A Quantitative View: Delay, Throughput, Loss

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September 26, 2018

Outline

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

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

Quantifying Data Transfer

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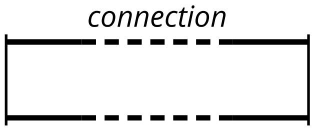
- ***Delay*** or ***Latency***
  - the time it takes for *one bit* to go through the connection (from one end to the other)
- ***Transmission rate*** or ***Throughput***
  - the amount of information that can get into (or out of) the connection in a time unit

Delay (Latency) and Rate (Throughput)



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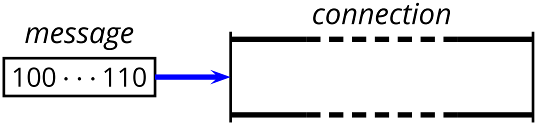

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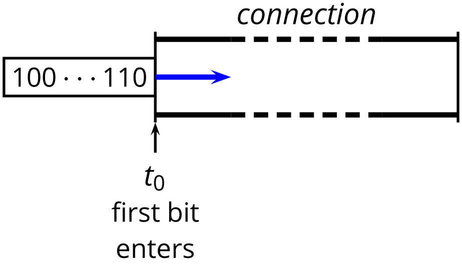

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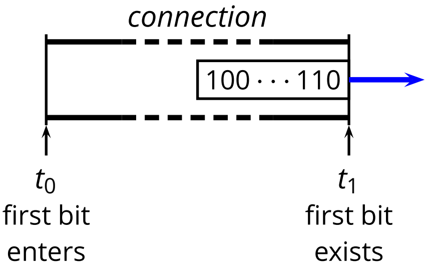

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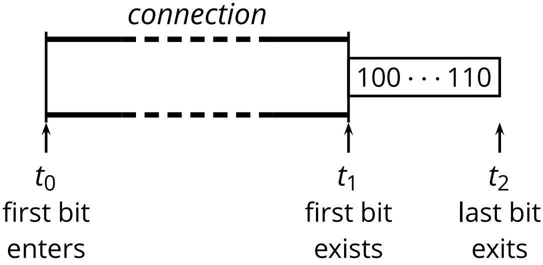

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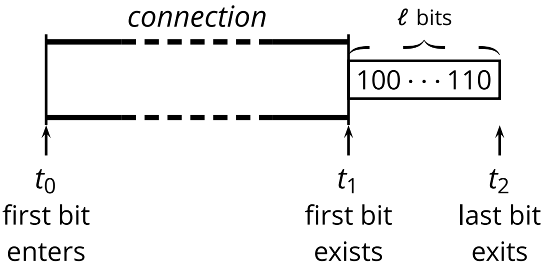

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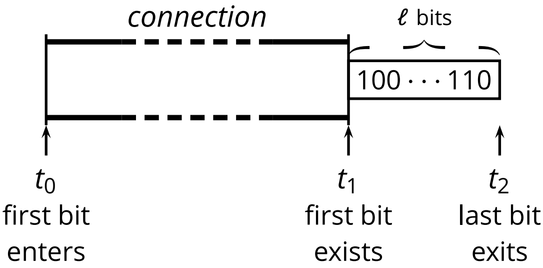

Propagation ***Delay*** $d_{prop} = t_1 - t_0$ sec

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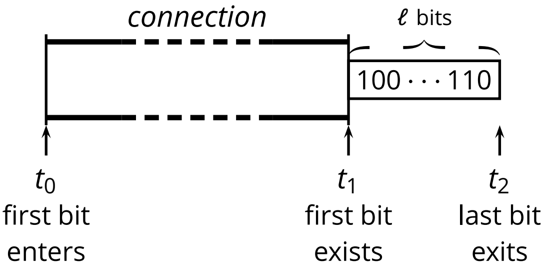

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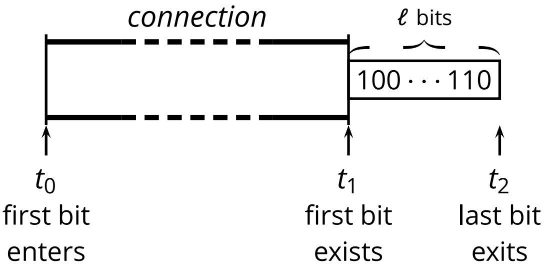

Propagation ***Delay***	$d_{prop} = t_1 - t_0$	sec
Transmission ***Rate***	$R = \dfrac{\ell}{t_2 - t_1}$	bits/sec
Total transfer time	$d_{end\text{-}end} = d + \dfrac{\ell}{R}$	sec

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

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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!

