An Architecture to Allow Dynamic Time-Sensitive Communications as a Service

ETR2026: École d'Été Temps-Réel 2026

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Université de Lorraine, CNRS - LORIA

When Timing Becomes Critical

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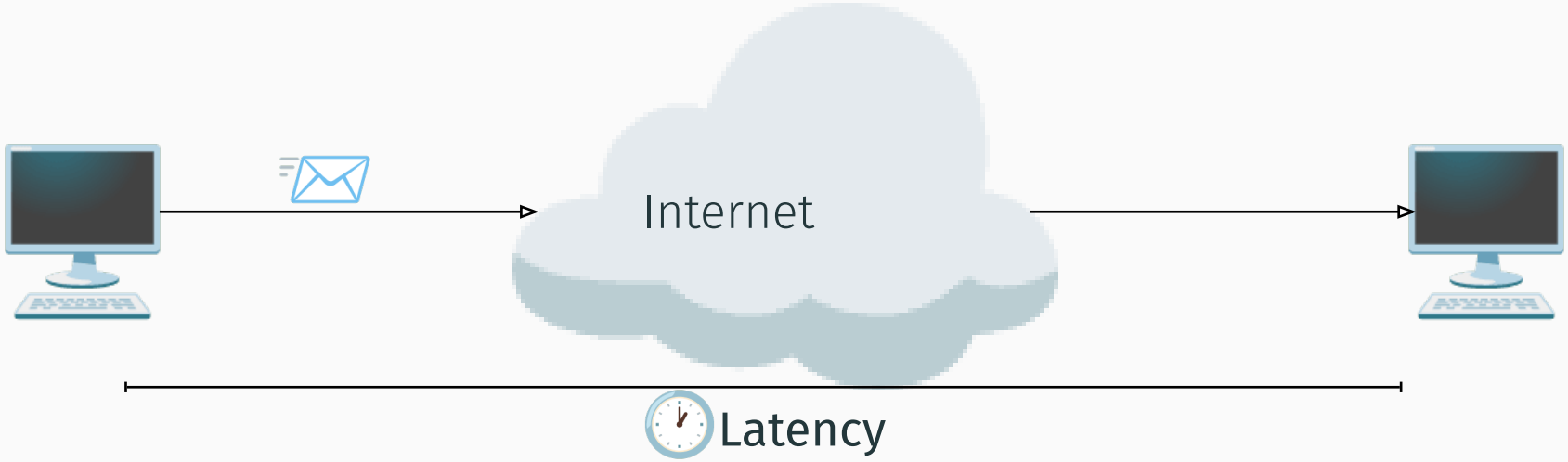

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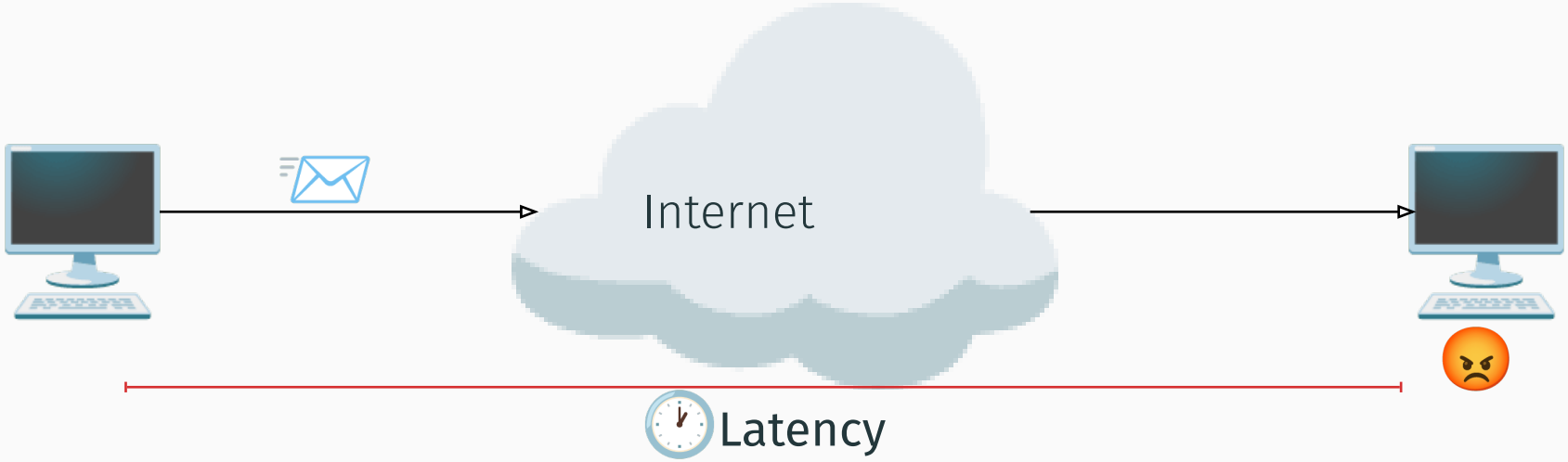

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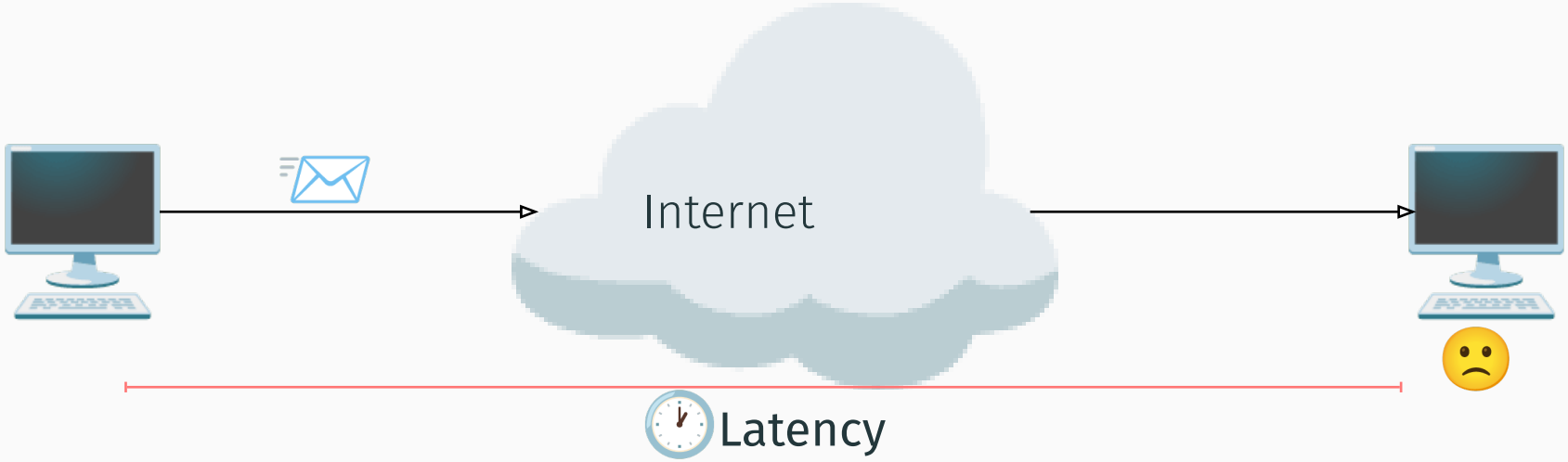

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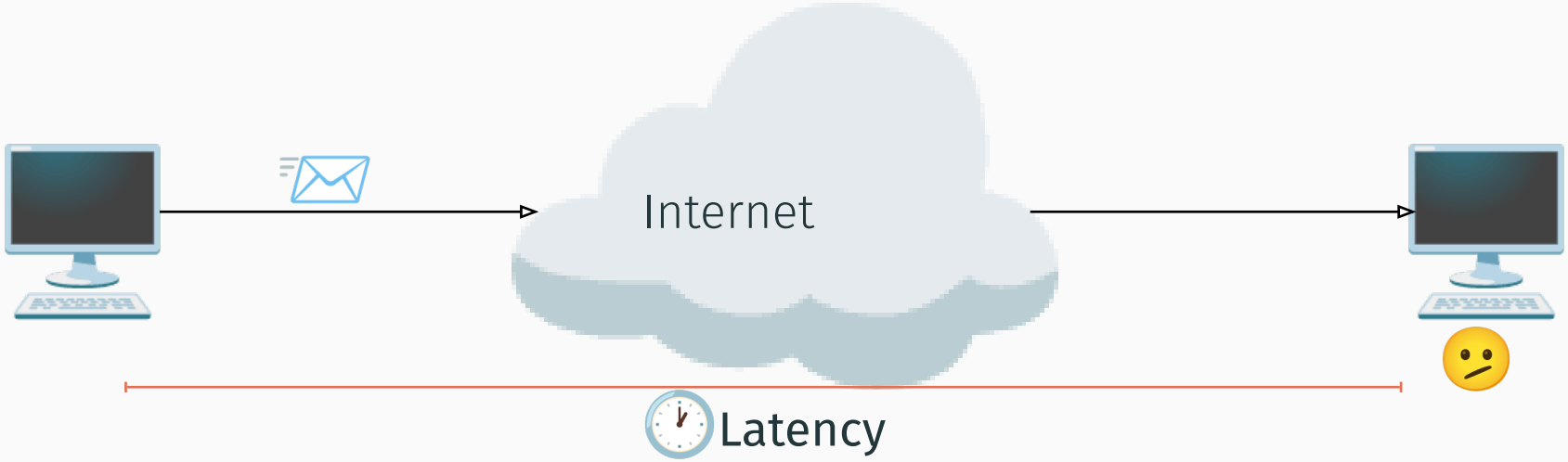

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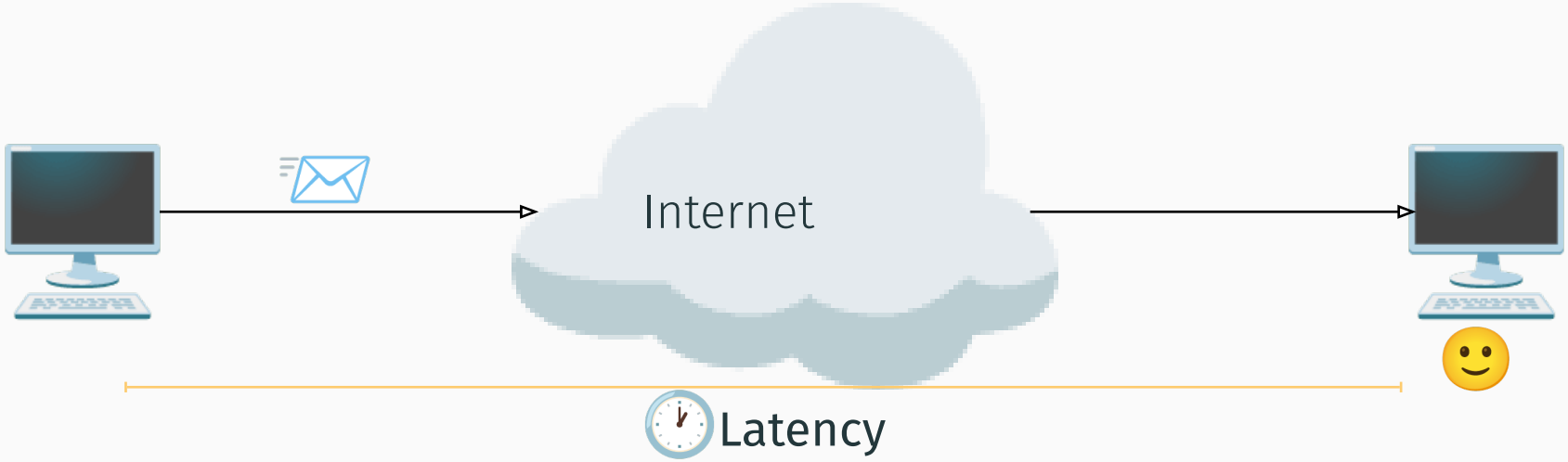

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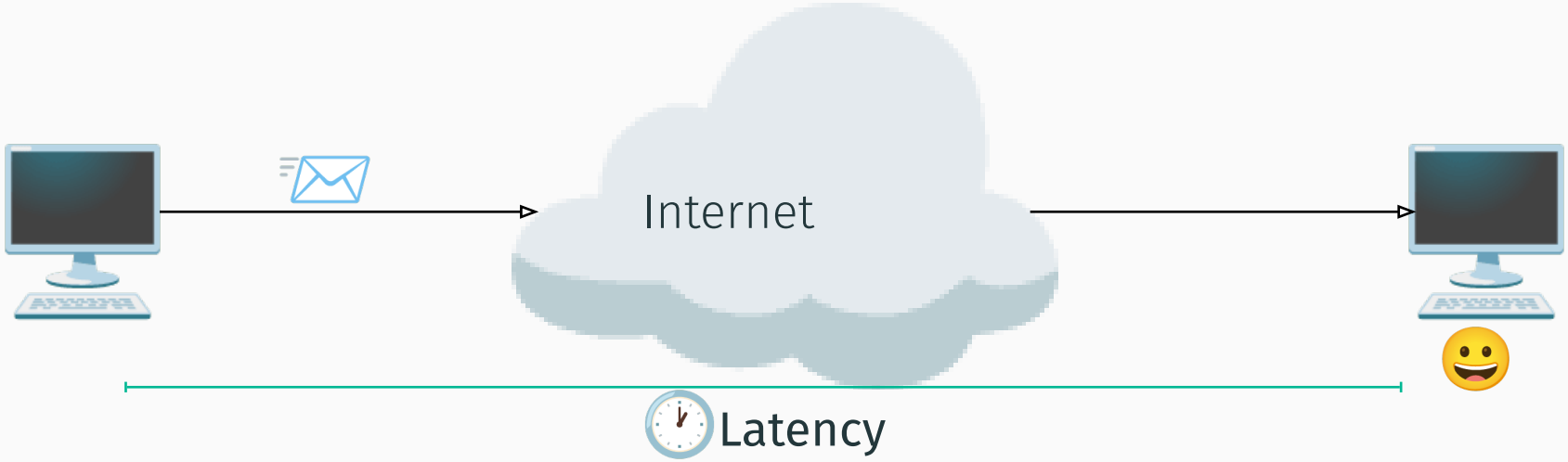

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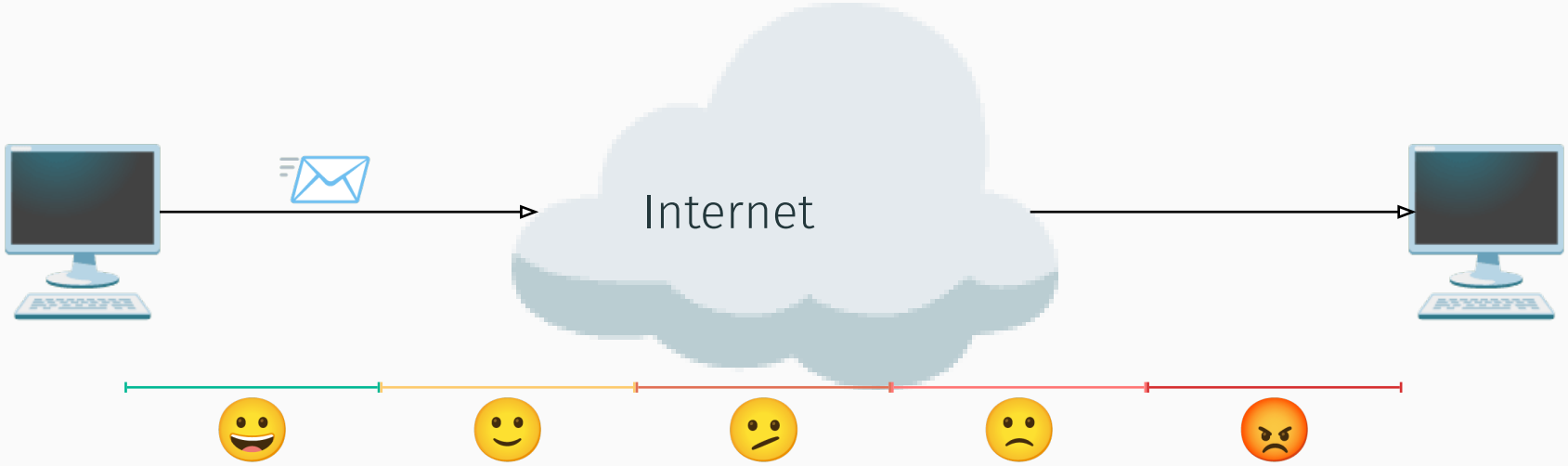

$\Longrightarrow$ In classical Internet, Quality of Service is mainly driven by user satisfaction.

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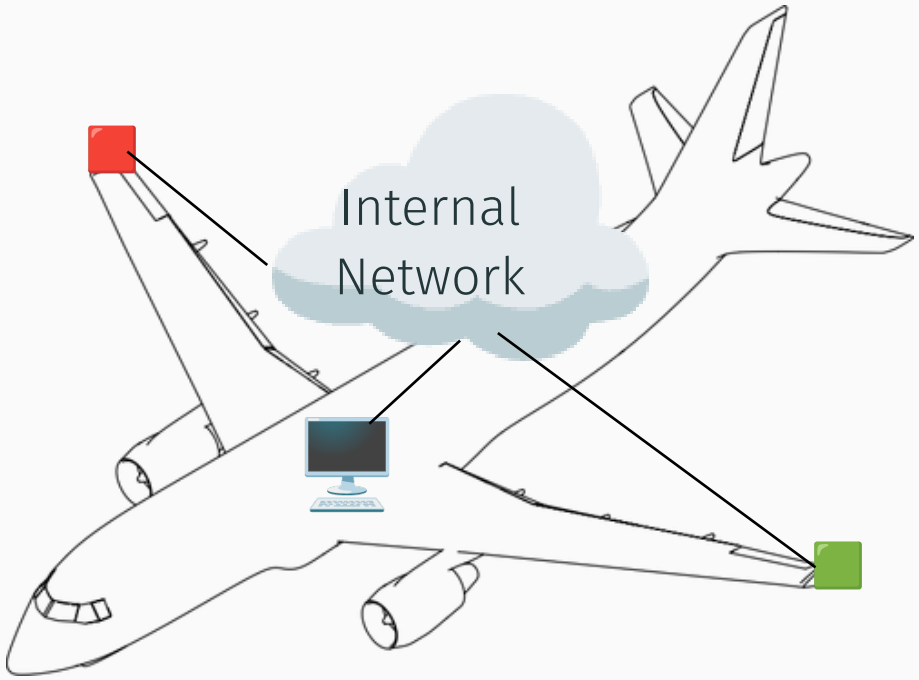

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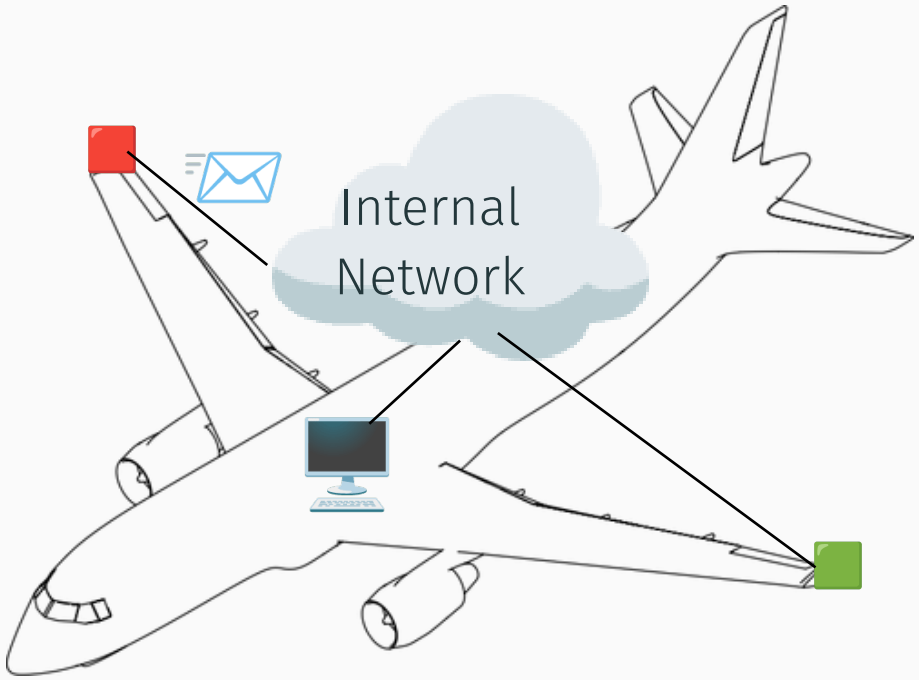

