Network Engineering

Lecture 1. Introduction

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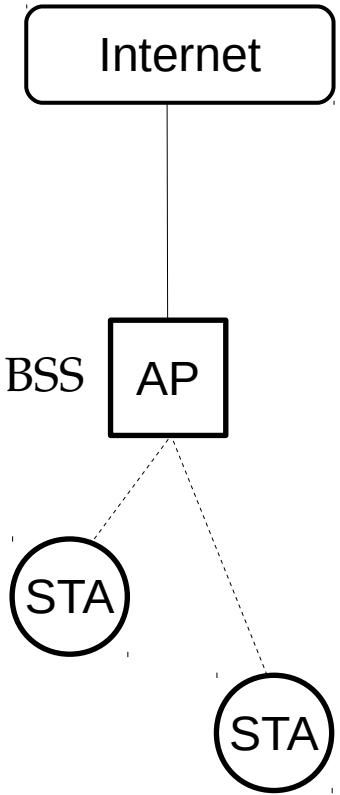
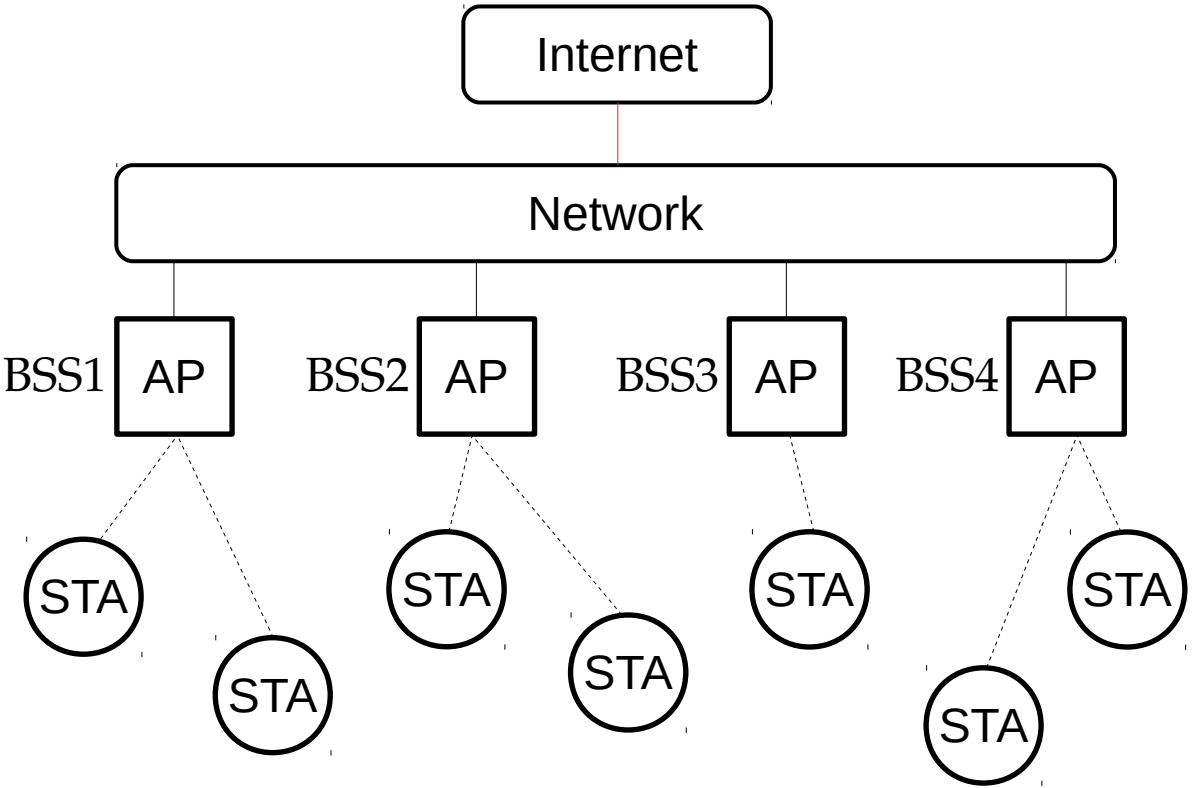
WN UPF *Wireless Networking*
https://www.upf.edu/web/wnrg

A WLAN at home (1 AP)



An Enterprise WLAN (many APs)



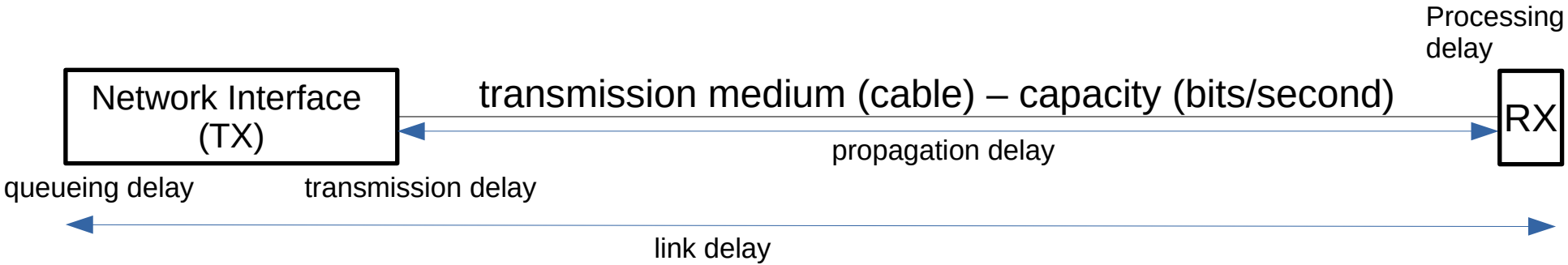
BSS: Basic Service Set

An engineering problem

- We are requested to select the ‘capacity’ of the link that interconnects a company’s network to Internet.
- In general, higher capacity means higher price, so the company wants to choose the ‘right’ capacity.

