Distributed FDIR Technique for Smart Distribution System

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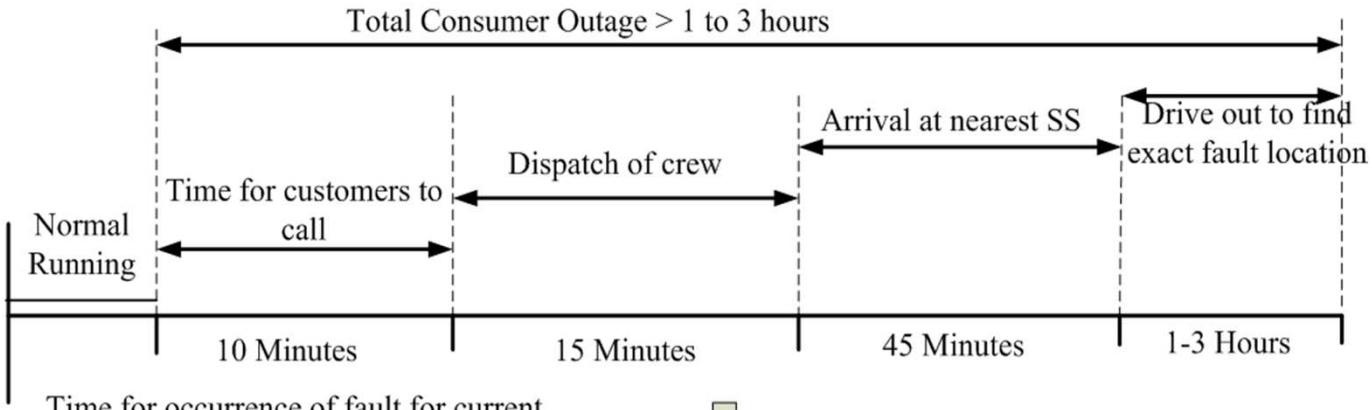
Outline

- FDIR - Benefits & Different Approaches
- Proposed D-FDIR Algorithm using IEC 61850 GOOSE
  - Examples with various scenarios
- Challenges & Possible Solutions

Why FDIR ?

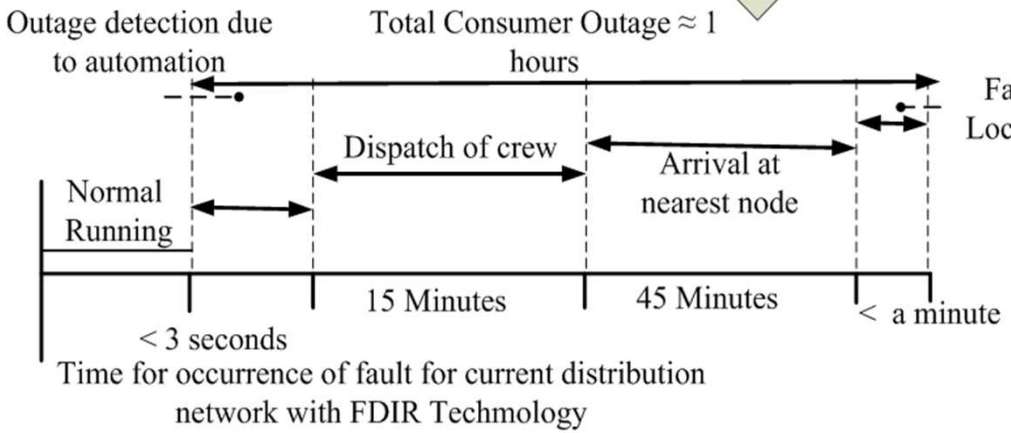
- Improving Reliability Indices by reducing outage time

No FDIR



Significant reduction in time due to FDIR

With FDIR



Various architectures of FDIR deployment

- Centralized FDIR (C-FDIR)
  - Distribution Management System (DMS) or Distribution-SCADA level.
  - More optimized re-configuration for complex networks
  - Easy to incorporate Voltage or power quality regulations
  - Large deployment is required for intended performance
  - The response time may be comparatively high

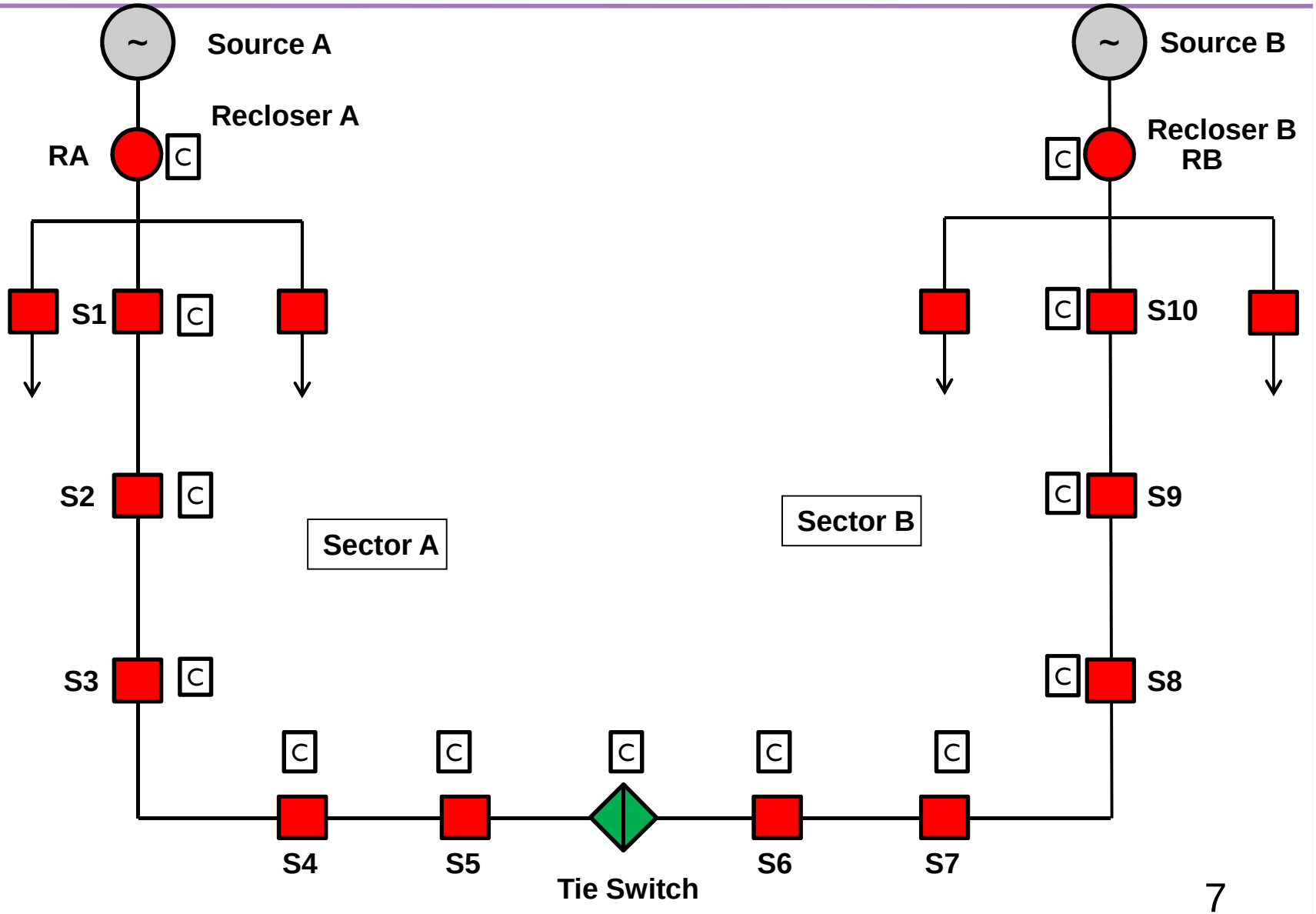
Various architectures of FDIR deployment

