The Smart Grid: A Use-Case for Large-Scale SDN Deployment

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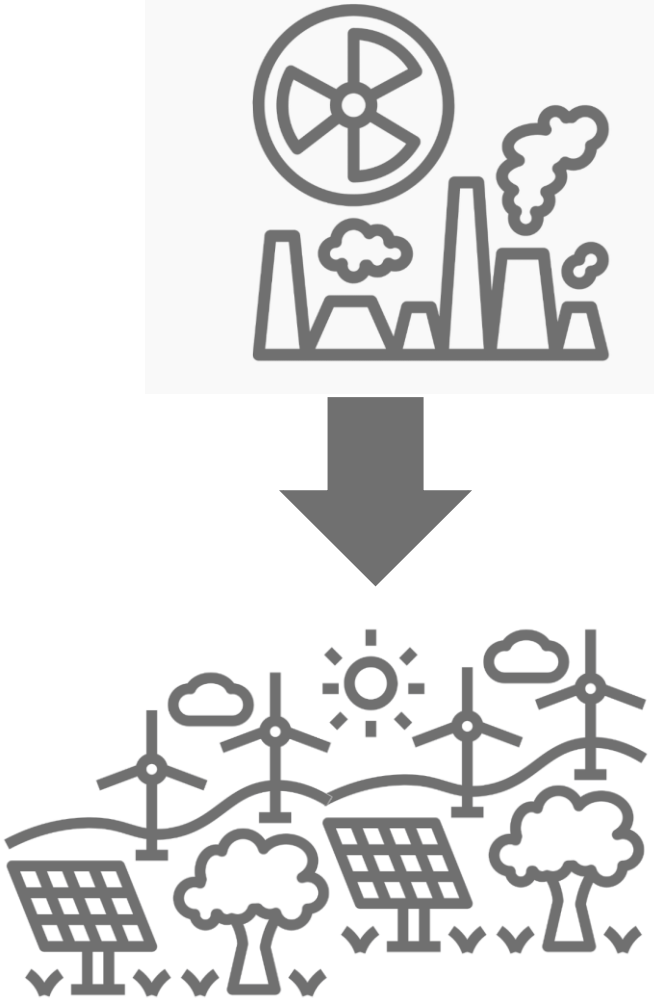
Energy Transition Challenges

- Energy transition creates **challenges for power grid**
  - Increased variability in demand and supply
  - Frequent state changes in the grid
  - Many distributed energy resources – no big power plants
  - Decreased stability through loss of big rotating masses

