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A Methodology for Monitoring and Control Network Design

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- Optimal security-aware network design
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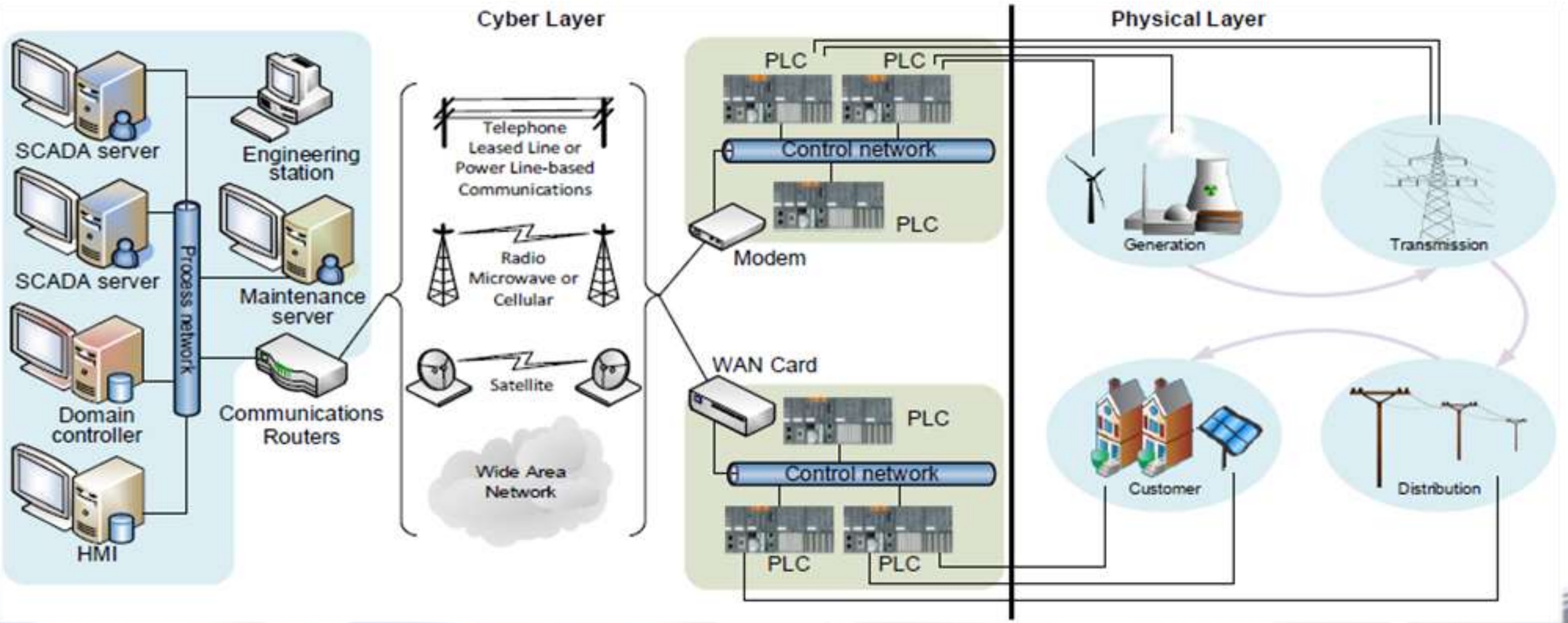
Introduction – ICS – the core of CI

- Architecture includes the cyber and physical domains.
  - Physical layer: sensors, actuators.
  - Cyber layer: Transmitters, PLC, SCADA servers, HMI, communication infrastructure.

