Seamless Ethernet (SEth) Approach without Ethernet frame modification

Jan. 2020

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Jong Myung Rhee

- North Carolina State University, Ph. D.
- Agency for Defense Development (ADD) 1978-1997
- Hanaro telecom CTO 1999-2005
- Myongji University, South Korea 2006-present

- Network Fault Recovery
  - ✓ HSR Traffic reduction techniques development
    (QR(=mode X, IEC 62439-3,HSR), PL, FHT, DVP, RDP, DSP)
  - ✓ Optic HSR
  - ✓ Seamless Ethernet
  - ✓ BSHSM (Balanced Synchronization Hierarchy with Spare Masters): better traffic performance over BMC

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Scope

SEth **is applicable to any industrial and time-critical applications that based on Ethernet technology and need seamless redundancy frames.**

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Aim

Provides path redundancy with zero recovery time (seamless) using the standard Ethernet frame (IEEE 802.3) for sending and receiving data without modifying the frame layout.

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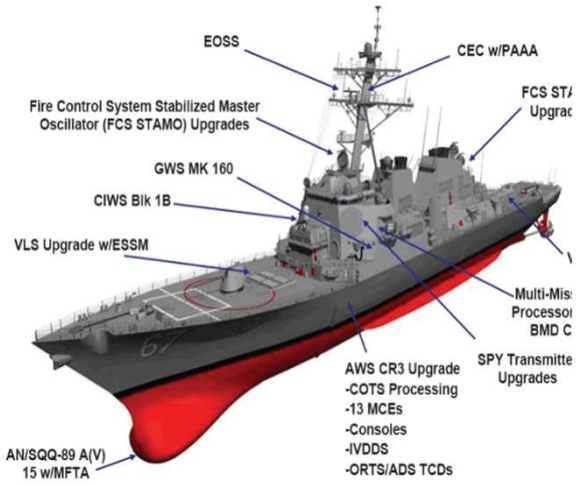
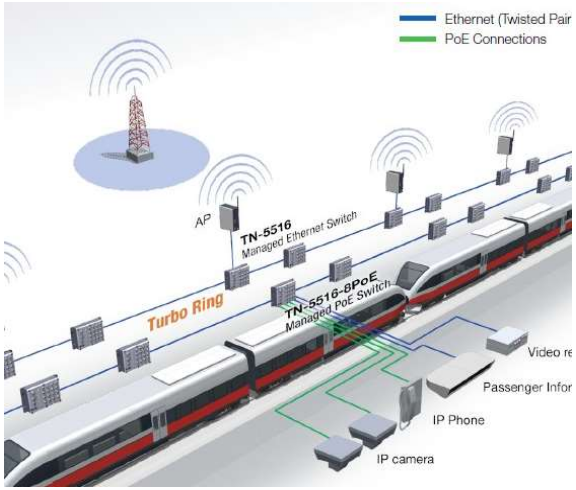
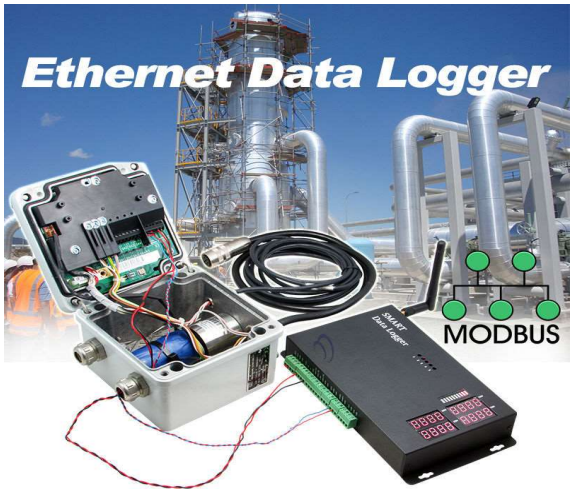
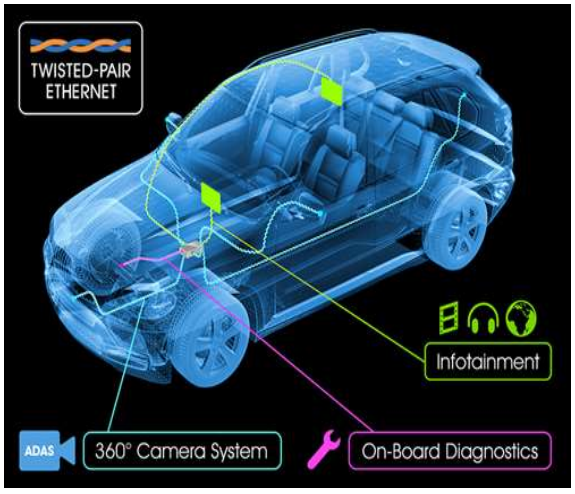
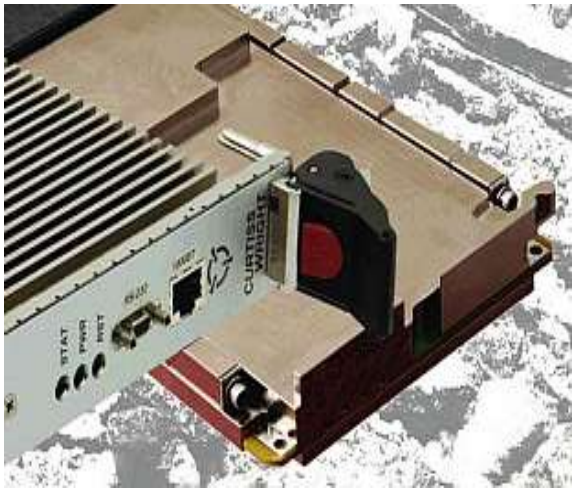
Ethernet Applications











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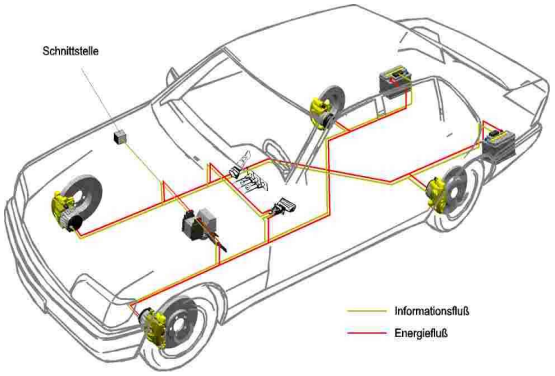
Fail-over Time Requirements: "Seamless" becomes more important

cement: < 10s

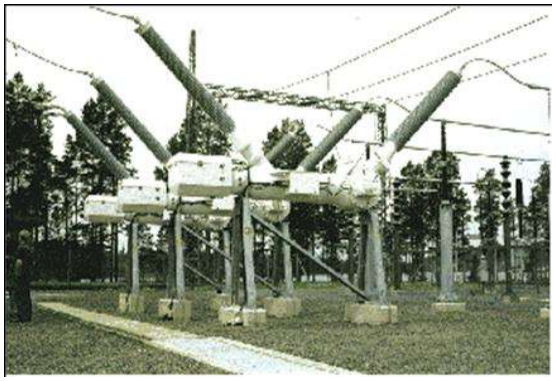
printing: < 20ms

chemical: < 1s

tilting train: < 100 ms



X-by wire: < 10 ms



substations: < 3 ms

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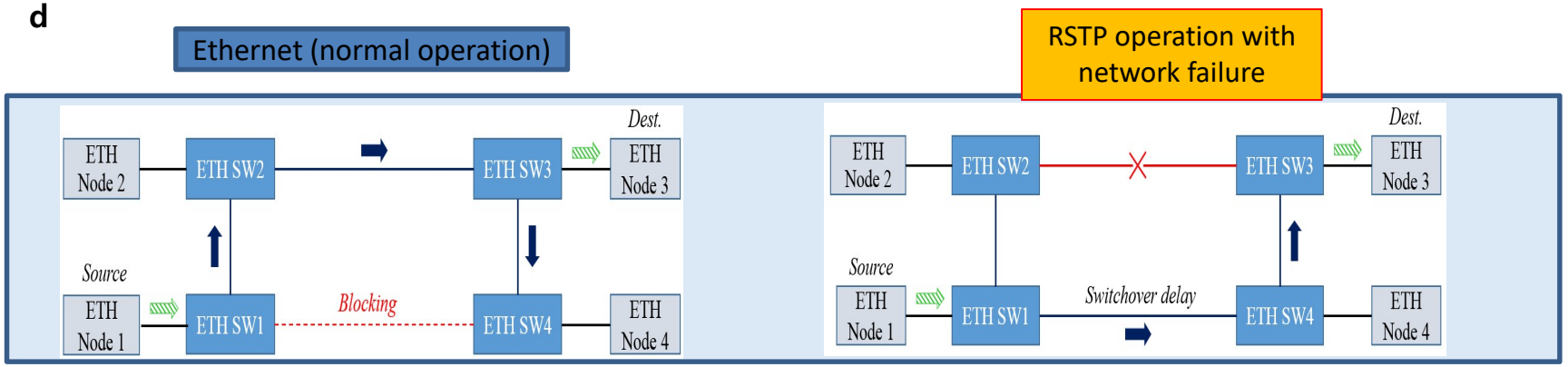
Ethernet : 802.1CB and HSR

- ☞ For wired network application, Ethernet (standardized as IEEE802.3) is dominant and usually adopts RSTP (Rapid Spanning Tree Protocol) for Fault Recovery.
- ☞ However, RSTP cannot provide "seamless" since it needs around one second for reconfiguration when the network fails.
- ☞ Therefore, IEC62439-3 HSR(High-availability Seamless Redundancy) or IEEE 802.1CB becomes potential candidate for real-time mission critical applications such as substation automation, in-vehicle network, military applications, and factory automation.

