D2/1 Consider telephone traffic on a link in an interval $[0, T]$, where $T = 20$ (time unit: min). The system is empty at time $t = 0$. New calls arrive at times

– 1, 2, 4, 5, 6, 9, 12, and 14.

The holding times of these calls (if they are not blocked) are, respectively,

– 9, 5, 4, 2, 7, 2, 4, and 4.

The capacity of the link is $n = 3$ channels.

(a) Construct a figure that describes the call arrival times, their holding times, and the number of ongoing calls (that is, the traffic process) as a function of time $t \in [0, T]$.

(b) What is the average number of ongoing calls?

(c) What is the fraction of calls that are blocked?

(d) What is the fraction of time that the system is full?

D2/2 Consider data traffic at the packet level in an output port of a router in an interval $[0, T]$, where $T = 20$ (time unit: μs). The system is empty at time $t = 0$. New packets arrive at the following times instants:

– 1, 2, 4, 5, 6, 9, 12, and 14.

The transmission times of these packets are, respectively,

– 2, 4, 1, 2, 1, 4, 2, and 1.

No packets are lost due to a full buffer, and the packets are transmitted in the same order as they arrived.

(a) Construct a figure that describes the packet arrival times, their waiting and transmission times, and the number of packets in the system (that is, the traffic process) as a function of time $t \in [0, T]$.

(b) What is the average number of packets in the system?

(c) What is the average waiting time of a packet?

(d) What is the average total delay of a packet (including both the waiting and the transmission time)?

D2/3 Consider elastic data traffic at the flow level on a link with speed 10 Mbps in an interval $[0, T]$, where $T = 20$ (time unit: s). The system is empty at time $t = 0$. New flows arrive at the following time instants:

- 1, 2, 5, 7, and 13.

The sizes (in Mb) of these flows are

- 20, 90, 20, 20, and 20.

The link capacity is shared evenly (that is, fairly) among all competing flows.

(a) Construct a figure that describes the flow arrival times, their total delays, and the number of flows in the system (that is, the traffic process) as a function of time $t \in [0, T]$.

(b) What is the average number of flows in the system?

(c) What is the average total delay of a flow?

D2/4 Consider streaming CBR data traffic at the flow level on a link in an interval $[0, T]$, where $T = 20$ (time unit: s). New flows arrive at the following time instants:

- 1, 2, 4, 5, 6, 9, 12, and 14.

The durations (in s) of these flows are

- 9, 5, 4, 2, 7, 2, 4, and 4.

The system is empty at time $t = 0$.

(a) Construct a figure that describes the flow arrival times, their durations, and the number of flows in the system (that is, the traffic process) as a function of time $t \in [0, T]$.

(b) What is the average number of flows in the system?

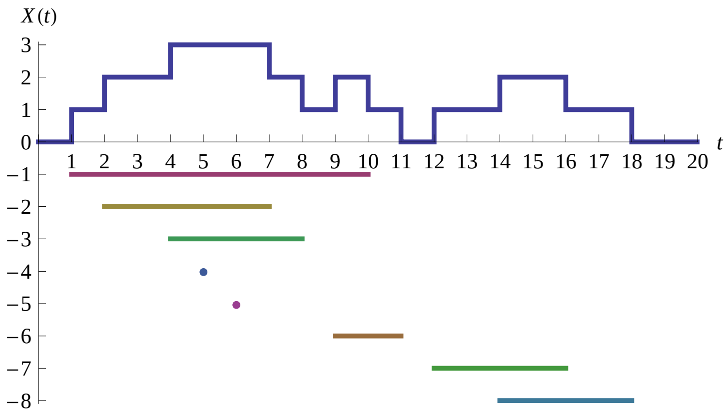
(c) What is the fraction of time with more than three flows in the system?

D2/1 (a) Figure 1, cf. L2/15.

