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IoV-TwinChain: Predictive Maintenance of Vehicles in Internet of Vehicles through Digital Twin and Blockchain

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Leveraging the Power of Three

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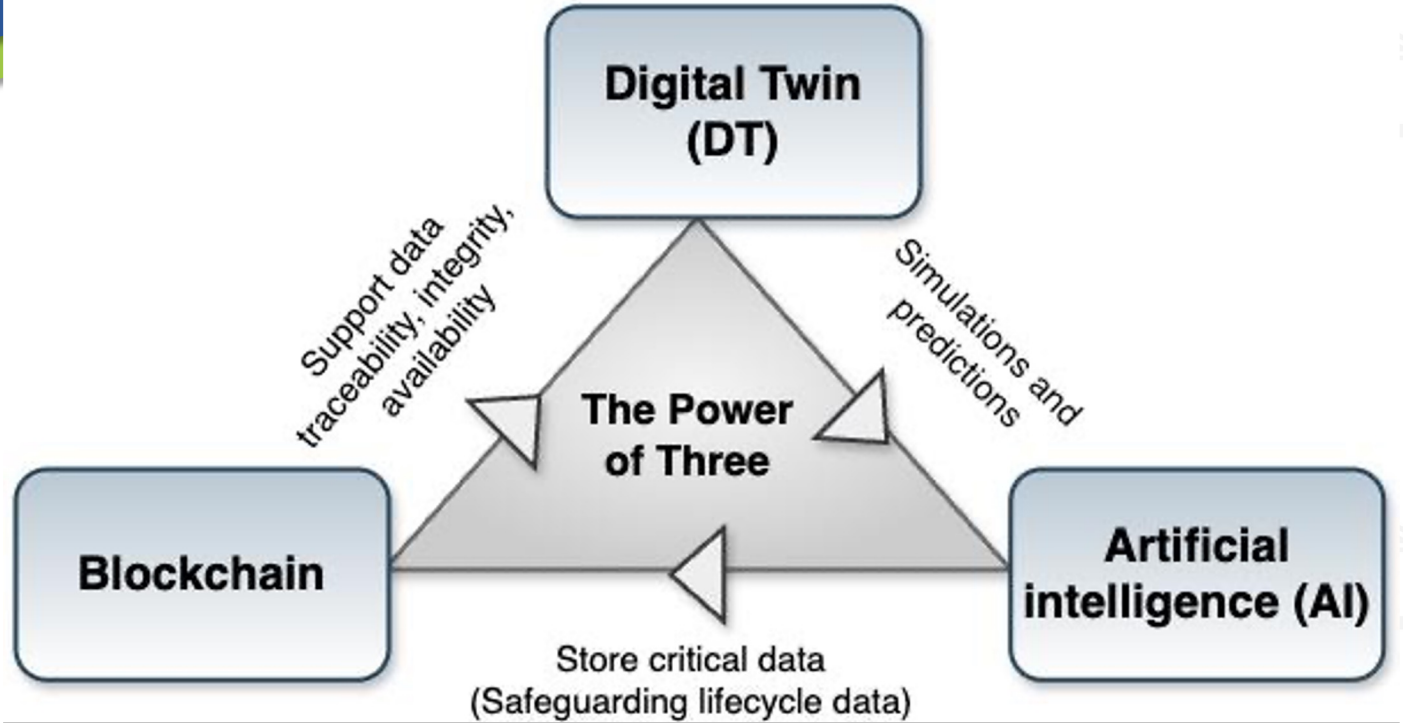
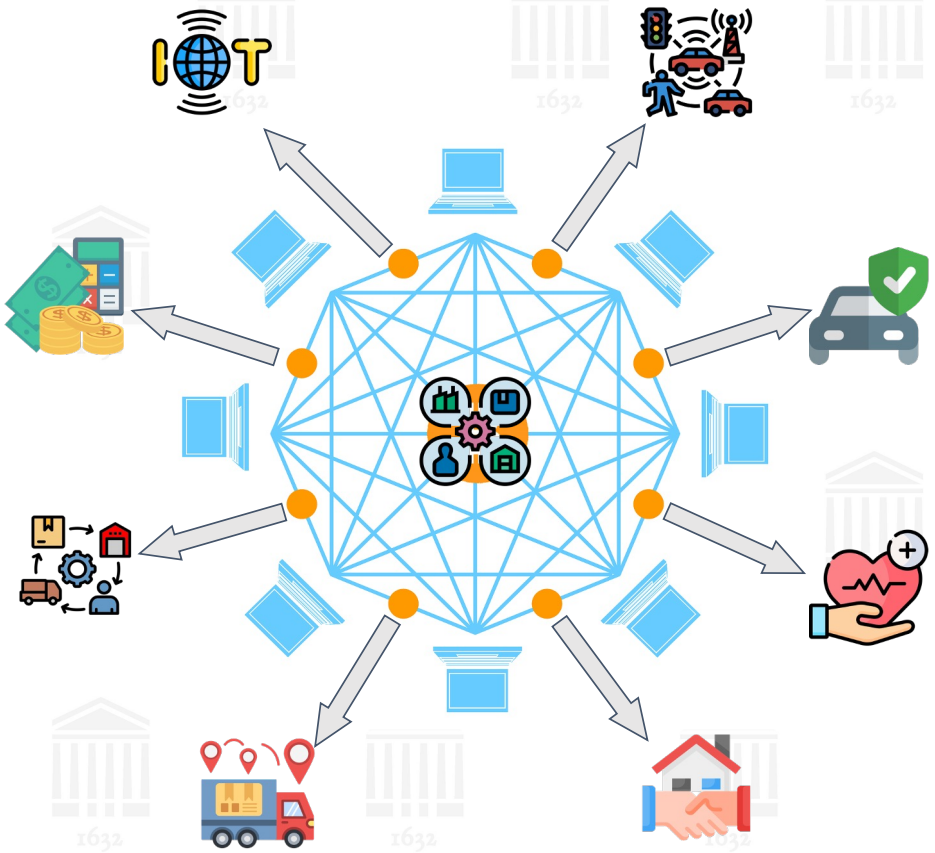


Blockchain

Decentralised and distributed ledger technology that securely records and verifies transactions across a network of computers



Digital Twin (DT)

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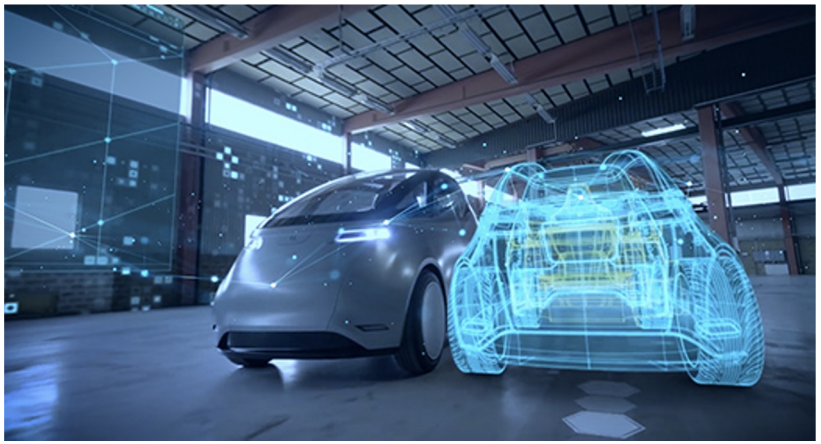
DTs are **virtual (digital)** representations

DTs can support the **continuous** and **accurate reflection** of the physical entity for **real-time monitoring, analysis**, and **simulation**



Artificial Intelligence (AI)

