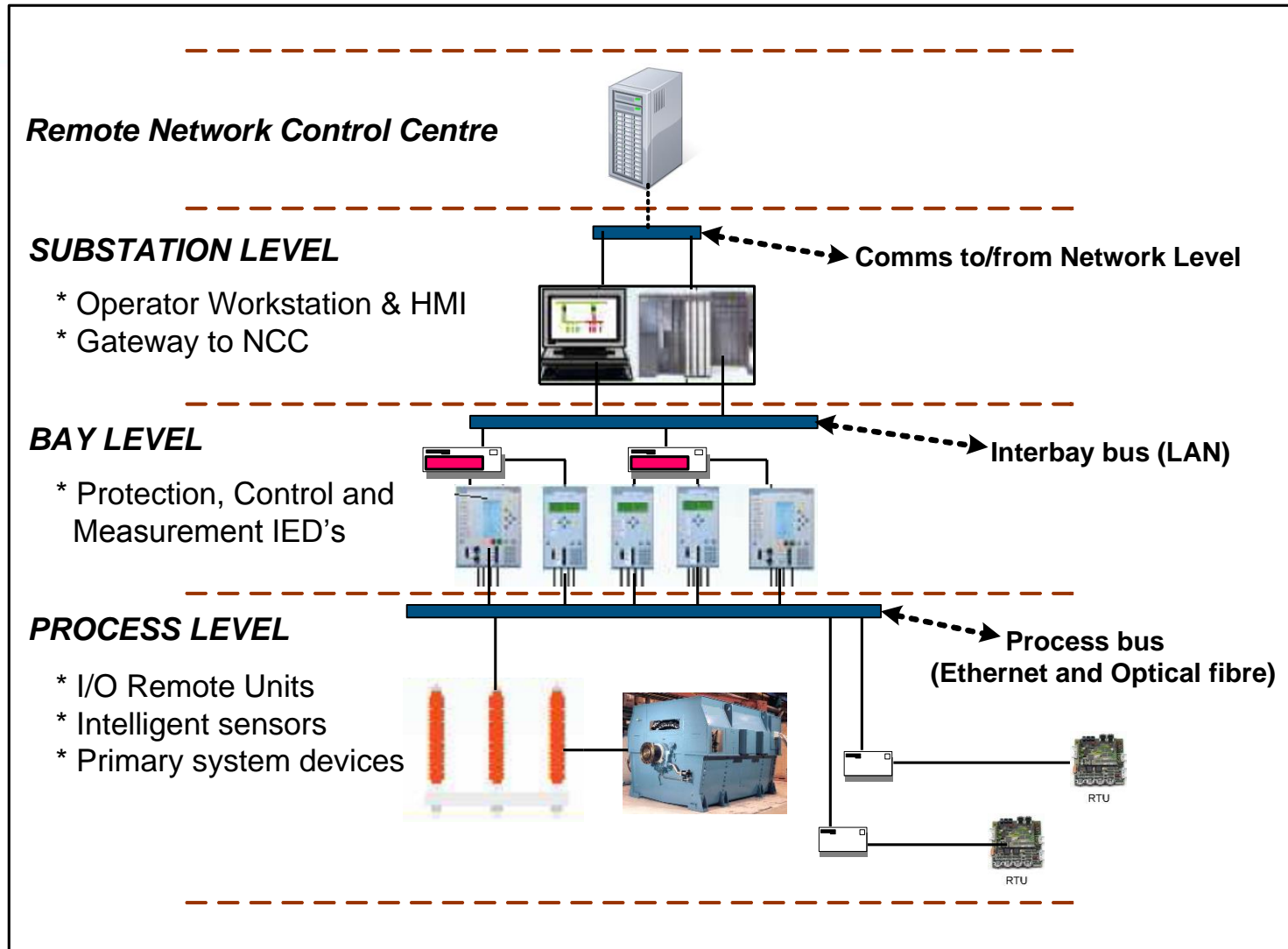Preferential Subject 1: Telecommunication networks for Time – Critical applications

