IoT Week 2022

Internet of Things & Digital Twins: Just a Buzzword or a Challenging Opportunity?

Marco Picone, Ph.D.

University of Modena and Reggio Emilia, Italy

https://www.marcopicone.net/

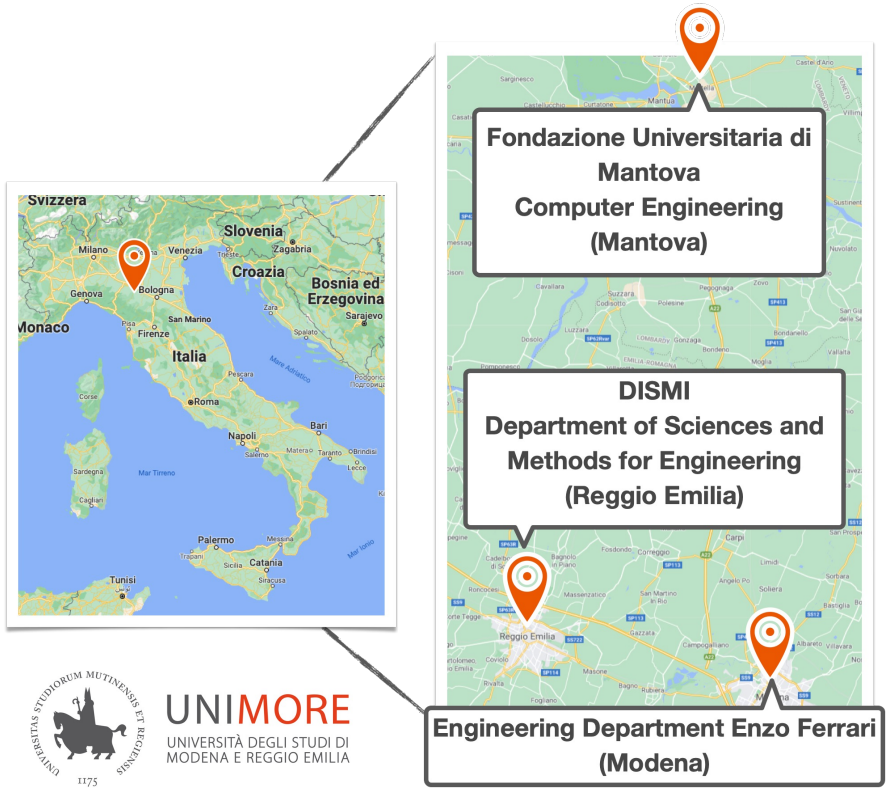
13/10/2022

@Me 

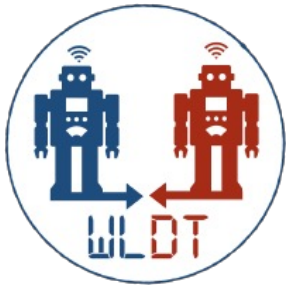
- **Assistant Professor** at the **University of Modena and Reggio Emilia** working in the **Distributed and Pervasive Intelligence (DIPI) Group** at the **Department of Sciences and Methods for Engineering (DISMI)**
- Ph.D. in Information Technology and the M.Sc. (cum Laude) in Computer Engineering from the University of Parma and he has also been a research visitor in the NetOS group at the Computer Laboratory, University of Cambridge (United Kingdom).
- My main research interests are currently mainly focused on:
  - Distributed Systems
  - Internet of Things
  - Edge/Fog Computing
  - Digital Twins

not alone but with colleagues ☺

- Definition & Modelling
- Ecosystem & Web Oriented Approaches
- Development
- Orchestration & Deployment
- IoT & IIoT Experimentation



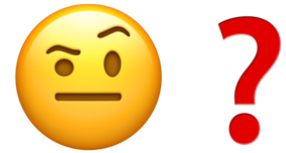
UNIMORE
UNIVERSITÀ DEGLI STUDI DI MODENA E REGGIO EMILIA



GitHub

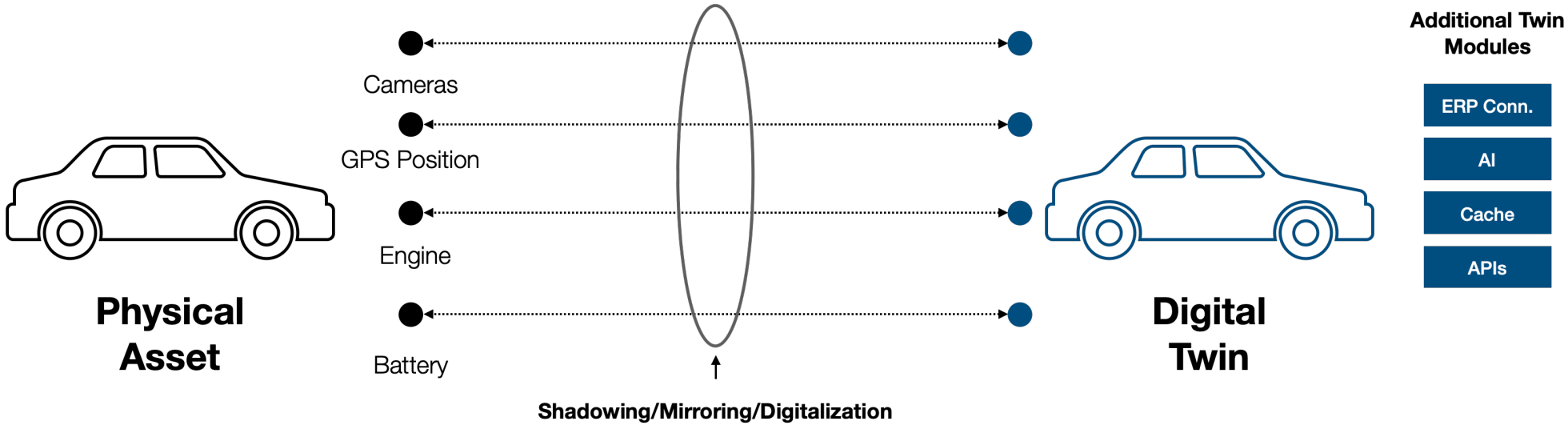
White Label Digital Twin Library
https://github.com/wldt

Internet of Things & Digital Twins: Just a Buzzword or a Challenging Opportunity?



Internet of Things & Digital Twins: Just a Buzzword or a Challenging Opportunity?