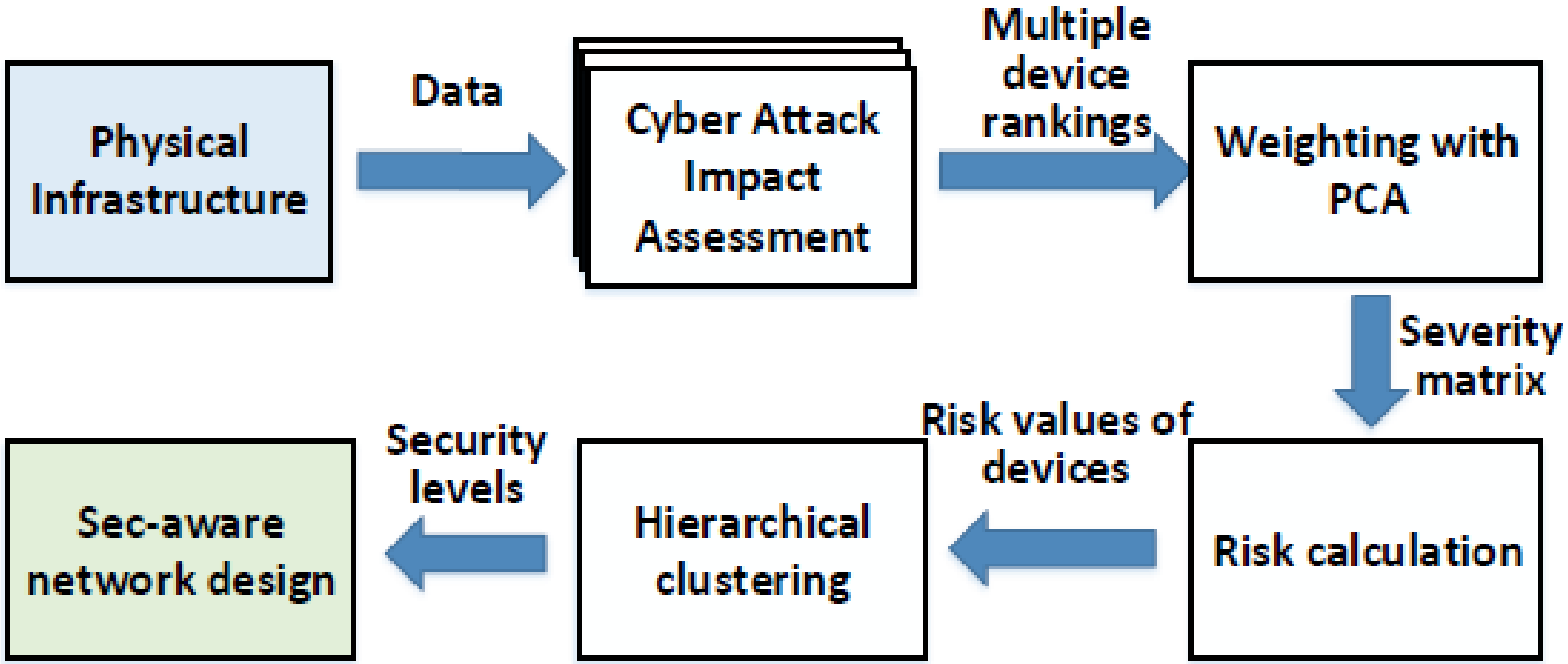


Overview of the proposed technique

- Measure the impacts of various cyber threats on the physical equipment.
- Summarize the impact values and determine a risk value for each cyber device of the ICS.
- Group the devices in a predefined number of security groups.
- Make the communication links to the concentrator nodes (switch, router, firewall, IDS) as desired by the security requirements.

