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Connected Car Overview: Solutions, Challenges and Opportunities

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***Abstract*— In this paper, we defined the key concepts of IoV as application of IoT: connected car and an overview of the different communication cases leaded from vehicle to-x namely, vehicle-to-vehicle (V2V), vehicle -to- Internet (V2I), and vehicle-to-road infrastructure (V2R). We also identify promising area of research, Intra-Vehicle Connectivity and the most candidate wireless technologies to build intra-vehicle wireless sensor networks. This paper highlighted also the most recurrent transport issues and the IoT outcome solutions, characteristics and challenges, within a focus on the Intra-Vehicular Wireless Sensor Networks.**

Keywords*— *Connected Car, IoV, Intra-Vehicle Connectivity, V2V, V2I, V2R, Wireless Technologies.

I. Introduction

The Internet of vehicles (IoV) is an Internet of things (IoT) application in the intelligent transport system, and which has prompted a lot of research. The IoV can be used to collect, transmit, identify, integrate and make use of information from cars. It can get intelligent identification, location, tracking, monitoring and management and is therefore considered to be the most likely to have the greatest industrial potential in the IoT application.

A. *Internet Of The Vehicle*

The number of vehicles has increased dramatically in recent times around the world and will continue to increase [1], as shown in the Figure1. Moreover, 90% of them will be connected, by 2020[3].

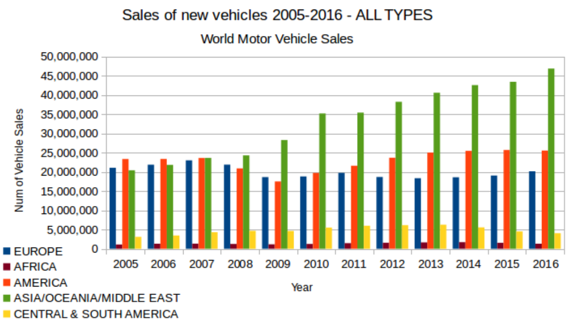

Figure 1: Sales of new vehicles 2005-2016 - ALL TYPES

This char is based on the statistics file "total-sales-2016.xlsx" available [2]

This section provides an overview of to the connected car notion and the in-vehicle networking.

B. *In-Vehicle Network*

The recent vehicle consists of 50–100 embedded computers [3], called electronic control units (ECUs), which are connected to each other in an in-vehicle network. ECUs are further connected to sensors and actuators, so that they can receive sensor information about the environment and send commands to actuators, to perform their tasks [4].

The in-vehicle network there is a variety of sub-networks of different bus system technologies: Controller Area Network (CAN), Local Interconnect Network (LIN), and FlexRay. The sub-networks are connected to each other through special gateway ECUs [18].

Specifications	CAN	LIN	FlexRay
Data rate	1 Mbps	20 Kbps	10 Mbps
Physical layer	dual wire	Single wire	dual wire, optical fiber
Architecture	Multi-master, typically 10 to 30 nodes	Single master, typically 2 to 10 slaves	Multi-master, up to 64 nodes
Message transmission type	Asynchronous	Synchronous	Synchronous and Asynchronous
Message Identification	Identifier	Identifier	Time slot
Usage	soft real time	Subnets	Hard real time
Latency	Load dependent	Constant	Constant

Table 1: Classic In-Vehicle Networking
This table done based on automotive Trier2 inputs [19]

Media Oriented System Transport (MOST)

MOST is a multimedia fiber optic network developed in 1998 by MOST cooperation [6]. The MOST protocol defines separate data channels and control channels. The control channels are used to set up the data channels for each link.

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Once the connection is established, data can flow continuously for delivering audio or video stream. MOST provides point-to-point audio and video data transfer with a data rate of 24.8 Mb/s. Thus, MOST is classified into Class D networks devoted to multimedia data.

