A Quantitative View: Delay, Throughput, Loss

Antonio Carzaniga

Faculty of Informatics
University of Lugano

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Outline

- Quantitative analysis of data transfer concepts for network applications
- Propagation delay and transmission rate
- Multi-hop scenario

Quantifying Data Transfer

- How do we measure the “speed” and “capacity” of a network connection?

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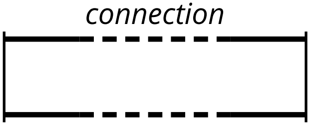
- ***Delay*** or ***Latency***
  - the time it takes for *one bit* to go through the connection (from one end to the other)

- ***Transmission rate*** or ***Throughput***
  - the amount of information that can get into (or out of) the connection in a time unit

Delay (Latency) and Rate (Throughput)



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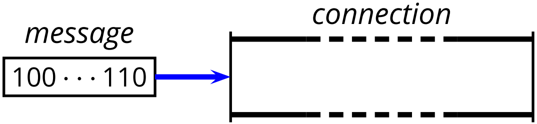

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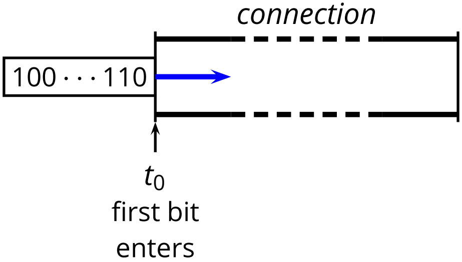

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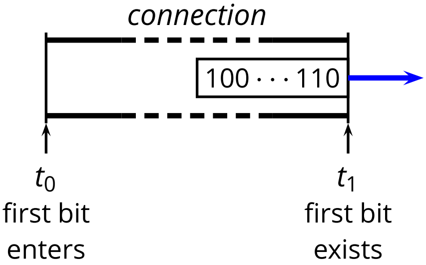

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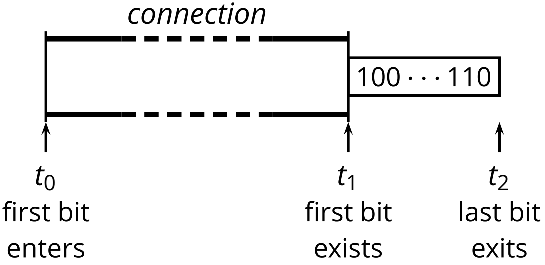

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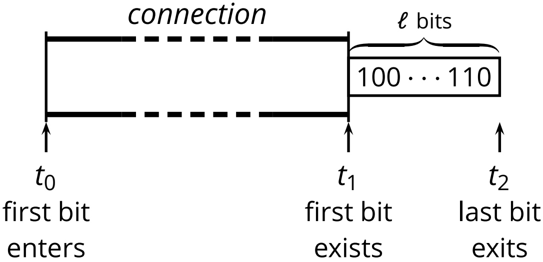

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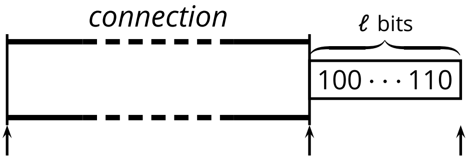

connection

ℓ bits

100 · · · 110

t_0
first bit
enters

t_1
first bit
exists

t_2
last bit
exits

Propagation ***Delay*** $d_{prop} = t_1 - t_0$ sec

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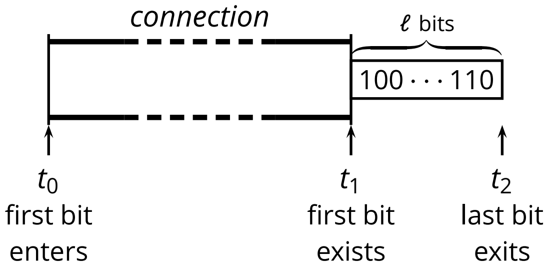