* But HSR or 802.1CB needs the modification of Ethernet frame. Here we propose seamless Ethernet which uses for conventional off-the-shelf Ethernet without modification.

d



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HSR

HSR (High-availability Seamless Redundancy) is an Ethernet (IEEE 802.3) protocol.

- Theoretical zero failover time.
- Any configuration possible: Rings, Connected Ring(Ring of Rings), Mesh.
- Several redundancy protocols have been developed by IEC.
  - Among theses, PRP and HSR provide “seamless”.

    But PRP needs duplicated hardware.

Protocol	CRP	DRP	MRP	BRP	RRP	PRP	HSR
IEC Std	62439-4	62439-6	62439-2	62439-5	62439-7	62439-3	62439-3
Topology	Mesh Cross	Ring Double Ring	Ring	Double Mesh	Single Ring	Mesh Ring	Ring Mesh
Fail-over time	1s	100ms	10-500ms	8.88ms	8ms, 4ms	0s	0s

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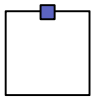
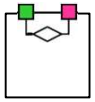
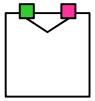
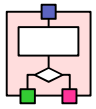
HSR notation


SAN singly attached node (not HSR)

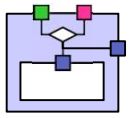

DANH node with 2 HSR ports

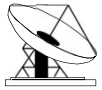

DANP node with 2 PRP ports


Redbox with one single port


Redbox switch (RSTP) to HSR

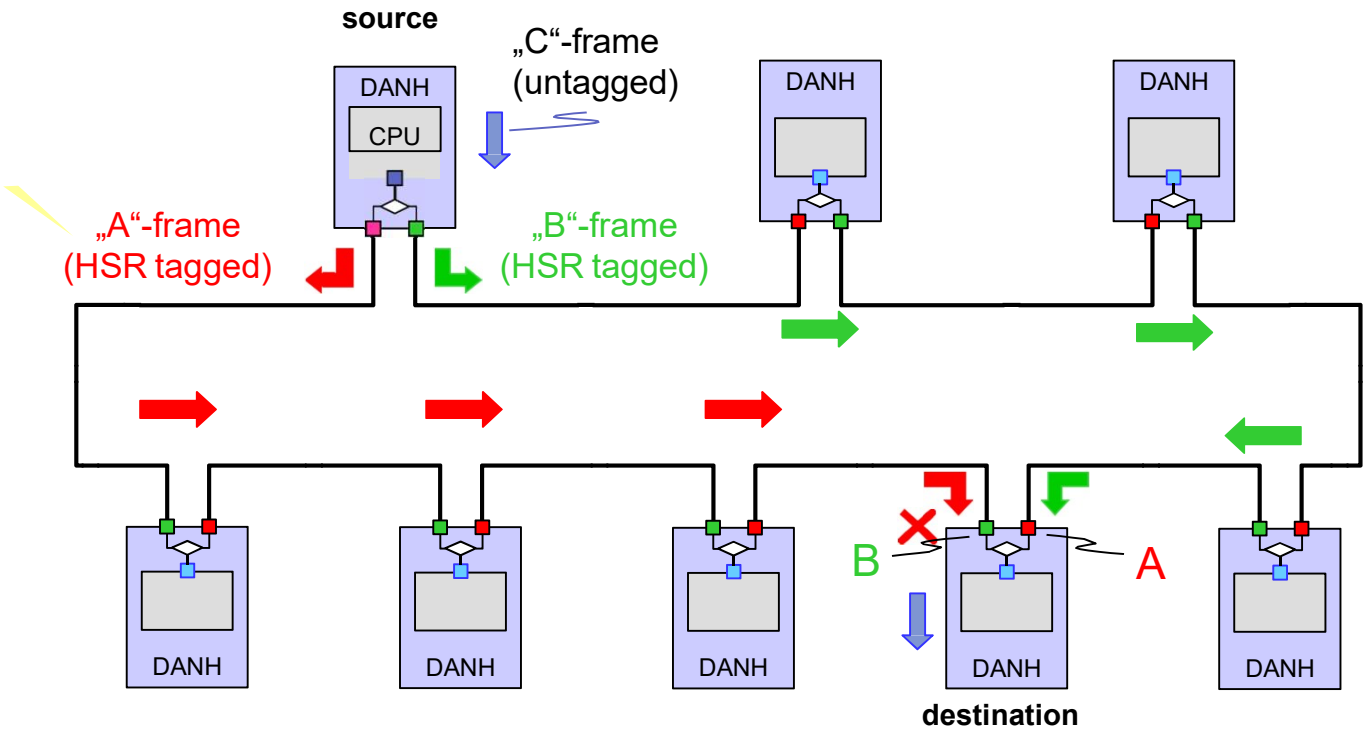

QuadBox


HSR node with auxiliary port


GPS time server

IEEE 1558 clock
GC = grandmaster clock
TC = transparent clock
BC = boundary clock
OOC = ordinary clock
NC = network clock

HSR (Unicast)


source
„C“-frame
(untagged)
DANH
CPU
DANH
DANH
„A“-frame
(HSR tagged)
„B“-frame
(HSR tagged)
DANH
DANH
DANH
B
A
DANH
DANH
destination

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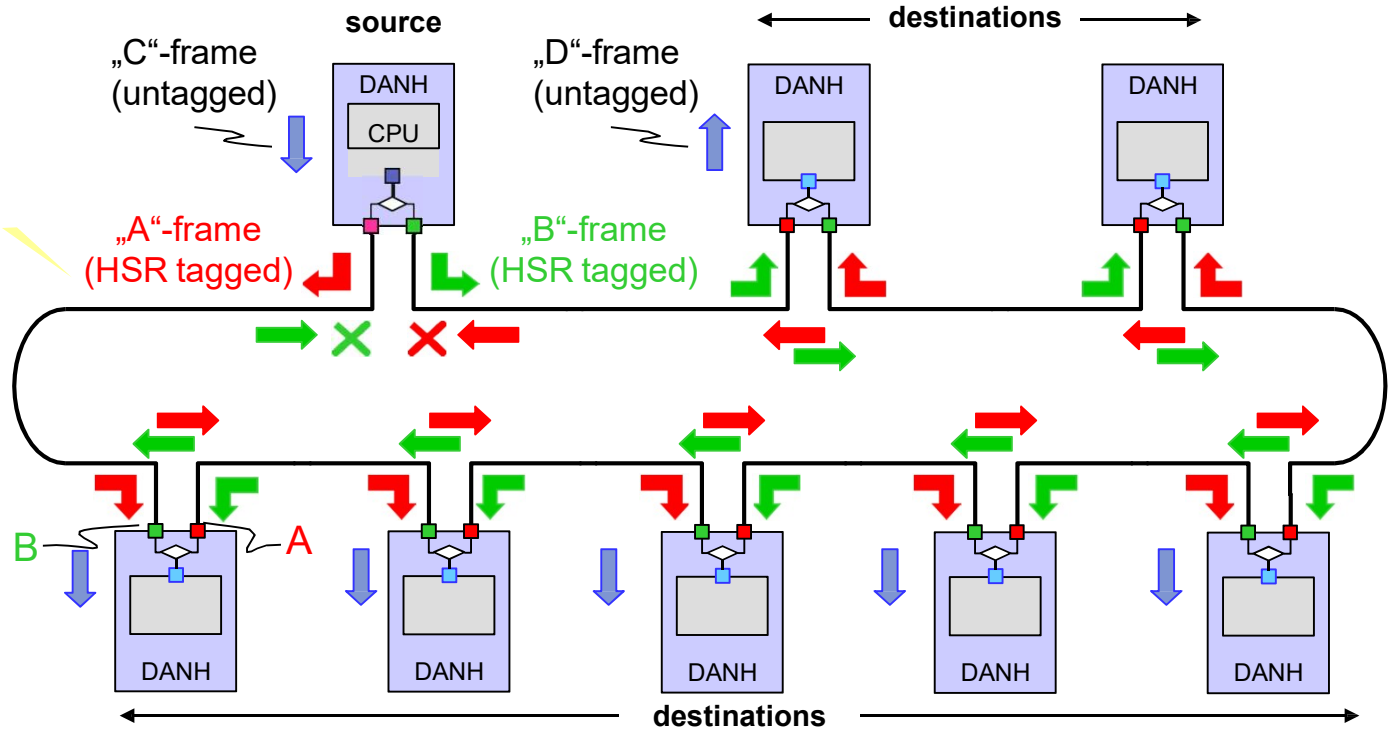
HSR (Multicast/Broadcast)



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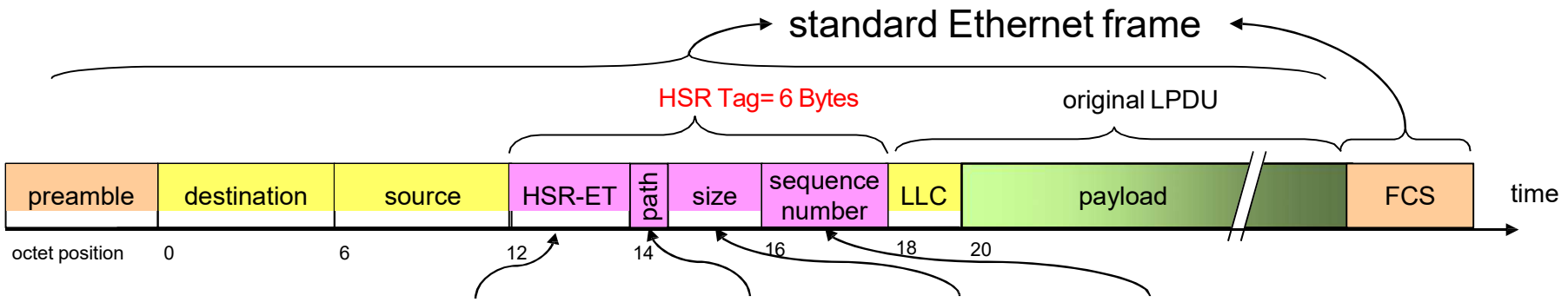
HSR frame layout



- There are HSR-Ethernet type, Path Indicator, Size and Sequence field. Also HSR Tag is included.

