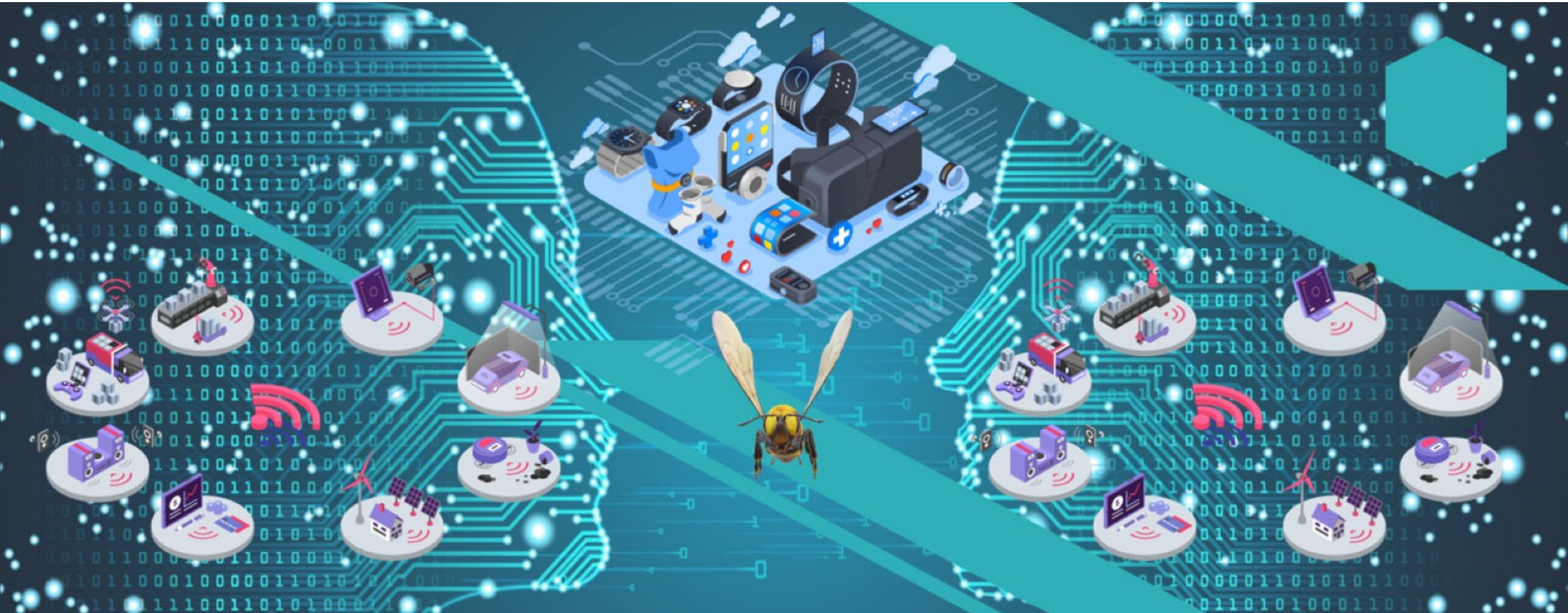


Autonomous self-organized edge IoT intelligent systems
Research directions

TECoSA, Thursday, February 3, 2022
KTH Royal Institute of Technology

Ovidiu Vermesan
Chief Scientist, SINTEF, NORWAY

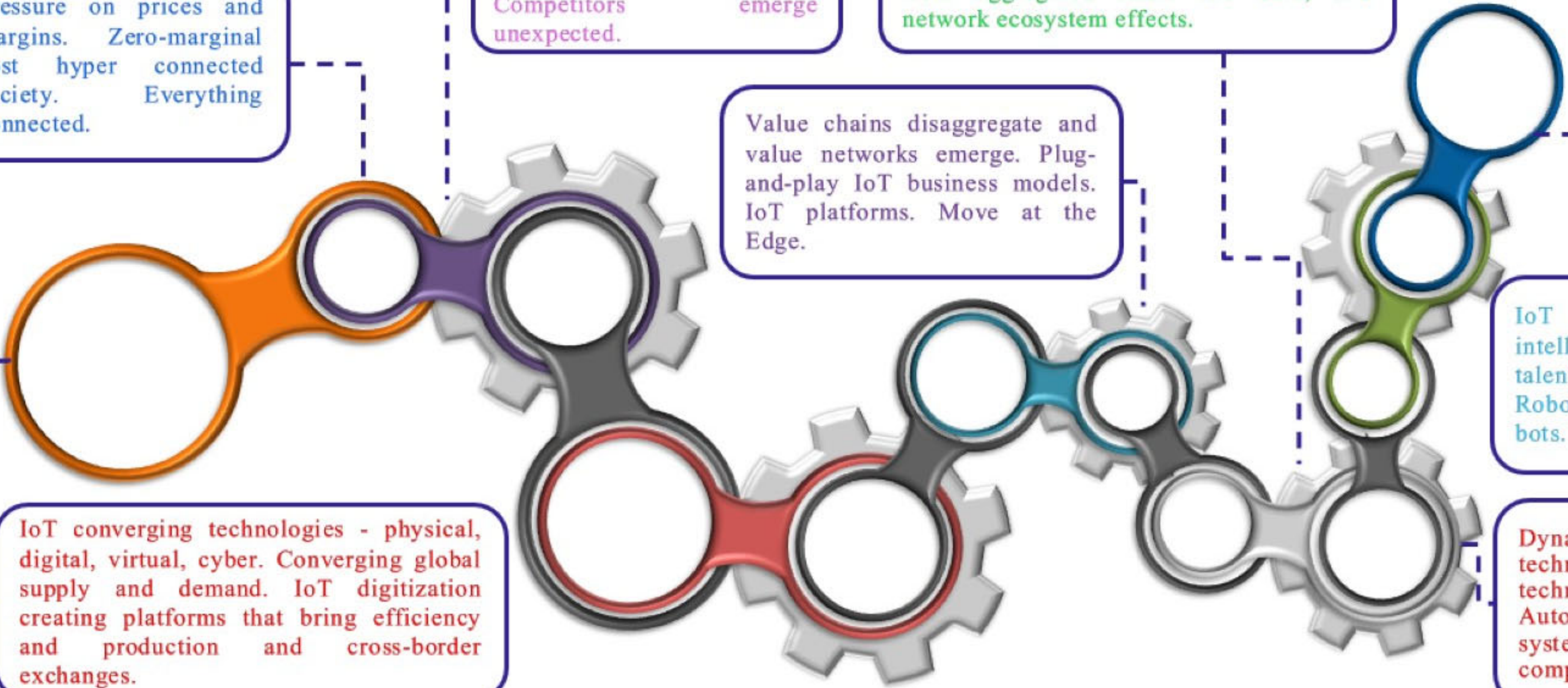
Hyperconnected Technologies

Pressure on prices and margins. Zero-marginal cost hyper connected society. Everything connected.

Digital dynamics change the barriers to entry and sources of product differentiation. Competitors emerge unexpected.

Winner-takes-all. Reduced transaction and labour costs, increased returns to scale from aggregated smart IoT data, and network ecosystem effects.

Value chains disaggregate and value networks emerge. Plug-and-play IoT business models. IoT platforms. Move at the Edge.



IoT M2M. Challenged by intelligent machines. Growing talent mismatches. Internet of Robotic Things. AI, IoT Co-bots. Distributed IoT edge.

IoT converging technologies - physical, digital, virtual, cyber. Converging global supply and demand. IoT digitization creating platforms that bring efficiency and production and cross-border exchanges.

Dynamic evolution of IoT technologies and rapid technology convergence. Autonomous IoT systems of systems and evolutionary computing.

