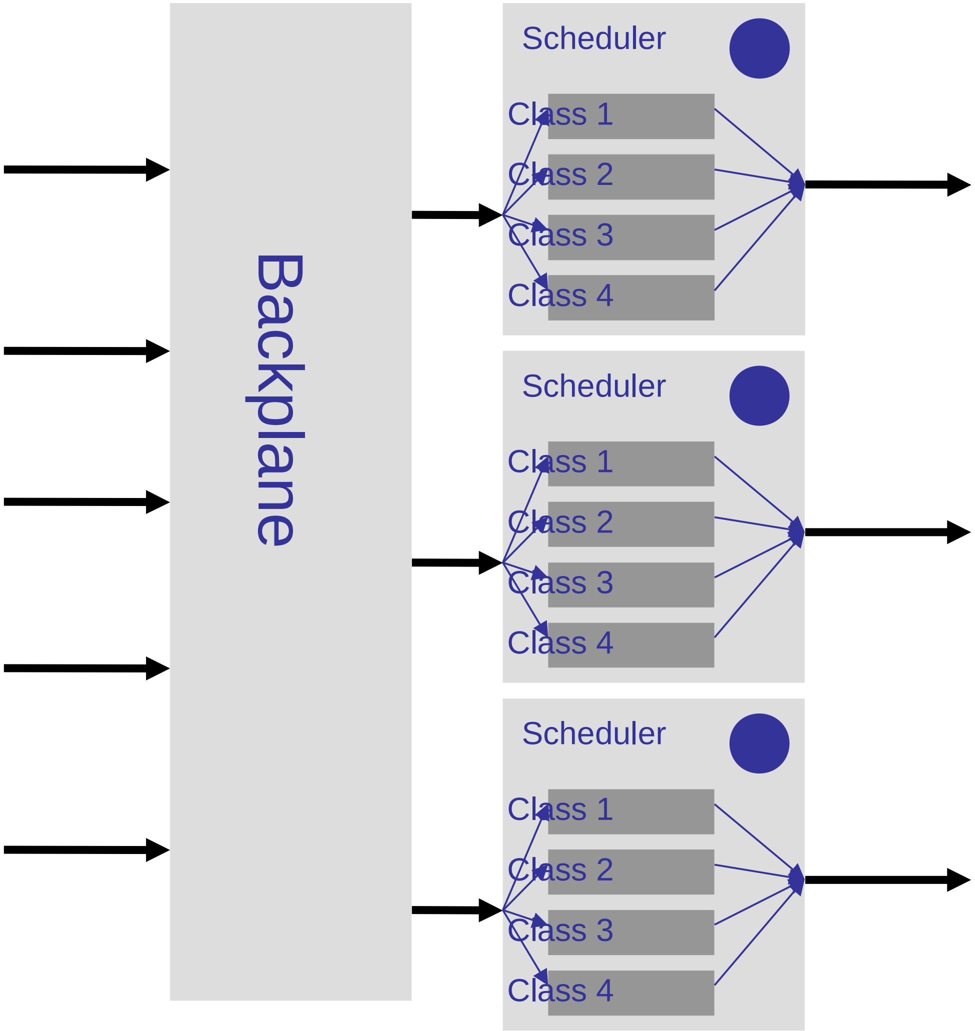
