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Seamless Ethernet (SEth) Approach without Ethernet frame modification

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CV

- SNU (BS,MS), NCSU(Ph.D., 1987), U of Mass.(postDoc, 1994)
  - electronics engineering(telecommunication)

- Agency for Defense Development, ADD(1978-1997),C4I and SATCOM PM
- DACOM (1997-1999), R&D Center Head
- Hanaro Telecom(CTO, Executive Senior VP, 1999-2005),
  - world-firstly serviced ADSL, CM
- Myongji University(2006-present)
  - Served as Executive vice-president, academic affair
  - Developed Ethernet fault tolerant HW and SW for battleship network, SAFE, RSAFE, 2006-2011,
  - Developed more than 10 HSR traffic reduction algorithms since 2012 (QR (=mode X , IEC62439-3), DVP, PL, EPL, FHT, MRT, RMT, and etc.)
  - Proposed wireless HSR and pure O(optic)HSR

* university startup (2015,10-) MPEES:
  HSR prototyping, optic XYZ color sensor, swimming pool IT

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Scope

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

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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 any modification or changes in the frame layout.

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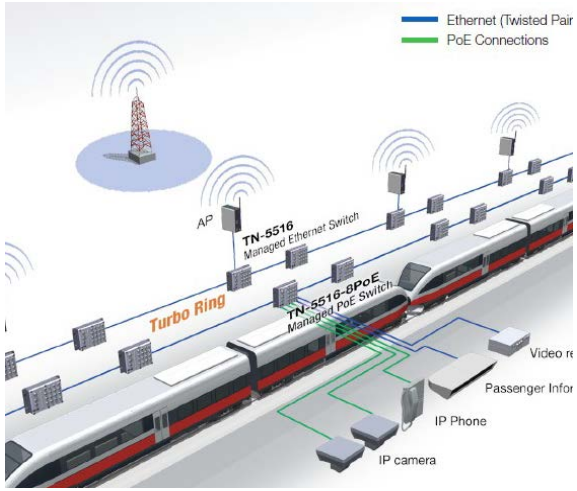
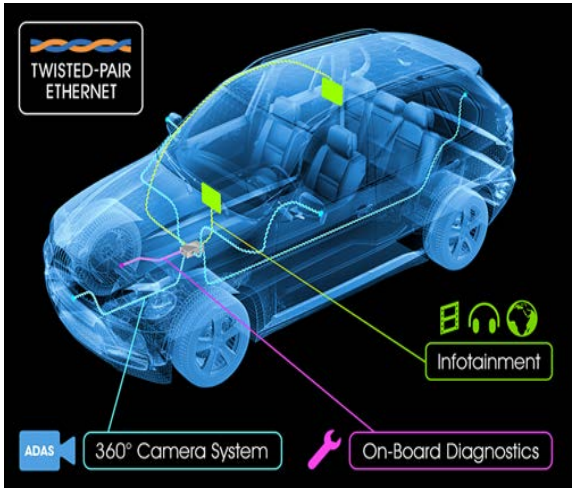
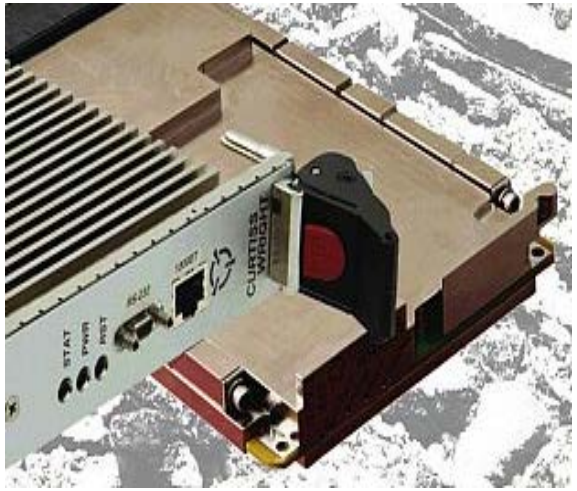
Ethernet Applications







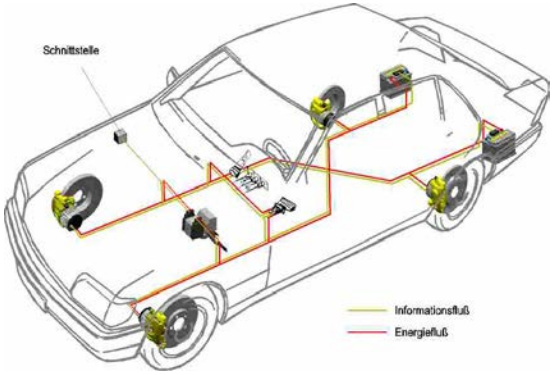
Fail-over Time Requirements: "Seamless" becomes more important

cement: < 10s

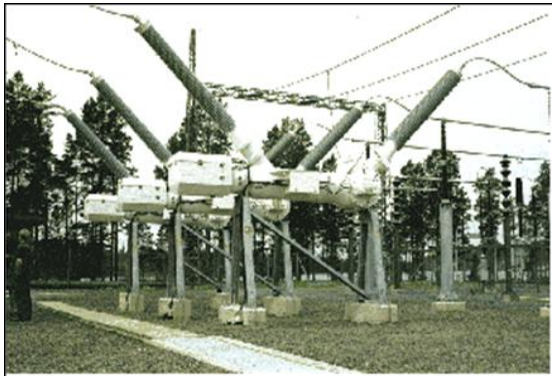
printing: < 20ms

chemical: < 1s

tilting train: < 100 ms



X-by wire: < 10 ms



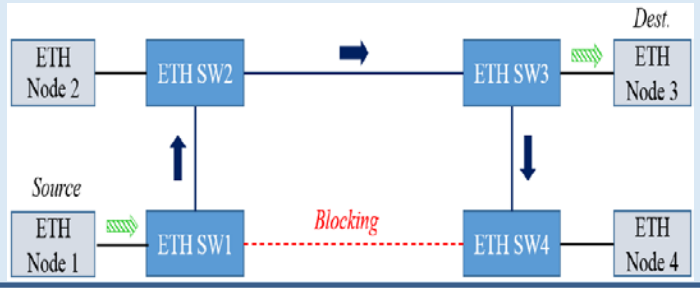
substations: < 3 ms

Ethernet and HSR

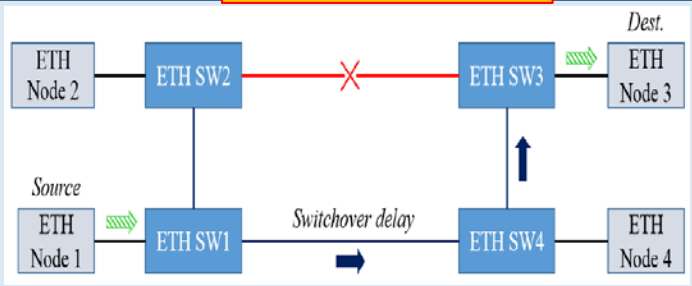
- ☞ For wired network application, Ethernet (standardized as IEEE802.3) is dominant and usually adopts RSTP (Rapid Spanning Tree Protocol) for Fault Recovery.
- ☞ However, RSTP cannot provide "seamless" since it needs around one second for reconfiguration when the network fails.
- ☞ Therefore, IEC62439-3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

* But HSR needs the modification of Ethernet frame. In this presentation we propose seamless Ethernet which uses conventional Ethernet without modification.

Ethernet (normal operation)



RSTP operation with network failure



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HSR

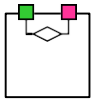
HSR (High-availability Seamless Redundancy) is an Ethernet (IEEE 802.3) protocol.

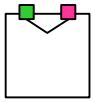
- Theoretical zero failover time.
- Any configuration possible: Ring, Connected Ring(Ring of Rings), Mesh.
- Several redundancy protocols have been developed by IEC.
  - Among theses, PRP and HSR provide “seamless”.
    But PRP needs duplicated hardware.

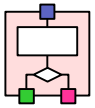
Protocol	CRP	DRP	MRP	BRP	RRP	PRP	HSR
IEC Std	62439-4	62439-6	62439-2	62439-5	62439-7	62439-3	62439-3
Topology	Mesh Cross	Ring Double Ring	Ring	Double Mesh	Single Ring	Mesh Ring	Ring Mesh
Fail-over time	1s	100ms	10-500ms	8.88ms	8ms, 4ms	0s	0s

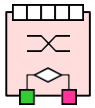
HSR notation


SAN singly attached node (not HSR)

