New Internet Design – AI Infrastructure

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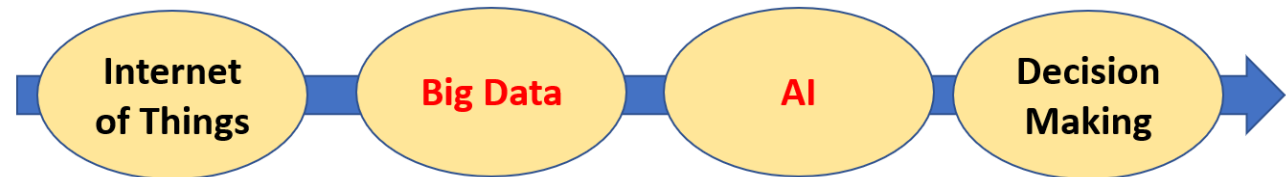
Professor, Liverpool John Moores University, UK

Contents

- Introduction

- New Internet

- Related Activities

- Designing AI Infrastructure

- Research Collaboration with VERSES

- Conclusion

Introduction

AI to create value from data

- **From connecting things to creating value**

+ Autonomy

+ Optimization

+ Remonte Control

Identification /Sensing

| Internet of Things | Big Data | AI | Decision Making |

INTERNET

Transfer information

TEXT   IMAGES   PROGRAMS   VIDEOS

Internet of Value

BLOCKCHAIN

Transfer ownership

MONEY   CONTRACTS   PATENTS   ASSETS
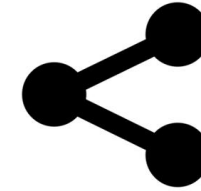
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The Ecosystem (scaling up)

- **The ecosystem of ecosystems**
  - Technology ecosystems
    - e.g., 5G/6G, Clouds, IoT, Big Data & AI, etc.
  - Vertical domain specific ecosystems
   - e.g., industrial, health, energy, etc.

Data **Share** **Reuse**

Data and AI Ecosystem (Stakeholders, Value-chain)

Data spaces as ecosystem

Key stakeholders and their roles
Who are the key stakeholders? What are their roles in the data ecosystem?
Who is the Data Ecosystem Orchestrator?
Who are the Data Providers?
Who are the Data Consumers?

Context
Services and infrastructure
Key stakeholders
Data and value flow
Ecosystem Orchestrator
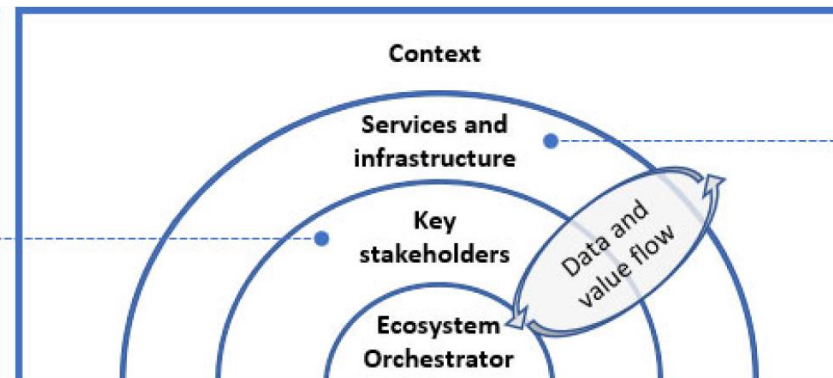
Services and infrastructure
What value adding services are needed in the ecosystem?
What infrastructure is required?
Who are the trusted intermediaries?

Problems of the current web

- **Walled garden**
  - centralised services provided by big companies such as Google, Facebook, Microsoft and Amazon

- With the current web
  - **risk**
  - **censorship**
  - **privacy concerns**

Decentralisation: the next big step for the world wide web

The decentralised web, or DWeb, could be a chance to take control of our data back from the big tech firms. So how does it work and when will it be here?

(Source) The Guardian, 8 September 2018

Data Spaces – GAIA-X

1 **Data sovereignty**
2 **Data level playing field**
3 **Decentralised soft infastructure**
4 **Public-private governance**

Architecture Requirements

Data Sharing

Data-sharing empowerment
Data-sharing trustworthiness
Data-sharing publication
Data-sharing economy
Data-sharing interoperability
Data space engineering flexibility
Data space community
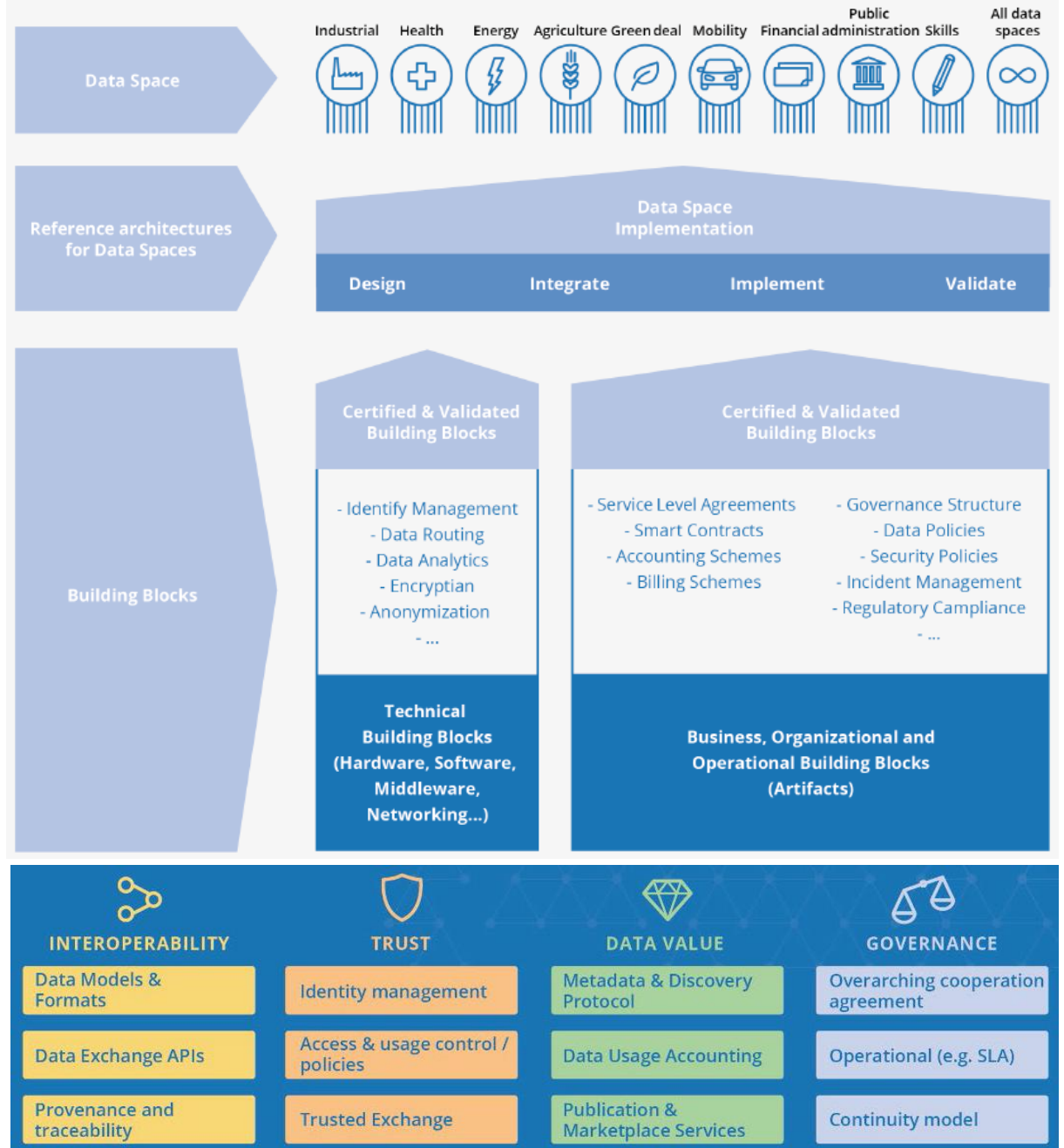
12 Principles for Data-Driven Ecosystem

	Principles	Challenges
1	Data spaces are **ecosystems of systems**	Structuring and operating an ecosystem of ecosystems
2	**Data usage** require provisioning from connecting devices	Creation of value associated with usage control
3	Data spaces support **data lifecycle**	Characterizing and managing data lifecycle
4	Data interoperability enabled by a **common language**	Common language for semantic interoperability
5	Data usage enabled by **common data models**	Common data models for behavioral interoperability
6	**Data curation**	Organisation, description, cleaning enhancing and preserving for public use
7	**Trust** in data sharing	Trustworthiness and risk management
8	**Governance** for ethical usage of data	Governance and ethics
9	**Decentralisation**	Decentralisation
10	**Integrated data management**	Data fabric
11	**Extensible data spaces**	Scaling-up data spaces
12	**User-centricity**	Business roles and interactions

Gyu Myoung Lee, AIOTI WG-ULA Technical Report, HSN workshop 2022, IoT Week 2022, etc.
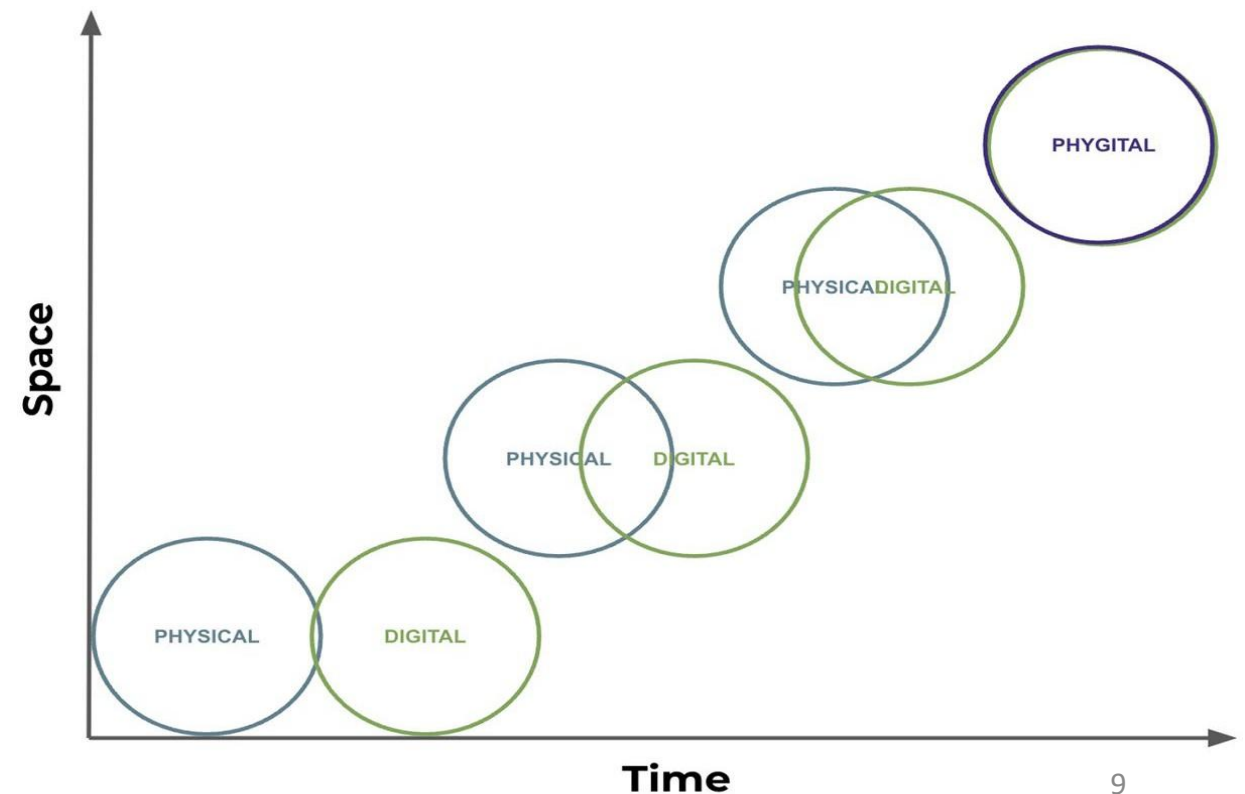
Digital Economy

- Platforms
  - Sharing participation/subscription

- Phygital era
  - On-Offline connection
  - Cyber-Physical Fusion

- Commons
  - Digital Assets
  - PCI Participation, Collaboration and Incentives

- **Commons (Concepts)**
  - Community
  - Transparency
  - Collaboration
  - User sovereignty
  - Incentives
  - Democratic decision making

New Internet

Declaration for the Future of the Internet

- An Internet that can deliver on the promise of connecting humankind and helping societies and democracies to thrive.

