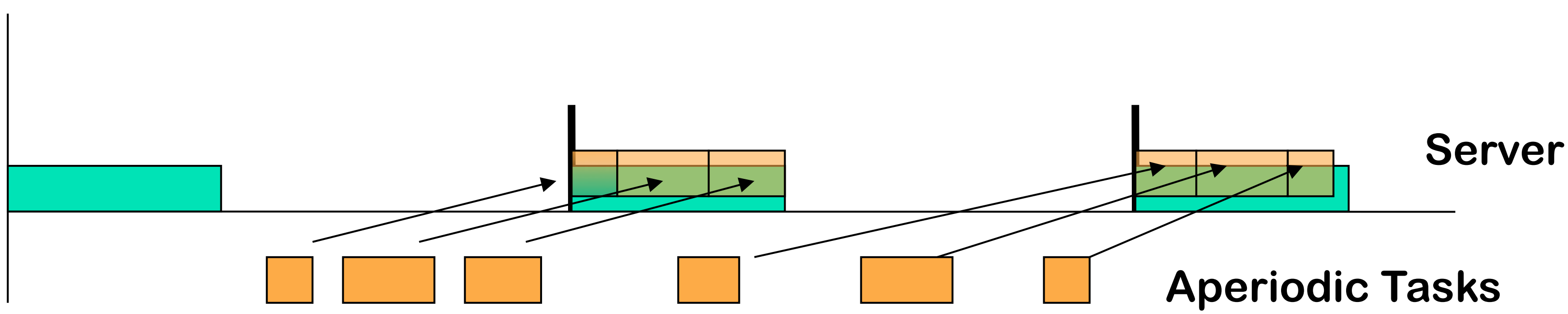
Servers for aperiodic tasks

Principles for server design
Explaining servers through example

Server-based systems

- Periodically invoke a service task ("server") to execute aperiodic tasks
- The server is modeled as a periodic task and can be included in schedulability analysis
- Allocate the server a computation budget C_s and a period P_s
- The server can serve aperiodic tasks until the budget expires; the budget can be replenished every period
- Many choices: Servers have different flavours depending on the details of when they are invoked, what priority they have, and when budgets are replenished



Principles of server design

- It is simple enough to represent the servers as periodic tasks
- So, why so many rules?
  - We want to reduce the response times for aperiodic tasks
  - Avoid the problems with the polling server: retain unused budget
  - If we want to retain the budget
    - When does it expire?
      - If a server has budget 2 and deadline 5, it cannot have a budget of 2 when t=4; there is only one unit of computation remaining but a budget of 2
      - We can not make the operating system do too much work. It only schedules by priority or deadline and does not verify if the deadline has expired or not.