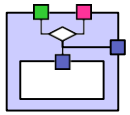

DANH node with 2 HSR ports

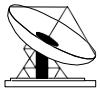

DANP node with 2 PRP ports


Redbox with one single port


Redbox switch (RSTP) to HSR

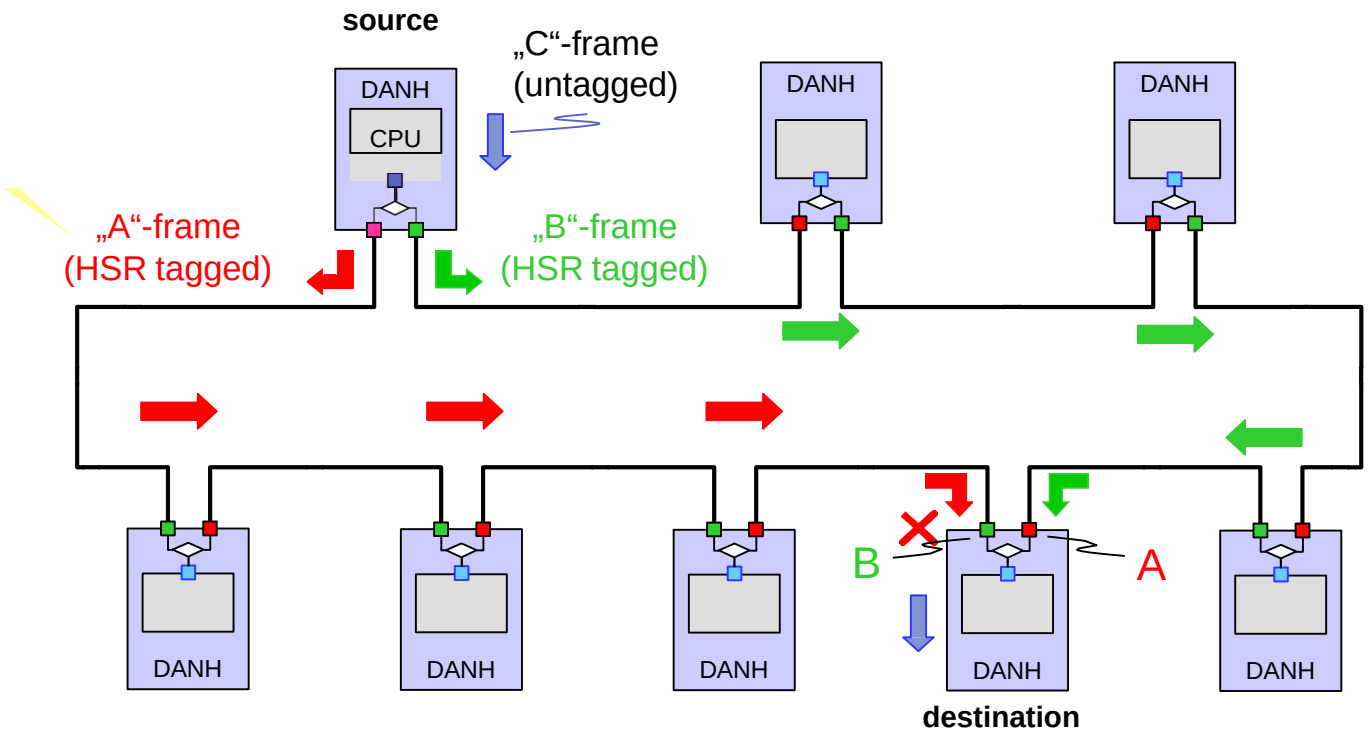

QuadBox


HSR node with auxiliary port

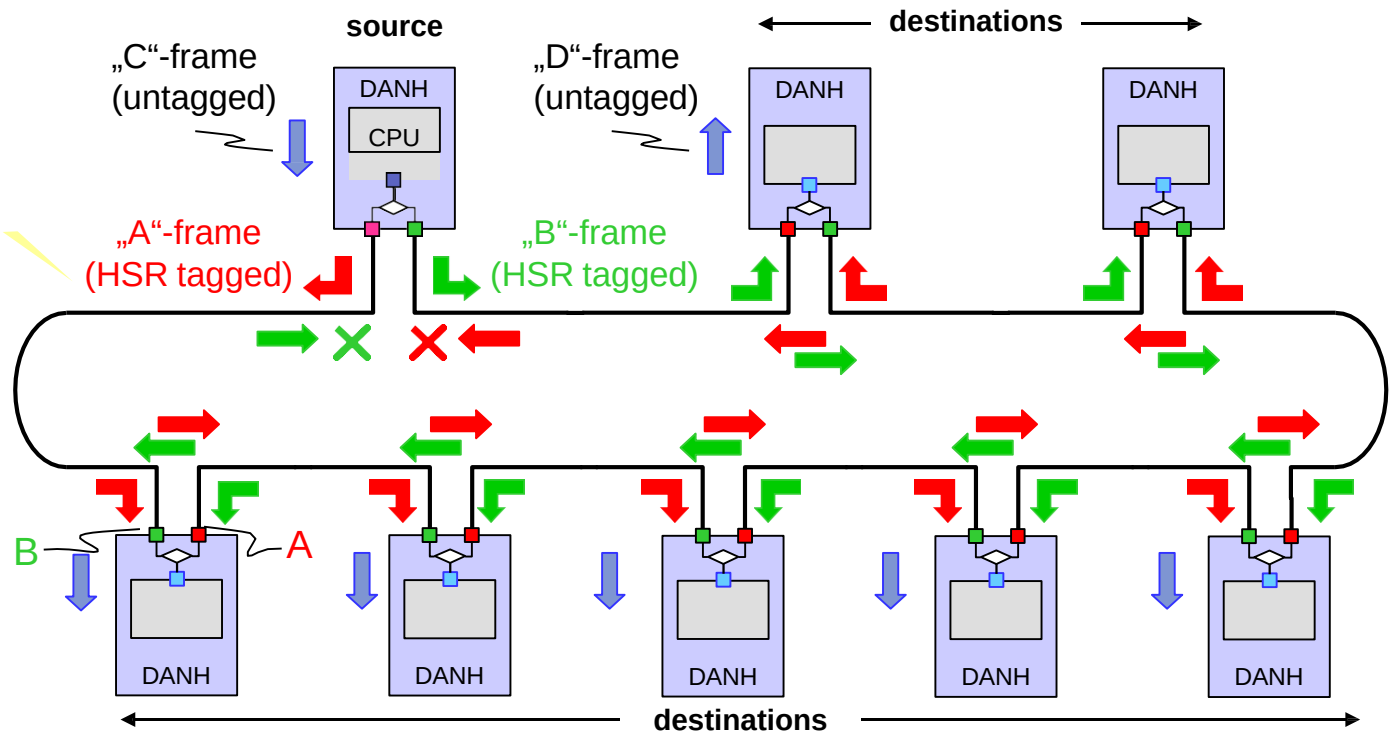

GPS time server

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

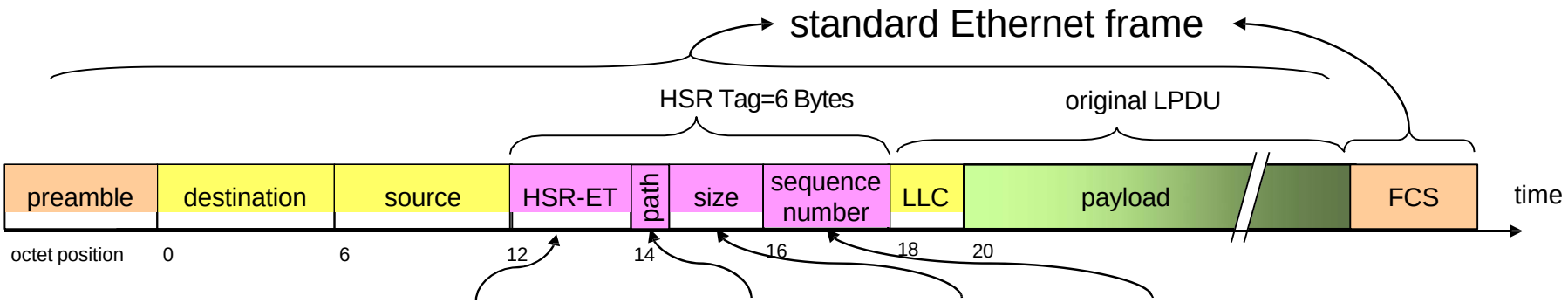
HSR (Unicast)


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

HSR (Multicast/Broadcast)



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 needs Ethernet frame modification due to HSR Tag.

- In this presentation we propose “seamless Ethernet” which provides zero failover time without Ethernet frame change.

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Terminologies

- **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 duplicates each sent frame and sends each copy through a port, whereas in receiving phase, it uses the ***SEth*** procedure to eliminate the redundant frames.

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Cont..

- **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 sends them out.

Whereas for receiving redundant frames, it uses **SEth** Approach for eliminating the redundant one.

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Operation 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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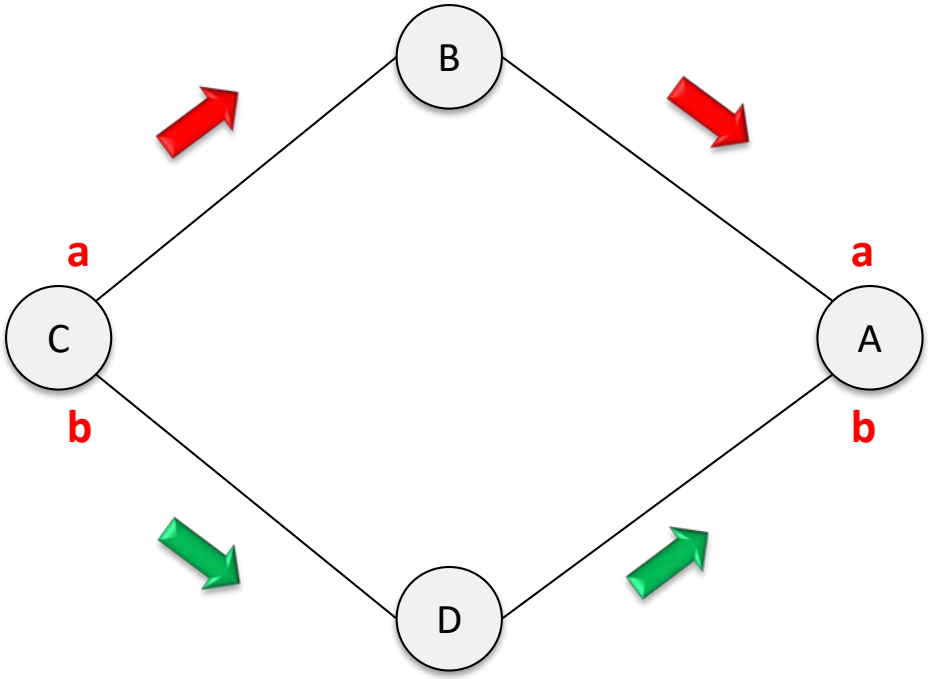
Operation Concept (Unicast Traffic)

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



- 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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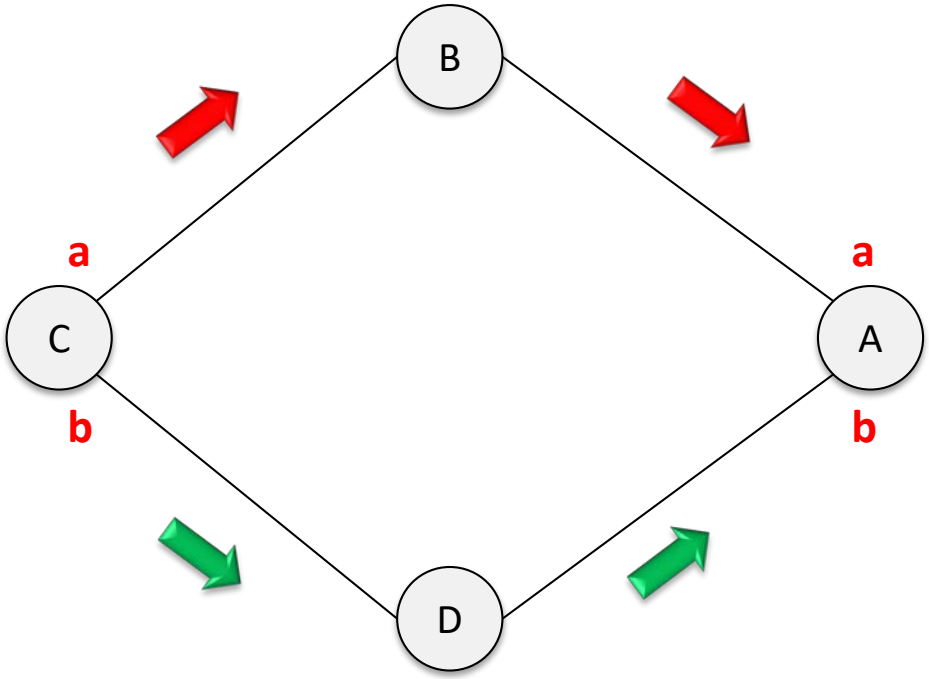
Cont…

- **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**.

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

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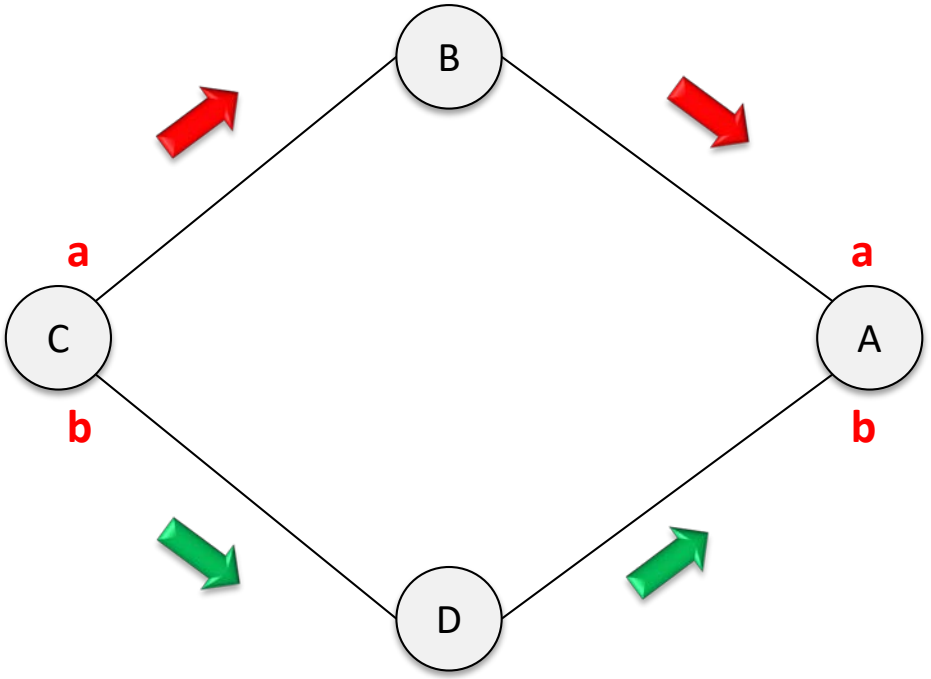
Cont…

- 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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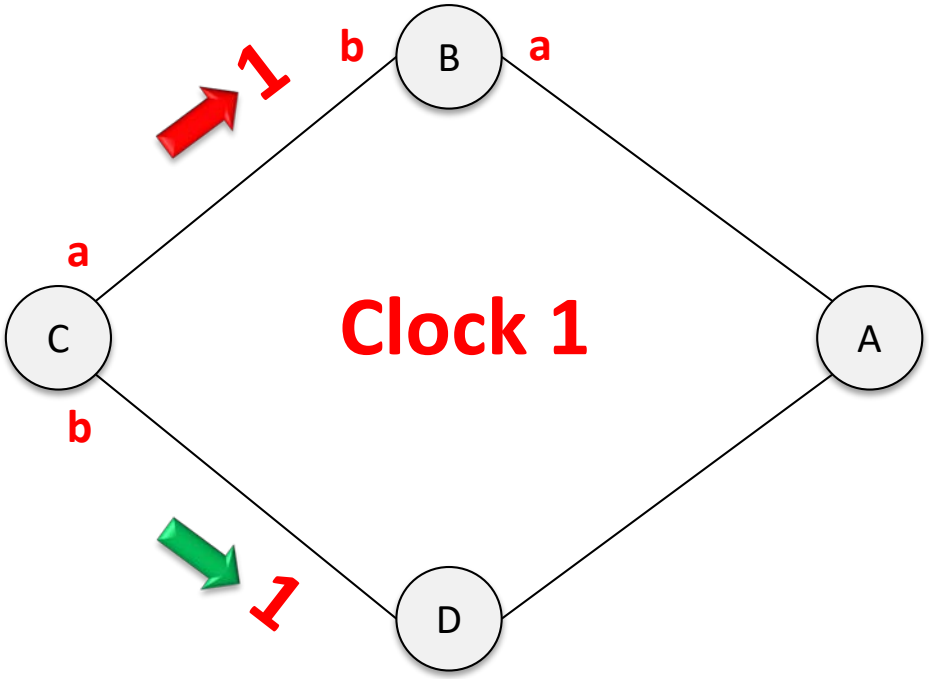
Cont…

- 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, when it was error-free.

