Co-Simulation of Distributed Engine Control System

EMSIG2015

ITOS Project Case

MAN Diesel & Turbo, DTU Compute

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Agenda

Volkswagen Group

12 brands

MAN Group

Key Figures 2014

MAN SE

Business areas	**Commercial Vehicles**		**Power Engineering**	
Divisions	**MAN Truck & Bus** Revenue ‘14: € 8.4 bn	**MAN Latin America** Revenue ‘14: € 2.3 bn	**MAN Diesel & Turbo** Revenue ‘14: € 3.3 bn	**Renk** (76 %) Revenue ‘14: € 0.5 bn
				
Investments	**Sinotruk** (25.0 % +1 share), **Scania** (17.4 %*)			

* Voting rights

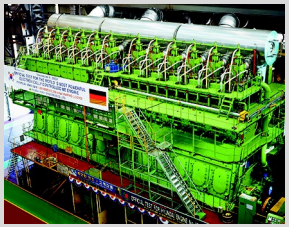
The MAN Group in 2014: €14.3 billion revenue, 55,903 employees

MAN Diesel & Turbo

A worldclass product portfolio

Engines & Marine Systems

Two-stroke and four-stroke engines for marine applications



Propellers and complete marine propulsion systems

Turbochargers

Power Plants

Two-stroke and four-stroke engines for stationary applications

Diesel and gas power plants

Turbomachinery

Compressors , gas turbines and steam turbines

Turnkey machinery trains

Chemical reactors

Service: MAN PrimeServ

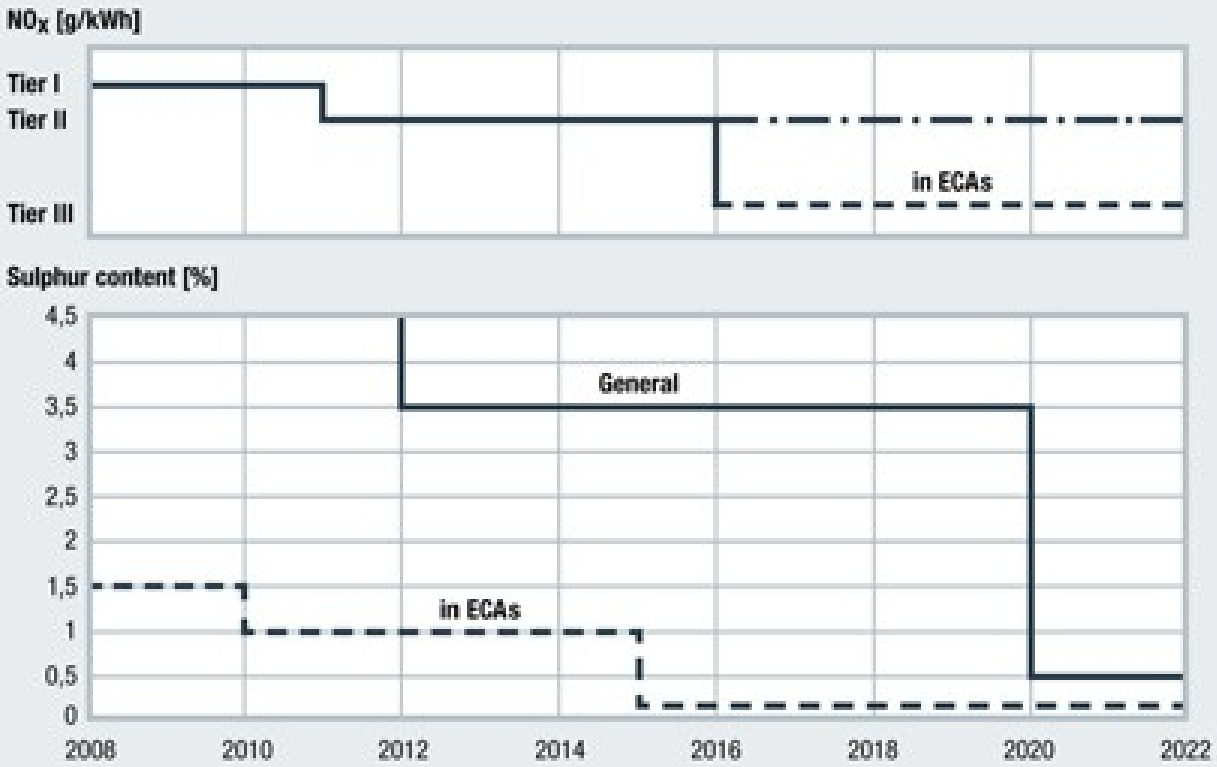
Worldwide network of service hubs: 24/7 OEM service around the globe