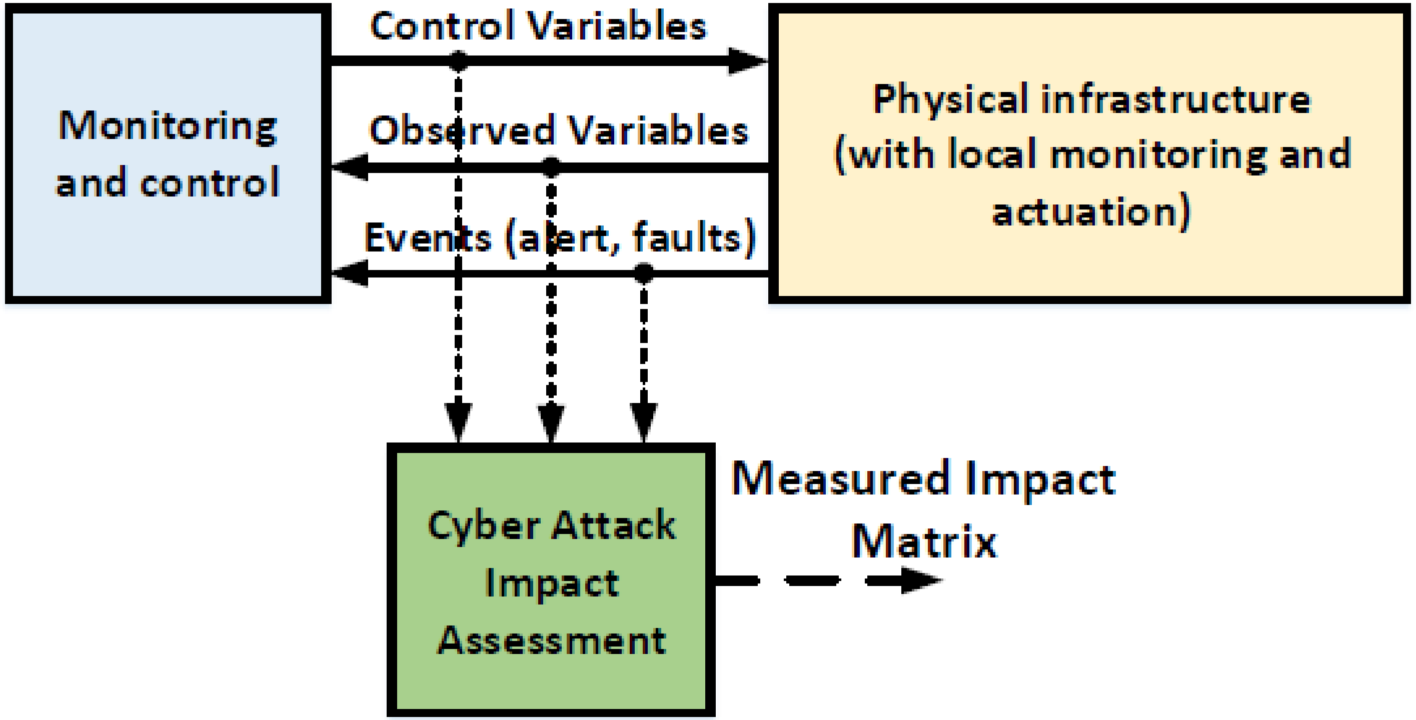
Cyber risk assessment

- How to measure the risk values associated with physical process/equipment?