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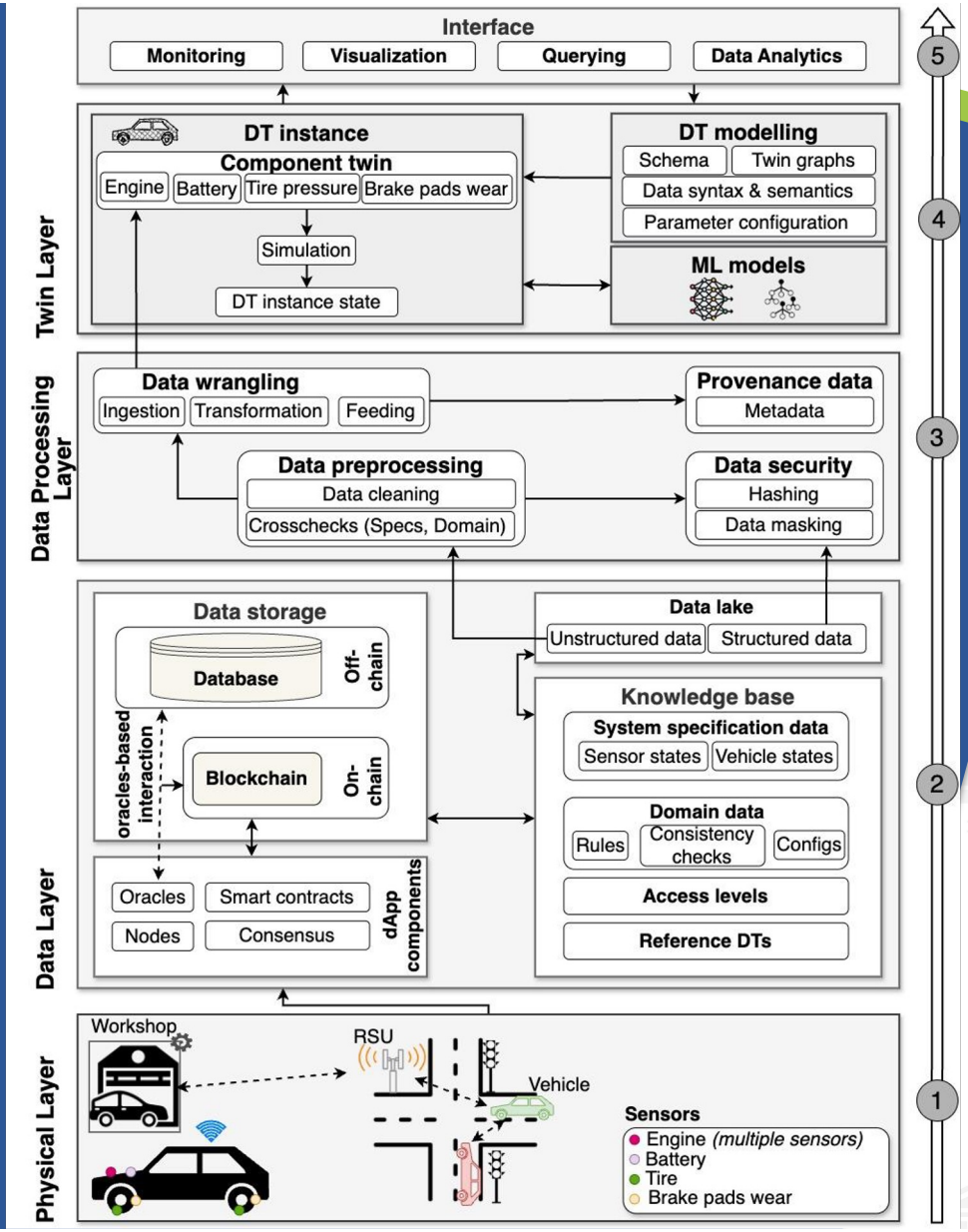
Simulation of human intelligence by software-coded heuristics

Definition by Investopedia, and image source is https://www.neilsahota.com/what-is-artificial-intelligence-how-does-it-work/

