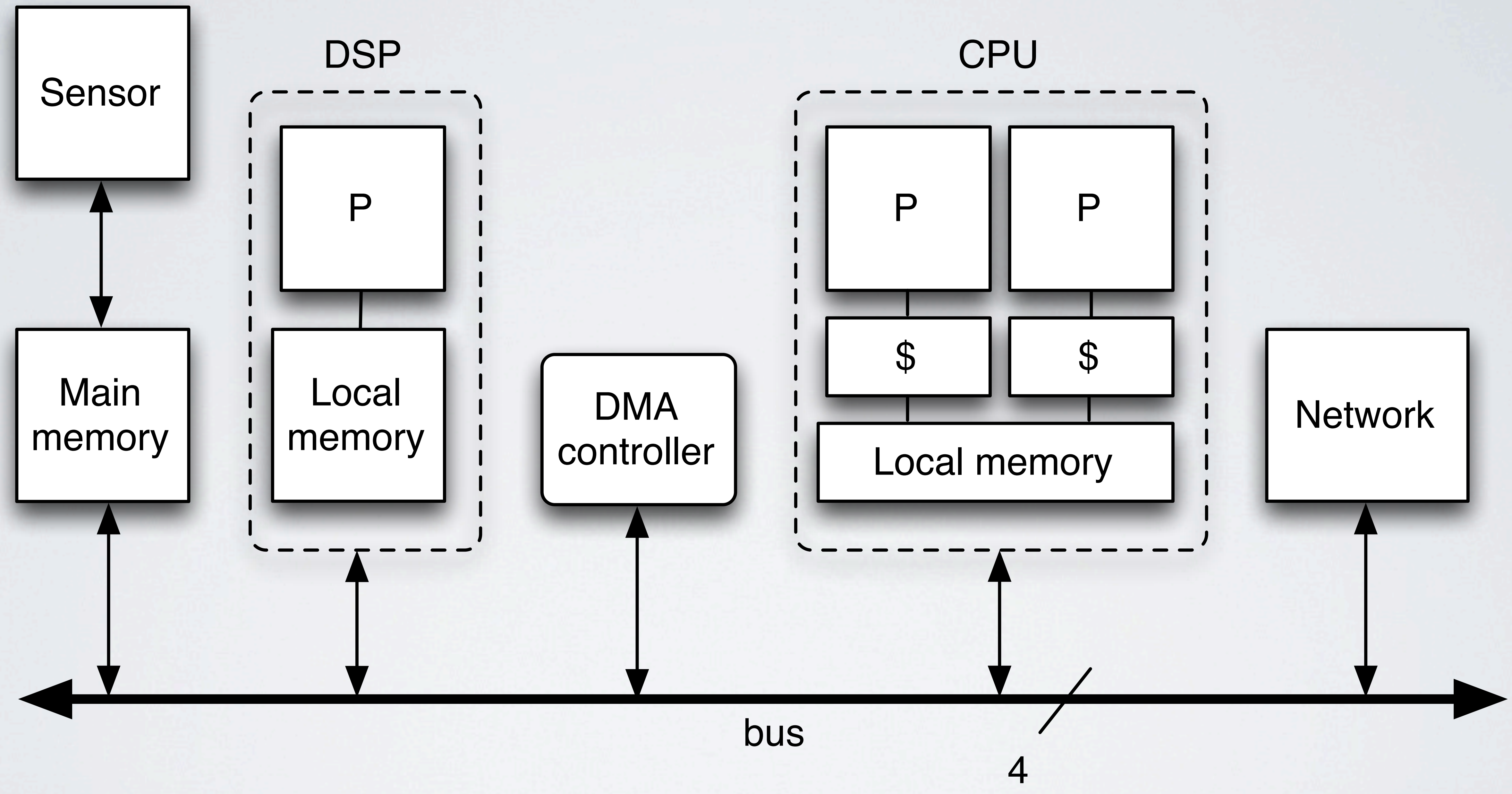
Parallel-Task Scheduling on Multiple Resources

