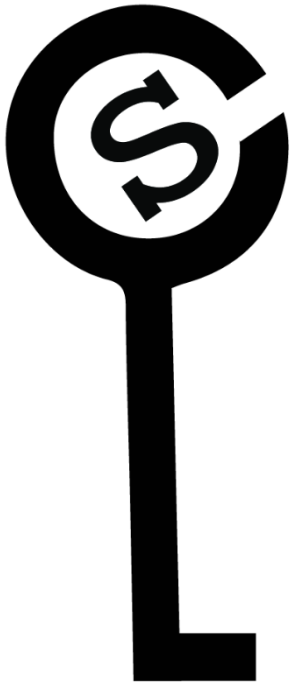
SnapShotter: Lightweight Intrusion Detection and Prevention System for Industrial Control Systems



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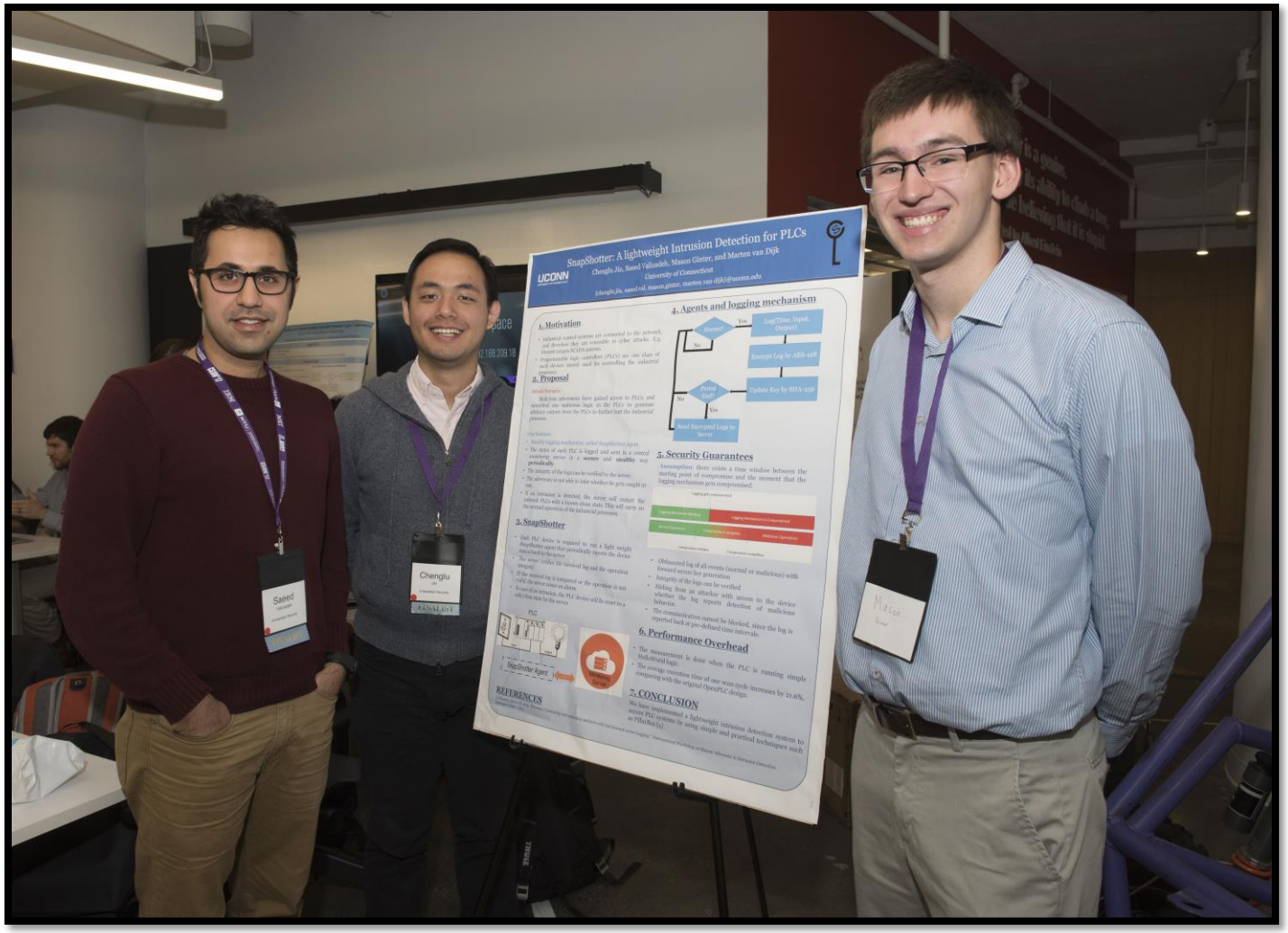
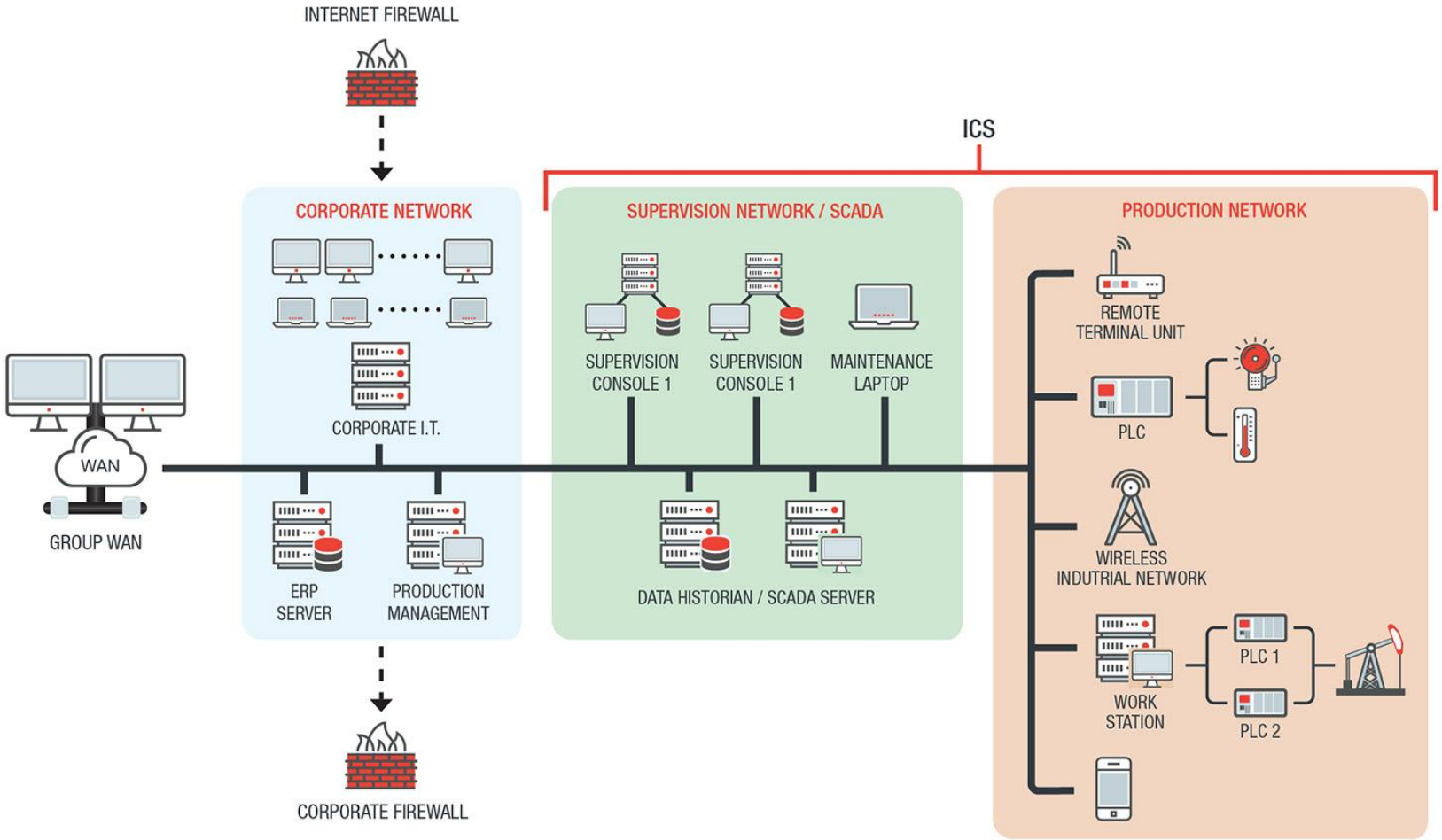
CSAW'17 Embedded Security Challenge



