Enhancing Smart Grid Resilience Using Software-Defined Networking

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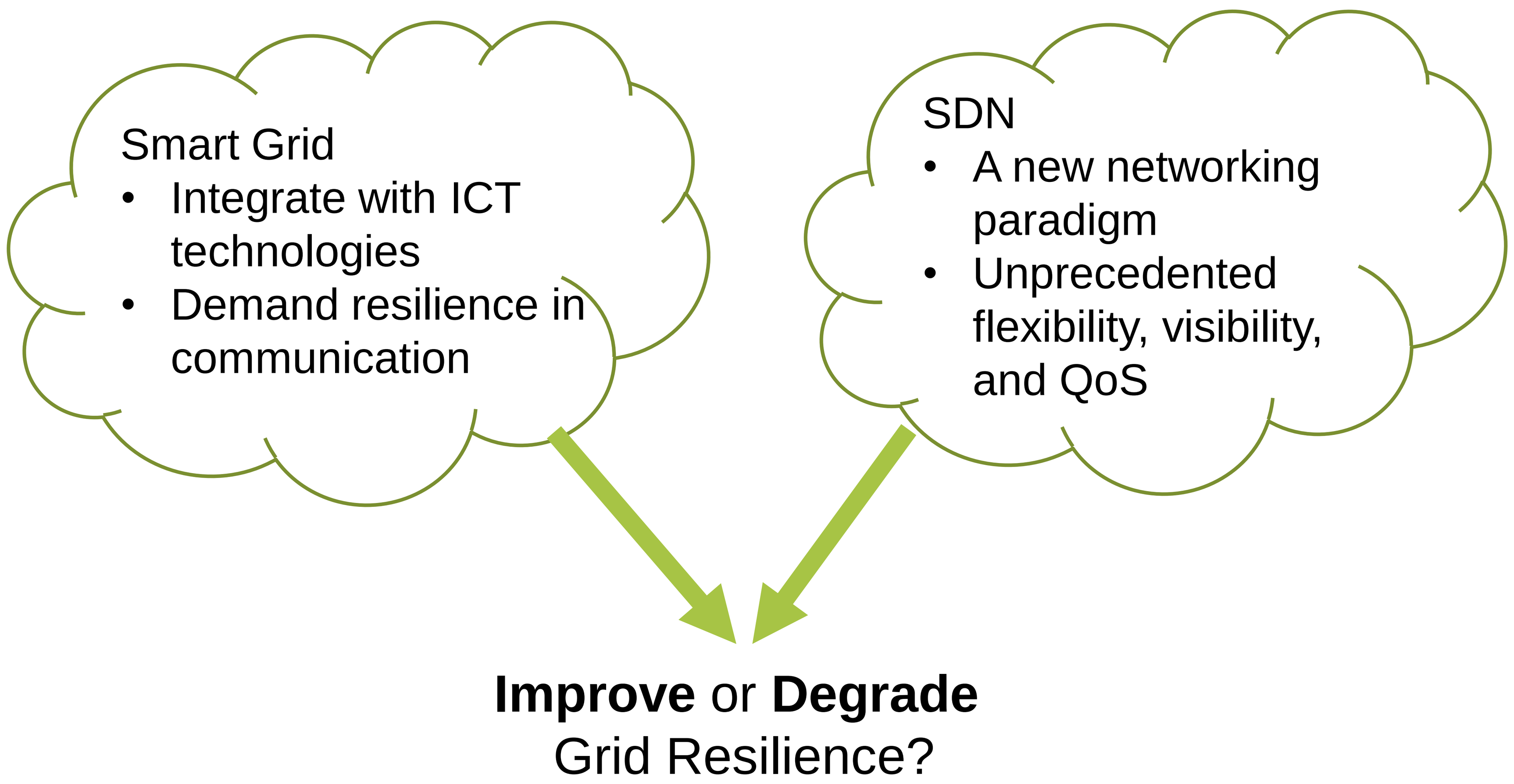
GOALS

