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UNROLLING THE LOOP

ELASTIC END-TO-END REDUNDANCY (EE2ER)

#OneStepAhead

UNROLLING THE LOOP

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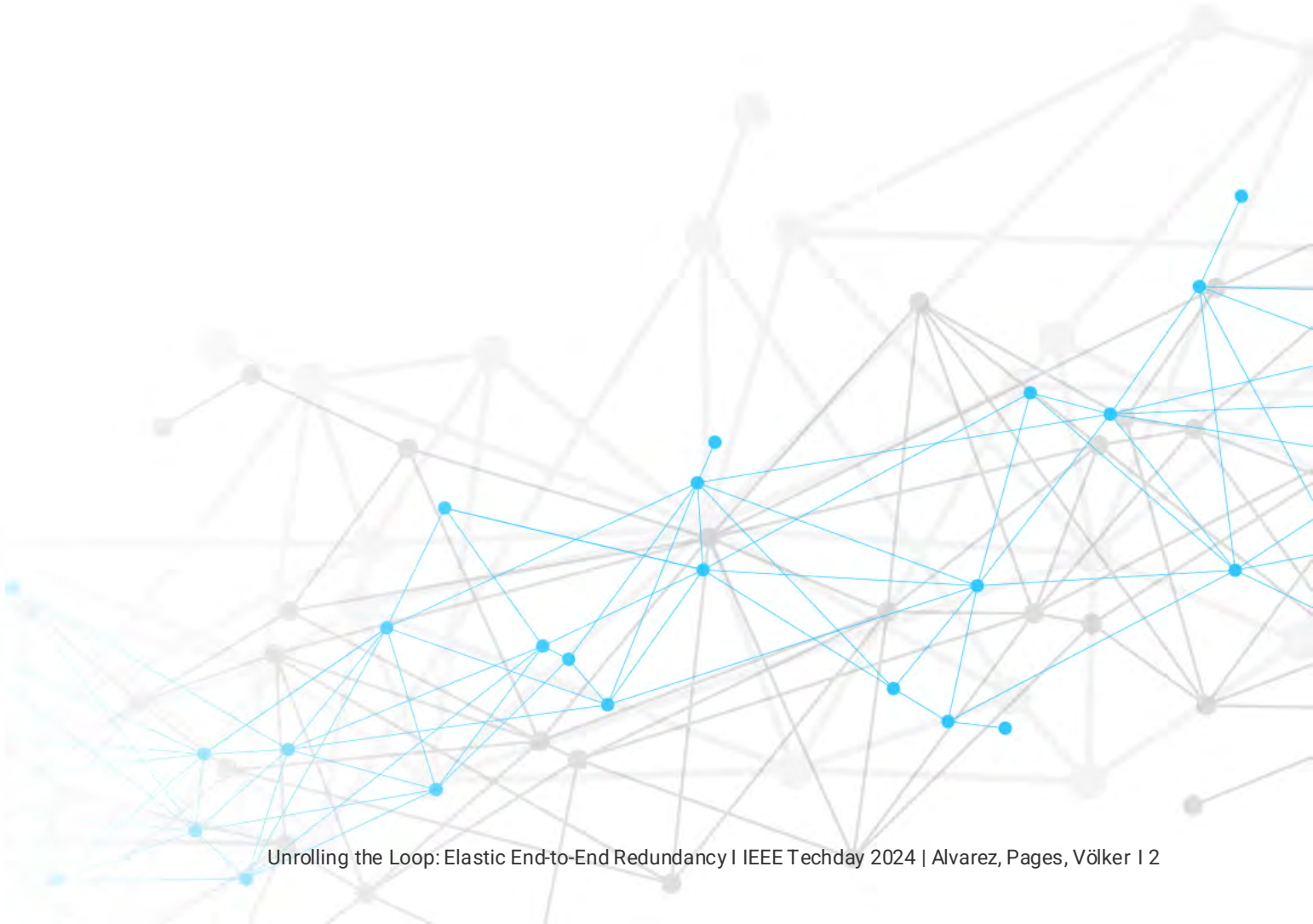

#1 UNROLLING THE LOOP

INTRODUCTION

INTRODUCTION

WHY IS EVERYONE TALKING ABOUT LOOPS?

- Safety Use cases with high availability goals exist:
  - Break-by-wire, steer-by-wire, autonomous driving, etc.
  - A system-level approach for redundancy is taken.
  - Often mixed communication technology.

- Ethernet-based redundancy can have benefits:
  - High bandwidth and lower latency allows more flexibility for SDV.

- Many approaches to redundancy on Ethernet exist already!
  - But do they solve the problem?

INTRODUCTION

WHAT IS THE STATE OF THE ART?

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	Strategy?	Reaction in?	Redundancy?	Detection of degradation?	Single Point of Failure	Cost Add
Spanning Tree Protocol (STP, RSTP, …)	Reactive	s – ms	Limited	Missing	Yes	Low
Ring protocols (e.g., ERPS)	Reactive	ms	Limited	Missing	Yes	Low
FRER (802.1CB)	Proactive	0	Limited	Missing	Yes	Low
Two independent Ethernet networks	Proactive	0	Full	Implicit	No	High

- Can you guarantee a reactive solution in critical scenarios?
- Redundancy needs to be “end-to-end” for cost-effective safety.
- Applications need to know the current state of redundancy.

- Running two Ethernet networks is too expensive!
- Can we create a more cost-effective solution?