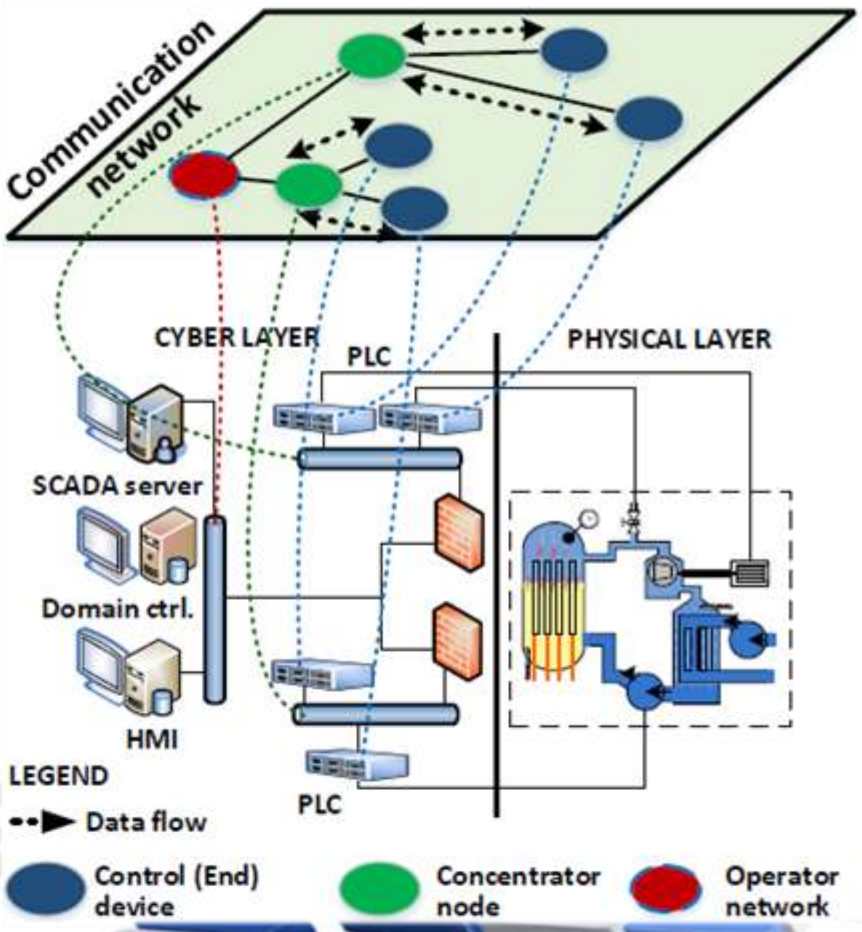
Cyber attack impact assessment

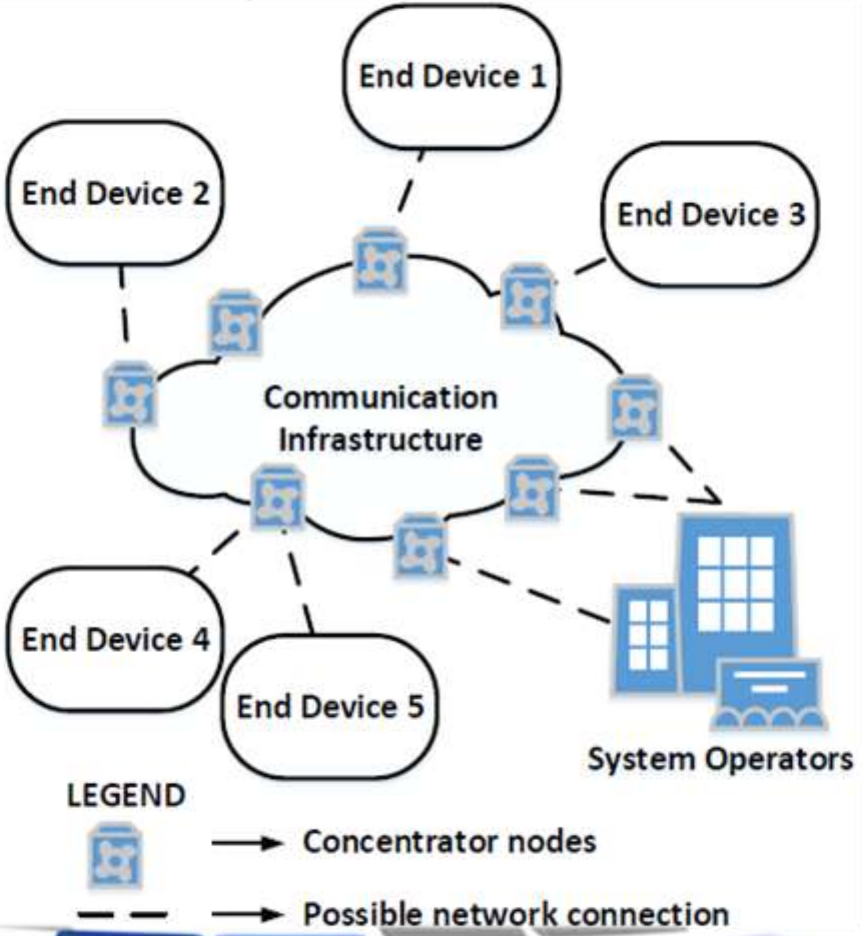
- How to measure the effects of cyber incidents on physical process/equipment?



Optimal security-aware network design

- Minimize End device - Concentrator node (switch, router, firewall + IDS) distances and maintain performance & **security constraints.**





Optimal, security-aware network design

- ILP problem
- Some mathematics
  - (10) – connection constraint
  - (11) – security constraint
  - (12) – link capacity constraint

Cost function

$$min\left(\sum_{\imath\in\mathcal{C}}\sum_{\jmath\in\mathcal{D}}[(x_\imath^{\mathcal{C}}-x_\jmath^{\mathcal{D}})^2+(y_\imath^{\mathcal{C}}-y_\jmath^{\mathcal{D}})^2]\cdot\nu_{\imath\jmath}\right), \tag{9}$$

With the following constraints:

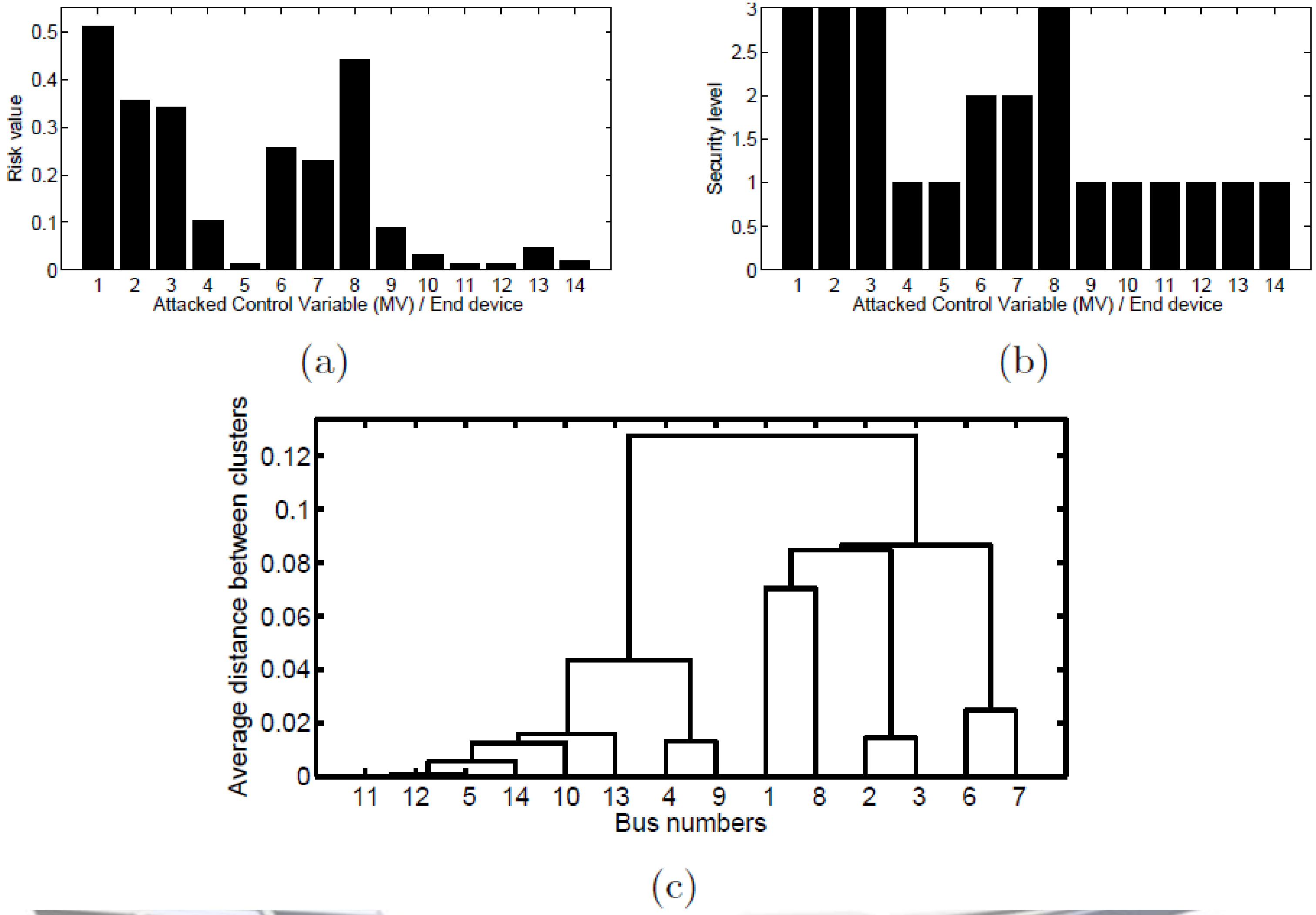
$$\sum_{\imath\in\mathcal{C}}\nu_{\imath\jmath}=1,\forall\jmath\in\mathcal{D}, \tag{10}$$

