Challenges for Cluster Simulation for FlexRay Systems

Dietmar Millinger, May 2008
EB Today

- Cutting-edge embedded technology solutions for **automotive** and **wireless** markets
  - superior technology skills
  - unique development culture
  - ability to lead the most challenging projects
  - anticipating changing and growing market and end-user needs
- Over 1700 employees
- Present in 7 countries on 3 continents.
- Net Sales of MEUR 144 or MUSD 211 in 2007, listed on OMX Helsinki
Facts and Figures EB Automotive

- Executive Vice President, Automotive: Otto Fössel
- Employees: approx. 500 (June 30th, 2007)
- Germany:
  - Erlangen
  - Munich
  - Böblingen
  - Gaimersheim
  - Braunschweig
- Austria: Vienna
- Japan: Tokyo
- USA:
  - Novi, MI
  - Bothell, WA
Automotive Software

Infotainment
Cockpit, Multimedia, Navigation, HMI, MOST
- Functional software, HMI development, tools
- References: HMI development of the MOST based infotainment system in the current A6 (direct order from AUDI)

Driver Assistance
Driver Environment Information, Predictive Systems
- Functional software, basic software, sensor fusion, pattern recognition, embedded 2D & 3D image processing, lane detection
- Software infrastructures for research, development and benchmarking
Automotive Software

Navigation

White label for mobile devices, fixed installation

- Navigation kernel, user interface, localization for Europe, North America, Asia, flexible feature extension
- References: Medion, Ford, Blaupunkt, Delphi, Falk, Freescale, Analog Devices, NXP

Body / Chassis / Comfort / Powertrain

Comfort electronic, x-by-wire, etc.

- AUTOSAR-compliant basic software
- FlexRay products and technologies
- References: BMW standard core, EB tresos® Automotive Standard Core
FlexRay Cluster Simulation

- Overview
- FlexRay properties
- Cluster simulation system
- Findings in first projects
Why Cluster Simulation?

- **Use areas are**
  - development of distributed functions
  - development and integration of ECU basic software
  - testing and validation of ECUs
  - production testing of ECUs

- **Objectives are**
  - simulation of function parts that are still under development
  - simulation of ECUs which are still under development or not available
  - control over network based system services
  - generation of stimuli for function testing
  - judgment of generated output of ECUs under development
Cluster Simulation Principle

Planned FlexRay network

Definition of simulation cluster

Development/Test cluster

Simulation cluster

Unit under test/development
Current Status of Cluster Simulation

- Widely used
  - multiple suppliers
  - broad customer basis
- Huge number of legacy systems for testing in operation
- Suitable for CAN network technology
- Soft real-time behavior
  - network and simulation system can align to each other
- Easy to configure
  - vendor specific databases
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Selected Properties of FlexRay

- Configuration
- Real-Time Protocol
- High bandwidth
- Startup
Configuration

- FlexRay requires an extensive configuration
  - TDMA pattern (global)
  - buffer layout (local)
  - register settings (local)

- Global part of configuration needs to be provided by network integrator
- Local part has to be calculated

- Configuration exchange format for FlexRay is FIBEX
  - FlexRay configuration parameters
  - System architecture information (ECUs, signals, functions,...)
FlexRay Configuration Space

64 Cycles by up to 2047 slots on two channels ➔ up to 130,000 cells on two channels

many constraints

Cycles

Symbol Window + Network

Idle Time

Deterministic periodic transmission

Guaranteed periodic & aperiodic

Best-Effort aperiodic

Static segment (m Static slots)

Dynamic segment (n Mini slots)
Missing Configuration in FIBEX

- FIBEX is the exchange file format for FlexRay network design
- Some parameters for cluster simulation configuration are missing in the FIBEX file
  - FlexRay parameters at register level
  - Allocation of receive and transmission buffers
  - Scheduling of communication driver tasks
  - Selection of ECUs in simulation cluster

Configuration tool needs to hide configuration complexity from test engineer and has to complete missing configuration information automatically
Real-Time Protocol

- FlexRay protocol executes a strictly periodic time regime

- Communication stack has to be executed synchronous to FlexRay
  - Ensure data consistency
  - Avoid loss of data

- In certain cases simulation tasks need to be executed synchronous to FlexRay
  - in-cycle response required (receive, process, transmit inside one cycle)
  - system services (e.g. round based algorithms, exactly one calculation per round)
  - manipulation of frames after complete assembly of frame (e.g., CRCs)
Real-time Execution