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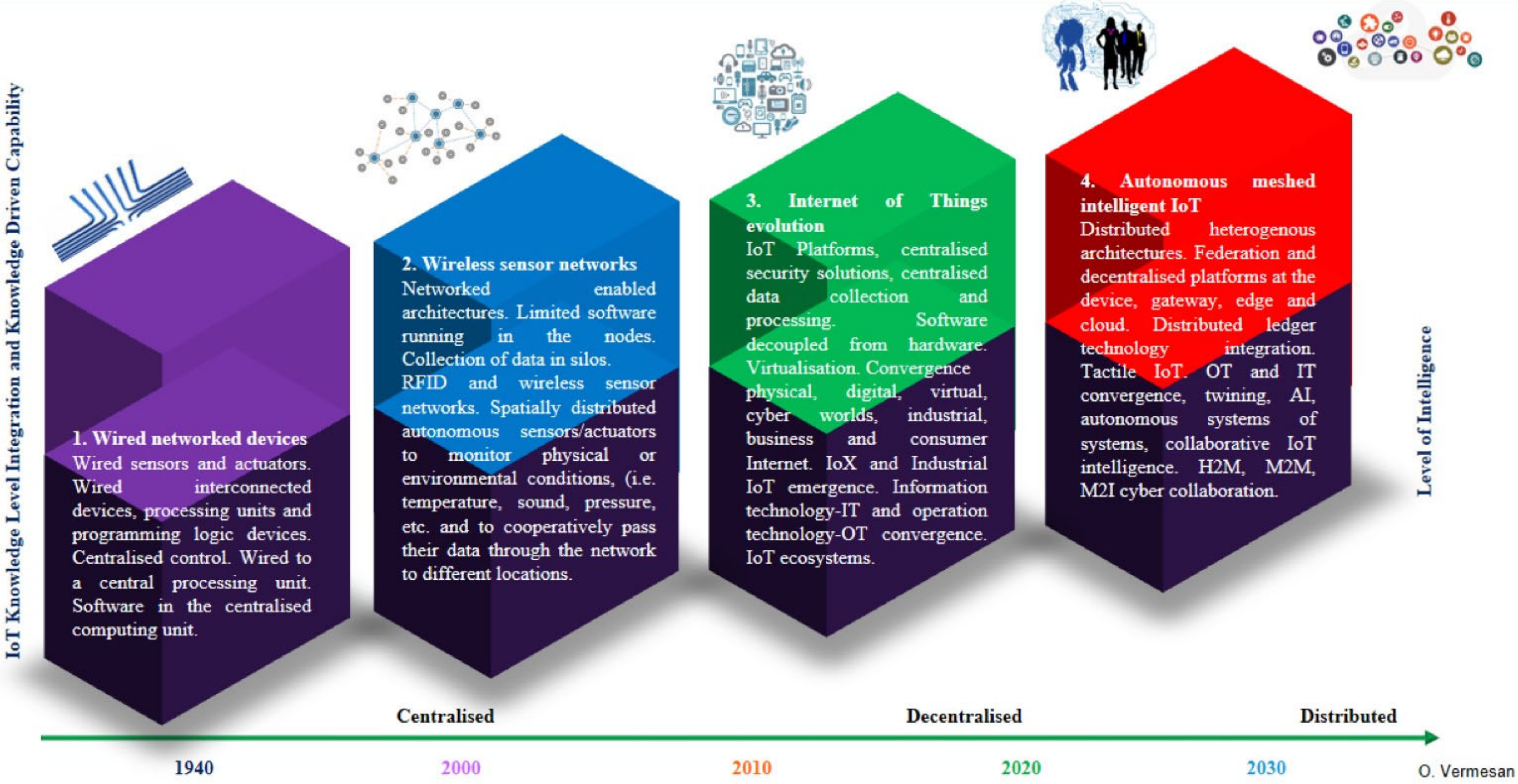
Internet of Intelligent Things Evolution



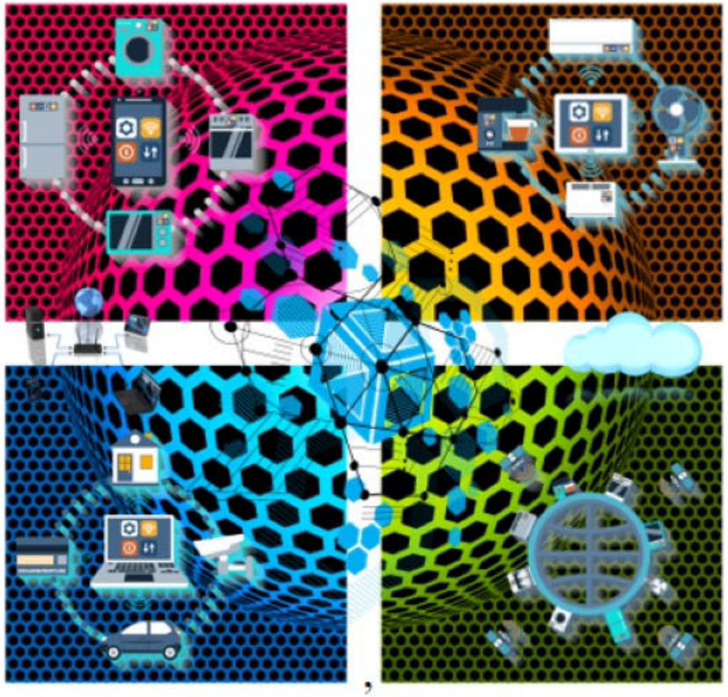
Everything Intelligent Everywhere

- Autonomous Systems
- Electricity Everywhere
- Digital Twining

Hyper-connected Society
Federated Intelligence

- Pervasive Sensing
- Edge Computing
- Autonomic and Organic

Everything connected, everything analysed,
Embedded intelligence everywhere



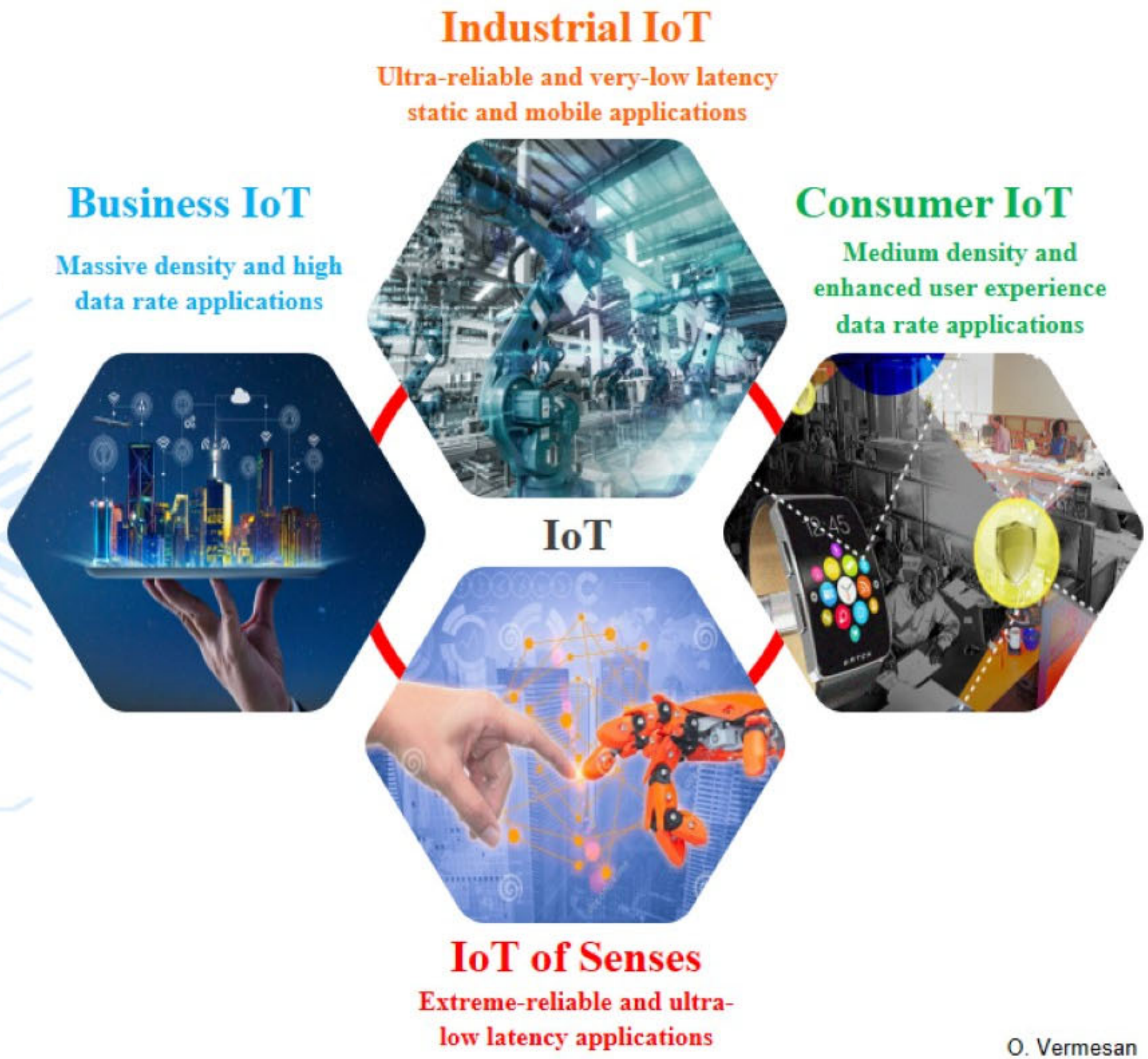
Embedded Artificial intelligence

- Physical, Digital, Virtual
- Perception - Cognition - Behaviour
- Sustainability Energy Efficiency

Human-Machine Interaction
Machine-Machine Collaboration

- Signal and Data Processing
- Ubiquitous Integration
- Autonomous Collaboration

IoT Consumer – Business - Industrial



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The Age of Ubiquitous Distributed Sensing, Mesh Networks, Edge Organic Computing, Embedded Intelligence.