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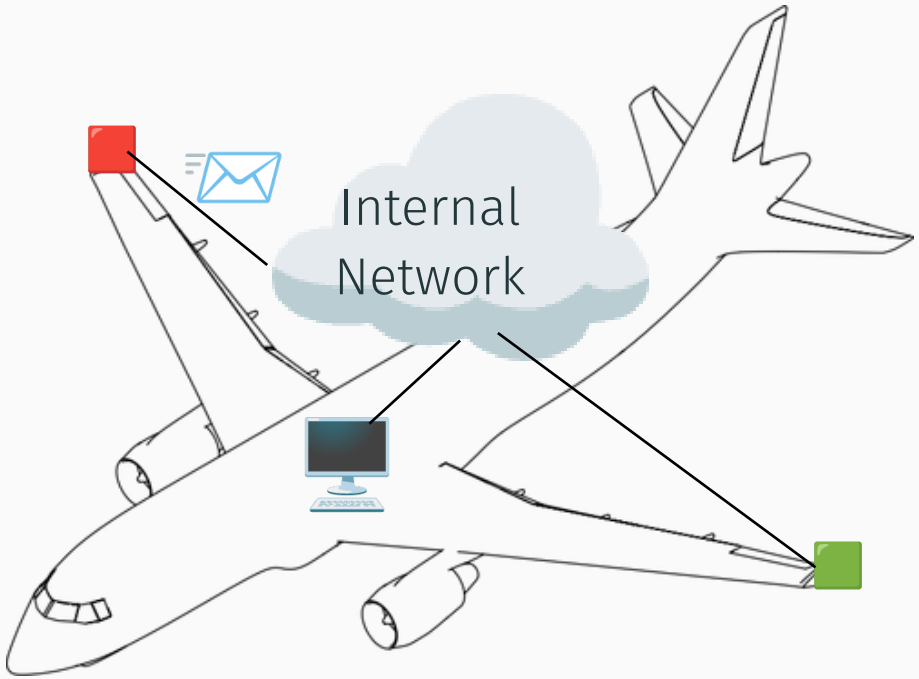

🕐 Latency

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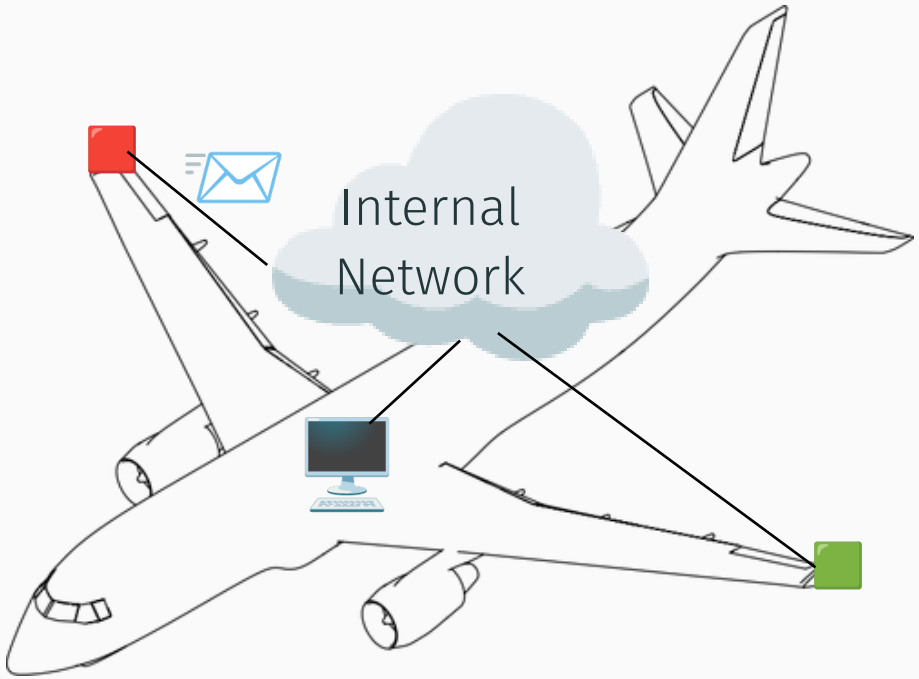

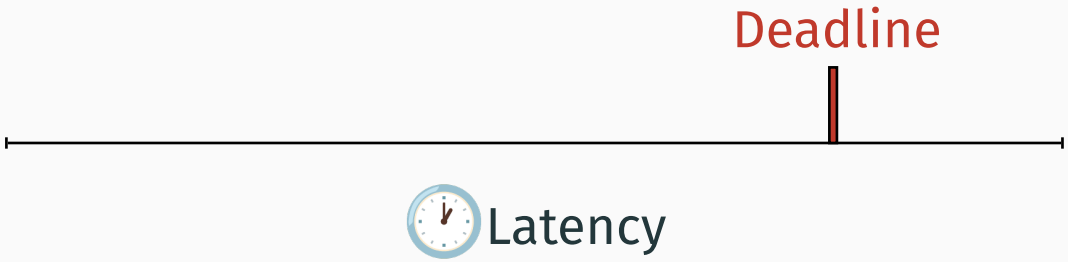

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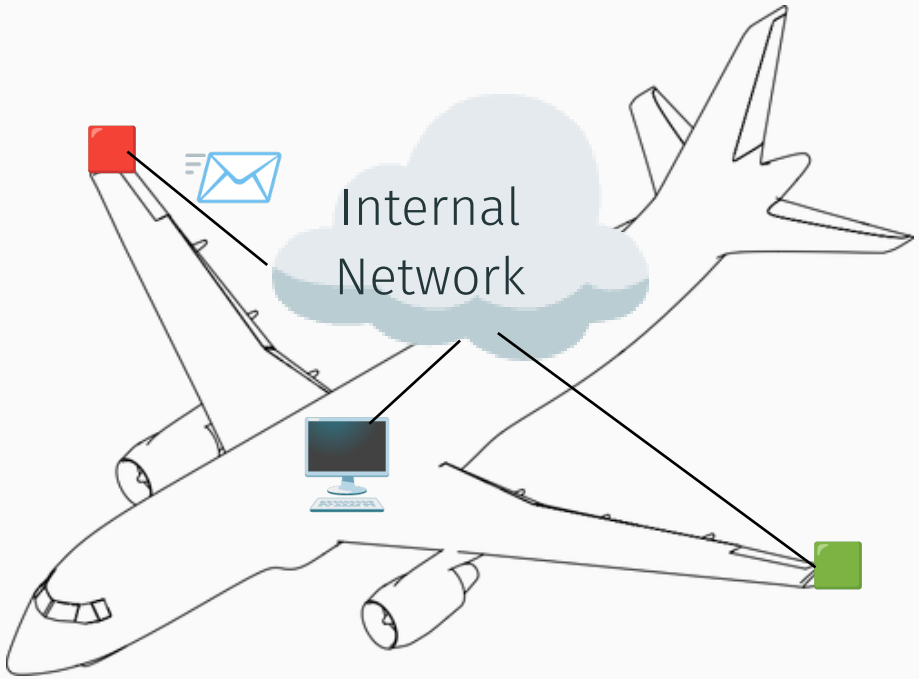

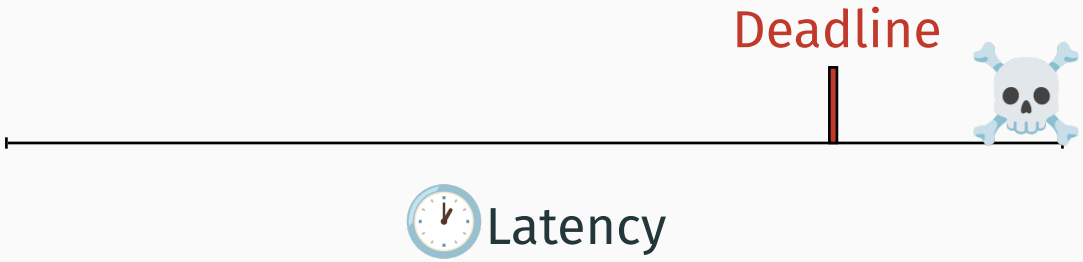

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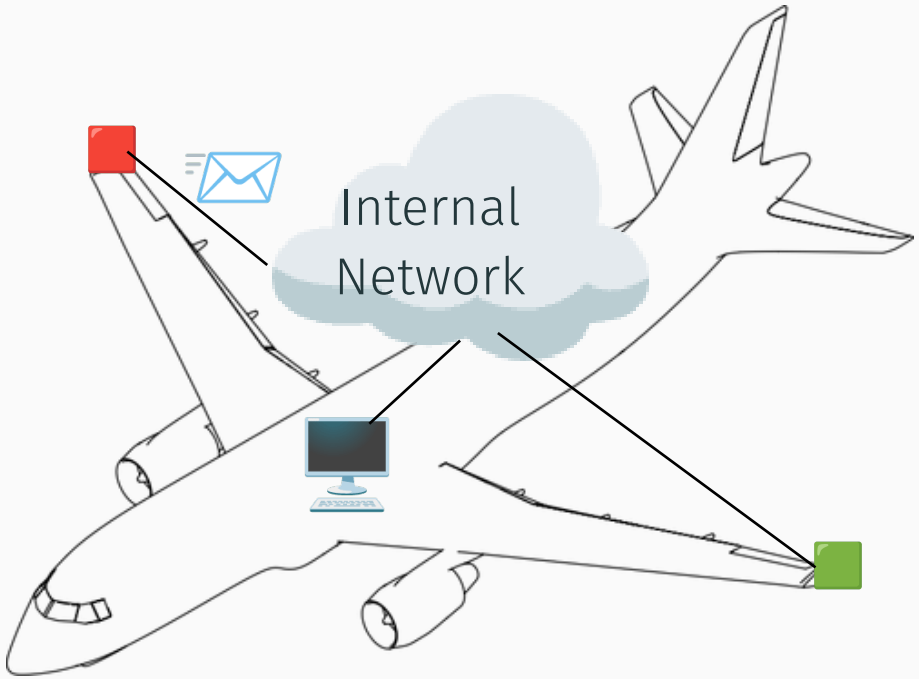

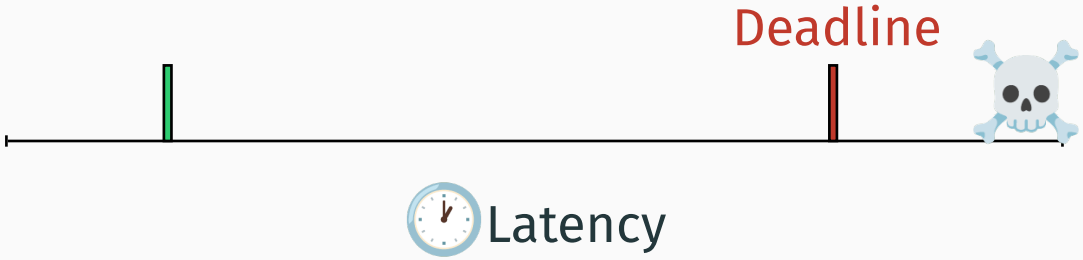

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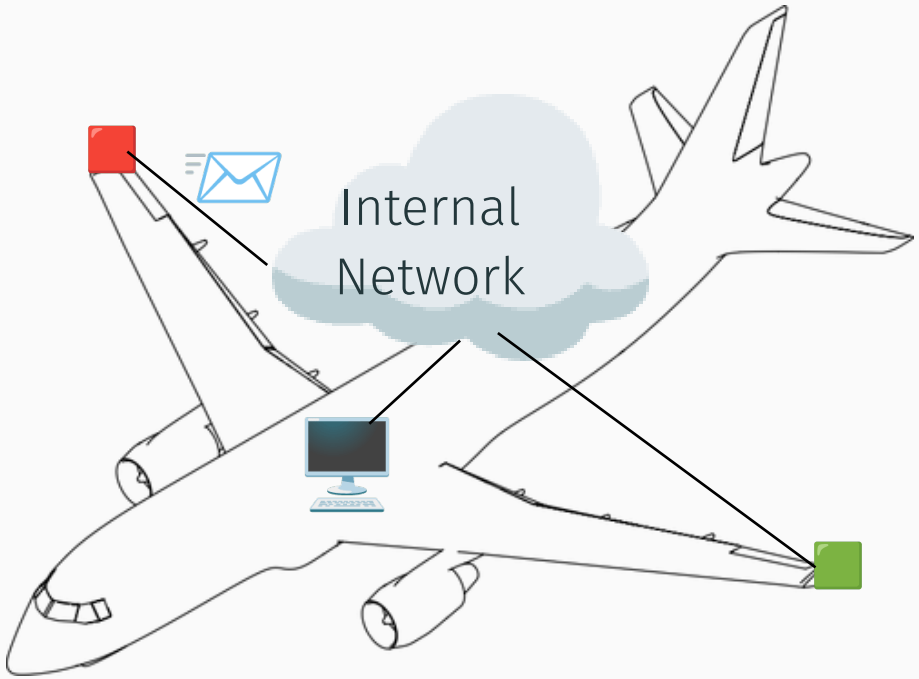

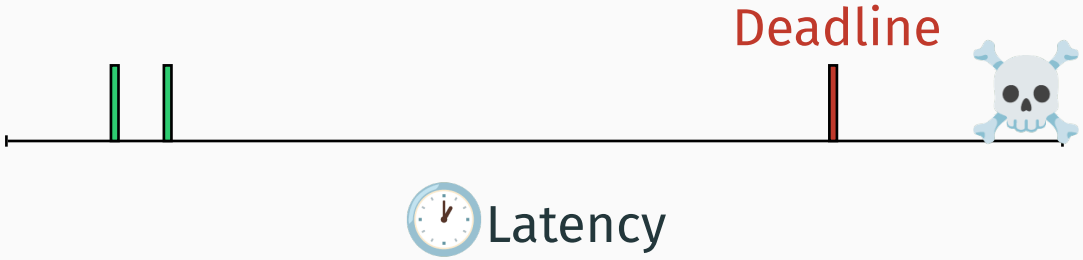

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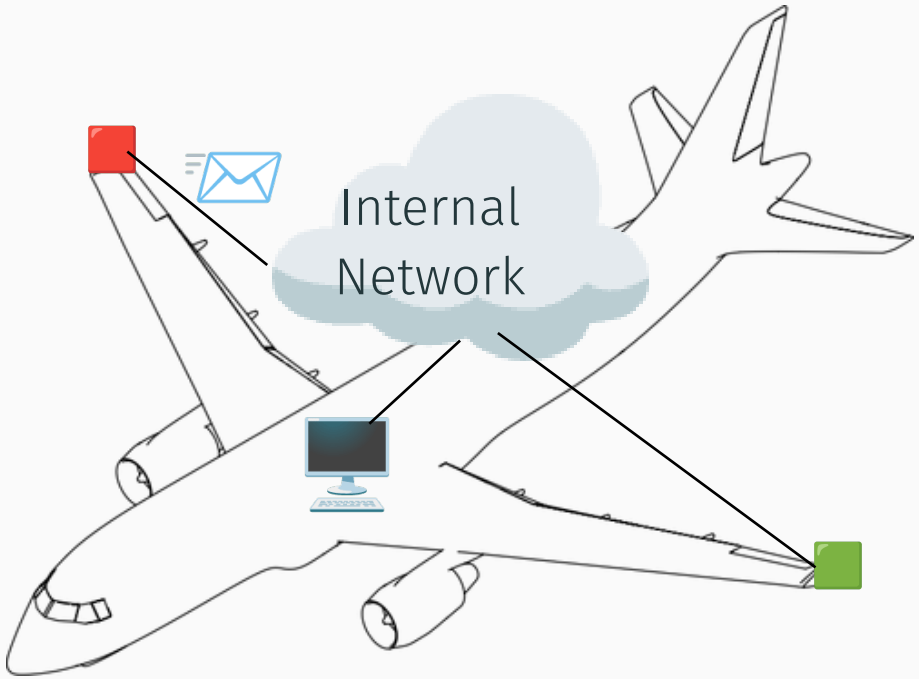

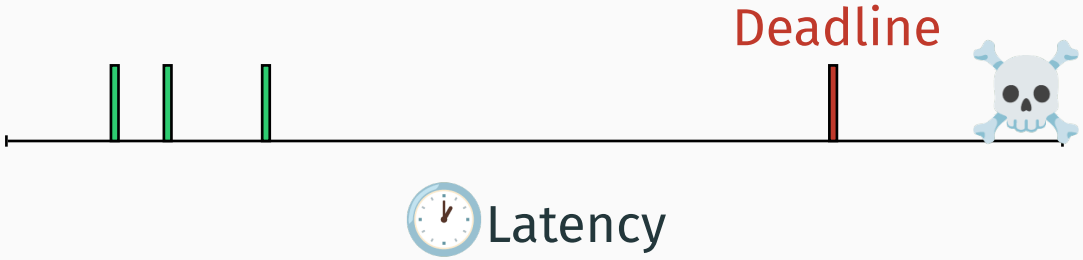

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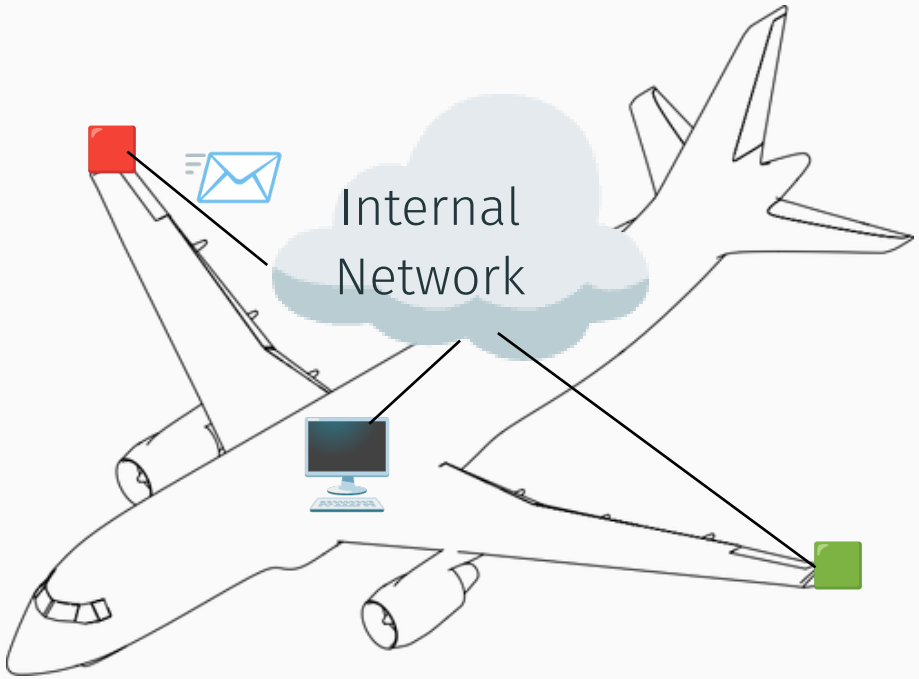

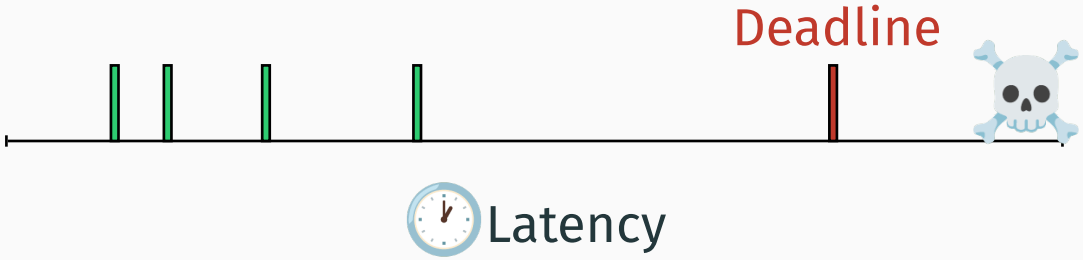

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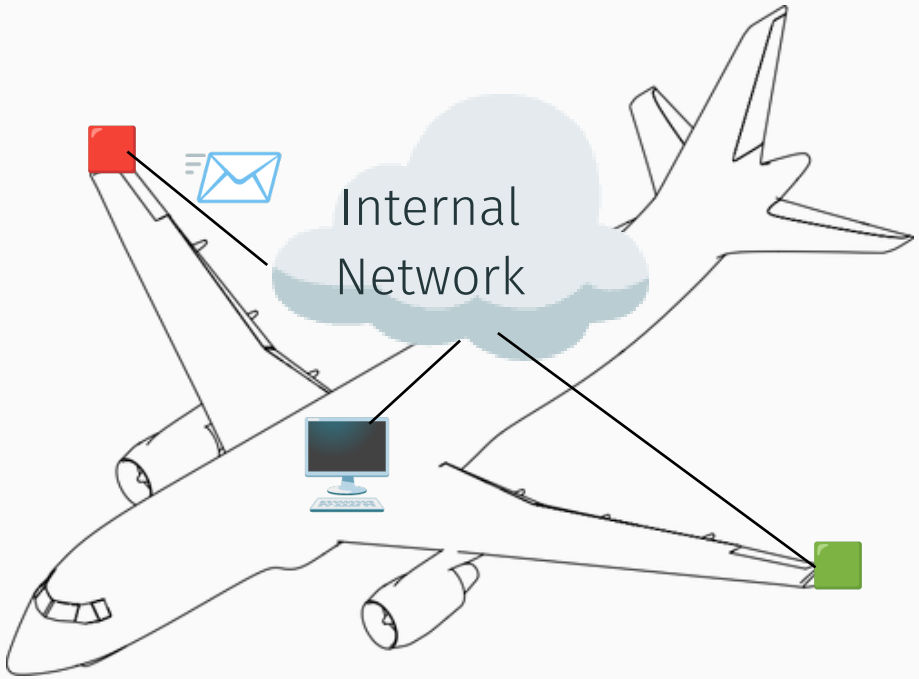

