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- Conclusion



Vehicular network emulation

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19th International Conference on Computer Communications and Networks (ICCCN 2010) 2-5 August 2010, Zurich, Switzerland

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- **3** Airplug-emu
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Intelligent Transport Systems

ITS motivations

- Improving transportation in terms of safety, mobility, productivity, environmental impact...
- main goals : reduce road fatalities, improve infrastructure management, offer new on-board services

ITS applications

- Infrastructure oriented applications for optimizing the infrastructure management (transit, freeway, freight, emergency organization...)
- Vehicle oriented applications for increasing the road safety (crash prevention, alerts, visibility distance...)
- Driver oriented applications for improving the road usage (traffic jam, road work information, payment...)
- Passenger oriented applications for offering new services on board (Internet access, distributed games, tourist info...)



network emulation B. Ducourthial

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• Next step in networking and distributed alg.

| wired network | mobile user | mobil termin | e mob al netw | ile mobile _{ork} ad hoc networks | dynamic ad hoc networ | ks dynamic |
|------------------------|----------------|-----------------|------------------|--|--------------------------|---------------|
| with infrastructure | | | | without infrastructure | | |
| routers, fixed servers | | hand-over | | virtual structures management (tree | ·) ? | |
| Internet, IF | 2 | MobileIP | Cellular | MANET | VANET | |
| | | | | | | |

• Impact of the dynamic

- impact on network layers link (2), network (3), transport (4)
- impact on distributed algorithms fault tolerance, data sharing...
- impact on trusty and security who believe? what information is reliable?
- algorithms necessary embedded context-aware optimization, adaption...
- Strong problems, new solutions expected





Scientific issues

Highly dynamic ad hoc networks

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How to validate new ideas

• By proofs :

- for distributed algorithms
- require communication and synchronization models
- + exact result ; models far from reality
- By simulations :
 - for networking protocols
 - require propagation and MAC model, packets traffic and node mobility model
 - + scalable; models far from reality
- By experiments :
 - for proof of concept and performance measuring *in situ*
 - require equipments and logistic
 - + exact results; not scalable, not reproducible
- Need for a complementary approach

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• Emulation : powerful tool for vehicular networks

- between theory and practice, road experiments and simulation
- parts are real : applications, protocols, mobility, traffic
- parts are artificially reproduced : layers 1 and 2
- How to efficiently reproduce layers 1 and 2?
 - Airplug-emu
 - can do hybrid emulation (including real links)
- The Airplug software suite a complete environment for studying dynamic networks





Contributions

Team

Vehicular network emulation

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- Université de Technologie de Compiègne

 4500 students, master degree (engineer diploma), PhD http://www.utc.fr
 - one of the first French engineering school for computer science
 - close to Paris and Charles de Gaulle airport



- Heudiasyc Lab. from the UTC & CNRS Automatic, Computer Science, Networking, Knowledge... http://www.hds.utc.fr
- Vehicular networks team
- Intelligent vehicles team several equipped cars





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Team



| HEUDI | SYC |
|-------|-----|
| | |



- Distributed system for vehicle dynamic evaluation Regional grant Heudiasyc - MIS 2008-2011
- Inter-vehicles cooperative perception for road safety National project ANR JC, (Heudiasyc) 2008-2011











2004-2007

2004-2008

2006-2010

2007-2010

2008-2010

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Some of the team contributions

| Distributed dynamic group service | e [SPAA | 2010] |
|--|------------|-------|
| V2I architecture | [Mobiwac | 2010] |
| Simulation of vehicular networks | [VTC | 2010] |
| Road experiments | [VTC | 2009] |
| Messages forwarding conditional transmissions | [IEEE TVT | 2007] |
| IEEE 802.11 fairness | [MedHocNet | 2006] |
| Capacity of vehicular networks | [VTC | 2005] |
| | | |



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Airplug architecture Process-based architecture

- Posix OS
- core program
 - user-space process
 - networking
- applications
 - user-space process
 - read on stdin
 - write on stdout
 - API close to IEEE WSMP
- ensure tasks and OS independence for robustness
- open to any programming language



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New protocols developed in user space processes

Airplug architecture

Facilities for developing new protocols

- open to new networking solutions
- cross-layer solutions facilitated





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• Airplug software suite

Applications for infrastructure, vehicles, drivers, passengers...

