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Advanced Features for Vehicular Networks: Grouping and Socialization
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Abstract

For future vehicular networks, some advanced features might be needed to facilitate use cases as platooning, proximity service awareness, autonomous driving and so forth. Thus, this draft intends to present two functions, known as vehicular grouping and socialization, for enabling some future-oriented use cases. These two functions could be built upon cross-layer identifiers, such as MAC, IP, and ID, which also have potential to formulate more value-added services for future vehicular networks.

Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119.

Status of this Memo

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1. Introduction

Nowadays, vehicular networks are under active development by different standard organizations (e.g., IEEE, IETF, ITU, ISO, 3GPP, ETSI, etc.), many industry alliances (e.g., Car2Car CC, OCF Automotive, 5GAA), and research institutes (e.g., NTU-SMP). As is well known, future networks demand high-throughput or massive low data-rate connections, low latency or deterministic delay, high mobility support with seamless communications, and inherent security built-in networks. Thus, vehicular networks become a typical use case satisfying all these future-oriented demands, and formulate one key scenario for future networks.

IP address plays an important role, as identifiers for end-to-end communications, in network layer for packet delivery, while other types of identifiers in cross-layers also function independently [Wet2010]. For achieving advanced features for future vehicular networks, all these identifiers could be properly grouped or even socialized to facilitate platooning, proximity service awareness, autonomous driving, and so forth. The following sections of this draft will elaborate vehicular grouping and socialization functions in more detail, for potential advanced features of vehicular networks, which may serve as partial requirement inputs for IETF IPWAVE WG with further investigations on more future-oriented features.

2. Requirements of Future Use Cases for Vehicular Networks

In this section, two typical scenarios for elaborating the functions of grouping and socialization are provided. Note that, for vehicular networks, there might exist more use cases to be developed.

2.1. Grouping Use Case

2.1.1. Platooning

One typical use case for orderly grouping is platooning, which has been described by some SDOs such as in [TR22.886]. Specifically, Platooning is a cooperative driving pattern for a group of vehicles which follow one another and maintain a small and nearly constant distance among them. Figure 1 illustrates this case on one road land while few cars are grouped together for platooning driving.

```
+++++++++RSU+++++++++++++++++++++++++++RSU+++++++++
LANE1        <<<Car1-Car2-Car3 [Platoon1]
LANE2
- - - - - - - - - - - - - - - - - - - - - - - - - -
LANE3
LANE4               [Platoon2] Car6-Car5-Car4>>>
+++++++++RSU+++++++++++++++++++++++++++RSU+++++++++
```

Figure 1: Example of Platooning

2.1.2. Requirements of Grouping

As shown in platooning [Jia2016], there exist some unique requirements, for instance: Initial platooning formulation; Dynamic joining or dismissing; Inter-vehicle distance control; Speed control; Security alerting. To realize these requirements, an integrated solution should be developed, which may exceed the scope of this draft focusing on requirements of advanced features for future networks. In particular, part of these platooning requirements will be discussed in Section III, with the discussion of dynamic grouping using cross-layer identifiers.

2.1.3. More Possibilities

In a smaller scale, the grouping normally happens among vehicles in tandem (as in above platooning case), or could be possibly operated among RSUs (Road-Side Units) and vehicles in parallel lanes towards the same driving direction. However, this case is much more dynamic and complicated than the former one, for which, we think, grouping in small scale cannot assume this function and thus a further discussion on socialization will be elaborated.

2.2. Socialization Use Case

2.2.1. Fully Socialized Vehicular Networks

The Thing-to-Thing socialization was initially proposed as SIoT (Social IoT) in [Atz2012], which serves as a paradigm to describe the relationships among heterogeneous IoT terminals.

