Seamless Redundancy Concept Refinement: Duplicate Elimination

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Objectives of this Presentation

- Seamless Redundancy concept was presented in San Diego:

  http://www.ieee802.org/1/files/public/docs2012/new-avb-kleineberg-jochim-seamless-redundancy-0712

- Joint effort (Industrial Control and Automotive)

- Concept was then discussed in Santa Cruz.
  - Some open questions have been identified.
  - The group recommended to further refine the concept.

- **Intention of this presentation is to do exactly that!**

Open Questions Addressed in this Presentation

- **Where do we generate and eliminate duplicates?**
  In bridges and in end stations.

- **How do we identify duplicates?**
  Based on tagged frames.

- **What is the duplicate elimination mechanism?**
  We will present a proposal that is based on a
  Duplicate Drop Database.

Structure of this Presentation

1. **Brief Recap of the Seamless Redundancy Concept**

2. **Topologies for Redundancy @ Industry & Automotive**

3. **Mechanism for Seamless Redundancy (based on each other):**
   a) Generation and elimination of duplicates in End Stations
   c) Generation and elimination of duplicates in Bridges

4. **Concept refinements:**
   a) Mechanism for duplicate elimination
   **b) Proposed extension of the frame format**

Duplication of frame & Redundant paths
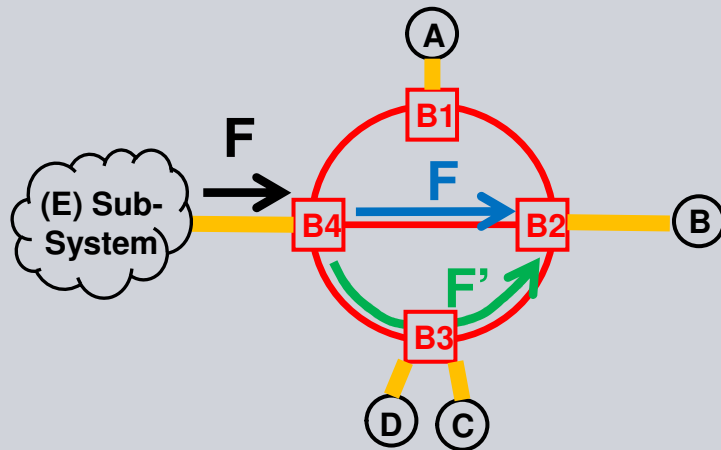
Red = 2-connected part of the network
Orange = disconnecting links

➤ Each bridge knows (by configuration or by protocol), which port is connected to a disconnecting link.

➤ Within the 2-connected core of the network, each bridge "knows" two independent paths to each other bridge.

➤ Only mission critical frames that enter a bridge via a disconnecting port will be duplicated and redundantly forwarded on two independent paths.

➤ Selection of independent paths:
  ▪ Required, but not part our work on a Seamless Redundancy Concept.
  ▪ The problem is addressed by the Internetworking Group

Elimination of Duplicates
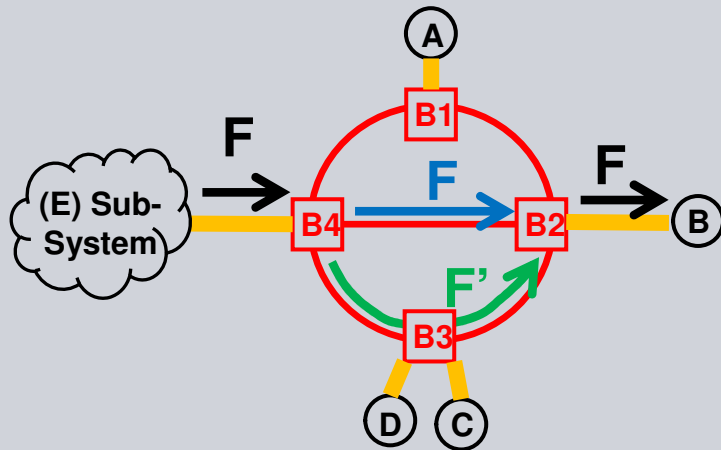
➢ Bridge B2 "knows":

    1) that the link to B is a Disconnecting Link **AND**

    2) that F and F' are mission critical frames.

➢ Therefore B2 will eliminate the duplicates and forward a single copy to B.

➢ B2 can forward the first copy (F or F') that arrives.

➢ B2 does <u>not</u> need to store the first copy that arrives until the other copy arrives!

➢ B2 just remembers:
"I have seen 1 of the 2 frames already!
If I ever see the other one, I will throw it away!"

➢ How long will B2 need to remember this?

➢ Answer: For Δt = "Max. duration of transmission of F' from B4 to B2"   minus
            "Min. transmission duration of F from B4 to B2"

Seamless Redundancy for Reserved and Scheduled Traffic only!

➤ We do <u>not require</u> Seamless Redundancy support for:

– Best Effort Traffic (Strict Priority Scheduling)

➤ We propose to provide Seamless Redundancy support for the following traffic classes:

– Reserved Traffic   (Credit based Shaper)

– Scheduled Traffic

➤ Of course it is NOT REQUIRED to send all reserved traffic or all scheduled traffic redundantly, but it is POSSIBLE.

➤ Seamless redundancy can be used for streams that we classify to be mission critical !

Seamless Redundancy for Reserved and Scheduled Traffic only!

For the rest of the presentation, keep in mind, that whenever we talk about "frames" or "streams" we will <u>exclusively</u> refer to those

- ➢ reserved traffic streams   or

- ➢ scheduled traffic streams

which have been classified to be mission critical and for which the seamless redundancy concept shall be applied.

Generation & Elimination of Duplicates

- ➢ So far this was just a brief summary of the concept that was presented in San Diego.

- ➢ Note that <u>so far, we exclusively talked about:</u>

    - ➢ Generation of duplicates in bridges

    - ➢ Elimination of duplicates in bridges

   **Within this presentation we will extend the concept to also allow generation and elimination in end stations !**

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   b) Proposed extension of the frame format

Multiple industrial and automotive use cases have been shown in previous presentations
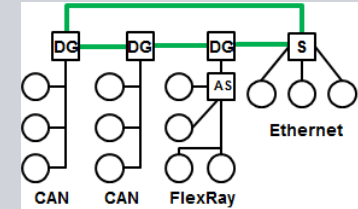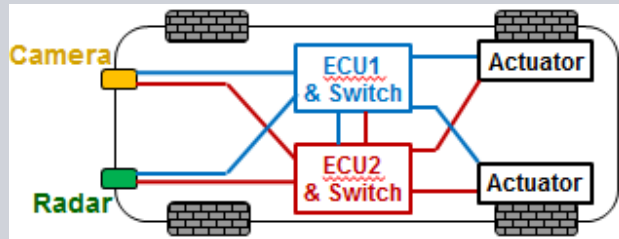
Earth fault introduced
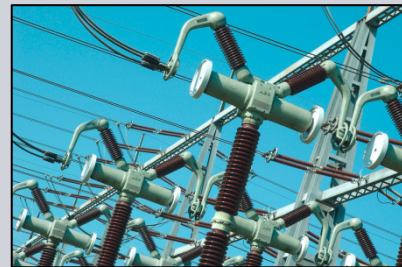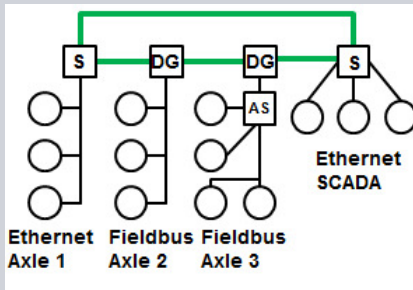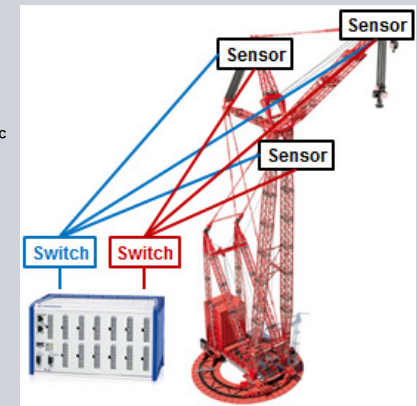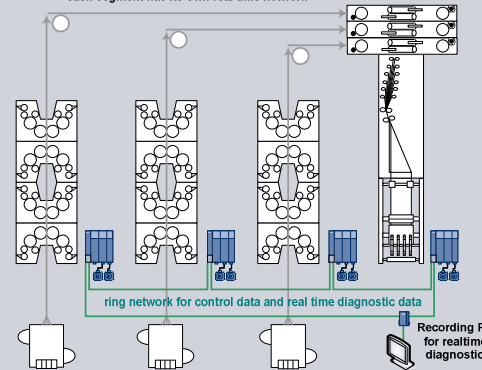
Redundant Topologies @ Industry