Mike Holenderski, Reinder J. Bril, Johan Lukkien

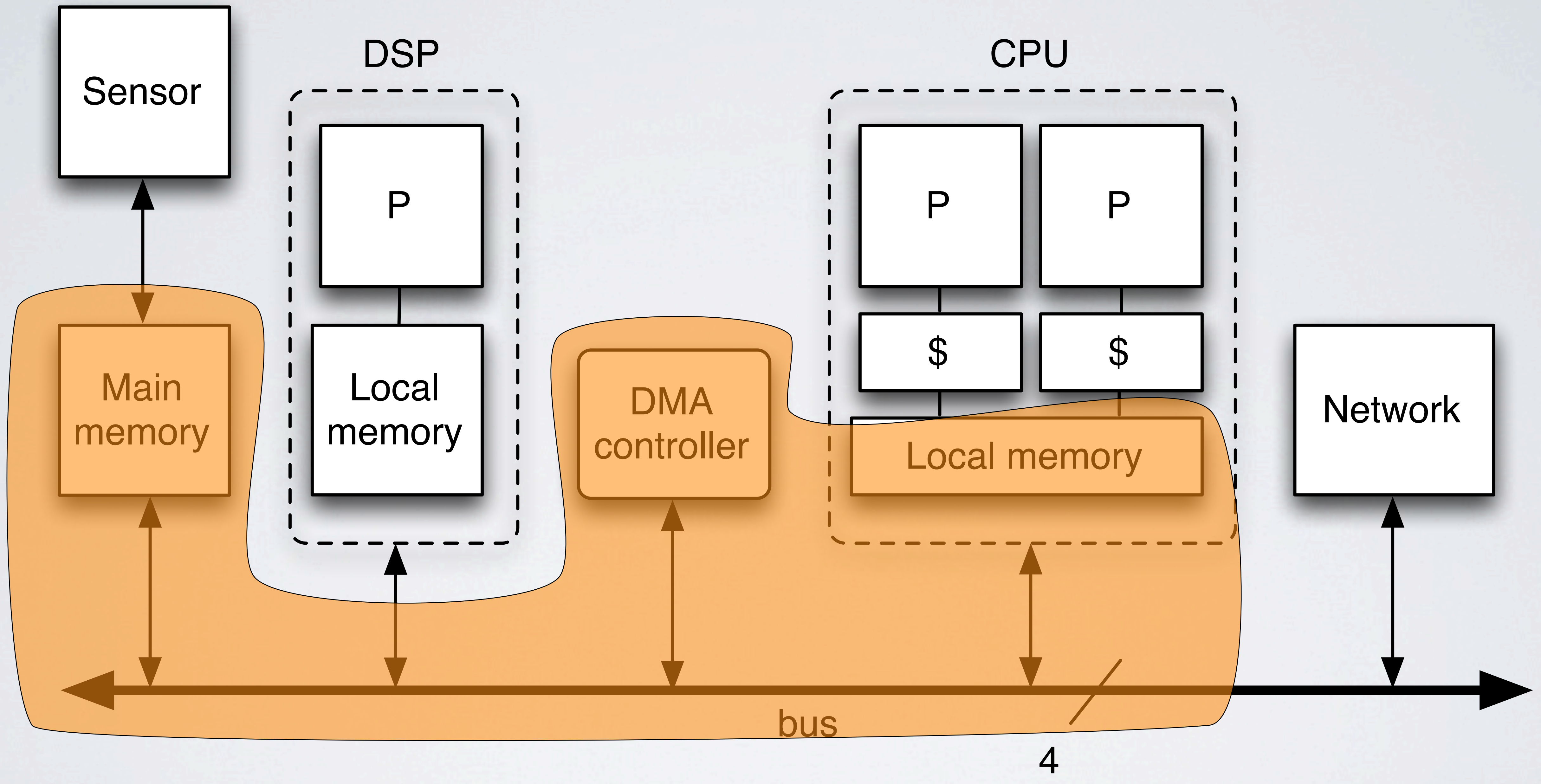
Eindhoven University of Technology

Surveillance camera

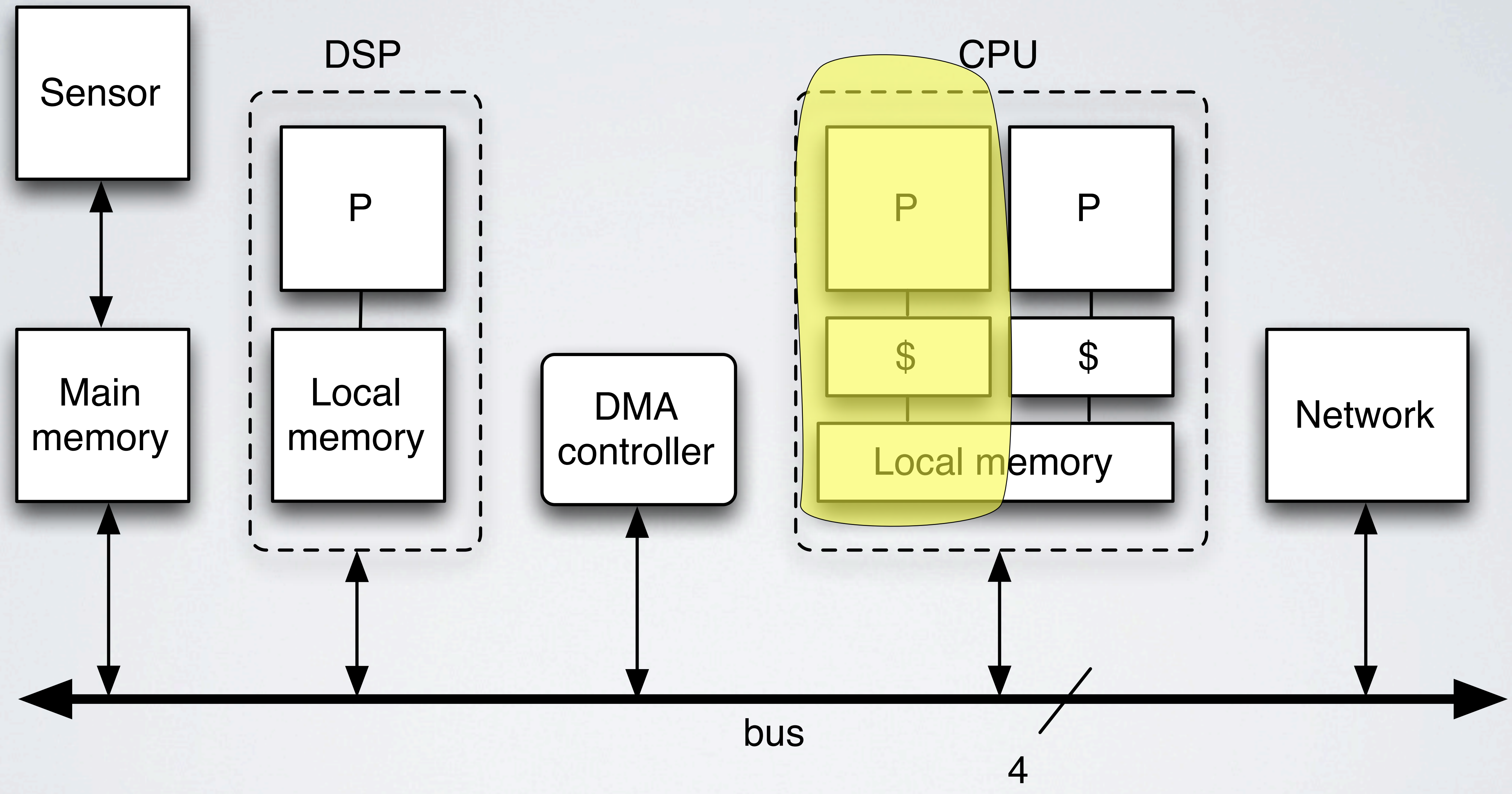
Surveillance camera



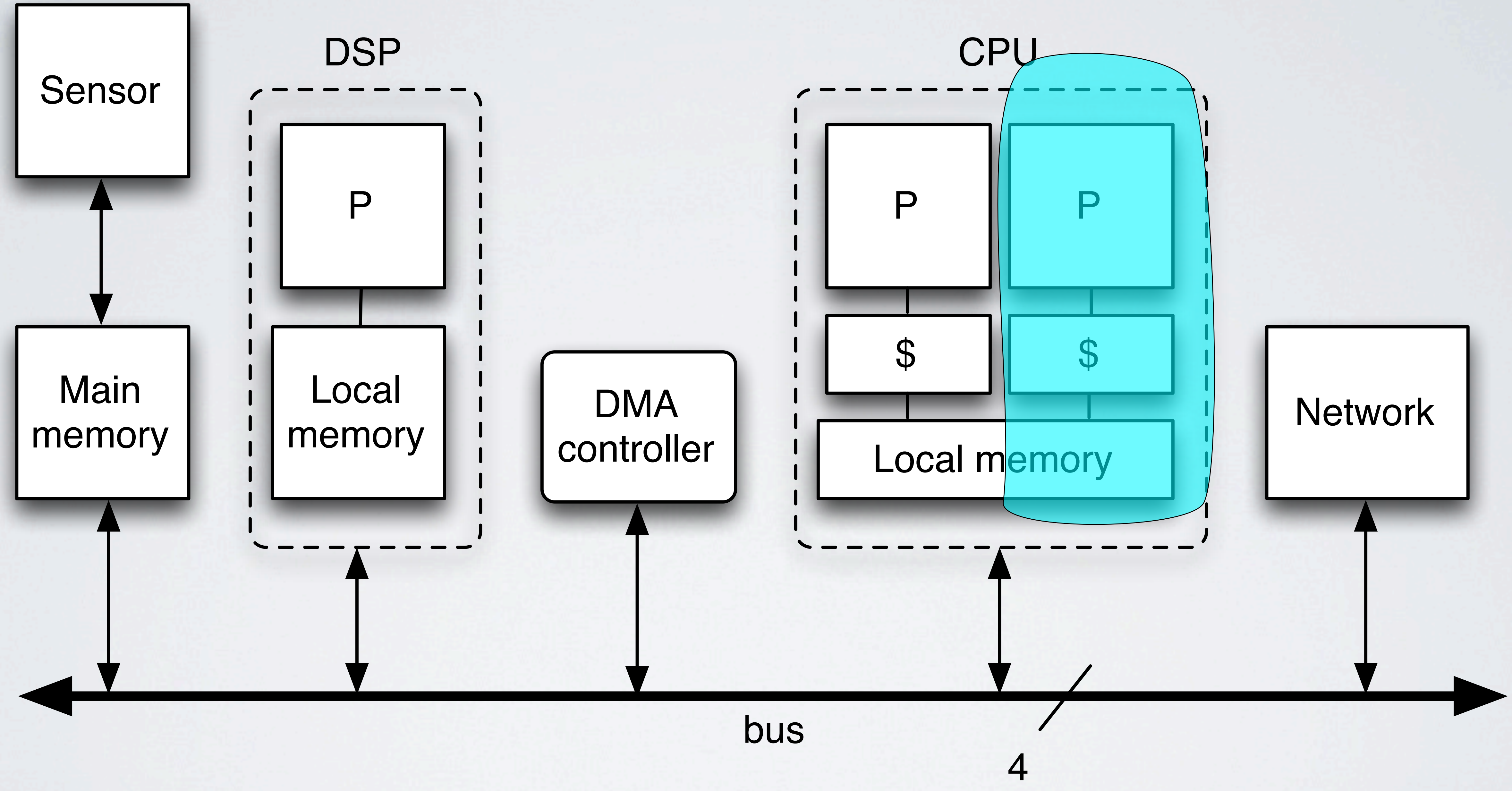
Surveillance camera



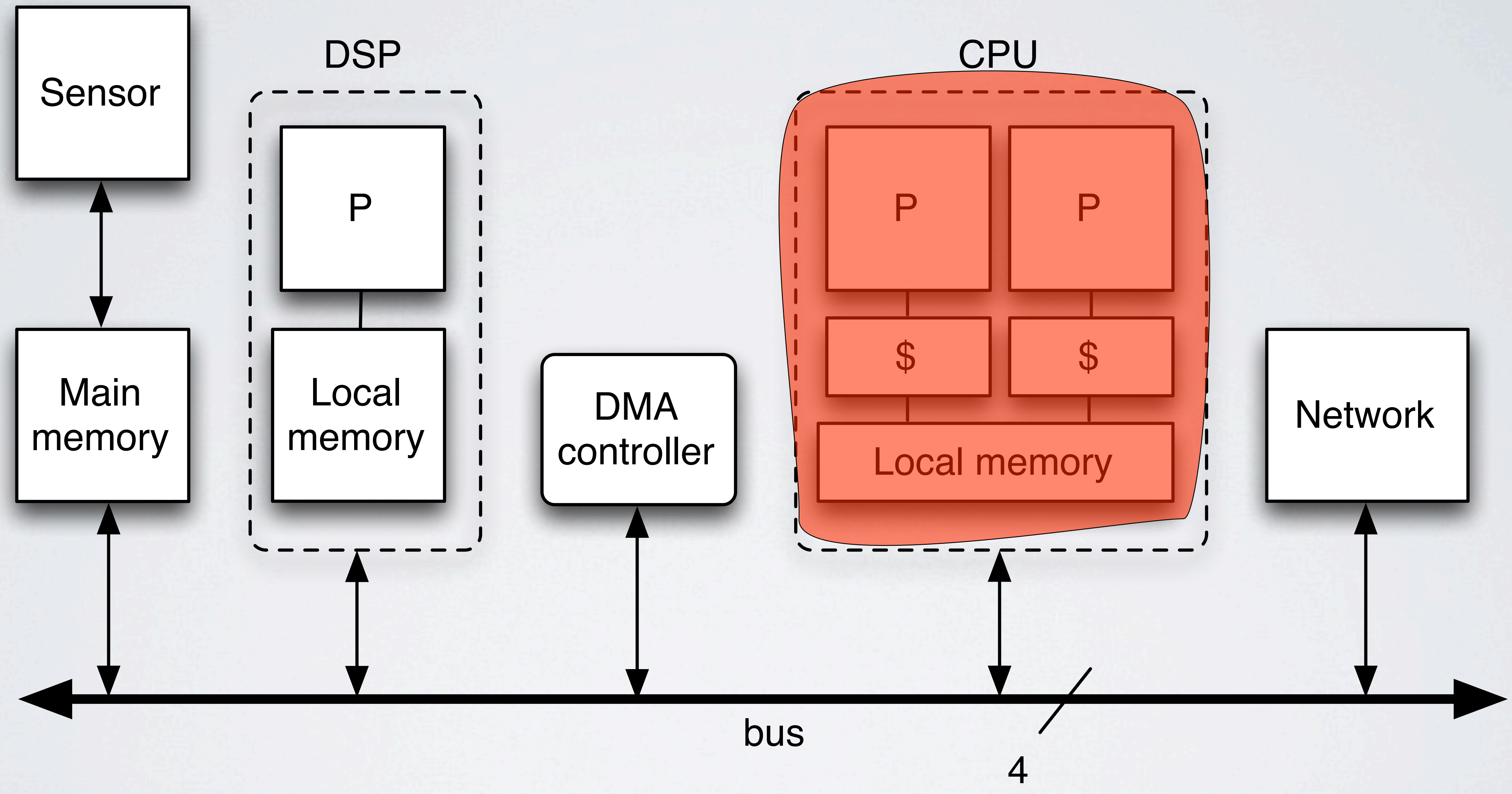
Surveillance camera



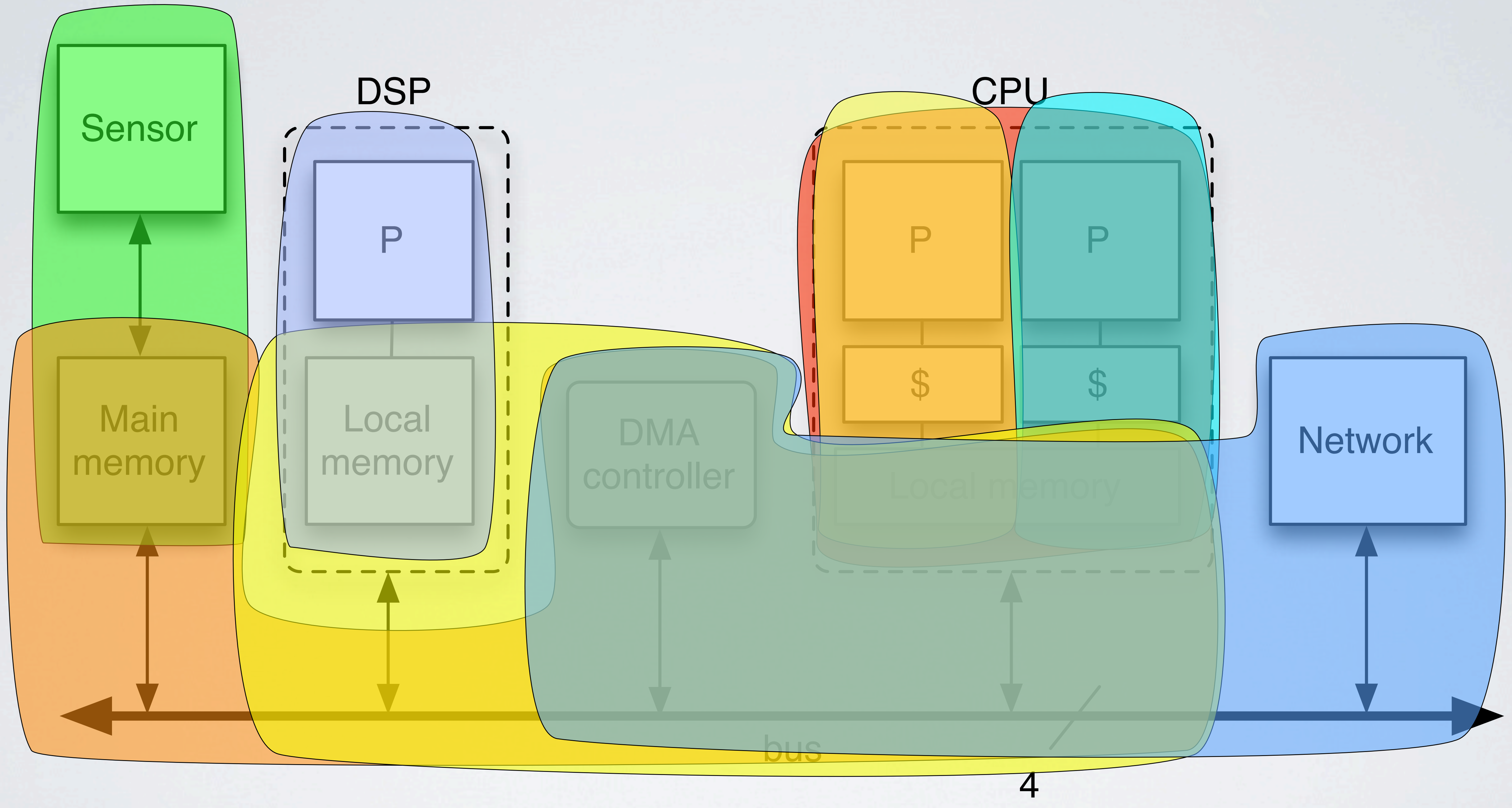
Surveillance camera



Surveillance camera



Surveillance camera



Problem

- Existing synchronization protocols for multiprocessors assume tasks execute on **one processor at a time**
- Existing parallel-task real-time scheduling algorithms assume **independent tasks**
- Simple approach of treating the entire platform as a single resource is **inefficient**

