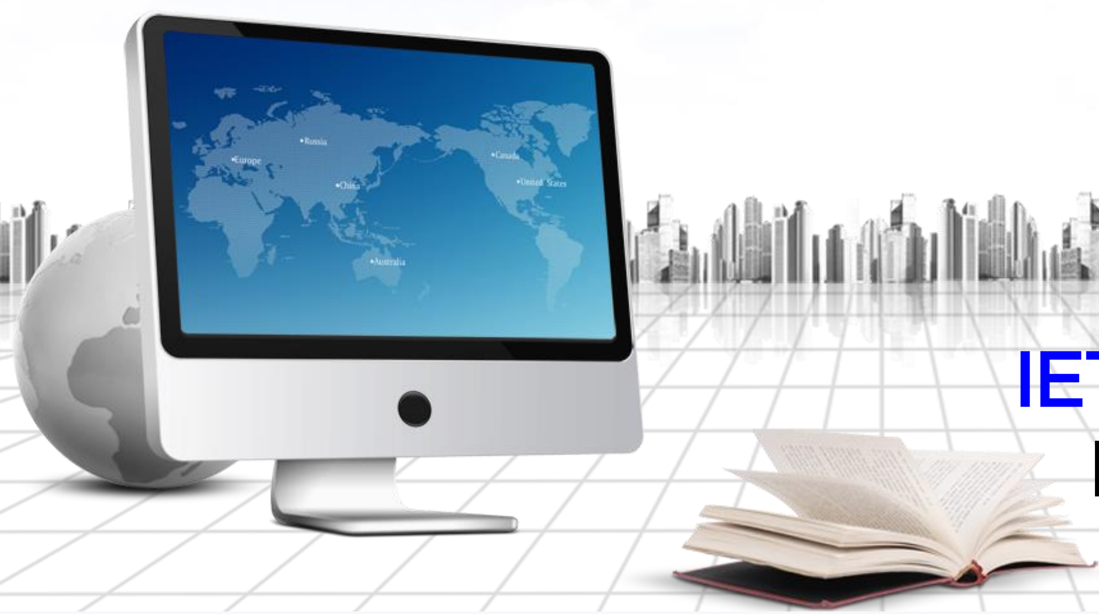
# Survey on IP-based Vehicular Networking for Intelligent Transportation Systems

(draft-jeong-ipwave-vehicular-networking-survey-00)



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# Updates from the Previous Version

- The previous version is draft-jeong-its-vehicular-networking-survey-01.
- Due to the forming of IPWAVE WG, a new version having Security Section is submitted:
  - draft-jeong-ipwave-vehicular-networking-survey-00
- Changes from the previous draft
  - Vehicular Network Security section is added.
  - Key Observations subsection is added for each section.
  - The editorial corrections are made.

# Introduction to Vehicular Networking

- Objective of this Draft
  - To survey the research activities of IP-based vehicular networks for Intelligent Transportation Systems (ITS).
- Assumptions for Vehicular Networks
  - **IEEE 802.11p** is considered as MAC protocol.
  - **IPv6** is considered as a 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.

# Categories for Vehicular Networking

1. IP Address Autoconfiguration

2. Vehicular Network Architecture

3. Vehicular Network Routing

4. Mobility Management in Vehicular Networks

5. **Vehicular Network Security (new section)**

# IP Address Autoconfiguration (1/2)

- Automatic IP Address Configuration in VANETs [1]
  - A **distributed dynamic host configuration (DHCP)** with a cluster leader as a DHCP server.

- Routing and Address Assignment using Lane/Position Information in a VANET [2]
  - **Each lane of a road segment** has a **unique IPv6 prefix** for IPv6 SLAAC.
  - A connected VANET is constructed per lane as a cluster.

- GeoSAC: Scalable Address Autoconfiguration for VANET Using Geographic Net Concepts [3]
  - A **link** is defined as a **geographic area** having a connected VANET for multicast.
  - Ad Hoc routing is performed to support such a multicast link for IPv6 SLAAC for an RA from an RSU.

