University of Melbourne

Interesting Learnning Group

ESD IOT

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1 Real Time Systems - 1

What makes a computer system a real-time computer system?

the correctness of the system behaviour depends not only on the logical results of the computations, but also on the physical time when these results are produced

Examples of real-time system:

Flight Control;Global Positioning System (GPS);Transport system; Navigation;Smart phone (real-time data);Power generation.

What are typical functions that a real-time computer system must perform?

Data collection

Direct digital control

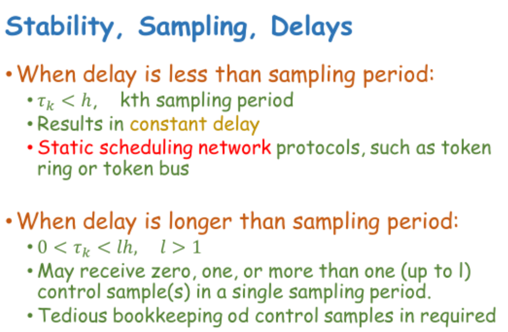
Man-machine interface.

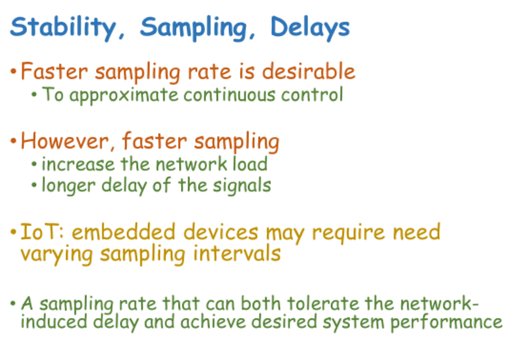
Give an example where the predictable rare-event performance determines the utility of a hard real- time system.

Nuclear power plant monitoring and shutdown system is a hard real-time system. The sole purpose of a nuclear power plant monitoring and shutdown system is reliable performance in a peak-load alarm situation. The utility of system failure will lead to catastrophic situations.

1.1 Definitions

Stability, Sampling, Delays





Hard deadline have severe consequences if missed (such as system failure).

Firm deadline a result has not utility beyond deadline (usefulness is zero) example:weather forecast,Real-time transport updates

Soft deadline a result has utility even after the deadline has passed (system degrades) examples:Video, Audio Streaming.

2 Real Time Systems and Time Measurement

What is a Causal system?
Output depends on input and past input; Not on future inputs

What is the difference between an instant, a duration and an event?
Instants are points in time on a directed timeline
Duration is a section of the timeline between two different instants
Event takes place at an instant of time and does not have a duration

2.1 Definitions

Objective Control the valve determining the flow of steam.

Jitter the difference between the maximum and the minimum values of the delay of the computer.(Used in quality of control)

Dead time the time interval between the observation of the RT entity and the start of a reaction of the controlled object due to a computer action based on this observation.

Reliability Reliability R(t) of a system is the probability that a system will provide the specified service until time t.

FITs (Failure In Time)

A failure rate of 1 FIT mean time to a failure (MTTF)of a device is 10^9 h, i.e, one failure occurs in about 115,000 years

Safety Safety is reliability regarding critical failure modes (or malign)

Maintainability Time interval required to repair a system after failure

Mean Time To Repair (MTTR)

Mean-Time-To-Failure (MTTF)

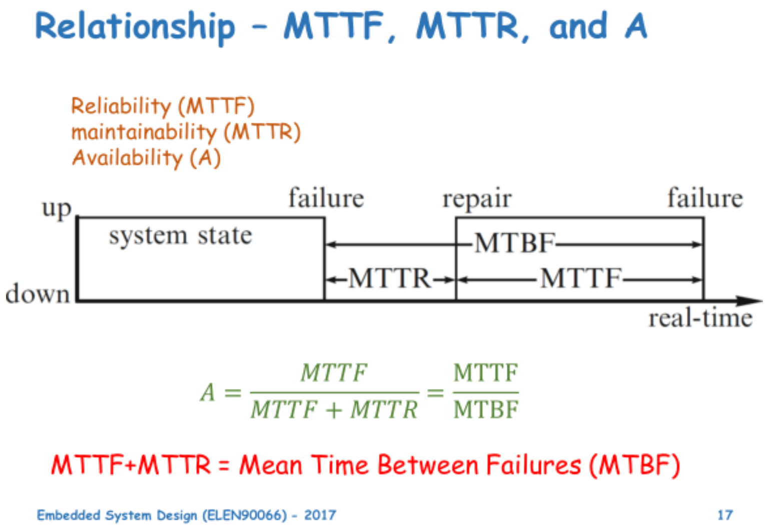


Figure 1: MTTF,MTTR and availability

3 Time Synchronization

What happens when nodes have different time in a distributed WSN?