- The Internet should operate as **a single, decentralized network of networks**
    - Protection of Human Rights and Fundamental Freedoms
    - A Global Internet
    - Inclusive and Affordable Access to the Internet
    - Trust in the Digital Ecosystem
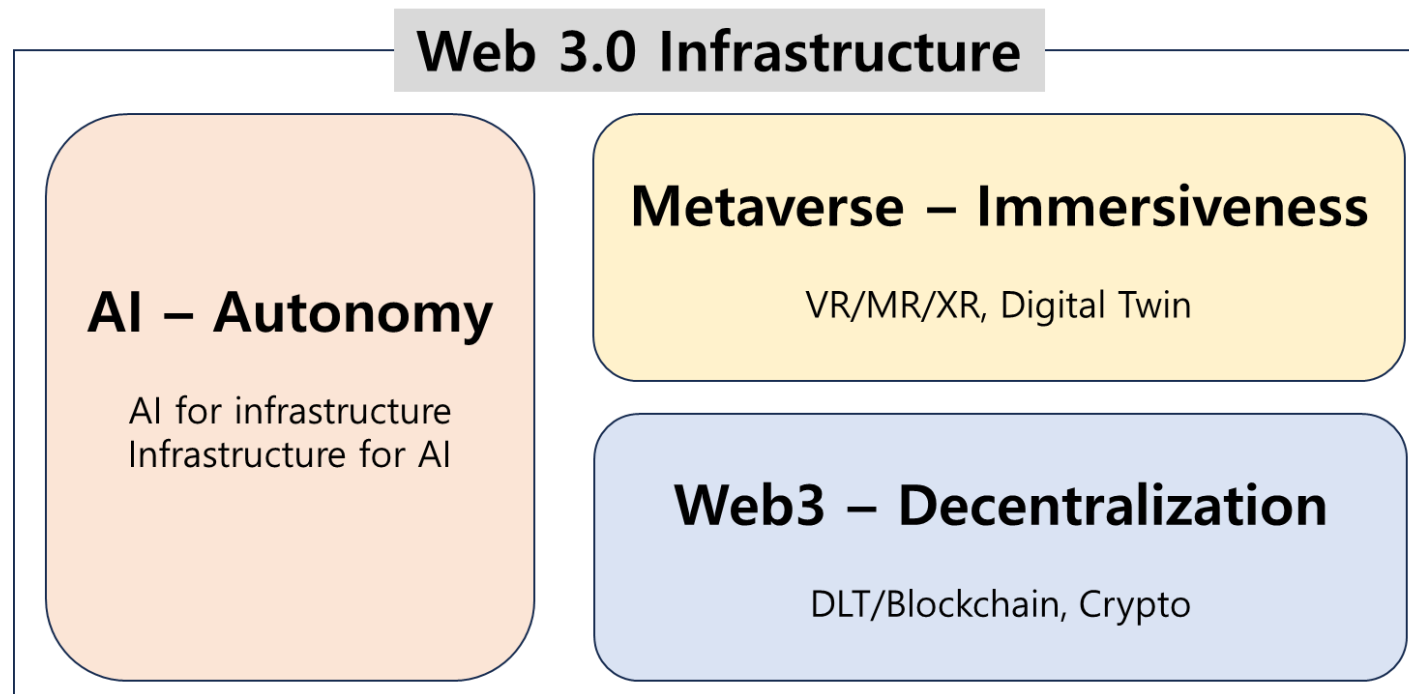   - Multistakeholder Internet Governance

https://www.state.gov/declaration-for-the-future-of-the-internet

Open Protocols
An effective regulatory framework will clearly differentiate between applications and protocols.

New Internet – Web 3.0

- Web 3.0 is the evolution of the Internet towards **user-centric intelligent services**
- From sharing economy to protocol economy (Commons)

Web 3.0 Infrastructure

AI – Autonomy

AI for infrastructure
Infrastructure for AI

Metaverse – Immersiveness

VR/MR/XR, Digital Twin

Web3 – Decentralization

DLT/Blockchain, Crypto

New Internet – Web 4.0

- The next stage in the evolution of the Internet, building upon the foundations of Web 3.0 - a more collaborative, user-centric, and intelligent approach to web creation and usage, leveraging technologies like AI, blockchain, and IoT
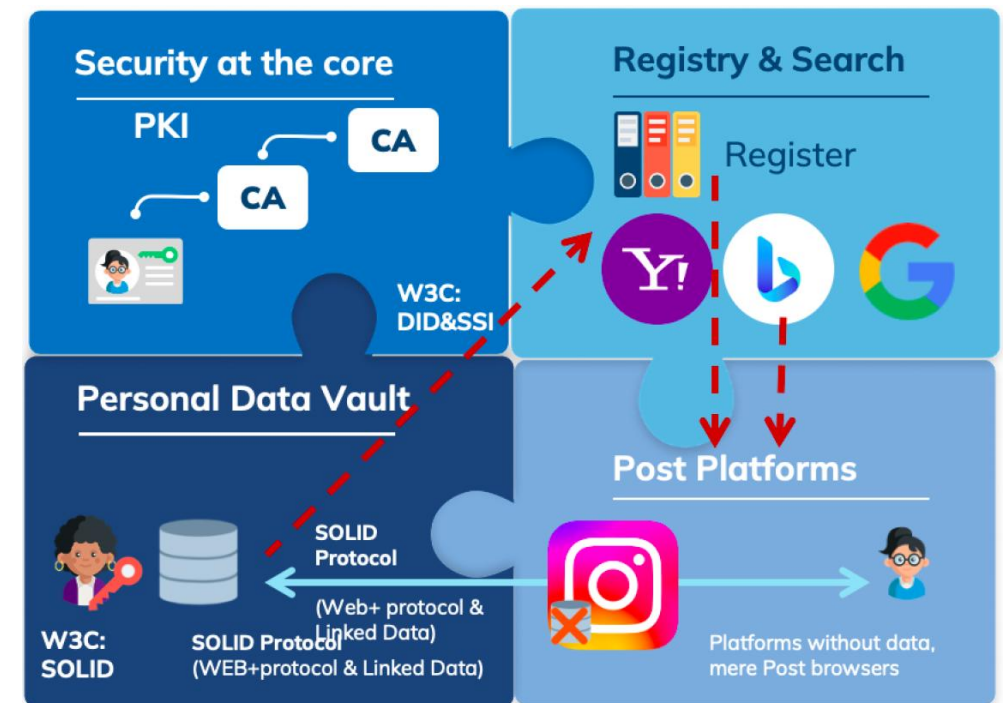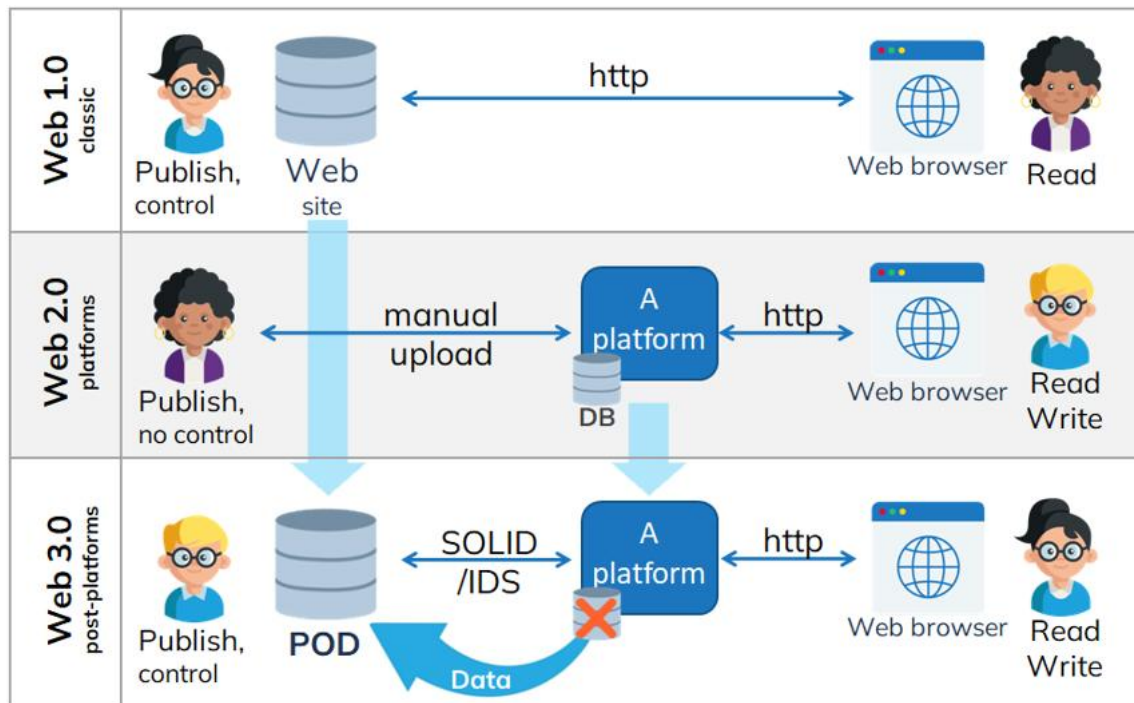
- **Collaborative and User-Centric**
- **Intelligent and Personalized**
- **Interconnected and Immersive**
- **Decentralized and Secure**
- **Data-Driven**

Web 1.0: The era of the static Internet
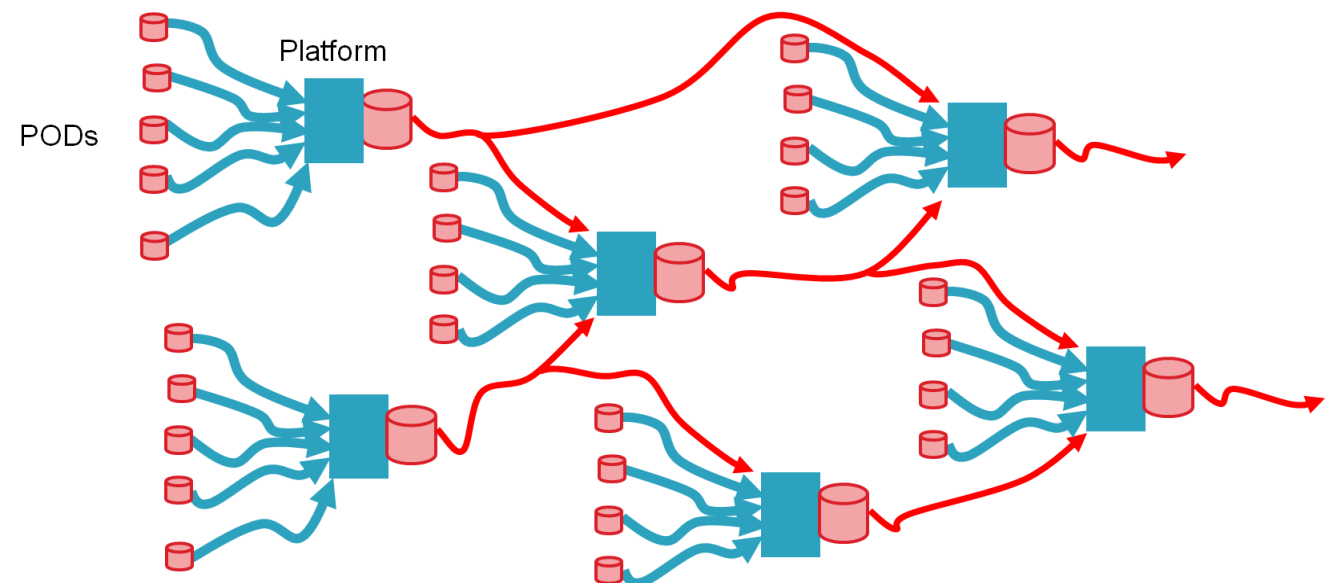**Web 2.0**: The participative, interactive era
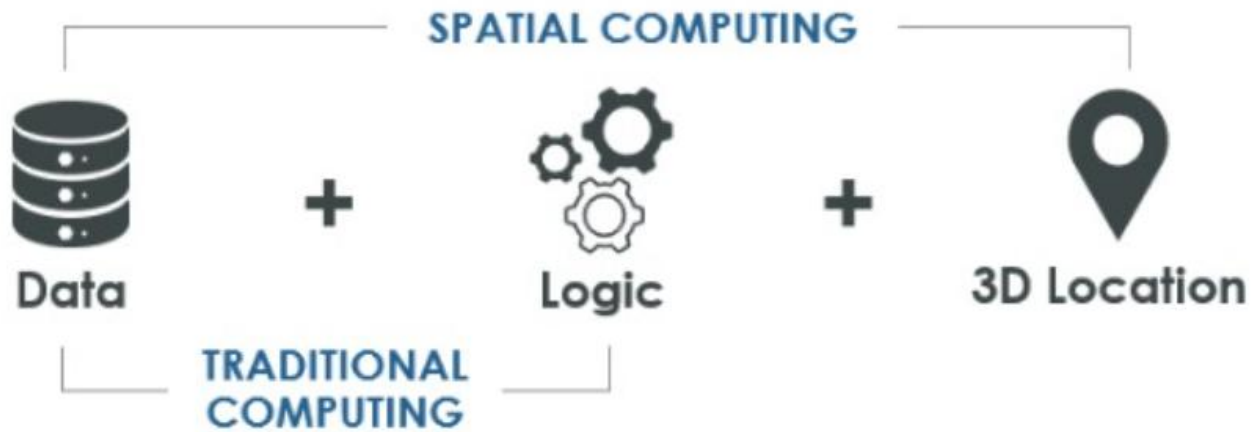**Web 3.0**: The networked future
Web 4.0: The intelligent future