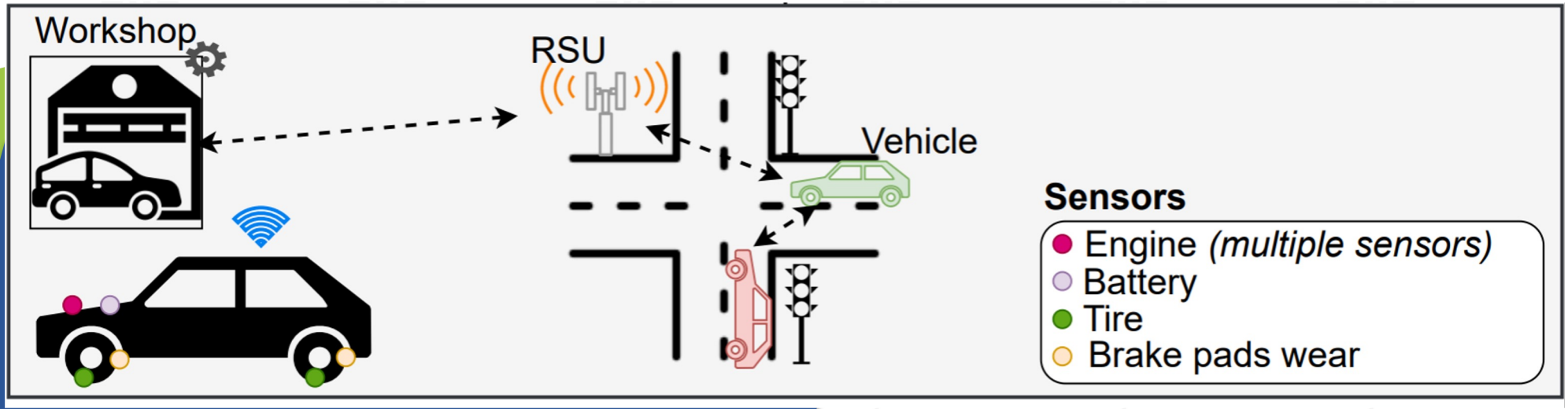


IoV-TwinChain Framework

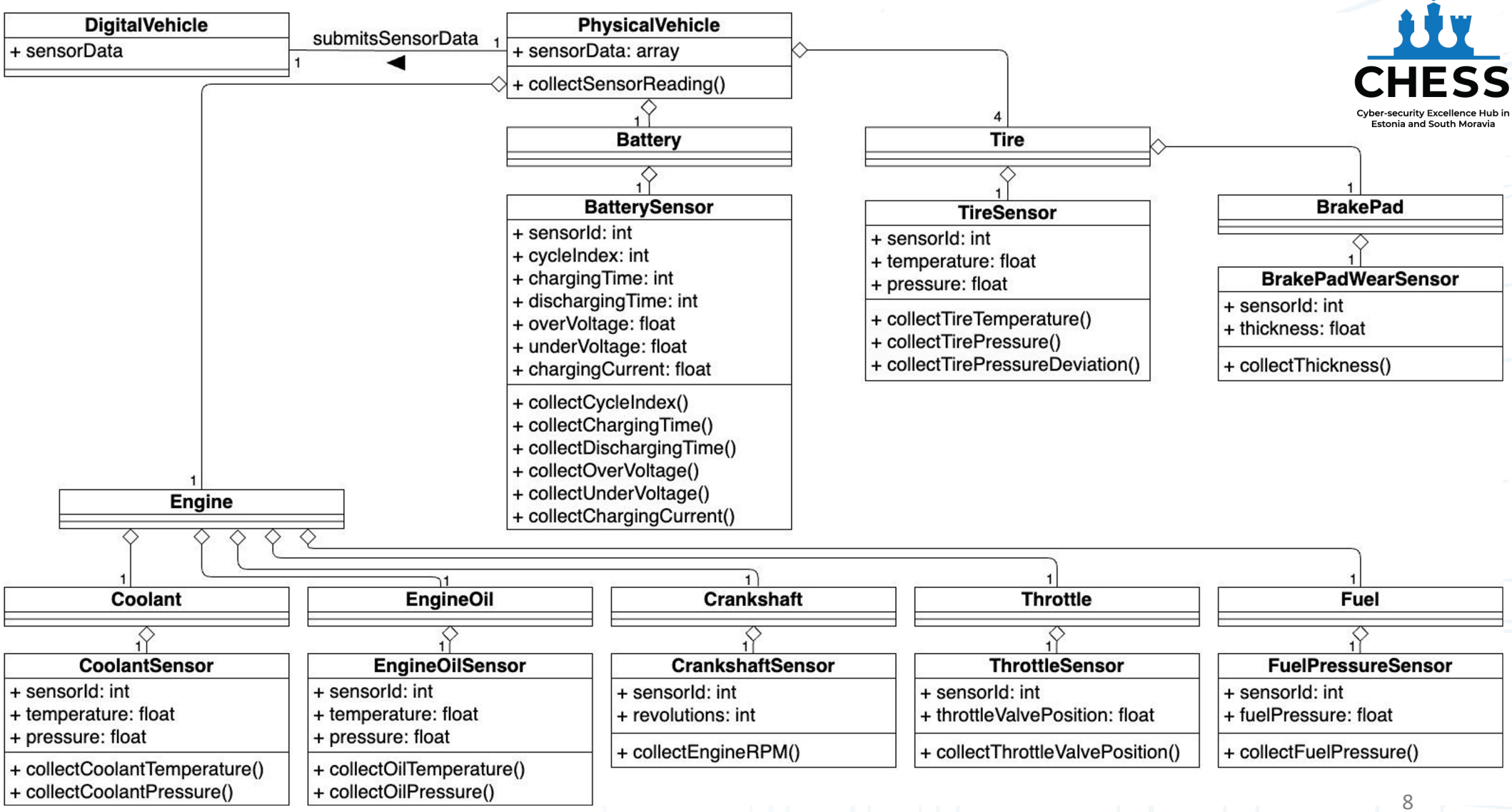
- *Physical layer*
- *Data layer*
- *Data processing layer*
- *Twin layer*
- *Interface*

IoT infrastructure comprising Physical assets

- *Sensors, communication devices, internet*
- *Vehicles*
- *RSUs*
- *Workshops*



Physical Layer



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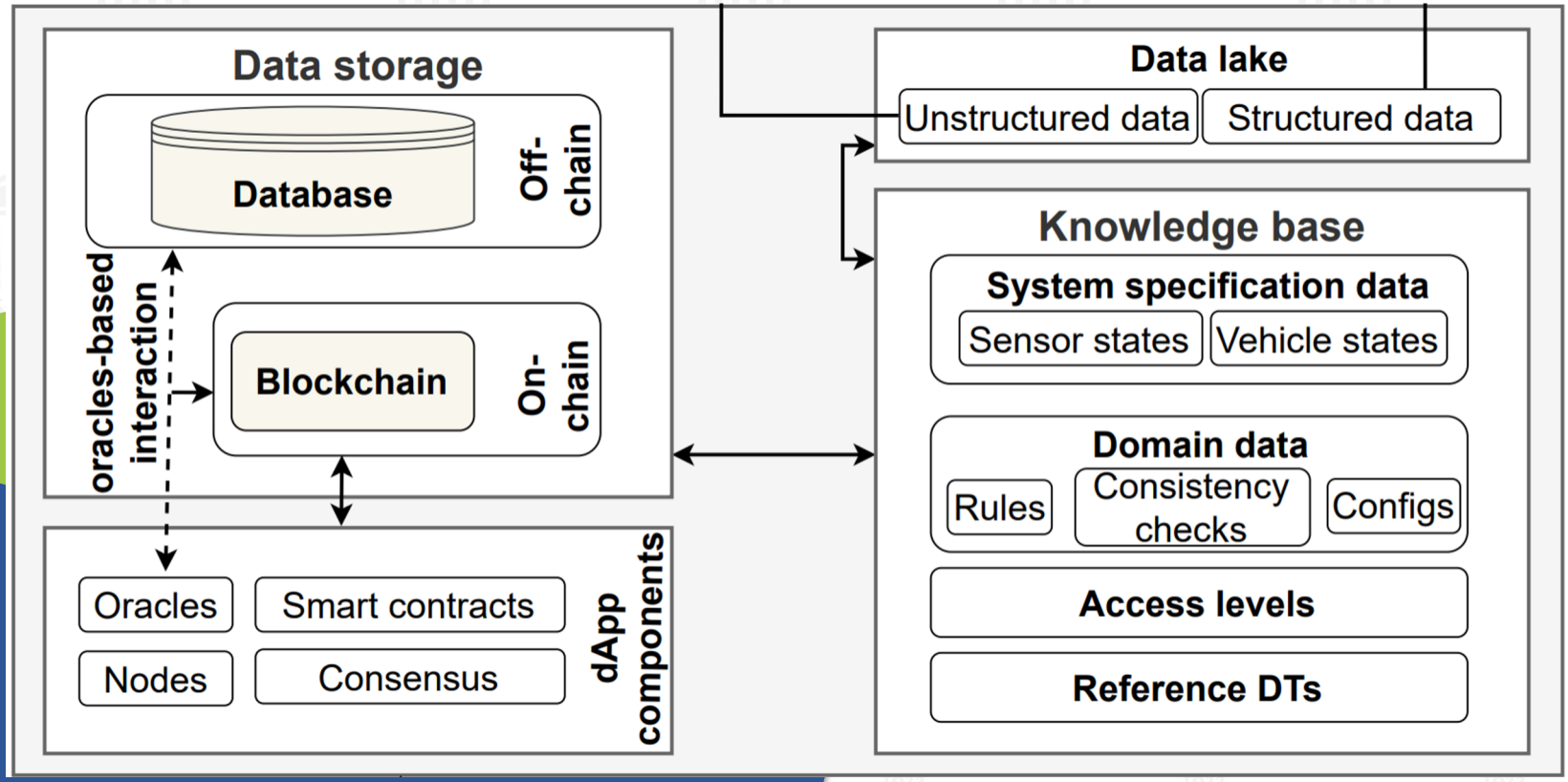
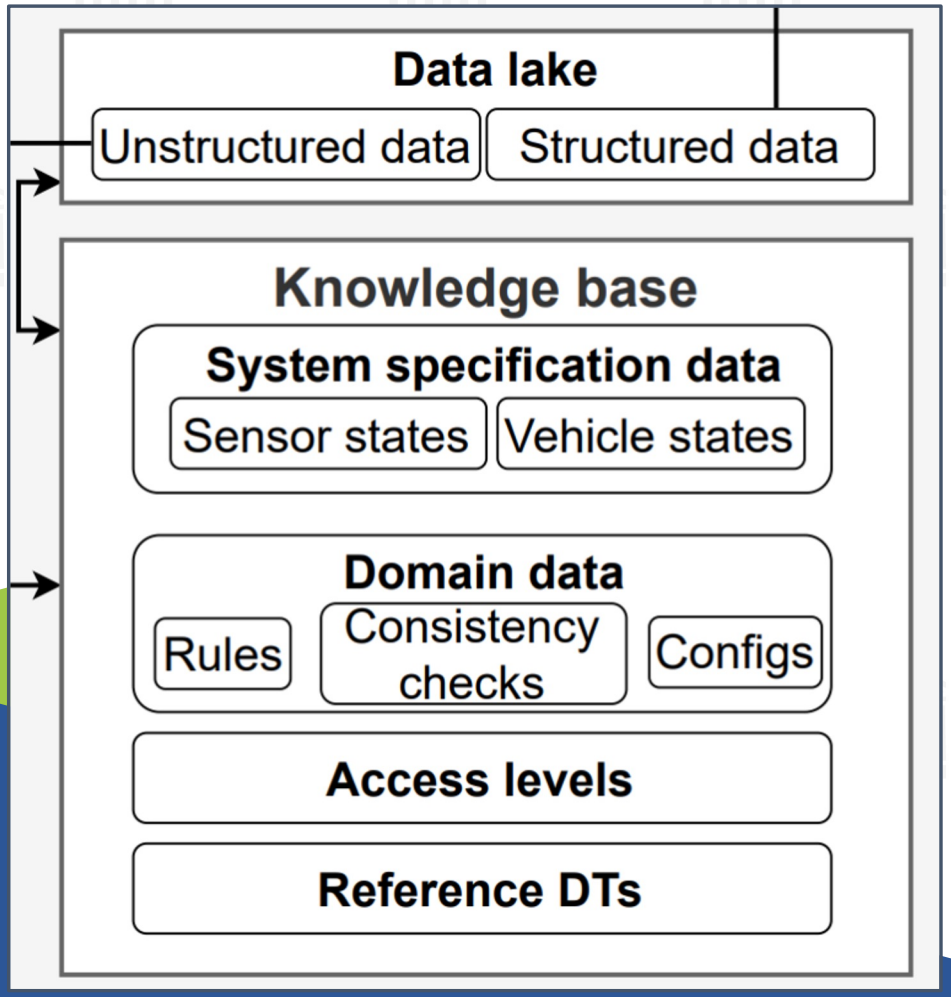
Historical and **real-time sensory data**