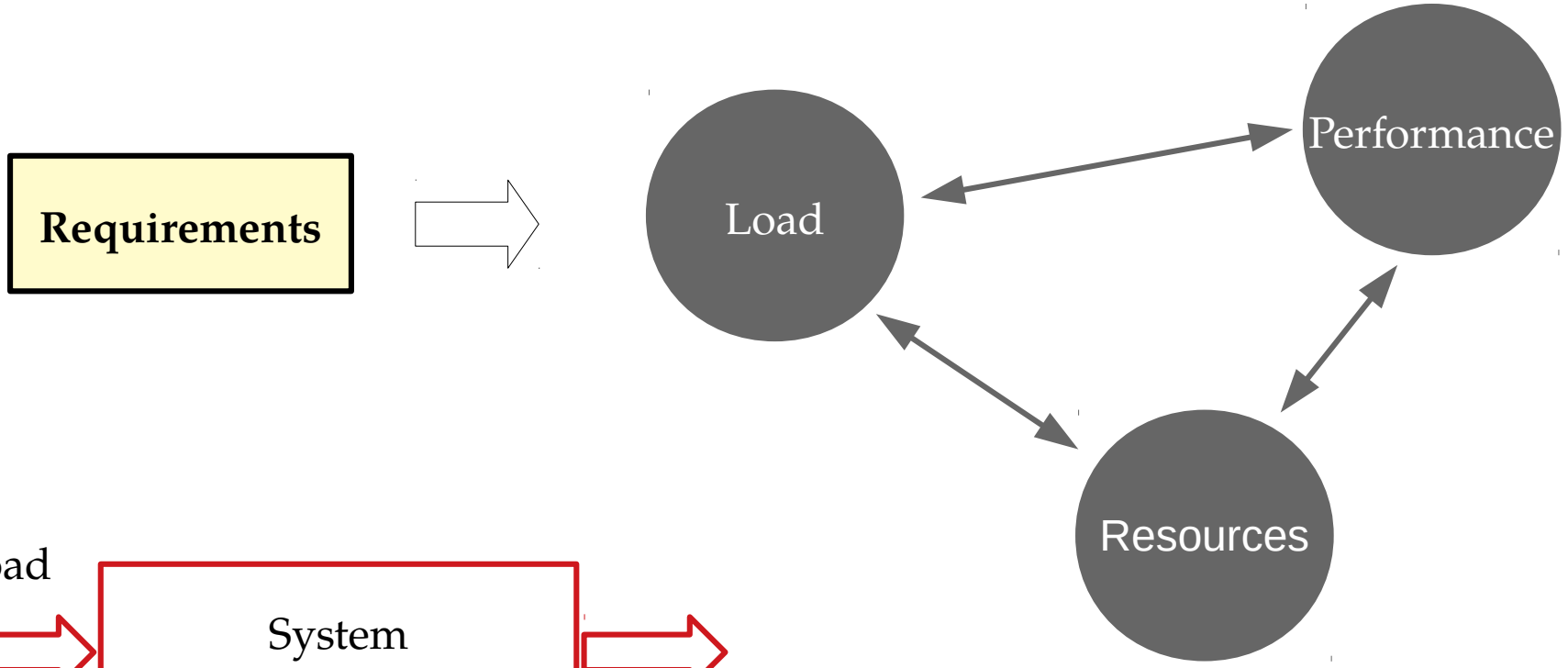
- Q: What should be taken into account to choose the right capacity of the link?
  - **Capacity**: maximum transmission rate over the link in bits / second.

What is a link?



- A couple of definitions
  - **Load of the link**: how much data traffic (bits / second) it has to carry
    - Depends on: number of users, and what they do (user activity), contents exchanged (apps)
  - **Expected performance of the link**: packet delay and packet losses
    - Quality of service (QoS)

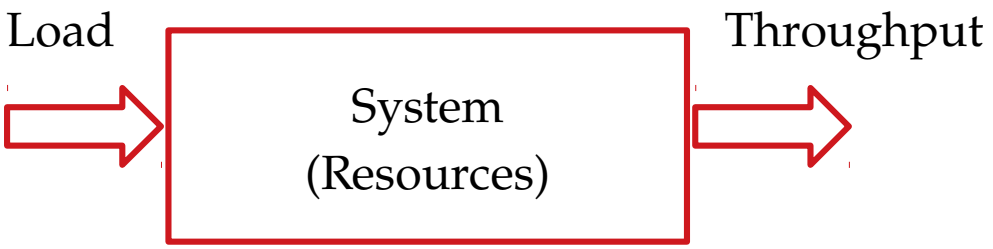
Three important concepts (interrelated)



Performance (how the system has dealt with the load)

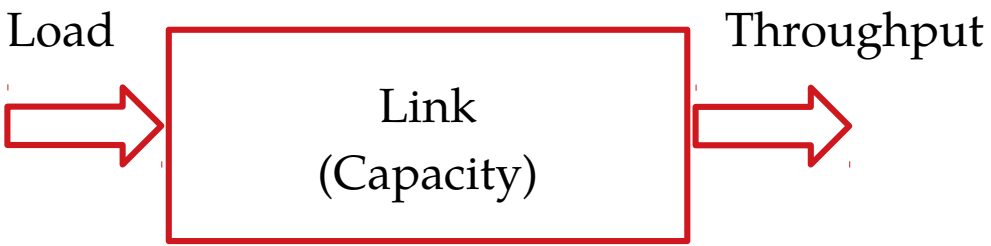
Some definitions (for networking cases)

- **Load**: amount of data (bits / packets / files) that arrive to a system to be processed (transmitted, analyzed, stored) per unit of time.
  - Also called: *traffic load*
- **Throughput**: amount of data successfully processed by the system per unit of time.
  - Also called: *carried traffic*



Some questions to discuss (in our problem)

- Is the load (bits / second) constant or variable?
- Is the capacity of the link (bits / second) constant or variable?

