



# Distributed Real Time Systems

## Introduction

### **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 1999

[2.3]Laplante, P.: Real-Time Systems Design and Analysis, IEEE Press, 2004

[2.4]Halbwachs, N.: Synchronous Programming of Reactive Systems, Kluwer 1990

[2.5]Zimmermann, W.; Schmidgall, R.: Bussysteme in der Fahrzeugtechnik, Vieweg 1998

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### **Journal Articles and Web Documents** *Original journal articles and documents*

[3.0]Albert, A.: Comparison of Event-Triggered and Time-Triggered Concepts with

[3.1]Müller, B.; Führer, T.; Hartwich, F.; Hugel, R.; Weiler, H.: Fault Tolerant TTCA

### Overview

Chapter 1 The Real-Time Environment

Chapter 2 Distributed Real-Time Systems

Chapter 3 Global Time

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Chapter 5 Real-Time Entities and Images

Chapter 6 Fault Tolerance

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### 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.

### 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.

### 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)

### 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

### 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



### 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

### 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

### 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

### Input and Output

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

### Real-Time Operating Systems: OSEK and AUTOSAR

- ▶ Task management
- ▶ Interprocess communication
- ▶ Time management
- ▶ Error detection
- ▶ OSEK and AUTOSAR

### Real-Time Scheduling

- ▶ The scheduling problem
- ▶ The adversary problem
- ▶ Dynamic scheduling, dynamic priority servers
- ▶ Static scheduling, fixed priority servers

### Validation

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

