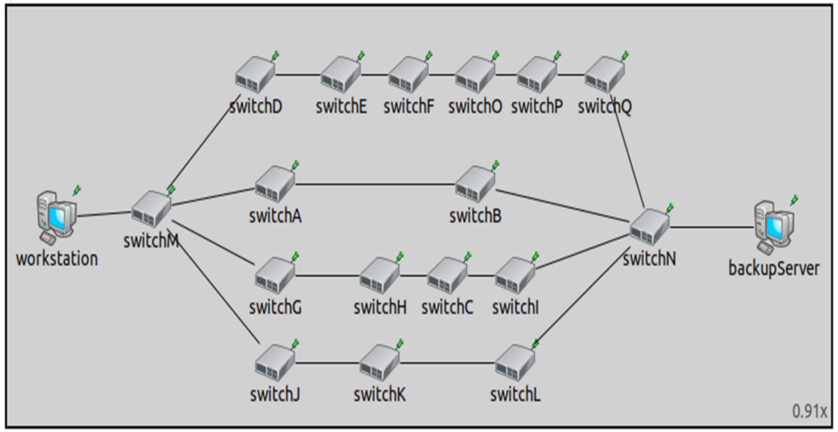
- Proof of concept
  - Without errors
  - Transient errors
  - Permanent errors
- Three different topologies used



Topology with four parallel paths



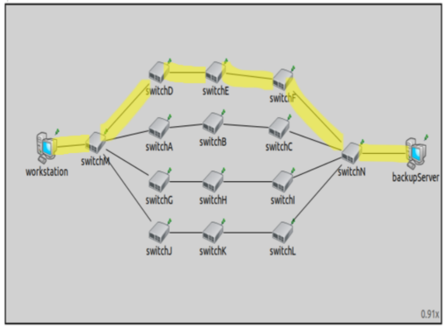
Topology with with interconnecting links between four parallel paths



Topology with different numbers of bridges on four parallel path

Without errors: topology with four parallel paths

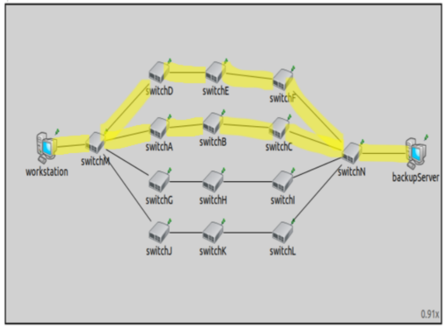
- Priority three



Message	Initial Time (µs)	Final Time (µs)	Packet Delay (µs)
1	10	53.984	43.984
2	40	83.984	43.984
3	70	113.984	43.984
4	100	143.984	43.984
5	130	173.984	43.984
6	160	203.984	43.984
7	190	233.984	43.984
8	220	263.984	43.984
9	250	293.984	43.984
10	280	323.984	43.984

Without errors: topology with four parallel paths

- Priority four
- Priority five



Message	Initial Time (µs)	Final Time (µs)	Packet Delay (µs)
1	10	53.984	43.984
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3	70	113.984	43.984
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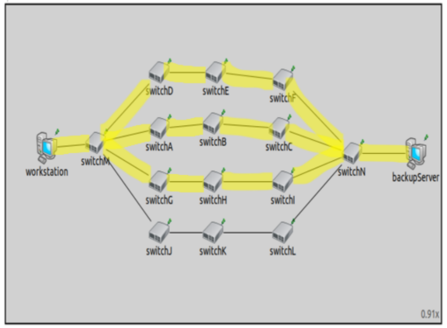
6	160	203.984	43.984
7	190	233.984	43.984
8	220	263.984	43.984
9	250	293.984	43.984
10	280	323.984	43.984

Without errors: topology with four parallel paths

- Priority six
- Priority seven



Message	Initial Time (µs)	Final Time (µs)	Packet Delay (µs)
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7	190	233.984	43.984
8	220	263.984	43.984
9	250	293.984	43.984
10	280	323.984	43.984