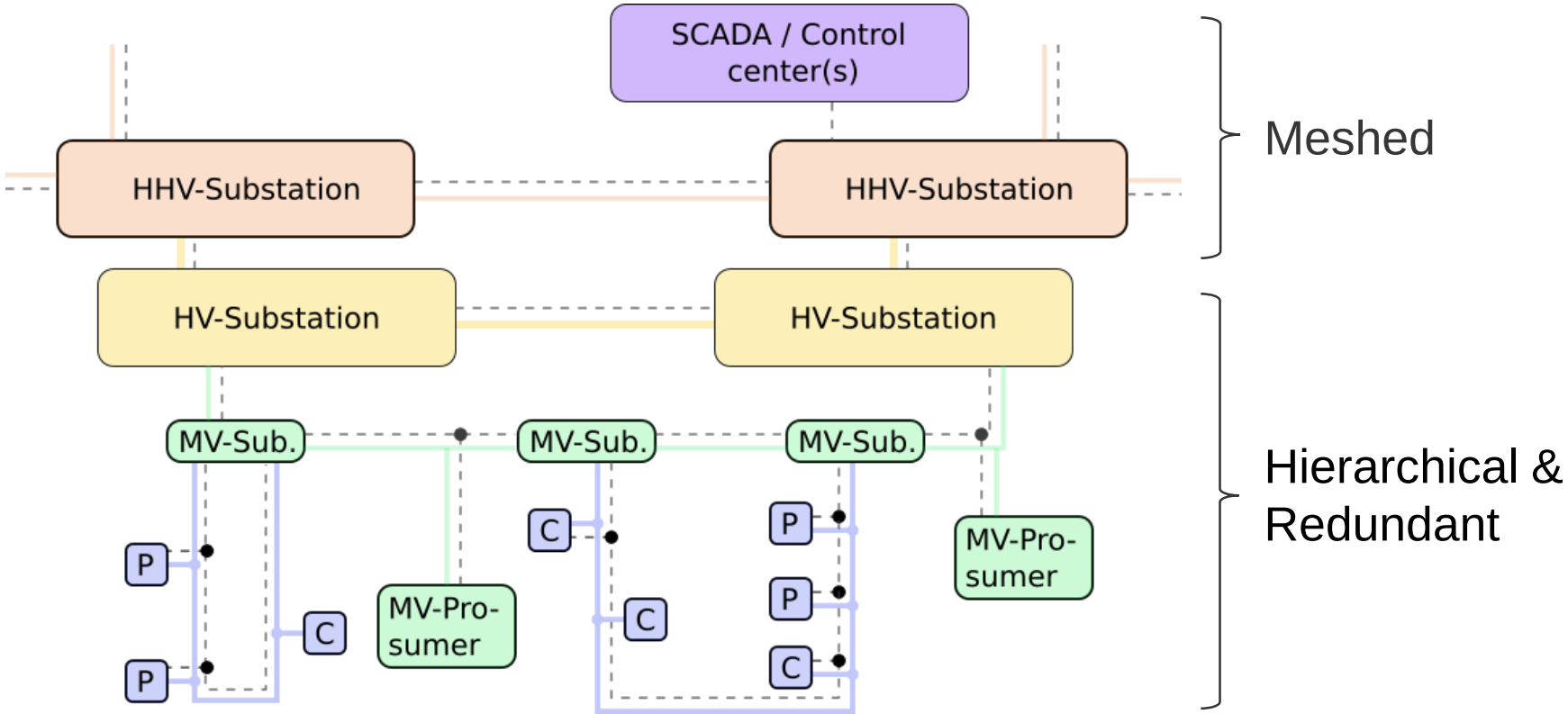
- Local control no longer sufficient ➡ **Smart Grid**
- Fast, reliable coordination becomes necessary
- Requires **fast, reliable communication**

➡ Dedicated backbone network



SDN-SG – Communication backbone structure

- Fiber links connect substations
- 1000s of substations
- Currently under construction
- Challenge:
  - Long distances!



SDN-SG - Requirements

Resilience in case of failures
- High availability required
- Large distances slow down conventional recovery

Reliable communication
- Rerouting takes too long
- Retransmissions take too long

Scaling across large areas
- Country-wide network
- 1000s of substations

Timely communication
- Little queueing allowed
- Bounded latency
- Guaranteed bandwidth