$$s^{\mathcal{D}}_{\jmath\kappa}\cdot\nu_{\imath\jmath}\leq s^{\mathcal{C}}_{\imath\kappa},\forall\imath\in\mathcal{C},\jmath\in\mathcal{D},\kappa\in\mathcal{S}, \tag{11}$$

$$\sum_{\jmath\in\mathcal{D}}\xi^{\mathcal{D}}_{\jmath}\cdot\nu_{\imath\jmath}\leq\zeta^{\mathcal{C}}_{\imath},\forall\imath\in\mathcal{C}, \tag{12}$$

Experimental assessment

- IEEE 14-bus electricity grid
  - (a) Pure risk values;
  - (b) Risk values enforced in 3 groups with different security levels;
  - (c) Risk assessment dendrogram.



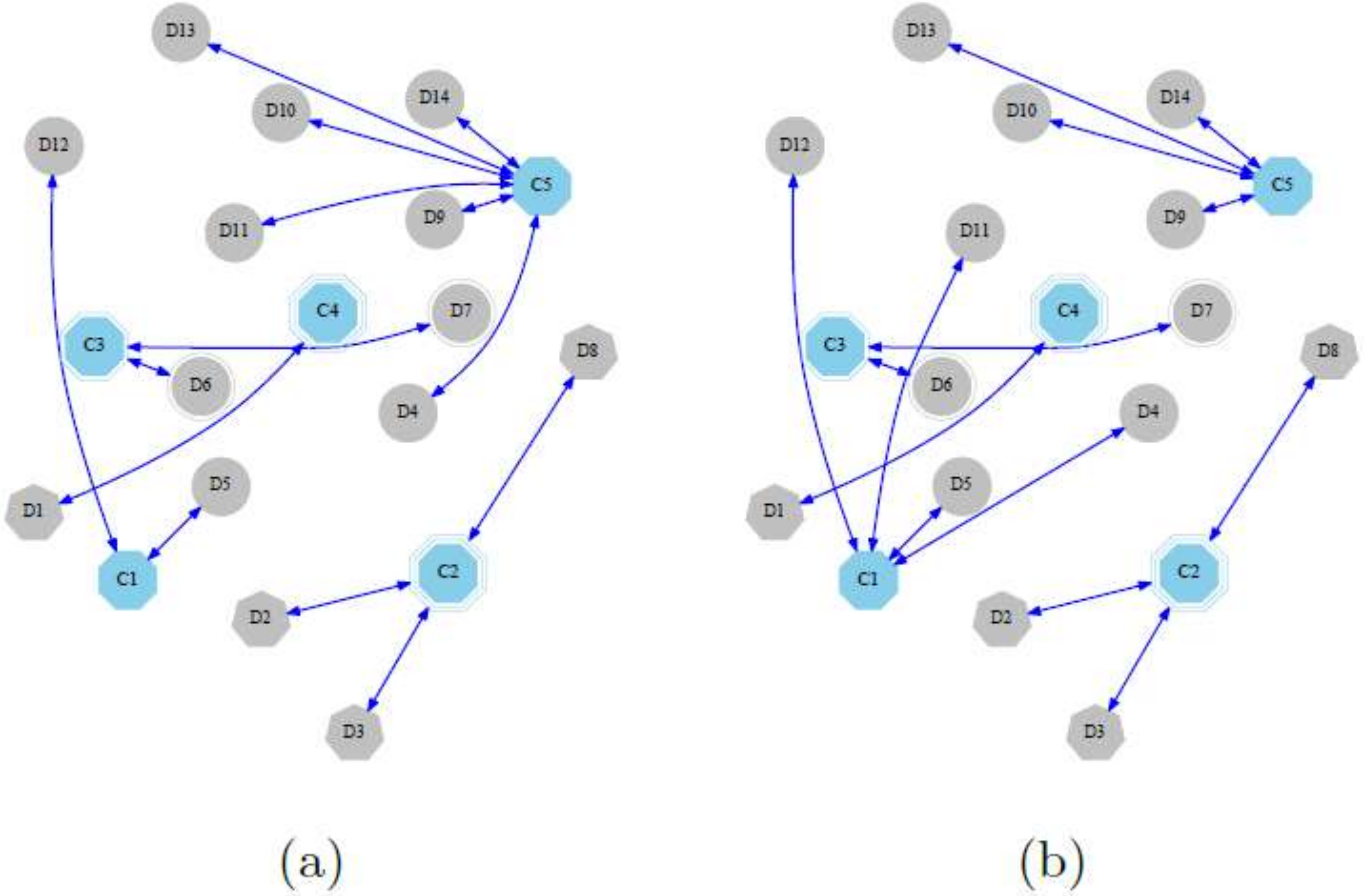
(a)

