

# Towards Smart Mobility: Vehicle-Centric View of Information and Communication Technologies

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Views expressed in this talk do not necessarily  
represent those of Toyota Motor Corporation.

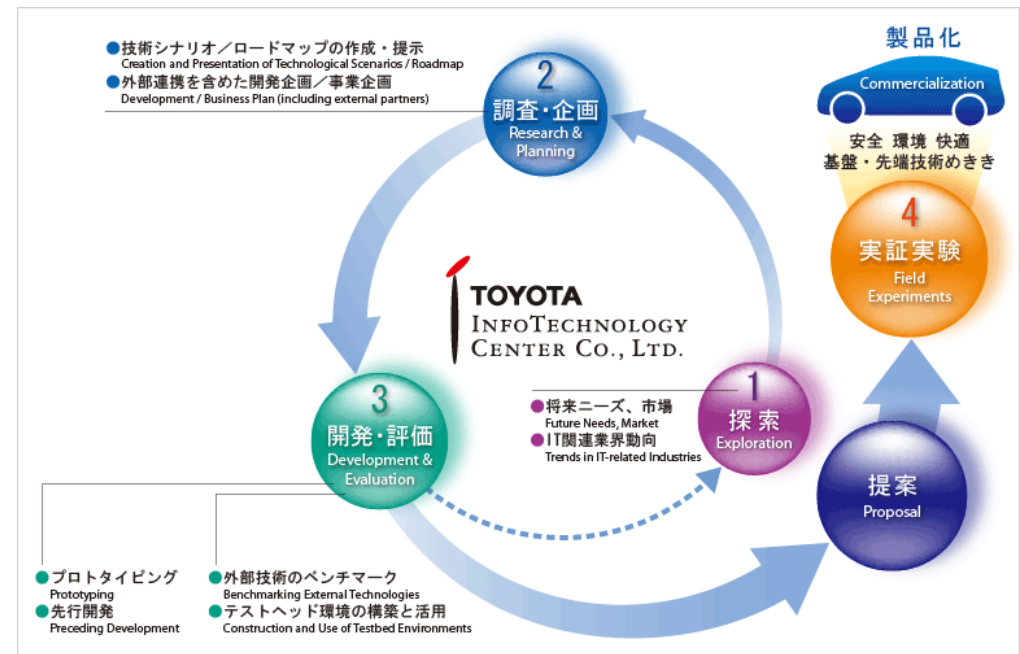
# Contents

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- Smart Mobility Concept
  - ITS, Energy Management, Urban Transport
- Cars as ICT Resources

