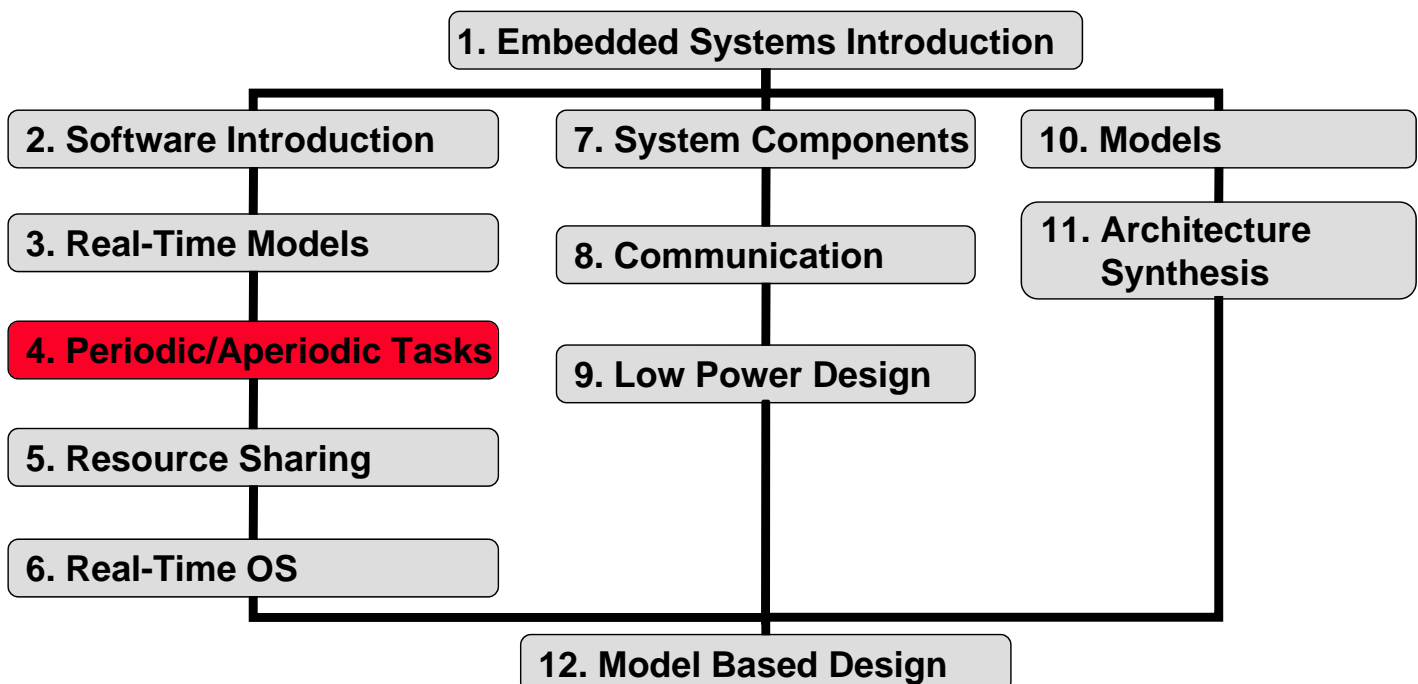


Embedded Systems

4a. Example Network Processor

Lothar Thiele

Contents of Course



*Software and
Programming*

*Processing and
Communication*

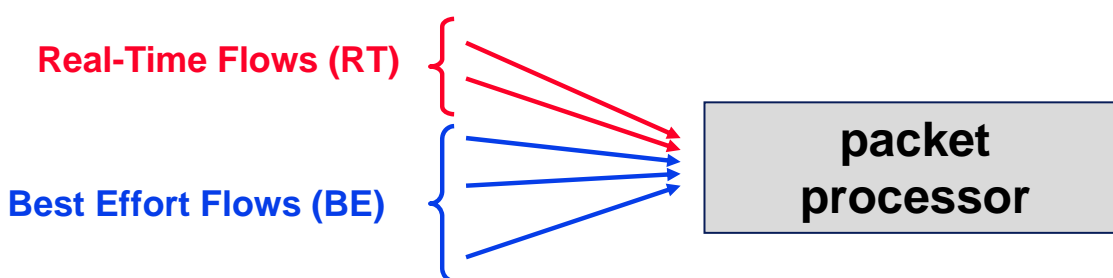
Hardware

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

