ETSI IoT Week 2022

Digital Twin for the green transformation: requirements and enabling technologies

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Digital Twin for the Green Transformation: the Green Twin

Green Transformation

- The transformation of national economies into modern and competitive economic systems with minimal environmental impact [1]
- Enormous effort from national governments and international bodies
  - Global sustainable investment reached USD 35.5 trillion in the five major markets [2]
  - EUR 1 trillion to support sustainable investments over the next decade in the European Union [3]
- Energy-efficiency is becoming the key challenge in every field
  - Transportation
  - Infrastructures and Cities
  - Network and Computing resources

[1] Cheba, Katarzyna, et al. "Directions of green transformation of the European Union countries." Ecological Indicators 136 (2022): 108601.
[2] 2020 Global Sustainable Investment Review (GSIR), http://www.gsi-alliance.org/wp-content/uploads/2021/08/GSIR-20201.pdf
[3] Press Release from the European Commission (Jan-2020): https://ec.europa.eu/commission/presscorner/detail/en/qanda_20_24

Digital Twin (DT)

- It is **a virtual representation of an object or system** that
  1. spans its lifecycle,
  2. is updated from real-time data,
  3. and uses simulation, ML and reasoning to help decision-making [4]

- Can represent any physical component or system or process
  - E.g., a building, a vehicle, a single vehicle component, an industrial process, etc. [5]

- Can answer questions without trying in the physical world
  - E.g., *what happens if I speed up the industrial process by 25%?*
  - *What happens if I open the windows of these room every time at 8 am in the morning?*

[4] Digital Twin definition from IBM: https://www.ibm.com/topics/what-is-a-digital-twin
[5] M. Bauer, F. Cirillo, J. Furst, G. Solmaz, and E. Kovacs, "Urban digital twins – a Fiware-based model," *at Automatisierungstechnik*, vol. 69, no. 12, pp. 1106–1115, 2021.

A Use Case for DT: the Green Twin

- Collect data from physical environments to build a DT
  - **Buildings:** one or multiple buildings, a campus
  - **Vehicles:** connected cars, busses, road traffic
  - **People:** wearable devices, mobile devices
  - **Network:** network devices, (radio) access net components

- Monitor and simulate systems' operation and people's activities to reduce energy consumption [...] while enhancing their quality of life [6]

- When the best configuration is found, can "push" it to the physical twin

Digital Twin + Green Transformation = Green Twin

[6] G. Solmaz, F. Cirillo, U. Fattore, ""Digital Twins in the Future Networking: A Use Case in IOWN", at the 2022 IEEE World Forum on Internet of Things (WF-IoT), IEEE, 2022.

Example: Green Twin of a Building

- Using a Digital Twin to capture several data and information coming from a building:
  - The 2D/3D model of the building
  - Sensors (e.g., thermometer, smart meter, etc.)
  - Energy (e.g., solar panels energy, consumption, etc.)
  - Device utilization (e.g., vending machines, HVAC, elevators)
  - Occupancy (e.g., in offices, meeting rooms, profile of occupants)

- Examples of possible “Green” decisions
  - Less people are coming in the building today…
    - What happens if I assign them all to one area of the building? Do I save energy?
  - Few energy forecasted from the solar panels in next weeks…
    - Can I change the office hours range to reduce consumption?

