Fraunhofer AISEC

SMART GRID PROTECTION AGAINST CYBER ATTACKS

SPARKS threat analysis using Attack Trees and Semantic Threat Graphs

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Joint work with Will Fitzgerald, Ewa Piatkowska, Norbert Wiedermann, Gerhard Hansch

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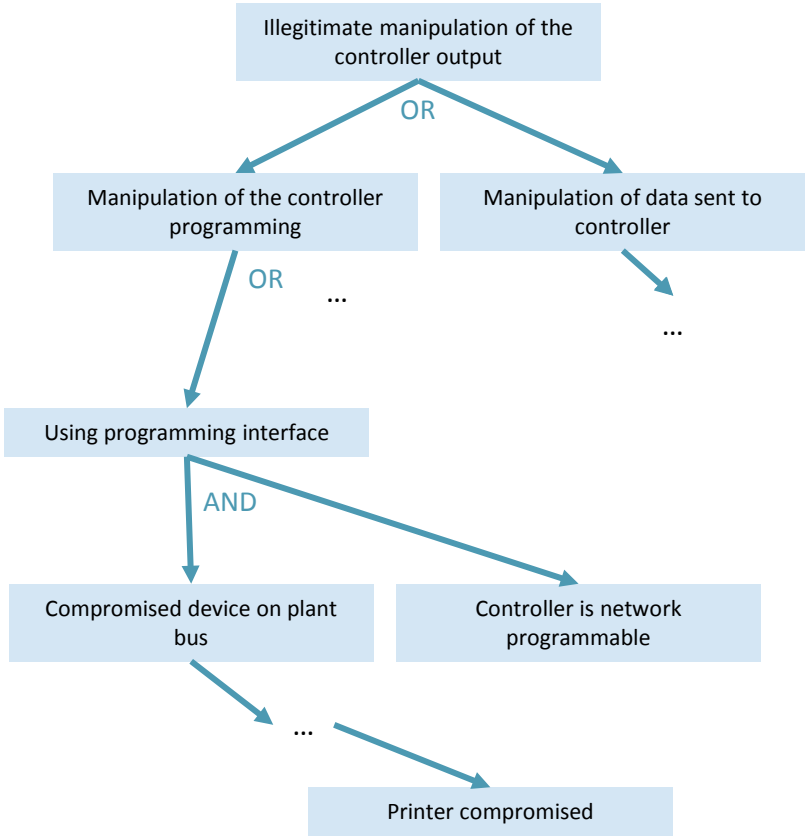
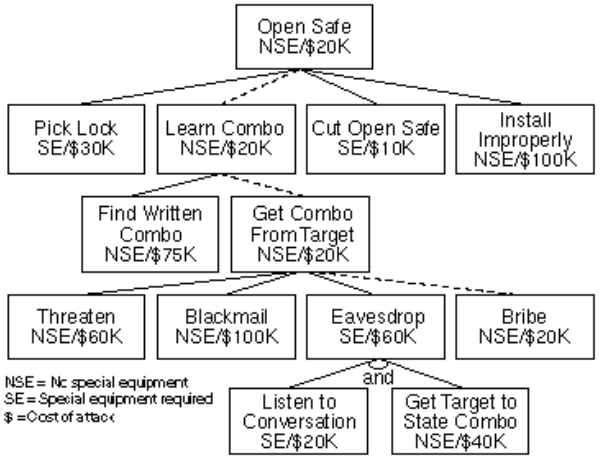
Attack Trees [Schneier 1999]

- Structured analysis of attack vectors from attacker's perspectives
  1. Identification of attack goals (violation of CIA of assets)
  2. Decomposition into sub-goals until sufficient fine granularity is reached (AND, OR)
  3. Evaluation of leaf trees with respect to likelihood
  4. Propagation of values to the root of the tree
     - AND: minimum of children
     - OR: maximum of children
  5. Identification of major attack paths (subgraph)



Attack Trees – State of the Art

- Attack Trees:
  - Introduced 1999 by Bruce Schneier to identify attack vectors [1]
  - Different Tree-Perspectives: Attack, Operation, System, Vulnerability, Fault/Failure, etc.
  - Attack Defense Trees (ADT) [2], Attack Countermeasure Tree (ACT) [3]
  - Sequential and ordered Attack Trees (EAT [4],OAT [5])
- Graphs
  - Directed acyclic graphs (DAG)
  - Vulnerability cause graphs (VCG) [6]
  - Security activity graphs (SAG) [6]
  - Semantic Threat Graphs (STG) [7]
- Applications:
  - Assessment of vulnerabilities in SCADA Systems [8]
  - Vulnerability analysis of digital instrumentation and control systems [9]



[1] Schneier, B., “Attack Trees: Modeling Security Threats,” *Dr. Dobb's Journal of Software Tools*, vol. 24, no. 12, 1999.

