Vehicular edge and software-defined vehicles

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Today’s standard car

- Computational capacity of 20 PCs
- Over 100-200 million lines of code
- 100 electronic control units (ECUs)
- Processes up to 25 gigabytes of data an hour
- High amount of different sensors

From internal functions to a comp platform

- Traditionally digital automotive technology has focused on optimizing the vehicle's internal functions
  - Smoothness of driving movements, speed control
  - Automatic distance, lane assistance
- Now turning to developing the car's ability to connect with the outside world and enhance the in-car experience
  - Context-awareness (traffic, weather, road condition, environment)
  - Route and traffic optimisation, communication between vehicles
  - Entertainment and educational aspects

The weather

Software-defined vehicle

A vehicle whose features and functions are primarily enabled through software

Ongoing transformation of the vehicle from a product that is hardware-based to a software-centric electronic device on wheels

Three powerful trends: **electrification, automation, and connectivity**

Reshaped customer expectations: driving is easy, safe, and effortless

Software for vehicles?

- Aim to decrease complexity updating the car systems
- Shorter innovation cycle and agile feature development and improvement
- **Software lifecycle and management – 20 years in car's lifetime?**

YOU WOULDN'T DOWNLOAD A CAR

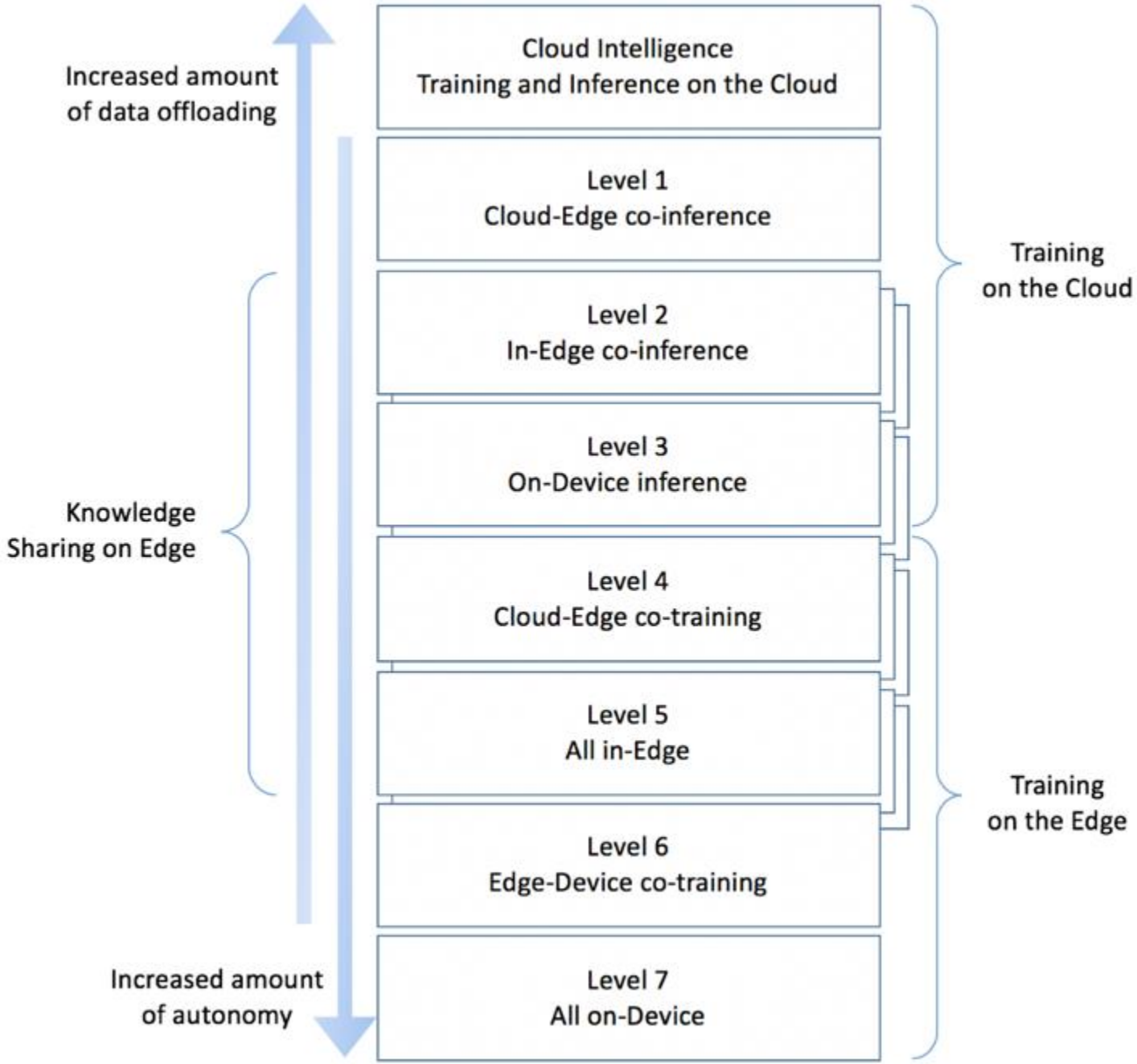
Future of vehicles that are

- **Connected** to internet and each other
- **Intelligent** i.e. capable in data processing, AI and machine learning, and
- **Software-defined** with multipurpose platform

Edge-cloud continuum

- **Edge computing**: paradigm that extends **cloud computing** into local computing devices
- Virtualisation over **multiple heterogeneous devices** and computing environments
- Continuum: **dynamic decision** making what to compute, where and when

Edge-cloud continuum: what to compute and where



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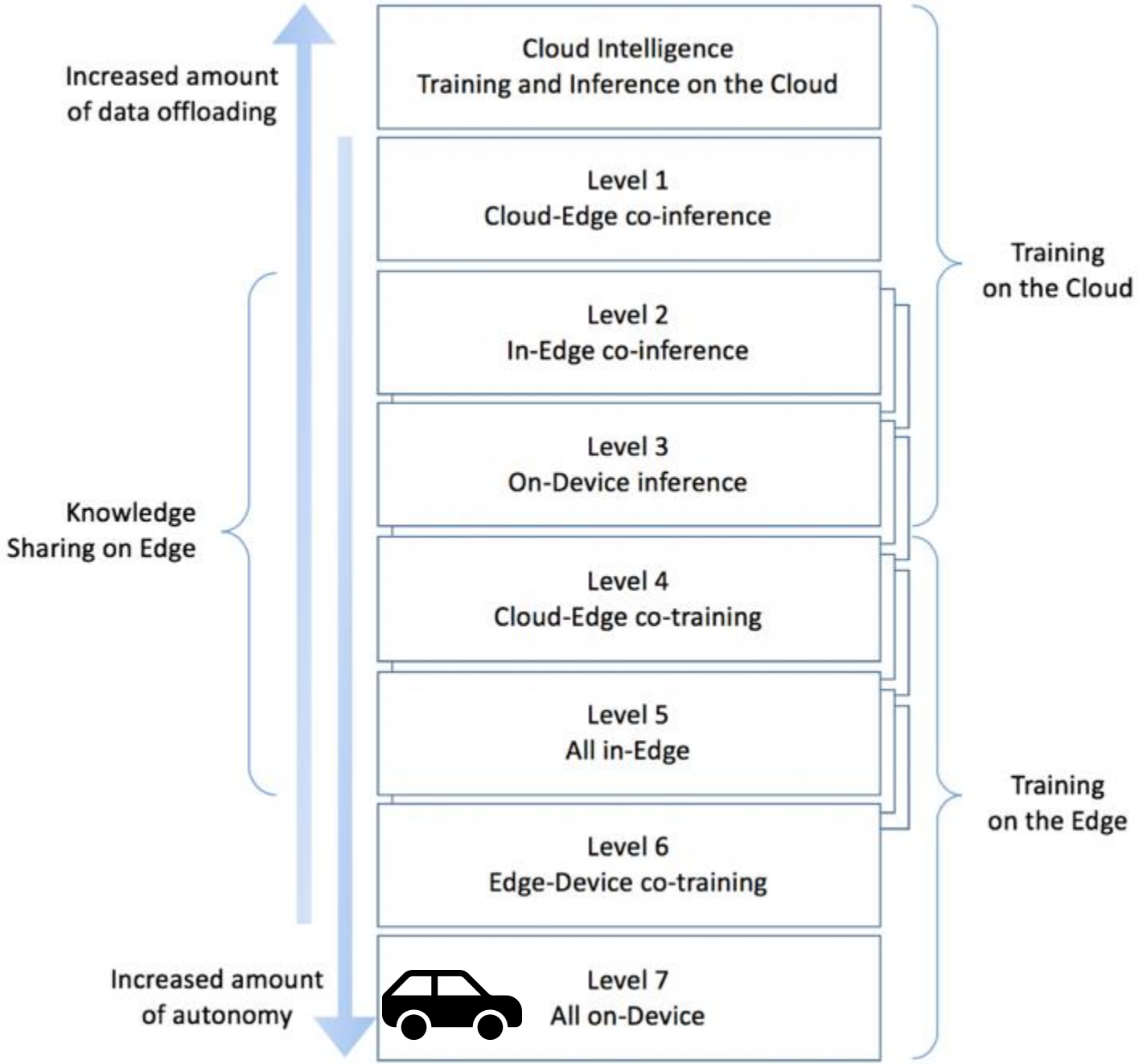
All in-car: limited data, limited knowledge – independent from network availability