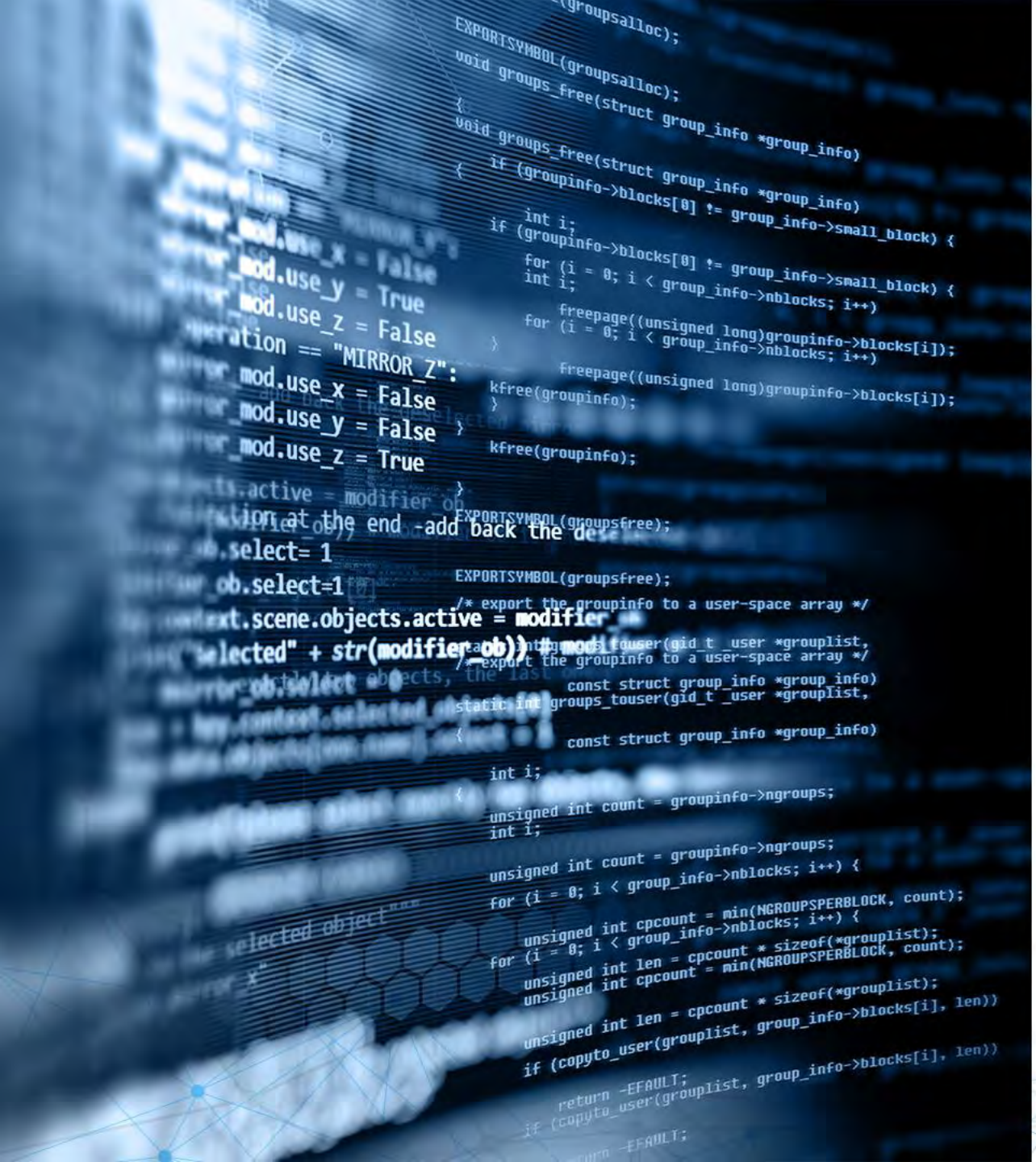
INTRODUCTION

WISH LIST FOR ELASTIC END-TO-END REDUNDANCY (EE2ER)

- What is needed for EE2ER as end-to-end redundancy solution:
  - Scalable: allowing “no single point of failure” in designs, if needed.
  - Proactive redundancy with no reaction time.
  - Monitoring of current state via E2E protection as proven mechanism.
  - Switches and intermediate systems with no ASIL requirements.
  - No changes to today’s semiconductors necessary.
  - Only minimal added cost.

- Ethernet ring between HPCs and Zonals?

- Can we achieve this?



#2 UNROLLING THE LOOP

SOLUTION

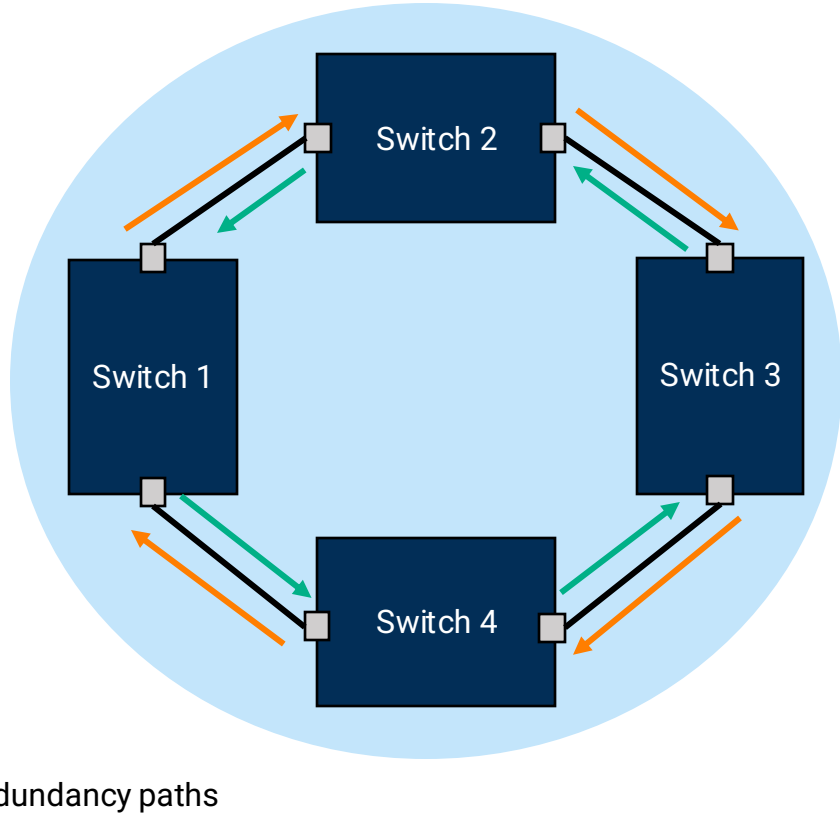
SOLUTION

BASIC APPROACH.

- Ring with traffic in both directions.

- Applications send data redundant and monitor all streams via E2E protection:
  - No reaction time.
  - No reaction mechanisms that can fail.
  - Proven mechanism for safety.
  - Minimal ASIL requirements (=cost) for switches.

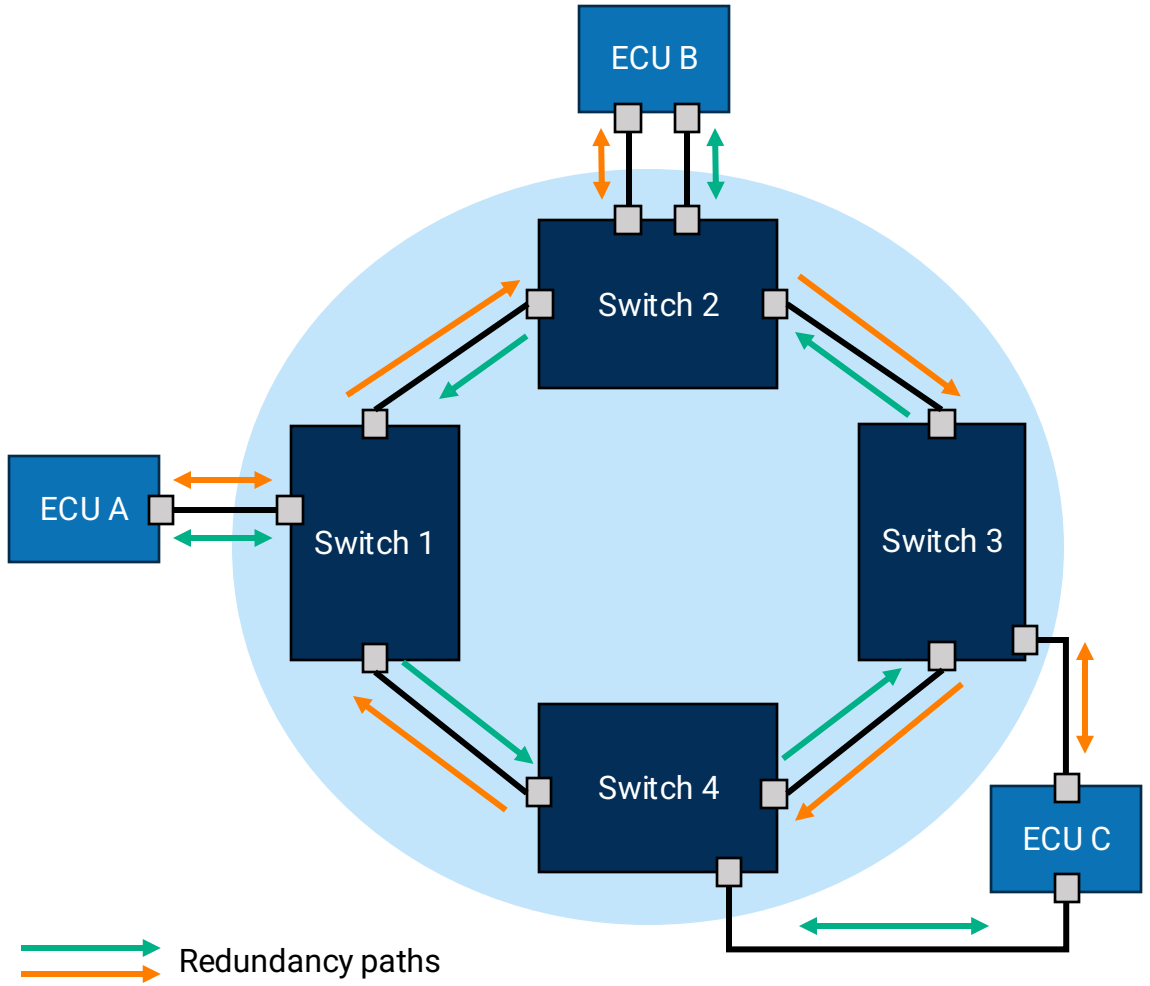
- Assumed traffic:
  - Multicast Signal-PDUs (CAN-like).
  - Multicast SOME/IP-based.
  - Only a few messages need redundancy.