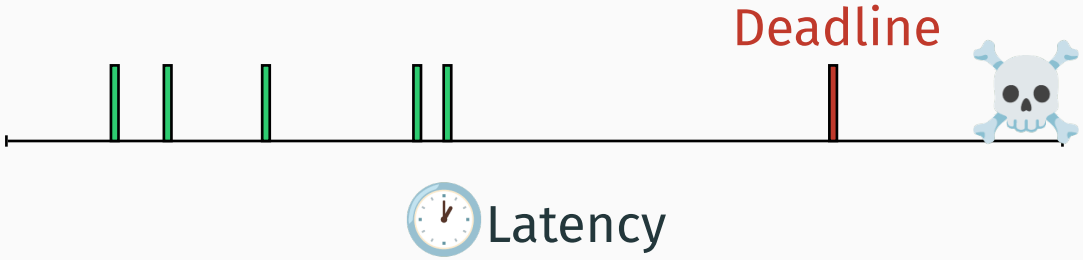

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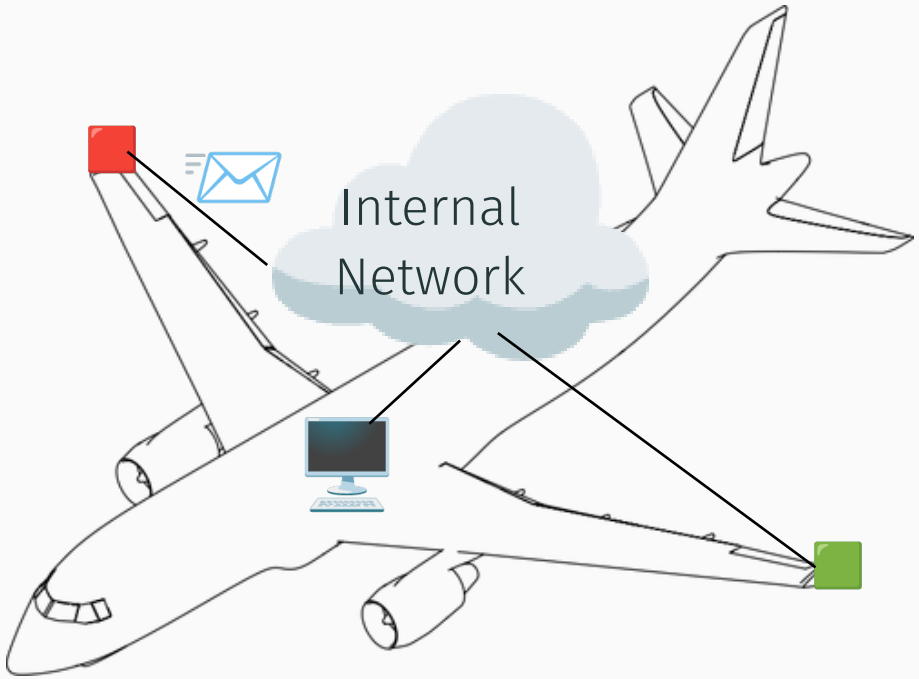

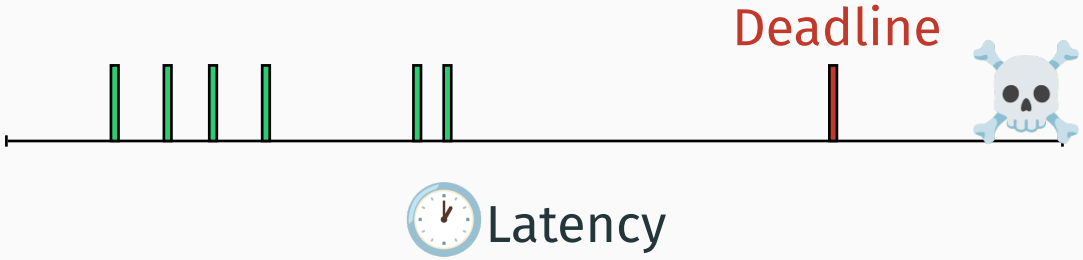

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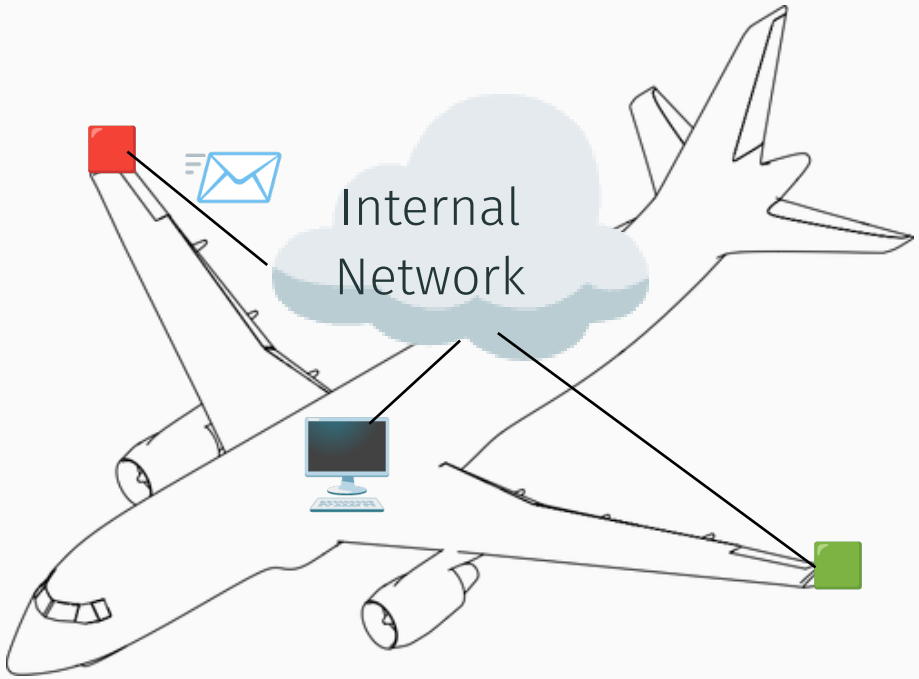

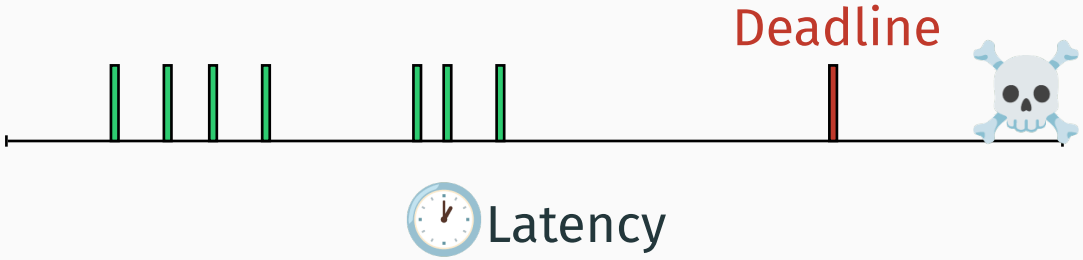

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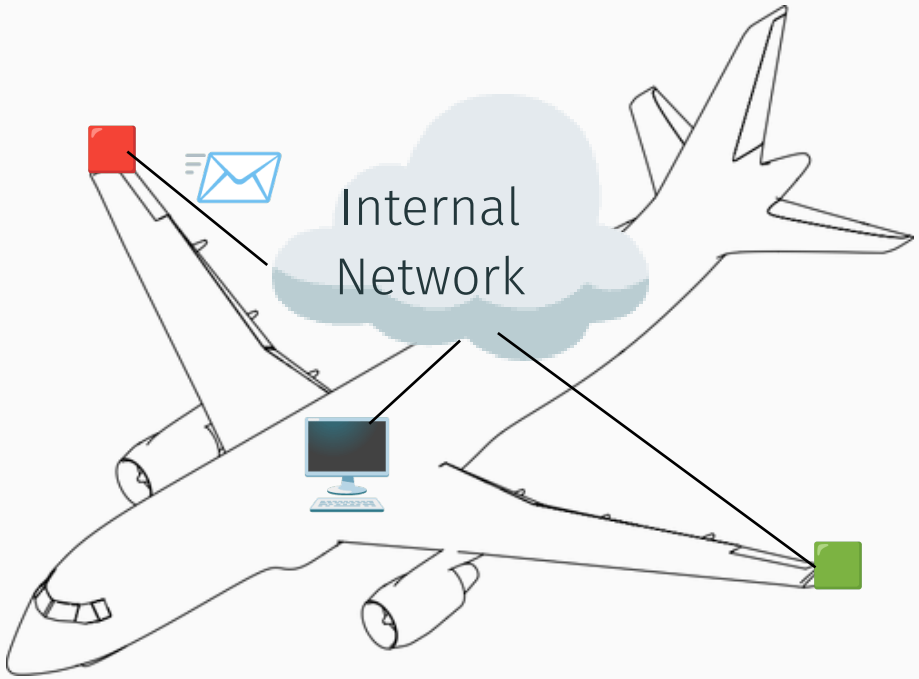

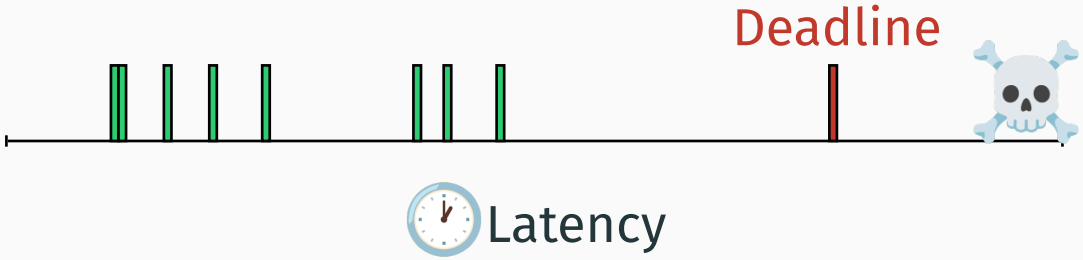

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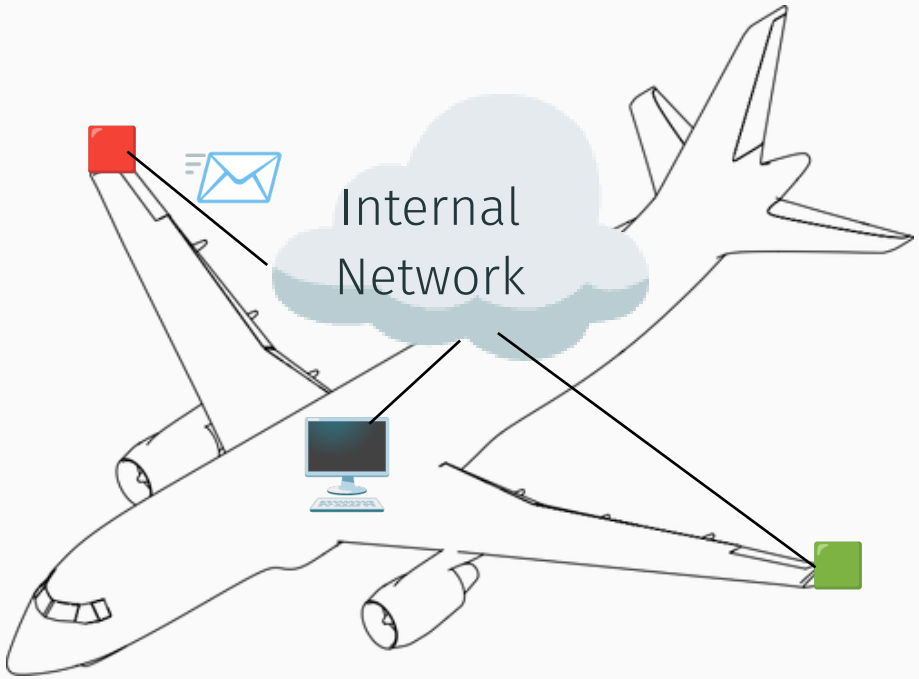

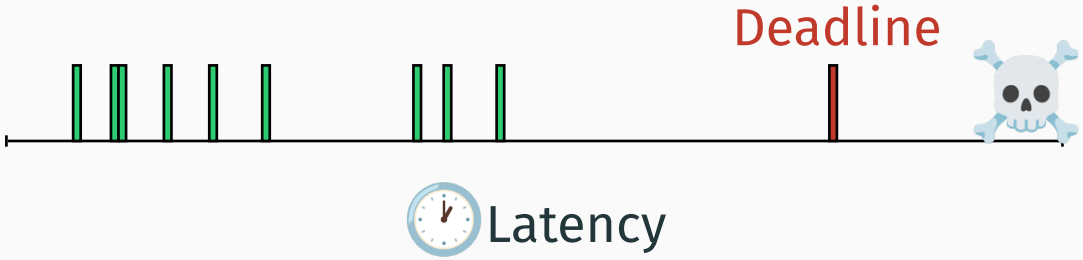

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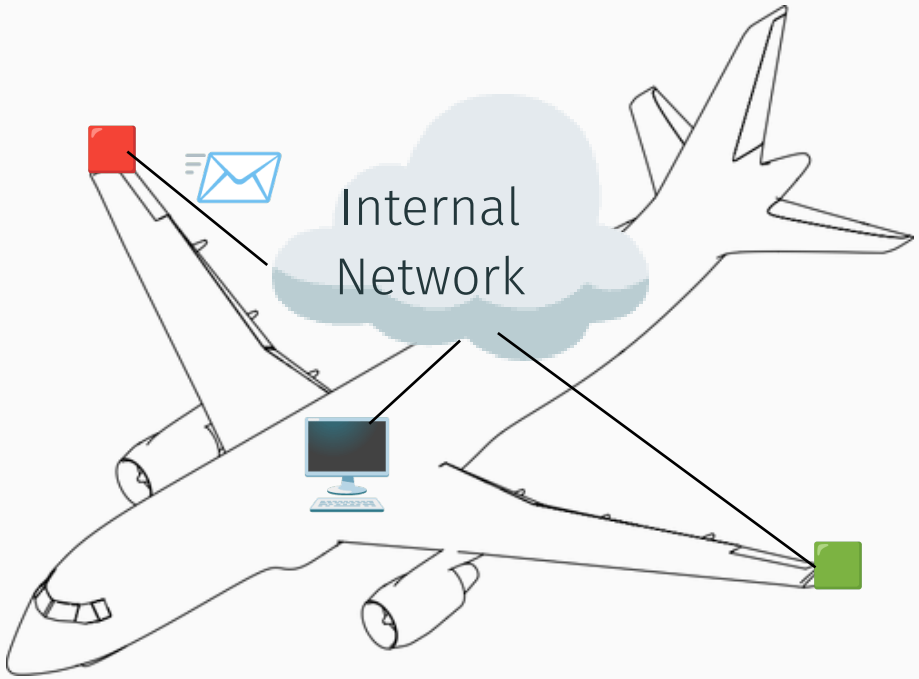

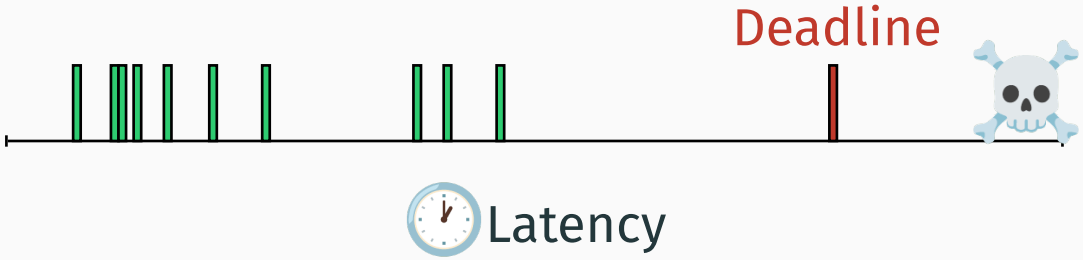

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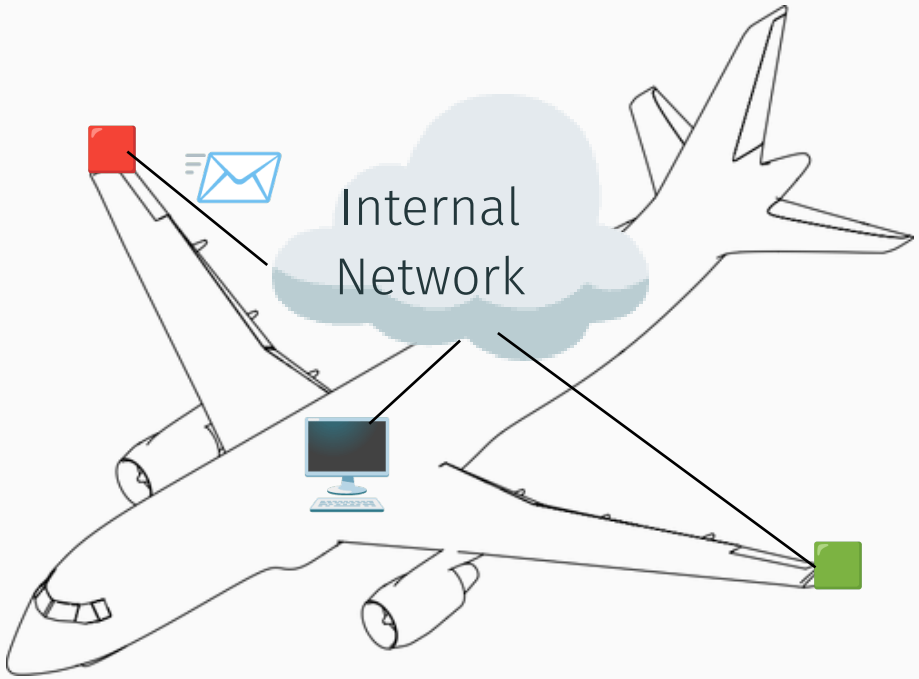

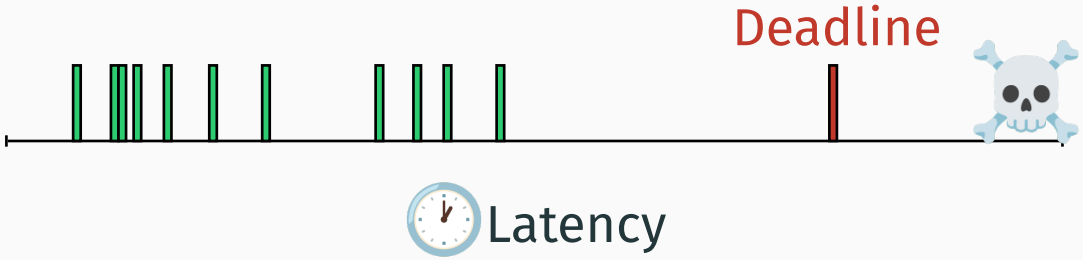

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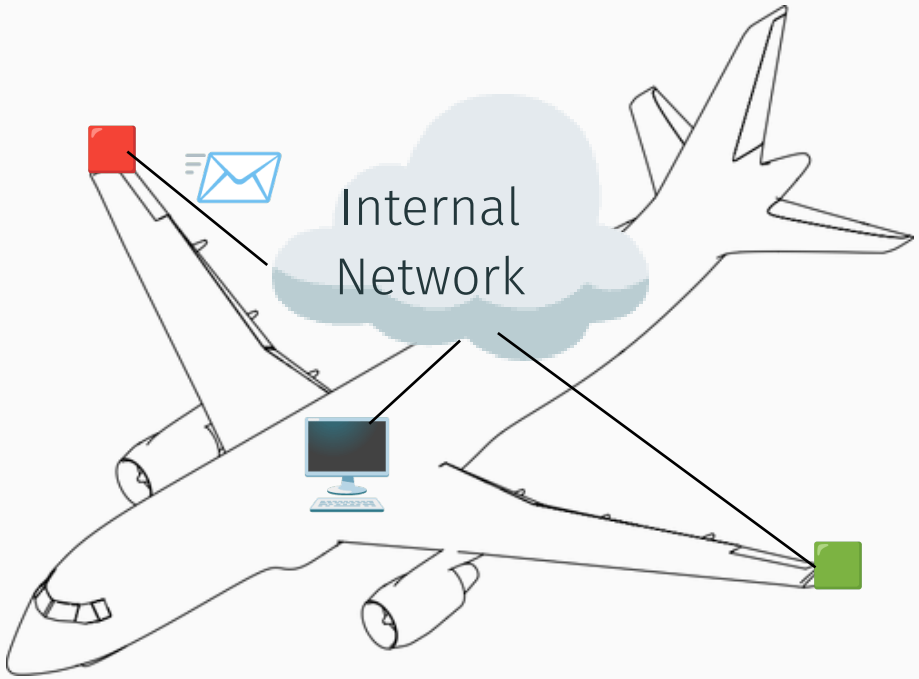