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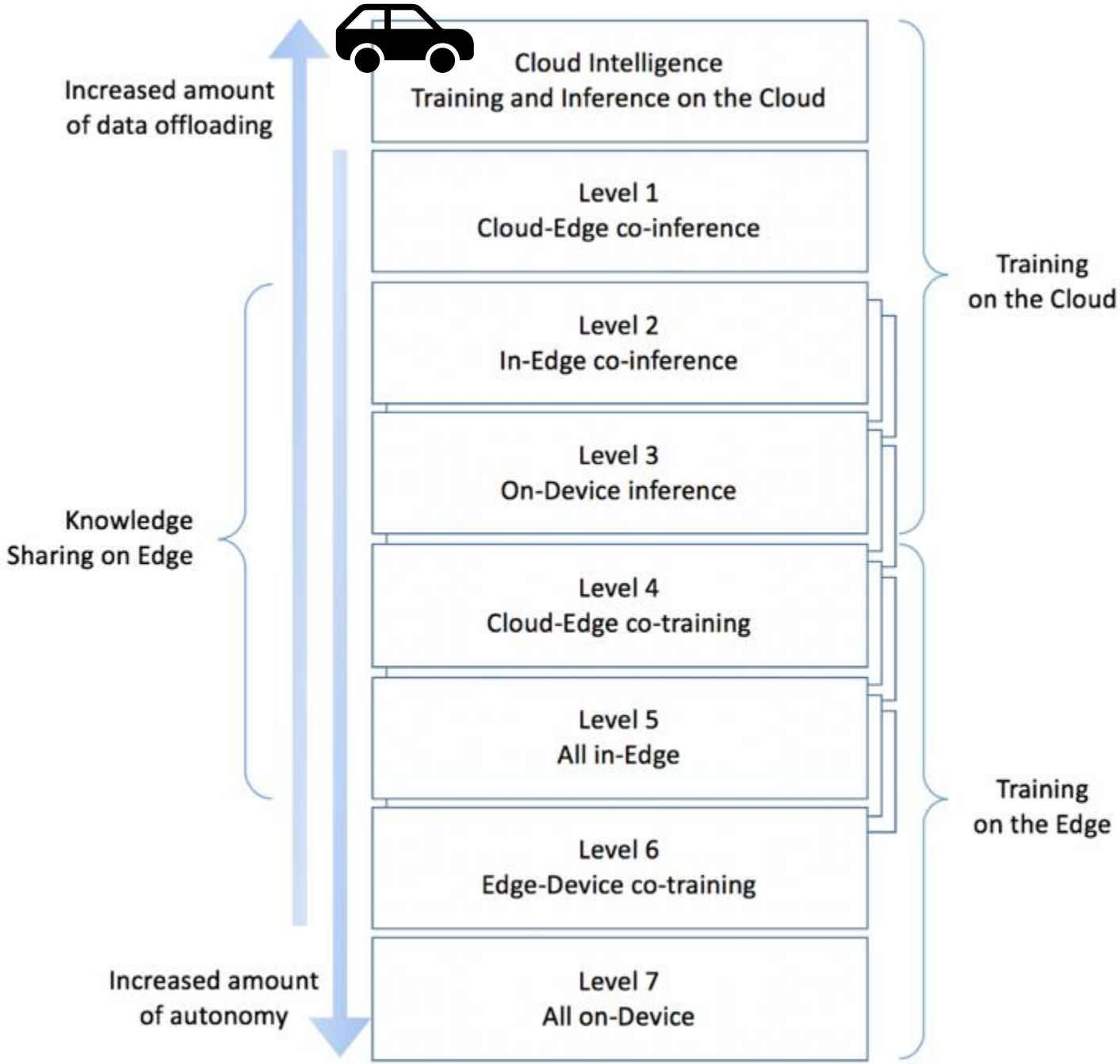
All in cloud: lots of knowledge – dependant on network availability



