WeVe: When Smart Wearables Meet Intelligent Vehicles

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Smart wearables and intelligent vehicles constitute indispensable parts of Internet of things (IoT). According to Cisco virtual networking index, global wearables will be more than 600 million in use in 2020, up from nearly 97 million in 2015. Meanwhile, according to GSMA, the market ratio of intelligent vehicles will reach 20% globally, which will reduce 85% car accidents by 2020.

The integration of smart wearables and intelligent vehicles would bring great convenience to and revolutionize every aspect of our daily lives, scaling from healthcare, transportation, entertainment, to communications. Automobile manufacturers (e.g., *Mercedes Benz, BMW, Nissan, Ford*) have noticed the necessity of such integration and developed apps that leverage the potential of wearables in automotive to improve the advanced driver assistance systems (ADAS) with biometric metrics and increase convenience, safety and efficiency of the driving experiences. For instance, BMW has developed a smartwatch app for Galaxy Gear that allows drivers to monitor their cars vitals and control vehicular features remotely.

Meanwhile, such integration faces a variety of unprecedented challenges, due to the unique characteristics of smart wearables and intelligent vehicles, in terms of various quality of service (QoS) requirements, highly dynamic network structure, the interoperability of the emerging communication technologies, etc. Thus the emerging technologies developed for IoT could not be applied directly.

Despite of all these remarkable development of wearable and vehicular technologies separately and the promising applications of such integrated system, there is not yet a clear vision of how the integrated system will look like under the umbrella of IoT ecosystem.

The aim of this project is to shape the integrated system of smart wearables and intelligent vehicles (WeVe) around development, research, and adoption of communication technologies. Moreover, a feasible hub-centric architecture is proposed for WeVe, which can be easily integrated with the existing protocol stack.

Fig. 1 illustrates the scenario of WeVe in the urban environments, where drivers and passengers in the vehicles, and pedestrians on the streets, are mounted with wearables. Such integration holds great promise in monitoring physiological information of drivers and passengers, alerting the relevant traffic lights and the nearest hospital when some healthcare emergency occurs, disseminating drunk warnings to the neighboring vehicles and pedestrians, providing driving entertainment, etc.

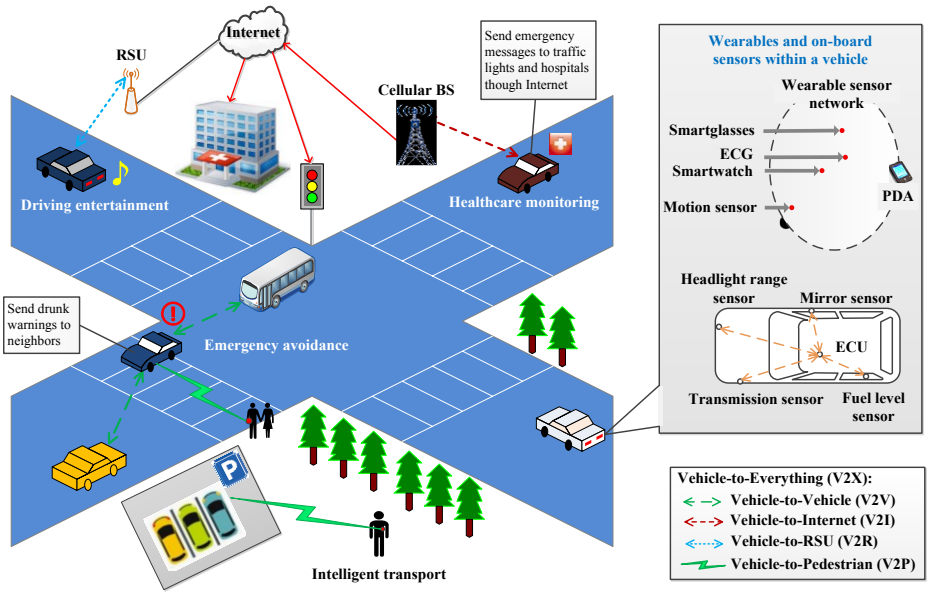

Fig. 1. The illustration of the scenario of WeVe in urban environments.

