Embedded Systems

4a. Example Network Processor

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Software and Programming
Processing and Communication
Hardware
Software-Based NP

Network Processor:
Programmable Processor Optimized to Perform Packet Processing

How to Schedule the CPU cycles meaningfully?
- Differentiating the level of service given to different flows
- Each flow being processed by a different processing function
Our Model – Simple NP

- Real-Time Flows (RT)
- Best Effort Flows (BE)

- Real-time flows have deadlines which must be met
- Best effort flows may have several QoS classes and should be served to achieve maximum throughput
Task Model

- Packet processing functions may be represented by directed acyclic graphs.
- End-to-end deadlines for RT packets.
Architecture

Real-time Flows

Packet Processing functions

Input ports

Classifier

$F_1$

$F_2$

$F_3$

$F_n$

Output ports

CPU Scheduler

Packet Scheduler

Best effort flows

Real-time Flows

Real-time Flows

Real-time Flows
CPU Scheduling

- First Schedule RT, then BE (background scheduling)
  - Overly pessimistic

- Use **EDF Total Bandwidth Server**
  - EDF for Real-Time tasks
  - Use the remaining bandwidth to server Best Effort Traffic
  - WFQ (weighted fair queuing) to determine which best effort flow to serve; not discussed here …
CPU Scheduling

Packet Processing functions

Real-time Flows

Classifier

F1

F2

F3

Fn

Has Deadlines

Use EDF

Assign Deadline using remaining CPU bandwidth

WFQ

Best effort flows

One Packet out

Real-time Flows

Best effort flows
CPU Scheduling

As discussed, the basis is the TBS:

\[ d_k = \max\{r_k, d_{k-1}\} + c_k / U_s \]

- computation demand of best effort packet
- deadline of best effort packet
- arrival of best effort packet
- utilization by real-time flows

**But**: utilization depends on time (packet streams)!

- Just taking upper bound is too pessimistic
- Solution with time dependent utilization is (much) more complex – BUT IT HELPS …
CPU Scheduling

Before

plain best effort + EDF scheme

deadline RT flows

end-to-end packet delay [sec]
CPU Scheduling

After deadline RT flows

c) approximation with two segments