Web 3.0 Data Space as a super-OS for platforms that provides everything they need, including user data and users themselves
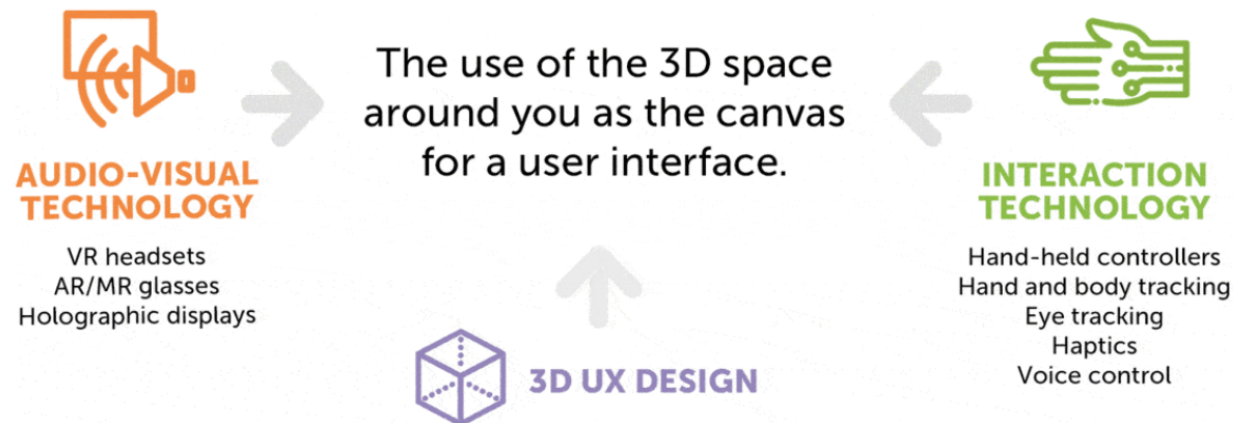
Spatial Computing/Web

SPATIAL COMPUTING

Data + Logic + 3D Location

TRADITIONAL COMPUTING

Spatial computing

The use of the 3D space around you as the canvas for a user interface.

AUDIO-VISUAL TECHNOLOGY
VR headsets
AR/MR glasses
Holographic displays

3D UX DESIGN

INTERACTION TECHNOLOGY
Hand-held controllers
Hand and body tracking
Eye tracking
Haptics
Voice control

https://www.ptc.com/en/blogs/corporate/what-is-spatial-computing

"The Spatial Web will transform every facet of our everyday lives."
Peter Diamandis

THE SPATIAL WEB

HOW WEB 3.0 WILL CONNECT HUMANS, MACHINES, AND AI TO TRANSFORM THE WORLD

GABRIEL RENÉ + DAN MAPES

Foreword by Jay Samit, former Independent Vice Chairman of Deloitte and author of Disrupt You!
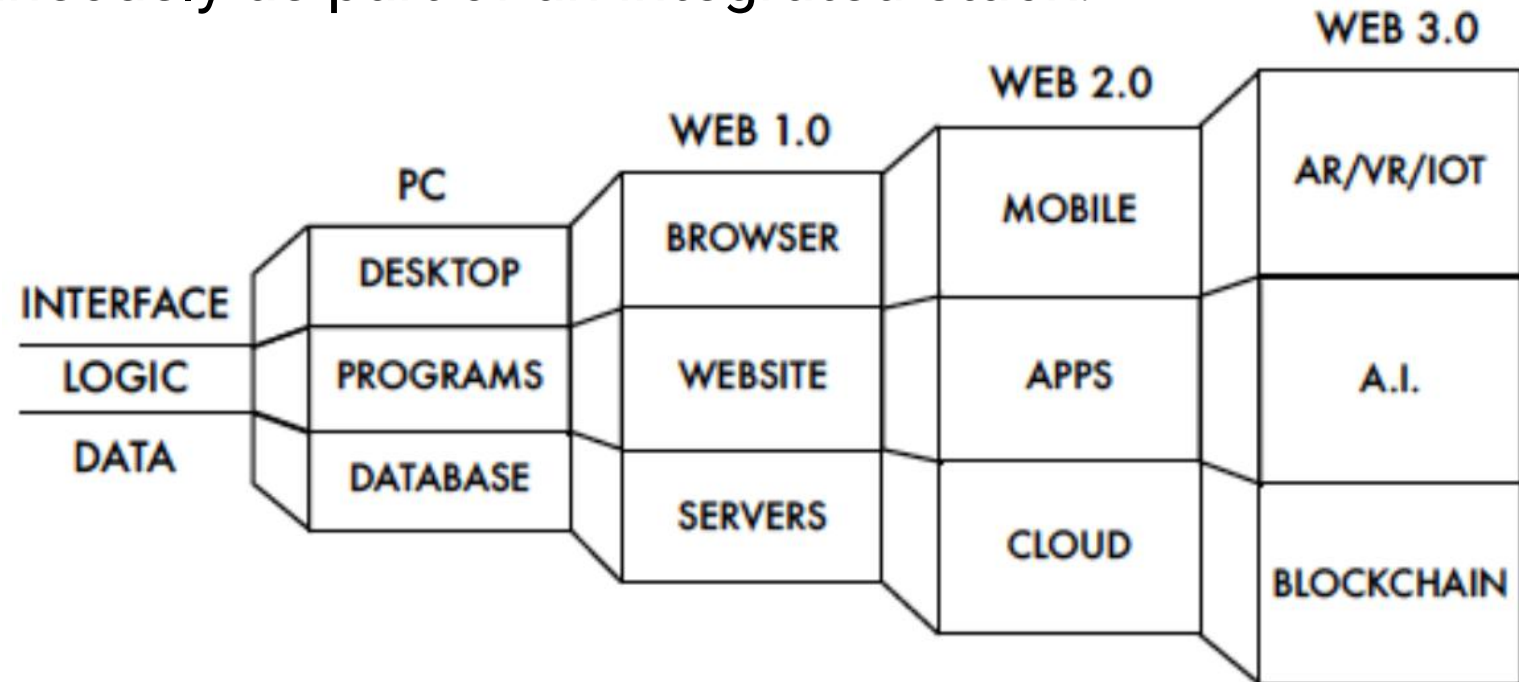
15
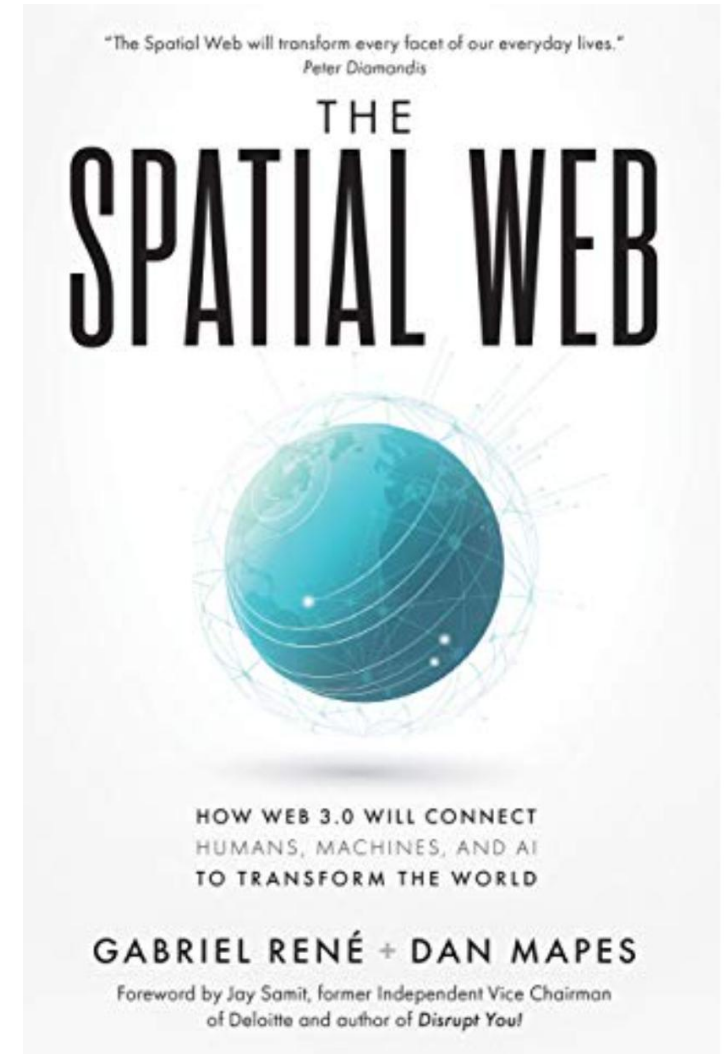
The Web 3.0 Stack Overview

Web 3.0 will utilize **Spatial** (AR, VR, MR), **Physical** (IoT, Wearables), **Cognitive** (ML, AI,) and **Distributed** (Blockchain, Edge) computing technologies, simultaneously as part of an integrated stack.

- **Interface Tier: Spatial**
- **Interface Tier: Physical**
- **Logic Tier: Cognitive**
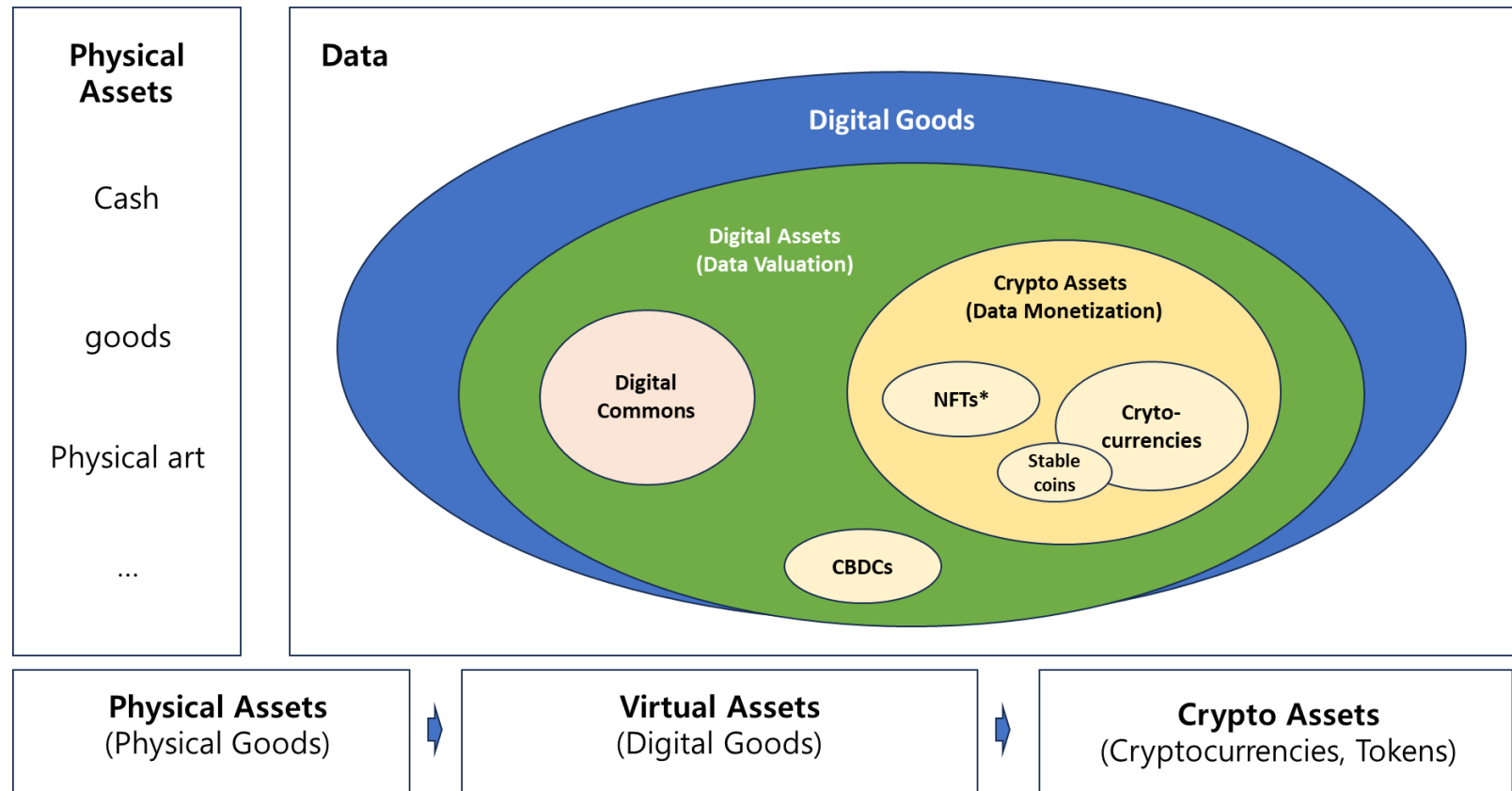- **Data Tier: Distributed**

