The GeoNet project: Combination of IPv6 & GeoNetworking

Geographic addressing and routing for vehicular communications
http://www.geonet-project.eu

Dr. Thierry Ernst INRIA – Mines ParisTech (LaRA)
thierry.ernst@inria.fr
GeoNet Technical Coordinator
What is IPv6 GeoNetworking and why do we need it?
ITS Vision: Cooperative Systems

- Cooperation is needed
  - Safety
  - Efficiency
  - Impact (pollution...)

- Cooperation requires communications
ITS Vision: Communications

- **Communicating vehicle**
  - Communication scenarios diversity (V2V, V2I, I2V, Internet)
  - Communications diversity (WiFi, WiMax, 3G, Satellite, ...)
  - Application diversity (road safety, road efficiency, infotainment, ...)

![Diagram of ITS communications](image)
ITS Vision: Everything connected

- Personal
- Central
- Vehicle
- Roadside

Communication Networks

Central System

VMS

Control Sensing
Why GeoNetworking?

Position Table

<table>
<thead>
<tr>
<th>ID</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>[5,0]</td>
</tr>
<tr>
<td>4</td>
<td>[10,0]</td>
</tr>
<tr>
<td>5</td>
<td>[12,1]</td>
</tr>
</tbody>
</table>

Destination 6 at [15,1]  Source 1 at [0,0]
Why IPv6 GeoNetworking?

- V2V: GeoNetworking is the addressing & routing packet forwarding approach favored in ITS communication architectures
  - C2C-CC
  - COMeSafety
  - ETSI TC ITS
  - ISO TC204 WG16 (CALM)

- ITS Architectures must also support Internet-based communications
  - IPv6: Internet Protocol version 6

- GeoNet: IPv6 and GeoNetworking must be combined in a common architecture
  - IPv6 expands the capabilities of GeoNetworking
  - GeoNetworking expands the capabilities of IPv6
Why IPv6 GeoNetworking?
Why IPv6 GeoNetworking?

- **GeoNet:** scenarios requiring both IPv6 and GeoNetworking

- **Scenario Type 1:** *sender is in the Internet*
  - Packets are transmitted in IPv6 until the RSUs serving the geographic area where they are GeoRouted through intermediate vehicles to the final destination(s).

- **Scenario type 2:** *receiver is in the Internet*
  - Packets are GeoRouted through intermediate vehicles (using GeoUnicast) until a RSU where they are transmitted in IPv6 to the final destination.

- **Scenario type 3:** *sender and receiver(s) are only reachable through the Internet*
  - Combination of Scenarios Type 1 & 2 where source and destination(s) are out of multi-hop wireless range
Why IPv6: address requirements

- Vehicles will be connected to the Internet
- In-vehicle IP network  => Several IP addresses / vehicle
- Number of cars worldwide
  - 1997: 600 millions
  - 2030: 1200 millions (at present trend)
- IPv4 does not fit to ITS requirements
  - \(2^{32} = 4,294,967,296\) addresses only
  - IPv4 address exhausted by may 2011
Why IPv6?

- IPv6: Internet Protocol version 6
  - Designed by the IETF since 1995 as a replacement of IPv4

- IPv6 is an evolution of IP
  - New IP header
  - Fully specified, implemented - operational deployment started

- IPv6 addressing
  - 128 bits instead of 32 ($2^{128}$ addresses instead of $2^{32}$)
  - Up to $3\,911\,873\,538\,269\,506\,102$ addresses / m²
  - An address for everything on the network

- IPv6 comprises new features absolutely needed for ITS
  - Auto-configuration
  - IP session continuity (NEMO)
  - Multiple wireless media supported at once (McoA)
  - Enhanced security
  - Embedded multicast
The GeoNet project
GeoNet: Genesis

GeoNet inherits from two mainstream topics (non exhaustive list)

GeoNetworking discussion in C2C-CC

GeoRouting as networking basis in C2C-CC manifesto

1st GeoNetworking experiment in Network-on-Wheels

GeoNetworking Requirement: CVIS (FP7)