Digital Twin Definition

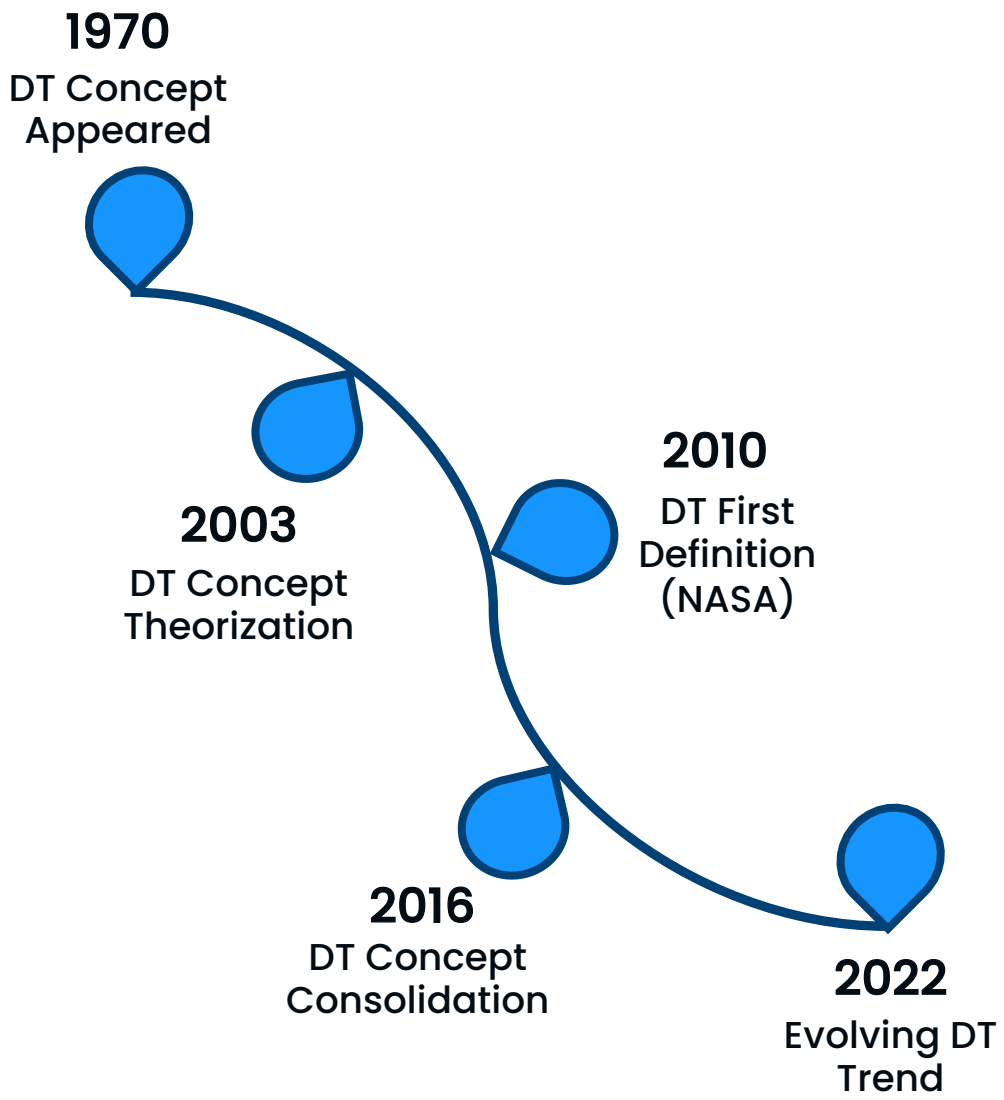


*"A **Digital Twin (DT)** is a **comprehensive software representation** of an individual **physical object**. It includes the **properties**, **conditions**, and **behavior(s)** of the real-life object **through models and data**. A Digital Twin is **a set of realistic models** that can **simulate an object's behavior** in the **deployed environment**. The Digital Twin **represents** and **reflects** its physical twin and remains its virtual counterpart **across the object's entire lifecycle**"*

S. Haag, and R. Anderl. "Digital Twin–Proof of concept." Manufacturing Letters 15 (2018)

Digital Twins Evolution

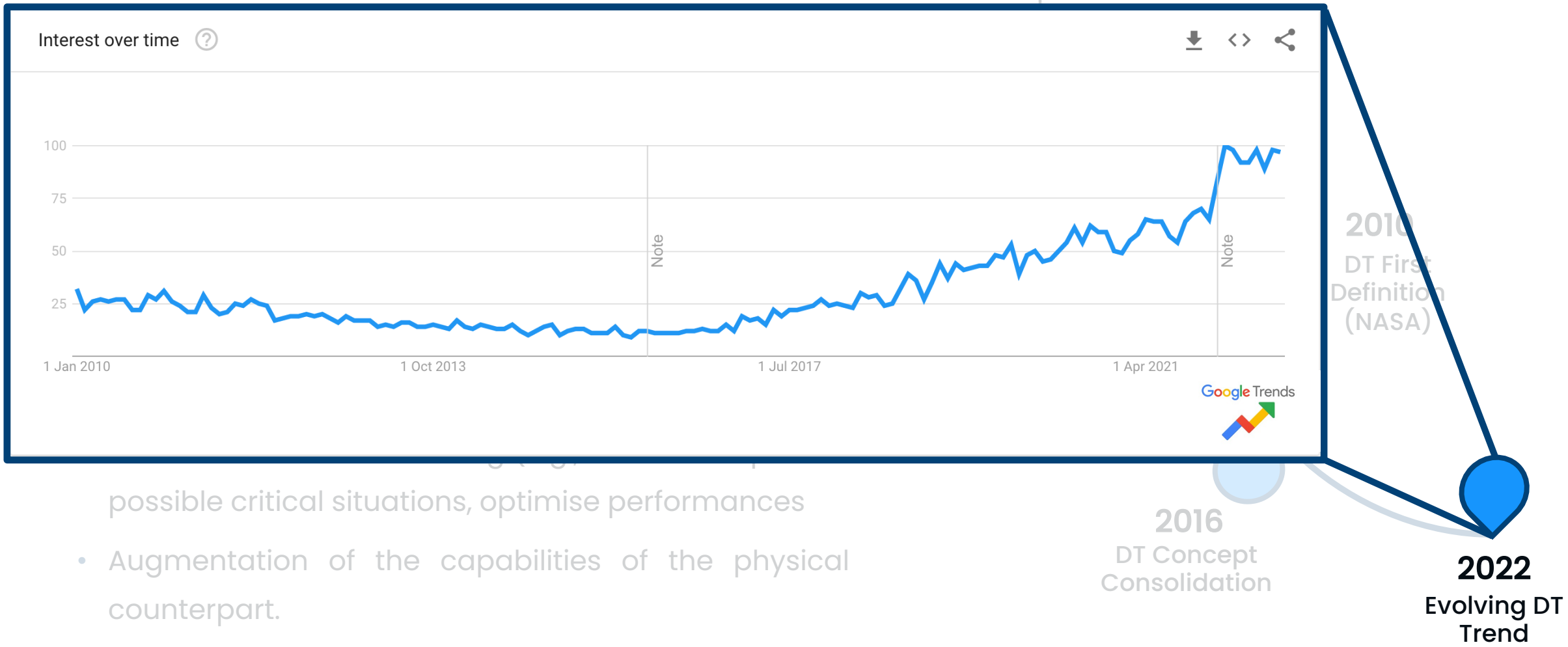
- In the last decade, the Digital Twin paradigm has been explored in different domains as an approach to virtualise entities existing in the real world, creating **software counterparts** that provide smart services upon them
- Such services may include (but are not limited to):
  - Tracking of the actual state of the physical entity or device
  - Smarter forms of monitoring (e.g., detect and predict possible critical situations, optimise performances)
  - Augmentation of the capabilities of the physical counterpart
  - Simulate and design new or existing products