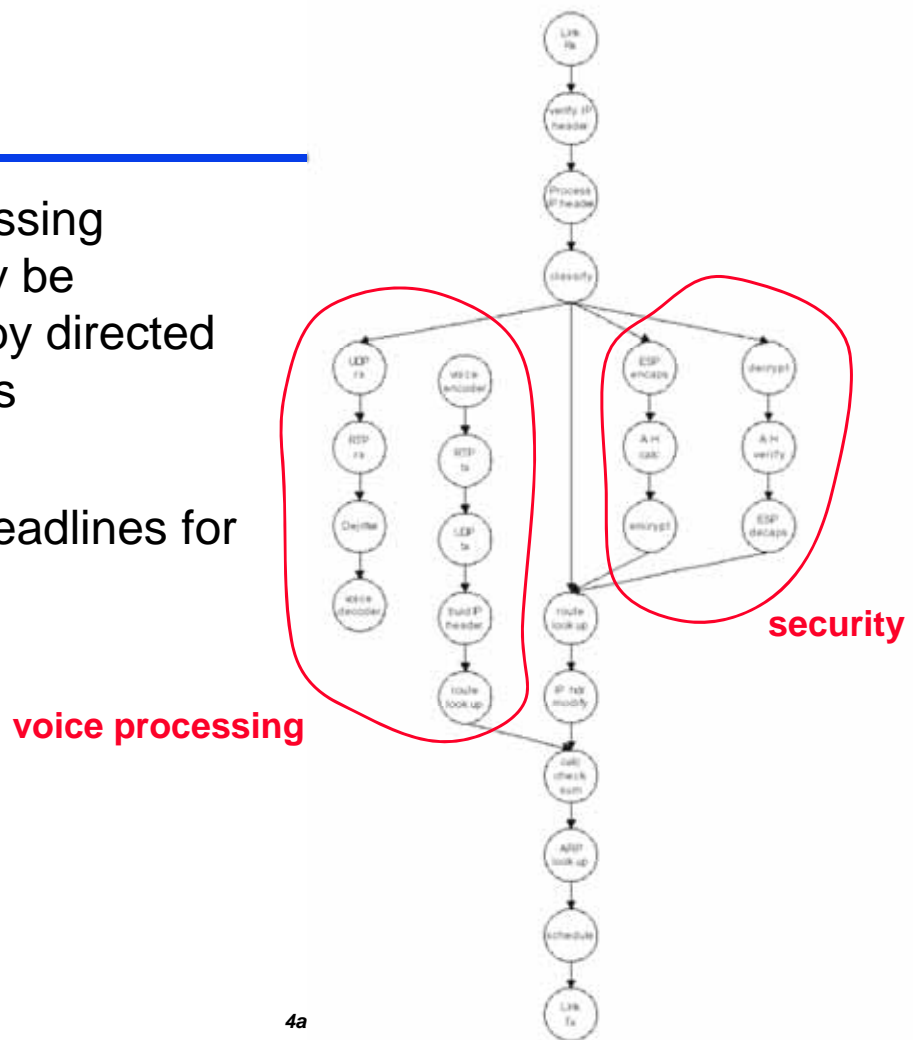
Our Model – Simple NP



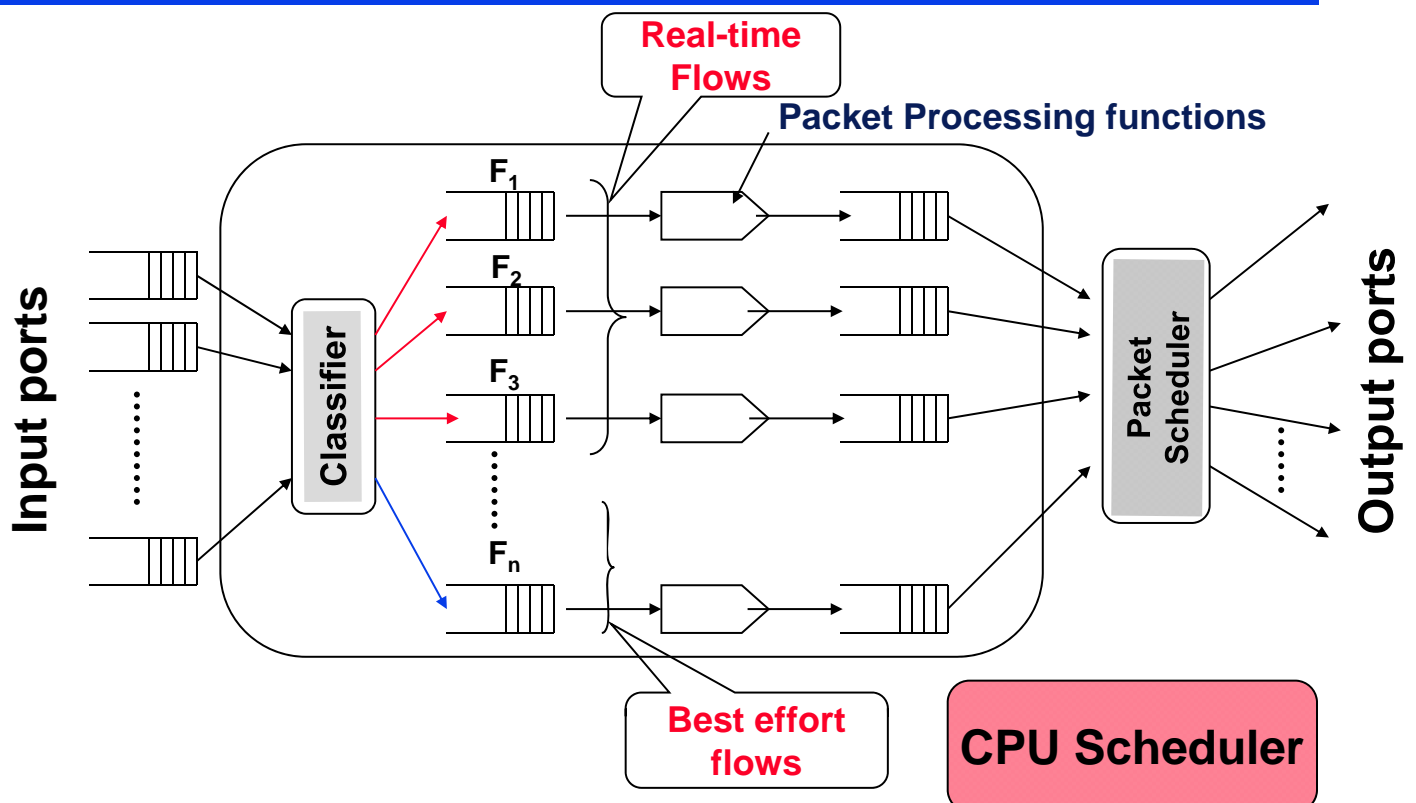
- ▶ Real-time flows have deadlines which must be met
- ▶ Best effort flows may have several QoS classes and should be served to achieve maximum throughput

