2. Traffic

Contents

Offered vs. carried traffic

- **Offered** traffic
  - traffic as it is originally generated in the sources
- **Carried** traffic
  - traffic as it is carried by the network

Characterisation of carried traffic

- Circuit-switched traffic
  - number of ongoing calls or active connections (erl)
  - may be converted into bit rate in digital systems
    - e.g. a telephone call reserves 64 kbps (= 8000*8 bps) in a PCM system
- Packet-switched traffic
  - bit stream (bps, kbps, Mbps, Gbps, …)
  - packet stream (pps)
  - number of active flows (erl)

Traffic units

- Telephone traffic:
  - **erlangs** (erl)
  - one erlang corresponds to one ongoing call or one occupied channel
- Data traffic:
  - **bits per second** (bps)
  - packets per second (pps)
- Note:
  - 1 byte = 8 bits
  - 1 kbps = 1 kbit/s = 1,000 bits per second
  - 1 Mbps = 1 Mbit/s = 1,000,000 bits per second
  - 1 Gbps = 1 Gbit/s = 1,000,000,000 bits per second

Traffic variations in different time scales (1)

- **Predictive** variations:
  - **Trend** (years)
    - traffic growth: due to
      - existing services (new users, new ways to use, new tariffs)
      - new services
  - Regular **year profile** (months)
  - Regular **week profile** (days)
  - Regular **day profile** (hours)
    - including “busy hour”
  - Variations caused by predictive (regular and irregular) **external events**
    - regular: e.g. Christmas day
    - irregular: e.g. televoting

Traffic variations in different time scales (2)

- **Non-predictive** variations:
  - **Short term random** variations (seconds - minutes)
    - random call arrivals
    - random call holding times
  - **Long term random** variations (hours - ...)
    - random deviations around the profiles
    - each day, week, month, etc. is different
  - Variations caused by non-predictive **external events**
    - e.g. earthquakes and other natural disasters
- Note:
  - Ordinary traffic theoretic models focus on **short term random variations**

Busy hour (1)

- For dimensioning,
  - an estimate of the traffic load is needed
- In telephone networks,
  - standard way is to use so called **busy hour** traffic for dimensioning

Busy hour ≈ the continuous 1-hour period for which the traffic volume is greatest

  - This is unambiguous only for a single day (let’s call it **daily peak hour**)
  - For dimensioning, however, we have to look at not only a single day but many more
- Different definitions for busy hour (covering several days) traffic have been proposed by ITU:
    - Average Daily Peak Hour (ADPH)
    - Time Consistent Busy Hour (TCBH)

Busy hour (2)

- Let
  - N = number of days during which measurements are done (e.g. $N = 10$)
  - $a_n(\Delta)$ = measured average traffic during 1-hour interval Δ of day n
  - $\max_\Delta a_n(\Delta)$ = daily peak hour traffic of day n
- Busy hour traffic a with different methods:

$$a_{\text{ADPH}} = \frac{1}{N}\sum_{n=1}^{N} \max_\Delta a_n(\Delta)$$

$$a_{\text{TCBH}} = \max_\Delta \frac{1}{N}\sum_{n=1}^{N} a_n(\Delta)$$

- Note that

$$a_{\text{TCBH}} \le a_{\text{ADPH}}$$

Demo: Funet

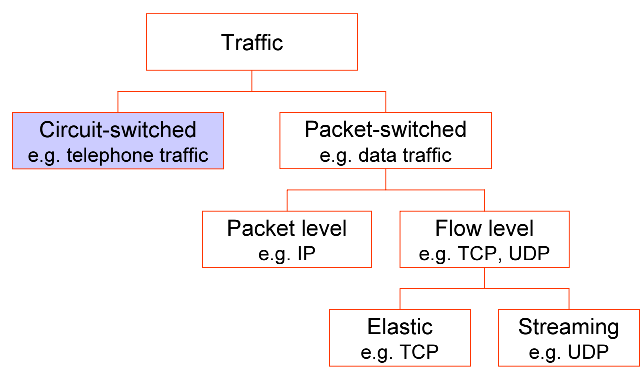
- Diurnal pattern, day profile
  - day vs. night
  - peak traffic, busy "hour"
  - changes in routing?
- Week profile
  - working days vs. weekend
- Month profile
  - special days: e.g. Christmas day
- Year profile
- Long-term trend?

http://www.csc.fi/suomi/funet/verkko.html.fi
http://www.csc.fi/suomi/funet/noc/looking-glass/wm