Spatial evolution of the web

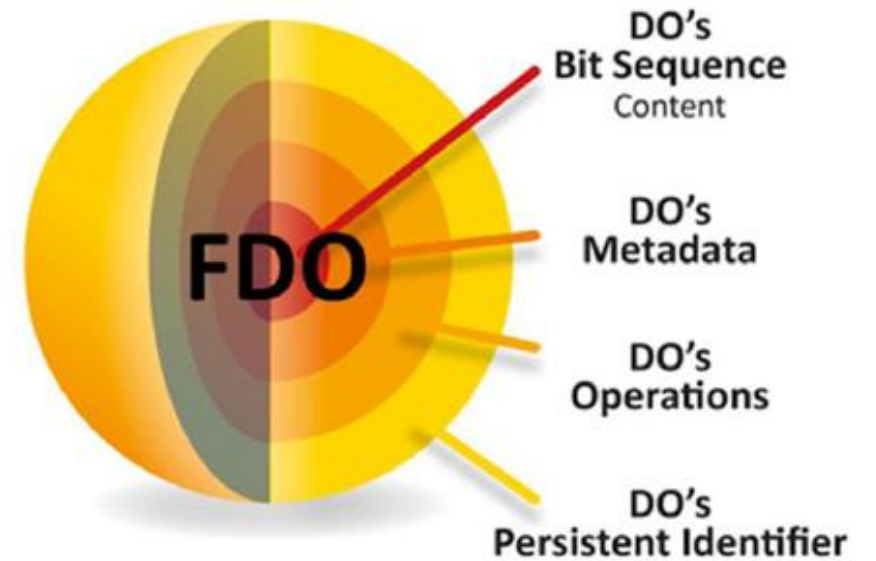**Connectivity of the web with the immersiveness of spatial computing**

Digital Assets

Digital Assets vs. Data

- A digital asset is anything that exists only in digital form and has a clear right of use or clear permission to use it.

- Data that does not have these rights is not considered an asset.

Physical Assets	Data
Cash goods Physical art ...	**Digital Goods** **Digital Assets (Data Valuation)** Digital Commons **Crypto Assets (Data Monetization)** NFTs* Cryto-currencies Stable coins CBDCs

Physical Assets (Physical Goods)	▶	Virtual Assets (Digital Goods)	▶	Crypto Assets (Cryptocurrencies, Tokens)

*Tokenized assets: utility tokens, asset tokens and payment tokens

Resources (Digital Assets) – FAIR Digital Objects

F indable   A ccessible   I nteroperable   R eusable

PID
contracts
metadata
descriptive   deep scien/ind   prov/context   rights
type
..... 24 23 22 20 18 16 14 14 16 18 20 22 23 15 .....

FDO

DO's Bit Sequence Content

DO's Metadata

DO's Operations

DO's Persistent Identifier
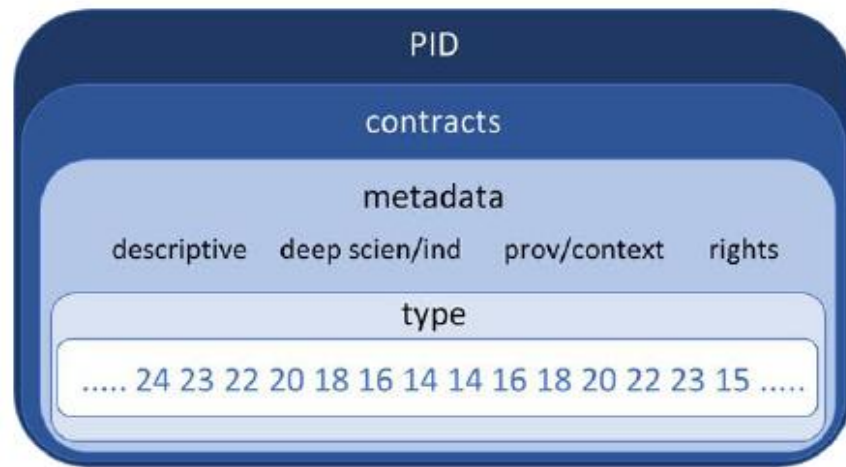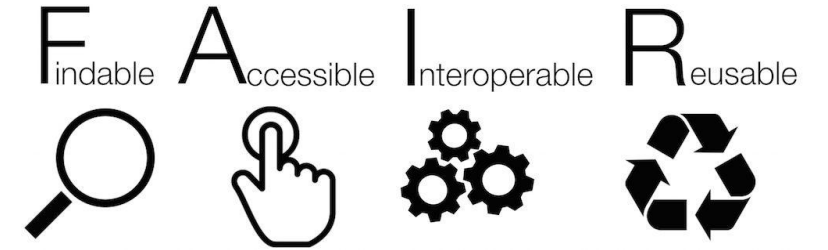
DO + "Machine Actionability" = FAIR DO

Digital Human

- A computer application that integrates the technologies of computer graphics, computer vision, intelligent speech, natural language processing. It can be used for digital content generation and human-computer interaction to help improve content production efficiency and user experience.
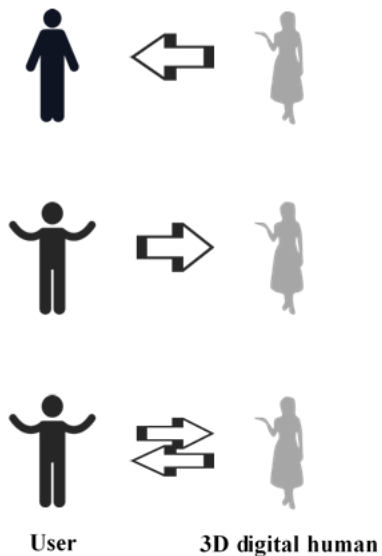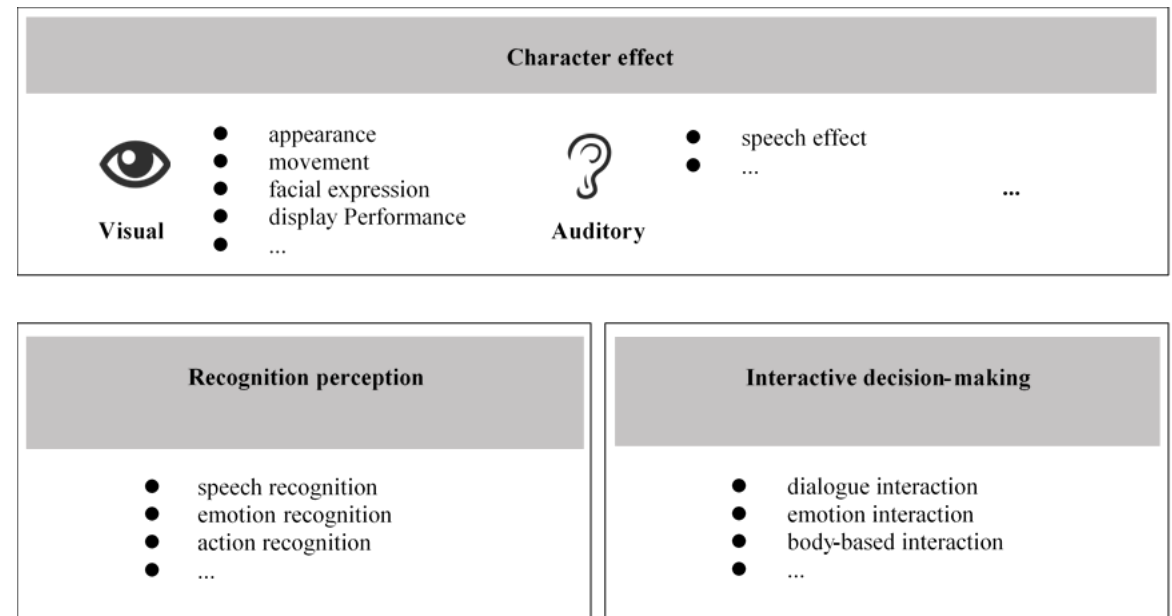

Character effect
The effects presented by digital humans that users directly perceive through sensory organs.

Recognition perception
The ability and effectiveness of digital humans to receive user input information.

Interactive decision-making
The ability of digital humans to interact "autonomously" with users.

User   3D digital human

Character effect

Visual
- appearance
- movement
- facial expression
- display Performance
- ...

Auditory
- speech effect
- ...
...

Recognition perception
- speech recognition
- emotion recognition
- action recognition
- ...

Interactive decision-making
- dialogue interaction
- emotion interaction
- body-based interaction
- ...

