IPWAVE Working Group
Internet-Draft
Intended status: Standards Track
Expires: May 20, 2020

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November 17, 2019

Neighbor Vehicle Discovery and Service in IP-Based Vehicular Networks
draft-yan-ipwave-nd-05.txt

Abstract

For Cooperative Adaptive Cruise Control (C-ACC), platooning and other typical use cases in ITS, direct IP communication between neighbor vehicles poses the following two issues: 1) how to discover a neighbor vehicle and the demanded service; and 2) how to discover the link-layer address of the neighbor vehicle and selected server. This document presents a solution to these problems based on DNS-SD/mDNS [RFC6762][RFC6763].

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.

Table of Contents

1. Introduction

As illustrated in [DNS-Autoconf], a naming scheme is needed for the vehicle devices to support the unique name auto-configuration. This can support the location based communicaton and scalable information organization in Intelligent Transportation Systems (ITS). Based on the naming scheme like this and the widely-used DNS-SD/mDNS protocol, this document illustrates how to discover a neighbor vehicle or the required services with DNS resolution logic. Before this, we make the following assumptions:

o Name: A vehicle SHOULD have a temporary name which is related to its geo-location.

o Address: A vehicle SHOULD have a global IP address which is routeable for the IP communications.

In this way, a standardized, efficient and scalable scheme can be used to retrieve the necessary information of the corresponding node (domain name, IP address, goe-location, link-local address and so on) for the further communications based on the DNS-SD/mDNS function. In addition, the IPv6 Neighbor Discovery (ND)'s messages (e.g., RA and RS messages) can also be used to exchange some required information (e.g., mobile network prefixes and link-local address) in ITS in combination with DNS-SD/mDNS [MNPP].

2. Prefix management

The network architecture which illustrates the prefix management of name and address is shown in Figure 1.

```
    +-------------+        +**********+        +-------------+
    | Router1     |--------* Internet *--------| Router2     |
    |[IP-Prefix1]|        +**********+        |[IP-Prefix2]|
    +-------------+                            +-------------+
          |                                          |
          |                                          |
     -----------                                -----------
     |         |                                |         |
     |         |                                |         |
+--------+    +--------+                   +--------+    +--------+
| RSU1   |    | RSU2   |                   | RSU3   |    | RSU4   |
|[Name1]|    |[Name2]|                   |[Name3]|    |[Name4]|
+--------+    +--------+                   +--------+    +--------+

+--------+
|Vehicle|--------moving---------->
+--------+
```

Figure 1: Name and address management architecture

As shown in Figure 1, Router1 and Router2 are two routers which can connect to the Internet and they hold different IP prefixes. RSU1 and RSU2 are two Road-Side Units (RSUs) under Router1 but hold different name prefixes, while RSU3 and RSU4 are two RSUs under Router2 but hold different name prefixes.

3. Name configuration

The RSU acts as an access router for the static and moving vehicles which want to be connected with the Internet. Based on [RFC3646], [RFC6106] or extended WAVE Service Announcement (WSA) message, the RSU can announce its location based name prefix to the vehicles covered by the RSU. This location based prefix may contain information such as country, city, street and so on, which will act

as the "domain_name" of the vehicle device name as spefified in [DNS-Autoconf].

4. Address configuration

The RSU may advertise the IP prefix to support the IPv6 Stateless Address Autoconfiguration (SLAAC) operation of vehicle devices and movement detection (in the IP layer). If the DHCP is used for the address configuration, RSU also acts as functional entity such as a DHCP proxy and DHCP server.

5. Neighbor vehicle and service discovery

(1) RSU based

Vehicles may have direct connection with the serving RSU and join the same link with the serving RSU. Then the RSU can maintain the registered vehicle or service in its serving domain. Otherwise, the RSU acts as a relay node for discovering in a proxy manner.

When a vehicle wants to locate the potential nearby neighbor and further establish the communication, the vehicle will trigger the direct unicast query to port 5353 or legacy unicast DNS query to the RSU. RSU may respond directly if it has the related information, otherwise, the RSU multicasts the DNS query to the multicast group to retrieve the related information. A unicast response is the first recommendation here because it can suppress the flooding, but of course, the DNS response message can also be multicasted as an active announcement of the verhicle or service existence.

(2) Ad-hoc based

Vehicles may communicate with each other or sense the front and rear neighbor vehicles with DSRC, WiFi, Bluetooth or other short-distance communication technologies, connecting each other in the Ad-hoc manner. Then the discovery can be executed in an infrastructure-less manner with the following phases, as specified in mDNS.

o Probing: When a vehicle starts up, wakes up from sleeping mode or the Vehicular Ad Hoc Networks (VANET) topology changes (after configuration of the name and address), it should probe the availability of the service with which it can provide other vehicles. Then the vehicle periodically announces the service and its existence with unsolicited multicast DNS response containing, in the Answer Section, all of its service name, DNS name, IP address and other information. The vehicle also updates the related information actively if there is any change.

- Discovering: To support the service and neighbor vehicle discovery in the dynamic and fragmentation-possible environment in VANET, different query modes of mDNS can be used for different scenarios: 1) One-Short Multicast DNS Query can be used to locate a specific vehicle. 2) Continuous Multicast DNS Query can be used to locate the nearby vehicles which are moving.

- Refreshing: After the neighbor discovery as illustrated above, the vehicles should continually exchange their DNS name, IP address, geo-location and other information in order to refresh the established communications. For example, the Multiple Questions Multicast Responses can be used to update the caches of receivers efficiently and Multiple Questions Unicast Responses can be used to support the fast bootstrapping when a new vehicle joins.

- Goodbye: When the vehicle arrives at its destination, stops temporarily or shuts down its communication or sensing devices, it will announce the service suspending and its inexistence with an unsolicited multicast DNS response packet, giving the same Resource Records (RRs) (containing its DNS name and IP address), but with zero Time-To-Live (TTL).

6. Mobility support

During the movement of the vehicle, it may cross different RSUs. When a vehicle enters the communication coverage of a new RSU, the new domain prefix and new IP prefix may be learned. Generally, there are two main cases for the mobility:

- The domain name changes and the IP prefix remains, as shown in Figure 1, the vehicle moves from the coverage of RSU1 to the coverage of RSU2. The vehicle will configure a new DNS name from RSU2 and may update the new DNS name in the local database (e.g., RSU). But the vehicle should keep its previous DNS name for a while until that all the communicating neighbors have learned its new DNS name. During this duration, the vehicle will contain both the previous and new DNS names in the DNS response message.

- Both the domain name and IP prefix change, as shown in Figure 1, the vehicle performs a handover from RSU2 to RSU3. The vehicle will configure both its new DNS name and new IP address from RSU3 and update them in the local database. Then the above scheme can also be used or with IP-layer mobility management protocols (e.g., Mobile IPv6 [RFC6275] and Proxy Mobile IPv6 [RFC5213]).

7. Signaling messages

To facilitate the further communication, the link-layer address and geo-information may be included in the DNS message in a piggyback manner. Otherwise, this information may be obtained through the following IPv6 Neighbor Discovery Protocol (NDP) or other procedures (e.g., DHCP and WSA).

8. Security considerations

In order to reduce the DNS traffic on the wireless link and avoid the unnecessary flooding, the related schemes in mDNS can be used, such as: Known-Answer Suppression, Multipacket Known-Answer Suppression, Duplicate Question Suppression and Duplicate Answer Suppression.

In order to guarantee the origination of the DNS message and avoid the DNS message tampering, the security consideration in mDNS should also be adopted.

9. References

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