

2. Traffic

Contents

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

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** \approx 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

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

Demo: Funet

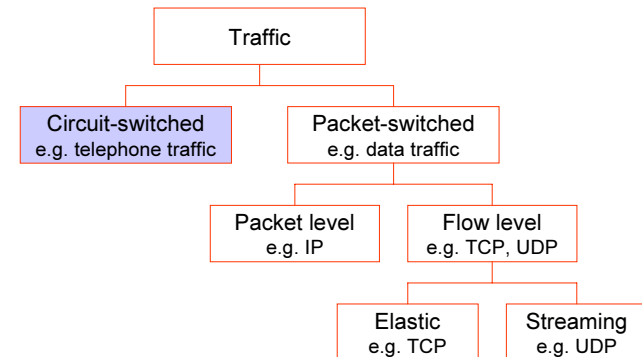
- Diurnal pattern, day profile
 - day vs. night
 - peak traffic, busy "hour"
 - changes in routing?
- Week profile
 - working days vs. weekend
- Month profile
 - special days: e.g. Christmas day
- Year profile
- Long-term trend?

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

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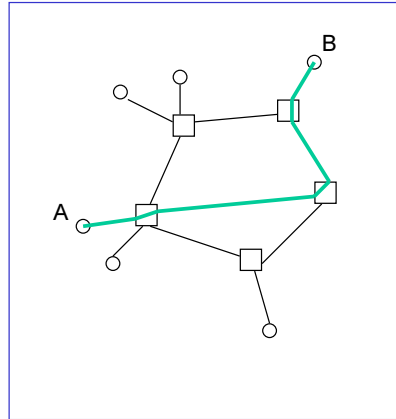
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Traffic classification



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**



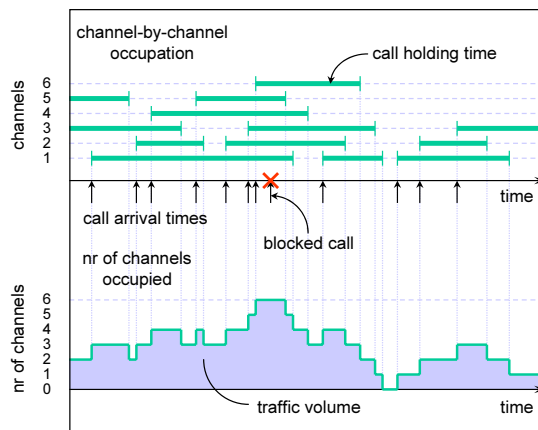
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Telephone traffic model

- **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

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Traffic process



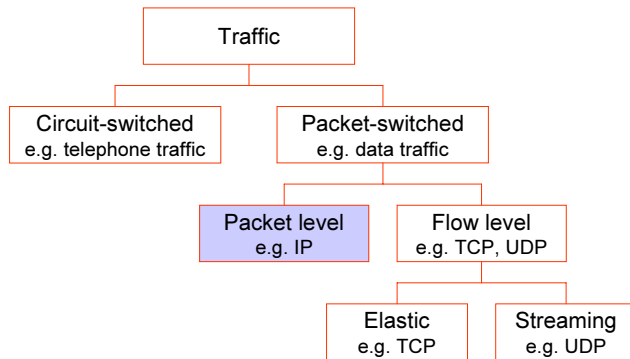
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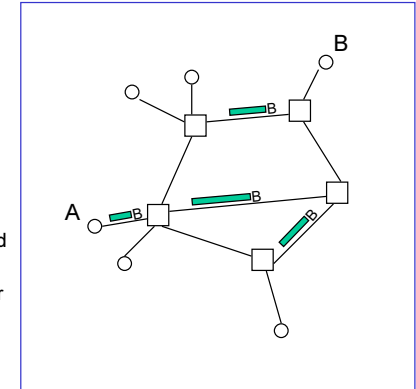
Traffic classification



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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
⇒ "intelligence" should be implemented at the edge nodes or terminals



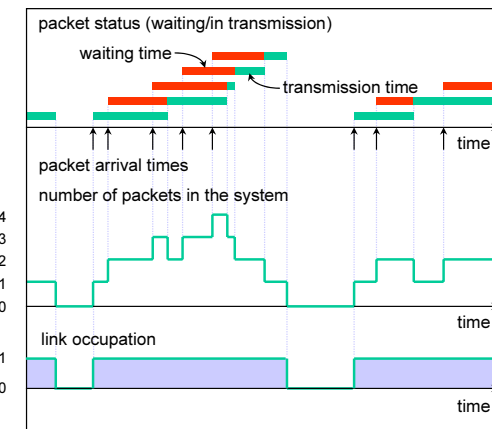
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Packet level model of data traffic