Without errors: topology with interconnecting links between four parallel paths

- Priority five

Message	Initial Time (μs)	Final Time (μs)	Packet Delay (μs)
1	10	53.984	43.984
2	40	83.984	43.984
3	70	113.984	43.984
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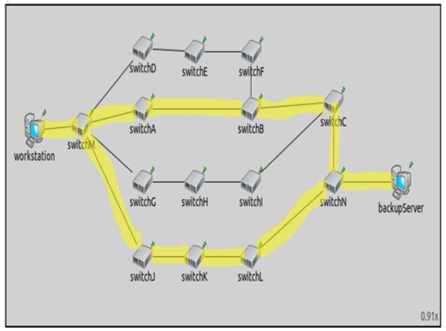
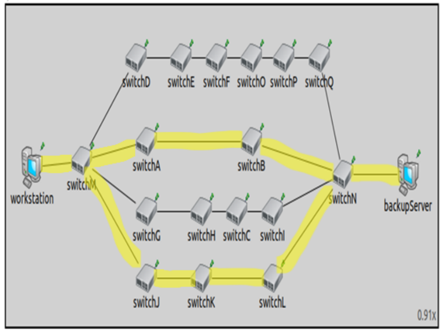


Without errors: topology with different numbers of bridges on four parallel paths

- Priority five



Message	Initial Time (µs)	Final Time (µs)	Packet Delay (µs)
1	10	45.82	35.82
2	40	75.82	35.82
3	70	105.82	35.82
4	100	135.82	35.82
5	130	165.82	35.82
6	160	195.82	35.82
7	190	225.82	35.82
8	220	255.82	35.82
9	250	285.82	35.82
10	280	315.82	35.82

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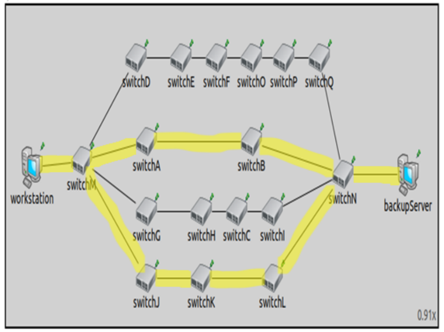
Transient error: topology with different numbers of bridges on four parallel paths

- Priority five
- Every third frame dropped



Message	Initial Time (µs)	Final Time (µs)	Packet Delay (µs)
1	10	45.82	35.82
2	40	75.82	35.82
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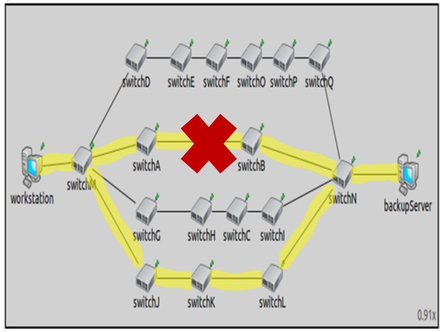
5	130	165.82	35.82
6	160	203.984	43.984
7	190	225.82	35.82
8	220	255.82	35.82
9	250	293.984	43.984
10	280	315.82	35.82

Permanent error: topology with different numbers of bridges on four parallel paths

- Priority five
- Route fails after 5th frame



Message	Initial Time (µs)	Final Time (µs)	Packet Delay (µs)
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10	280	323.984	43.984

Permanent error: topology with different numbers of bridges on four parallel paths

- Priority five
- New route is established

Message	Initial Time (µs)	Final Time (µs)	Packet Delay (µs)
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3	70	105.82	35.82
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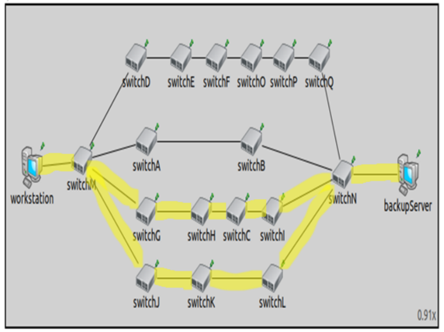

Conclusion and future work

- Development of a simulation model for the IEEE 802.1CB standard (FRER) for reliability in time-sensitive networks
- Integration of supplements for FRER standard
  - Which frames should be duplicated?
  - How many times a frame should be duplicated?
  - What happens in the case of a permanent path error?
- Different topologies are tested under different conditions
  - Simulation results show that that the model works as expected and protects against transient and permanent errors

- Future work: configuration of the model at runtime

Thank you for your attention!

Questions?