GeoNet project develops a baseline solution

1st IPv6 NEMO ITS experiments: OverDrive (IST), InternetCAR (Keio), Nautilus6 (WIDE)

IPv6 NEMO in ITS standards: ISO CALM IPv6 Networking

Year

2002 2003 2004 2005 2006 2007 2008 2009
GeoNet: Genesis

- Launched by technical partners who foresaw the need
  - IPv6 architecture in CVIS (non-safety critical): ISO CALM
  - Non-IP GeoNetworking in C2C-CC and Safespot
  - Risk of divergence

- Supported by C2C-CC, Safespot, COOPERS, CVIS
  - Were aware of the risk
  - Will to integrate GeoNet development into their architecture

- Close contacts with many partners
  - Projects, standardization organization...

- GeoNet was a good opportunity
  - Theme: need for convergence effort
  - Timing: in line with projects and standards
GeoNet: Fact Sheet

- Budget: 3 M€
- Funding: 1.9 M€
- 7 partners
  - 2 Research Institutes (INRIA and IMDEA)
  - 1 SME (Broadbit)
  - 4 industrial partners (Hitachi, NEC, Lesswire & Efkon)

- Web: http://www.geonet-project.eu
  - News, deliverables, presentations

- Objective: Design the concepts linking geographic addressing and routing with IPv6 mobility mechanisms (IPv6 GeoNetworking)
GeoNet: Work Packages

- WP0: Management (INRIA)
- WP1: Architecture (INRIA)
- WP2: Specification (Efkon - Broadbit)
- WP3: Implementation (NEC)
- WP4: Conformance testing (Broadbit)
- WP5: Emulation Environment Development (Hitachi)
- WP6: Integration & Porting (Lesswire)
- WP7: Experimental validation (INRIA)
- WP8: Dissemination & use (INRIA)
GeoNet: Scope

- 3 main axes:
  - **Knowledge**: elaborate a unified IPv6 GeoNetworking architecture compliant with best practices in vehicular communications;
  - **Standards**: produce a *reference IPv6 GeoNetworking specification* and push it to SDOs (ISO, ETSI, IETF);
  - **Software**: produce two *prototype implementations* and disseminate it to existing consortia (particularly SafeSpot, CVIS, COOPERS and C2C-CC).
GeoNet: Design Goals (D1.2)

- Architecture combining IPv6 and GeoNetworking
- Communication modes
  - **Vehicle-based**: without infrastructure (V2V)
  - **Roadside-based**: with roadside infrastructure (V2I)
  - **Internet-based**: with the Internet
- Destination set
  - Single destination
  - Multiple destinations
- Preserve security and location privacy
- Compatibility and interoperability
- Maintain IPv6 connectivity for the in-vehicle network
GeoNet Design: Scope

- **Active Safety Application**
- **Traffic Efficiency Application**
- **Infotainment Application**

- **C2C Transport**
- **TCP / UDP / Other**

- **GeoNet's scope**
  - **IPv6 (NEMO)**
- **C2C Network**

- **MAC / LLC**
  - C2C MAC Layer Extension
  - European IEEE 802.11p
  - IEEE 802.11 a,b,g

- **PHY**
  - European IEEE 802.11p
  - IEEE 802.11 a,b,g

- **Other Radio**
  - (e.g. UMTS)
GeoNet: Functional Modules

Upper Layer
- 3A: IP Forwarding
  - IPv6 over Ingress
  - IPv6 over C2CNet
- 3B: Mobility Support
  - NEMO
  - MCoA
- 3C: Multicast

IP Layer
- 0A: Geo-destination
- 0B: Security & Privacy
- 0C: Position Sensor

C2CNet Layer
- 2.5A: Geo-position calculation
- 2.5B: Geo-routing
  - Geo-unicast
  - Geo-broadcast
  - Geo-anycast
- 2.5C: Location Management
  - Beaconing
  - Location Table
  - Location Service
- 2B: Ingress Interface
  - Geo-broadcast
  - Geo-anycast
  - Topology broadcast
  - Store & Forward