Overview of an Industrial Control System



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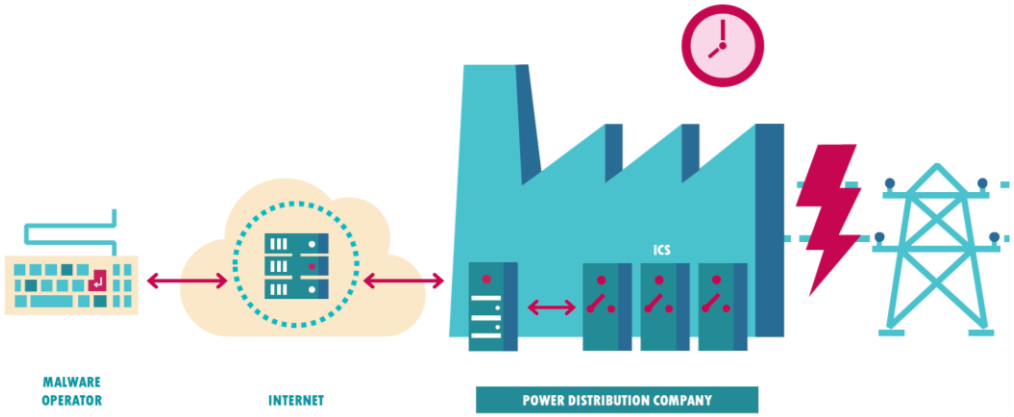
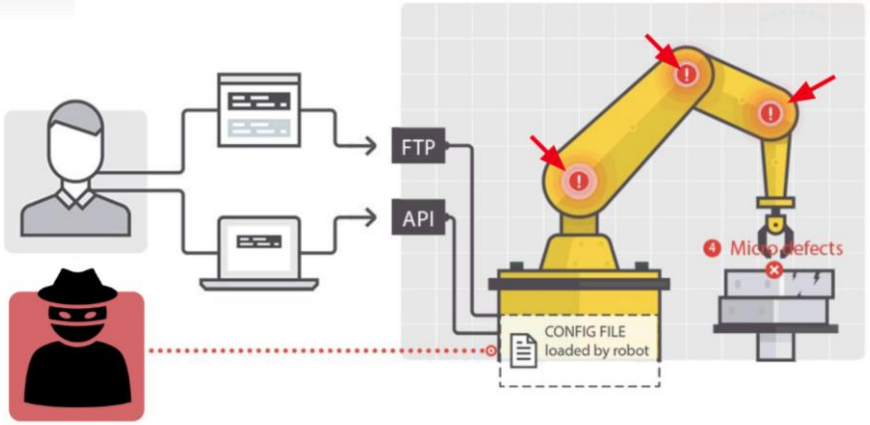
Holy grail of cyberwar?

- 2010: STUXNET
  - Advanced malware (worm), Targeting SCADA systems
  - Causing substantial damage to nuclear plants (specially designed to sabotage the Iranian nuclear project)
- 2014: HAVEX
  - Semi-Stuxnet worm, Targeting ICS and SCADA systems
  - Impacted as many as 2,000 infrastructure sites, a majority of which were located in Europe and the United States
  - Capable of possibly disabling hydroelectric dams, overload nuclear power plants, and even can shut down a country's power grid with a single keystroke.
- 2015: BlackEnergy
  - A Trojan that is used to conduct DDoS attacks, cyber espionage and information destruction attacks
  - Mostly targeted ICS, energy, government and media in Ukraine
- 2016: Industroyer
  - A modular malware, capable of gaining direct control of switches and circuit breakers at an electricity distribution substation.
  - Attack on Ukraine's power grid that deprived part of its capital, Kiev, of power for an hour

And still, more attacks are on the way!





