# Embedded Systems

6a. Example Network Processor

Lothar Thiele

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

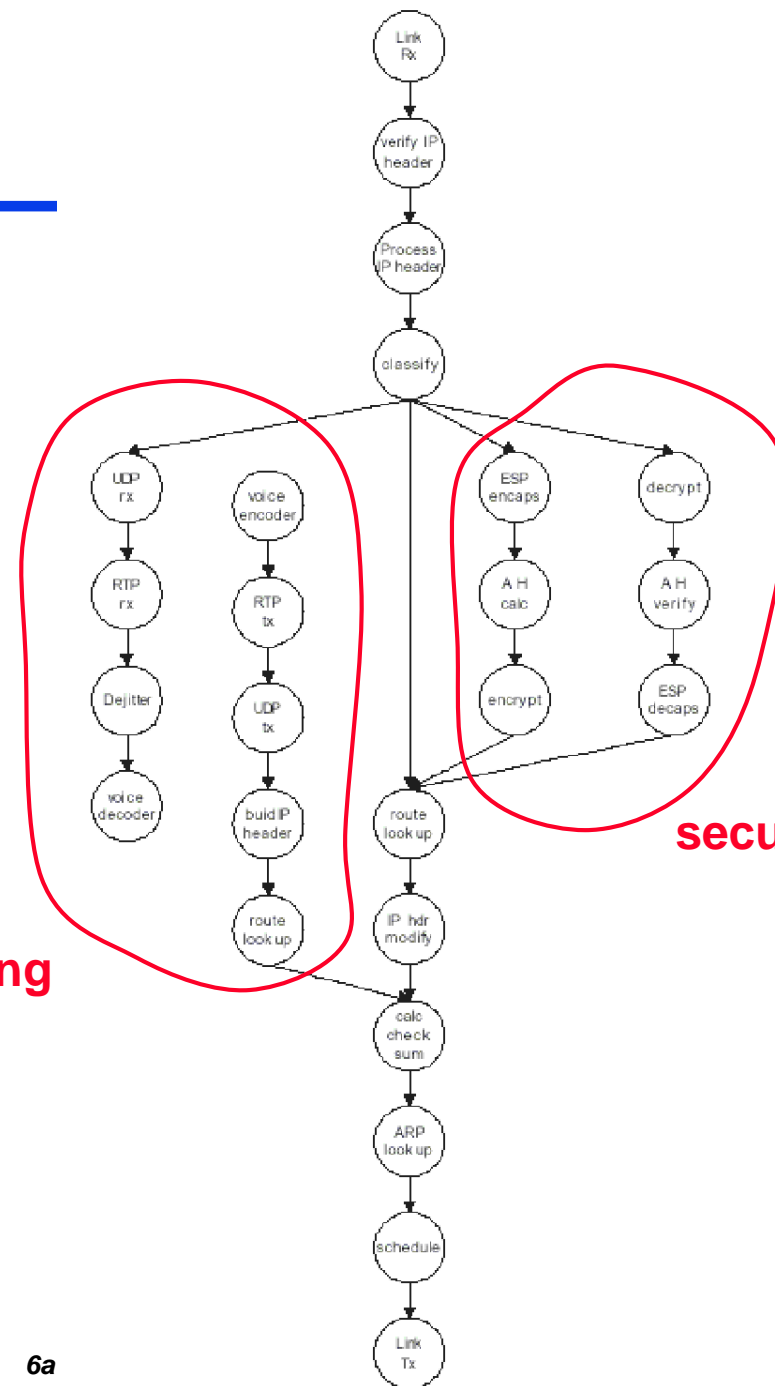**Real-Time Flows (RT)**