Goal

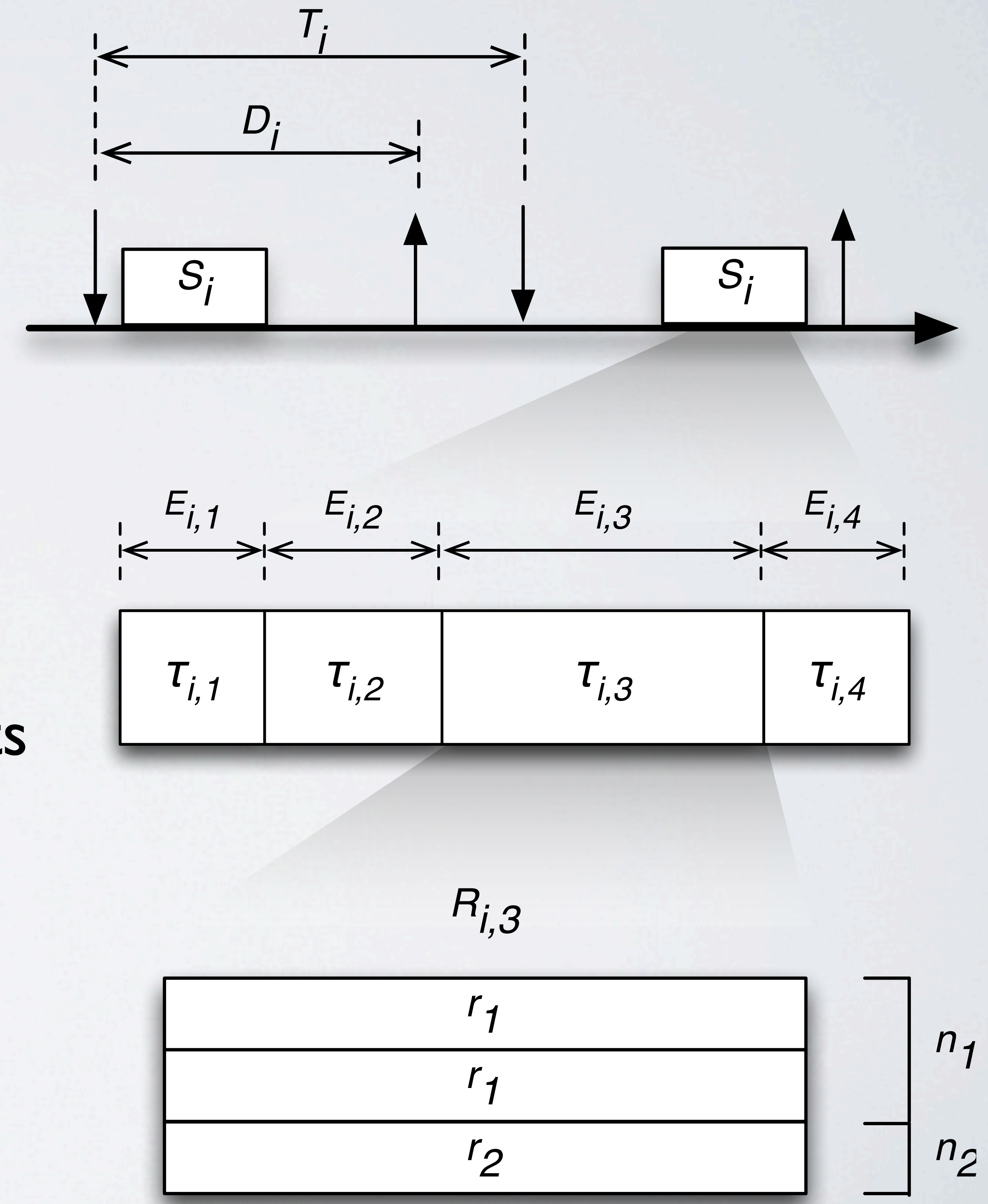
- Scheduling algorithm for **parallel tasks** with **real-time** constraints
- Exploit parallelism on a platform comprised of **multiple heterogeneous resources**.

Multiple heterogeneous resources

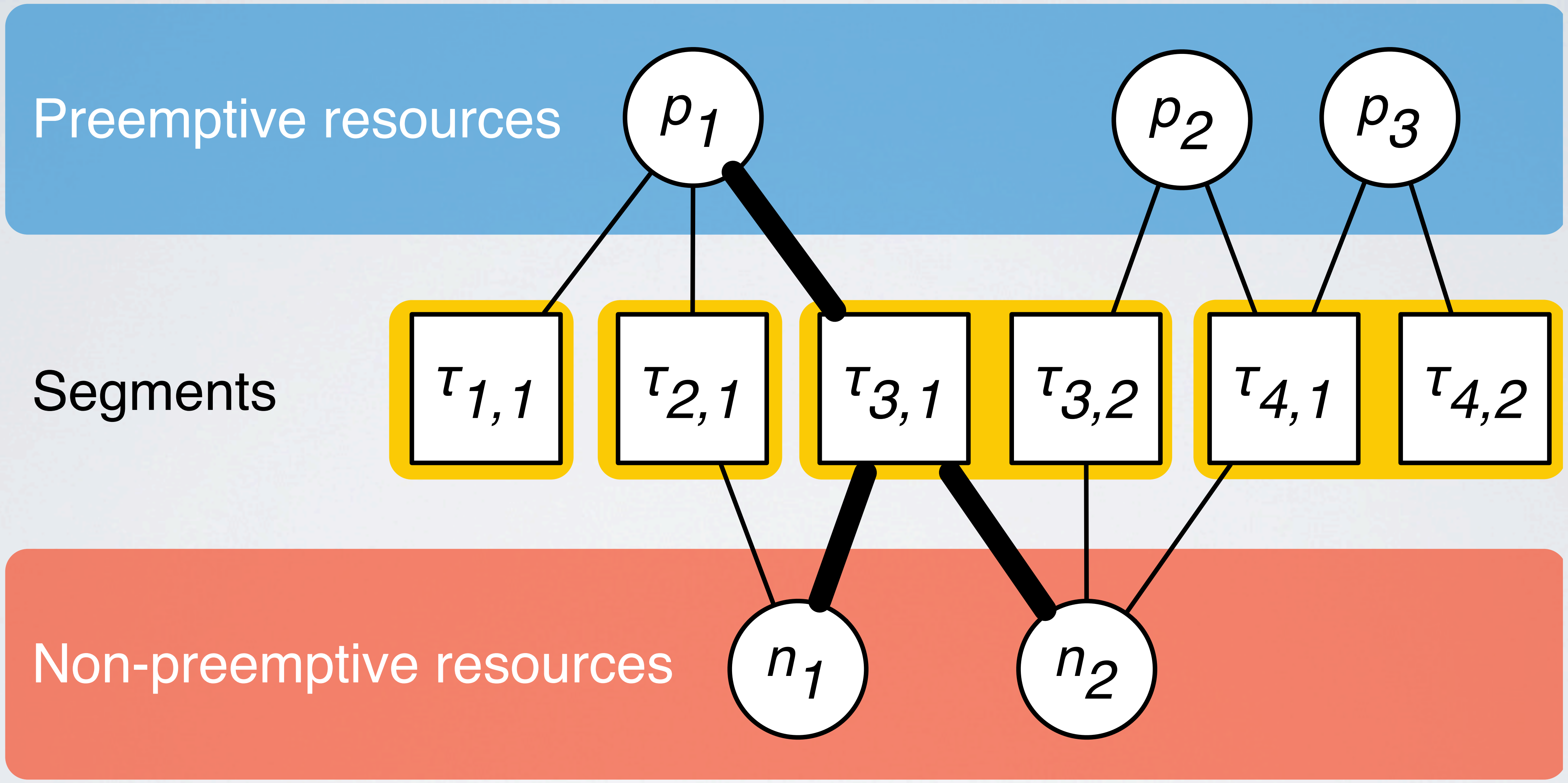
- Each resource consists of **multiple units**
  - Each unit is a serially accessible entity
  - Each resource has a **capacity** $\geq$ **1**
- Each resource is either **preemptive** or **non-preemptive**
  - Preemption does not corrupt a preemptive resource