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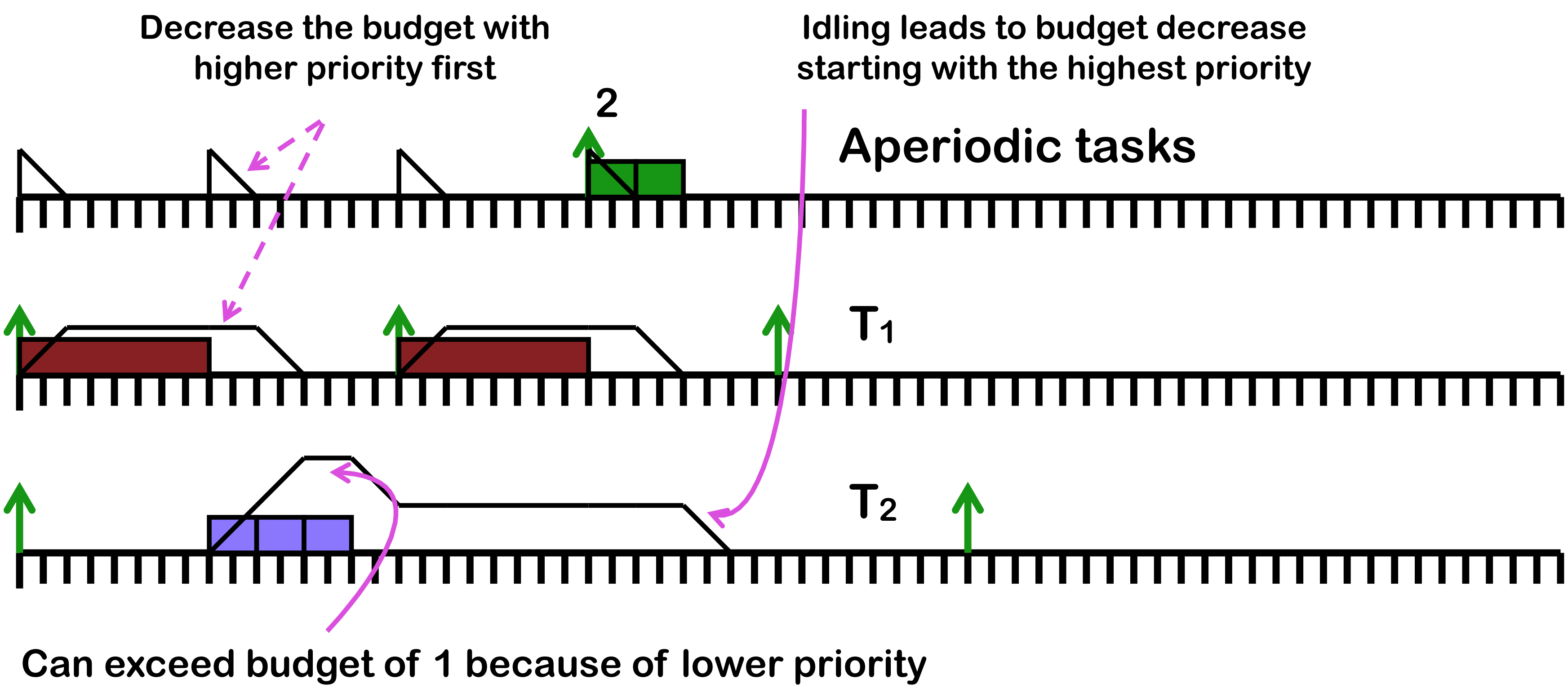
  - We want to reduce the response times for aperiodic tasks
  - Avoid the problems with the polling server: retain unused budget
  - If we want to retain the budget
    - When does it expire?
    - When does it increase?
      - If we consume a portion of the budget, when do we restore it?
    - We cannot allow the server to use more than the allotted fraction of the processor: if the server has a utilization of 0.4, it can not use more than 2 units of time every 5 units (or 4 in every 10, 8 in every 20, ...)
    - How can we implement these easily? [The polling server is easy to implement.]

Priority Exchange Server

- Like the deferrable server, this server retains its budget until the end of the server period
- Unlike the deferrable server, this server's priority slips over time: when not used, the priority is exchanged for that of the executing periodic task
- Note that if a server has utilization 0.25, it can
  - Use 1 time unit every 4 units
  - Use 2 units every 8 units
  - …
  - *As priority slips, the budget may increase*

Priority Exchange Server: Example

T_1: (P_1=8,C_1=4)
T_2: (P_2=20,C_2=3)
Priority exchange server: (P_s=4,C_s=1)



Sporadic Server

- Server is said to be active if it is in the running or ready queue, otherwise it is idle.
- When an aperiodic task arrives and the budget is not zero, the server becomes active
- Every time the server becomes active, say at t_A, it sets replenishment time one period into the future, $t_A + P_s$ (but does not decide on replenishment amount).
- When the server becomes idle, say at t_I , set replenishment amount to capacity consumed in $[t_A, t_I]$