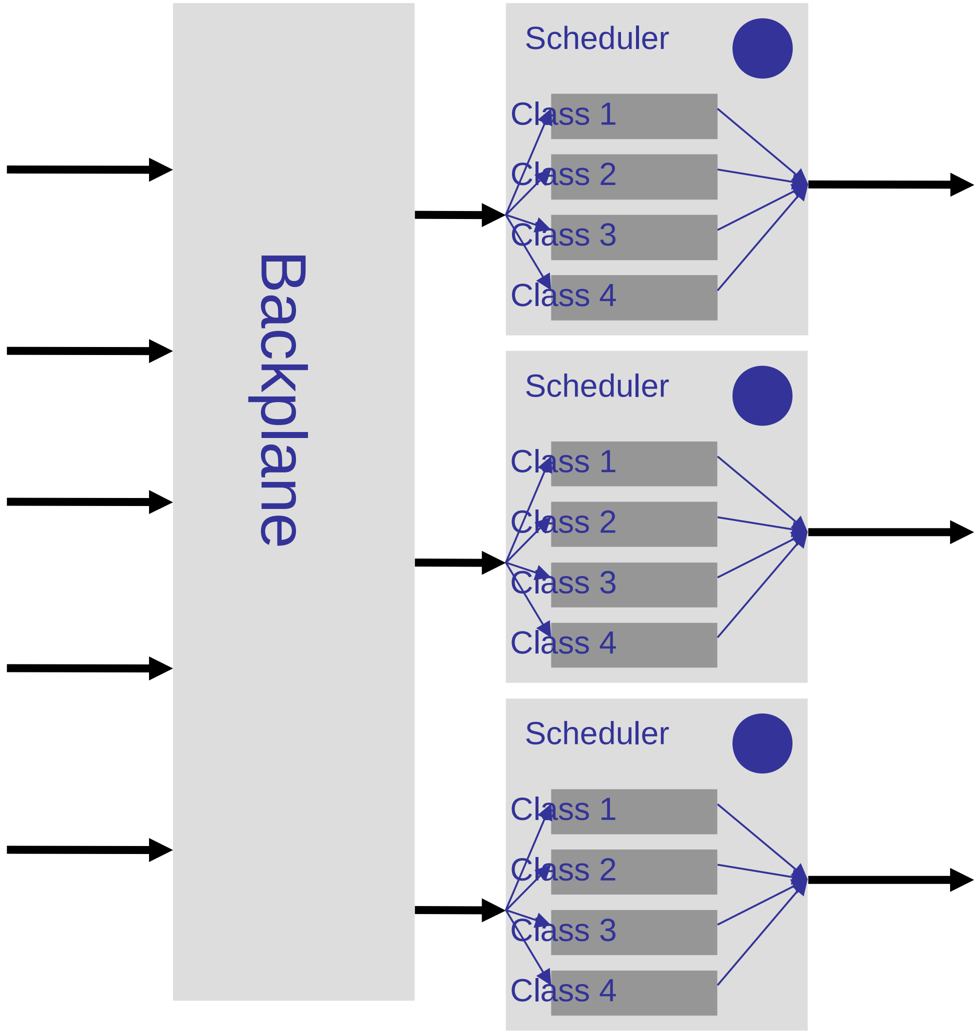
Scheduling

