IP-based Vehicular Networking: Use Cases, Survey and Problem Statement

(draft-ietf-ipwave-vehicular-networking-01)

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Updates from the Previous Version

- Previous two drafts:
  - draft-ietf-ipwave-vehicular-networking-survey-00
  - draft-ietf-ipwave-problem-statement-00

- Now merged into a new draft:
  - draft-ietf-ipwave-vehicular-networking-01

- Changes from the previous versions
  - Routing Section:
    - Analysis of a new research paper:
      - Location-Aided Gateway Advertisement and Discovery Protocol for VANets
    - Moving a research paper to Mobility Management Section:
      - An IP Passing Protocol for Vehicular Ad Hoc Networks with Network Fragmentation
    - Enrichment of Gap Analysis in Problem Statement subsection.

Introduction to Vehicular Networking

- Objective of this Document
  - To survey the activities of academia, SDOs, and industry of IP-based vehicular networks for Intelligent Transportation Systems (ITS) along with use cases.
  - To specify the problem statement for **IPv6-based** **Vehicle-to-Infrastructure (V2I)** or **Vehicle-to-Vehicle (V2V)** networking.

- Assumptions for Vehicular Networks
  - **IEEE 802.11 Series** (a, b, g, n, OCB) or **Cellular Links** (3G-UMTS, WCDMA, 4G-LTE, 5G-New Radio (NR)) are considered as main link types.
  - **IPv6** is considered as the Network-layer protocol.
  - **Road-Side Unit (RSU)** is connected to the Internet as an access point for vehicles.
  - **Traffic Control Center (TCC)** is a central node for managing vehicular networks as vehicular cloud.

Vehicular Networking Topics

1. Use Cases
2. Vehicular Network Architectures
3. Standardization Activities
4. IP Address Autoconfiguration
5. Routing
6. Mobility Management
7. DNS Naming Service
8. Service Discovery
9. Security and Privacy

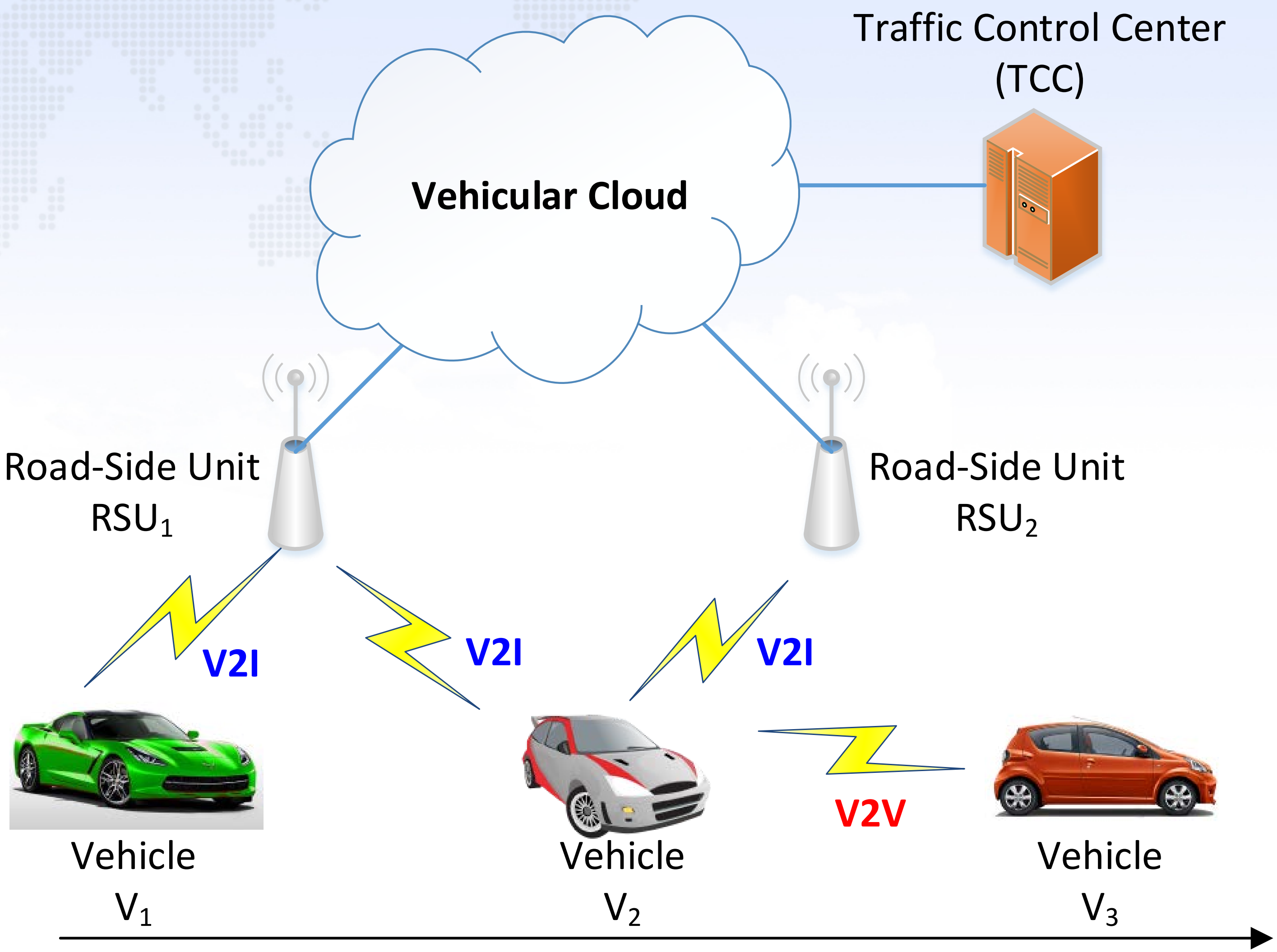
Use Cases for Vehicular Networking (1/2)