  - Ethernet frame: 64-1,518Bytes
  - HSR frame: 70-1,524 Bytes

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- HSR & 802.1CB need original Ethernet frame modification due to Tag insertion.

- In this presentation we propose “seamless Ethernet” which provides zero failover time without insertion any tag or Ethernet frame modification.

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Two *SEth* components: node and switch

- **Seamless Ethernet Node (SEthNode)**: It is an Ethernet node that similar to an HSR node-DANH type, has two ports sharing the same IP and MAC address. It uses the standard Ethernet frame (IEEE 802.3) format for sending and receiving frames. It duplicate each sent frame and send each copy through a port, whereas in receiving phase, it uses the ***SEth*** procedure to eliminate the redundant frames.

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- **Seamless Ethernet Switch (SEthSwitch)**: It is an Ethernet switch that uses the standard Ethernet frame (IEEE 802.3) format for sending and receiving frames. It uses the duplication and also the elimination concept to provide seamless redundancy with zero recovery time. It duplicates each sent frame and send them out. Whereas for receiving redundant frames, it uses **SEth** Approach for eliminating the redundant one.

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Operational Concept

- ***SEth*** **approach is a synchronized approach that sends and receives data frames on each clock time.**
- **For this we suggest to use IEEE 1588 PTP protocol for clock synchronizing.**

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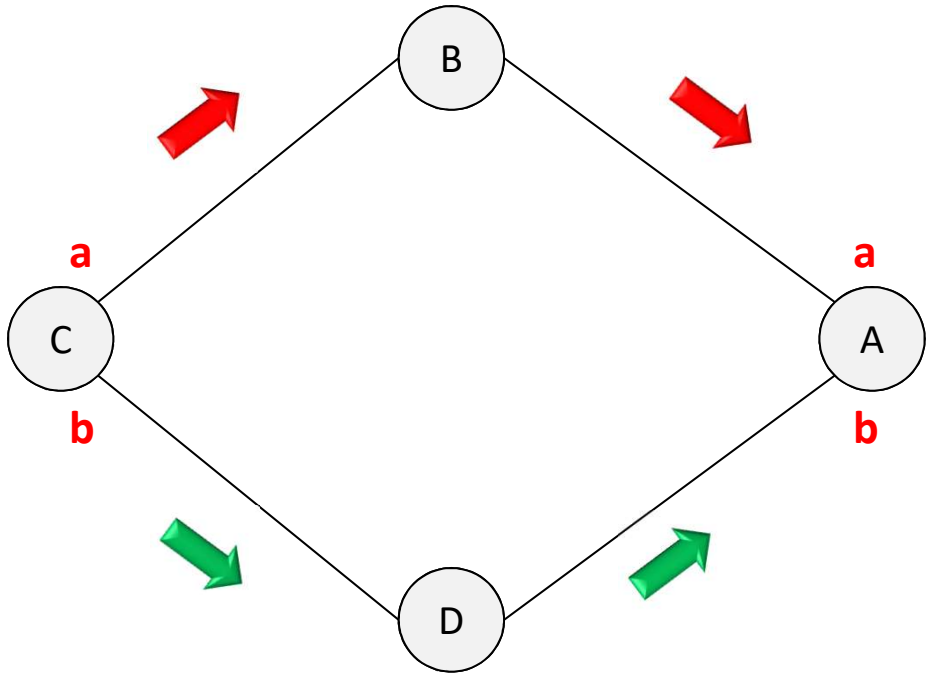
Operational Concept (Unicast Traffic)

- Assume SEthNode C sends stream of frames to SEthNode A.
- EtherNode C duplicates each sending frame and then send each copy through port a and b.



- SEthNodes D and B will forward each sent copy of SEthNode C into the opposite direction towards SEthNode A; the destination node.

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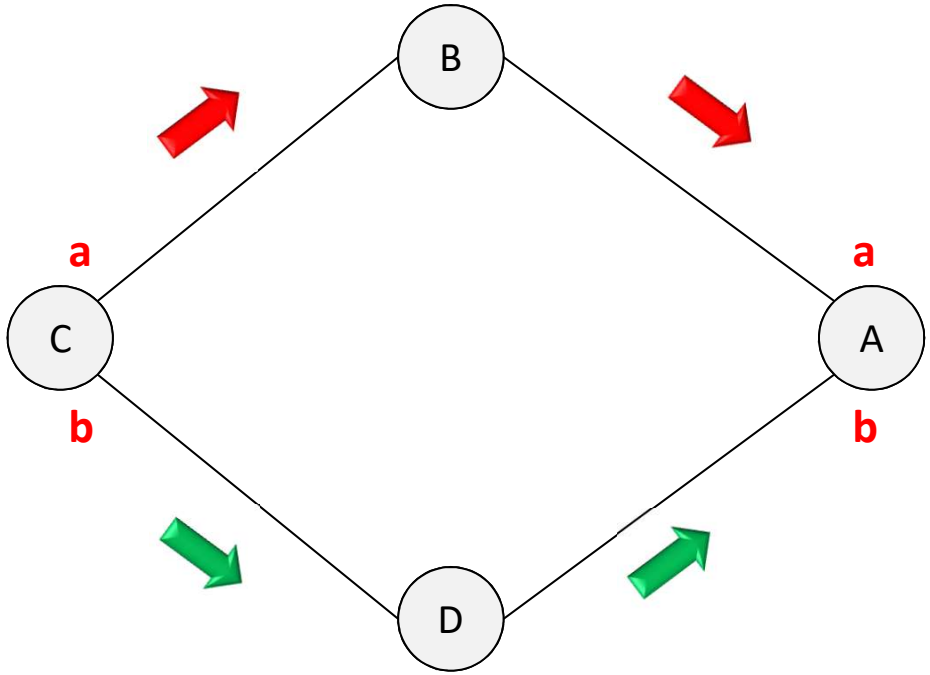
Cont…

- SEthNode A establishes a counter in each of its ports.
- These counters are established per each sending node (source node).



- Therefore, SEthNode A will have the following two counters that associated to SEthNode C.

$$Count^{C}_{a} \qquad Count^{C}_{b}$$

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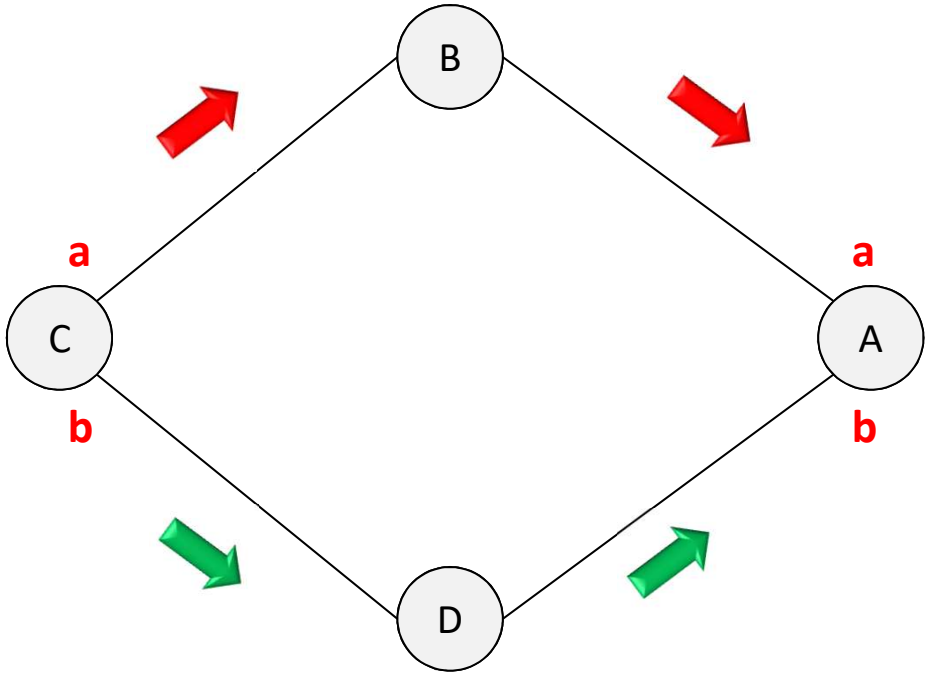
Cont…

- SEthNode A will consume the frame from the port that has counter value greater than the other port, and will delete the other copy.
- However, the consumed frame copy must be error-free, else; SEthNode A will delete it and consume the other one of the second port.



