Performance and Scalability Analyses of Federation-based V2X Simulation Systems

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Agenda

• Requirements for the proper simulation of vehicular communication scenarios

• Introduction in our Simulation Runtime Infrastructure VSimRTI

• Performance analyses of VSimRTI simulations
Pre-Assessment of Novel Cooperative ITS Solutions Needed

- Reduced travel time, more safety, more comfort
- Required penetration rate of the application?
- Requirements on the application logic?
- How to optimize application efficiency?
- Communication network disconnections?
- Communication network congestion?
- Influences of the region (rural/urban)?
- Influences of the traffic density?
- Influences of the road network structure?

Aspects for the Simulation of Vehicular Communication Scenarios

- Realistic road networks and vehicles traffic
- Wireless communication (cellular and ad-hoc)
- In-vehicle and smartphone applications
- Evaluation tools
- Performance decrease
Need for Interaction of Different Simulators

Traffic Simulator

Application

Communication Simulator
**V2X Simulation Runtime Infrastructure (VSimRTI)**

**Flexibility – extend the scope to other areas!**
- VSimRTI couples well-established simulators for traffic, communication, and application simulation
- Easy exchange of simulators (if one component is updated, no change of other components necessary)
- Easy integration of further simulation tools (number of coupled simulation tools is not limited)

**Usability**
- All-in-one environment
- Central management to handle all complex management tasks (e.g. synchronization)
- Sophisticated data analysis tools facilitate evaluation

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**VSimRTI Architecture**

[Diagram of VSimRTI Architecture with Federate 1 and Federate X, including Simulator 1 and Simulator X]
VSimRTI Simulation Runtime

Communication Simulator
(Ad-hoc Networks)

Traffic Simulator

Preparation and Evaluation Tools

VSimRTI

Communication Simulator
(Cellular Networks)

Application Simulator

VSimRTI Simulation Runtime

Communication Simulator
(Ad-hoc Networks)

Traffic Simulator

Preparation and Evaluation Tools

VSimRTI

Communication Simulator
(Cellular Networks)

Application Simulator
• Allows to check the scalability of VSimRTI in detail depending on different interaction properties
### Configuration Parameters to Specify a Virtual Federate

<table>
<thead>
<tr>
<th>Virtual Federate</th>
<th>Type</th>
<th>Conservative/Optimistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Event Duration</td>
<td>X msec</td>
<td>Next Event Interval</td>
</tr>
</tbody>
</table>

**Virtual Message**

- **Published Message**
  - trigger
  - trigger Id
  - deterministic
  - multiplier
  - probability

- **Subscribed Messages**
  - MessageID

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### Example: Influences of Different Synchronisation Mechanisms on the Performance

**Discrete Event-Based Simulation**

Local Causality Constraint:

*Local Event Processing MUST happen in time stamp order*
Sequential Synchronization

- Process next event with lowest timestamp
- Violation of local causality constraint impossible
- No parallel execution → Poor Performance

Source: N. Naumann

Conservative Synchronization

- Lookahead (L) indicated lowest timestamp for next event
- Concurrent execution within T and T+L
- Problem: Small or zero lookahead

Source: N. Naumann
Optimistic Synchronization

- Processing of local events regardless of dependencies
- **Rollback** if event is scheduled in the past
- Time Warp: Save/Restore States, Anti-Messages

Example: Influences of Different Synchronisation Mechanisms on the Performance

The chart illustrates the impact of interaction probability on total simulation runtime for different synchronization mechanisms. The x-axis represents interaction probability (%), and the y-axis represents total simulation runtime (sec). The mechanisms include Optimistic, 50% Optimistic, and Conservative. The graph shows how the total runtime varies with different interaction probabilities, demonstrating the effectiveness of each synchronization approach.
Example: Influences of the Simulation Scenario on the Performance

Results:
- Runtime more affected by stronger interaction of traffic simulator than by a higher activity of the communication simulator.
- Finer granularity of traffic simulation exerts stronger influences on performance than dimensions of the simulation scenario, the traffic density, number of vehicles.

Conclusion

VSimRTI enables:
- Flexible coupling of simulation tools
- Easy integration of further simulators
- Detailed modelling of applications and their environment

Several optimization techniques, such as optimistic synchronization

Assessment for a wide scope of smart mobility solutions
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VSimRTI:
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