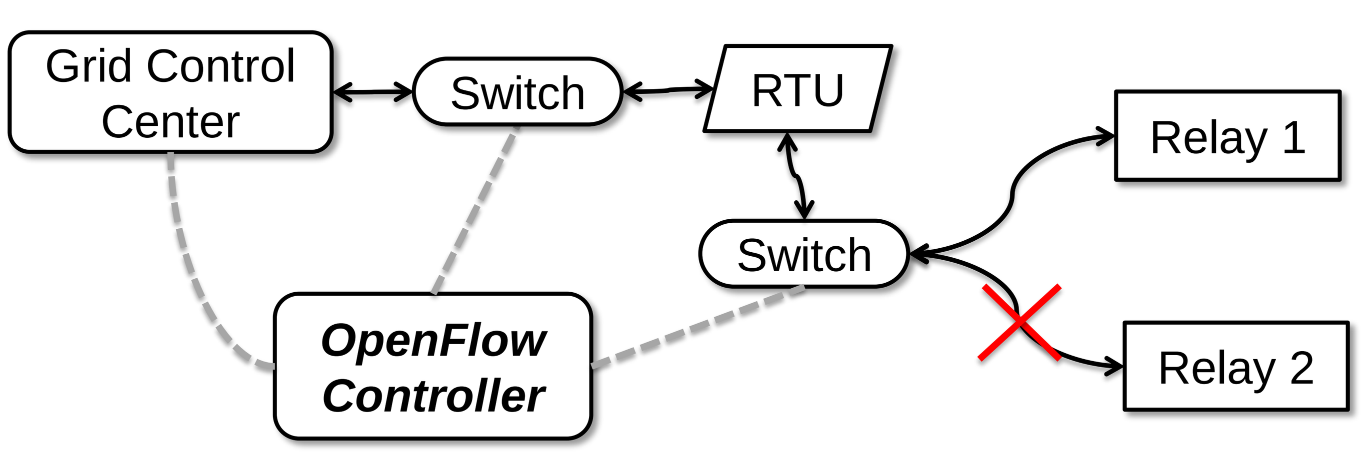
- Evaluate the application of software-defined networking (SDN) to smart grids for enhancing system resilience.
  – Recover and maintain critical services despite accidental failures and malicious attacks.
- Discuss the following questions through illustrative examples:
  – What are the opportunities for SDN to enhance smart grid resilience?
  – What are the security risks that SDN brings to smart grids?
  – How do we evaluate the enhanced resiliency and possible increased risk from SDN?
- Design and develop a testbed that integrates the simulations of both cyber and physical infrastructure of smart grids.