Next-Wave Ubiquitous

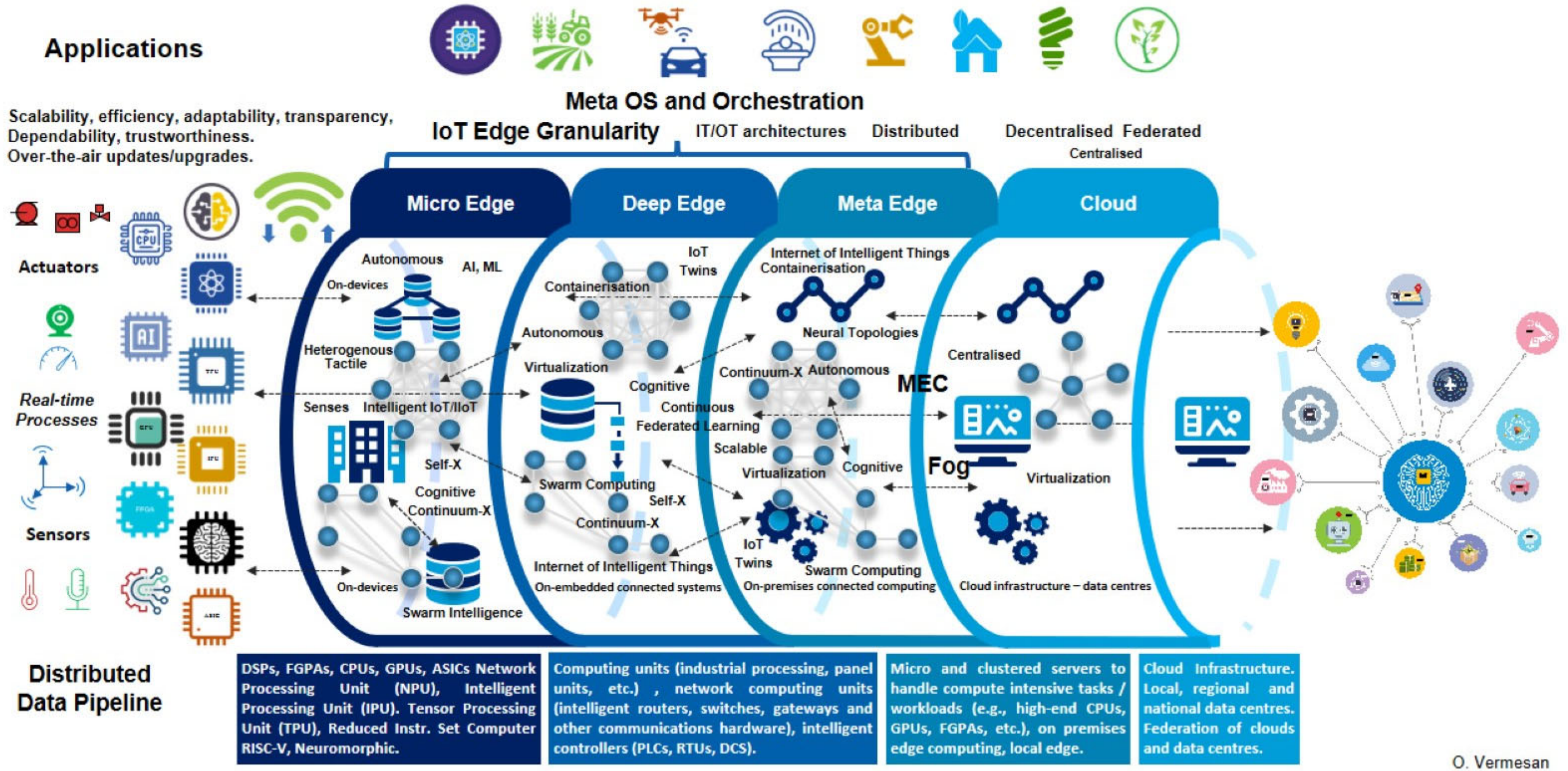
A^6= Anyone, Anything, Anytime, Anywhere Any path, Any service

"When wireless is perfectly applied the whole earth will be converted into a huge brain, which in fact it is, all things being particles of a real and rhythmic whole.........and the instruments through which we shall be able to do this will be amazingly simple compared with our present telephone. A man will be able to carry one in his vest pocket."

1926 – Nikola Tesla
Interview with Colliers magazine.

C^6= Create, Collect, Connect, Cache, Compute, Cognize, Create O. Vermesan

Computing Continuum – IoT Edge Granularity



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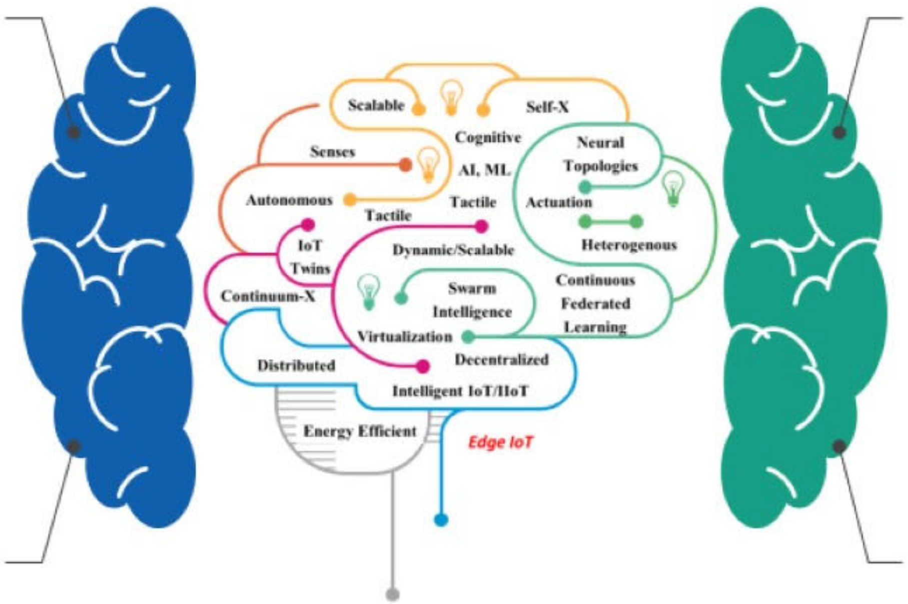
Internet of Intelligent Things – Research Directions

Convergence of Technologies

- IoT Granularity
- IoT and X-Continuum Paradigm
- Intelligent Connectivity
- Energy-Efficient Intelligent IoT and Edge Computing Systems
- Heterogeneous Cognitive Mobile IoT Edge Mesh
- IoT Digital Twins, Modelling and Simulation Environments
- IoT Swarm Systems
- Internet of Things Senses – Tactile IoT



- Pre-normative and standardisation

- Decentralized and Distributed IoT Edge Systems
- Federated Learning and AI
- OS and Autonomous Orchestration
- Dynamic Programming Tools and Environments
- IoT Systems Integration
- IoT sectorial and Cross-Sectorial Open Platforms
- IoT Verification, Validation and Testing Methods
- IoT Trustworthiness and Systems Dependability