Lower Layer
- 2A: Egress Interface
  - 802.11p
- Lower Layer
C2CNet Layer: Design

- C2CNet layer takes care of routing packets within the GeoNet domain
  - C2C-CC specification taken as starting point
  - It has been extended and improved (multi-hop, etc)

- 3 main components
  - Geo-position calculation
  - Position based routing
  - Location management (Beaconing / Location service / Location table)
C2CNet: GeoNetworking

- Packet forwarding
  - GeoUnicast: from one node to a single node
  - GeoAnycast: from one node to any node in area
  - GeoBroadcast: from one node to all nodes in area
  - TopoBroadcast: from one node to all nodes n-hop away
  - Message buffering (with GeoNetwork triggered re-evaluation)
C2CNet: Location Mngt

- Location management
  - Beaconing (periodic single-hop broadcast)
  - Location Table
  - Location Service (lookup of unknown destinations)

![Diagram of Location Management](image)

- **NET BEACON PACKET**
  - Position Vector

- **Location Table**
  - | NEIGH | POS |
    |------|-----|
    | A    | Pos(A) |
    | D    | Pos(D) |
    | E    | Pos(E) |
C2CNet: Location Service

- Location service
C2CNet: GeoUnicast Packet

Common header

Source node position vector

Destination node ID

Destination node Latitude

Destination node Longitude

Payload
C2CNet: GeoBroadcast Packet

![Diagram of GeoBroadcast Packet]

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>+-------+---------+---------+---------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common header</td>
<td>:</td>
<td>:</td>
<td>:</td>
<td>:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Source node position vector</td>
<td>:</td>
<td>:</td>
<td>:</td>
<td>:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reserved</td>
<td>:</td>
<td>:</td>
<td>:</td>
<td>:</td>
</tr>
<tr>
<td>Radius</td>
<td>:</td>
<td>:</td>
<td>:</td>
<td>:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Destination node Latitude</td>
<td>:</td>
<td>:</td>
<td>:</td>
<td>:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Destination node Longitude</td>
<td>:</td>
<td>:</td>
<td>:</td>
<td>:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Payload</td>
<td>:</td>
<td>:</td>
<td>:</td>
<td>:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
GeoNet: IP Layer

IP Layer

3A: IP Forwarding
- IPv6 over Ingress
- IPv6 over C2CNet

3B: Mobility Support
- NEMO
- MCoA

3C: Multicast

IP-UL

Upper Layer

MNG-UL

0A: Geo-destination

MNG-IP

0B: Security & Privacy

MNG-C2C

0C: Position Sensor

C2C-IP

C2CNet Layer

2.5A: Geo-position calculation

2.5B: Geo-routing
- Geo-unicast
- Geo-broadcast
- Geo-anycast
- Topology broadcast
- Store & Forward

2.5C: Location Management
- Beaconing
- Location Table
- Location Service

MNG-C2C

C2C-LL

Lower Layer

2A: Egress Interface

802.11p

Lower Layer
IP Layer: Design

- Comply with ETSI and ISO architectures
  - NEMO is used to guarantee reachability at a permanent address and maintaining sessions
  - The Mobile Router entity at the OBU manages the connectivity on behalf of all the in-vehicle nodes
- Re-use existing IETF IPv6 standards, minimise impact on existing systems
- GeoNet hides GeoNetworking from the IP layer
  - Enhancements required at the IP layer for location privacy (pseudonyms) & direct V2V (IPv6 prefix exchange)
- IPv6 is not Geo-Aware
  - How IPv6 packets could be transmitted to a destination(s) in a specific geographic location?
- GeoNet relies on IPv6 multicast
  - Several GeoDestination – IP Group ID encoding approaches
IP Layer: In-vehicle IP network

- On-board units (OBU / IPv6 Mobile Router)
  - Maintains **Internet access** through RSU (IPv6 Access Router)

- Application Unit (AU / IPv6 Host)
  - e.g. HMI displaying traffic hazards reports
IP Layer: In-Vehicle Network