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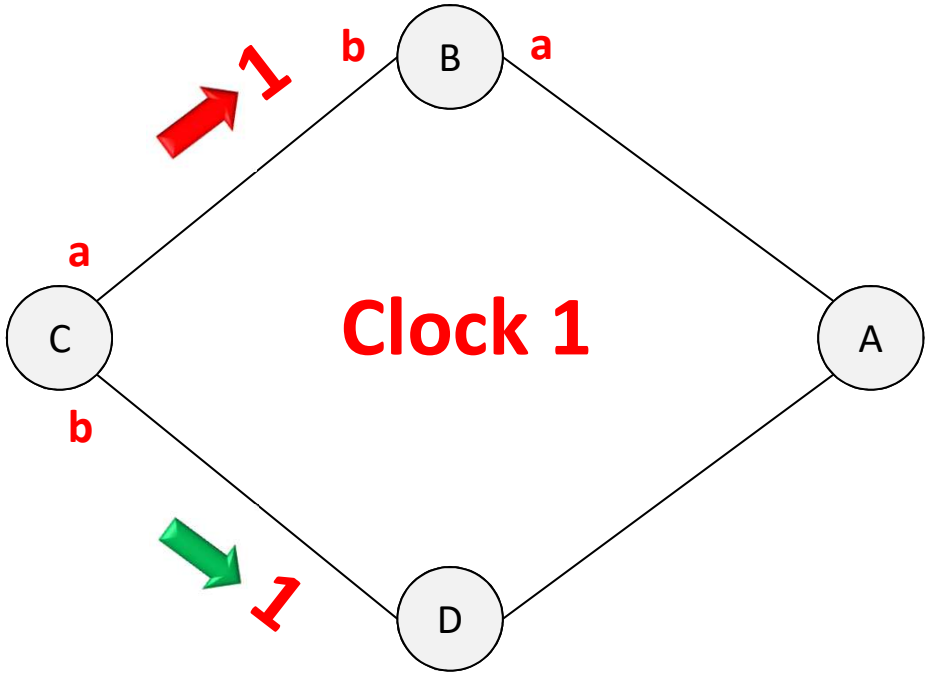
- Assume SEthNode C sends 3 frames to SEthNode B, so in the first clock time, SEthNode B will get the fastest copy through port b, assuming that it was error-free. Therefore, SEthNode B will consume it and will delete the copy of port a after delivering it in the next 2 clocks



Count $^{C}_{a}$ = 0 , Count $^{C}_{b}$ = 1

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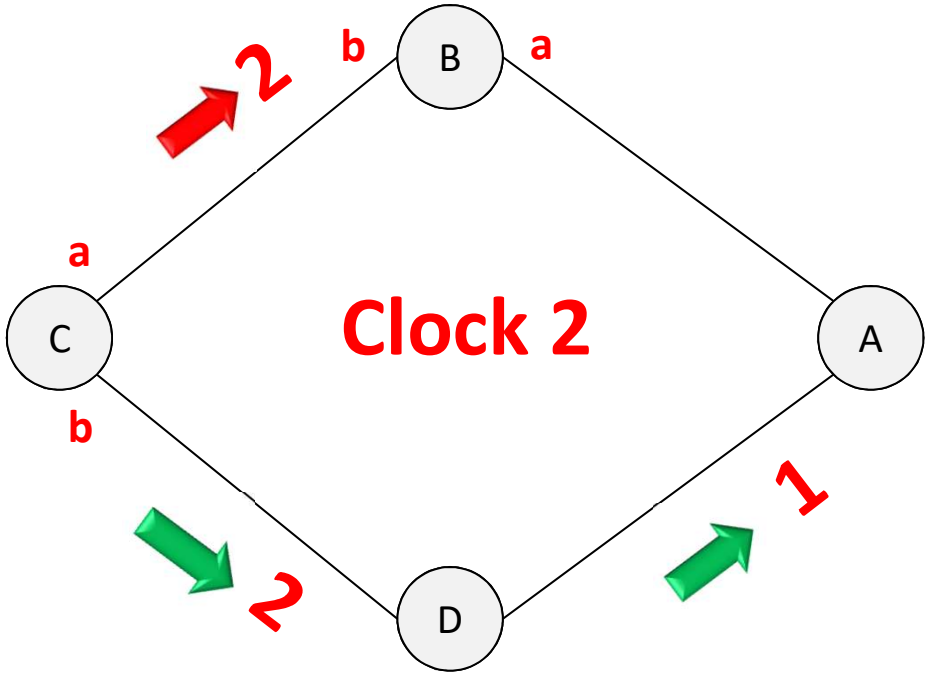
Cont…

- Assume that in clock 2, the delivered frame to SEthNode B through port (b) has an error, so SEthNode B will delete it , then



Count $^{C}_{a}$ = 0 , Count $^{C}_{b}$ = 2

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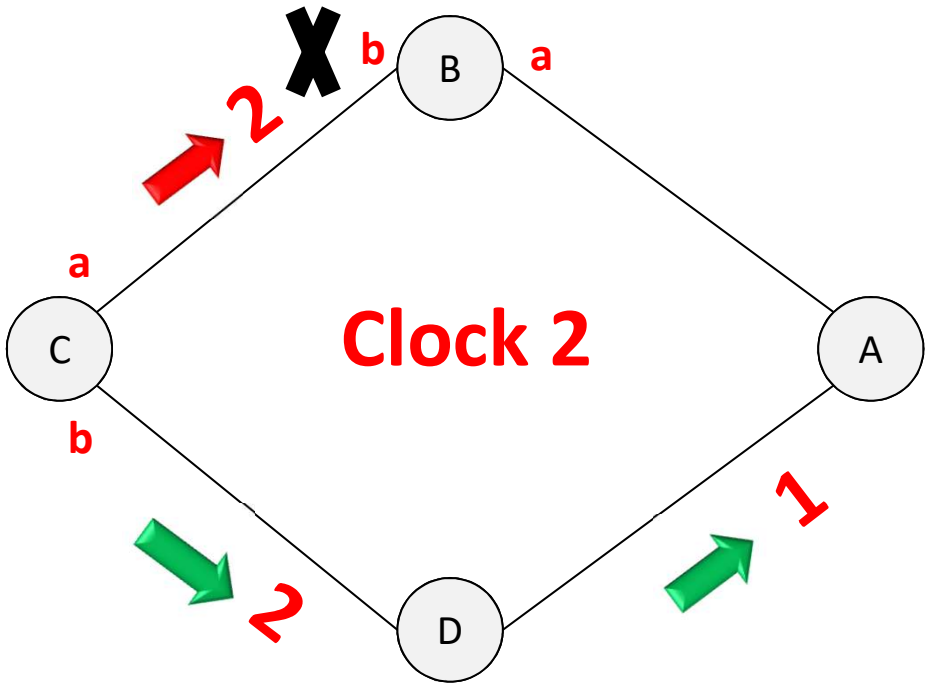
Cont…

- List the clock number that SEthNode B could not receive an error-free frame during it. The listing will be done in a table called the "Lost frames", therefore, SEthNode B shall receive the other copy from port (a) after two more clocks.



Count $^{C}_{a}$ = 0 , Count $^{C}_{b}$ = 2

Clock number	Port number that should receive from
2	a

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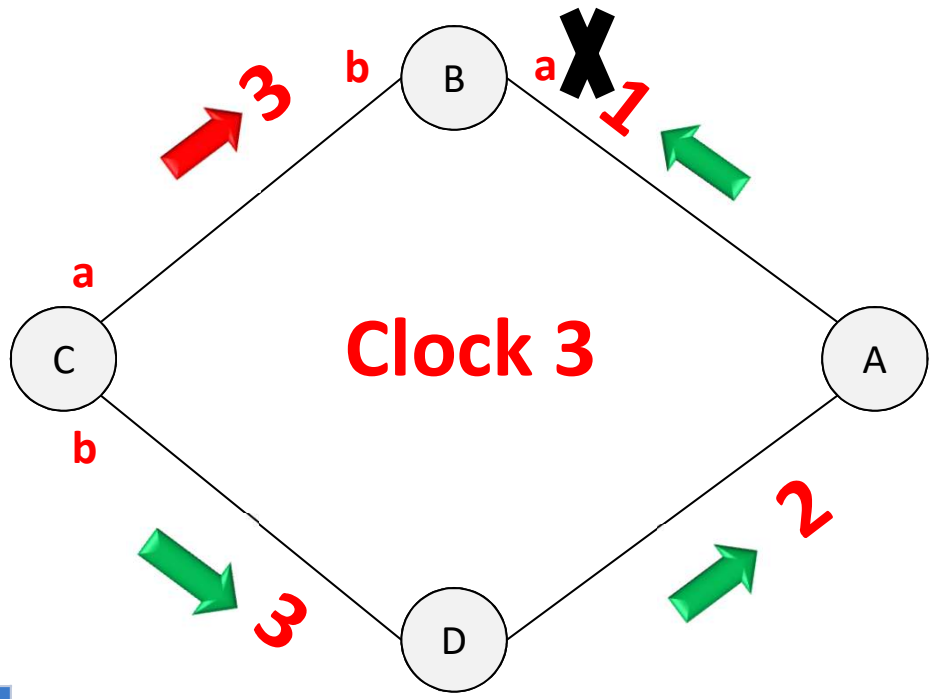
Cont…

- In the third clock, SEthNode B will receive the third copy from port (b) and delete the first copy of port (a) because it is already received.