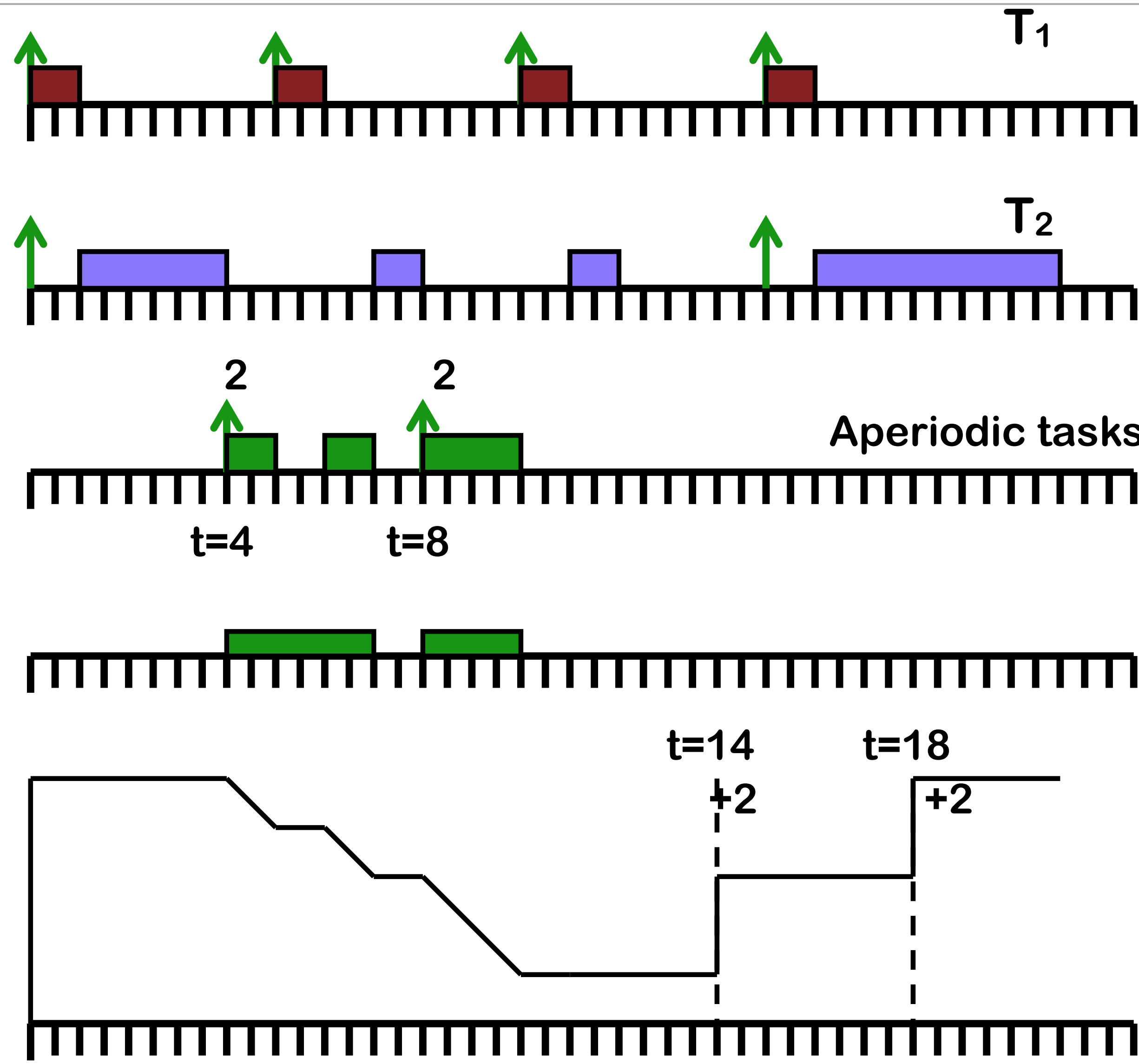
Sporadic Server: Example

Two periodic tasks
T_1: (P_1=5, C_1=1)
T_2: (P_2=15, C_2=5)

Sporadic Server
P_s=10, C_s=5

Sporadic server activity

Sporadic server budget



Dynamic priority aperiodic task servers

Dynamic priority exchange server

- Server has period P_s and budget C_s
- At the beginning of each period, a server capacity $C_S^d = C_s$ is allotted with deadline d.
- A capacity $C_{Si}^{di} = 0$ is initially allotted at the priority of each of the periodic tasks
- If the highest-priority task is an aperiodic capacity, C:
  - If aperiodic requests are pending, execute them and decrement the capacity.
  - If no aperiodic requests are pending, execute the top priority periodic task, say i. Subtract the execution interval E_i from C and add E_i to C_{Si}^{di}.
  - If no periodic tasks exist either, subtract the execution interval E_i from C.
- Schedulable if $U_p + U_s < 1$