Store-And-Forward Delay

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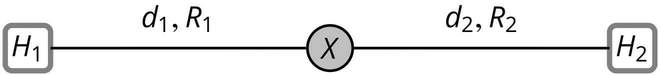

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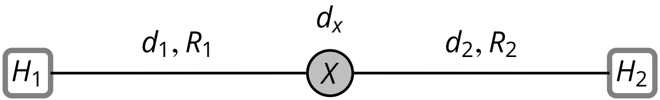

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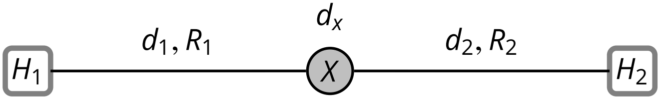

$$d_{end\text{-}end} = d_1 + \frac{\ell}{R_1}$$

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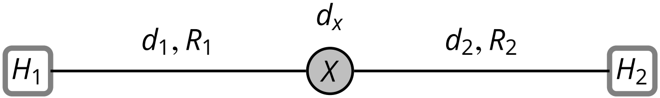

$$d_{end\text{-}end} = d_1 + \frac{\ell}{R_1} + d_x$$

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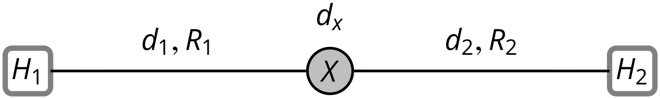

$$d_{\textit{end-end}} = d_1 + \frac{\ell}{R_1} + d_x + \frac{\ell}{R_2}$$

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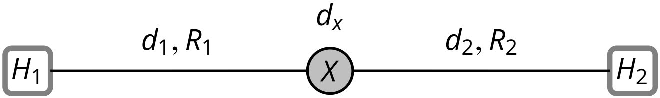

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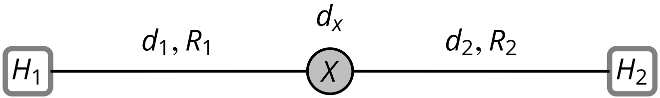

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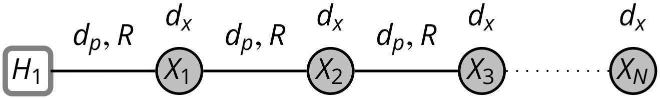

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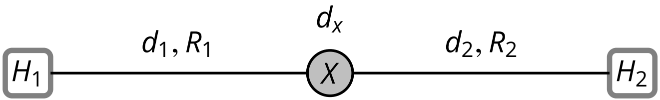

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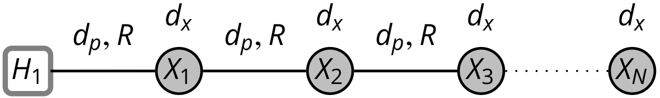

$$d_{end\text{-}end} = N\left(d_p + \frac{\ell}{R} + d_x\right)$$

End-toEnd Throughput

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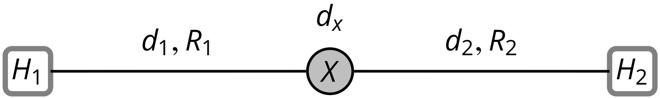

