**Distributed Real-Time Systems**

Chapter 1 The Real-Time Environment

Chapter 2 Distributed Real-Time Systems

Chapter 3 Global Time

Chapter 4 Modeling Real-Time Systems

Chapter 5 Real-Time Entities and Images

Chapter 6 Fault Tolerance

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Chapter 8 Time-Triggered Protocols

Chapter 9 Input and Output

Chapter 10 Real-Time Operating Systems: OSEK and AUTOSAR

Chapter 11 Real-Time Scheduling

Chapter 12 Validation

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# Literature for this lecture

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| **Text books for this lecture** | | |
| [1.1] | Kopetz, H.: | Distributed Real-Time Systems, Springer 2008 |
| [1.2] | Buttazzo, G.: | Hard Real-Time Computing Systems, Springer 2005 |

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| **Complementing texts**  *Some books complementing the material treated in this lecture* | | |
| [2.1] | Liu, J.S.: | Real-Time Systems, Prentice Hall 2000 |
| [2.2] | Vérissimo, P; Rodrigues, L.: | Distributed Systems for System Architects, Kluwer 2001 |
| [2.3] | Laplante, P.: | Real-Time Systems Design and Analysis, IEEE Press, 2004 |
| [2.4] | Halbwachs, N.: | Synchronous Programming of Reactive Systems, Kluwer 1993 |
| [2.5] | Zimmermann, W.; Schmidgall, R.: | Bussysteme in der Fahrzeugtechnik, Vieweg 2006 (German only) |

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| **Journal Articles and Web Documents**  *Original journal articles and documents from the web pertaining to this lecture* | | |
| [3.0] | Albert, A.: | Comparison of Event-Triggered and Time-Triggered Concepts with Regard to Distributed Control Systems, Embedded World, 2004, Nürnberg,  http://www.semiconductors.bosch.de/pdf/embedded\_world\_04\_albert.pdf |
| [3.1] | Müller, B.; Führer, T.; Hartwich, F.; Hugel, R.; Weiler, H.: | Fault Tolerant TTCAN Networks, Proceedings 8th International CAN Conference; 2002; Las Vegas, NV  http://www.semiconductors.bosch.de/pdf/Fault\_Tolerant\_TTCAN.pdf |
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**Chapter 1: The Real-Time Environment**

* Definition of a real-time system.
* Simple model with operator, computer system, and controlled object.
* Introduction of distributed real-time systems.
* Hard real-time systems and soft real-time systems.
* Functional, temporal, and dependability requirements.
* Sphere of control
* Event-triggered versus time-triggered systems.

**Chapter 2: Distributed Real-Time Systems**

* Distributed system architecture overview, clusters, nodes, communication network
* Structure of node with host computer, communication network interface, communication controller
* Event and state messages, gateways.
* Concept of composability.
* Event- and time-triggered communication systems.
* Scalability, dependability, issues of physical installation.

**Chapter 3: Global Time**

* Notions of causal order, temporal order, and delivery order
* External observers, reference clocks, and global time base
* Sparse time base to view event order in a distributed real-time system
* Internal clock synchronization to compensate for drift offset. Influence of the communication system jitter on the precision of the global time base.
* External time synchronization, time gateways, and the Internet network time protocol (NTP)

**Chapter 4: Modeling Real-Time Systems**

* Introduction of a conceptual model for real-time systems
* Tasks, nodes, fault-tolerant units, clusters
* Simple and complex tasks
* Interface placement and interface layout
* Temporal control and logical control
* The history state

**Chapter 5: Real-Time Entities and Images**

* Real-time entities
* Observations, state and event observations
* Real-time images as current picture of real-time entity, and real-time objects
* Temporal accuracy and state estimation to improve real-time image accuracy
* Permanence in case of race conditions and idempotency with replicated messages
* Replica determinism to implement fault-tolerance by active redundancy

**Chapter 6: Fault Tolerance**

* Failures, Errors, and Faults
* Error Detection
* A Node as a Unit of Failure
* Fault Tolerant Units
* Reintegration of a Repaired Node
* Design Diversity

**Chapter 7: Real-Time Communication**

* Real-Time Communication Requirements
* Flow Control
* OSI Protocols for Real-Time
* Fundamental Conflicts in Protocol Design
* Media-Access Protocols
* Performance Comparison: ET versus TT
* The Physical Layer

**Chapter 8: Time-Triggered Protocols**

* Introduction to Time-Triggered Protocols
* Overview of the TTP/C Protocol Layers
* The Basic CNI
* Internal Operation of TTP/C
* TTP/A for Field Bus Applications

**Chapter 9: Input and Output**

* The dual role of time
* Agreement protocol
* Sampling and polling
* Interrupts
* Sensors and actuators
* Physical installation

**Chapter 10: Real-Time Operating Systems: OSEK and AUTOSAR**

* Task management
* Interprocess communication
* Time management
* Error detection
* OSEK and AUTOSAR

**Chapter 11: Real-Time Scheduling**

* The scheduling problem
* The adversary problem
* Dynamic scheduling, dynamic priority servers
* Static scheduling, fixed priority servers

**Chapter 12: Validation**

* Building a Convincing Safety Case
* Formal Methods
* Testing
* Fault Injection
* Dependability Analysis