CS 352
Demultiplexing; UDP

Lecture 10

http://www.cs.rutgers.edu/~sn624/352-F22

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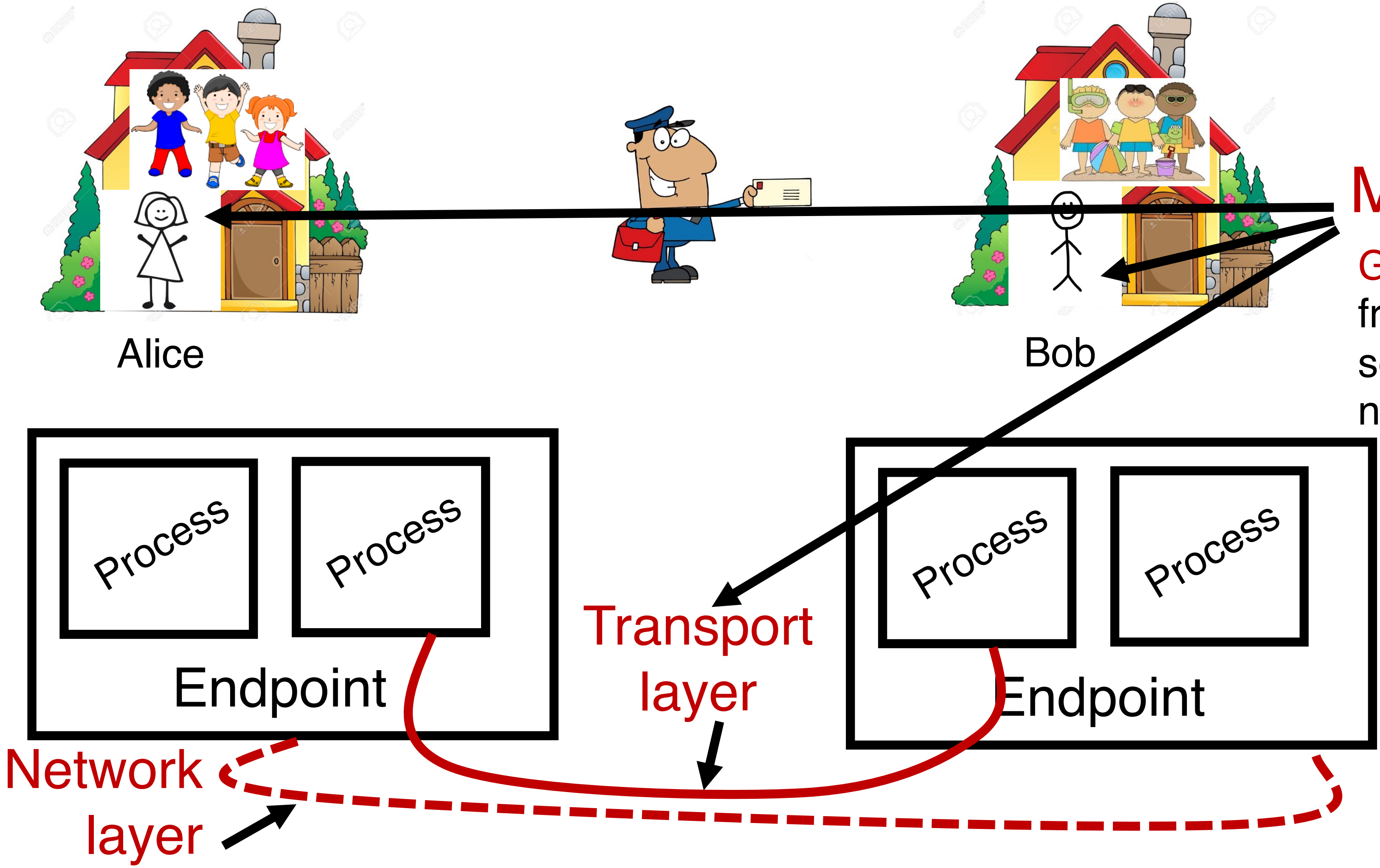
Recap of Concepts



Multiplex & Demultiplex

Gather messages from processes to send into the network.