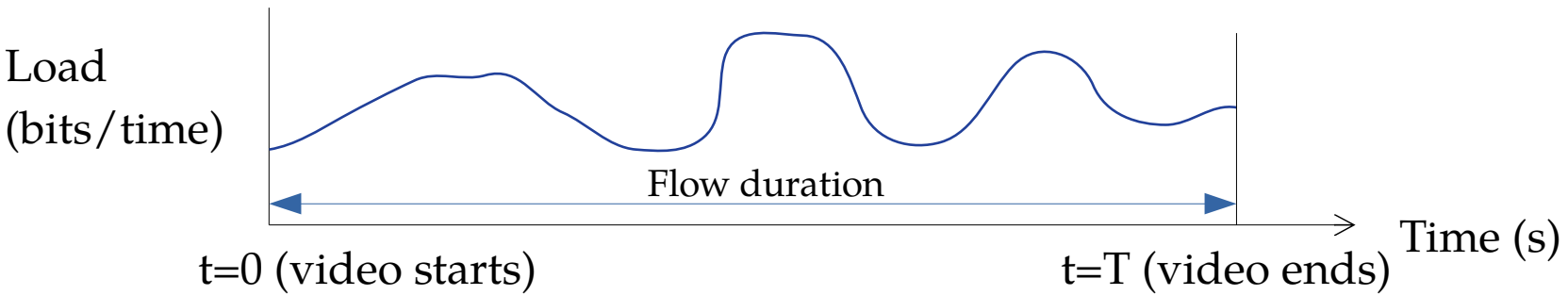


User activity

- Users (people, things, objects, etc.) generate and process data as they perform some activities.
  - Examples:
    - watching a film → the user receives an stream of data
    - chatting → the user sends and receives data as it is typed
    - video conference → the user sends and receives images and voice data
    - Web browsing → the user sends ‘commands’ and gets contents.
- User actions are somehow random: it is difficult to know when exactly a user will start a new video conference, or when a user will open a new web page.
- **The ‘traffic load’ generated by a user is also random.**

