Software Defined Networking for Smart Grid Resilience

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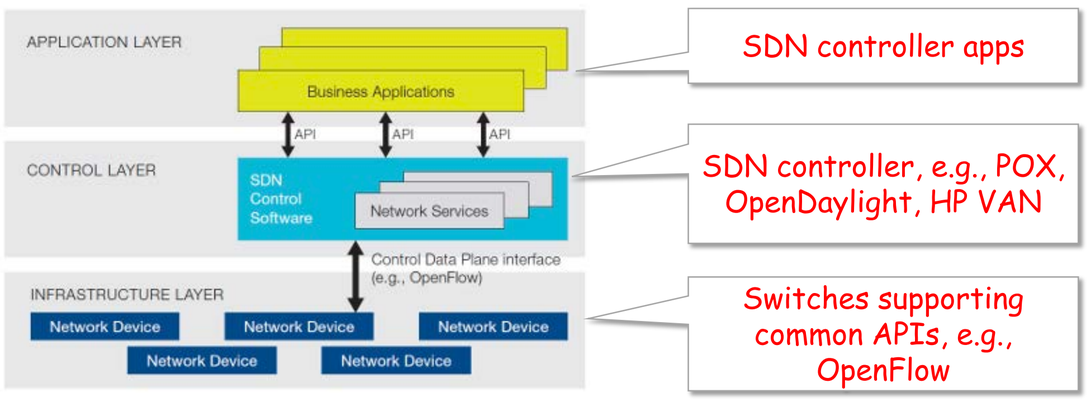
Software Defined Networking

Software Defined Networking (SDN)

- Unprecedented flexibility, visibility, and QoS compared to "vertically-integrated black boxes" of old networking devices
- Enables various applications, e.g., optimize QoS, enhance network resilience, etc.



* Chart courtesy of http://twimgs.com/networkcomputing/2012/5/sdn-arch.png

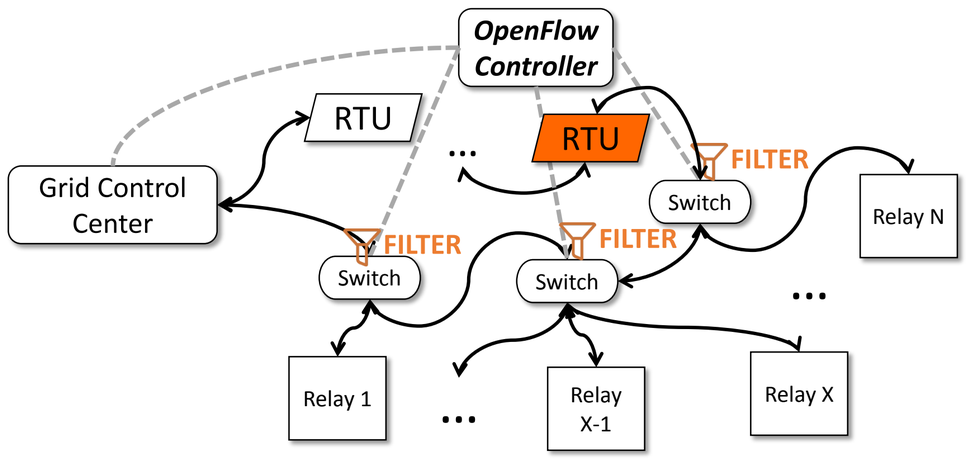
Applying SDN to strengthen smart grid operations

- Smart grid: critical infrastructure leveraging information and communications technology
- Initial industrial effort towards SDN-enabled smart grid
  - SEL-2740S switch 

SDN for the Grid: Opportunities & Risks

SDN for greater resilience in smart grid [1]

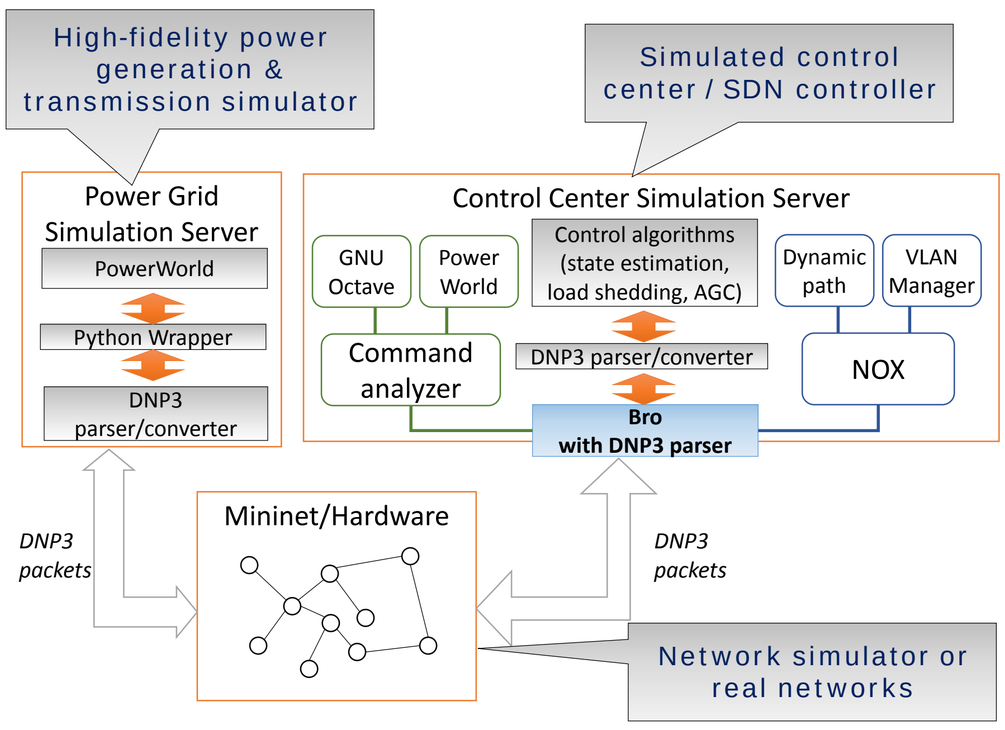
- Example 1: detecting malicious command forwarding behaviors
- Example 2: filtering out flooded responses from control and field devices caused by spoofed requests