EFECTS OF THE NETWORK TOPOLOGY IN THE RECOVERY TIME A PRACTICAL CASE STUDY

Daniel Espinosa

Jaume Darné

Esaú Marcelo

Remote Network Control Centre

SUBSTATION LEVEL

* Operator Workstation & HMI
* Gateway to NCC

Comms to/from Network Level

BAY LEVEL

* Protection, Control and Measurement IED's

Interbay bus (LAN)

PROCESS LEVEL

* I/O Remote Units
* Intelligent sensors
* Primary system devices

Process bus
(Ethernet and Optical fibre)

RTU

RTU

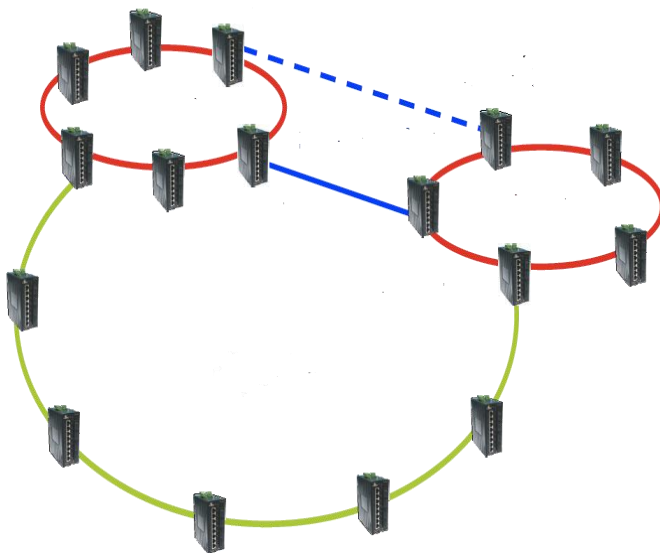❏ **Three main possibilities:**

- ▪ **Single and double star**
  - • Only 1 or 2 Main Switches
  - • High Number of ports per switch
 - • High performance Switch necessary

- ▪ **Single and double three**
  - • IEDs are chained towards the Bay Level
  - • Latency in transversal Communications
 - • Improved resiliency compared with star

- ▪ **Single and multiple rings**

- Standard de facto in Industrial Ethernet Networks
- Single element failure protected
- Multiple variants
  - Single ring
  - Multiple rings chained
  - Ring of the rings
- Interconnecting points does not increases significantly the risk
- Deterministic topology
- Balanced trade off between efficiency and cost