(b) The average number of ongoing calls: $28/20 = 1.40$ calls

(c) The fraction of calls that are blocked: $2/8 = 1/4 = 0.25$

(d) The fraction of time that the system is full: $3/20 = 0.15$



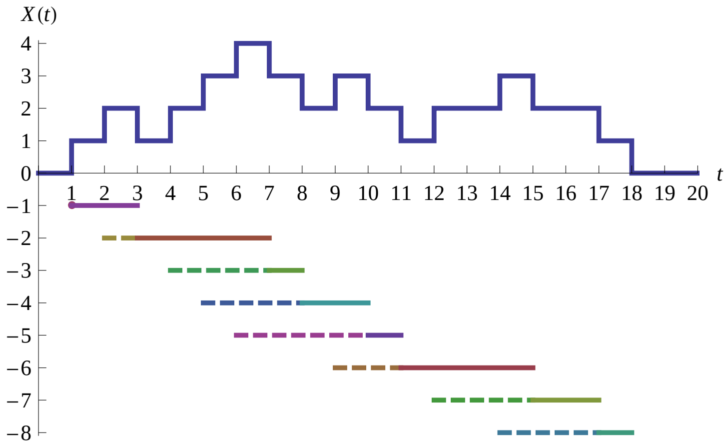
Kuva 1: [D2/1] Traffic process $X(t)$ as a function of time t (above the x-axis). Call arrival and holding times (below the x-axis). Note that the calls arriving at times 5 and 6 are blocked.

D2/2 (a) Figure 2, cf. L2/20.

(b) The average number of packets in the system: $36/20 = 1.80$ packets

(c) The average waiting time of a packet: $19/8 = 2.37$ μs

(d) The average total delay of a packet: $36/8 = 4.50$ μs

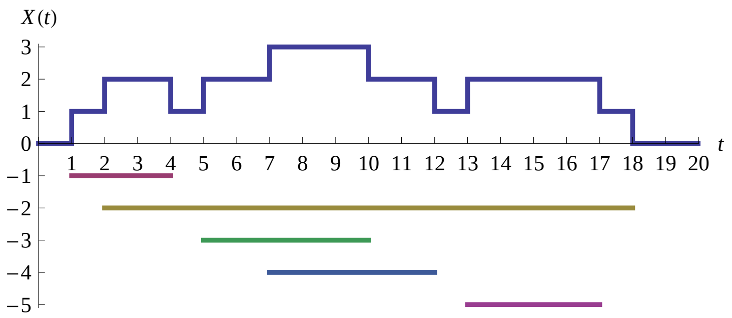


Kuva 2: [D2/2] Traffic process $X(t)$ as a function of time t (above the x-axis). Packet arrival, waiting, and transmission times (below the x-axis).

D2/3 (a) Figure 3, cf. L2/30.

(b) The average number of flows in the system: $33/20 = 1.65$ flows

(c) The average total delay of a flow: $33/5 = 6.60$ s

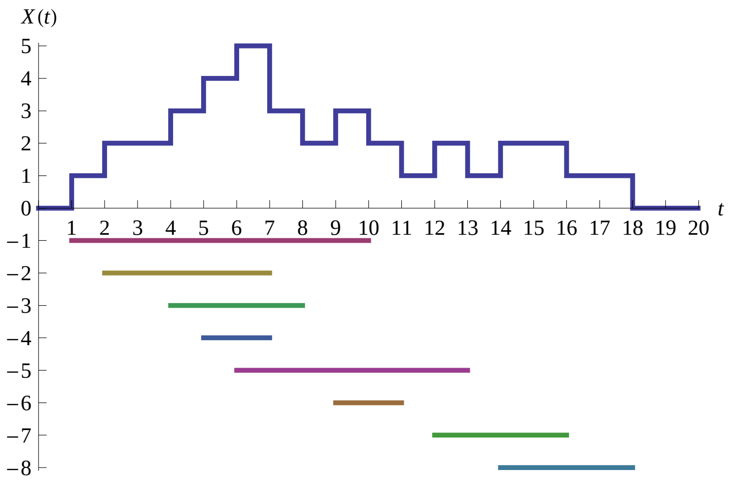


Kuva 3: [D2/3] Traffic process $X(t)$ as a function of time t (above the x-axis). Flow arrival times and their total delays (below the x-axis).

D2/4 (a) Figure 4, cf. L2/34.

(b) The average number of flows in the system: $37/20 = 1.85$ flows

(c) The fraction of time with more than three flows in the system: $2/20 = 0.10$



Kuva 4: [D2/4] Traffic process $X(t)$ as a function of time t (above the x-axis). Flow arrival times and their durations (below the x-axis).