Asynchronous simulation execution

Simulation
Driver
FlexRay
Task
DR
MTX
Task
DR
MTX
Task
DR
MTX
Task
DR
MTX

Simulation Cycle
FlexRay Cycle

Synchronous simulation execution

Task
DR
MTX
Task
DR
MTX
Task
DR
MTX
Task
DR
MTX

FlexRay Cycle
Synchronous Models

In-cycle response

One execution per round

FlexRay Cycle
Real-Time Task Execution

- Simulation tasks run asynchronous to FlexRay cluster
  - usual case, since HIL is hard to synchronize with FlexRay
- Simulation task runs synchronous to FlexRay

- In case of asynchronous model execution, some simulation tasks must be encapsulated and executed synchronously (real-time modules)
- In both execution models consistent data exchange must be ensured

Cluster simulation needs to support both types of real-time execution in one system
FlexRay Bandwidth

- 10 MBit/s bandwidth on one channel
- 7.6 MBit/s bandwidth on one channel available for application payload
- e.g. 254 bytes each 266 µs

- FlexRay bus can produce a very high CPU load for data handling

A cluster simulation solution for FlexRay should keep CPU load for FlexRay handling encapsulated
FlexRay Startup

- An isolated FlexRay controller does not perform startup
- An isolated FlexRay controller does not establish a continuous communication
- Due to the distributed clock synchronization mechanism in FlexRay at least one partner node is required
- For a stable development environment of one ECU at least two additional communication partners are required

A cluster simulation solution should provide a stable network for the ECU under development
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Cluster Simulation System
Control system

- Configuration tool
- HIL Control System
- Cluster Simulation System
  - HIL Type
  - Desktop Type

PC

FIBEX
Cluster Simulation System
HIL Type

Cluster Simulation System (HIL)

Active Bus Interface

Firmware synchronous with FlexRay Communication cycle

Signal Access Functions

Simulation model

ECU(s) under test

FlexRay
Cluster Simulation System
Desktop Type

Cluster Simulation System (HIL or PC)

Desktop FlexRay Interface Box

Active Bus Interface

Firmware synchronous with FlexRay Communication cycle

uC

Simulation model

Signal Access Functions

ECU(s) under test

FlexRay

USB/Ethernet
Configuration tool

- Import of FIBEX database
- Selection of ECU or controllers to simulate
- Generation of configuration for active interface card
- Download of configuration
- Definition of real-time modules
- Dynamic load/unload of real-time modules
Active Bus Interface

- Sufficient CPU resources for driver task handling
- Real-time modules
  - Execute application functions synchronous with FlexRay
- Mechanism to synchronize HIL with FlexRay
- Standard interface to download configuration
  - USB, Ethernet, PCI, …
- High performance interface to HIL simulator
  - PCI, PCIeXpress, PXI, VME, compactPCI,…
  - Ethernet, USB
- Flexible support of different physical layer silicon
Signal Access Functions

- Signal level data access
- Signal conversion
  - conversion between coded format and physical format of signal
- Consistent PDU access
  - in asynchronous task execution model mandatory
  - in synchronous task execution advantageous
- Adaptation to HIL environment
  - Operating system
  - Simulation system
  - Easy to port
  - Library to be integrated in simulation system
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Findings in first projects

- Several projects for OEM and Tier 1 companies evaluated
- Encapsulation of hard real-time execution very important
- Strong request to encapsulate FlexRay configuration complexity
- OEM specific services
  - real-time modules with OEM specific service simulation are valuable assets
- Communication channel between simulation and real-time modules
  - Control behavior of real-time modules (e.g. fault-injection, …)
- Dynamic Change of FlexRay Configuration to support different schedules
  - different schedules for flashing, ECU sensor/actuator tests, application tests
  - fast change of configuration to support fast test turn-around time
Findings from first projects

- Editing of FlexRay configuration in FIBEX
  - complete FIBEX information
  - adapt FIBEX information to reflect new development states
  - FIBEX is not FIBEX is not FIBEX (different OEM flavors)

- Installed hardware base varies widely
  - Flexible solution required
Conclusion

- Cluster simulation and testing for FlexRay is possible even in existing systems
- A range of challenges has to be taken
- Hard real-time regime of FlexRay drives these challenges
- A strong FlexRay development partner and suitable products help you to focus on your test jobs
Discover the Experience