- De-Centralized FDIR (DC-FDIR)
  - Deployed at the substation level
  - Easy and lower cost deployment at small scale level
  - Comparatively faster with lower communication requirements
  - Not the best coordinated/optimized solution
  - Difficulties with complex distribution networks

Various architectures of FDIR deployment

- Distributed FDIR (D-FDIR)
  - Feeder level using switch/recloser controllers
  - The IEC 61850 GOOSE based peer-to-peer
  - Similar Pros & Cons with DC-FDIR approach, in addition
  - Single or multiple failures are tolerable with some level degradation
  - Communication requirements is higher comparatively
  - Complexity in configuration & upgrade of controllers

A Typical Distribution Loop



Basic FDIR Process

1. Fault detection: Determine or locate faulty feeder section
2. Fault isolation: isolate the faulty feeder section by opening available switches on both sides
3. Capability Estimation: determine if healthy feeder can meet some additional loads
4. Restoration: restore the service by energizing appropriate feeder sections

IEC 61850 GOOSE Message

- Digitals/Bits in GOOSE Messages

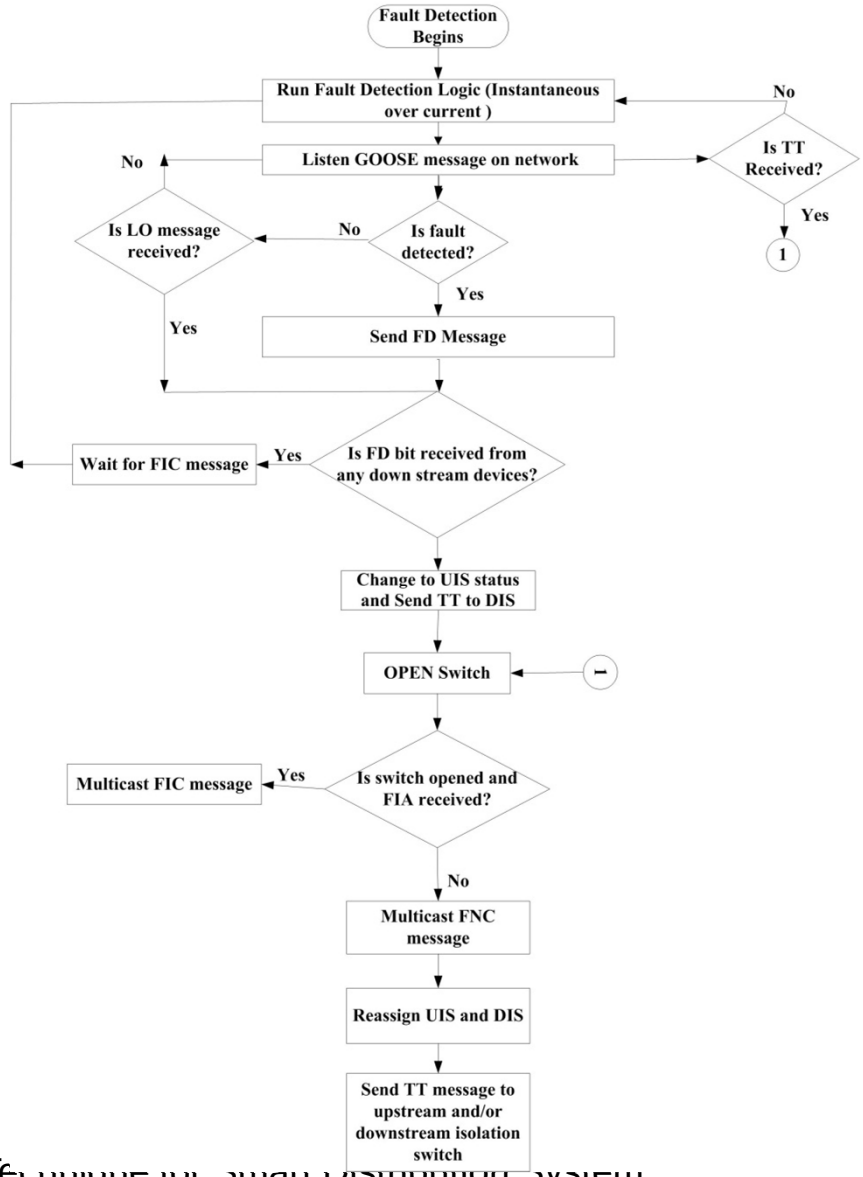
GOOSE message Bits	Description
LO	Lock Out message
FD	Fault Detection message
TT	Transfer Trip message
FIA	Fault Isolation Acknowledgement
FIC	Fault Isolation Complete confirmation
FNC	Fault Not Isolated
SM	Sufficient Margin available
NSM	No Sufficient Margin
RC	Restoration Complete
RT	Restoration Terminated

- Analog values in GOOSE messages
  - Pre-fault load current and power, Transformer loading, available feeder section capacity, available switch load margin