Application

- Each task τ_i has a
  - π_i : fixed priority
  - T_i : period
  - D_i :deadline ($D_i \leq T_i$)
  - S_i : sequence of segments
- Each segment $\tau_{i,j} \in S_i$ has a
  - $E_{i,j}$: worst-case execution time
  - $R_{i,j}$: set of resource requirements
- Each resource requirement $(r_k, n_k) \in R_{i,j}$ has a
  - r_k: required resource
  - n_k: number of required units

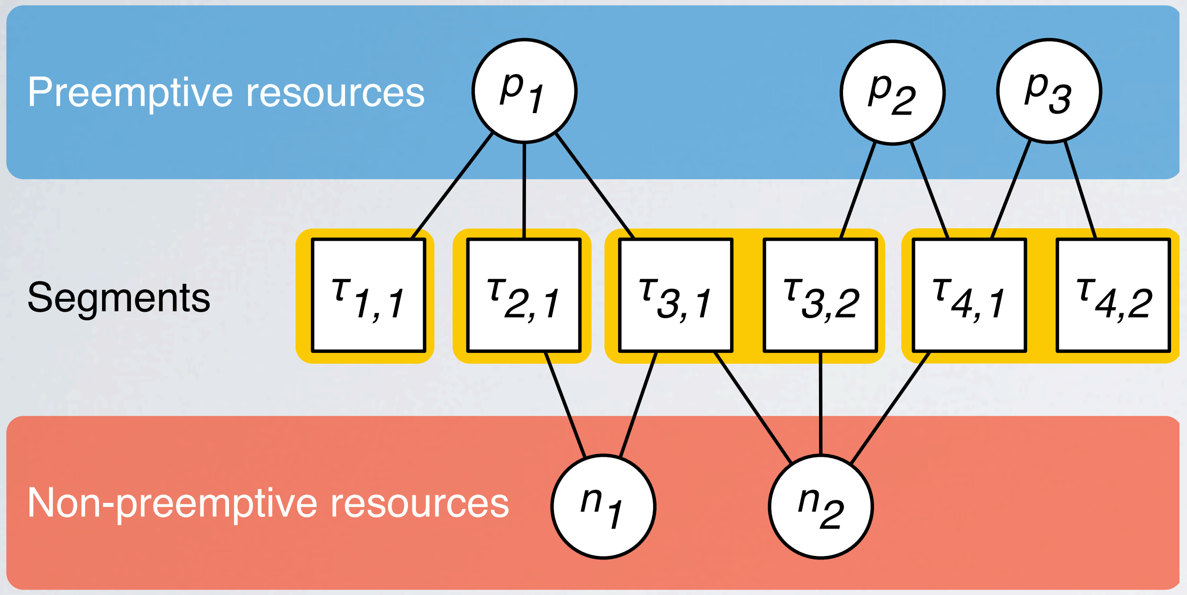


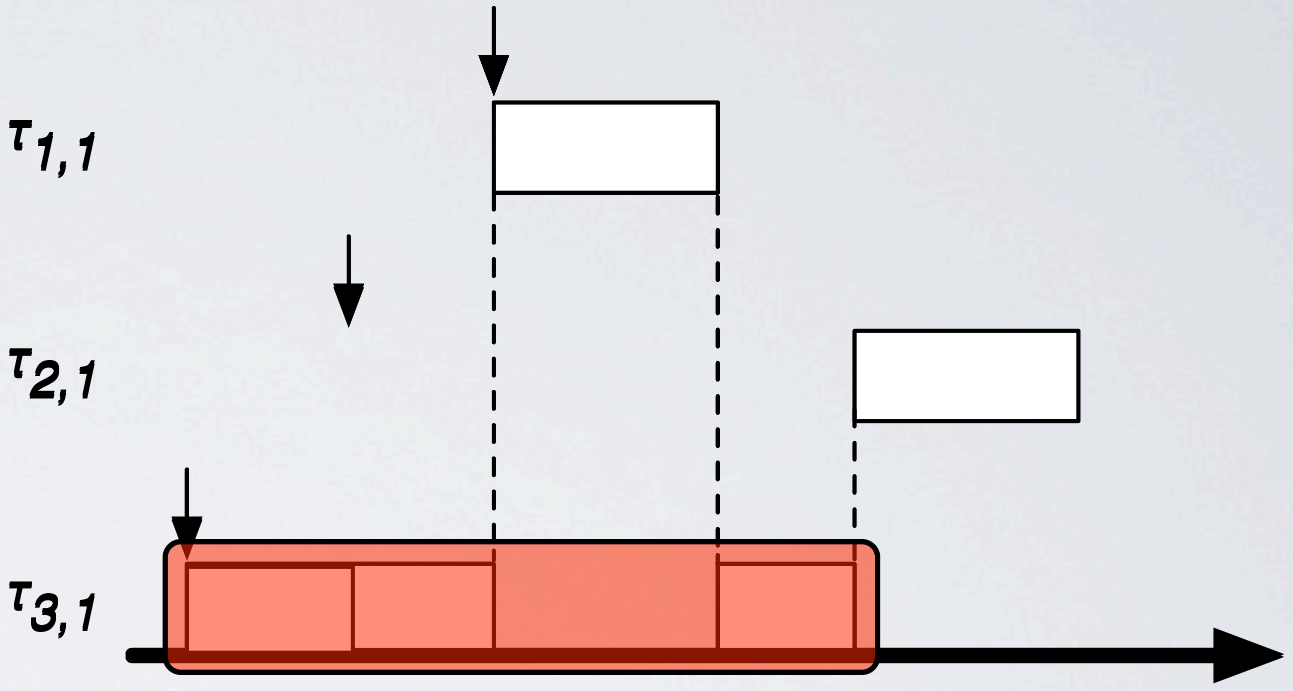
Resource requirements graph



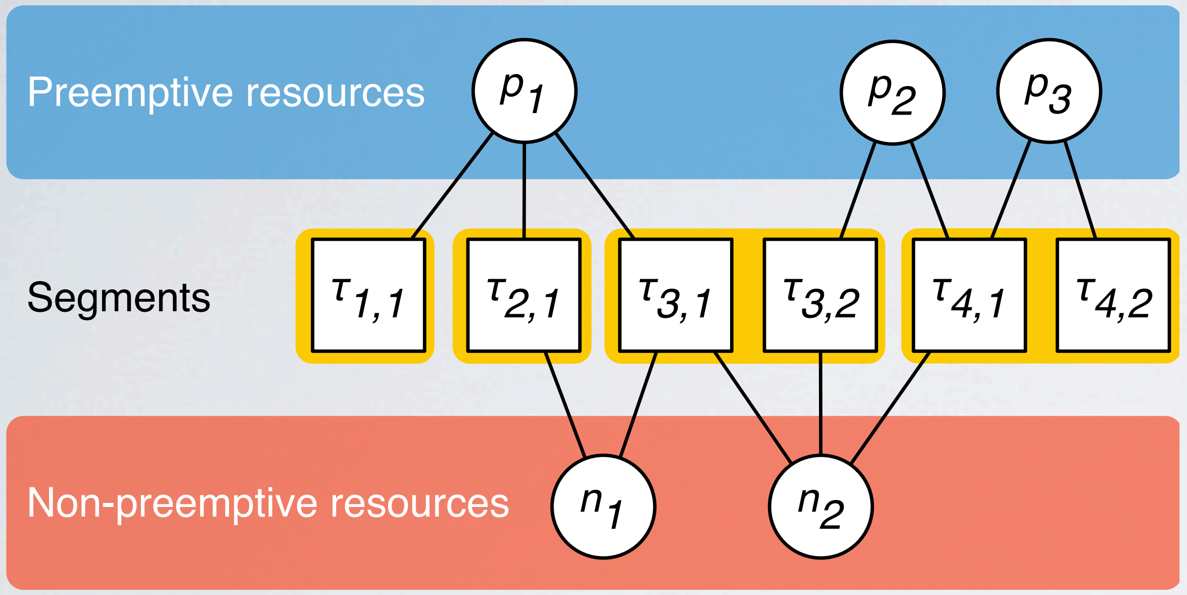
Resources are accessed simultaneously

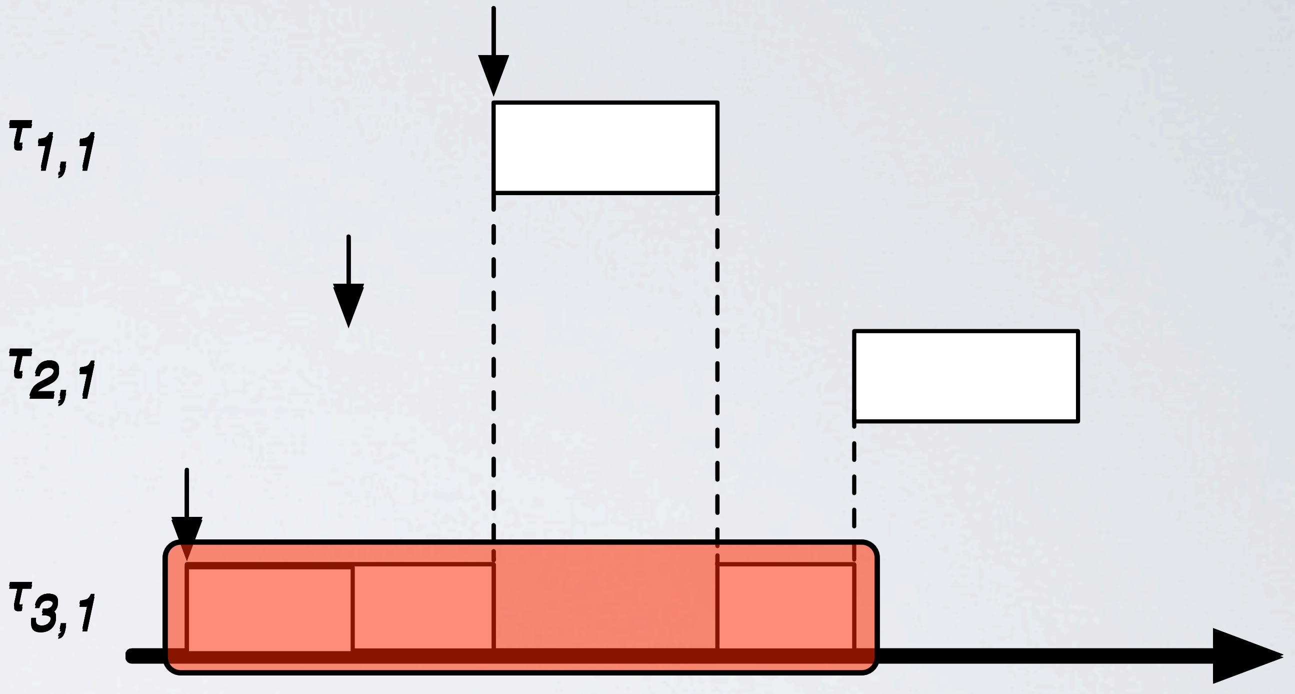
Local vs. global resources