FUNDAMENTAL CHALLENGES

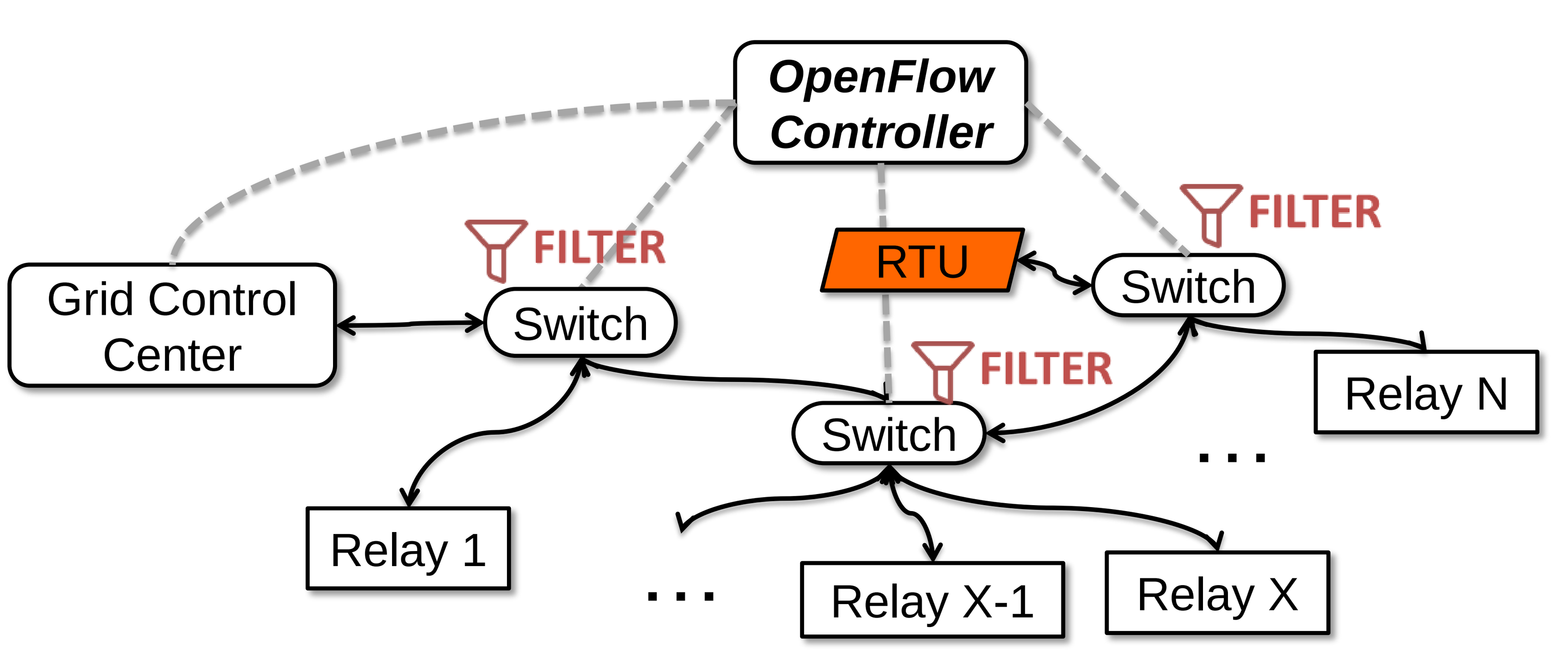


OPPORTUNITIES TO IMPROVE GRID RESILIENCE

- Opportunity (1): prevent attackers from compromising commands.
  – Ensure correct commands from the control centers are delivered to the intended control devices.
  – Monitor actual communication path of the command traffic.



