Model Checking of Security Patterns Implementation: Application to SCADA

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Objectives

- Apply security patterns on SCADA.
- Model checking of security patterns implementations.
- Complexity evaluation of security patterns modeling.
- A first pitch to finding a law of automatically applying security patterns.

Plan

- Objectives
- Security Patterns, SCADA
- Development Environment
- Experimentation and Results
- Patterns Patching
- Conclusion

Security Patterns

- A security pattern is a reusable architectural solution:
  - Proved to be efficient.
  - Resolves highly occurring security problem(s).

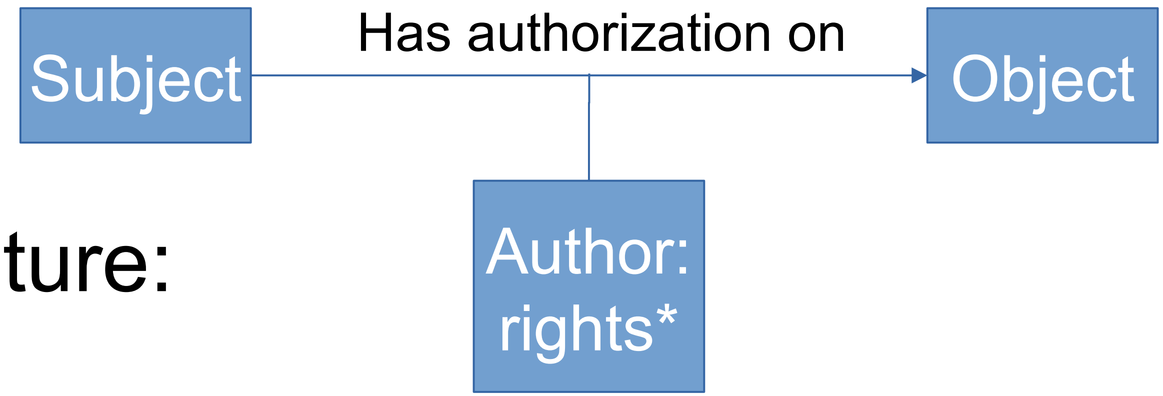
- Not all developers are security experts:
  - Security experts create and publish security patterns.
  - Patterns are explained in common standards (exp. UML diagrams).
  - Developers can reuse the published security patterns.

- Security concerns exist in every development phase:
  - Requirement phase: Which assets need protection?
  - Design phase: Should satisfy security requirements.
  - Implementation phase: Implementing patterns chosen in the design.

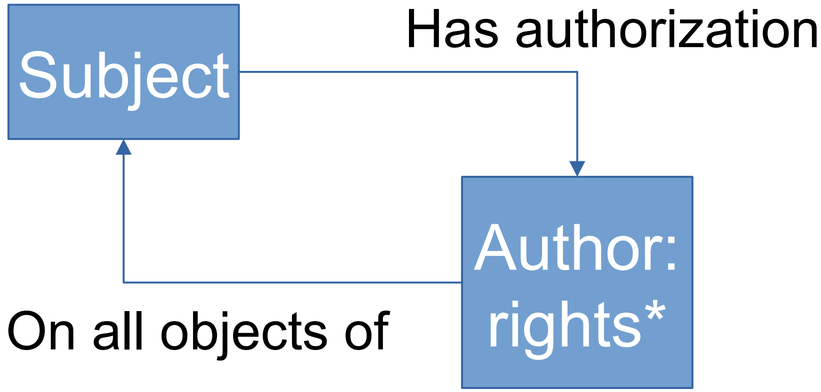
[Yoder and Barcalow 1998, Fernandez and Pan 2001]

Security Patterns: Authorization pattern

In literature:



In our case:



SCADA

- Supervisory Control and Data Acquisition (SCADA):
  - Remote controlling and data transfer.
  - Most industrial facilities exp. power plants, oil refineries, etc.