Ring & Coupled Rings:

• Industrial Automation

• Energy Automation

• Rail Systems

• …

Ring

Coupled Rings

Backbone Segment

Sub-Segment 2   …..   Sub-Segment n

Coupled Rings

Network Segment 1

Network Segment 2

IEEE 802.1 Meeting – San Antonio
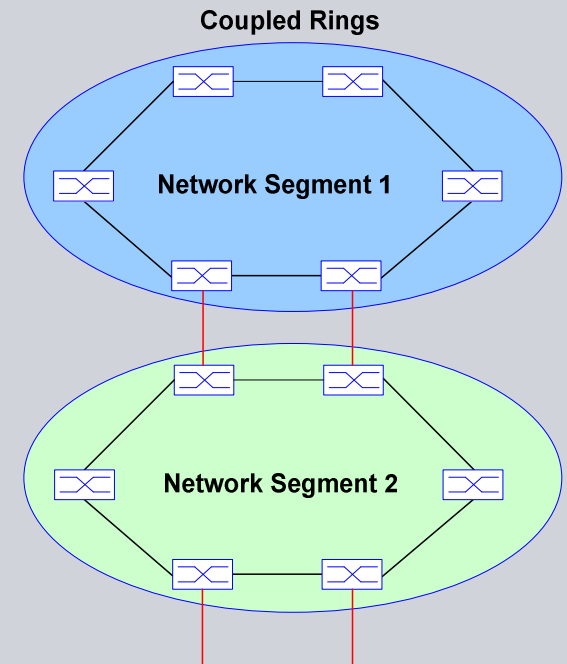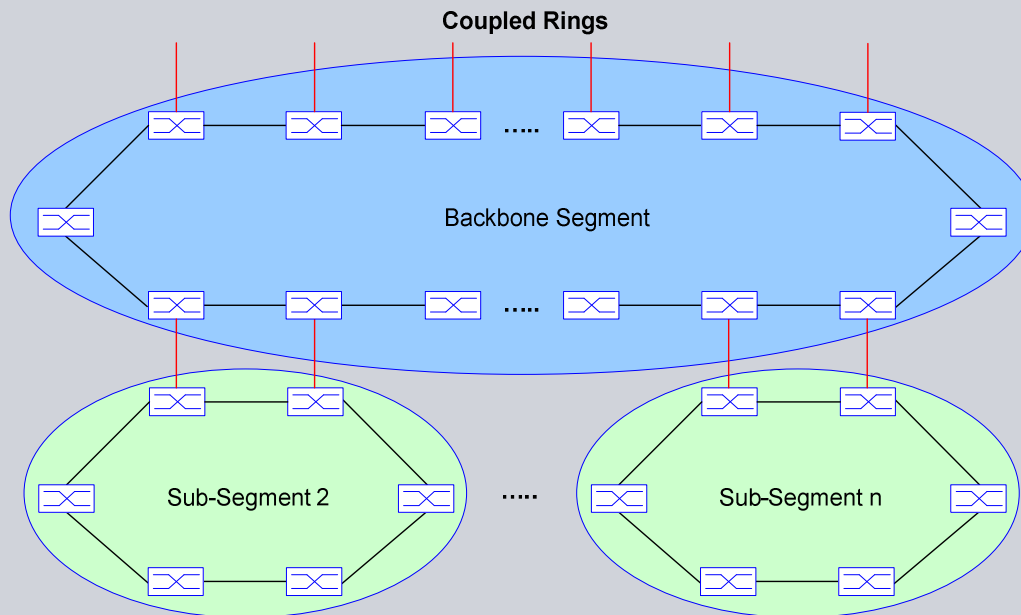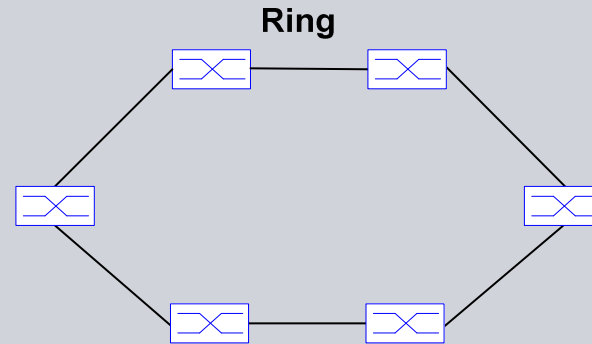
Redundant Topologies @ Industry

Parallel Networks:

- Industrial Automation
- Energy Automation
- ...

Parallel Network

Parallel Network / Dual Homing

Double Ring

Ring 1

Ring 2
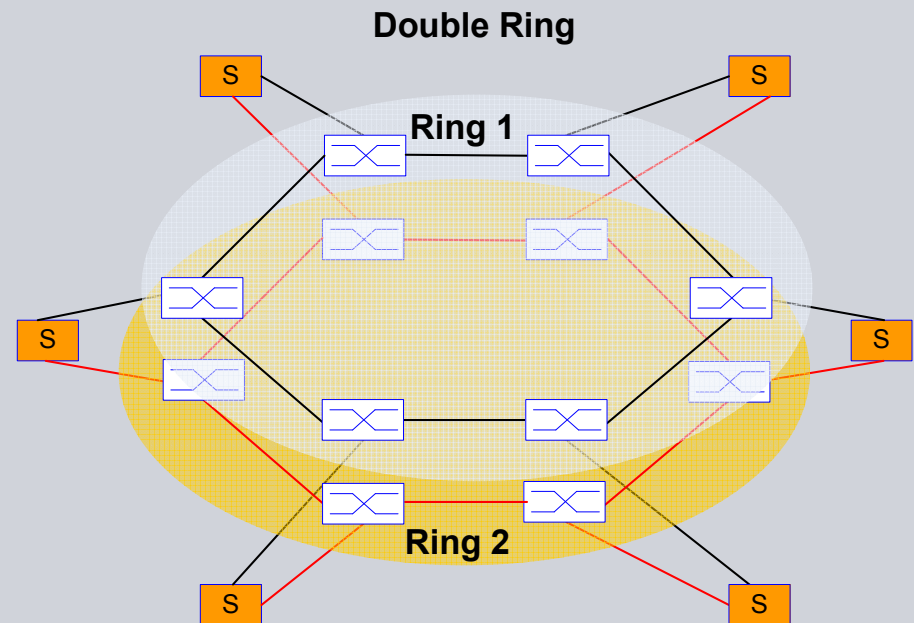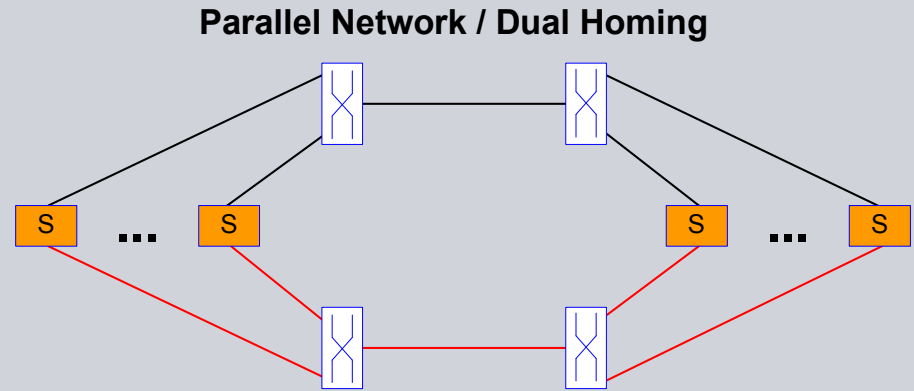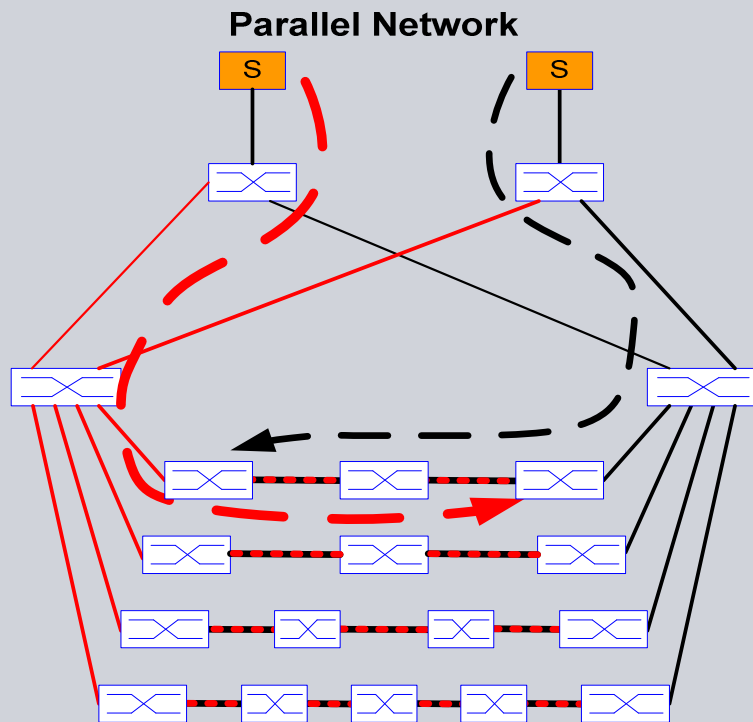
Redundant Topologies @ Automotive

