Abstracting and Interacting with Vehicles in the Web of Things

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Abstract. The Web of Things offers a platform-independent solution for interacting with connected devices. An important vertical of the WoT is the transportation domain with, at its core, autonomous systems and among others, connected vehicles. They can be seen as complex artefacts, as they are composed of many sensors and actuators, legacy specifications and safety criticality, which leads to additional challenges for cross-domain interoperability, scalability and safety. In this paper, we argue that the specifications around the Web of Things used with domain specific ontologies such as VSSo and the driving context ontology are relevant for connected vehicles. Our position is that Thing Descriptions require adaptations for complex Things or networks of Things: fine-grained access control and safety impacted by security. We propose a demonstration of a connected vehicle and a discussion on the topics of complex connected things acting as gateways of Things.

1 Introduction

Current and future automotive innovations are based on the interconnection of systems such as the vehicle, infrastructure back-ends and external data sources from Internet of Things (IoT) devices. Besides the sheer amount of data [13] and the communication challenges [4] (out of the scope of this paper), vehicle data is either unstructured or very specific to certain use-cases. Thus, robust and well-maintainable interpretation across the industry is desirable but hard to achieve [11]. We focus on three key aspects regarding the vehicle data itself: (1) the lack of interoperability, (2) the need for vehicle data simplification, and (3) the lack of semantics reusability.

Current research regarding connected vehicle [1, 12, 15] shows that interconnection of various vehicle-related systems, as well as their growing autonomy, requires a mean for them to understand their surroundings and share this knowledge. We notice a growing interest in using semantic technologies to define a formal model of vehicle signals [2]. Semantic Web technologies provide a certain number of standards such as the SSN/SOSA ontology [6] for enabling cross-domain interoperability among IoT ecosystems. The Thing Descriptions (TD) allows non-experts to interact with devices independently from the potentially complex technologies and protocols required.

In previous work, we developed VSSo and the driving context ontology to formally model vehicles and their contexts in order to be compatible with the WoT ontology [3, 11]. By combining such standards, we want to enable access and interaction to vehicle signals from the web, to provide the data with some explicit machine readable semantics and to make the data reusable for integration. The vehicle data we are mostly interested in are the static characteristics of a car and its signals generating highly dynamic data.

2 Discussion

As a potential major contributor to the IoT networks, connected vehicles[4] have requirements that differ from IoT devices of other domains:

- **Safety.** Vehicles must ensure safe trips to their passengers;
- **Complexity.** Vehicles embed complex networks of sensors and actuators which raise the question whether a vehicle is a single thing or a network of things, and more generally, how to model vehicles;
- **Legacy.** Several proprietary standards and fine-grained access rights on the various Electronic Control Units (ECU) exist.

We believe that the WoT can provide a standard for interacting with connected vehicles. Nevertheless, it must first comply with these vertical's technical requirements.

A concrete example would consist in creating a WoT TD for a vehicle with interactions on every signal provided by VSSo. This would lead to about 300 properties and at least 300 actions available on a unique interface. For instance the property of a `vsso:FuelType` and the action to turn on or off the ABS (`vsso:ABSIsActive`). This interface raises important safety questions, as well as a challenge in handling important number of interactions with potentially obscure signals.

2.1 Challenges

Since ecosystems of connected devices grow exponentially[5], the IoT and WoT face many challenges related to security, privacy and structure [14]. The automotive domain has, in addition, specific challenges[6]. One should consider the following aspects:

[4] `https://www.statista.com/topics/1918/connected-cars/`
[5] `https://www.ericsson.com/en/mobility-report/internet-of-things-forecast`
[6] `https://www.machinedesign.com/industrial-automation/3-critical-challenges-integrating-iot-traffic-networks`

- **Interoperability.** The automotive domain, like many others verticals (e.g. smart home, smart city) is highly self-centered. This is partially due to the domain specificity and legacy of vehicle manufacturers, but more generally, to the fragmentation of the IoT;
- **Domain complexity.** Vehicles are not simple devices but rather large sets of sensors and actuators[7], that often require domain expertise to be correctly and safely handled;
- **Infrastructure.** The amount of data, which is created and processed in a vehicle is enormous. The network of connected vehicles is still in development [5] and most of the global infrastructure remain to build;
- **Security/Safety/Privacy.** Connected vehicles are critical things in regard to user safety if security breaches are left, and potentially contain highly personal user data[8].