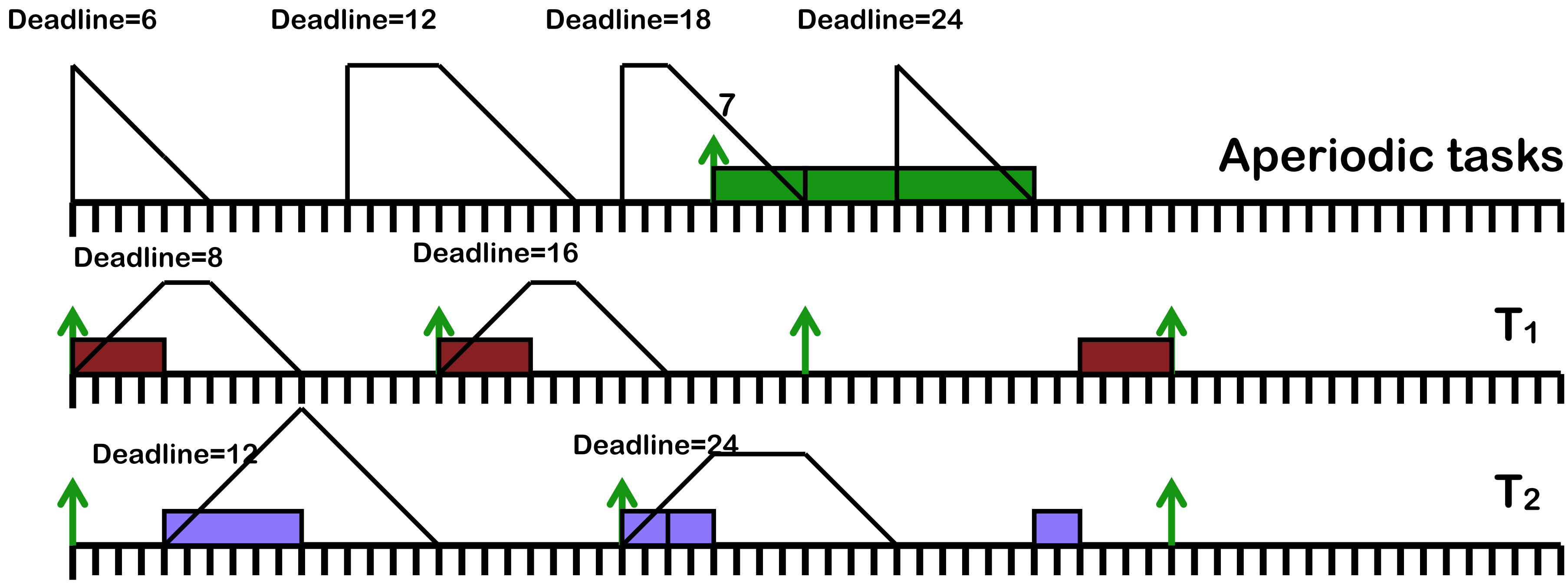
Example of DPE server

Two periodic tasks

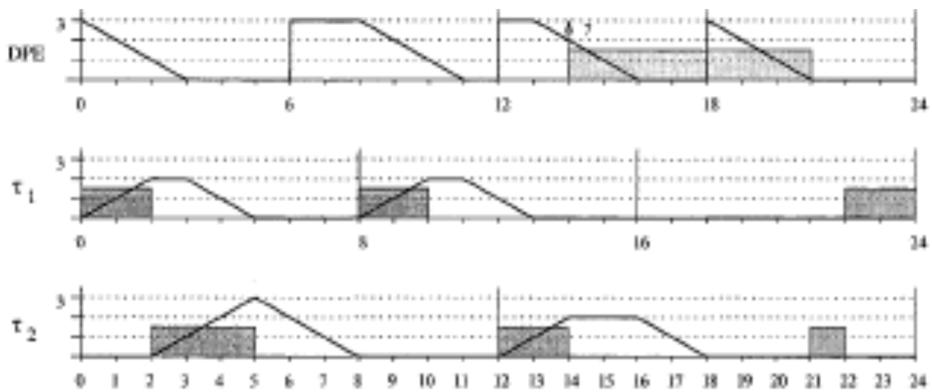
T_1: (P_1=08, C_1=2)

T_2: (P_2=12, C_2=3)