- **Use Cases for V2I Networking**
  - Navigation Systems
    - SAINT: Self-Adaptive Interactive Navigation Tool for Cloud-Based Vehicular Traffic Optimization
    - SAINT+: Self-Adaptive Interactive Navigation Tool+ for Emergency Service Delivery Optimization
  - Intersection Management
    - Cooperative Vehicle Intersection Control Algorithm for Connected Vehicles (CVIC)
  - Emergency Network System
    - First Responder Network Authority (FirstNet)
  - Pedestrian Protection System
    - SANA: Safety-Aware Navigation Application for Pedestrian Protection in Vehicular Networks

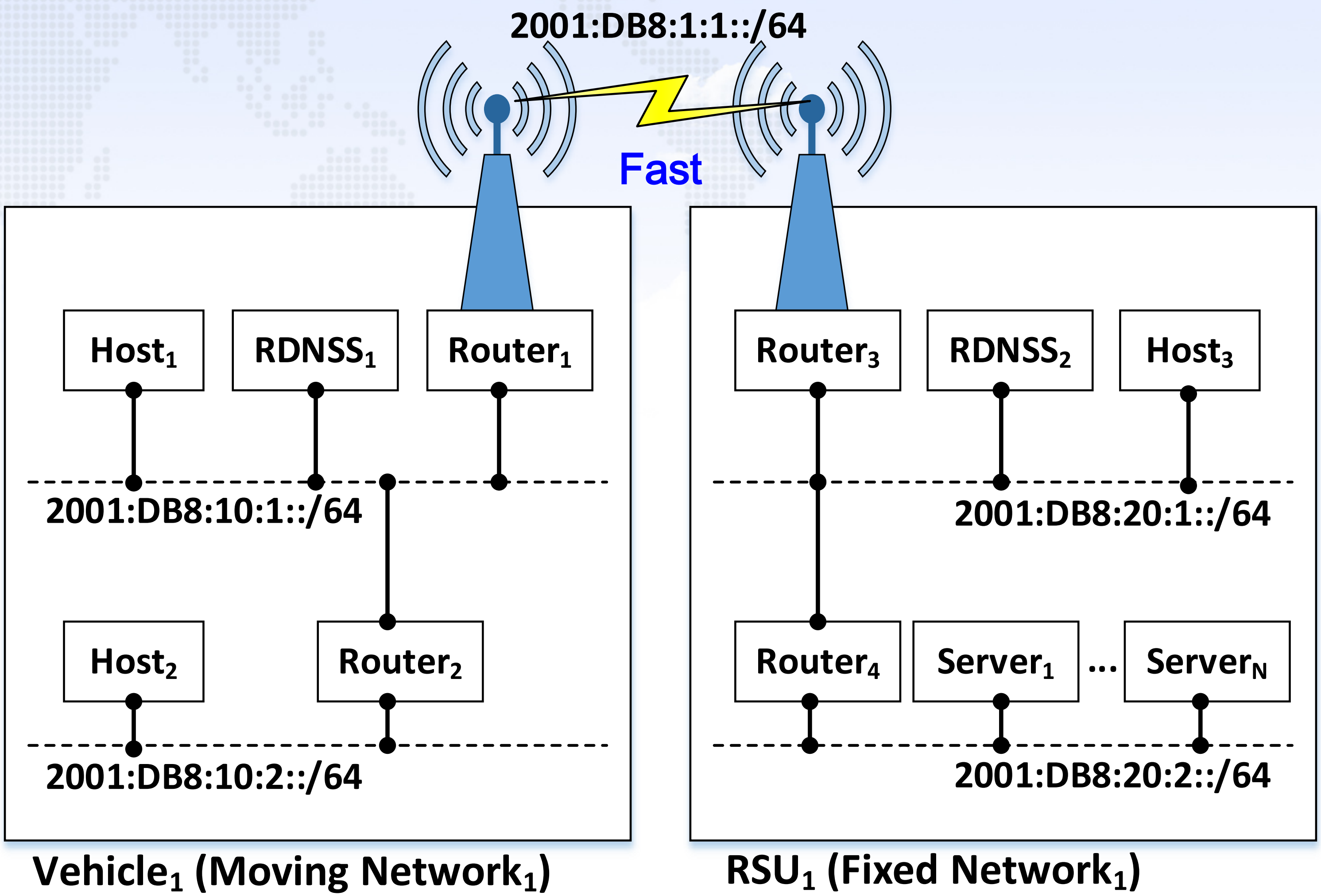
Use Cases for Vehicular Networking (2/2)

- **Use Cases for V2V Networking**
  - Driving Safety Systems
    - CASD: A Framework of Context-Awareness Safety Driving in Vehicular Networks
  - Automated Driving Systems
    - Cooperative Adaptive Cruise Control
    - Automated Truck Platooning
  - Vehicle-to-Vehicle Warning System
    - Coyote marketed black-boxes warning about speed limits and traffic hazards, in community, over GPRS with IP
    - Waze and TOMTOM Live Services

