VIN6: A VIN-BASED NAMESPACE FOR EVOLUTIONARY FUTURE VEHICULAR INTERNET

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OUTLINE

• Introduction
• Background and Related work
• Problem statement
• VIN-based IPv6 Networking: What and Why
• VIN6: a VIN-based Network-layer Architecture
• Early validation and next steps
• Conclusion
INTRODUCTION (1/2)

SDOs (IEEE, ISO, ETSI) envision IPv6 as the de facto standard for IP-based communications in vehicular networks, with some restrictions.

**ETSI-ITS protocols stack**

- **Application support**
- **Session support**
- **Information support**

**Network & Transport**
- **ITS Transport**
- **ITS Local Network**
- **Geonetworking**

- **External interfaces**
  - IR, MM, M5, GPS, Bluetooth, 2G/3G/LTE, Ethernet...

**Security**

**Applications (Road safety, Traffic efficiency, and Other)**

- **Facilities**
- **Information support**

**Management**

**WAVE protocols stack**

- **Applications (safety and non-safety)**
- **WSMP (WAVE Short Message Protocol)**

**WAVE Security Services**

- **Management procedures**
- **LLC**
- **WAVE MAC (Including channel coordination)**
- **PHY**

**ISO CALM protocols stack**

- **CALM Application Block**
  - **Application Management ISO 24101**
  - **CALM-Aware**
  - **Non-CALM**
    - **ISO 15628**
    - **IP**

- **CALM Network Block**
  - **TCP/UDP IPv6**
  - **CALM Fast**
  - **OEM**

- **Management (ISO 21210, 24102)**

**C2C protocols stack**

- **Applications (safety and non-safety)**
- **UDP**
- **TCP**
- **Car2Car Transport**

**Information Connector**

- **IPv6 & Mobility Extension**

**Other LLC**
- **802.11 a/b/g LLC**
- **C2C LLC (802.2 EU)**

**Other MAC**
- **802.11 a/b/g MAC**
- **C2C MAC (802.11 EU)**

**Other PHY**
- **802.11 a/b/g PHY**
- **C2C PHY (802.11p EU)**
INTRODUCTION (2/2)

- **Mandatory** support of IPv6 for link-local, global, and multicast communications
- **Operation conditions** for IPv6 Neighbor Discovery **limited and not specified**
- **Announcement** of IP configuration and services through WAVE Service Advertisement (in WSMP)
- **Lack** of Duplicate Address Detection and Multi-hop communication support

What evolutions should IPv6-based communications undergo in order to make it feasible for vehicular networks?

GENERAL CONTEXT

Main addressing architectures taxonomy

Usual approaches for IP-based vehicular communications include:

- Prefix delegation, Neighbor Discovery extensions, GeoNetworking

Very recently **Future Internet** paradigm has been applied to IP and Post-IP vehicular communications

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**[RFC4941]**

**[LISP]**

**[CCN]**
• Evolution of IP is closely and unarguably tied to some fundamental building blocks
  • End-to-end argument, Network of networks, Datagrams as the unit, Layering, Evolutionary design
  • Unique and universal naming and numbering space (IP)

• Naming, Addressing and their consequences on Routing
  • Seminal papers on naming and addressing [Shoch78] [Saltzer93] [Chiappa00]
  • Object **names** must be **invariant** across a certain **scope**
  • Addresses identifies **where** it is and a Route a **way** to get there
  • Applications require **location-independent** names

• Lack of tools and distributed databases to enhance services
  • Use DNS and IP only!
  • Resolve Mobility management, Multihoming, Security, and more challenges

• This design resulted in some network-layer addressing invariants
  • **Non mutability** : Source and Destination IDs Sent are the IDs received
  • **Location independence** : IDs do not change during the course of an association (session)
  • **Reversibility** : Return header can be formed by reversing SRC and DST IDs.
  • **Omniscience** : Each host knows what IDs a peer host can use to send packets to it

• Other accepted core-network properties
  • **Topology and Addressing** are inter-dependent (Rekhter’s Law)
  • **Isolation property** for the Core Network

The wind of change: Locator/IDentifier split

- IP semantics overload has to be solved to narrow the explosion of inter-routing tables in the core network (mobility and multihoming in particular)
  - Locator/Identifier split is the key challenge in Future Internet paradigm

- Evolving the Internet as a system by an evolutionary or a revolutionary approach
  - Evolutionary through map-and-encap (LISP) or address rewrite (ILNP)
  - Revolutionary by redefining the concepts and challenges (Data Centric Networking, Routing on flat labels) (ex. CCN, ROFL, NIRA)

PROBLEM STATEMENT

On the feasibility of Future IP-based Vehicular Communications

• Today
  • IPv6 must be enhanced to be widely accepted for vehicular networking
  • Locator/Identifier split is the key challenge in Future Internet paradigm
  • Naming and addressing challenges reached the vehicular networking area

• Approach
  • Enhance the networking tools with a new namespace to derive new kind of objects with different semantics proper to vehicular networks
  • Provider Independent for addressing and Indirection (two-tier) for routing