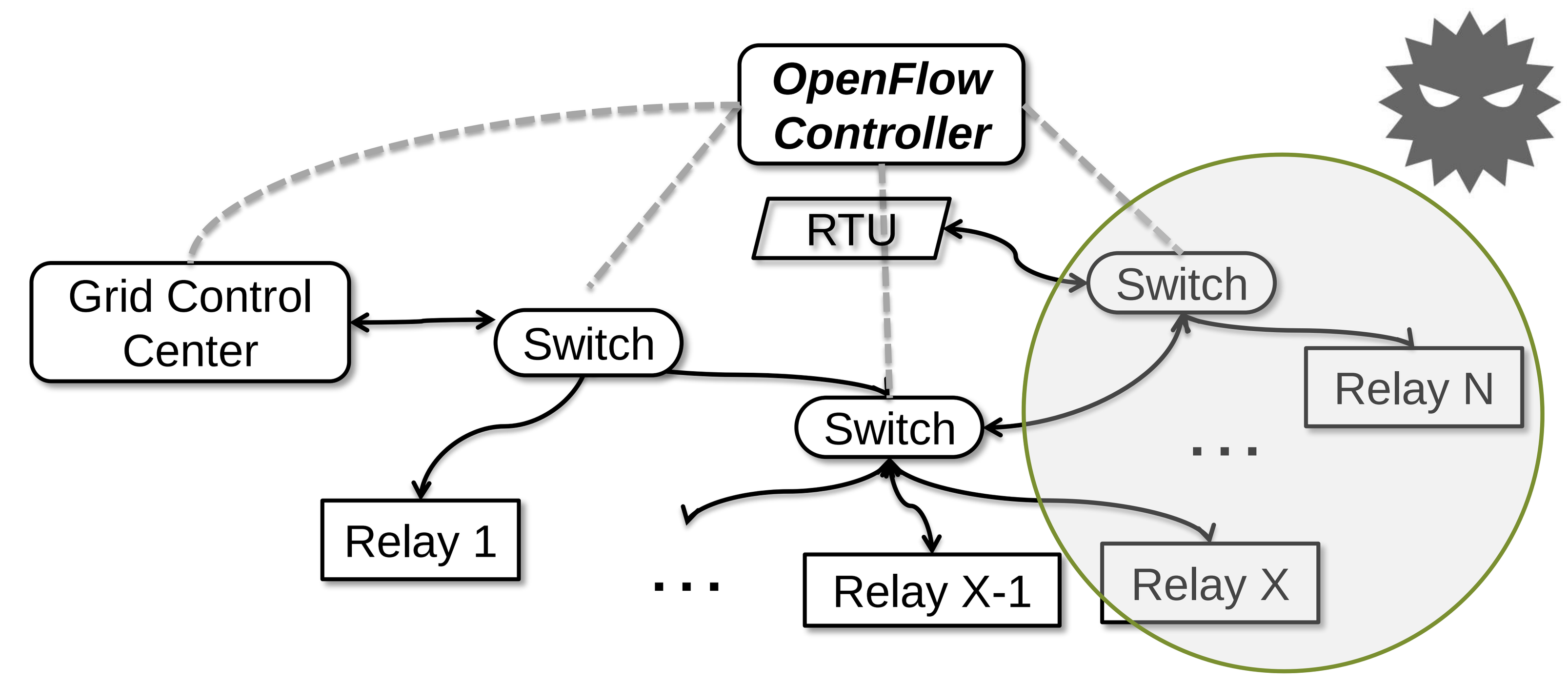
- Opportunity (2): prevent Denial-of-Service attacks.
  – Filtering out flooded responses from control and field devices caused by spoofed requests.



- Opportunity (3): detect subtle, suspicious behaviors in smart grids.
  – E.g., packet delays: Due to surreptitious attacks? Due to transient failures? Due to unusual but non-malicious bursts of traffic?
  – These are difficult to confirm, but highly detrimental to grid operations.
- Opportunity (4): isolate devices affected by attacks or accidents.
  – Hot-swapping of public-private network links.
  – Trade-offs between physical isolation and bandwidth.
  – Weighing different under catastrophic situations.