Ring Structures for robust backbones

CAN   CAN   FlexRay
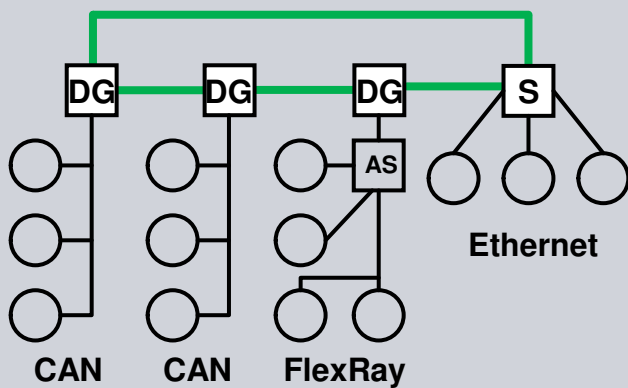
Parallel Networks for safety critical control applications

Camera

Radar

ECU1 & Switch

ECU2 & Switch

Actuator

Actuator

send   m   receive

m'

or

μC

node
(μC connected to 2 independent ports)

2 independent channels
(Dual homing)
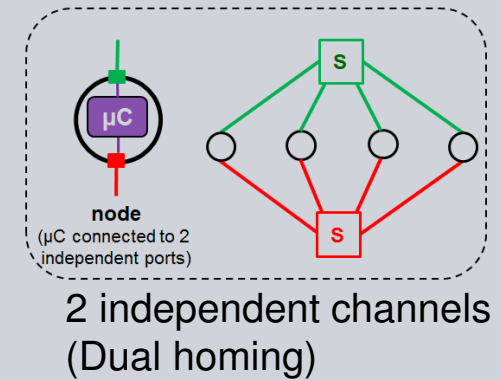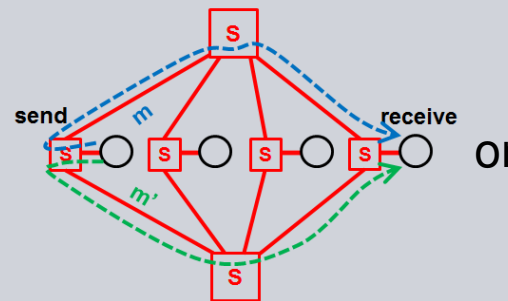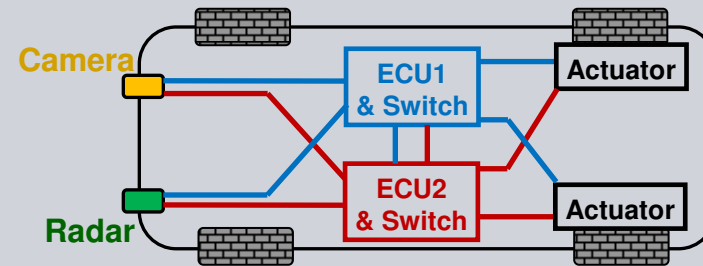
Conclusions:
➢Similar topologies in automotive and industry
➢Typically larger number of nodes in industry.

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   c) Generation and elimination of duplicates in Bridges

4. **Concept refinements:**
   a) **Mechanism for duplicate elimination**
   b) **Proposed extension of the frame format**

How do we implement this?

➢ The communication path for Reserved- or Scheduled-Traffic is given by e.g. ISIS-SPB-PCR

➢ Duplicate elimination requires the ability to identify redundant frames or "frame pairs" (F, F').

The table gives a high level overview about the information we propose to use for the purpose of identifying frame pairs:

Information	Purpose
VLAN ID	• F and F' are transmitted on independent paths on different VLANs. • VLAN ID's are used to mark redundant path (Path A, Path B, …)
MAC Address	• If F and F' have the same MAC Address, they belong to the same stream. • A stream MAC address (destination) is unique for VLAN ID's used to mark the redundant path (A, B, …).
Sequence Number	• A Sequence Number in the frame will enable to identify individual frames within a stream. • We are always looking for two frames with the same MAC Address and the same Sequence number that are transmitted on different VLANs. (This is our assumption, that we need to discuss with the Internetworking Group, since this group is working on multiple paths.)

Generation of duplicates in End Station (Talker T)

For Reserved- or Scheduled Streams
which shall be transmitted over multiple
path End Stations we need to add:

1. **VLAN ID for path A or path B and**

2. **Stream specific Sequence Number**
(Redundant streams have identical
Sequence Number for path A and path B)

T talker – single homing

Path A
Path B
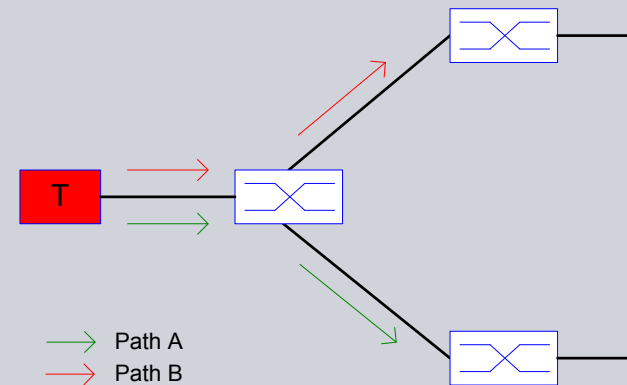
T talker – dual/multiple homing
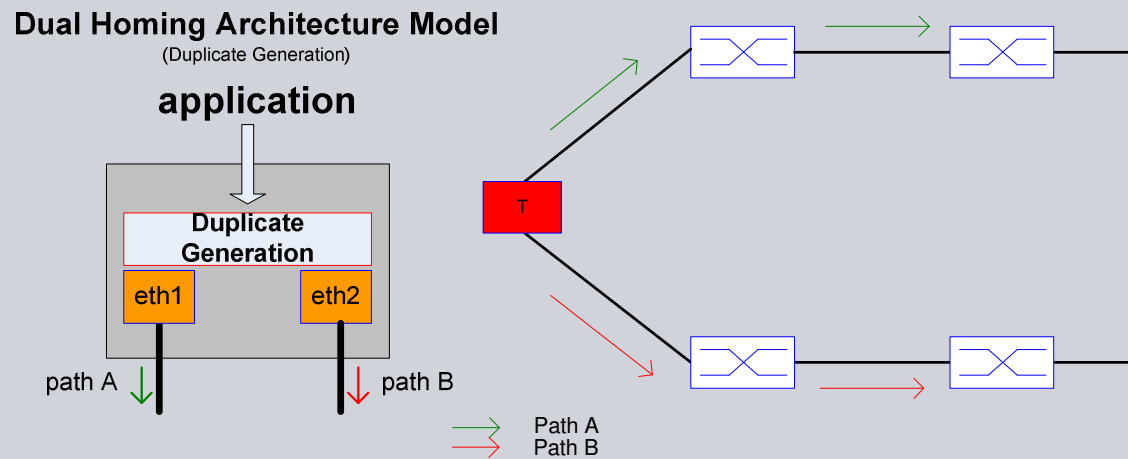
Dual Homing Architecture Model
(Duplicate Generation)