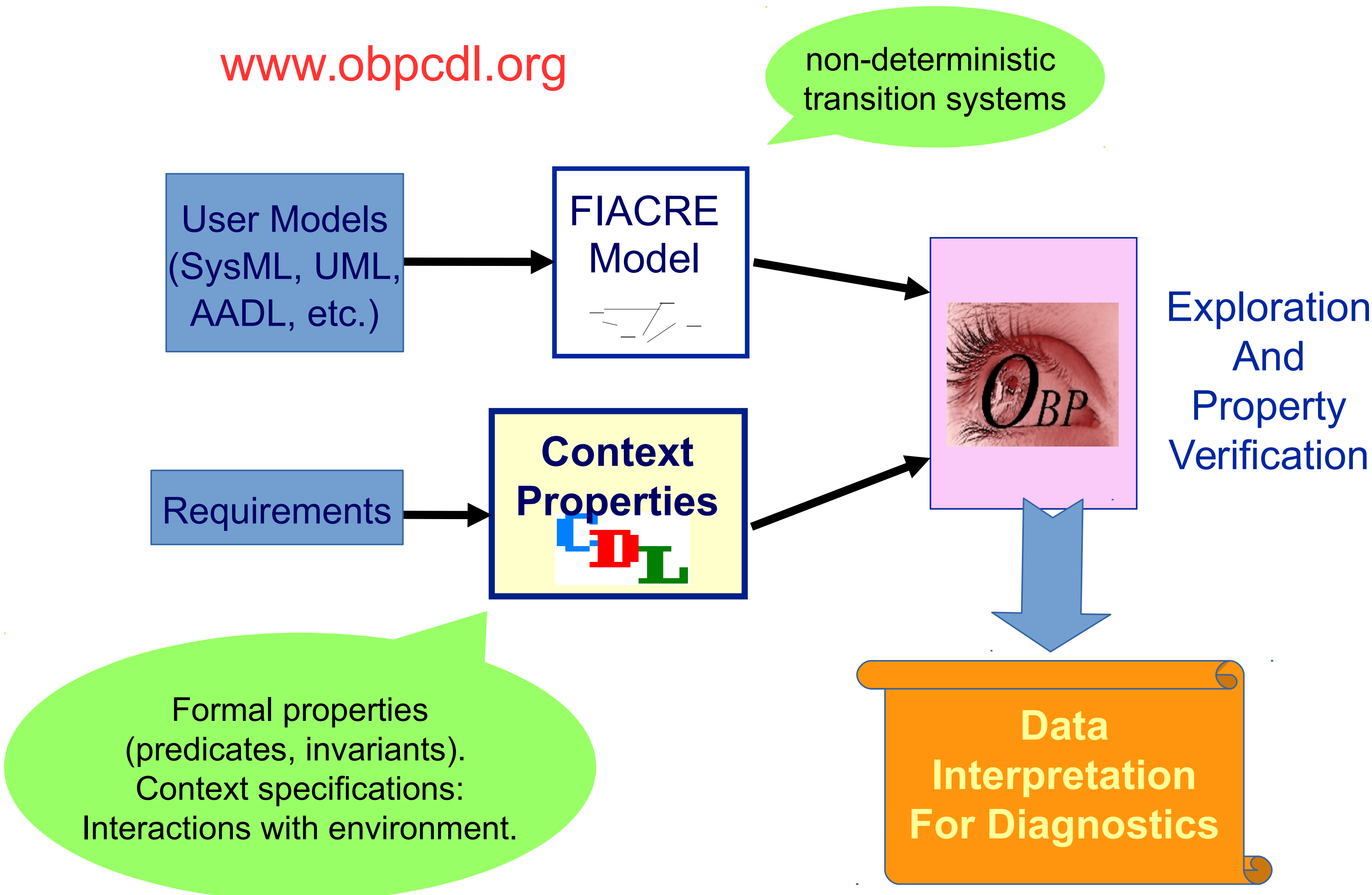
- Difference from normal networks?
  - Special purpose embedded computing devices.
  - Nonstop for years.
  - Very sparse and geographically extensive, exp. Pipelines.
  - Hard physical conditions, exp. chemical factories.

- Issues:
  - Open standards protocols, COTS hardware and software.
  - Vulnerable protocols, lack of cryptography.

- Difficulties:
  - Hard to upgrade: very sparse, and should always be available.
  - Cryptography would oppose to real-time computation.

[Zhu, Joseph, and Sastry 2011]

Development Environment

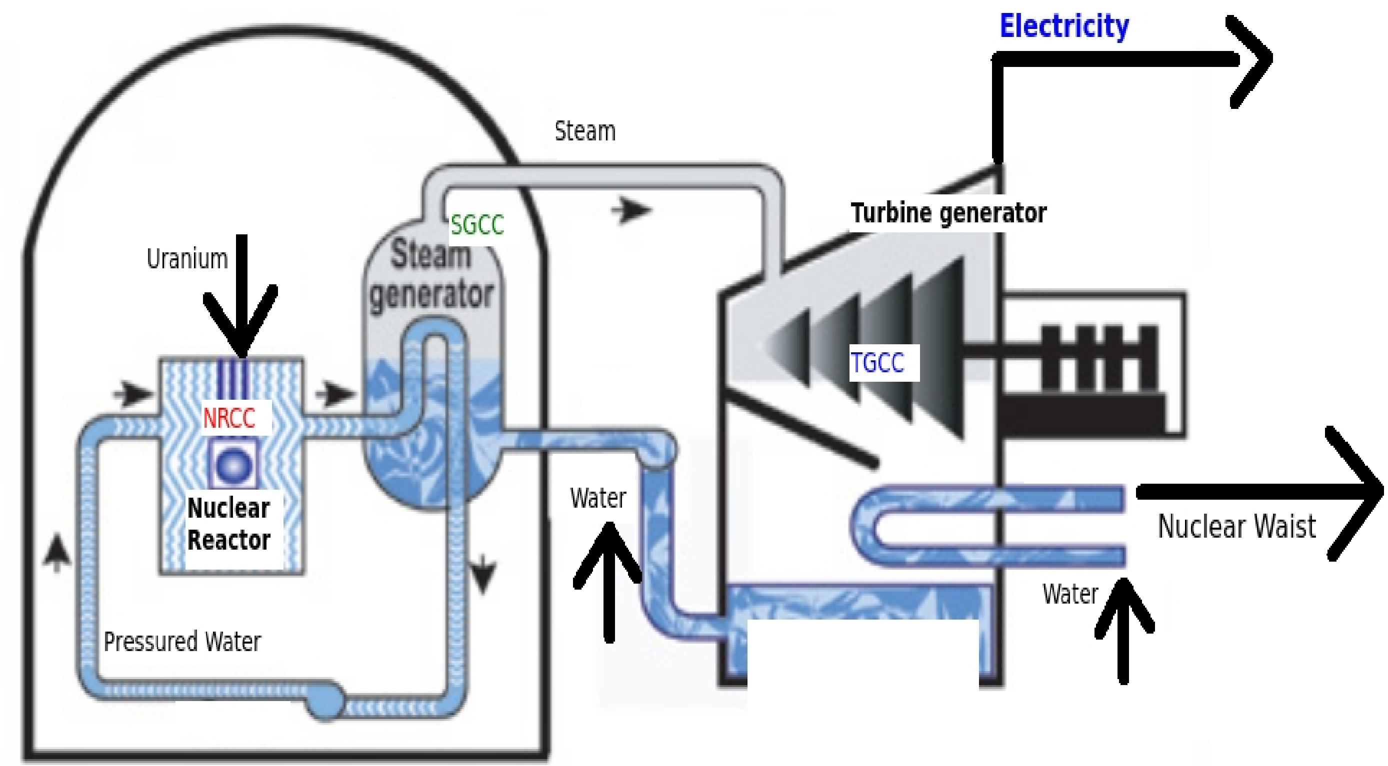


Experimentation: System representation

The system is a SCADA example of a nuclear power plant.