Digital Twins Evolution

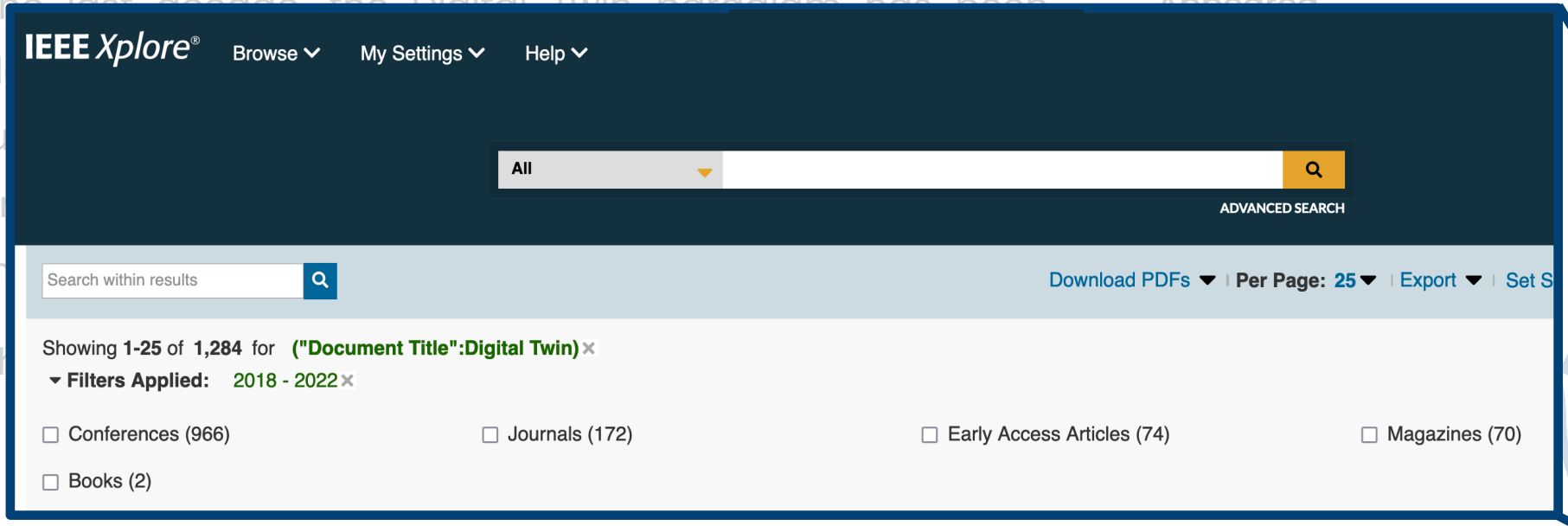
possible critical situations, optimise performances

- Augmentation of the capabilities of the physical counterpart.



Digital Twins Evolution

- In the last decade, the Digital Twin paradigm has been expl
virtu
cou
ther
- Such