application

Duplicate
Generation

eth1   eth2

path A   path B

Path A
Path B
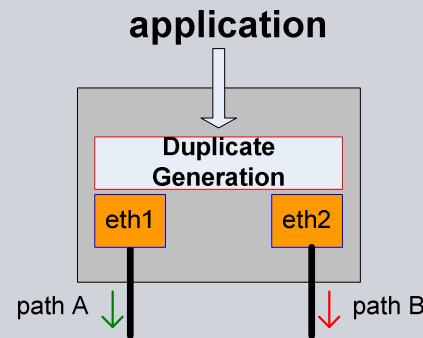
Elimination of duplicates in End Station (Listener L)

L listener – single homing

Duplicate Elimination is based on:

- **MAC address of Reserved- or Scheduled Streams**
- **and Sequence Number**

Locations for duplicate elimination in end stations:

Single Homing:

- **Network Interface**
- **Network Device Driver**

Path A
Path B
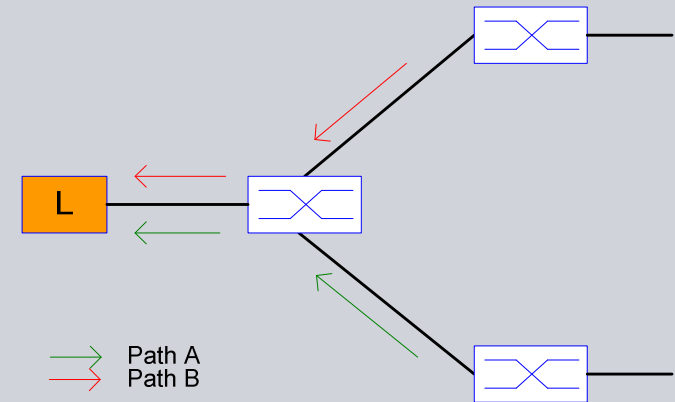
L listener – dual/multiple homing

Dual Homing Architecture Model
(Duplicate Elimination)

Single & Multiple Homing:

- **Application**
- **Duplicate Elimination Module**

application

Duplicate Elimination

eth1   eth2

path A   ↑ path B

Path A
Path B
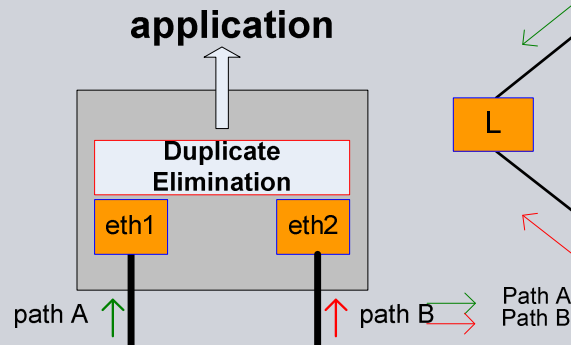
Two Examples for Duplicate Generation and Elimination in End Stations

- Reserved- or Scheduled Streams are transmitted over given redundant path (one common stream for multiple listener)

- Each listener L receives Reserved- or Scheduled Streams twice

Coupled Rings
Talker (T) with multiple listener (L)

Ring – Talker (T) with multiple listener (L)

Path A
Path B

Path A
Path B
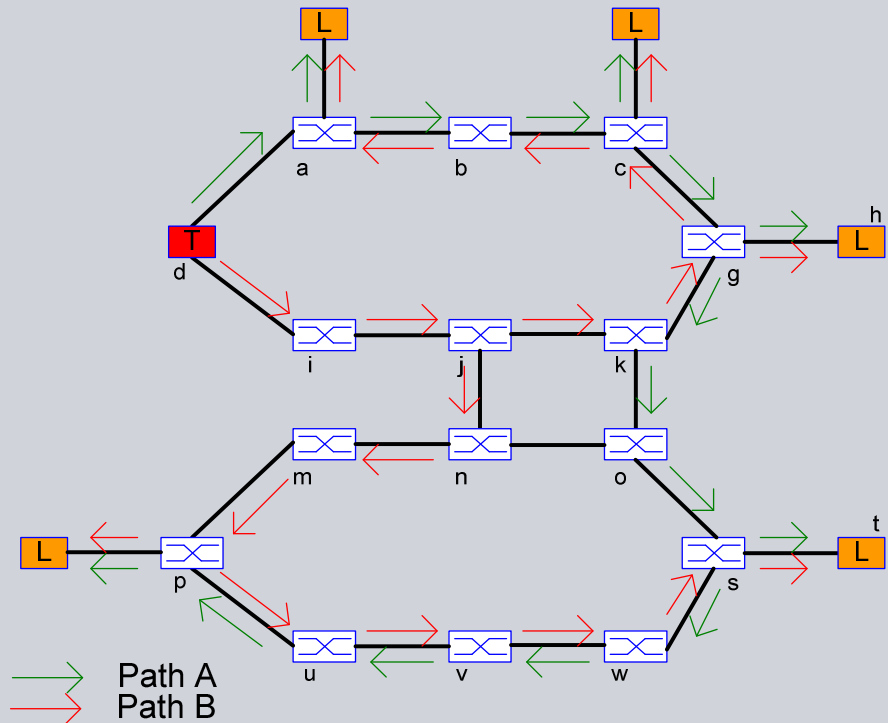
Elimination of Duplicates in Bridges (edge port)

Justification:

• For simple End Stations e.g. sensors with limited computing power and low power consumption

• Avoid bandwidth bottleneck on edge port

• Simplify integration of legacy devices

• Network Segment Protection
(To handle one single point of failure in each network segment, this is very important which will be explained later)

Only one of the duplicates which are transmitted over path A or path B will be received by a listener!

L

duplicate elimination

Path A
Path B
Path A or B
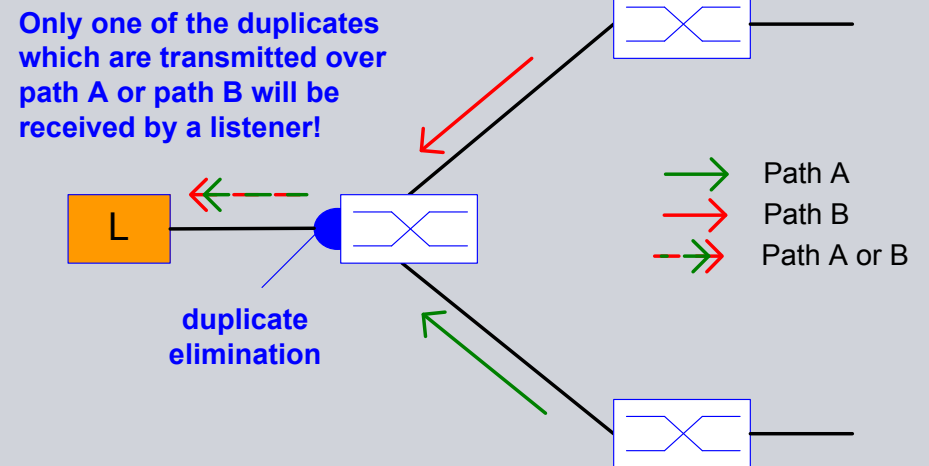
Frame path A received before frame path B