802.11p

In-vehicle IPv6 network
IP Layer: IP over C2CNet

- IPv6 C2CNet link: viewed as virtual link with GeoNetworking capabilities
IP Layer: IPv6 over C2CNet

IPv6 viewpoint:

- AU
- OBU C
- OBU B
- OBU A
- RSU

from the Internet

Wired/Wireless

-L2
+Wireless Multi-Hop

IP Layer: IPv6 over C2CNet

Internet

road access network

RSU

area n+1

area n

area n-1

IEEE 802.11

IPv6

IPv6 over C2CNet

L2 (e.g. IEEE 802.3)

IEEE 802.11p

C2CNet

IPv6 over C2CNet

IEEE 802.11p

C2CNet

IPv6 over C2CNet

IEEE 802.11p

C2CNet

IPv6 over C2CNet

IEEE 802.11p

C2CNet

IPv6 over C2CNet

IEEE 802.11p

C2CNet

IPv6 over C2CNet

IEEE 802.11p

C2CNet

IPv6 over C2CNet

IEEE 802.11p

C2CNet

IPv6 over C2CNet

IEEE 802.11p

C2CNet

IPv6 over C2CNet

IEEE 802.11p

C2CNet

IPv6 over C2CNet

IEEE 802.11p

C2CNet

IPv6 over C2CNet

IEEE 802.11p

C2CNet

IPv6 over C2CNet

IEEE 802.11p

C2CNet

IPv6 over C2CNet

IEEE 802.11p

C2CNet

IPv6 over C2CNet

IEEE 802.11p

C2CNet

IPv6 over C2CNet

IEEE 802.11p

C2CNet

IPv6 over C2CNet

IEEE 802.11p

C2CNet

IPv6 over C2CNet

IEEE 802.11p

C2CNet

IPv6 over C2CNet

IEEE 802.11p

C2CNet

IPv6 over C2CNet

IEEE 802.11p

C2CNet

IPv6 over C2CNet

IEEE 802.11p

C2CNet

IPv6 over C2CNet

IEEE 802.11p

C2CNet

IPv6 over C2CNet

IEEE 802.11p

C2CNet

IPv6 over C2CNet

IEEE 802.11p

C2CNet

IPv6 over C2CNet

IEEE 802.11p

C2CNet

IPv6 over C2CNet

IEEE 802.11p

C2CNet

IPv6 over C2CNet

IEEE 802.11p

C2CNet

 IPv6 viewpoint: AU OBU C OBU B OBU A RSU

from the Internet

IPv6 over C2CNet over lower layer
- C2CNet: sub-IP layer for IPv6
- C2CNet identifier: identifier at sub-IP layer & IPv6 interface id

802.11 p header | C2CNet header | IP header | Data

- C2CNet link: IPv6 link
  - C2CNet provides IPv6 with a multicast link
  - including nodes within a non-overlapping GeoArea
IP Layer: C2CNet Link

C2CNet IPv6 link (defined according to radius or number of C2CNet hops)
IP Layer: GeoNet domain
IP Layer: IP over C2CNET

- Linux virtual TUN interface
C2C-IP SAP between C2CNet & IP

- Defines the transmission of IPv6 packets from/to the C2CNet layer
  - 5 alternative approaches have been investigated for encoding the GeoDestination into IP
  - ETSI WG3 should select the most suitable one(s) for the geonetworking standard.
• Each car may have an in-vehicle network
  NEMO Basic Support is used to guarantee transparent connectivity and mobility
  AUs configure addresses out of an IPv6 prefix assigned to the car (called, MNP)
• The Mobile Router / OBU manages the connectivity on behalf of all the in-vehicle nodes
  For communications with the Internet, another node is also involved: the Home Agent
  For V2V communications, a new solution, called MNPP has been proposed
IP Layer: IPv6 Mobility Support

IPv6 + NEMO

- C2CNet
- IEEE 802.11p
- Link layer tech (e.g. IEEE 802.3)