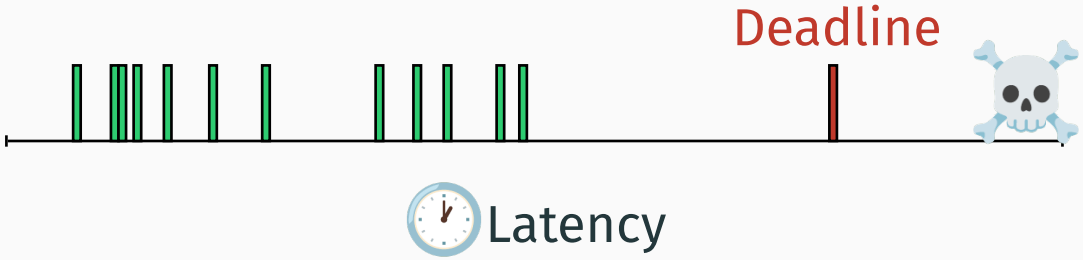

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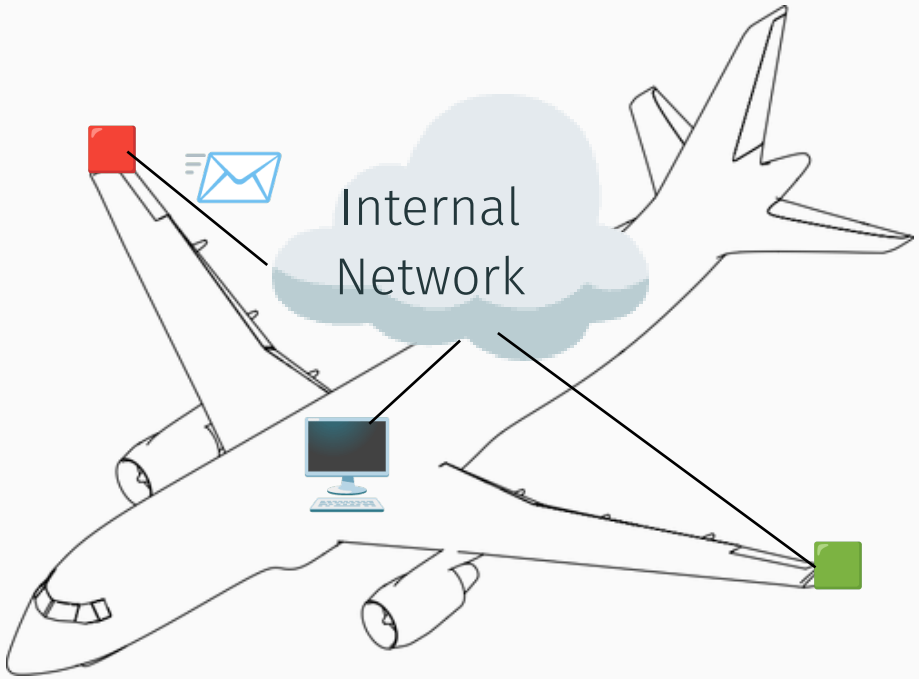

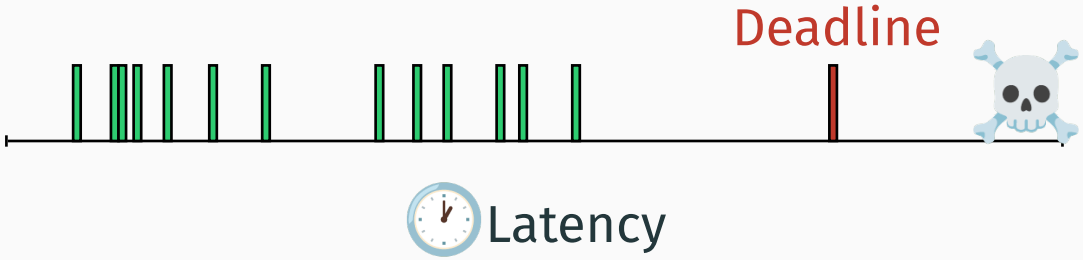

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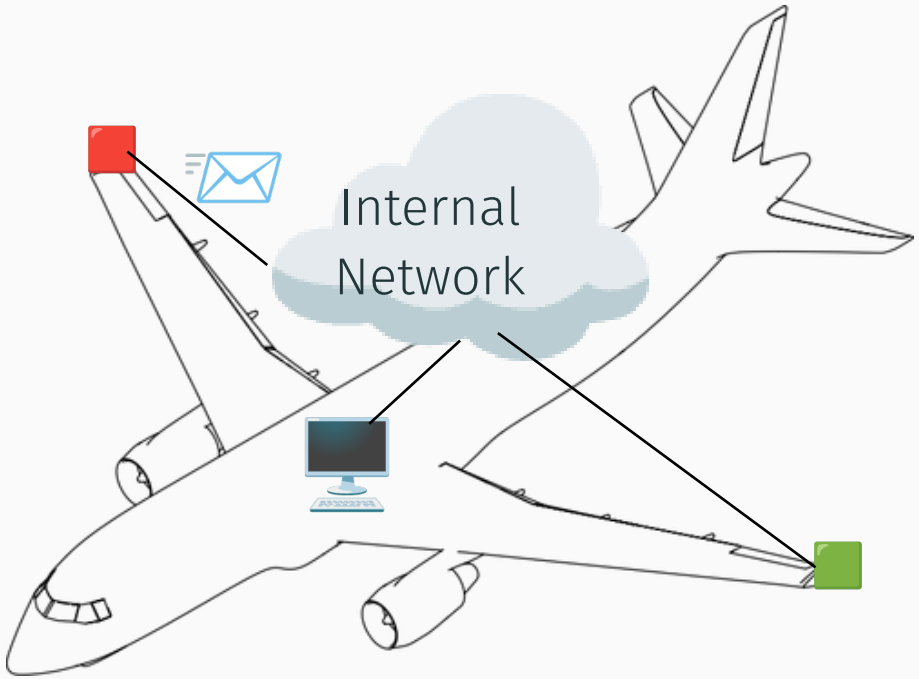

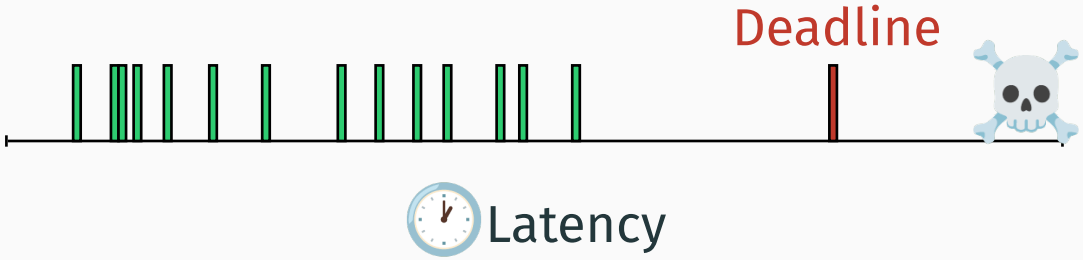

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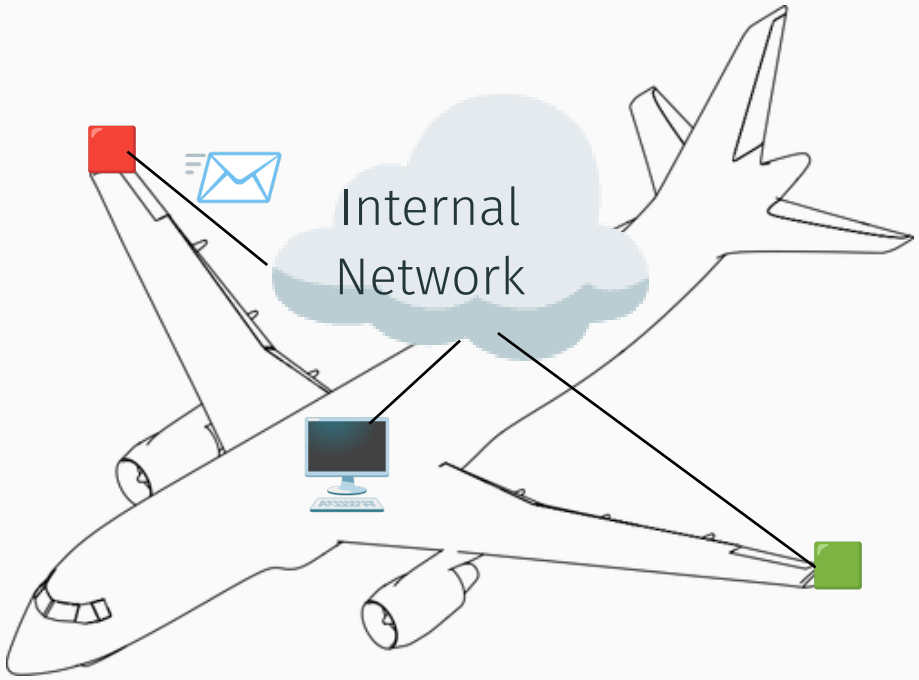

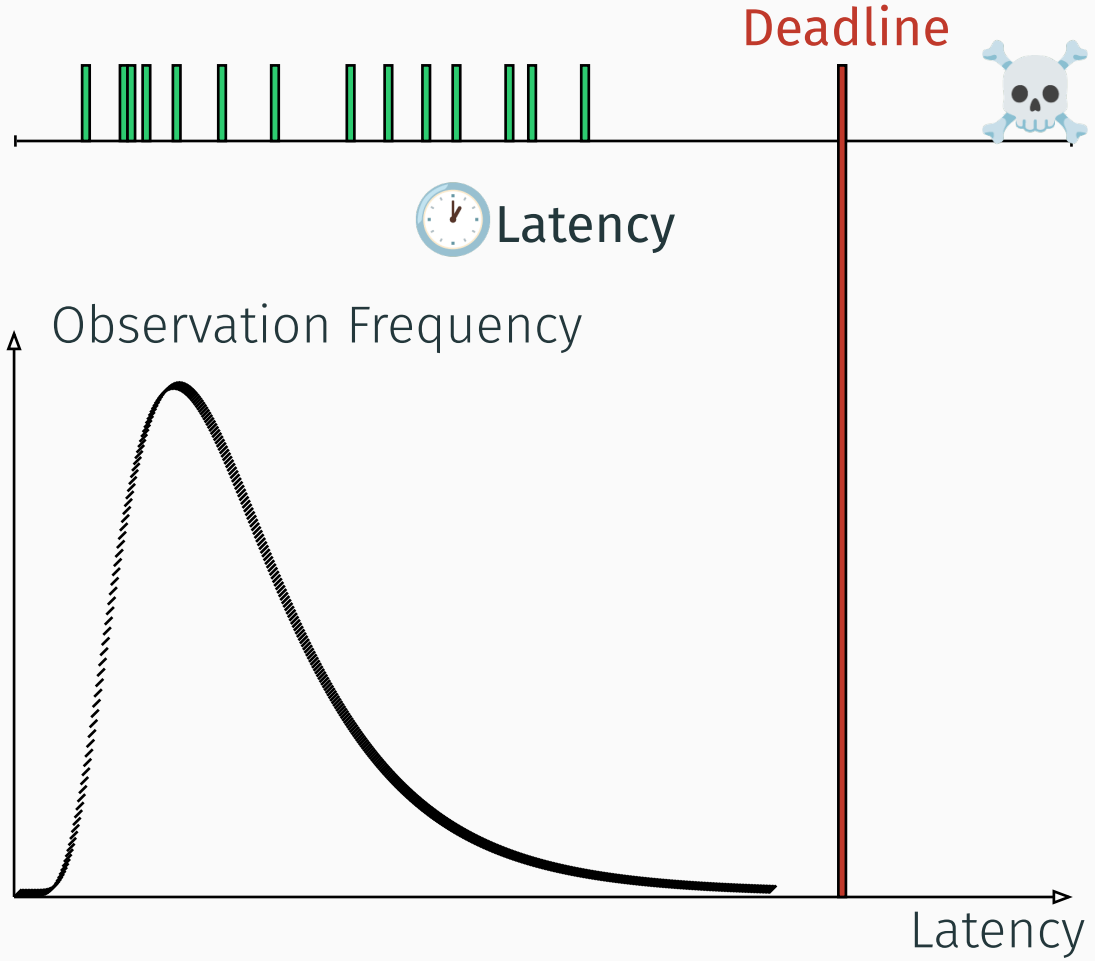

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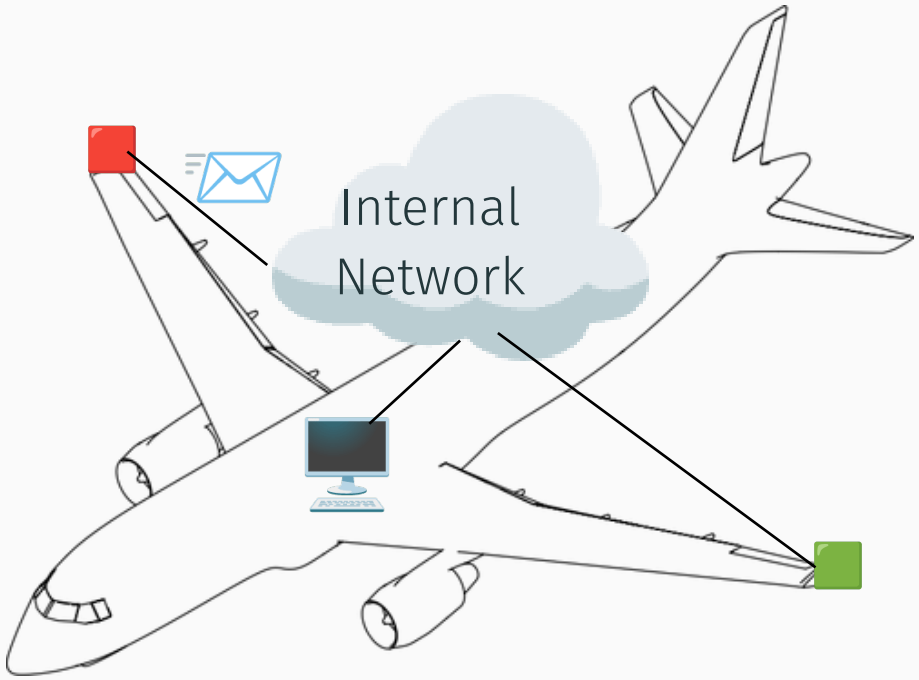

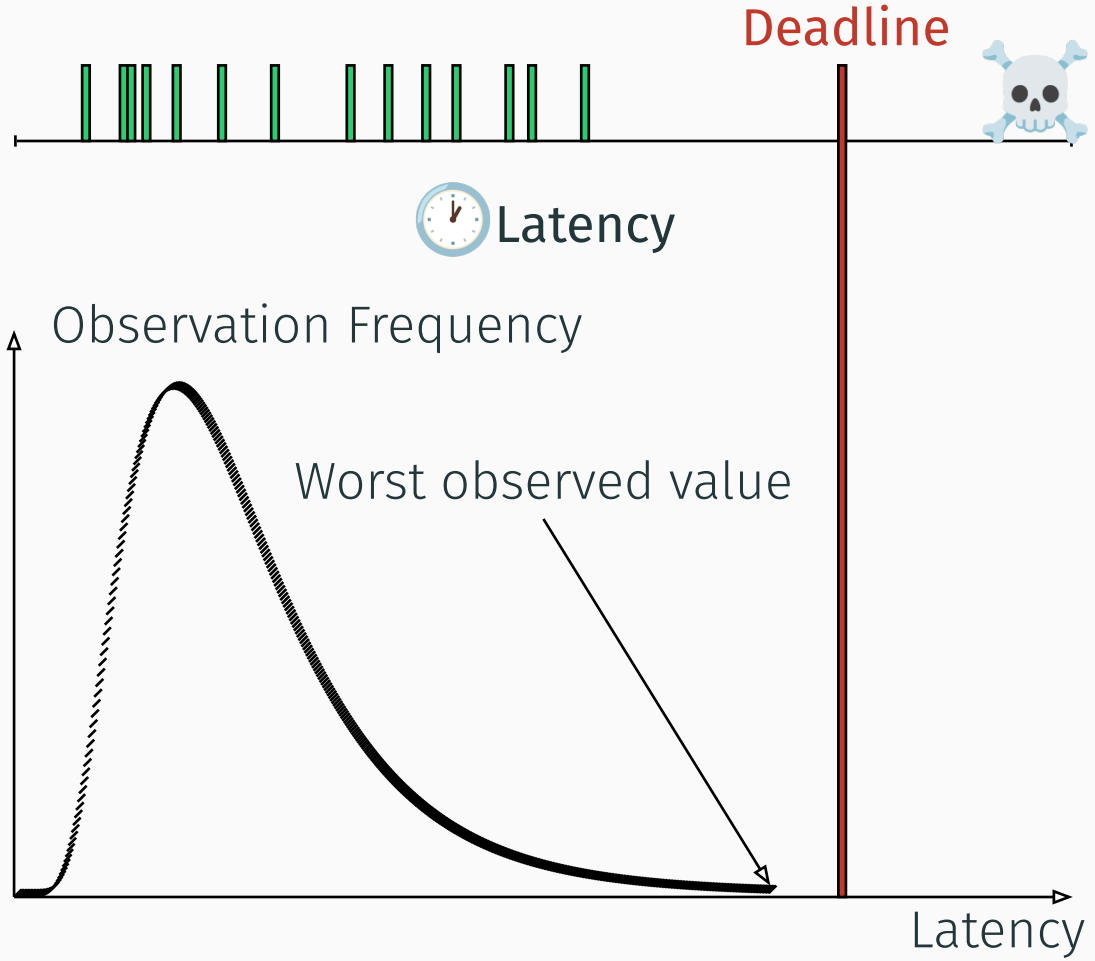

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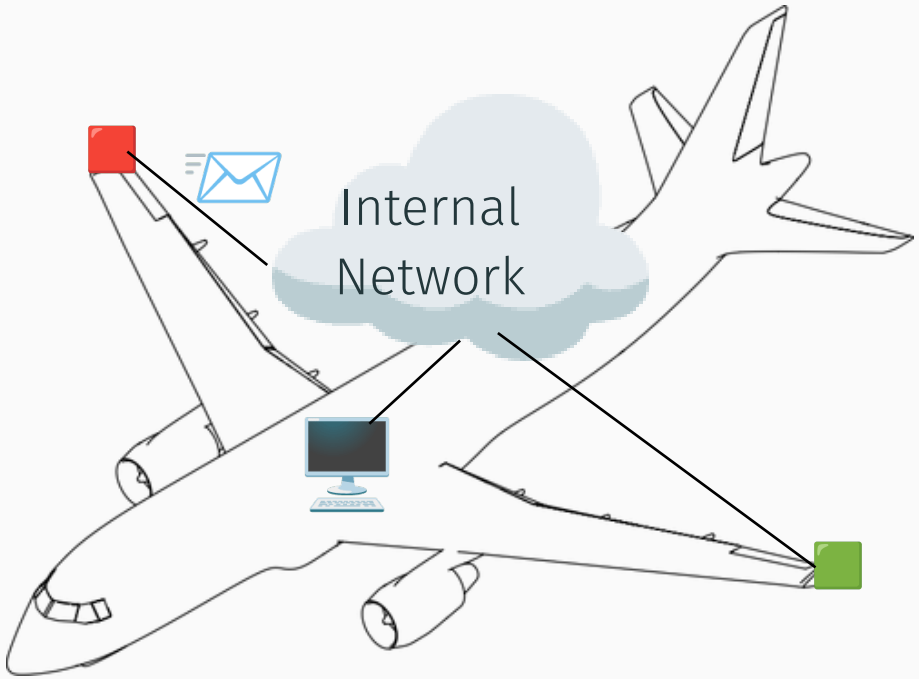