Supply chain and trading with marketplace

- IETF software supply chain use case
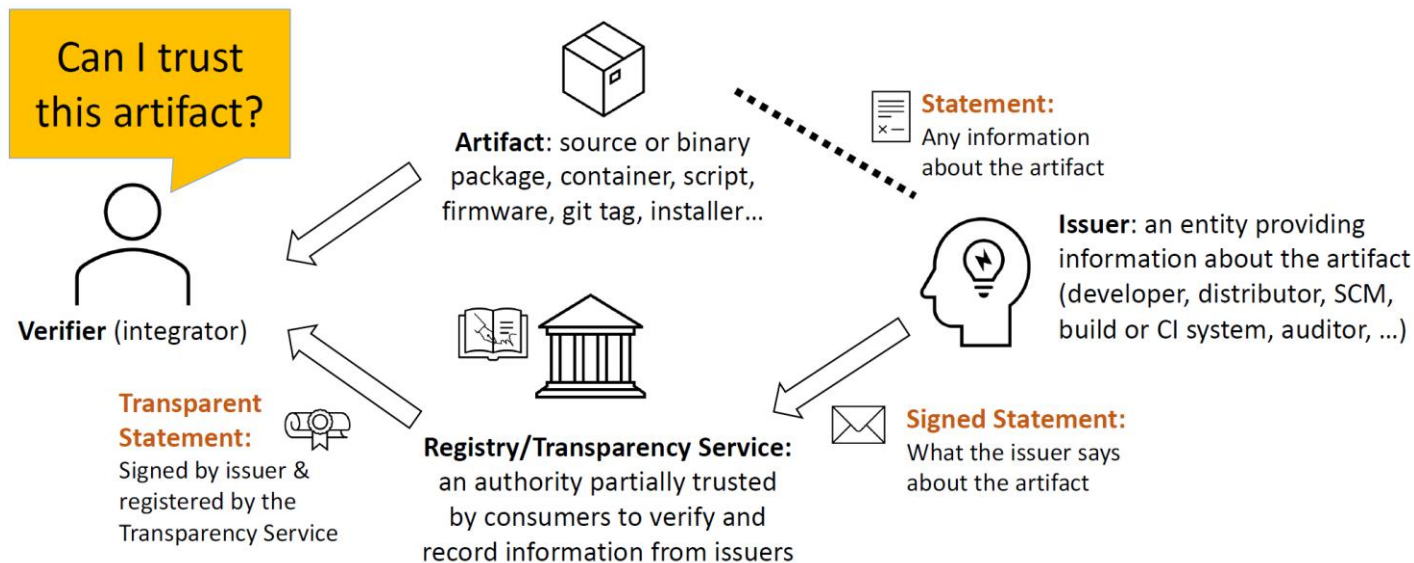
Quantifying data (digital assets) quality and value
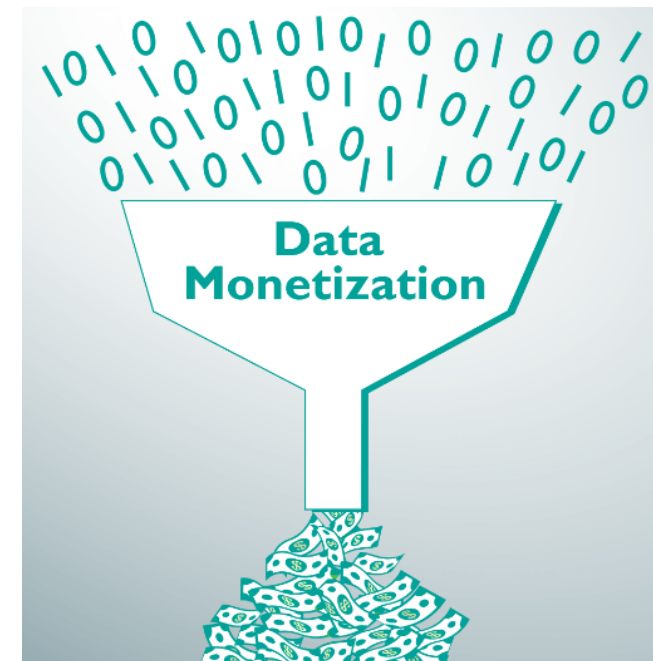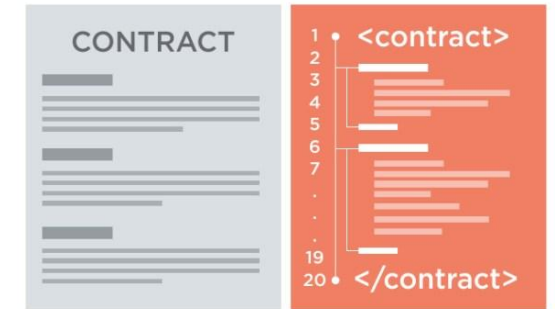
Trust and Governance
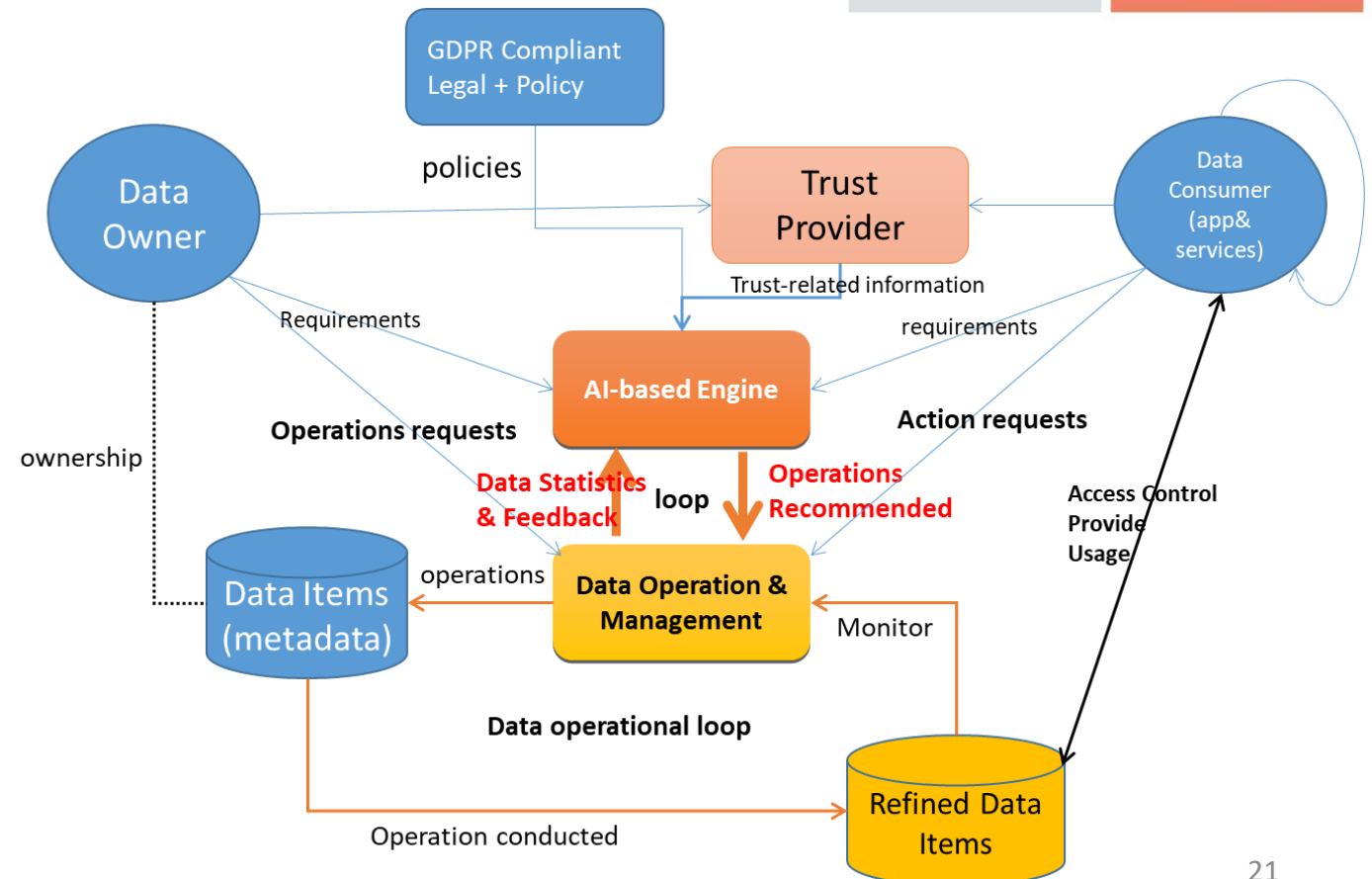
CONTRACT

`<contract>`
`</contract>`

- **TRiSM** - Trust, Risk and Security Management
  - Consent to share
  - Control of personal data
  - Privacy (GDPR Compliance)
  - Transparency
  - Accessibility
  - Fairness
  - Accountability
  - Security and data integrity
- **Governance by Technology**
  - Regulatory Sandbox
  - Lifecycle Management

GDPR Compliant Legal + Policy

policies

Data Owner

Trust Provider

Data Consumer (app& services)

Trust-related information

Requirements

requirements

AI-based Engine

Operations requests

Action requests

ownership

Data Statistics & Feedback

loop

Operations Recommended

Access Control Provide Usage

operations

Data Operation & Management

Data Items (metadata)

Monitor

Data operational loop

Refined Data Items

Operation conducted

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Trust in AI

#1: Explainability
Can I explain the decision?

#2: Robustness
Is it secure and compliant?

#3: Bias
Have I been unfair?

Provenance · Data · Trust · Credibility

REBOOTING AI
Building Artificial Intelligence We Can Trust

DATA FOR THE PEOPLE
HOW TO MAKE OUR POST-PRIVACY ECONOMY WORK FOR YOU
ANDREAS WEIGEND

$\widehat{P}_A \lesseqgtr P_H$
Decision-Making
Human

Choice behavior — Observe

$\widehat{P}_H \lesseqgtr P_A$
Observe & Detect
TCAI

Selection Problem

P_H Human — System Transparency — P_A Task-AI

TCC
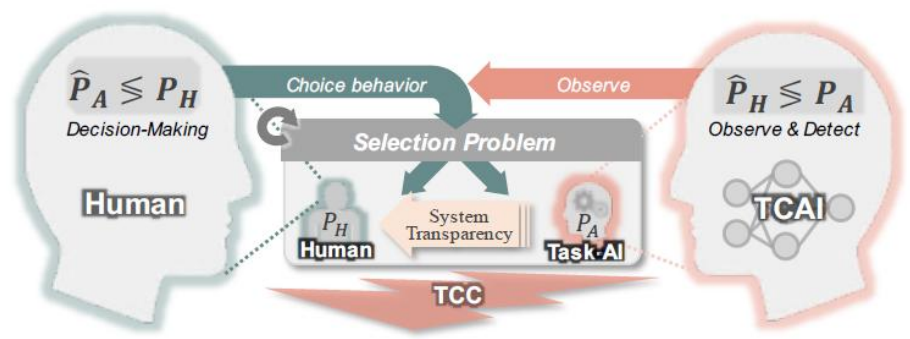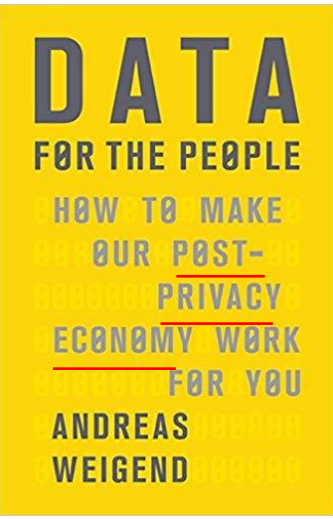
TCAI: Trust Calibration AI, TCCL Trust Calibration Cues

	Same operator	AI service provider	3rd party provider	
App Layer	Inter-App Trust	App Trustworthiness	Stakeholder Trust	AI App Trust
	Other Apps — AI Service →	AI App — AI Service →	AI App User	
		Prediction, Decision or Classification ↑		
Model Layer		Model Execution	Model Validating Capabilities Trust	AI Model Trust
	Design Trust / Process Trust	Stakeholder Trust		
	Model Design → Model Implemen-tation — Model →	Model Sandbox ← Model —	Model Seller	
Data Layer		Data Pre-processing	Data Processing Capabilities Trust	Data Trust
	Device Trust	Stakeholder Trust		
	Data Source (Sensor) — Data / Network Trust →	Data Storage(DB) ← Data / Network Trust —	Data Seller	

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Towards AI Infrastructure

- **AI for Infrastructure**
  - how AI-inspired techniques can pilot and monitor the continuum and, in so doing, provide solutions

- **Infrastructure for AI**
  - re-designing the infrastructure to efficiently deal with data analysis and machine learning

- **AI for Science, Industry and Societal Challenges**
  - the ever-increasing need to exploit AI techniques for extreme-scale, combining Data and Compute through the interpretation and coupling of computing results, measurements and observations

https://etp4hpc.eu/digital-continuum/

Smart Networks and Services with AI

- Future 6G networks will be fully integrated with all societal infrastructure: smart networks and services

Smart Networks and Services: it is not about end-to-end transport any more

Smart Networks and Services: a distributed, virtual, tailored ICT services factory with AI

Key approaches for innovation

- **Microservices – Containerization**
  - Create applications from many different services
  - Application is comprised of several smaller parts and Microservices can be containerized.
- **Composable modular approach**
  - Challenges for user driven service creation and composition
- **Fluid Platform**
  - Architectural consistency and composability (A unifying architectural principle)
- **Data Pipeline and Data Fabric**
  - A series of steps
  - An integrated data management platform
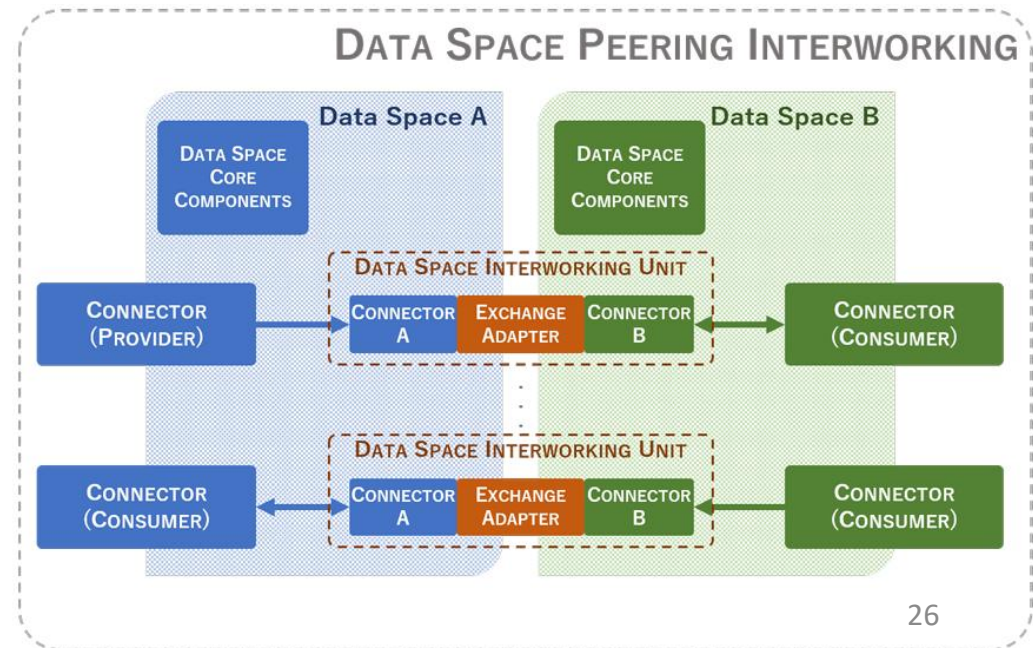
Architectural framework

- Composable architecture – Modular approach
  - Gartner
    - Super-apps (2023)
    - Composable Application (2022)
    - Intelligent Composable Business (2021)

- FIWARE – Connector
  - TRUE (TRUsted Engineering) Connector

**Gartner's Reference Model for Intelligent Composable Business Applications**

DATA SPACE PEERING INTERWORKING
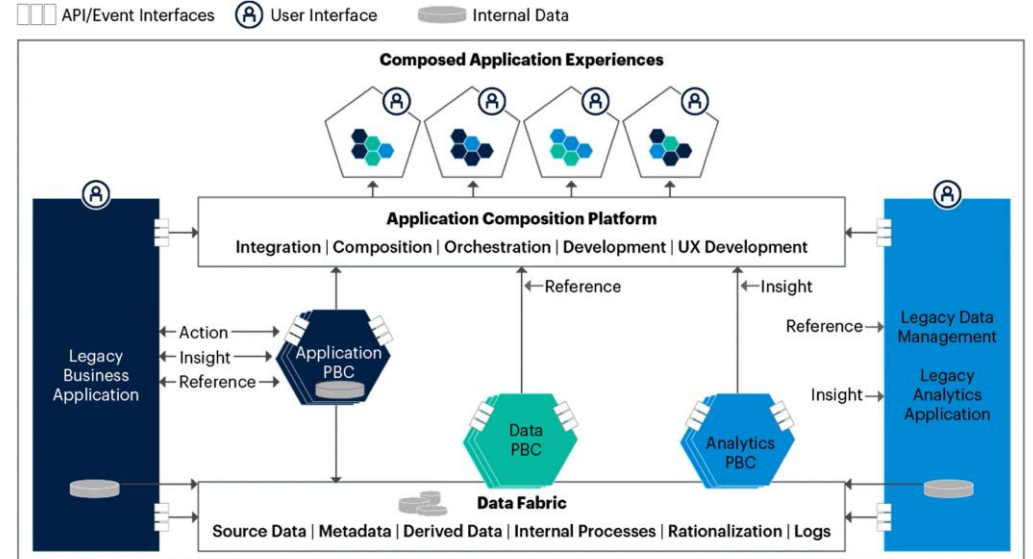
Digital Twins and AI

- Digital twin serves as interaction interface for integrating the virtual and physical worlds, allowing users to extend their experience beyond the confines of the virtual environment.