More specifically, in terms of vehicular networks, the focused entities are different types of vehicles (e.g., sedan, ambulance, police wagon, etc.) on the road, which generally have high mobility and have frequent interconnections with surrounding vehicles, infrastructures (e.g., traffic lights, monitors, road-side sensors, etc.), pedestrians with handheld devices, UAVs, and road-side service points (e.g., gas station, restaurants). Based on this observation, there exists a potential for future vehicles to setup a variety of relationships with all the surrounding terminals with communications capabilities, for broader value-added functions. Figure 2 shows one possible scenario regarding this socialization among heterogeneous terminals. One more specific embodiment is also provided in [Far2015].

```
          |)     |^^^^^^^^^^|           BS1
          |)     |Restaurant|
          |      |          |  P1   P2             P3
     +++++++++++RSU+++++++++++++++++++++++++++RSU+++++++++++
     LANE1                 <<<Car2
     LANE2          <<<Car1
     - - - - - - - - - - - - - - - - - - - - - - - - - - - -
     LANE3      Car5>>>                     Car3>>>
     LANE4                     Car4>>>
     +++++++++++RSU+++++++++++++++++++++++++++RSU+++++++++++
                     |           |  P4   P5         |
             BS2     |Gas Station|                 (|   BS3
                     |___________|                 (|
```

Figure 2: Example of Socialized Environments for Vehicular Networks

2.2.2. Requirements of Socialization

To properly model the social relationships among vehicles and surrounding fixed or mobile terminals, some researches have been carried out recently [Ala2015] and more functions need to be explored as well [Atz2012]. Among which, a lot of relevant functions should be developed such as: relationship management (establish, update, dismiss, etc.), relation-based services (proximity, data delivery, etc.), mapping, lifecycle, access control and so forth.

3. Grouping for Vehicular Networks

This section is aimed to elaborate the grouping and its sub-functions, along with some key issues regarding to identifier-based dynamic grouping method. Some lower layer technical details (e.g., PHY layer) and specific upper layer implementations are currently beyond the scope of this draft.

3.1. Grouping Sub-functions

Grouping is not a trivial function, which should include multiple sub-functions, which are listed below:

- Group establishment: This could be carried out in both distributed or centralized manner, while one group head (e.g., Platoon head car) can take in charge of grouping, or alternatively, one central control node is responsible for grouping (RSU, or BS).

- Group head selection: In distributed manner, there should be a head car in one group who manages the group proactively. Thus, this head car should be selected at the beginning.

- Group member management (join or dismiss): Subsequent cars can join an existing group, or dismiss from the group.

- Group head delegation: With distributed grouping, the head may leave the group at certain moment. Thus, it should delegate its role to another member in the group.

- Group status maintenance: Dynamic joining or dismissing of member cars should be reflected and group status information should be exchanged as well. This may contain more information such as average speed, driving direction, fuel consumption, etc.

All the above functions are demanded for realizing proper grouping in vehicular networks. This draft focuses on networking identifiers for grouping, while other aspects are briefly discussed for future investigations.

3.2. Grouping via Cross-Layer Identifiers

In above listed functions of grouping, there must have certain type of identifiers to be used for labeling group members and make associated management.

3.2.1. MAC as Identifier

The MAC address (48 bits) is a typical identifier for grouping at MAC layer, while one typical use case is Bluetooth cluster (one Master with several Slaves, being associated by MAC addressed in a group).

3.2.2. IP as Identifier

The IP address is used at network layer for packet delivery, which could be locally valid or globally reachable. Both IPv4 and IPv6 can be used for identifying communications endpoints at network layer, so as to function as grouping identifiers. IP over WAVE is well studied in [Ces2013].

3.2.3. Application-Level Identifier

As proposed in [Wet2010], a set of dedicated application-level identifiers are formulated for vehicular networks. These identifiers have a IPv4-like length, which could be extended further in a IPv6-like manner to better uniquely identify objects in a global scale.

3.2.4. Independent Identifier Layer

Traditionally, IP address assumes an overloaded semantics, which serves both as endpoint identifier and routing locator [RFC6830][RFC7401]. Thus, many ILS (Identifier/Locator Split) schemes have been studied in the past decades, for the purpose of future network evolution [Fen2017]. Based on the same principle, it is possible to have an independent identifier layer above IP layer and below application layer, to serve for the intention of endpoints' communications or other purposes. This ILS paradigm also supports native mobility of moving nodes regardless of locator changes [Ces2015], so as to support vehicle mobility.

It is worth noting that vehicular networks normally require to uniquely identify individual vehicles, known as VID (Vehicle ID).

Based on previous descriptions, this VID could be derived from MAC address or other types of identifiers, as suggested in ETSI or IEEE. However, it might formulate VID in the independent identifier layer proposed here.