Hub-centric System for WeVe

We propose a hub-centric system for WeVe, which can be easily integrated with the existing protocol stack (wired, wireless, or hybrid). Fig. 2 illustrates the proposed WeVe architecture, where the communication of wearables and vehicles could be divided into internal of WeVe (communication among wearable and on-board devices inside a vehicle) and external of WeVe (communications among the current vehicle and other smart objects, e.g., other vehicles, RSU, Internet, pedestrians). A centralized hub, called WeVe hub, mounted on the vehicle, is designated to coordinate the communication of internal of WeVe and external of WeVe, allocate resources, and mitigate interferences.

Internal of WeVe

Internal of WeVe refers to the communication among wearable and on-board devices inside a vehicle. For internal of WeVe, there are persons with intelligent wearables, either drivers or passengers, and a variety of on-board automotive sensors. Wearable sensors collect the physiological information of a person, while automotive sensor is wired to a new electrical control unit (ECU) device, which then communicates with each other through a backbone network or through wireless communication technologies. There are several kinds of backbone network buses that can be used to connect ECUs and sensors, such as controller area network (CAN), local interconnect network (LIN), media oriented systems transport (MOST) and FlexRay. Internal of WeVe leverages on short range communication technologies for wireless communication.

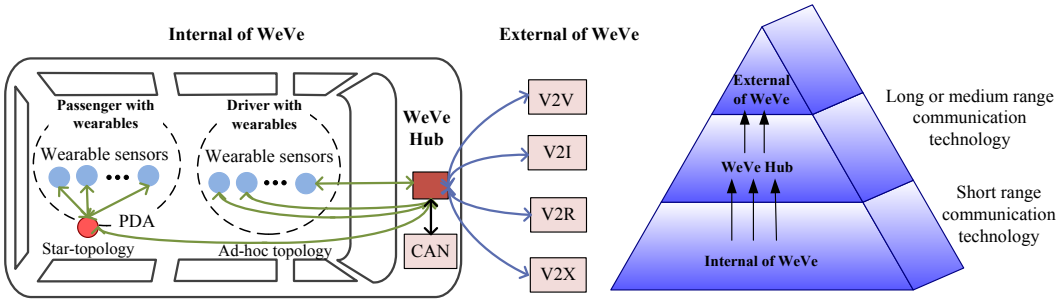

Fig. 2. Illustration of the proposed hub-centric architecture for WeVe.

External of WeVe

The external communication of WeVe refers to applications, services, and technologies that connect a vehicle to its surroundings. Particularly, on the streets, information generated by a vehicle (e.g., on-board computer, on-board sensors, control system, or wearables inside a vehicle) can be effectively disseminated among vehicles in the vicinity, or to vehicles multiple hops away in a vehicular ad hoc network, or to Internet, RSU, or pedestrians on the streets, i.e., vehicle-to-vehicle (V2V), vehicle-to-Internet (V2I), vehicle-to-road side unit (V2R), vehicle-to-pedestrian (V2P), referred to as vehicle-to-everything (V2X). In this case, a vehicle is treated as a mobile node or router. External of WeVe leverages on medium and long range communication technologies for effective communication between vehicles with dynamic mobility.

WeVe hub is mounted on the vehicle as a communication coordinator for intelligent wearables, on-board devices, as well as the communication interface for V2X communications. Fig. 3 shows the main functionalities of WeVe hub, which are detailed as follows.

Communication coordination: WeVe hub works as a coordinator for communication between internal and external of WeVe. After data processing from the wearables and on-board automotive sensors, the hub transmits the information to other vehicles or Internet. As various transmission protocols and standards exist in wearables and vehicles, WeVe hub needs to be capable of transmitting and receiving using various communication technologies, process the information from different sources, and determine the respond messages.

Resource allocation: WeVe hub is responsible for resource allocation for both internal and external communication of WeVe. A high volume of information-rich and unpredictable data will be exchanged by WeVe with different priorities and QoS requirements. With the highly dynamic network structure, channel characteristics and the available network resources are also highly viable and difficult to predict. WeVe hub needs to allocate resources from highest priority data to lowest priority data stream to meet the stringent QoS requirements under network dynamics.