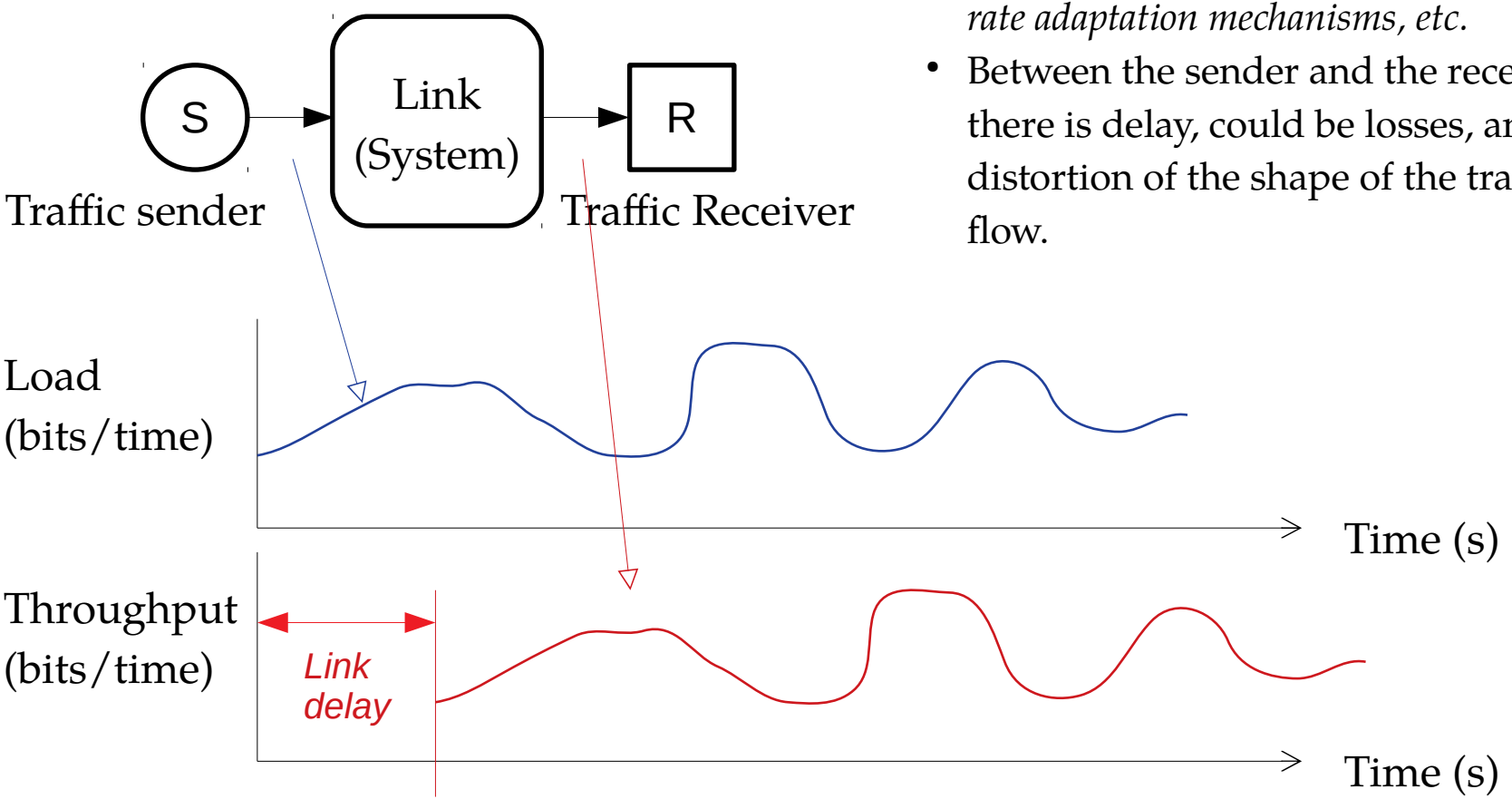
Traffic flow

- We will say that the data generated by a given application in a session is a ‘traffic flow’.
  - Example: the data generated when watching an on-line video

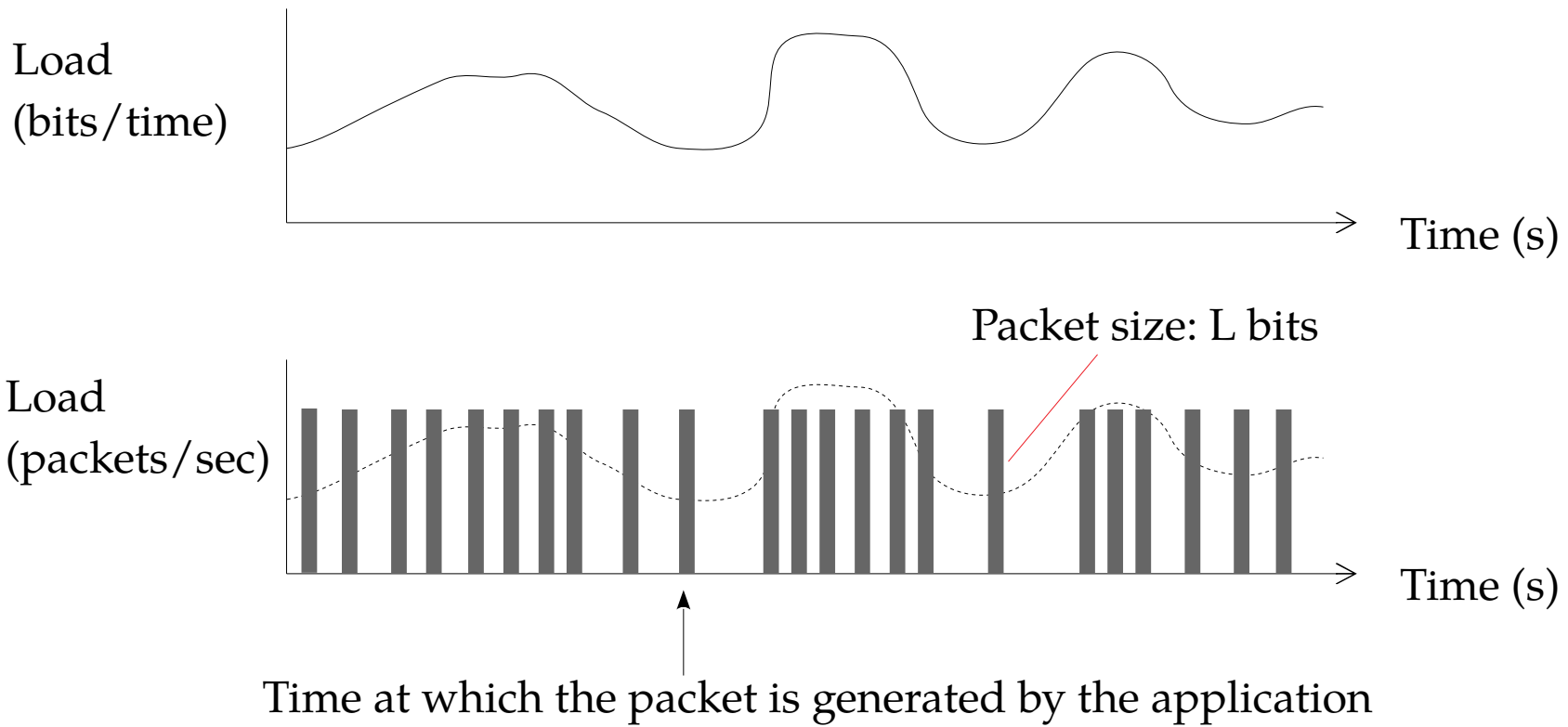


Traffic flows

- The traffic load of a flow varies with time: *Contents transmitted, user actions, rate adaptation mechanisms, etc.*
- Between the sender and the receiver, there is delay, could be losses, and distortion of the shape of the traffic flow.