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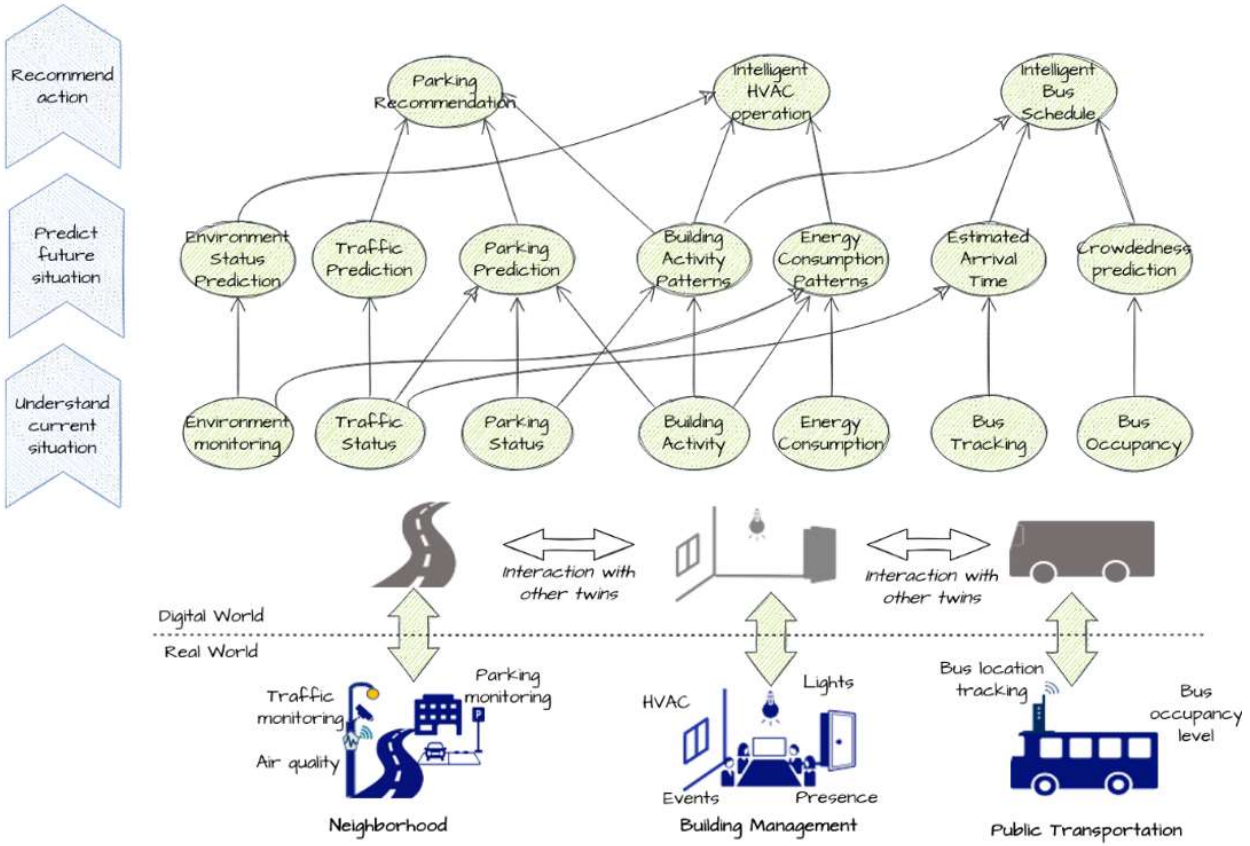
Bringing together Data: cross-domain interoperability

Data from multiple domains

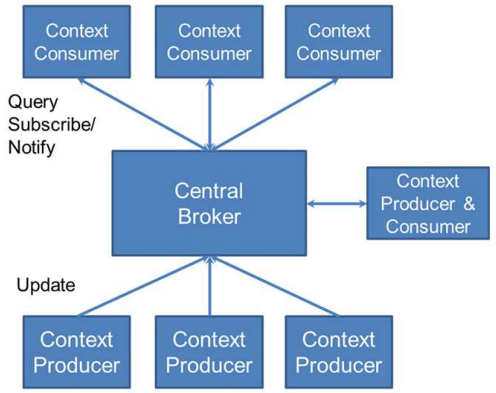
- Green Twin merges data from very different domains
- But…
  - Data can be in very different formats
    - Linking could be challenging
  - Data can belong to different owners
    - Owners may want to limit the use of their data to other domains



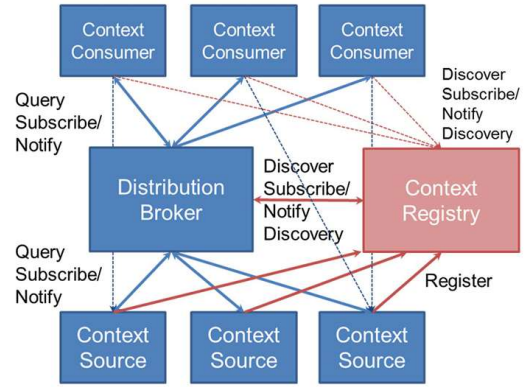
Data interoperability

- *Challenge: Support data integration, harmonization and enrichment among different data sources*
  - High complexity to harmonize and manage linked data
- **TrioNet:** A solution for data integration & harmonization [7]
  - Create an adapted data matching model with low efforts
  - Using AI for the development of data matching models
- **Scorpio:** A solution to support Data Spaces [8]
  - Enables applications to request context information
    - Including management, subscription to changes, registration and discover of new data sources
  - Implementation of the NGSI-LD API as specified by the ETSI CIM [9]