Convergence of Infrastructure

Alliance for Internet of Things Innovation

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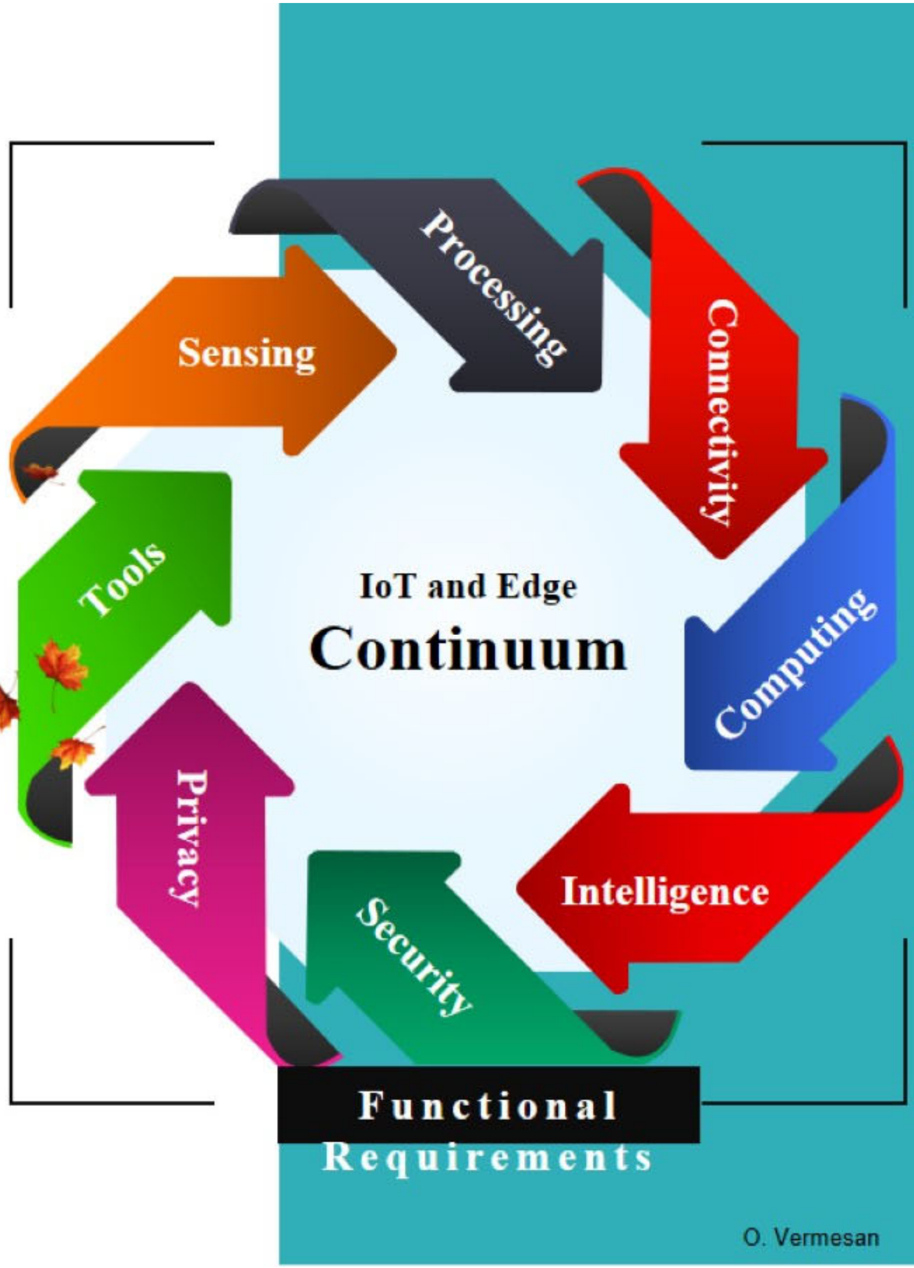
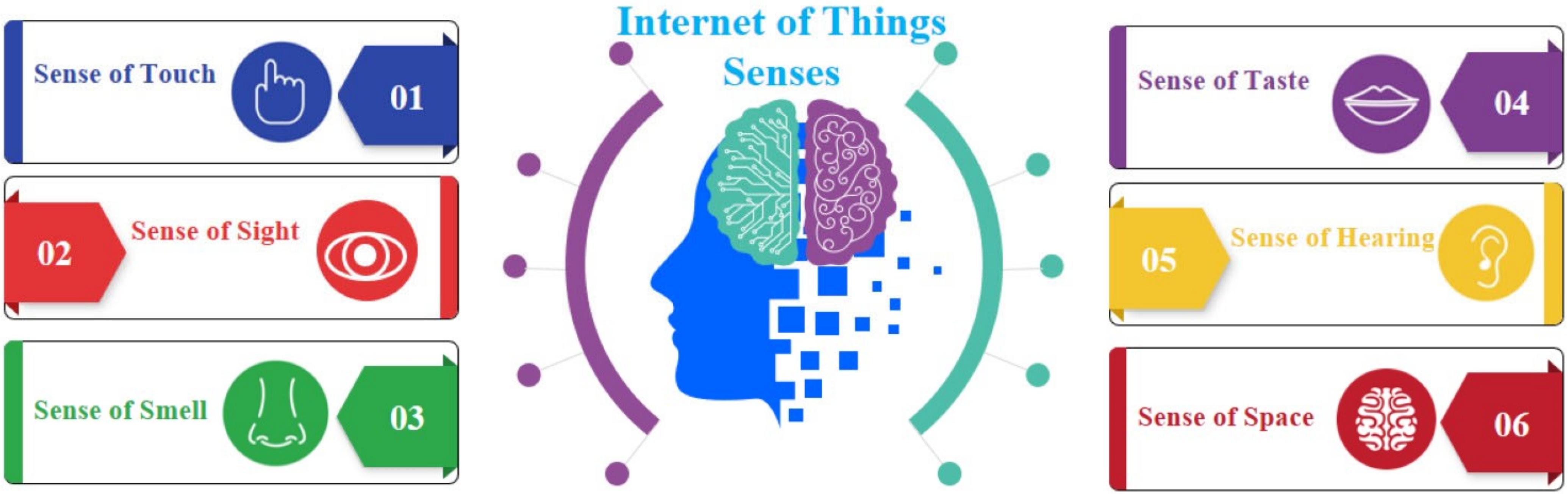
Continuum-X

- Continuum-X across the edge granularity combined with the AI approached as a technology stack that consists of several technologies including different types of hardware, software, algorithms.
- Challenges:
  - IoT edge functions for distributed and federated learning
  - Integration of heterogenous computing paradigms (perversive, edge, swarm, organic, etc.)
  - Collective intelligence, self-supervised learning, meta-learning, continual and multitask learning.
  - The edge nodes are optimised based on the energy, connectivity, size, cost The computing resources are constrained by these parameters.
  - IoT edge digital twins modelling, representation and simulation across the edge granularity and continuum-x



Internet of Things Senses (IoTS)



Complements and extends the capabilities of IoT applications by including other senses (e.g. vision, hearing, touch, taste, smell, pain, mechanoreception-balance, temperature, etc.) and providing new perceptions and experiences by integrating augmented intelligence and information across senses, time, and space.

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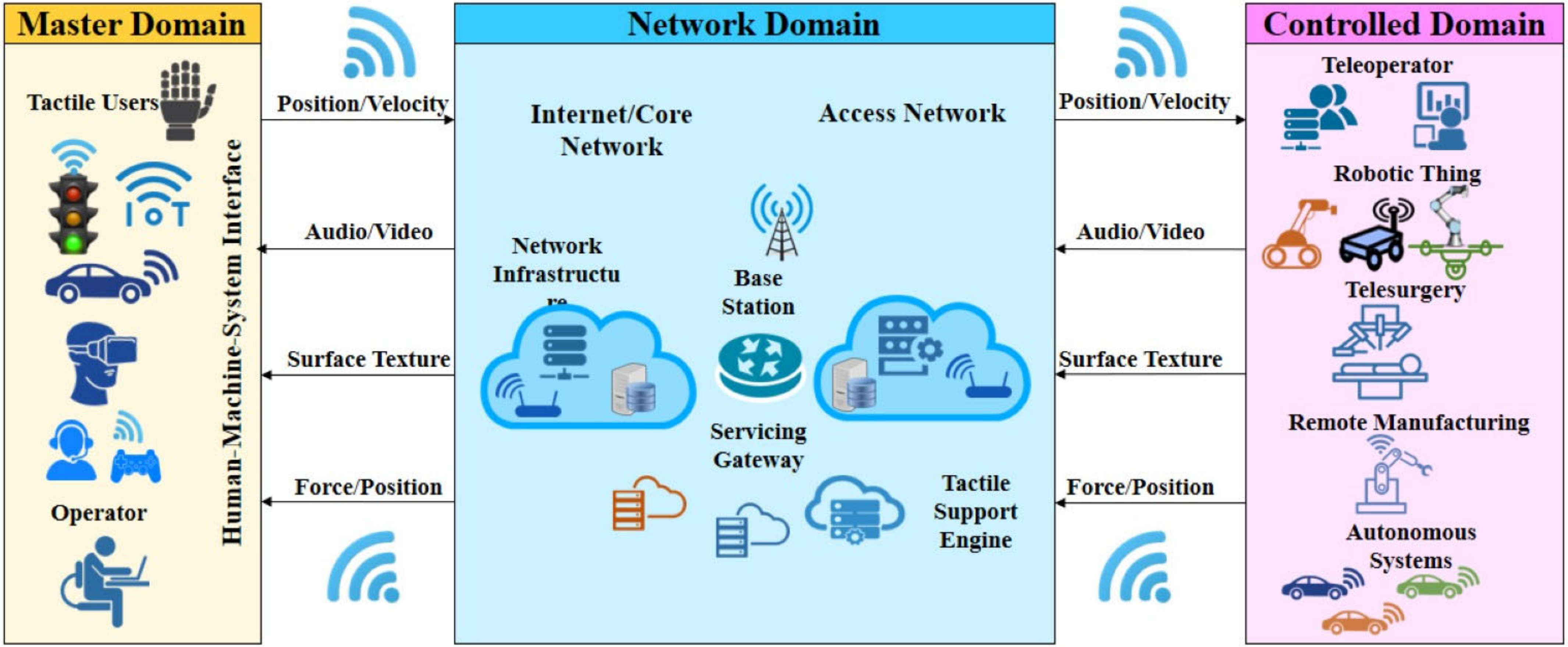
Tactile Internet of Things Senses (IoTS)



