

CS4220 Embedded Systems CS6235 Real-Time Systems

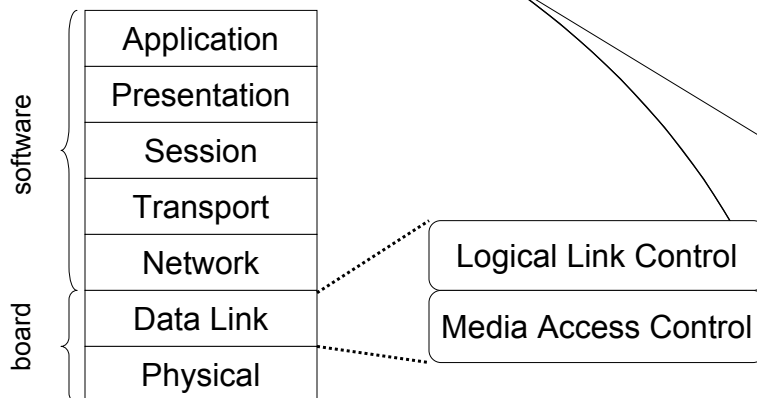
6B: Network Scheduling

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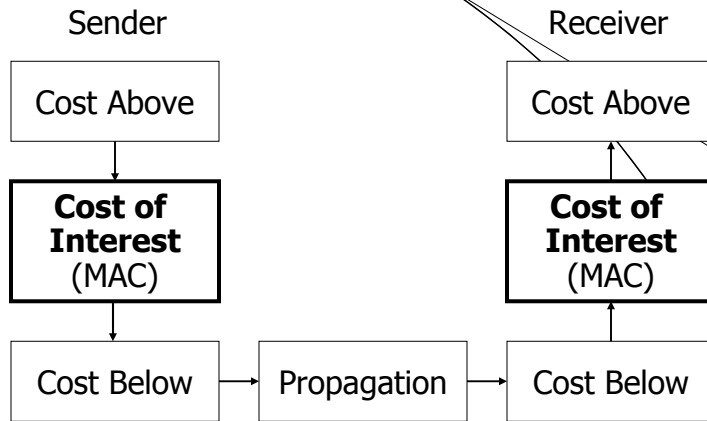
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OSI Reference Model



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Transmission Time



Message Classification

- Synchronous messages
 - Periodic, predictable stream (sensor data)
 - Arrival time: job creation
 - Length: job resource requirement
 - Deadline: job completion requirement
- Asynchronous messages
 - Aperiodic task communications, alerts
 - Unpredictable arrivals, length, deadline

Access Arbitration

- Network as a shared resource
 - Rate monotonic scheduling of bandwidth
- Desirable properties
 - Bandwidth utilization (for synchronous)
 - Robustness: not brittle
 - Timing fault isolation and limitation
 - Accommodate asynchronous messages
 - Low run-time overhead

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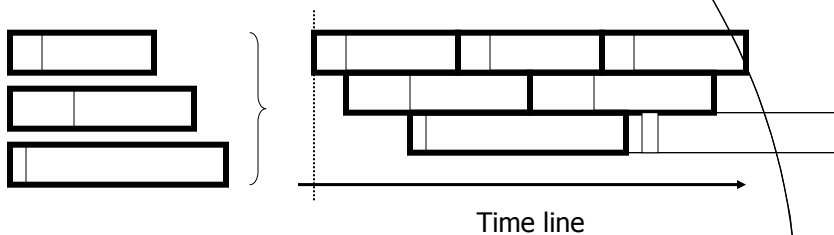
Rate Monotonic Scheduler

- Classic hard real-time CPU scheduler
 - May appear later
- Decides who gets the resource next
 - CPU in the original work
 - Network bandwidth in MAC
- Static scheduler: fixed priorities
 - No dynamic priority adjustments
 - Not a static schedule

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RM Scheduling Algorithm

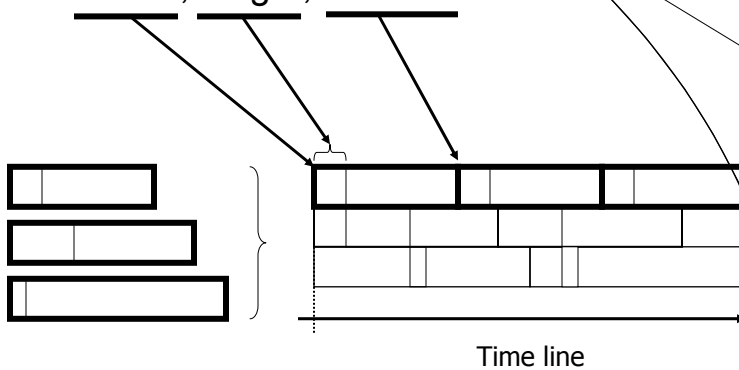
- Assumptions
 - ◆ Jobs are periodic, marked by start and end
 - ◆ Jobs are independent
- Shorter period jobs get higher priority