Nevertheless, SDN may also bring in additional risks to smart grid

- Example 1: "darknets" created by SDN rootkits
- Example 2: denial-of-service attacks from weakness with the SDN controller

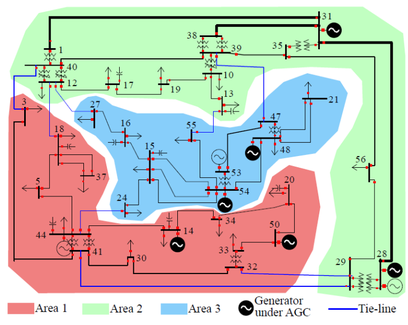
Cyber-Physical Simulation & Testbed



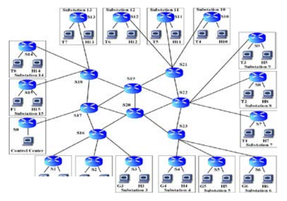
Fault Injection on SDN-Enabled Grid

Control plane faults
Controller failure, switch connection failure, app bug, infinite loop, memory exhaustion, flow rule modification, flow entry deletion, control message drop, undefined control message, delayed controller response, time desync, etc.

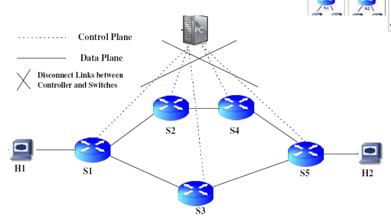
→ **Data plane performance** → **Physical impact on grid**



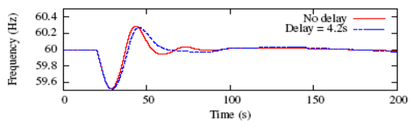
37-bus power system



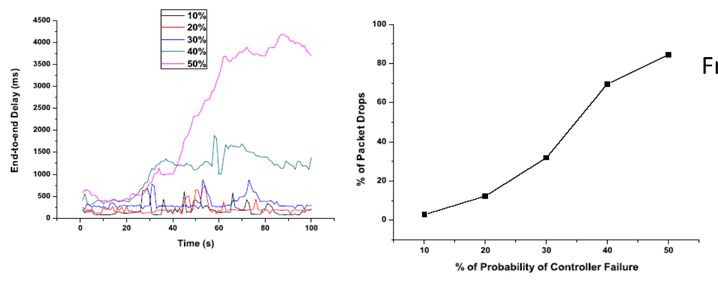
SDN topology in Mininet



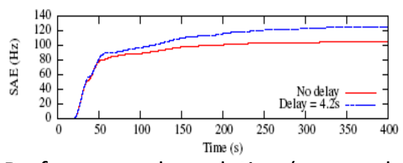
Hardware switch setup



Frequency transients after a load increase of 3% w/ & w/o communication delay



Packet drop & communication delays under random controller failures [2]



Performance degradation (summed absolute error) versus data plane communication delay

SDN with Synchronized Clock

[Ongoing work] Investigating the practical benefits of having time-synchronized network updates

- Preventing varying degrees of packet loss
- Eliminating ambiguous states when access control policy is integrated into SDN switches
- Requiring less changes compared to packet versioning

References
[1] Software-Defined Networking for Smart Grid Resilience: Opportunities and Challenges. Xinshu Dong, Hui Lin, Rui Tan, Ravishankar K. Iyer, Zbigniew Kalbarczyk. In Proceedings of The 1st Cyber-Physical System Security Workshop (CPSS), April 14-17, 2015, Singapore.
[2] A Simulation Study on Smart Grid Resilience under Software-Defined Networking Controller Failures. Uttam Ghosh, Xinshu Dong, Rui Tan, Zbigniew Kalbarczyk, David K. Y. Yau, Ravishankar K. Iyer. The 2nd Cyber-Physical System Security Workshop (CPSS 2016), co-located with AsiaCSS, May 30, 2016, Xi'an, China.

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