Towards the Vehicular Cloud: From Connected Cars to Smart Cities

Falko Dressler
dressler@ieee.org
Outline

✧ Vehicular Cloud
   ✧ Motivation and Concepts

✧ Towards Smart Cities
   ✧ Making the car the central ICT component

✧ Vehicular Cloud Solutions
   ✧ Using Parked Vehicles
   ✧ Peer to Peer

✧ Conclusions
Towards Autonomous Driving
Inter-Vehicle Networking for Situation Awareness
Towards Heterogeneous Vehicular Networks

Many communication channels available

Which to pick when?

- mmWAVE
- cellular
- DSRC
- Wi-Fi
- VLC
Dedicated spectrum for inter-vehicle communication in Europe (ECC), the US (FCC), and Japan

IEEE DSRC/WAVE and ETSI ITS G5
   - Both build upon IEEE 802.11p

Situation awareness as major year-one-application
   - ETSI DCC (Decentralized Congestion Control)

But many fundamental research questions still unanswered
   - Scalability, real-time capabilities, use of heterogeneous networks

Dagstuhl seminar series identified key challenges
VEHICLES AS THE INFORMATION HUB IN SMART CITIES
Self-Organizing Network of Cars

✧ ...can serve as distributed data store and retrieval mechanism
✧ May include even parked cars as information highway
1. Sharing data with other users.
2. Sharing data with specific location.
3. Uploading data without direct Internet access.
4. Live data from disaster area.
5. Wide Area Data Storage.
7. …
Making Cars the Central ICT Component

- Cars are ubiquitously available
- Feature all kinds of communication technology

- Relaying of messages
  - has been shown to work quite well
  - but will fail in low density/penetration areas

- Parked Cars
  - are readily available, especially in low-density areas
  - park in strategically promising positions – along the street and next to obstacles
  - can be used as relaying nodes in order to increase cooperative awareness for moving vehicles
Besides communication vehicles provide...

Vehicular resources are available not only for vehicles themselves but also for humans and “things.” Vehicles store, process, and convey the information generated by human or things.
Control Plane

- Continuous update of
  - Neighbors, i.e., candidates to route messages
  - Services, i.e., destinations for services
Process View: Access Communication

- **Access Broadcasts**
  - Access Request
  - Reply with grant (either yes or no)

- **Send offer** (contains identifier of the service)
  - **User**

- **Send request** (contains identifier of the service)
  - **Request Answer** (contains list of potential service providers)
  - **User**

- **Access Messages**
  - **Offer Messages**
  - **Request Messages**

**Check User Eligibility**

**Check Service Table**
Naming

✧ Using concepts from NDN/ICN

✧ Hash tags to identify services

✧ Meta data for fine grained description

<table>
<thead>
<tr>
<th>Hash tag</th>
<th>Meta data</th>
<th>User</th>
</tr>
</thead>
<tbody>
<tr>
<td>hash(file1)</td>
<td>location = Tokyo, type = video, size = 2GB</td>
<td>1</td>
</tr>
<tr>
<td>hash(file1)</td>
<td>location = Tokyo, type = video, size = 2GB</td>
<td>3</td>
</tr>
<tr>
<td>hash(file1)</td>
<td>location = Paderborn, type = video, size = 2GB</td>
<td>7</td>
</tr>
<tr>
<td>hash(file1)</td>
<td>location = Paderborn, type = video, size = 2GB</td>
<td>7</td>
</tr>
<tr>
<td>hash(file2)</td>
<td>type = image</td>
<td>1</td>
</tr>
<tr>
<td>hash(file2)</td>
<td>type = image, size = 500MB</td>
<td>12</td>
</tr>
<tr>
<td>CPU</td>
<td>location = Paderborn, type = ARM</td>
<td>7</td>
</tr>
<tr>
<td>Storage</td>
<td>location = Paderborn, type = hours, size = 78GB</td>
<td>7</td>
</tr>
</tbody>
</table>

Figure 4. Three examples of identifier usage – two for an exact match using the hash and one for subset matching.
Discovery Latency in an Urban Environment

The graph shows the success rate of discovering nodes over different discovery latencies in an urban environment. The x-axis represents the discovery latency (in s), while the y-axis shows the success rate. Different lines represent various car densities per square kilometer: 35, 85, 170, 260, and 415. The graph indicates that as the car density increases, the success rate decreases for the same discovery latency.
CLOUD STORAGE USING PARKED CARS
Parked cars in cities offer similar benefits as RSUs

A single car as RSU is not optimal
- Limited storage space
- Limited communication range
- Only data available that was stored on the car

Hence organizing parked cars in small independent, self-organized networks
- Capable of storing and retrieving data items by driving cars in the established networks

Scenario
Virtual Coordinate based Routing

✧ Virtual Cord Protocol (VCP)
  ✧ IEEE Trans on Mobile Computing 2011

✧ Greedy forwarding along the Cord
  ✧ Always guarantees reachability
  ✧ Speedup by exploiting local short-cuts

✧ DHT based data storage

<table>
<thead>
<tr>
<th>Node 0.25</th>
<th>Neighbors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Successor 0.4</td>
<td>0.0</td>
</tr>
<tr>
<td>Predecessor 0.13</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>0.5 (0.55)</td>
</tr>
</tbody>
</table>

IDR + VCP

- VCP creates and maintains a virtual topology, which is (mostly) *independent* of the physical world, but which incorporates *topological properties*
- Using address (space) identifiers is not possible

---

“Slim”-Mode

▫ Reduced functionality to a minimum
  ▫ No cord creation
  ▫ Limited router functionality
    ▪ Communication always via most recent „freshest“ gateway
▫ Driving cars remain silent until a hello message has been received
  ▫ After that normal hello messages are broadcast
  ▫ Broadcast is stopped after N hello messages
    ▪ Counter is reset with every new received hello
Performance Evaluation

✧ Using the VEINS simulation framework
Successful Domain Creation

nodes with valid positions (%)

0.0 0.2 0.4 0.6 0.8 1.0

0 100 200 300 400 500

simulation time (s)

ct(s): 20
ct(s): 40
ct(s): 60
ct(s): 80
ct(s): 100
ct(s): 120
ct(s): 140
ct(s): 160
ct(s): 180
ct(s): 200
CONCLUSIONS
Today, we studied

✧ Challenges and opportunities of using connected cars concepts
  ✧ Capability to connect everyone and everything
  ✧ Can be seen as a big data storage
  ✧ Help improving our daily road traffic experience and safety

✧ Not discussed
  ✧ Security issues: Strong debate about privacy vs. security

... as can be seen, there are many open challenges and questions for another decade of interesting research 😊
More Information?

Vehicular Networking
(Cambridge University Press)

IEEE Vehicular Networking Conference (VNC)

- Tokyo, New Jersey, Amsterdam, Seoul, Boston, Paderborn

- Next: Kyoto in Dec 2015

20% off