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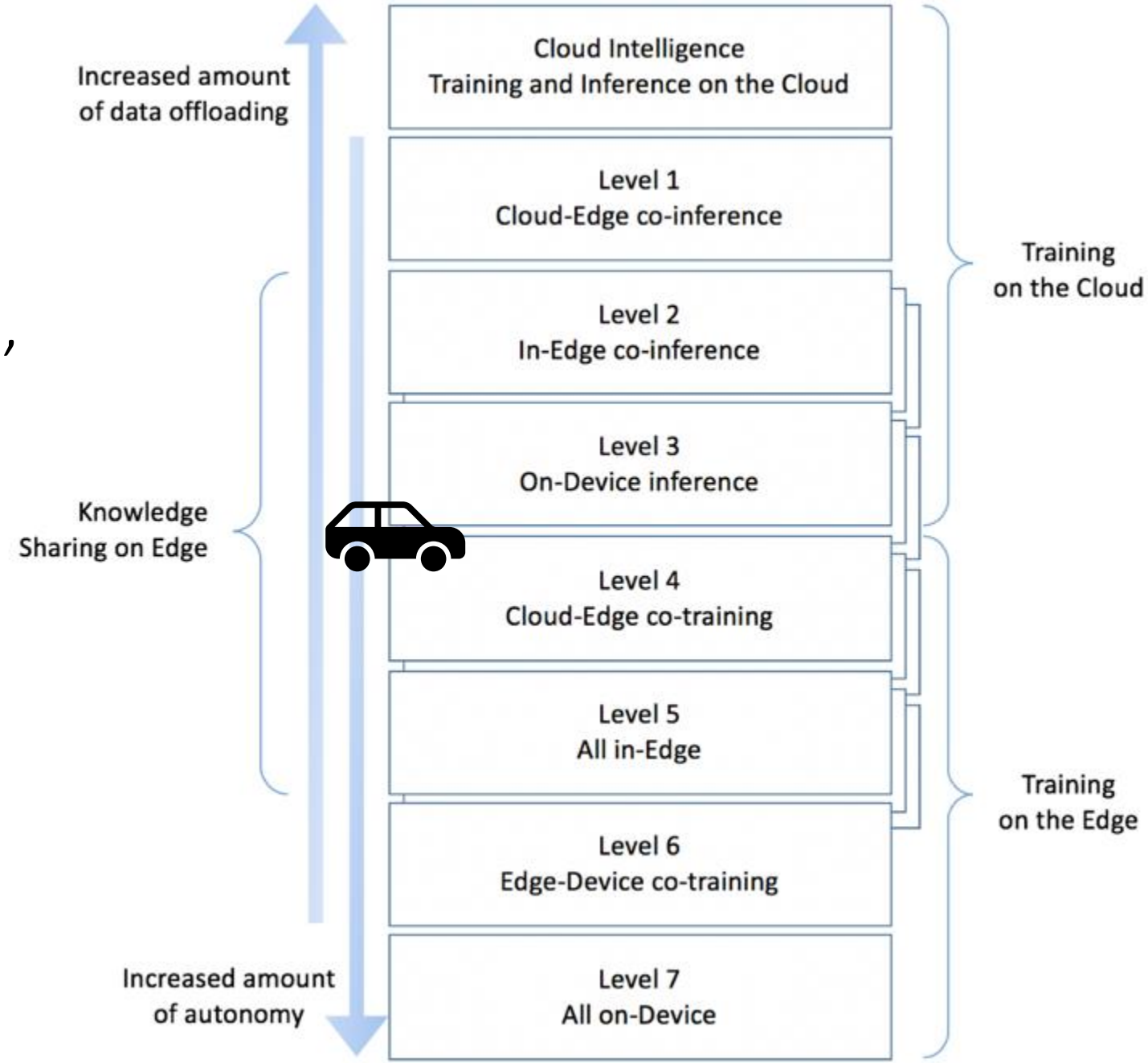
Edge computing and distributed intelligence: how to access capabilities, do we have them?



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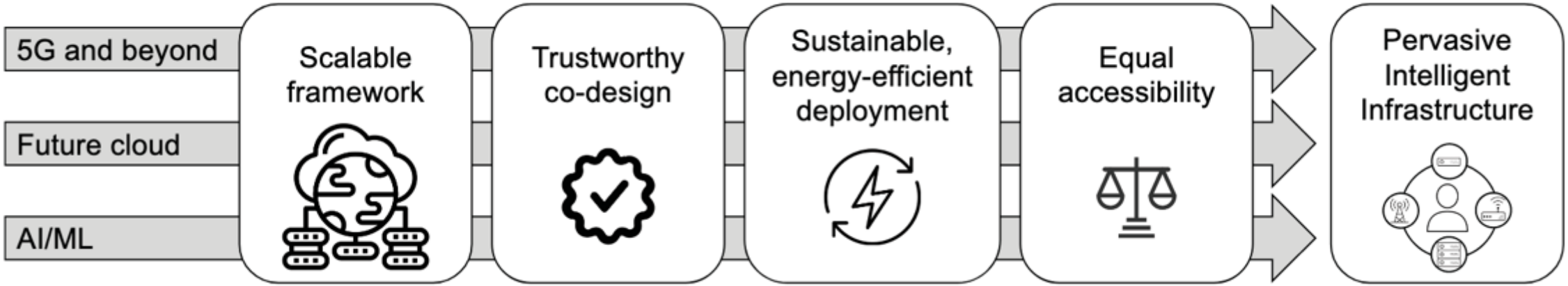
Edge-cloud continuum, the roadmap