IPv6

- HA
- IPv6 + NEMO
- Link layer tech (e.g. IEEE 802.3)

IEEE 802.11p

- MNN/AU
- IPv6 + NEMO
- Link layer tech (e.g. IEEE 802.3)

IPv6

- AR/RSU
- IPv6 + NEMO
- Link layer tech (e.g. IEEE 802.3)
Module 3A: Dynamic IPv6 routing table updating is based on Neighbor Discovery extension (MNPP)

Module 3B: Network mobility support using NEMO
IP Layer: IPv6 Multicast

- **Concept**
  - IP Multicast: only one copy of a message is transmitted on any given IPv6 interface iff there is a group member
  - C2CNet GeoCast: flooding in a bounded geographic area

- **Design goal:** extend IPv6 multicast to also support a geographical scope
  - Multicast groups based on the geographical location of the receivers are possible
  - The sender may also be in the Internet
IP Layer: GeoDestination Encoding

- **GeoDestination**
  - Transmitted from the application to GeoNetworking layer
  - 5 encoding approaches
  - Simplest one implemented

- **GeoNet simplified implementation**
  - Application provides GeoDestination ID
  - IPv6 multicast address encodes GeoDestination ID
  - C2CNet retrieves GeoDestination mapped to ID
IP Layer: IPv6 Multicast

- Multicast management is based on MLDv2 mechanism
- Multicast handling is fully integrated with C2CNet layer
GeoNet: Management Layer

Upper Layer
- 3A: IP Forwarding
  - IPv6 over Ingress
  - IPv6 over C2CNet
- 3B: Mobility Support
  - NEMO
  - MCoA
- 3C: Multicast

IP Layer
- 2.5A: Geo-position calculation
- 2.5C: Location Management
  - Beaconing
  - Location Table
  - Location Service
- 2.5B: Geo-routing
  - Geo-unicast
  - Geo-broadcast
  - Geo-anycast
  - Topology broadcast
  - Store & Forward

C2CNet Layer
- 2A: Egress Interface
  - 802.11p
Management Layer: Design

- Takes are of cross-layer issues
- A critical module is “Security and Privacy”
- Deals with issues raised by the combination of IPv6 and GeoNetworking protocols:
  - Location Privacy (tracking)
  - Revealing geographic location from the IPv6 address used as communication identifier
  - Secure binding between the IPv6 address and the GeoCast (C2CNet) layer id
  - IPv6 address spoofing

- Example: Location privacy
  - Each vehicle has a number of different C2CNet Ids
  - Periodically, the used C2CNet IDs are changed
  - This implies a change of IP addresses
GeoNet: C2CNet Layer

**Upper Layer**

3A: IP Forwarding
- IPv6 over Ingress
- IPv6 over C2CNet

3B: Mobility Support
- NEMO
- MCoA

3C: Multicast

**IP Layer**

0A: Geo-destination

0B: Security & Privacy

0C: Position Sensor

**C2CNet Layer**

2B: Ingress Interface

2.5A: Geo-position calculation
- Geo-unicast
- Geo-broadcast
- Geo-anycast

2.5B: Geo-routing
- Geo-unicast
- Geo-broadcast
- Geo-anycast
- Topology broadcast
- Store & Forward

2.5C: Location Management
- Beaconing
- Location Table
- Location Service

**Management**

**Lower Layer**

2A: Egress Interface
- 802.11p
A lower layer adaptation module has been defined to support multiple underlying MAC/LLC types.