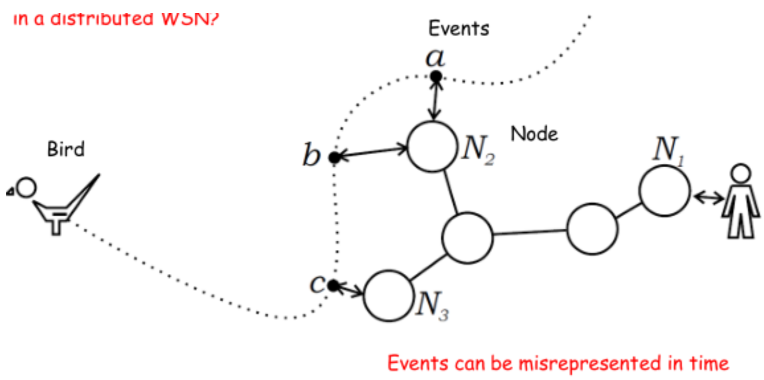


Figure 2: Wireless Sensor Network - Example

What causes different time? Ageing of hardware
- Temperature (environment)
- Phase noise (interrupts, OS calls)
- Frequency noise (variation in frequency)
- Asymmetric delay (communication path delay)
- Clock glitches (sudden jumps)

3.1 Definitions

Offset Difference between clock time and the real time Is given by $C_a(t) - t$ Offset relative to C_b is $C_a(t) - C_b(t)$.

Skew Difference in the frequencies of the clock and the perfect clock Skew of C_a relative to $C'_a(t) - C'_b(t)$. Difference of time between two clocks at any instant (relative measure)

Drift (rate) Second derivative Drift of C_a relative to $(C''_a(t) - C''_b(t))$ Rate at which clocks run (fast;slow;perfect)Clocks tick at different rate

Precision The maximum offset between any two clocks of the ensemble is precision $\prod$

Accuracy The accuracy denotes the maximum offset of a given clock from the external time reference.

Internal re-synchronization mutual re-synchronization of an ensemble of clocks to maintain a bounded precision

External re-synchronization periodically re-synchronized with an external time reference.

Gobal time Assume that all of the clocks are internally synchronized with a precision $\prod$, then for any two clocks j,k and all microticks i, then

$$|z(microtick_i^j) - z(microtick_k^j)| < \prod$$

4 Time Synchronization - 2

Given a distributed real-time embedded system with global time base of granularity g^{global}, what are the fundamental limits of time measurement?

Whenever two events in the physical subsystem occur close together, compared to the granularity of the global time, it is not possible to reconstruct the physical temporal order of the events in the computer system faithfully.
What is the relationship between convergence function $\emptyset$ drift Γ and $\prod$

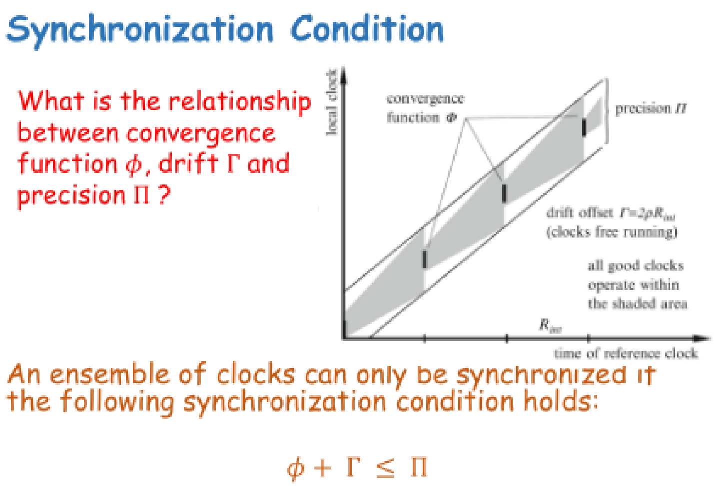


Figure 3: Lecturenote 19-15

Given a latency jitter of 20 ms, a clock drift rate of 10^{-5} seconds per second, and a re-synchronization period of 1 second, what precision can be achieved by the central master algorithm?