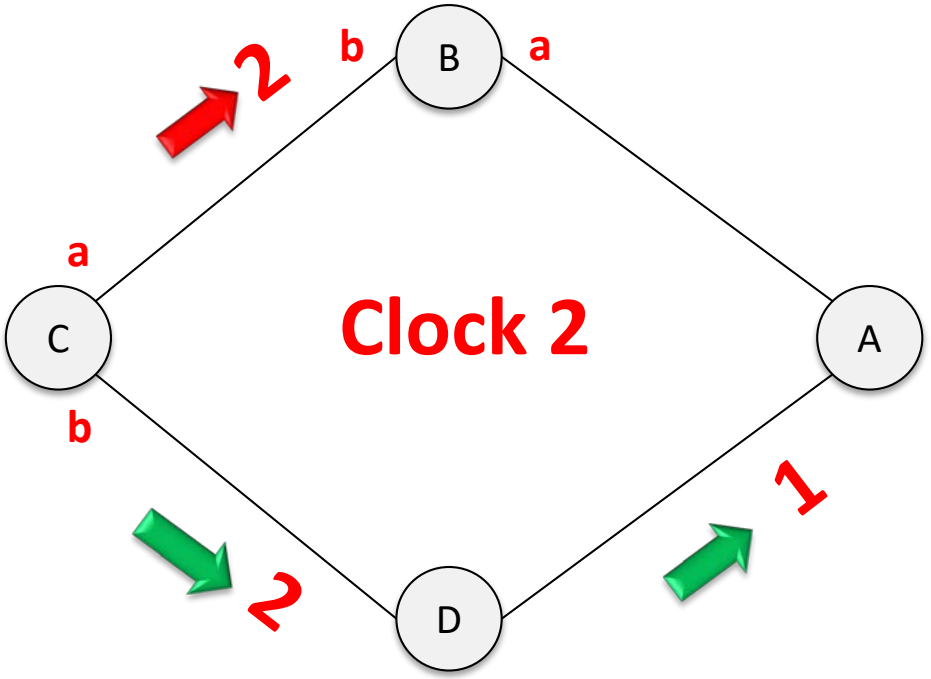
Therefore, SEthNode B will consume it and will delete the copy of port a after delivering it in the next 2 clocks



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

Cont…

- Assume 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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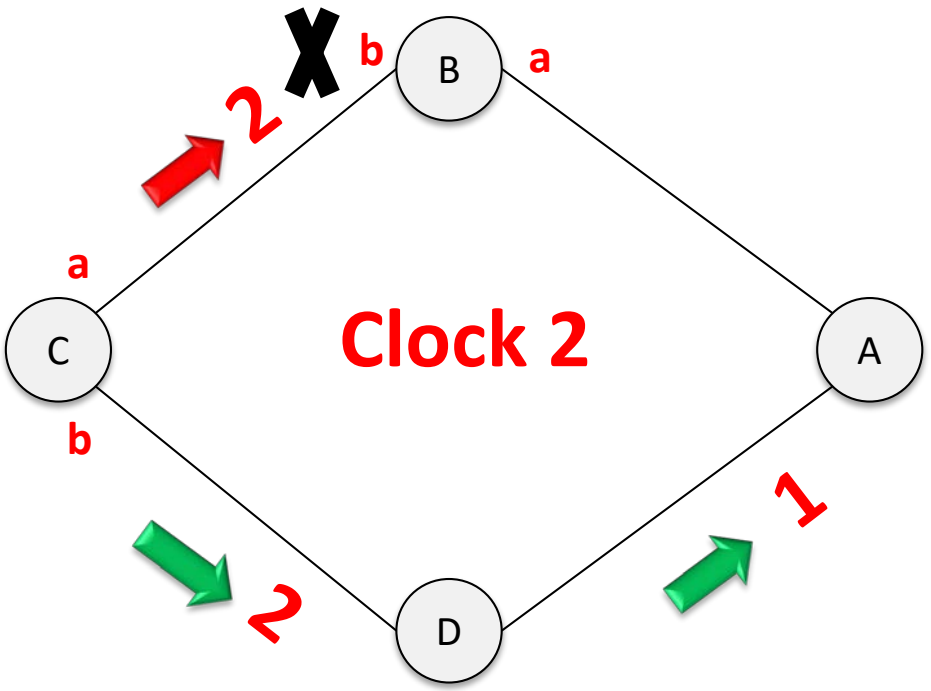
Cont…

- 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) during port (a) second clock.



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

Clock number	Port number that should receive from
2	a

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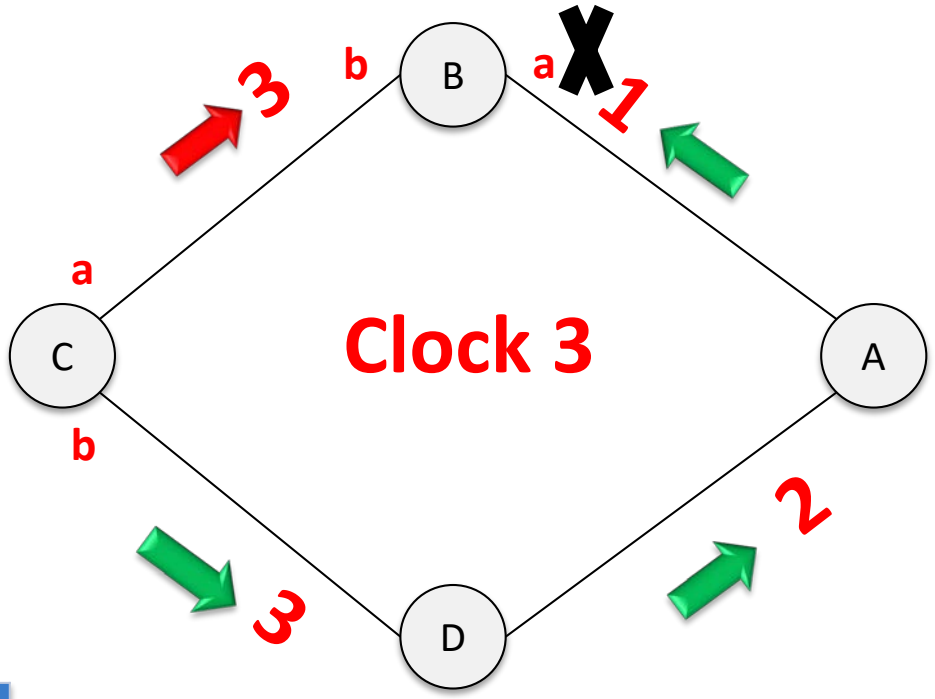
Cont…

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



Clock number	Port number that should receive from
2	a

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

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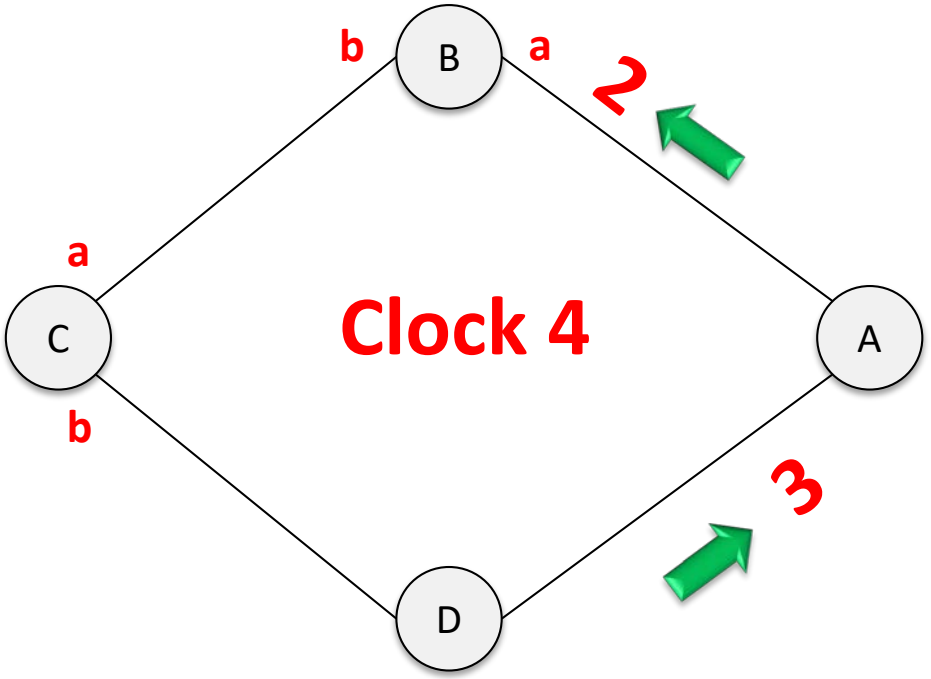
Cont…

- 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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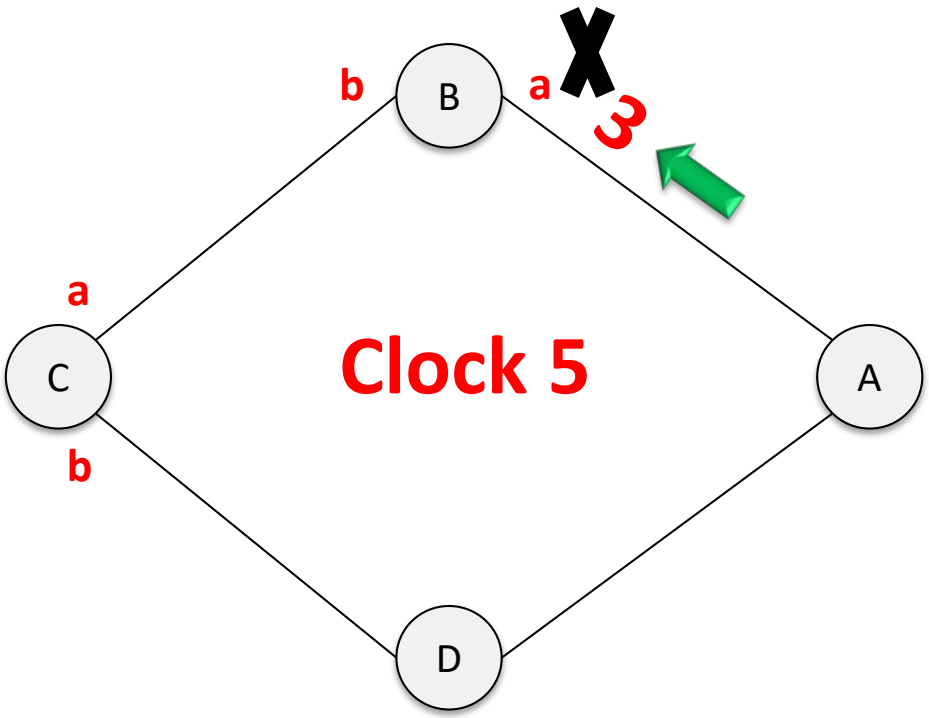
Cont…