Task Model

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



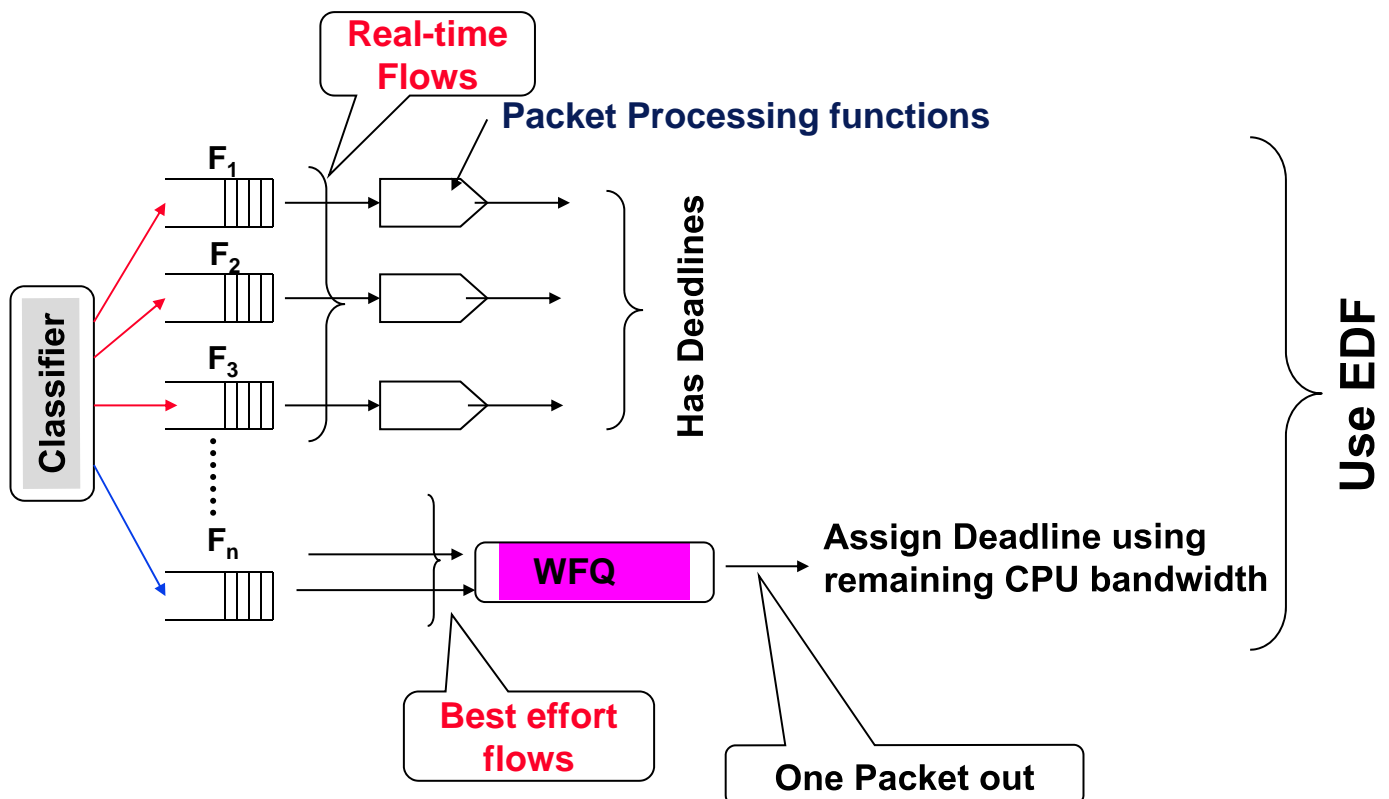
Architecture



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



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