1970
DT Concept
Appeared

2010
DT First
Definition
(NASA)

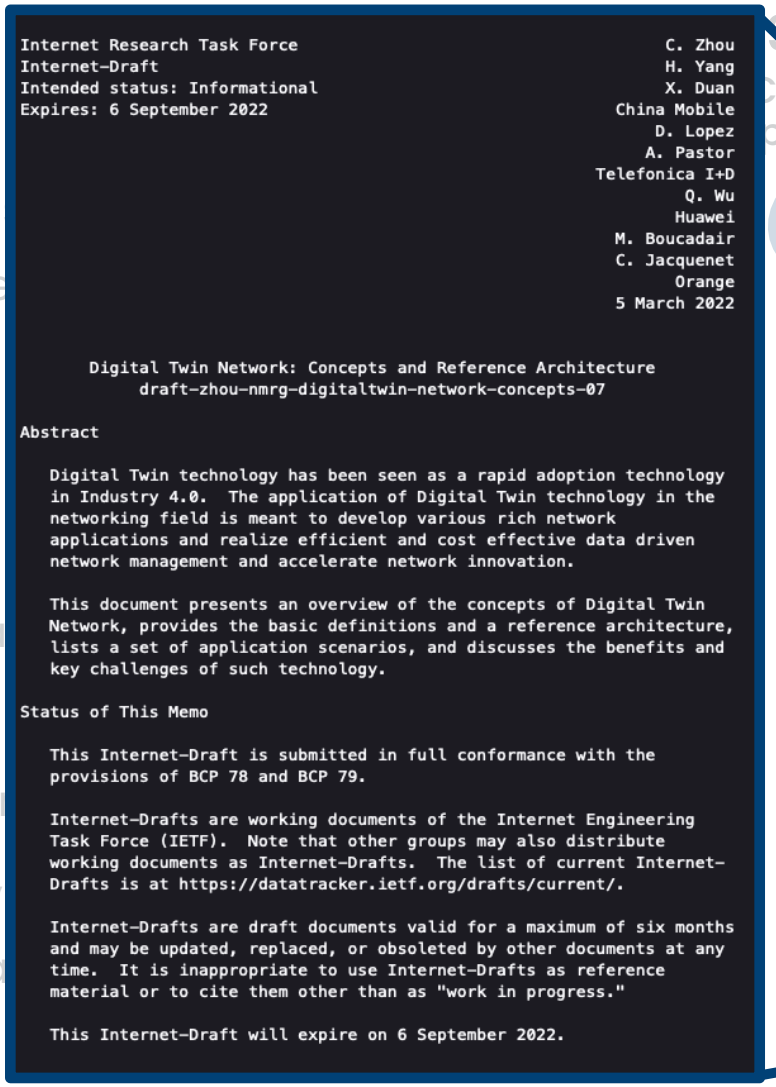
2016
DT Concept
Consolidation

2022
Evolving DT Trend

- Smarter forms of monitoring (e.g., detect and predict possible critical situations, optimise performances
- Augmentation of the capabilities of the physical counterpart.

Digital Twins Evolution

- In the last decade, the Digital
  explored in different domain
  virtualise entities existing in the re
  counterparts that provide
  them
- Such services may include
  - Tracking of the actual sta
    device
  - Smarter forms of monitori
    possible critical situations,
  - Augmentation of the co
    counterpart.



Internet Research Task Force
Internet-Draft
Intended status: Informational
Expires: 6 September 2022

C. Zhou
H. Yang
X. Duan
China Mobile
D. Lopez
A. Pastor
Telefonica I+D
Q. Wu
Huawei
M. Boucadair
C. Jacquenet
Orange
5 March 2022

Digital Twin Network: Concepts and Reference Architecture
draft-zhou-nmrg-digitaltwin-network-concepts-07

Abstract

Digital Twin technology has been seen as a rapid adoption technology in Industry 4.0. The application of Digital Twin technology in the networking field is meant to develop various rich network applications and realize efficient and cost effective data driven network management and accelerate network innovation.

This document presents an overview of the concepts of Digital Twin Network, provides the basic definitions and a reference architecture, lists a set of application scenarios, and discusses the benefits and key challenges of such technology.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at https://datatracker.ietf.org/drafts/current/.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on 6 September 2022.

https://www.ietf.org/archive/id/draft-zhou-nmrg-digitaltwin-network-concepts-07.txt

Digital Twin (Extended) Definition

"A Digital Twin is a comprehensive software representation of an individual physical object. It includes the ***properties, conditions, and behavior(s)*** *of the real-life object through models and data. A Digital Twin is a set of stic models that can* ~~***simulate***~~ *an object's behavior in the deployed environment. The tal Twin represents and reflects its physical twin and remains its virtual counterp cross the object's entire lifecycle. [1]"*

S. Haag, and R. Anderl. "Digital Twin–Pro ncept." Manufacturing Letters 15 (2018)

properties, conditions, ***relationships*** *and behavior(s)*

DTs may also be responsible to model and characterize existing relationships in the physical world in order to map them also in the digital world.

Digital Twin (Extended) Definition

"A Digital Twin is a comprehensive software representation of an individual physical object. It includes the properties, conditions, and behavior(s) of the real-life object through models and data. A Digital Twin is a set of realistic models that can ~~***simulate***~~ *an object's behavior in the deployed environment. The Digital Twin represents and reflects its physical twin and remains its virtual counterpart a[illegible]s the object's entire lifecycle. [1]"*

S. Haag, and R. Anderl. "Digital Twin–Pro[illegible]ncept." Manufacturing Letters 15 (2018)

A Digital Twin is a set of realistic models that can ***digitalize*** *an object's behavior in the deployed environment.*

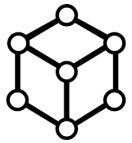
The recent shared idea is that DTs can be used not only for simulation purposes but to support and enable any digital services or application

Digital Twin's Pillars

Physical Communication

Software

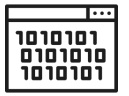
A Digital Twin is a comprehensive **software representation** of an individual **physical object**. It includes the **properties, conditions, relationships and behavior(s)** of the real-life object through **models and data**. A Digital Twin is a set of realistic models that can **digitalize** an object's behavior in the deployed environment. The Digital Twin represents and reflects its physical twin and remains its virtual counterpart across the object's entire **lifecycle**.