Propagation ***Delay***	$d_{prop} = t_1 - t_0$	sec
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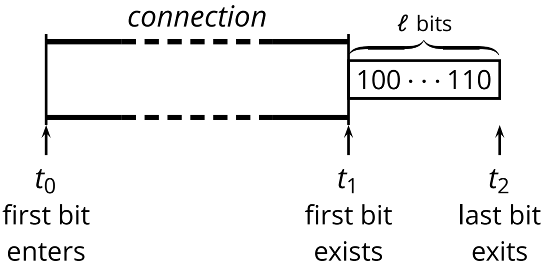

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Total transfer time	$d_{end\text{-}end} = d + \dfrac{\ell}{R}$	sec

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  E.g., a (short) e-mail message

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\ell &= 4\text{Kb} \\
d_{prop} &= 500\text{ms} \\
R &= 1\text{Mb/s} \\
d_{end\text{-}end} &= 500\text{ms} + 4\text{ms} = 504\text{ms}
\end{aligned}
$$

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If you need to transfer a couple of SSD cards from Lugano to Zürich, and time is crucial… then you might be better off riding your Vespa to Zürich rather than using the Internet.

For more than 5 cards, you might also prefer the Post office!

Two Hops, Stream

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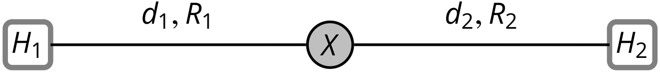

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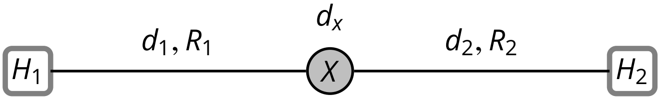

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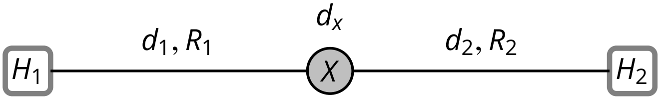

$(R_1 < R_2)$ $\quad d_{end\text{-}end} \quad = d_1 + \frac{\ell}{R_1}$

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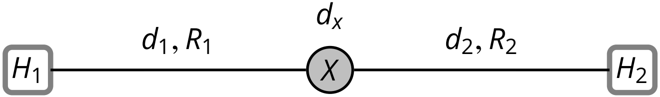

$$(R_1 < R_2) \qquad d_{end\text{-}end} \qquad\qquad = d_1 + \frac{\ell}{R_1} + d_x$$

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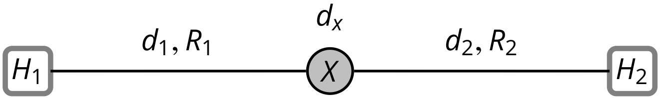

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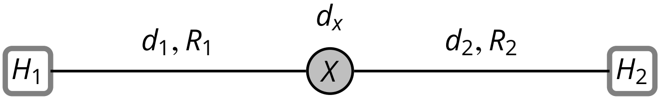

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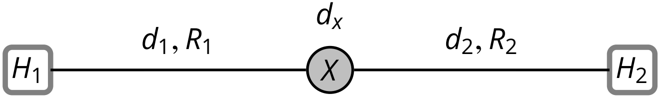

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$$d_{end\text{-}end} = d_1 + d_x + d_2 + \frac{\ell}{\min\{R_1, R_2\}} \qquad \text{sec}$$

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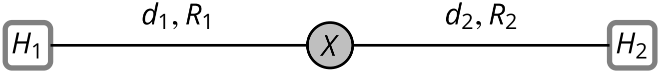

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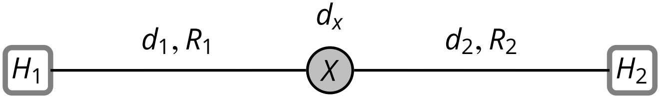

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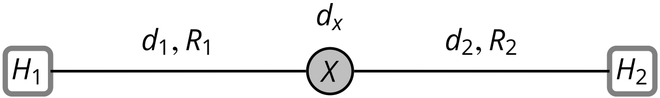