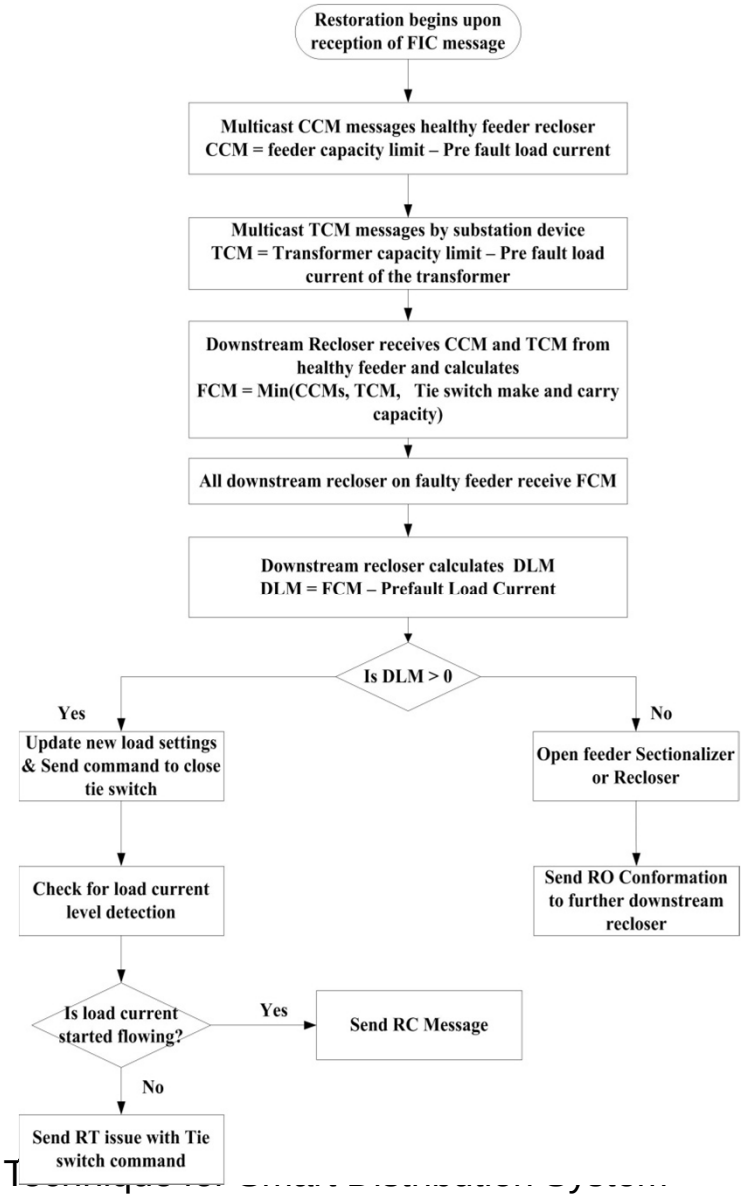
Algorithm Requirements / Assumptions

- Major requirements are:
  1. The recloser controllers have battery backup power, sufficient to complete the D-FDIR algorithm.
  2. The transformer, feeder/switch capacity are programmed into the recloser controllers prior to algorithm operation.