[2] Kordy, B. et al., “Attack-defense trees”, 2014

[3] Roy, A., Kim, D. S., and Trivedi, K. S., “Attack countermeasure trees (ACT): towards unifying the constructs of attack and defense trees”, 2012

[4] Jhawar, R et al., “Attack Trees with Sequential Conjunction” 2015.

[5] Camtepe, S. A. and Yener, B., “Modeling and detection of complex attacks,” In *2007 3rd International Conference on Security and Privacy in Communications Networks and the Workshops - SecureComm 2007*, 234–43.

[6] Ardi, S., Byers, D., and Shahmehri, N., “Towards a structured unified process for software security”, 2006

[7] Foley, S. N. and Fitzgerald, W. M., “Management of security policy configuration using a Semantic Threat Graph approach”, 2011

[8] Eric J. Byres, Matthew Franz, and Darrin Miller, “The use of attack trees in assessing vulnerabilities in scada systems”, 2004

[9] Hutle, M. and Seidel, F., “Vulnerability analysis of digital instrumentation and control systems important to safety – a methodical approach,” 2015.

Objective:
Refining the attack tree approach to fit in the SPARKS risk assessment

- There is a lot of freedom when designing attack trees
- Strategy for tree decomposition
  - mapping SGAM model (components on layers) to attack trees
  - good coverage
  - develop best practices, catalogues (library of sub-trees)
- Attack trees tend to become intractable large and redundant
  - library of already created trees
  - modularity
  - combination with network analysis
    - attacker paths
    - attack trees for details
  - tool support

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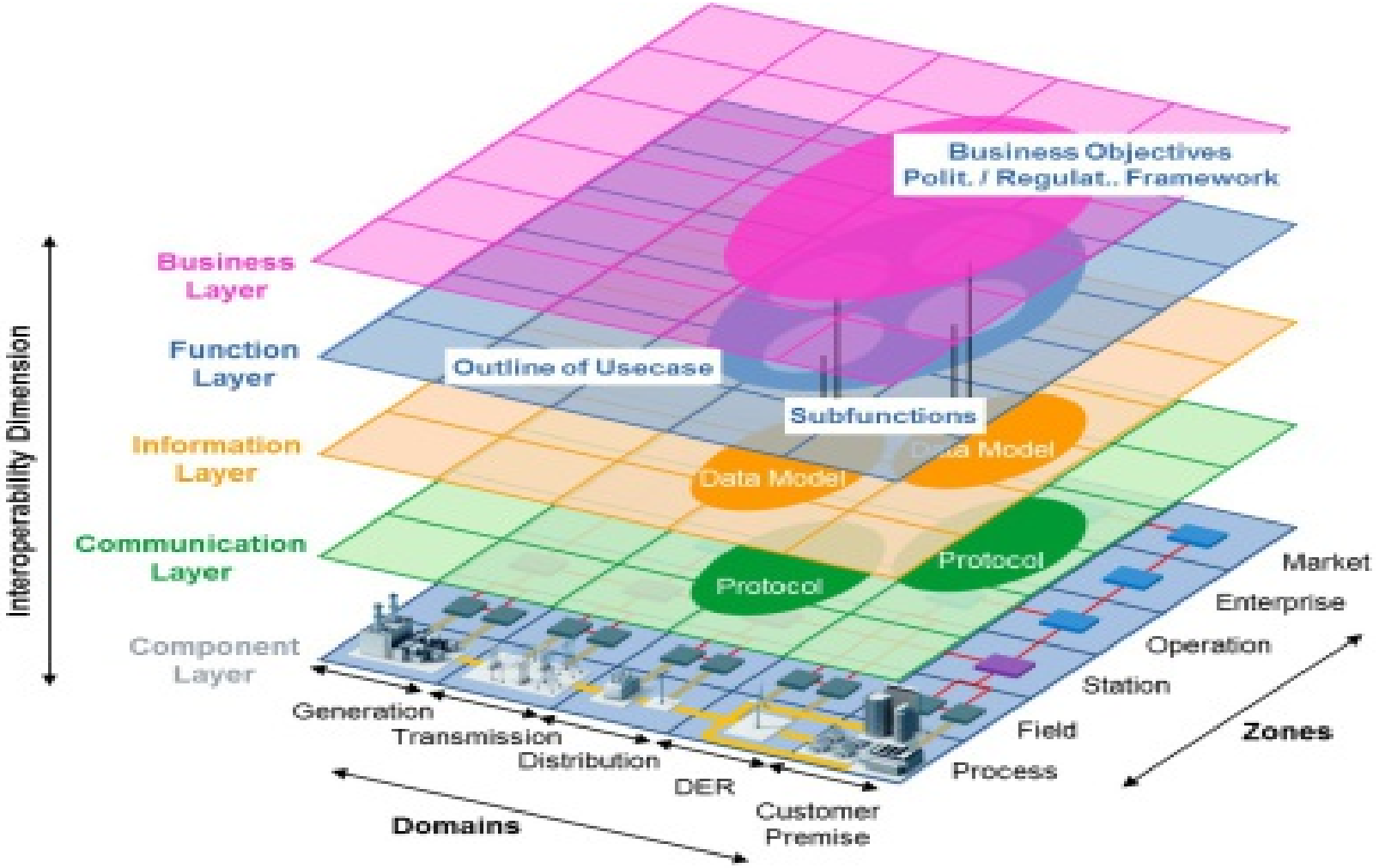
The Smart Grid Architecture Model (SGAM)