Ethernet

IEEE 802.3 Ethernet is a commonly utilized CSMA/CD communication bus protocol due to its low cost, fast speed and high flexibility [17]. Not surprisingly, Ethernet is the technology of choice for much of the Internet and the most popular technology for local area network (LAN) in computer networking. The motivation to implement Ethernet in in-vehicle network is the ever-increasing bandwidth demanded by automobile applications, especially video-based Advance Drive Assistance System (ADAS).

This combination of networks used to answer a different network requirements. Infotainment systems for instance call for a higher bandwidth, where other systems require fault tolerant networks. Therefore, a variety of network topologies is used within cars [8]:

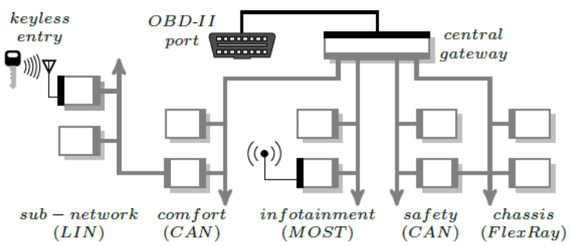

Figure 2: Schematic overview of various in-car networks

Image from [8]

C. Connected car

The connected car can be considered as an embedded system or a multi-layered platform equipped with a wireless network gateway connecting the in–vehicle network to an external network, and data collection, processing systems.

The connected vehicle allows the exchange of several information between the vehicle and its surroundings using WIFI, Bluetooth, GPS. The connection of the vehicle to the Internet is ensured either by a transmitter / receiver unit integrated with the vehicle itself, or via third-party systems such as smart phones.

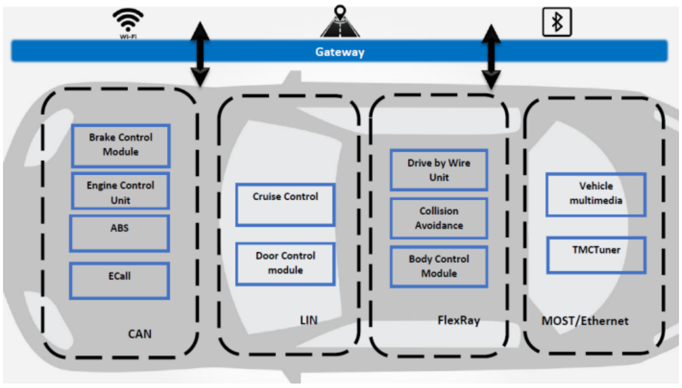

Figure 3: Connected Car Architecture

In the Figure3, we identified which networks are present in a modern vehicle Based on a variety of sources [7], [8], [9]. We assume that all networks are somehow connected, whatever networks are used within cars. This can be directly or indirectly via a gateway ECU.

The Introduction section, gives a state of the art concerning the IoT in transportation as well as definition of serval key concept were defined starting from Internet of Vehicle, In-vehicle Network and the car connected.

In second section, will briefly define the most popular architecture Inter-Network vehicle communication.

While the third section extend the intra-vehicle connectivity the most technologies used.

The last section, present the discussion of the IoV solutions already adopted and challenges to be overcome.

II. INTER-VEHICULE COMMUNICATIONS

As shown in Figure 3, the connected cars have multiple communication possibilities to connect to other vehicles (Vehicle-to-Vehicle) or exchange information with the external environments (Vehicle-to-road infrastructure), networks and services (Vehicle To Internet). These interactions, provide a promising opportunity to address the increasing transportation issues, such as heavy traffic, congestion, and vehicle safety.

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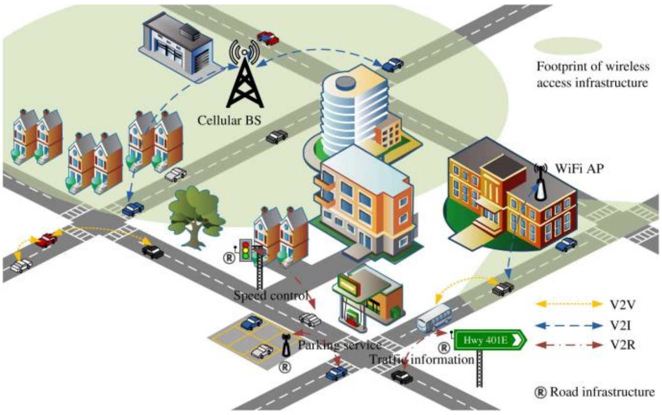

Figure 4: Overview of connected vehicles

Image from [9].