Data Processing & Model

Description Language

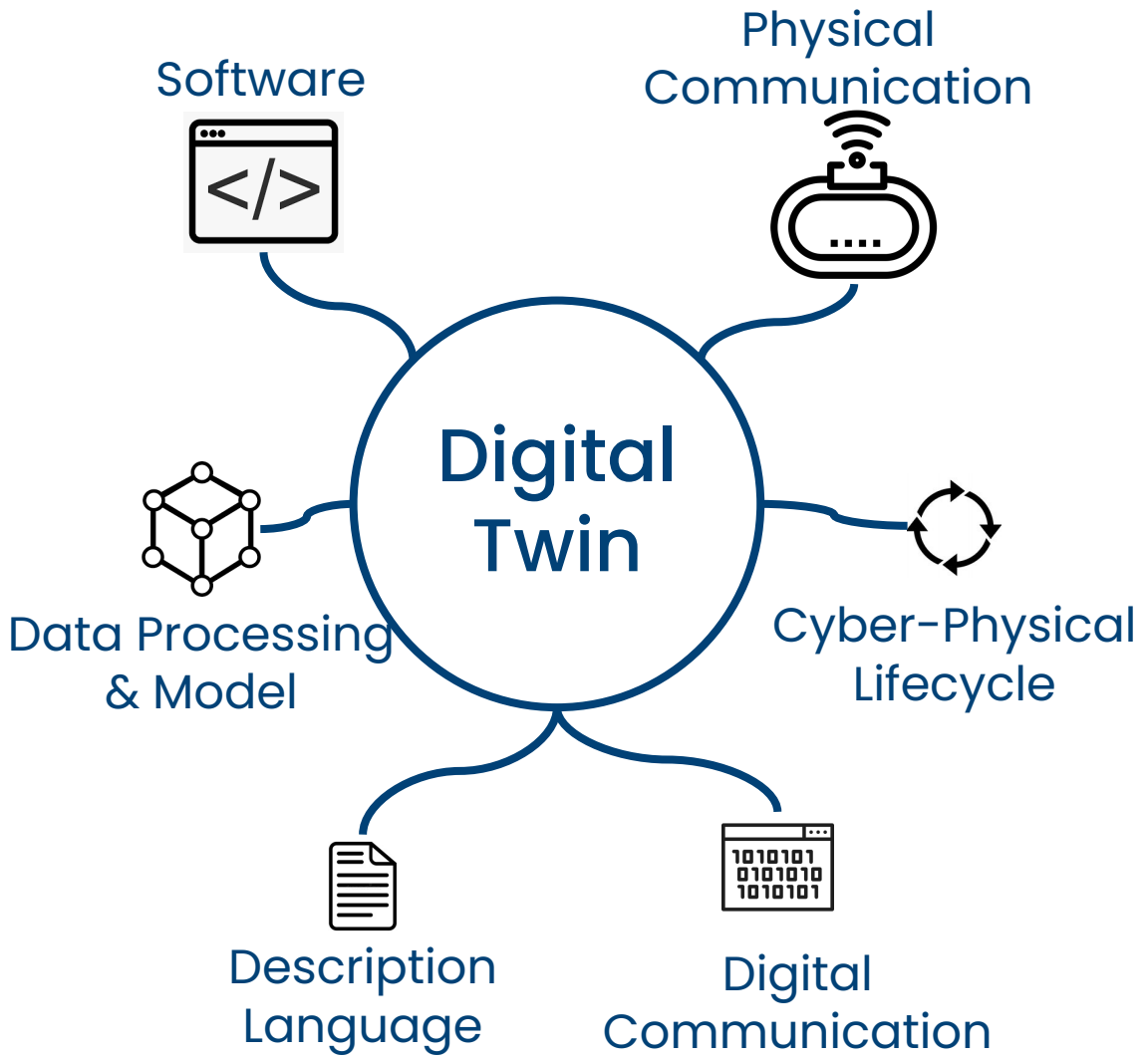
Cyber-Physical Lifecycle



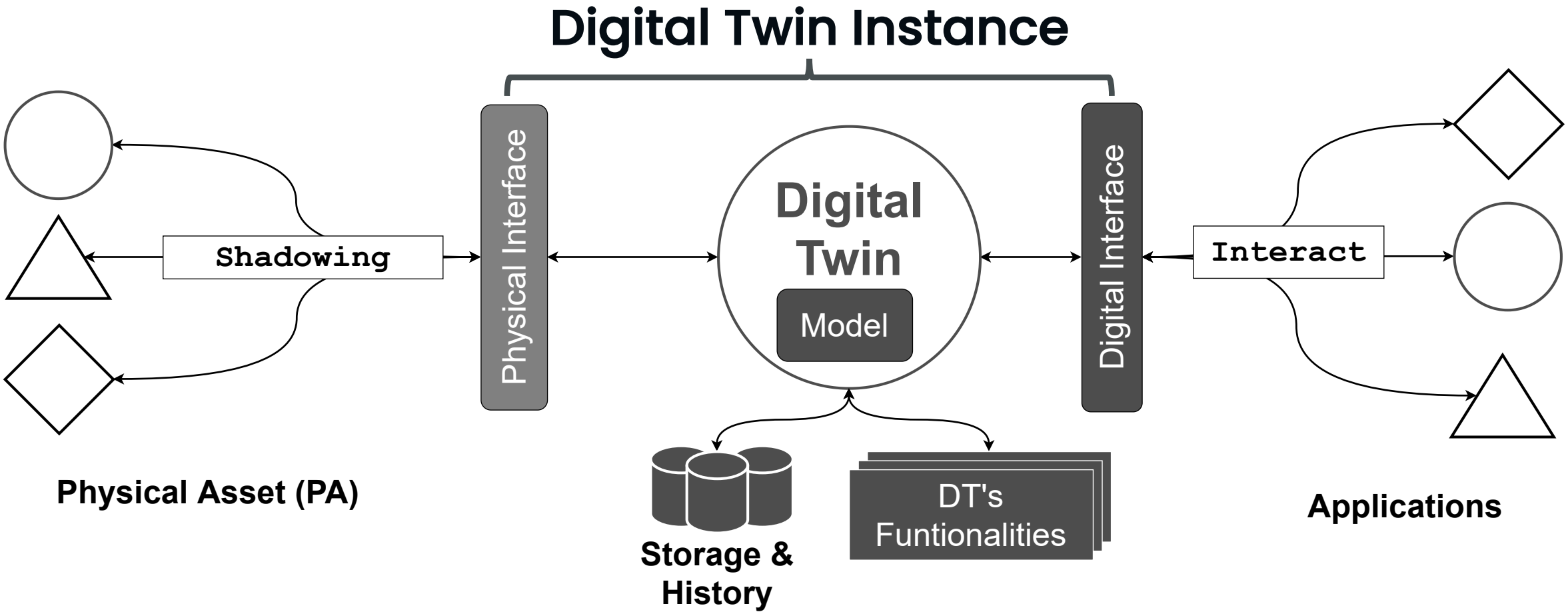
Digital Communication

Digital Twin's Pillars (and questions)

- **Software:**
  - How can we **design** and structure DT's code ?
  - How can we **deploy** DTs ?
  - How can we **monitor** DTs ?
- **Physical & Digital Communications:**
  - How a DT can **interact** with the **physical** and the **digital** layers ?
- **Data Processing & Model:**
  - How can we **define**, **update** and **execute** the DT's **model** ?
- **Cyber-Physical Life Cycle:**
  - How the DT **evolve over time** and with respect to the physical and the digital worlds ?
- **Description Language:**
  - How can we **describe** a DT through a **uniform**, and **interoperable representation** ?