- In other architectures, buffering and service occur on a per-flow basis
- That is, there is a buffer for each individual flow and the service of each individual flow is differentiated
- In this way, it is possible to obtain a very fine differentiation of service
- However, this presents scalability issues, as the schedulers of a core network node may have to manage several thousands of individual flows
- There is an upper limit of flows that can be meneged on an architecture differentiating the service of individual flows



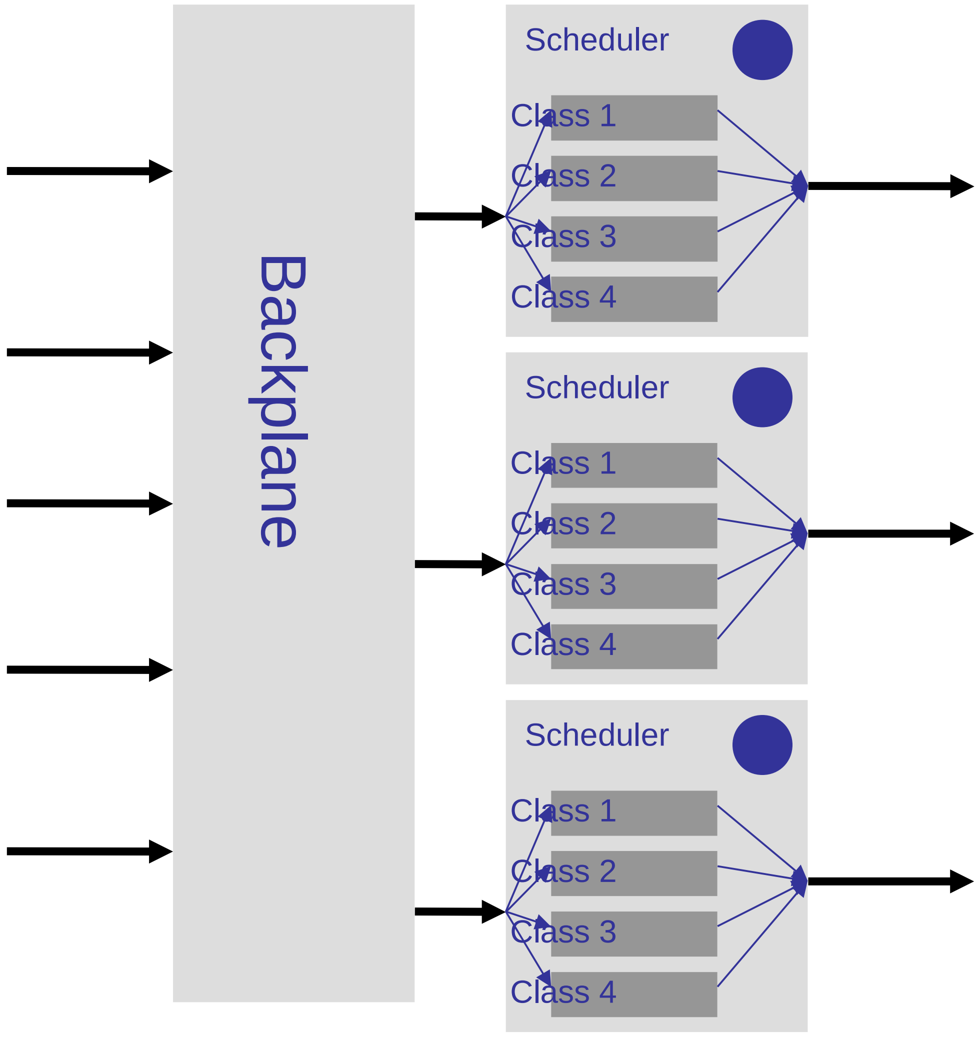
Scheduling

- Managing service classes instead of individual flows eliminates the scalability issue
- The number of service classes is much smaller than the number of flows that a scheduler sustains
- For example, 10,000 VoIP flows would fit in one service class inside a class-based scheduler
- To the contrary, a per-flow based scheduler would have to istantiate 10,000 buffers and it would have to select among 10,000 flows for the transmission of each packet