3.2.5. An Overview of Cross-Layer Identifiers for Grouping

Collectively, the following Figure 3 shows all potential layered identifiers for grouping.

```
    +---------------------------------+
    |  Application Layer Identifier   |
    +---------------------------------+
    |   TCP/UDP for Transport Layer   |
    +---------------------------------+
    |  Independent Identifier Layer   | --> Vehicle ID
    +---------------------------------+
    |  Internet Protocol Identifier   |
    +---------------------------------+
    |  Data-Link Layer MAC Identifier |
    +---------------------------------+
    |         Physical Layer          |
    +---------------------------------+
```

Figure 3: An Overview of Cross-Layer Identifiers for Grouping

3.3. Grouping Management

Due to the nature of high mobility and desired pseudonymity for privacy protection, grouping in vehicular networks has many challenges ahead [Pet2015]. This sub-section discusses two important aspects on grouping management, which should be of importance for further studies.

3.3.1. Dynamic Grouping Management

As described in Section 3.1, there exist few sub-functions for appropriately managing grouping, while the highly dynamic nature of vehicle networks requires all the relevant functions to be implemented quickly whenever a grouping event occurs.

In a distributed manner, the group head should be promptly aware of any change in its group. Such as in platooning case, the group head should control overall speed of all group member with their relative distance between each other. Additionally, the group head should manage the change of members (joining or dismissing), and delegate its role to another vehicle if it cannot serve as the group head any more.

In a centralized manner, one central controller/node should manage the formation of group and member changes.

3.3.2. Pseudonymity and Batch Update of Identifiers

The pseudonymity is a prominent feature that should be well considered in future IoT networks in general, for protecting any specific moving node from being tracked, so as to achieve location privacy with other associated private and sensitive information. Particularly, under the circumstance of vehicular networks, pseudonymity requires frequent updates of communications identifiers (e.g., MAC, or IP address). This also presents a challenge for grouping, which may be built upon multiple cross-layer identifiers.

Different layers utilize their respective identifiers to label vehicles, which may result in dynamically changing higher-layer identifiers dependent on varying lower-layer identifiers. For instance, IP addresses may be adopted by a central node to maintain a group of vehicles, while these IP addresses are associated with lower-layer MAC addresses. When MAC addresses are updated, the corresponding IP addresses may need to be modified as well.

One possible solution is that, using persistent VID (Vehicle ID) that may reside on the independent identifier layer (or defined in other layers) to build a vehicular group, and further make a dynamic binding between VIDs and underlying identifiers (e.g., IP, or MAC). In such case, the paradigm of ILS could be well suited, once the VIDs are not often exposed in the networks with proper protection.

4. Socialization for Vehicular Networks

This section intends to introduce an additional novel feature for future vehicular networks, which originates from SIoT concept [Atz2012]. Note that the distinction of socialization as compared to previously introduced grouping is that socialization is actually a social-link graph for all inter-linked objects, while grouping is simply a set of objects.

4.1. Socialization Sub-functions

As depicted in Figure 2, when vehicles are moving, they interact with all available surrounding environments and capable sensors or devices, which should be very practical in future if all infrastructures are deployed with intelligent IoT sensors or devices. In such scenario, the main entity i.e., the vehicle in vehicular networks, should have differentiated relationships with surrounding devices that may happen to encounter, often see each other on the road, always follow similar routine, bound with same services, or sharing similar applications, and so forth. Thus, it needs to realize a set of functions for socialized vehicular networks, which are stated below (not limited to):

- Relationship type definition: The vehicle-to-thing relationship is heuristic, since there does not have a standardized way to perfectly define this novel relationship at present. Previous SIoT studies show some typical relationship as given [Atz2012]. For vehicular networks, some useful relationships could be parental (same vehicular brand or manufacturer), co-location (co-geolocation), ownership (same owner), and social relationship (vehicle-to-thing friendship due to frequent interactions).

- Relationship management (establish, update, dismiss, etc.): Individual relation between any pair of vehicular objects should be properly managed, including relationship establishment, update and dismiss.

- Relationship storage: All relationships should be stored, mostly in a distributed manner, while some static relationships could be stored in a central server.

- Scalable query: Each vehicle may only store relationships from its own perspective, thus vehicle-to-vehicle relationship query should resort to some scalable query methodology.

- Relationship-based services: Based on vehicle-to-anything relationship, some advanced services could be enabled, such as

proximity service (e.g., road-side discount information), and alerting service (e.g., alert is sent by the traffic light that this vehicle passing through every day).