NGSI-LD centralized architecture [8]



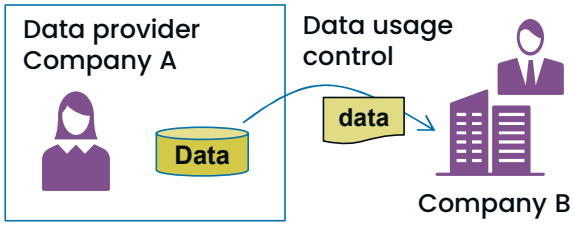
NGSI-LD distributed architecture [8]



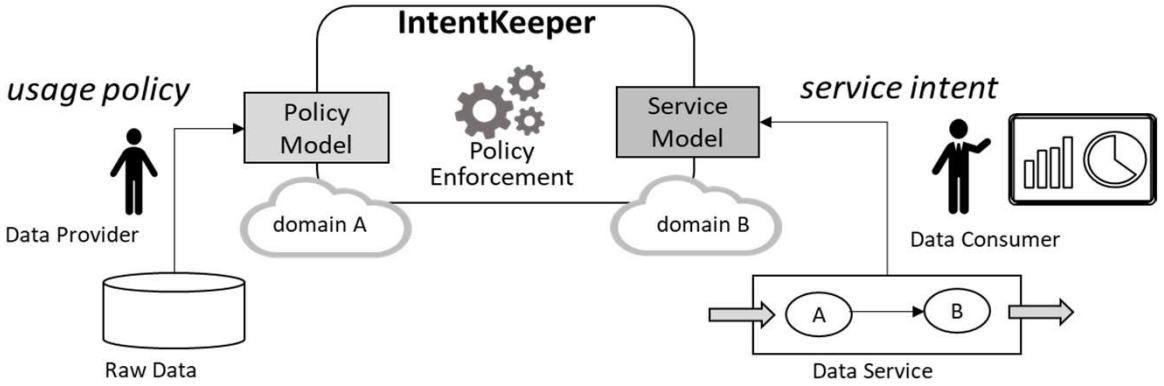
[7] B. Cheng, J. Fuerst, M. F. Argerich, M. Hayakawa, A. Kitazawa, U.S. Patent Application No. 17/013,688.
[8] NEC, "Scorpio NGSI-LD Broker," https://github.com/scorpiobroker/scorpiobroker, 2021.
[9] ETSI GS CIM 009 - Context Information Management (CIM); NGSI-LD API; v1.5.1 (Nov-2021) https://www.etsi.org/deliver/etsi_gs/CIM/001_099/009/01.05.01_60/gs_CIM009v010501p.pdf

Data Usage Control

- *Challenge: Allow Data Provider to have full control of the future usage of shared data*
  - Highly complex when dealing with dynamic data processing flows
  - Policy enforcement needed already during the construction of data



- **IntentKeeper**: an Intent-oriented approach [10][11]
  - Proactive and simple data usage control
    - A Usage Policy for data is provided by the data provider
    - A Service Intent is provided by the data consumer and verified by the Policy Enforcement engine
  - Decentralized policy enforcement
  - Loose-coupling between Data Provider and Consumer



[10] F. Cirillo, B. Cheng, R. Porcellana, M. Russo, G. Solmaz, H. Sakamoto, S. P. Romano, "Intentkeeper: Intent-oriented data usage control for federated data analytics". In *2020 IEEE 45th Conference on Local Computer Networks (LCN)* (pp. 204-215). IEEE, Nov-2020.
[11] B. Cheng, G. Solmaz, F. Cirillo, E. Kovacs, K. Terasawa, A. Kitazawa, "FogFlow: Easy programming of IoT services over cloud and edges for smart cities". *IEEE Internet of Things journal,* 5(2), 696-707. 2017.

