Best effort network
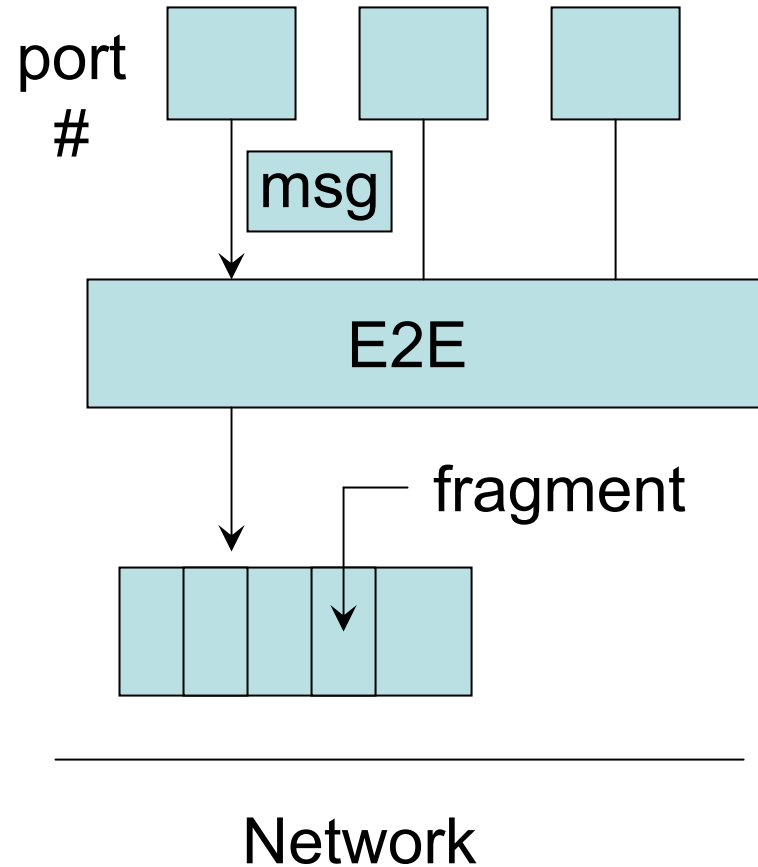
- Losses ⟵
- Reordering
- Delays / Congestion

E2E Layer

- Multiplexing

- Fragmentation

- Delays / Congestion

Stream →
loss-free, in-order

port
#

msg

E2E

fragment

Network

Loss

"At least once" delivery
"At most once" ➔ "exactly once"

At least once
    Acknowledgement (ACK) → Nonce

Setting Timers

Q: how long to wait?

timeout = $\underline{RTT}$ + slop

EWMA

Samples of RTTs $S_1, \dots, S_{new}$

$$rtt \leftarrow (1 - \alpha)\, S_{new} + \alpha \cdot rtt$$

slop = $\beta \cdot$ var $0 \leq \alpha \leq 1$

$\quad\quad\quad\quad\quad \hookrightarrow$ diff between predicted and actual RTT

At most once

Suppress duplicates

Tombstones

Exactly once

"Lock step"

$$\text{tput} = \frac{512 \text{ bytes}}{100 \text{ ms}} \approx 50 \text{ kbits/sec}$$

Performance prob. Multiple overlapping xmissions

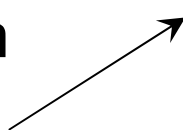# Flow Control

Receiver driven

Fixed <u>windows</u>

Sliding windows

how much data the receiver
can accept at one time

Pick window size

small windows ➔ underutilization

how big is window?

window size ≥ <u>rate</u> x <u>rtt</u>