- Data delivery: Based on one-hop and multiple-hop relationships from one specific vehicle, the data delivery could be performed according to some relationship-based policies. For instance, when one alerting event happens, the vehicle is able to automatically inform all nodes in direct relationship and optionally inform nodes in multiple-hop relationship.

- Access control: Relationship may provide an additional dimension for access control, while limited relationships can be granted access rights.

- Trustworthiness: Different relationships should have differentiated trustworthiness, which shall support privacy protection over sensitive information.

4.2. Socialization via Identifiers

Similarly, as stated in Section 3.2, there exist multiple types of identifiers which could be used to label two endpoints of one relationship link. However, due to different characteristics of socialization, a self-certifying and privacy-protected identifier is wanted to serve for the purpose of socialization for vehicles and surrounding environmental sensor or devices. Thus, as indicated in Figure 3, VID defined in an independent identifier layer, could be a promising candidate.

With the considerations of massive IoT terminals and upper-layer support, one IPv6-like VID (same length with IPv6, but have distinct connotation) is recommended below, as shown in Figure 4.

```
  28 bits        4 bits         96 bits
+---------------------------------------------+
| VID Flag |  Vehicle Type | PKI-Hashed VID |
+---------------------------------------------+
```

Figure 4: One embodiment of VID

In Figure 4, VID Flag is 28-bit length, which resembles the function of HIP Orchid (Overlay Routable Cryptographic Hash IDentifiers) [RFC7401], and Vehicle Type serves the purpose of ITS Station Type defined in [Wet2010] with broader options. The last 96 bits adopt CGA (Cryptographically Generated Address) principle, which is actually a cryptographic hash of the public key of one particular vehicle. Note that this embodiment of VID can be regarded as pseudo-persistent identifier for vehicular networks, once it is well protected in the network (e.g., encryption via transmission). Thus, the frequency of reconstructing such VID becomes low, which potentially supports socialization functions mentioned above. In addition, IBS (Identity-Based Signature) might be utilized to construct such VID as well.

Particularly, for Vehicle Type segment shown in Figure 4, it could be defined as follows, in line with [Wet2010]:

- 0000: Central ITS Station

- 0100: Roadside ITS Station

- 1000: Vehicle ITS Station

- 1100: Personal ITS Sation

The additional two bits are open for future definitions, which could be that 0101 means traffic light and 1011 indicates ambulance.

4.3. Socialized Services

Once the vehicles and surrounding environmental sensors or devices are socialized, there may develop lots of innovative future vehicular services. Some of potential services are provided below:

- Proximity service: When co-location (co-geolocation) relationship is detected, the services attached by VID could be delivered, such as upper-layer application coupon information.

- Socialized vehicular status sharing: When two vehicles happen to see each other on the road, and their VID indicates same brand, they may activate the service of concerned information sharing, such as oil consumption, most vulnerable component, etc.

- Social relationship based alerting service: When emergency event happens, it normally resorts to human social relation to broadcast the information, if this service is previously subscribed by vehicle owners. However, in future vehicular networks, individual vehicles and other surrounding devices are equipped with intelligence inside, so they may actively exchange some useful information or even build their own machine-type social networks. In this case, when emergency

occurs, the corresponding vehicle could search its own social graph to find the closest devices to inform emergent events.

- Socialized Autonomous Driving: Fully autonomous driving will come true in the next decade, while an integrated solution with in-vehicle interconnections, intra-vehicle communications, fast data processing, intelligent planning should be developed. Then, socialization could be one enabler for this vision as well, which could support not only long-term relationship and also can support ephemeral relationship for cooperative autonomous driving.

Furthermore, given this new socialization feature, there should have more services available for further investigations, such as the socialized vehicular navigation studied in [Far2015].

5. Security Considerations

For the two features discussed previously in this draft, there exist lots of security issues that need to be well considered in near future. First of all, for dynamic group or social relationship management, it must ensure credible nodes to join, while preventing any malicious node. Then, the identifiers used at cross-layers should be securely managed and updated, such as VID is long-term used and should not be transmitted explicitly to unwanted targets. Furthermore, some low-latency and sensitive information should be explored along the social graph when all vehicles are socialized, which introduces trustworthiness problem as well. In addition, VID-attached data or some aforementioned services must be genuine, so that individual vehicles can utilize them in a secure manner.

6. References

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