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



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

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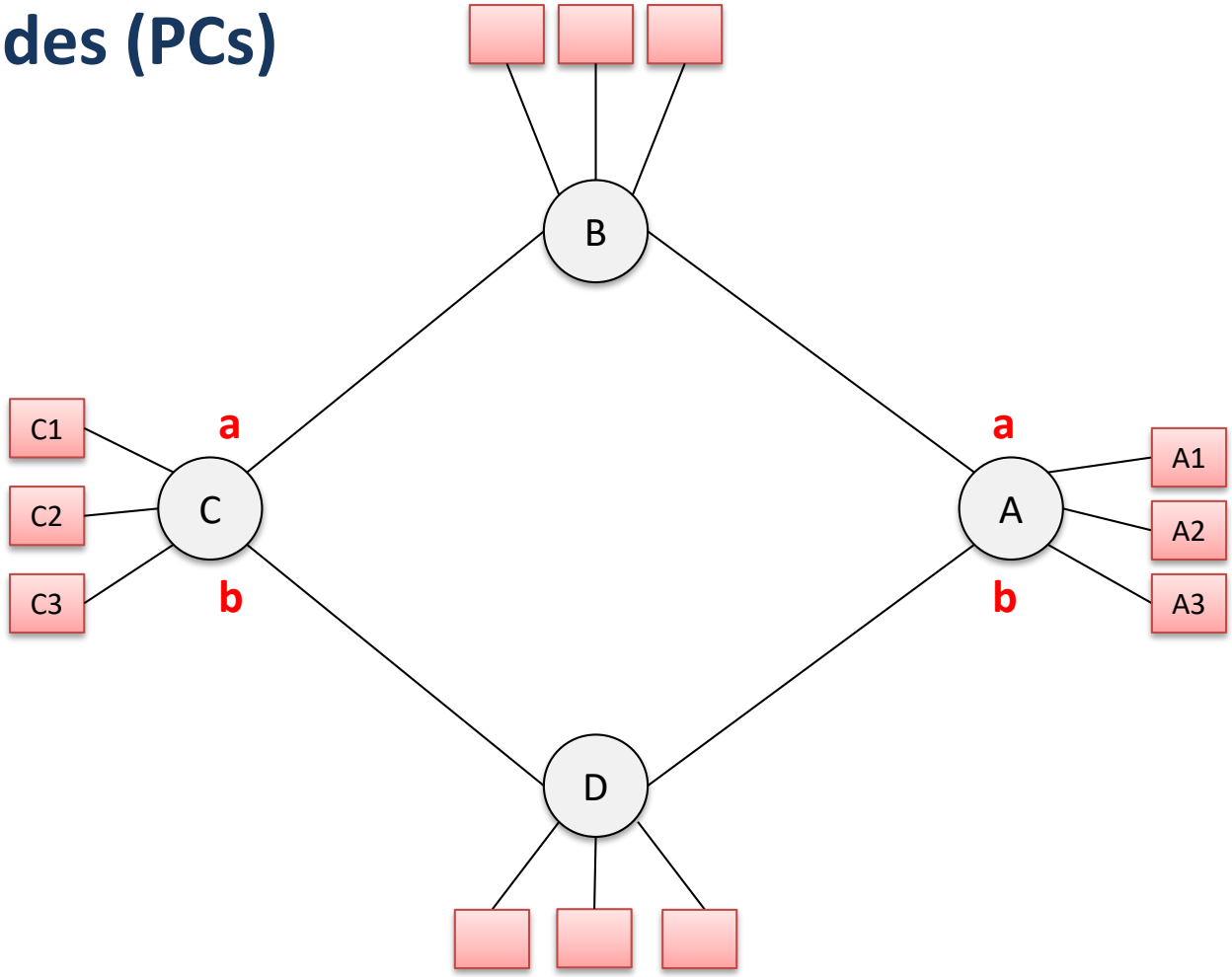
- **SEthSwitch and off-the-shelf Ethernet nodes (PCs) connected to the SEthSwitches.**

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



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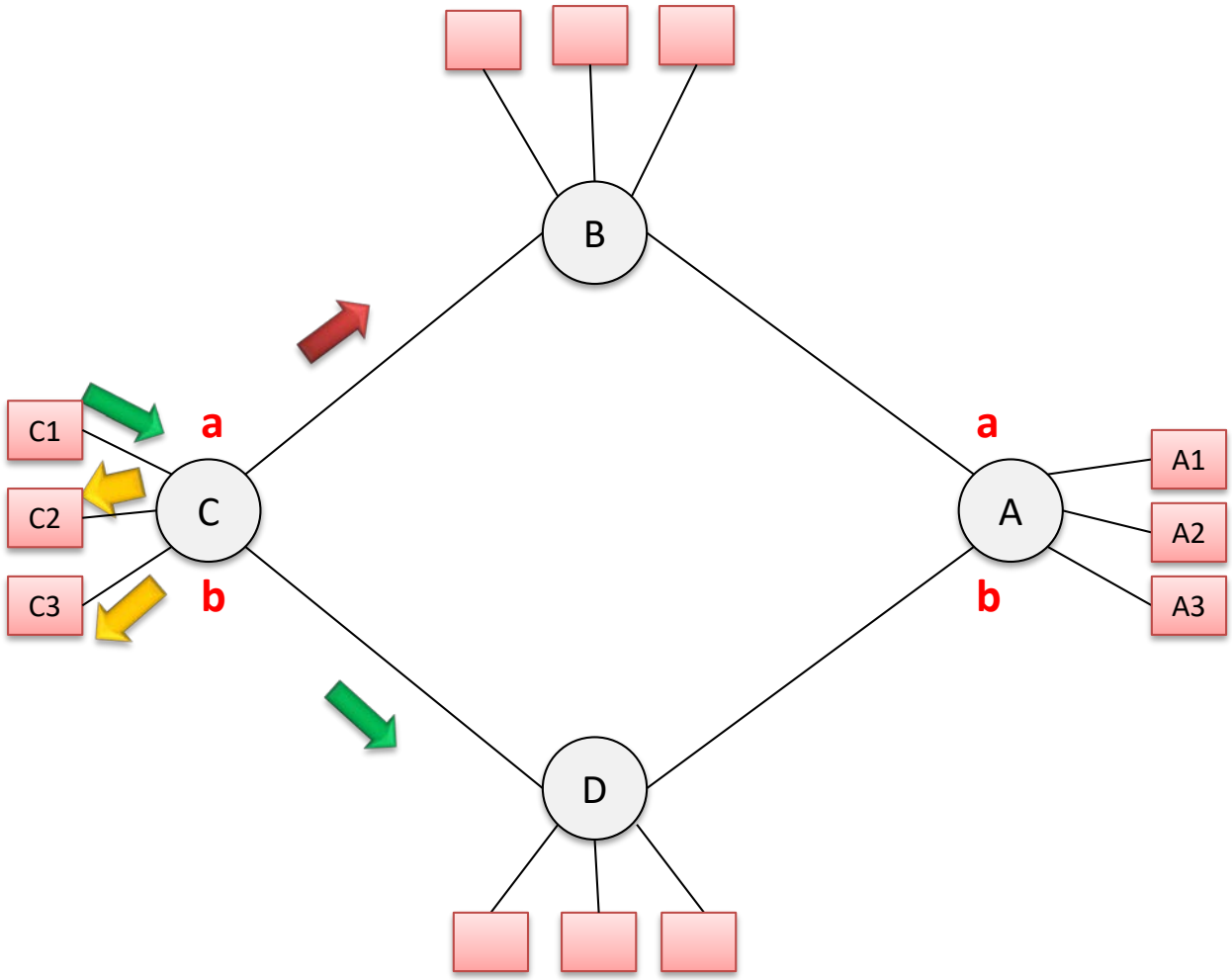
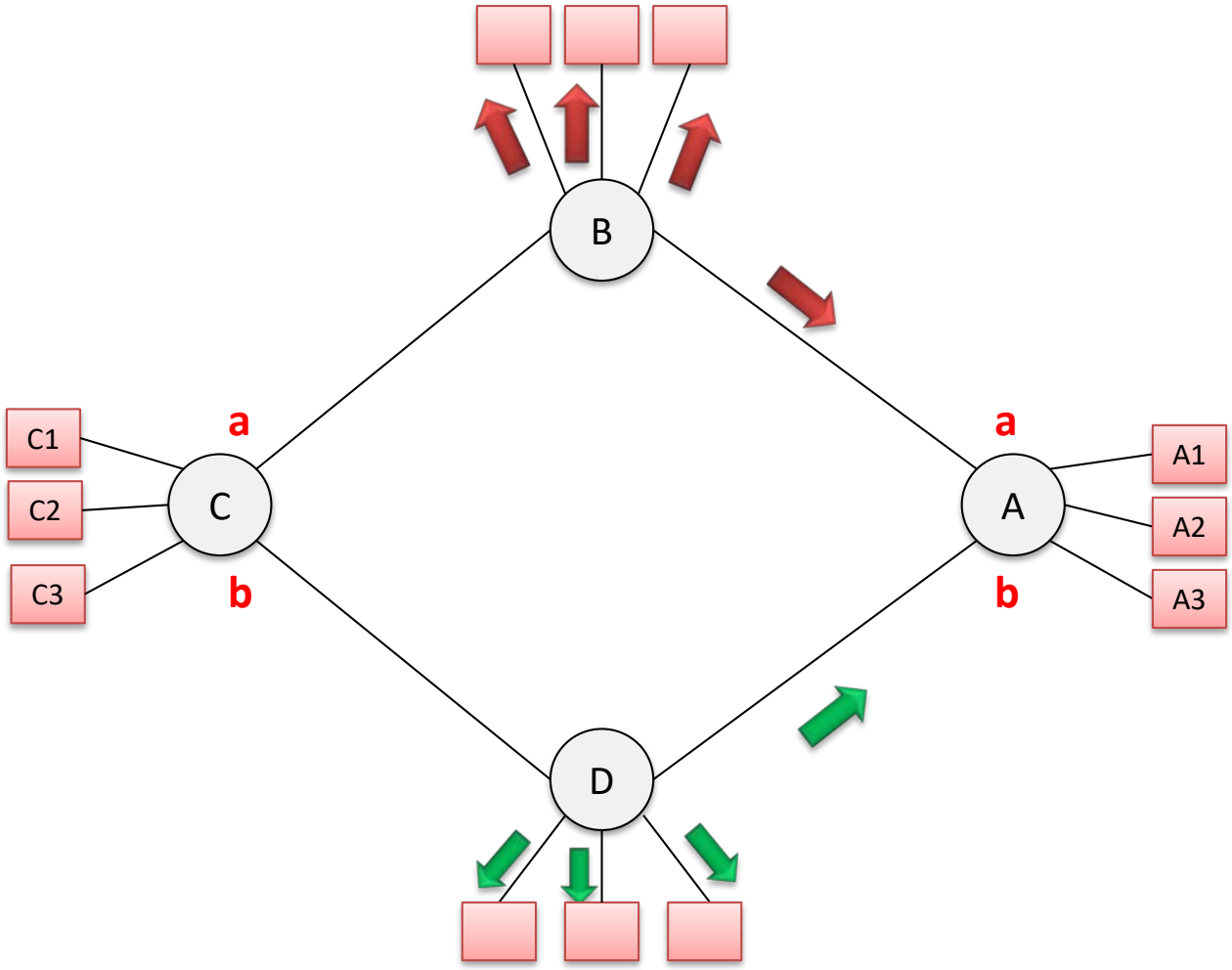
- In this case, SEthSwitch C will receive the frame from node C1, and then flood it into its local ports as well as its trunk port (Assume empty MAC address table).



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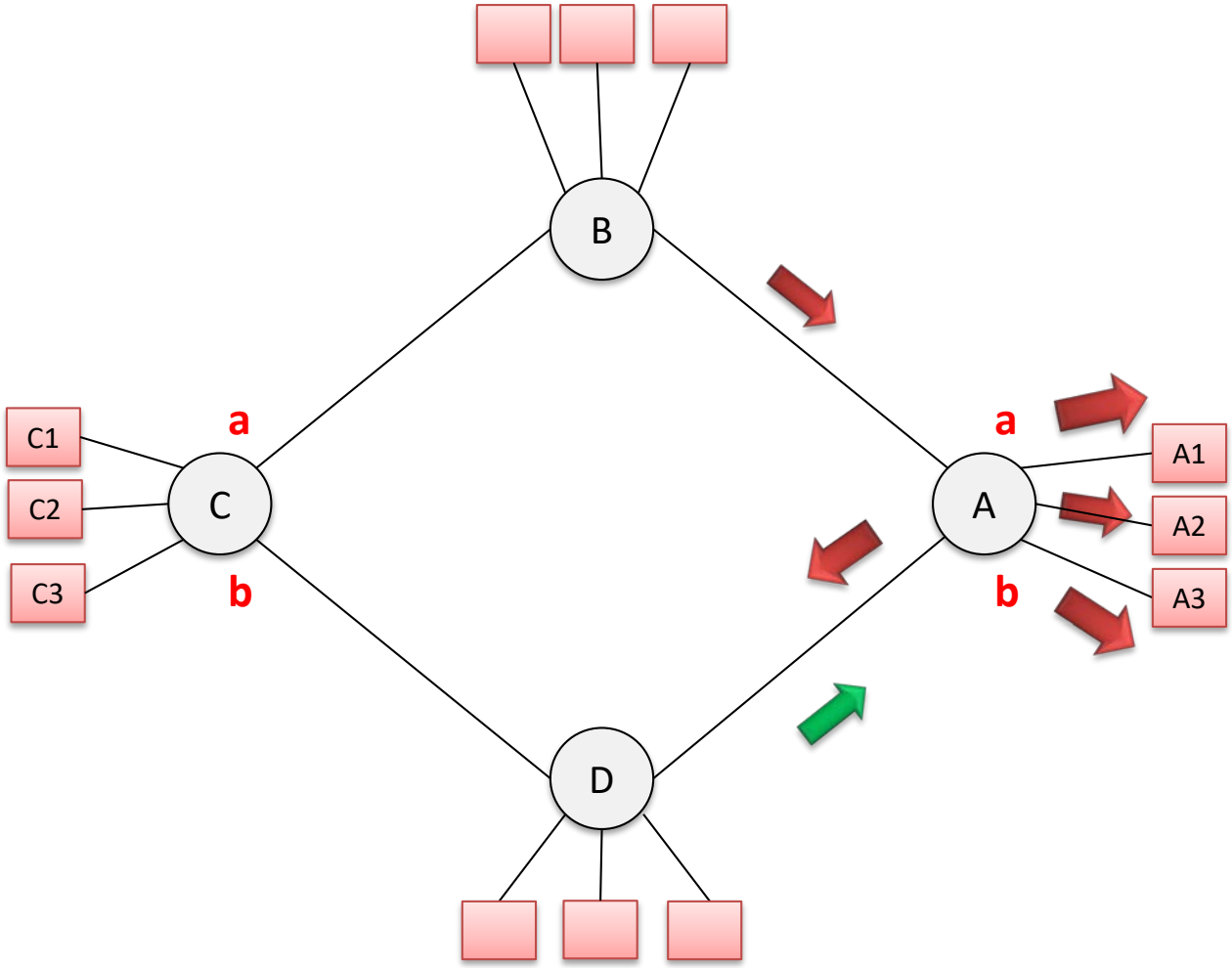
- Assume **SEthSwitch A** receives the fastest copy through port (a), so it will flood it as long as it has not yet learned to which port node A1 is connected.