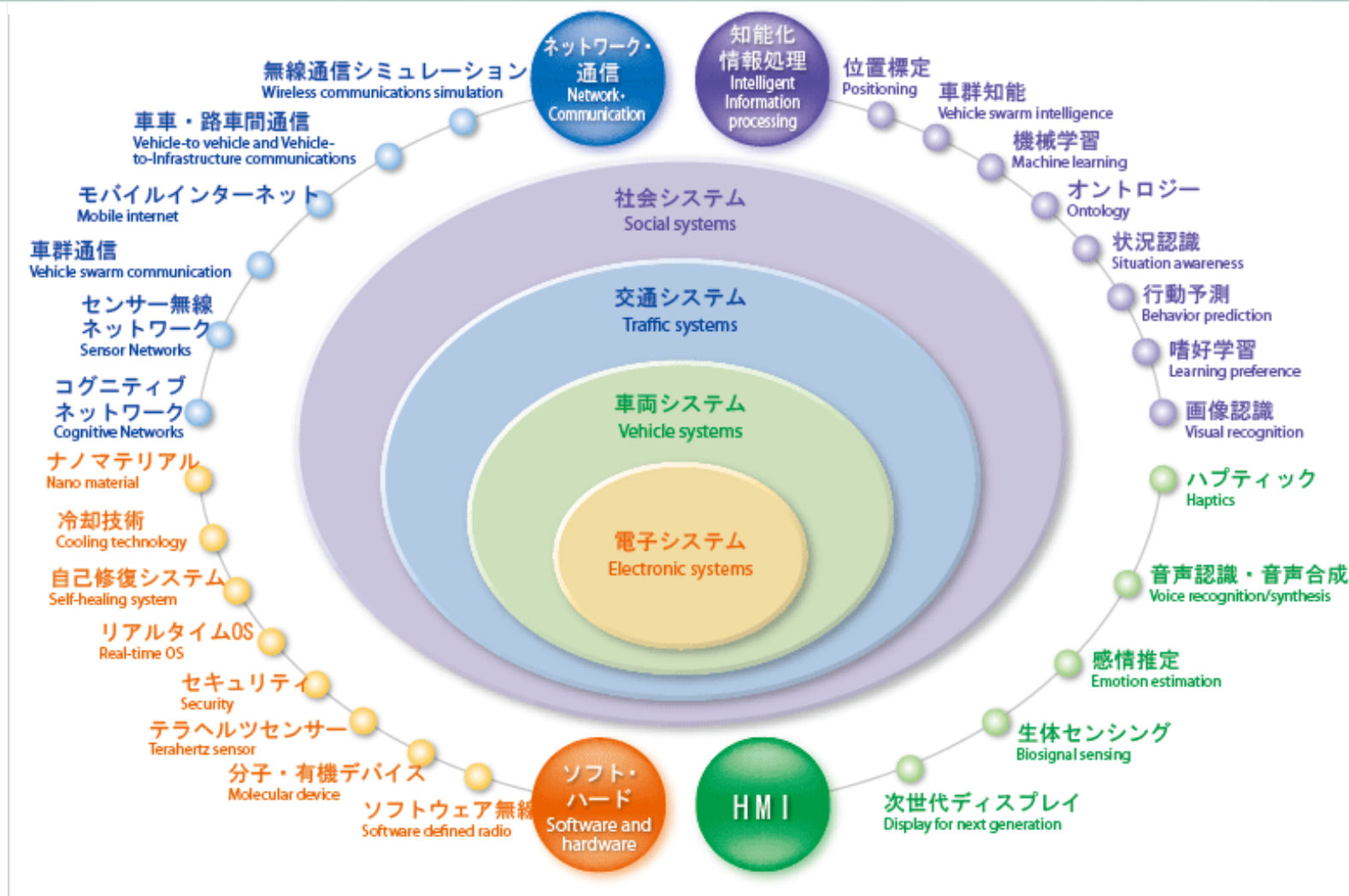
# About Us

- TOYOTA InfoTechnology Center established in January 2001 in Tokyo
- Joint venture of eight companies:
  - Toyota Motor Corporation, DENSO, KDDI and other Toyota group companies
- Presence in the USA:
  - Toyota InfoTechnology Center, U.S.A. in Mountain View, California
  - Business Research office in New York City



# TOYOTA ITC Research Activities

Vision of the vehicle which spans from a technical system to an integral part of the society



# Smart Mobility

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## Toyota's Vision

- Next Generation Telematics
- ITS
- Energy Management
- Next Generation Urban Traffic System

Source: <http://www.toyota-global.com>

# Next Generation Telematics

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## Connecting cars and people

- IT is changing the relationship with car.
- Suggestions on everything from routes to restaurants.
- Based on personal preferences, daily drive will be more pleasant.

## Connecting cars and smartphones

- Your car will be controlled remotely with your smartphone.
- Turn on the air conditioner or check your battery levels.

Source: <http://www.toyota-global.com>

# Intelligent Transport Systems (ITS)

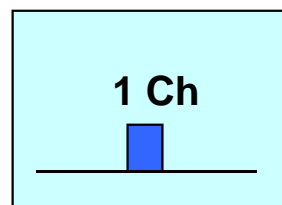
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ITS technology that virtually connects vehicles with other vehicles, pedestrians, and the road, to build a safer mobile society.

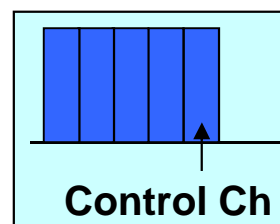
Source: <http://www.toyota-global.com>

# V2V/V2R Standardization

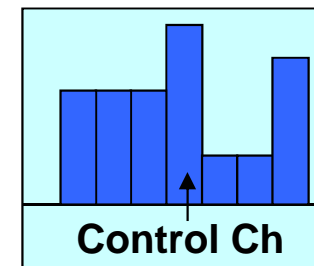
Communication Layers	Japan	Europe	USA
Message Set (Applications)	Safety	Safety, Non-safety	Safety, Non-safety
Network	IVC-RVC	ETSITS 102 637-1/2/3	SAE J2735
MAC	CSMA/CA	ETSITS 102 636-1/2/3/4	IEEE 1609.3
PHY	Ref. 802.11p ARIB STD-T109	ETSI ES 202 663, 802.11	IEEE 1609.4 IEEE 802.11p
		TCP/UDP, IPv6	TCP/UDP, IPv6



755 - 765 MHz



5855 - 5905 MHz



5850 - 5925 MHz

**+ Current ETC/DSRC**  
**5775 - 5845 MHz**

Source: S. Sai, et al., "Comparisons of Non-Line-of-Sight Inter-vehicle Communications in the Urban Environment Between 5.9GHz and 700MHz Bands," in IEEE Vehicular Networking Conference 2012



# ITS Services Starting in 2015 (Japan)

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## Right Turn Collision Warning

Alerts the driver of oncoming vehicles that can be difficult to see and pedestrians crossing the road

## Red Light Warning

Alerts the driver when the light ahead has changed or is about to change

# ITS Services Starting in 2015 (Japan)

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## Emergency Vehicle Notification

Driver is notified when an emergency vehicle approaches

## Cooperative-adaptive Cruise Control

Cars share information on speed changes in real-time.