Emission Controls Department

3.4 g/kWh (2016)

0.1% (2015)

0.5% (2020)



Implementation schedule SO_x and NO_x limits according to IMO MARPOL 73/78 Annex VI

MAN Challenges

Increased portfolio complexity:

Emission control:

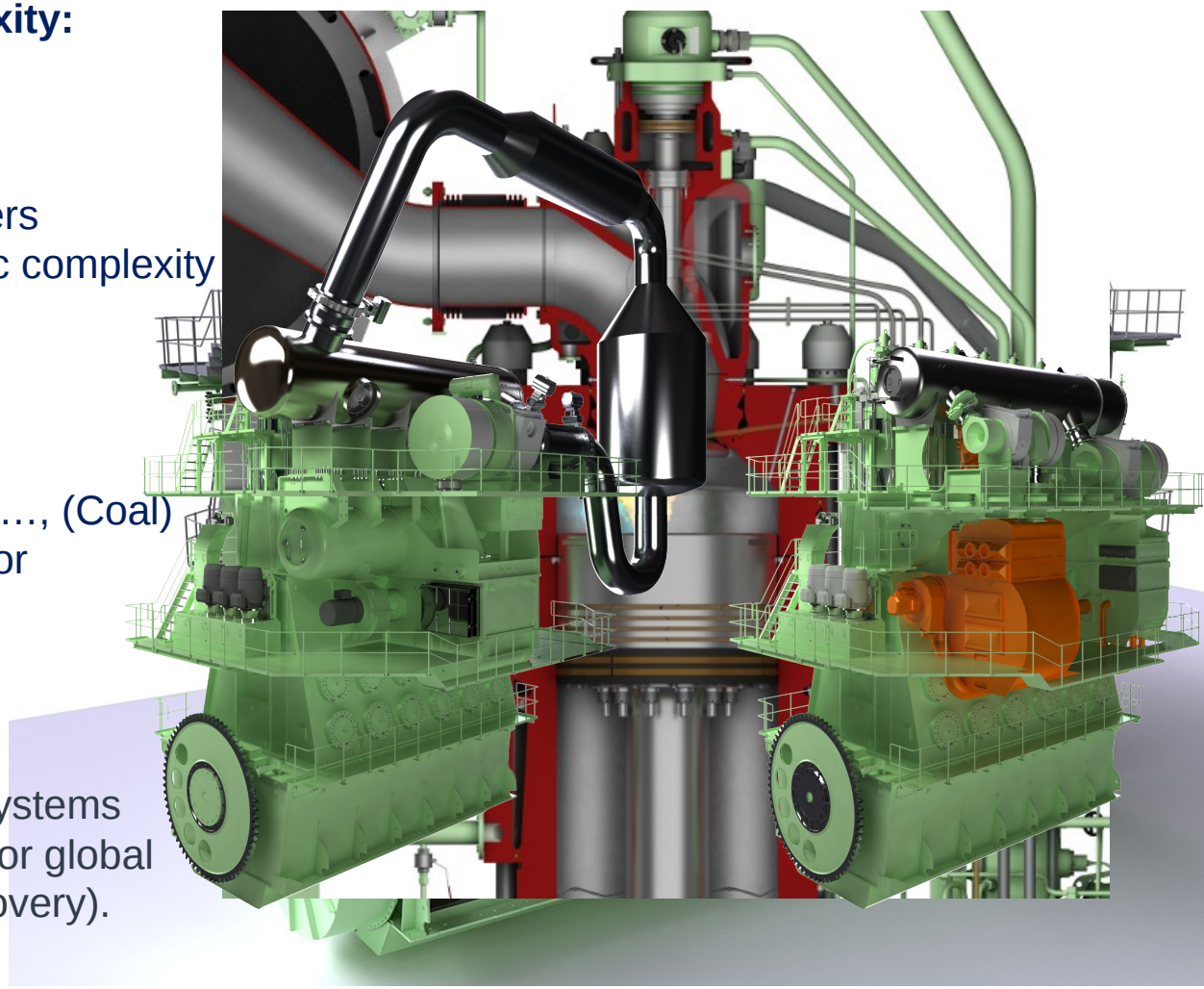
- SCR, EGR, SOx-Scrubbers
- Increased thermodynamic complexity
- Observer-based control

Dual fuels:

- Ethanol, Methanol, LNG, …, (Coal)
- Increased requirements for temporal execution

Auxiliary systems:

- Data sharing with other systems
- Closer coupled systems for global optimization (Waste heat recovery).