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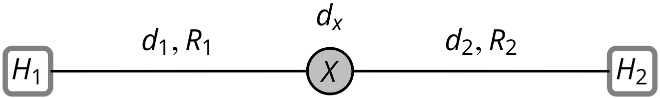

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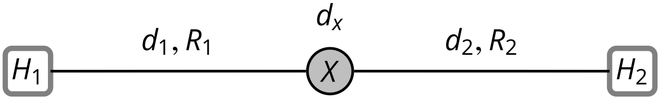

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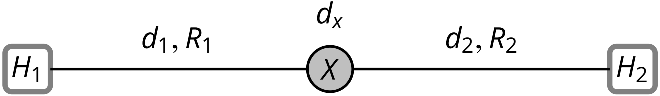

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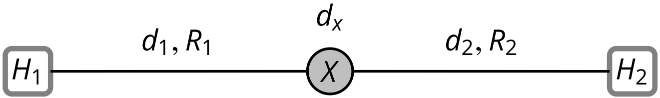

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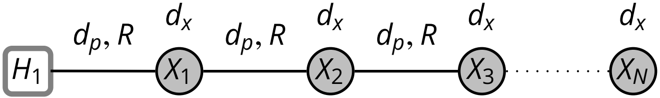

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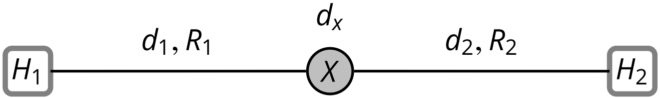

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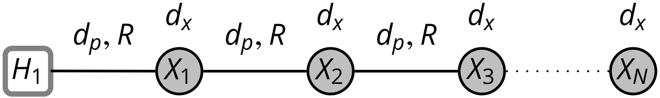

$$d_{end\text{-}end} = N\left(d_p + \frac{\ell}{R} + d_x\right)$$

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What happens with an arrival rate $\lambda_{in} > R_x$?

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$\ldots R_x$ is also the rate at which packets get out of the queue

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- ***Extreme case:*** constant input data rate

$$\lambda_{in} > R_x$$

In this case $|q| = (\lambda_{in} - R_x)t$ and therefore

$$d_{queue} = \frac{\lambda_{in} - R_x}{R_x}t$$

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- Steady-state queuing delay

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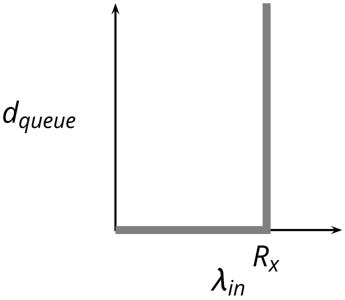

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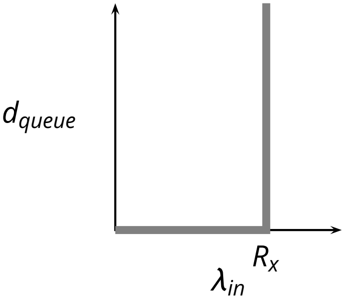

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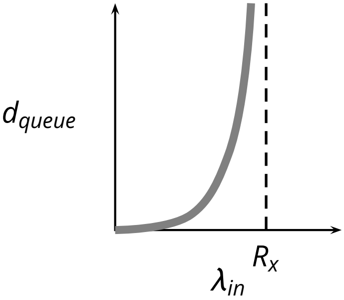

realistic input flow
λ_{in} variable

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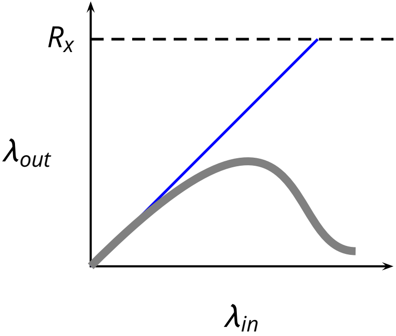

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