Extending OMNeT++ Towards a Platform for the Design of Future In-Vehicle Network Architectures

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CoRE iNET

Hochschule für Angewandte Wissenschaften Hamburg
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Introduction

- In-vehicle networks face a paradigm change
- Communication architectures today:
  - CAN
  - FlexRay
  - LIN
  - MOST
- Switched real-time Ethernet is promising candidate for future communication architectures[1]
- Stepwise transition from heterogeneous bus architecture towards a single flat Ethernet topology

[1] Kirsten Matheus and Thomas Königseder: Automotive Ethernet. Jan. 2015.

Introduction

- Current tools focus on bit-correct fieldbus simulation
- New tools are required for design and evaluation
- These environments have to support analysis of congestion and jitter
- The OMNeT++ platform provides a perfect base
- We want to provide an easy to use environment
- In this work we contribute:
  - Simulation models
  - Tools to design
  - Tools to evaluate
  - A uniform workflow

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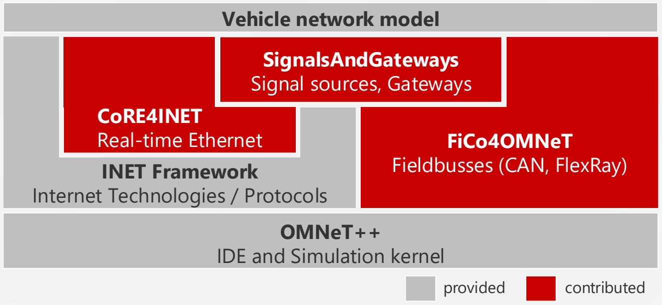
Simulation Models
Overview



- CoRE4INET
  (Communication over Real-time Ethernet for INET)
- FiCo4OMNeT
  (Fieldbus Communication for OMNeT++)
- SignalsAndGateways

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- Currently supported standards:
  - TTEthernet protocol suite (AS6802)
  - AVB traffic shapers (IEEE 802.1Qav)
  - Ethernet with priorities (IEEE 802.1Q)
- Currently supported features:
  - Models to map IP traffic to real-time traffic classes
  - Incoming traffic selection and constraint checks
  - Models for oscillators, timers and schedulers
  - Application models for traffic patterns
  - Flexible combining of media access strategies
- Checked against analytical models and empirical tests

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- Currently supported standards:
  - CAN
  - FlexRay
- Currently supported features:
  - Models for oscillators and timers
  - Application models for traffic patterns
- Checked against results of CANoe simulation environment

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- Fills the gap between CoRE4INET and FiCo4OMNeT
- Gateway translate between (real-time) Ethernet and fieldbusses
- For flexibility it contains three submodules:
  - Routing
  - Buffering
  - Transformation
- Gateway can host applications

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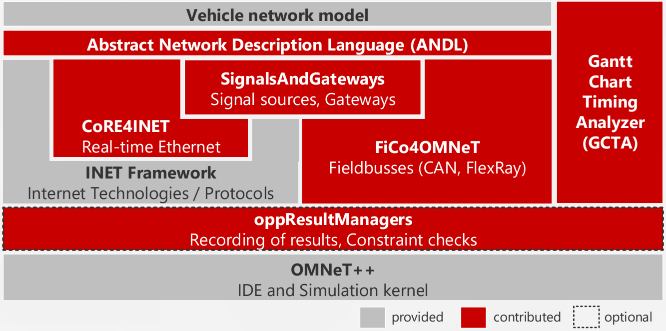

- Eclipse Updatesite (https://sim.core-rg.de/updates) -> get plugins
- CoRE model installer (OMNeT++ plugin) -> get simulation models

- Configuring large heterogeneous networks is complex and lengthy
- Domain Specific Language (DSL) reduces effort
- Eclipse plugin using Xtext technology
- Supported features:
  - Syntax highlighting
  - Code completion
  - Scheduling algorithms (for TDMA technologies[2])
  - Simple inheritance
  - Inline ini configuration

[2] Jan Kamieth et al.:"Design of TDMA-based In-Car Networks: Applying Multiprocessor Scheduling Strategies on Time-triggered Switched Ethernet Communication". 2014.