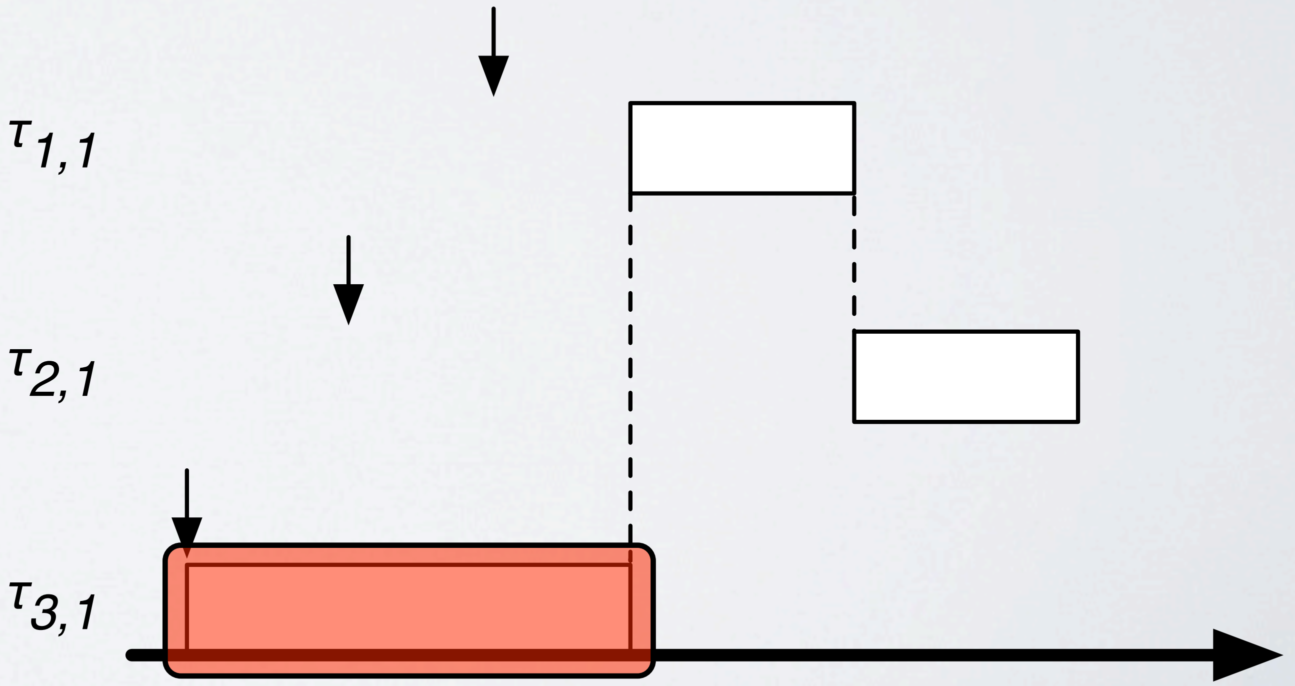




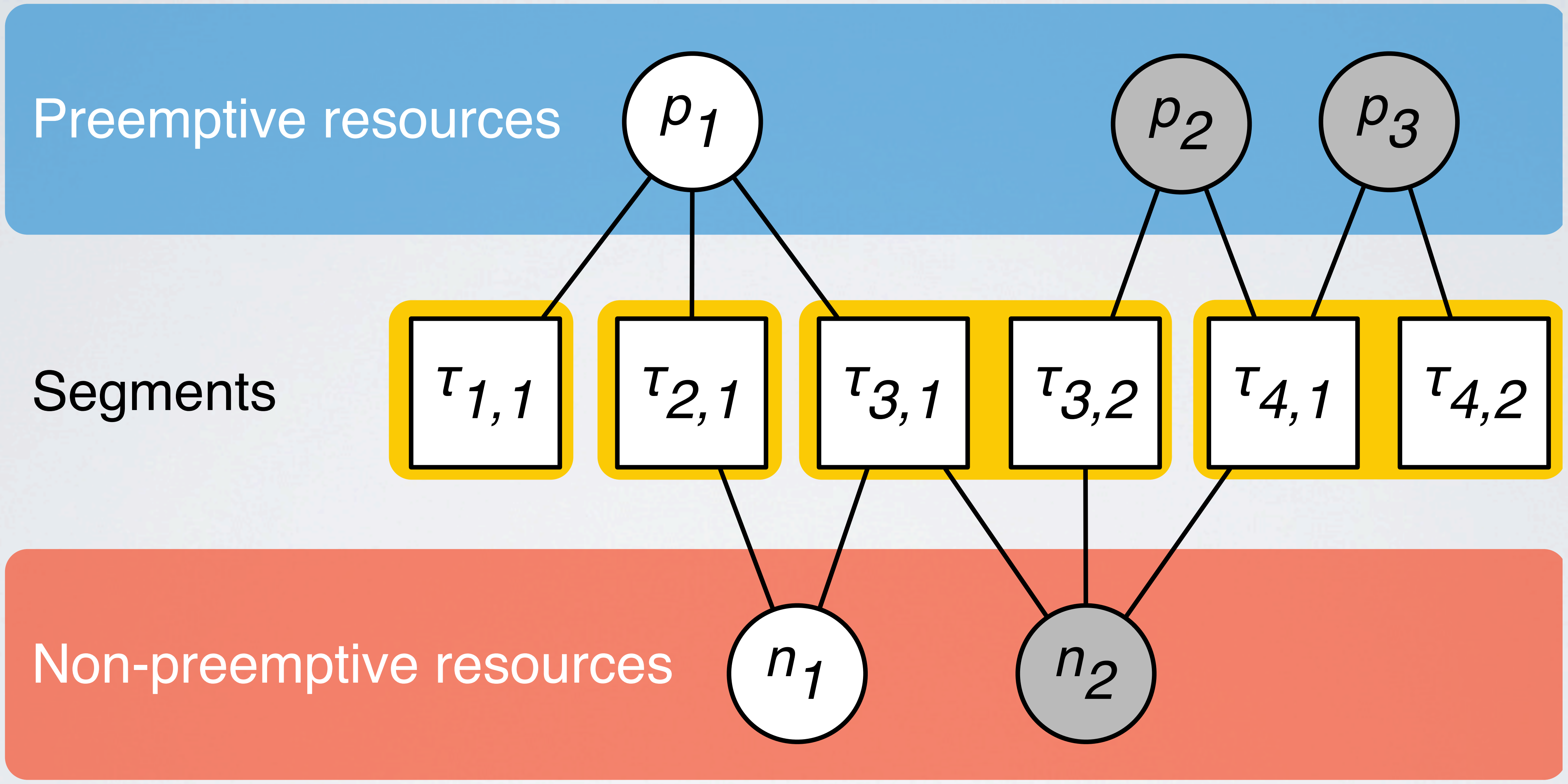
Local vs. global resources





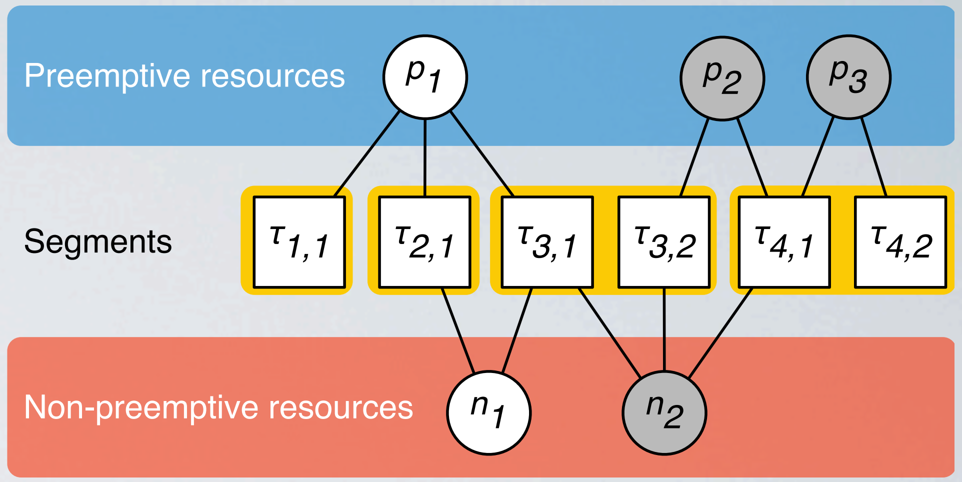


Local vs. global resources



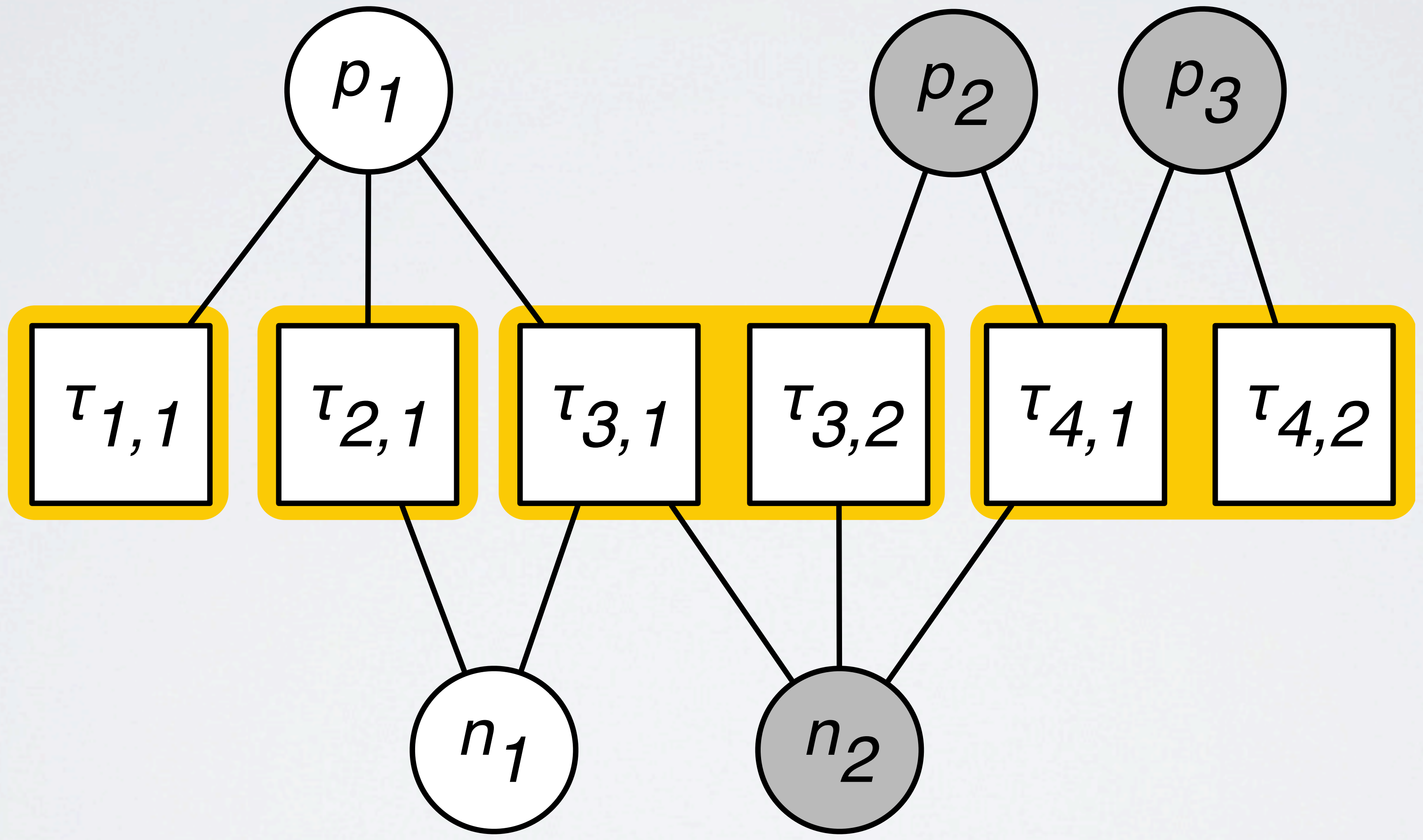
○ Local resources ● Global resources

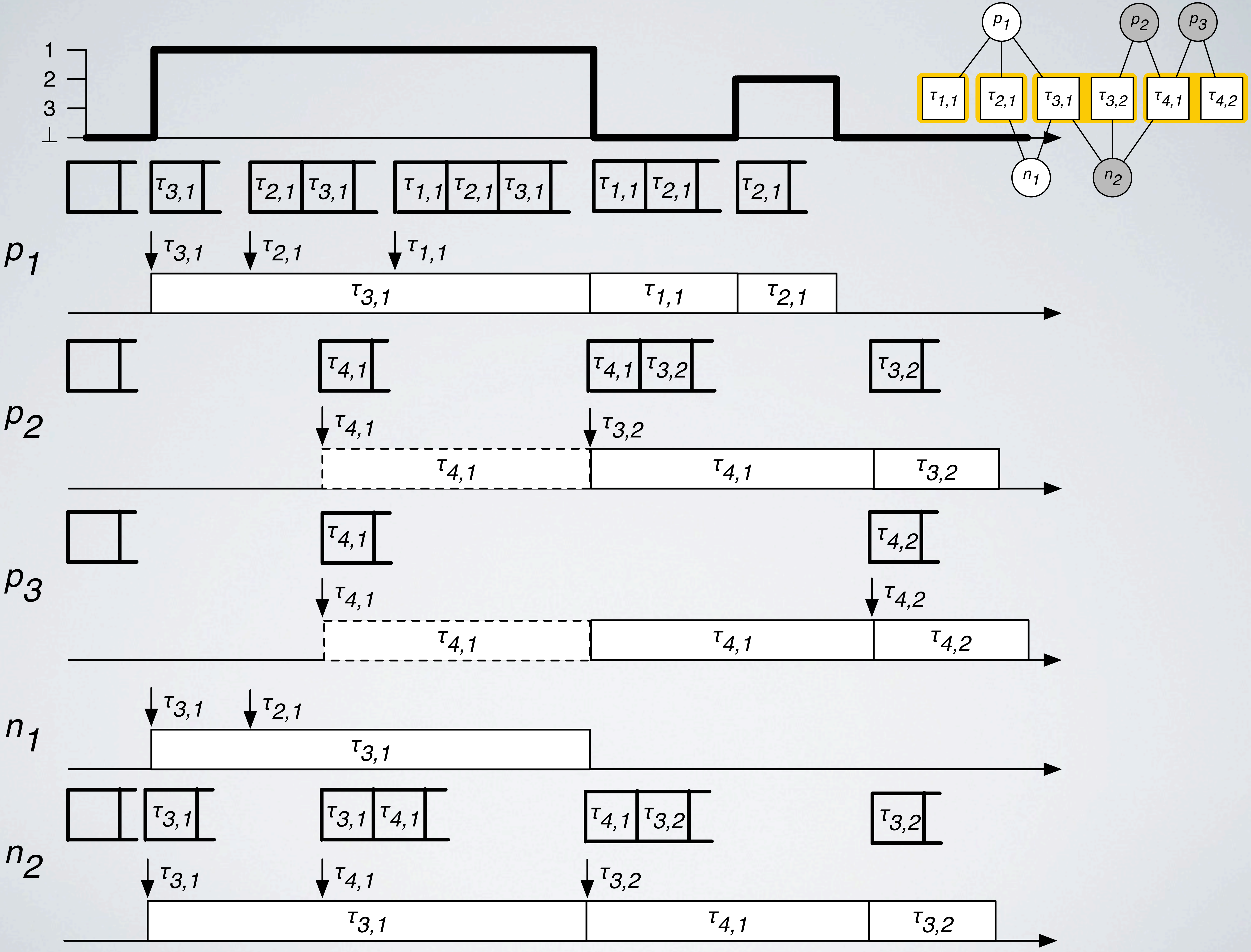
PSRP



- Equip each ...
  - local preemptive resource with a priority queue
  - global resource with a FIFO queue
  - local non-preemptive resource with a ceiling (according to SRP)
  - local preemptive resource with a system ceiling π_p (according to SRP)
  - global resource with ceiling = highest task priority