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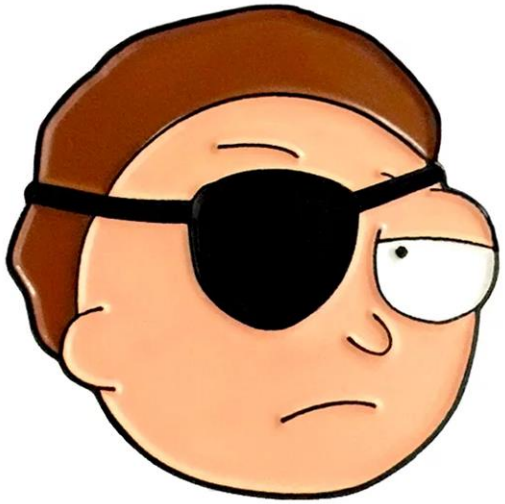
So, why do attackers target ICS?



- Easy targets!
- Big financial gains!
- Industrial espionage!
- Huge physical impact and damage!
- Many other malicious intents and/or maybe mental problems!

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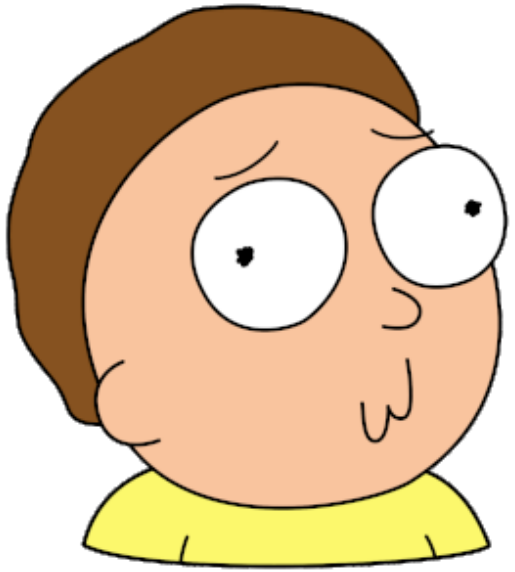
So, what is the problem?

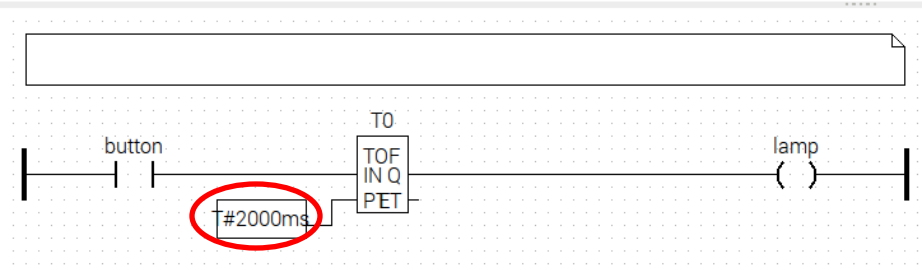


- Widespread applications in critical infrastructure
  - Transportation, Manufacturing, Power grids, Oil/gas processing, etc.
- Lack of security considerations in the design and lifecycle of traditional ICS
- Exposure to outside world (i.e., the Internet)
- Increased connectivity via embracing the new information technologies

Adversarial Model

- Strong(est) Malicious adversaries
  - Are capable to get remote/physical access to Programmable Logic Controllers (PLCs)
  - Can submit any arbitrary (malicious) logic to the PLCs to generate arbitrary outputs from the PLCs to further hurt the industrial processes.
- What the attacker cannot do:
  - Physically tampering the PLC hardware

#	Name	Class	Type	Location	Initial Value	Option	Documentation
1	button	Local	BOOL	%IX0.0			
2	lamp	Local	BOOL	%QX0.0			
3	T0	Local	TOF				



Expected logic

Description: Class Filter: All

#	Name	Class	Type	Location	Initial Value	Option	Documentation
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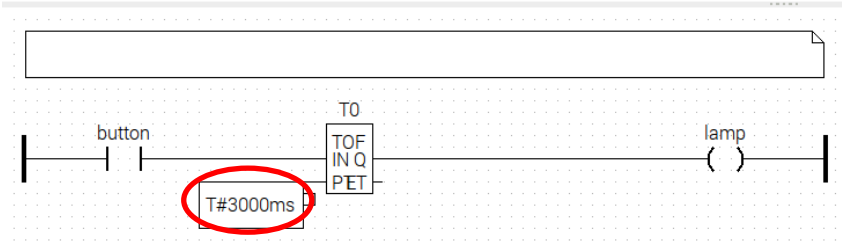