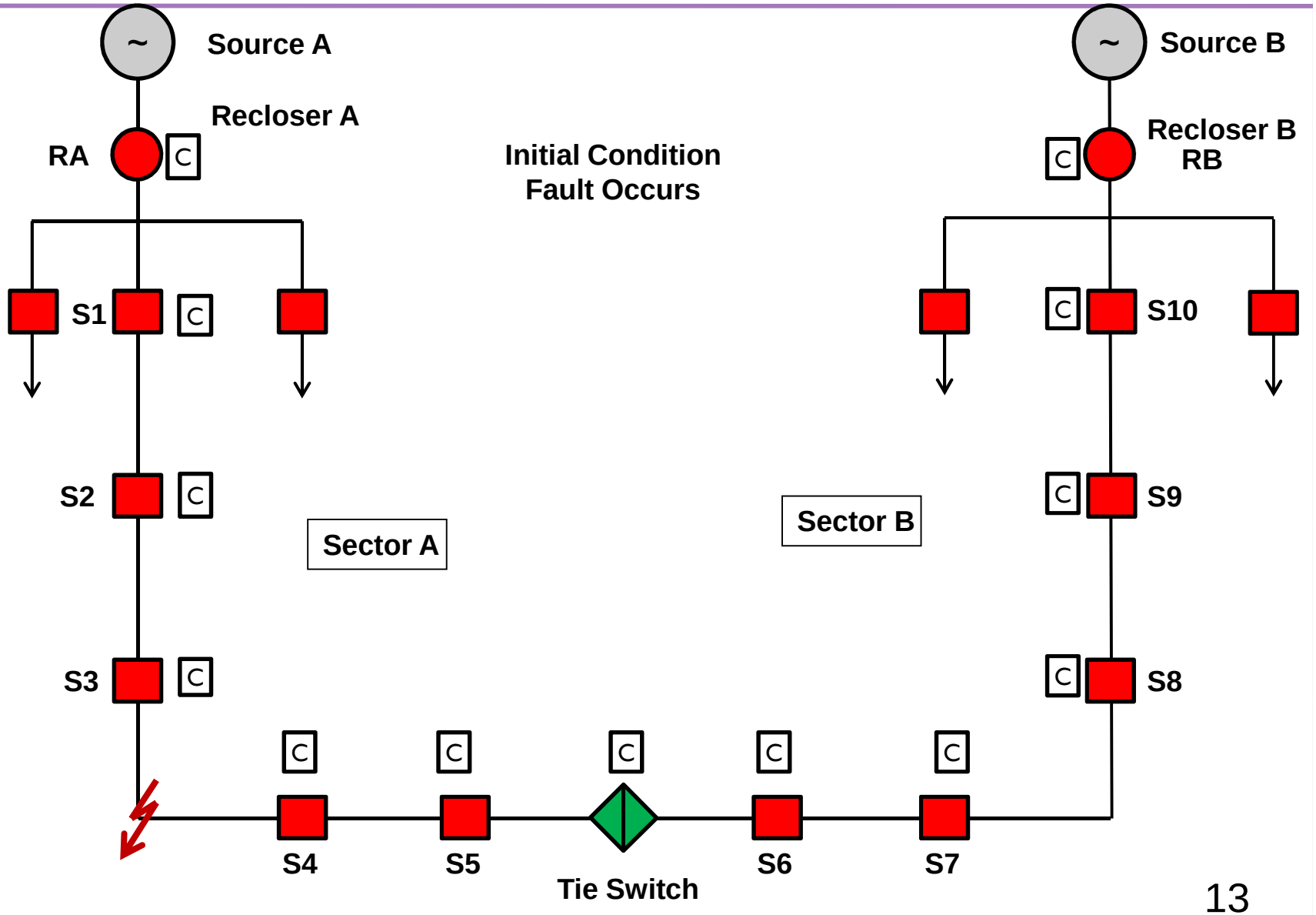
Fault Detection and Isolation Algorithm



System Restoration Algorithm



Examples: Scenario-1