In this section, we listed succinctly the various types of communications for a connected car detailed in the literature [12] and [13].

A. Abbreviations and Acronyms Vehicle-to-Vehicle (V2V).

The term vehicle-to-vehicle (V2V) explains that connected vehicles can communicate wirelessly with each other. With this technology, drivers can take measures to reduce the severity of the collision or avoid it altogether, improve safety and road traffic efficiency. The National Highway Traffic Safety Administration (NHTSA) [14] affirms: "V2V technology has the potential to address approximately 80 percent of multi-vehicle crashes".

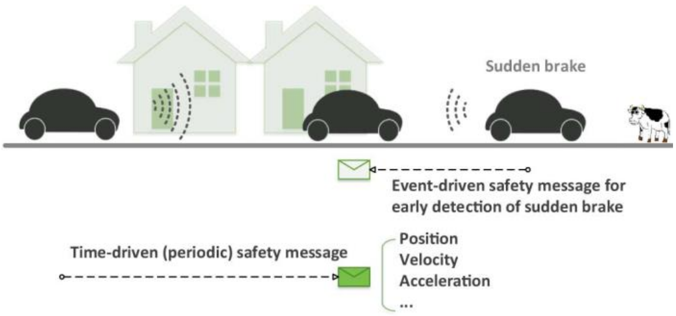

Figure 5: application of V2V to avoid collision

The dissemination of emergency braking message, as shown in the Figure 5, is an example of V2V application intended to collision avoidance.

B. Vehicle To Internet (V2I)

Is the fundamental requirement for a connected car; Modern vehicles must be able to access to Internet to experience dedicated services and access to multimedia information. The solutions available today connect vehicles to the Internet using cellular network infrastructures, using a Subscriber Identity Module (SIM) to allow the vehicle to get connected to the 3G/4G network.

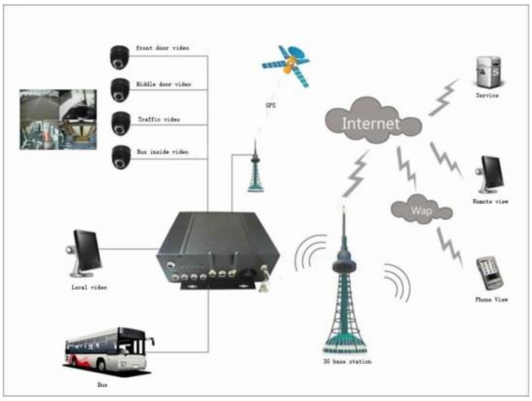

Figure 6: 3G Vehicle Monitoring Solution

The Command centers can query the location using 3G/4G network, of vehicles at any time, analysis of historical data, video playback, oil and weight loss; this application is illustrated in the Figure 6.

A. Vehicle-to-road infrastructure(V2R)

V2R connectivity is critical to avoid or mitigate the effects of road accidents, and to enable the efficient management of ITSs.

An example could be a parking lot with WIFI network, infrared devices, and parking belts to detect miss parked cars, illustrated in the literature [11].

Scenario description:

- When a car enters the parking lot and heads to the reserved parking slot, the entrance booth will validate the reservation.
- If the parking spot is validated, a direction-related guidance will be uploaded to the car for finding the reserved spot.
- The infrared device, lights, and parking belt will work together to detect and prevent mismarking. As shown in Figure 7, the Bluetooth communication will be activated when the front wheel presses the belt-a.
- The tamper-resistant device (TRD) and belt-a in Figure 4 will validate reservation confirmation as necessary.
- The infrared device is used to validate whether the car is parked instead of using the slot for a temporary purpose.