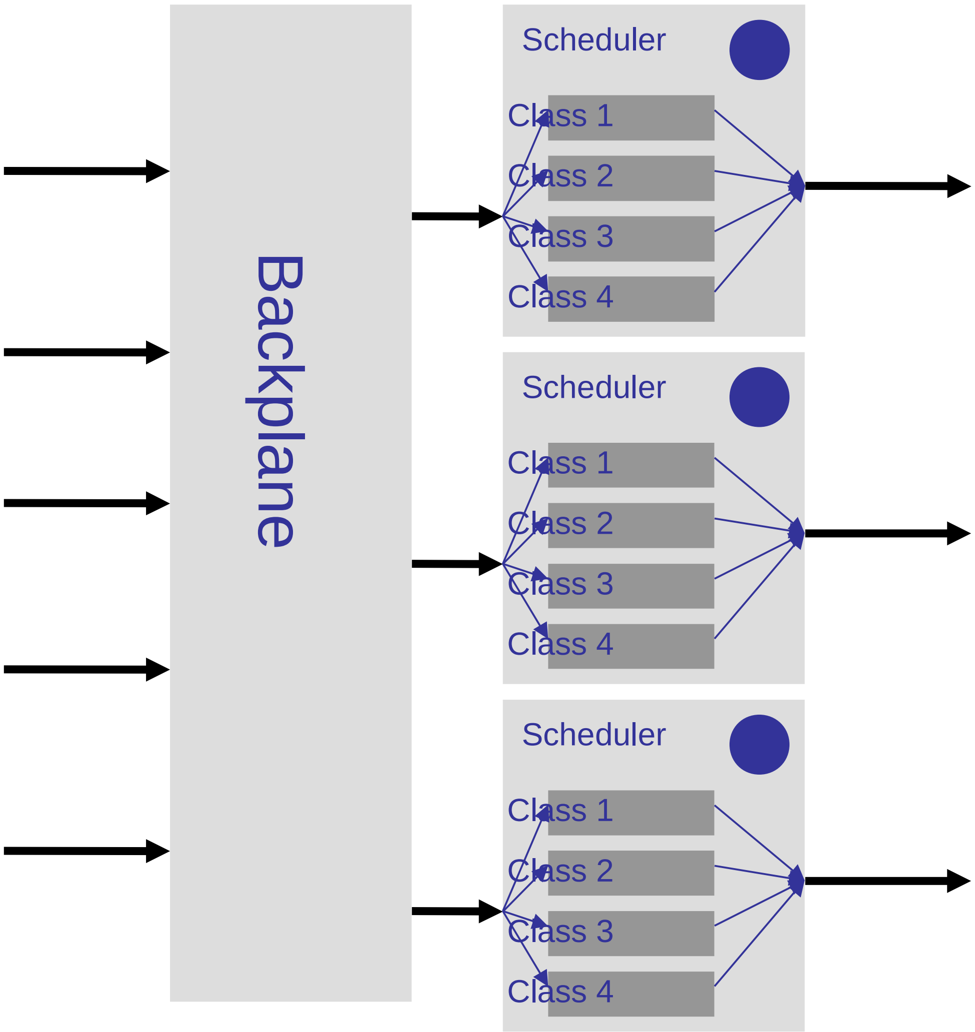
Scheduling

- Scheduling can be a complex function
- The amount of resources needed to meet the SLA of all service classes sharing a link depends on
  - The compound TCA of each service class
  - The SLA of each service class
  - The scheduling policy (algorithm)
- Connection admission control can be performed properly only if all these items are known



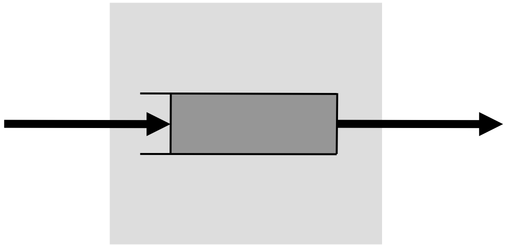
Scheduling

- Given the compound TCA of a service class on a link's scheduler, referred to as TCAi
- Given the SLA of that service class, referred to as SLAi
- The total link's capacity *C* consumed by the service classes sharing that link is a function (indeed complex) of the TCAs and SLAs and of the scheduling policy
  - *C = f((TCA1, SLA1), (TCA2, SLA2), (TCA3, SLA3), (TCA4, SLA4),policy)*