DPE server: *P_S=6; C_S=3*



Example of DPE server



Two periodic tasks

T_1: (P_1=08, C_1=2)

T_2: (P_2=12, C_2=3)

DPE server

P_S=6

C_S=3

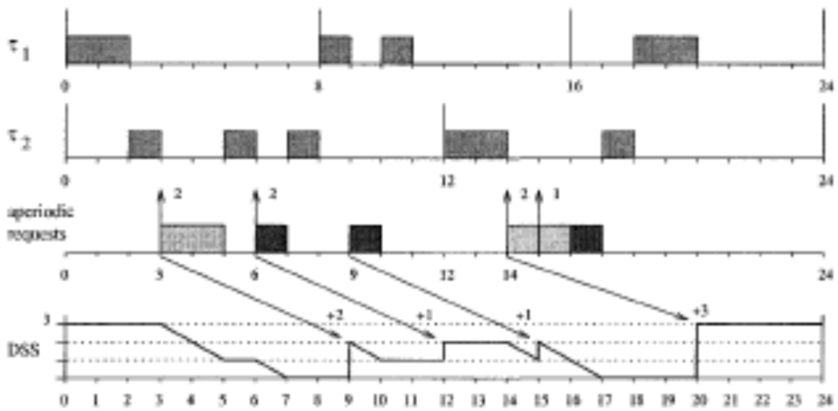
If the highest-priority task is an aperiodic capacity, *C*:

- **If aperiodic requests are pending, execute them and charge the capacity.**
- **If no aperiodic requests are pending, execute the top priority periodic task, say *i*. Subtract the execution interval E_i from *C* and add E_i to C_{Si}^{di}.**
- **If no periodic tasks exist either, subtract the execution interval E_i from *C*.**

Dynamic sporadic server

- When the server is created its capacity C_s is initialized.
- When there is an aperiodic task and $C_s > 0$, server becomes “active”
  - Set a replenishment time one period into the future (deadline)
- When the server becomes inactive set the replenishment amount as the capacity consumed

Example for dynamic sporadic server



Two periodic tasks

T_1: (P_1=08, C_1=2)

T_2: (P_2=12, C_2=3)

Dynamic sporadic server

P_S=6

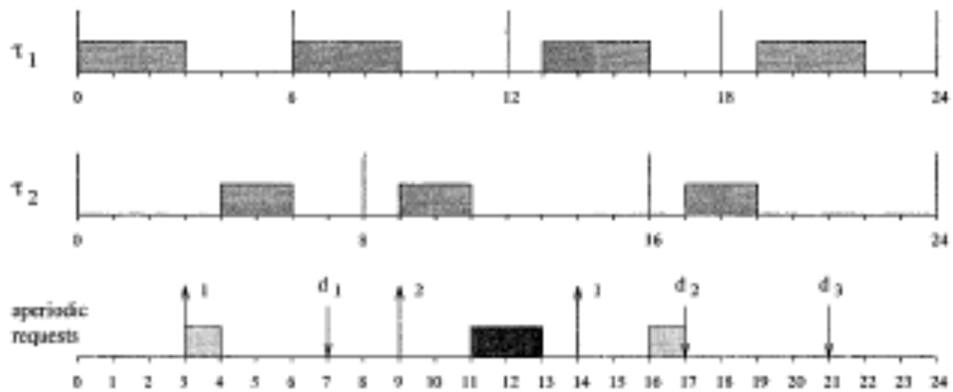
C_S=3

- When the server is created its capacity C_s is initialized.
- When there is an aperiodic task and $C_s > 0$, server becomes "active"
  - Set a replenishment time one period into the future (deadline)
- When the server becomes inactive set the replenishment amount as the capacity consumed

Total bandwidth server

- When the k^{th} aperiodic request arrives at time $t=r_k$, give it a deadline:
  - $D_k = \max(r_k, d_{k-1}) + C_k/U_s$
  - where U_s is the utilization alloted to the aperiodic task server
- There is no need to specify a budget and a period for the server
- Note that $U_P+U_S <= 1$ ensures schedulability
  - U_P is the utilization of the periodic tasks