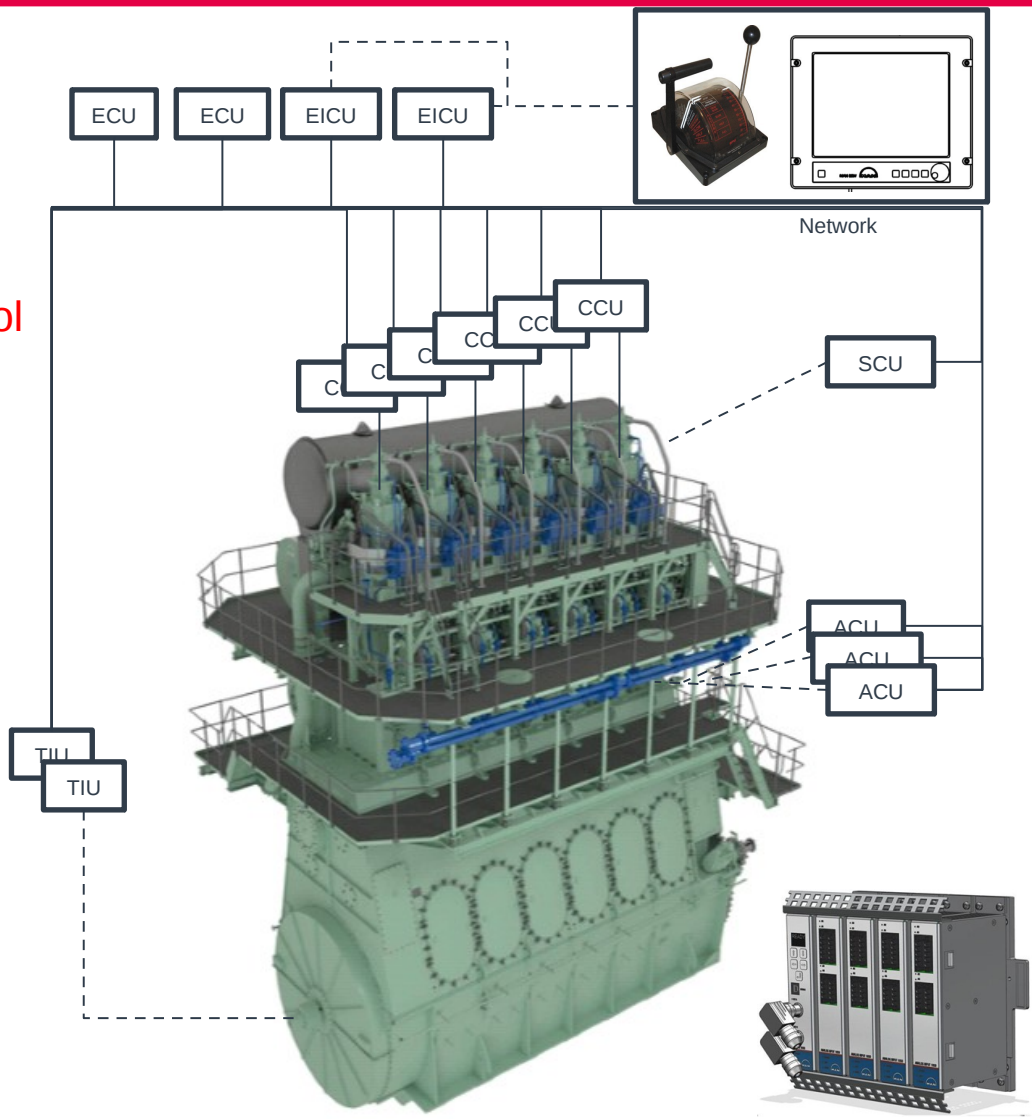
Motivation

Current Simulation Approach:

- Simplified Control models for engine design.
- Simplified Engine dynamics for control design.
- Multiple development environments.
- Network dynamics manually tested

Future Simulation Approach:

- Co-simulation of control dynamics, engine dynamics and ship dynamics.
- Integration of multiple development environments.
- Network design-space exploration.