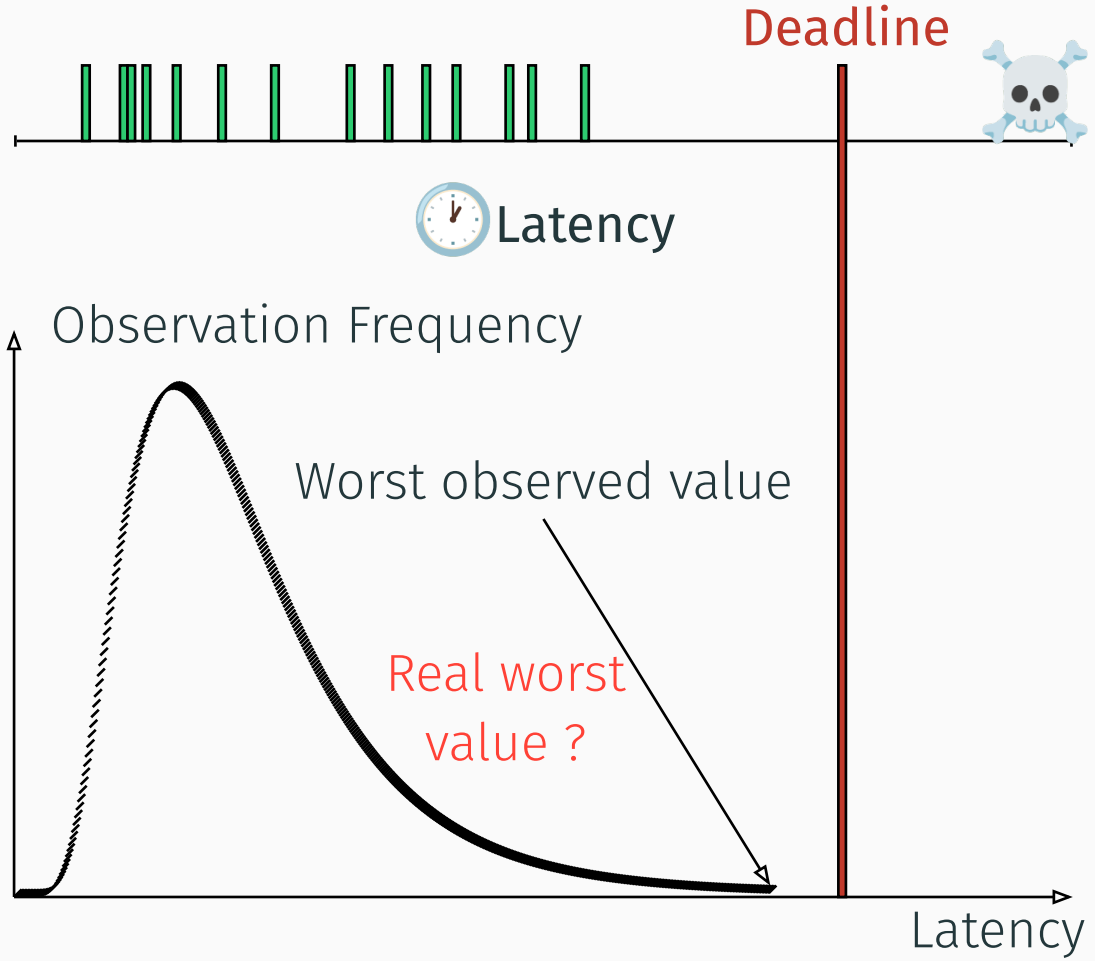

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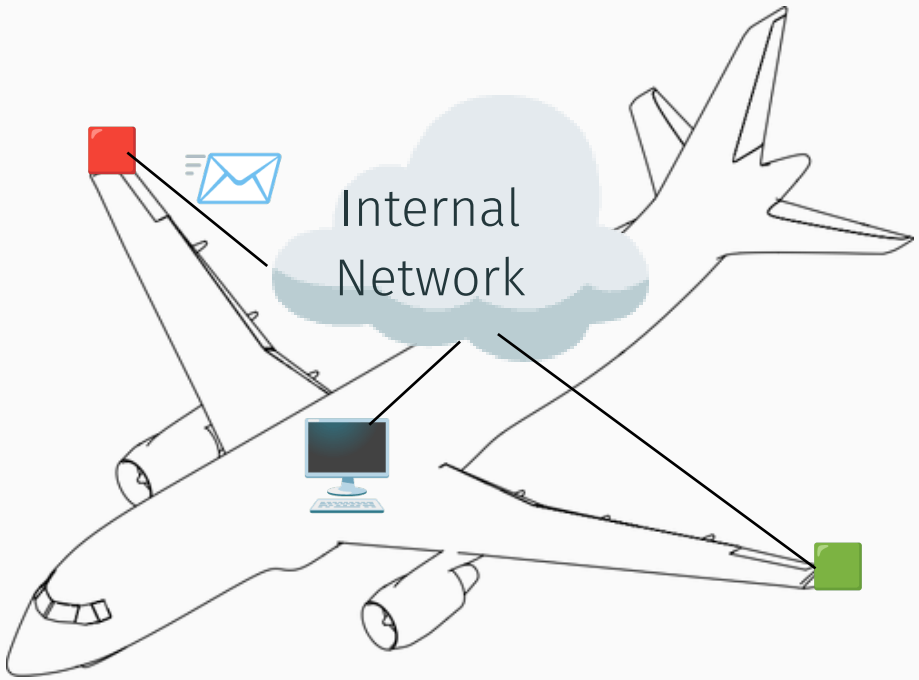

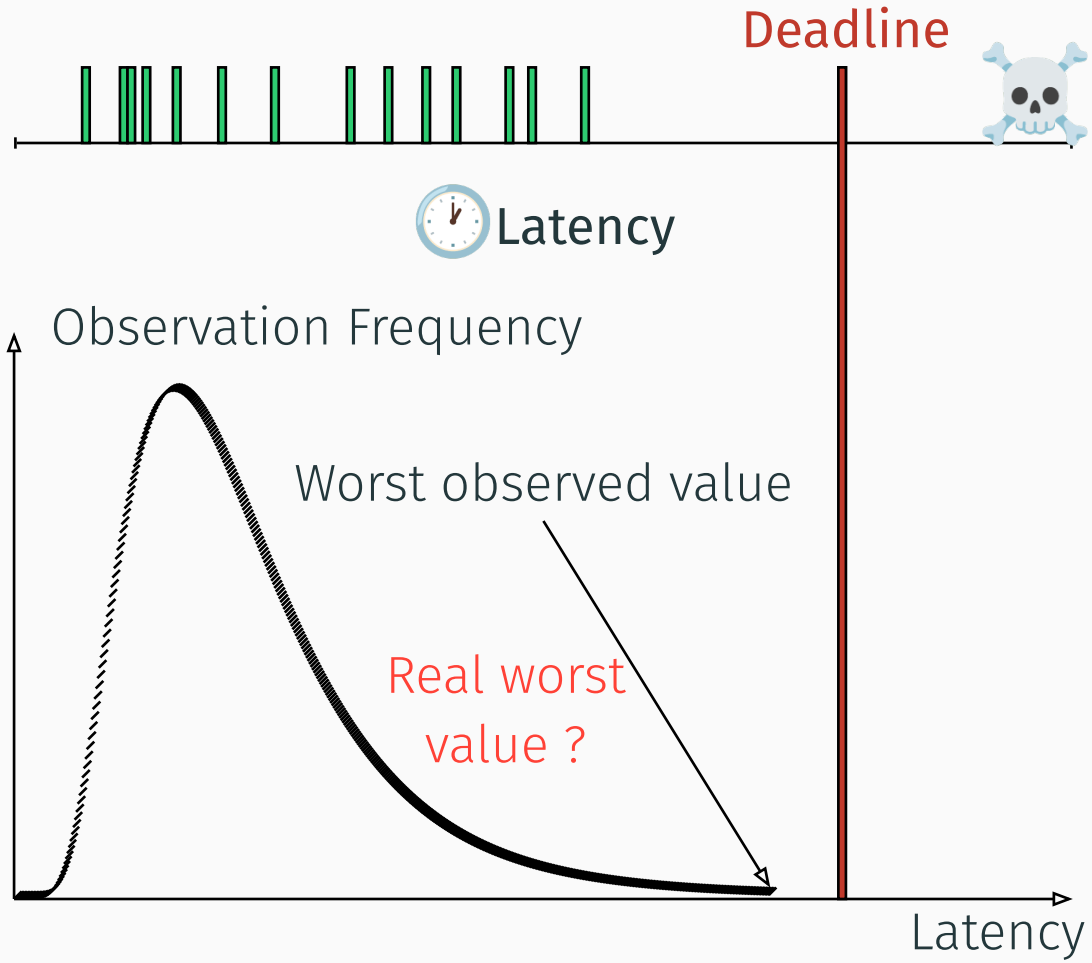

⟹ In time-sensitive networks, worst observed values provide insight but not assurance

Time-Sensitive Networks Architecture

Though, assurance is mandatory, as deadline violations may have life-threatening consequences.

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$\Longrightarrow$ Need of specific technologies

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IEEE TSN / IETF DetNet

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IEEE TSN / IETF DetNet

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- Reliability

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Network Calculus

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Network Calculus

- Set of math results

Time-Sensitive Networks Architecture

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IEEE TSN / IETF DetNet

- Synchronization
- Reliability
- Latency
- Resource Management

$\Longrightarrow$ Need of formal proofs

Network Calculus

- Set of math results
- Validation / verification

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$\Longrightarrow$ Need of specific technologies

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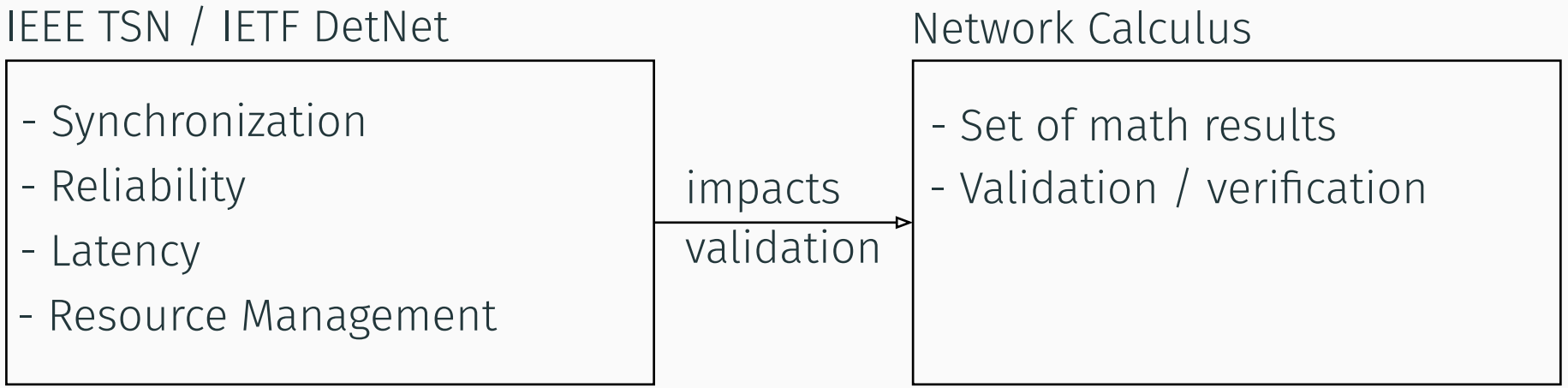

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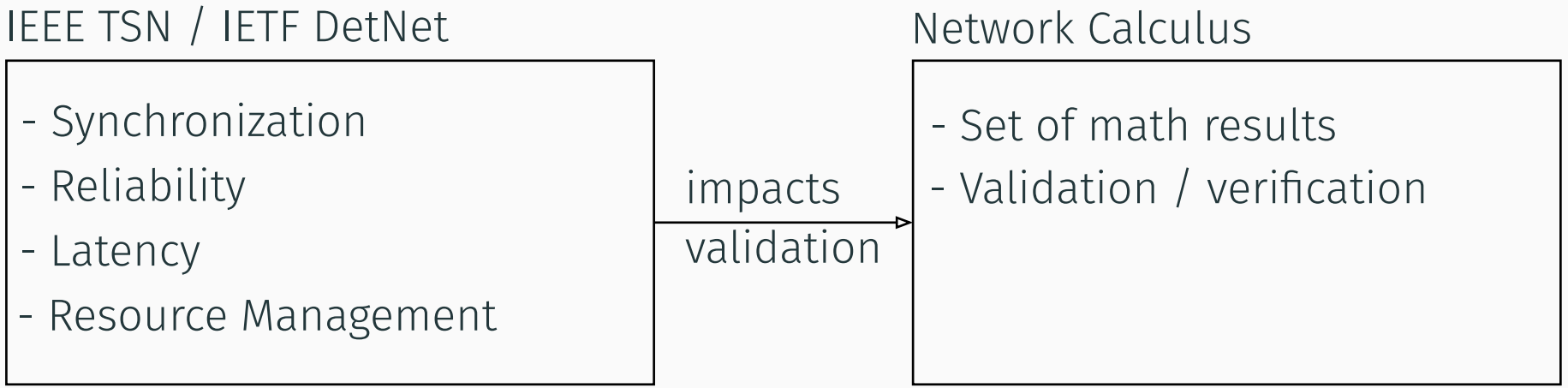

$\Longrightarrow$TSN and DetNet provide precise control over network communications.

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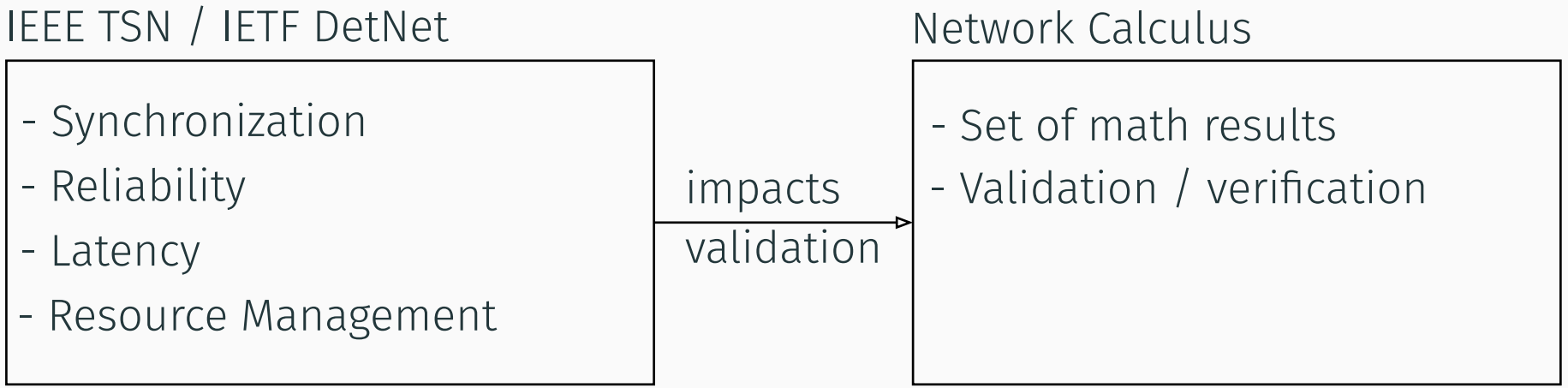

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$\Longrightarrow$Network Calculus allows formal validation and delay-bound computation based on the configurations of TSN / DetNet.

TSN: Determinism at Layer 2

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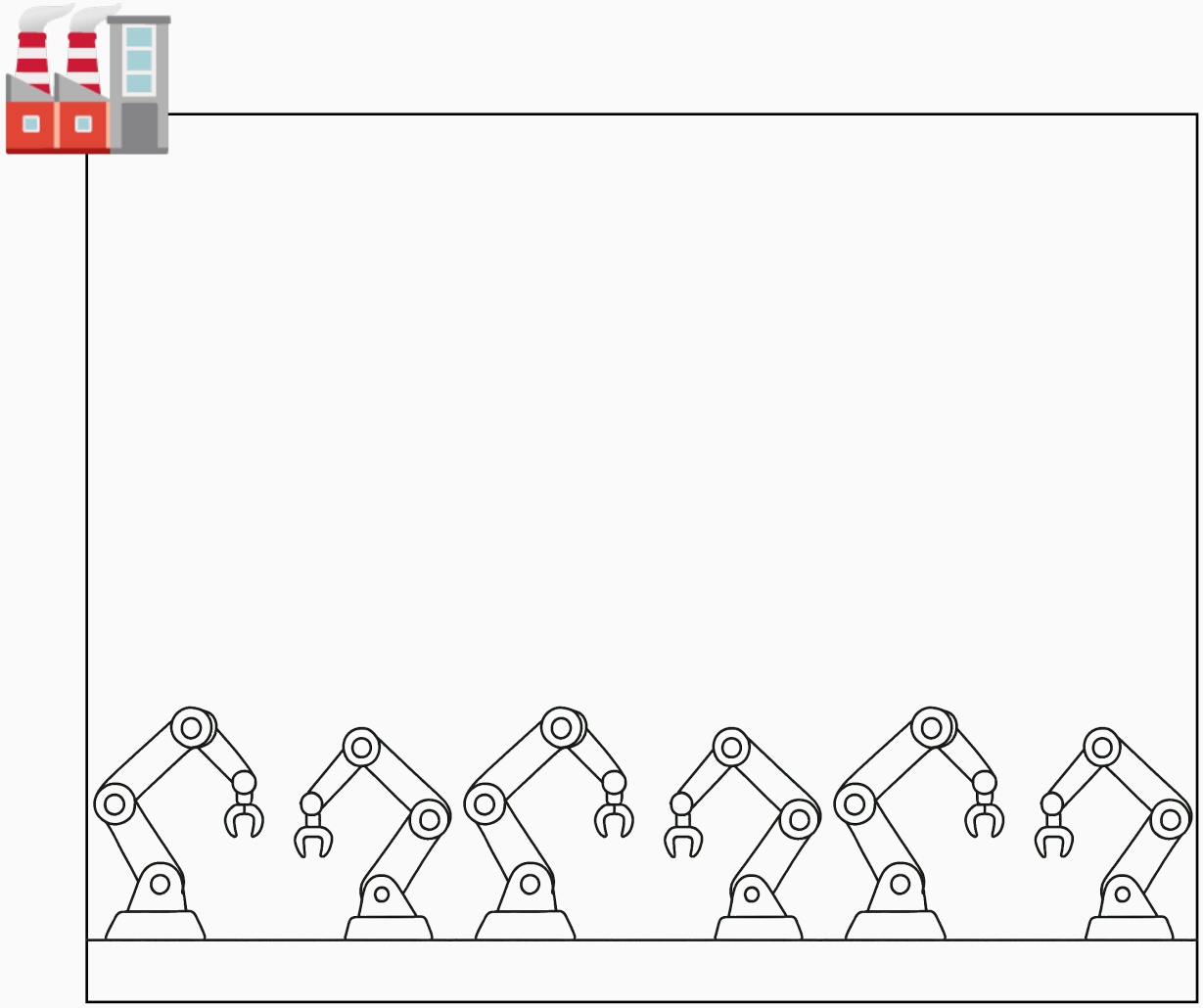
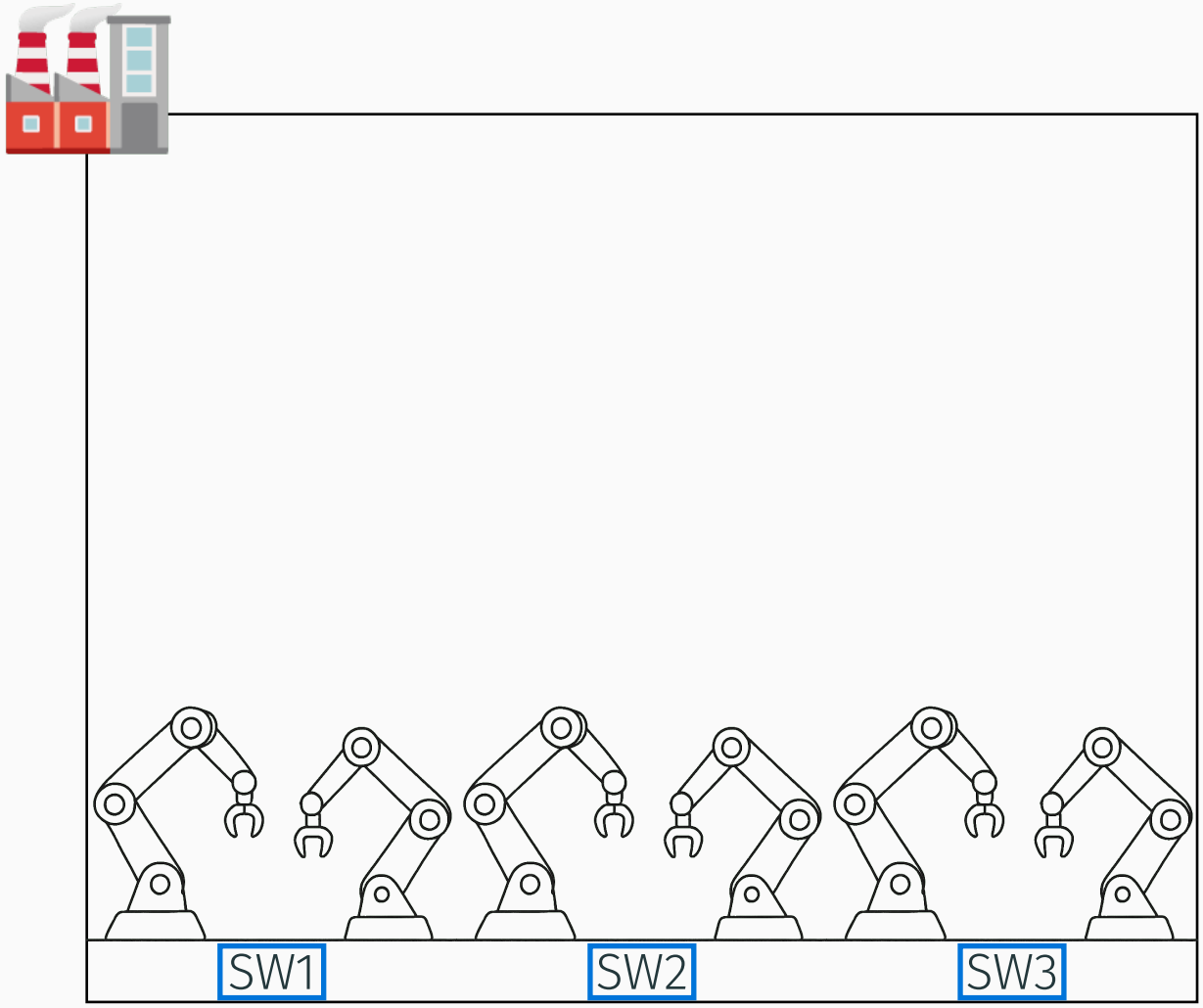
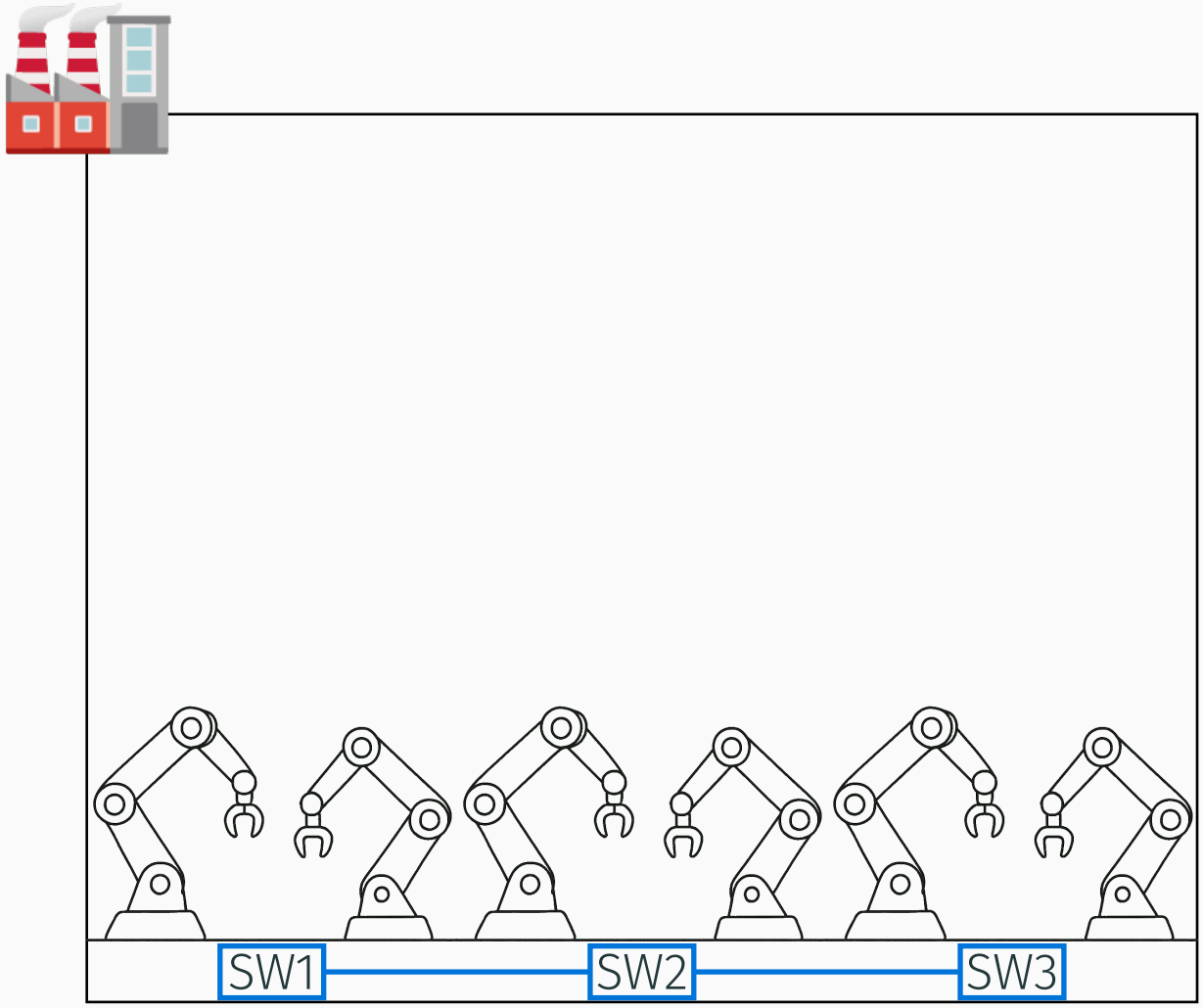