**When frame path A is correct
-> Forwarding frame path A (no waiting for frame path B)
-> Frame path B will be discarded**

Path A

frame path A

in this case discarding frame path B

duplicate elimination

Path B

frame path B

time
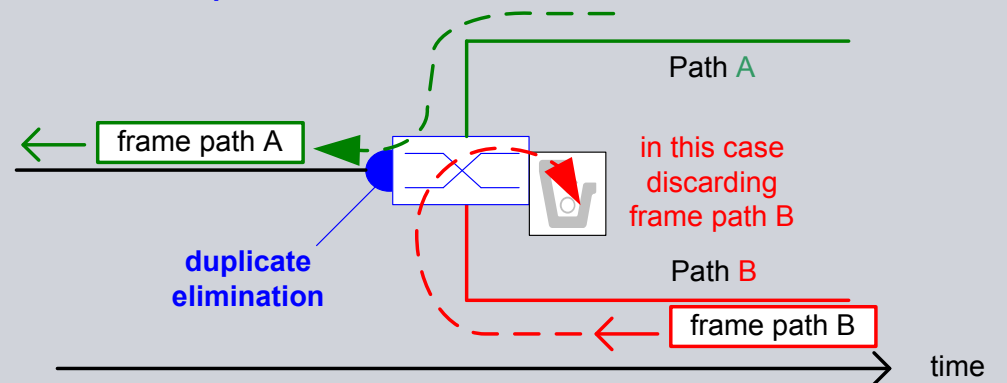
Two Examples for Duplicate Generation in End Stations and Elimination in Bridges (edge port)

Redundant coupled rings

One Ring

Two disjoint path for Reserved- or Scheduled Traffic

Two disjoint path for Reserved- or Scheduled- Traffic

Path A
Path B
Path A or B
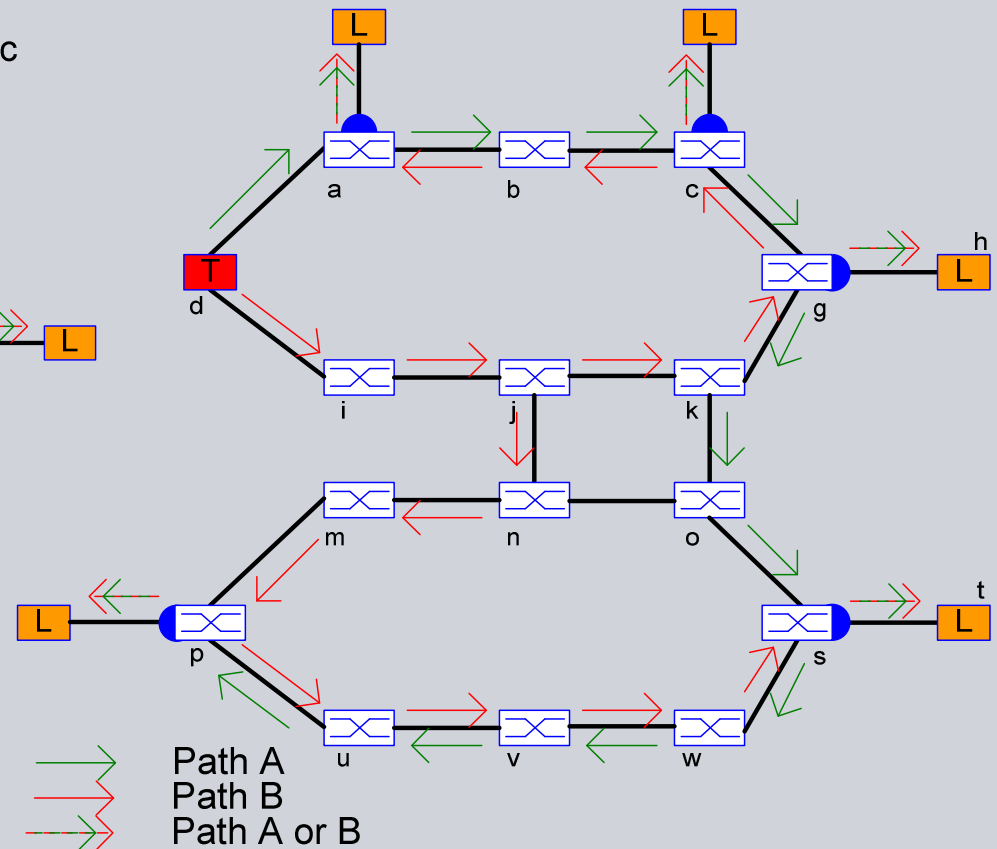
Generation of duplicates in Bridges (1)

Justification:

• For simple End Stations e.g. sensors with limited computing power and low power consumption

• Avoid bandwidth bottleneck on edge port

• Simplify integration of legacy devices

• Network Segment Protection
(To handle one single point of failure in each network segment, this is very important which will be explained later)

Talker (T) transmits a stram with
- **Sequence Number** and
- **VLAN ID for path A**

Bridge port with functionality adding VLAN ID for path A

Bridge port with functionality adding VLAN ID for path B
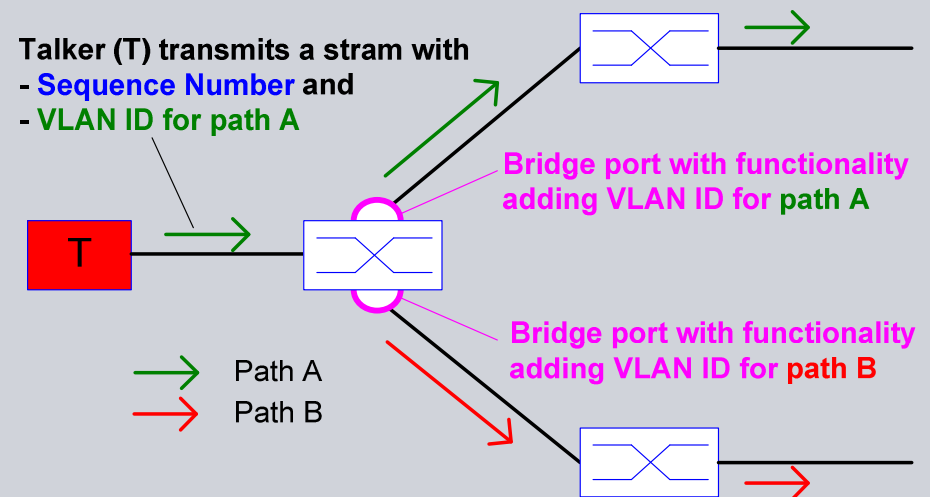
Path A
Path B

Generation of duplicates in Bridges (2)
Network Segments coupled with single Link

Reminder: Bridges do no generate sequence number!
Bridges have to provide functionality to change path A <-> B VLAN ID

Bridge edge port with
L2 duplicate filtering

Only **one** Reserved- or Scheduled- path A or B
Frame is forwarded over the link