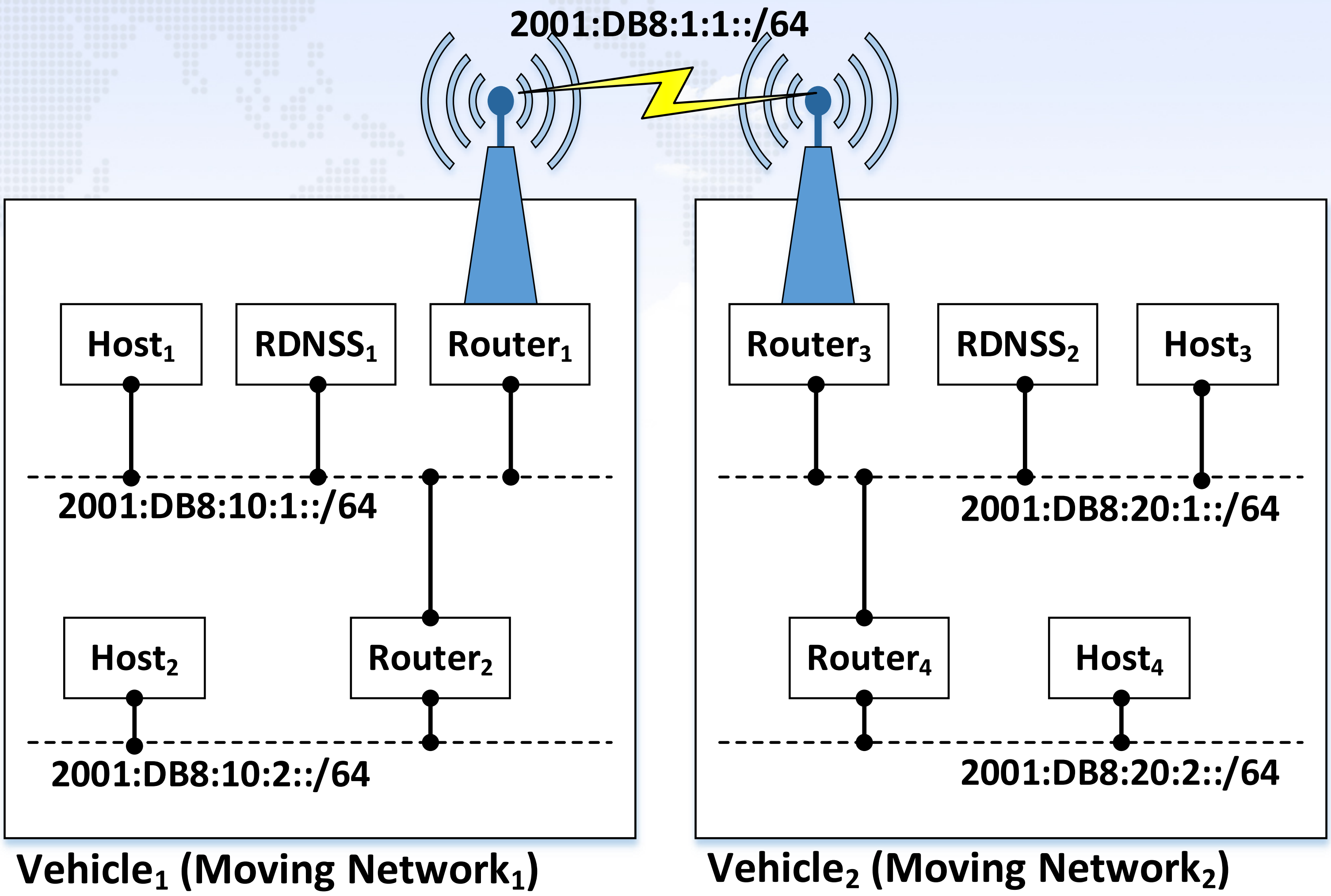
Vehicular Network Architecture



Internetworking between Vehicle Network and RSU Network



Internetworking between Two Vehicle Networks



Issues for IPv6 Vehicular Networking (1/6)

- **IPv6 Addressing Problem for V2I**
  - Two policies for IPv6 addressing
    - Local IPv6 addresses for vehicular networks
    - Global IPv6 addresses for internetworking
  - Local IPv6 addresses
    - Usage for road network services (e.g., emergency notification and navigation)
    - e.g., **Unique Local IPv6 Unicast Addresses (ULAs) [RFC 4193]**
  - Global IPv6 addresses
    - Usage for general Internet services (e.g., email, web surfing, and entertainment)
  - Policies for global IPv6 addresses
    - Multi-link subnet for multiple RSUs and cars
    - Single subnet per RSU
    - Single subnet between neighboring cars

Issues for IPv6 Vehicular Networking (2/6)

- **IPv6 Addressing Problem for V2V**
  - **Address Configuration Problem**
    - **In-vehicle addresses** may be pre-configured or configured dynamically from a network deployed along the road (for 802.11-OCB or cellular NIC).
  - **Communication Path Setup Problem**
    - How to establish **IP communication paths** between the computers in one vehicle and a nearby vehicle?
  - **Discovery and Exchange Sub-problems**
    - **Discovery Sub-problem**
      - How can edge routers in vehicles discover each other?
    - **Prefix Exchange Sub-problem**
      - How can edge routers in vehicles exchange routing information?