Contents

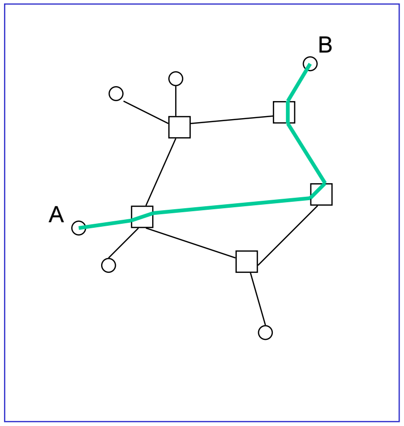
- Traffic characterisation
- Telephone traffic modelling
- Data traffic modelling at packet level
- Data traffic modelling at flow level

Traffic classification



Telephone network

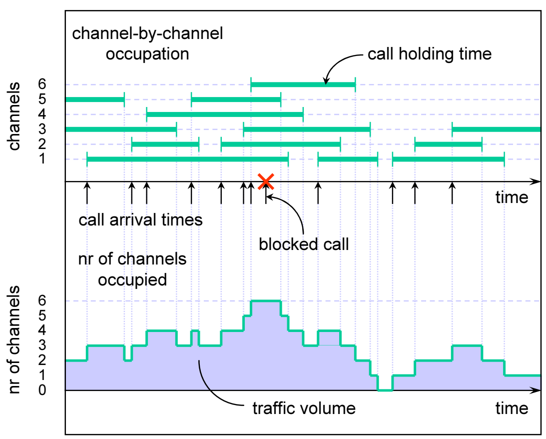
- Connection oriented:
  - connections set up end-to-end before information transfer
  - resources reserved for the whole duration of connection
  - if resources are not available, the call is blocked and lost
- Information transfer as continuous stream



Telephone traffic model

- Telephone traffic consists of **calls**
  - a call occupies one channel from each of the links along its route
  - call characterisation: **holding time** (in time units)
- Modelling of offered traffic:
  - **call arrival process** (at which moments new calls arrive)
  - **holding time distribution** (how long they take)
- Link model: a pure **loss system**
  - a server corresponds to a channel
  - the service rate μ depends on the **average holding time**
  - the number of servers, n, depends on the **link capacity**
  - when all channels are occupied, **call admission control** rejects new calls so that they will be blocked and lost
- Modelling of carried traffic:
  - **traffic process** tells the number of ongoing calls = the number of occupied channels

Traffic process



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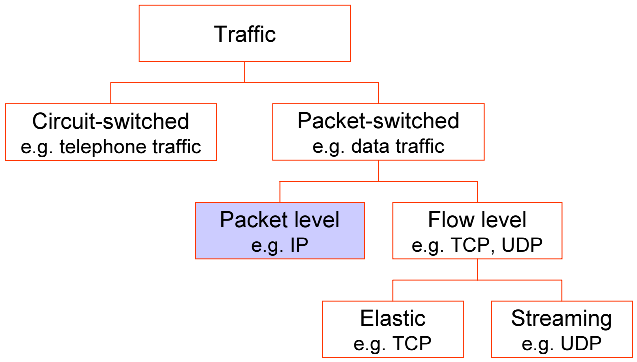
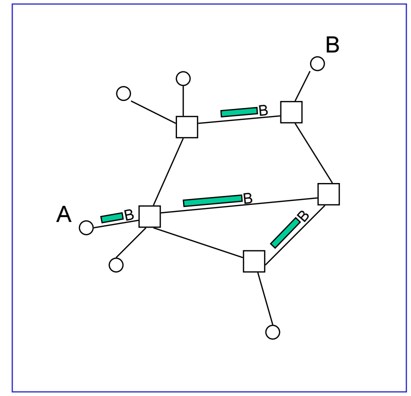
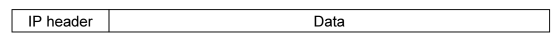


Network layer in IP networks

- **IP** = Internet Protocol
- Connectionless:
  - no connection establishment
  - no resource reservations
- Information transfer as discrete packets
- **Best Effort** service paradigm
  - Network nodes (routers) forward packets "as well as possible"
  - Packets may be lost, delayed or their order may change
    $\Rightarrow$ "intelligence" should be implemented at the edge nodes or terminals