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A new supporting infrastructure: the IOWN GF case

Data volumes analysis example [12]

- Example: The “school of Medicine” building in the Campus of University of Murcia (ES)
  - 6 floors, 500 rooms, 40 hallways
  - https://www.um.es/web/universidad/mapas/medicina

ESTIMATED DATA VOLUME AND VELOCITY REQUIREMENTS FOR GREEN TWIN ENTITIES: SMART BUILDING, PERSON, VEHICLE TWINS.

Twin entity	Data sources	Number of units per entity	Data size per unit (bps)	Data velocity	Data volume
Smart Building	Video camera Meters Building sensors	180 700 380.000	20.000.000 500 20	Total velocity: $\sim$ 3.5 Gbps	20 years period Operation time: 24h/day $\sim$ 2.200 PB
Person	Cameras/VR Body sensors <persons/building>	1 10 400	20.000.000 10.000	Per building w/ people: $\sim$ 8 Gbps	1 year period Operation time: 16h/day $\sim$ 168 PB
Vehicle	4K stereo-cam Short-dist. cam Vehicular sensors <vehicles/building>	4 4 [1, 4] 30	1.000.000.000 250.000.000 240.000.000	Per building w/ vehicles around: $\sim$ 68 Gbps	10 years period Operation time: 16h/day $\sim$ 28.500 PB

[12] Solmaz, G., Cirillo, F., Fattore, U., “"Digital Twins in the Future Networking: A Use Case in IOWN", at the 2022 IEEE World Forum on Internet of Things (WF-IoT), IEEE, 2022.

How to support expected Data Volumes?

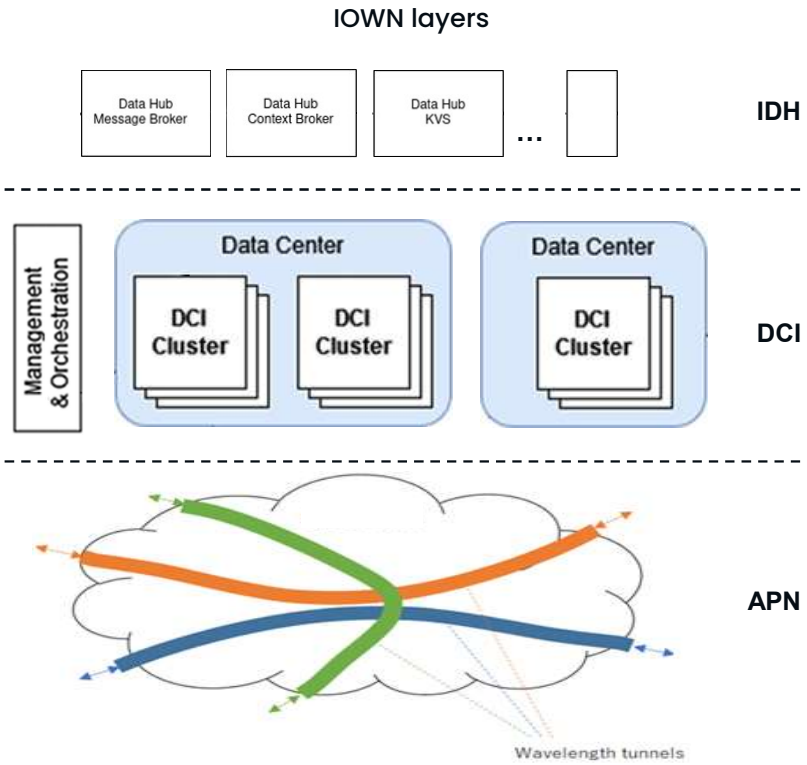
- The natural candidate is 5G technology
  - virtualized and disaggregated RAN patterns [13]
  - Multi-access Edge Computing (MEC) [14]

- But…
  - 5G antennas downlink and uplink
    - 20 Gbits peaks in downlink
    - and 10 Gbits in uplink
  - limited in flexibility for the mobile plane [15]