SOLUTION

WHY A RING?

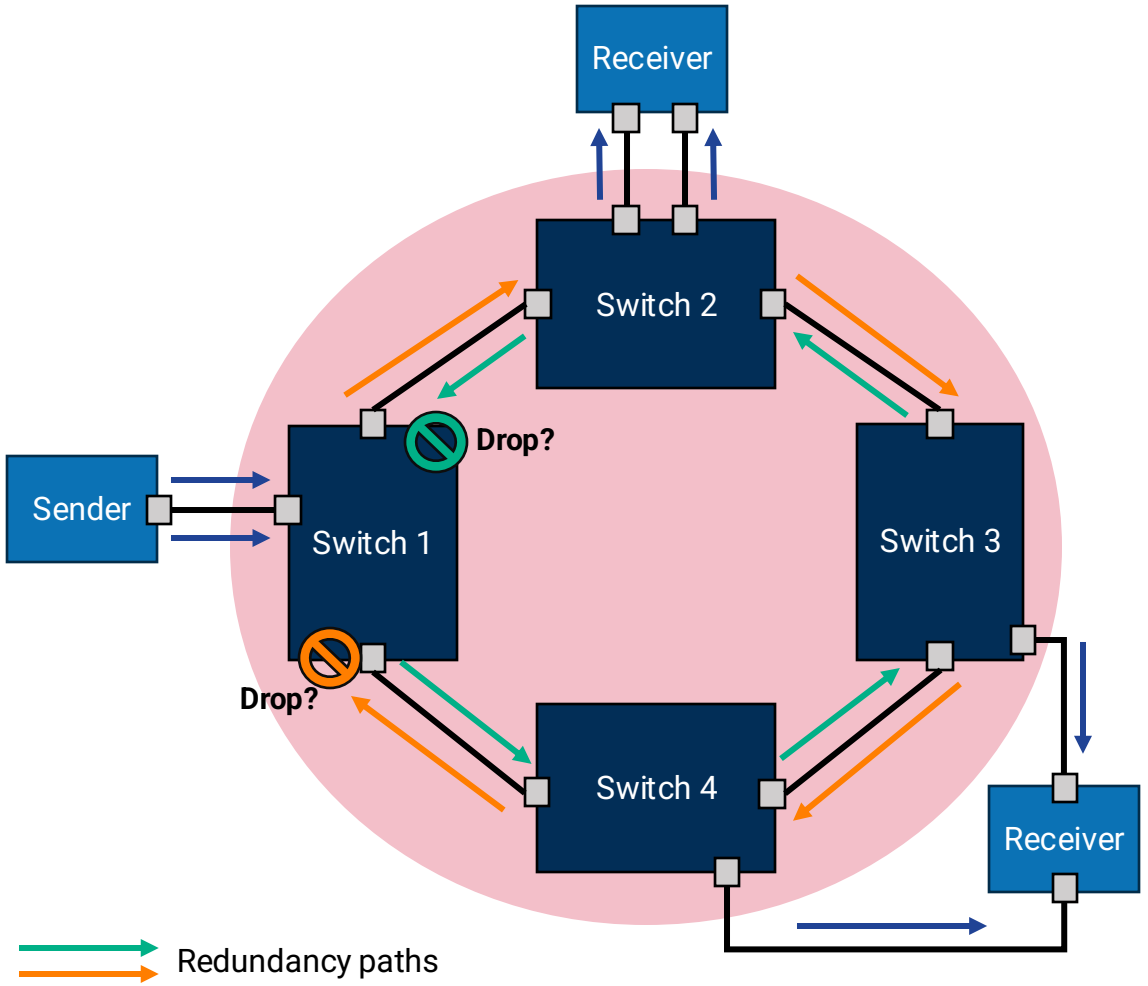
- A ring can avoid single point of failure.
- Different redundancy levels possible:
  - ECU A: attached to single Ring Switch.
  - ECU B: attached to single Ring Switch twice.
  - ECU C: attached to two Ring Switches.
- We can add regular traffic as today
  - Single direction on ring.
- Cost-effective design possible!



SOLUTION

ETHERNET VS. THE LOOP!

- We just created a loop!
- How to avoid the loop?
  - Just drop frames before they loop.
- Possible options:
  - Drop by source MAC Address.
  - VLAN-ID-based Hop Counter.
  - Drop by VLAN ID on specific input port.

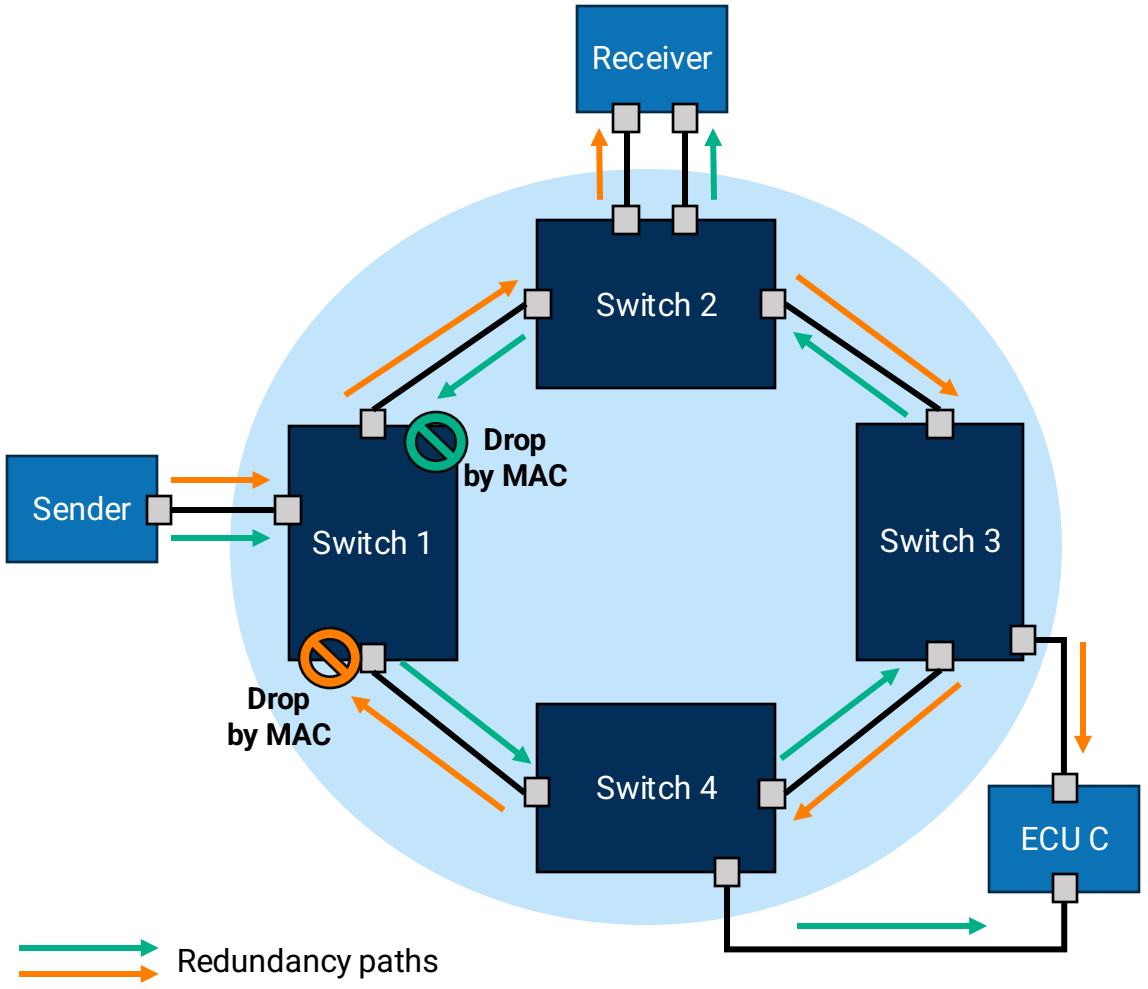


Redundancy paths and loop breakpoints only shown for the assigned sender/receiver roles.

