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
Packet processing functions may be represented by directed acyclic graphs.

End-to-end deadlines for RT packets.
Architecture

Input ports

Classifier

F1

F2

F3

Fn

Real-time Flows

Packet Processing functions

Output ports

Packet Scheduler

Best effort flows

CPU Scheduler

Real-time Flows

Best effort 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

Real-time Flows

Packet Processing functions

Classifier

F_1

F_2

F_3

... F_n

Has Deadlines

Use EDF

Assign Deadline using remaining CPU bandwidth

WFQ

Best effort flows

One Packet out

CPU Scheduling

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As discussed, the **basis is the TBS:**

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

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

**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

c) approximation with two segments

deadline RT flows

simulation time [sec]

RT video flow

nRT ftp flow

RT video flow