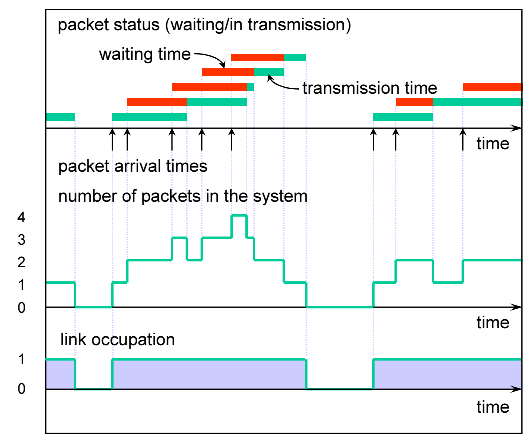




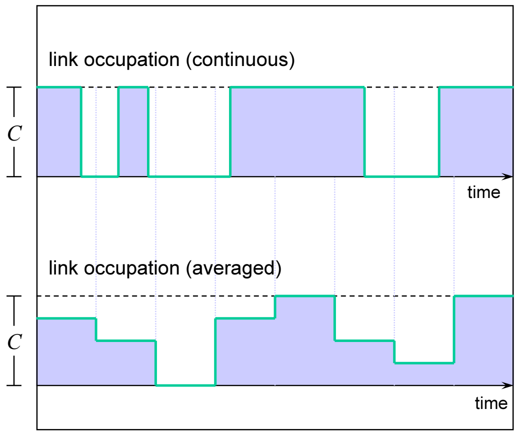
Packet level model of data traffic

- Data traffic consists of **packets**
  - packets compete with each other for the processing and transmission resources (statistical multiplexing)
  - packet characterisation: **length** (in data units)
- Modelling of offered traffic:
  - **packet arrival process** (at which moments new packets arrive)
  - **packet length distribution** (how long they are)
- Link model: a **single server queueing system**
  - the service rate μ depends on the **link capacity** and the **average packet length**
  - when the link is busy, new packets are buffered, if possible, otherwise they are lost
- Modelling of carried traffic:
  - **traffic process** tells the number of packets in the system (including both the packet in transmission and the packets waiting in the buffer)

Packet level traffic process (1)



Packet level traffic process (2)



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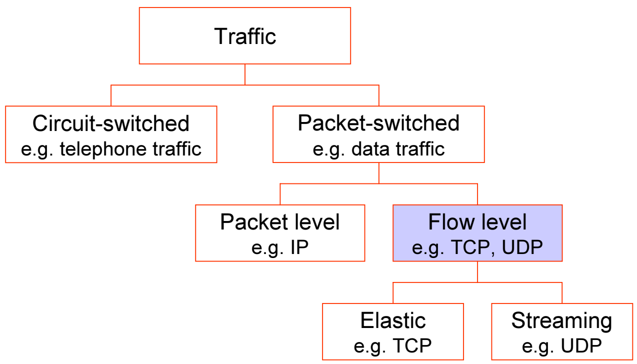
Traffic classification



Transport layer in IP networks

- On top of the network layer (IP) there is the **transport layer**
  - takes care of handling the IP packets in the terminals
  - operates **end-to-end**
- Transport layer protocols:
  - **TCP** = Transmission Control Protocol
    - transmission rate adapts to traffic conditions in the network by a congestion control mechanism
    - suitable for non-real time (elastic) traffic, such as transfers of digital documents
  - **UDP** = User Datagram Protocol
    - transmission rate independent of traffic conditions in the network
    - suitable for transactions (interactive traffic with short transfers)
    - used also for real time (streaming) traffic with the help of upper layer protocols, such as RTP

TCP

- **TCP** = Transmission Control Protocol
  - **connection oriented** end-to-end transmission layer protocol
  - for a reliable byte stream transfer on top of IP
    - the delivery of packets in the right order is checked using acknowledgements and retransmissions
  - Protocol specific flow and congestion control mechanisms for traffic control
    - based on the use of an **adaptive sliding window**
  - **flow control**: prevents over flooding the receiver
    - the receiver tells who many bytes it can receive
  - **congestion control**: prevents over flooding the network
    - the transmitter has to find out when the network is congested
    - a **packet loss** indicates congestion: when a packet is lost, the window is decreased, otherwise gradually increased (to detect the network state)

IP header	TCP header	Data

UDP

- **UDP** = User Datagram Protocol
  - **connectionless** end-to-end transmission layer protocol
  - on top of IP, but only for multiplexing
  - no guarantees of packet transfer (unreliable)
  - no flow control: may overload the receiver
  - no congestion control: may overload the network