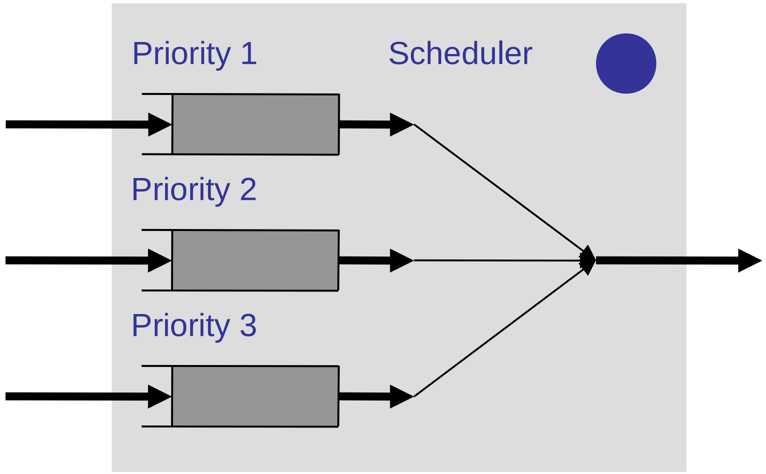
FIFO scheduler

- The FIFO (First-In First-out) scheduler is the simplest
- However, it is the less useful to offer differentiated QoS
- All packets, independently on their service class, are stored in the same buffer and they are served in the same order of their arrivals
- Clearly, only one SLA can be offer to all flows
- In order to meets all SLAs concurrently, the most stringent SLA must be guaranteed
- This is clearly very inefficent
- As a matter of fact, the FIFO scheduler can be used only for Best-Effort networks



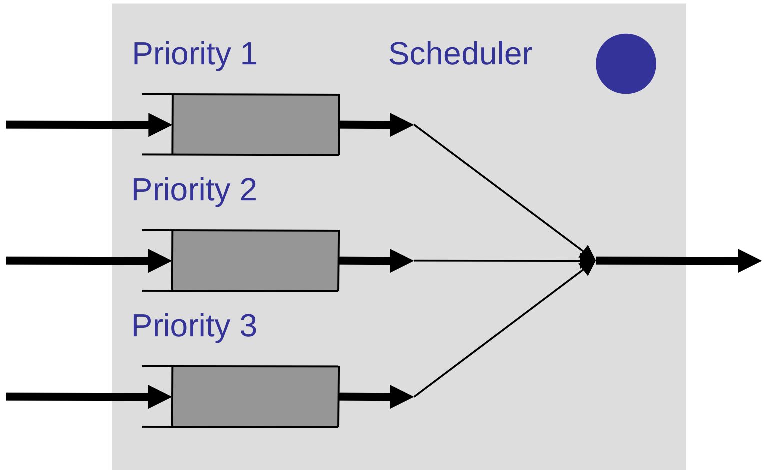
The strict priority scheduler

- The strict priority (SP) scheduler is simple but effective
- The SP scheduler, when it has to select the next packet to be served, at first examines the highest priority queue (priority 1)
- If the queue stores at least one packet, a packet is fetched from the queue and served
- If the priority-1 queue is empty, the scheduler examined the priority-2 queue and, if a packet is present, it is served
- The priority-3 queue is served only if the other queues are empty



The strict priority scheduler

- For example, with the strict priority scheduler
  - traffic with stringent QoS requirements can be assigned to the highest priority level
  - Best_Effort traffic can be assigned to the lowest priority level
  - Traffic with intermediate QoS requirements can be served within the second priority level