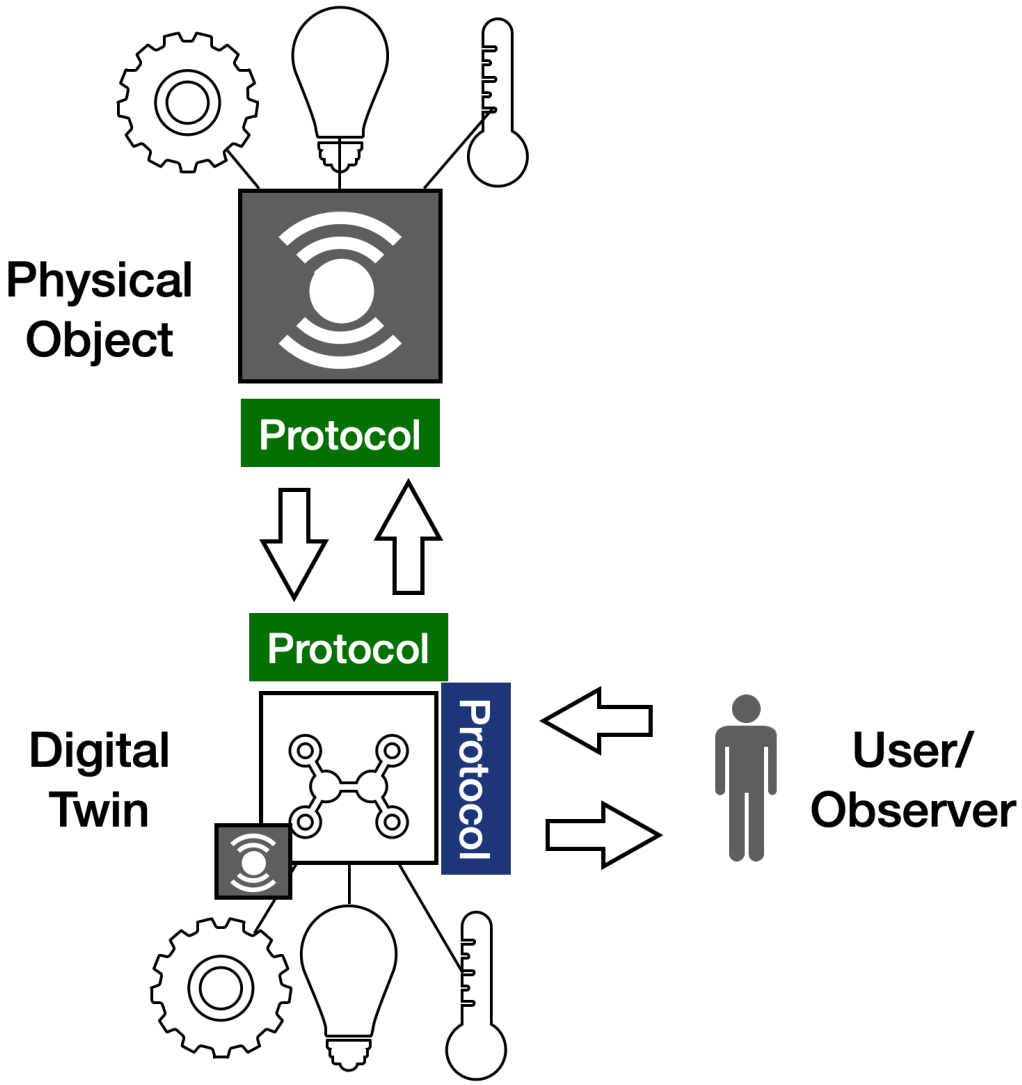


Digital Twin's Abstraction



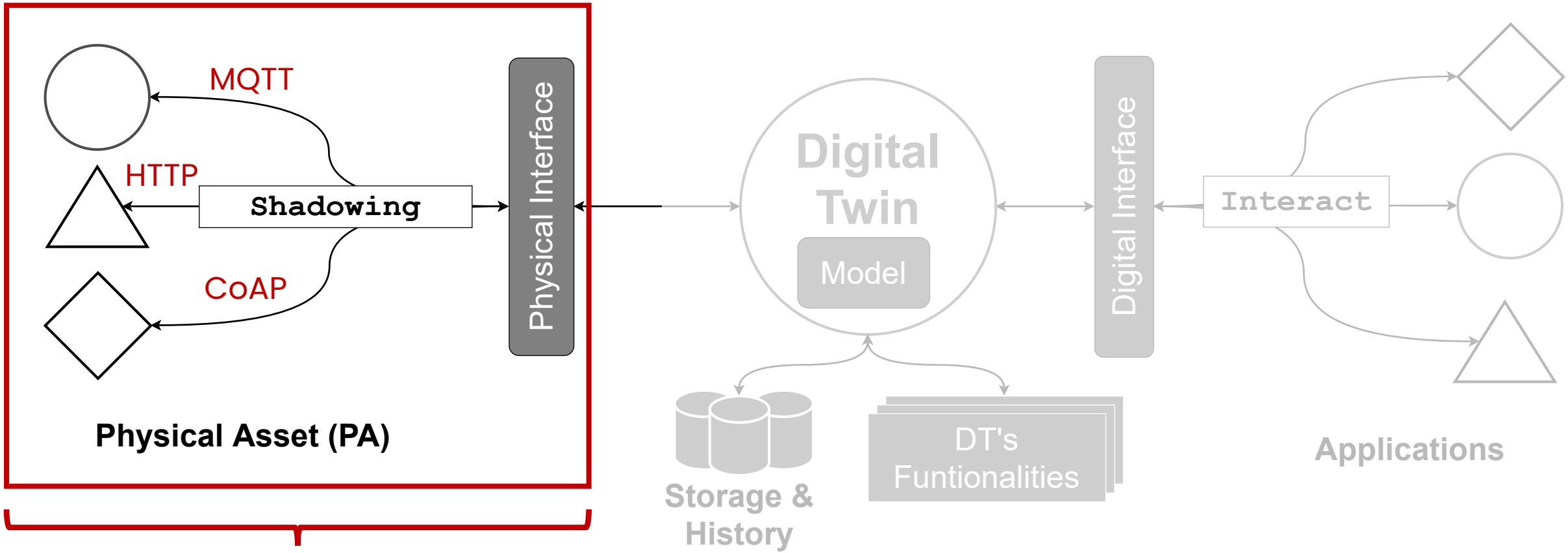
Internet of Things & Digital Twins: Just a Buzzword or a Challenging Opportunity?