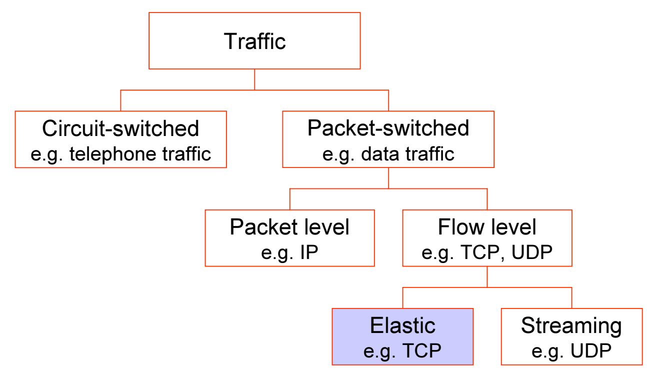
IP header	UDP header	Data

Data traffic at flow level

- In a longer time scale, data traffic may be thought to consist of **flows**
  - A single flow is described as a **continuous bit stream** with a possibly varying rate (and not as discrete packets)

- Flow classification:
  - **Elastic flows**
    - transmission rate adapts to traffic conditions in the network by a congestion control mechanism
    - e.g. transfers of digital documents (HTTP,FTP,...) using **TCP**
  - **Streaming flows**
    - transmission rate independent of traffic conditions in the network
    - e.g. real time voice, audio and video transmissions using **UDP**

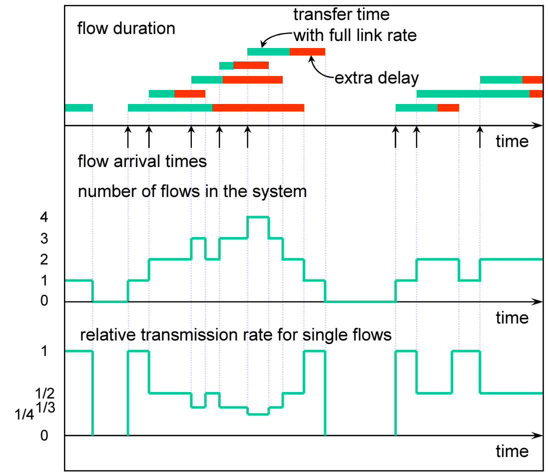
Traffic classification



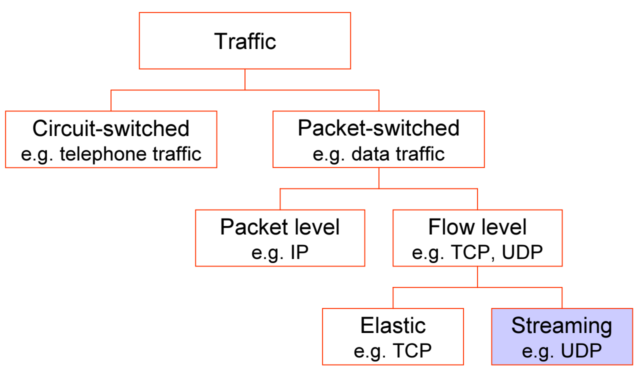
Flow level model of elastic traffic

- Elastic traffic consists of adaptive TCP **flows**
  - flow characterisation: **size** (in data units)
  - the transfer rate and the duration of an elastic flow are not fixed but depend on the network state dynamically
- Modelling of offered traffic:
  - **flow arrival process** (at which moments new flows arrive)
  - **flow size distribution** (how large they are)
- Link model: a **sharing system**
  - due to lack of admission control, no flows are rejected
  - the service rate μ depends on the **link capacity** and the **average flow size**
  - in the model, the adaptation of the transmission rate is immediate, and the link capacity is shared evenly (fairly) among all competing flows
- Modelling of carried traffic:
  - **traffic process** tells the number of flows in the system

Flow level traffic process for elastic flows



Traffic classification



Streaming traffic classification

- **CBR** = constant bit rate
  - e.g. CBR coded voice/audio/video
  - packet level: fixed size packets generated regularly with uniform intervals
  - flow level: constant rate bit stream
  - flow characterisation: **bit rate** and **duration**
- **VBR** = variable bit rate
  - esim: VBR coded voice/audio/video
  - packet level: variable size packets generated irregularly
  - flow level: variable rate bit stream
  - flow characterisation: **bit rate as a function of time**

Flow level model of streaming CBR traffic

- Streaming CBR traffic consists of UDP flows with constant bit rate
  - flow characterisation: **bit rate** and **duration**
- Modelling of offered traffic:
  - **flow arrival process** (at which moments new flows arrive)
  - **flow duration distribution** (how long they last)
- Link model: an **infinite system**
  - due to lack of admission control, no flows are rejected
  - the service rate μ depends on the **average flow duration**
  - transmission rate and flow duration are insensitive to the network state
  - no buffering in the flow level model: when the total transmission rate of the flows exceeds the link capacity, bits are lost (uniformly from all flows)
- Modelling of carried traffic:
  - **traffic process** tells the number of flows in the system, and, as well, the total bit rate

Flow level traffic process for streaming CBR flows