arrival of best effort packet

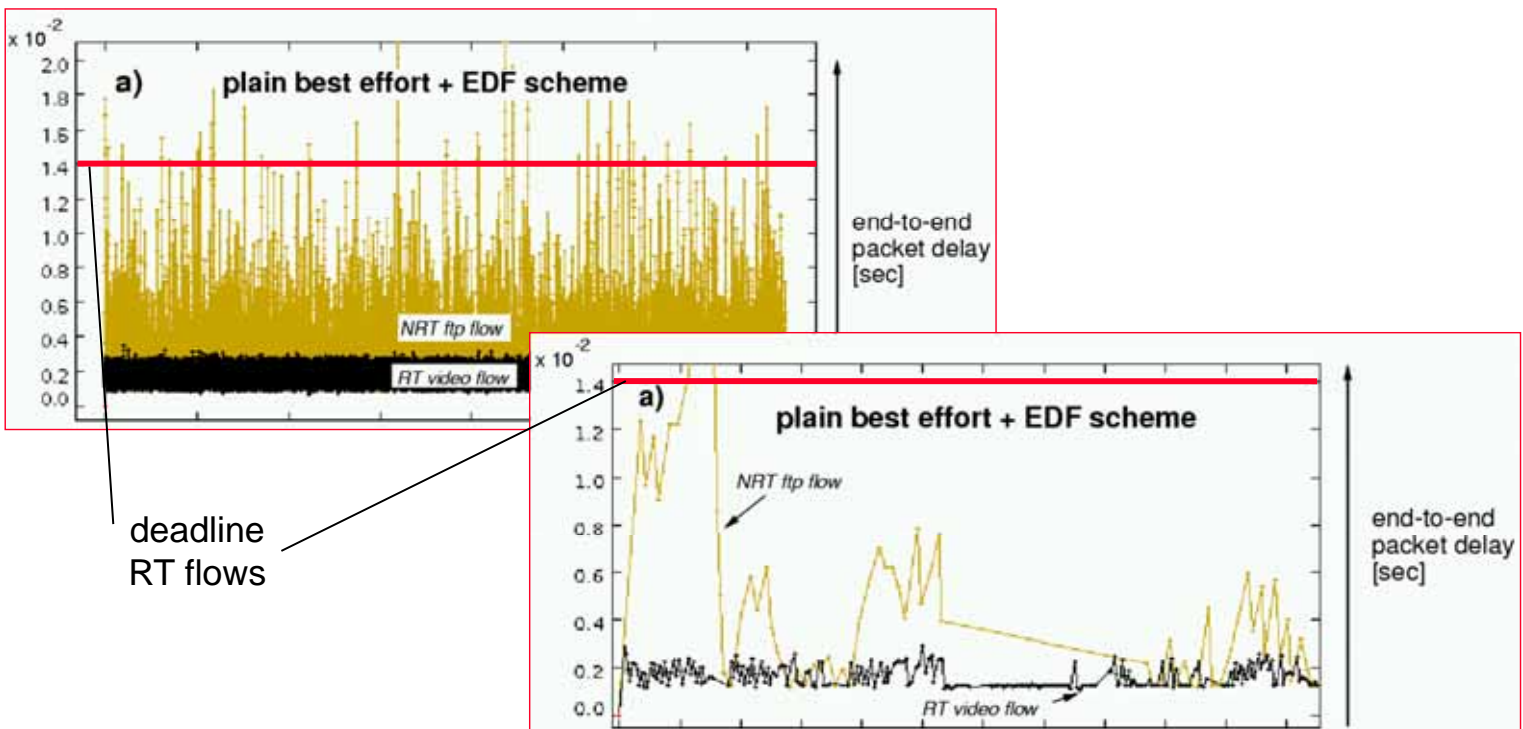
utilization by real-time flows

deadline 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



CPU Scheduling

► After