SOLUTION

APPROACH 1: DROP BY SOURCE MAC ADDRESS.

- Approach:
  - Flood Multicast in two VLANs.
  - Drop frames via Source MAC to cut loop.
- Pros:
  - Simple configuration.
- Cons:
  - MAC addresses need to be known a-prior.
  - Large number of filtering rules.
  - Different configuration for every switch.
  - Topology change requires config change.
- A Hop Counter could solve this!?

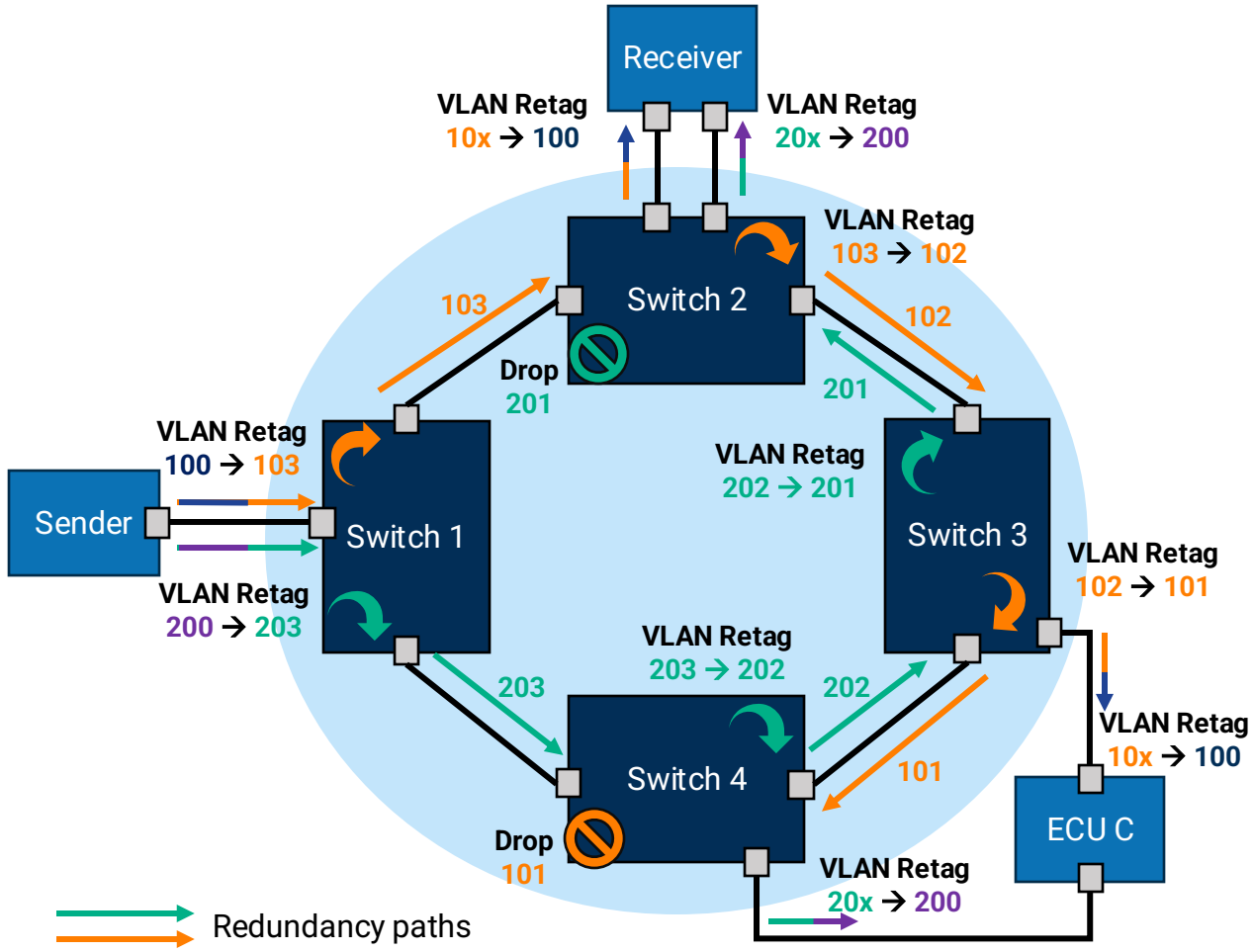


Redundancy paths and loop breakpoints only shown for the assigned sender/receiver roles.

SOLUTION

APPROACH 2: VLAN-ID-BASED HOP COUNTER.

- Approach
  - Send with starting hop counter.
  - VLAN-ID is decremented at every hop
  - Drop, when Hop Counter would go to “0”.
- Pros
  - Fixed number of VLAN-IDs.
  - Sender MAC Addresses do not matter.
- Cons
  - Config depends on number of switches!
- Can we further improve this?