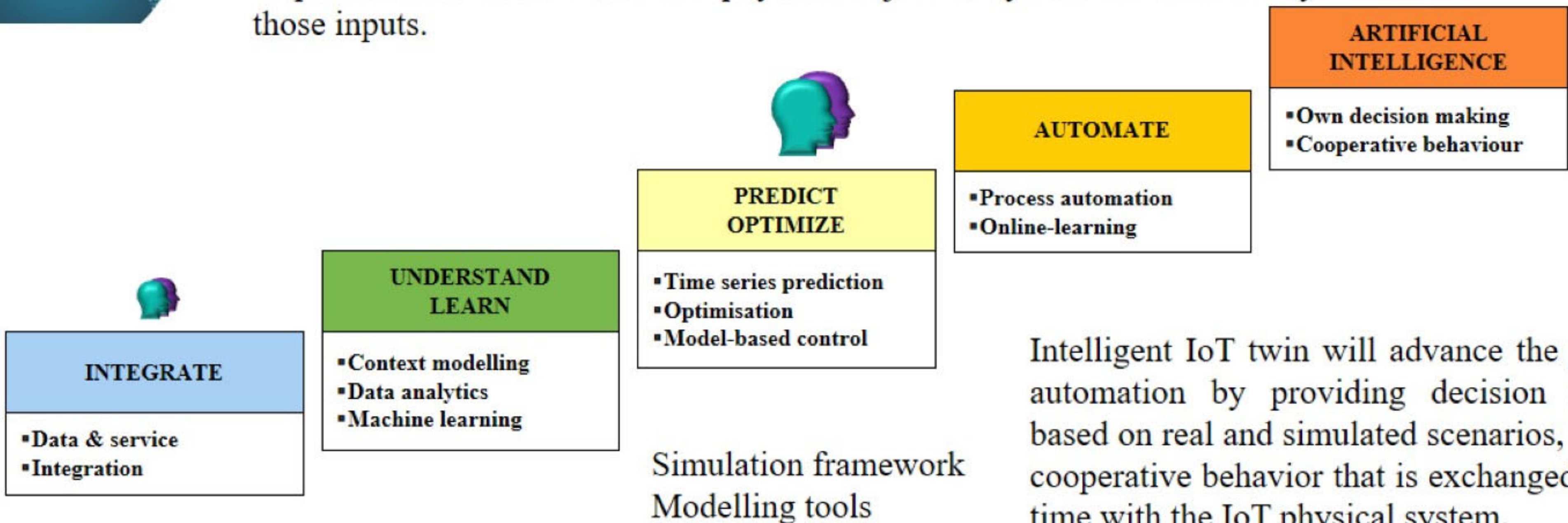
Tactile IoT/IIoT combines ultra-low latency with extremely high availability, reliability and security and enables humans and machines to interact with their environment, in real-time, using haptic interaction with visual feedback, while on the move and within a certain spatial communication range.

Internet of Things Senses

- Challenges:
  - Haptic edge sensors/actuators
  - Surface sensing and actuation
  - Multi-modal sensory and information fusion
  - Collaborative multi-user haptic communications
  - Stability for haptic control
  - Energy-efficient haptic codecs integrated into the kinesthetic and tactile information.
  - Ultra-high reliability, ultra-low-latency connectivity
  - Performance metrics –evaluation methods beyond Technology Readiness Level (TRL) such as Experience Readiness Level (ERL) that include new QoS metrics, Quality-of-Experience (QoE) and Quality-of-Task (QoT)

IoT Digital Twin

- A digital or virtual representation of a IoT physical device, object or system.
- IoT digital twin implementation that collects the real-world data about an IoT physical object or system as inputs and produces as outputs simulations or predications of how that IoT physical object or system are affected by those inputs.



Intelligent IoT twin will advance the process automation by providing decision making based on real and simulated scenarios, include cooperative behavior that is exchanged in real time with the IoT physical system.

IoT Digital Twin

- Challenges
  - Aggregation of models in a layered architecture
  - IoT digital twin precision to duplicate the IoT physical object, abstraction, computing capabilities
  - IoT digital twin that models and simulates the future state and behavior of the IoT device
  - Simulation and modelling of the communication channels and influence of the environments on the communication parameters of the IoT digital twins
  - Modelling and simulation of the energy consumption for the IoT digital twins
  - Virtual sensing/actuation functions and simulation of IoT digital twins
  - IoT digital twins counterfeiting identification and mitigation
  - Elimination and isolation of fake digital twins

Functional Requirements

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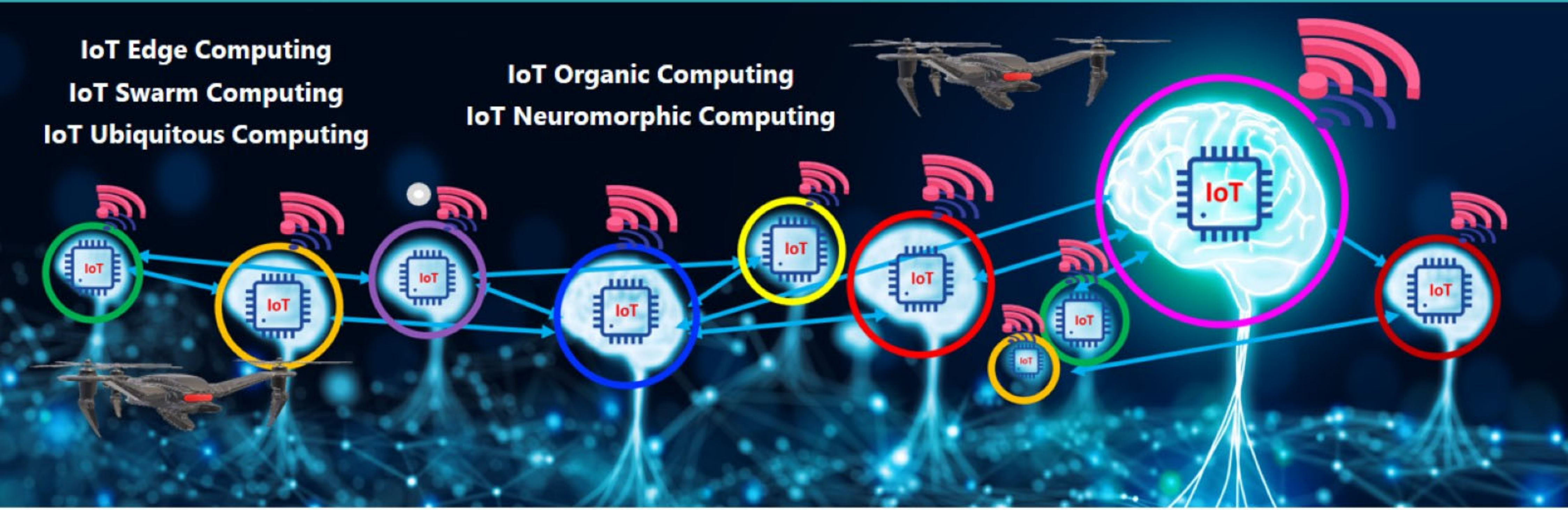
Evolutionary IoT Computing - IoT Swarm Intelligence



SI as the collective behavior of decentralized, self-organized and autonomous systems. Implementing the collective behaviour of physical and virtual artificial intelligent decentralised and distributed IoT systems based on collective and collaborative intelligence of things into applications such as AV, IoRT, Internet of Intelligent Mobile Things, Intelligent IoT Device Colonies.

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IoT Swarm Intelligence

- Challenges
  - Aggregation of intrinsic and extrinsic intelligence
  - Centralization vs Decentralization
  - Collision-free and deadlock-free movement of IoT swarms, real-time algorithms and perception, connectivity.
  - Local and global sensing and control
  - Intra-IoT warm relative sensing, relative localization, collaboration, collision avoidance
  - IoT swarm supervising and federated learning

Functional Requirements

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Internet of Intelligent Things (IoIT)

Internet of Vehicles (IoV)

Internet of Energy (IoE)

Internet of Health (IoH)

Industrial Internet of Things (IIoT)

Internet of Robotic Things (IoRT)

Internet of Autonomous Things (IoAT)

Internet of Food and Farming (IoF)

Green Internet of Things (GIoT)

Internet of Things Senses (IoTS)

Tactile Internet of Things (TIoT)

Artificial Intelligence of Things (AIoT)

Source: IERC Cluster Book 2020 Internet of Things – The Call of the Edge Everything Intelligent Everywhere

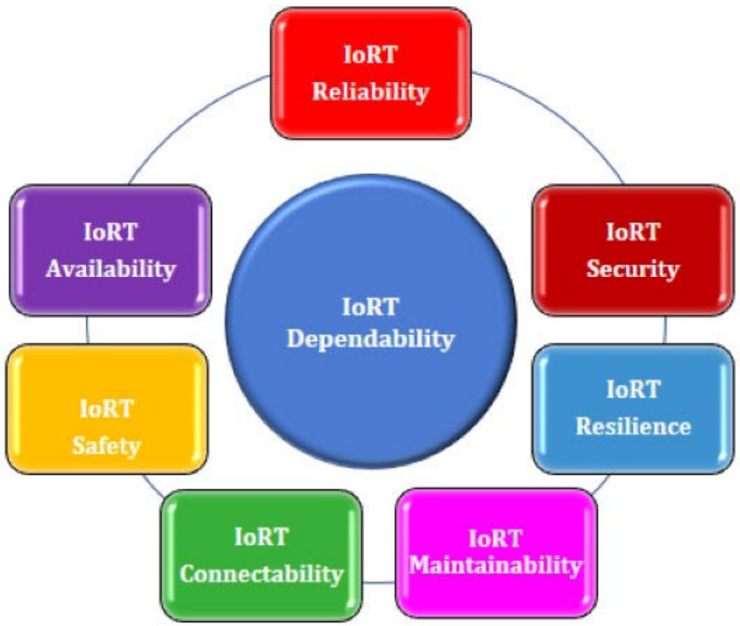
Dependability Components - Trustworthiness

Autonomous self-organized edge IoT intelligent systems

Continuity of correct service within given constrains

Ability to deliver service when requested and readiness for correct service

Recognise hazards to achieve an acceptable level of risk against faults



Ability to identify hazards to achieve an acceptable level of risk against intruders and hackers

Ability to transform, renew, resist, respond and recover timely from damaging effects and states

Design to connect securely, anytime, anywhere, to any available network.