Best Effort Flows (BE)
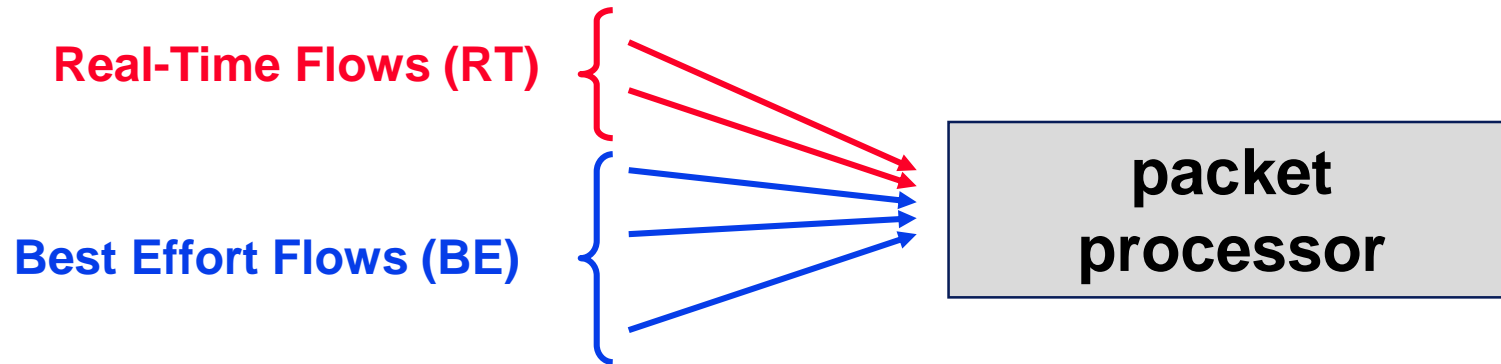
packet
processor

▶ 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
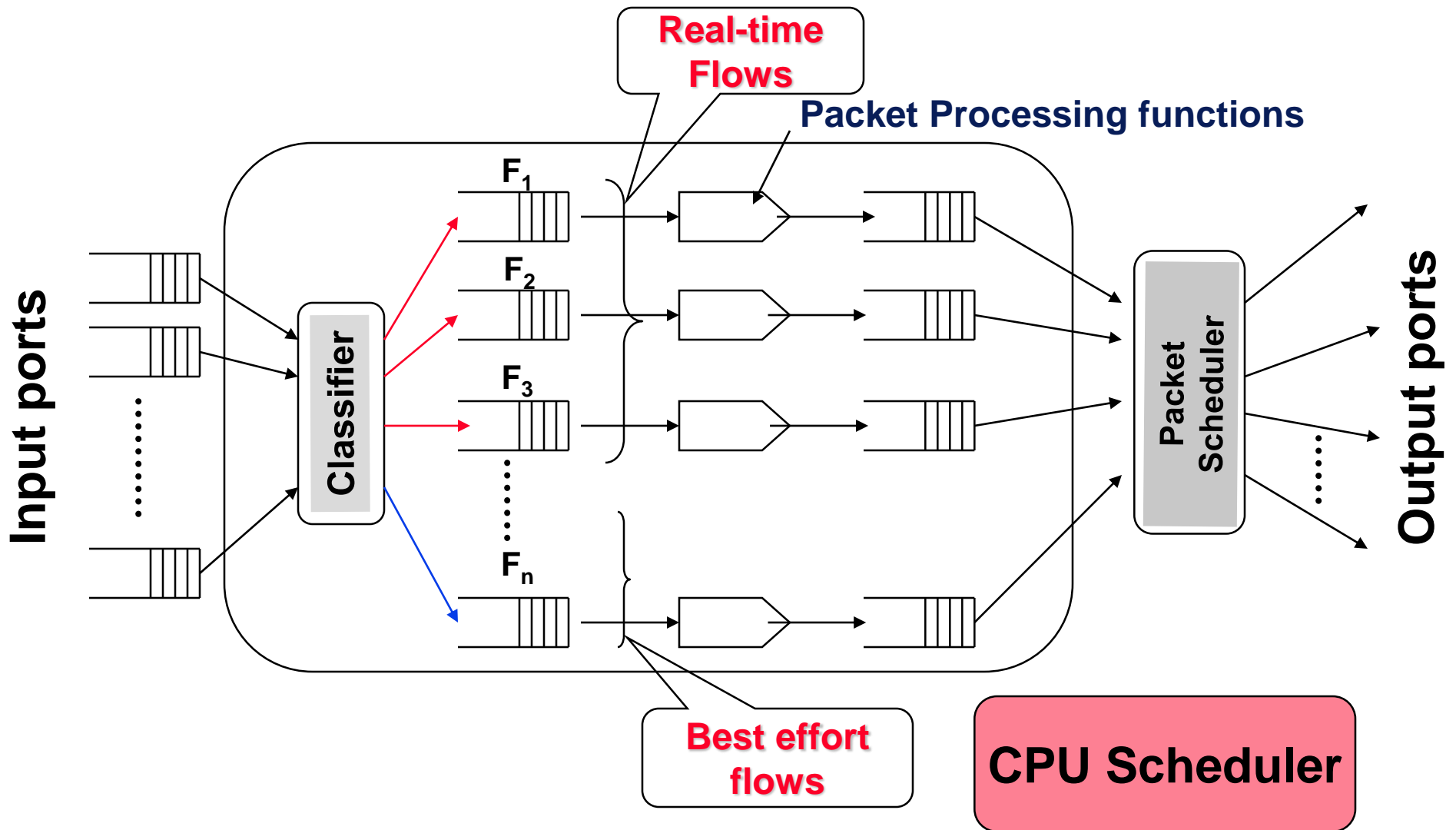
Task Model