Solution

Functional Mock-up Interface: (FMI)

- Co-Simulation
- Clear definition of variables
- Ease access of models across departments

SystemC Network Simulation Library: (SCNSL)

- Introduce Network modeling.
- Explore alternative protocols and network typology.
- Investigate latency and transport delay
- Fault injection

Cyber-Physical System

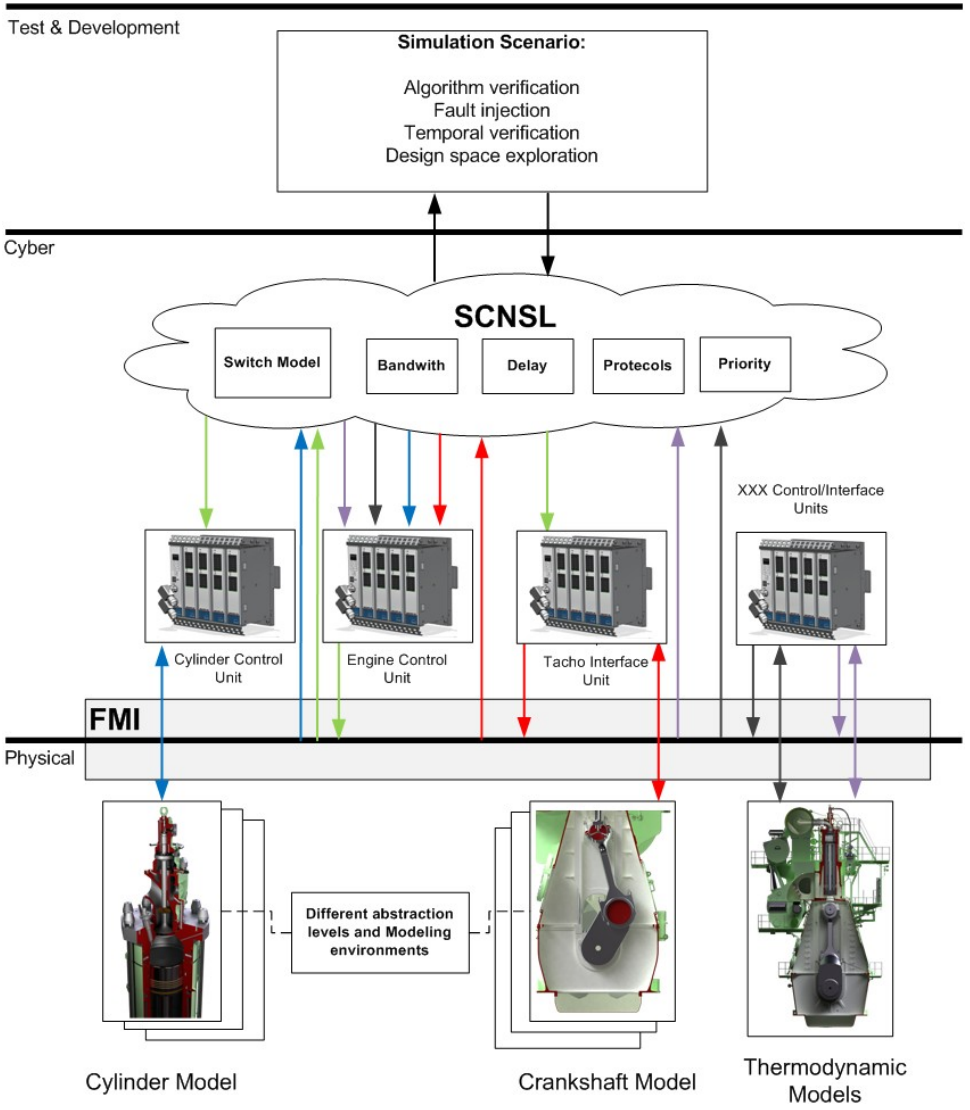
Cyber-Physical System:

Integration of computation, network and physical processes

- **Physical-Layer:**
  Physical processes with sensors & actuators connecting computational units.

- **Cyber-Layer:**
  Communication between computational units.