Airplug Software suit



http://www.hds.utc.fr/~ducourth/airplug



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Complete research platform

[VTC 2009]

• On the road : airplug-road

- in Compiègne, France
- 2005 in Michelin circuit, France
- 2007 test-bed with 6 cars with France Telecom R&D
- 2009 test-bed with 7 cars with France Telecom R&D [see movies on-line

http://www.hds.utc.fr/~ducourth/airplug]





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Complete research platform

- On the road : airplug-road
- In the laboratory : airplug-lab
 - GPS position replaying
 - new trajectories derived → convoys
 - out of range messages filtered (soon)









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|) | On the road : airplug-roa | [\ | /TC 2009] | | | | | |
|---|---|---------------------------|---|--------------|--|--|--|--|
|) | In the laboratory : airplu | g-lab | | | | | | |
| | In a computer : airplug | licco | CN 2010] | | | | | |
| | a using chall facilities | [iee. | | | | | | |
| | • using shell facilities | | | | | | | |
| | emulation of vehicu | lar netwoi | rks | × | | | | |
| | DDS- | [airplug] app=D | DS ident=10 | | | | | |
| | | Re-tran | smission du message 3 | | | | | |
| | Ref Philas Lettergue | DDS, ident = 10] Messag | jes acceptés : 3. Messages i | ignorés : O. | | | | |
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| | Cometiere 4 | Réglages du dessin Vue | Fenêtre | Animatio | | | | |
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| | Emission (DDS, ident - 1) | | | | | | | |
| | | | | | | | | |
| | Prémier message Prémier message Prémier message | | | | | | | |

Complete research platform



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Complete research platform

[VTC 2009]

- On the road : airplug-road
- In the laboratory : airplug-lab
- In a computer : airplug-emu [ICCCN 2010]
- Remotely : airplug-rmt
 - a specific application controls remote access from external applications
 - portability of the applications transparent usage stand-alone / remotely / locally
 - · heterogeneous vehicular networks emulation



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Platform



• On the road : airplug-road [VTC 2009] In the laboratory : airplug-lab [ICCCN 2010] In a computer : airplug-emu Remotely : airplug-rmt In Network Simulator : airplug-ns [VTC 2010] ٥

Complete research platform

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Platform



Complete research platform On the road : airplug-road [VTC 2009] In the laboratory : airplug-lab [ICCCN 2010] In a computer : airplug-emu Remotely : airplug-rmt In Network Simulator : airplug-ns [VTC 2010] In all these usages, the same codes are used (ALT) VIS WTR CTD MSG JEUX ALT WTR CTD | MSG IMG DIF Se PTH MVS TST FTP IMG DIF Se PTH MVS CNV CNV NBH HOP NBH HOP GPS GPS IO TNL ' CTL TNL CTL AIRPLUG AIRPLUG

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Airplug architecture

Application Programming Interface

Vehicular network emulation

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API



Addressing for dynamic networks [WINITS 2007]

- area : LCH, AIR, ALL
- applications :
 - a given application
 - all those that subscribed to the sender app
- Note · similarities with
 - IEEE WAVE Short Messages Protocol
 - messages-oriented frameworks (eg. JMS)
- Three types of communication
 - to simplify the development
 - what, whatwho, whatwhowhere
 - automatic guessing or safe mode
- Libraries for easy developments eg. message formating
- Hierarchical makefile for easy installation

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Airplug-emu

Airplug software suit

3 Airplug-emu Node Mobility Scenarios Core program

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Summary

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Communications

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- Airplug applications rely on standard IO for communication → can be managed by the shell
- Examples
 - Unidirectional communication