Clock number	Port number that should receive from
2	a

Count $^{C}_{a}$ = 1, Count $^{C}_{b}$ = 3

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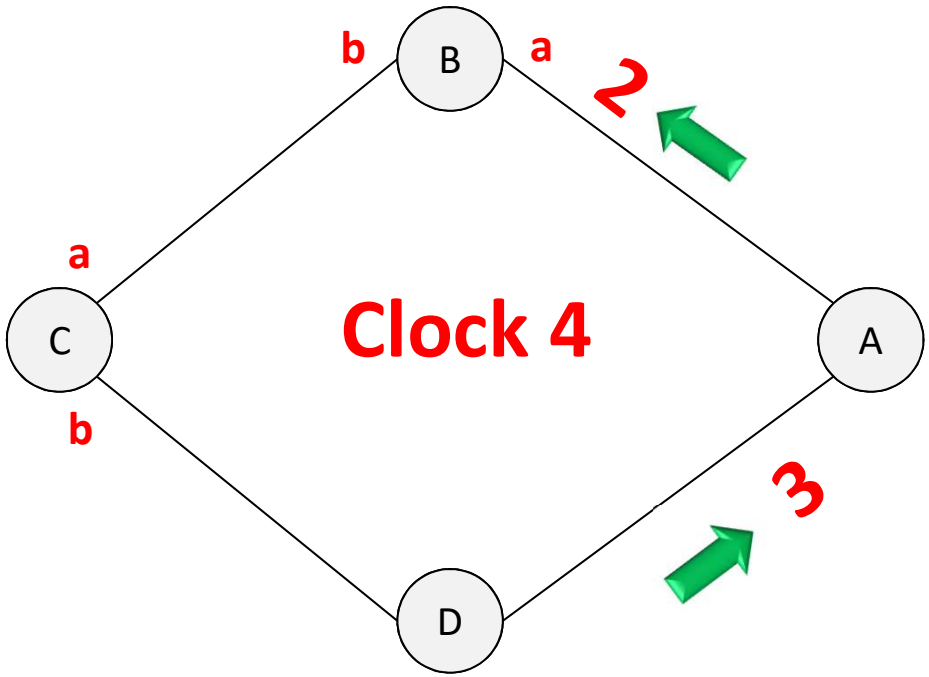
Cont…

- In the fourth clock, SEthNode B will receive the second copy from port a because it is listed in the "lost frames" table.



Clock number	Port number that should receive from
2	a

Count $^{C}_{a}$ = 2, Count $^{C}_{b}$ = 3

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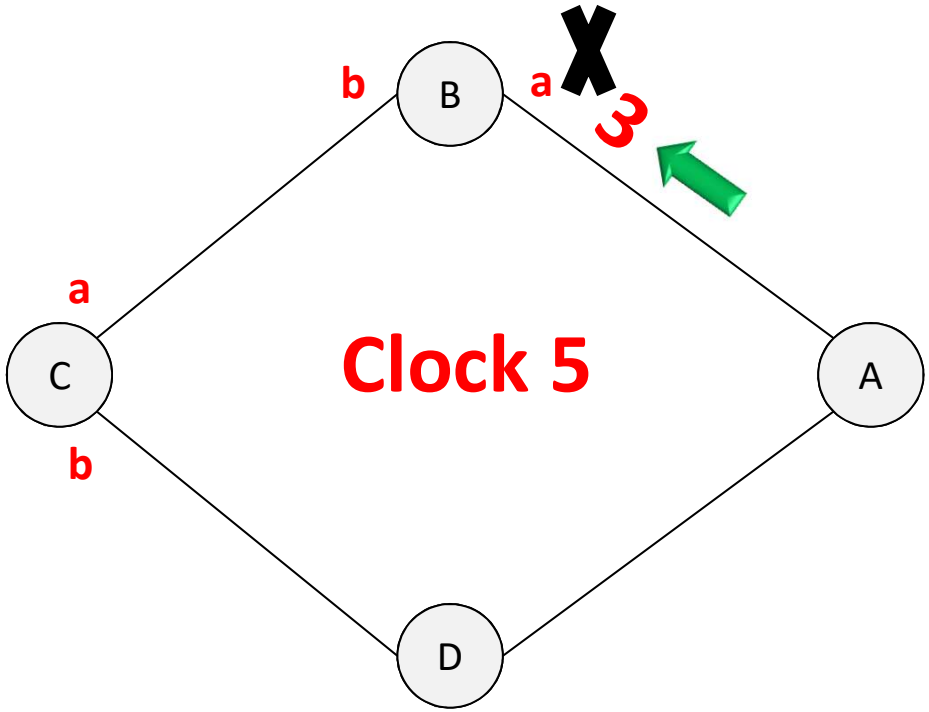
Cont…

- In the fifth clock, SEthNode B will delete the third copy of port (a) because it is already received earlier.



Count $^{C}_{a}$ = 3, Count $^{C}_{b}$ = 3

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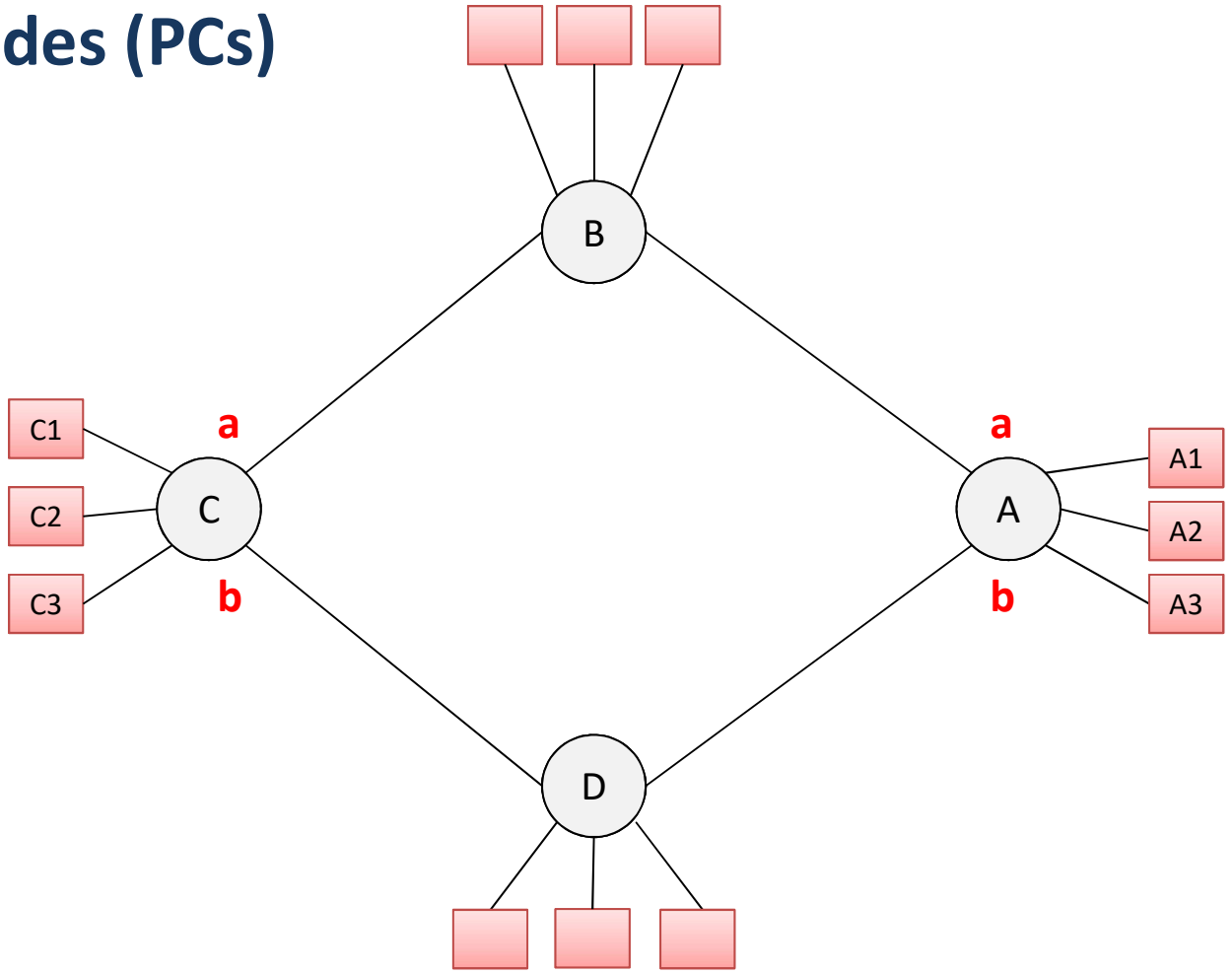
Operational Concept (Unicast)

- **SEthSwitch and off-the-shelf Ethernet nodes (PCs) connected to the SEthSwitches.**

