ns-3 workshop
Rome - March 2nd, 2009

ns-3 scalability constraints in heterogeneous wireless simulations: iTETRIS a case study

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iTETRIS (an Integrated Wireless and Traffic Platform for Real-Time Road Traffic Management Solutions)

- European project funded within the 7th Framework Programme
- Consortium of different research groups: THALES, CBT, City of Bologne, DLR, Eurecom, Hitachi, Innovalia, Peek Traffic and UMH

Main iTETRIS objectives

- Implement an open-source integrated wireless and traffic simulation platform
- Estimate the impact of cooperative vehicular communications on traffic management
- Test and optimize V2V and V2I communications and networking protocols
- Test and optimize cooperative traffic management policies
- Large scale trials (traffic data of the city of Bologne)
Integration of two widely used open source platforms
- ns-3 (Network Simulator 3)
- SUMO (Simulation of Urban MObility)

CTMC (Cooperative Traffic Management Centre)
- Decision on routing traffic flows
- Inform vehicles using the MxC functional block

MxC (Message eXchange Communications)
- Also provides the CTMC with traffic condition estimates (derived from V2X communication)
The iTETRIS wireless platform will follow the European ITS communications architecture determined by COMeSafety.

- This architecture has many similarities with the CALM architecture developed under the ISO.
- Spectrum divided into three 10MHz sub-channels

- WAVE MAC/PHY for CCH and SCH
ns-3 scalability capabilities

- **ns-3 advantages over ns-2**
  - Good scalability, modularity and multi-technology (from the beginning)

- **ns-3 performance for large scale simulations**
  - Capable to simulate large amount of nodes (20000 nodes or more)
  - High execution times for large and dense scenarios
  - Work needed to achieve feasible runtimes for iTETRIS
    - Parallellization techniques (planned for June 2009)
    - Simplification of ns-3 communication modules

- **Factors directly impacting on simulation performance**
  - Total number of vehicles
  - Traffic density
  - Implementation accuracy
  - Interference range
  - Packet generation rate
Impact of number of vehicles and vehicle density

Scenario under evaluation

- 802.11 one-hop periodic broadcast

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nodes’ speed</td>
<td>70km/h (maximum)</td>
</tr>
<tr>
<td>Mobility model</td>
<td>RandomWalk2dMobilityModel</td>
</tr>
<tr>
<td>Propagation model</td>
<td>LogDistancePropagationLoss</td>
</tr>
<tr>
<td>Interference range</td>
<td>700m (default)</td>
</tr>
<tr>
<td>Packet tx rate</td>
<td>10 packets/second (default)</td>
</tr>
<tr>
<td>Data rate</td>
<td>6Mbps</td>
</tr>
<tr>
<td>Simulation time</td>
<td>40s</td>
</tr>
</tbody>
</table>

Influence of vehicle density on simulation performance

- Close related to number of neighbours (packets to be processed)
- Simulations with different traffic densities
Impact of number of vehicles and vehicle density

- Impact of traffic density on execution time (40s 5000 nodes)
  - Execution time linearly increases with traffic density

- Influence of traffic density and number of vehicles on simulation performance
  - Unworkable execution times for 1h simulation
  - Improvements need to be introduced into the simulator

<table>
<thead>
<tr>
<th>Traffic density</th>
<th>Execution time [days]</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>397</td>
</tr>
<tr>
<td>Low</td>
<td>170</td>
</tr>
</tbody>
</table>

1h 20000 nodes
Reduction of physical layer accuracy

- ns-3 spends most of the time at the physical layer
  - Packets processing and interference calculation
- Simplification of PHY models
  - Removal of interference calculation
- Performance analysis
  - Around 35% of reduction time
Reduction of interference range and packet rate

- Congestive scenarios
  - Vehicles adapt transmission range and packet rate to reduce interference

- Impact of interference range on simulation performance
  - Execution times increases with interference range

- Impact of packet rate on simulation performance
  - Simulations run 80% faster reducing transmission rate from 10 to 2 packets per second

- Realistic congestive scenario
  - High density (D10)
  - Interference range of 100m
  - 2 packets per second
  - 1h simulation with 20000 nodes would take 30 days
  - Execution time much more feasible for iTETRIS

Impact of interference range on simulation performance

Simulations run 80% faster reducing transmission rate from 10 to 2 packets per second

Impact of packet rate on simulation performance

Realistic congestive scenario

<table>
<thead>
<tr>
<th>Interference range</th>
<th>Estimated execution time [days]</th>
</tr>
</thead>
<tbody>
<tr>
<td>700m</td>
<td>397</td>
</tr>
<tr>
<td>400m</td>
<td>245</td>
</tr>
<tr>
<td>100m</td>
<td>149</td>
</tr>
</tbody>
</table>
Conclusions

- iTETRIS presents demanding requirements in terms of simulation platform scalability
  - Multi-technology platform
  - Large-scale scenarios
  - Long simulation times to obtain valid results

- ns-3 capable of simulating large scale scenarios and high traffic densities
  - Default distribution takes considerable time

- Need for future enhancements for optimization
  - More efficient scheduler
  - Parallelization techniques
  - Staged simulation techniques
  - Grid-based decomposition
  - Code performance improvement
  - Further suggestions and proposals