Rate Monotonic Analysis

Introduction

Periodic tasks

Extending basic theory

Synchronization and priority inversion

Aperiodic servers

Case study: BSY-1 Trainer

Purpose of Tutorial

Introduce rate monotonic analysis

Explain how to perform the analysis

Give some examples of usage

Convince you it is useful

Tutorial Format

Lecture

Group exercises

Case study

Questions welcome anytime

RMARTS Project

Originally called Real-Time Scheduling in Ada Project (RTSIA).

- **focused on rate monotonic scheduling theory**
- **recognized strength of theory was in analysis**

Rate Monotonic Analysis for Real-Time Systems (RMARTS)

- **focused on analysis supported by (RMS) theory**
- **analysis of designs regardless of language or scheduling approach used**

Project focused initially on uniprocessor systems.

Work continues in distributed processing systems.

Real-Time Systems

Timing requirements

- meeting deadlines

Periodic and aperiodic tasks

Shared resources

Interrupts

What's Important in Real-Time

Criteria for real-time systems differ from that for time-sharing systems.

	Time-Sharing Systems	Real-Time Systems
Capacity	High throughput	Schedulability
Responsiveness	Fast average response	Ensured worst-case latency
Overload	Fairness	Stability

- ***schedulability*** **is the ability of tasks to meet all hard deadlines**
- ***latency*** **is the worst-case system response time to events**
- ***stability*** **in overload means the system meets critical deadlines even if all deadlines cannot be met**

Scheduling Policies

CPU scheduling policy: a rule to select task to run next

- **cyclic executive**
- **rate monotonic/deadline monotonic**
- **earliest deadline first**
- **least laxity first**

Assume preemptive, priority scheduling of tasks

- **analyze effects of non-preemption later**

Rate Monotonic Scheduling (RMS)

Priorities of periodic tasks are based on their rates: highest rate gets highest priority.

Theoretical basis

- **optimal fixed scheduling policy (when deadlines are at end of period)**
- **analytic formulas to check schedulability**

Must distinguish between scheduling and analysis

- **rate monotonic scheduling forms the basis for rate monotonic analysis**
- **however, we consider later how to analyze systems in which rate monotonic scheduling is not used**
- **any scheduling approach may be used, but all real-time systems should be analyzed for timing**

Rate Monotonic Analysis (RMA)

Rate monotonic analysis is a method for analyzing sets of real-time tasks.

Basic theory applies only to independent, periodic tasks, but has been extended to address

- **priority inversion**
- **task interactions**
- **aperiodic tasks**

Focus is on RMA, not RMS.

Why Are Deadlines Missed?

For a given task, consider

- ***preemption*: time waiting for higher priority tasks**
- ***execution*: time to do its own work**
- ***blocking*: time delayed by lower priority tasks**

The task is *schedulable* if the sum of its preemption, execution, and blocking is less than its deadline.

Focus: identify the biggest hits among the three and reduce, as needed, to achieve schedulability

Rate Monotonic Theory - Experience

IBM Systems Integration Division delivered a "schedulable" real-time network.

Theory used successfully to improve performance of IBM BSY-1 Trainer.

Incorporated into IEEE FutureBus+ standard

Adopted by NASA Space Station Program

European Space Agency requires as baseline theory.

Supported in part by Ada vendors

Rate Monotonic Analysis - Products

Journal articles (e.g., *IEEE Computer*, Hot Topics)

Videotape from SEI

Courses from Telos and Tri-Pacific

***A Practitioner's Handbook for Real-Time Analysis: Guide to Rate Monotonic Analysis for Real-Time Systems* from Kluwer**

CASE tools from Introspect and Tri-Pacific

Operating systems and runtimes from Alsys, DDC-I, Lynx, Sun, Verdix and Wind River

Standards: Futurebus+, POSIX, Ada 9X

Summary

Real-time goals are: fast response, guaranteed deadlines, and stability in overload.

Any scheduling approach may be used, but all real-time systems should be analyzed for timing.