[13] L. Diez, C. Hervella, and R. Aguero, "Understanding the performance ¨ of flexible functional split in 5g vran controllers: A markov chain based model," *IEEE Transactions on Network and Service Management*, vol. 18, no. 1, pp. 456–468, 2020.
[14] L. Zanzi, F. Cirillo, V. Sciancalepore, F. Giust, X. Costa-Perez, S. Mangiante, and G. Klas, "Evolving multi-access edge computing to support enhanced iot deployments," *IEEE Communications Standards Magazine*, vol. 3, no. 2, pp. 26–34, 2019.
[15] U. Fattore, F. Giust, and M. Liebsch, "5gc+: An experimental proof of a programmable mobile core for 5g," in *2018 IEEE 23rd International Workshop on Computer Aided Modelling and Design of Communication Links and Networks* (CAMAD). IEEE, 2018, pp. 1–6.

The Innovative Optical and Wireless Network Global Forum (IOWN GF) [16]

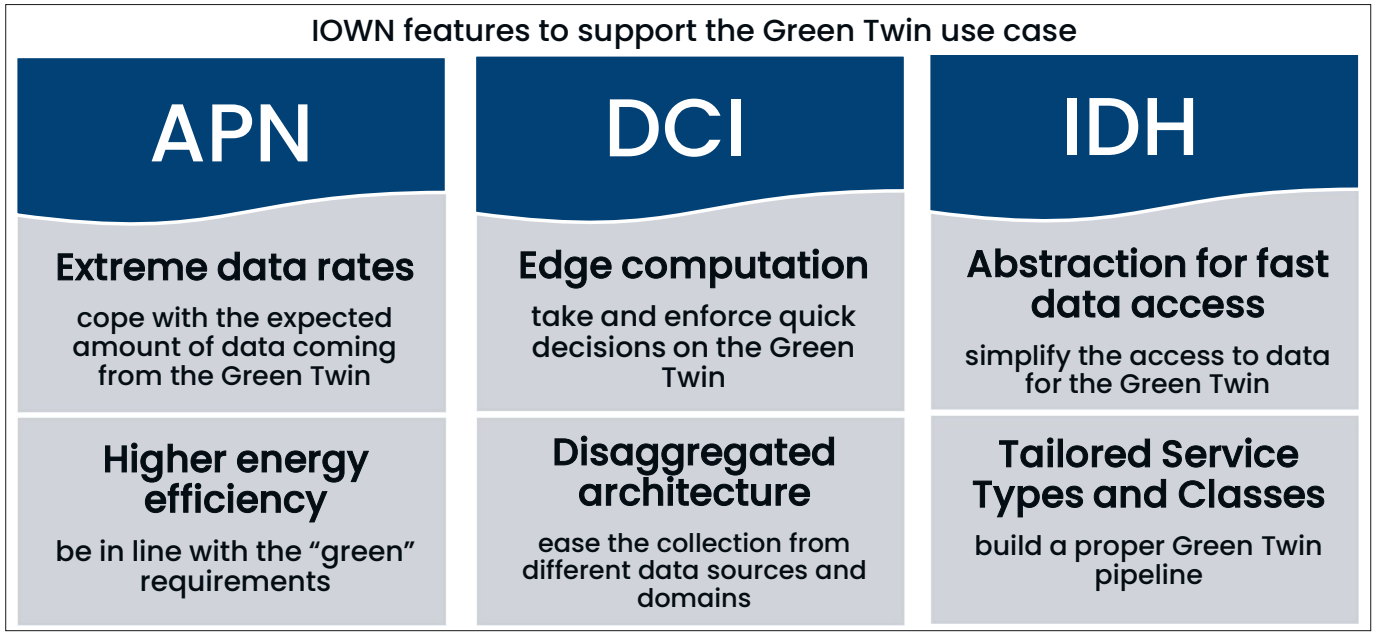
- **Open All-Photonic Network (APN)** [17]
  - optical-based multi-vendor's transport layer connecting endpoints with dynamical created optical paths
- **Data-Centric Infrastructure (DCI)** [18]
  - distributed and heterogeneous computing and networking environment including latest acceleration technologies
- **IOWN Data Hub (IDH)** [19]
  - fast&trusted data management and sharing infrastructure