L

L

L

T

network segment 1

Bridge edge port with
L2 duplicate filtering

L

L

network segment 2

L

Path A
Path B
Path A or B

Bridge port with functionality
adding VLAN ID for path B

Bridge port with functionality
adding VLAN ID for path A
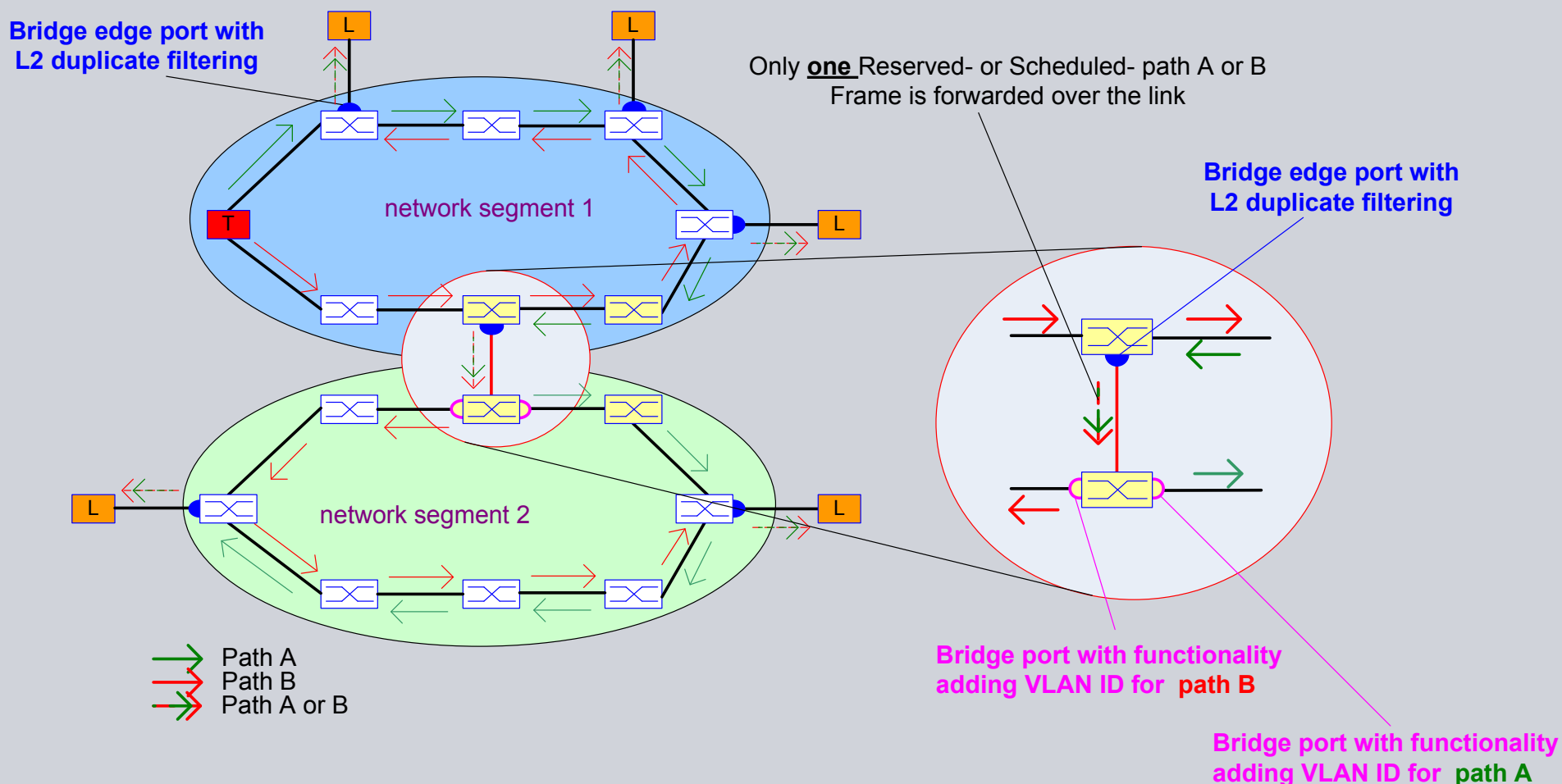
Generation of duplicates in Bridges (3)
Network Segments coupled with redundant Links

Bridge edge port with
L2 duplicate filtering

Path A
Path B
Path A or B

network segment 1

network segment 2

Solution

couple links

**Bridge port with duplicate elimination
and functionality adding VLAN ID for path A or path B**

**Bridge port with functionality
adding VLAN ID for path A or path B**
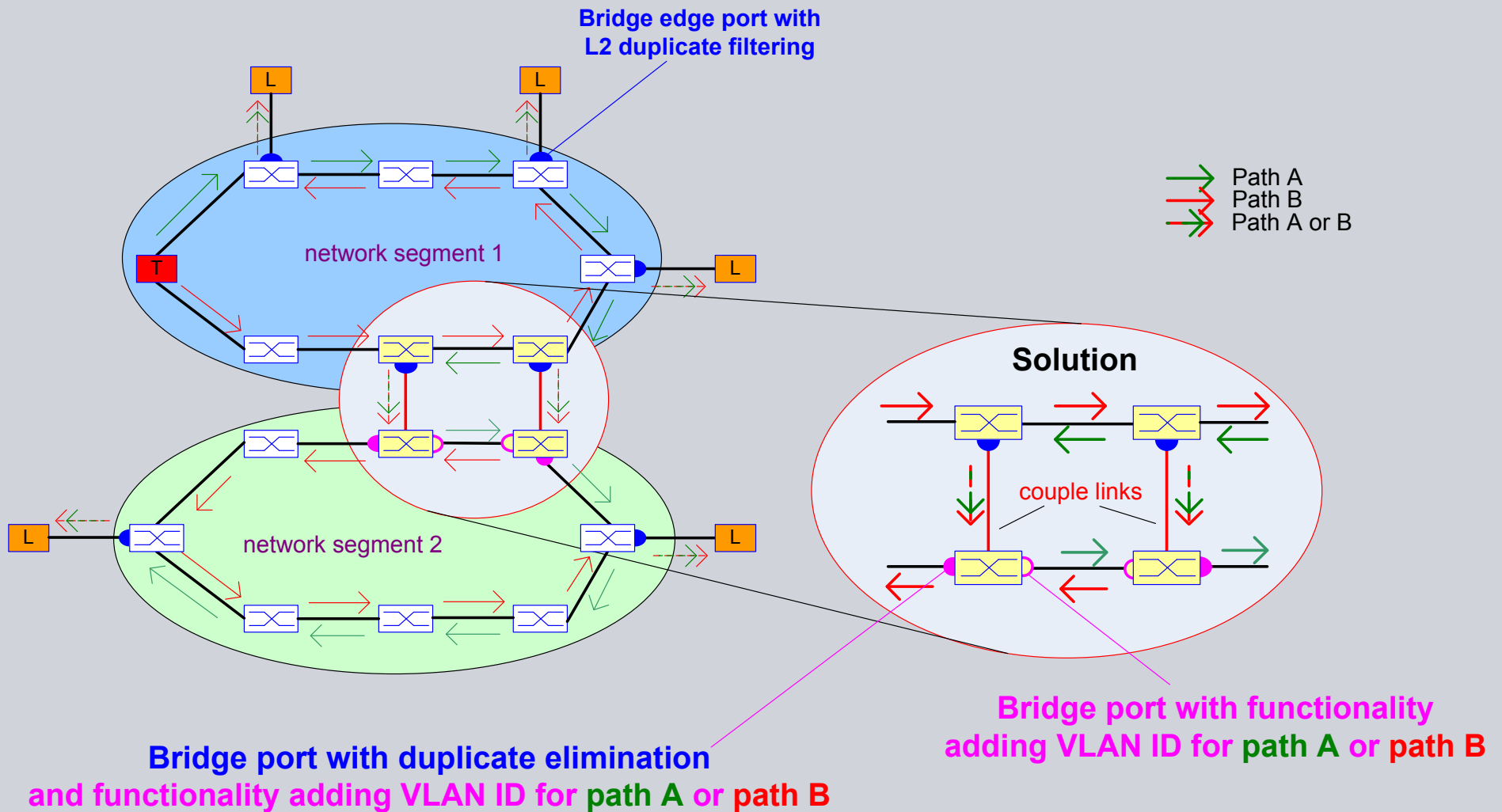
Generation of duplicates in Bridges (4)
Network Segment Protection (1)

Justification:

A single point of failure within one network segment should not reduce the availability for Reserved- or Scheduled-Traffic in other network segments!