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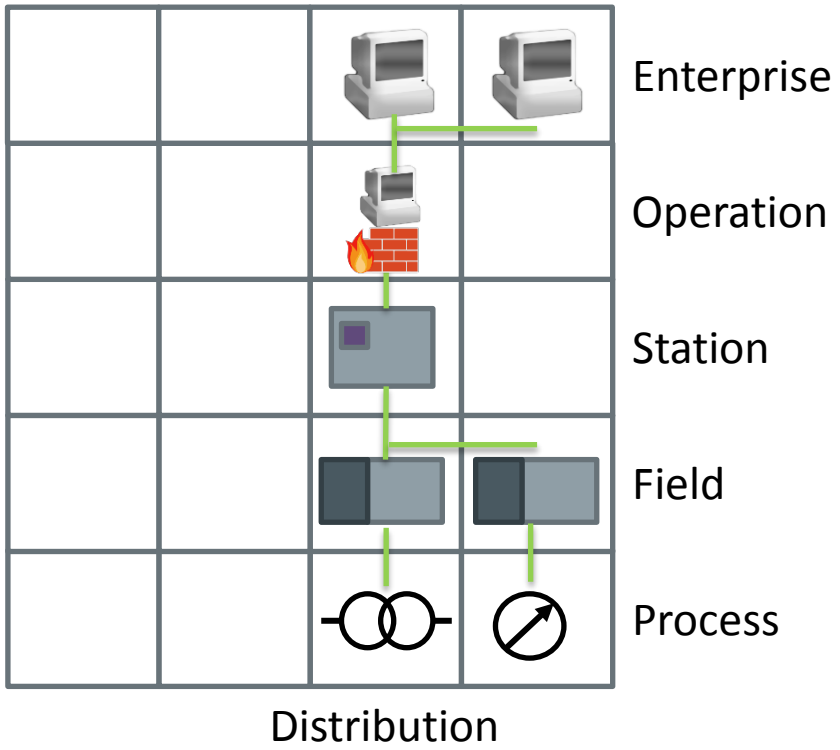
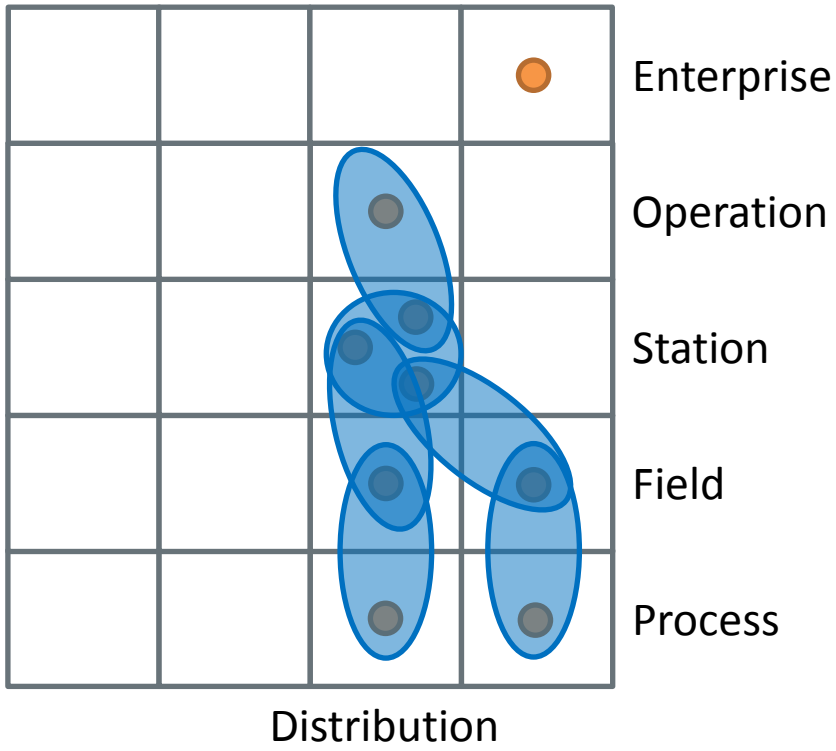
SGAM:
Component and communication layer