Example for TBS

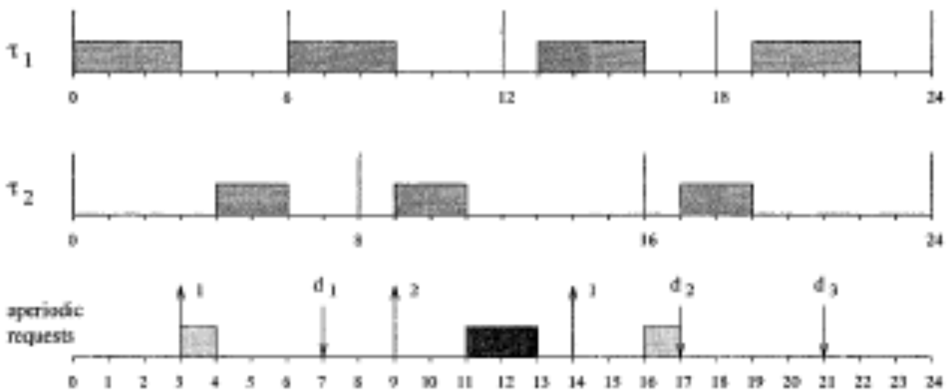


Two periodic tasks
T_1: (P_1=6, C_1=3)
T_2: (P_2=8, C_2=2)

Total bandwidth server
U_s = 0.25

- When the k^{th} aperiodic request arrives at time $t=r_k$, give it a deadline:
- $d_k = \max(r_k, d_{k-1}) + C_k/U_s$
- where U_s is the utilization alloted to the aperiodic task server

Example for TBS

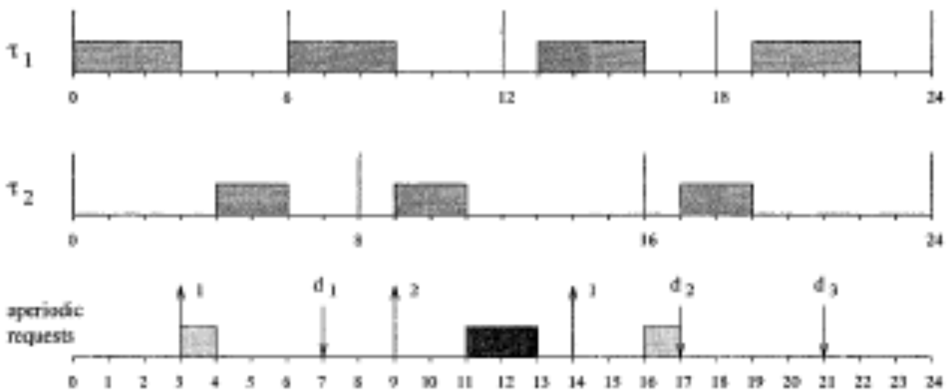


Two periodic tasks
T_1: (P_1=6, C_1=3)
T_2: (P_2=8, C_2=2)

Total bandwidth server
$U_s = 0.25$

- $d_0 = 0$
- The first aperiodic job arrives at t=3 and requires 1 unit of computation
- $d_1 = \max(r_1, d_0) + 1/0.25 = max(3,0)+4=7$

Example for TBS



Two periodic tasks

T_1: (P_1=6, C_1=3)

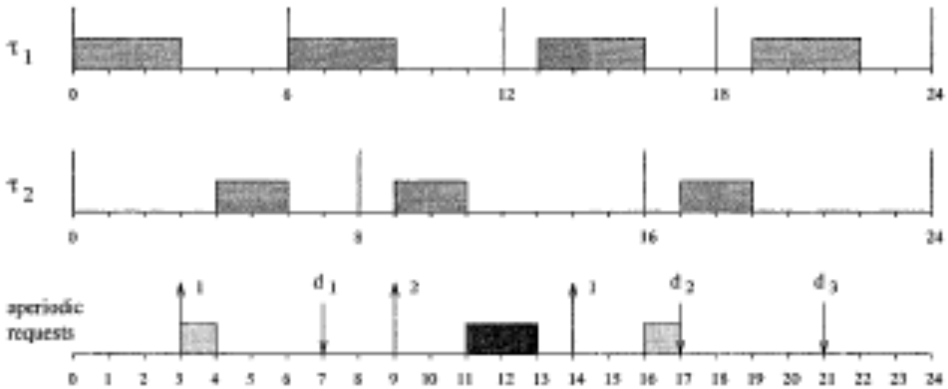
T_2: (P_2=8, C_2=2)