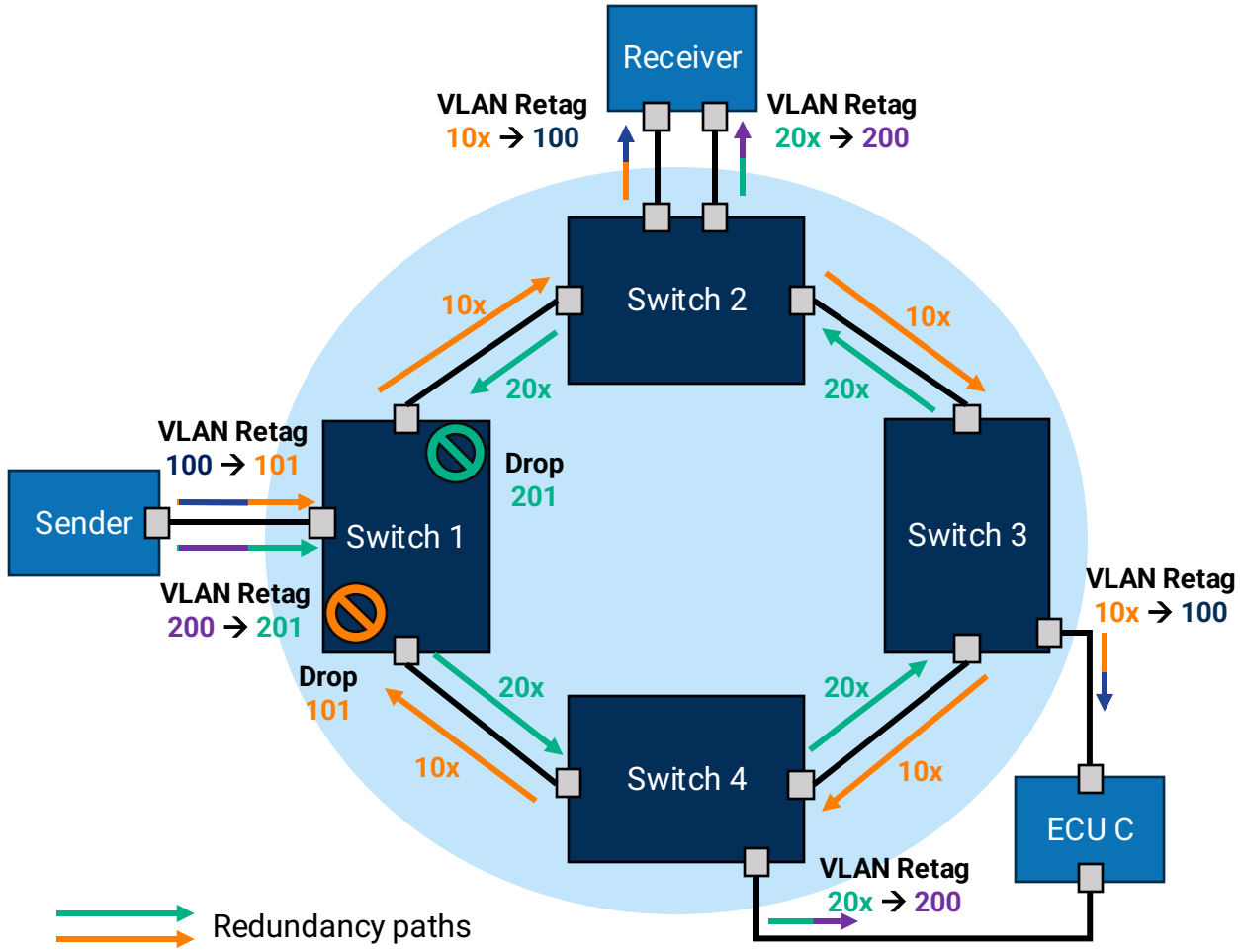


Redundancy paths and loop breakpoints only shown for the assigned sender/receiver roles.
VLAN retagging performed always on switch egress as specified in OA TC11.

SOLUTION

APPROACH 3: ENCODE INPUT PORT IN VLAN ID.

- Approach
  - Virtual rings per source switch.
  - Define VLAN ranges per direction: 10x, 20x
  - Unique VLAN-ID per entrance into ring.
  - Switch drops its VLAN-ID, when receiving.
- Pros
  - Ring size can be scaled afterwards!
  - VLAN retagging only at enter/exit of ring.
- Cons
  - Different config per switch.



Redundancy paths and loop breakpoints only shown for the assigned sender/receiver roles.
VLAN retagging performed always on switch egress as specified in OA TC11.

SOLUTION

CONCLUSION – SO FAR …

- A redundant ring with today's hardware seems possible.

- We choose Approach 3 for EE2ER:
  - Allows us to build a redundancy ring.
  - Supports vehicle variant management (most flexible).
  - Best approach found.

- Two main questions remain:
  - Does this work on real hardware?
  - Can we reduce the added configuration complexity?

#3 UNROLLING THE LOOP

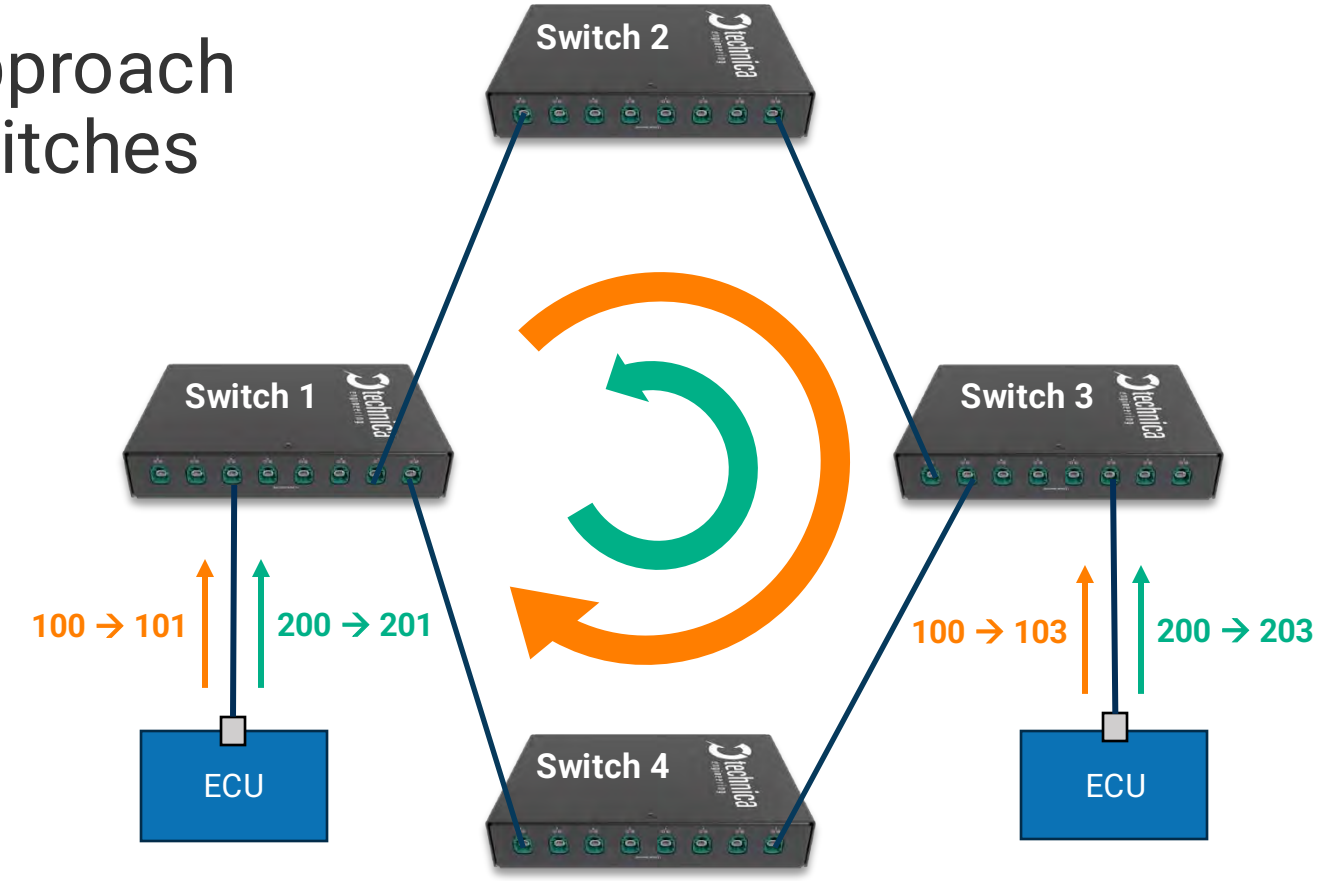
IMPLEMENTATION

IMPLEMENTATION

OVERVIEW

We have implemented our approach with standard automotive switches

- No new hardware necessary!