Data Layer



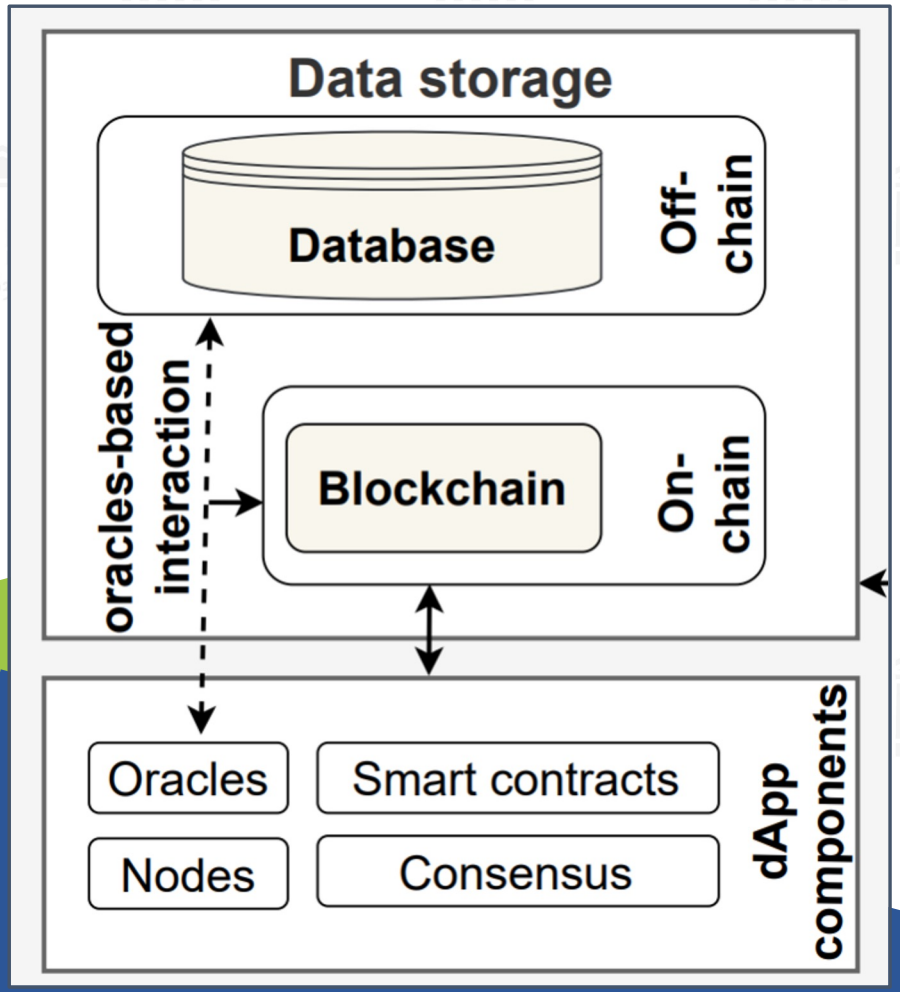
Data Lake and Knowledge Base

Data lake

- **Structured data**
  - *e.g., knowledge base*
- **Unstructured data**
  - *e.g., sensory data*

Knowledge base

- Physical vehicle states
- DT and sensor states
- Domain data
  - *e.g., rules, configurations, and twin consistency checks*
- Access levels
- Reference DTs



Data Storage

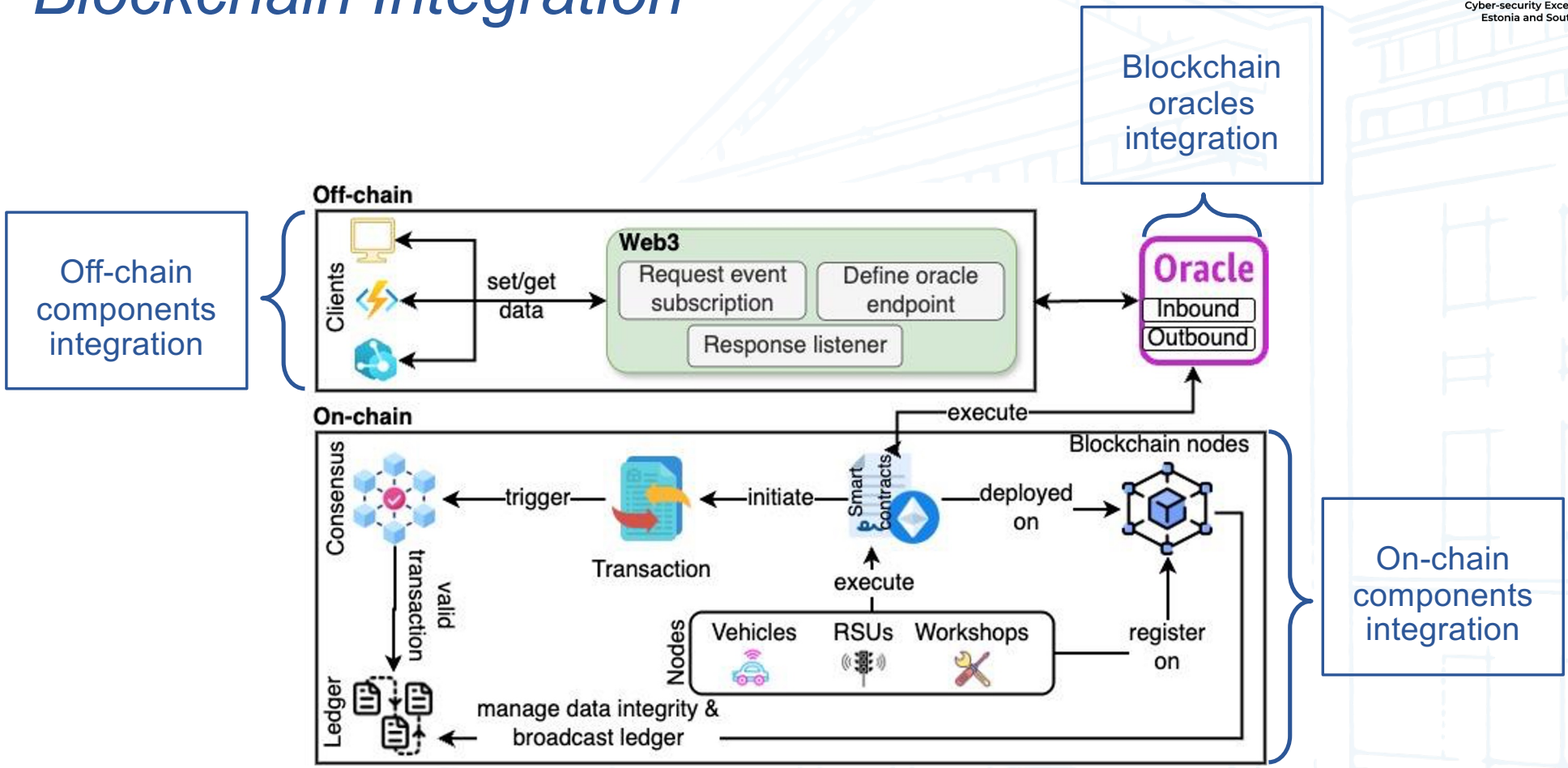
Off-chain storage

On-chain storage

DApp components

- Oracles
  - *Facilitates on-chain and off-chain communication*
- Nodes
- Smart contracts
- Consensus