• Results
  • Narrow the explosion of the routing tables size in the core
  • Provide scalable and sustainable hierarchical addressing architecture
    • $2^{35}$ vehicles identified per manufacturer
    • $2^{16}$ manufacturers
  • Up to $2^{13}$ (8192) addressable devices inside the vehicle
  • Possible use of pseudonyms and evolutionary deployment of more functionalities
GENERAL CONTEXT

Main addressing architectures taxonomy

- **Prefix Delegation**
  - Using DHCPv6
    - Relay
      - MIPv6
    - Server
      - MIPv6
  - Server
    - MIPv6
    - MIPv6

- **ND Extension**
  - Using Neighbor Discovery
    - TREBOL
    - VIP-Wave
  - GeoRouting
    - GeoSAC

- **Future Internet**
  - Revolutionary
    - CCN
  - Evolutionary
    - VIN6

**[VIP-Wave]**

**[GeoSAC]**

**[CROWN]**
VIN TO IP (1/2)

Provider Independent Addressing and Indirection Routing

1. WHAT IS IT?
VIN is a 17 characters long alphanumeric hierarchical code that uniquely identifies a vehicle worldwide
- ISO-3779 and 3780 standard
- Mandatory, unique, and present in every vehicle

2. WHAT FOR?
Define a hierarchical namespace to derive stable and permanent Provider Independent addressing for identification

3. WHY?
VIN is Provider Independent and reflects the Manufacturer topology: a vehicle is permanently present at Manufacturer domain and temporarily in the operator network

4. LIMITS?
- VIN provides an indication about the identity but not the location
- Identity Privacy must be handled separately

VIN is a 17 characters long alphanumeric hierarchical code that uniquely identifies a vehicle worldwide.
1. Properties
- Mandatory, unique, and present in every vehicle
- ISO-3779 and ISO-3780 standard for the format and content
- Hierarchical vehicular-specific endpoint identifier

2. Objective
Conserve those properties after mapping

3. Approach
- Consider the VIN as a number written in the numeral system VIN-base
- Dig into the semantics in order to conserve the above properties after conversion

4. Result
Uniqueness conservation among the distributed population of vehicles and High bit compression ratio in order to create prefixes, addresses, and mobile node identifiers
VALIDATION

Uniqueness Conservation, Bit compression, and Privacy

Benefits

- **Uniqueness property** preserved through VIN-IPv6 conversion algorithm
- Up to $2^{51}$ distinct hierarchical vehicular-specific endpoint identifiers and prefixes
- **Scalability** of addressing and routing in the core network
- Possible use of multiple **pseudonyms** ($2^{35}$ vehicle ID per manufacturer)

16 bits of compression gain over state of the art, 32 distinct prefixes per vehicle, 8192 devices per prefix and up to 65536 addressable devices
Objectives

- Re-establishing scalable end-to-end communications with indirection
- Hierarchical vehicular-specific VIN-based addresses introduce manufacturer domain in the architecture (Location-independence)
- Evolution of the network to include vehicular communications (isolation)
Two-tier Routing Architecture (ongoing work)

Incoming packets

- If the session is already established, forward
- If no session is established, permanent devices only can establish a new session

Outgoing packets

- If the session is already established, forward
- If a new session is established, distinguish between the permanent and mobile devices
# EVALUATION