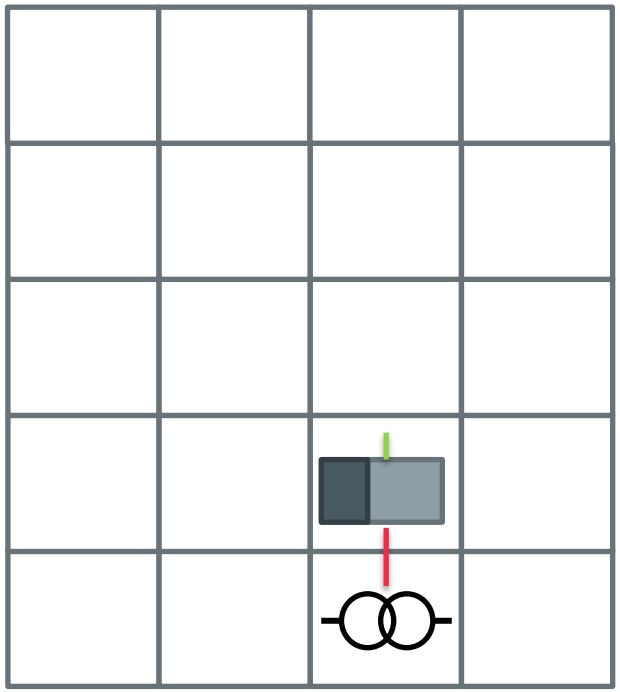
- Components
  - individual steps of an attacker in a multi-stage attack
- Protocols / Connections
  - propagation paths

SGAM:
Information and function layer



- Information elements
  - potential assets for our analysis
- Functions
  - influence on primary assets by function