Rate monotonic analysis

- **based on rate monotonic scheduling theory**
- **analytic formulas to determine schedulability**
- **framework for reasoning about system timing behavior**
- **separation of timing and functional concerns**

Provides an engineering basis for designing real-time systems

Plan for Tutorial

Present basic theory for periodic task sets

Extend basic theory to include

- **context switch overhead**
- **preperiod deadlines**
- **interrupts**

Consider task interactions:

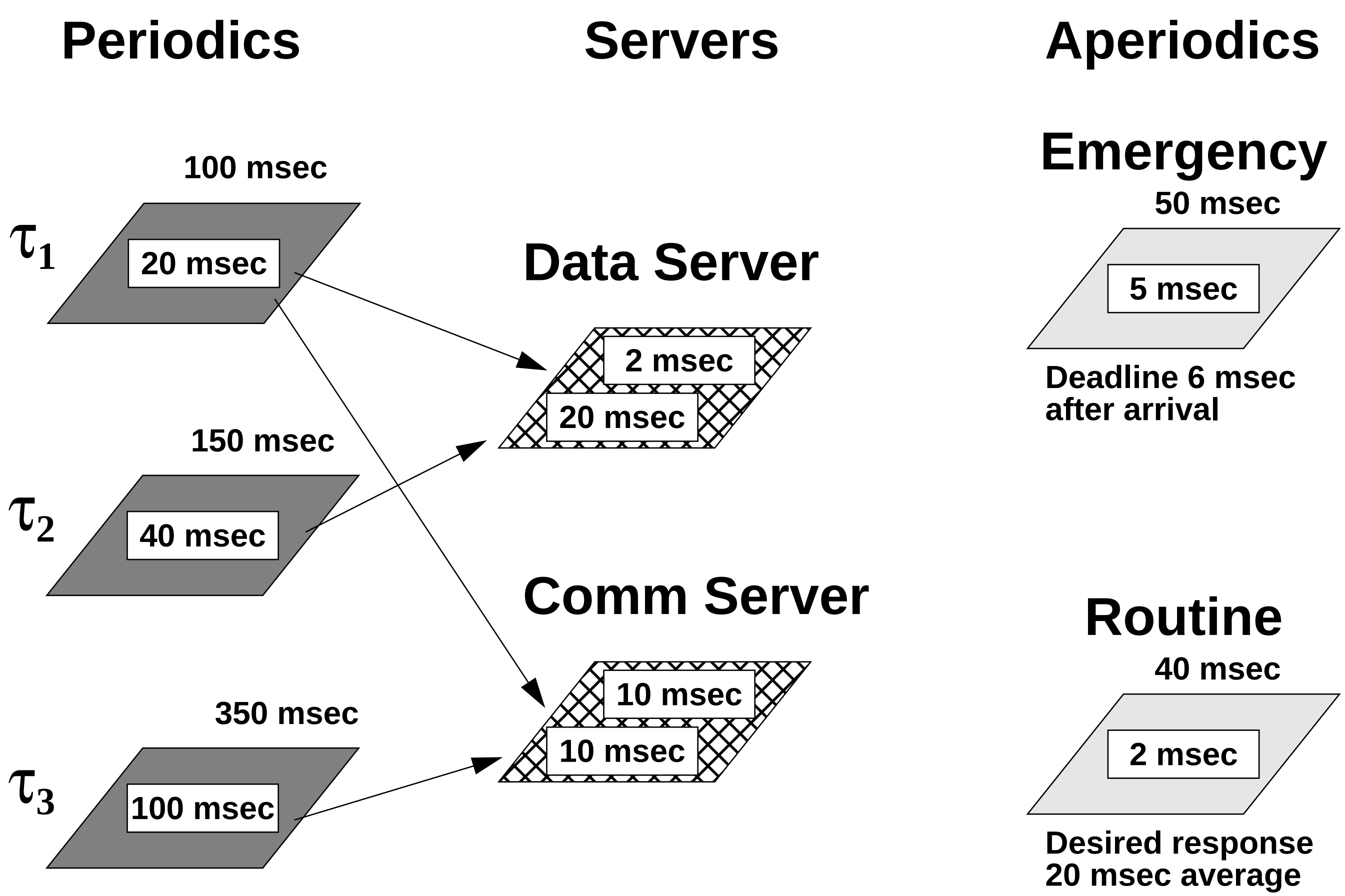
- **priority inversion**
- **synchronization protocols (time allowing)**

Extend theory to aperiodic tasks:

- **sporadic servers (time allowing)**

Present BSY-1 Trainer case study

A Sample Problem



τ_2's deadline is 20 msec before the end of each period