The plant is divided into 3 sections:

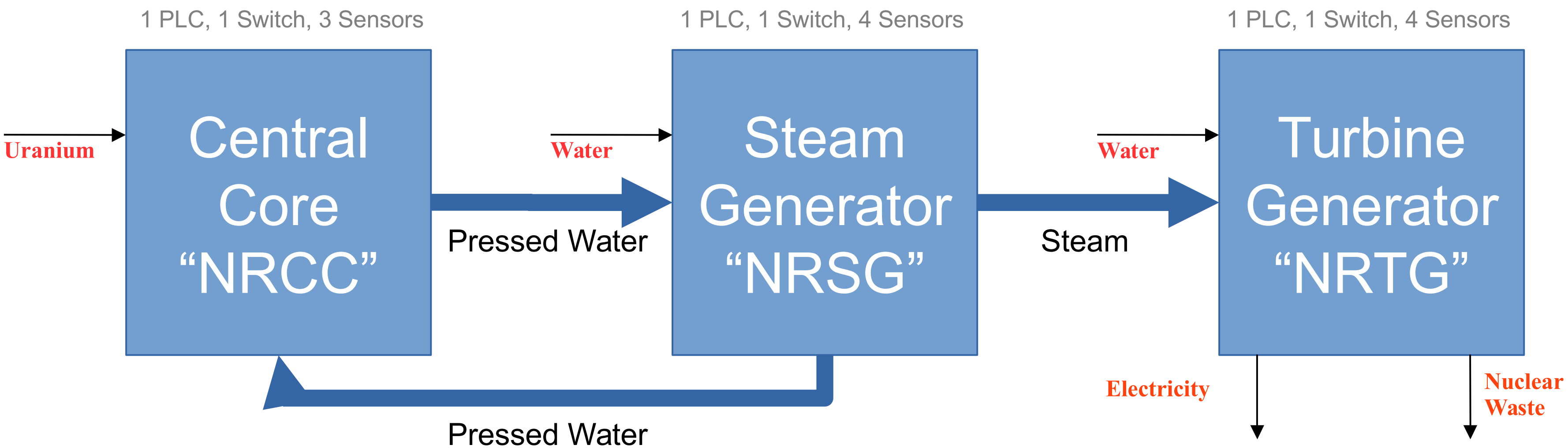
- **Central core :** Uranium + Pressed water → Heated pressed water
- **Steam generator :** Heated pressed water + Water → Pressed steam
- **Turbine generator :** Pressed steam → electricity