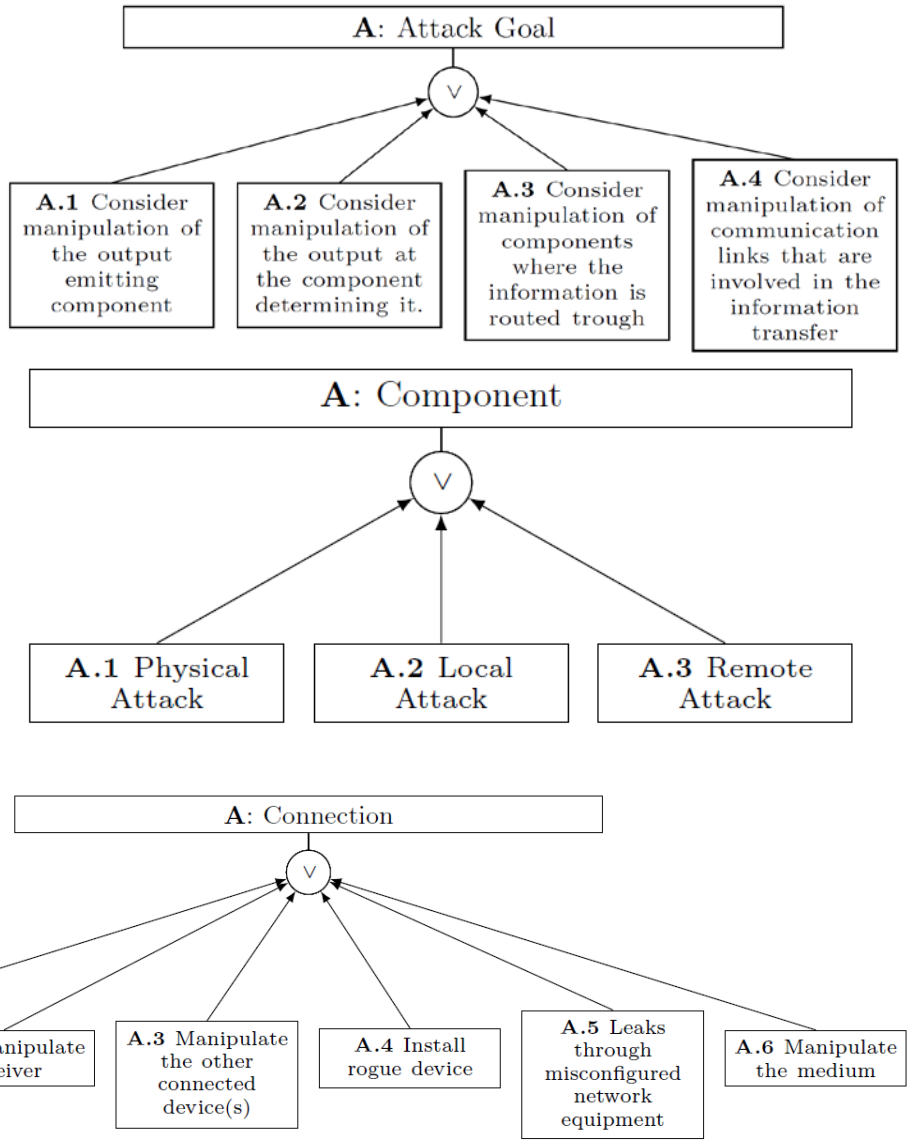
Threat analysis



- Start with primary asset
  - output to process
  - output to HMI
  - output to external system
- Identify attack goal:
  - violation of security objective (CIA) of a primary asset

Patterns

- set of typical attack graph patterns that occur in networked CPS
  - root (attack goal)
  - component
  - connection
  - functional dependency
- can be extended when needed
- stop when a new component is reached



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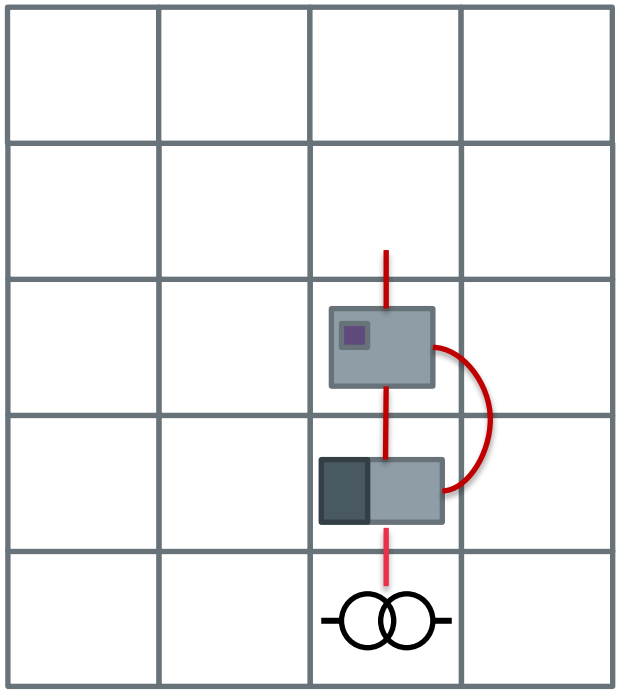
Continue with next component



- evaluated attack graph for each component
- can be combined by the “has access to” nodes
- results (theoretically) in a large overall threat graph
- evaluating the external interfaces
  - Internet
  - mobile networks
  - local (Wi-Fi)
  - physical