Allows for a more efficient adaptive cruise control system. Multiple cars will drive as if they were a single unit, making highway driving more comfortable, safer, and simpler.

Reduced braking and accelerating, will help to ease traffic, cut carbon dioxide emissions, and decrease fuel costs.

Source: <http://www.toyota-global.com>

# Energy Management

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Cars will connect with homes and communities to optimize energy use across entire cities.

## **Connecting cars and the community**

Homes, offices, stores, and factories in a community will link together via cloud technology. Working together, this can create a low-carbon society.

Source: <http://www.toyota-global.com>

# Energy Management

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- The Home Energy Management System (HEMS) developed to share electricity between battery-powered vehicles such as plug-in hybrid vehicles (PHV) and home.
- Using HEMS, users can charge vehicles with solar energy during off-peak hours and efficiently power their homes using their vehicles during peak hours.
- Toyota PHVs can supply enough energy on one tank of gas using its engine to power a standard home for around four days (40 kWh)

Source: <http://www.toyota-global.com>

# Next Generation Urban Transport

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By combining cars with public transit and last-mile-mobility systems, the next generation urban traffic system helps to enable a stress-free commute.

Ha:Mo

Harmonious Mobility Network

“Toyota is developing a community network called Ha:mo for optimal use of cars and other personal vehicles in combination with public transportation.”

Source: <http://www.toyota-global.com>

# Ha:mo

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Society with great freedom of movement  
(Improved convenience and accessibility)

Green society  
(Reduced CO<sub>2</sub> emissions, less energy consumption waste)

Revitalizing local communities  
(Improving local excursion ease and effective use of space)

Source: <http://www.toyota-global.com>

# Ha:mo Testing

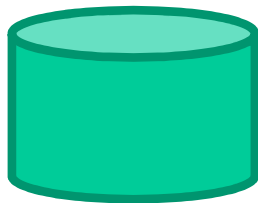
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- Tests first in Toyoda City, then in Grenoble, France and currently in Tokyo
- Grenoble: 3 year car sharing trial (started in October 2014)
- Toyota is providing use of the necessary sharing system, 35 vehicles each of the ultra-compact EVs: TOYOTA i-ROAD and the COMS.
- Tokyo: Testing is underway in conjunction with a city-wide parking lot operator (April-September 2015)
- Central downtown Tokyo is selected.

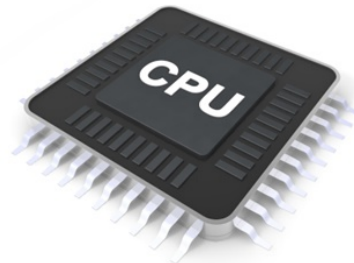
Source: <http://www.toyota-global.com>

# A New Role for Vehicles: ICT infrastructure

- Vehicle as “resource”
  - Storage
  - Communications/networking capability
  - Information/signal processing capability
  - Electric power
  - Sensing