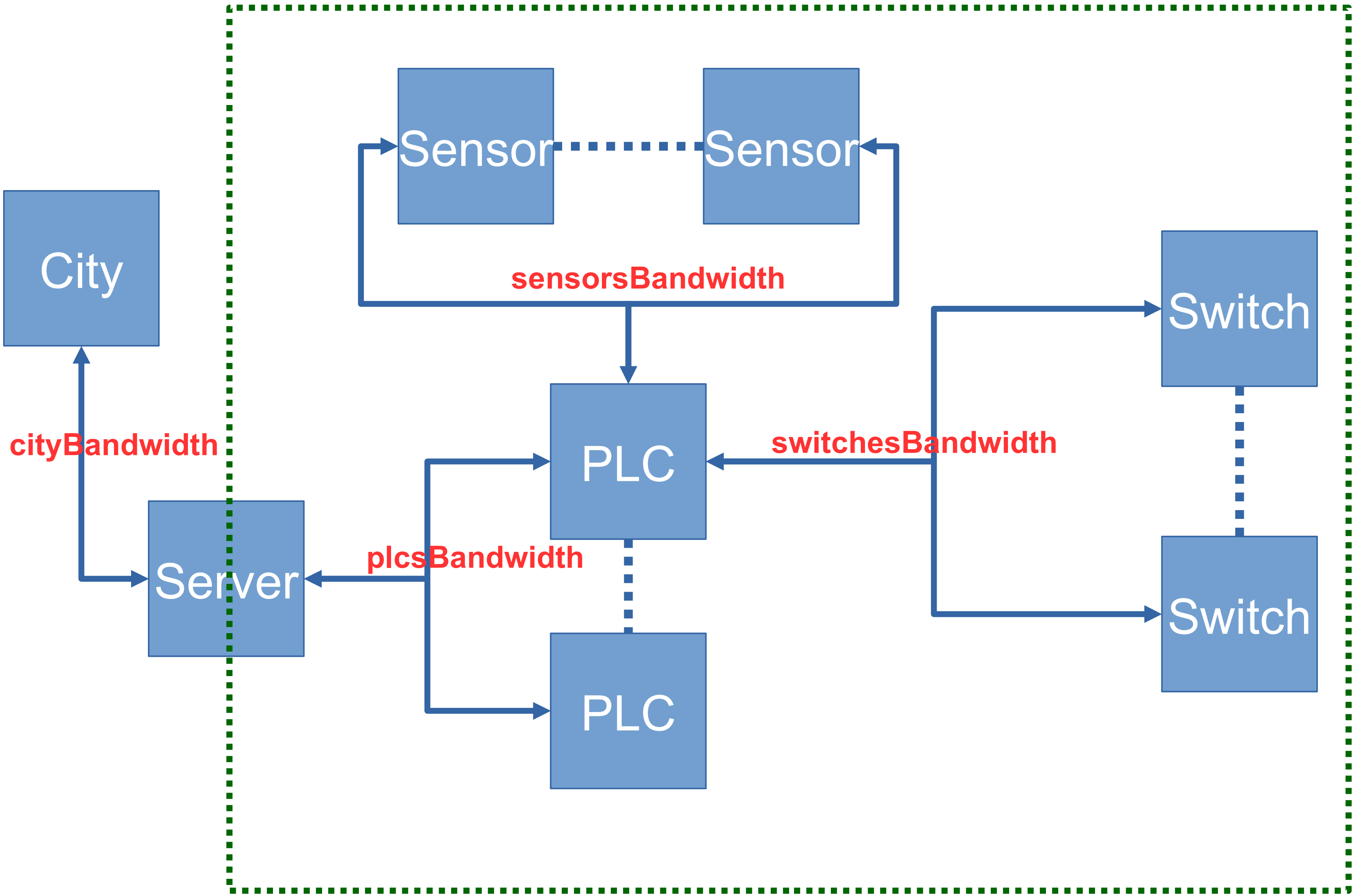
Experimentation: Model

Each section is controlled and monitored by:

- One PLC: Controls a section.
- Switch(es): Controls levels exp. quantity of pumped water.
- Sensors: monitors values changes exp. quantity of steam.