(b)

(c)

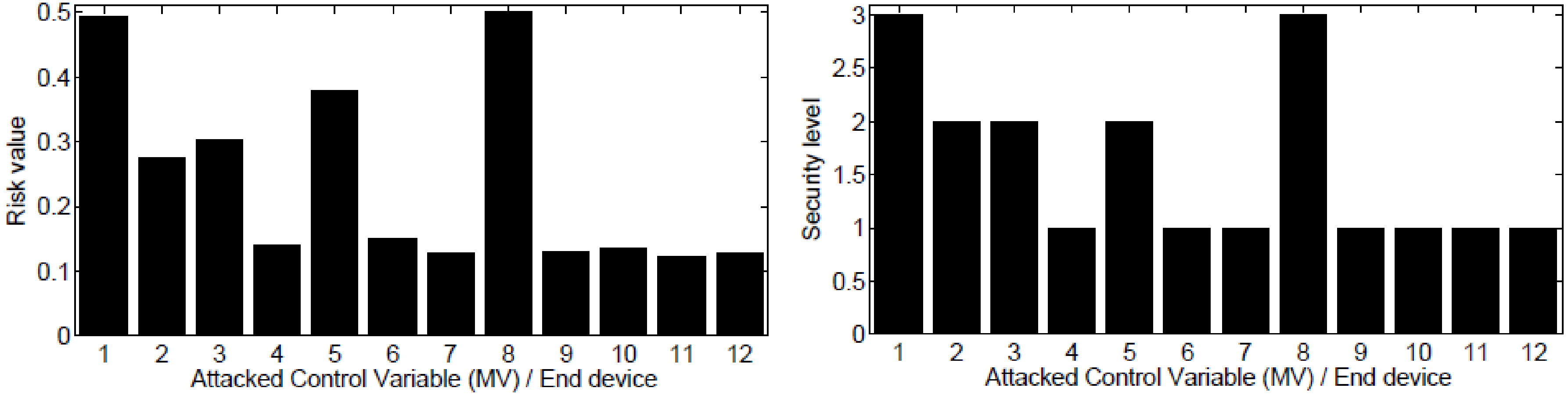
Experimental assessment

- IEEE 14-bus electricity grid
  - (a) unconstrained;
  - (b) constrained by the link capacity of C5.



Experimental assessment

- Tennessee Eastman chemical plant
  - (a) Pure risk values;
  - (b) Risk values enforced in 3 security level groups