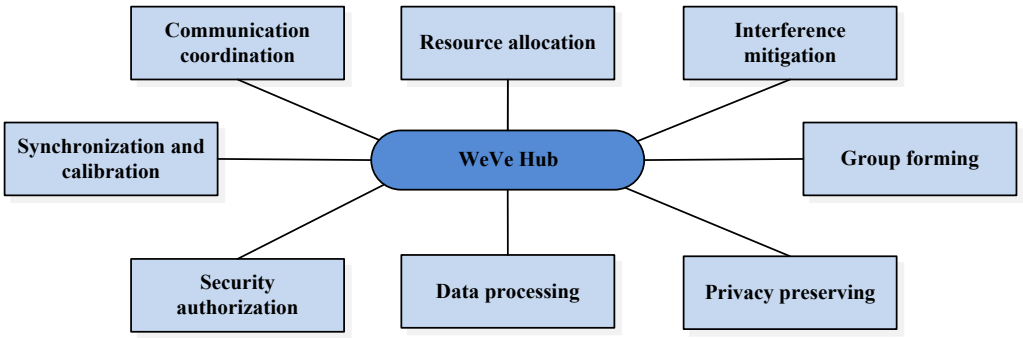

Fig. 3. The functionalities of WeVe hub

Interference mitigation: For internal of WeVe, wearables and on-board sensors co-exist in the limited space of a vehicle, sharing the industrial, scientific and medical (ISM) frequency band. When different vehicles move into the interference range of each other and transmit simultaneously in the same vicinity, the transmission of internal of WeVe may interfere each, consuming extra energy and causing error message delivery. In this case, WeVe hub should detect the interference situation dynamically and re-schedule the transmission channel and time slots in order to avoid the performance deterioration.

Group forming: With the highly dynamic network structure, WeVe hub is required to developing forming and disbanding framework for groups of wearables and on-boards sensors, or groups of vehicles and pedestrians, depending on the specific applications. Moreover, based on the stability and activity of the group, WeVe hubs in a group of vehicles need to determine the qualification of a group leader.

Privacy preserving: WeVe hub needs to protect the processed intimate information from the adversaries. Any agents that request to get access to WeVe need to get approval from WeVe hub.

Data processing: After collecting information from various sources such as persons or vehicles, WeVe hub would analyze the information along the sources. For instance, some information together indicates the abnormal healthcare information of a specific person, while some information from group of vehicles shows an accident. WeVe hub is responsible for indicating these events from the information, and prioritizing the follow-up actions for wearables or vehicles.

Security authorization: WeVe hub is responsible for checking the identity and authenticity of the requesting entities, preventing adversary attacks from other wearables, vehicles, or Internet. The hub also works as an advanced security protection for vehicles. That is to check the activity pattern of the driver or passenger. When susceptible person is detected, the vehicle could send warning information to the owner of the vehicle and other relevant agents.

Synchronization and calibration: WeVe hub is responsible for synchronizing and calibrating biomedical sensors and automotive sensors. As distributed devices do not share a power supply, accurate synchronization and calibration are required. As such sensors need to be waken up from sleep,

synchronization is essential for delivering life-critical information.

System Requirements

In the integrated system of intelligent wearables and vehicles, there are some performance requirements in terms of QoS provision, privacy, and security.

QoS provisioning: The communication system needs to accommodate heterogeneous sensor nodes with various QoS requirements, in terms of throughput, transmission delay, error rate, bandwidth, etc. In WeVe, when several traffics request the use of bandwidth simultaneously, network resource needs to be allocated according to QoS requirements.

Privacy: Wearable and vehicular devices are able to infer intimate information about the users, such as the trajectory, the heartbeat information, the disease history of the user, especially when combined with other context information. Therefore, WeVe has to ensure that information can be only accessed by authorized entities.

Security: As both wearables and vehicles are mounted around human beings, the malfunction of such devices would be life-critical. Thus WeVe needs to have countermeasures against adversary attacks.

We have developed an integrated system of smart wearables and intelligent vehicles (WeVe). Moreover, we proposed a hub-centric communication architecture for WeVe. Since the standardization of communication technologies for IoT are still on-going, it is meaningful to further investigate the interoperability of the emerging communication technologies in WeVe.