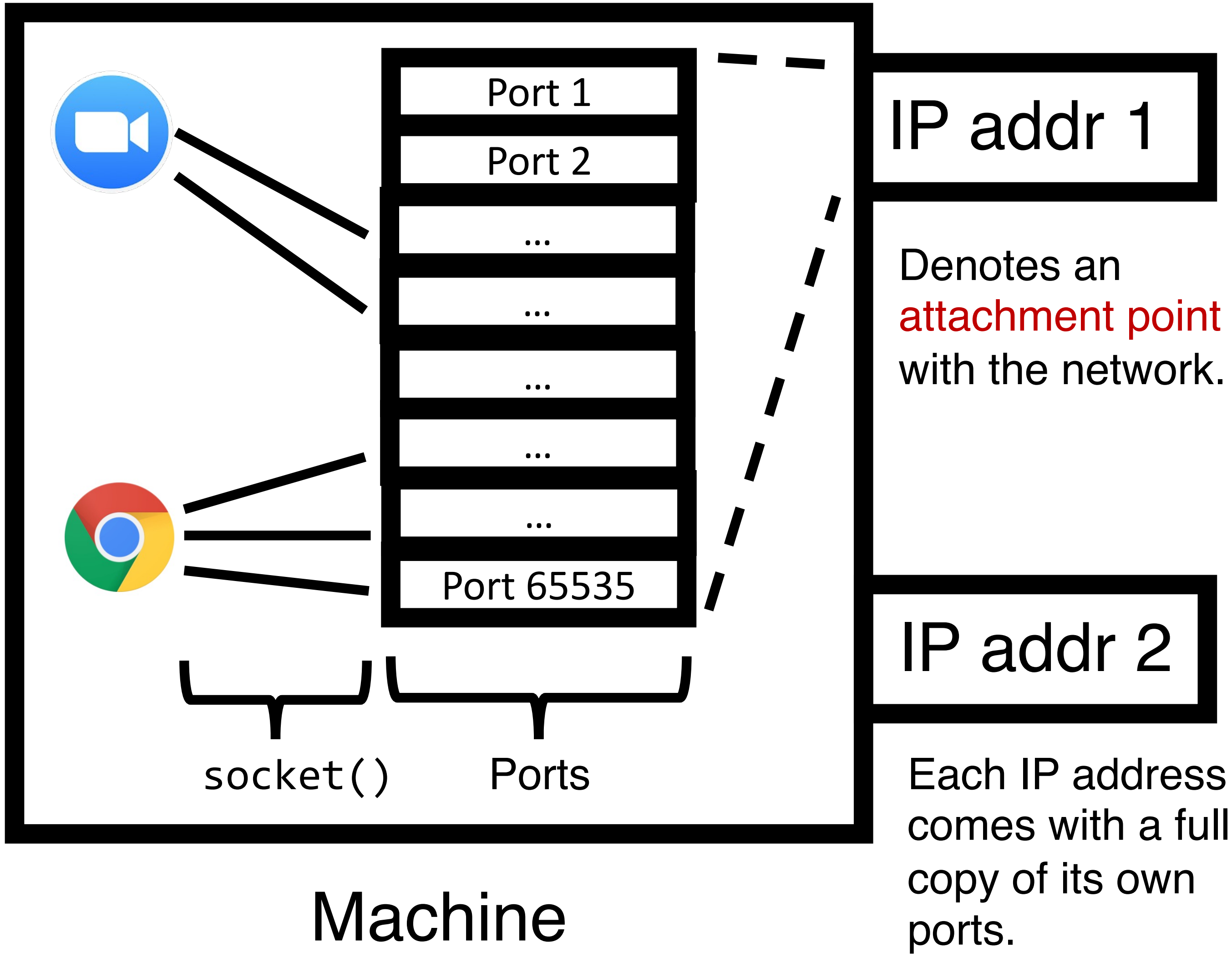
Distribute messages from the network to the processes.

UDP Simple wrapper around packet delivery

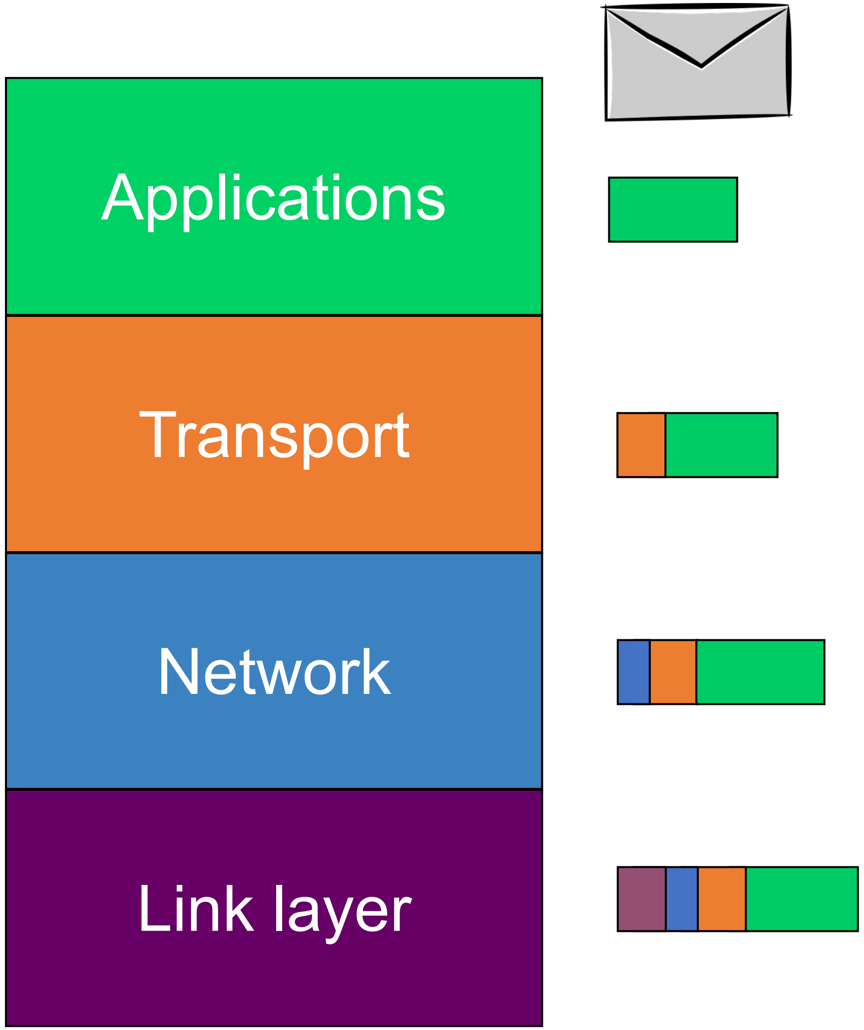
TCP Delivery guarantees: reliability, ordering, efficient & fair bandwidth use