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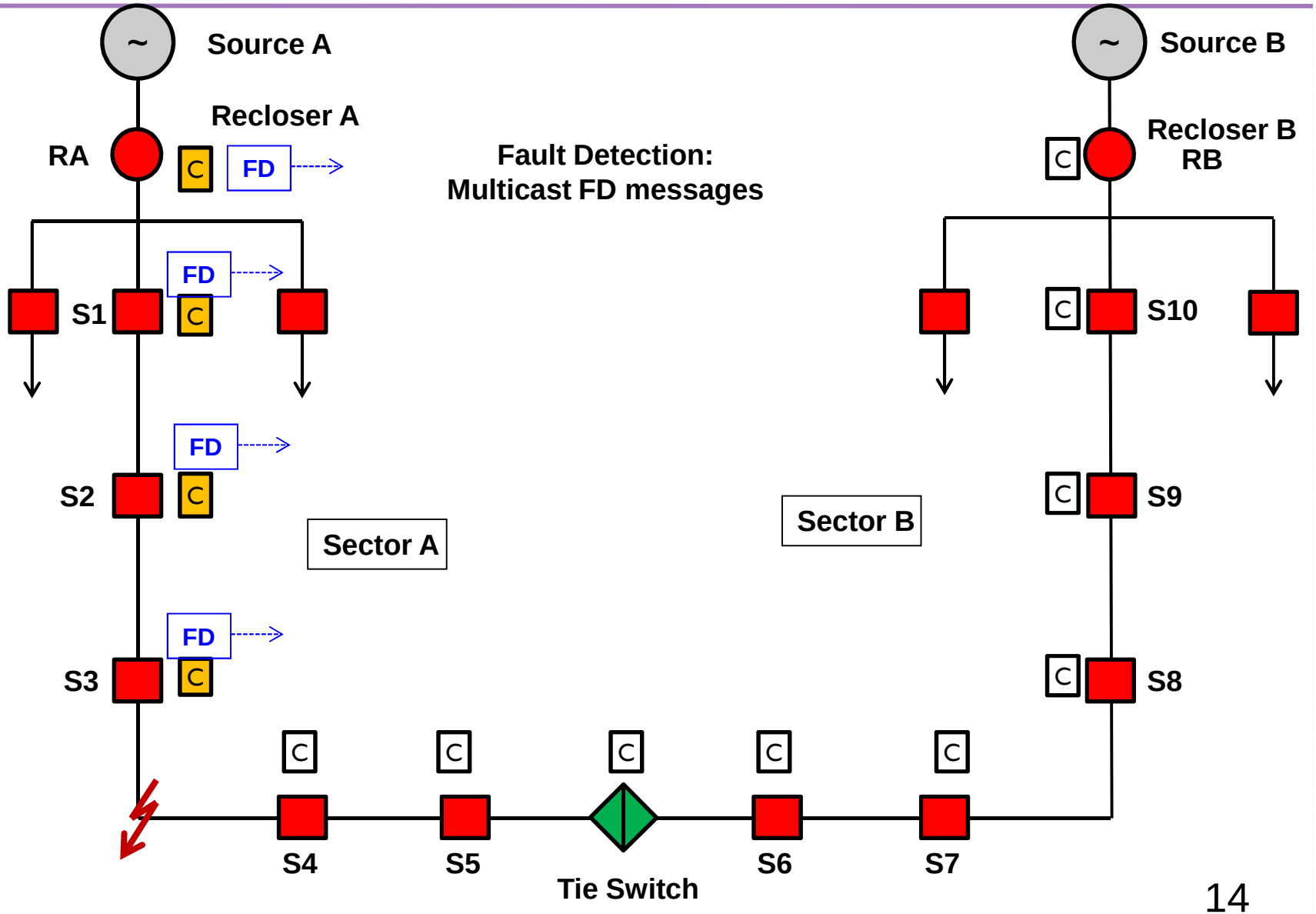
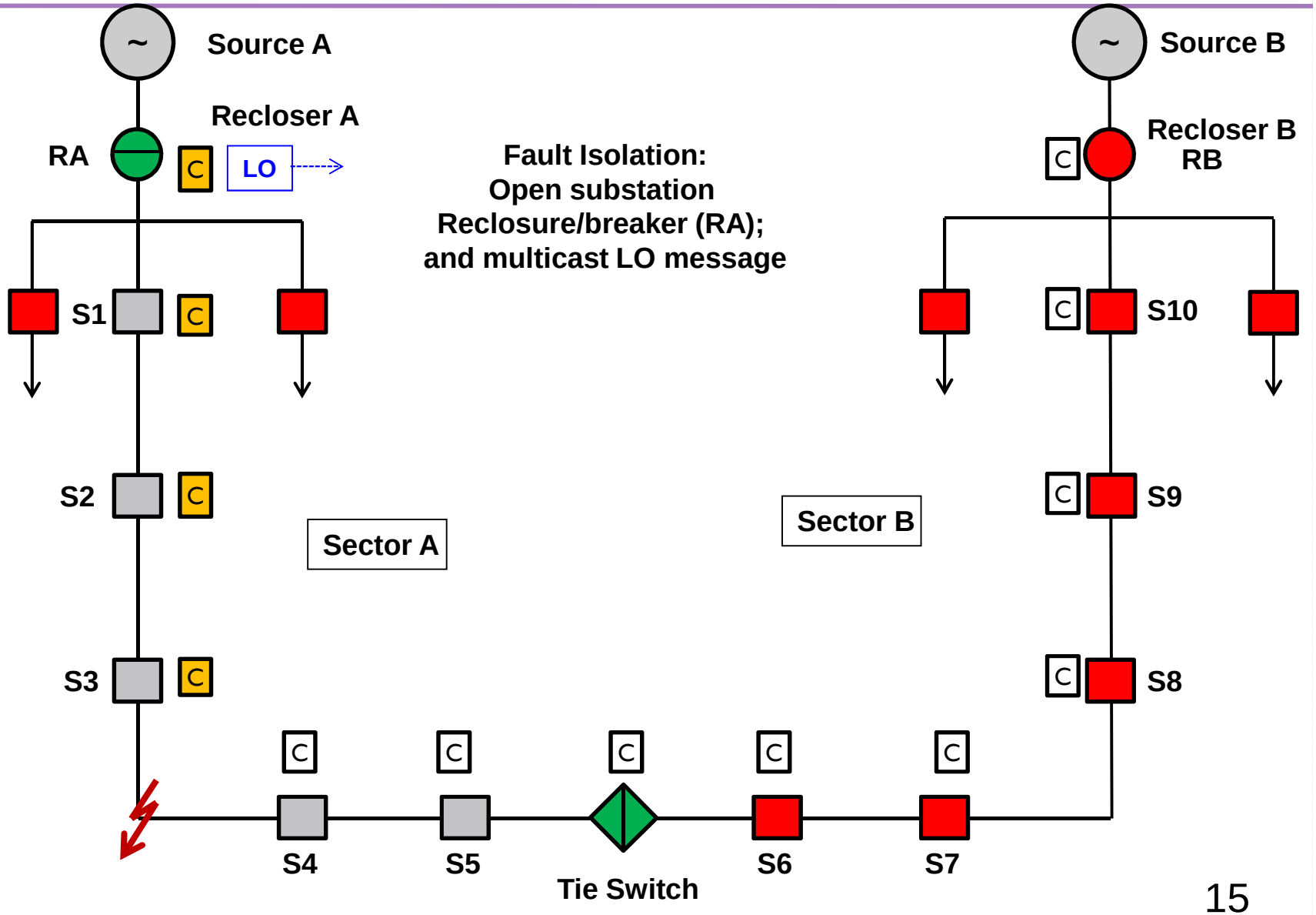
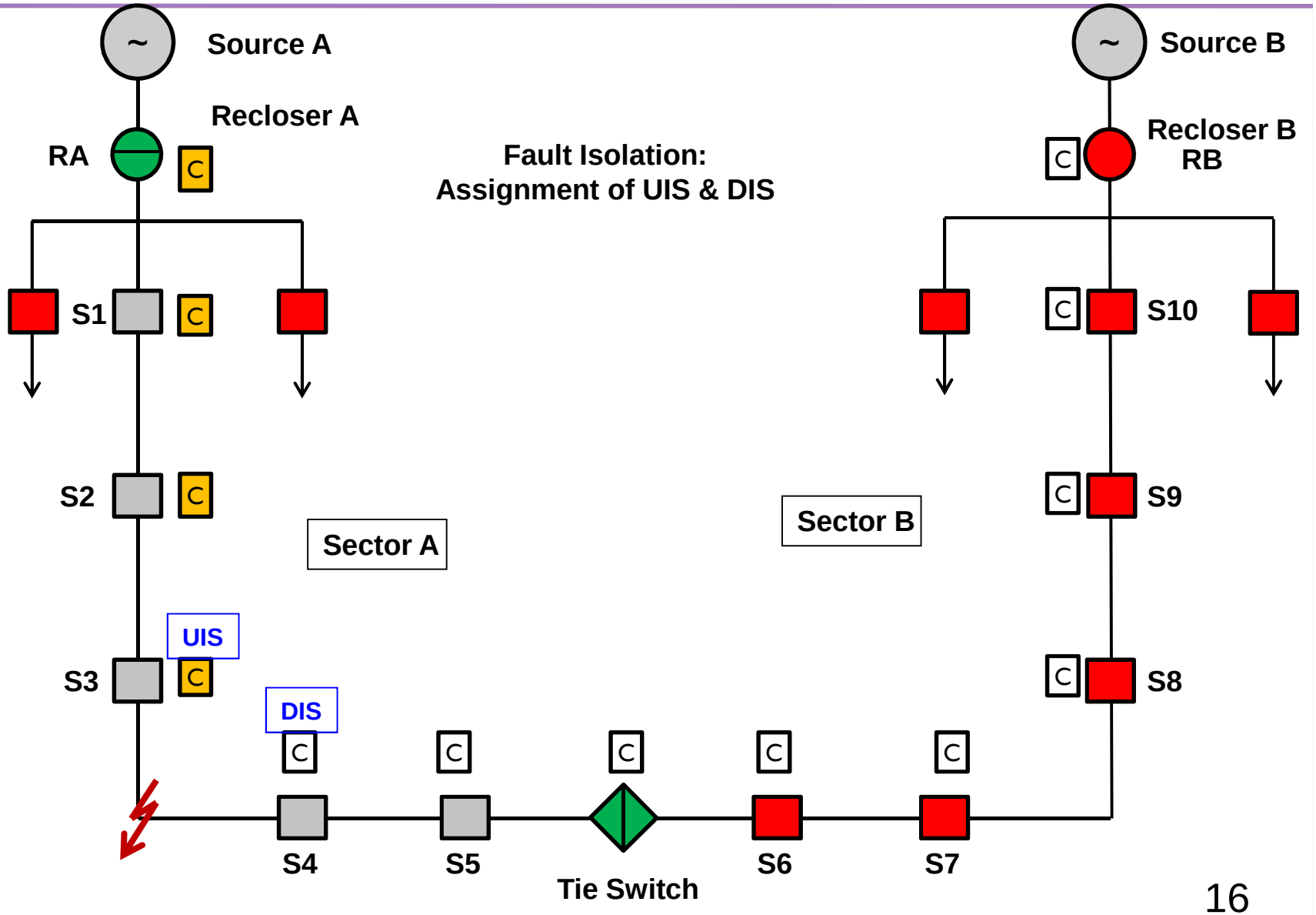