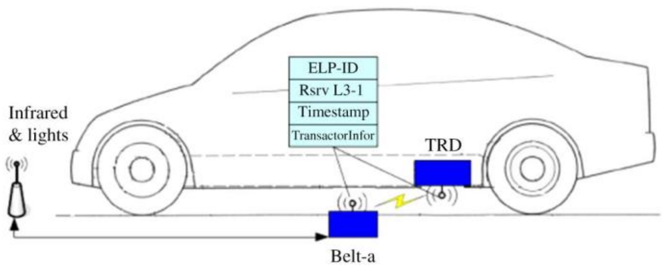

Figure 7: Vacancy of parking slot detections by sensors

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This section summarizes the most potential wireless communication standards used to perform automotive functions inside a vehicle such as: "IEEE 802.15.1 - Bluetooth", "IEEE 802.15.3 – Ultra Wideband (UWB), high data rate", and "IEEE 802.15.4 - ZigBee, low data rate", "Radio-frequency identification (RFID) "," IEEE 802.11 - WIFI".

III. Intra-Vehicle Connictivity

The number of sensors is fore-casted to reach as many as 200 per vehicle by 2020 [15]. Such a big quantity of sensing elements is required to report event-driven or time-driven messages to the electrical control units (ECU) and receive feedback if necessary. To do so, an intra-vehicle communication network should be carefully designed [10].

There exist multiple candidate wireless technologies to build intra-vehicle wireless sensor networks, and the feasibility of different wireless options to in-vehicle environments. We present bellow the wireless technologies have been investigated extensively in the literature.

Wireless Technologies

- **Bluetooth:** is a short-range wireless technology based on the IEEE 802.15.1 standard and operating in the industrial, scientific, and medical (ISM) frequency band (2.4 GHz). It allows the communication between portable devices at a data rate up to 3 Mb/s, and is highly commercialized for consumer electronics [21]. The Bluetooth devices are common in current automobiles, such as the Bluetooth headset and rearview mirror. However, the Bluetooth transmission requires a high-power level so that it might not be viable for battery-driven sensors in vehicles [12]. Moreover, due to the poor scalability, a Bluetooth network can only support eight active devices (seven slave devices and one master device) [22].

- **ZigBee**: is a short-range wireless technology based on the IEEE 802.15.4 physical radio standard. The ZigBee devices operate in ISM bands at 2.4GHz and have transmission rates of 250 Kb/s at the 2.4 GHz band with 16 channels, 40 Kb/s at the 915 MHz band with 10 channels and 20 Kb/s at the 868 MHz band with 1 channel. Transmission range varies from 10 to 1,600 meters depending on the chosen transmission power [20].

- **Radio-Frequency Identification:** The feasibility of using the radio-frequency identification (RFID) technology. The rationale of the considered passive RFID solution is that each sensor is equipped with an RFID tag and a reader connected to the ECU, which periodically retrieves the sensed data by sending an energizing pulse to each tag [10].

- **Ultra Wideband(UWB)**: operates on unlicensed frequency band between 3.1 and 10.6 GHz, can support a STA with mobility of 10 kph. It supports low power operation, low power dissipation, robustness for multi-path fading and higher throughput of up to 480 Mbps. Like Bluetooth, it has a transmission range of 10m. In Vehicular Ad hoc Networks (VANET), it can be used for collision avoidance [21].

- **Wi-Fi**: WLAN is based on the IEEE 802.11standard family. The most common current versions are 802.11b and 802.11g standards operating in 2.4 GHz bandwidth and capable of up to 54 Mbps or 11 Mbps data speeds, respectively. Recently also some devices supporting forthcoming standard have been published, expected to be able to provide up to hundreds of Mbps data speeds [22].