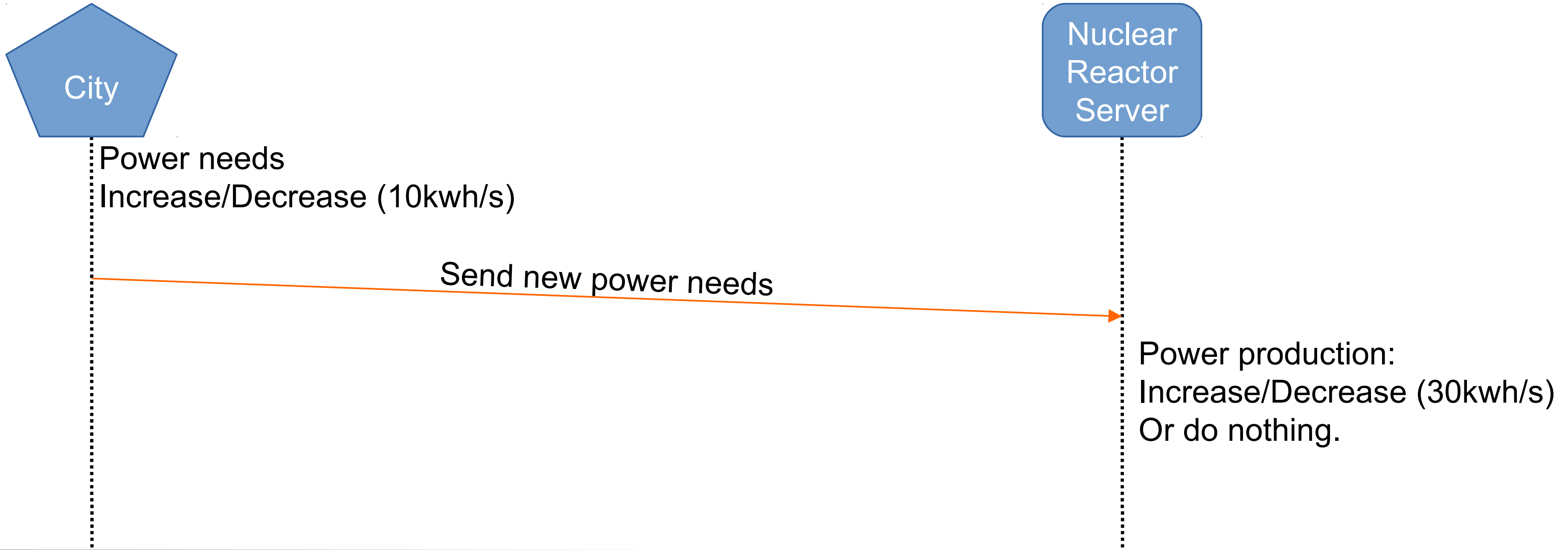
Experimentation: System Architecture



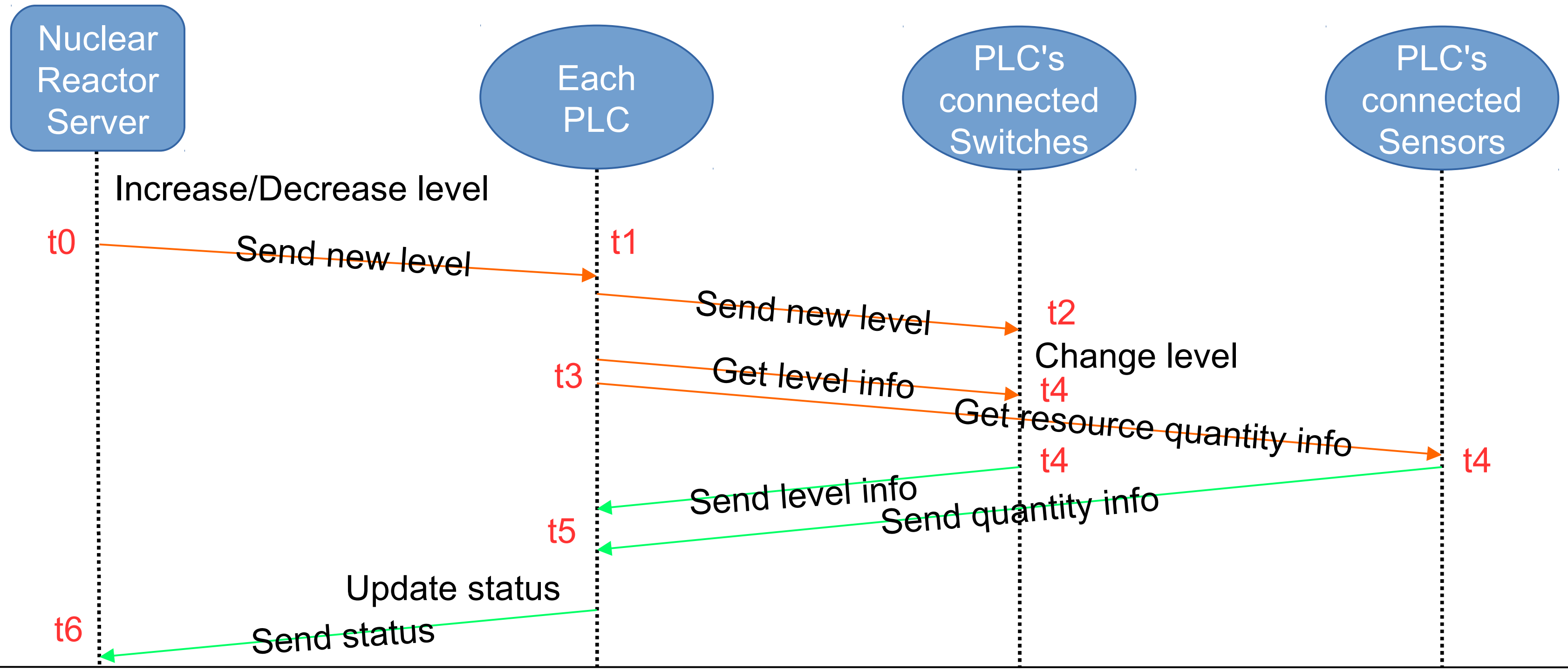
Experimentation: Power Needs

Power needs/production vary between 180kwh/s and 240kwh/s

Production is considered high if the plant can decrease its level and still produce enough power.