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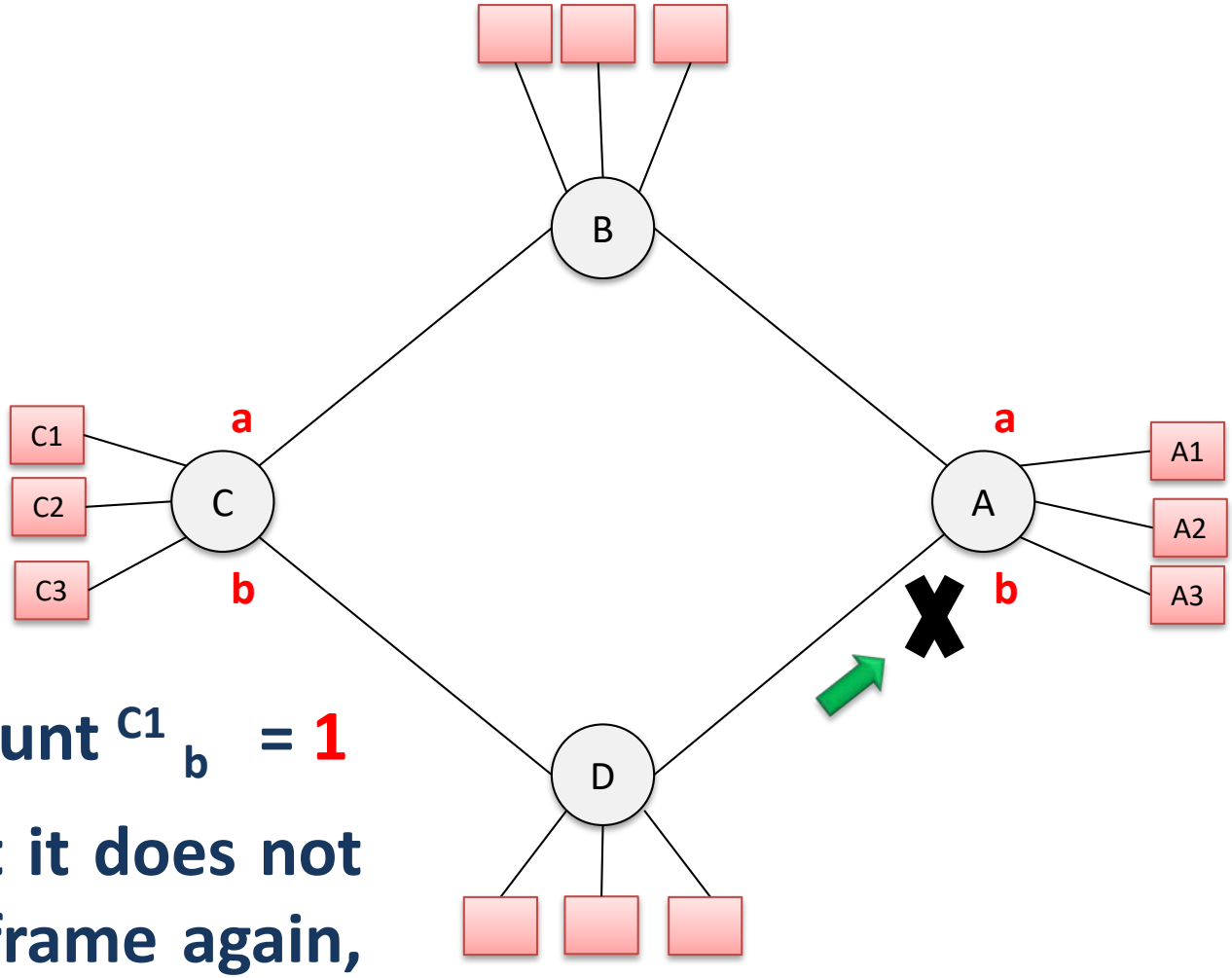
- Then **SEthSwitch A** will receive the second copy from port (b).
- In this case,



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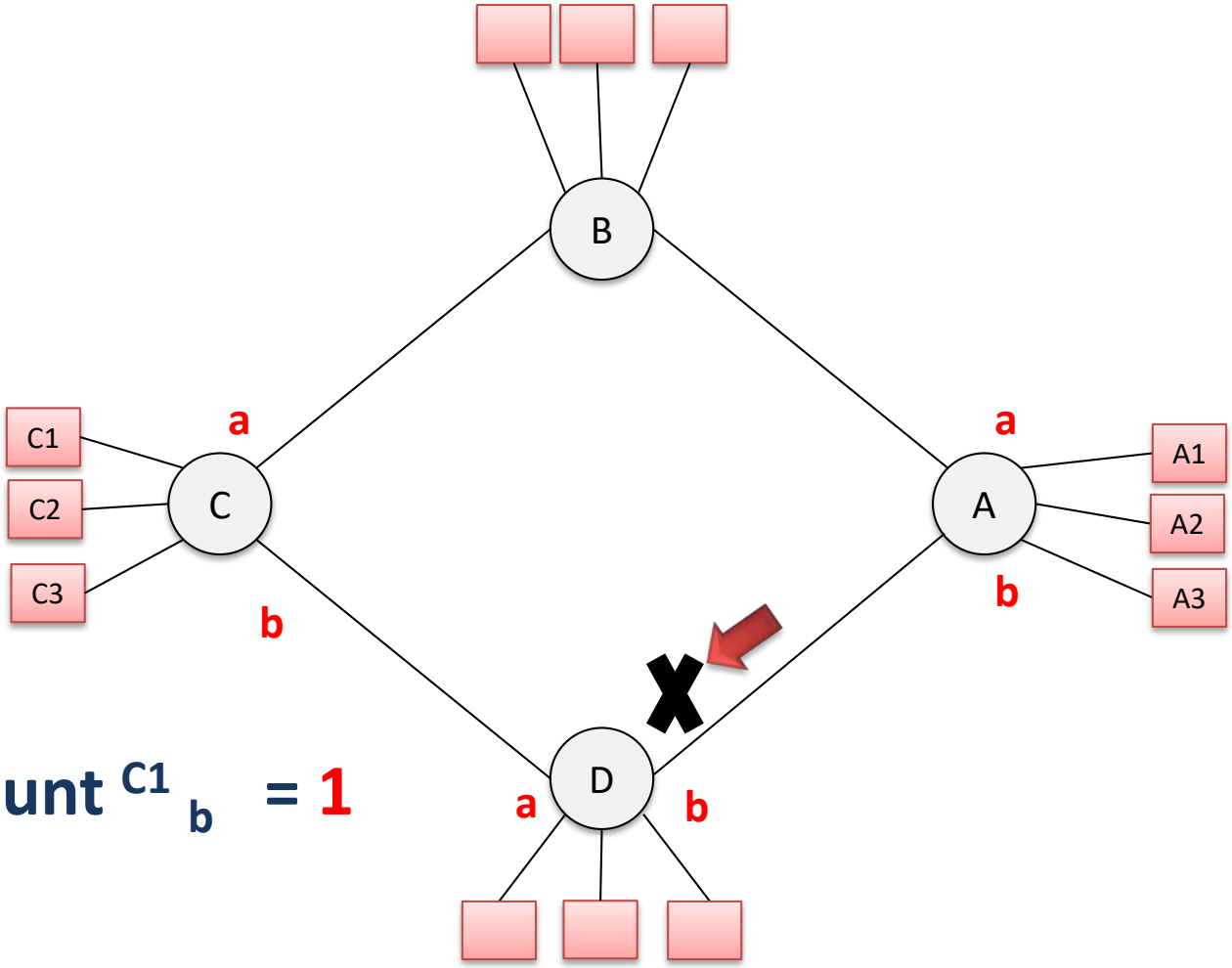
- However, SEthSwitch D will receive a copy from port (b) after received the first one through port (a), in this case,



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

So, SEthSwitch D will drop the copy.

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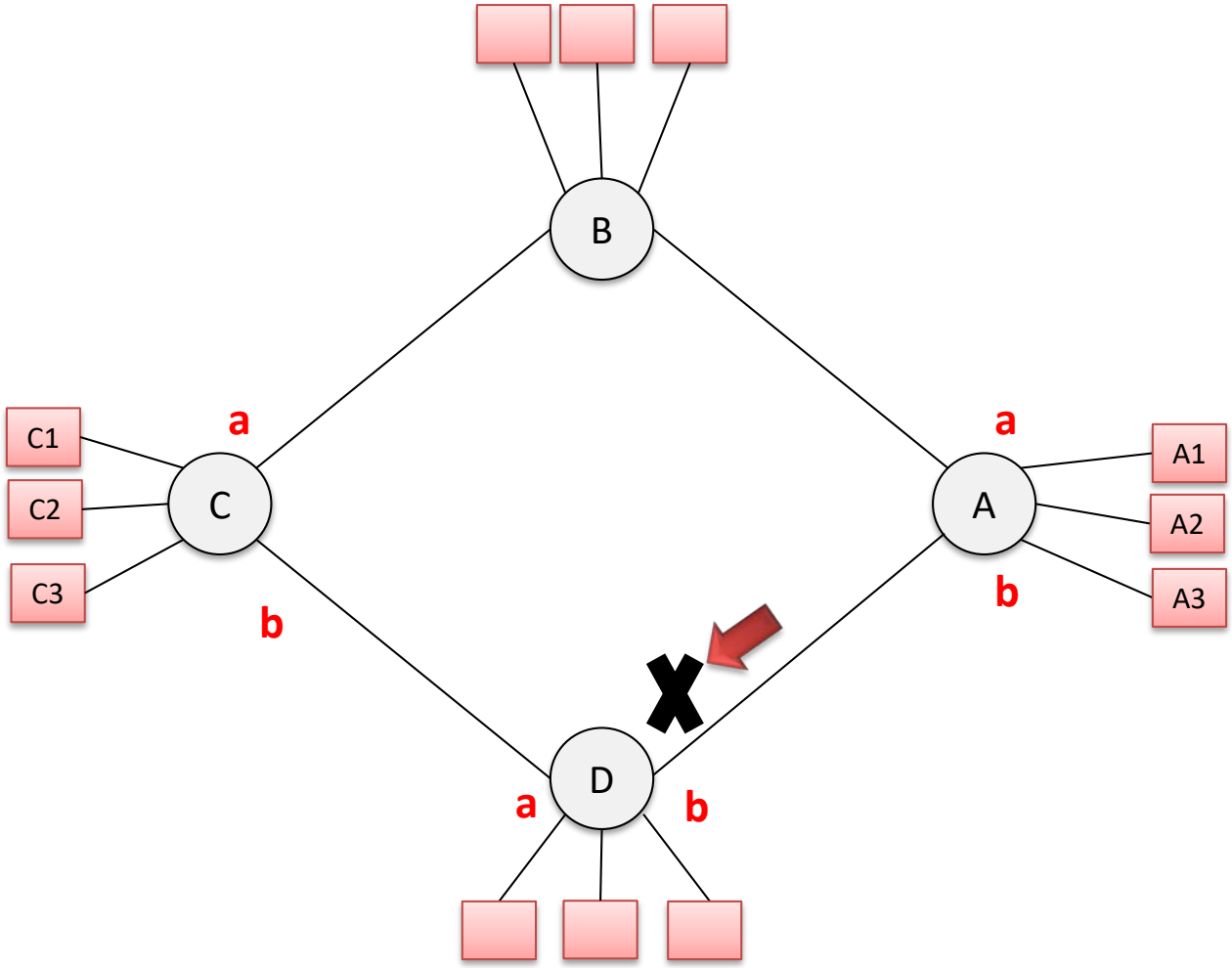
- This behavior of SEth approach also prevents the circulation of any frame with unknown destination MAC address.