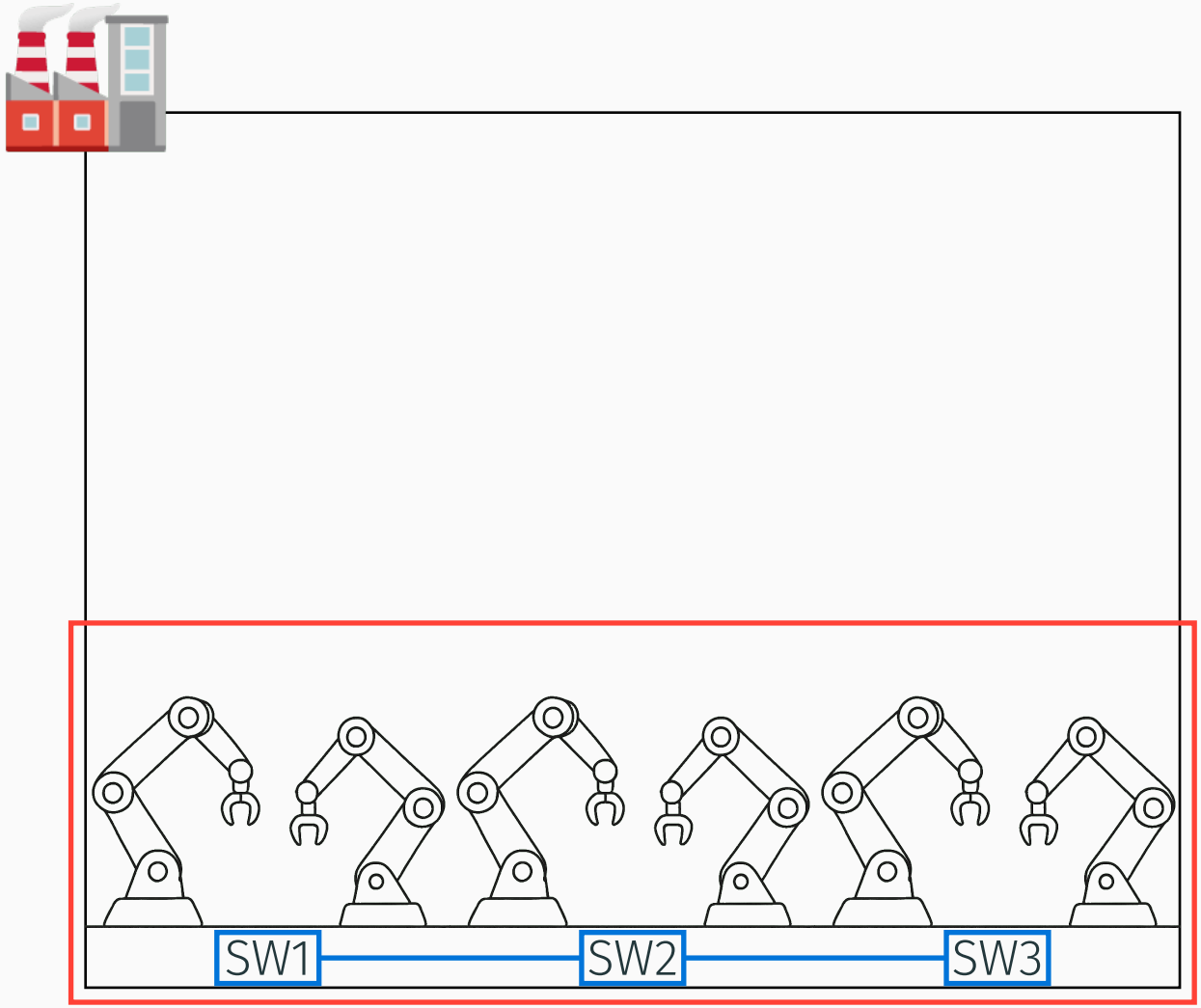
TSN: Determinism at Layer 2



TSN: Determinism at Layer 2

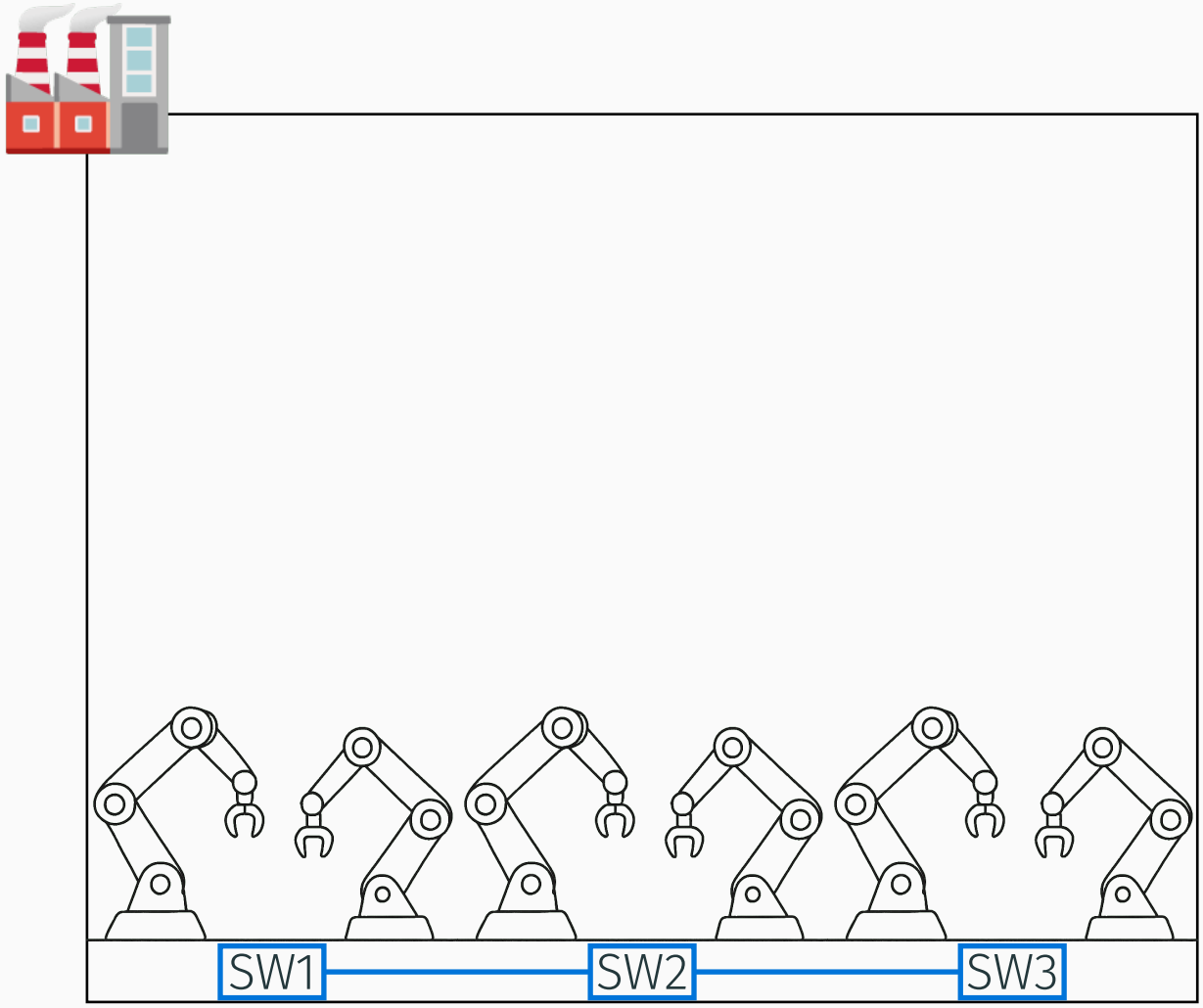


TSN: Determinism at Layer 2

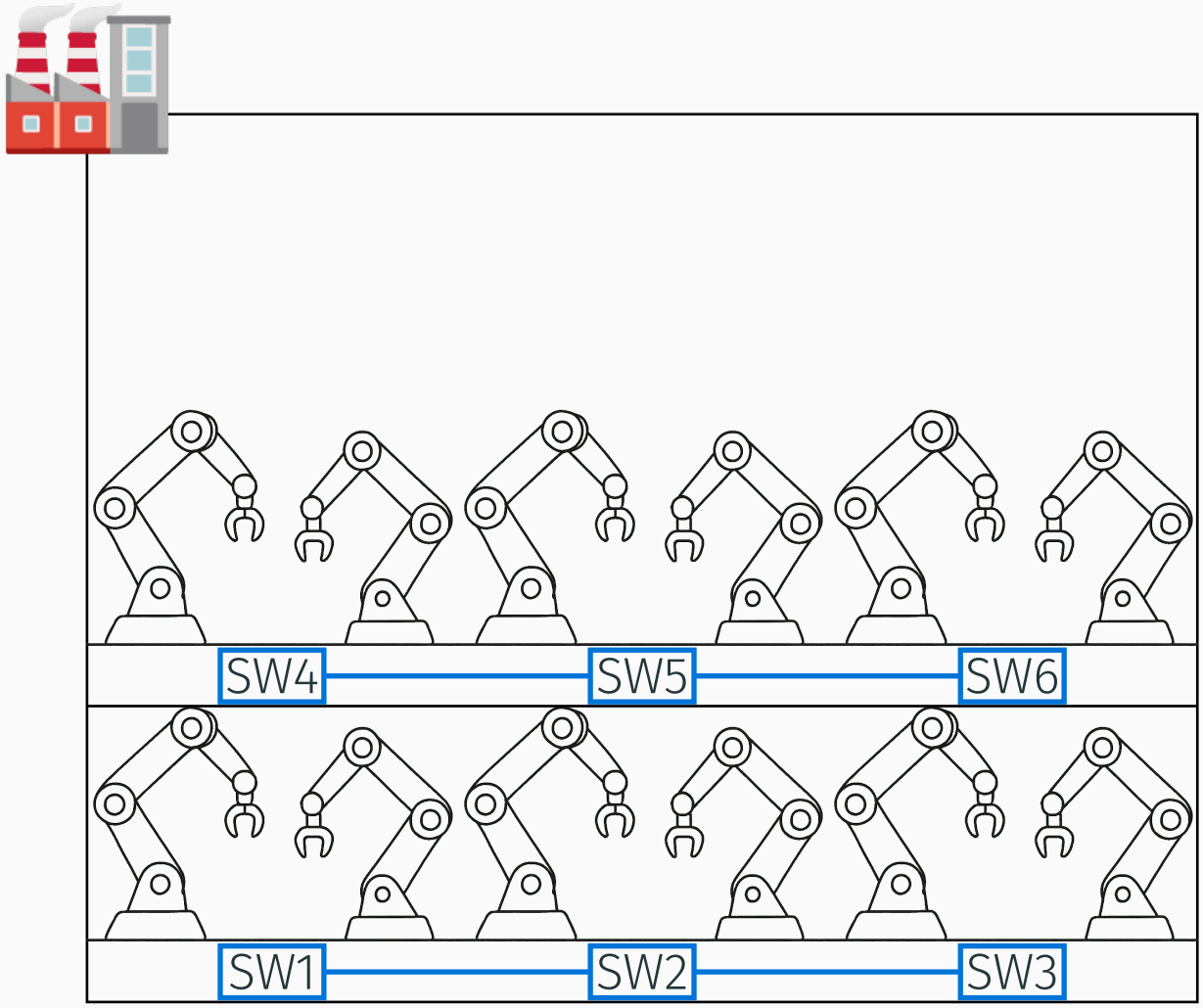


$\Longrightarrow$ TSN enables time-sensitive communications within local, tightly controlled networks.