- Specialized analysis tool as OMNeT++ plugin
- Traces jitter and delay in cyclic communication
- Uses a timing log (.tlog) file written during simulation
- GCTA compresses all occurrences of a cyclic message into one single chart

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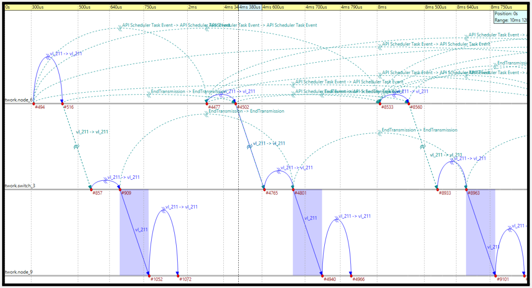

tIn = 0,00µs tOut = 147,32µs tModuleLatency = 147,32µs msg: vl_211
t in µs
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
End to End
node_6
BC
WC
switch_3
BC
WC
node_9
BC
WC
Best Case (BC)
Worst Case (WC)

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- Set of modules for OMNeT++ simulations: called ResultManagers
- OMNeT++ vector and scalar recording are build-in instances of ResultManagers
- Contributed in oppResultManagers:
  - PCAPng
  - SQLite & postgreSQL
  - Constraint Checks
  - Multiple
- Functionality is not restriced to our simulation models

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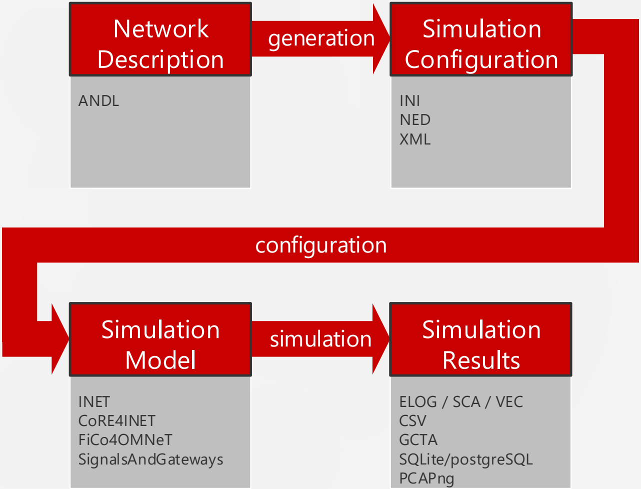

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Abstract Network Description Language File:

```
types std {                //Types can be defined and reused
  ethernetLink ETH {       //Definition for Ethernet link
    bandwidth 100Mb/s;     //Link has bandwidth of 100MBit/s
  }
}   //it is also possible to define types in a separate file

network smallNetwork{      //network name is smallNetwork
  inline ini{              //Inline ini for special parameters
    record-eventlog = false
  }                        //Parameters are inserted into .ini

  devices{                 //Define all devices in the network
    canLink bus1;          //First CAN bus
    canLink bus2;          //Second CAN bus
    node node1;            //First CAN node
    node node2;            //Second CAN node
    gateway gw1;           //Gateway for first CAN bus
    gateway gw2;           //Gateway for second CAN bus
    switch switch1;        //Real-time Ethernet Switch
  }
```