Issues for IPv6 Vehicular Networking (3/6)

- **Adaptation of Neighbor Discovery (ND)**
  - Adjusts ND time-related parameters (e.g., router lifetime and NA interval), considering high-speed vehicles and vehicle density.
- **IP Address Autoconfiguration (SLAAC and DHCPv6)**
  - Supports the fast configuration, considering high-speed vehicles.
  - RSU can perform IPv6 Stateless Address Autoconfiguration (SLAAC) including the Duplicate Address Detection (DAD) proactively on behalf of the vehicles as an ND proxy.
  - DHCPv6, DHCPv6-PD or Stateless DHCPv6 need to be adapted for fast moving vehicles in the vehicular network whose RSUs have different subnets.
  - Signal strength measurement from IP RA or WAVE Short Message (WSM) can be used to evaluate stable links.

Issues for IPv6 Vehicular Networking (4/6)

- **DNS Naming Service**
  - **IPv6 host DNS configuration** for Recursive DNS Server (RDNSS) and DNS Search List (DNSSL)
    - Through RA Options [RFC 8106] and DHCP Options [RFC 3646].
  - **DNS name resolution** through an appropriate RDNSS
    - Within a vehicle’s moving network or an RSU’s fixed network.
  - **DNS name autoconfiguration** of in-vehicle devices
    - Through DNS Name Autoconfiguration (DNSNA) [draft-jeong-ipwave-iot-dns-autoconf-01], mDNS [RFC 6762], and DNS Update [RFC 2136].
    - In-vehicle devices or hosts need to register their DNS name and IPv6 address into a local DNS server in a vehicle or an RSU.

Issues for IPv6 Vehicular Networking (5/6)