$\prod = \varepsilon + \Gamma = \varepsilon + 2\rho R_{int} = 20 \times 10^{-3} + 2 \times 10^{-5} \times 1 = 20.02ms$

(ε: lentency ; Γ: drift offset)

4.1 Definitions

Global Time Global time is an abstract notion, real clocks are not prefect Local clocks of nodes approximate global time

Time stamps The single event e is time-stamped by the two clocks j and k with a difference of one tick.

Master-Slave Sync Condition $\prod_{central} = \varepsilon + \Gamma$

5 Time Synchronization in Distributed Applications

What are two factors affecting synchronization?

Drift and skew

An organization has decided to setup embedded devices to synchronize with a time server. For the time stamps give in the figure below, calculate elapsed time, time to be set by the client and synchronization error using Cristians algorithm.

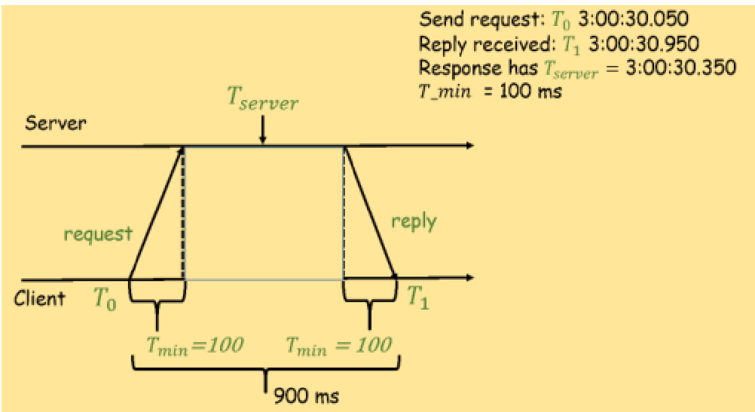


Figure 4: Lecturenote 20-14

Elapsed time: $T_1 - T_0 = 900ms$

Time to be set by the client: $T_{server} + \frac{T_1 - T_0}{2} = 3:00:30.800$

synchronization: $3:00:30.800 + ERROR = 3:00:30.800 + (\frac{T_1 - T_0}{2} - T_{min}) = 3:00:30.800 \pm 350ms$

5.1 Definitions

Limitations of Cristians Algorithm Problem of failure of single time sever;Imposter server providing false clock readings

Network Time Protocol (NTP) Enables devices on the Internet to be; Provide reliable service; Clients will be synchronized frequently and offsets the clock drifts.

6 Timing, Precedence Relations and Scheduling Constraints in Real-time Systems

Prove that for a given set of n independent tasks, any algorithm that executes the tasks in order of non-decreasing deadlines is optimal with respect to minimizing the maximum lateness.

This is the Jackson's rule

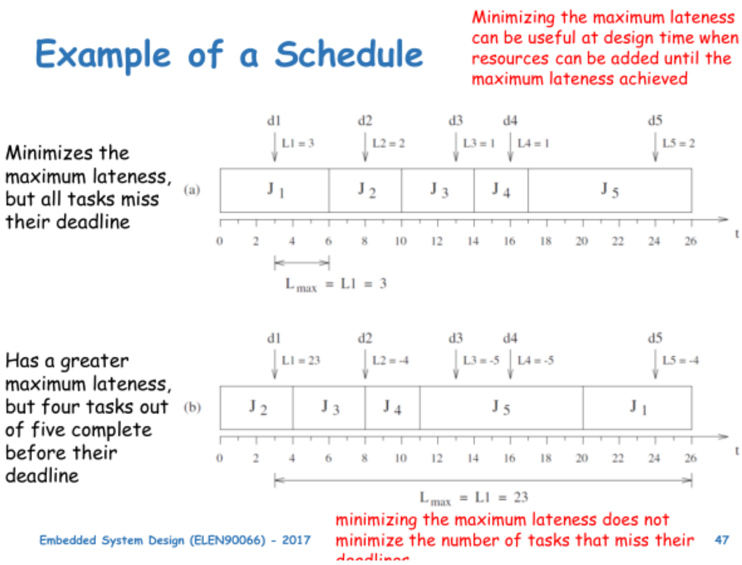


Figure 5: Lecturenote 21-47

minimizing the maximum lateness does not minimize the number of tasks that miss their deadlines