- 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)

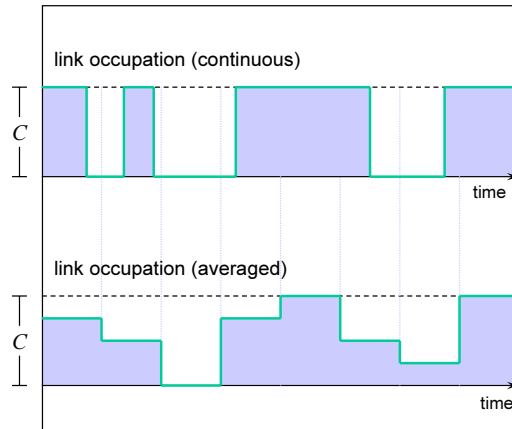
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Packet level traffic process (1)



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Packet level traffic process (2)



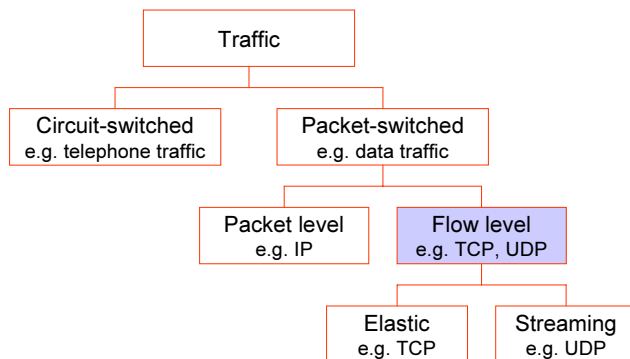
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Traffic classification



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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

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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)



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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



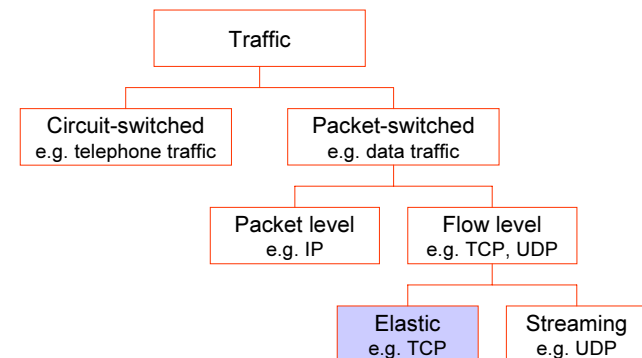
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Data traffic at flow level

- 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**

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Traffic classification



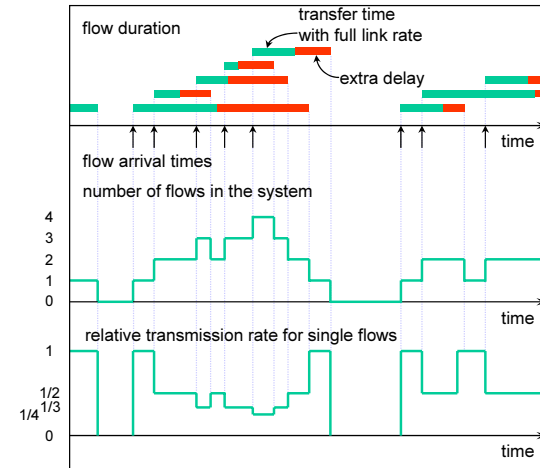
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Flow level model of elastic traffic

- 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

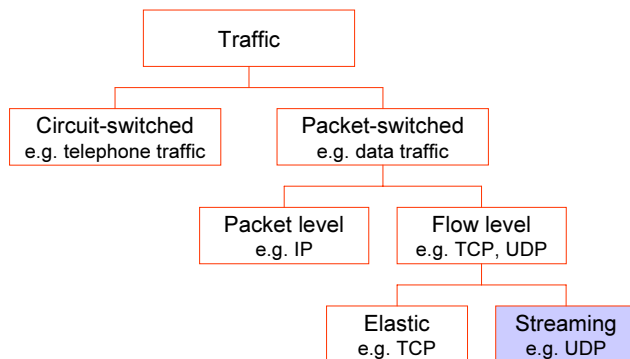
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Flow level traffic process for elastic flows



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Traffic classification



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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**

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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