Traffic flows

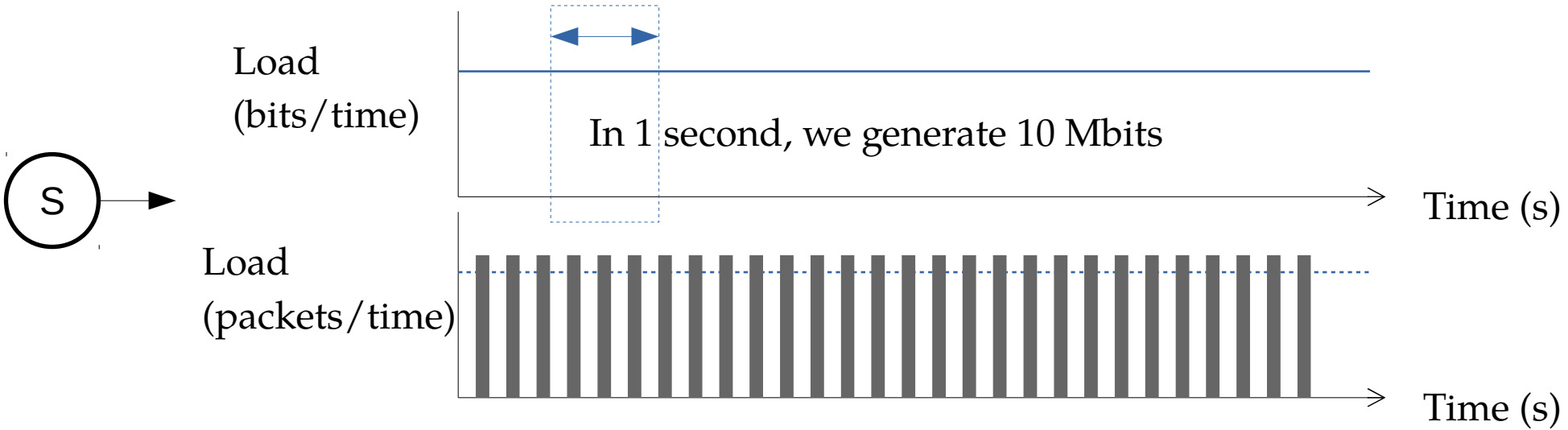


Rigid and elastic traffic flows

- **Rigid flow**: the application decides the traffic load independently of the network conditions.
  - Example: a server is broadcasting video at 20 Mbps using UDP.
- **Elastic flow**: the application adapts the traffic load to the network conditions.
  - It requires a feedback mechanism from the network and/or the other side of the communication.
  - Example: a TCP connection that reacts to network congestion.

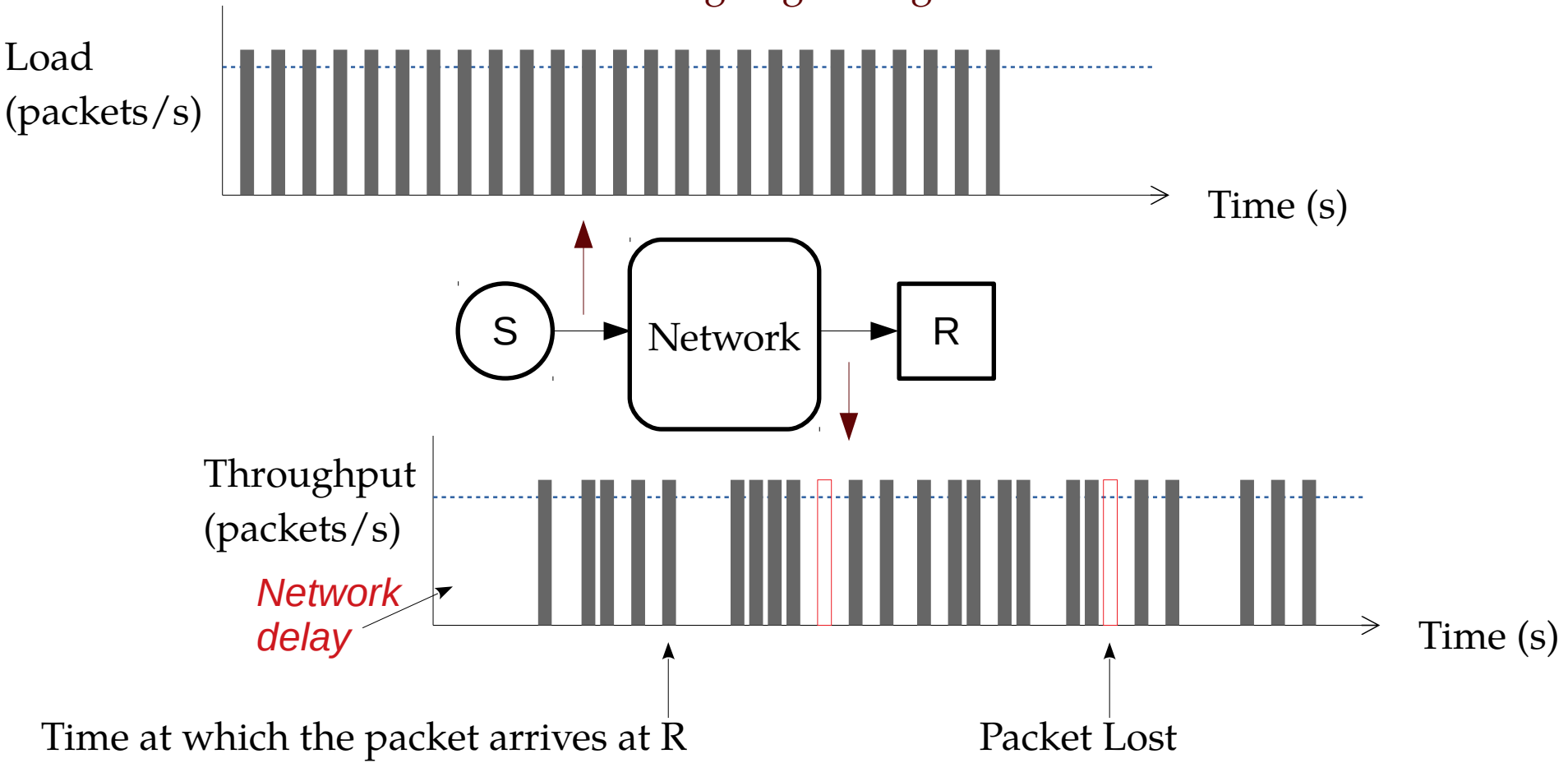
Example

- S generates a flow of traffic load **B = 10 Mbits/second**
- S generates packets of constant size **L = 8000 bits**
- The packet generation rate is **λ = B/L = 1250 packets/second**