➡ SDN as the enabler

SDN-SG - Key Concepts

I

Separation into control domains

- No single points of failure

resilient

scalable

II

Topological & packet redundancy

- Retransmission takes too long

100%
reliable

timely

III

Unimpeded communication paths

- No gateways between substations

100%
reliable

timely

IV

Resource reservation & traffic differentiation

- Soft real time guarantees

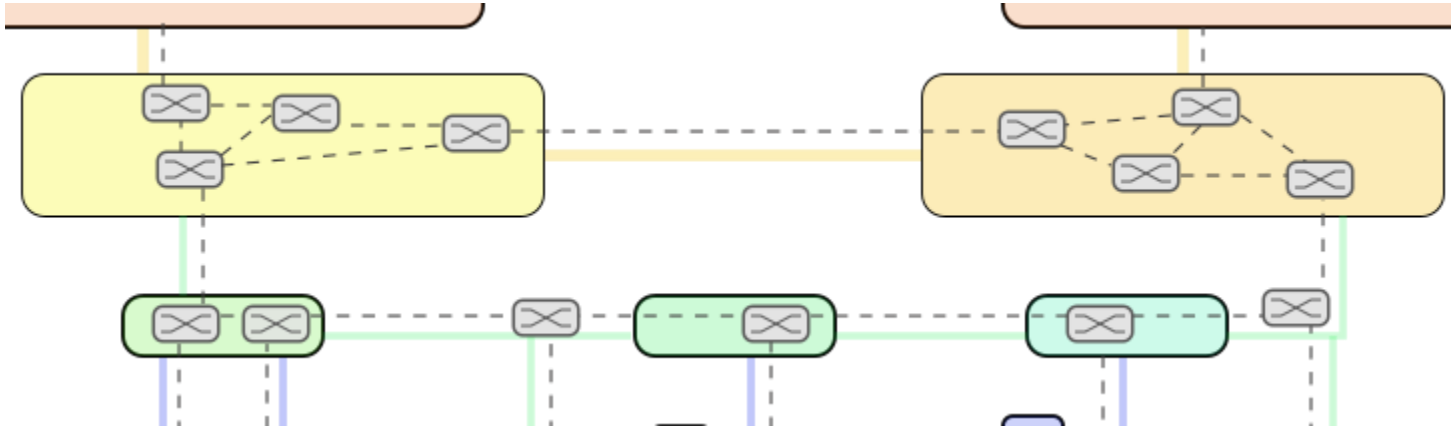
100%
reliable

timely

resilient

I Control Domains / Failure Domains

- Separation into SDN-subnetworks
  - Dedicated controllers in each domain
  - Autonomous, self-sustaining
  - Avoid single point of failure
  - In-band communication between domains



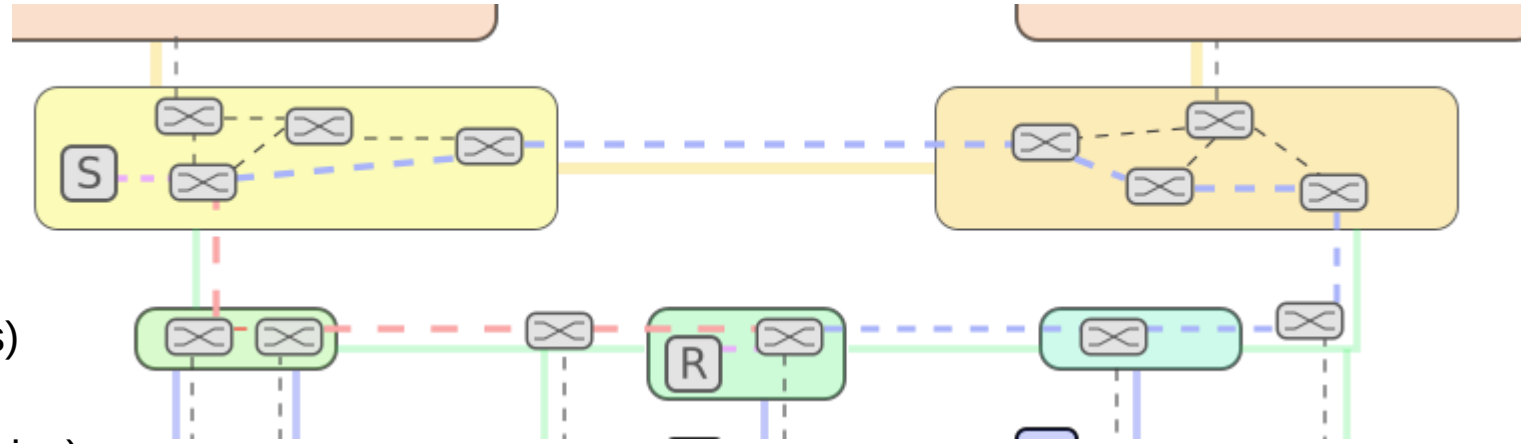
- Advantages:
  - Local optimization & decision making
  - Scales well for large areas