Design to avoid modifications and repairs

Reliability

- **Ability of the IoRT autonomous system to deliver and accomplish services as specified within given constrains.**

Safety

- **Ability of the IoRT autonomous system to operate without harmful states and catastrophic failures.**

Security

- **Ability of the IoRT autonomous system to protect itself and the autonomous system information from unauthorised actions, deliberate and accidental intrusion/attacks.**

Resilience

- **Ability of the IoRT autonomous system to transform, renew, resist, respond and recover timely from damaging effects and states**

Connectability

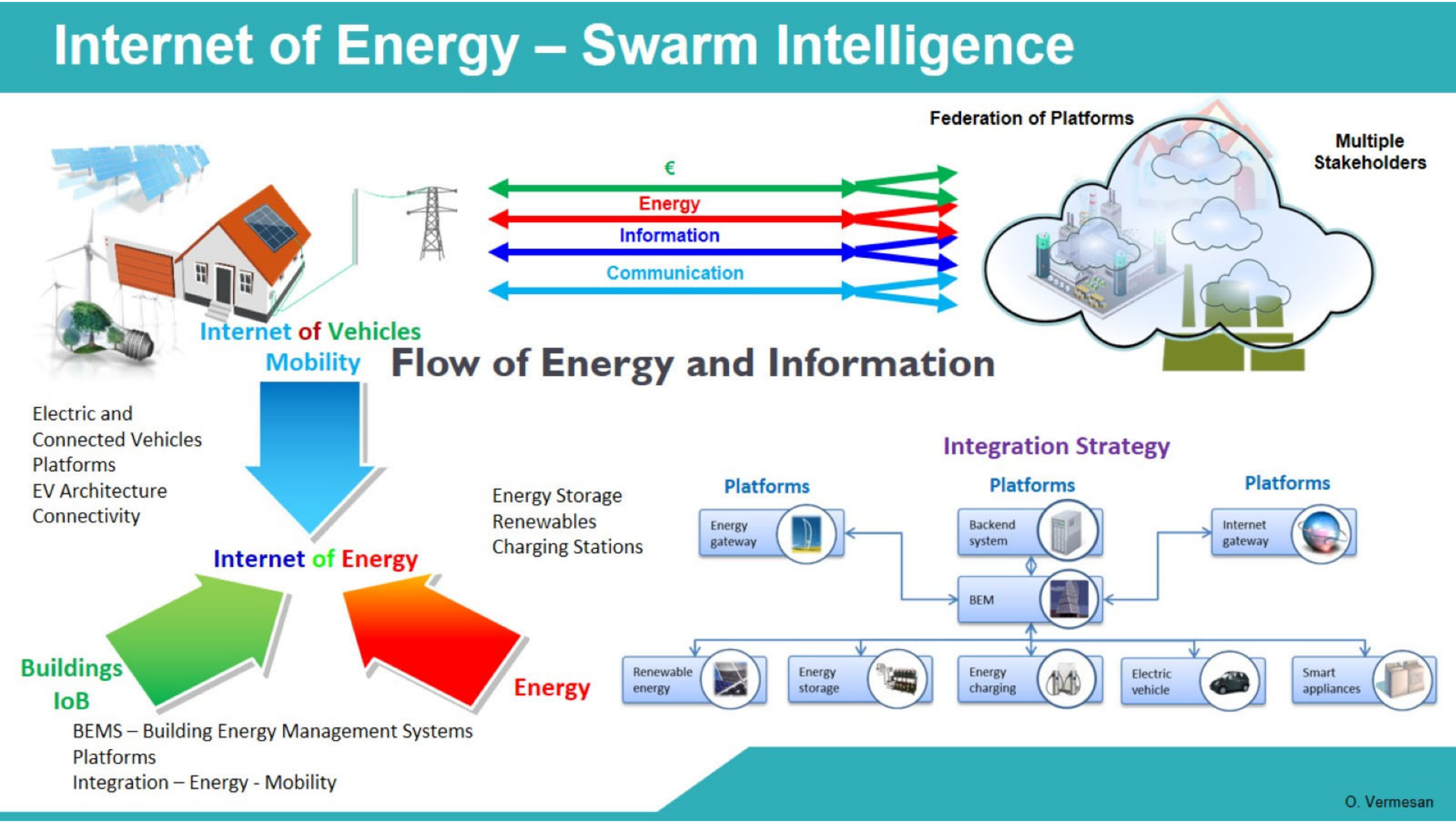
- **Ability of the IoRT autonomous system to connect securely, anytime, anywhere, to any available network.**

Availability

- **Ability of the IoRT autonomous system to deliver services and information when requested.**

Maintainability

- **Ability of the IoRT autonomous system to avoid modifications and repairs.**



Internet of Energy – Swarm Intelligence
Federation of Platforms
Multiple Stakeholders
€
Energy
Information
Communication
Internet of Vehicles
Mobility
Flow of Energy and Information
Electric and
Connected Vehicles
Platforms
EV Architecture
Connectivity
Energy Storage
Renewables
Charging Stations
Internet of Energy
Integration Strategy
Platforms
Platforms
Platforms
Energy gateway
Backend system
Internet gateway
BEM
Renewable energy
Energy storage
Energy charging
Electric vehicle
Smart appliances
Buildings
IoB
Energy
BEMS – Building Energy Management Systems
Platforms
Integration – Energy - Mobility
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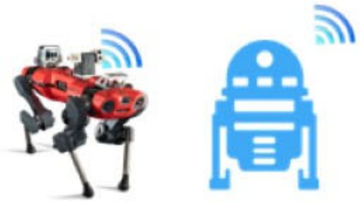
Internet of Robotic Things

LOCATE

- High definition dynamic maps, GPS, GNSS, local correction data to GNSS, RT2X, network positioning.

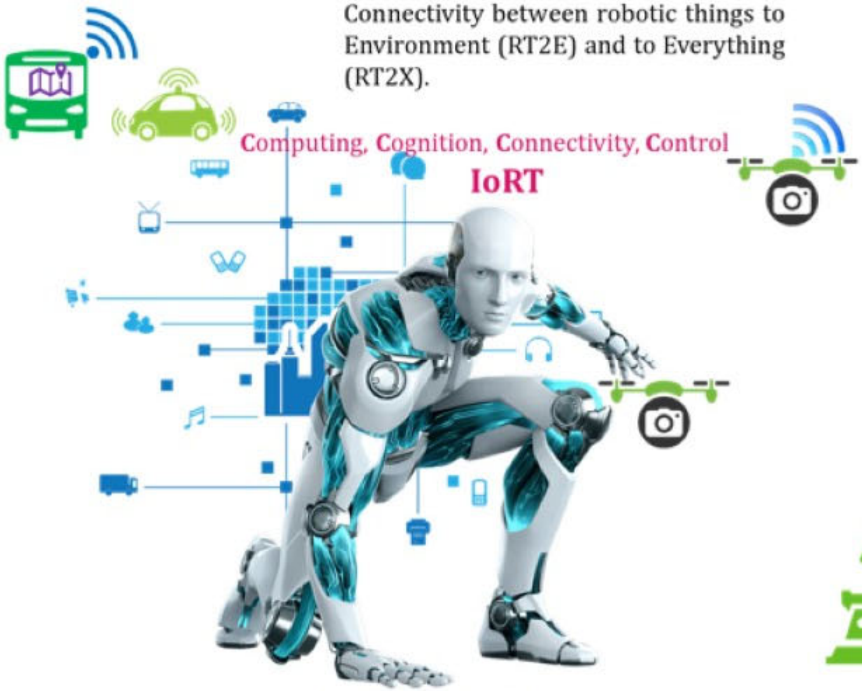
SENSE

- Data streams from the perception domain radars, LiDARs, cameras, ultrasound sensors.



CONNECT

Connectivity between robotic things to Environment (RT2E) and to Everything (RT2X).



THINK

- Computing, cognition, connectivity and control to provide the performance and intelligence for executing autonomous functions, workloads and decisions.