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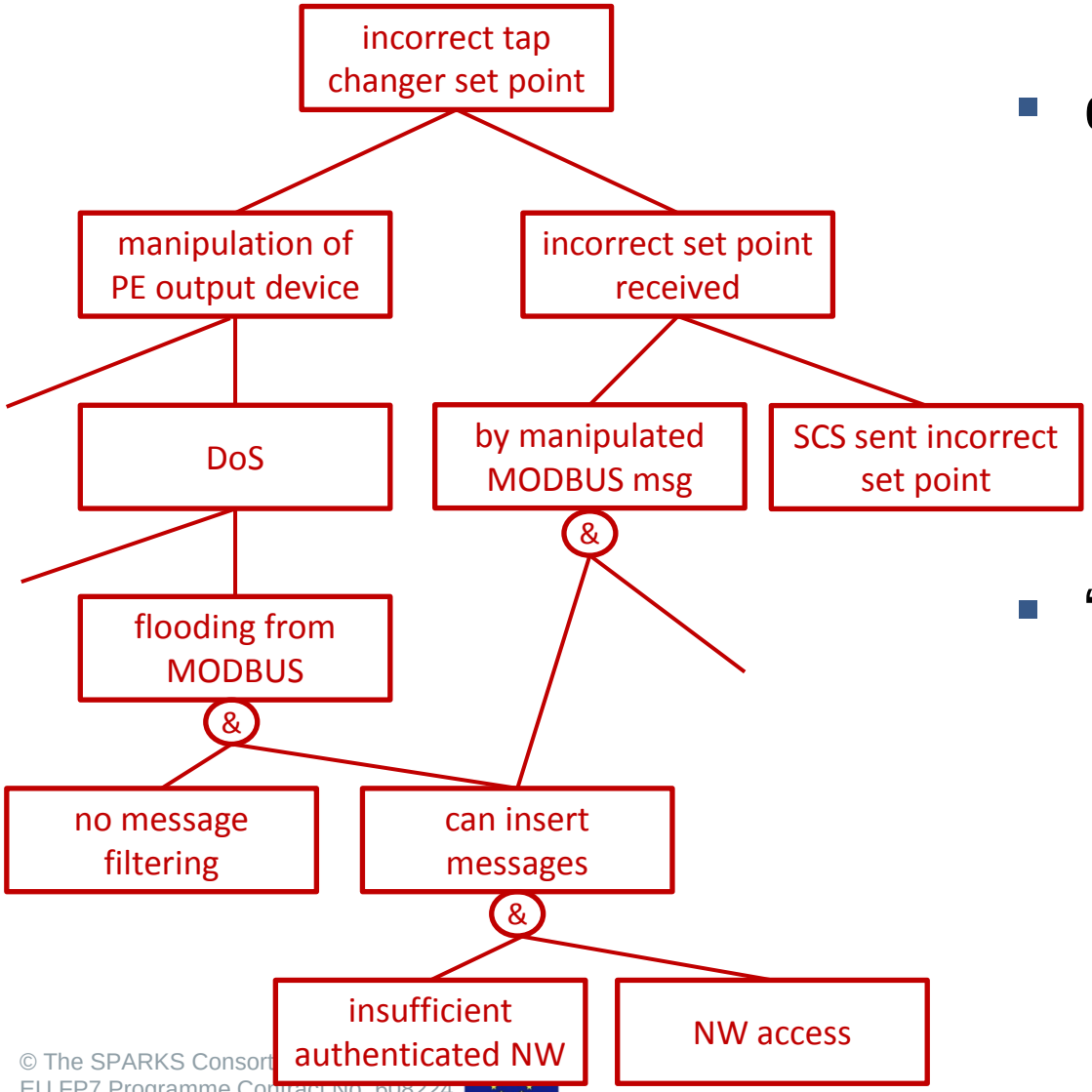
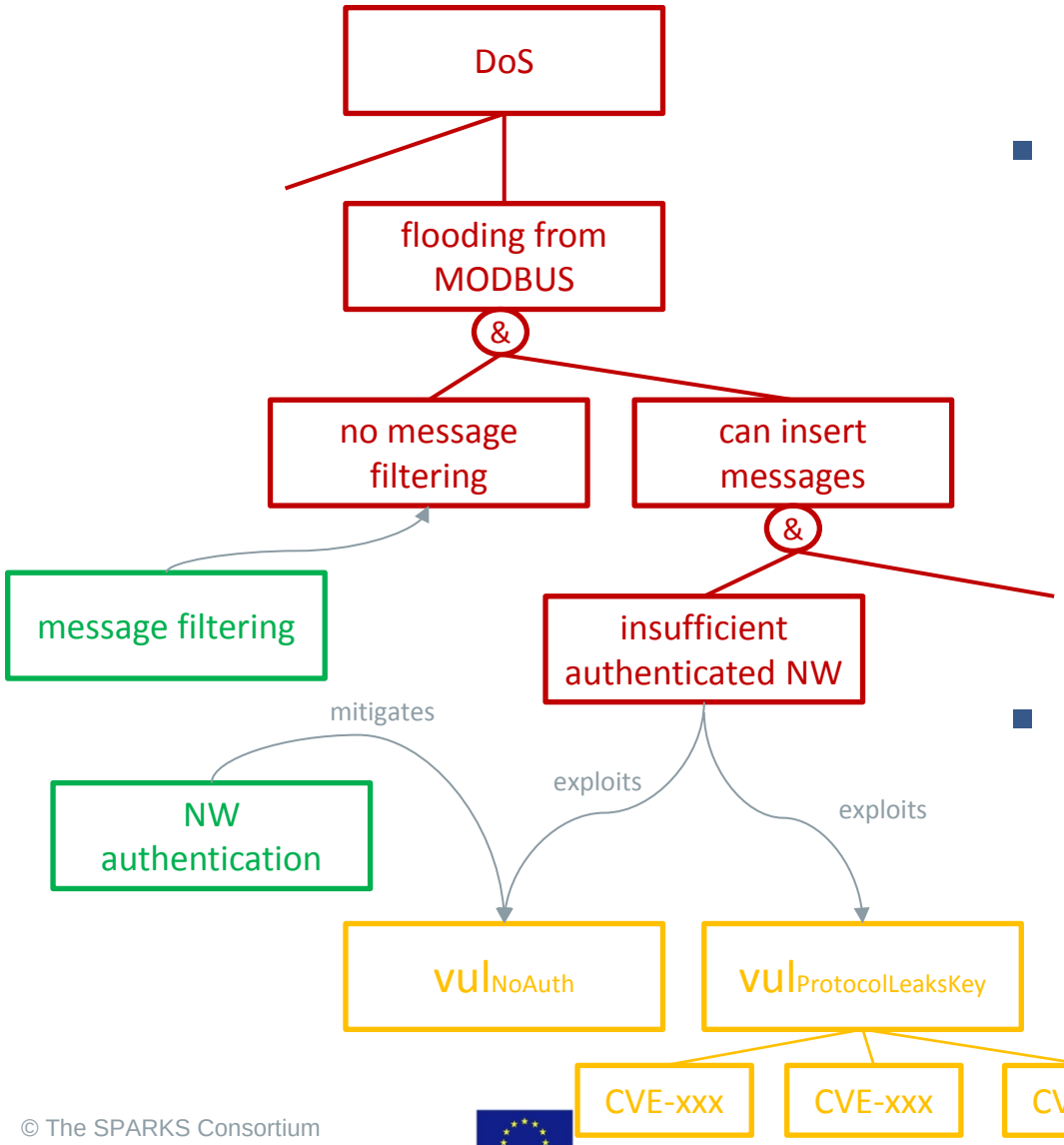
Attack graphs



- decomposing threats
  - by patterns as described before
  - library information (standard threat catalogues)
- "likelihood" evaluation
  - determine threat level for each source node
  - propagate to root
    - overall threat level
    - dominant attack trajectories

Adding semantic threat graphs



- construct STG around leaf nodes
  - threats
  - countermeasures
  - assets
  - vulnerabilities
- allows us to derive countermeasures by machine-based reasoning

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Conclusion

- Threat analysis method for SPARKS
- Based on attack trees and STG
- Not another AT extension, but guidance for establishing good attack graphs
  - completeness
  - complexity
- Uses SGAM as input and uses patterns on this input
- Combination with semantic threat graphs
  - deeper understanding of the specific attack
  - machine-based reasoning (ontologies)
  - catalog-based derivation of countermeasures

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Thank you for your attention!

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