./gps | ./pro | ./pro

Communications emulation

• Bidirectional link between two applications

mkfifo link1 link2
./pro < link1 > link2
./pro < link2 > link1

• Several neighbors

tee link2 link3 < link1</pre>

• Moving nodes :

kill -STOP pid create new connections kill -CONT pid kill -KILL old_connections

• Advantages : simple, powerful, robust



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frozen when the connections are updated

Node architecture



• RCP :

receives messages from neighbor nodes, can delay or loss some of them

• TST and HOP :

two Airplug-compatible applications on this node

• DIR :

analyzes message header to forward messages either locally or to neighbor nodes

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Communications Node

Mobility

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Airplug GPS application :

- can decode NMEA frames sent by the GPS device (on the road)
- can forward positions to applications willing them
- can store and replay positions
- can modify them to create new realistic ones



Airplug-emu can use :

- GPS logs
- ns-2 traces
- fixed positions
- other mobility generators outputs (customizable)

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• Scenarios are described using an XML configuration file :

```
<map width="2500" height="2500">
 <node id="vehicle 1">
   <app name="TST" zone="LCH" exe="./tst.tk" />
   <app name="HOP" zone="AIR" exe="./hop.tk" />
   <move type="gpsfile" path="../data/log.gps" delay="0"/>
 </node>
 <node id="vehicle_2">
    <app name="TST" zone="LCH" exe="./tst.tk" />
   <app name="HOP" zone="AIR" exe="./hop.tk" />
    <move type="gpsfile" path="../data/log.gps" delay="10"/>
 </node>
  <node id="vehicle 3">
                                                            < 🗇 >
   <app name="TST" zone="LCH" exe="./tst.tk" />
                                                           < ∃⇒
                                                           < ∃→
   <app name="HOP" zone="AIR" exe="./hop.tk" />
                                                             э
   <move type="gpsfile" path="../data/log.gps" delay="20"/&c</pre>
 </node>
  </map>
```



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 Init : read the XML file, launch the processes applications and protocols run in independent processes as on the road

• Loop : with a user-defined frequency,

- read new positions
- compute the links
 - using range and hazard to avoid perfect disk
 - positions remain in lists ordered by x and y
 → complexity generally less than O(n²)
- update the shell links

Messages : forwarded by the shell can be lost or delayed, allows to mimic the road

- Hybrid emulation : remote nodes connected by WiFi
- Output :
 - real-time animation
 - shell-script to reproduce all the emulation using only the shell

Airplug-emu core program



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- Delays and loss rates measured on the road
 → Airplug-emu → results
- Accuracy depends on inter-packet gap (IPG) Left : exact values for each test. Right : mean values



FMU NS

Lab

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Left : convoy of 7 stopped vehicles. Right : moving convoy of 5 vehicles

NS

• Average inputs only for Airplug-emu and ns-2



Road EMU







Reproducing road testbeds





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Conclusion 1 : emulation of vehicular networks

• Strong motivations for ITS Intelligent Transport Systems

Lot of applications imagined and studied interesting scientific challenges

- link / network / transport layers
- distributed algorithms
- security

• How to validate?

- proofs...
- simulations...
- real testbeds...

• Place for network emulation !

- Airplug-emu : simple and robust architecture
- Good performances





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Conclusion 2 : Airplug-emu advantages

• Designing new protocols

- facilities using interface and on-line parameters range, link robustness, network dynamic...
- easy scenarios creation mobility from GPS, ns-2 or others
- Protocols study
 - easy to reproduce experiments with new sets of parameters
 - tuning, performance evaluation
- Accuracy of the results
 - · depends on inputs from the testbed
 - mean measures only → very good approximation for IPG larger than 100 ms
- Protocol deployment
 - in network simulator ns-2 with very few transformation if written in Tcl/Tk
 - on the road





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$Conclusion \ 3: \ complete \ platform$

• The Airplug Software Suite a platform for studying dynamic networks

- on the road Airplug-road
- on the lab Airplug-lab
- on the emulator Airplug-emu
- on Network Simulator Airplug-ns
- + remote access
- Used by research teams and for teaching
- Large set of applications developed and tested
- Easy to design new protocol or application
- Available on demand

[http://www.hds.utc.fr/~ducourth/airplug]