# IP Address Autoconfiguration (2/2)

- Key Observations
  - **High-speed mobility** should be considered for a light-overhead address autoconfiguration.
    - **A cluster leader** can have an IPv6 prefix [1].
    - **Each lane in a road segment** can have an IPv6 prefix [2].
    - **A geographic region** under the communication range of an RSU can have an IPv6 prefix [3].
  - **IPv6 Neighbor Discovery (ND)** should be extended to support the concept of a link for an IPv6 prefix in terms of multicast.
    - Ad Hoc routing is required for the multicast in a connected VANET with the same IPv6 prefix [3].
    - **A rapid Duplicate Address Detection (DAD)** should be supported to <u>prevent or reduce</u> **IPv6 address conflicts**.

# Vehicular Network Architecture (1/3)

- VIP-WAVE: On the Feasibility of IP Communications in 802.11p Vehicular Networks [4]
  - VIP-WAVE provides three schemes:
    - An efficient mechanism for the IPv6 address assignment and DAD,
    - On-demand IP mobility based on Proxy Mobile IPv6 (PMIPv6), and
    - one-hop and two-hop communications for I2V and V2I networking.

- IPv6 Operation for WAVE - Wireless Access in Vehicular Environments [5]
  - IEEE 1609.3 minimizes IPv6 operation over WAVE.
    - IPv6 Neighbor Discovery is not recommended.
  - IPv6 link model does not hold in WAVE.
    - Unidirectional links in WAVE may exist due to interference and different Tx power levels.
    - Interfaces with the same prefix may not on the same IP link due to node mobility and highly dynamic topology.

# Vehicular Network Architecture (2/3)

- A Framework for IP and non-IP Multicast Services for Vehicular Networks [6]
  - Distributed mechanism allowing to configure a common multicast address: Geographic Multicast Address Autoconfiguration (GMAA), without signaling.
- Joint IP Networking and Radio Architecture for Vehicular Networks [7]
  - Three classes of nodes are defined for all required IP ITS topologies: Leaf Vehicle (LV), Range Extending Vehicle (REV), and Internet Vehicle (IV)
  - VANET ITS interference may be controlled by separating each WiFi/ITS-G5 channel as IP subnetworks and advertising them through REVs.
- Mobile Internet Access in FleetNet [8]
  - Re-introduction of a foreign agent (FA) in MIP located at the IGW, so that the IP-tunneling can remain in the back-end, not on the air.
- A Layered Architecture for Vehicular Delay-Tolerant Networks [9]
  - DTN Bundle Layer between L2 and L3 to keep it transparent to IP.

# Vehicular Network Architecture (3/3)

- Key Observations
  - **Unidirectional links** exist and must be considered.
  - **Control Plane** must be separated from **Data Plane.**
  - **ID/Pseudonym change** requires a **lightweight DAD.**
  - **IP tunneling** should be **avoided.**
  - **Vehicles** do **not** have a **Home Network.**
  - **Protocol-based mobility** must be **kept hidden** to both the vehicle and the correspondent node (CN).
  - **An ITS architecture** may be composed of **three types of nodes**: Leaf Vehicle (LV), Range Extending Vehicle (REV), and Internet Vehicle (IV)

# Vehicular Network Routing (1/3)

- Different routing protocols categories in VANET.
  - Geocast/position/broadcast/cluster-based ad hoc routing.
- An IP Passing Protocol for Vehicular Ad Hoc Networks with Network Fragmentation [10]
  - It tackled the issue of network fragmentation in VANET environments.
  - It can postpone the time to release IP addresses to the DHCP server and select a faster way to get the vehicle's new IP address.

# Vehicular Network Routing (2/3)

- Experimental Evaluation for IPv6 over VANET Geographic Routing [11].
  - It proposes **a combination** of **IPv6 networking** and a **Car-to-Car Network routing protocol (C2C Net)** of the Car2Car Communication Consortium.
  - C2CNet is an architecture using a **geographic routing**.
  - The combination of **IPv6 multicast** and **GeoBroadcast** was implemented.
  - The test results show that **IPv6 over C2CNet** does not have too much delay (less than 4ms with a single hop) and is feasible for vehicular communication.
  - In the outdoor testbed, they developed **AnaVANET** to enable hop-by-hop performance measurement and position trace of the vehicles.