- The Role of AI for Digital Twins
  - optimization (model creation)
  - optimization (model updating)
  - generative modelling
  - data analytics
  - predictive analytics
  - decision making
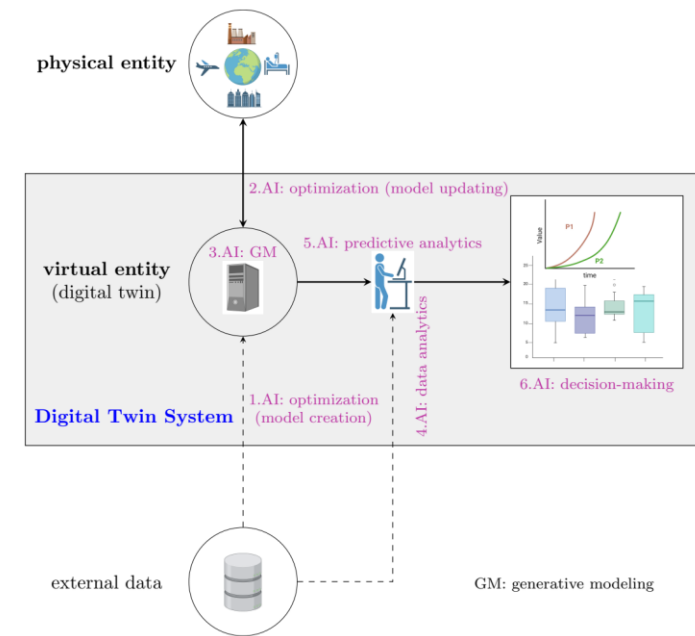
Source: What Is the Role of AI for Digital Twins? mdpi.com/2673-2688/4/3/38
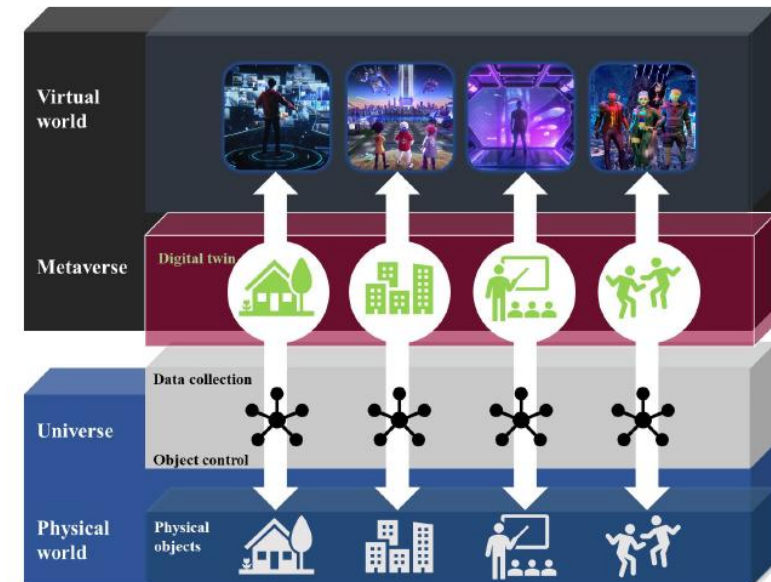
Source: FGMV-28

Related Activities

ITU-T – Web 3.0 ad-hoc activities

Web 3.0: **Decentralized online ecosystem based on DLT/Blockchain technology, forming a token-based economics**

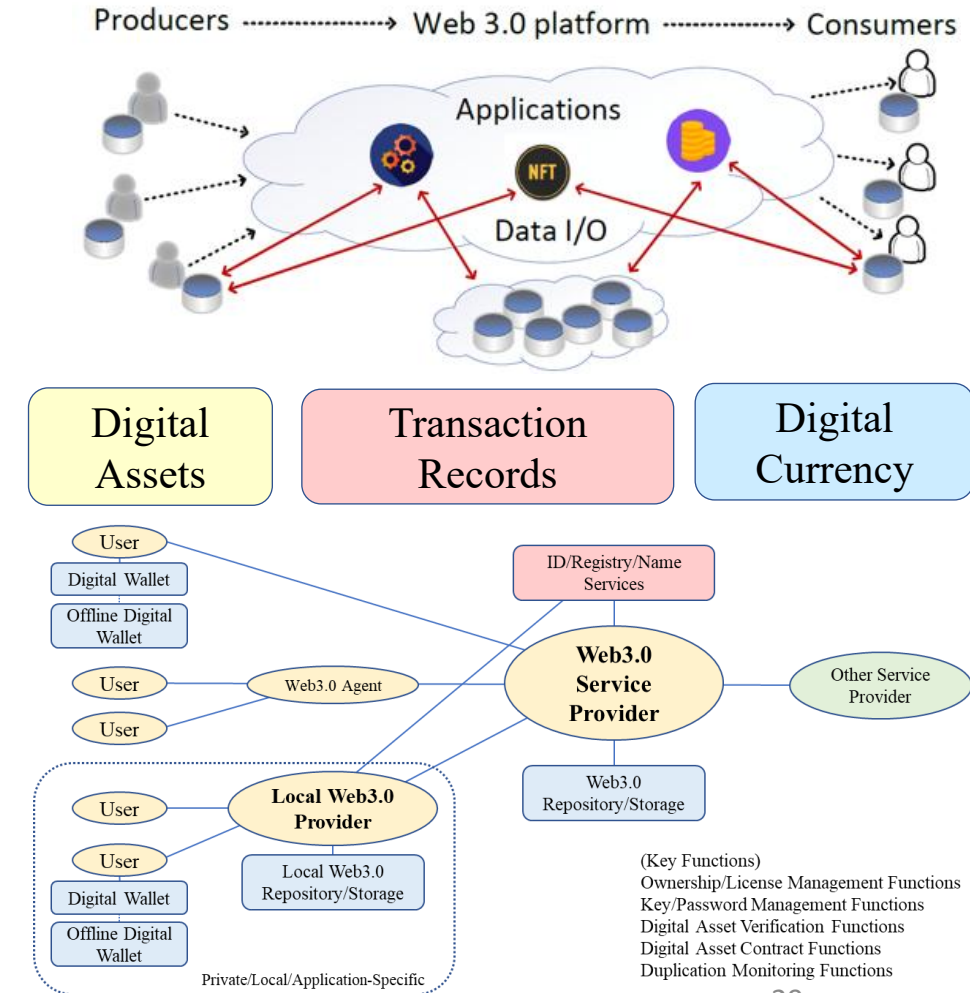## Ad-hoc group on "Future ICT evolution for emerging Web era" in ITU-T

- Technical Report - "**Trustworthy Data Infrastructure for Digital Assets Trading**"
- Technical Report - "Network enhancement for supporting Web 3.0"

Technical Challenges for Web 3.0

- Ownership and usage rights of digital assets
- ID provisioning for digital assets
- Privacy protection and repositories
- Smart contract and legal inspection
- Data modelling of digital assets

Key capabilities for digital asset trading

- **ID management**: User authentication, authorization management, KYC functions
- **Digital asset management**: Creation, storage, transfer, ownership registration, tracking, encryption of digital assets
- **Trading management**: Smart contracts, compliance, tracking of illegal activities
- **Security management**: Digital asset protection, encryption key management

IEEE - Spatial Web

APPLICATION SCENARIOS

Warehouse Robot | Industrial XR | Urban Autonomous Mobility | Global Supply Chain | Cultural Location Tourism | Urban Digital Twin: Smart Cities | Digital Earth: Greenhouse Gases | Entertainment XR

STAKEHOLDER PERSPECTIVES

Virtual Representations of Physical Entities | Immersive Shared Experiences | Multi-scale Cognitive Computing | Hyperspace Geography | Federated Governance

HSML ENTITIES — Domain, Channel, Activity, Space, Credential

COMPUTING CONTINUUM — User Clients; Local Servers & Cloud Computing; Edge Computing; Physical Devices

HSTP USE CASES — Actor; Spatial Web Client; HSTP Message HSML Content; Spatial Web Node

COMPLIANCE TARGETS

HSML Implementation Specification | HSTP Implementation Specification | Distributed UDG System Specification | Spatial Web Federation Governance | Domain Architecture Specifications

Ref) IEEE P2874 Working Group
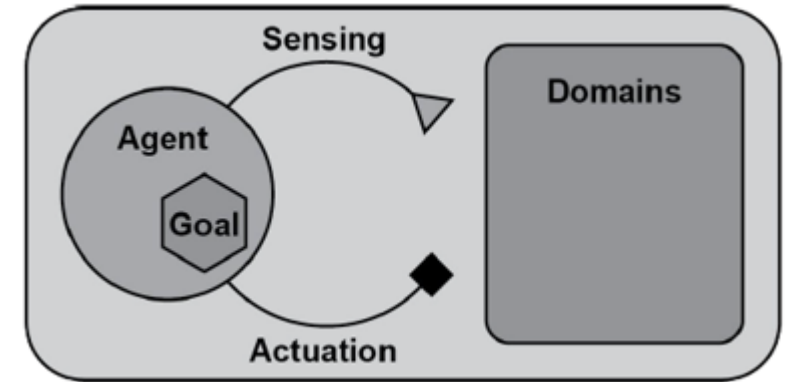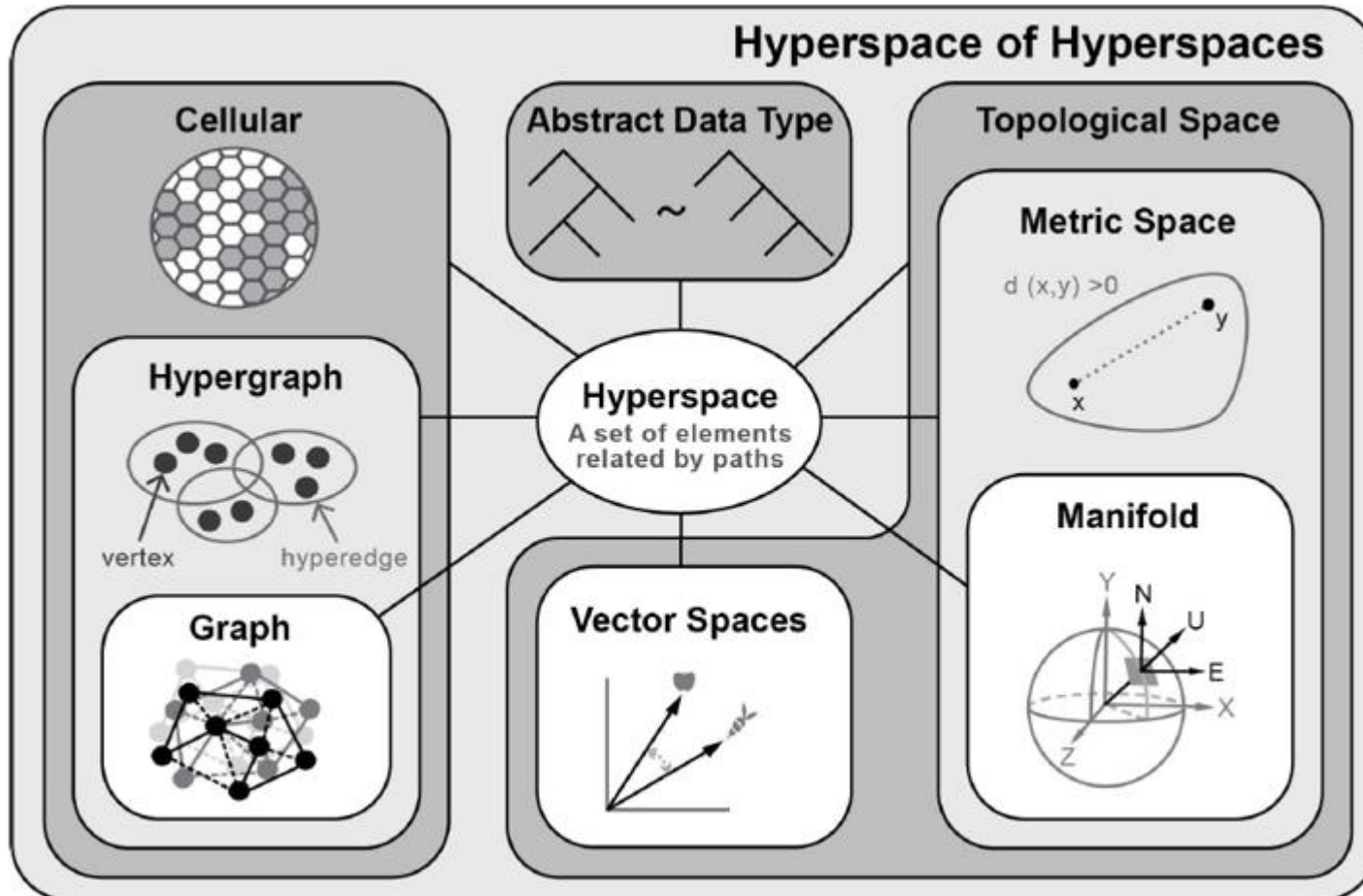
Hyperspace