- Upon arrival of $\tau_{i,j}$, it is added atomically to all queues in $R_{i,j}$
- Upon completion of $\tau_{i,j}$, it is removed from all queues in $R_{i,j}$
- $\tau_{i,j}$ can start if ...
  - $\tau_{i,j}$ is at the head of all queues in $R_{i,j}$, and
  - $\pi_i > \pi_p$ for all $p \in R_{i,j}$
- Schedule segments starting from the head of queues, as long as:
  - enough resource units are available, and
  - all other resources required by the segment are available
    - otherwise busy wait (on global resources)

PSRP example




1
2
3
⊥
p_1
p_2
p_3
n_1
n_2
$\tau_{1,1}$
$\tau_{2,1}$
$\tau_{3,1}$
$\tau_{3,2}$
$\tau_{4,1}$
$\tau_{4,2}$

Analysis

- Compute the worst-case response time of each segment
- Worst-case response time of a task =
  Worst-case response time of its last segment
- Analysis is exponential in the number of tasks
  (for tasks which contain more than one segment)

SEE PAPER

Conclusions & future work

✓ First scheduling algorithm for
  - partitioned parallel tasks
  - with real-time constraints
  - requiring multiple heterogenous resources

✓ Improved parallelism vs. treating the entire platform as a single resource

- Preemptive resources have capacity = 1
- Potentially large delays for high priority tasks
  - Global resource queues are sorted according to FIFO
  - Global resources are scheduled non-preemptively