IV. Discussion

With the rapid growth in the number of vehicles, energy consumption and environmental pollution in urban transportation have become a worldwide problem. Efforts to reduce urban congestion and provide green intelligent transport become a hot field of research.
The open-up of automotive sector to adopt IoT approach is a promoted area of solutions to the increasing transportation problems. The table illustrate the application of IoT cited in some papers for inter-Network and Intra-Network communication solutions provided versus the challenges to overcome.

	papier	Transport problem	IoT application Solution	IoT application Challenge
Inter-Network Communication	[21]	Reduce accident and avoid Traffic congestion	V2V application	Data Security and Delay Constraints.
	[12]	Increase a Traffic Safety	V2I application	bandwidth constraint
	[11]	Smarter car and more intelligent systems in the vehicle	V2R application	The Roadside infrastructure involves additional installation costs.
Intra-Network Communication	[24]/[25]	Weight, maintenance cost reduction and fuel consumption	Intra-Vehicular Wireless Sensor Networks	Interferences, malicious attack, Real-time requirements, malicious attacks

Figure 7: Resume of the IoV applications intra/Inter Network communication

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Solution and opportunities

The evolution of automotive technology, Advanced Driver Assistance Systems (ADAS) integrates dedicated functions into more complete systems, require additional components, more sensors and more cameras and more wires and therefore more weight is needed to build larger smarter systems.

Cables and other accessories nowadays can add significant weight (up to 50 kg) to the vehicle mass [12]. Moreover, the installation and maintenance of aftermarket sensors (providing add-on functions) are inconvenient using cable connection. Recent advances in wireless sensor communication and networking technologies have paved the way for an intriguing alternative, where ECU and sensors are composed of an intra-vehicle wireless sensor network, leading to a significant reduction of deployment cost and complexity.

As result, more functions could be added ending to smatter and safer automobile without introducing additional weight.

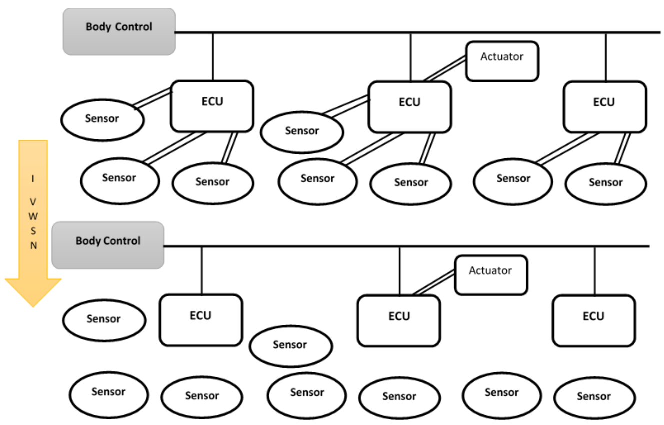

Figure 8: Intra-Vehicular Wireless Sensor Networks(IVWSN)

There are advantages to the hybrid wireless concept [25], such as:

- The weight reduction due to the replacement of the signal wires
- A simpler electrical wiring
- The maintenance of the electrical submodules would also be easier.
- A systems approach to this idea replaced an initial component-level approach.
- Availability and reliability of the off-the-shelf components (ECU, Sensor, actuator…) including wireless communication ability.

Characteristics and Challenges

The intra-vehicle wireless sensor networks have specific characteristics:

- Sensors are stationary so that the network topology does not change over time.
- Sensors are typically connected to ECU through one hop, which yields a simple star-topology.
- There is no energy constraint for sensors having wired connection to the vehicle power system.

Despite favorable factors, the design and deployment of intra-vehicle wireless sensor networks are still challenging.

- Data transmissions require low latency and high reliability to satisfy the real-time requirements.
- Interference from neighboring vehicles in a highly dense urban scenario may not be negligible.
- Security is critical to protect the in-vehicle network and control system from malicious attacks [23].

CONCLUSION & PERCEPECTIVES

- This paper present of the state-of- the-art of Internet of vehicle. We have discussed the potential challenges of building an intra-vehicle wireless sensor networks and identified the space for future improvement reduce the future car weight, thereby to increase the margin to meet the regulations of CO_2 emission continuously tightened by the governments.
- The next step will be selecting, modeling and simulating a vehicle system (ECU and Sensors eventually actuators) applying the IoT architecture to migrate it from wire communication to a wireless communication system to demonstrate that cable removal is possible while ensuring the same safe functioning.

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