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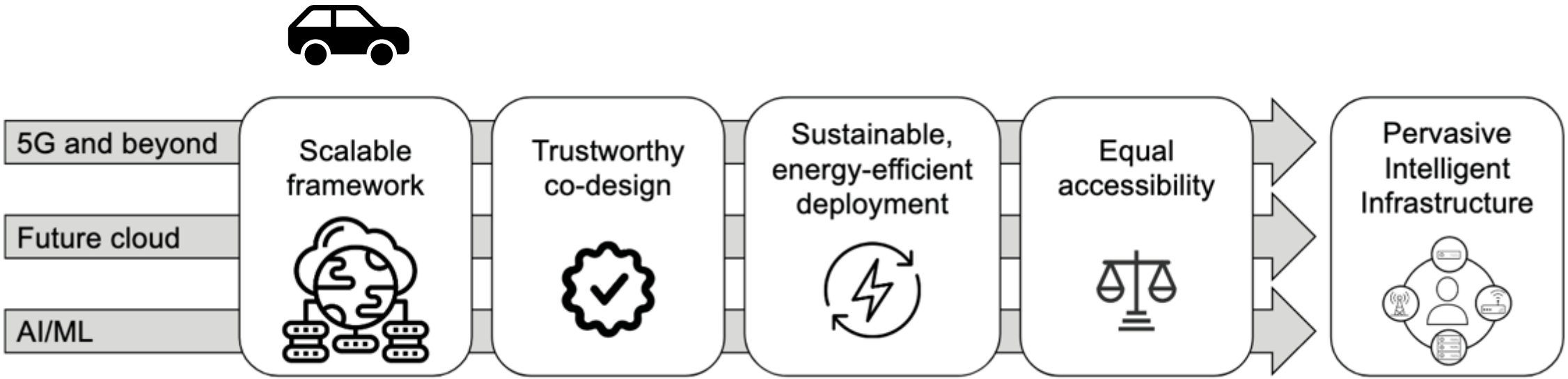
Edge-cloud continuum, vehicular perspective



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Vehicular edge-cloud continuum

Big Data analytics
Large-scale AI/ML
General knowledge

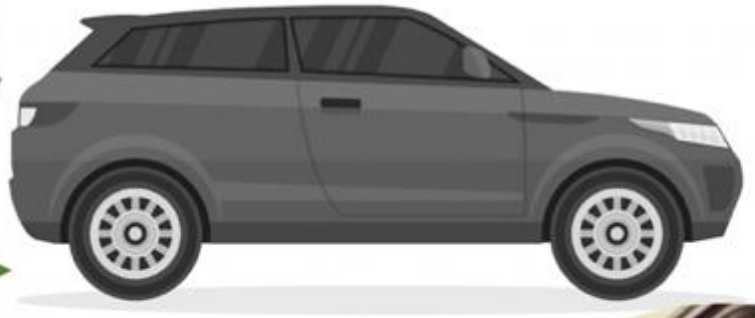
Edge-cloud-infrastructure

Vertical communication: increase accuracy of locally learned models

Vehicular sensors

- Automatic and semi-automatic driving support
- Environmental sensing, e.g. road and weather conditions
- Vehicle's state and condition, e.g. performance capacity, gasoline/electricity level, maintenance

Local context-awareness and human-in-the-loop
Real-time learning from smaller data
Mixed inference of local and cloud-based models



Horizontal communication: critical information exchange on rapidly changing environment