Path A
Path B
Missing path B
Path A or B

network segment 1

single point of failure

network segment 2

Path A
Path B
Missing path B
Path A or B
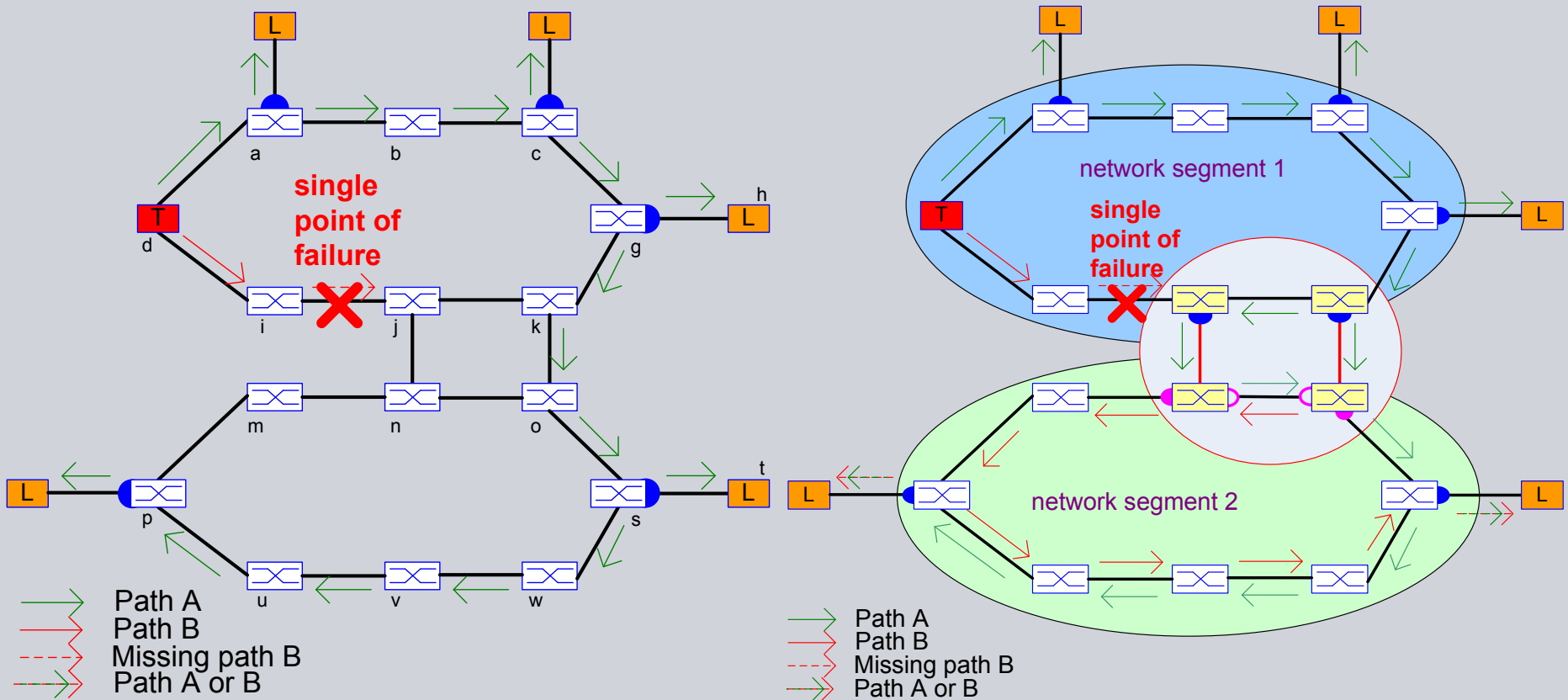
Generation of duplicates in Bridges (5)
Network Segment Protection (2)

The Mechanism for segment protection guarantees connectivity!
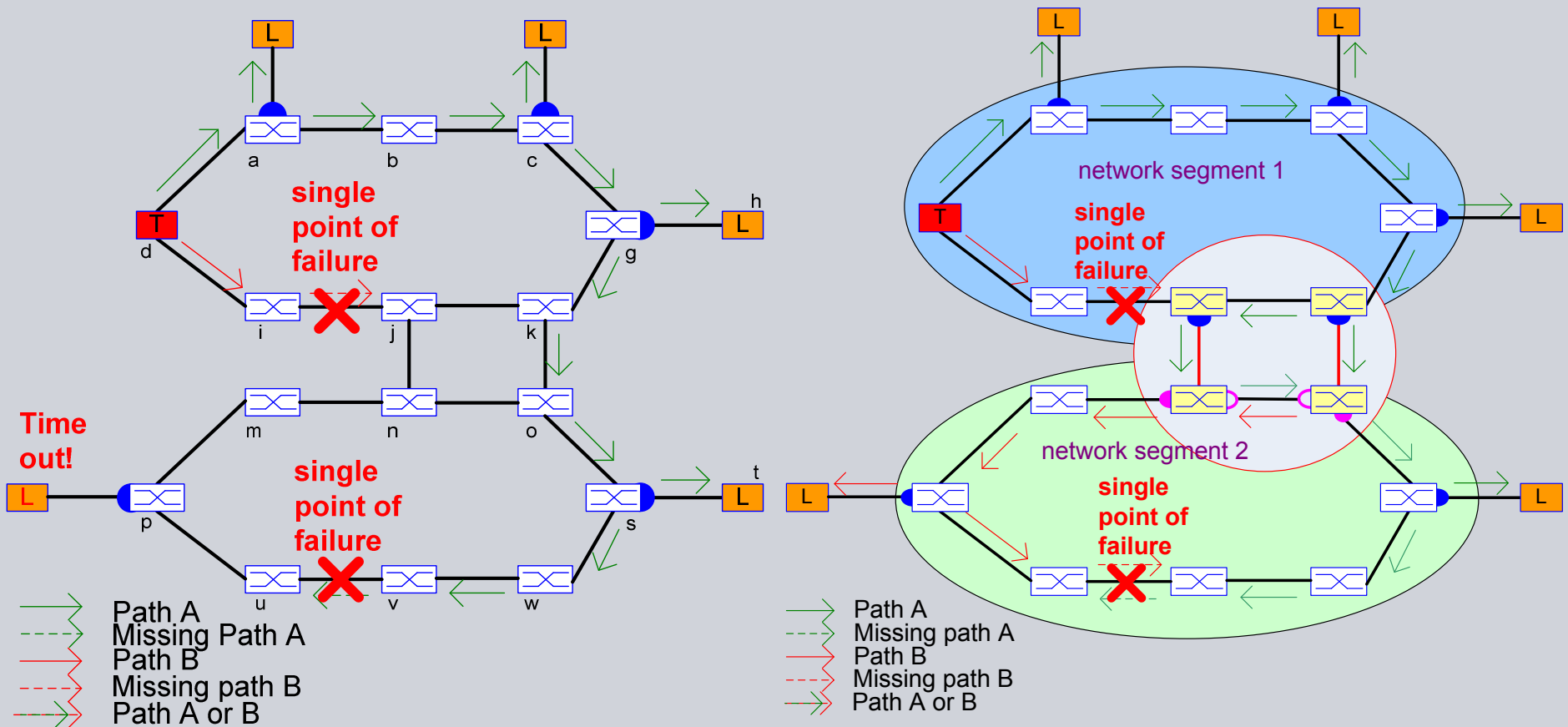
Path A
Missing Path A
Path B
Missing path B
Path A or B

network segment 1

network segment 2

Path A
Missing path A
Path B
Missing path B
Path A or B

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L2 Duplicate Elimination Mechanism Model (1)

Repetition of our Assumptions:

- Seamless Redundancy only for Reserved- or Scheduled-Traffic (also called stream)
- MAC address (destination address) of Stream is unique
- MAC address & sequence numbers are used for duplicate elimination

Data structure:

- Duplicate-Drop-Window: The size for the window depends on:
    - **Latency for path A**
    - **Latency for path B**
    - **Transmission period of Reserved- or Scheduled- Stream**

latency path A

latency path B

Path A
Path B
Path A or B

Sequence Number

Old -> drop frame

255 / 0

20

Duplicate-Drop-Window

68

36

highest actual sequence number

New -> accept frame

Example for
Duplicate Generation & Elimination in Bridges (1)

SIEMENS

Use Case 1:

- MAC: 91:E0:F0:00:00:00
- VLAN ID: **4**
- Sequence Number: **20**

frame path A → Path A

Detail

frame path A →
- MAC: 91:E0:F0:00:00:00
- VLAN ID: **4**
- Sequence Number: 20

frame path B → Path B
- MAC: 91:E0:F0:00:00:00
- VLAN ID: **5**
- Sequence Number: **20**

**Bridge port with duplicate elimination
and functionality adding VLAN ID for path A or path B**

Duplicate elimination model for Reserved- or Scheduled- Traffic

Filtering Data Base (FDB)

FID	MAC-DA (6 Bytes)	Port(s)	Pos. DE
VID = 4	91:E0:F0:00:00:00	1, 2	32
VID = 5	91:E0:F0:00:00:00	1, 2	32
……	……	……	……
VID = 1	91:E0:F0:00:00:01	...	255
VID = 9	04:7A:CF:34:A0:01	...	255
VID = 2	04:7A:CF:34:A0:03	...	255

NEW!

