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MODELING A CYBER RESILIENT SMART GRID
USING SOFTWARE DEFINED NETWORKS

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SCIENCE OF SECURITY
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IP-BASED COMMUNICATIONS IN THE SMART GRID

- Digital intelligence to the power system network.
- Intelligent Electronic Devices (IEDs) used to monitor the state of the power system
- IP-based communications also increase the likelihood of successful IP-based network attacks
- *Challenge*: Enabling the smart grid communication network become cyber resilient
- **DOE Vision:** *By 2020, resilient energy delivery systems are designed, installed, operated, and maintained to survive a cyber incident while sustaining critical functions*

SECURITY QUANTIFICATION MODEL

- The cyber resilient model depends on the security score of IEDs in the smart grid network
- The score for a particular threat based upon its susceptibility s_i and countermeasure factor c_i is given by:

$$t_i = s_i \left(1 - c_i\right)$$

- The score for the *jth* IED with m_j threats becomes:

$$E_j = \sum_{i=1}^{m_j} t_i * S_R \qquad (1)$$

  - Where S_R is security requirement of an IED
  - If this IED were to be compromised, how much impact would it have on the smart grid?

- Overall security score of the network with *n* IEDs:

$$R = 10 - \min\left(10, \sum_{j=1}^{n} E_j\right) \qquad (2)$$

SDN FRAMEWORK FOR CYBER RESILIENCE

- Develop an OpenFlow controller that constantly monitors network utilization
- When an attack is detected, the controller calculates the security score of the network using (1) and (2)
- The controller then takes into account:
  - The current security posture
  - Cyber resilience requirements (tradeoffs)
  - Network topology and network traffic
  - Previous similar attacks
  - Available network resources
- The controller makes an informed decision on the SDN mitigation method to use:
  - Reroute, rate limit, or drop flows
  - Migrate virtualized IED
  - Prioritize flows, etc.

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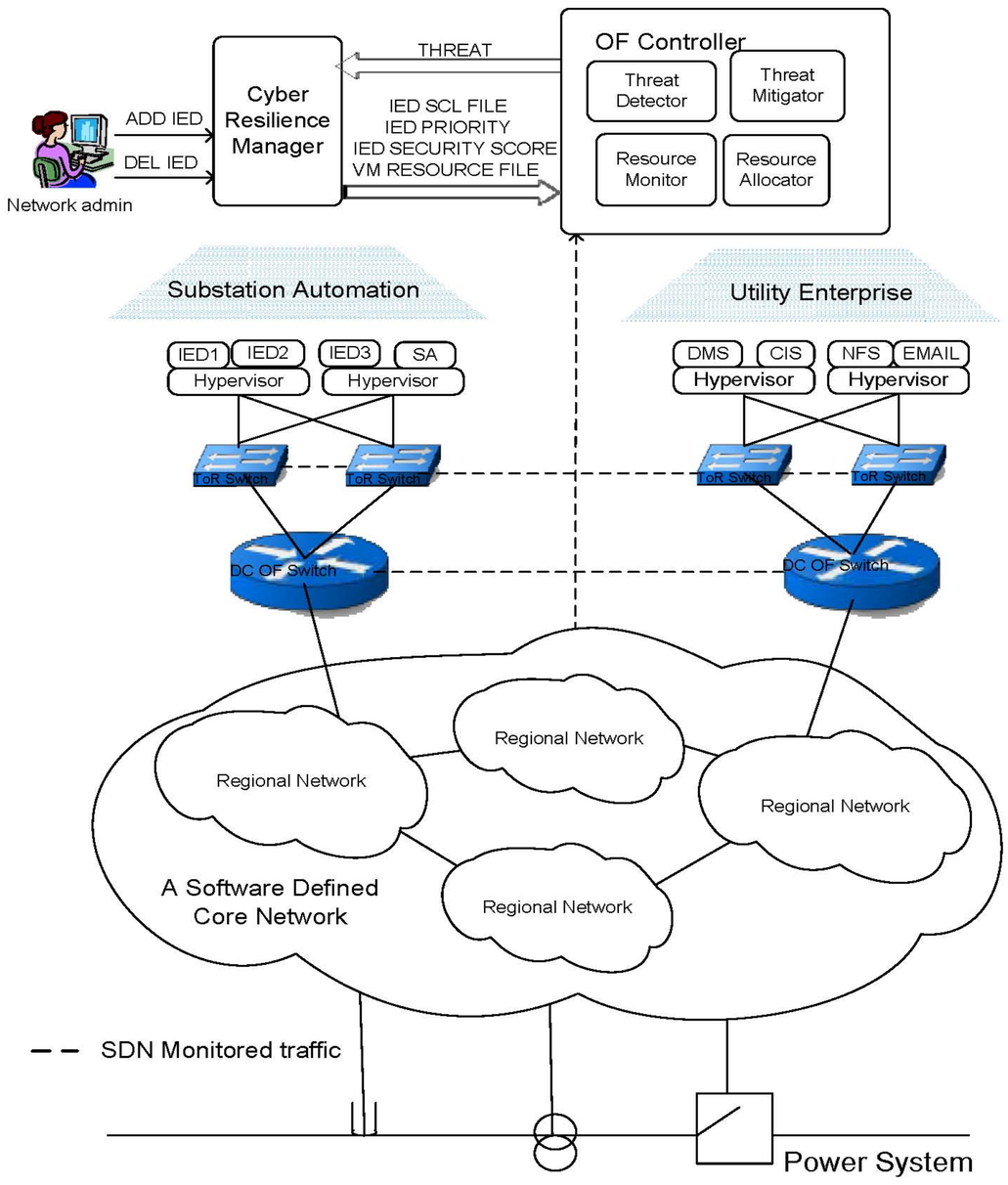
A CYBER RESILIENT SOFTWARE DEFINED SMART GRID



PRELIMINARY IMPLEMENTATION

- Consider a windmill collector substation with:
  - 2 Current Differential and Overcurrent IEDs
    - ✓ Transmission domain (medium critical)
  - 1 Distribution Substation Transformer Monitoring IED
    - ✓ Substation domain (most critical)
  - 3 Distribution Feeder protection and control IEDs
    - ✓ Distribution domain (Least Critical)
  - 6 OpenFlow switches, 3 end hosts and 3 servers
- Mininet used to simulate the OpenFlow switches
- Triangle Microworks IEC61850 suite to simulate IEDs
- Ryu for implementing the OpenFlow controller

TABLE 1: SECURITY SCORE FOR THE SUBSTATION IED

DoS Attack	Si	Ci	Ti
Energy based DoS over LAN	0.2	1	0
Bulky messages over LAN	0.2	0	0.2
Low rate link foods over LAN/WAN	0.2, 1	0, 0	1.2
Protocol based DoS over LAN/WAN	0.2, 1	0, 0	1.2
Software based DoS over LAN/WAN	0.2, 1	0, 0	1.2
Ej			5.74

CONCLUSION

- Classified criticality of IEDs and developed a model for security posture of smart grid networks
- Modeled SDN framework for cyber resilient smart grid
- *Next Phase:* Implement the OF controller in the SDN framework

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