IMPLEMENTATION

CUTTING THE LOOP BY DROPPING VLAN – EXAMPLE ON SWITCH 1

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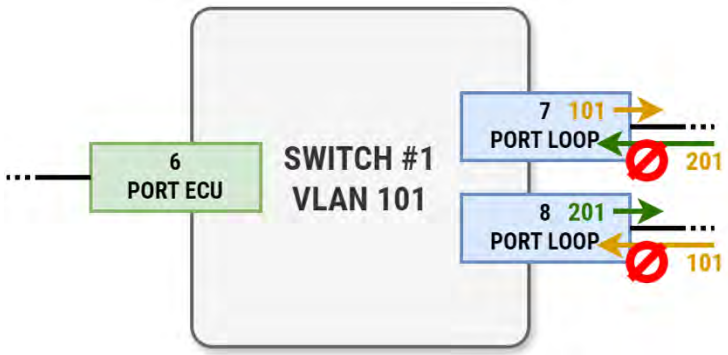
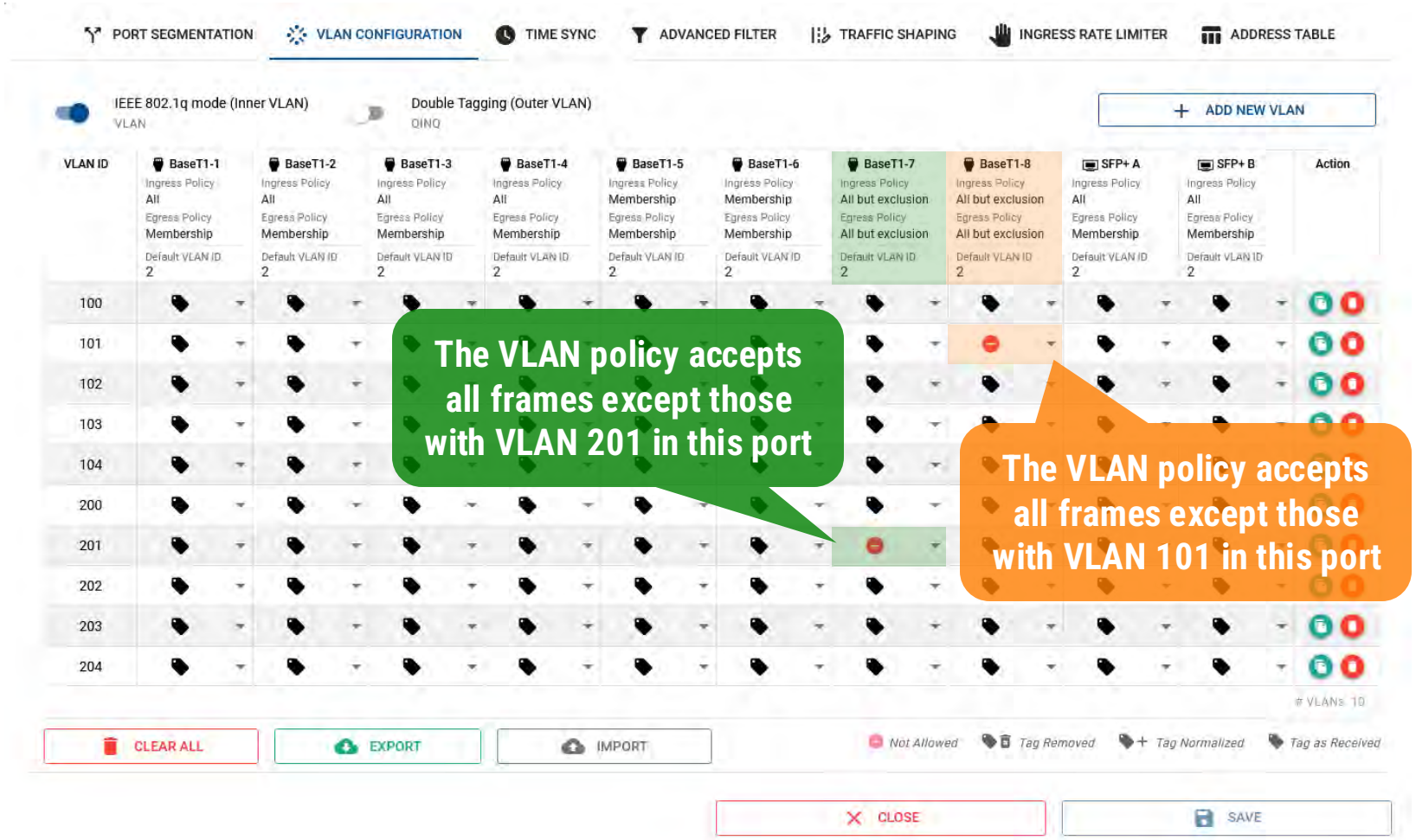
VLAN cuts the loop

- Drop is done via regular VLAN membership





IMPLEMENTATION

VLAN RETAGGING AT RING ENTRANCE – EXAMPLE ON SWITCH 1

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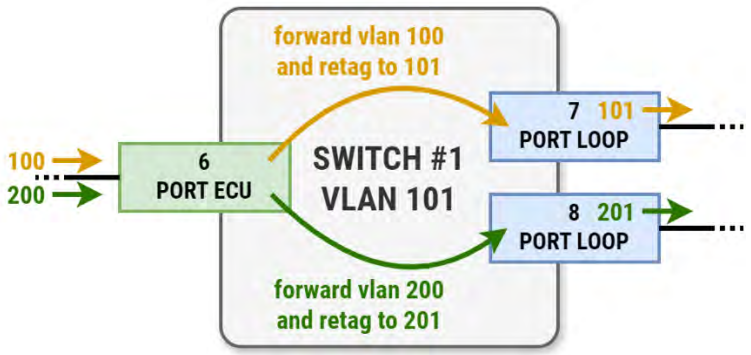
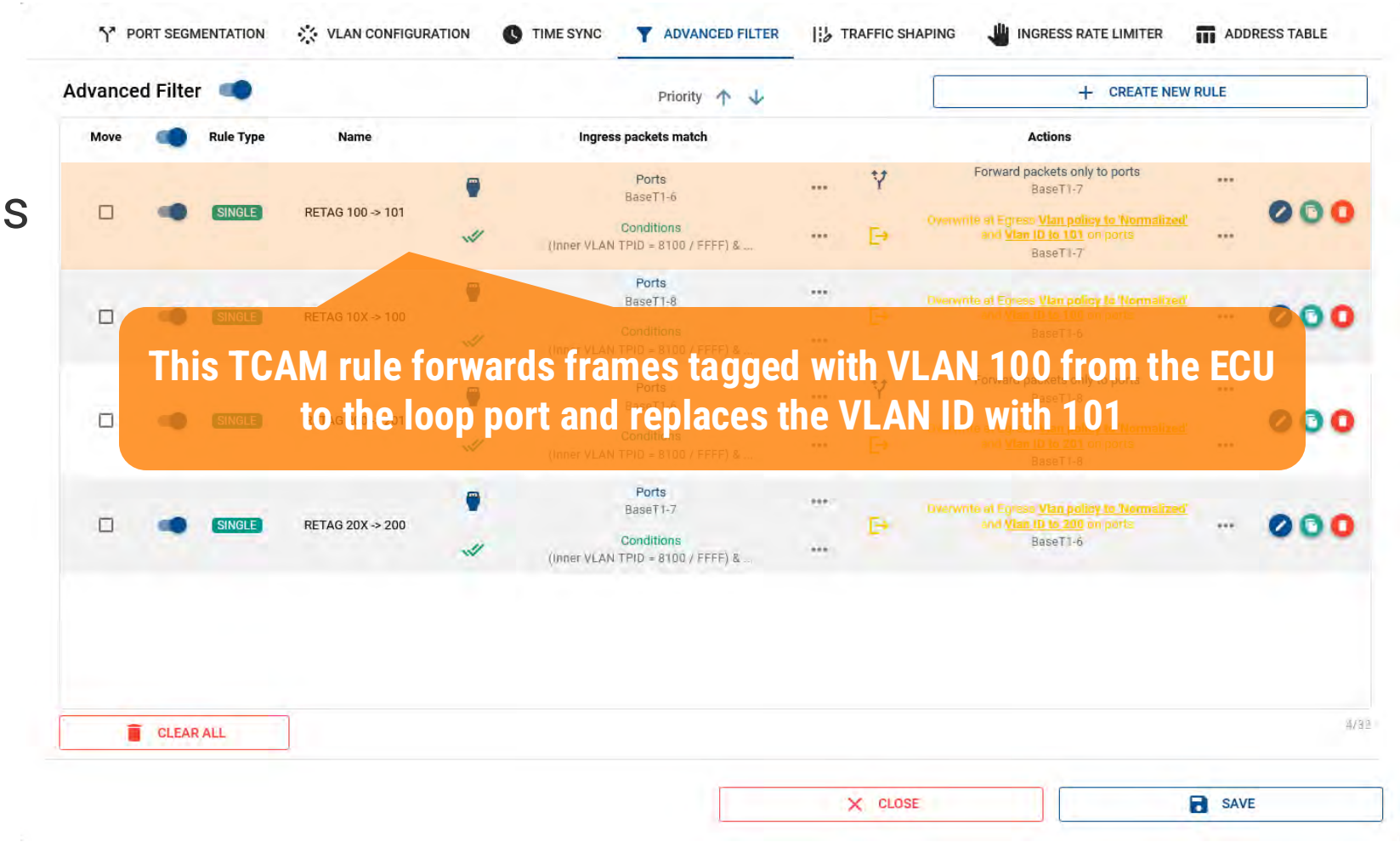
Entering the ring