- Agents provide the critical layer of intelligence that transforms data into meaningful action

- HSML Activities support the encoding, decoding, execution, and governance of those actions

NOTE – HSML: Hyper**space** Modeling Language

Self-sovereign identity

- W3C
  - Decentralized Identifiers (DIDs) v1.0
- IETF
  - Supply Chain Integrity, Transparency, and Trust (SCITT)
    - Software Supply Chain Use Cases
  - Trust Enhanced Networking
    - Identity Management for Trust
- ITU-T FG-Metaverse
  - Requirements and framework for digital identity system
  - Interoperability and migration of identity of things across metaverses

(Source) Decentralized Identifiers and Self-sovereign Identity in 6G
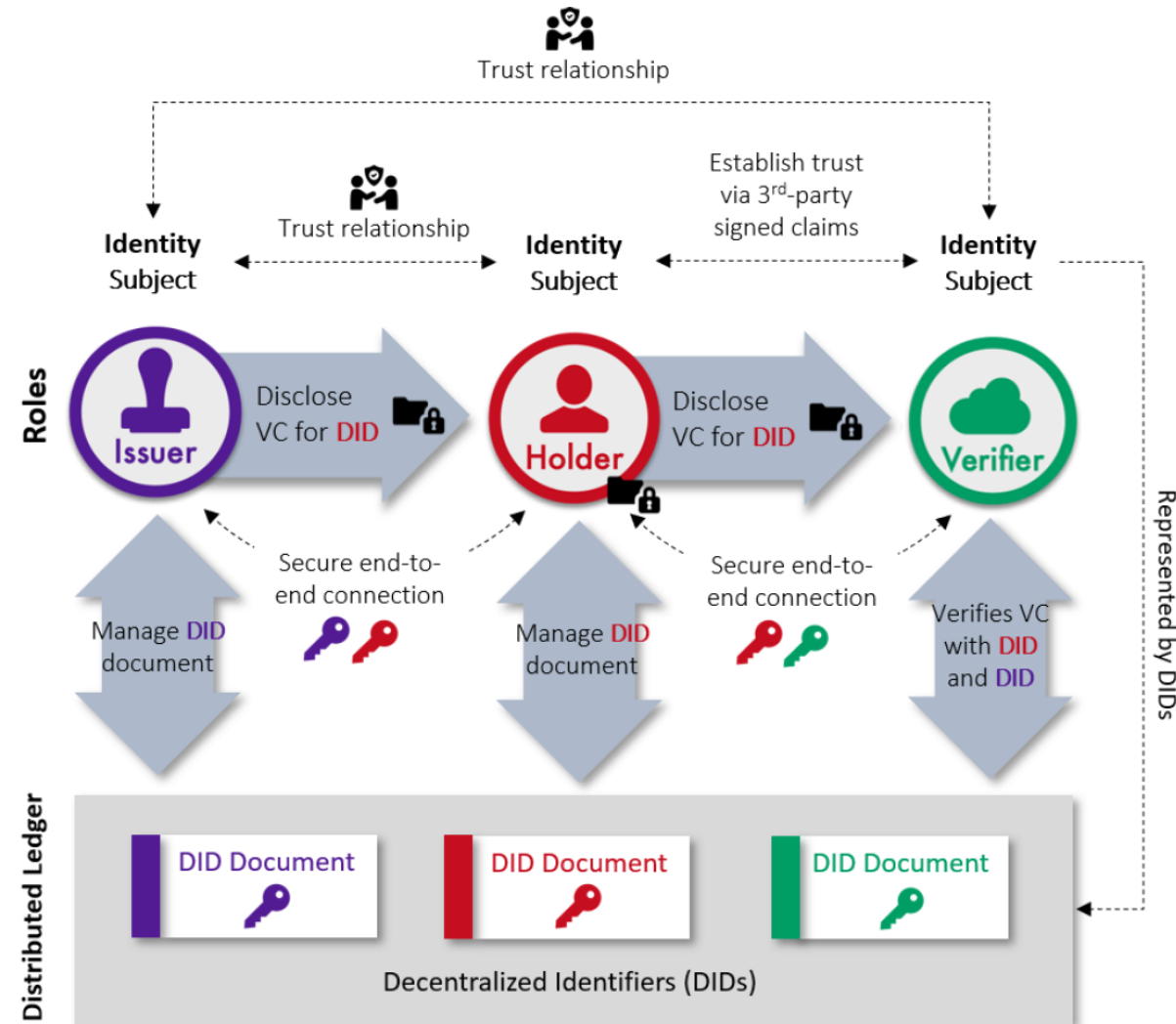
Designing AI Infrastructure

Digital Platform as AI infrastructure

- From Cloud to Edge: Decentralization

- AI/Computing/Trust Native: In-network native and modular approach (energy efficient)

- Multi-tier heterogeneous resources: Minimizing complexity with AI

- Service mining: Crowd driven AI-powered Trustworthy Service Composition

- Trustworthy services: TrustChain (Lightweight distributed ledger with smart contract)

- Autonomous operations: SelfOps (Self-evolving and self-adapting service operations)

- Participation, Collaboration and Incentives: Collaboratively Evolving Platforms at Scale

Considerations

- Users (prosumers, contributors, creators)
  - Personalized services, user-centric service creation and management, rich experience, adding values to services
- Different types of resources
  - Data (digital assets, sensing data, trained data,...), computing, communication, learning (AI models, parameters,....), composable digital twins/microservices, ...
- Operation (Self-evolving and self-adapting)
  - Mining + service composition/chaining
- Optimization
  - Energy efficiency, minimize complexity
- Trust
  - Testing and validation, distributed ledgers
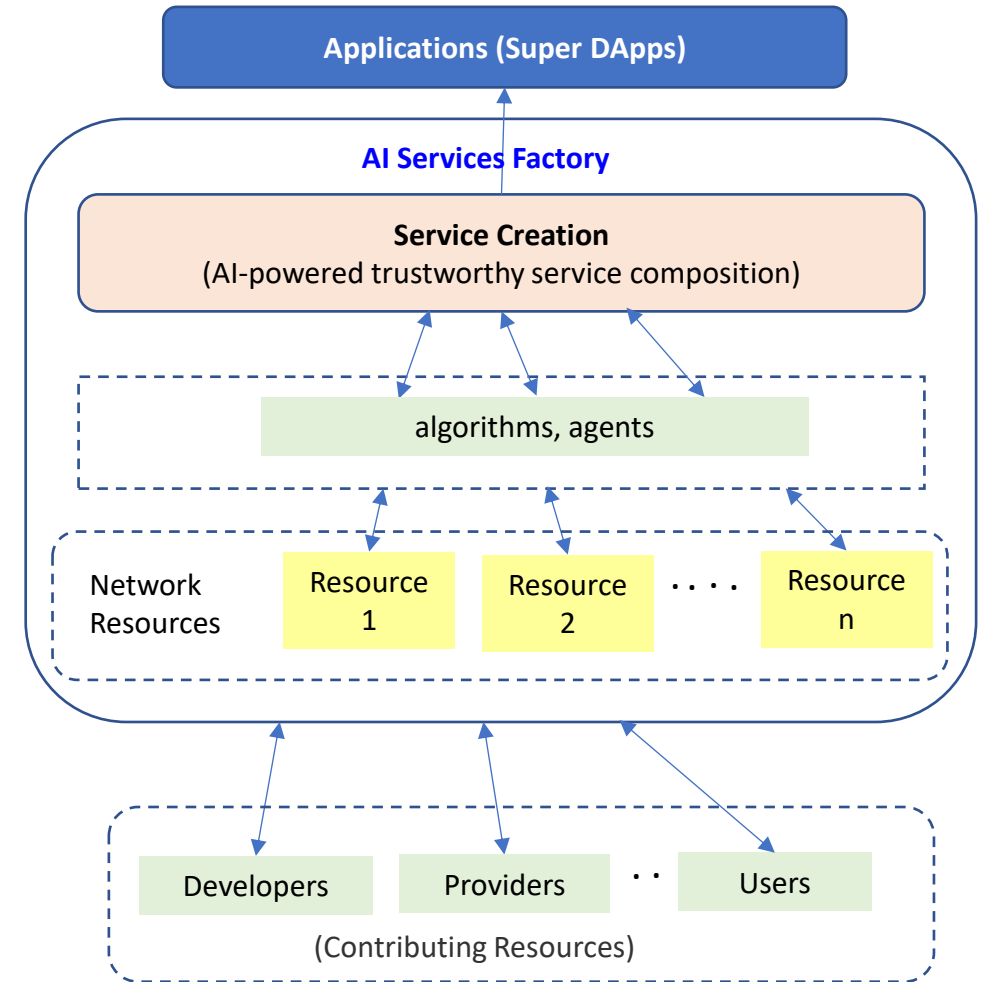
Technical Features

- **Componentization (Composability)**
  - Large services are divided into small sets of services and literally they should communicate with each other independently without relying on shared resources. Further, several components at the bottom layer may join to compose new services at upper layers.

- **Bottom up approach (Contribution driven)**
  - The approach encourages researchers and developers to start with simpler versions of services which fulfil the preliminary requirements of the final goal and improve each individual composable service in an iterative manner for greater performance.

- **Collaboration and Incentives**
  - With the P-C-I concept, composable services engage collaborative exchange information during execution time to fulfil the goal of a given AI task with a competition-reward business strategy to incentivise resource/mining contributions and reward resource/energy-efficient data services.

- **Hierarchical fluid decision management**
  - The architecture decomposes the burden of decision-making by integrating vertical decision-making hierarchy. The bottom level comprises comparatively smaller intelligent agents, but they can act quickly on emergency in a real-time manner. On the other hand, upper layer services do the handling of decisions which requires high computational resources but in a non real-time manner.

AI, Computing and Trust Native

- **AI Native**
  - To support the growing demand for AI-enabled cloud-edge-IoT and its applications, an AI Native feature identifies various AI models and characteristics of each set of data and responds accordingly.
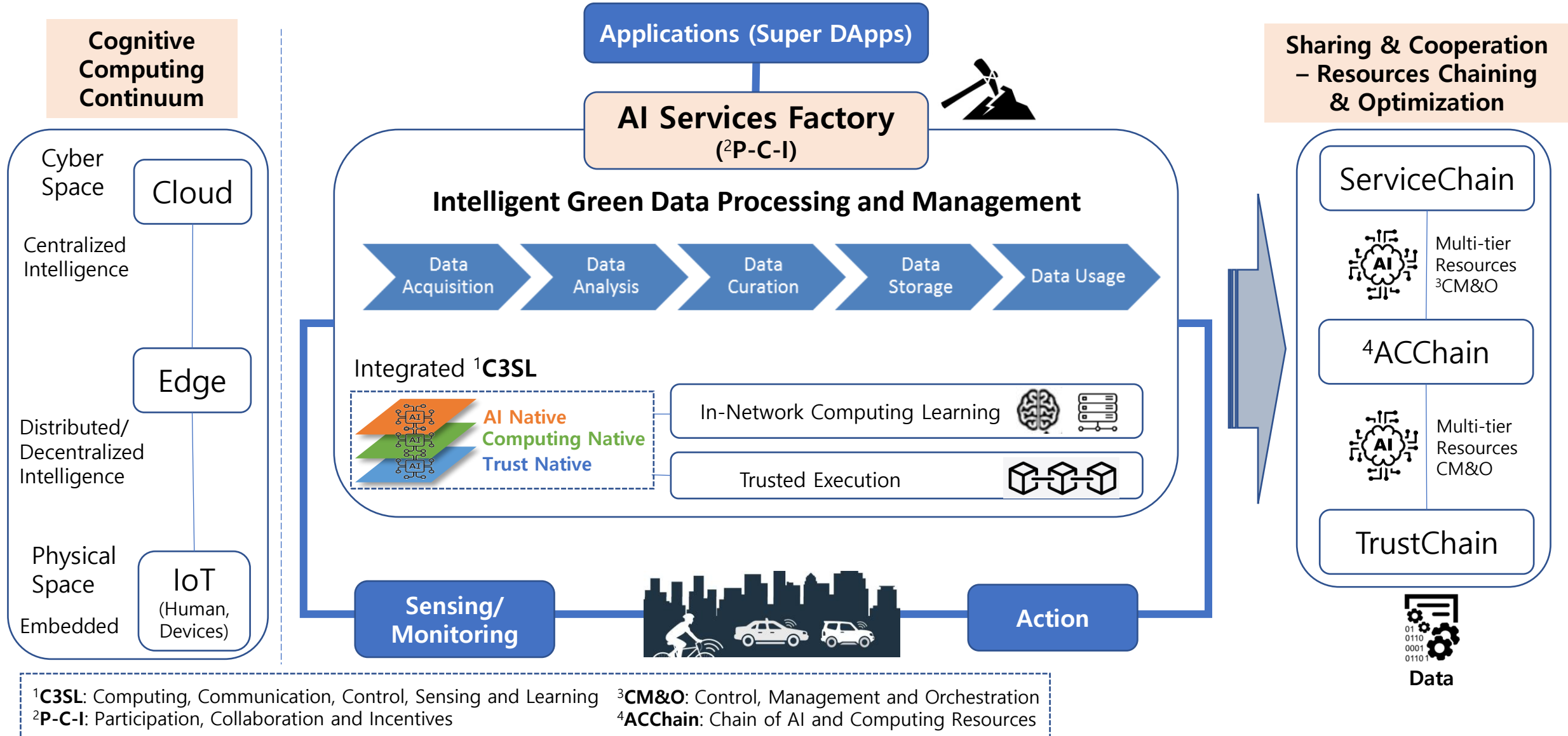
- **Computing Native**
  - Evolving cloud-edge services and applications require in-time computing, and in order for the network to accommodate these requirements, a Computing Native feature supports AI acceleration.