Prasant Mohapatra's Network Research Group. UC Davis
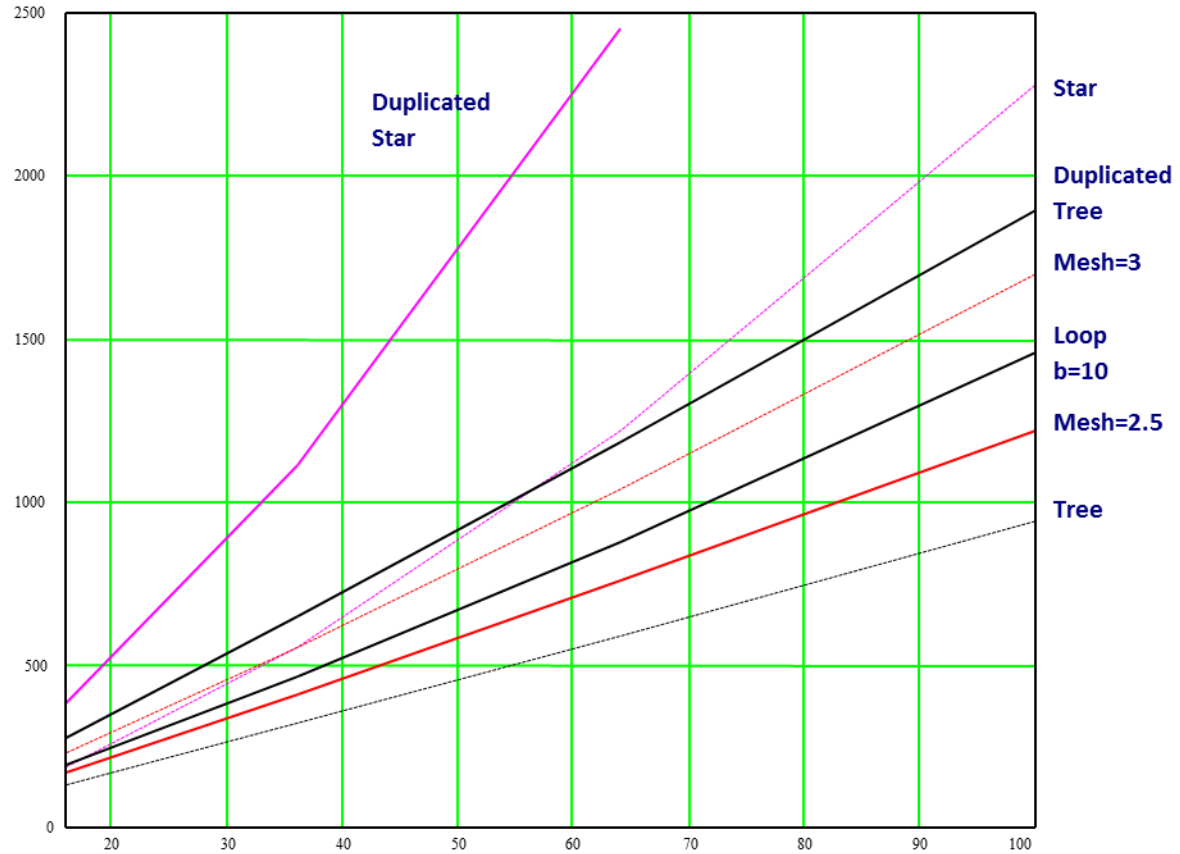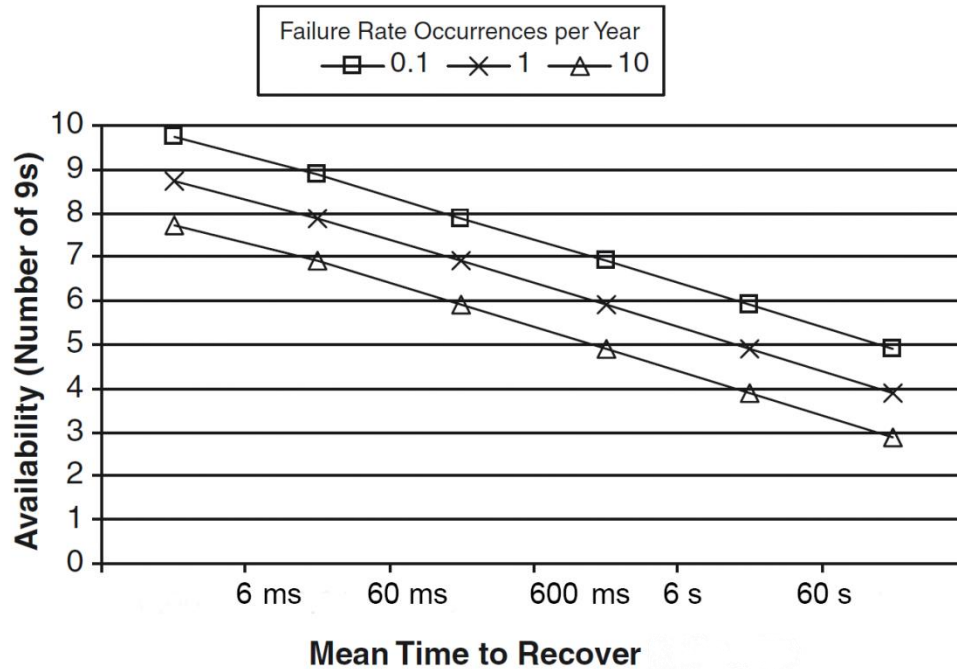
| Application layer 20% |
| Presentation layer 5% |
| Session Layer 5% |
| Transport Layer 15% |
| Network Layer 25% |
| Link Layer 10% |
| Physical Layer 20% |