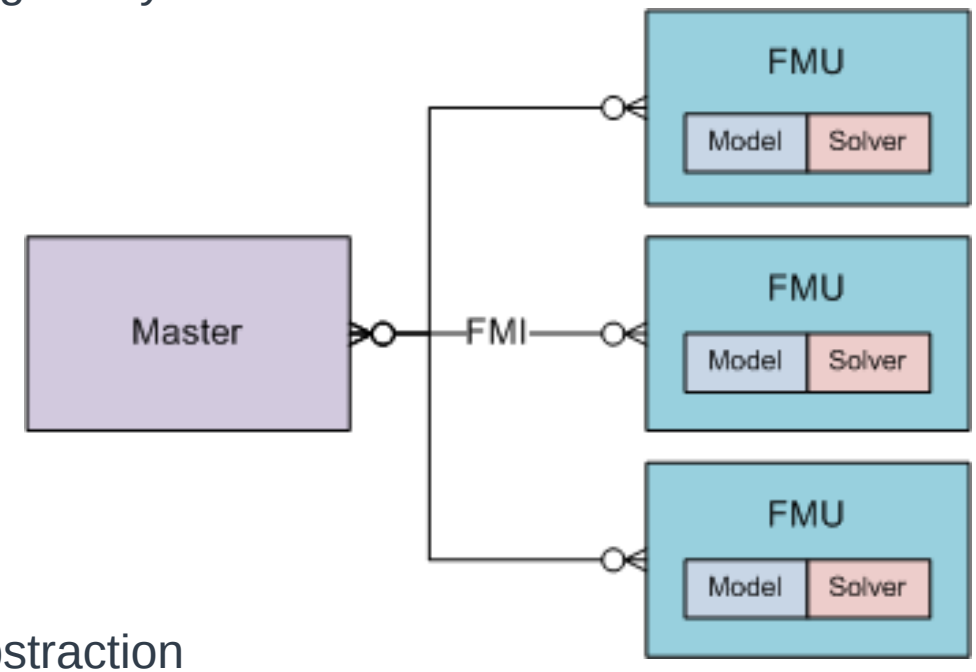
- **Environment-Layer:**
  Where development- and test-engineers can access the system and specify simulations scenarios.



Co-Simulation - FMI

FMI 2.0 for Co-Simulation: (MODELISAR part of the European project ITEA 2)

- Standardized interface for coupling subsystems.
- Environment independent.
- Description schema
- FMI application interface



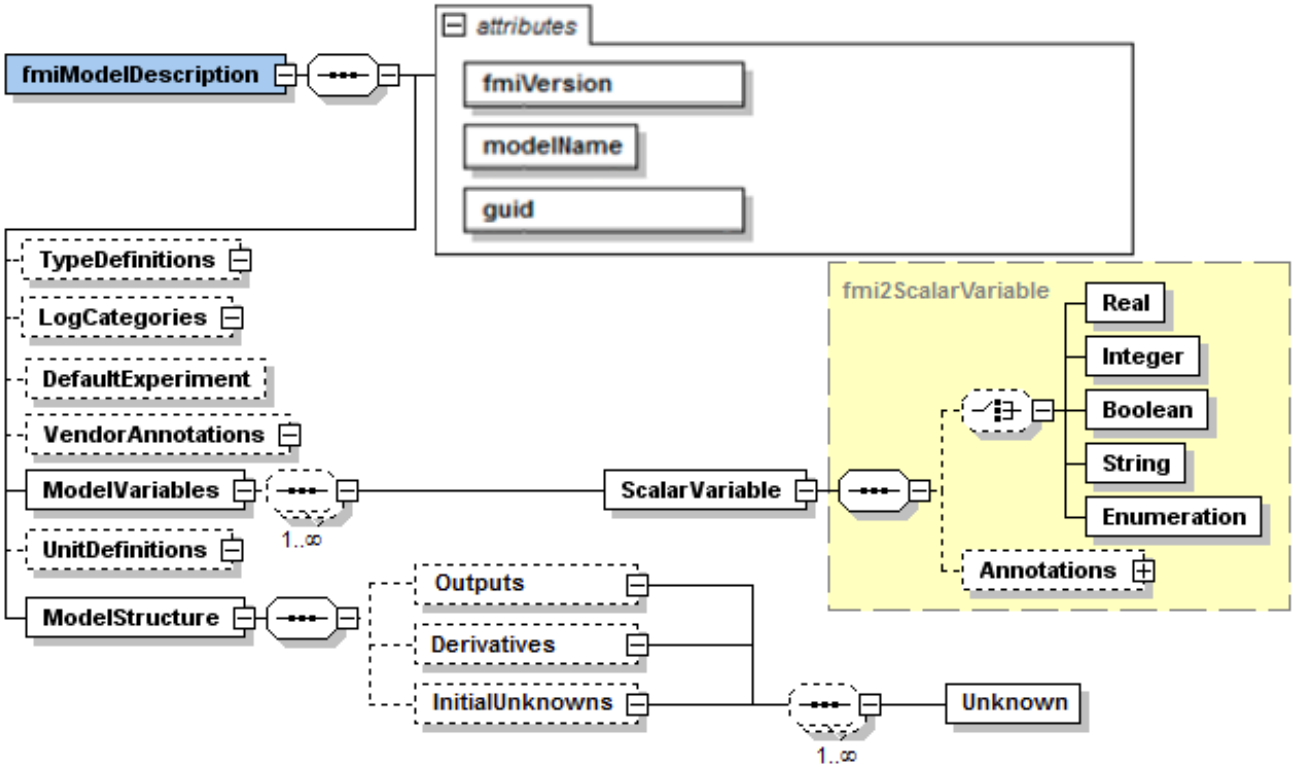
Description Schema:

XML-file with different levels of abstraction

FMI – Description Schema

Description Schema:

- XML-Configuration
- Defines FMU interface

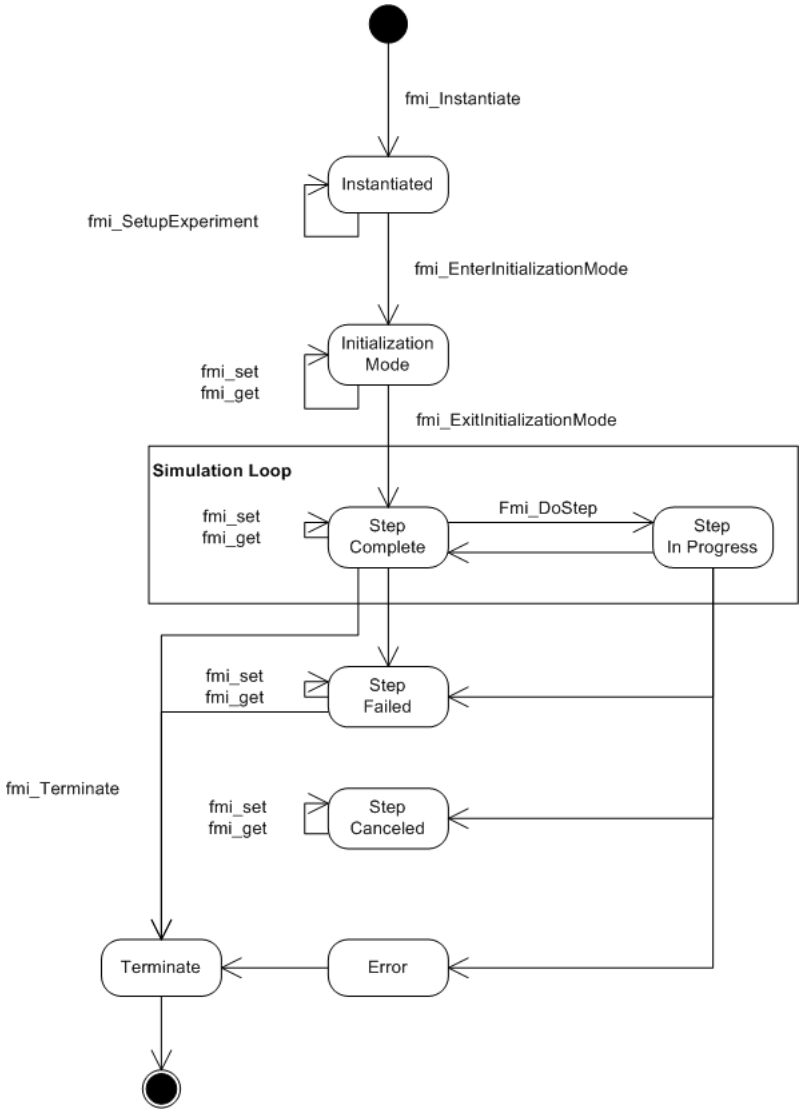


FMI – Application Interface

Application Interface:

The application should be implemented on the each FMU and compiled as a dynamic-link library.