Blockchain Integration



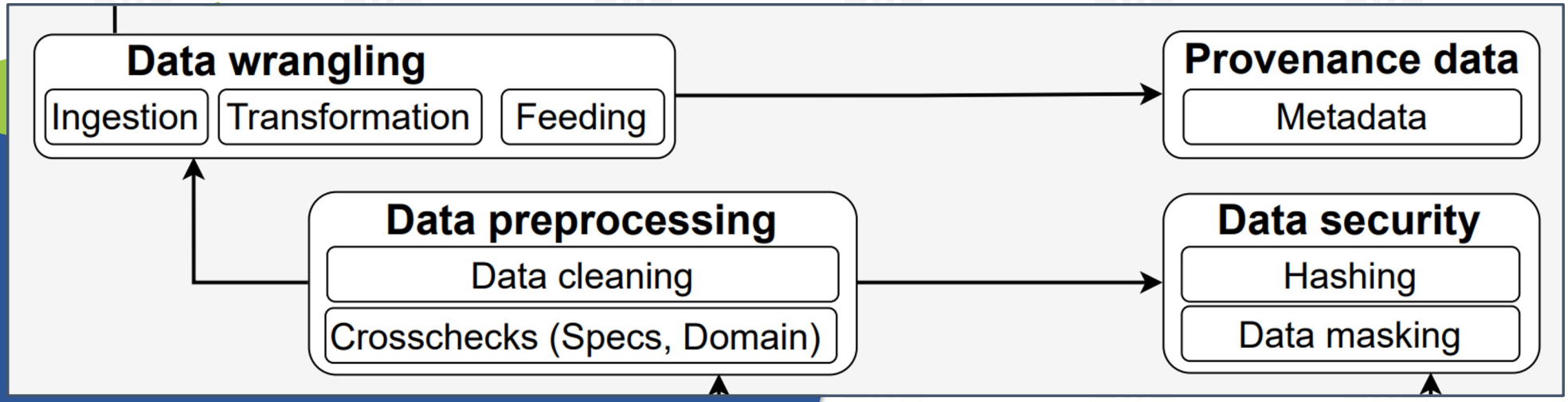
Data cleaning

- *e.g., removing duplicates, missing, incomplete, or invalid values from the collected data*

Data wrangling

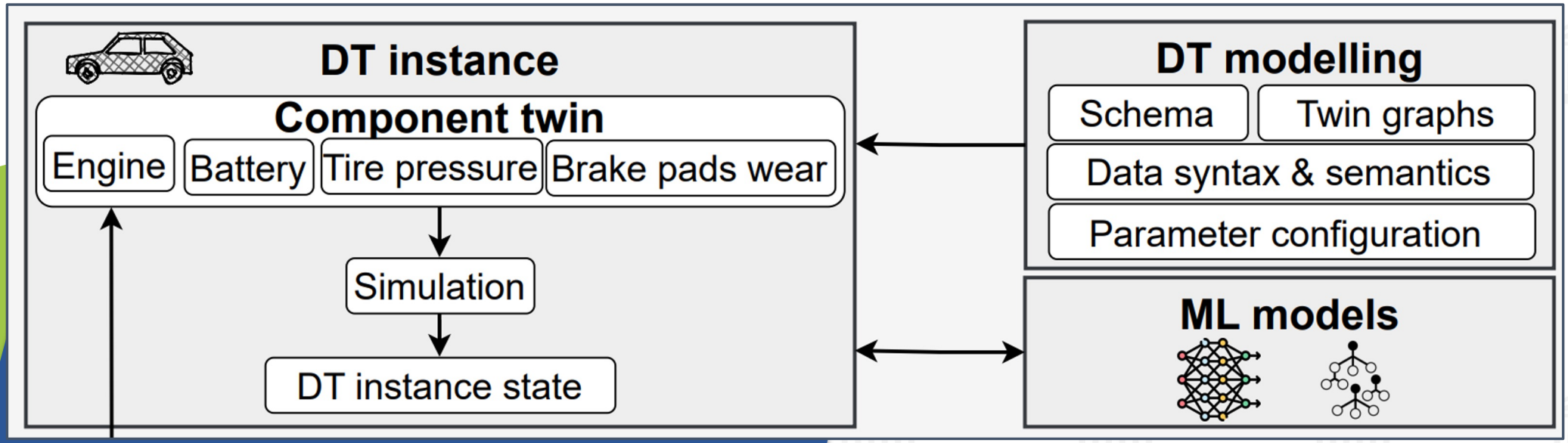
- *e.g., data ingestion, transformation, and feeding*

Provenance and data security



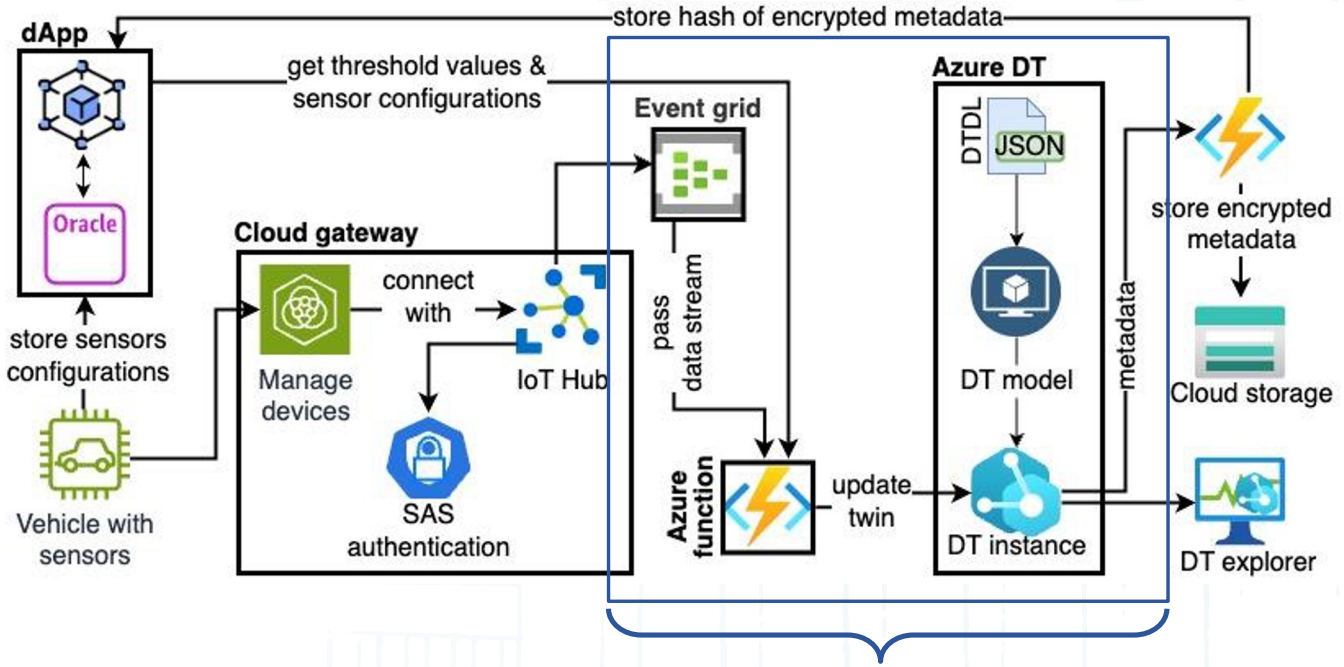
Data Processing Layer

DT instance modeling following composable DT-based modular approach



Twin Layer

DT Modeling and Development using Microsoft Azure DT



Receive data from **Azure IoT hub**, process it in **Azure function**, and deliver to **Azure DT instance**.