# Vehicular Network Routing (3/3)

- Key Observations
  - **IP address autoconfiguration** should be manipulated to support the efficient networking.
  - Due to **network fragmentation**, vehicles cannot communicate with each other temporarily.
  - **IPv6 Neighbor Discovery (ND)** should consider the temporary network fragmentation.
  - **IPv6 link concept** can be supported by **Geographic routing** to connect vehicles with the same IPv6 prefix.

# Mobility Management in Vehicular Net (1/3)

- A Hybrid Centralized-Distributed Mobility Management [12][13]
  - Hybrid centralized-distributed mobility management (DMM + PMIPv6)
  - A vehicle obtains a prefix from the mobile access router through DMM and another prefix from the PMIPv6 domain.

- NEMO-Enabled Localized Mobility Support for Internet Access in Automotive Scenarios [14]
  - It enables IP mobility for moving networks in a network-based mobility scheme based on PMIPv6.
  - The functionality of the MAG is extended to the mobile router.

- Network Mobility Protocol for Vehicular Ad Hoc Networks [15]
  - Using a NEMO-Based protocol, vehicles acquire IP addresses from other vehicles through V2V communications in highway scenarios.
  - Cars on the same or opposite lane are entitled to assist the vehicle to perform a pre-handoff.

# Mobility Management in Vehicular Net (2/3)

- Performance Analysis of PMIPv6-Based Network MObility for Intelligent Transportation Systems [16]
  - It adapts PMIPv6 to enable IP mobility for the moving network, instead of a single node as in the standard PMIPv6.
  - It adopts the fast handover approach standardized for PMIPv6 in [RFC5949].
- A Novel Mobility Management Scheme for Integration of Vehicular Ad Hoc Networks and Fixed IP Networks [17]
  - It uses information provided by vehicular networks to reduce mobility management overhead.
- SDN-based Distributed Mobility Management for 5G Networks [18]
  - Hybrid PMIP-DMM is used, where mobility functions are located in Open Flow Switches (data plane).
  - One or more SDN controllers handle the Control plane.

# Mobility Management in Vehicular Net (3/3)

- Key Observations
  - Mobility Management (MM) solution design varies, depending on scenarios: highway vs. urban
  - Hybrid schemes (NEMO + PMIP, PMIP + DMM, etc.) usually show better performance than pure schemes.
  - Most schemes assume that IP address configuration is already set up.
  - Most schemes have been tested only at either simulation or analytical level.
  - SDN can be considered as a player in the MM solution.

# Vehicular Network Security (1/2)

- Securing Vehicular IPv6 Communications [21]
  - A secure vehicular IPv6 communication scheme is proposed using
    - Internet Key Exchange version 2 (IKEv2) and
    - Internet Protocol Security (IPsec).
  - The aim of the proposed scheme is
    - To support the security of IPv6 Network Mobility (NEMO) for in-vehicle devices inside a vehicle, and
    - To use a Mobile Router (MR) in a vehicle, which has multiple wireless interfaces (i.e., IEEE 802.11p, WiFi, and WiMAX).

- Providing Authentication and Access Control in Vehicular Network Environment [22]
  - A security scheme for vehicular networks is proposed using
    - Authentication, authorization, and accounting (AAA) services
  - The support of confidential data transfer between communicating parties by using IEEE 802.11i (i.e., WPA2)

# Vehicular Network Security (2/2)

- Key Observations
  - The security for vehicular networks should provide vehicles with AAA services in an efficient way.
  - It should consider not only horizontal handover, but also vertical handover since vehicles have multiple wireless interfaces.

# Summary and Analysis (1/3)

- Fitness 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 infotainment.

- IPv6 ND Adaption
  - 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 such 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 the vehicular cloud.
  - DAD for unique IP addresses can be performed by the infrastructure 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 as a dedicated navigation system or a 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 supports RSUs to perform data packet routing and handover proactively.

# Next Steps

- Enhance this draft to be **a basis document** of **"ITS General Problem Area"** and **"Problem Statement" drafts** in IPWAVE WG with
  - More Academia Papers for Vehicular Networking,
  - Industry Activities for Vehicular Networking (e.g., GMC, Toyota, Honda, and BMW), and
  - Standards Development Organization (SDO) Activities for Vehicular Networking (e.g., IEEE, ETSI, and ISO).

- We will welcome comments from IPWAVE WG.

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