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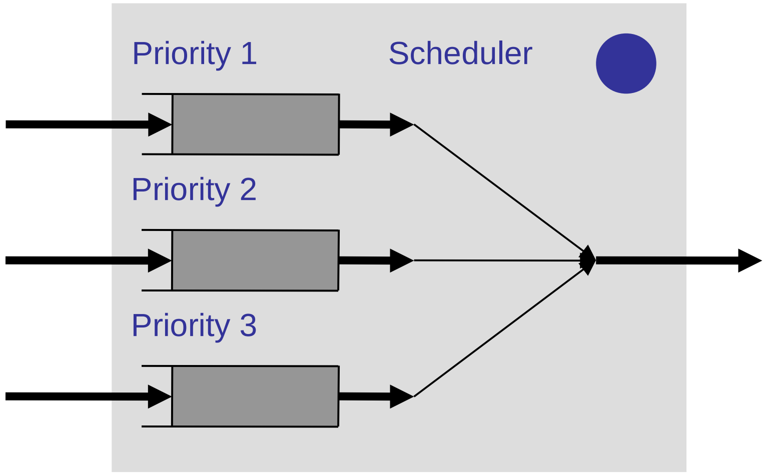
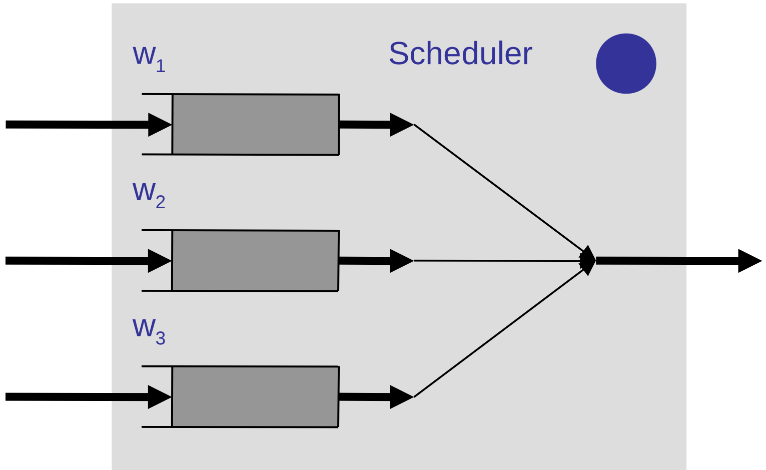


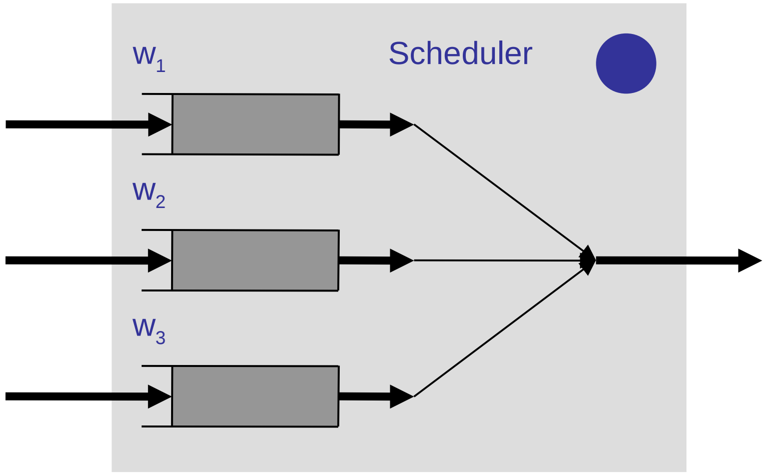
The General Processor Sharing scheduler

- In the *General Processor Sharing* scheduler (GPS), each service class is assigned a weight, ranging from 0 to 1
- The sum of weigth is 1
  - $w_1 + w_2 + w_3 = 1$
- The *i*th service class receives at least a transmission capacity equal to $w_i C$, where C is the link's capacity
- If a service class is momentarily silent, spare capacity is available
- In this case, the spare capacity is distributed among the non-silent service classes, proportionally to their respective weight



The General Processor Sharing scheduler

- For example, let $w_1=0.3$, $w_2 = 0.5$, $w_3 = 0.2$
- If service class 3 is silent, the fraction of link's capacity received by service class 1 is equal to
  - *0.3 + 0.2 x 0.3 / (0.3 + 0.5) = 0.375*
- And the fraction of capacity received by service class 2 is equal to
  - *0.5 + 0.2 x 0.5 / (0.3 + 0.5) = 0.625*
- When service class 3 returns active, the link's capacity is divided according to the respective weights of service classes



The General Processor Sharing scheduler

- GPS schedulers are referred to also as rate-based schedulers, as they assign explicitly a rate of service to each service class
- There are several implementations of GPS schedulers, such as the family of weighted fair queueing schedulers