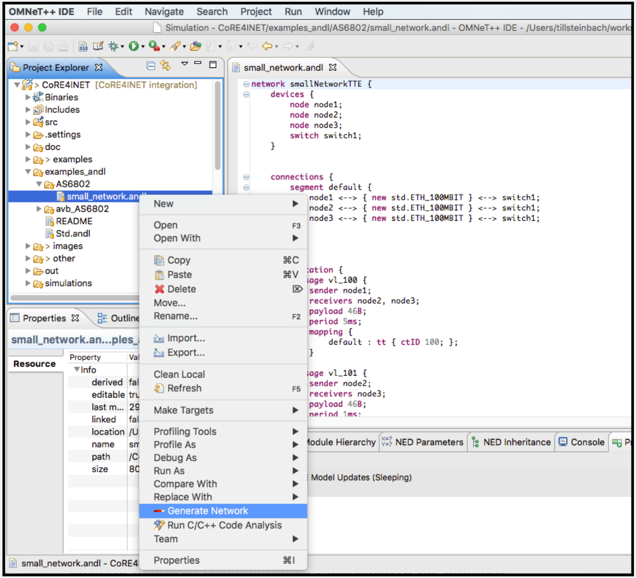
Continued on next slide...

```
connections{      //Physical connections (Segments = groups)
  segment backbone { //Ethernet Backbone part
    gw1 <—> {new std.ETH} <—> switch1; //Ethernet Link
    gw2 <—> {new std.ETH} <—> switch1; //Ethernet Link
  }
  segment canbus{     //CAN bus part (busses share config)
    node1 <—> bus1; //CAN node connected to first bus
    gw1 <—> bus1;   //Gateway connected to first bus
    node2 <—> bus2; //CAN node connected to second bus
    gw2 <—> bus2;   //Gateway connected to second bus
  }
}

communication{        //Communication in the network
  message msg1{       //Message definition
    sender node1;     //First CAN node is sender
    receivers node2;  //Second CAN node is receiver
    payload 6B;       //Message payload is 6 Bytes
    period 5ms;       //5ms cyclic transmission
    mapping{  //mapping to traffic class, id, gw strategy
      canbus: can{id 37;};        //Message ID 37 on CAN
      backbone: tt{ctID 102;};    //TT traffic on backbone
      gw1: pool gw1_1{holdUp 10ms;};   //Aggregation time
    }
  }
}
}
```

Workflow

Simulation Configuration / Model



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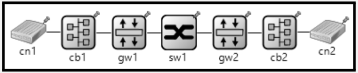
- Uses all three simulation models and INET
- Generated config (.ini/.ned/.xml) > 250 lines
- Resulting network:



- Additonal configuration of ResultManagers in ini file:
  - postgreSQL:

```
outputscalarmanager-class="cPostgreSQLOutputScalarManager"
outputvectormanager-class="cPostgreSQLOutputVectorManager"
postgresqloutputmanager-connection="dbname=testdb user=
    testuser password=testuser port=15432"
```

  - PCAPng:

```
eventlogmanager-class = "PCAPNGEventlogManager"
```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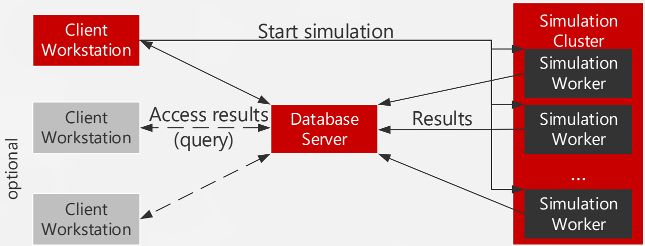
- OMNeT++ (scalar, vector and eventlog)
- WireShark (PCAPng)
- GCTA (timinglog)
- Database (mySQL, postgreSQL)

Use-case postgreSQL database:



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Conclusion

- In-car communication technologies are changing
- Simulation on system-level supports the process
- We contribute a simulation environment with:
  - Simulation models
  - Development tools
  - Analysis tools
- Specialized tools can support the workflow
- OMNeT++ is a solid foundation for the development of such plugin tools

Outlook

- Adding new technologies to our simulation suite:
  - Ethernet with frame preemption (discussed in IEEE 802.1Qbu)
  - CAN with flexible data rate (CAN FD)
- Refinement of result analysis tools

Questions

Thank you for your attention!

- Website of CoRE research group: https://core-rg.de/
- Website of simulation models: https://sim.core-rg.de/

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References I

[1] Kirsten Matheus and Thomas Königseder. Automotive Ethernet. Cambridge, United Kingdom: Cambridge University Press, Jan. 2015.

[2] Jan Kamieth et al. "Design of TDMA-based In-Car Networks: Applying Multiprocessor Scheduling Strategies on Time-triggered Switched Ethernet Communication". In: 19th IEEE International Conference on Emerging Technologies and Factory Automati Barcelona: IEEE Press, 2014, pp. 1–9. DOI: 10.1109/ETFA.2014.7005119. ieeexplore: 7005119.