[16] IOWN GF official website: https://iowngf.org/
[17] IOWN GF, Open All-Photonic Network (APN) Functional Architecture, Dec-2021: https://iowngf.org/wp-content/uploads/formidable/21/IOWN-GF-RD-Open-APN-Functional-Architecture-1.0-1.pdf
[18] IOWN GF, Data-Centric Infrastructure (DCI) Functional Architecture, Dec-2021: https://iowngf.org/wp-content/uploads/formidable/21/IOWN-GF-RD-DCI-Functional-Architecture-1.0-1.pdf
[19] IOWN GF, Data Hub Functional Architecture, Dec-2021: https://iowngf.org/wp-content/uploads/formidable/21/IOWN-GF-RD-Data-Hub-Functional-Architecture-1.0-1.pdf

Green Twin use case in IOWN

- Green Twin is an use cases on top of IOWN
- Many other use cases are considered in IOWN:
  - **AI-Integrated Communication (AIC)** use cases [20]
  - **Cyber-Physical System (CPS)** use cases [21]



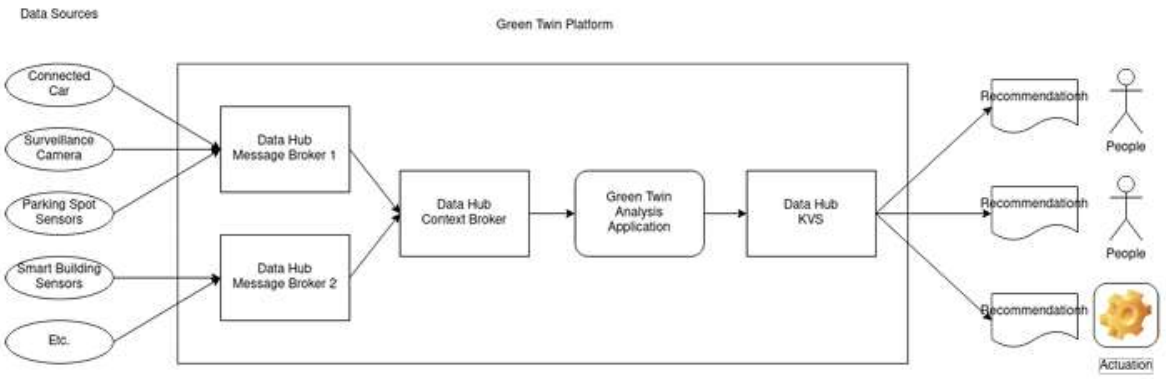
[20] IOWN GF, "AI-Integrated Communications Use Case Interim Report," 2021. https://iowngf.org/wp-content/uploads/formidable/21/IOWN-GF-RD-AIC_Use_Case_1.0.pdf
[21] IOWN Global Forum, "CyberPhysical System Use Case Interim Report, Version 2.0," 2021 https://iowngf.org/wp-content/uploads/formidable/21/IOWN-GF-RD-CPS_Use_Case_1.0.pdf

Service Types in IOWN Data Hub [22]

- IDH defines many different Service Types to offer multiple functionalities
  - Distributed Relational Databases
  - Key-Value Store (KVS)
  - Graph Store
  - Message Broker
  - Context Broker (e.g., the Scorpio Broker)
  - etc.

DATA FLOW	PREFERRED IDH SERVICE TYPE
Inference results	Distributed Relational Database
Surveillance video	Object Storage
LiDAR data	Key-Value Store or Object Storage
Notification messages	Message broker
User status	Key-Value Store
Voice messages	Message broker

  - Service Types can be combined for a specific use case
    - e.g., for the Green Twin



[22] IOWN GF, Data Hub Functional Architecture, Dec-2021: https://iowngf.org/wp-content/uploads/formidable/21/IOWN-GF-RD-Data-Hub-Functional-Architecture-1.0-1.pdf

Conclusions & Future Works

1. SDOs, companies, governments, people are pushing towards green transformation
2. Digital Twin can give a strong help in the “green” direction
3. Data Interoperability, Usage Control, and an enabling network and computation infrastructure are fundamental to enable DT
4. NLE and IOWN will continue on the Green Twin use case for Building, Vehicles, People
   - Green Twin for Network is yet to come!

\Orchestrating a brighter world

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