- **node C1 sends a frame to node A1.**



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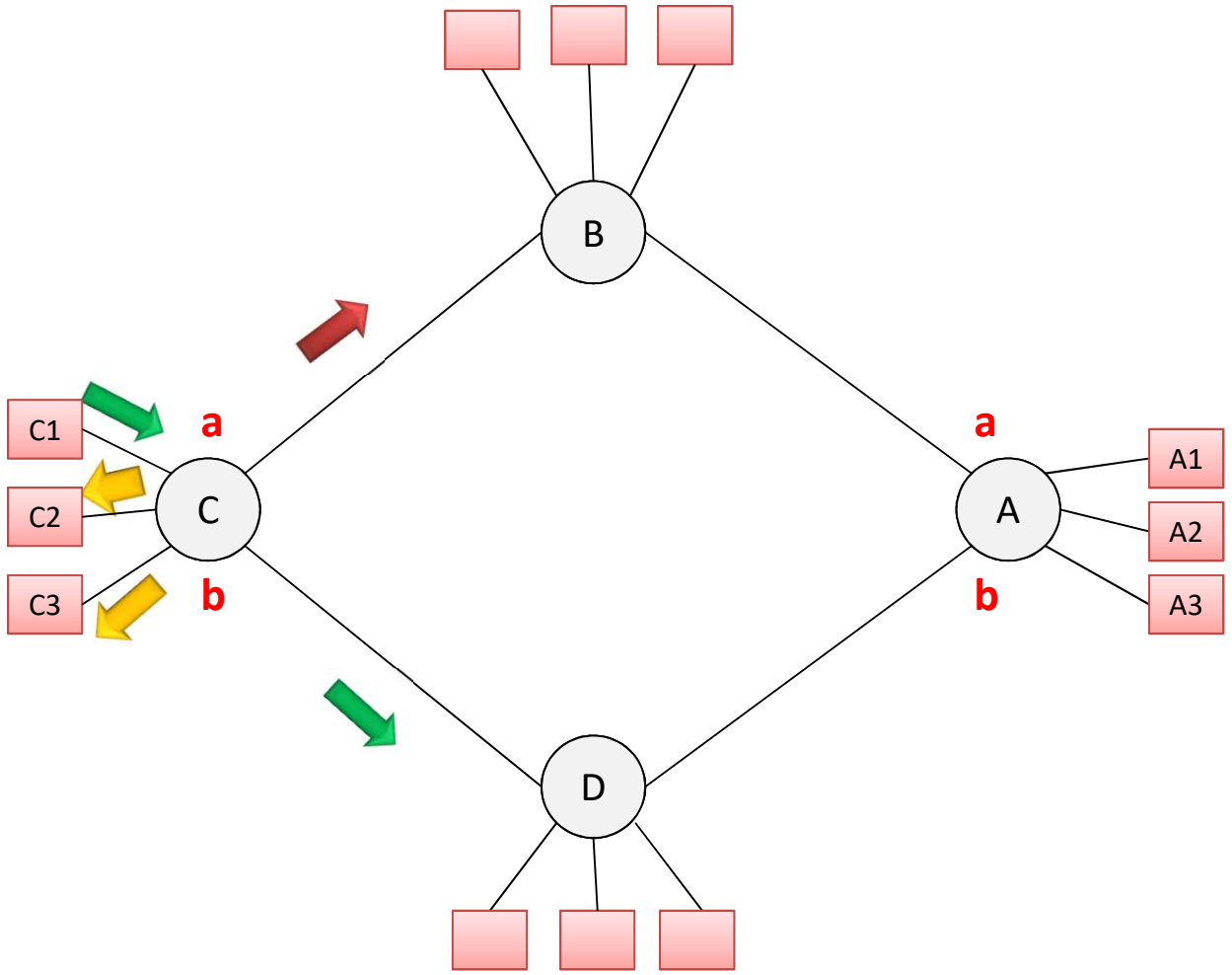
- In this case, SEthSwitch C will receive the frame from node C1, and then flood it into its local ports as well as its trunk port (Assume empty MAC address table).



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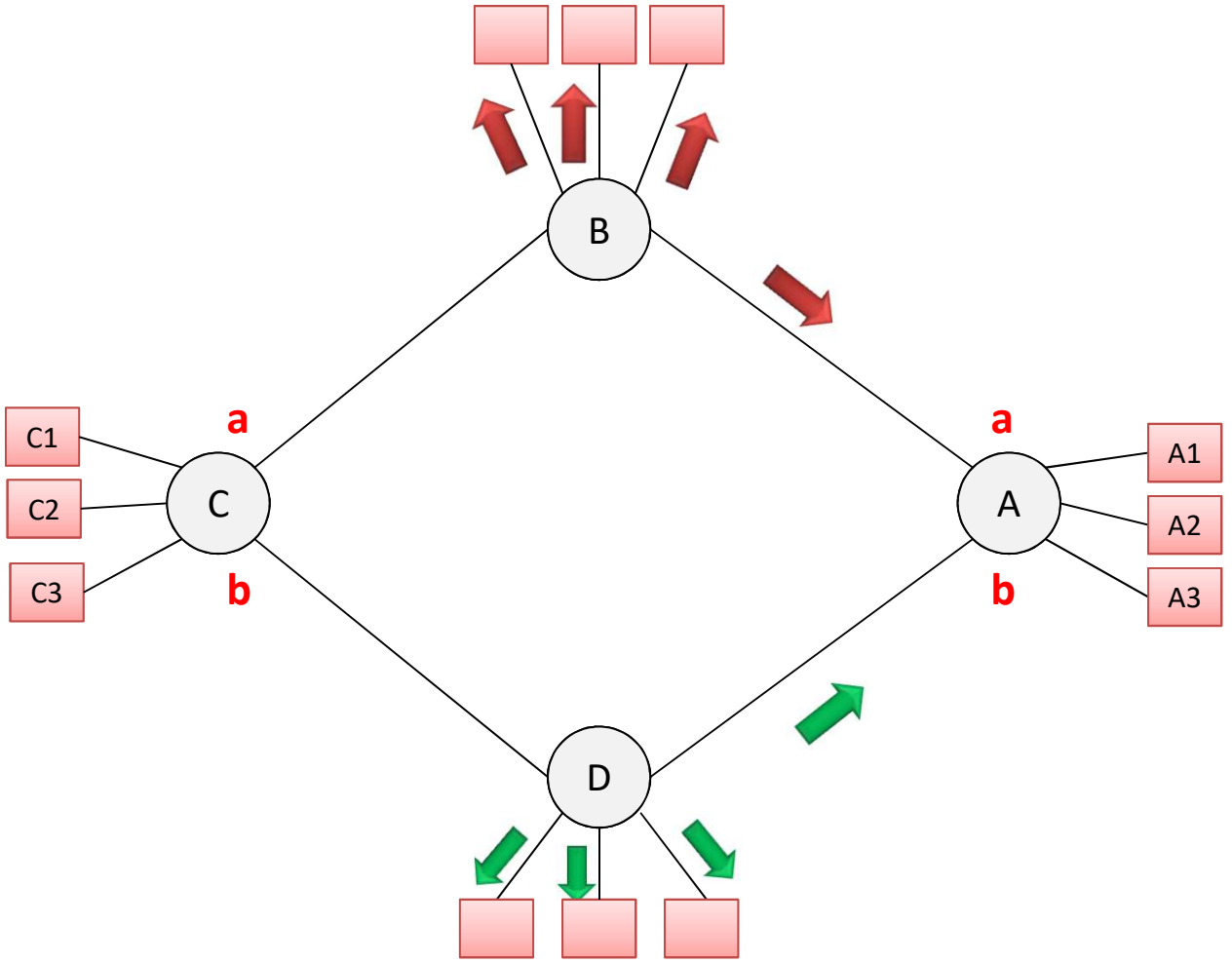
- SEthSwitches B and D will do the same step of SEthSwitch C.
- Finally, SEthSwitch A will receive two copies, one from each port.