Malicious logic

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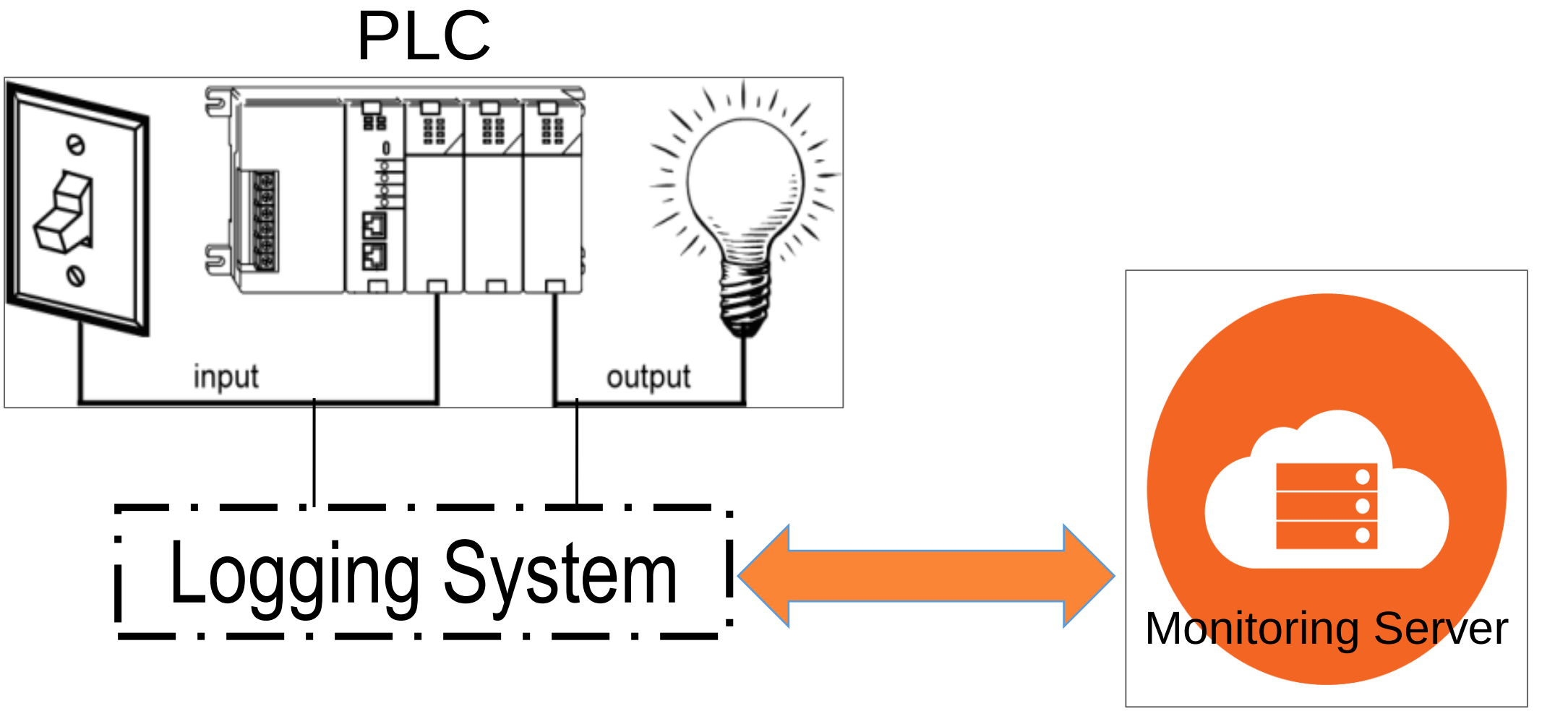
Simple Idea

- Hmm, we need a secure and trustable logging mechanism:



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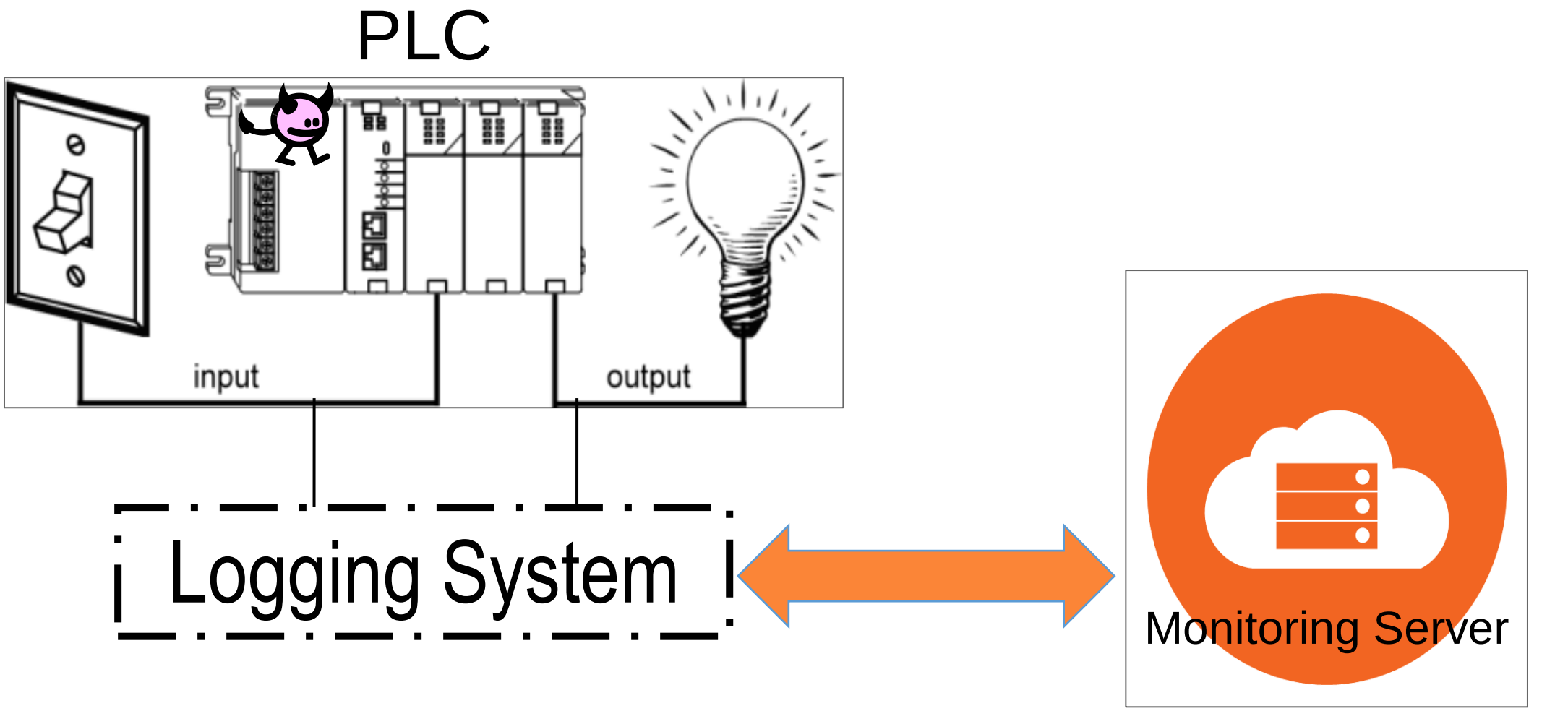