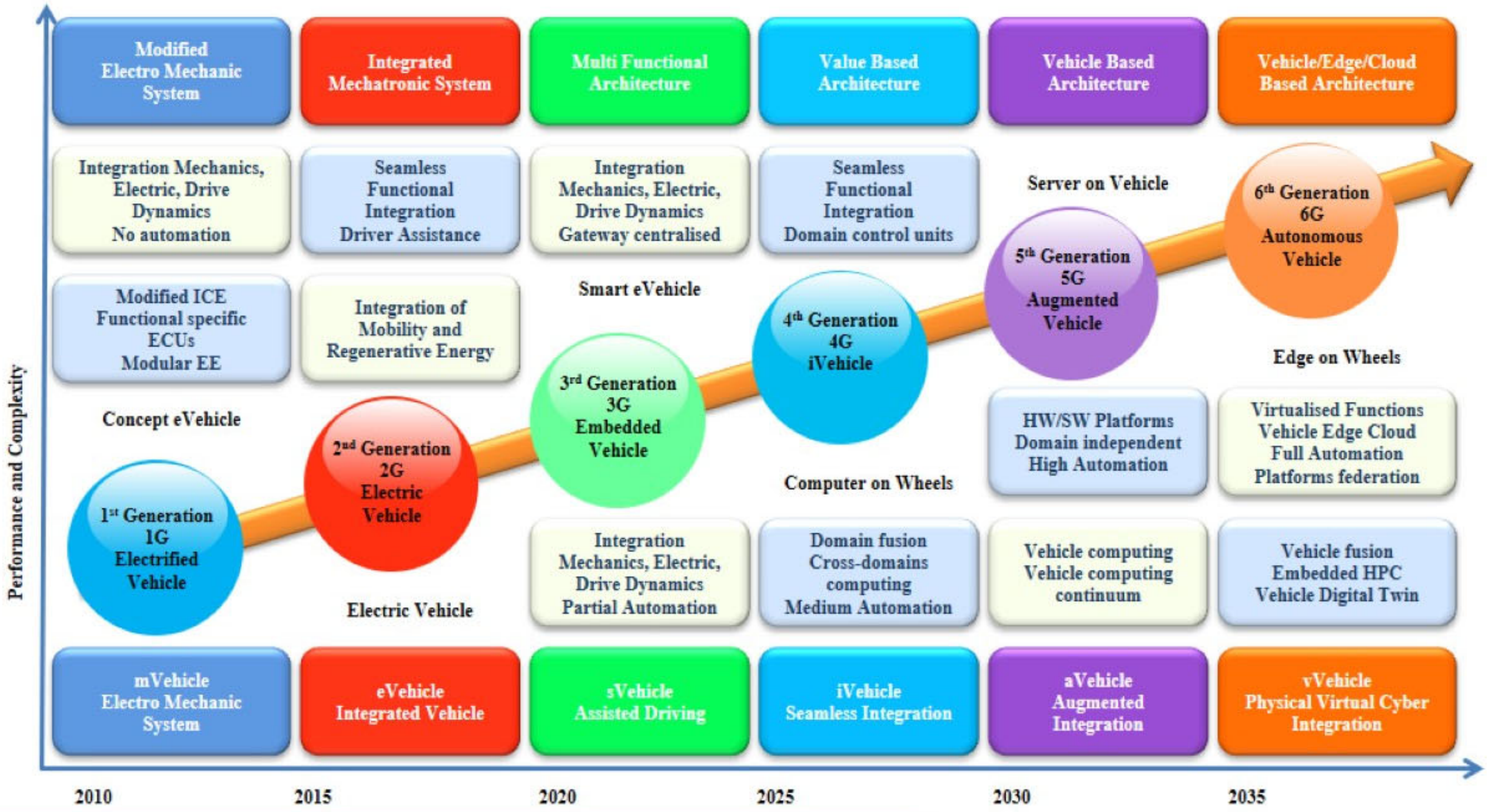
ACT

- Decisions to determine the best, safest course of action, acting on the propulsion domain by changing direction, speed, stopping.

COLLABORATE

- Activities with other robotic things, autonomous vehicles, animals, environment, infrastructure (physical and digital, edge/cloud, etc.).

Internet of Vehicles



Electric
Connected
Autonomous
Shared
Vehicles

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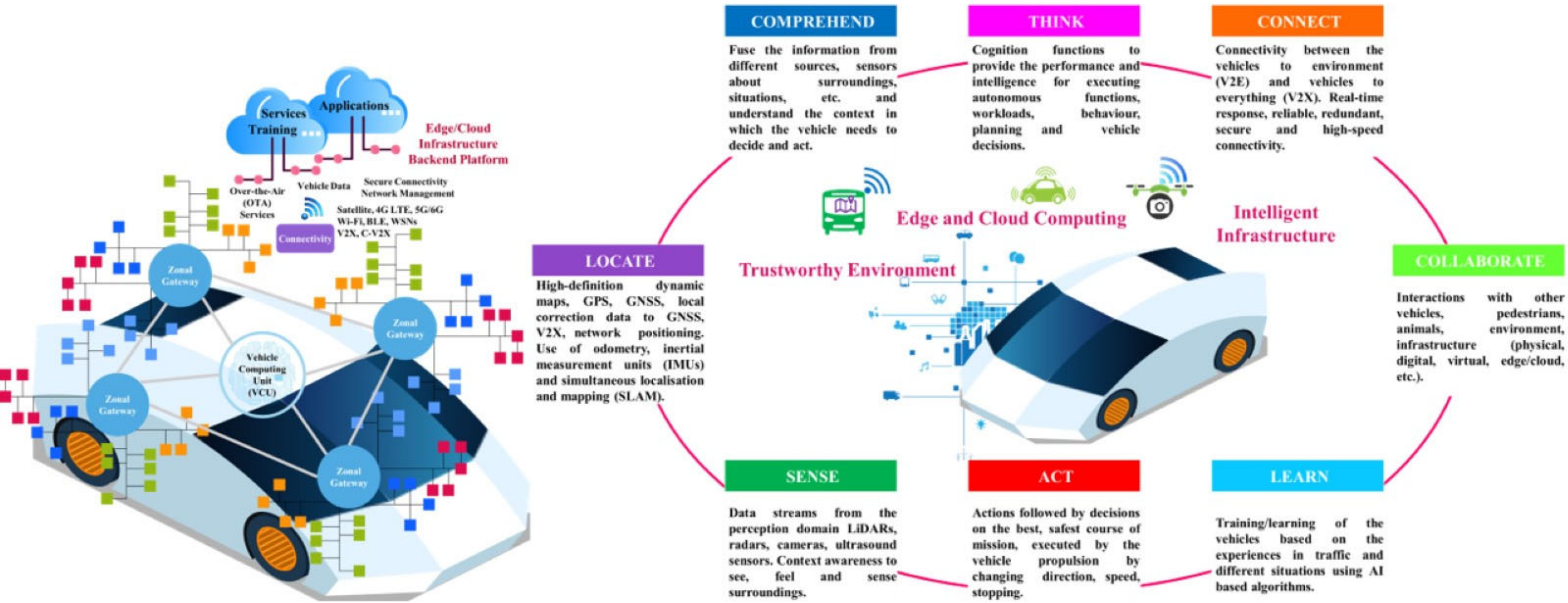
Internet of Vehicles - Intrinsic Intelligence



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Internet of Vehicles - Connectivity

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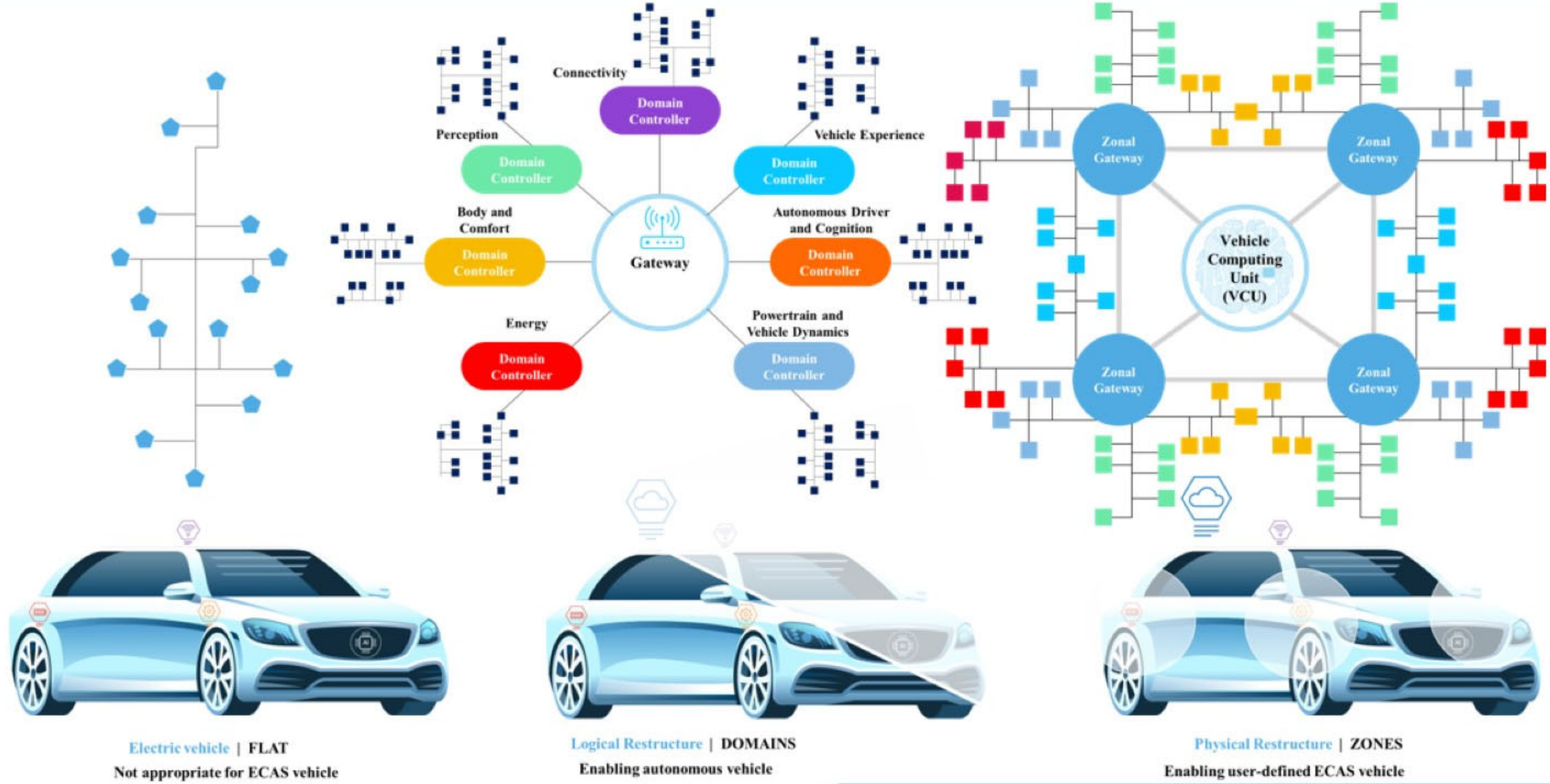
Internet of Vehicles – Architectures Evolution