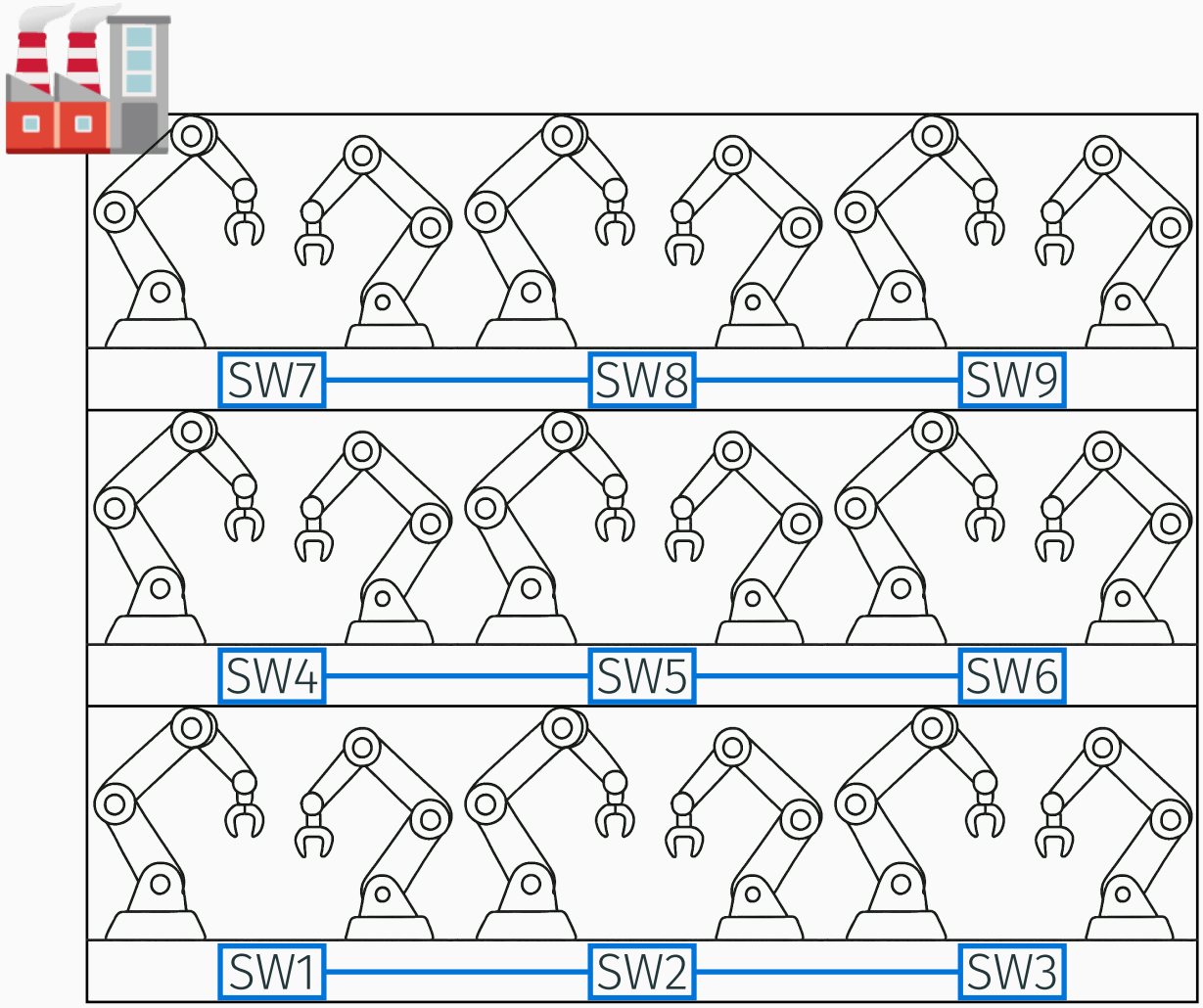
DetNet: Determinism at Layer 3



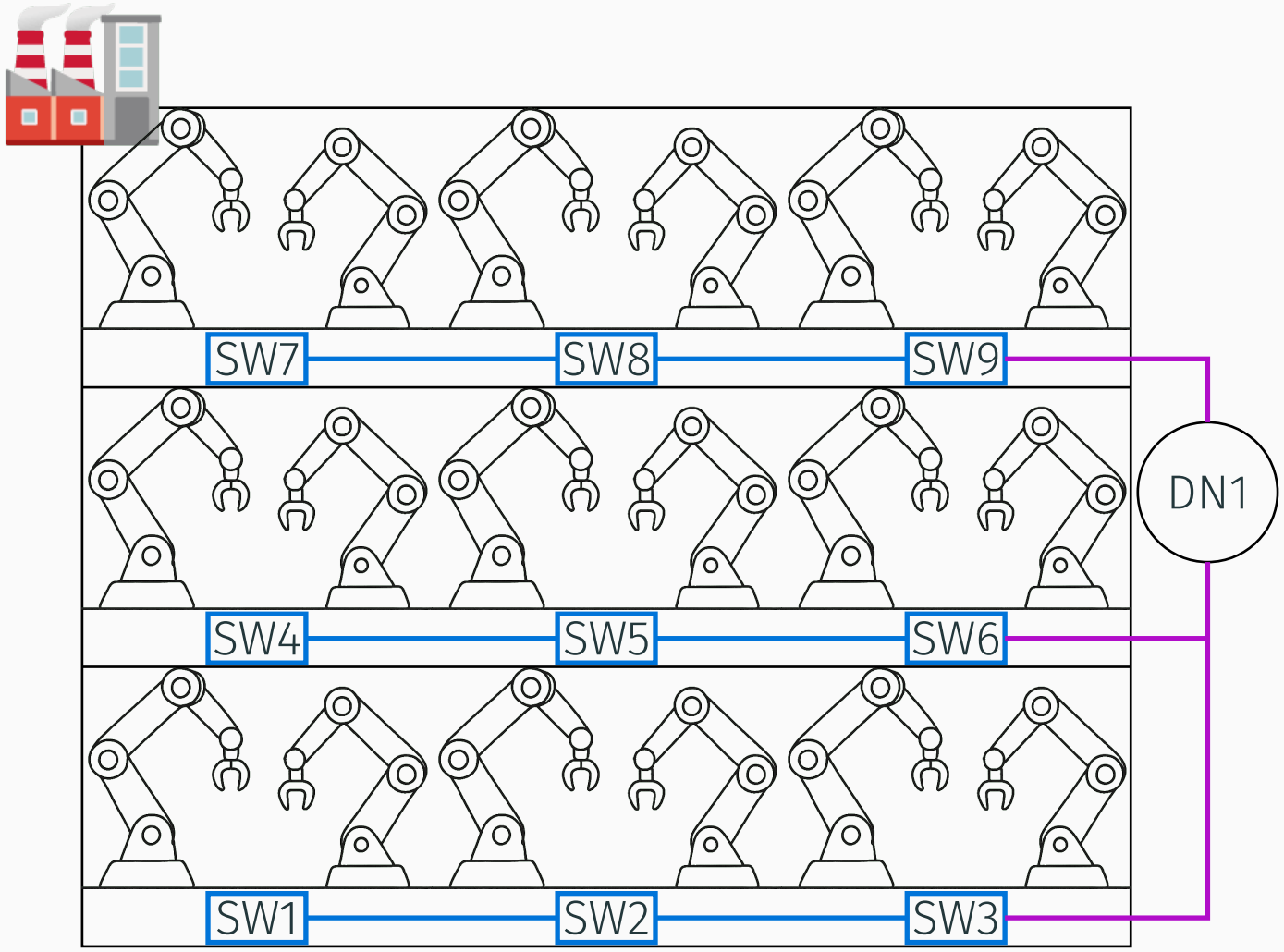
DetNet: Determinism at Layer 3



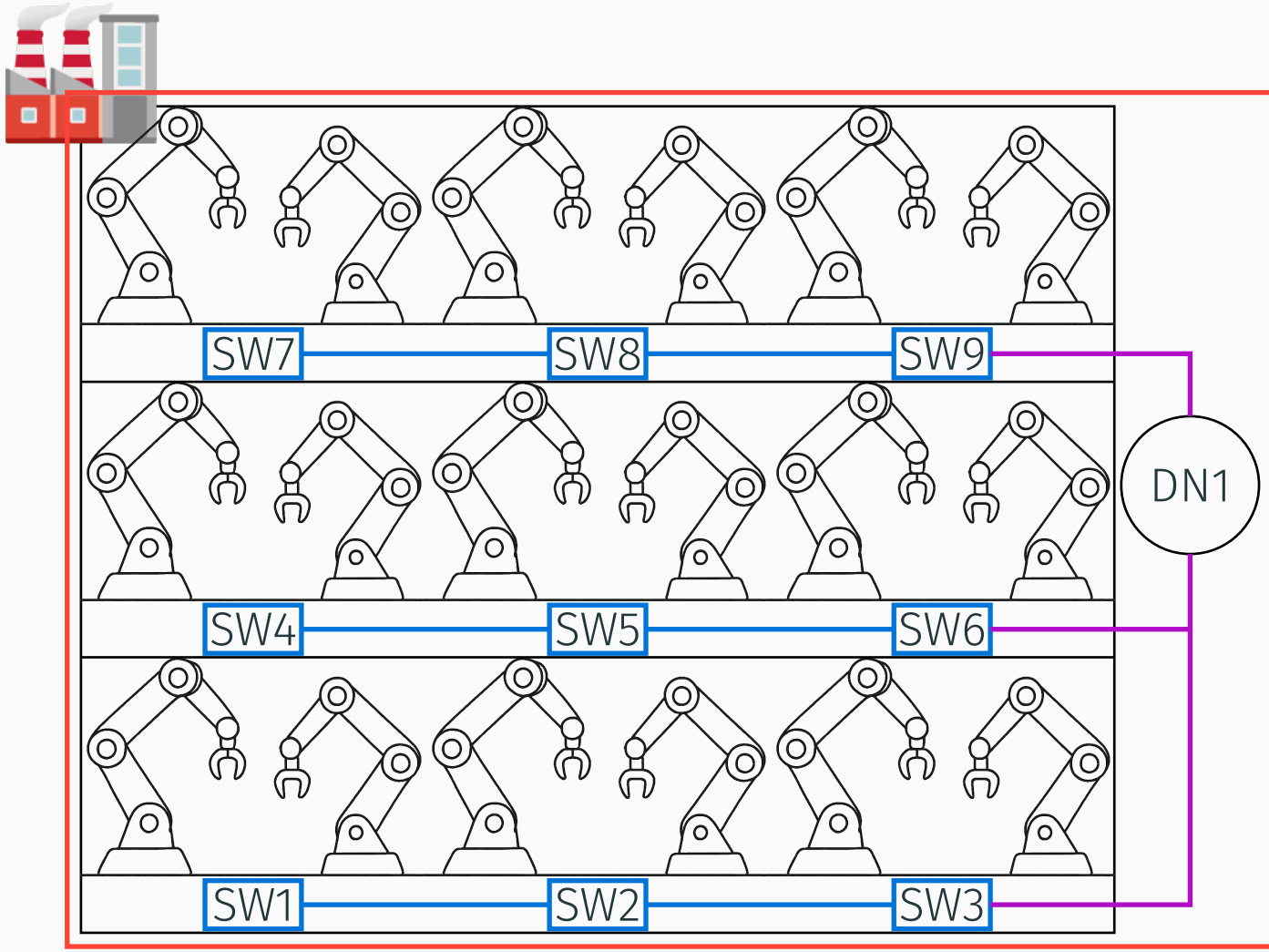
DetNet: Determinism at Layer 3



DetNet: Determinism at Layer 3

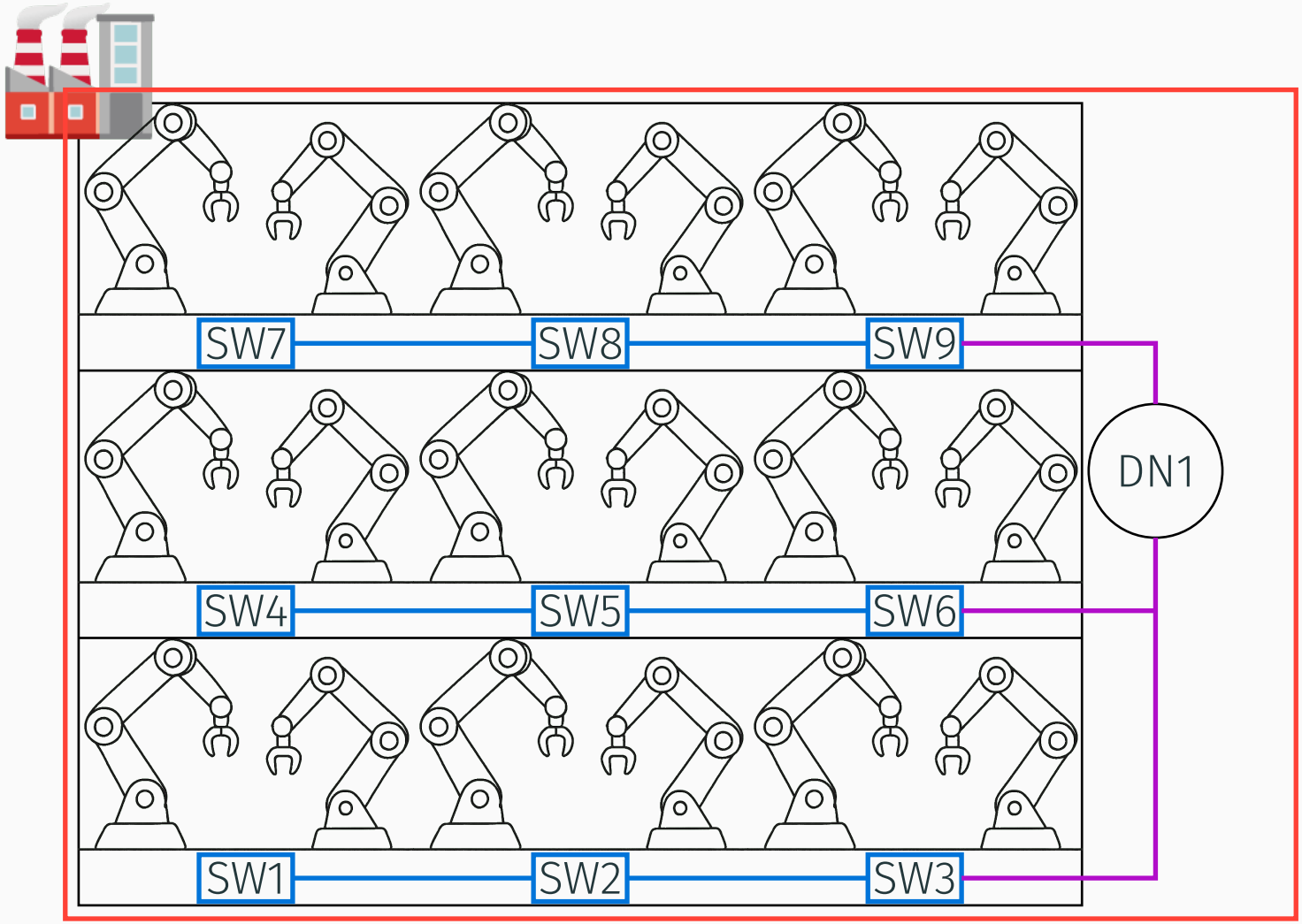


DetNet: Determinism at Layer 3



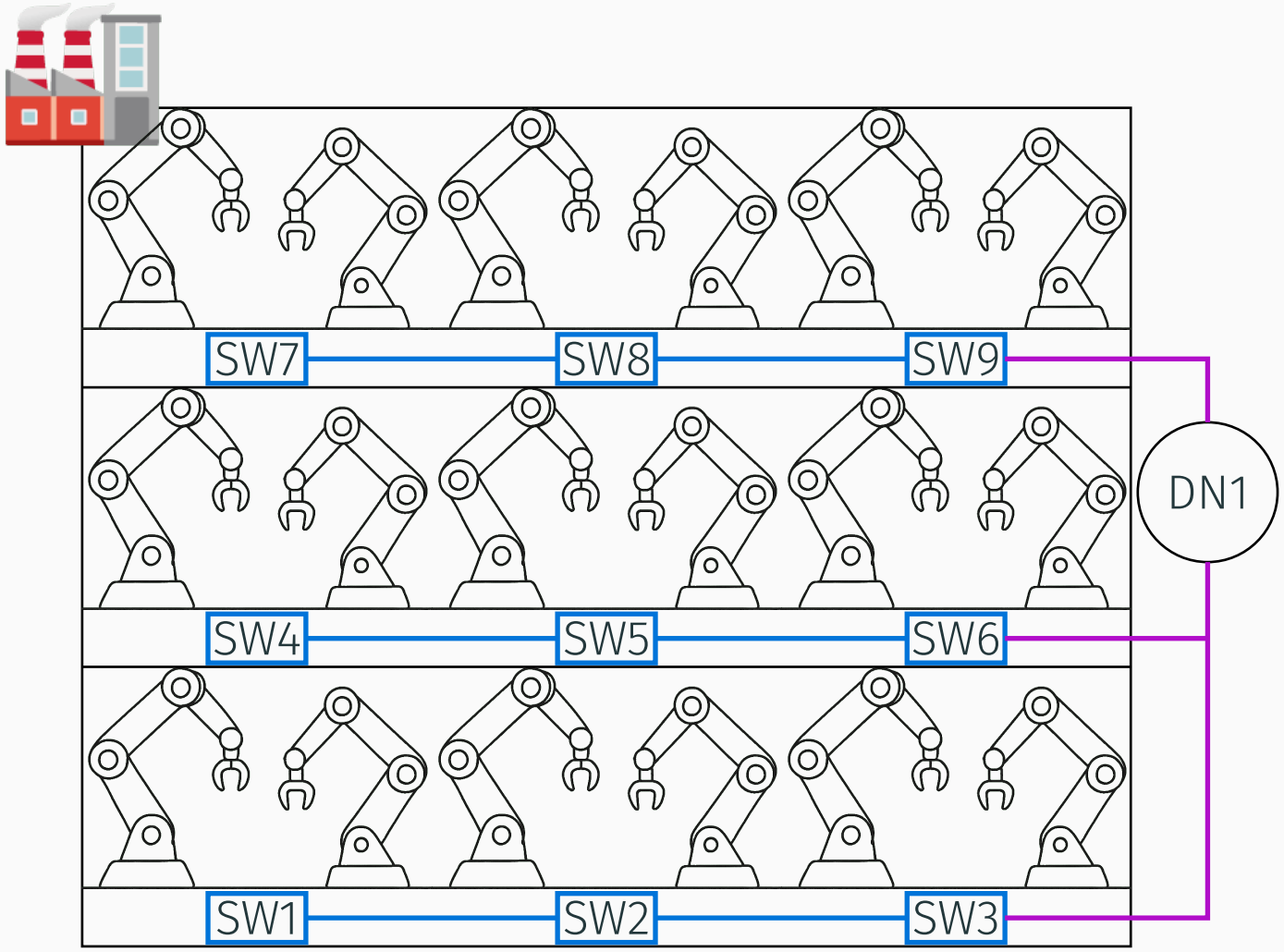
$\Longrightarrow$ DetNet extends these guarantees to L3 heterogeneous networks.

DetNet: Determinism at Layer 3

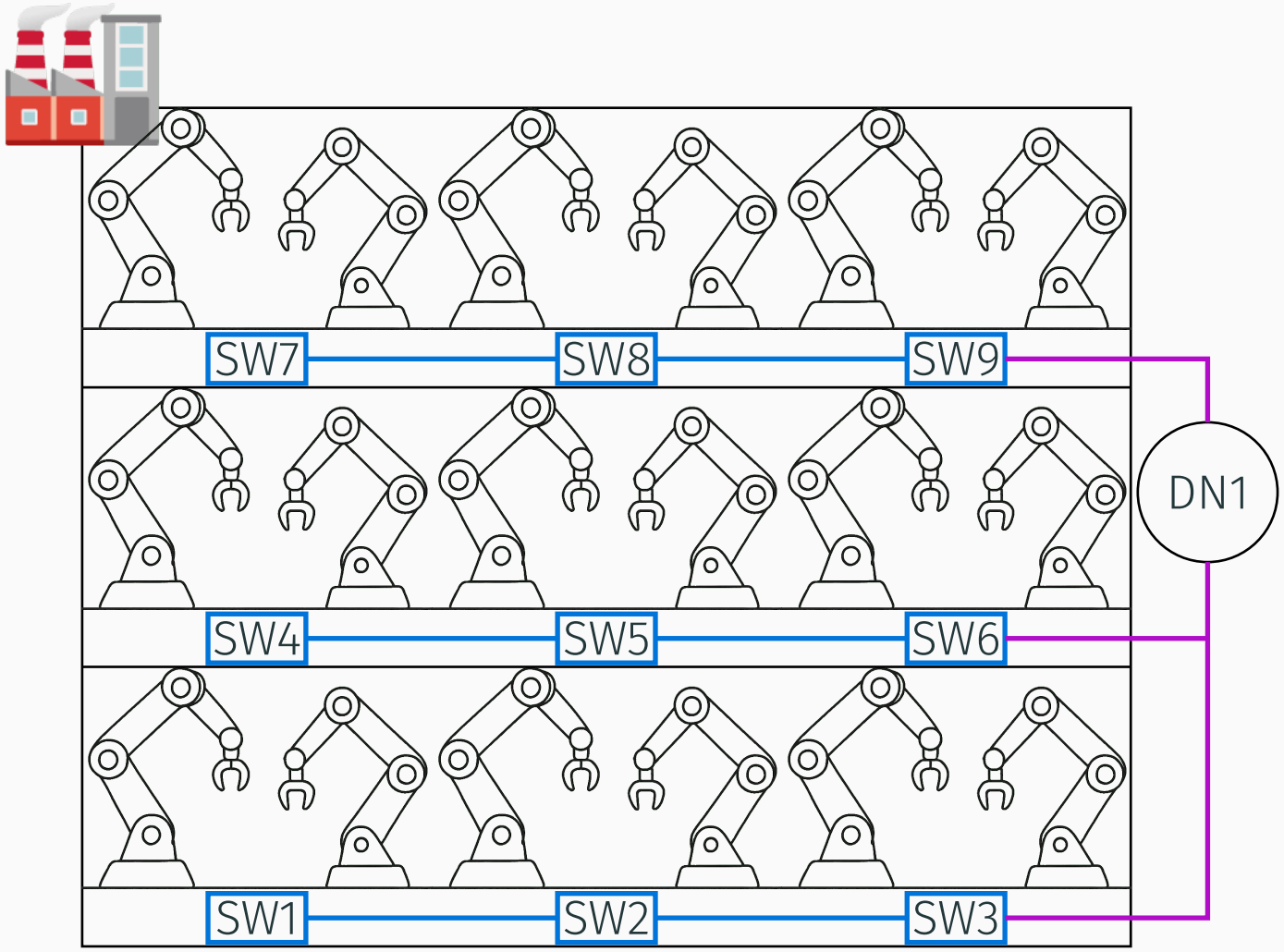


$\Longrightarrow$ DetNet extends these guarantees to single-entity L3 heterogeneous networks.