Give two aperiodic tasks J_1 and J_2 with weights $w_1 = 3$ and $w_2 = 1$ in the figure below, compute: (i) average response time, (ii) total completion time, (iii) weighted sum of completion times, (iv) maximum lateness, and (v) maximum number of late tasks.

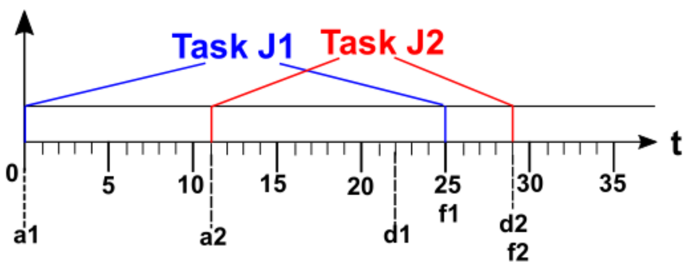


Figure 6: Lecturenote 21-51

Average response time: $\frac{(f1-a1)+(f2-a2)}{2} = 21.5$
Total completion time: $f_max - a_min = 29 - 0 = 29$
Weighted sum of completion times: $t_w = \frac{\sum_{i=1}^{n} f_i - a_i}{\sum w_i} = \frac{25\times3+18\times1}{1+3} = 23.25$
maximum lateness: $L_{max} = max(f_i - d_i) = 3$
maximum number of late tasks: $\sum_{i=1}^{n} missf_i = 1$

6.1 Definitions

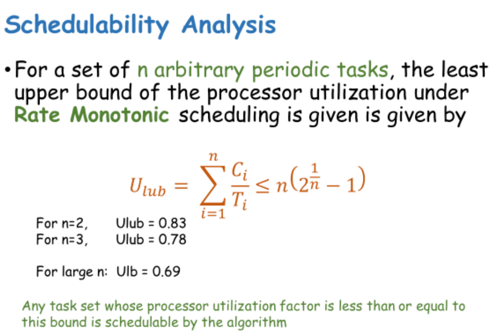
Schedule Concepts Ready queue: tasks waiting for the processor are kept in a queue
Queues: OS that handle different types of tasks may have more than one ready queue
Example: If tasks T1 and t2 are both ready, processor need to select between T1 and T2

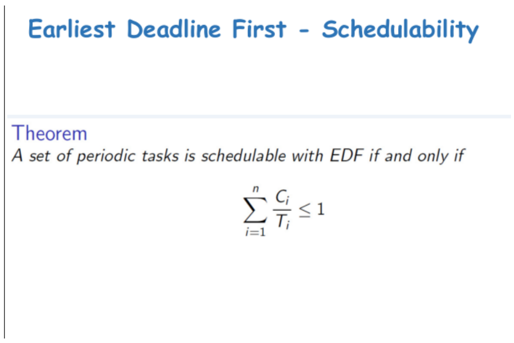
Periodic task infinite sequence of identical activities activated at a constant rate.

7 Periodic Scheduling

Verify the schedulability under RM(Rate Monotonic) and EDF of the following task set

	C_i	T_i
τ_1	1	4
τ_2	2	6
τ_3	3	8





$U = \frac{1}{4} + \frac{2}{6} + \frac{3}{8} = 0.96$
$U_{lub} \leqslant 3(2^{\frac{1}{3}} - 1) = 0.78$ the task set is NOT schedulable by RMS algorithm
$U = 0.96 < 1$ the task set is schedulable under EDF
U:Processor Utilization Factor; If this factor is greater than 1, the task set cannot be scheduled by any algorithm.

C:computation time; T: Period