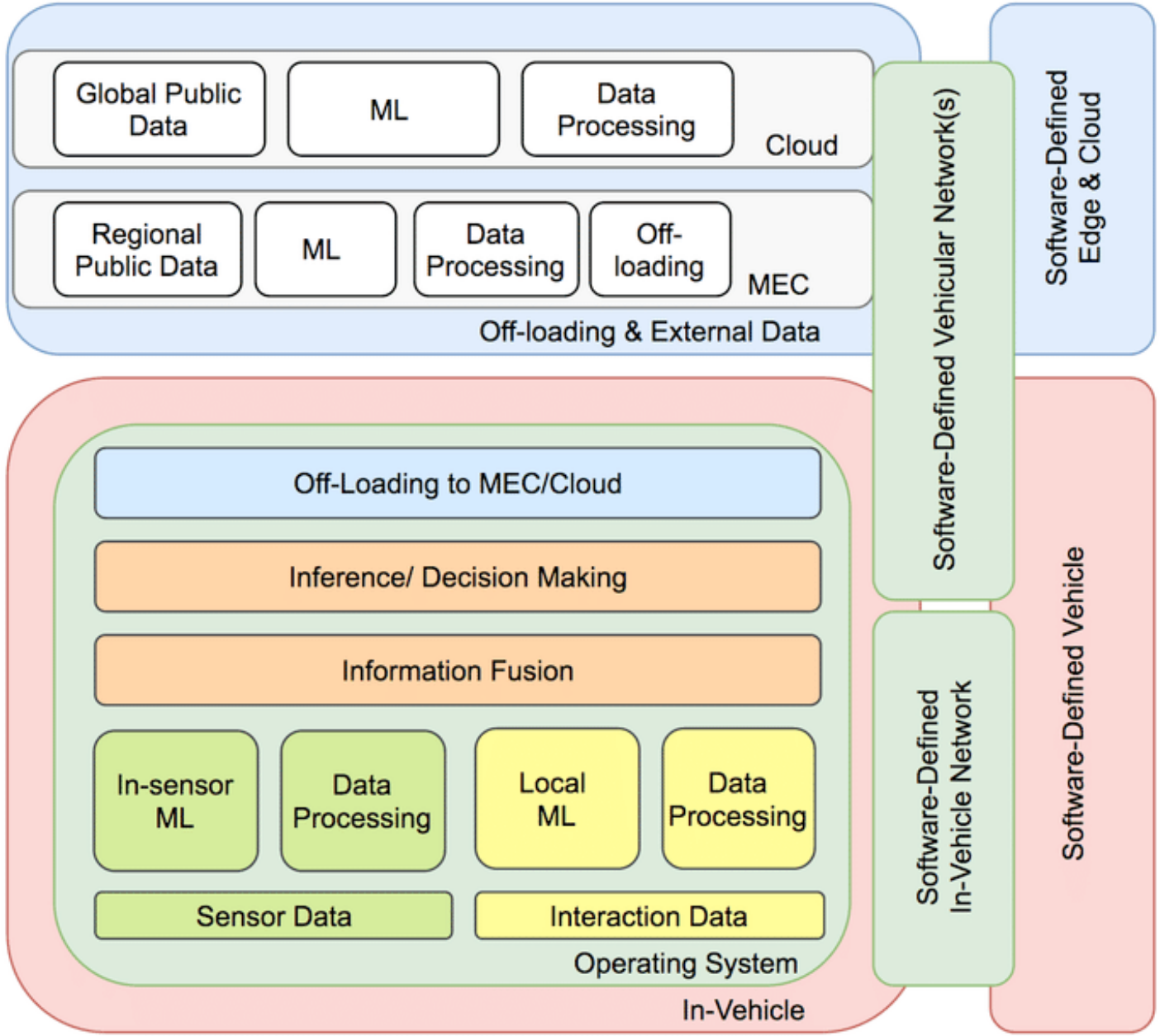
Human in the loop:

- Measuring health and driving condition
- Provide feedback through vehicular UIs
- Exchange control and decision making in critical situations