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RM for Networking

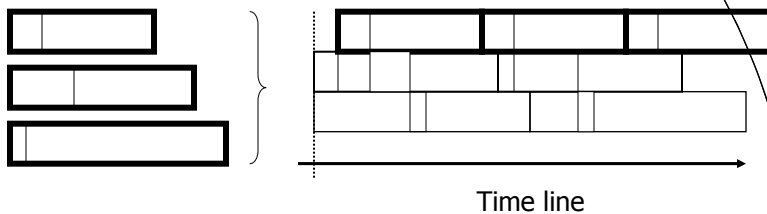
- Synchronous messages
 - ◆ Arrival, length, deadline



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Preemption in Networks

- Simulate preemption
 - ◆ Divide message into packets (unit of scheduling)



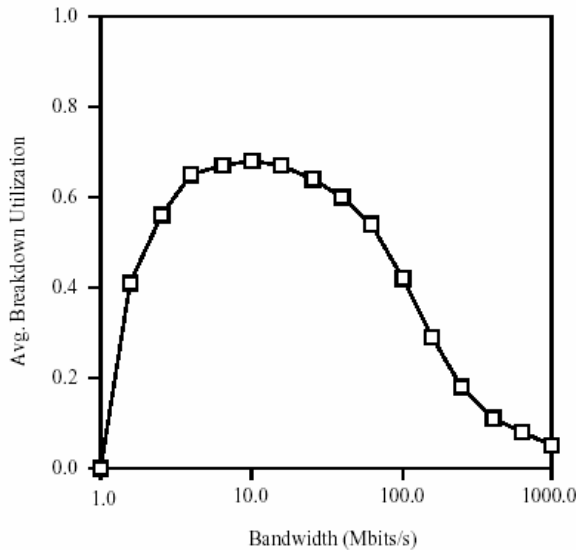
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Discussion of RM

- Evaluation criteria
 - Bandwidth utilization: guaranteed theoretical limit of 0.693 for CPU
 - Robustness: OK if below the 0.693 limit
 - Timing fault: limited by preemption
 - Asynchronous messages: high priority until the 0.693 limit
 - Run-time overhead: may be high (fig. 4)

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Preemption Overhead



100 nodes
100 meters between nodes
Bit delay per node = 4 bits
Packet length = 512 bytes
Average period = 100 ms
Signal propagation speed =
0.75 * (speed of light)

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Transmission Control

- Timed token protocol
 - Nodes are arranged in a ring
 - Each node receives the token in sequence
 - Node k transmits H_k packets (predefined)
 - Token rotation time bounded (half of minimum deadline)
 - If token arrives early, send asynchronous messages

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Scheduling Analog

- Timed token protocol
 - Nodes are arranged in a ring (round robin)
 - Each node receives the token in sequence
 - Node k transmits H_k packets (time slice)
 - Token rotation time bounded (to guarantee the equivalent of preemption)
 - If token arrives early, send asynchronous messages (different priorities)

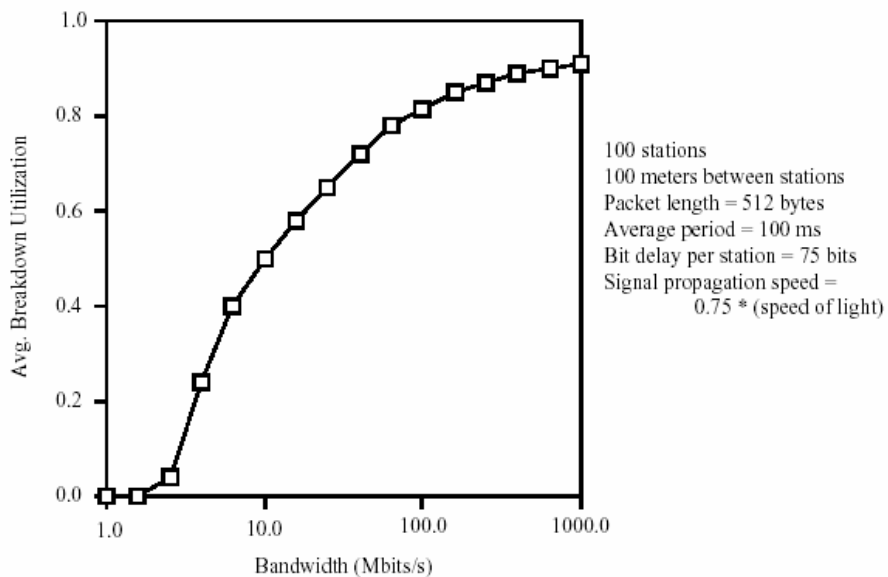
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Discussion of Timed Token