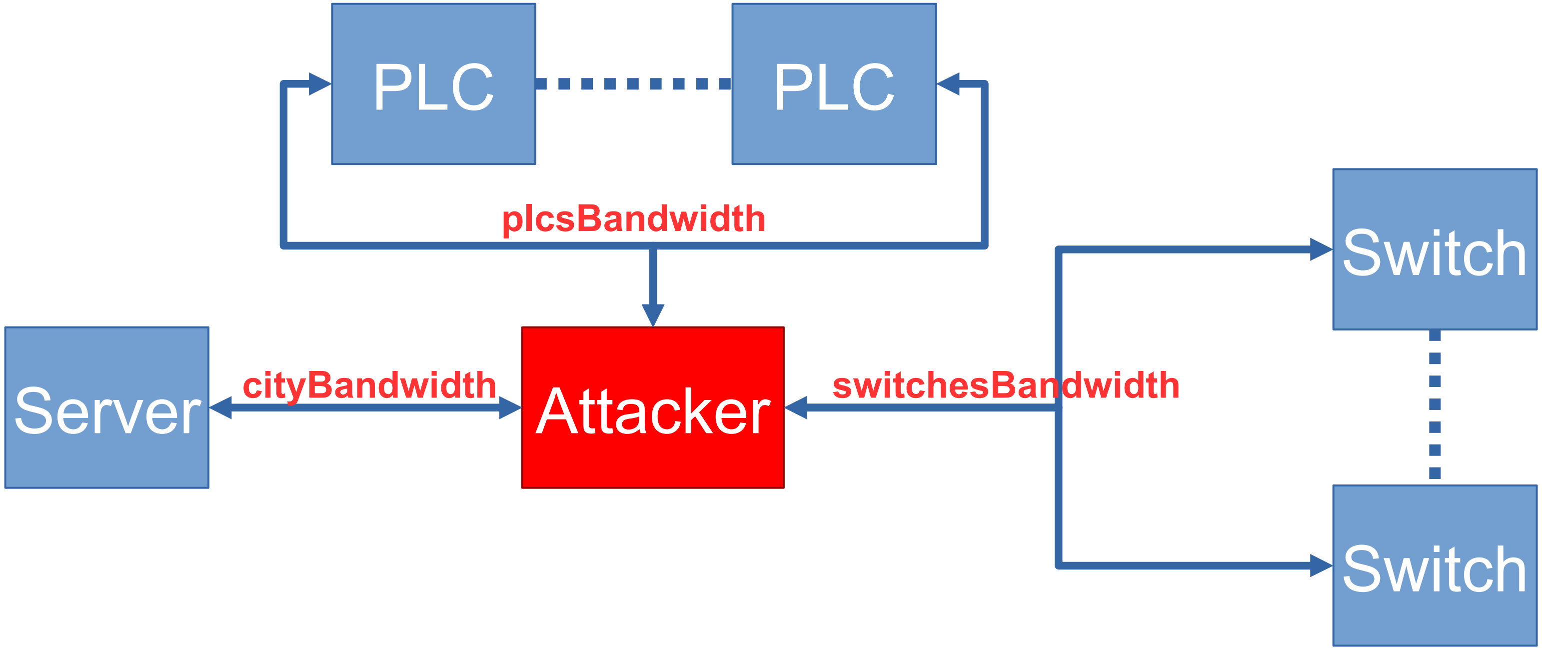
Experimentation: Sequence Overview



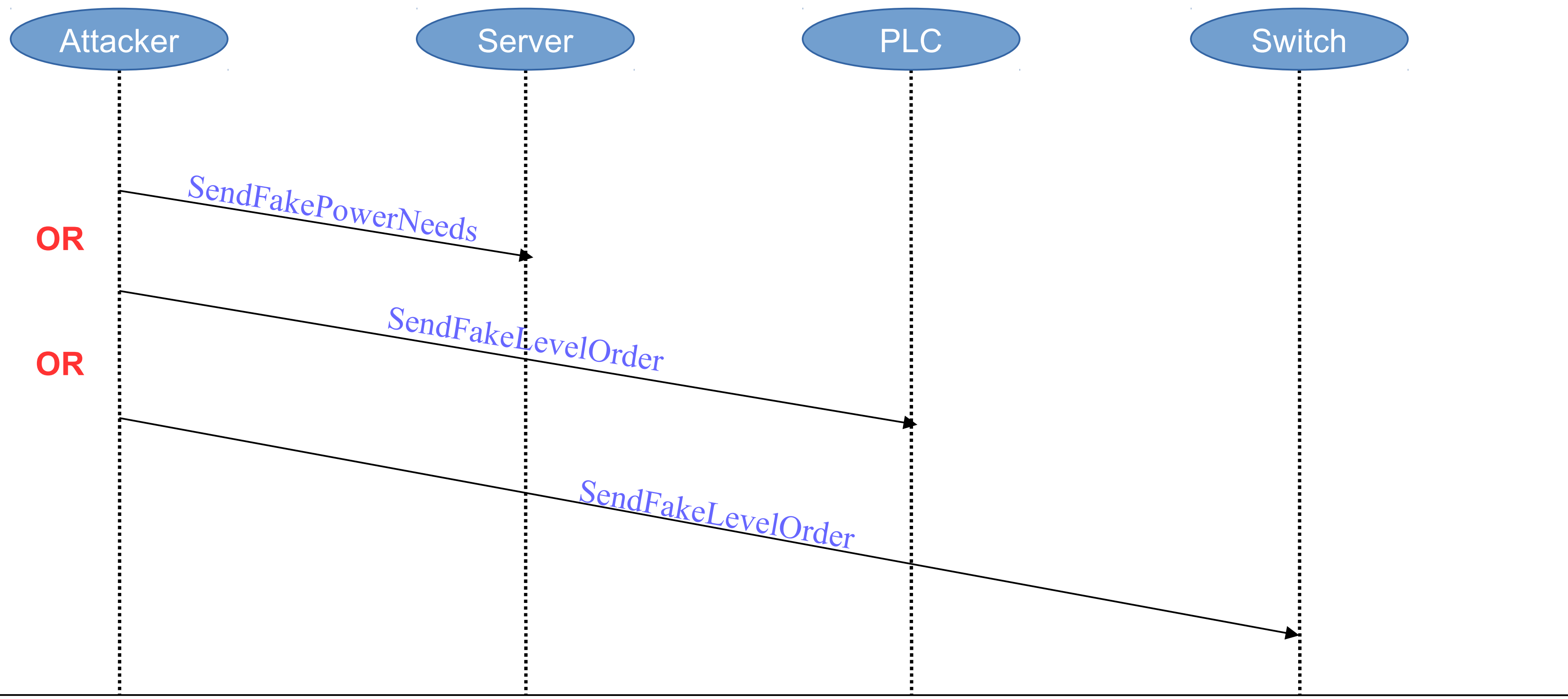
t4 is mentioned multiple times because the order of the multiple t4s is nondeterministic

Experimentation: Attacker

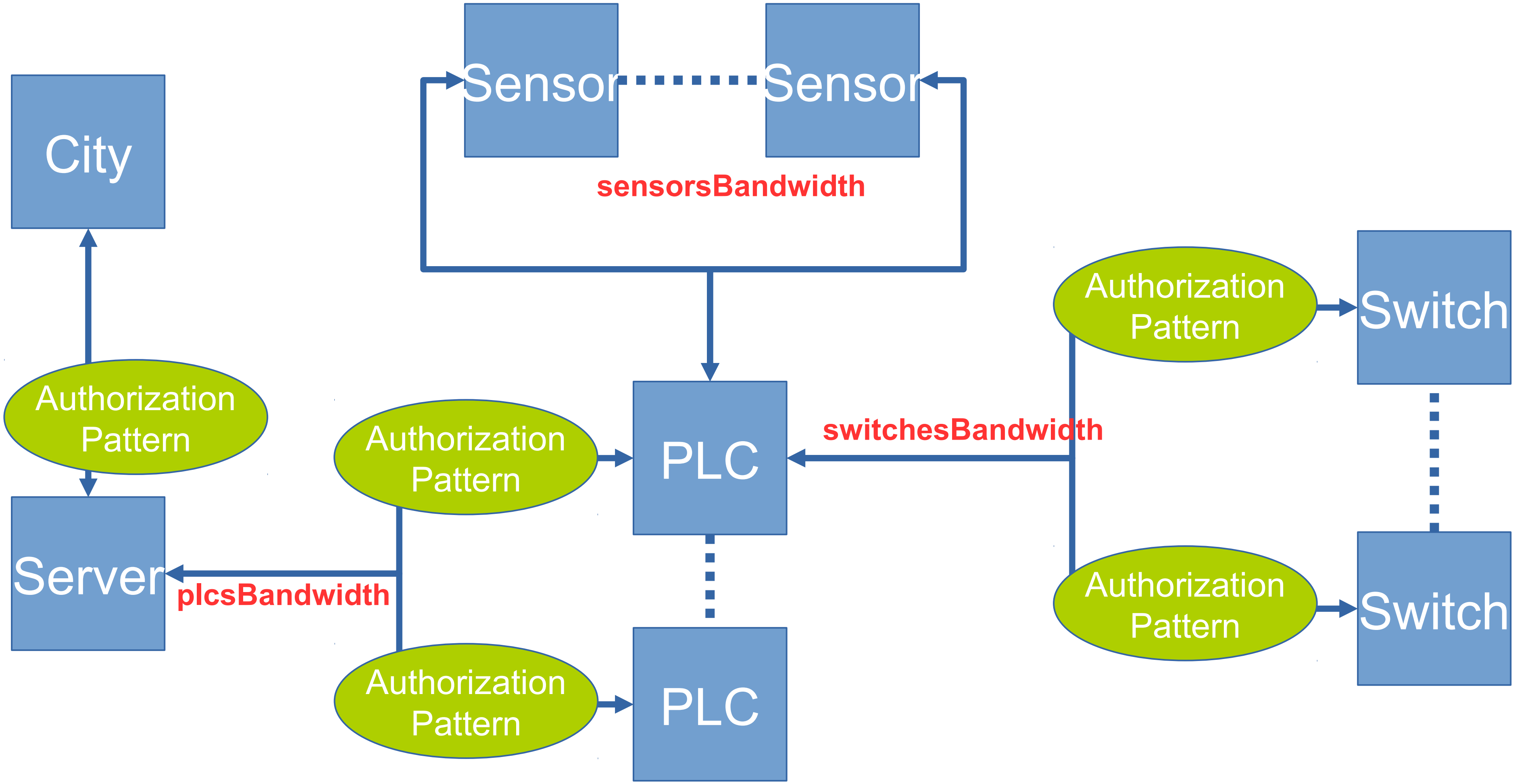
- The attacker: A simple unauthorized process that tries to manipulate others.
- The attacker can not send (nor edit) messages using others identifications:
  - Signature is supposed perfect.
- The attacker can not delete/redirect messages:
  - As if we are using messages broadcasting.