Storage



Processing



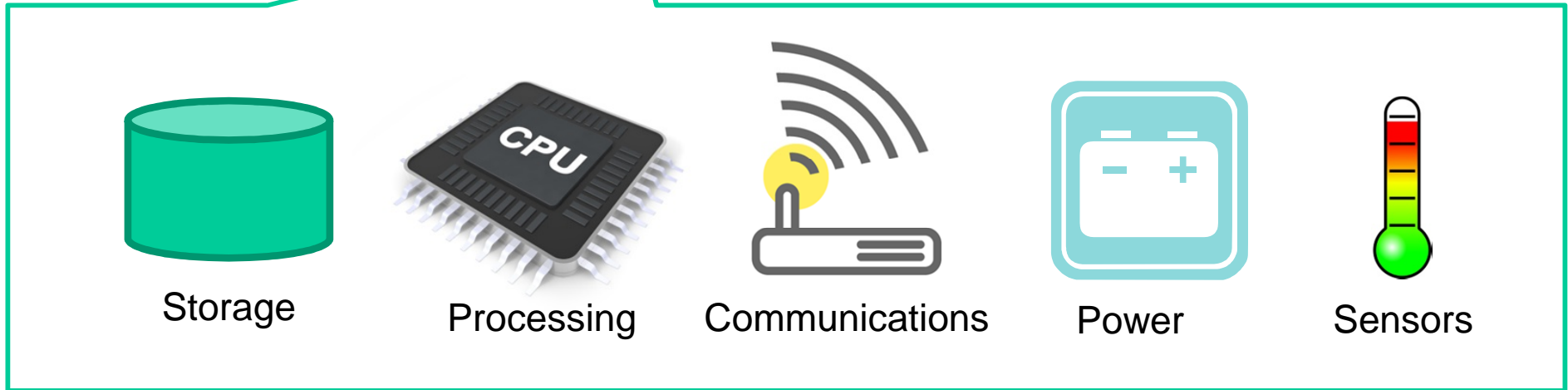
Communications



Power

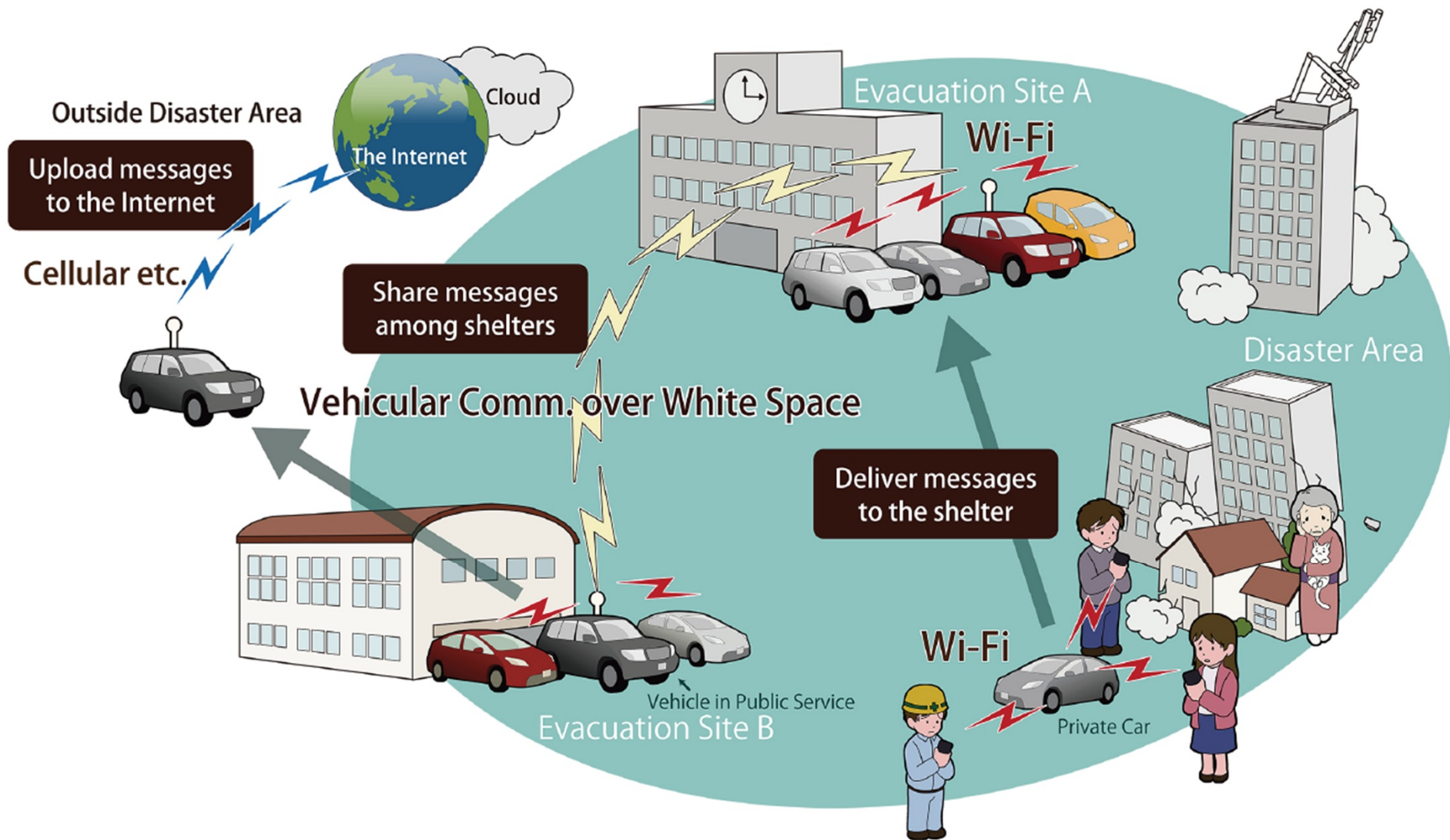


Sensors