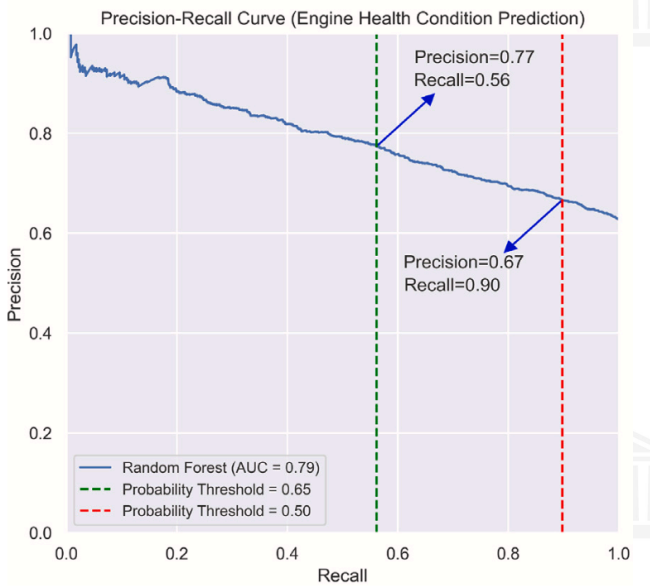
AI integration

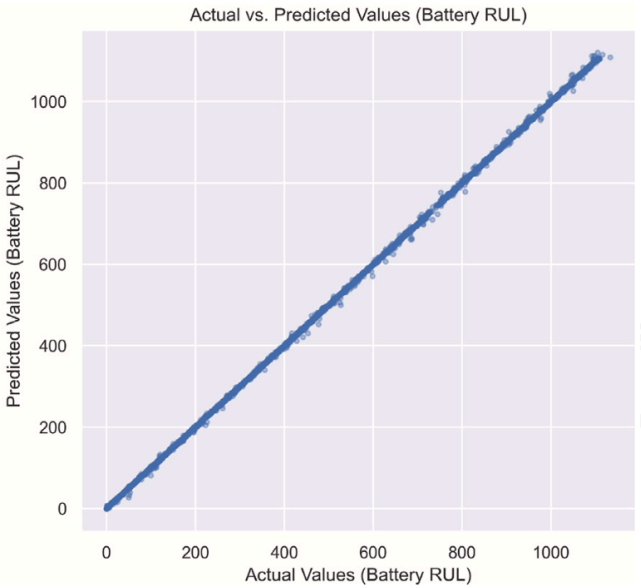
ML models

- *Random Forest*
- *eXtreme Gradient Boosting* (Xgboost)

Datasets

- *The **engine health dataset**, comprises 19,535 labelled examples*
- *The **vehicle batteries** remaining useful life dataset comprises 5,064 labelled examples*





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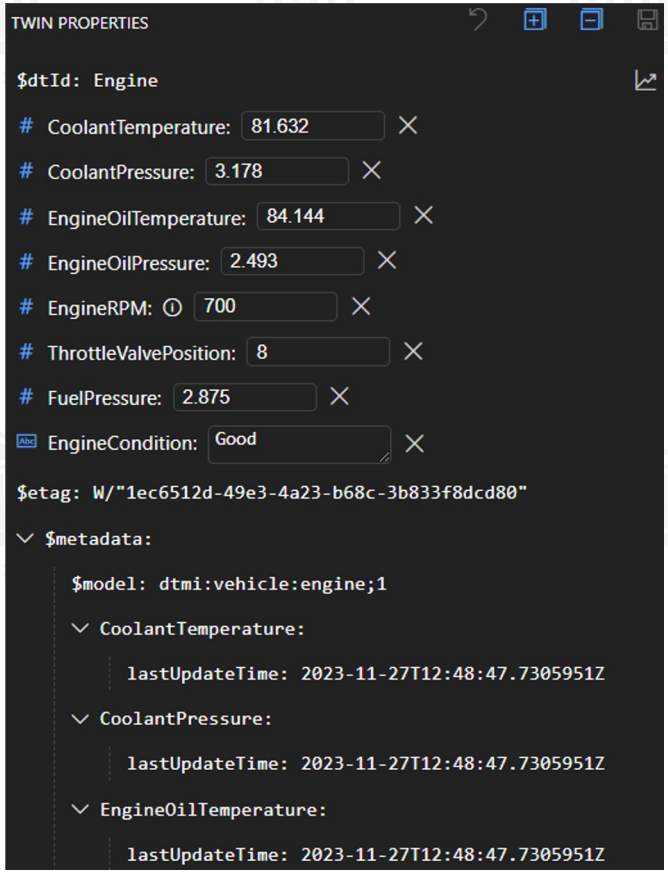
SELECT * FROM DIGITALTWINS
WHERE IS_OF_MODEL (’ dtmi: vehicle: **coolant_sensor;1**’) AND **CoolantTemperatueAlert** = ’High ’)