Failure distribution in OSI layers

- **RSTP + IEEE 802.1D**
  - ✓ Popular and Universal use
  - ✓ Compatible with all Topologies
  - ✓ Ring enhancements boost the recovery times up to 10 ms.

- **MRP IEC 62439-2**
  - ✓ Single ring topology only. Uniform ring
  - ✓ R.T. depends of the switch count: 14 Sw / 10 ms, 50 Sw / 30 ms
  - ✓ Ethernet Filtering Database (FDB) flushed during Transition

- **PRP IEC 62439-3**
  - ✓ Two independent networks with any topology
  - ✓ Zero packet loss but un-deterministic in some cases
  - ✓ Protocol implemented at the Endpoints. No recovery time

- **HSR IEC 62439-3**
  - ✓ Standard HSR unpractical outside of ring topology.
  - ✓ Implemented on two port IEDs with bridging functionality
  - ✓ Zero packet loss. Un-deterministic. Duplicates the ring traffic

- **MOXA's V-ON PROTOCOL**
  - ✓ Initially developed for multicast streaming on uniform ring
  - ✓ Based on previous Turbo- Ring and Turbo-Chain protocols.
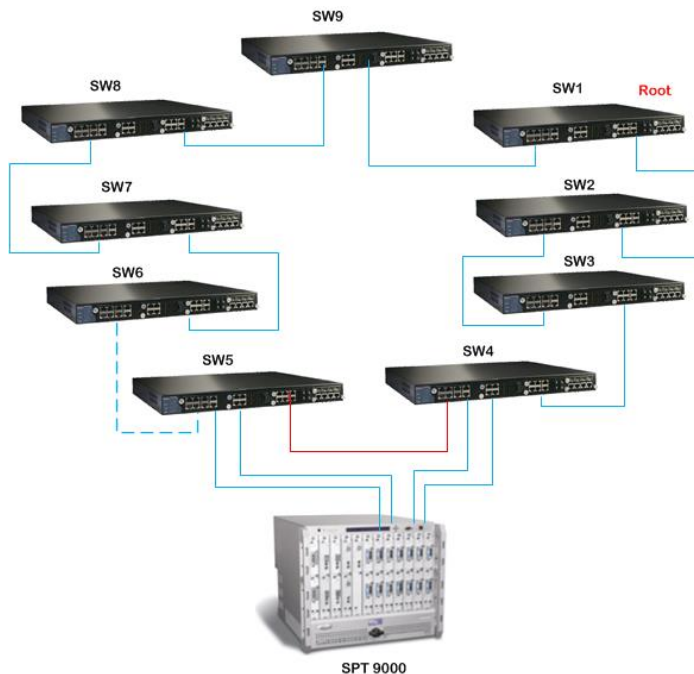 - ✓ Recovery time: 20 to 50 ms

- **KYLAND's DT-RING**
  - ✓ Ring specific protocol. Uniform Ring
  - ✓ Recovery time: 40 ms for a 15 nodes network
  - ✓ Strongly dependent of the position and device count

- **KORENIX's SUPER RING**
  - ✓ Works with single or multiple uniform rings
  - ✓ Recovery time 5 ms. Packet loss during transition
  - ✓ Proprietary patented protocol suite