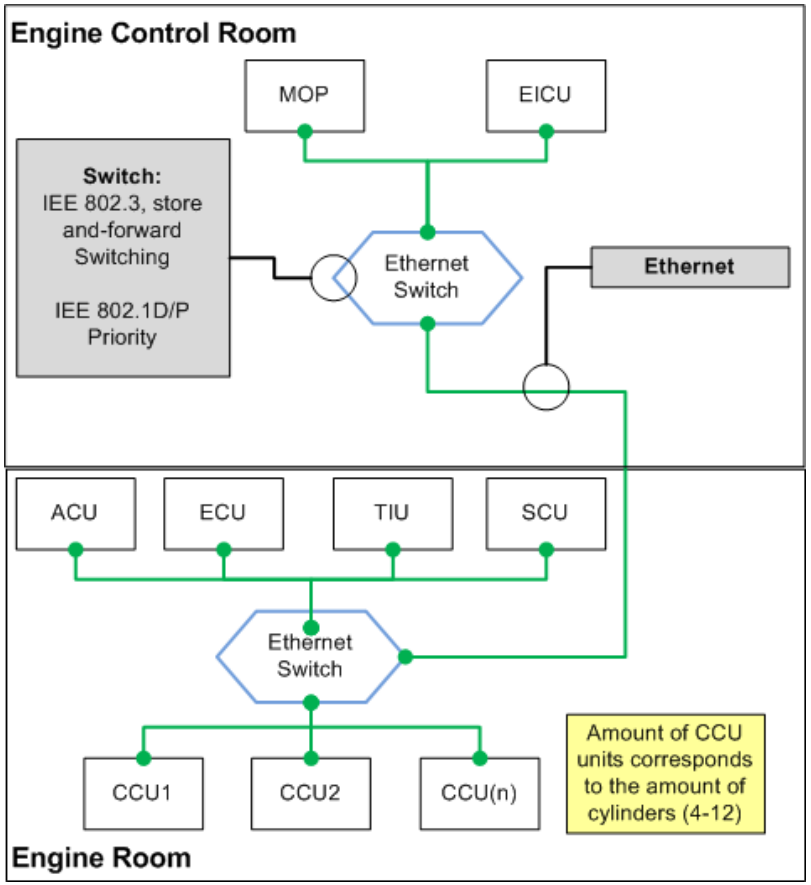
- **C-functions-prototypes**
- **Type and data definitions**
- **Simulation state machine**



Network Model – MAN

MAN Network Model:

Simplified network model of a MAN Diesel & Turbo engine control system.



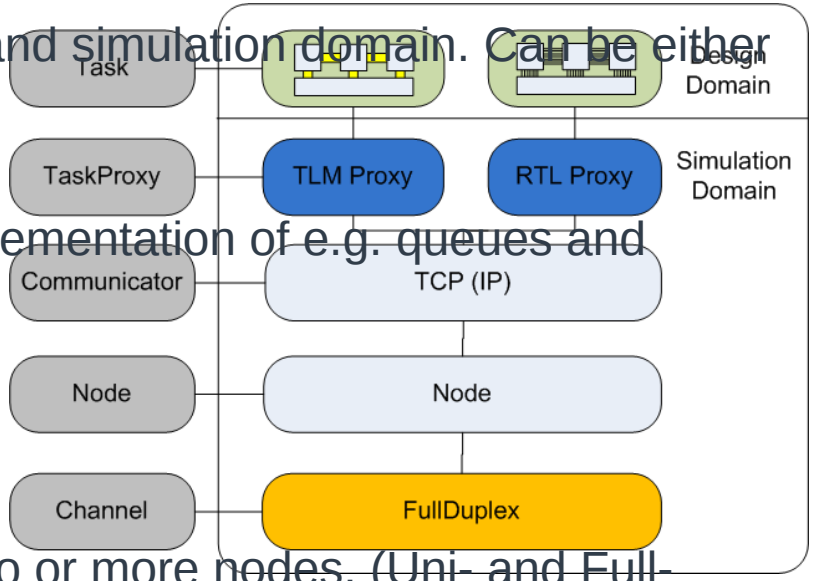
OSI	Ethernet			
Layers 5/6/7	Application			
Layer 4	CNET (MAN Protocol)	ARP (Address Resolution Protocol)	IEEE 1588 (Distributed Clock Synchronization)	TACHO
Layer 3				
Layer 2	MAC			
Layer 1	802.3			

Network Model - SCNSL

SCNSL:

An extension to SystemC introducing network components.