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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 this is that SEthSwitches duplicate and send each frame out to the required destination through the trunk ports only(flood the frames into the trunk ports only).

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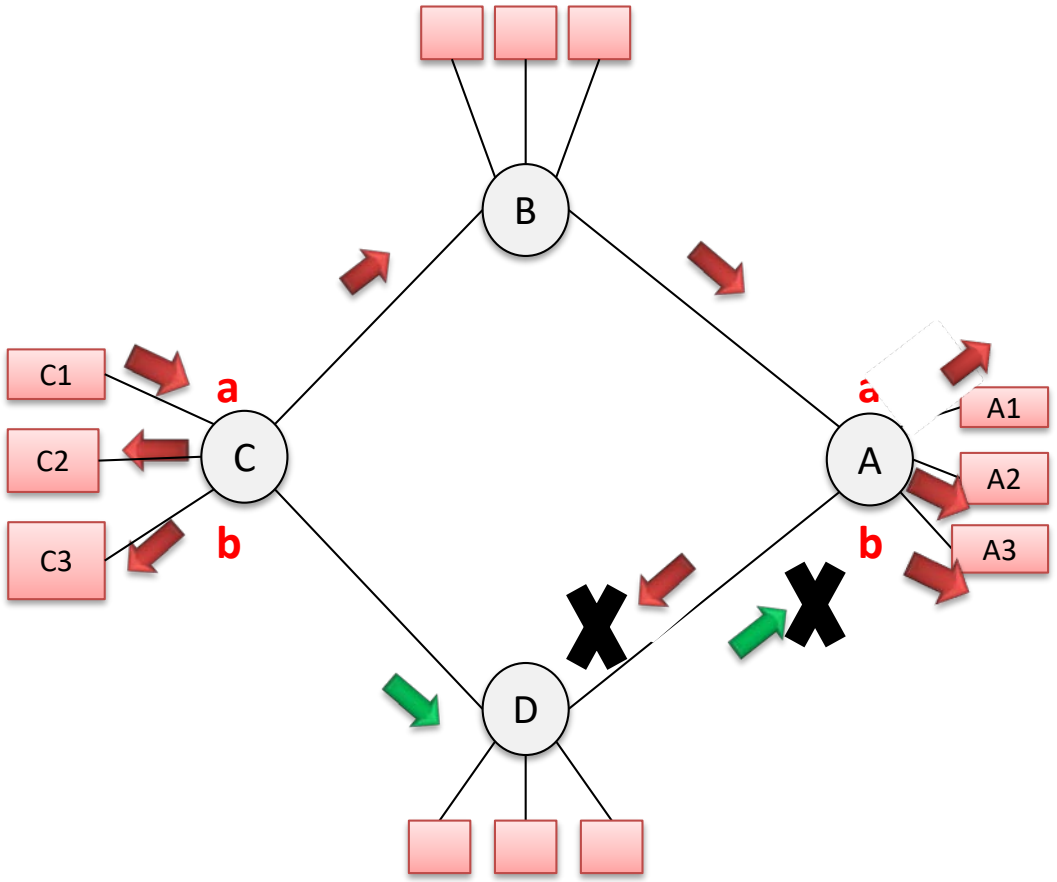
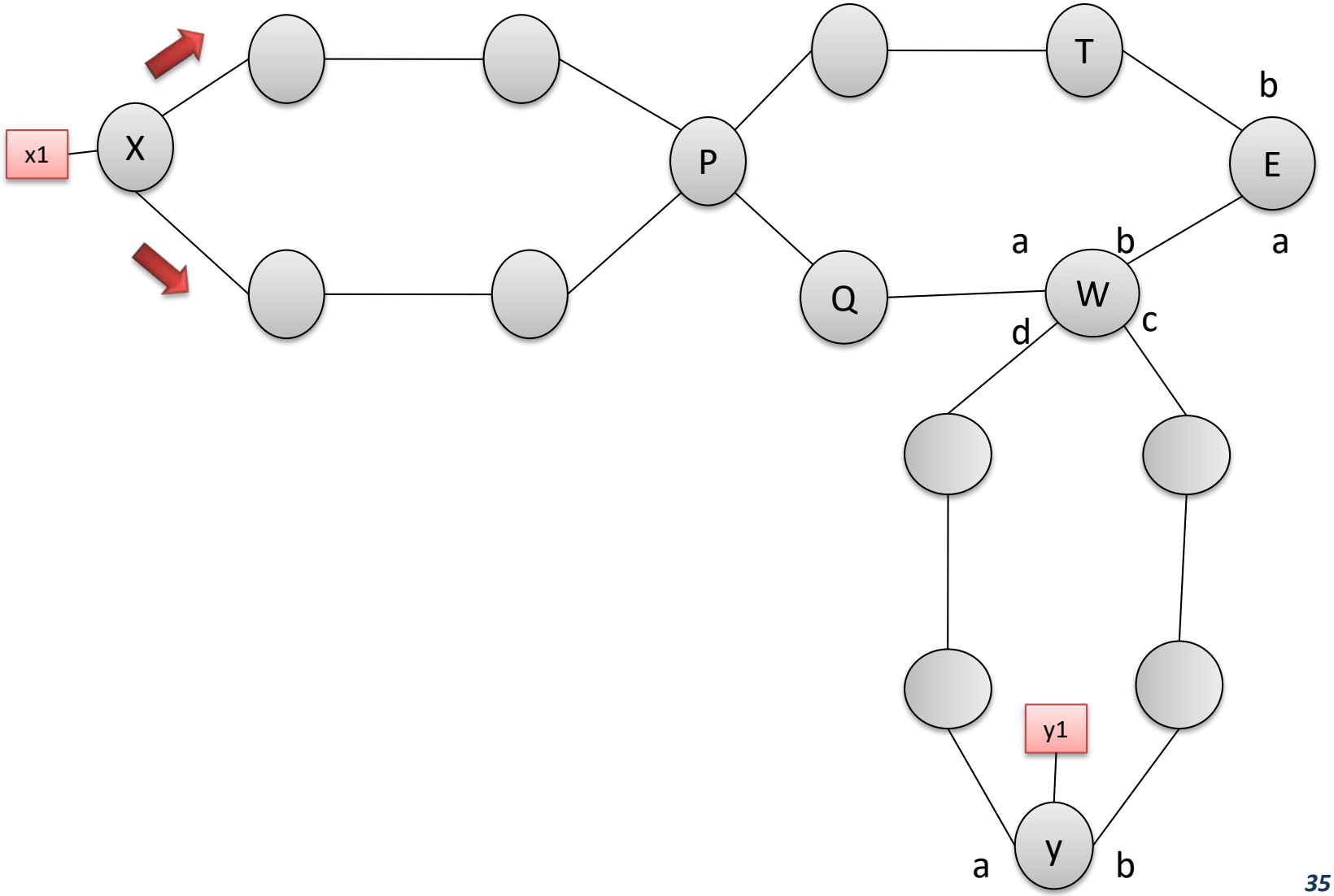
Operation Concept (Multi/Broadcast)

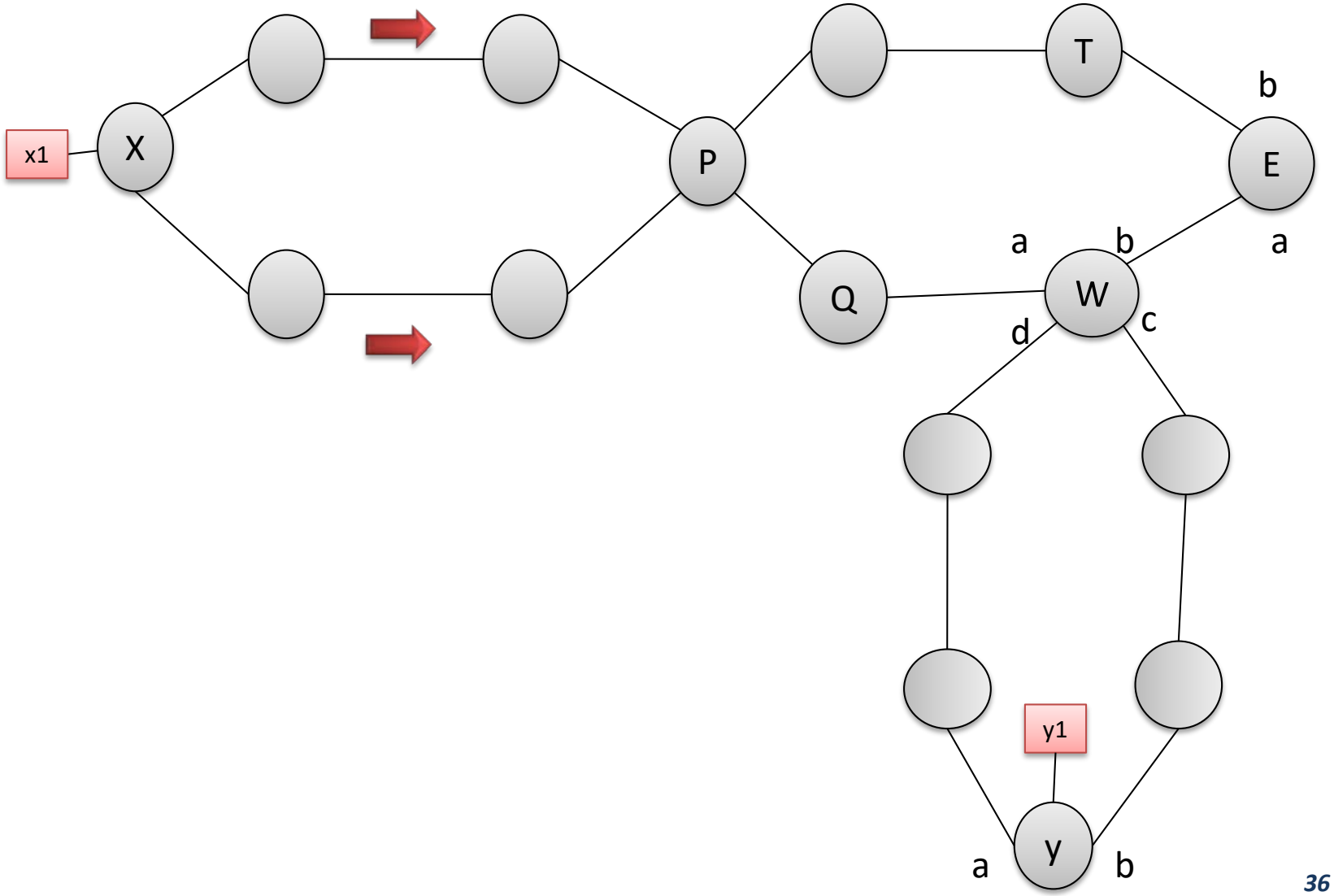
- If C1 broadcasts frames, then SEthSwitch A will flood it.
- SEthSwitches B and D will do the same.
- SEthSwitch A will receive the fastest copy, delete the second copy and then forward it to A1 or flood it into access ports.
- SEthSwitches B and D will delete the returning frames .