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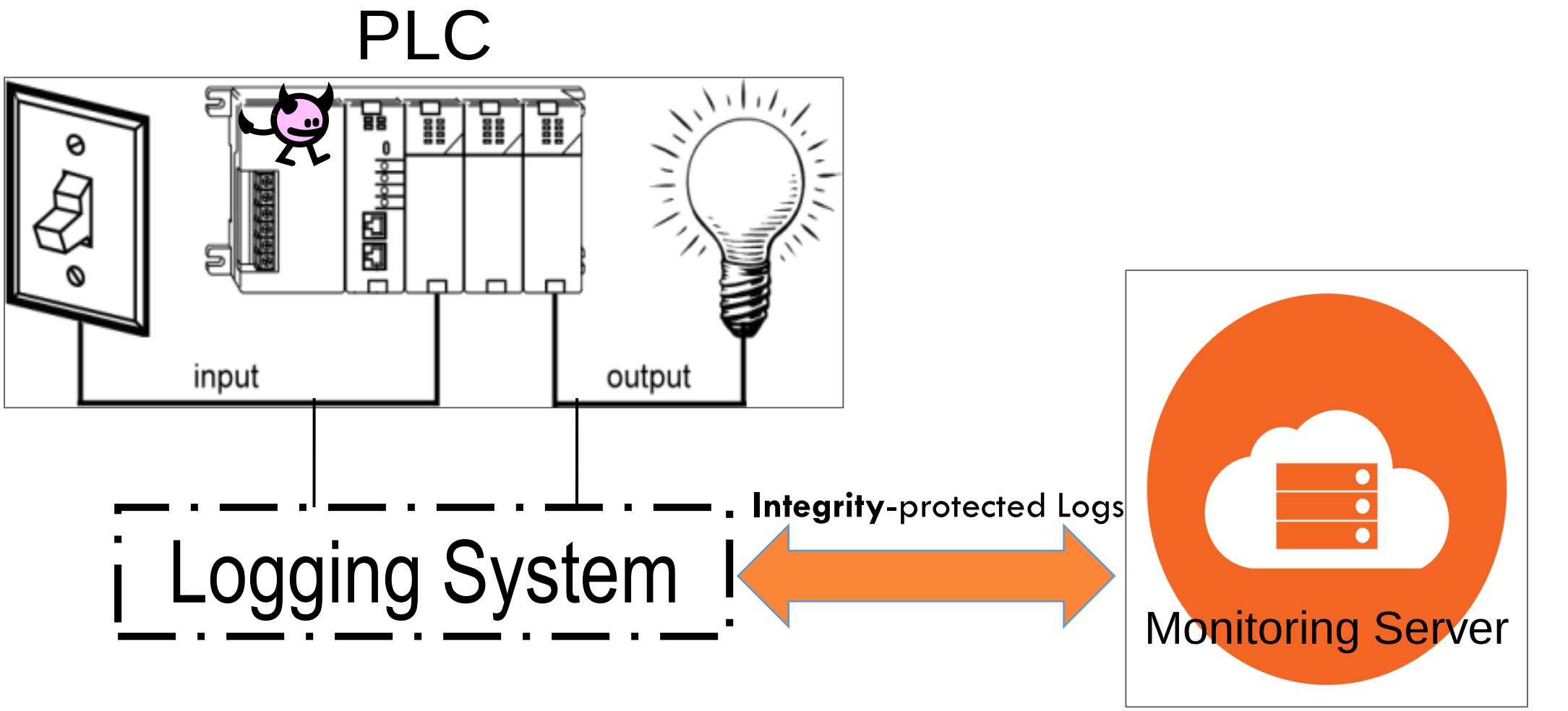

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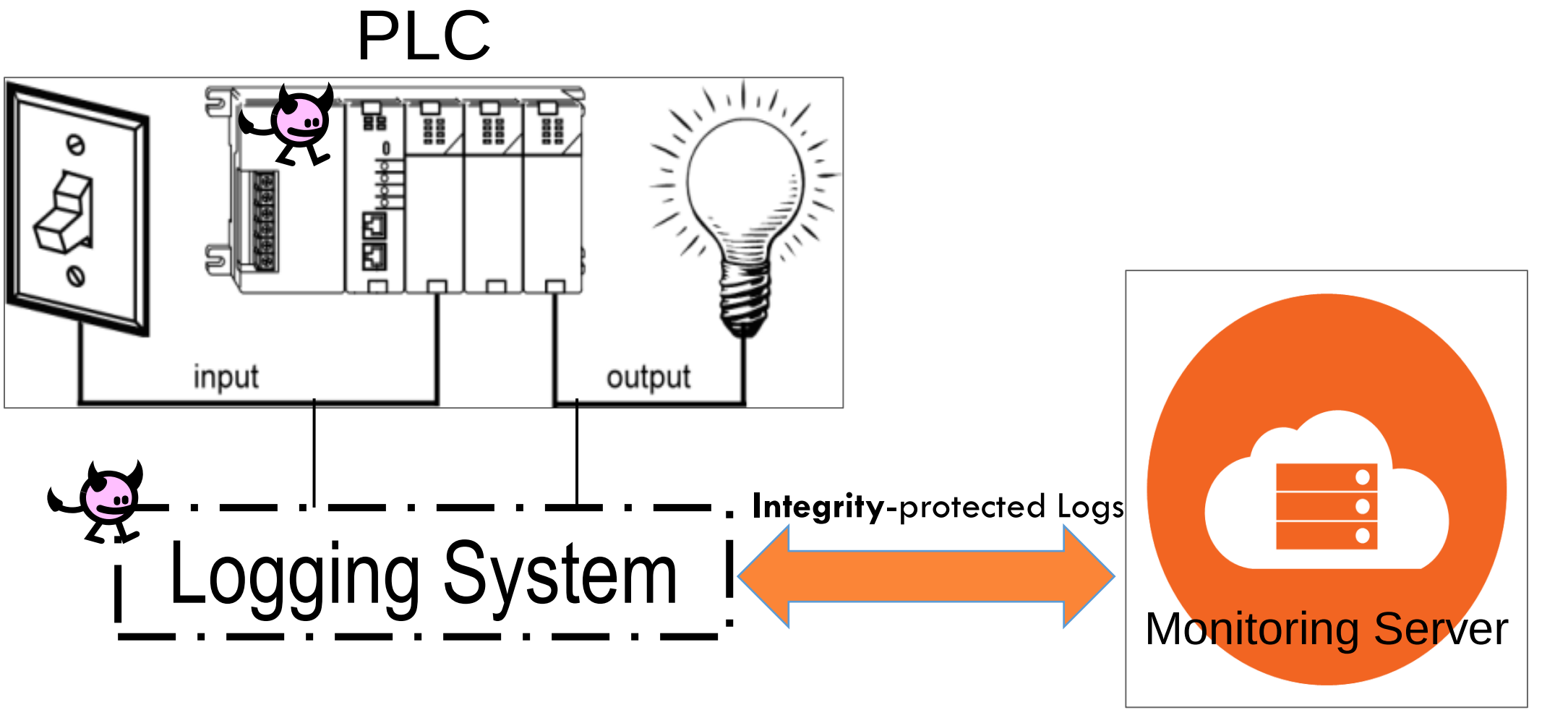