Network effects

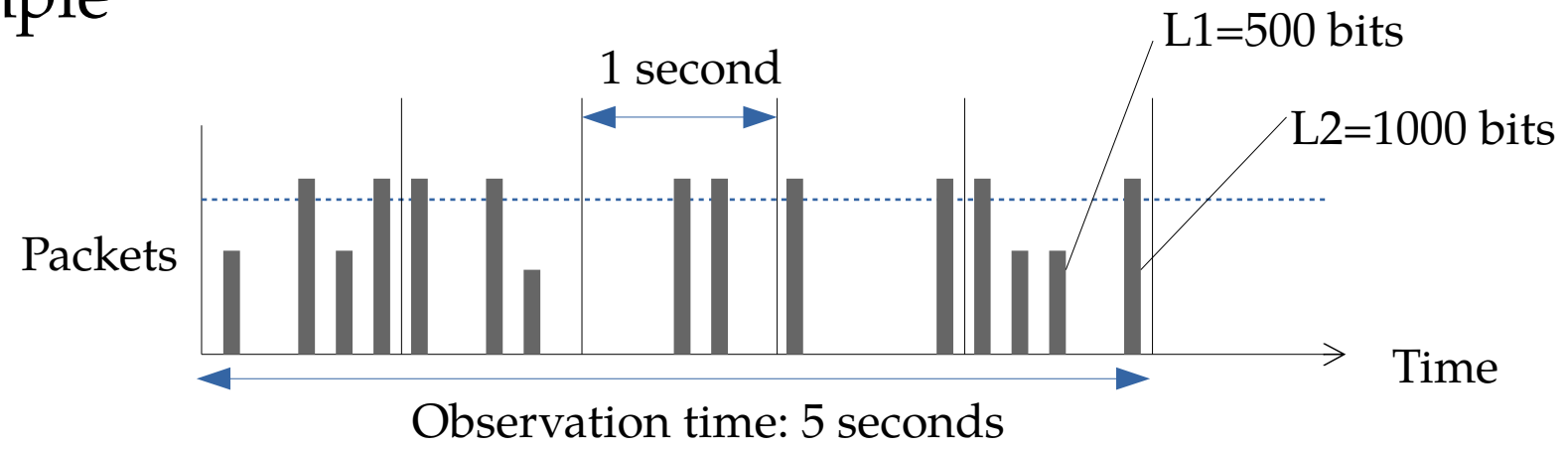
The network changes the shape of the traffic: a 'constant' load may become 'random' after going through the network.



Packet generation process: basic parameters

- The amount of bits / second may change with time (or not)
  - If it changes: variable; If not: constant
  - We usually work with the mean packet generation rate:
    - **λ [packets/second]**
- Packet of the same flow can have different sizes
  - If they change: variable; If not: constant
  - We usually work with the mean packet size:
    - **E[L] [bits]**