Examples: Scenario-1



Examples: Scenario-1



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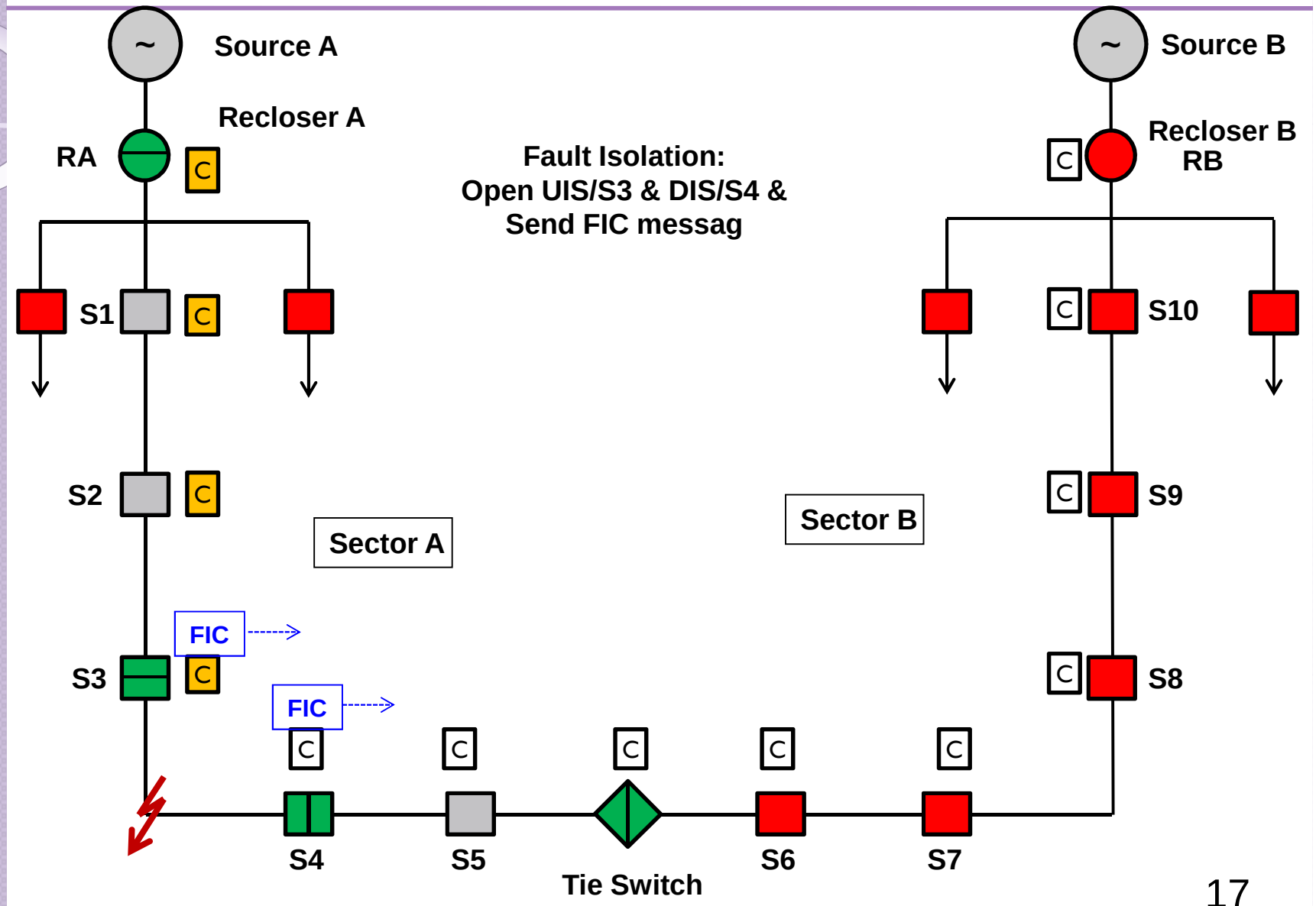
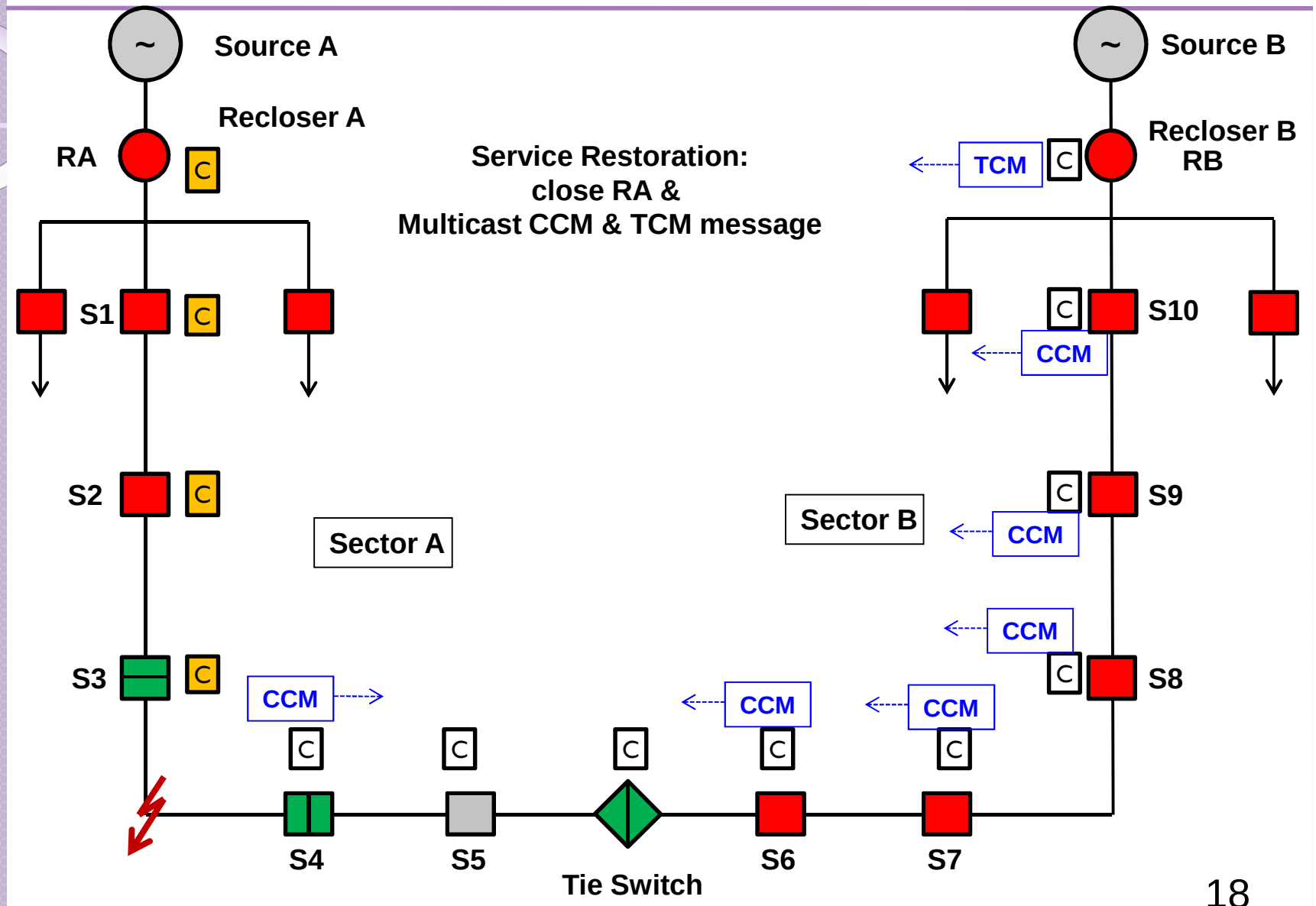
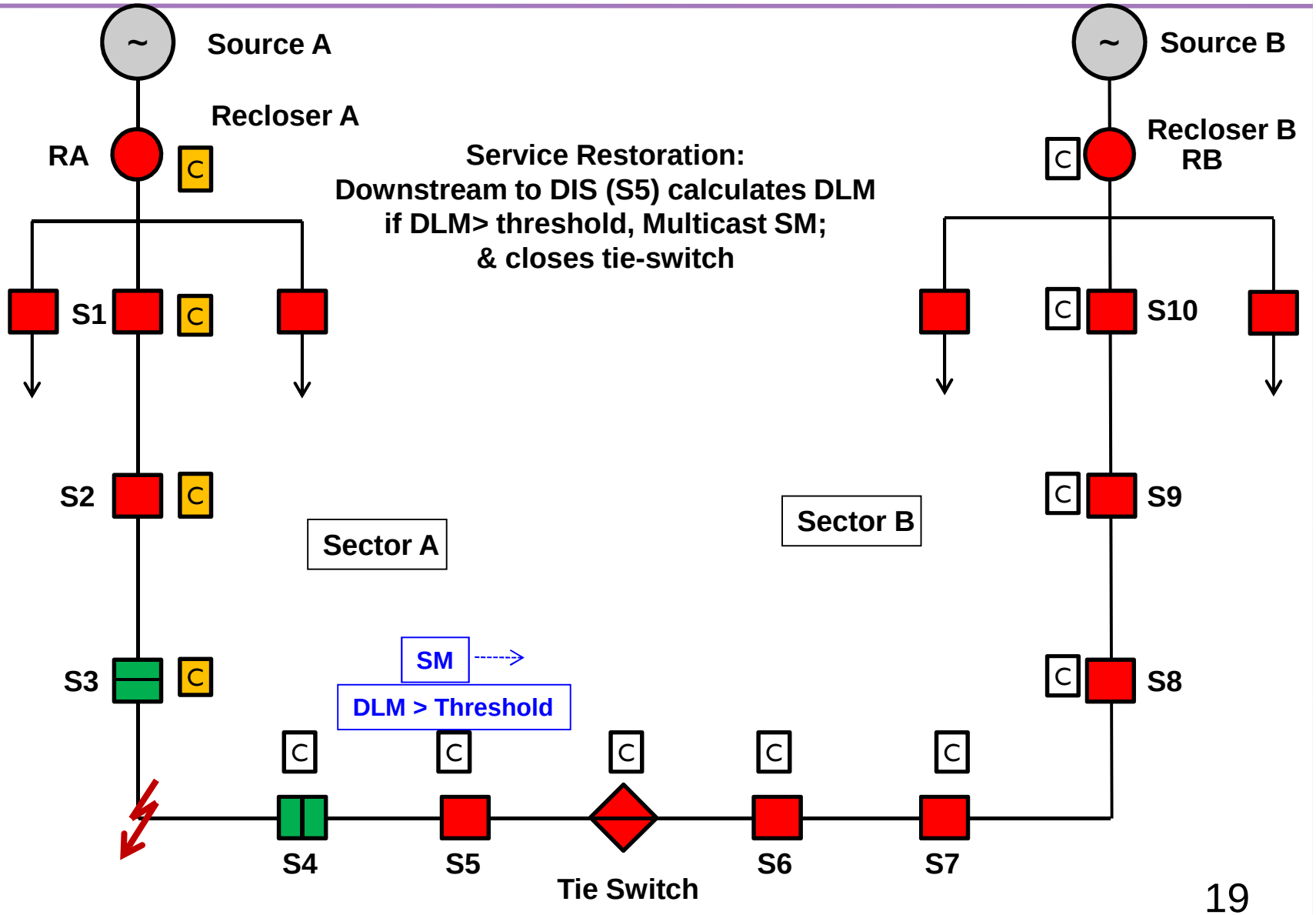