▶ Packet processing functions may be represented by directed acyclic graphs

▶ End-to-end deadlines for RT packets
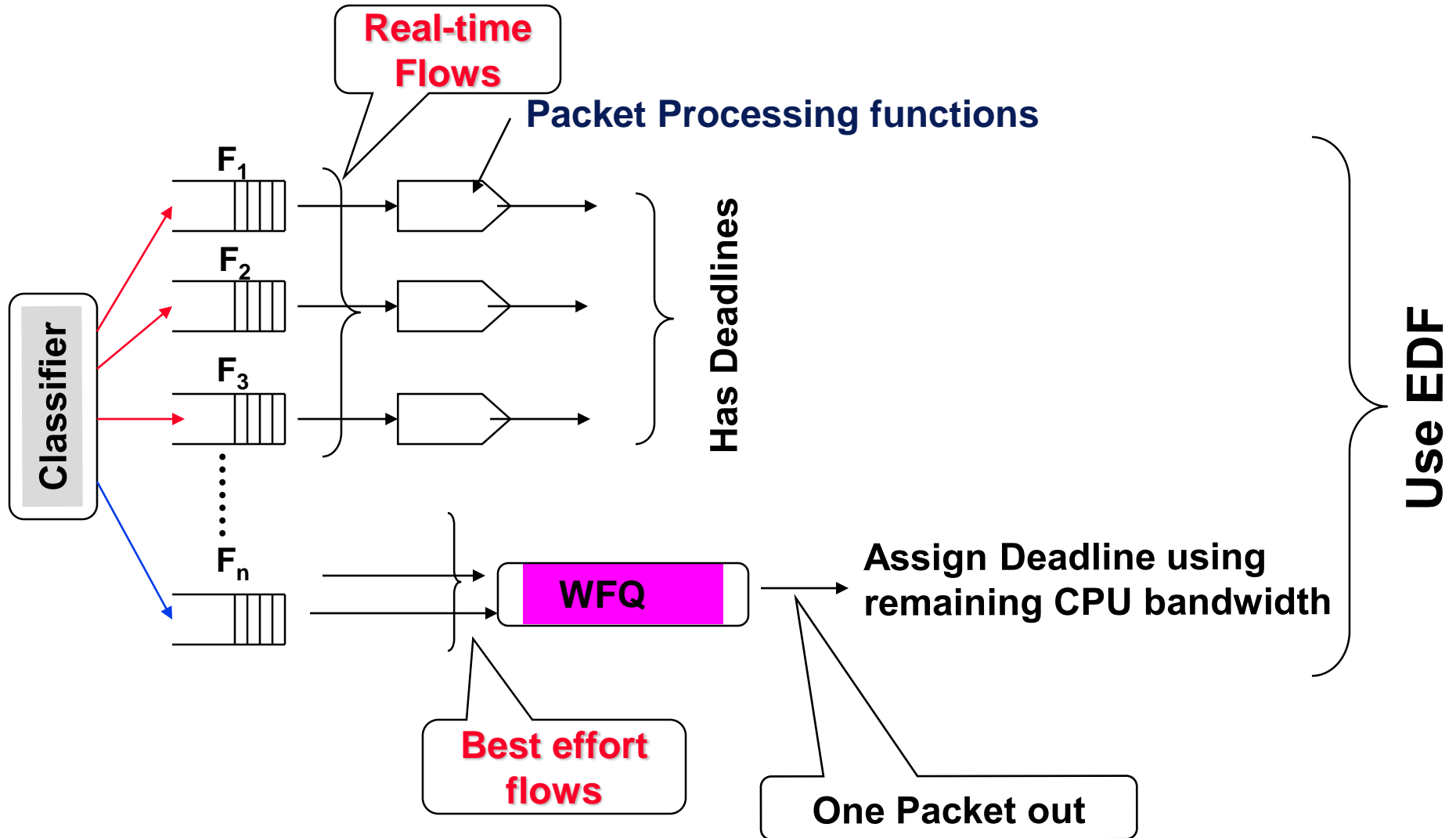
voice processing

security

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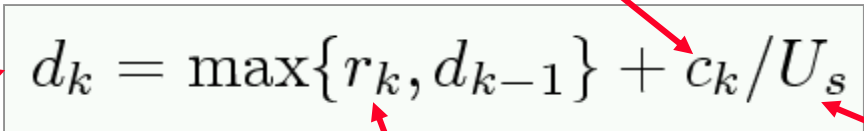
- As discussed, the *basis is the TBS*:

computation demand of best effort packet

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

deadline of best effort packet
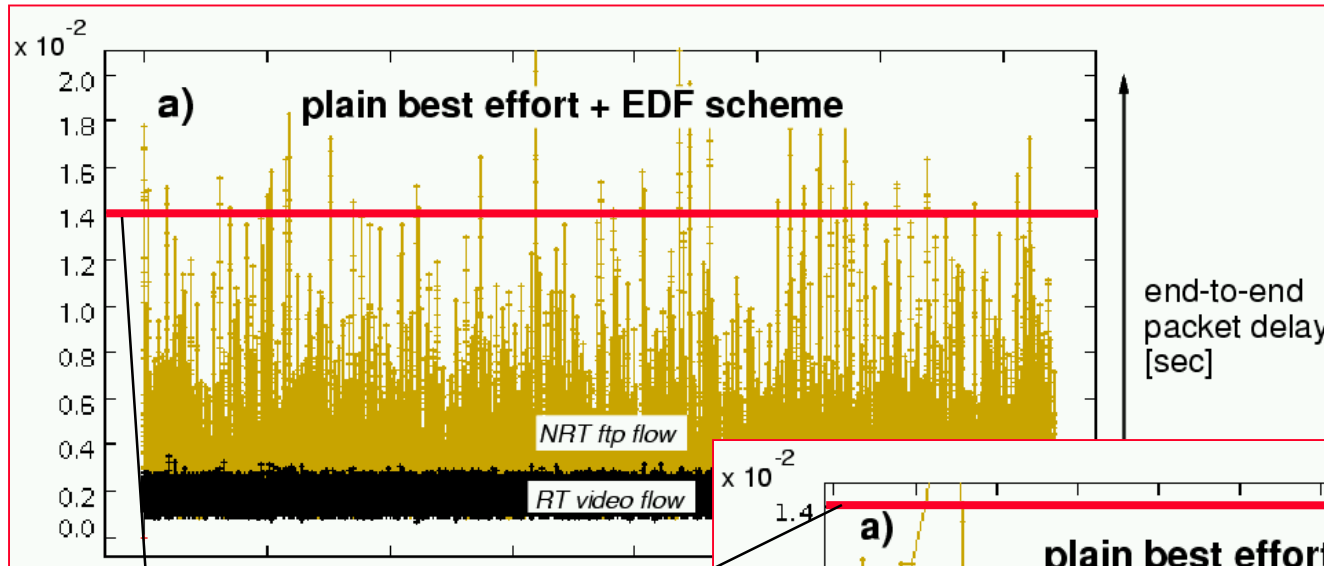
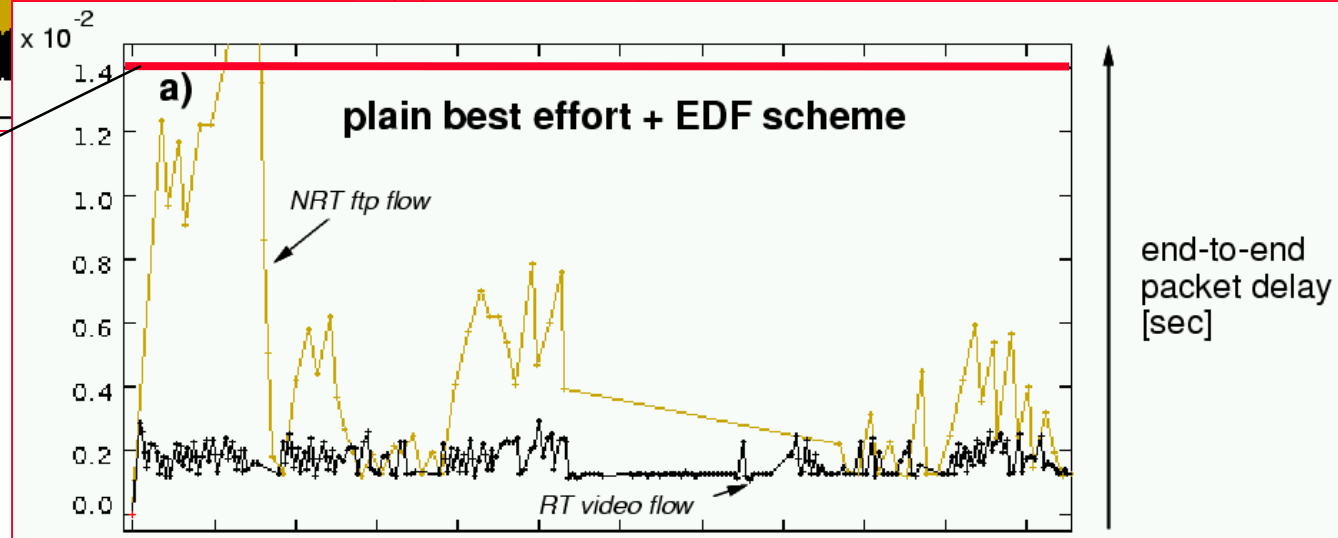**arrival of best effort packet**

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

deadline
RT flows

CPU Scheduling

▶ After

deadline
RT flows