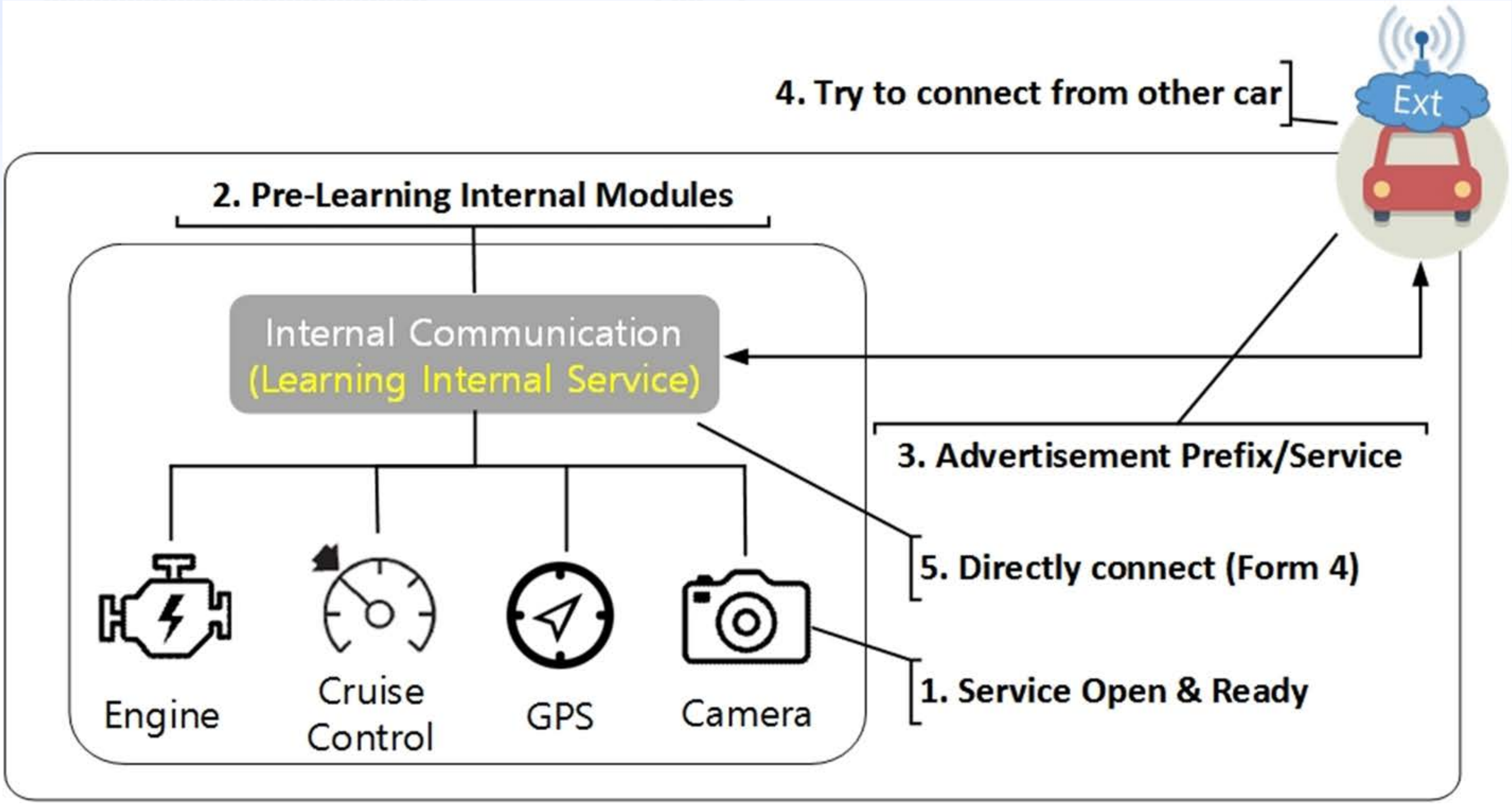
- **IP Mobility Support for V2I**
  - In a single subnet per RSU, vehicles keep crossing the **merged communication coverage** of adjacent RSUs.
  - During this crossing, TCP/UDP sessions can maintained by IP mobility support, such as **Mobile IPv6** (MIPv6) [RFC 3775], **Proxy MIPv6** [RFC 5213], and **Distributed Mobility Management** (DMM) [RFC 7333, RFC 7429].
  - The **parameter adjustment** is required for high-speed vehicles.
  - With the periodic reports of the mobility information from the vehicles, TCC can coordinate RSUs for the proactive mobility management of the moving vehicles.

Issues for IPv6 Vehicular Networking (6/6)

- **Service Discovery**
  - Vehicles need to discover services (e.g., road condition notification, navigation service, and entertainment) provided by internal nodes in an RSU's network.
  - Possible Solutions
    - DNS-based Service Discovery (DNS-SD) [RFC 6763]
      - Uses Service (SRV), Pointer (PTR), and Text (TXT) records
    - IPv6 ND Extension for the Prefix and Service Discovery
      - **A piggyback service discovery** during the prefix exchange of network prefixes for the networking between a vehicle's moving network and an RSU's fixed network.

Service Discovery (1/2)

- Internal Service Registration into a Vehicle



Service Discovery (2/2)