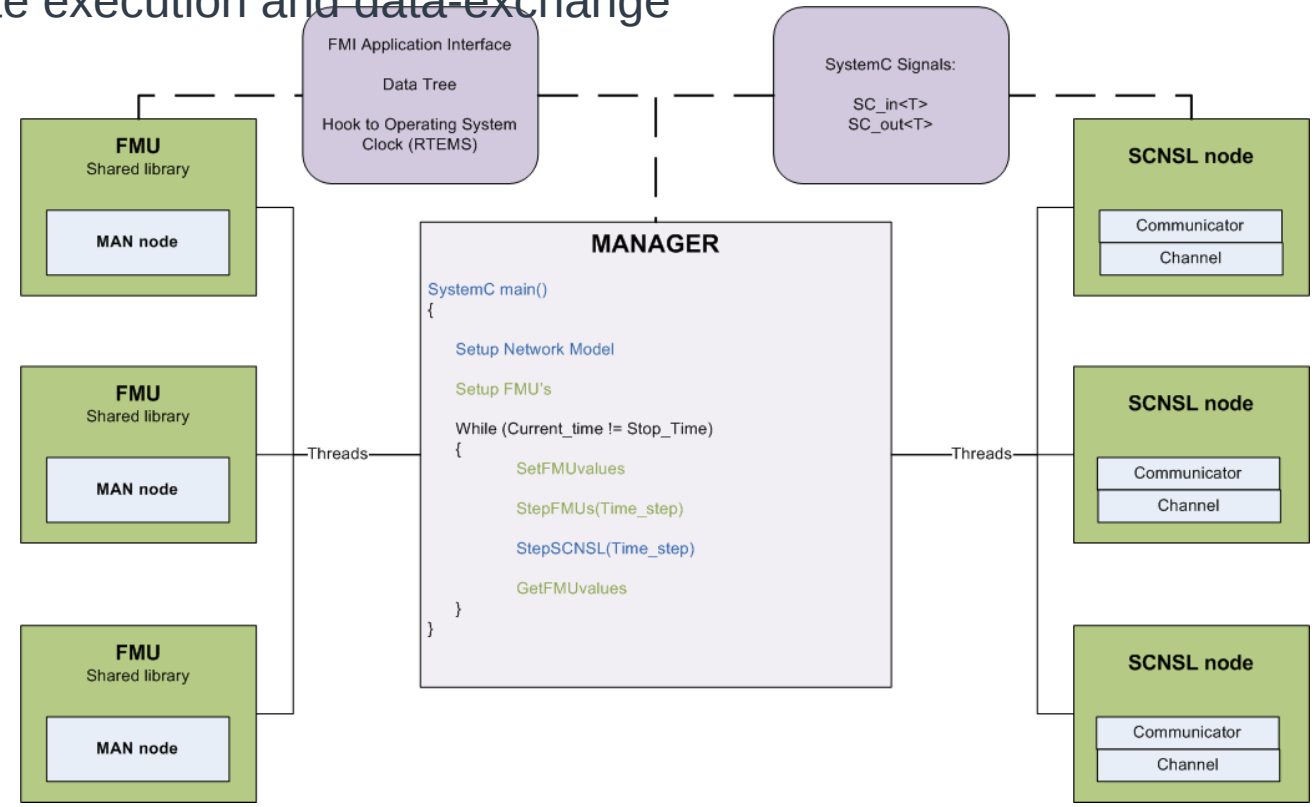
- **Kernel:**
  Uses the SystemC kernel responsible for temporal execution.
- **Task:**
  Application to interact with the network.
- **TaskProxy:**
  The intermediate layer between design and simulation domain. Can be either TLM or RTL.
- **Communicator:**
  Define network simulation behavior. Implementation of e.g. queues and protocols.
- **Node:**
  A network host.
- **Channel:**
  The physical medium which connects two or more nodes. (Uni- and Full-Duplex, Shared).



Implementation

Simulation Manager:

- SystemC Kernel
- Multi-threaded
- Discrete execution and data-exchange
- FMI



Discussion & Perspectives

Standardization vs. Customization

Complex simulation configuration

- Configuration
- Parameter binding
- FMI Schema

Performance

- Amount of FMU's
- Parallelization

Co-Simulation & Code Generation

- MATLAB/Simulink – Modelon
- Modelica – Open Modelica, Dymola

Hardware in the loop testing

Virtual Ship

Do you have any more questions?

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