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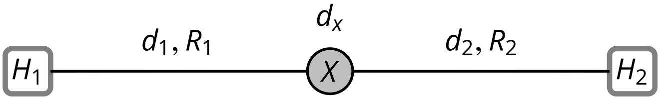
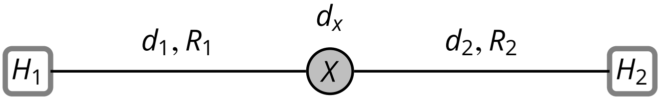


$$R_{end\text{-}end} =$$

End-toEnd Throughput



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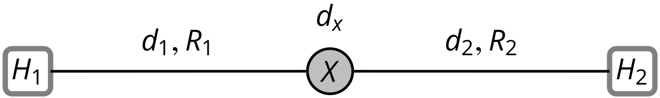

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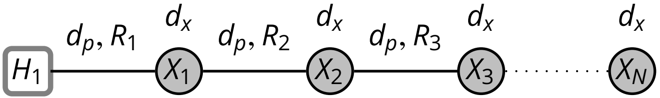

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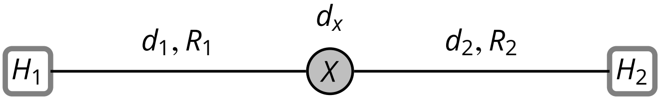

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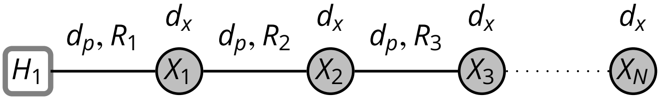

$$R_{end\text{-}end} = \min\{R_1, R_2, \ldots, R_N\}$$

Processing and Queuing Delays

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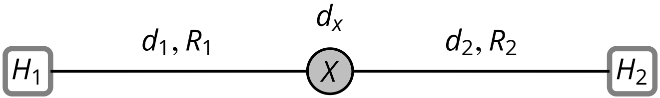

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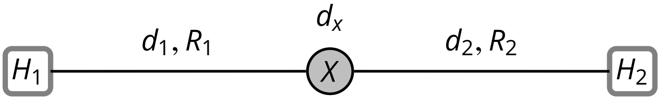

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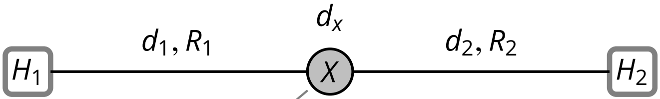

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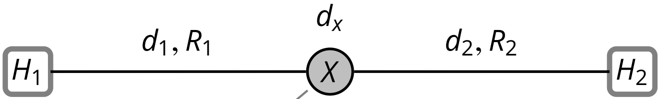

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queue length

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

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$$\lambda_{in} < R_x$$

In this case the $d_{queue} = 0$, because $|q| = 0$

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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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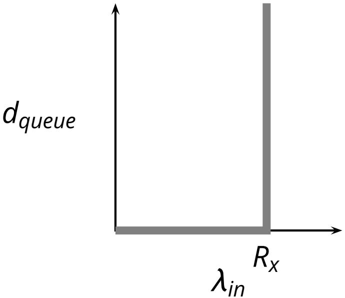

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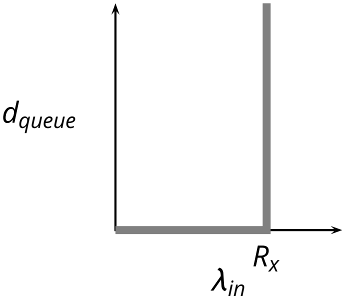

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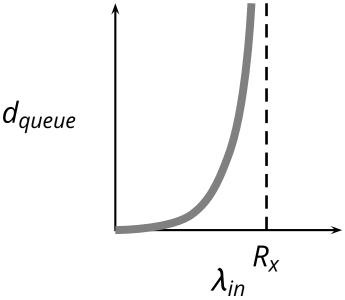

realistic input flow
λ_{in} variable

Queuing Delay

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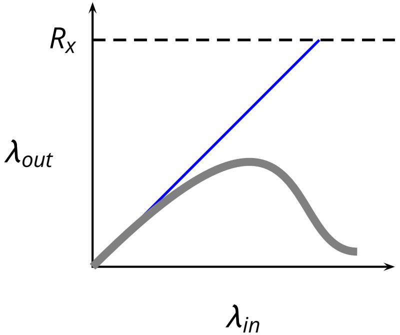

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