Duplicate Drop Data Base(DDD)

Pos DE	ActSeqN	Sliding Duplicate Drop Window (sDDW)
1	773	1 0 0 1 1 0 1 1 1 1 1 1 1 0 1 1
	……	……
30	890	1 1 1 1 1 1 0 1 1 1 1 1 1 1 0 1
31	54	1 0 1 1 1 1 1 1 1 1 0 0 1 1 1 1
32	19	1 1 0 1 1 0 1 1 1 1 1 1 1 1 1 1

Sliding Duplicate Drop Window (sDDw)

<< shift 1

| OLD | 1 0 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 | NEW |

actual sequence number (ActSeqN = 20)

Example for
Duplicate Generation & Elimination in Bridges (2)

SIEMENS

Use Case 2:

- MAC: 91:E0:F0:00:00:00
- VLAN ID: **4**
- Sequence Number: **8**

Path A

frame path A

Detail

frame path A

- MAC: 91:E0:F0:00:00:00
- VLAN ID: **4**
- Sequence Number: **8**

frame path A

frame path B

Path B

- MAC: 91:E0:F0:00:00:00
- VLAN ID: **5**
- Sequence Number: **8**

**Bridge port with duplicate elimination
and functionality adding VLAN ID for path A or path B**

Duplicate elimination model for Reserved- or Scheduled- Traffic

Filtering Data Base (FDB)

FID	MAC-DA (6 Bytes)	Port(s)	Pos. DE
VID = 4	91:E0:F0:00:00:00	1, 2	32
VID = 5	91:E0:F0:00:00:00	1, 2	32
……	……	……	……
VID = 1	91:E0:F0:00:00:01	…	255
VID = 9	04:7A:CF:34:A0:01	…	255
VID = 2	04:7A:CF:34:A0:03	…	255

NEW!

Duplicate Drop Data Base(DDD)

Pos DE	ActSeqN	Sliding Duplicate Drop Window (sDDW)															
1	773	1	0	0	1	1	0	1	1	1	1	1	1	1	0	1	1
	……							……									
30	890	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1
31	54	1	0	1	1	1	1	1	1	1	1	0	0	1	1	1	1
32	20	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1

Sliding Duplicate Drop Window (sDDw)

Offset = 12

OLD | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | NEW

actual sequence number (ActSeqN = 20)

Example for
Duplicate Generation & Elimination in Bridges (3)

SIEMENS

Use Case 3:

Path A

frame path B

- MAC: 91:E0:F0:00:00:00
- VLAN ID: **5**
- Sequence Number: **8**

Detail

in this case discarding
frame path B

Path B

**Bridge port with duplicate elimination
and functionality adding VLAN ID for path A or path B**

Duplicate elimination model for Reserved- or Scheduled- Traffic

Filtering Data Base (FDB)

FID	MAC-DA (6 Bytes)	Port(s)	Pos. DE
VID = 4	91:E0:F0:00:00:00	1, 2	32
VID = 5	91:E0:F0:00:00:00	1, 2	32
……	……	……	……
VID = 1	91:E0:F0:00:00:01	…	255
VID = 9	04:7A:CF:34:A0:01	…	255
VID = 2	04:7A:CF:34:A0:03	…	255

NEW!

Duplicate Drop Data Base(DDD)

Pos DE	ActSeqN	Sliding Duplicate Drop Window (sDDW)															
1	773	1	0	0	1	1	0	1	1	1	1	1	1	1	0	1	1
	……							……									
30	890	1	1	1	1	1	1	0	1	1	1	1	1	1	0	1	
31	54	1	0	1	1	1	1	1	1	1	1	0	0	1	1	1	1
32	20	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	

Sliding Duplicate Drop Window (sDDw)

Offset = 12

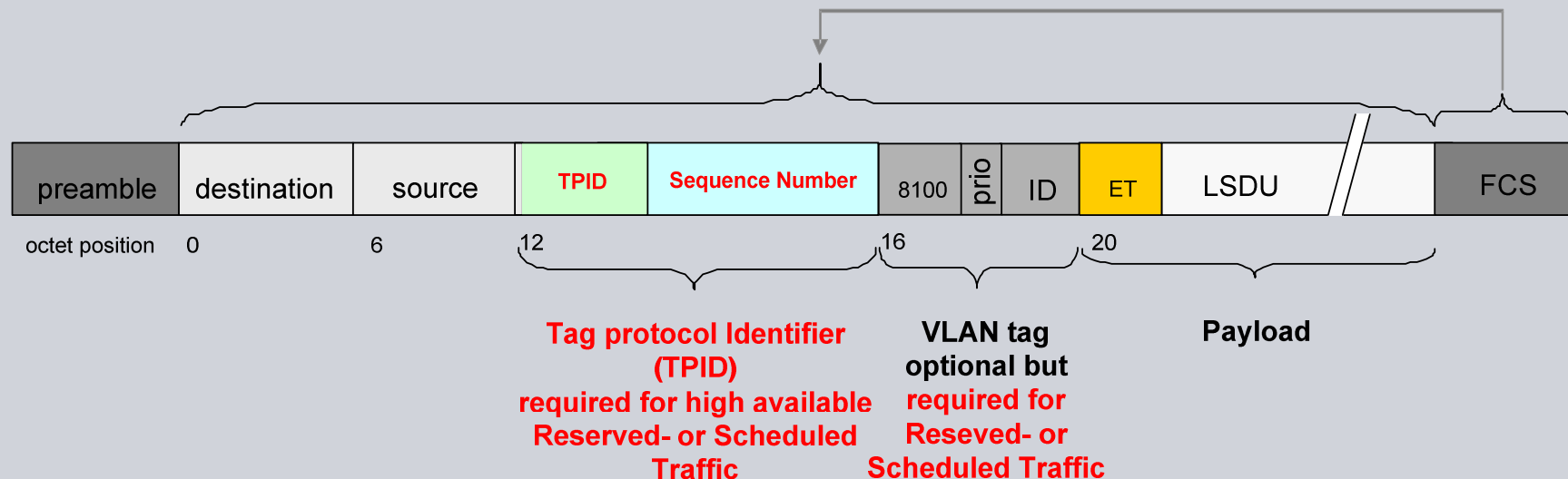| OLD | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | NEW |

actual sequence number (ActSeqN = 20)

Proposed Solution:
Encapsulation for Duplicate Elimination

SIEMENS

Requirements:

- **Duplicate elimination information shall be protocol neutral** (support a wide range of protocols)

- **Duplicate elimination per stream** (unique destination address)

| preamble | destination | source | TPID | Sequence Number | 8100 | prio | ID | ET | LSDU | FCS |

octet position   0   6   12   16   20

Tag protocol Identifier (TPID) required for high available Reserved- or Scheduled Traffic

VLAN tag optional but required for Reseved- or Scheduled Traffic

Payload

Encapsulation for duplicate information:

- **TPID** : Duplicate Elimination Tag

- **Sequence Number** : Talker end station have to administrate sequence number stream specific

Discussion of our Proposals

Overview of proposals:

➢End Stations and Bridges should be able to generate duplicates.

➢End Stations and Bridges should be able to eliminate duplicates.

➢A frame format extension was proposed for duplicate identification.

➢A duplication elimination mechanism was proposed.
(Keyword: Duplicate Drop Database)

How are we going to proceed?

➢We need to agree on a plan…