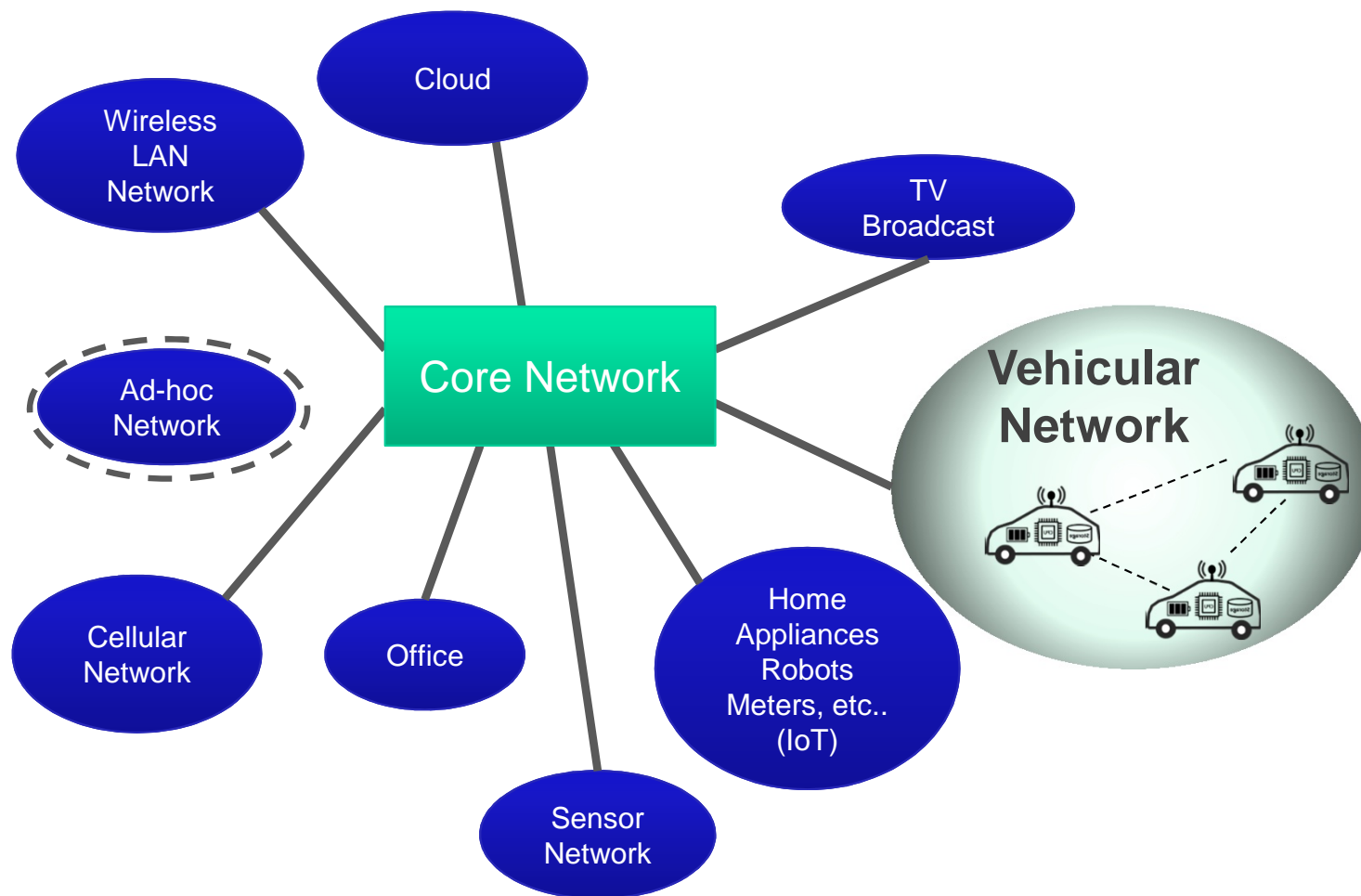


# Vehicles Carrying Data

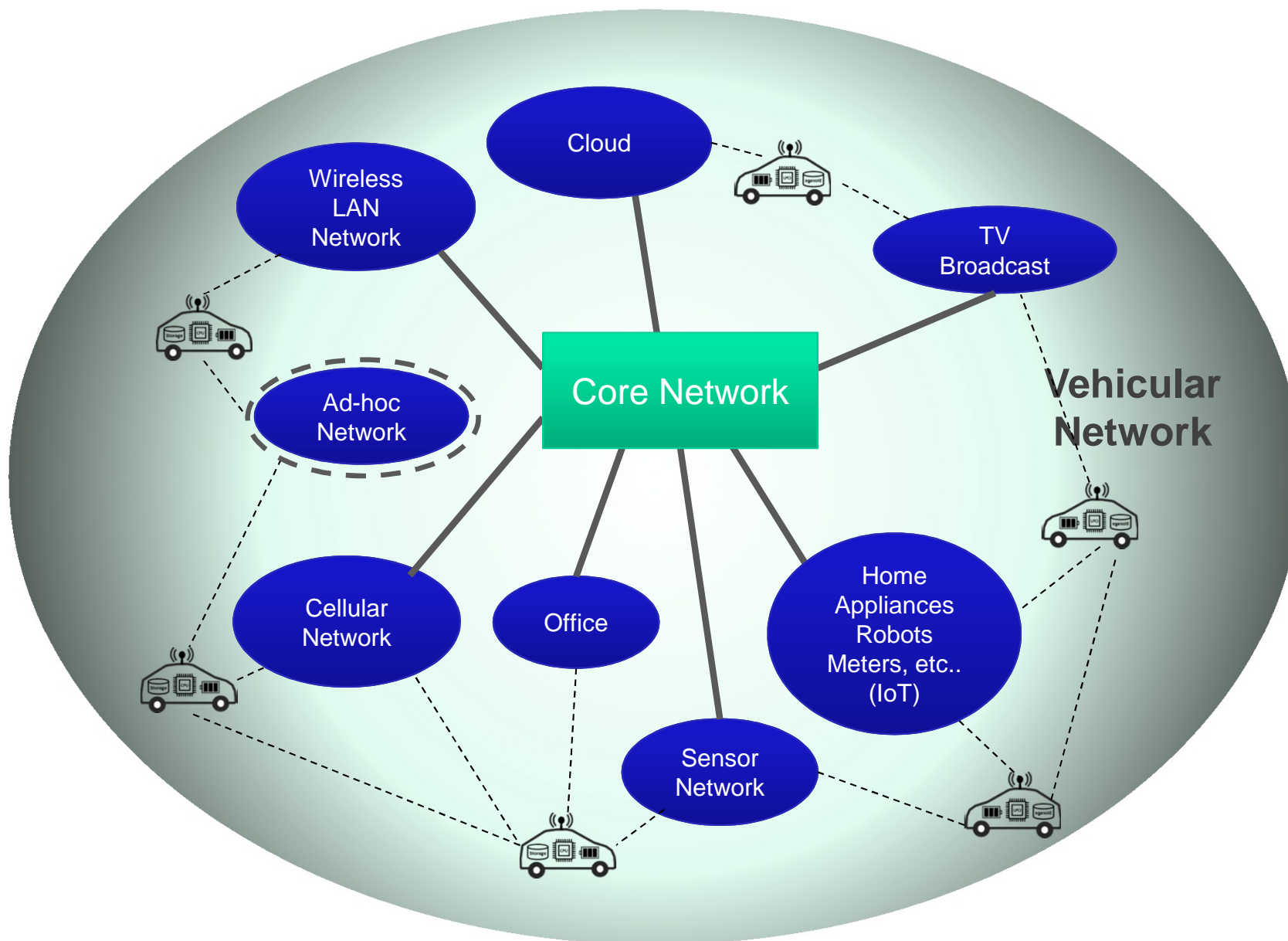


O. Altintas, et.al, "Vehicles as Information Hubs During Disasters: Glueing Wi-Fi to TV White Space to Cellular Networks," IEEE Intelligent Transportation Systems Mag., Spring 2014