- **Vehicular ND** vs. **mDNS** for Prefix and Service Discovery

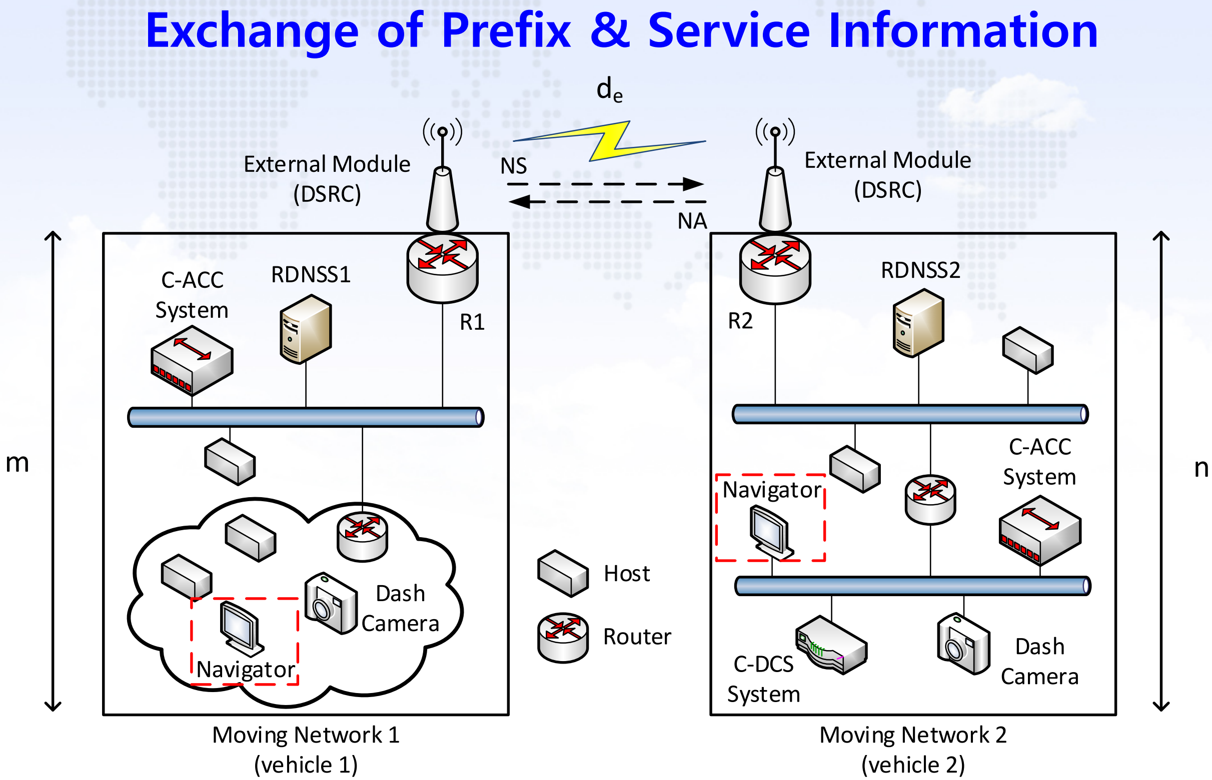


TABLE III
THE PARAMETERS FOR DELAY ANALYSIS

Parameter	Description
D_n	The delay of prefix and service discovery with the proposed IPv6 ND
D_o	The delay of prefix and service discovery with a routing algorithm and mDNS
D_{sd}	The delay of service discovery with mDNS
D_{pd}	The delay of prefix discovery with a routing algorithm
h_1	Hop count between a service querier (a host) and an external interface (a router) in MN1
h_2	Hop count between an external interface (a router) and a service querier (a host) in MN2
d_e	The E2E delay of MN1 and MN2
α	One-way link delay of one hop

Note: e is the number of hosts in a vehicle.

$$D_{pd} = \max(O(m), O(n)). \quad (1)$$
The delay of the prefix discovery in the worst case

$$D_{sd} = (2\alpha \cdot (h_1 + h_2) + 2d_e) \cdot e. \quad (2)$$
The delay of the service discovery of each host is executed sequentially

$$D_o = \max(O(m), O(n)) + (2\alpha \cdot (h_1 + h_2) + 2d_e) \cdot e. \quad (3)$$
Total delay

$$D_n = \alpha \cdot \max(h_1, h_2) + d_e. \quad (4)$$
Our proposed method with vehicular ND

Security and Privacy (1/3)

- **Authentication and Access Control**
  - A Vehicle Identification Number (VIN) for authentication
  - Multiple car certificates per vehicle for authentication
  - Cellular soldered SIM card, Software credentials, or Hardware Security Module (HSM) based Authentication
  - An RSU can be used to give vehicles the connectivity with an authentication server in TCC.
  - Transport Layer Security (TLS) [RFC 5246] certificates can be used for the authentication and access control in secure communications.