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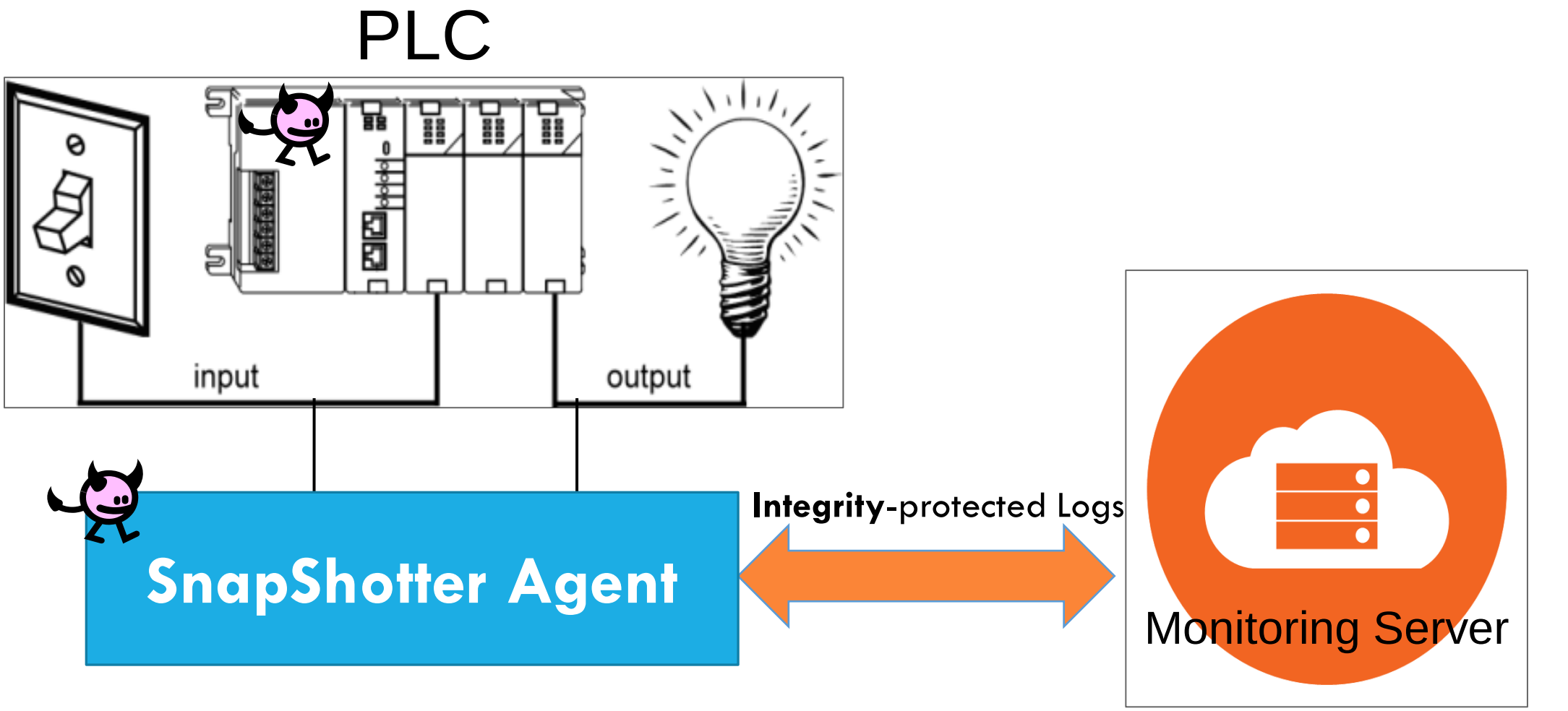

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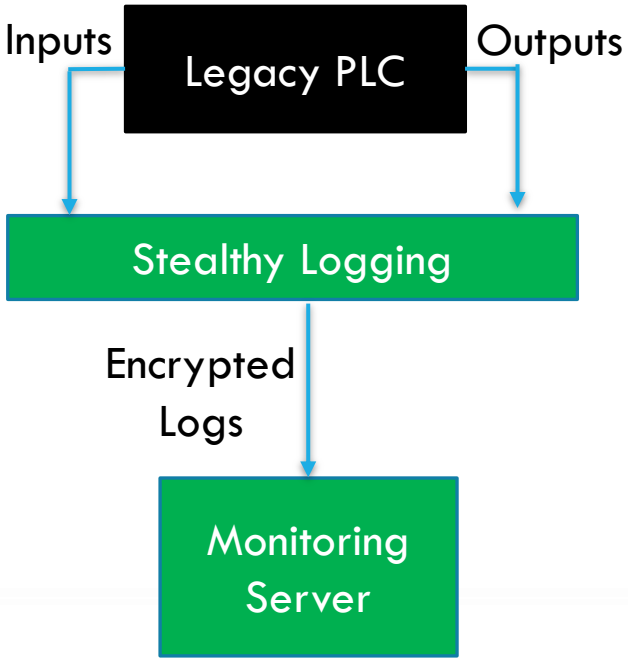
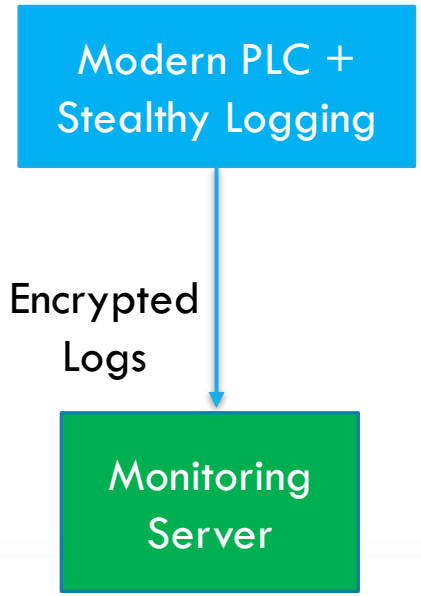
Modern vs Legacy Systems