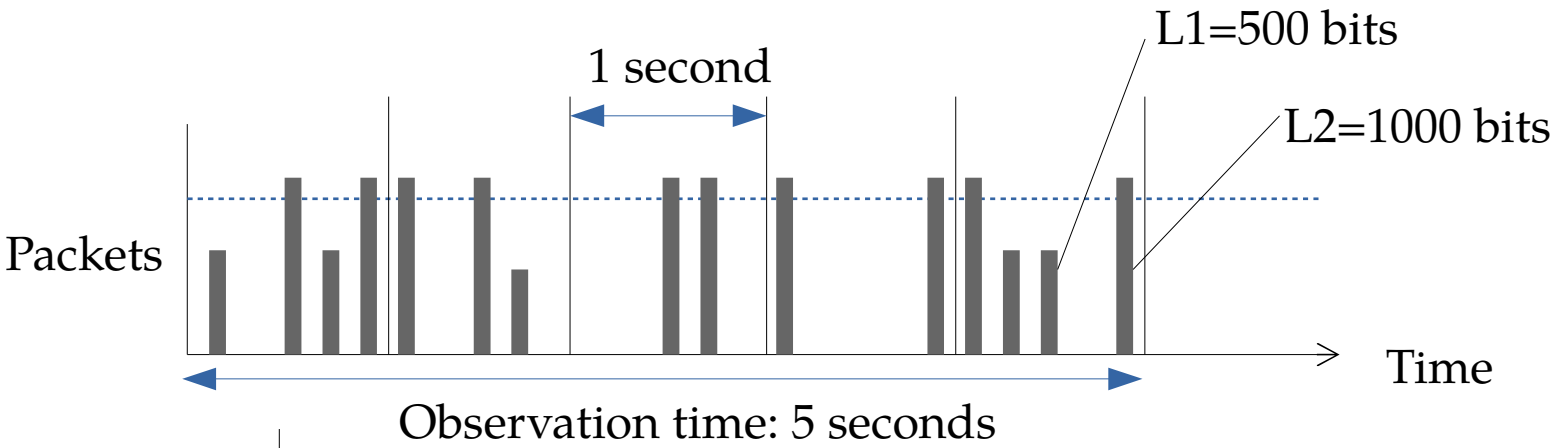
Example

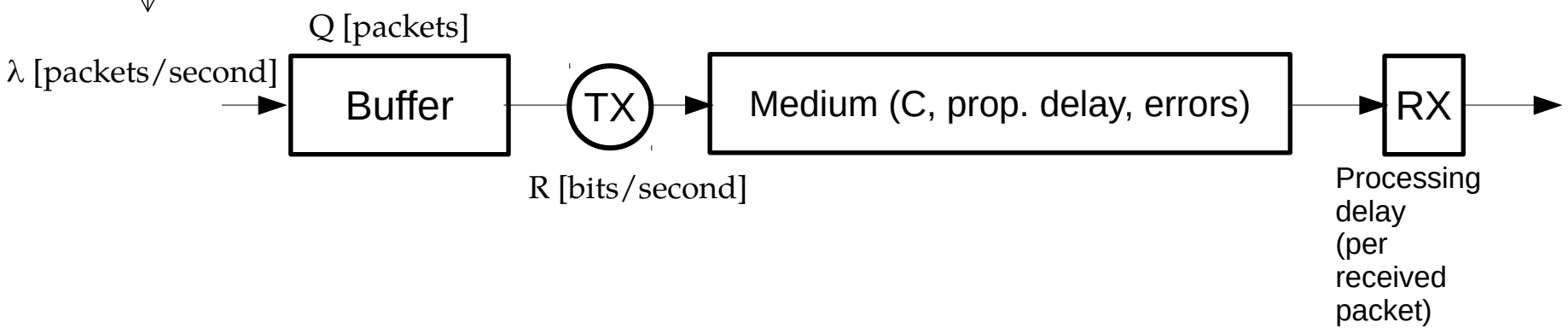


- The average packet generation rate is
  - **λ=(4+3+2+2+4)/5=3 packets/second**
- The average packet size is
  - **E[L] = (5·L1 + 10·L2)/15 = (5/15)·500 + (10/15)·1000 = 833.33 bits**

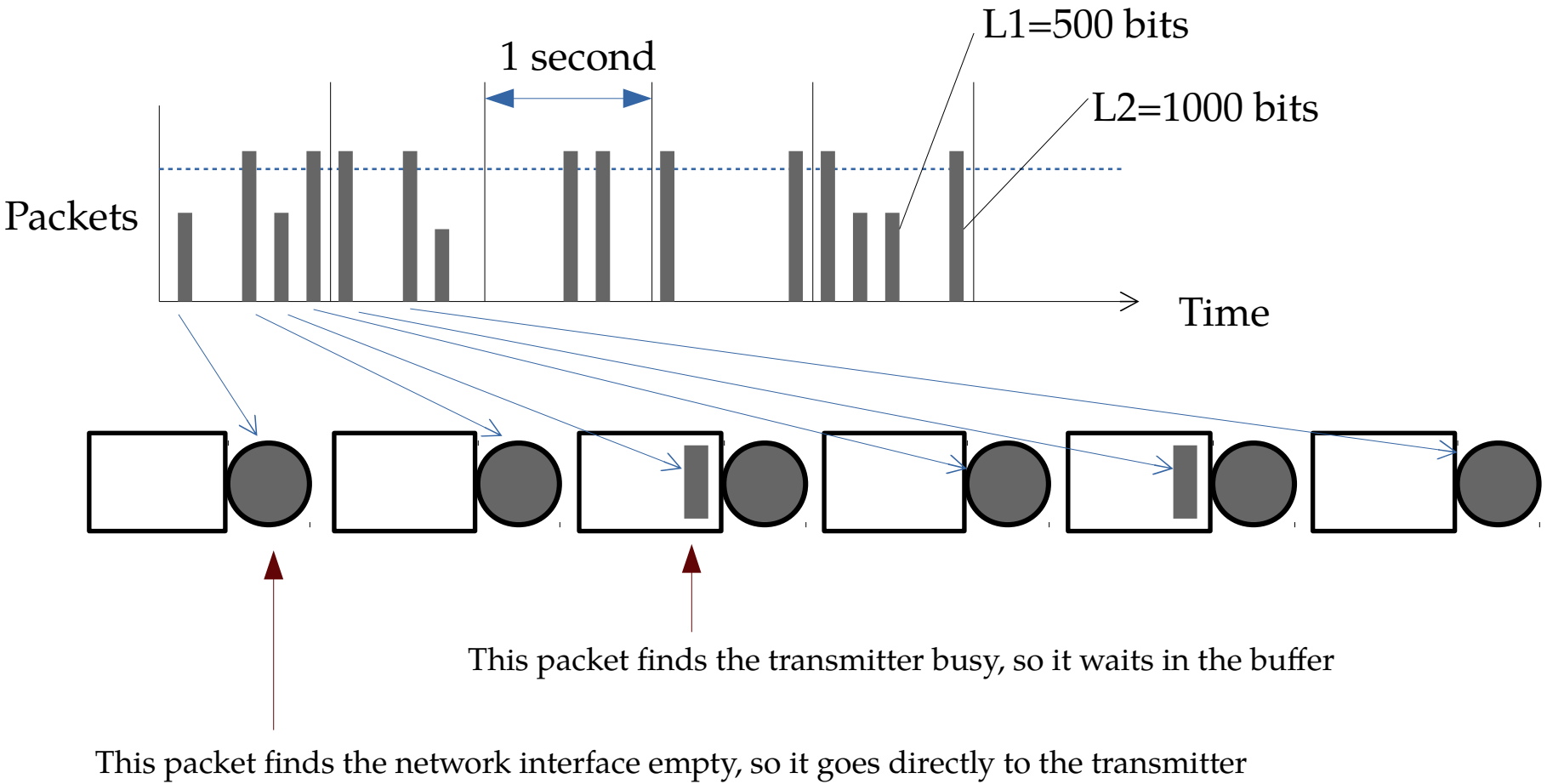
In this example the packet generation rate and the packet size are variable!