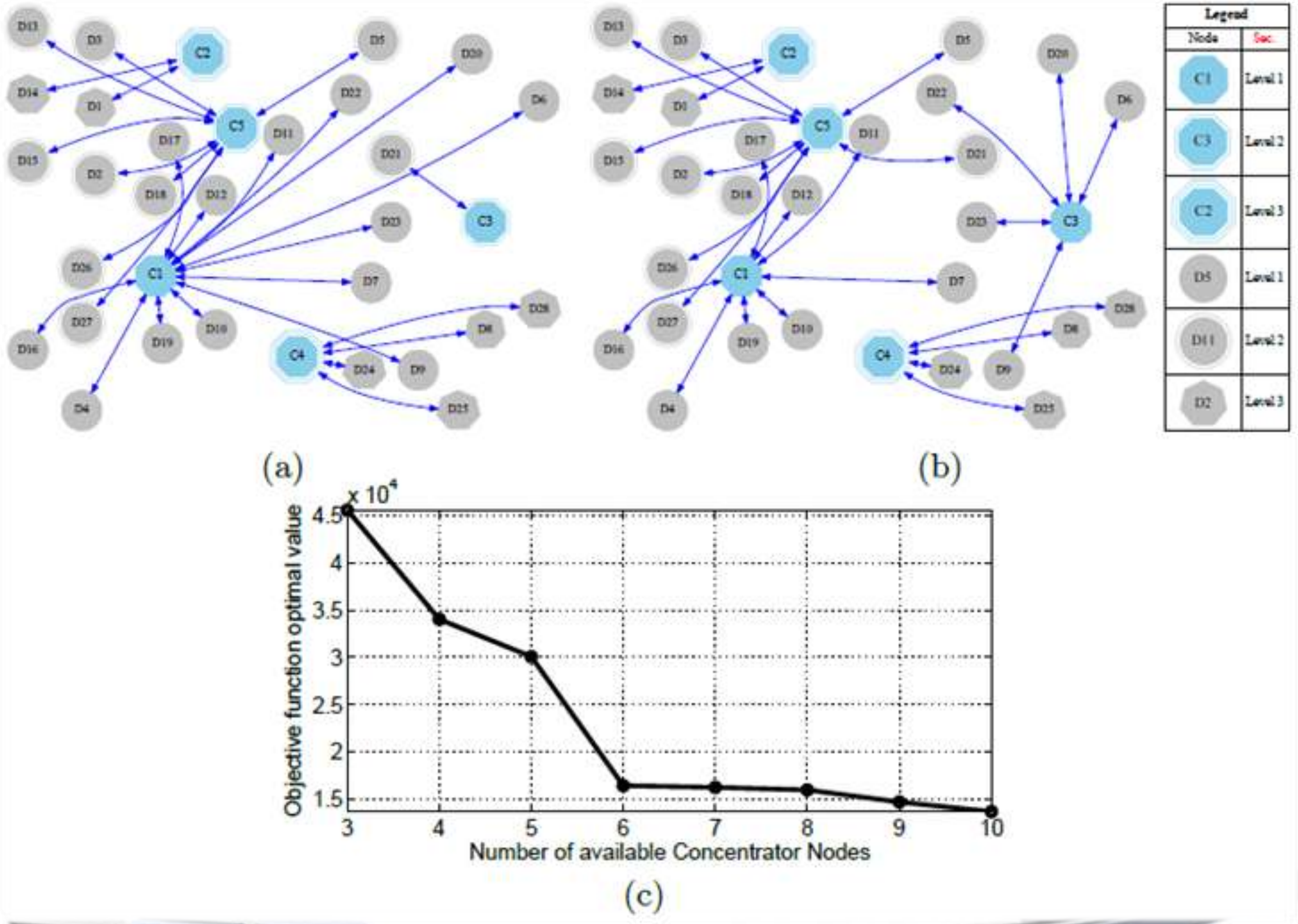


(a)

(b)

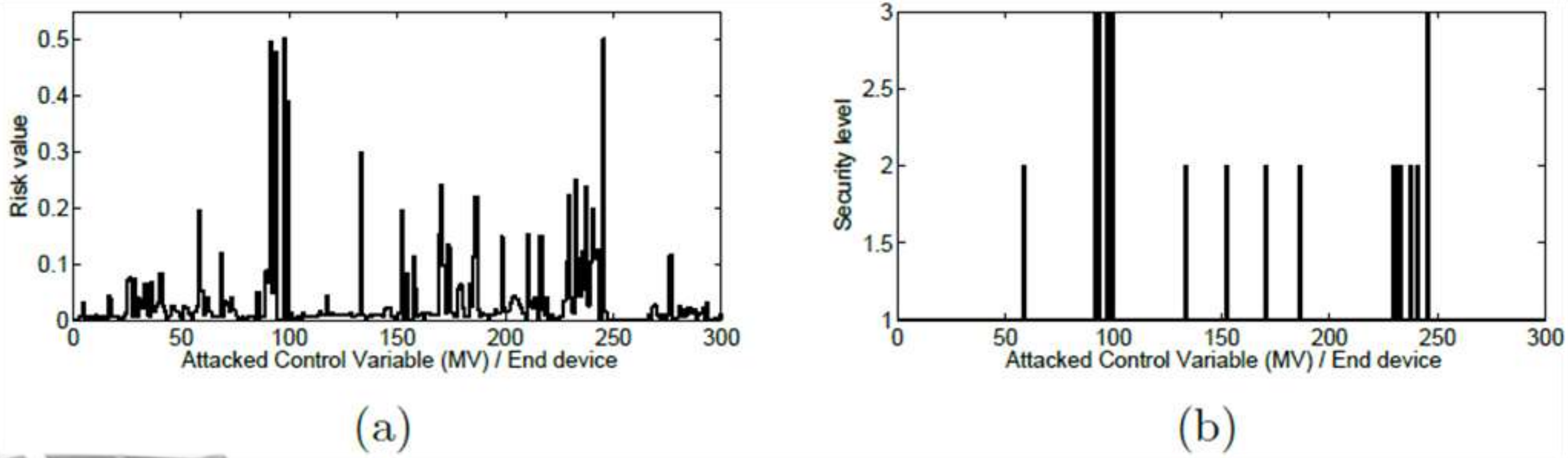
Experimental assessment

- Tennessee Eastman chemical plant
  - (a) with initial parameters;
  - (b) with C3's security level changed to 1;
  - (c) Objective function's optimal values for different number of CN.