SW9
SW8
SW1 Root
SW7
SW2
SW6
SW3
SW5
SW4
SPT 9000

TEST BED CONDITIONS
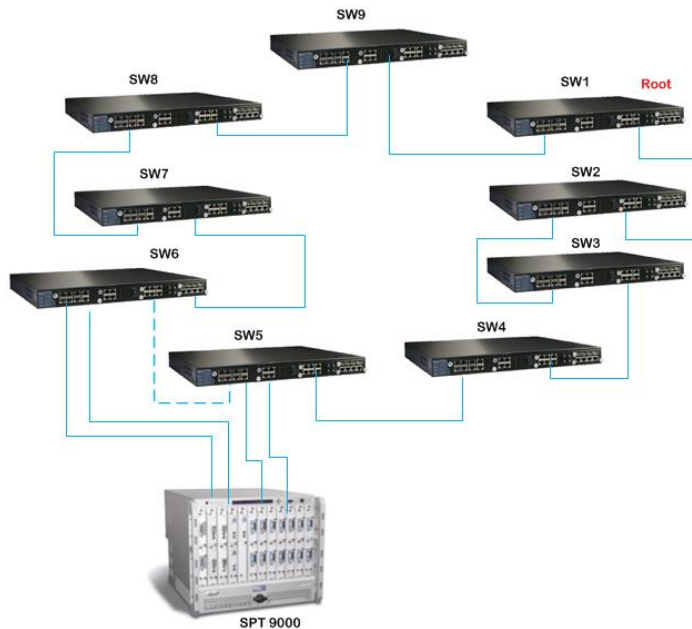
✓ Test with 9 switches on ring topology.

✓ All ports not involved in the ring are in EDGE mode.

✓ All switches have equal cost, except SW 1

✓ Due that RSTP opens the ring between SW5 and SW6

TRAFFIC PROFILE

✓ 2 separate streams of 100 KPS Unicast + 1 KPS Multicast each.

✓ Measurements taken on the Multicast packets

PULLNET
Telecom for energy

CFE

Test Number	Link Recovery ms)	SW1 power shutdown (ms)
1	8.2	9.87
2	5	8.42
3	4.7	10.33
4	5.5	8.19
5	5	11.33
6	5.43	8.08
7	7.51	8.68
8	5.42	11
9	7	10.59
10	6.24	8.04
11	6.07	9.96
12	7	10.23
13	4.33	9.9
14	5.29	11
15	6.2	9.38
16	8	9.32
17	5.14	10.91
18	6	8.48
19	8	10.31
20	6.36	11.17
Average	6.12	9.76

TEST BED CONDITIONS

- ✓ Test with 9 switches on ring topology.
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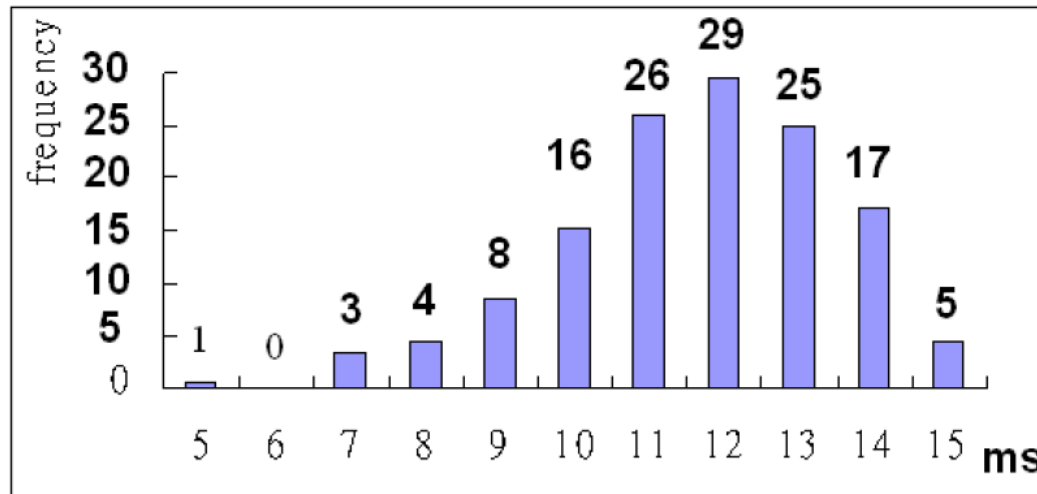
TRAFFIC PROFILE