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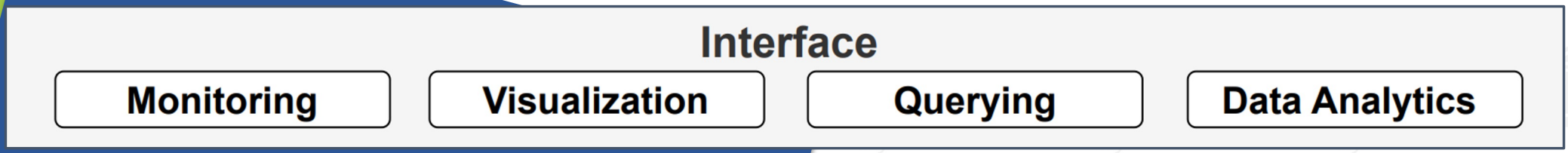
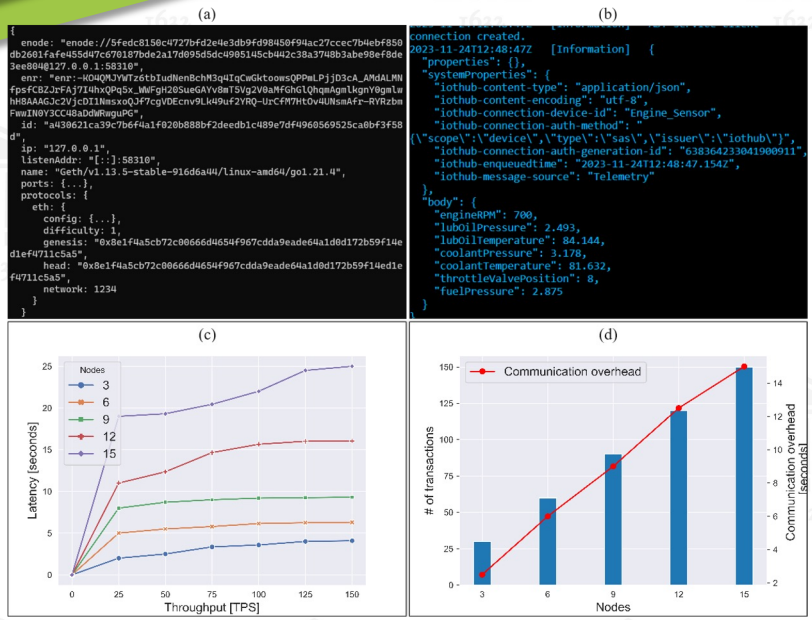
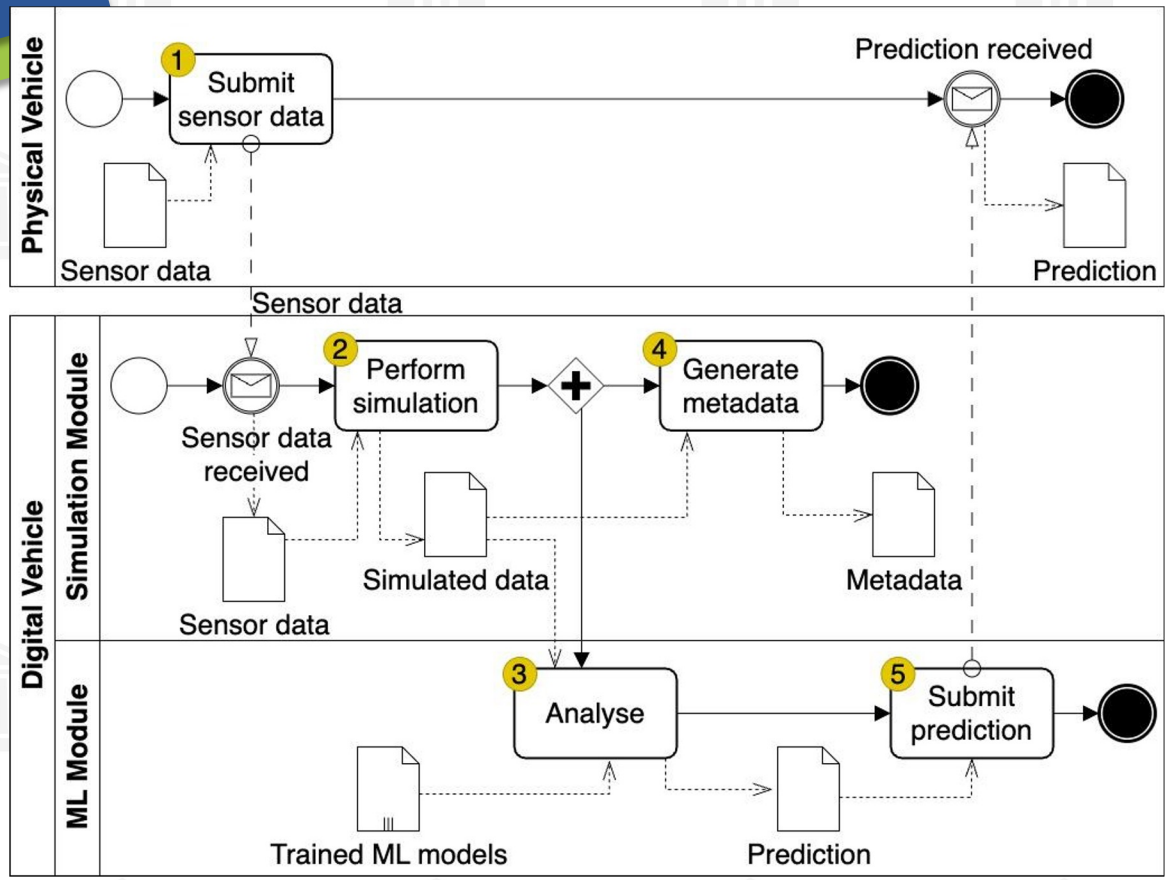


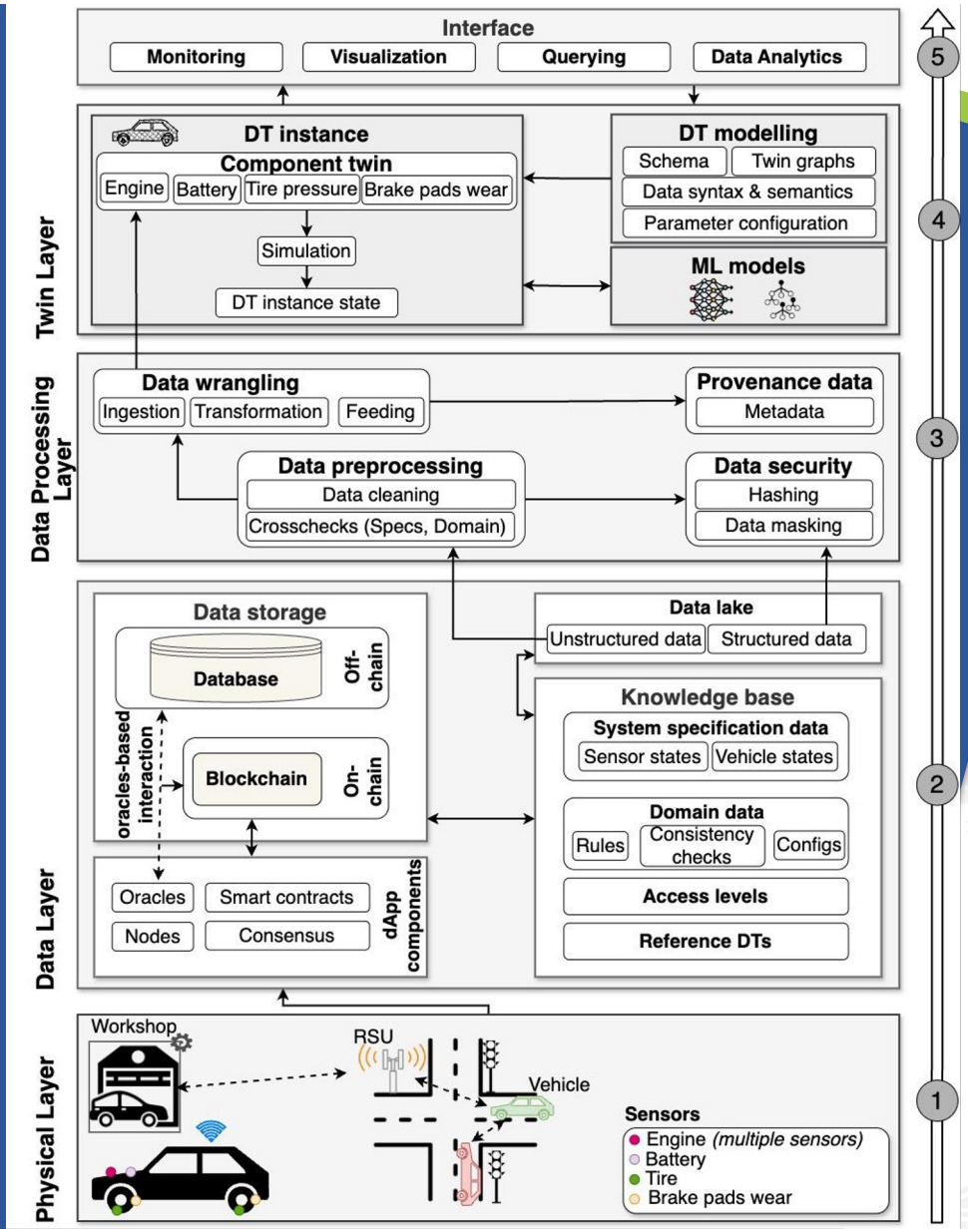
Interface

IoV-TwinChain execution

- Demo execution
- Performance execution
  - Throughput and communication overhead