resilient

scalable

II Topological & Packet Redundancy

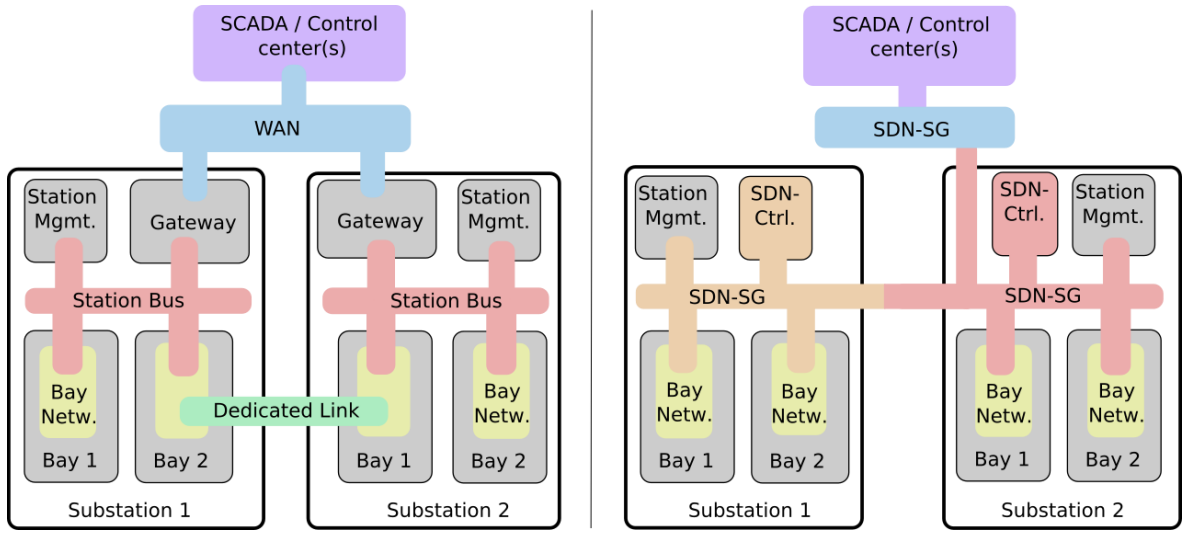
- In-network packet de-/duplication
- Without SDN:
  - Manual route configuration
  - Static equipment configuration
- SDN enables :
  - Disjoint path routing (across domains)
  - Route reservation (across domains)
  - Provision deduplication (across domains)



- Advantages:
  - Reduces packet loss probability
  - Compensates individual network failures
  - Ensures critical communication in case of failures

III Unimpeded Communication Paths

- Change substation model
  - Replace gateways with SDN-switches
  - Provide fast paths for critical traffic
  - Use dedicated links to construct SDN
- Advantages of SDN:
  - Redirect non-critical traffic to firewall
  - Manage substation network
- Improvements:
  - Lower delays across substations
  - Dynamic reconfiguration based on network conditions



IEC 61850 SDN-SG

IV Resource Reservation & Traffic Differentiation

- SDN enables:
  - Per-flow resource reservation
  - Per-flow traffic differentiation
  - Traffic policing and dynamic reorganization
  - Aggregation of reservation information
  - TSN bounded latency model

- Advantages:
  - Enables soft real-time assurances 

  - Enables protecting critical flows

  - Enables reacting to DoS attacks 

SDN and TSN - Division of Labor

- TSN for very time-critical communication inside substations
  - Selective usage of TSN for very demanding services
- SDN manages backbone
  - Avoid time-consuming schedule generation
  - Avoid desynchronization risks
  - More manageable and flexible
- Additional SDN-benefits:
  - In-network functions (ex. NFV)
  - Self-organization
  - Security features
  - …

Conclusion

- SDN-SG:
  - Resilient backbone for the smart grid
  - Timely & reliable communication across long distances
  - No single point of failure

- Key benefits of SDN:
  - Control plane flexibility
  - In-network functions

END