



Distributed Real-Time Systems

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1. Summary

2. Bibliography

Chapter 1: The Real-Time Environment

- ▶ Definition of a real-time system
- ▶ Simple model with operator, computer system, and controlled object
- ▶ Introduction of distribute real-time systems
- ▶ Hard real-tiem dystems and soft real-time systems.
- ▶ Functional, temporal, and dependable requirements.
- ▶ Sphere of Control
- ▶ Event-triggered versus time-triggered systems.

Chapter 2: Distributed Real-Time Environment

- ▶ Distribute 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

Text books for this lecture



Kopetz, H: Distributed Real-Time Systems, Springer, 2008



Buttazo, G: Hard Real-Time Computing Systems, Springer 2005

Complementing texts Some books complementing the material treated in this lecture



Liu, J.S.: Real-Time Systems, Prentice Hall 2000



Verissimo, P; Rodrigues, L.: Distributed Systems for System Architects, Kluwer 2001



Laplace, P.: Real-Time Systems Design and Analysis, IEEE Press, 2004



Halbwachs, N.: Synchronous Programming of Reactive Systems, Kluwer 1993



Zimmermann, W.; Schmidgall, R.: Bussysteme in der Fahrzeugtechnik, Vieweg 2006 (German only)

Journal Articles and Web Documents Original journal articles and documents from the web pertaining to this lecture



Albert, A.: Comparison of Event-Triggered and Time-Triggered Concepts with Regard to Distributed Control Systems, Embedded World, 2004, Nuernberg,



Mueller, B.; Fuehrer, T.; Hartwich, F.; Huegel, R.; Weiler, H.: Fault Tolerant TTCAN Networks, Proceedings 8th International CAN Conference; 2002; Las Vegas, NV