Legacy System



Modern System



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Agent and Server tasks in a nutshell

- Intrusion detection agent (i.e., the Snapshotter)
  - Security-related information gathering (e.g., integrity of the logic, paramount file accesses, I/O operations)
  - Checking the occurrence of events or state updates of the monitored device
  - Fast forward-secure logging
  - Transmitting the logs to the server

- The Trusted Server:
  - Logs integrity verification
    - Making sure logs are valid and not tampered by an adversary
  - Log analysis and incident identification
    - Tracing deviations from expected PLC profiles (Potentially stablished during system Installation)
    - Checking if the device is functioning properly and not compromised
    - Raising a flag, If log' integrity check fails or system state is recognized as compromised
  - Incident response
    - Further investigation of device status
    - Recovering the infected machine to a clean state
    - Activating a redundant (backup) PLC

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SnapShotter Agent in more details

- **Secure and reliable logging mechanism with Forward Secure Key Management System.**
- The status of each PLC is logged and sent to a central monitoring server in a **secure** (and potentially **stealthy)** way **periodically**.
- The **integrity** of the logs can be verified by the server.
- The adversary is not able to infer whether he/she gets caught or not, even when he/she compromised the device completely, including the **logging mechanism** and **secret key**.
- If an intrusion is detected, the server can take effective actions, e.g., **restore** the infected PLCs to a known **clean state +** Activate a redundant PLC. This will carry on the normal operation of the industrial processes.

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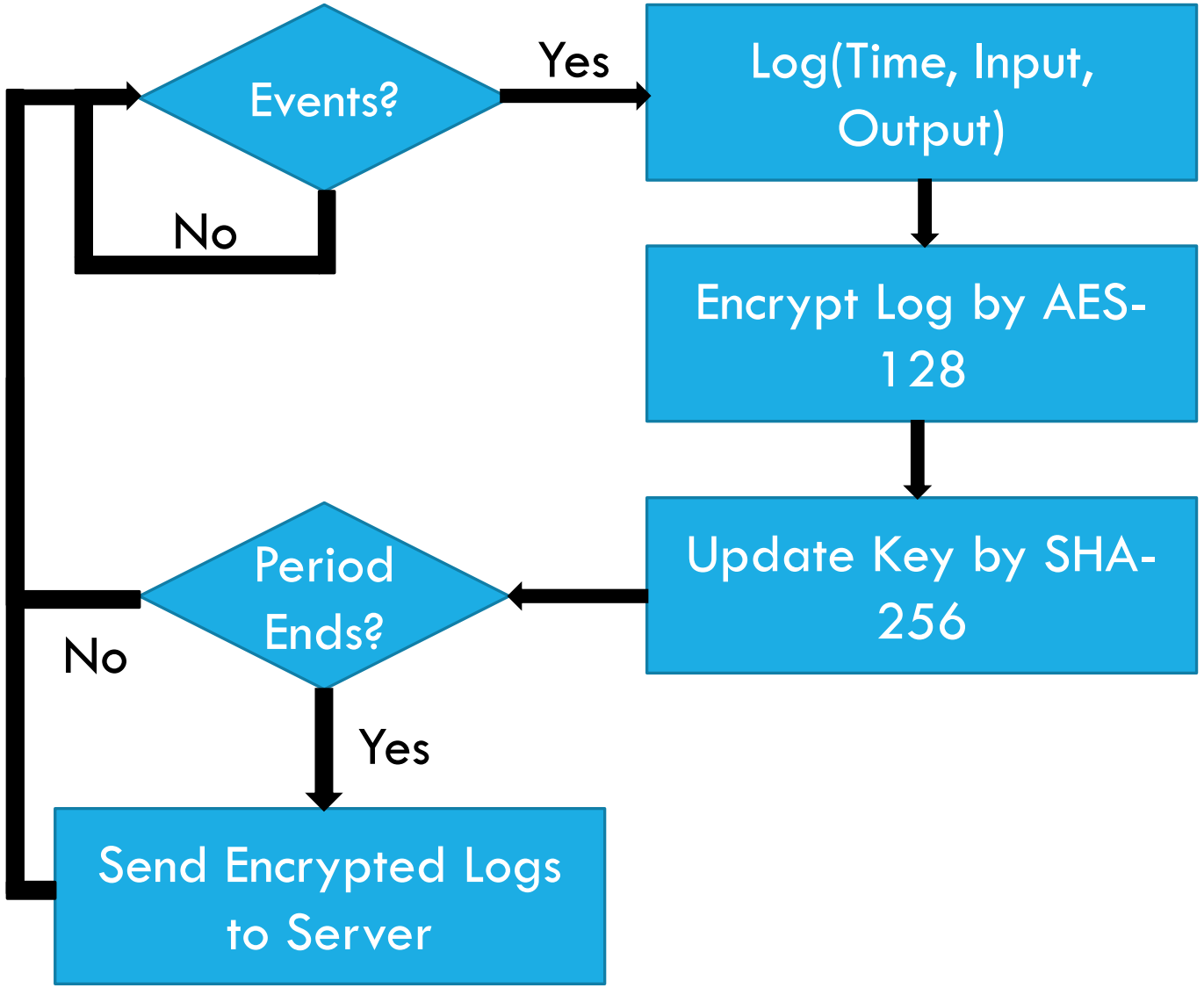
Logging Mechanism