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IoV-TwinChain Framework

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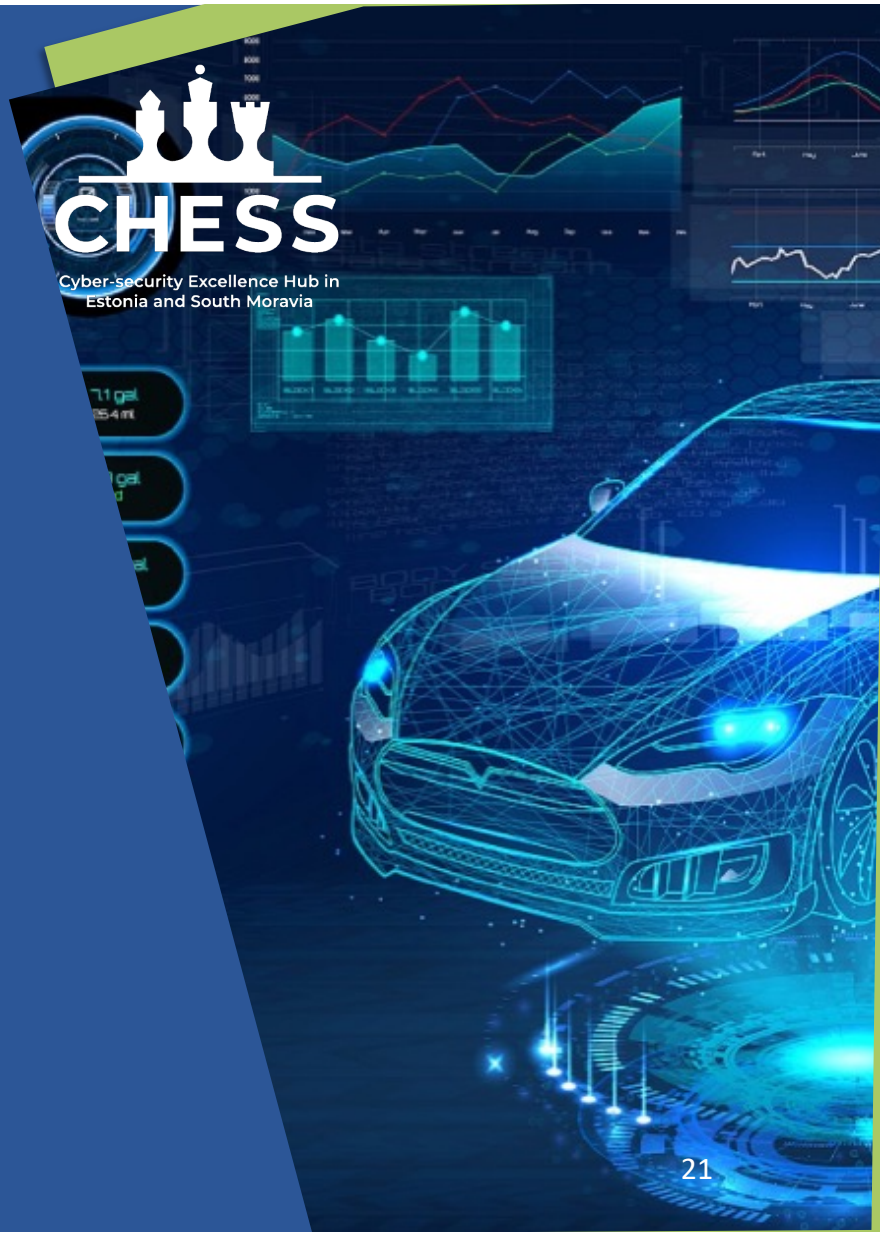
Challenges

- Blockchain scalability
- Digital twin synchronisation
  - *Low fidelity vs high fidelity*
- AI models accuracy and adaptability
- Data availability for training AI models
- Lack of standards and frameworks



Highlights

IoV-TwinChain enhances road safety by proactively monitoring vehicle operating conditions

Digital Twin enables real-time monitoring and simulation of vehicle operating conditions

Machine learning facilitates data-driven predictions for vehicle predictive maintenance

Blockchain guarantees data integrity and traceability across the physical vehicle and its twin

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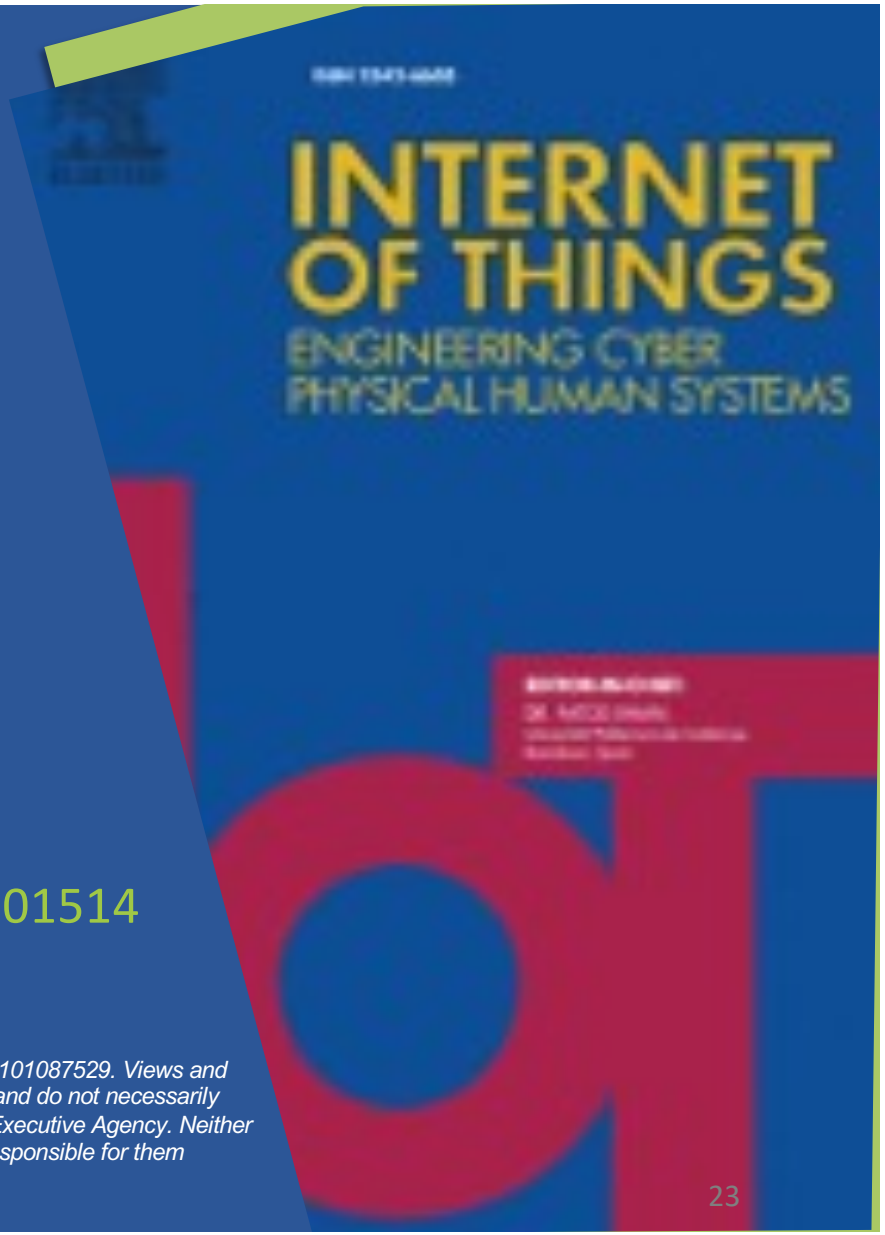

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