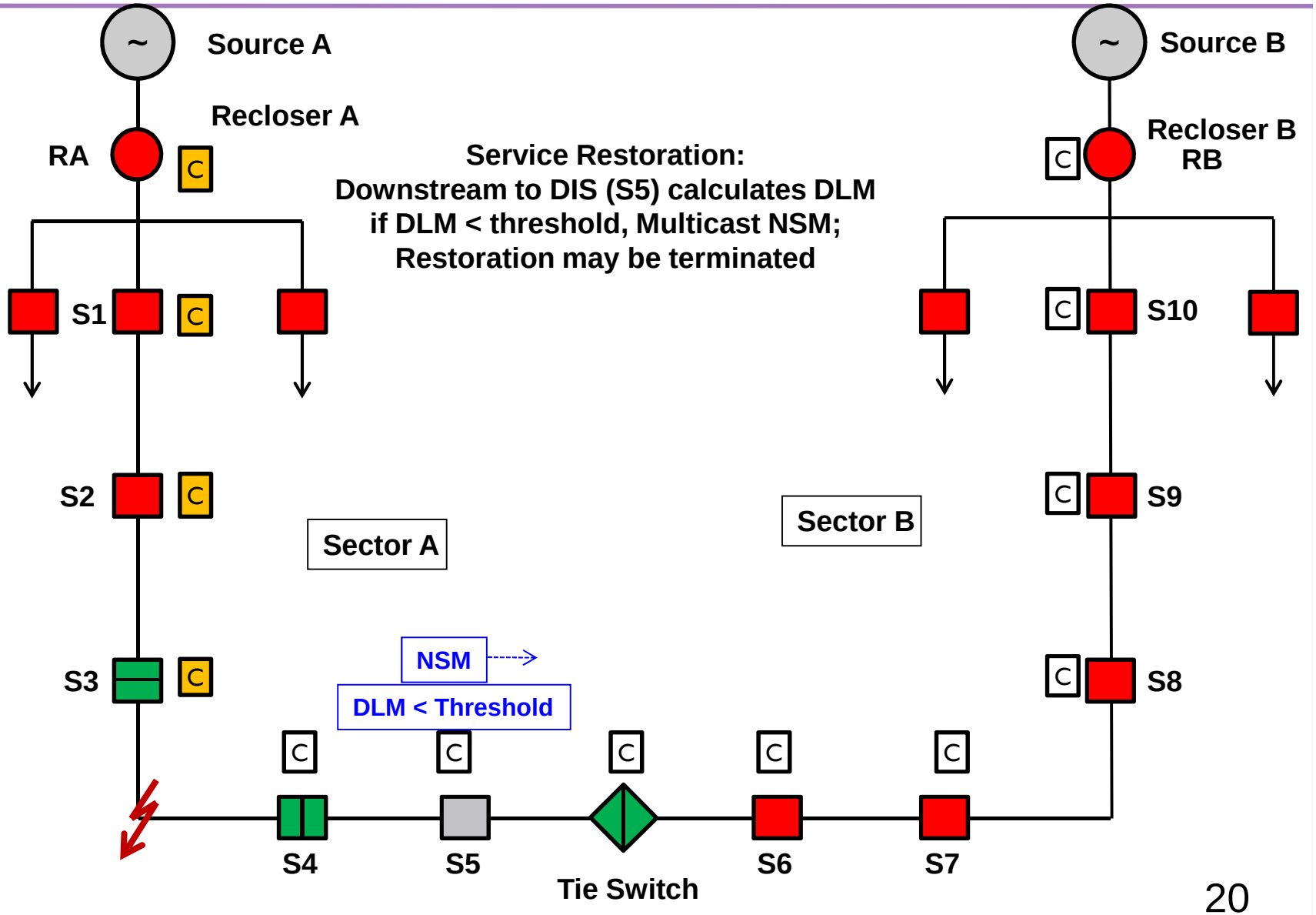
Examples: Scenario-1



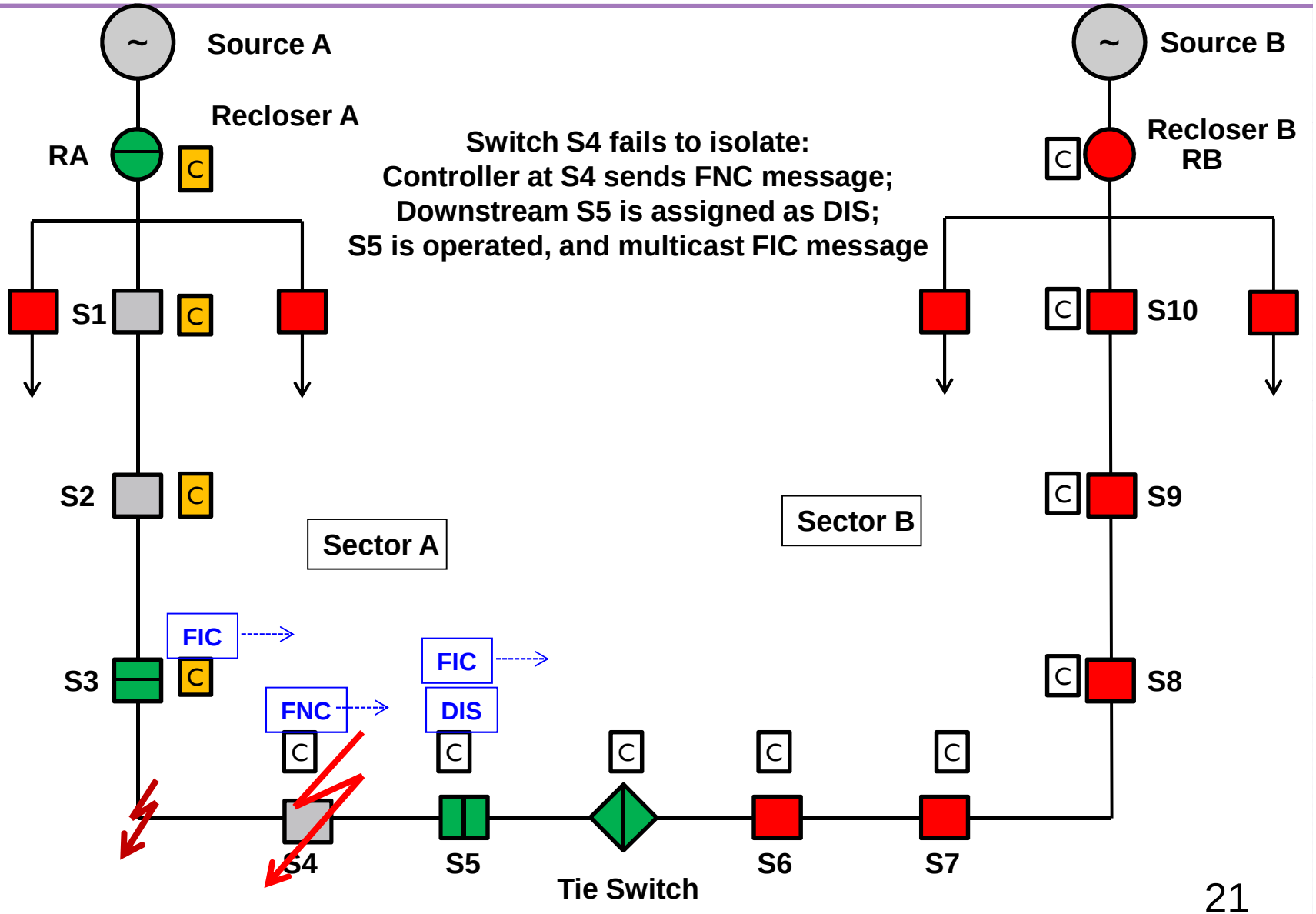
Examples: Scenario-1



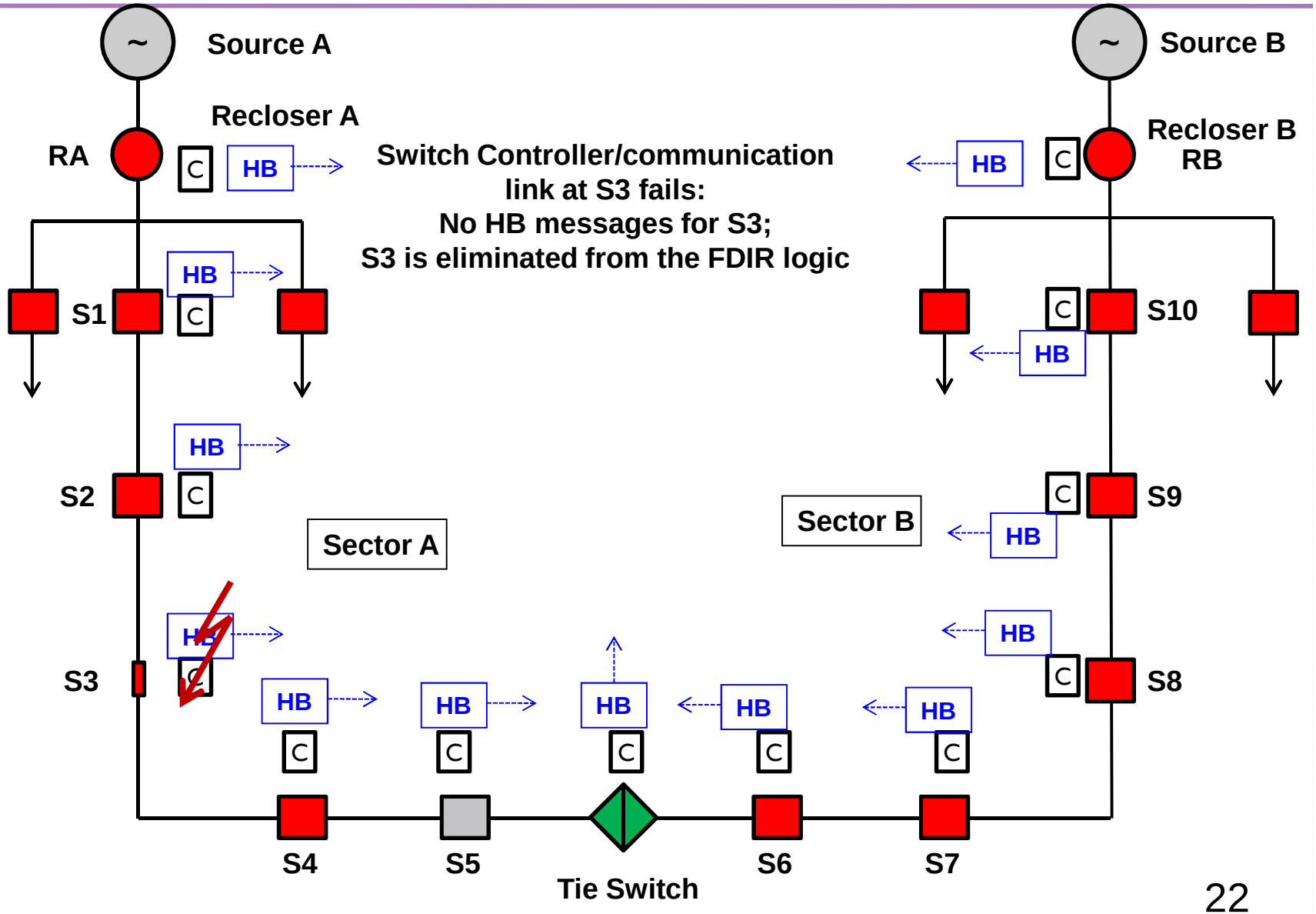
Examples: Scenario-2 (No Sufficient Margin)



Examples: Scenario-3 (Switch/Mechanical Failure)



Examples: Scenario-4 Communication/Controller Failure



Challenges & Possible Solutions

- Communication Requirements
  - Peer-to-peer GOOSE communication
  - Coverage, Bandwidth & latencies requirements

Possible solution: Wireless technologies (WiMAX, Spread Spectrum Radio) can be potentially considered. See more details in the paper.

Challenges & Possible Solutions

- Complex distribution network & Voltage regulation
  - Complex networks: multi-loop or mesh network
  - Voltage regulation or power quality constraint

Possible solution: Coordinated with Centralized DMS;

Hybrid approach of C-FDIR & D-FDIR

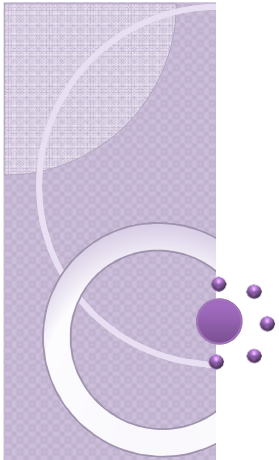
Challenges & Possible Solutions

- Immediate or simultaneous fault
  - Second fault may occur immediately before restoration from first fault is completed
  - There may be multiple faults occur at the same time at different locations

Possible solution: Algorithm holds restoration process and locate potential location of the second fault; if fault encounters even after restoration, run FDIR again for this new fault location

Conclusion

- A D-FDIR algorithm based on IEC 61850 GOOSE messaging to reduce service outage time.
- FDIR process discussed with identified different types of IEC 61850 GOOSE messages.
- Restoration algorithm also considers various capability limits of the feeder, switch and transformer.
- Various contingency scenarios and limitations of the algorithm, and solutions to each of these identified challenges proposed.



Thank You

Questions?