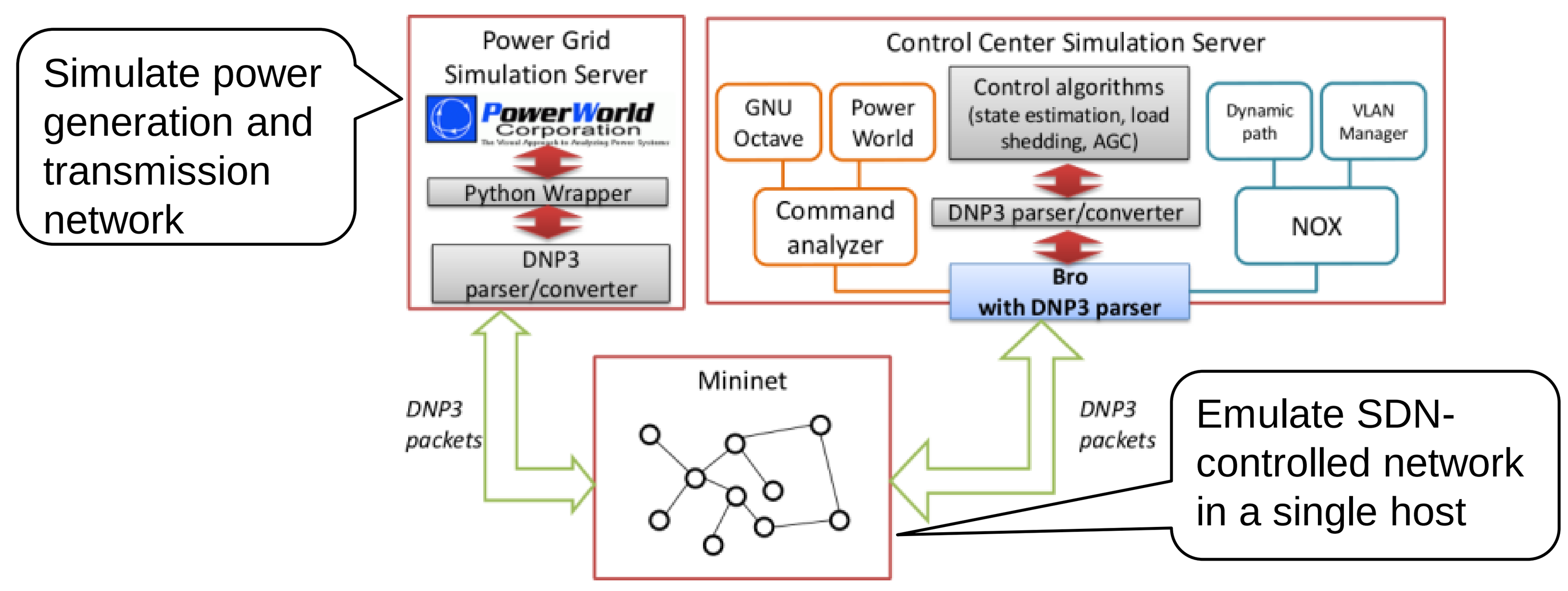
THREATS TO GRID RESILIENCE

- Threat (1): "Darknets" created by SDN rootkits.
  – Attackers compromise part of the control plane.
  – Manipulate the communications to critical field devices.
    • E.g., compromising measurements in false data injection.



- Threat (2): Denial-of-Service attacks accelerated by centralized control.
  – Well-studied, still challenging to resolve.
- Threat (3): topology destruction by malicious SDN controller.
  – Change the configurations of the communication network.
  – Undermine the performance of grid control applications.

TESTBED DEVELOPMENT



- Interconnected simulation that integrates both the cyber and physical infrastructure of smart grids.
  – Inject faults in simulated communication networks, e.g., Mininet.
  – Evaluate physical impacts in transmission network models, e.g., PowerWorld.
- Example case:
  – Characterize the consequences of such communication latency on automatic generation control (AGC).

INTERACTION WITH OTHER PROJECTS

- Collaborate with International Computer Science Institute (ICSI) and the University of Illinois' National Center for Supercomputing Applications (NCSA).
  – An NSF award is being used to support further work.
- Collaborate with the Advanced Digital Sciences Center (ADSC).
  – Under the project *Towards a Resilient Smart Power Grid: A Testbed for Design, Analysis, and Validation of Power Grid Systems.*

FUTURE EFFORTS

- Use simulated testbed for research experiments.
  – Evaluate the proposed intrusion detection and response mechanism.
- Build testbed in real OpenFlow controllers and switches instead of simulations.
- Evaluate how network activities impact the transient stability of power systems.

SELECTED PUBLICATIONS

1. Xinshu Dong, Hui Lin, Rui Tan, Ravishankar K. Iyer, and Zbigniew T. Kalbarczyk, "Software-Defined Networking for Smart Grid Resilience: Opportunities and Challenges," in *Proc. CPSS*, ACM, 2015.
2. Hui Lin, Adam Slagell, Zbigniew Kalbarczyk, Peter W. Sauer, and Ravishankar K. Iyer, "Runtime Semantic Security Analysis to Detect and Mitigate Control-related Attacks in Power Grids," in *IEEE Transactions on Smart Grid*, accepted.

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