## Feature comparison of IPv6 Auto-configuration techniques

<table>
<thead>
<tr>
<th>Feature</th>
<th>Additional Entities</th>
<th>DHCPv6-PD</th>
<th>ND-PD</th>
<th>TREBOL</th>
<th>VIP-WAVE</th>
<th>GeoSAC</th>
<th>VIN6</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DHCPv6 Server, Relay(s) and MIPv6 HA</td>
<td>DHCPv6 Server and MIPv6 Home Agent</td>
<td></td>
<td>No</td>
<td>PMIPv6’s LMA and MAG</td>
<td>Not in GeoSAC but MIPv6 HA in other works [6]</td>
<td>No</td>
</tr>
<tr>
<td>Messages to configure IV</td>
<td>2 BU/BA + 4 DHCPv6</td>
<td>2 BU/BA + 4 DHCPv6</td>
<td>1 CM</td>
<td>1 WSA + 2 PBU/PBA</td>
<td>1 RA</td>
<td>1 RA</td>
<td></td>
</tr>
<tr>
<td>Address conf. Delay for IV</td>
<td>( T_{RA} + 2 \times T_{BU} + T_{DHCPv6} )</td>
<td>( T_{RA} + 2 \times T_{BU} + T_{DHCPv6} )</td>
<td>( T_{RA} )</td>
<td>( T_{WSA} + 2 \times T_{PBU} )</td>
<td>( T_{RA} )</td>
<td>( T_{RA} )</td>
<td></td>
</tr>
<tr>
<td>Messages to configure LV</td>
<td>4 DHCPv6 if IV is Server, 8 DHCPv6 if IV is Relay</td>
<td>2 ND-PD messages (IV always Server)</td>
<td>1 CM from the IV or the RSU</td>
<td>1 WSA from relay (IV) if non-extended service, 1 WSA + 2 PBU/PBA if extended</td>
<td>1 RA from the IV or RSU</td>
<td>1 RA from IV</td>
<td></td>
</tr>
<tr>
<td>Address conf. Delay for LV</td>
<td>( 4 \times T_{DHCPv6} ) if IV is Server, ( 8 \times T_{DHCPv6} ) if IV is Relay</td>
<td>2 ( \times T_{nd-pd} )</td>
<td>( T_{backoff} + T_{CM} )</td>
<td>( T_{WSA} + 2 \times T_{PBU} )</td>
<td>( T_{relay} )</td>
<td>( T_{RA} )</td>
<td></td>
</tr>
<tr>
<td>Messages to configure L nested vehicles</td>
<td>( 4 \times \sum_{k=1}^{L} 2^{k} ) if IV is Server, ( 4 \times \sum_{k=0}^{L} 2^{k} ) if IV is relay</td>
<td>( 2 \times 2^{L} ), no relay is possible</td>
<td>( \sum_{k=1}^{L} 2^{k} )</td>
<td>( \sum_{k=1}^{L} 2^{k} )</td>
<td>( \sum_{k=1}^{L} 2^{k} )</td>
<td>( \sum_{k=1}^{L} 2^{k} )</td>
<td></td>
</tr>
<tr>
<td>Need for MIPv6</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
<td>YES (PMIPv6 for extended services)</td>
<td>Not for GeoSAC but other GeoNet approaches do [6]</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Addressing Scope</td>
<td>Global</td>
<td>Global</td>
<td>Global</td>
<td>Global</td>
<td>Global</td>
<td>Global and Local</td>
<td></td>
</tr>
<tr>
<td>Addressing topology</td>
<td>Hierarchical</td>
<td>Hierarchical</td>
<td>Flat</td>
<td>Flat</td>
<td>Flat but routing on 2-levels</td>
<td>Hierarchical (2-level)</td>
<td></td>
</tr>
<tr>
<td>Infrastructure dependency</td>
<td>Initialization</td>
<td>Initialization</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
<td></td>
</tr>
</tbody>
</table>
CONCLUSION

Hints and Next steps

• Operation and performance of IPv6 over WAVE are rather minimal
  • Configuration and Neighbor Discovery protocol as the unknowns

• Use cases involving Internet and Infrastructure would benefit from IP communications
  • Leverage the deployment and accelerate the market penetration

• Ongoing efforts in Future Internet discipline try to separate Name and Location from the IP numbering space
  • Leverage the growth of the core network routing tables and entropy
  • Including gradually the vehicular population has the potential to worsen the situation

• VIN-based Provider Independent addressing as an approach to tackle naming and location separation
  • The vehicle is uniquely addressed and the manufacturer domain a trusted indirection point

• Two-tier routing to separate the action of « sending » from « receiving » a packet (translation or map-and-encap)
Thanks for your attention!

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ANNEX

CCN’s new hourglass
Données
- VIID avec 11 bits non utilisés
- VULA avec 5 bits non utilisés
- GUA donné par l’opérateur

Objectif
- Communications globales des réseaux embarqués du IV et des véhicules avoisinants à travers lui

Aujourd’hui
1- DHCPv6-Prefix Delegation pour obtenir un Prefix Global et l’utiliser
2- Tourner MIPv6/NEMO sur tout les véhicules et gérer l’itinérance

Problèmes
1.1- Les opérateurs ne supportent pas tous DHCPv6-PD
1.2- Sérieux problèmes de délais (ETSI le déconseille ETSI TS 102 636-6-1, section 10.2.2)
1.3- Complexité de management (timers, taille du pool)
1.4- Pas de continuité de sessions
2.1- LV doit obtenir une @globale sur son egress (Lancer BU/BA) donc un problème de Nested Mobility, ou DHCPv6-PD pour IV
2.2- Problèmes d’overhead et sous-optimisation associés à MIPv6
Scénario:

- **But:** Créer un arbre de routage IPv6 (en modifiant un peu RA de sorte à propager le même préfixe) et router en IP dans une zone appelée la TREBOL area
- **Concurrents:** GPSR.

« In order to avoid unnecessary control overhead, Duplicate Address Detection (DAD) is disabled, since we can safely assume that in a vehicular environment there exist unique identifiers that can be used to generate IPv6 addresses.»

<table>
<thead>
<tr>
<th>Table I</th>
<th>Simulation framework</th>
<th>OMNeT++ and MIMIX</th>
<th>Wireless Device</th>
<th>802.11b @ 6Mb/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel Model</td>
<td>Pathloss with channel fading</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coverage radius</td>
<td>225m</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance between RSGs [m]</td>
<td>1000, 1500, 2000, 3000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data traffic</td>
<td>ICMP Echo Request / Reply (packet size: 1KB)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Intéressant: Plus de sauts car plus consciencieux