- ✓ 2 separate streams of 100 KPS Unicast + 1 KPS Multicast each.
- ✓ Measurements taken on the Multicast packets

Test Number	Disconnecting point	Recovery time ms
1	SW1---SW9	8.57
2	SW1---SW2	9.86
3	SW2---SW3	10.47
4	SW3---SW4	9.9
5	SW4---SW5	6.52
6	SW6---SW7	12
7	SW7---SW8	7.58
8	SW8---SW9	8.14
9	SW9---SW1	7.93
10	SW1---SW2	10.86
11	SW2---SW3	10.22
12	SW3---SW4	9.88
13	SW4---SW5	6
14	SW6---SW7	9
15	SW7---SW8	8.39
16	SW8---SW9	11.1
17	SW9---SW1	9.75
18	SW1---SW2	10.37
19	SW2---SW3	10.56
20	SW3---SW4	10.38
Average		9.37

Recover Time

- Average time: 12.0297ms
- Min time: 5.65ms
- Max time: 15.88ms
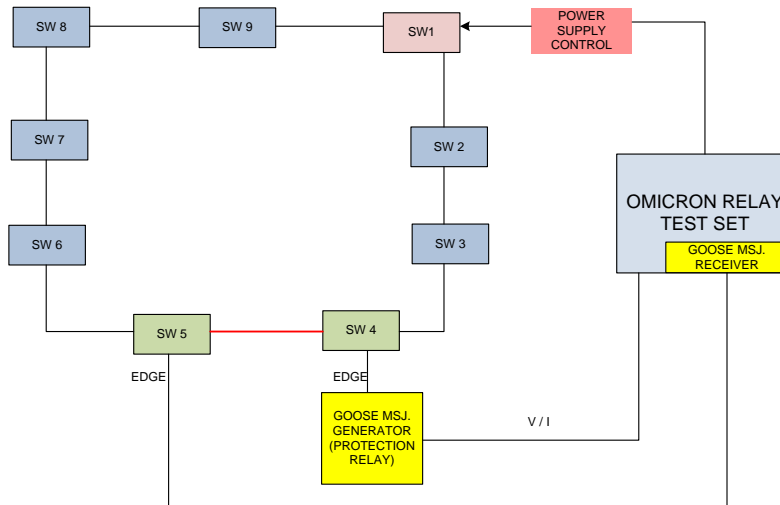
SW 8 — SW 9 — SW1 ← POWER SUPPLY CONTROL

SW 7

SW 6

SW 2

SW 3

OMICRON RELAY TEST SET

GOOSE MSJ. RECEIVER

SW 5 — SW 4

EDGE   EDGE

GOOSE MSJ. GENERATOR (PROTECTION RELAY)

V / I

TEST BED CONDITIONS

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- ✓ Due that RSTP opens the ring between SW5 and SW6

TRAFFIC PROFILE

- ✓ Omicron Tester provokes a relay trip at the same time disconnect the power supply of the root switch.
- ✓ Measurements taken on the GOOSE messages sent by the relay

	Measured Value (ms)	Total Recovery Time (ms)
Average	60.68	38.27
Maximum	64.20	41.79
Minimum	51.70	29.29
Deviation	4.00	4.00

- ✓ Ring topology is de facto the Industry Network Standard.
- ✓ RSTP (802.1D) stills in use with some improvements back compatible
- ✓ Other protocols (IEC62439-#) are only auto compatibles
- ✓ Traffic Engineering and appropriate setting of parameters becomes necessary for efficient networks
- ✓ Use of VLANs improves the efficiency and resilience of the network.
- ✓ Tests carried out shows a suitable recovery time of RSTP based switches
- ✓ Test results shows that recovery time seems independent of the switch position in the ring

QUESTION **?**

Thank you!