Two lower layer packet types are supported in current GeoNet implementation:
- C2C Demo packet format
- CVIS packet format
GeoNet experimental validation & demonstration
# Evaluation: Methodology

<table>
<thead>
<tr>
<th>Configurable parameter</th>
<th>Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implementation</td>
<td>HITACHI/INRIA</td>
</tr>
<tr>
<td>Network configuration</td>
<td>Single hop</td>
</tr>
<tr>
<td>Test environment</td>
<td>Indoor</td>
</tr>
<tr>
<td></td>
<td>Distance</td>
</tr>
<tr>
<td>Communication Type</td>
<td>UDP</td>
</tr>
<tr>
<td></td>
<td>Pack size, Sending rate</td>
</tr>
<tr>
<td>Evaluation Metric</td>
<td>Packet Delivery Ratio, throughput, Jitter, Hop count</td>
</tr>
</tbody>
</table>

AnaVANET (developed tool) maps geographic parameters with evaluation metrics.
### Evaluation: Methodology

- **Communication Metric**
  - Bandwidth
  - RTT
  - Jitter
  - Packet Delivery Ratio

- **Geographic Metric**
  - Hop count
  - Speed
  - Position
  - Distance between cars

- **Communication Type**
  - UDP
  - TCP
  - ICMPv6

- **Issues on Measurement**
  - Paths unawareness
  - Unknown hop performance
  - Movement unawareness

---

sender (Iperf, Ping6) ![Diagram showing cars and communication paths](image)

receiver
Evaluation: Methodology

- Requirements
  1. Path detection
  2. Hop by hop performance measurement
  3. Movement awareness

- The system
  0. Generate Packets with UDP, TCP and ICMPv6, then
  1. Capture packets at all the nodes,
  2. Trace them packet by packet
  3. Match them with location
Evaluation: AnaVANET tool
Evaluation: AnaVANET output

- Google Maps shows metrics with...
  - Movement
  - Distance
  - Obstacle

- Graphs generated by gnuplot shows...
  - All history of experiments

http://www.geonet-project.eu/demonstration/geonet/
Evaluation: Distance

- Radio range is 450 meters

Packet delivery ratio recovers at 250 meters

Packet delivery ratio is very good until 450 meters

Bandwidth decreases gradually until 270 meters. And it doesn't come back
Evaluation: Static test

- Packet Delivery Ratio is 90.18%
- RTT is 5.81 ms, when it is stable
- RTT varies from 4.6 ms to 5080 ms (very unstable because of route change)

<table>
<thead>
<tr>
<th>Test</th>
<th>Metric</th>
<th>Minimum</th>
<th>Average</th>
<th>Maximum</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>UDP 3 vehicles</td>
<td>PDR (%)</td>
<td>21.88</td>
<td>90.18</td>
<td>98.13</td>
<td>14.99</td>
</tr>
<tr>
<td></td>
<td>Bandwidth (Kbps)</td>
<td>274.56</td>
<td>901.95</td>
<td>998.4</td>
<td>151.31</td>
</tr>
<tr>
<td></td>
<td>Jitter (ms)</td>
<td>1.25</td>
<td>2.89</td>
<td>39.2</td>
<td>5.27</td>
</tr>
<tr>
<td>ICMPv6 3 vehicles</td>
<td>RTT (ms) all 300 sec</td>
<td>4.6</td>
<td>477.43</td>
<td>5080</td>
<td>992.31</td>
</tr>
<tr>
<td></td>
<td>RTT (ms) stable 25 sec</td>
<td>4.74</td>
<td>5.81</td>
<td>9.66</td>
<td>1.46</td>
</tr>
</tbody>
</table>

220 meters

115 meters
Evaluation: Dynamic (~30Km/h)

- 1 floor buildings does not always block radio
- INRIA is not best place to emulate urban environment

Route change doesn't have negative impact to overall packet delivery ratio
Evaluation: Dynamic (~100km/h)

- Packets take single hop (two hop for request and reply) most of the time of the test
- Network is table when vehicles stop at the traffic light
GeoNet: Final Demonstration
GeoNet: Demo Scenario

- **Road safety scenario:** traffic hazard warning

- Green Car reporting traffic hazard around RSU2

- Traffic center notifies traffic hazard to geographic area around RSU1

- Black car around RSU2 acts as a forwarder

- Red car displays received traffic hazard notifications
GeoNet: Demo Configuration