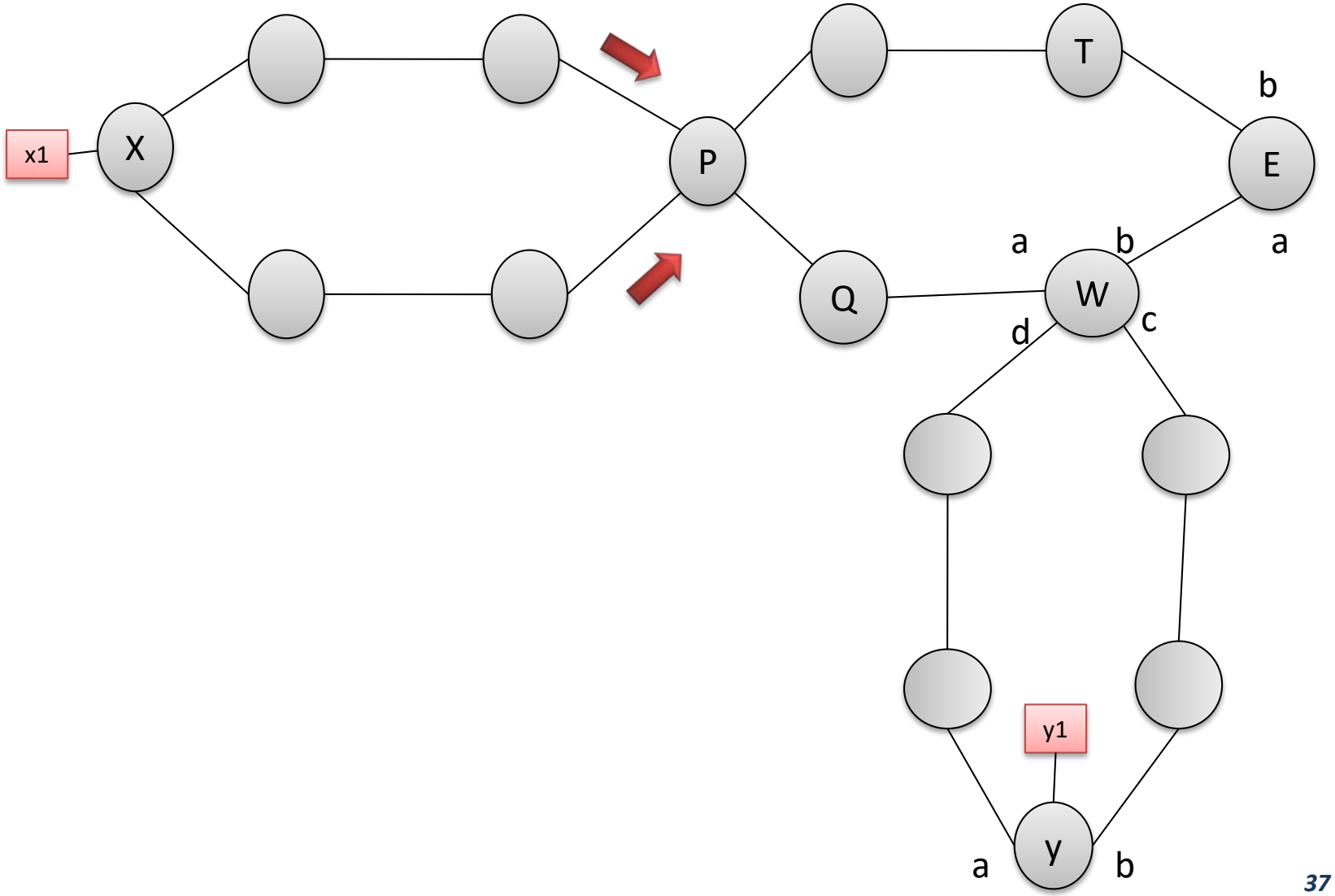
Example: Connected ring (Unicast)