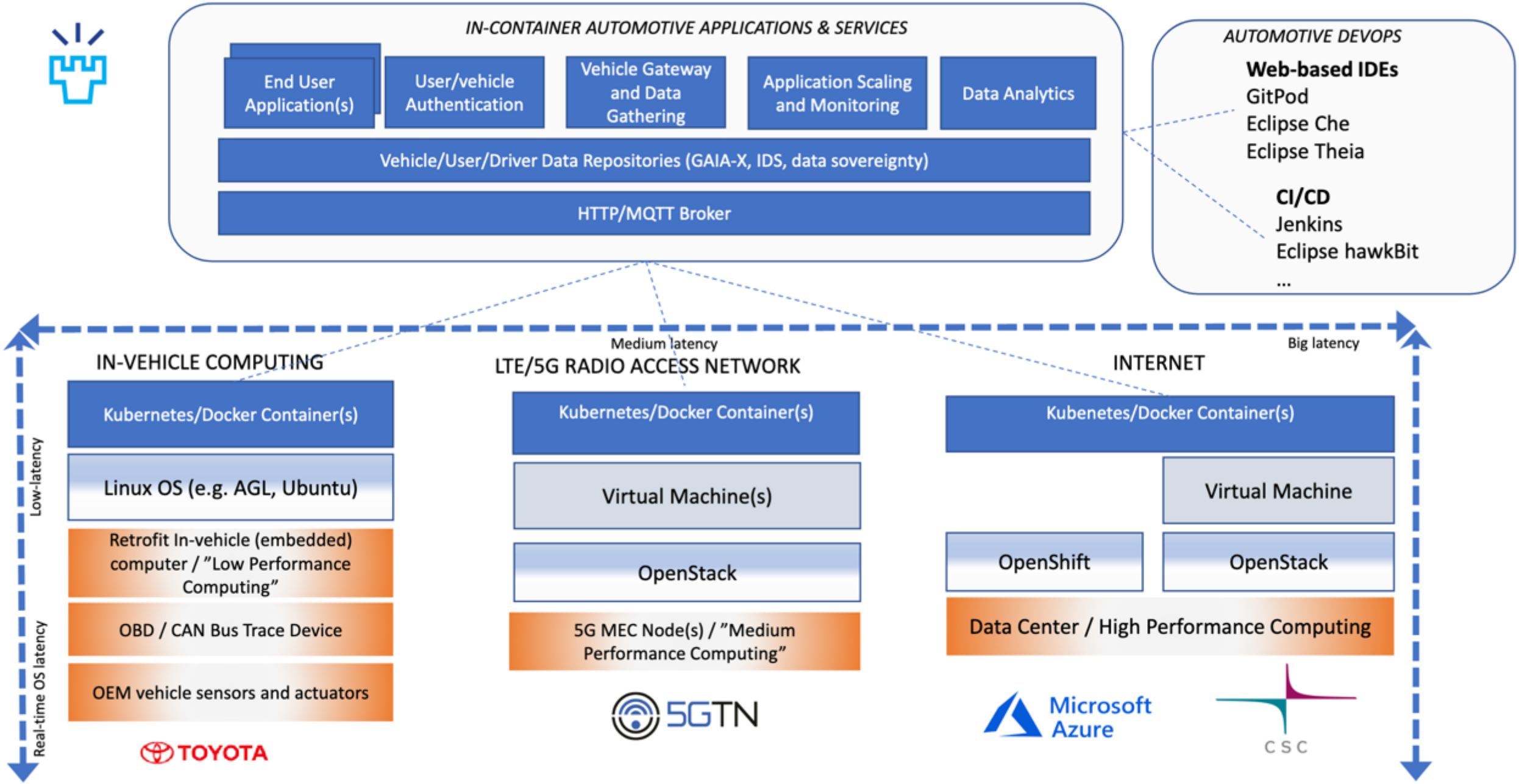
Connected vehicles + automotive edge

- Massive research area for next 15+ years
- What to compute and where, when, and how fast?
- How to manage data and ML/AI models?
- How to provide necessary privacy and security features?
- How to include efficient software development practices and open APIs?