Internet of Things & Digital Twins



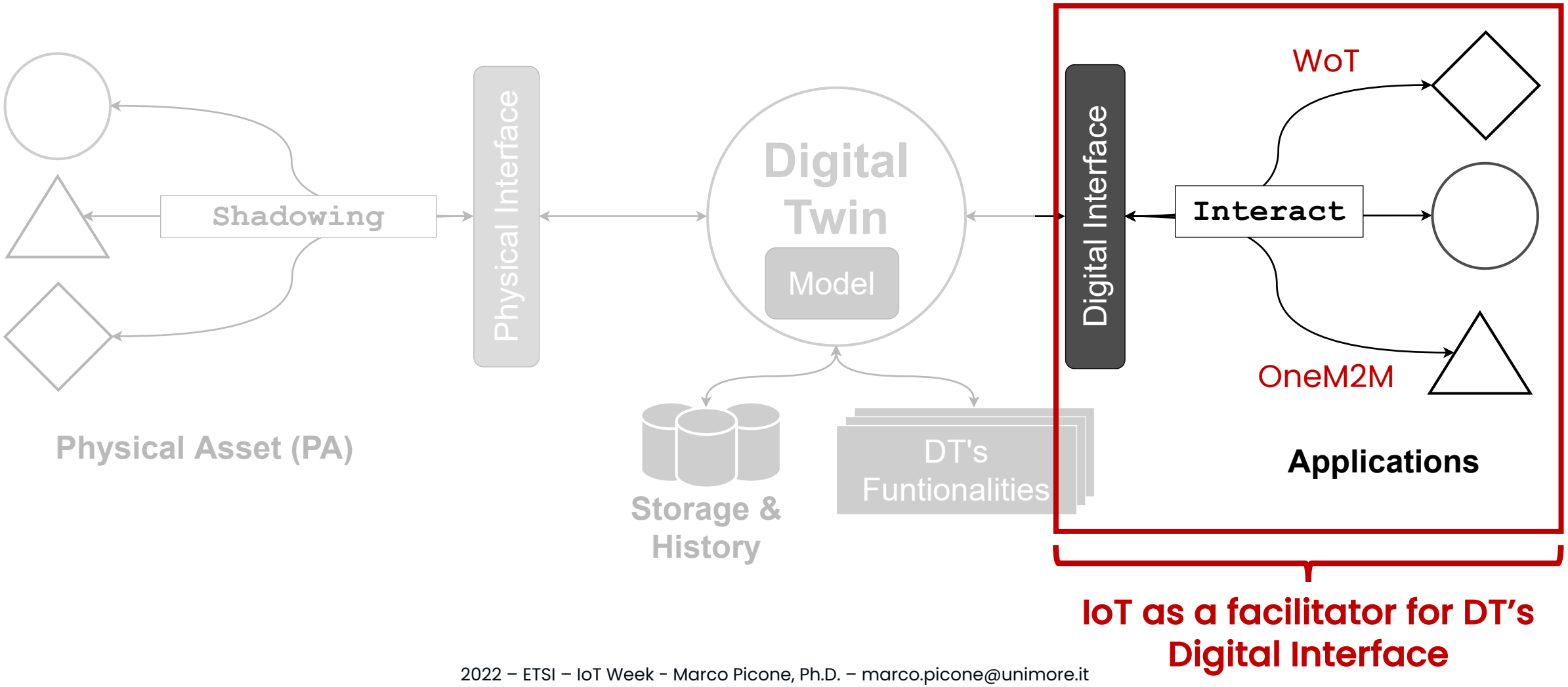
- It's only thanks to the Internet of Things that the idea of **Digital Twins has become cost-effective** to implement thanks to the possibility to "easily" communicate with a physical connected device
- **IoT** technologies represent the strategic enablers to design and **build DT's physical interfaces** allowing twins to talks through multiple languages and data formats with the aim to **read** information, **synchronize** the state, and **interact** with the environment
- At the same time, **DTs** represents an appealing opportunity to **digitalize/softwarize the physical world** (composed by a multitude of heterogeneous assets) and **simplify its complexity** to digital applications

Internet of Things & Digital Twins



IoT as the enabler for DT's Physical Interface

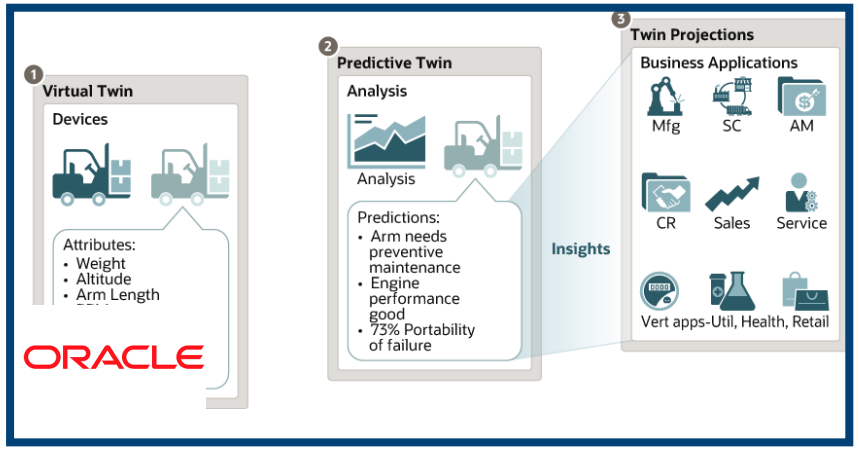
Internet of Things & Digital Twins

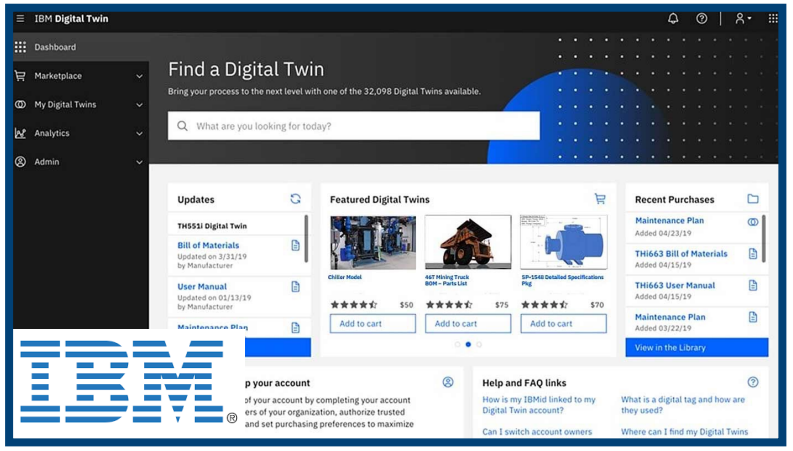


Internet of Things & Digital Twins: Just a Buzzword or a Challenging Opportunity?