Security and Privacy (2/3)

- **Privacy Support by Periodic Change of MAC and IP Addresses**
  - To prevent a vehicle from being tracked by an adversary, the MAC and IP addresses of the vehicle can be changed periodically with randomness.
  - This address update should not interrupt the communications between a vehicle and an RSU
    - In the level of the network layer (i.e., IP) or transport layer (e.g., TCP and UDP).

Security and Privacy (3/3)

- **Confidential Data Exchange**
  - To protect data packets exchanged between a vehicle and an RSU, **IPsec** can be used.
  - **Confidentiality for Data Packets**
    - It can be provided by efficient encryption and decryption algorithms (e.g., **IP Encapsulating Security Payload (ESP)** [RFC 4303]).
    - It can use an efficient key management scheme (e.g., **Internet Key Exchange Protocol Version 2 (IKEv2)** [RFC 7296][RFC 4306]).

Summary and Analysis (1/3)

- **Suitability of IPv6 over WAVE**
  - IPv6-based vehicular networking can be well-aligned with IEEE WAVE standards for various vehicular network applications,
    - such as driving safety, efficient driving, and entertainment.

- **IPv6 ND Adaptation for Vehicular Networking**
  - The IEEE WAVE standards do not recommend to use the IPv6 neighbor discovery (ND) protocol for the communication efficiency under high-speed mobility.
  - It is necessary to adapt the ND for vehicular networks with high-speed mobility such that ND can operate rapidly with little overhead.

Summary and Analysis (2/3)

- **Support of IPv6 Link Concept**
  - The concept of a link in IPv6 does not match that of a link in VANET.
  - This is caused by the physical separation of communication range in a connected VANET.
  - The IPv6 ND should be extended to support this multi-link subnet of a connected VANET through either ND proxy or VANET routing.
- **IP Address Autoconfiguration**
  - In mobility management, a vehicle's IP address should be updated/configured proactively along its movement via vehicular networks.
  - DAD for unique IP addresses can be performed by the infrastructure (e.g., RSU) rather than a vehicle.

Summary and Analysis (3/3)

- **Routing and Mobility Management using Vehicle Trajectory**
  - Most of vehicles are equipped with a GPS navigator (e.g., a dedicated navigation system or smartphone App).
  - With this GPS navigator, vehicles can share their current position and trajectory (i.e., navigation path) with TCC.
    - TCC can predict the future positions of the vehicles with their mobility information (i.e., the current position, speed, direction, and trajectory).
  - With the prediction of the vehicle mobility, TCC permits RSUs to perform data packet routing and handover proactively.

Next Steps (1/2)

- **Synchronization with IPv6-over-802.11ocb**
  - We will improve gap analysis and problem statement with draft-ietf-ipwave-ipv6-over-80211ocb-11.

- **Enhancement of Use Cases Section**
  - Automotive Companies (e.g., GM, Toyota, Honda, and BMW)
  - CAR 2 CAR Communication Consortium (C2C-CC)
  - 5G Automotive Association (5GAA)
  - European Automotive-Telecom Alliance
  - Use Cases from ETSI Intelligent Transport Systems (ITS): Basic Set of Applications (ETSI TR 102 638)

Next Steps (2/2)

- **Enhancement of Terminology Section**
  - draft-ietf-ipwave-ipv6-over-80211ocb-11
  - ISO 21217 (ITS station/communication architecture) and ISO 21210 (IPv6 networking for ITS)
  - FCC (CFR 90.7 - 2010)
  - FHWA (Vehicle to Infrastructure Deployment Guidance and Products – 2015)

- **Inclusion of Physical Communication Constraints**
  - The main idea and impact of these constraints on Vehicular Networking

- **Plan: WGLC in IETF 101**