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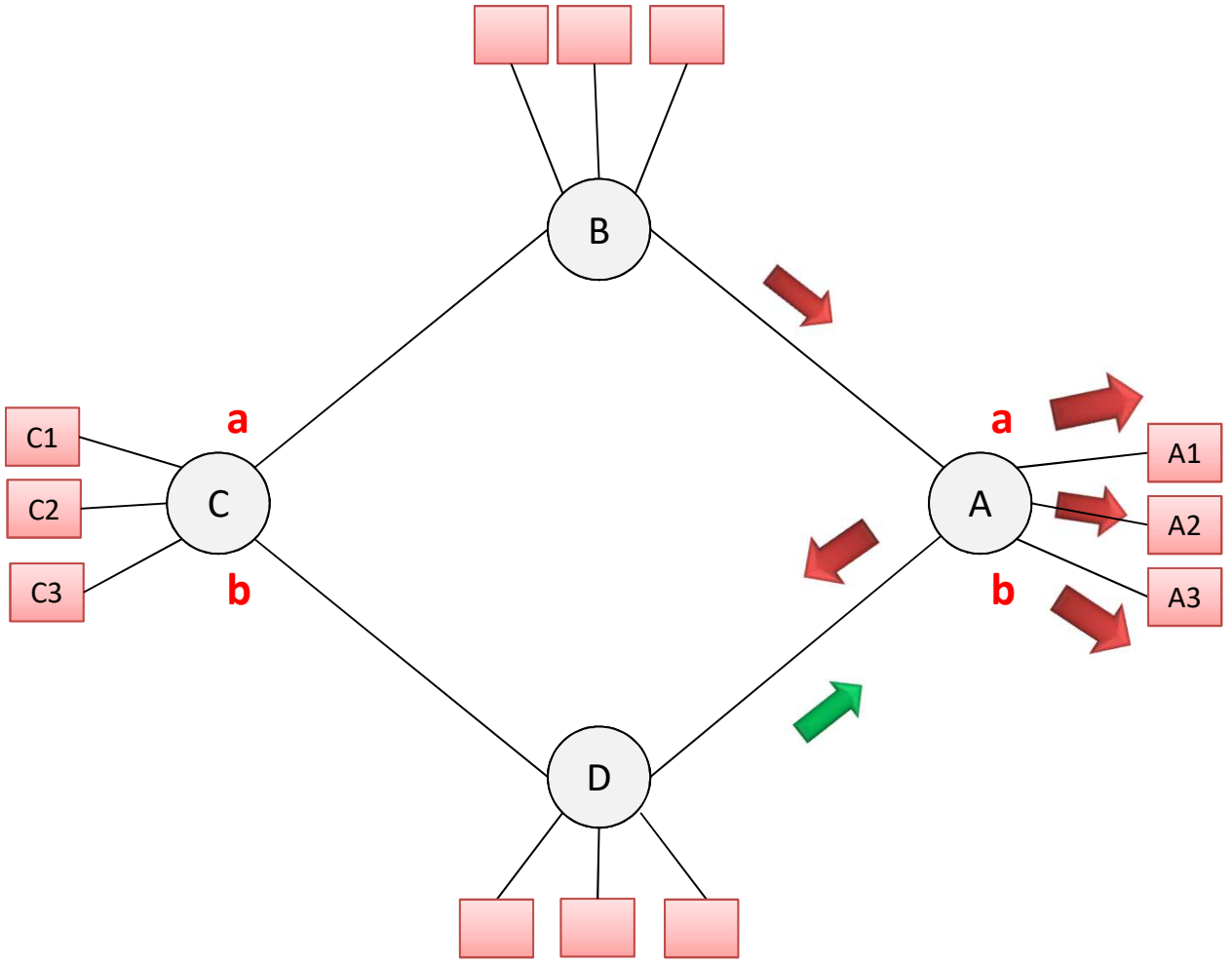
- Assume **SEthSwitch A** receives the fastest copy through port a, so it will flood it as long as it does not yet learned to which port node A1 is connected.



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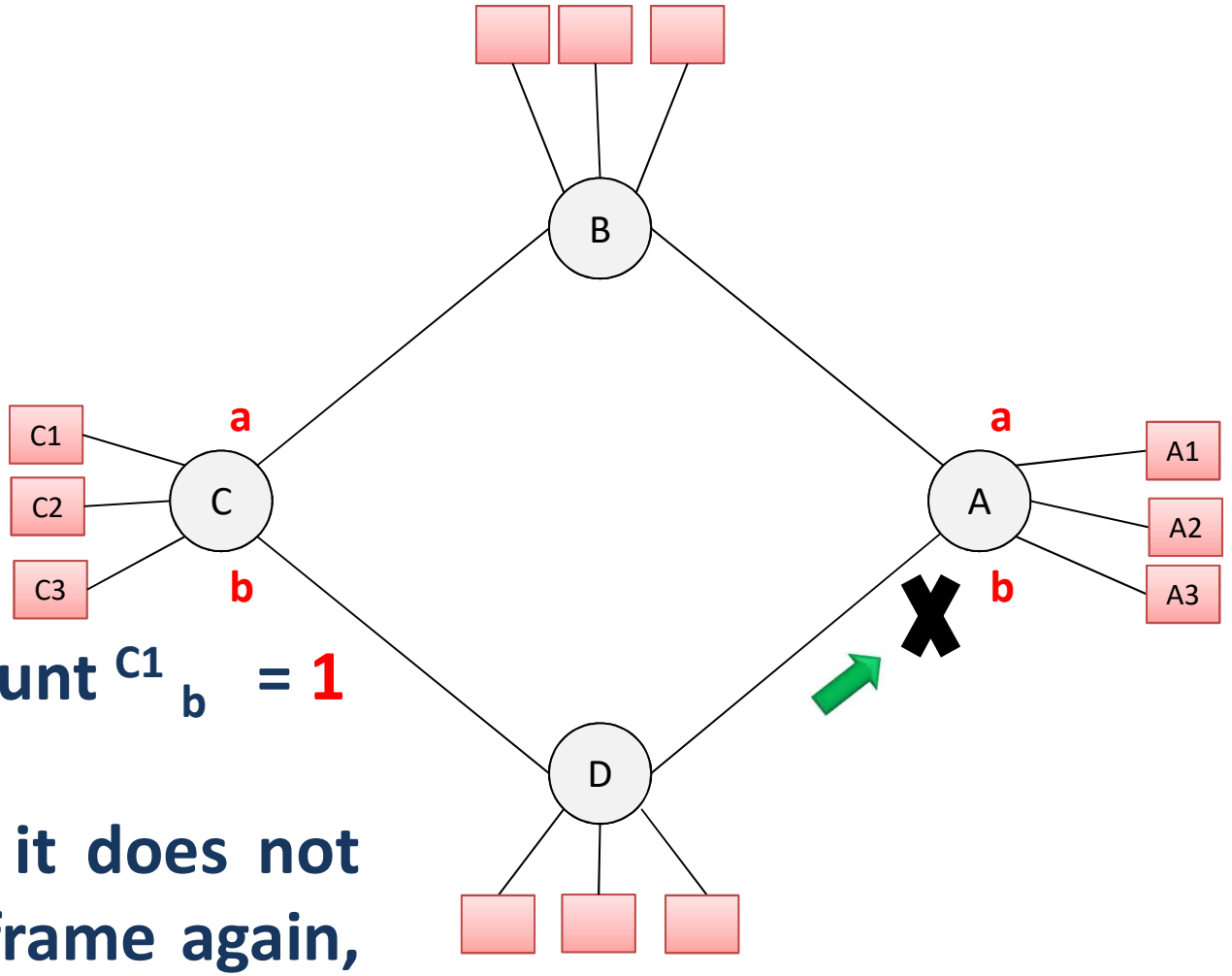
- Then **SEthSwitch A** will receive the second copy from port b.
- In this case,



Count $^{C1}{}_{a}$ = 1 , Count $^{C1}{}_{b}$ = 1

Which means that it does not need to flood the frame again, so it will drop it.

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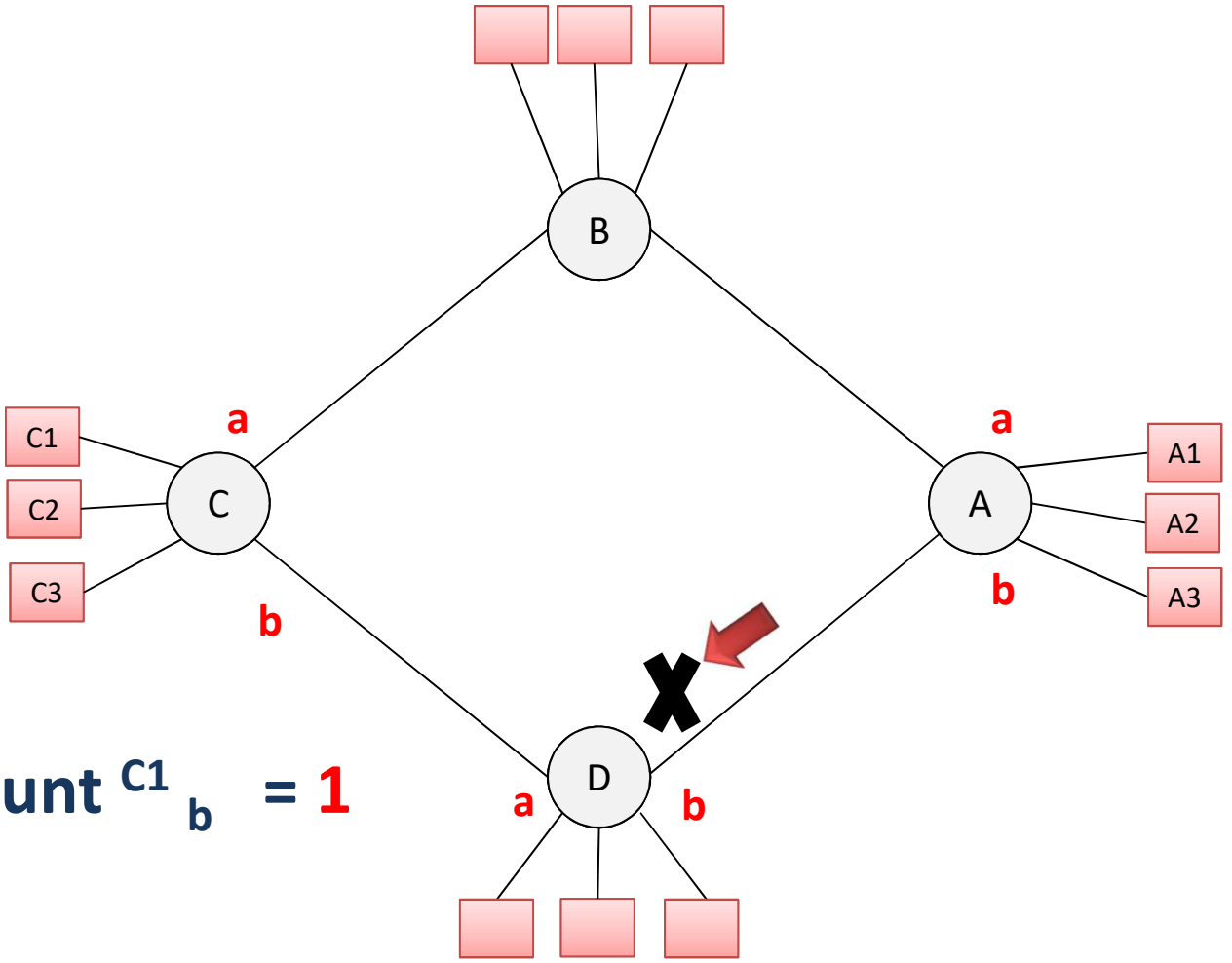
- However, SEthSwitch D will receive a copy from port b after received the first one through port a.
- In this case,

Count $^{C1}{}_{a}$ = 1 , Count $^{C1}{}_{b}$ = 1

So, SEthSwitch D will drop the copy.