Digital Twins as a Massive Trending Topic

Almost "Everyone" is talking and building Digital Twin in their own way, with independent platforms and fragmented modelling …





and counting ….

Digital Twin as a Trending Topic

Almost "Everyo … own way, with inde … ng …

and counting ….

The Current Digital Twin Ecosystem

- **IMPORTANT:** Existing Digital Twin platforms and solutions represent amazing contributions to the domain and a tremendous effort toward a widespread experimentation and adoption **-> But they are just the starting point ☺**
- (Some of) Existing Issues:
  - Mainly **centralised/monolithic approaches** where all DTs are aggregated and deployed in the same point (the Cloud)
  - Digital Twins are mainly **passive entities** co-located at the same architectural layer of the platform itself and **subordinated to external modules** to control their properties, data and behaviours
  - Digital Twins are often **"just" data structures** that can be used to represent an application scenario **without a model** and any active behaviour
  - **Platform Specific** Digital Twin **Description**
  - **Proprietary vertical technology** stacks which are built around a central point of control and which **don't always talk to each other** -> when they do talk to each other it requires **per-vendor integrations** to connect those systems together

Are DTs a buzzword ? -> **No** they represent a "new" technology that needs a lot of work to be effective without fragmentation and the definition of a unified conceptual framework

New Digital Twin Opportunities

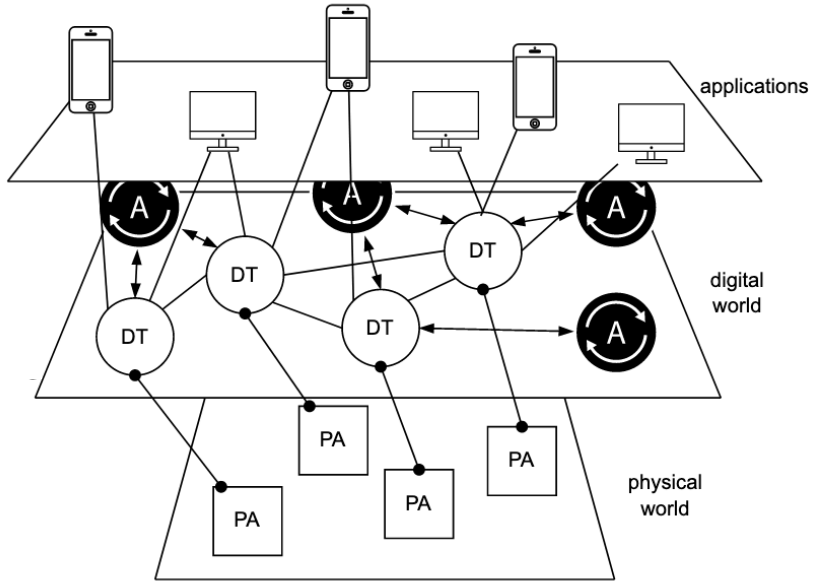
Current Digital Twin Software Evolution

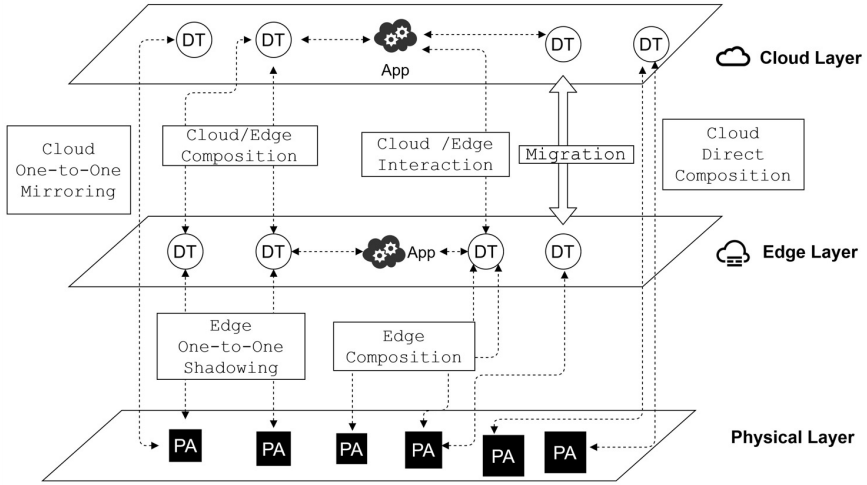
Next Generation of Digital Twin Software

Internet of Things & Digital Twins: Just a Buzzword or a Challenging Opportunity?

(Some) Open Challenges

- **Definition & Modelling**
  - DTs can be **active software entities** with an **internal model** responsible to define how to **digitalize their physical counterparts** and **implements** their own **behaviours** (there are not just data structures ☺)
  - There is the need to **identify a basic set of foundational properties, a common set of features and a naming conventions** that can be used to fully describe and specify the characteristics of the DT in several application domains*
  - The objective is to **offer/build a unified conceptual framework** for clarifying the foundational concepts and providing a possible **consolidated definition of the DT and its features and functionalities**
- **Description Language**
  - Definition of a **shared** and **"standard" description language** to enable a through **interoperability** and **integration** among heterogeneous DTs and digital services across multiple applications domains
- **Deployment**
  - Switch from a centralized point of view to a **distributed vision** where DTs can co-exists and collaborate across multiple architectural layers (Edge, Fog and Cloud) according to their requirements and responsibilities
- **and more …**





*R. Minerva, G. M. Lee and N. Crespi, "Digital Twin in the IoT Context: A Survey on Technical Features, Scenarios, and Architectural Models," in Proceedings of the IEEE, vol. 108, no. 10, pp. 1785-1824, Oct. 2020, doi: 10.1109/JPROC.2020.2998530.

Build a Digital Twin Ecosystem

Envision a **pervasive softwarisation of the physical world** in terms of highly dynamic ecosystems of **connected** and **interoperable DTs**, across **different** application **domains** and different **network levels** (from cloud to edge).

To make DTs a real opportunity we need a structured **cross-field fertilization and collaboration** (e.g., Software Engineering, Networking, Standardization Bodies, Companies, Universities …)

IoT Week 2022

Internet of Things & Digital Twins: Just a Buzzword or a Challenging Opportunity?

Marco Picone, Ph.D.

University of Modena and Reggio Emilia, Italy

https://www.marcopicone.net/

13/10/2022