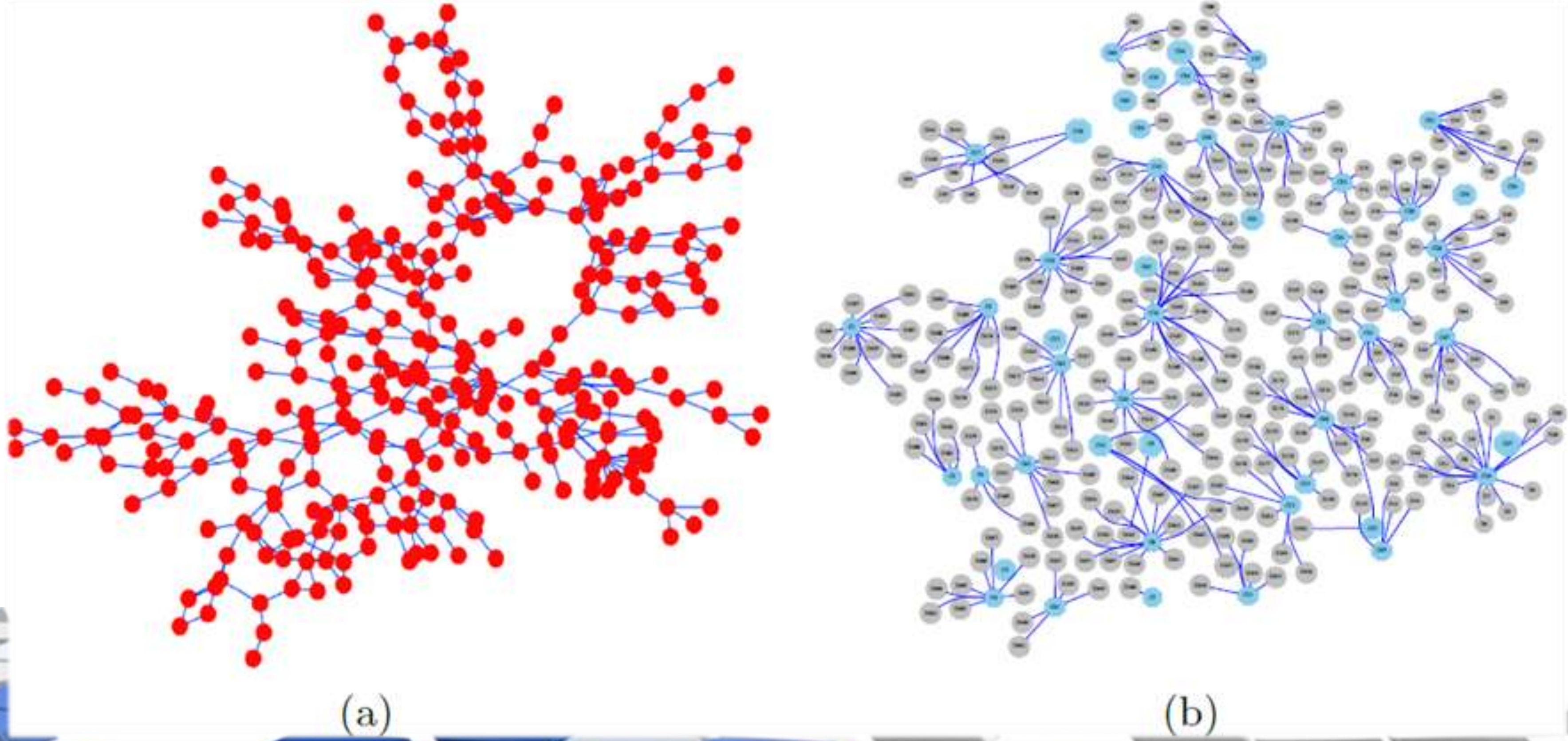
Experimental assessment

- IEEE 300-bus large-scale electricity grid
  - (a) Pure risk values;
  - (b) Risk values enforced in 3 security groups.



Experimental assessment

- IEEE 300-bus large-scale electricity grid
  - (a) electrical topology[1];
  - (b) communication infrastructure with 50 CN.



[1] P. Hines, S. Blumsack, E. Cotilla Sanchez, and C. Barrows. The topological and electrical structure of power grids. *In System Sciences (HICSS), 2010 43rd Hawaii International Conference on*, pages 1-10, Jan 2010.

Conclusions

- We developed a methodology for the optimal design of industrial networks.
- The approach relies on a risk assessment technique and an optimization problem to minimize connection distances, while enforcing security and capacity requirements.
- The preliminary studies and the experiments revealed the importance of considering cyber security in the design phase of ICS.

Thank you!

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