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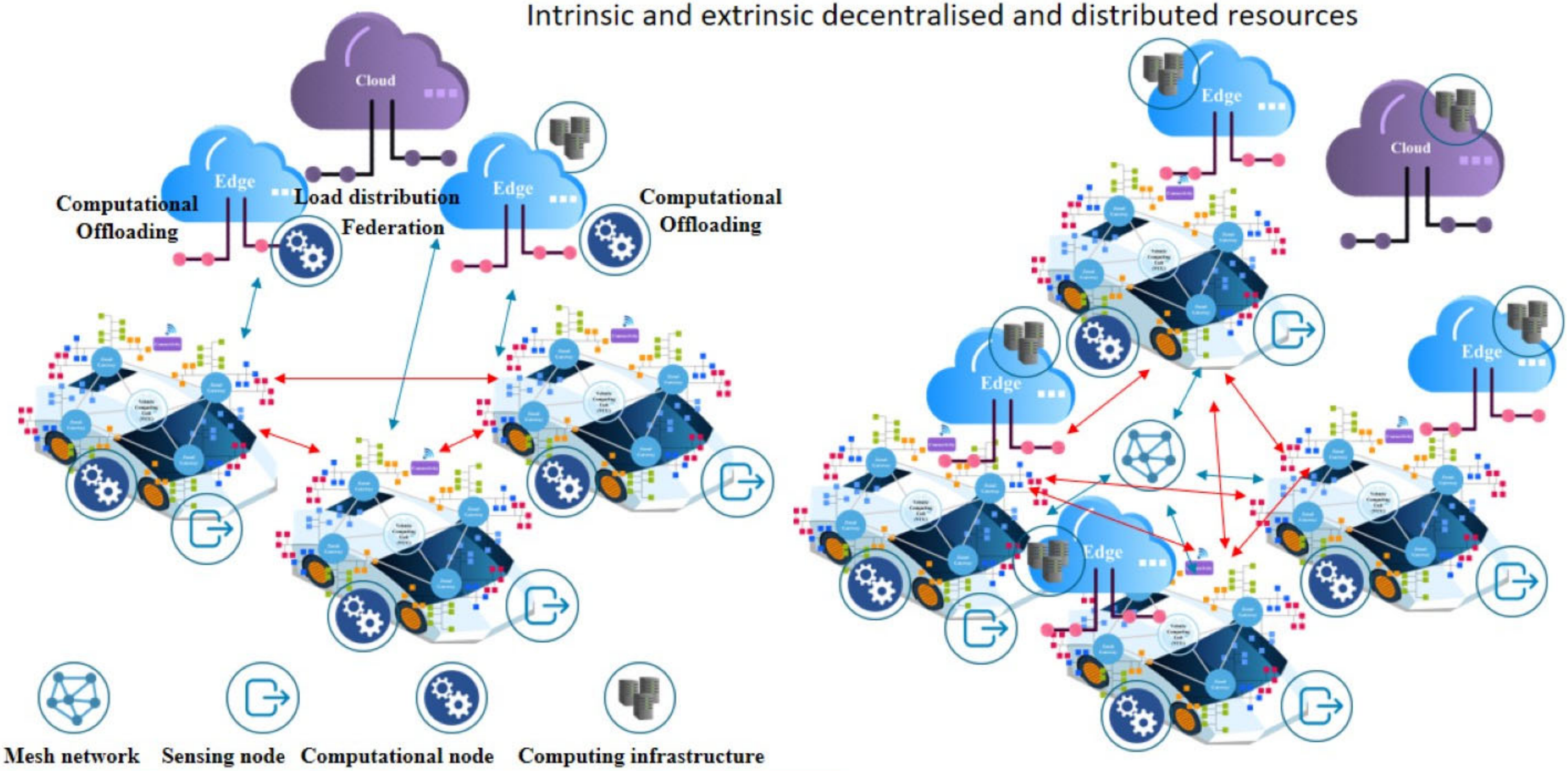
Internet of Vehicles – Swarm Intelligence

Intrinsic and extrinsic decentralised and distributed resources



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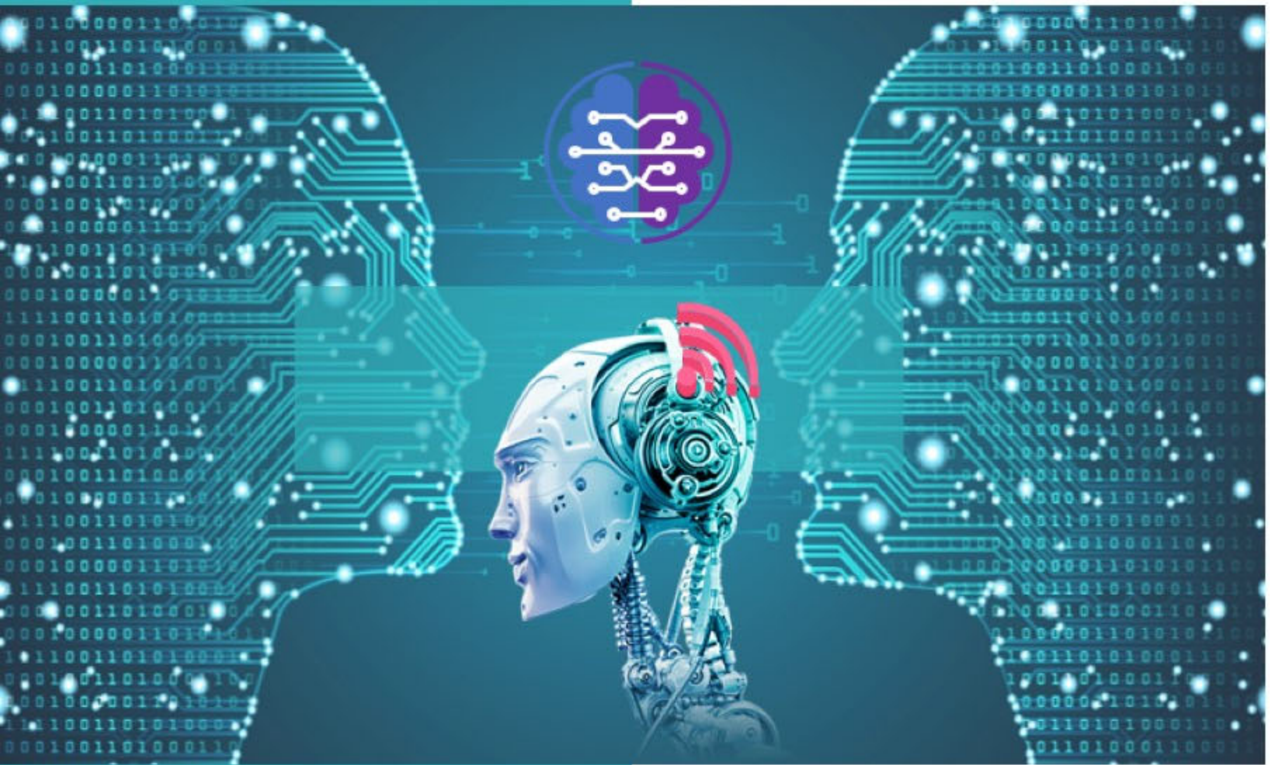

THANKS

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