Total bandwidth server

$U_s = 0.25$

- $d_1 = 7$
- The second aperiodic job arrives at t=9 and requires 2 units of computation
- $d_2 = \max(r_2, d_1) + 2/0.25 = \max(9,7)+8=17$

Example for TBS



Two periodic tasks
T_1: (P_1=6, C_1=3)
T_2: (P_2=8, C_2=2)

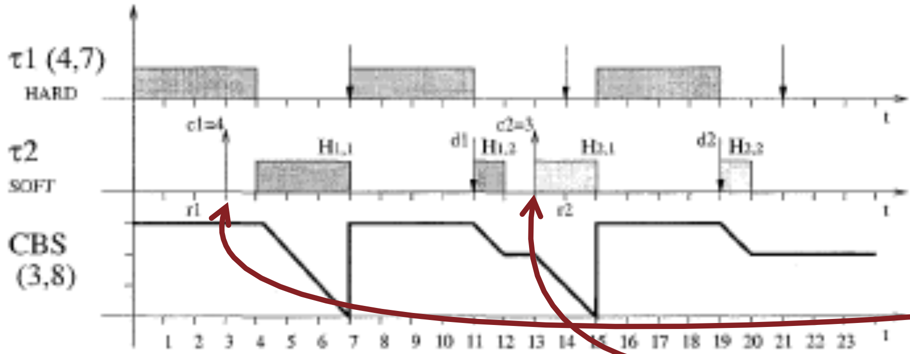
Total bandwidth server
$U_s = 0.25$

- $d_2 = 17$
- The third aperiodic job arrives at t=14 and requires 1 unit of computation
- $d_3 = \max(r_3, d_2) + 1/0.25 = \max(14,17)+4=21$

The constant bandwidth server

- Server has a maximum budget Q_s and a period P_s
- The server is said to be active if jobs are pending, otherwise it is idle
- When an aperiodic job arrives it inherits the server deadline, d_s
- When an aperiodic job executes the server budget is decreased by the same amount
- When the budget is zero it is recharged to Q_s and deadline d_s is increased by P_s
- When a job arrives at time t and the server is idle:
  - If remaining budget (C_s) > $(d_s - t)\, U_s$, the deadline is advanced to $t + P_s$
- The main advantage of the CBS is that it can deal with overruns -- when jobs exceed their estimated computation times

Example for CBS



One hard periodic task
T_1: $(P_1=7,\ C_1=4)$

One soft task served by a CBS
$P_S=8,\ Q_S=3$

Maximum budget

$J_{2,1}$ has computation time *4* and arrives at $t=3$
$J_{2,2}$ has computation time *3* and arrives at $t=13$

Current budget

The first instance of Task 2 ($J_{2,1}$) arrives at $t=3$. At $t=3$, $d_s=8$ and $C_s=3$. $C_s = 3 > (d_s\text{-}t)U_s = 15/8$. Therefore the server budget is recharged to *3* and the deadline is set to $3+8=11$.

At $t=7$, the budget is exhausted so the new deadline is set to $11+8=19$ and the budget replenished. At $t=12$, $J_{2,1}$ is complete.

At $t=13$, $J_{2,2}$ is released. $C_s = 2 < (d_s\text{-}t)U_s = 9/4$. $J_{2,2}$ starts executing with deadline *19*.

At $t=15$, the budget is exhausted. The new deadline of $19+8=27$ is assigned to the server and the budget is reset to 3. $J_{2,2}$ completes at $t=20$.

Summarizing aperiodic servers

- Quite a few aperiodic server mechanisms
  - Dynamic priority exchange server
  - Dynamic sporadic server
  - Total bandwidth server
  - Constant bandwidth server
- The difference between these schemes concerns performance and complexity (implementation, memory etc.)
- CBS is used most often: reasonable performance and easy implementation

Lecture summary

- Aperiodic task servers
  - Static priorities
    - Priority Exchange Server
    - Sporadic Server
  - Dynamic priorities
    - Dynamic Priority Exchange Server
    - Dynamic Sporadic Server
    - Total Bandwidth Server
    - Constant Bandwidth Server