# Classic way of looking at vehicular networks

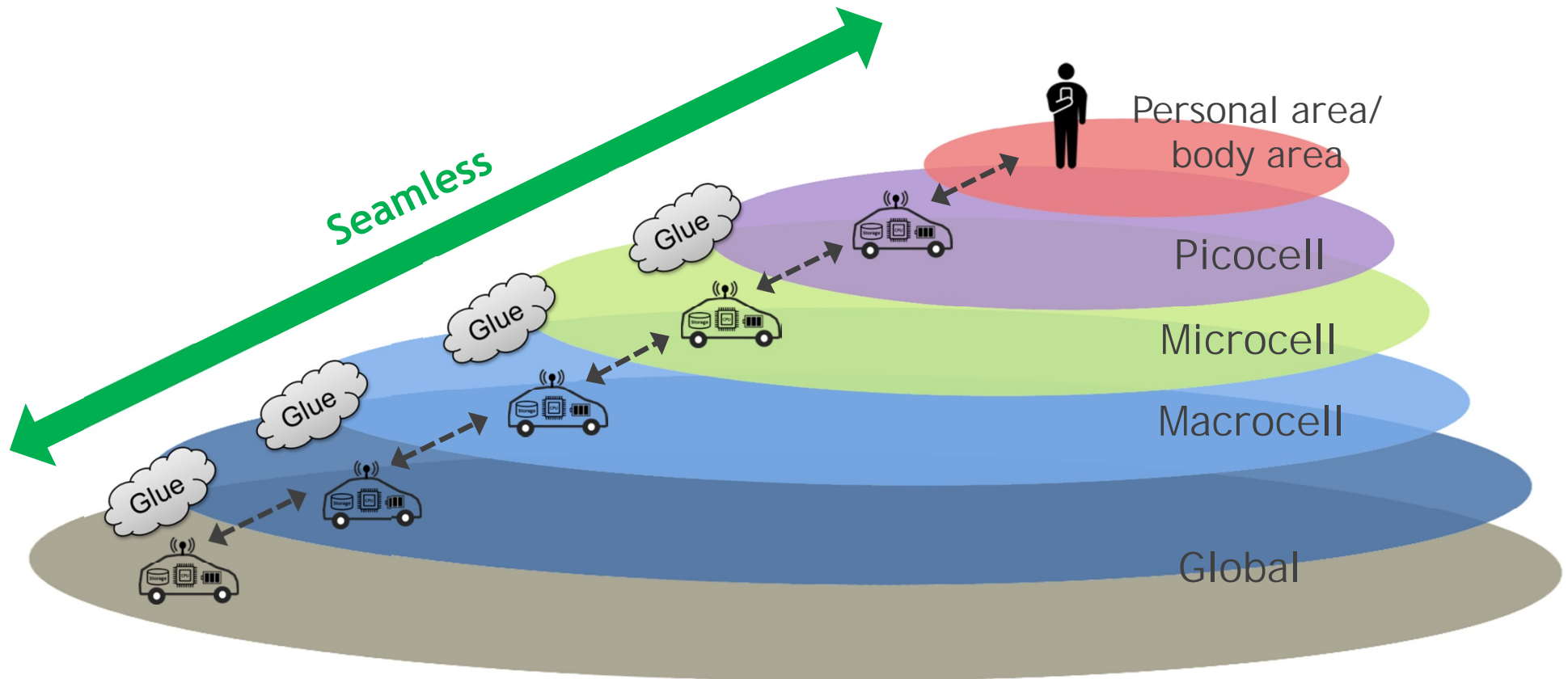


# Another way of looking at vehicular networks



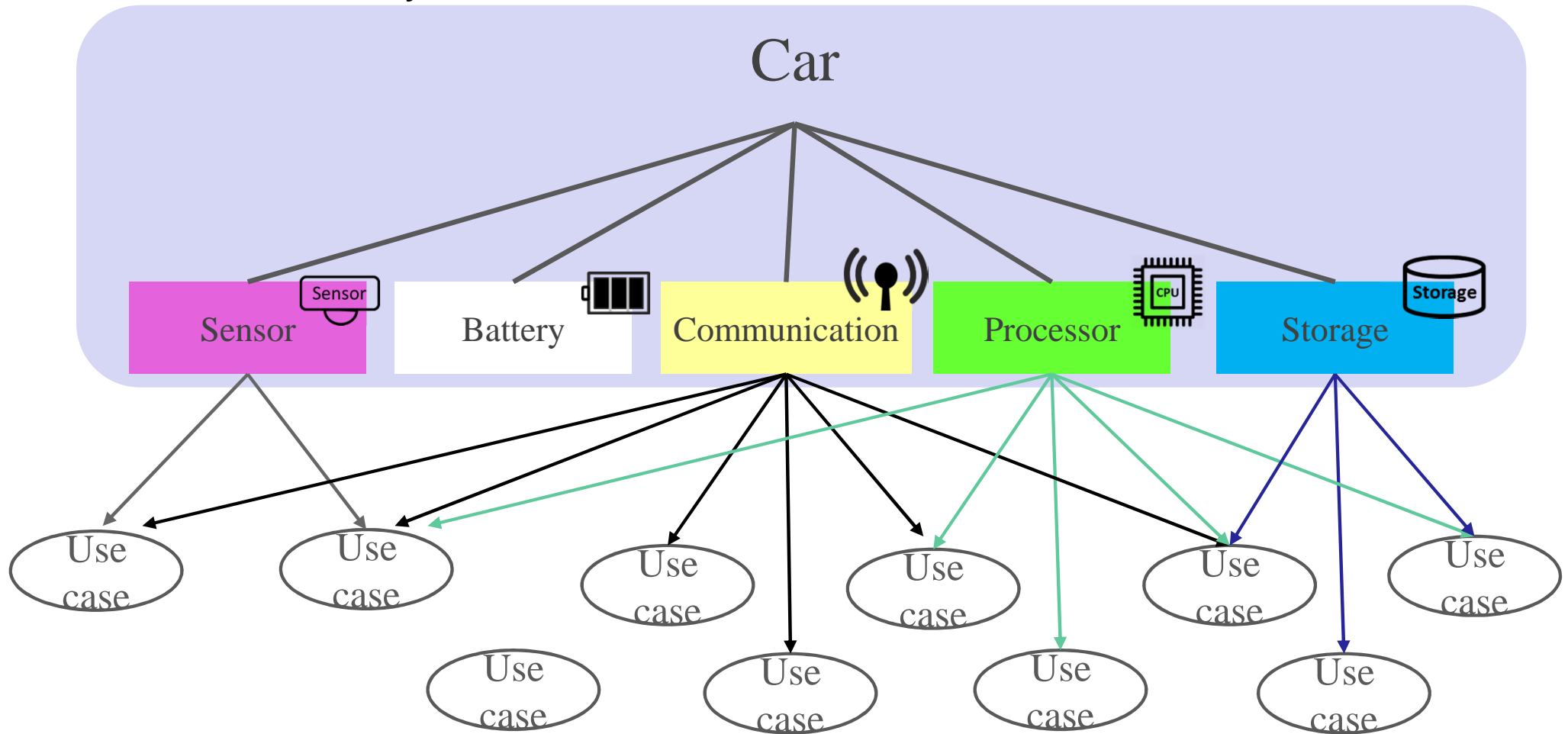
# Car for ICT

- Vehicles become “glue” between different networks



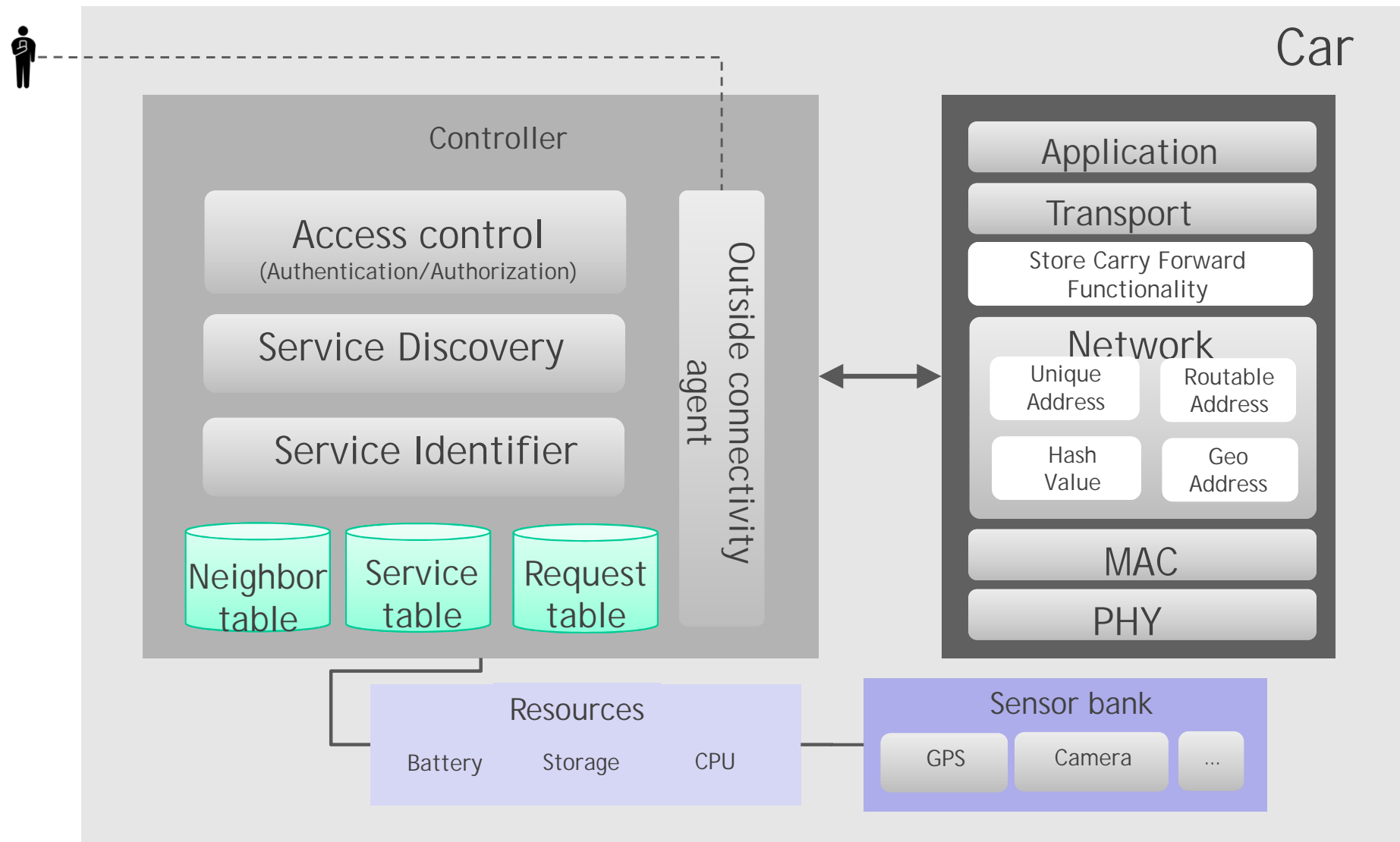
# Car for ICT

- But its's not only the network...



Vehicular resources are available not only for vehicles themselves but also for humans and "things"  
Vehicles store, process, and convey the information generated by human or things.

# Car for ICT Architecture



O. Altintas, F. Dressler, et.al, "Making Cars a Main ICT Resource in Smart Cities,"  
SmartCity 2015 Workshop in conjunction with IEEE INFOCOM 2015