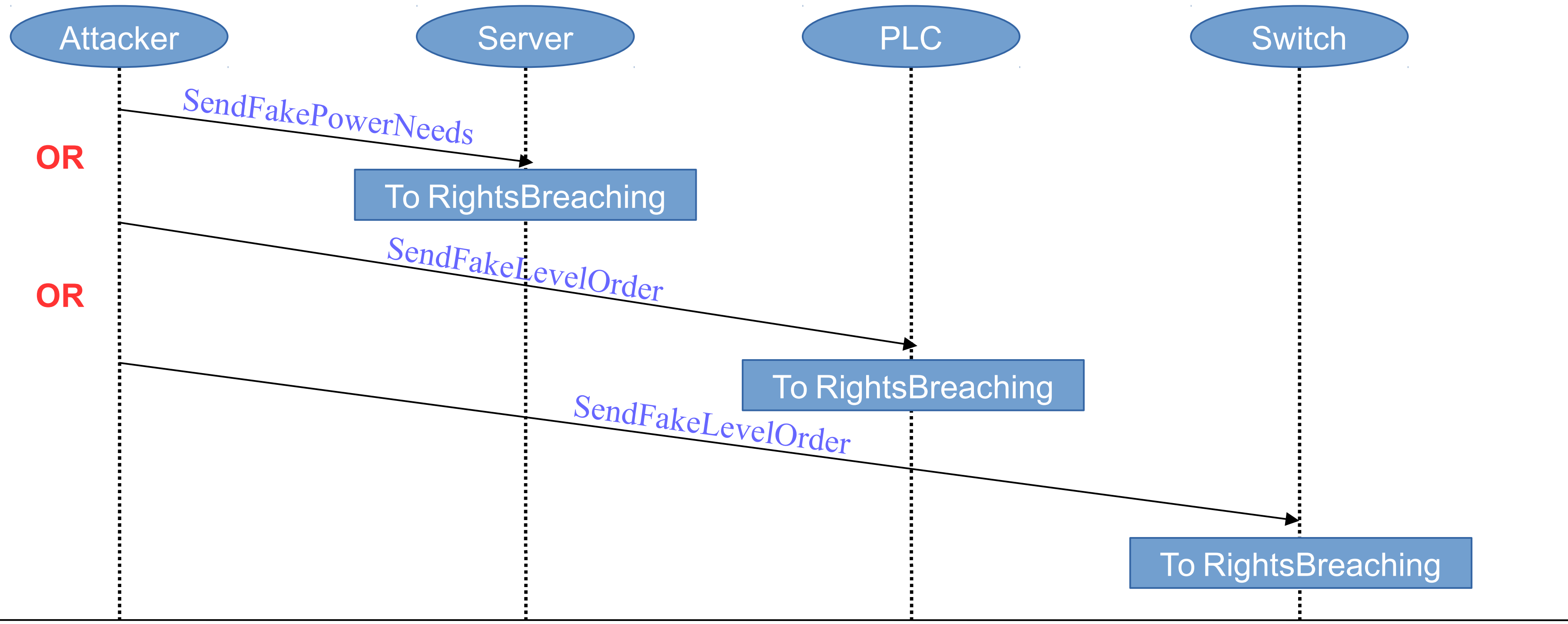
Experimentation: Attacker



Experimentation: Authorization Pattern



Experimentation: Authorization Pattern



Experimentation: Security Properties

- The plant (with no outside intervention) always has sufficient and not too much power production.

- A successful attack would cause:
  - Insufficient power production (bad).
  - Too much power production (bad).
  - No change to power production (no problem).