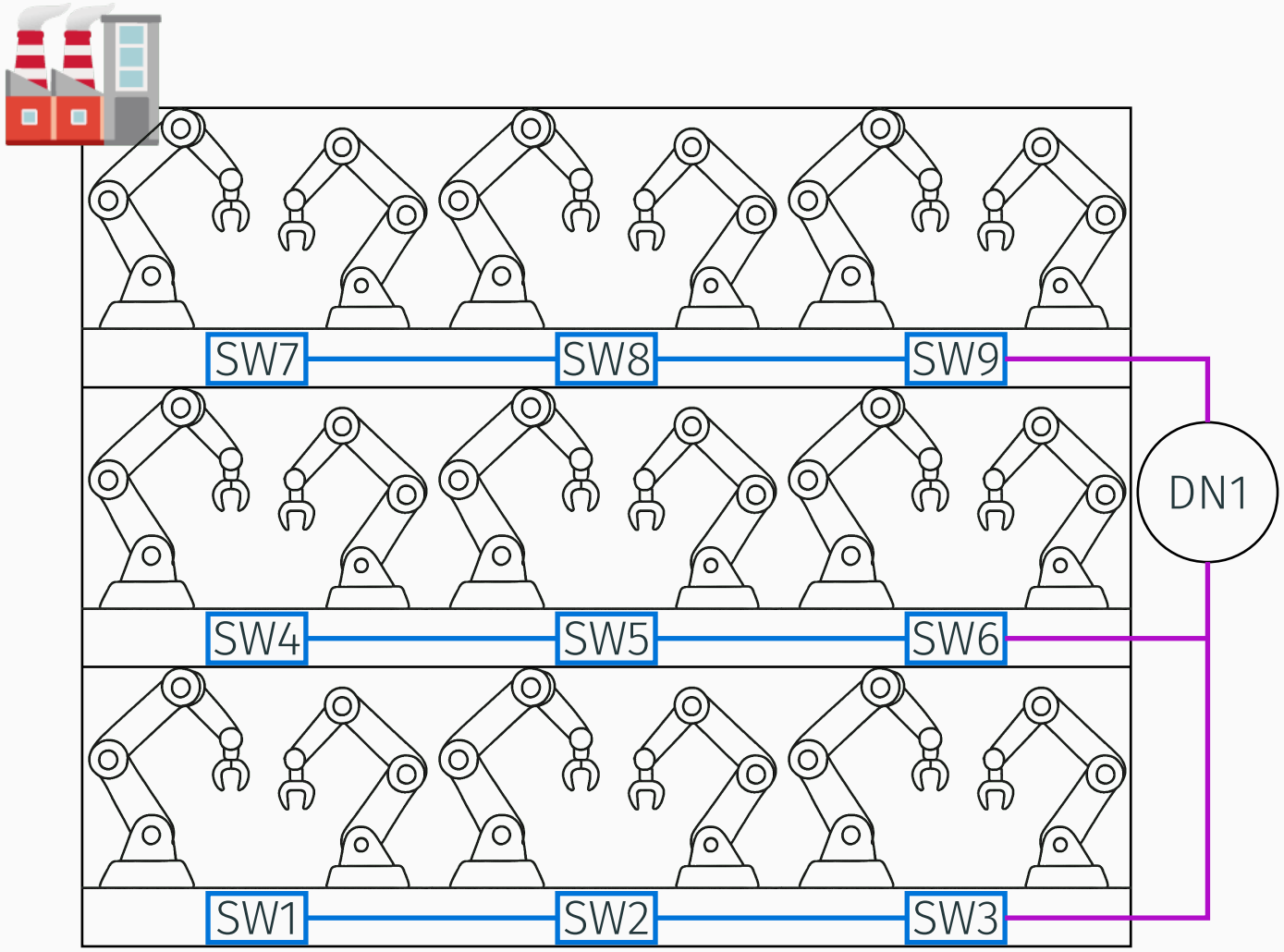
DetNet's Problem: The Trust Gap



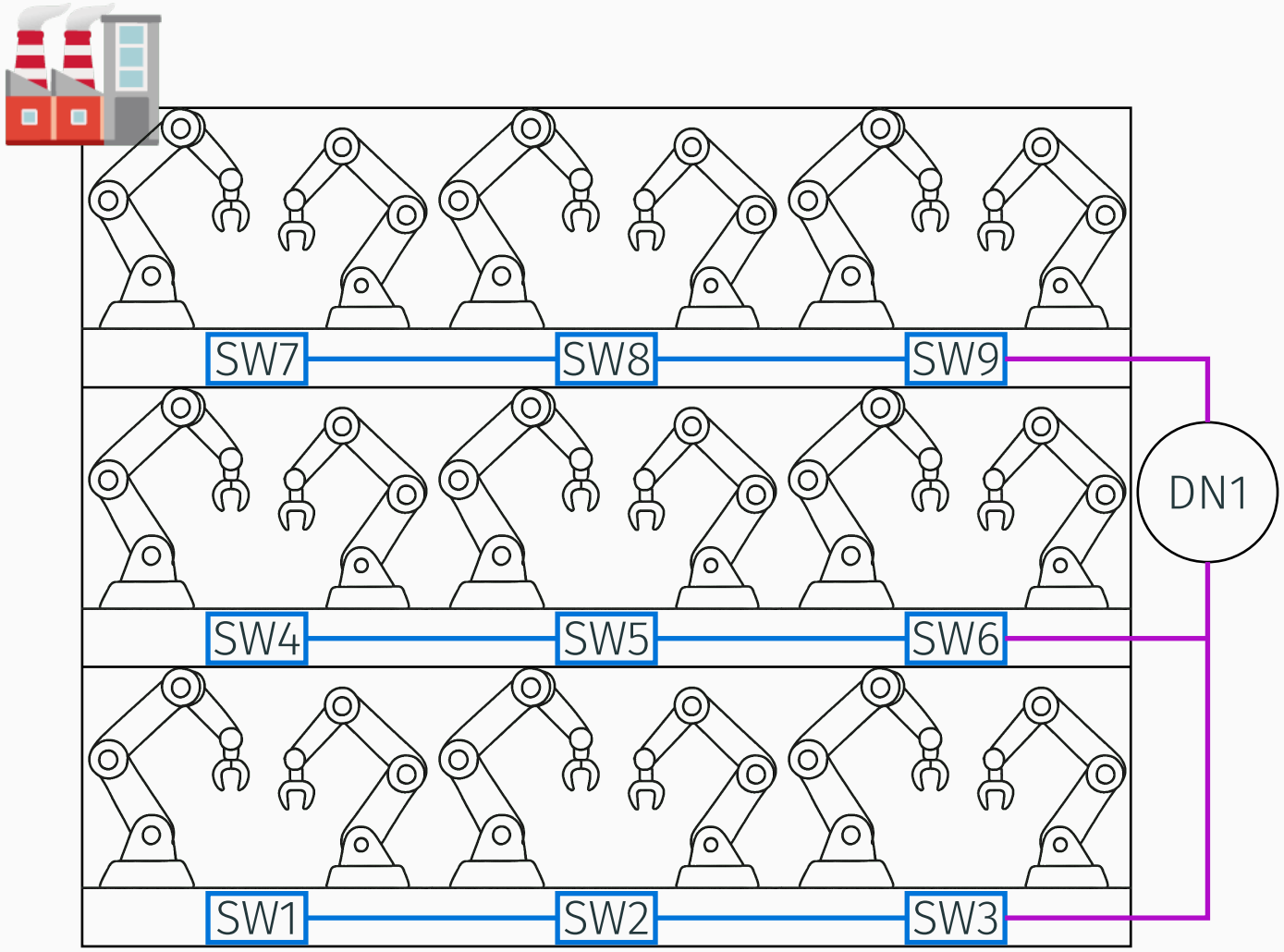
DetNet's Problem: The Trust Gap



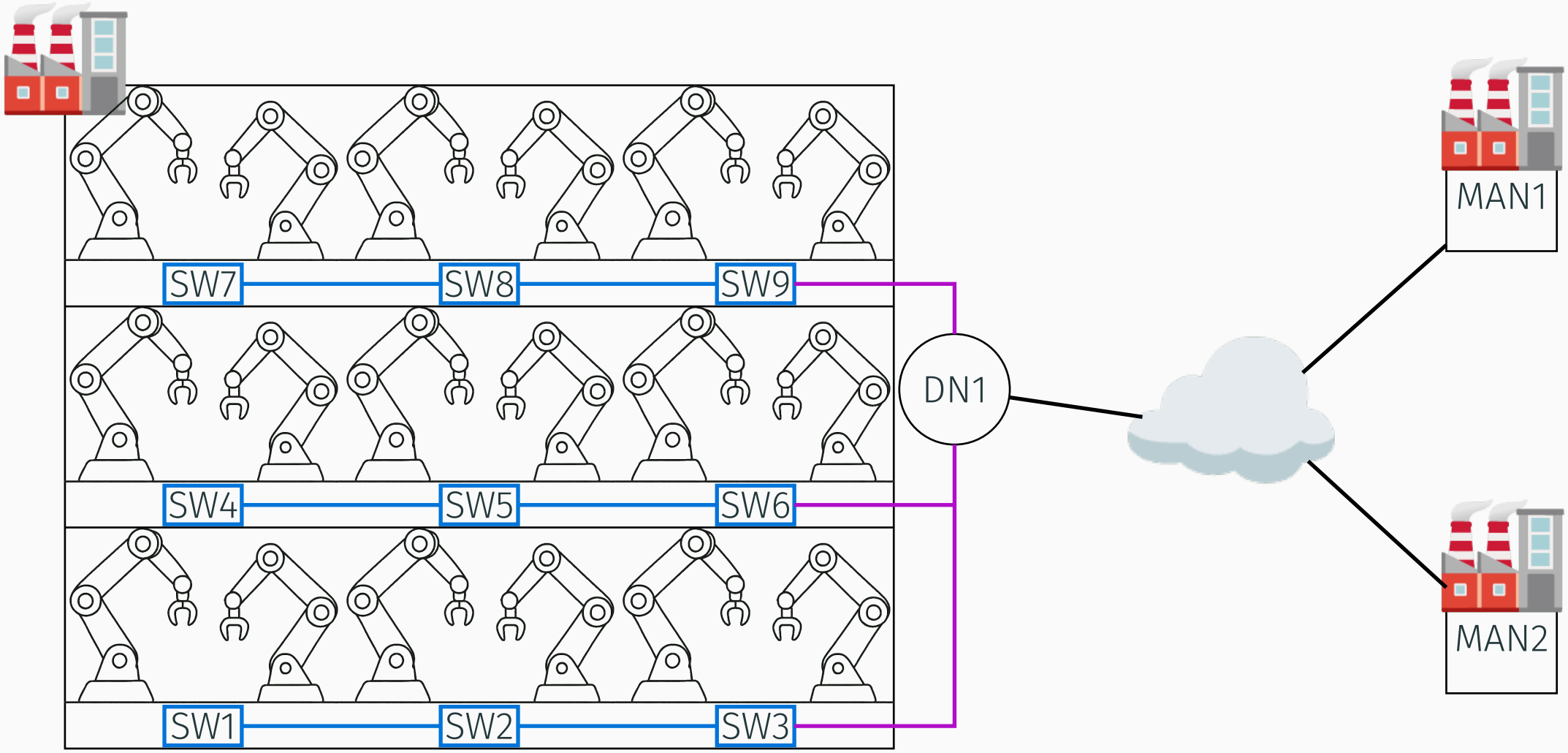
DetNet's Problem: The Trust Gap



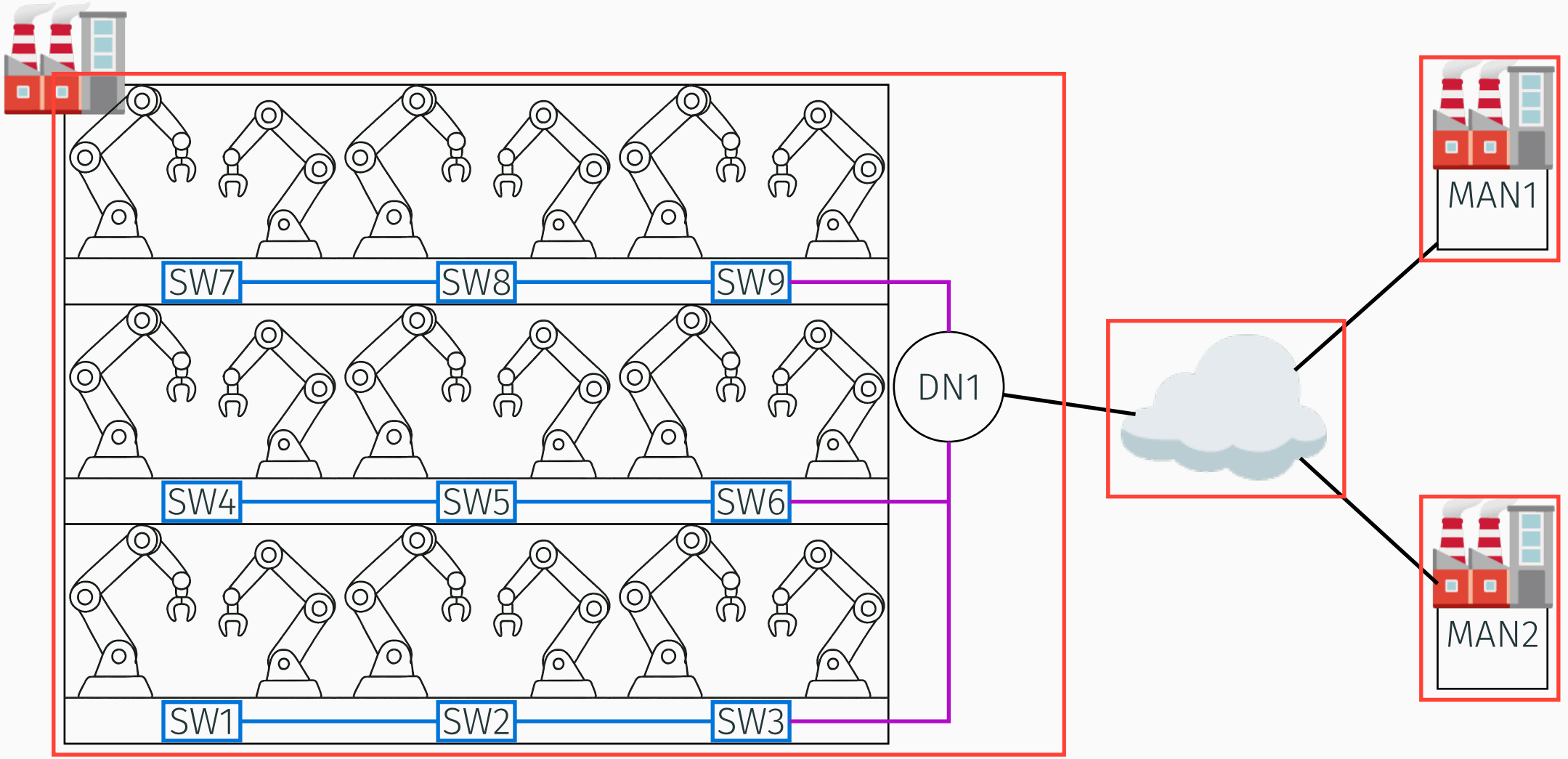
DetNet's Problem: The Trust Gap



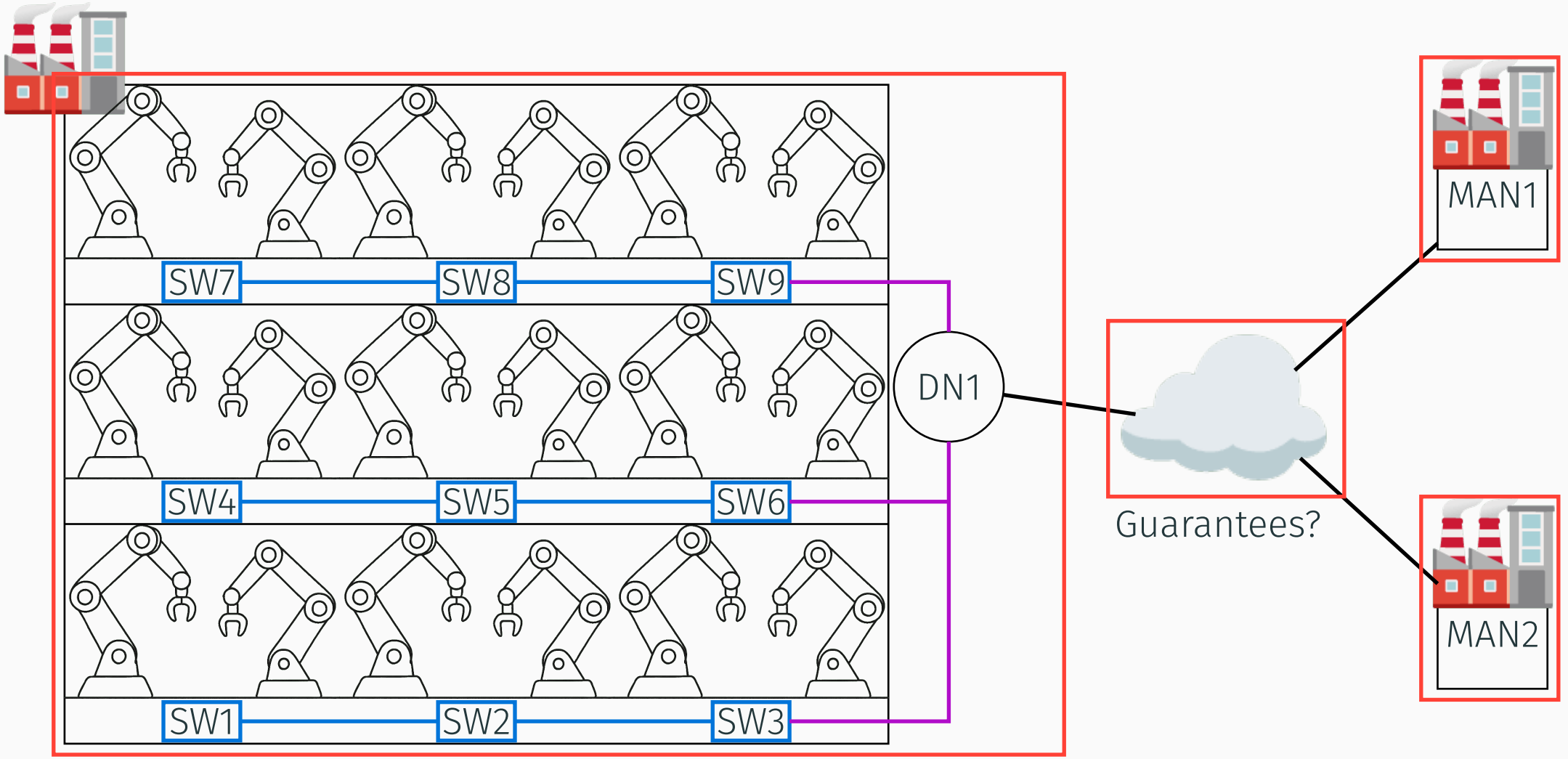
DetNet's Problem: The Trust Gap



DetNet's Problem: The Trust Gap



DetNet's Problem: The Trust Gap



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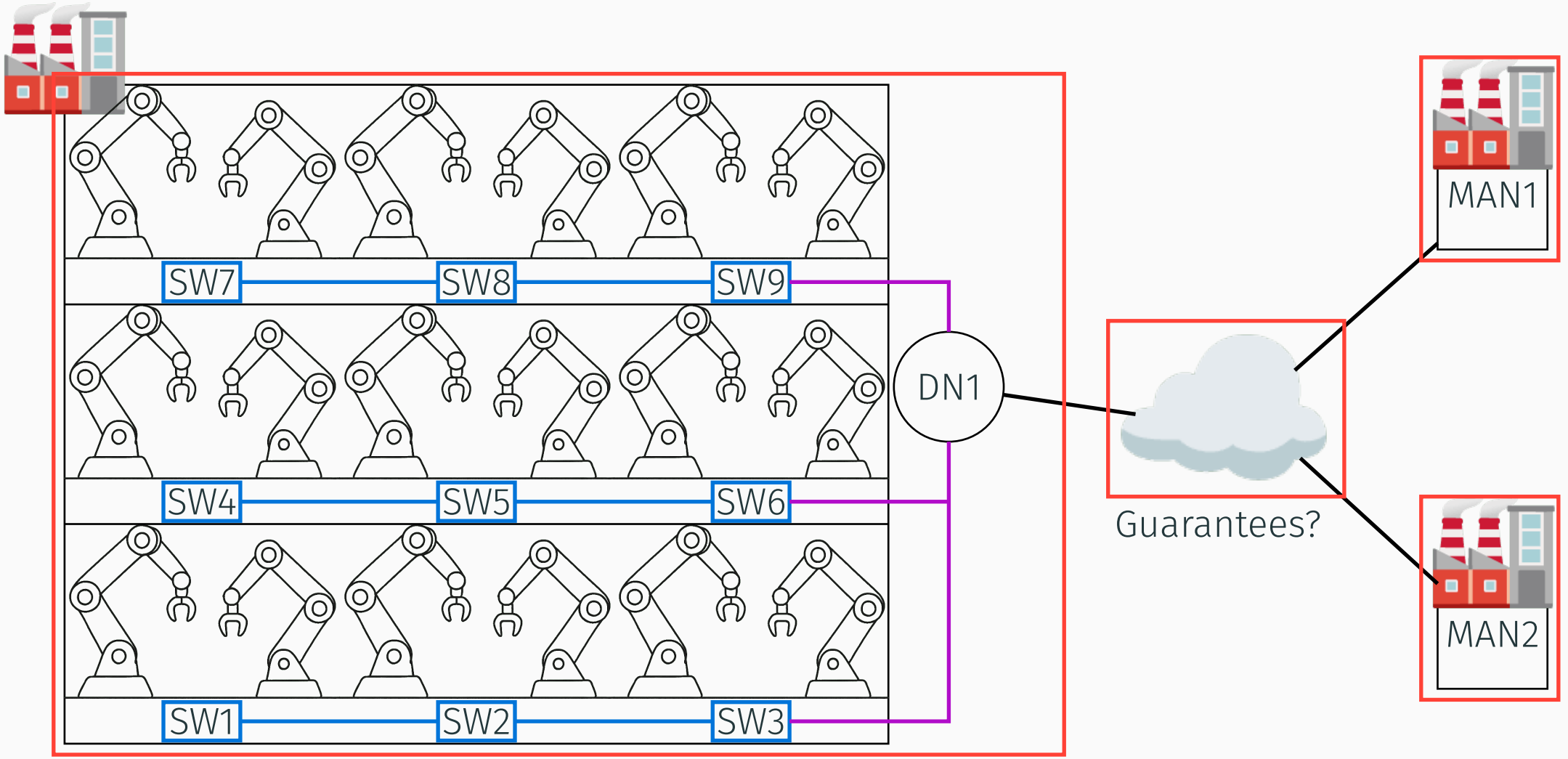


$\Longrightarrow$ Time-sensitive networks do not naturally extend to multi-domain networks.

An Architecture to Allow Dynamic Time-Sensitive Communications as a Service

Matthieu AMET [1] supervised by Ludovic THOMAS[1] and Ye-Qiong SONG[1]
[1] LORIA - Université de Lorraine / CNRS

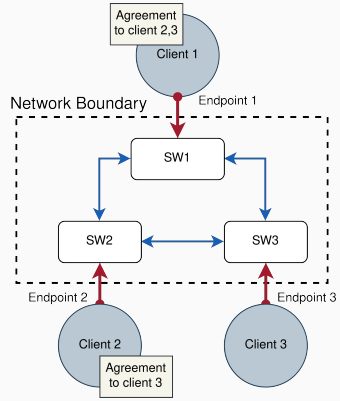
Time-Sensitive Networks · Blockchain · Privacy · Trustworthiness

Context

- Time-sensitive networks are typically operated within a **single administrative domain**.
- Extending time-sensitive services **across multiple administrative domains** introduces new **trust challenges**.
- When we consider multi-administered domains, communicating parties need to trust that the **promised guarantees are fulfilled**.

Goal: Enable cross-domain time-sensitive communications by providing verifiable evidence that the required guarantees are fulfilled.

Network Model

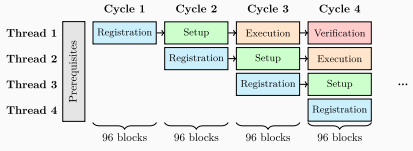


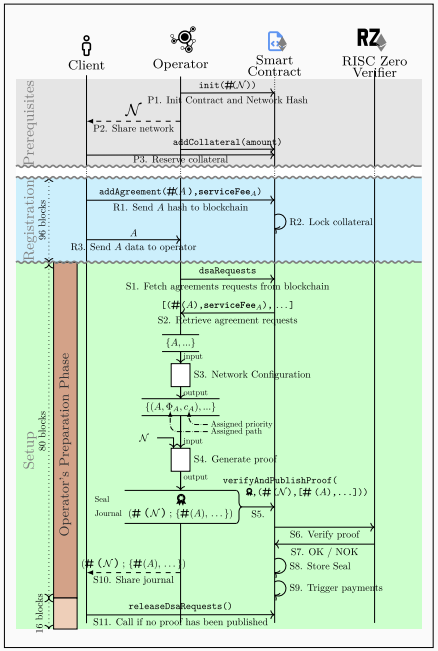
We consider a network spanning multiple administrative domains and first define the following key terms:

- **Operator**: An entity that manages and controls a collection of TSN [1] /DetNet [2] compliant devices
- **Clients**: An entity that requests deterministic communication services from an operator's network.
- **Agreement**: A formal deterministic-service agreement between a client and an operator that specifies the requested deterministic-network guarantees along with the associated terms and rewards.

Framework

We propose a framework [3] that enables an operator to prove to clients that, given a network topology and a set of agreements, a configuration exists that fulfills the requested guarantees.





Conclusion

We designed a framework leveraging blockchain and zero-knowledge proofs to provide deterministic guarantees based on network-calculus for large-scale DetNet environments.

The framework allows:

- Control of bounded-latency and no loss by congestion
- Formal verification of feasible flow configurations
- Confidentiality of service agreements and operator policies
- Trustless interaction between independent actors

Bibliography

[1] "IEC/IEEE 60802 Time-Sensitive Networking Profile for Industrial Automation," no. IEC/IEEE 60802. IEEE, Mar. 2023.

[2] N. Finn, P. Thubert, B. Varga, and J. Farkas, "Deterministic Networking Architecture," Request for Comments RFC 8655, Oct. 2019. doi: 10.17487/RFC8655.

[3] M. Amet, L. Thomas, and Y.-Q. Song, "DNaaS: Towards Scalable and Trusted Time-Sensitive Networks," in *IEEE INFOCOM 2026 - IEEE Conference on Computer Communications*, May 2026, pp. 1–10. doi: 10.1109/INFOCOM59046.2026.11571313.