- Ethernet
- IEEE802.11

Traffic info to the server
RSU2
Reporter
OBU
AU

Traffic info to the Geo-area
RSU1
OBU
Forwarder
Receiver
Data Center
Server

Moving
Geo-area
Wireless range of RSU1

Traffic info OFF
Traffic info ON
Conclusions
Summary: GeoNet output

- Reference architecture and specification

- C2CNet Layer:
  - 2 independent implementations
  - Multihop forwarding
  - Position-based routing

- IP Layer: extensions of the Linux IPv6 stack / UMIP
  - SAP C2C-IP
  - MNP provisioning (MNPP): exchange of in-vehicle IPv6 prefixes
  - Pseudonyms
  - IP multicast configuration

- A conformance testing suite is available for validating future implementations
GeoNet: Summary

- IPv6 + GeoNetworking = Enabling technology for better
  - Road safety
  - Traffic efficiency
  - Value added services

- Well supported at time of set-up
  - C2C-CC, SafeSpot, Coopers, CVIS
  - Adopted by PRE-DRIVE C2X

- Status
  - 1 reference specification
  - 2 prototype implementations (Linux 2.6 / UMIP)
  - Experimentation on a fleet of 4 vehicles
  - Conformance tests: TTCN-3
  - Emulation with NCTUns
  - CVIS selected as the target platform

- Effective dissemination in SDOs (ISO, ETSI, IETF)
GeoNet Limitations & future work

- C2C Transport layer over C2CNet is yet to be defined

- Only single radio channel is defined currently, multi-radio support is to be defined yet (multiple instances of the C2CNet demon can be run in parallel presently)

- Congestion control has not been specified

- A mechanism for sharing Location Table (i.e. neighbor awareness data) with Application Layer has been described, but not fully specified

- The most suitable alternative(s) to transmit GeoDestination information from Application Layer to C2CNet Layer (IP-layer encoding) should be analyzed and selected
GeoNet: Work Ahead

- Progress work items in SDOs
  - ETSI: GeoNetworking (TS 102-636-4-1)
  - ETSI: IPv6 GeoNetworking (TS 102-636-6-1)
  - ISO CALM

- Validation in large-scale Field Operational Tests (FOTs) needed
  - DRIVE-C2X, FOTsis, SCORE@F, ...

- Expand the architecture / specification
  - IPv6 GeoNetworking within the ITS station architecture (FP6 CVIS => FP7 ITSSv6 project)
  - Tighter integration with ITS facilities & management layers
  - Develop position aware IP applications
  - GeoDestination encoding within IPv6 multicast
  - IP-layer security & QoS
  - Transport layer
  - Congestion control
GeoNet: Documents

- Most deliverables are public and available online
  - Check [http://www.geonet-project.eu](http://www.geonet-project.eu)

- D1.2 Final GeoNet Architecture Design
  - [http://www.geonet-project.eu/?download=GeoNet-D.1.2-v1.2.pdf](http://www.geonet-project.eu/?download=GeoNet-D.1.2-v1.2.pdf)

- D2.2 Final GeoNet Specification
  - [http://www.geonet-project.eu/?download=GeoNet-D.2.2_final.pdf](http://www.geonet-project.eu/?download=GeoNet-D.2.2_final.pdf)

- D4.1 Conformance test plan & results
  - [http://www.geonet-project.eu/?download=GeoNet-D.4.1_final_revised-1.1.pdf](http://www.geonet-project.eu/?download=GeoNet-D.4.1_final_revised-1.1.pdf)

- D6.1 GeoNet porting and integration guideline

- D7.1 GeoNet Experimentation results

- D8.3 GeoNet handbook
  - [http://www.geonet-project.eu/?download=GeoNet-D.8.3-v1.0.pdf](http://www.geonet-project.eu/?download=GeoNet-D.8.3-v1.0.pdf)

- GeoNet Final Workshop demonstration
  - [http://www.geonet-project.eu/?p=223](http://www.geonet-project.eu/?p=223)
Most deliverables are public and available online at http://www.geonet-project.eu

Dr. Thierry Ernst INRIA – Mines ParisTech (LaRA) thierry.ernst@inria.fr GeoNet Technical Coordinator