Properties examples (CDL):

- **NotEnoughPower (*pty1*):**
  - predicate pred1 is: consumption > production
  - event ev is: pred1 becomes true
  - property pty1 is: start -- / / ev1 / -> reject (*Requirement 1*)

- **TooMuchPower (*pty2*):**
  - predicate pred2 is: production - consumption >= 30.
  - event ev2 is: pred2 becomes true
  - property pty2 is: start -- / / ev2 / -> reject (*Requirement 2*)

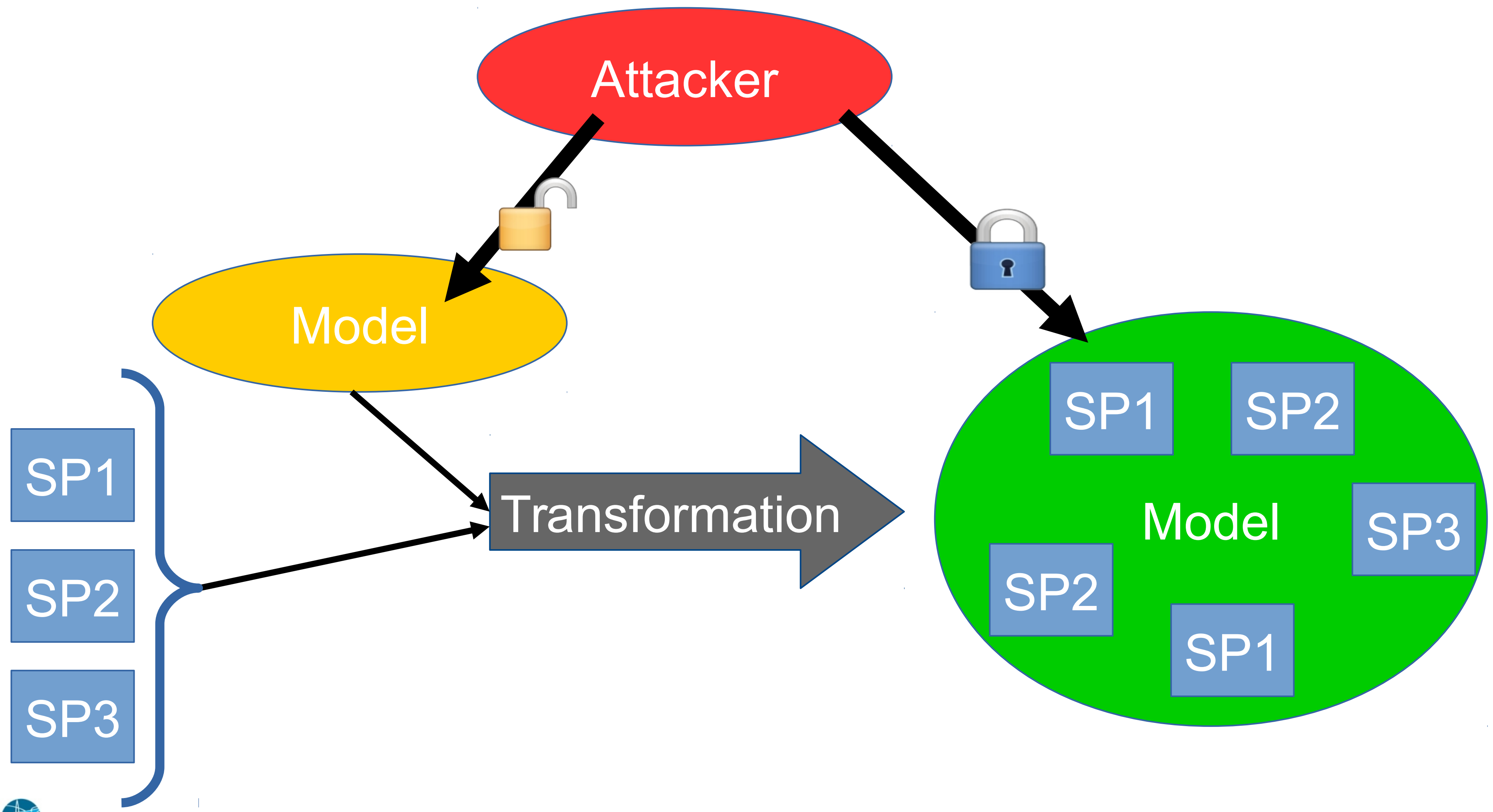
Results

Tests were carried on 4 different configurations:

- Normal model (NM): simply the planet working correctly.
- Normal model with attack (NMWA): Added the attacker to NM.
- Secured model (SM): Added the authorization pattern to NM.
- Secured model with attack (SMWA): Added the attacker to SM.

Config.	nb. states	nb. transitions	Time needed (seconds)	Rejected properties (out of 2)
NM	75255	159084	8.676	0
NMWA	715286	2151963	75.877	2
SM	75255	159084	9.203	0
SMWA	301728	864677	34.31	0

Patterns Patching



Patterns Patching

Automatic pattern patching:

– Using hashtags

- ReadMessage(to,from,m). - #AuthPatt(to,from,m). - DoSomething(m).	Transformation →	- ReadMessage(to,from,m). - If not AuthPatt(to,from,m): Alert!. Else: - DoSomething(m).

– Using keywords

- ReadMessage(to1,from1,m1). - DoSomething(m1). - Send(to2,from2,m2)#PassPatt	Transformation →	- ReadMessage(to1,from1,m1). - If not AuthPatt(to1,from1,m1): Alert!. Else: - DoSomething(m1). - Send(to2,from2,m2)

Utility: Forgetting not to secure something is better than forgetting to secure it!

Conclusion

Security measurements needed in SCADA.

Interesting to study security patterns efficiency in securing SCADA.

Model checking can verify security patterns implementation.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