The WoT provides relevant specifications with respect to the interoperability, domain complexity and security/safety/privacy challenges.

2.2 Risks

The current specification is generic enough to be used in various domains. However, one of the main driver in the sense of demonstrations and examples is the smart home domain. As stated here, the automotive domain has some very specific requirements and implementations in place. The main risk might be to develop a standard, which might not fulfil the automotive requirements in terms of security and scalability or which might be hard to combine with existing solutions. In other words, if WoT and IoT specify how vehicles should be described and how they should interconnect, there will be a risk of opposition from vehicle manufacturers and their providers that have domain-specific standards and good practices. Instead, the automotive-specific standards should be linked to the WoT. This is for instance what VSSo [11], or the W3C automotive Working Group Vehicle Information Server [8] have been developed for.

2.3 Standards

Many standards are emerging to solve parts of these challenges: the WoT defines technology and protocol-independent interactions with Web Things, GENIVI's Vehicle Signal Specification[9] defines paths and a vocabulary for car signals, and SOSA/SSN [7] defines ontologies for Observations, Sensors and Actuators. All those standards enable partially a semantic enrichment of dynamic automotive data.

[7] `http://www.newelectronics.co.uk/electronics-technology/automotive-sensors-market-is-booming/149323/`
[8] `http://cardatafacts.eu/vehicle-makers-protect-personal-data-privacy/`
[9] `https://github.com/GENIVI/vehicle_signal_specification`

Already largely used on the web, especially by search engines and the schema.org initiative, semantic web technologies are more and more extended to physical devices in the IoT[10] and automotive domain[11].

2.4 Issues

We see two major issues in the WoT approach to connected vehicles: WoT TD are mostly defined and used for small devices but the complexity of vehicles makes this solution practically limited. Cross-domain interoperability seems possible only if the domain complexity is reduced.

There is, as of today, no explicit way of dividing a TD into a network of sub-Things. There is the possibility of using *Capabilities* as a means to cluster interactions, but this does not define, for instance, access control at the capability level. Vehicle data need preprocessing and more generally the development of adapted vehicle servers to interface proprietary technologies and open Web standards.

2.5 Possible solutions

A well-thought combination of ontologies may enable queries about complex driving contexts. It may include car signals, location, time and external data as well as labels tagging the driver, extracted from sensor data. For this purpose, we developed VSSo [9, 11] from the domain knowledge of VSS and good practices from both SSN/SOSA. This ontology helps modeling formally-enriched vehicle signals and attributes. We also developed the driving context ontology [10] to include driving contextual features, such as the driver behavior, traffic or weather, in a WoT-compatible fashion.

We have tested previous versions of the WoT specifications with connected vehicles and simulated vehicles, and have had positive results and feedback [9, 11]. However, those implementations are limited to few signals and interactions on static vehicles.

3 Possible work items

We propose for the workshop a discussion on complex Things and how to model them, using the example of connected vehicle as a first example but open to other verticals. We argue that especially the domain of smart home could benefit from a Thing network model.

In addition, we propose a demonstration of a connected vehicle adapted to the latest version of the WoT specification. We will build adapted interfaces and propose an access for developers to experiment on the vehicle data.

The WoT seems to be a great opportunity to enable interoperability and interactions between connected vehicles and other connected Things. This will

[10] `http://iot.schema.org`
[11] `http://auto.schema.org`

only be possible at the cost of a combination of proprietary domain-specific solution with the open Web standards.

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