- The TCAM module retags the VLAN from 0x100 to 0x101 at egress





This TCAM rule forwards frames tagged with VLAN 100 from the ECU to the loop port and replaces the VLAN ID with 101

IMPLEMENTATION

VLAN RETAGGING AT RING EGRESS – EXAMPLE ON SWITCH 1

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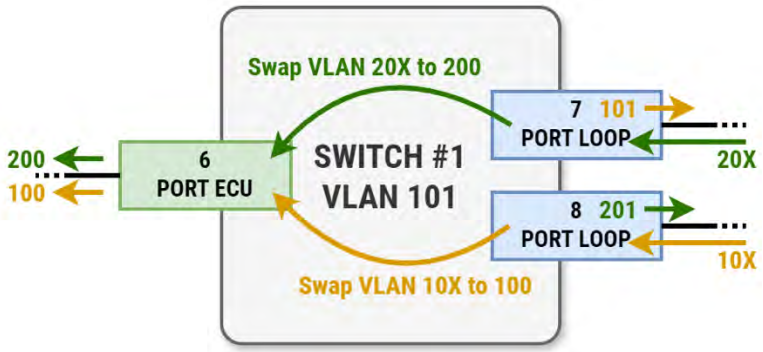
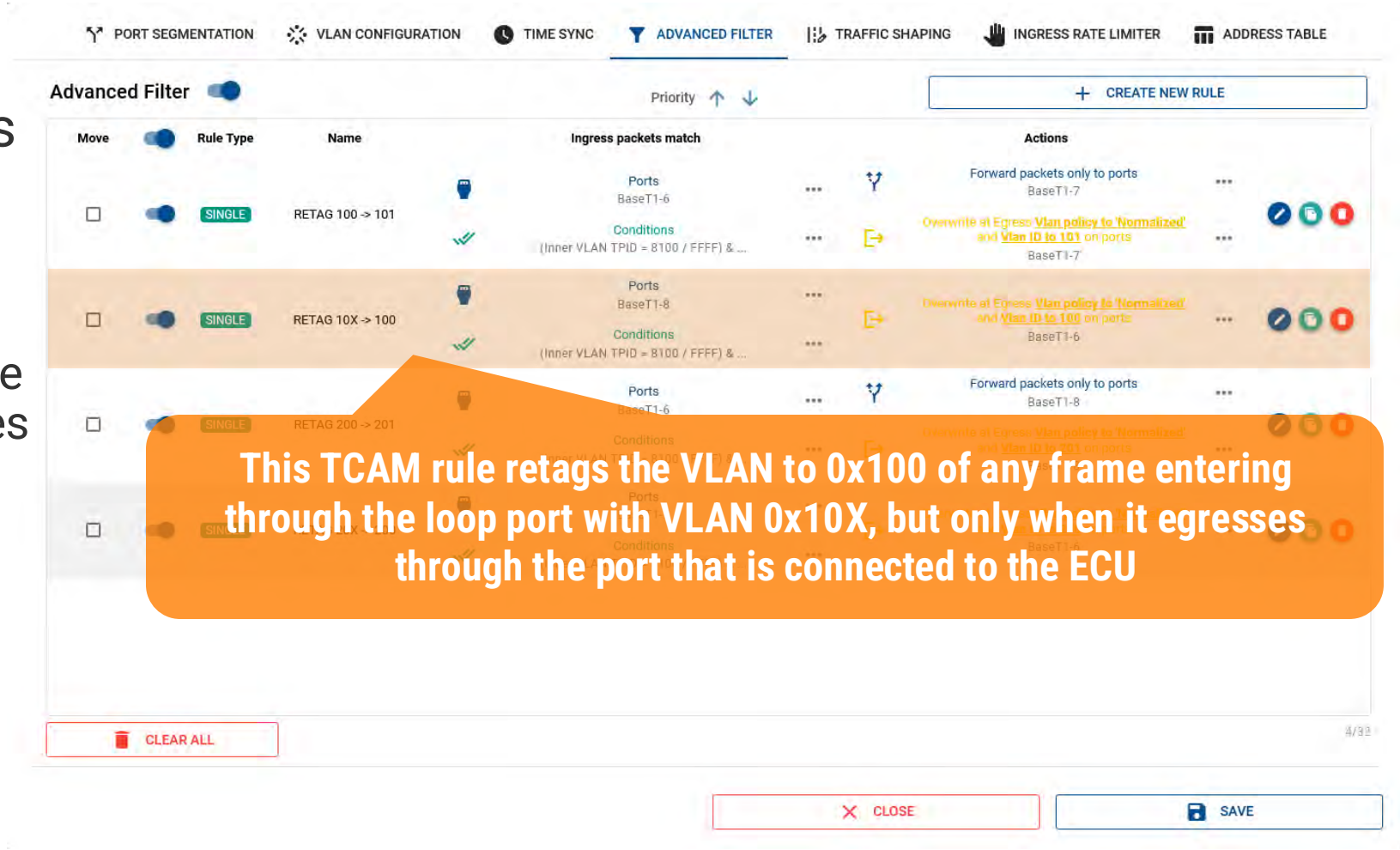
Leaving the ring

- The TCAM module retags VLANs from 0x10X to 0x101 at egress
  - This is done via a mask
  - In real vehicles you would use binary and not decimal ranges