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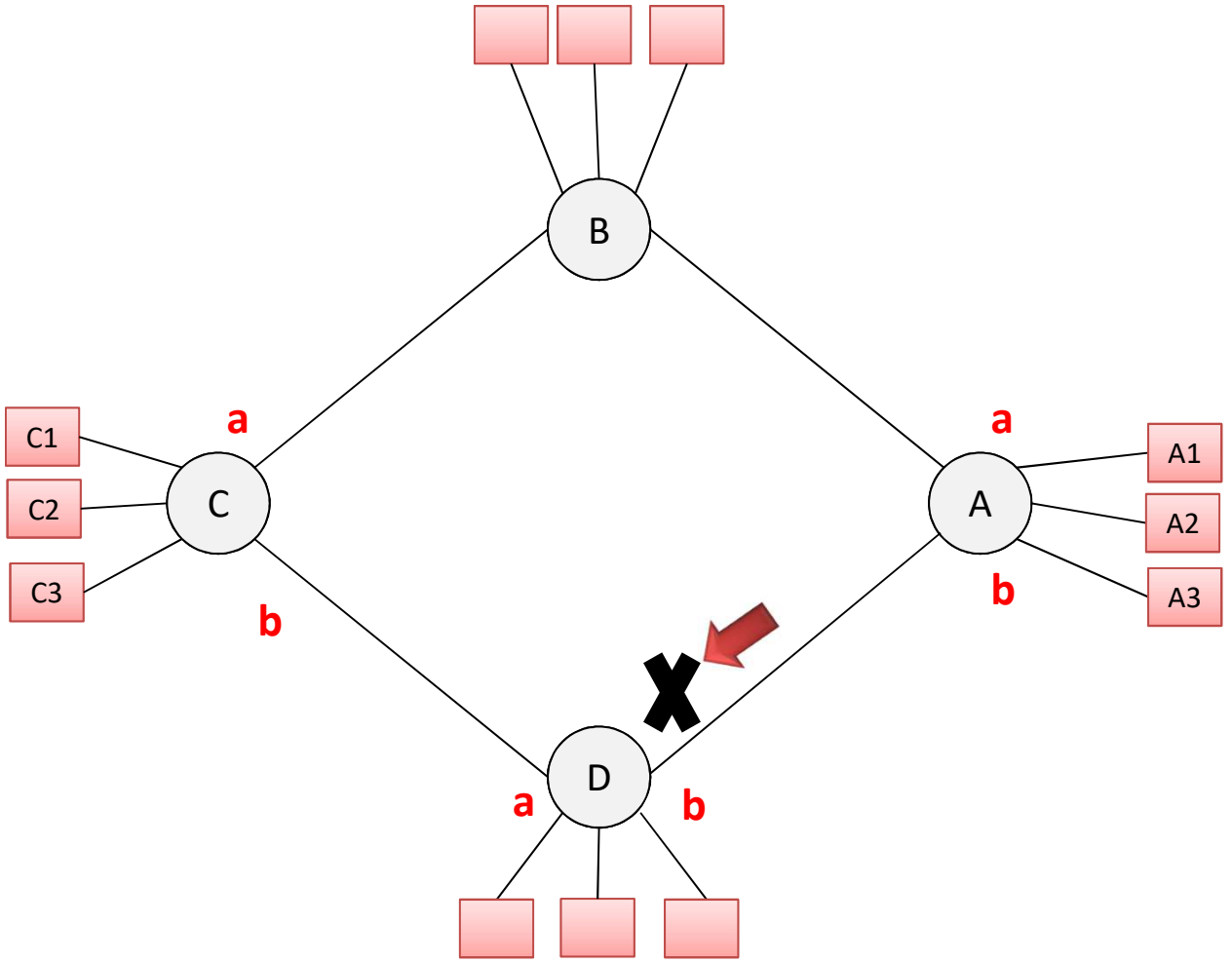
- This behavior of ***SEth*** approach also prevents the circulation of any frame with unknown destination MAC address.



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- **Important Note**

In *SEth* approach, the SEthSwitches will only list the MAC addresses of the local nodes that are connected to them, not all the domain's nodes. The reason behind that is that SEthSwitches duplicate and send each frame out to the required destination through the trunk ports (flood the frames into the trunk ports only).

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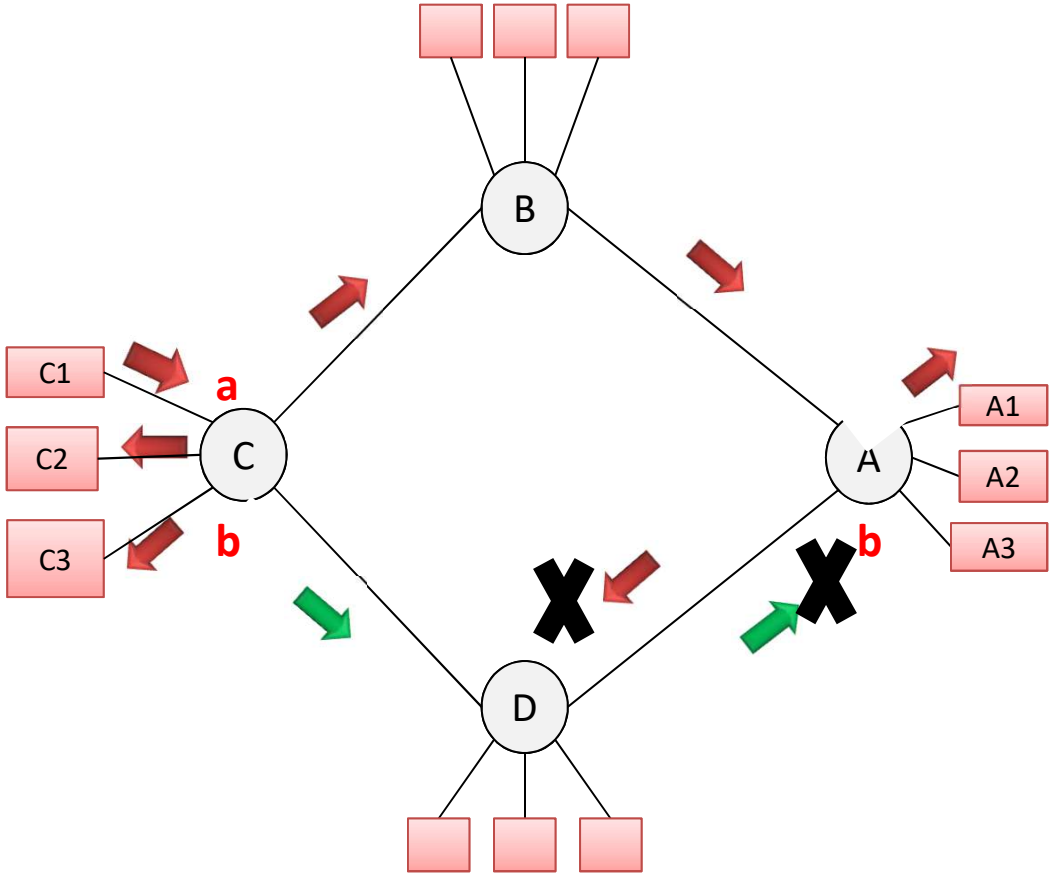
Operational Concept (Multi/Broadcast)

- If C1 broadcasts frames, then SEthSwitch C will flood it.
- SEthSwitches B and D will do the same.
- SEthSwitch A will receive the fastest copy, delete the second copy and then forward it to A1,2,and 3. Also flood it into trunk port.
- SEthSwitch A and D will delete the returning duplicated frames .



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Conclusions

- ***SEth*** can provide Ethernet redundancy without modifying the frame layout of IEEE 802.3. Consequently, all off-the-shelf Ethernet devices will have the capability to connect and run directly on the **SEthSwitch** without any modifications.
- All the network ports of the ***SEth*** nodes will be active, no need to block any of them.
- Can be applied on any topology type. It only needs some nodes that have more than two ports.
- Less traffic and processing time than standard HSR

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Thank you very much