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Log Data Format

#Byte	1 Byte	2 Bytes	2 Bytes	4 Bytes	2 Bytes	2 Bytes	2 Bytes	1 Byte
	Start	Event ID	Device ID	Time	Digital Inputs	Digital Outputs	Analog Outputs	End
Example	0xFF	0x0002	0x1234	0x00000010	0xC000	0x8000	0x7832	0xFF

16 Bytes in total

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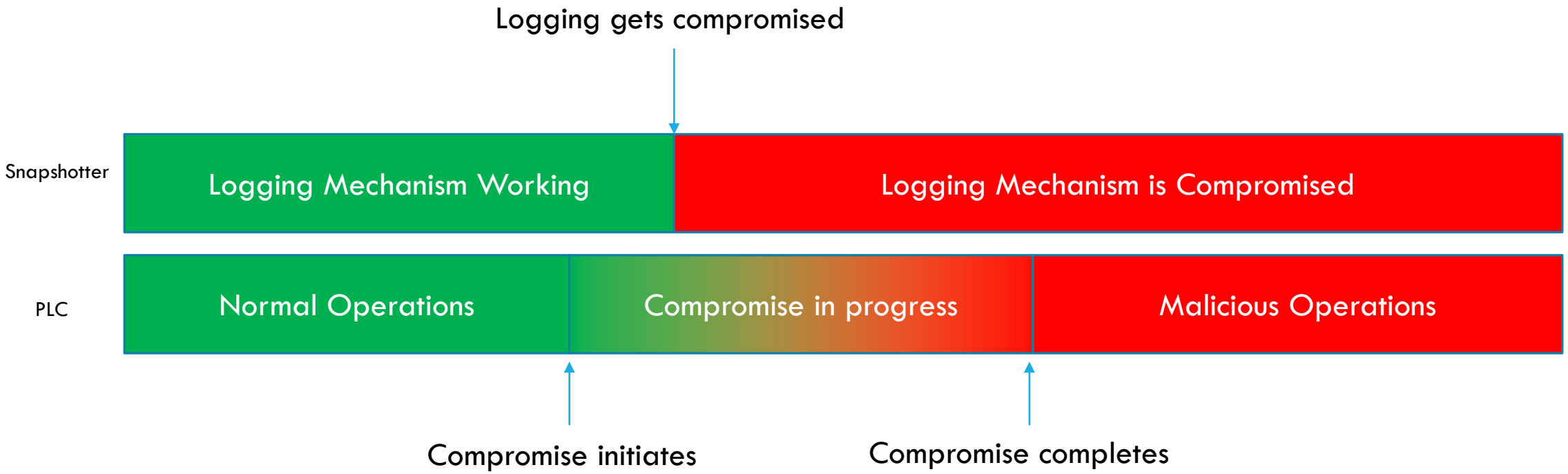
Assumption



Assumption: Some logs are generated between the beginning of the attack and the moment that the logging system gets compromised.

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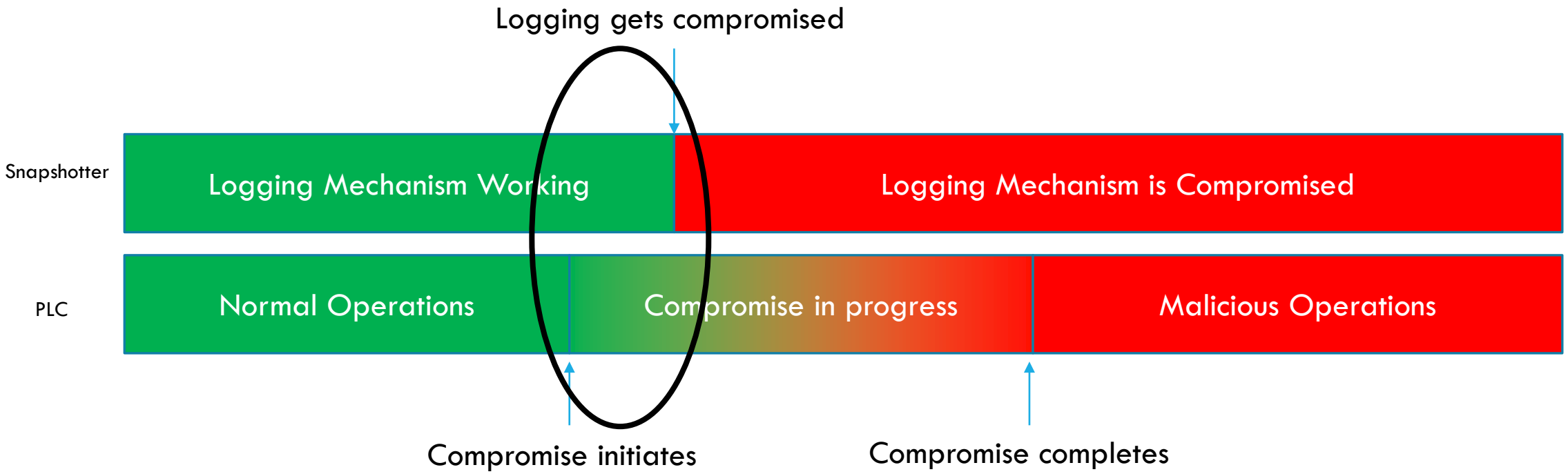

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- Packet dropping!

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Performance Overhead

- The performance overhead we measured on our platform is at most 54 μs per scan cycle comparing with the original OpenPLC design.
- We tested our implementation by uploading a malicious logic to the controller, the server was able to catch the intrusion immediately after receiving the logs from the agent

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Conclusion

- We have implemented a lightweight intrusion detection system to secure PLC systems by using simple and practical techniques.

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Questions?