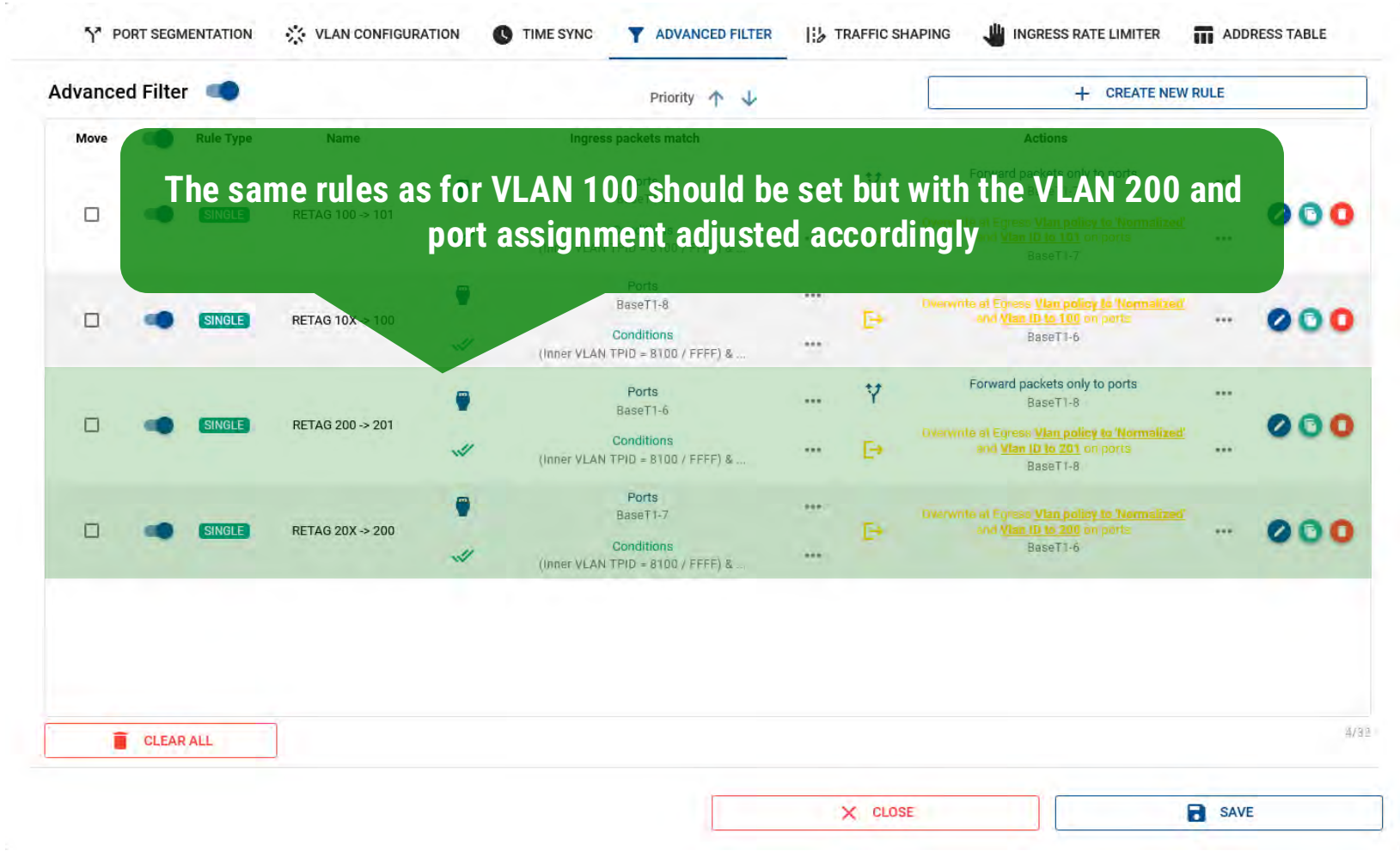
This TCAM rule retags the VLAN to 0x100 of any frame entering through the loop port with VLAN 0x10X, but only when it egresses through the port that is connected to the ECU

IMPLEMENTATION

ADDING THE OTHER DIRECTION TOO – EXAMPLE ON SWITCH 1

Two more rules to control the other direction of the loop

And yes, it works…



IMPLEMENTATION

VISIT OUR BOOTH TO EXPERIENCE EE2ER IN ACTION

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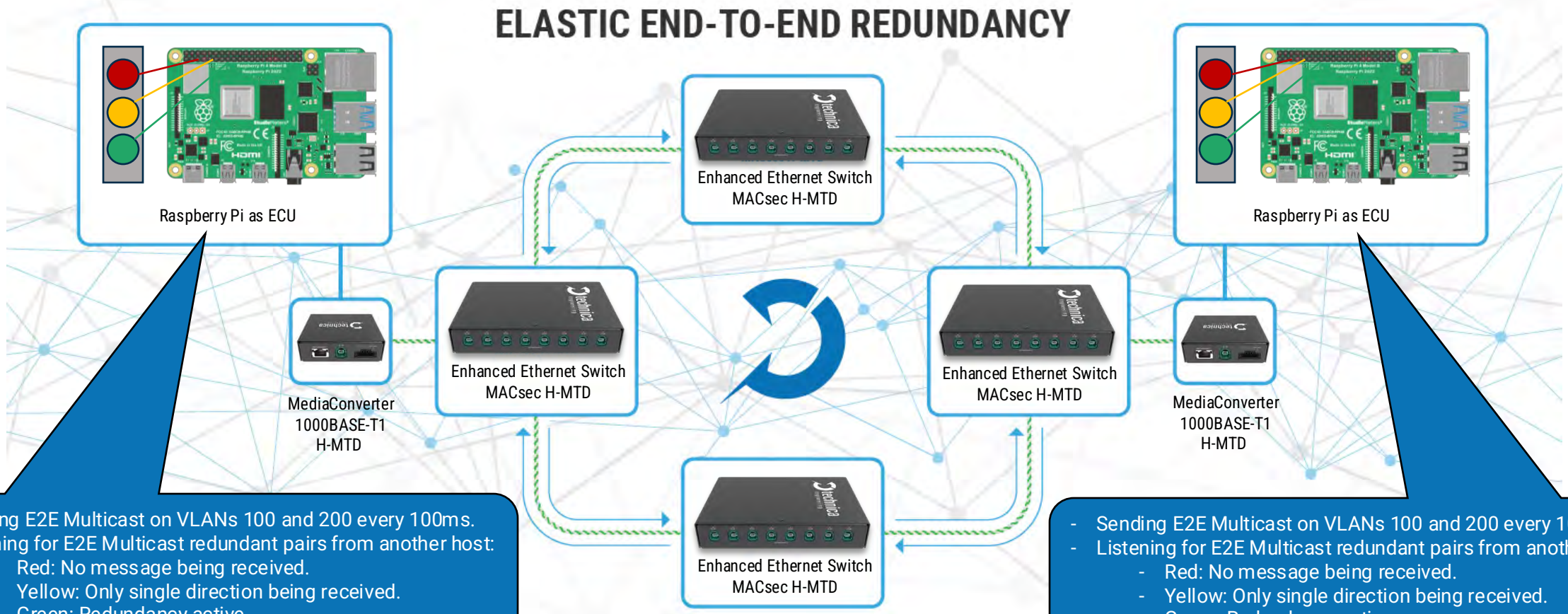

- Sending E2E Multicast on VLANs 100 and 200 every 100ms.
- Listening for E2E Multicast redundant pairs from another host:
  - Red: No message being received.
  - Yellow: Only single direction being received.
  - Green: Redundancy active.

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#4 UNROLLING THE LOOP

SUMMARY / NEXT STEPS

CONCLUSION AND NEXT STEPS

SUMMARY

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	Strategy?	Reaction in?	Redundancy?	Detection of degradation?	Single Point of Failure	Cost Add
Spanning Tree Protocol (STP, RSTP, …)	Reactive	s – ms	Limited	Missing	Yes	Low
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FRER (802.1CB)	Proactive	0	Limited	Missing	Yes	Low
Two independent Ethernet networks	Proactive	0	Full	Implicit	No	High
Elastic E2E Redundancy (EE2ER)	**Proactive**	**0**	**Full**	**Via E2E**	**No**	**Low**

- EE2ER fulfils the wish list and solves the problems of alternatives.
  - Combining the full end-to-end redundancy with minimum cost.
  - Runs on today's hardware.

- What about configuration complexity?

CONCLUSION AND NEXT STEPS

NEXT STEPS

- Configuration Toolchain needs to support EE2ER for ease of use:

	Open Source?	Topology model?	Automotive?	SDV compatible?	EE2ER?
ARXML	Not allowed?	Incomplete	Yes	No	TBD
FIBEX	Possible	Incomplete	Yes	No	Unlikely
YANG/NETCONF	Yes	Incomplete	No	Unclear	Unlikely
Goal for toolchain	***Yes***	***Yes***	***Yes***	***Yes***	***Yes***

- Upcoming Automotive Switch Configuration Toolchain
  - Open Source and SDV compatible
  - With EE2ER support

- See the EE2ER demo at our booth and start the conversation!

Technica Engineering GmbH

Leopoldstraße 236
80807 Munich
Germany

IAGO ÁLVAREZ
Lead Engineer
iago.alvarez@technica-engineering.de

ROMÀ PAGÈS
Senior Software and Hardware Engineer
roma.pages@technica-engineering.de

DR. LARS VÖLKER
Technical Fellow
lars.voelker@technica-engineering.de