- Evaluation criteria
 - Bandwidth utilization: 0.33 WCAU
 - Robustness: OK if below the 0.33 limit
 - Timing fault: limited by H_k (time slice)
 - Asynchronous messages: squeezed in
 - Low run-time overhead: good scalability (fig. 5)

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No Preemption Overhead



Asynchronous Messages

- Unpredictable arrivals
- Guarantees in dynamic scheduling
 - **Periodic server**: reserved bandwidth (affects synchronous messages)
 - **Conservative estimation**: worst case analysis of all messages (under-utilization)
 - **Dynamic reservations**: control message to reserve future bandwidth (overhead)

“Best Effort” Scheduling

- Minimum laxity first (MLF)
 - Laxity = time to latest feasible start time (when the job can still complete)
 - Run the job closest to failing first
 - Optimal in minimizing deadline failures
 - Earliest-Deadline First (EDF) also optimal
 - MLF = EDF when jobs have same length
 - “*deadline-driven scheduling*”

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MLF in Networking

- MLF in bandwidth scheduling
 - Send first the messages w/ minimum laxity
- Some drawbacks when priority-based
 - Overhead in priority arbitration
 - MLF requires dynamic re-prioritization
 - Priority inversion due to insufficient number of priority levels

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Summary of Survey

- Message (job) classification
 - Synchronous messages (periodic jobs)
 - Asynchronous messages (aperiodic jobs)
- Scheduling strategies
 - Access arbitration: who gets to use the resource (network bandwidth or CPU)
 - Transmission control: how long one gets to use the resource (bandwidth)

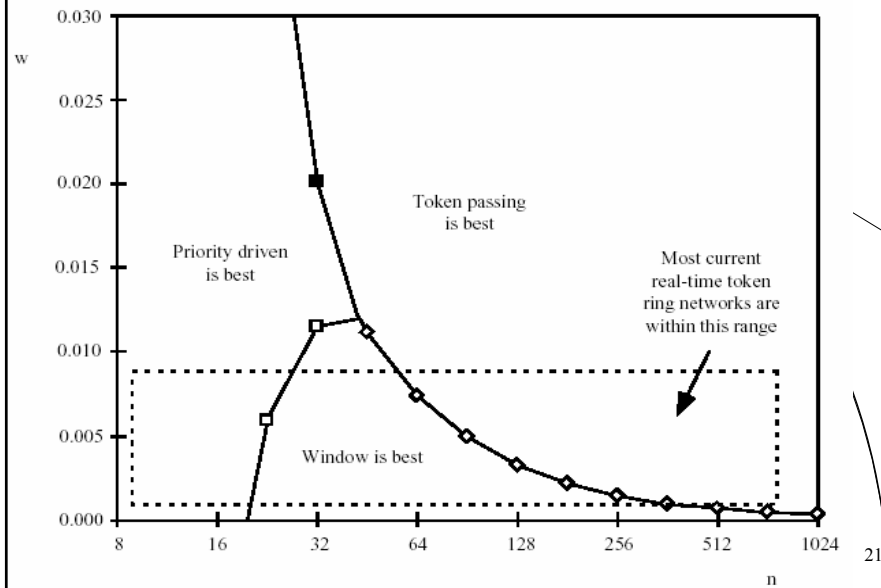
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Scheduling Algorithms

- Rate monotonic for periodic jobs
 - Shorter period gets higher priority
 - Tight worst case achievable utilization
- Minimum laxity first for aperiodic jobs
 - Closer to failure gets higher priority
 - Optimal in minimization of failures
 - Related to EDF

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Analytical Graph



Classification

- Scheduling algorithms fail at overload
- Prevent overload
 - Static schedules
 - Admission control
- Overload management
 - Congestion control
 - Adaptive (QoS-driven) resource management

Admission Control

- Asynchronous messages
 - Guaranteed dynamically
 - Conservative estimation: worst-case analysis of all messages in a node
 - Main problem: under-utilization
- How to sharpen the estimation and increase network utilization

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Assumptions

- Network model
 - Diffserv architecture (with classes)
- Resource management components
 - **Configuration**: class & route determination
 - **Run-time admission control**: enforce admission policies when under overload
 - **Packet forwarding**: class-based static priority policy, FIFO within class

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Utilization-Based

- Utilization-based admission control
 - Run-time decisions on flow establishment
 - Current utilization the only criterion
- Bandwidth availability along flow path
 - Safe levels of utilization
 - Determined during configuration

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Conservative Estimation

- Configuration-time delay computation
 - *Traffic constraint* bounds usage per link
 - *Server delay bound*
 - Iterate the delay calculation on all servers
- Safe route selection
 - Satisfy deadlines of each class and route
 - Heuristics: min distance, min delay

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Maximize Utilization

- Max utilization bounds depend on network diameter (theorem 4)
 - Given a utilization level, find safe routes
 - Converge on max utilization that has safe routes
- Their result (45%) is better than Shortest Path (33%)