Link Model


1 second
L1=500 bits
L2=1000 bits
Packets
Time
Observation time: 5 seconds


Q [packets]
λ [packets/second]
Buffer
TX
Medium (C, prop. delay, errors)
RX
R [bits/second]
Processing delay (per received packet)

Queueing


L1=500 bits
1 second
L2=1000 bits
Packets
Time
This packet finds the transmitter busy, so it waits in the buffer
This packet finds the network interface empty, so it goes directly to the transmitter

An engineering problem

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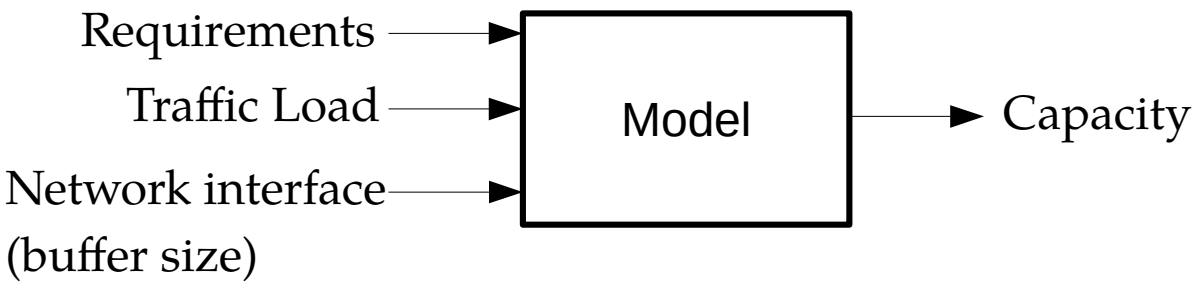
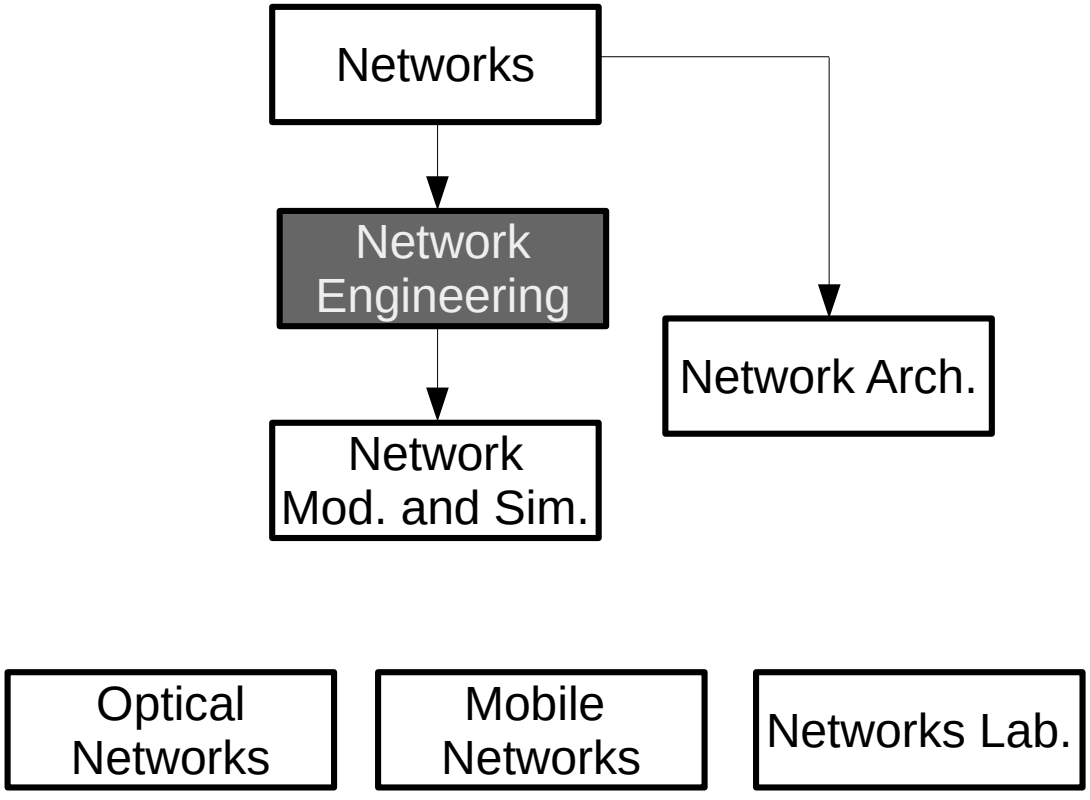
An engineering problem

- Once we get the system requirements in terms of packet delay and packet losses, such as:
  - Delay 100 ms, Packet losses < 0.001 (less than 1 packet of every 1000)
- … and the characteristics of the traffic load at the busy hour
  - Mean of 150 Mbps, Variance of 100 Mbps



We need tools (models) to predict network/system performance in the design phase

They must be accurate enough to be representative of the network /system performance once it is operating


Networks
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Network Arch.
Network Mod. and Sim.
Optical Networks
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