Connected vehicles + automotive edge

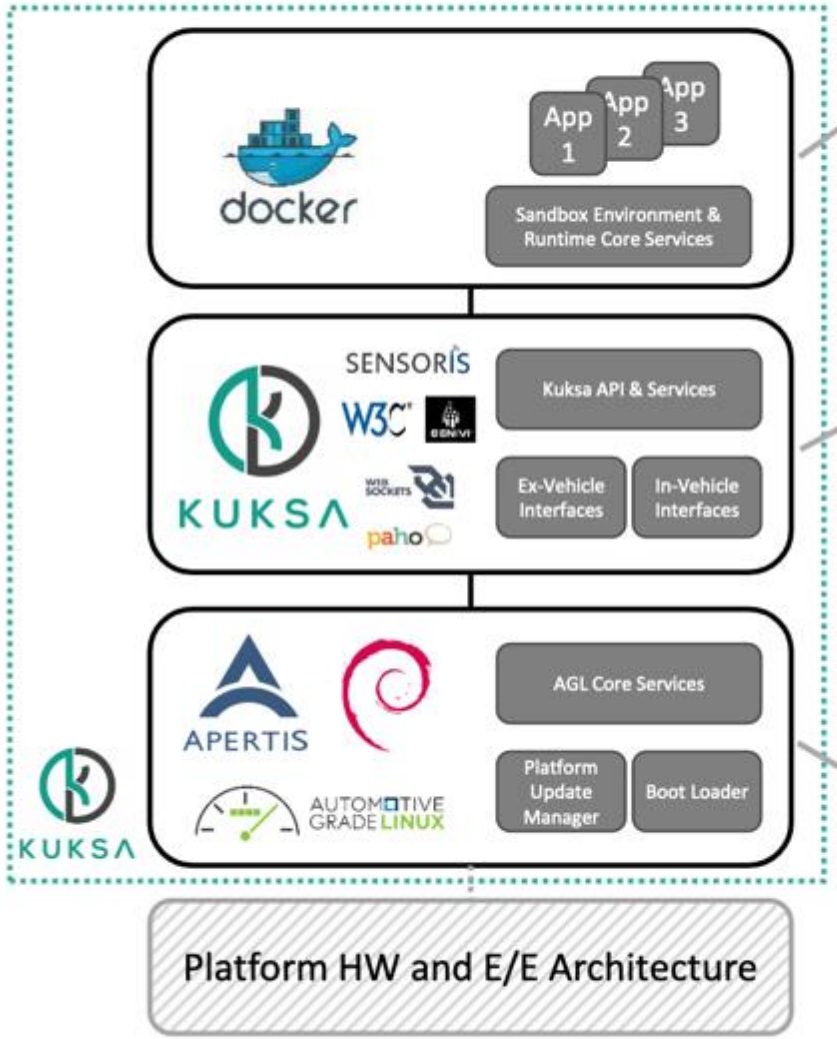


Peltonen, E., Sojan, A., & Päivärinta, T. (2021, June). Towards real-time learning for edge-cloud continuum with vehicular computing. In *2021 IEEE 7th World Forum on Internet of Things (WF-IoT)* (pp. 921-926). IEEE.


IN-CONTAINER AUTOMOTIVE APPLICATIONS & SERVICES
End User Application(s)
User/vehicle Authentication
Vehicle Gateway and Data Gathering
Application Scaling and Monitoring
Data Analytics
Vehicle/User/Driver Data Repositories (GAIA-X, IDS, data sovereignty)
HTTP/MQTT Broker
AUTOMOTIVE DEVOPS
Web-based IDEs
GitPod
Eclipse Che
Eclipse Theia
CI/CD
Jenkins
Eclipse hawkBit
...
Low-latency
Real-time OS latency
Medium latency
Big latency
IN-VEHICLE COMPUTING
Kubernetes/Docker Container(s)
Linux OS (e.g. AGL, Ubuntu)
Retrofit In-vehicle (embedded) computer / "Low Performance Computing"
OBD / CAN Bus Trace Device
OEM vehicle sensors and actuators
TOYOTA
LTE/5G RADIO ACCESS NETWORK
Kubernetes/Docker Container(s)
Virtual Machine(s)
OpenStack
5G MEC Node(s) / "Medium Performance Computing"
5GTN
INTERNET
Kubenetes/Docker Container(s)
Virtual Machine
OpenShift
OpenStack
Data Center / High Performance Computing
Microsoft Azure
CSC

Eclipse Kuksa

Kuksa In-Vehicle Platform



Application layer:

- Runs 3rd party apps on the platform
- Contains a Sandbox Environment & Additional Services

Middleware layer:

- APIs to abstract the vehicles' E/E architecture (W3C VISS, Sensoris…)
- Communication Services to manage network access and provide data from the vehicle
- Includes communication libs, protocols, security layers,…

OS layer:

- Reuse of OE's existing services, layers, HW abstractions, AGL services, Debian, Apertis, etc.

Kuksa

Where to go from here?

- Eclipse Kuksa Open Source project
  - Contribute with own ideas and development
  - Use and try the software
  - Be part of the development community

https://www.eclipse.org/kuksa/

https://github.com/eclipse?q=kuksa

Future research directions in Oulu

- New ecosystems around in-vehicular sensing data, autonomous driving, mobility as a service, and connected cars
- Open-sourced platforms that enable wide automotive app development
- Data collection in real-life situations
- Automotive digital twins and simulation environments

Collaboration?

- Vehicular sensing and IoT devices, such as wearables worn by the driver
  - ML/AI, signal processing, data management and representation…
- Vehicular software development and edge-cloud computing
  - SE solutions for vehicular edge, software-defined vehicles, edge-cloud orchestration for vehicular computing…
  - Docker + Kubernetes, SOA, microservices, vehicular CI/CD…
- Driving modelling and management, connected vehicles
  - Situational awareness, contextual information sharing, safe and privacy-preserving communication protocols…

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