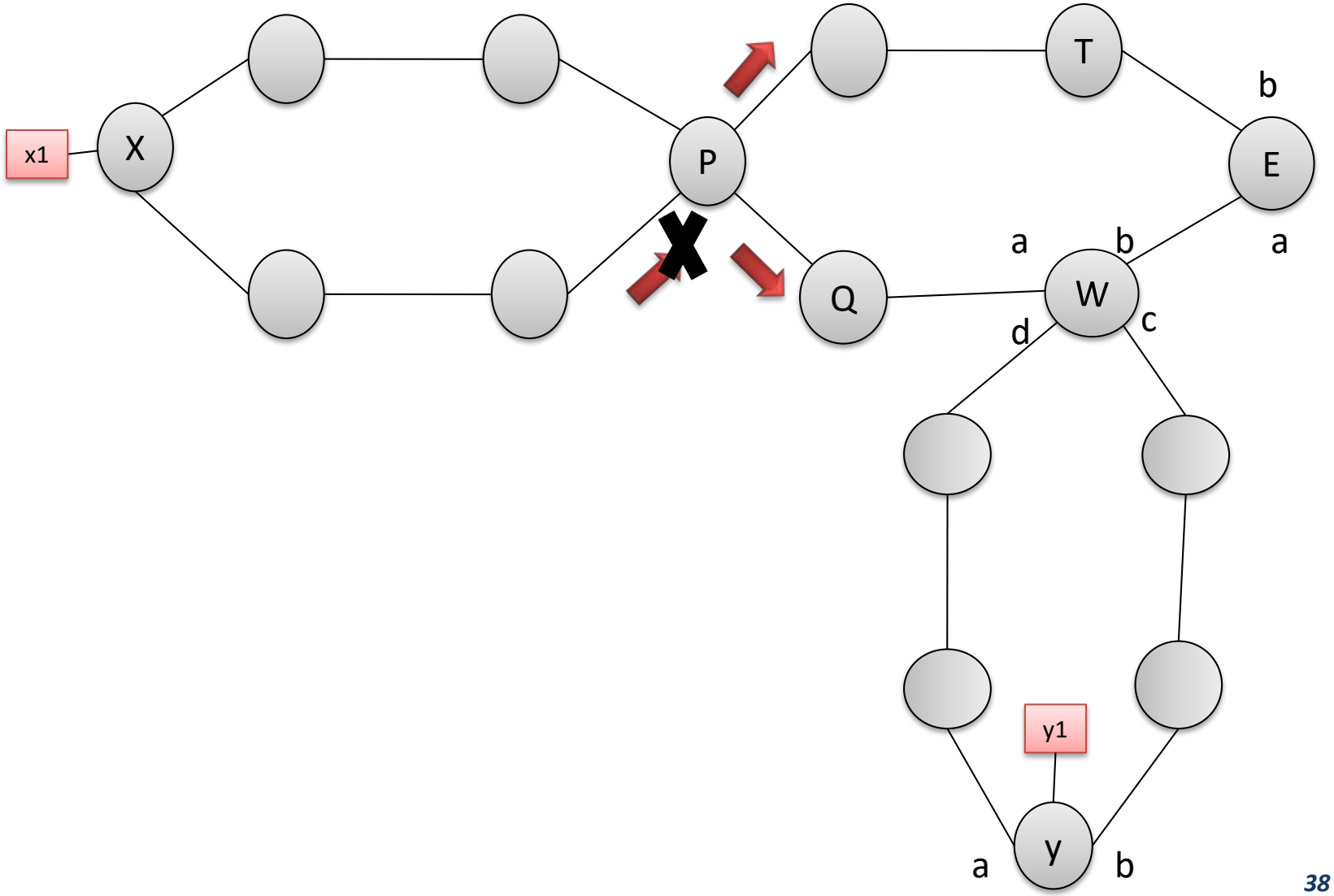
Example: Connected ring



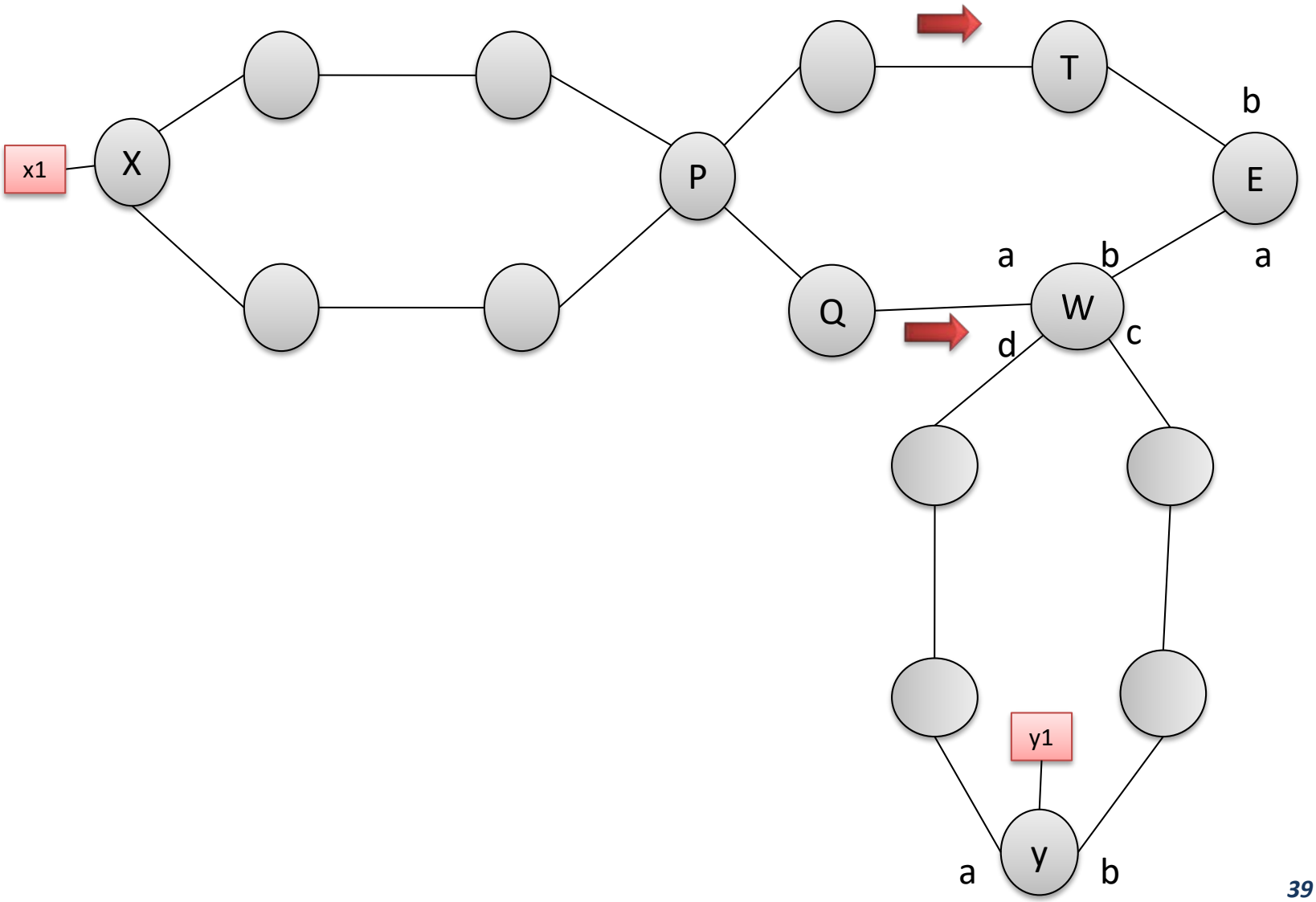
Example: Connected ring



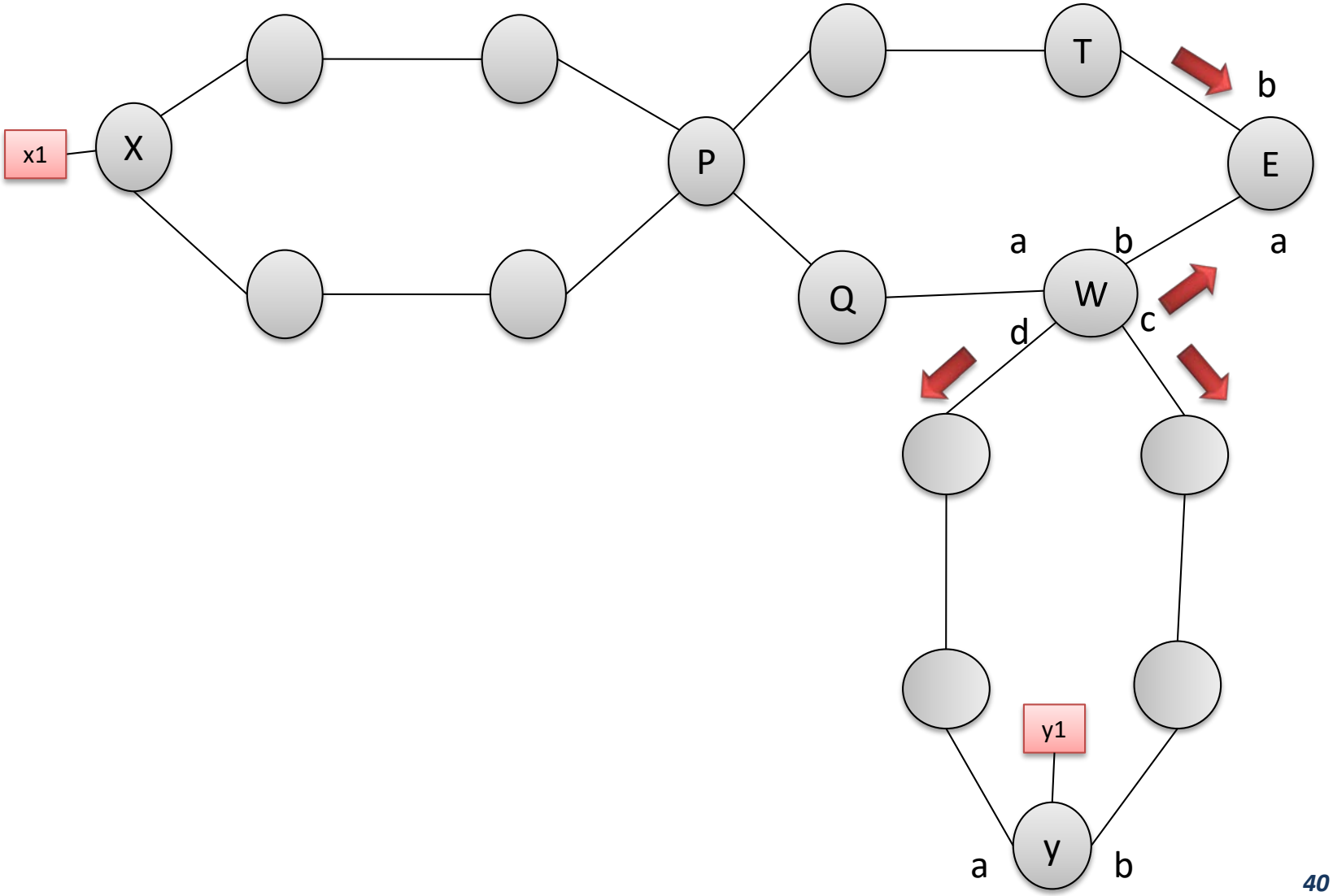
Example: Connected ring



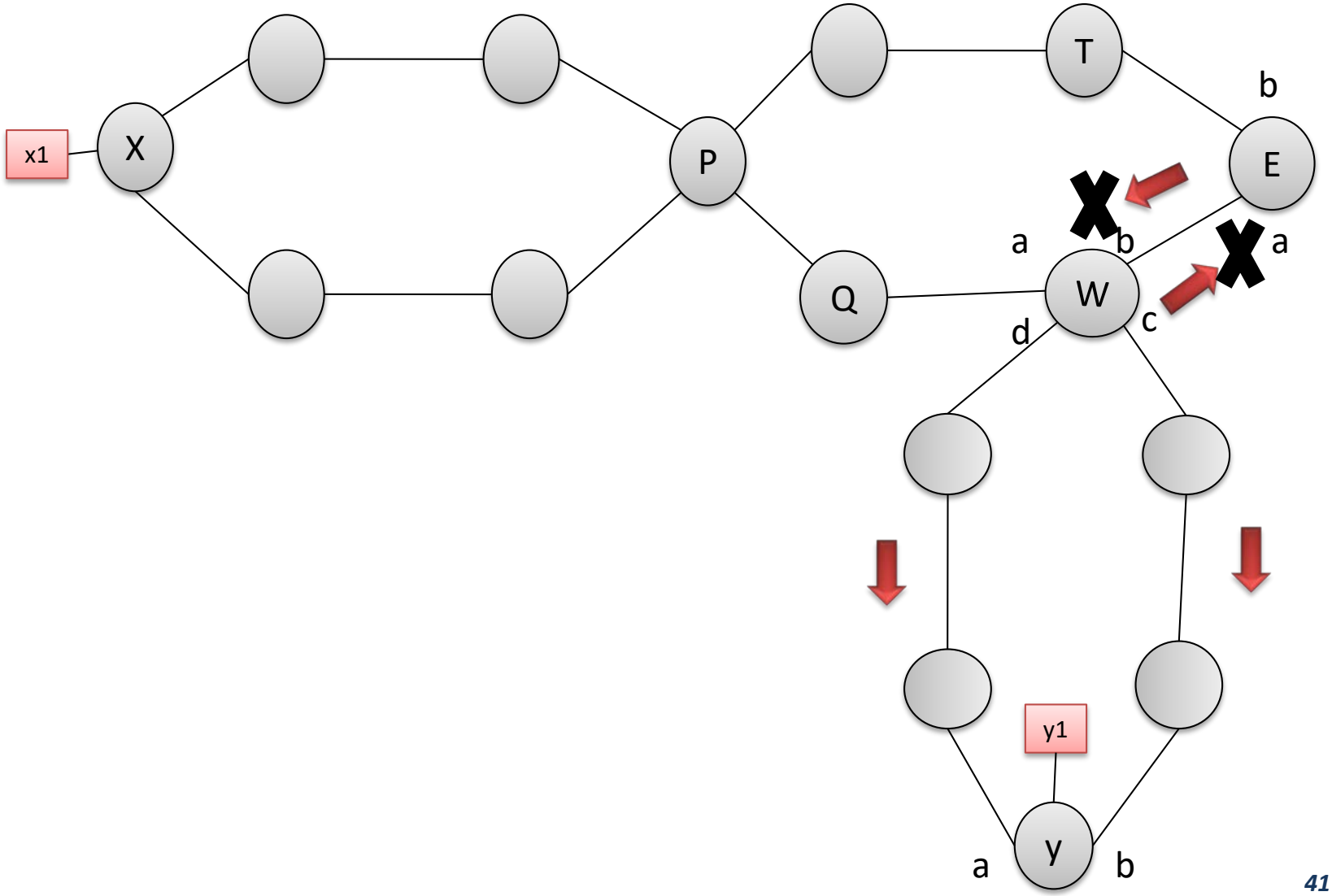
Example: Connected ring



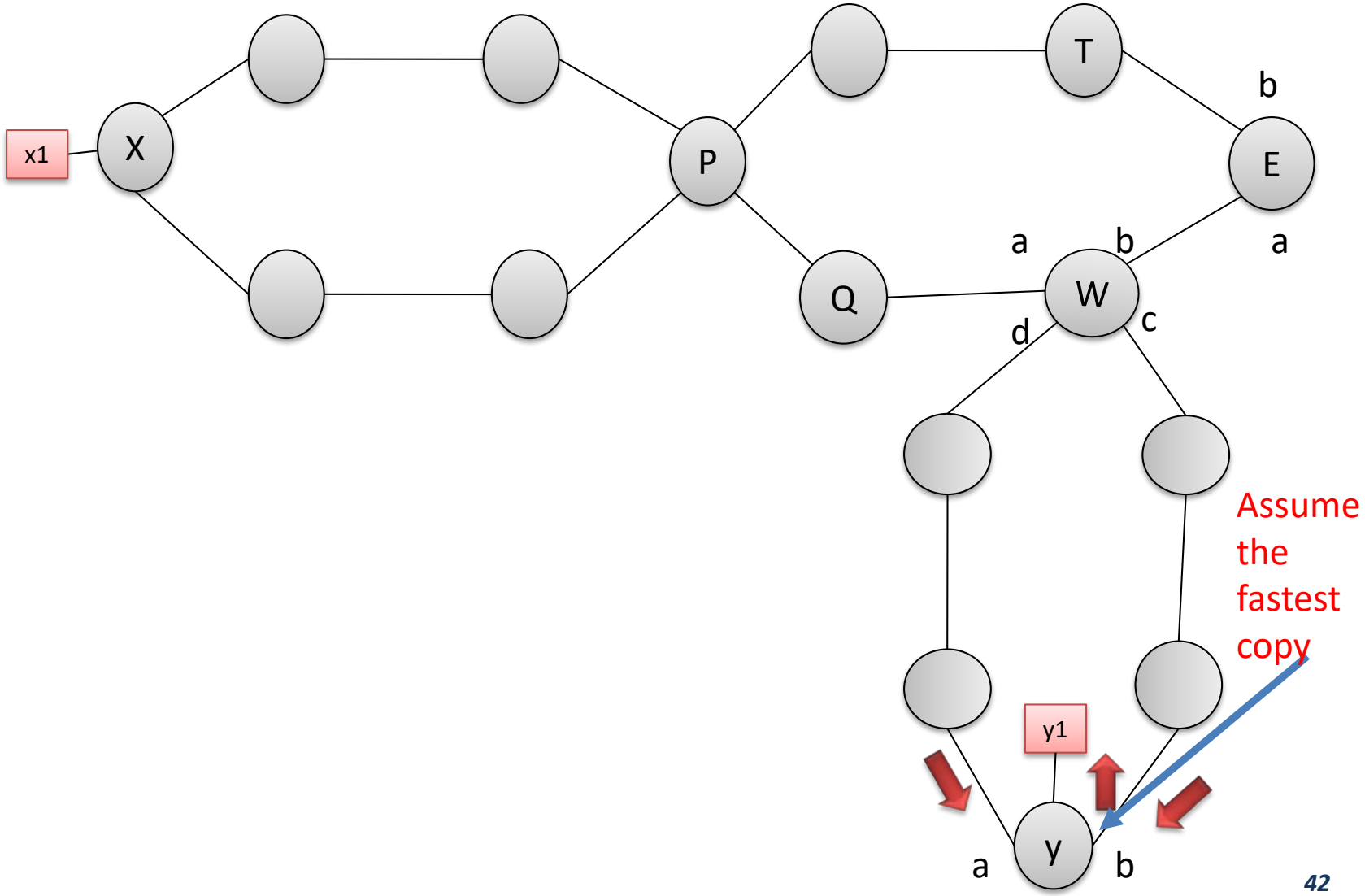
Example: Connected ring



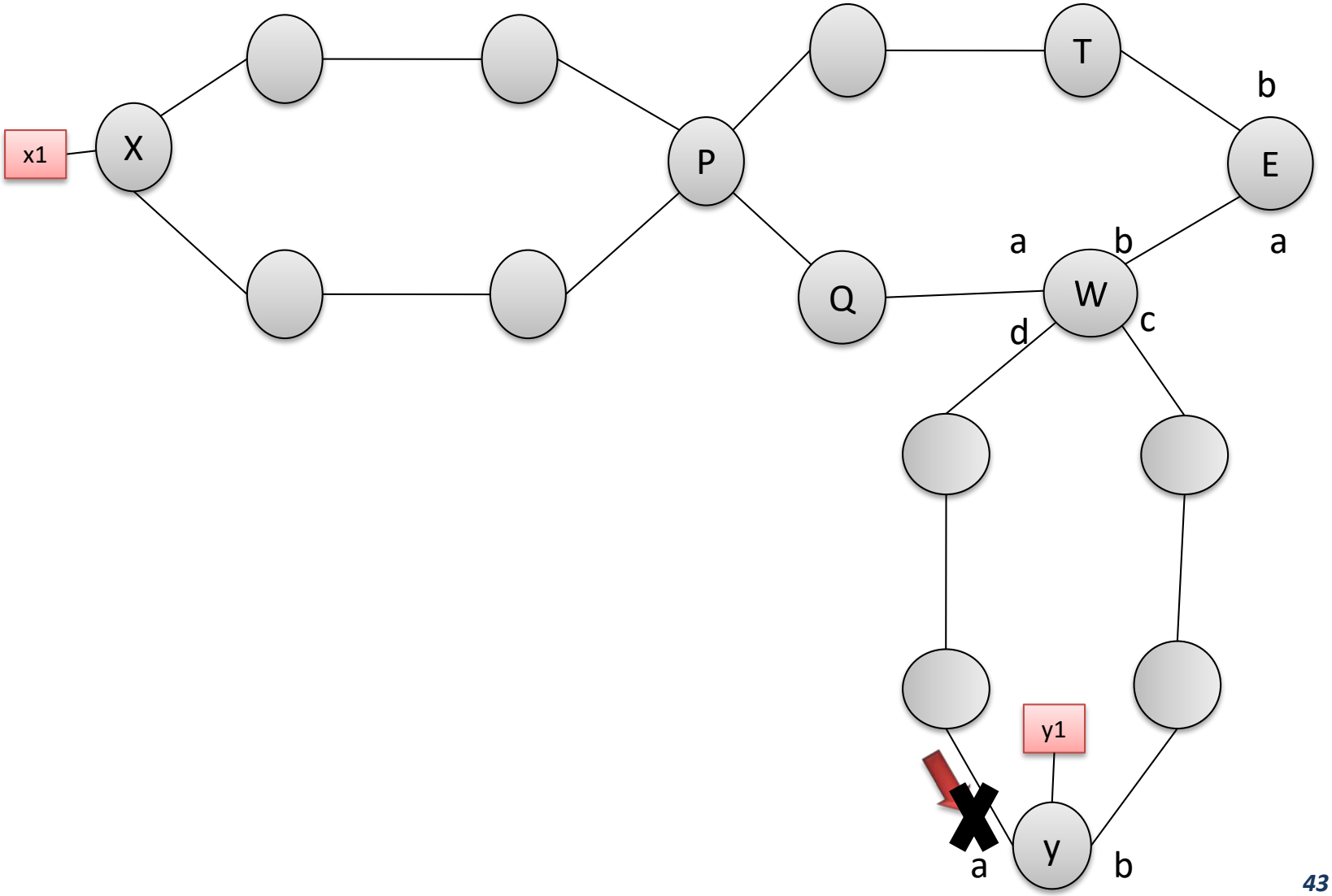
Example: Connected ring



Example: Connected ring



Example: Connected ring



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Conclusions

- SEthNode and SEthSwitch Provide Ethernet with seamless 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 will be active without need to block any of them.
- We think SEth can be applied to any topology type.
- Less traffic than standard HSR or PRP protocols.

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Thank you very much