- **Trust Native**
  - As a large number of data and model parameters must be transmitted through the network for distributed AI (learning/inference), a Trust Native feature provides a reliable execution environment as well as the services running atop.

Autonomous Trustworthy AI Services for Intelligent Green Data Processing and Management

Applications (Super DApps)

AI Services Factory (^{2}P-C-I)

Sharing & Cooperation – Resources Chaining & Optimization

Cyber Space

Cloud

Centralized Intelligence

Distributed/ Decentralized Intelligence

Edge

Physical Space

IoT (Human, Devices)

Embedded

Intelligent Green Data Processing and Management

Data Acquisition → Data Analysis → Data Curation → Data Storage → Data Usage

Integrated ^{1}**C3SL**

AI Native
Computing Native
Trust Native

In-Network Computing Learning

Trusted Execution

Sensing/ Monitoring

Action

ServiceChain

Multi-tier Resources ^{3}CM&O

^{4}ACChain

Multi-tier Resources CM&O

TrustChain

Data

^{1}**C3SL**: Computing, Communication, Control, Sensing and Learning ^{3}**CM&O**: Control, Management and Orchestration
^{2}**P-C-I**: Participation, Collaboration and Incentives ^{4}**ACChain**: Chain of AI and Computing Resources

Co-creation of AI powered digital twins

- User-driven Composable Digital Twins using trusted and federated concepts
  - Creation of personalized atomic digital twin with data sovereignty and embedded intelligence
  - Composition of atomic digital twins
  - Building up large scale federated digital twins with AI capabilities
  - Supporting ICO (Interoperability, Composability and Orchestration)

Collaboratively Evolving Infrastructure

- Self-evolving and self-adapting
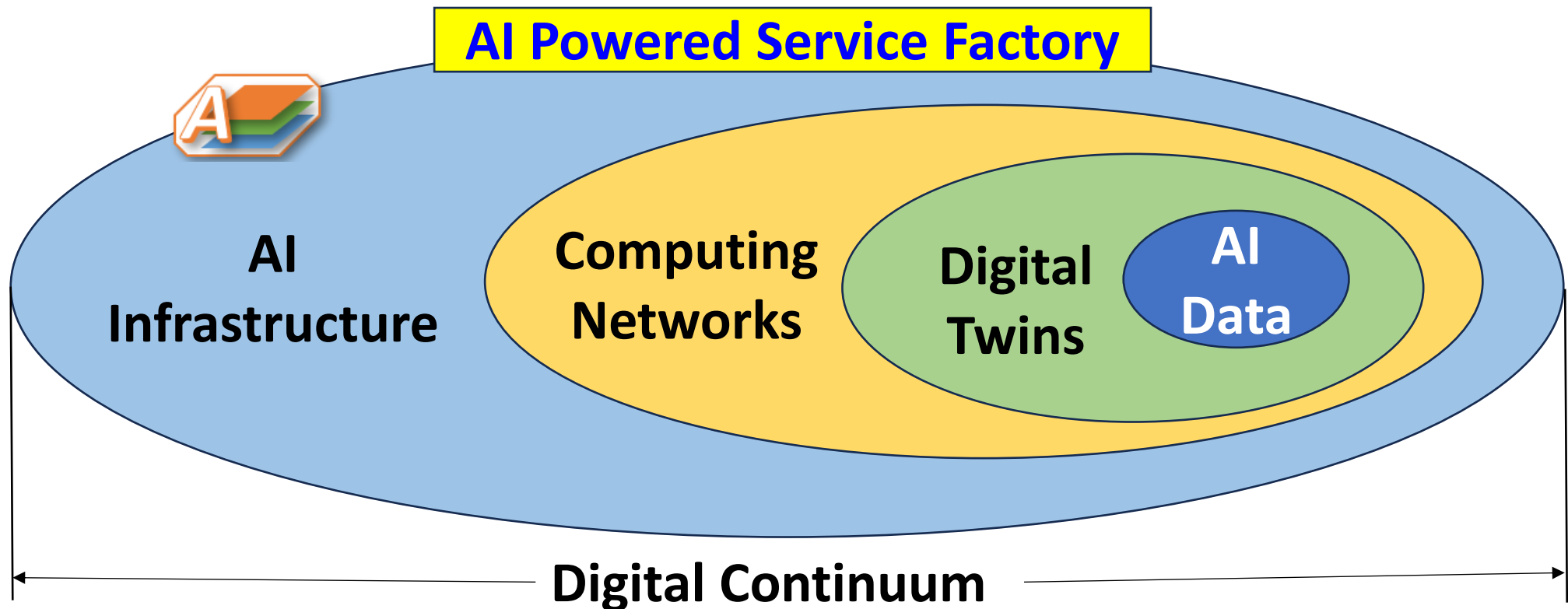- AI-Ops
- Data lifecycle
- Workflow management

Source: Gartner

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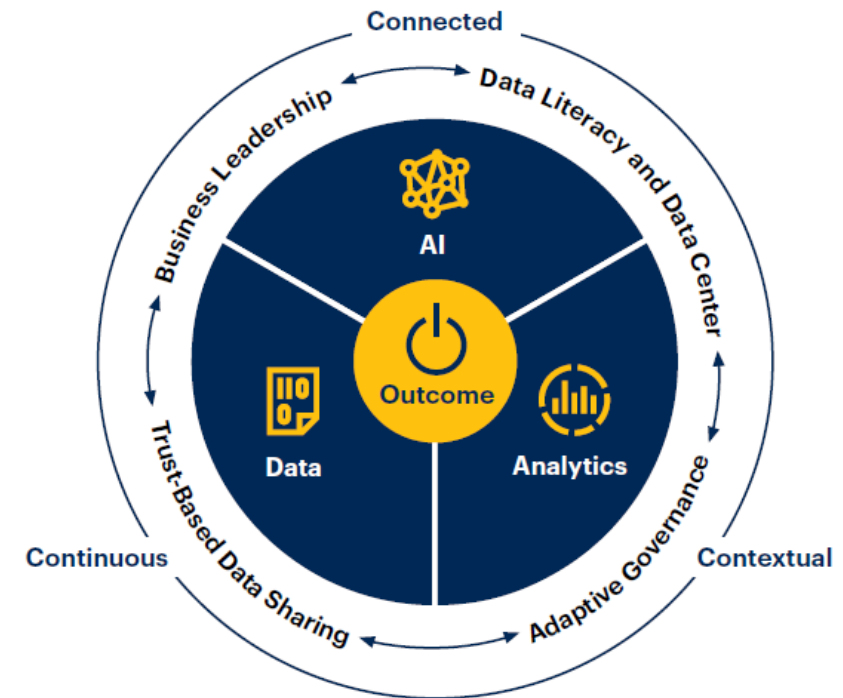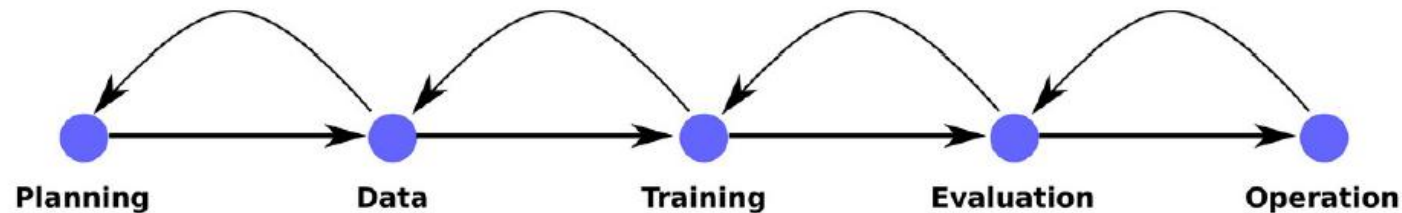
The Role of AI Infrastructure

- Fully automated infrastructure with connected intelligence
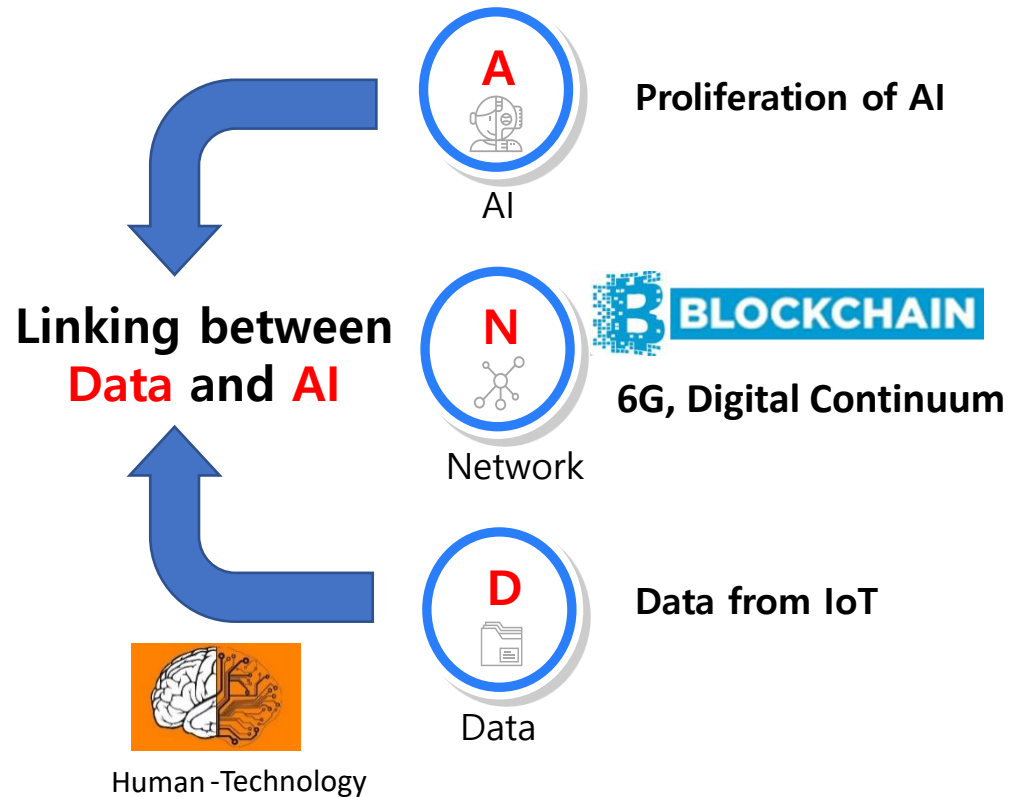 - **Trustworthy Decentralized AI Infrastructure – AI everywhere**

Research for the future of the Internet

- **Web 4.0: Human-centric digital continuum**
  - Design a new Internet infrastructure towards a shared vision for Web 4.0 with the concept of the digital continuum
  - Build a decentralised, collaborative and trustworthy DNA (Data-Network-AI) ecosystem for an intelligent future
  - Develop human-centric, autonomous services and applications to create highly personalised, spatial Web experiences
  - Adopt emerging quantum technologies, such as quantum computing, communication and sensing

Conclusion

Towards Digital Economy with AI Infrastructure

AI Infrastructure

Linking between Data and AI

- **A** — AI — Proliferation of AI
- **N** — Network — BLOCKCHAIN — 6G, Digital Continuum
- **D** — Data — Data from IoT

Human -Technology

Trustworhiness in DNA Ecosystem

- Transparency
- Data protection
- Privacy preserving
- Policy and regulatory issues
- Ethics