Demultiplexing Packets

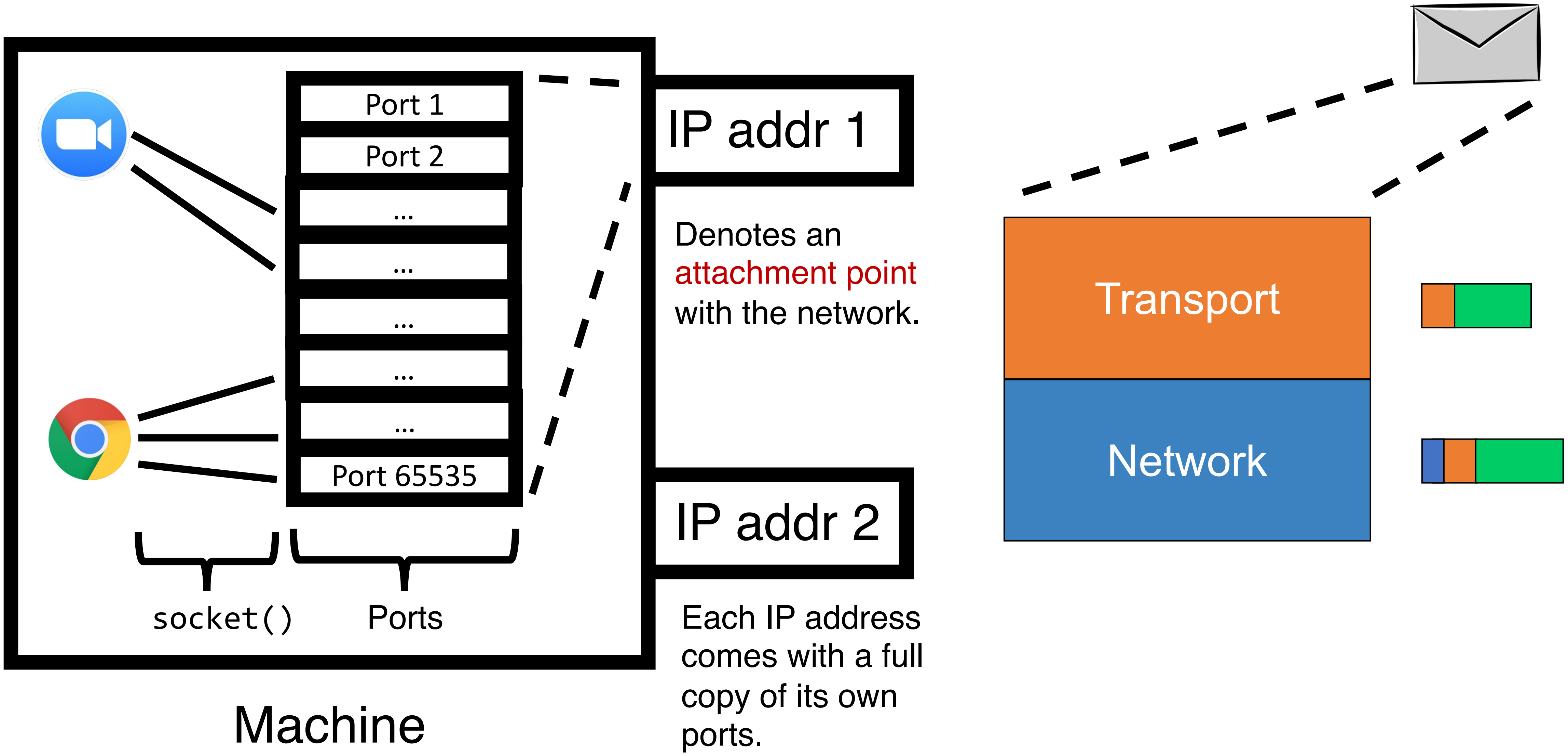
Demultiplexing



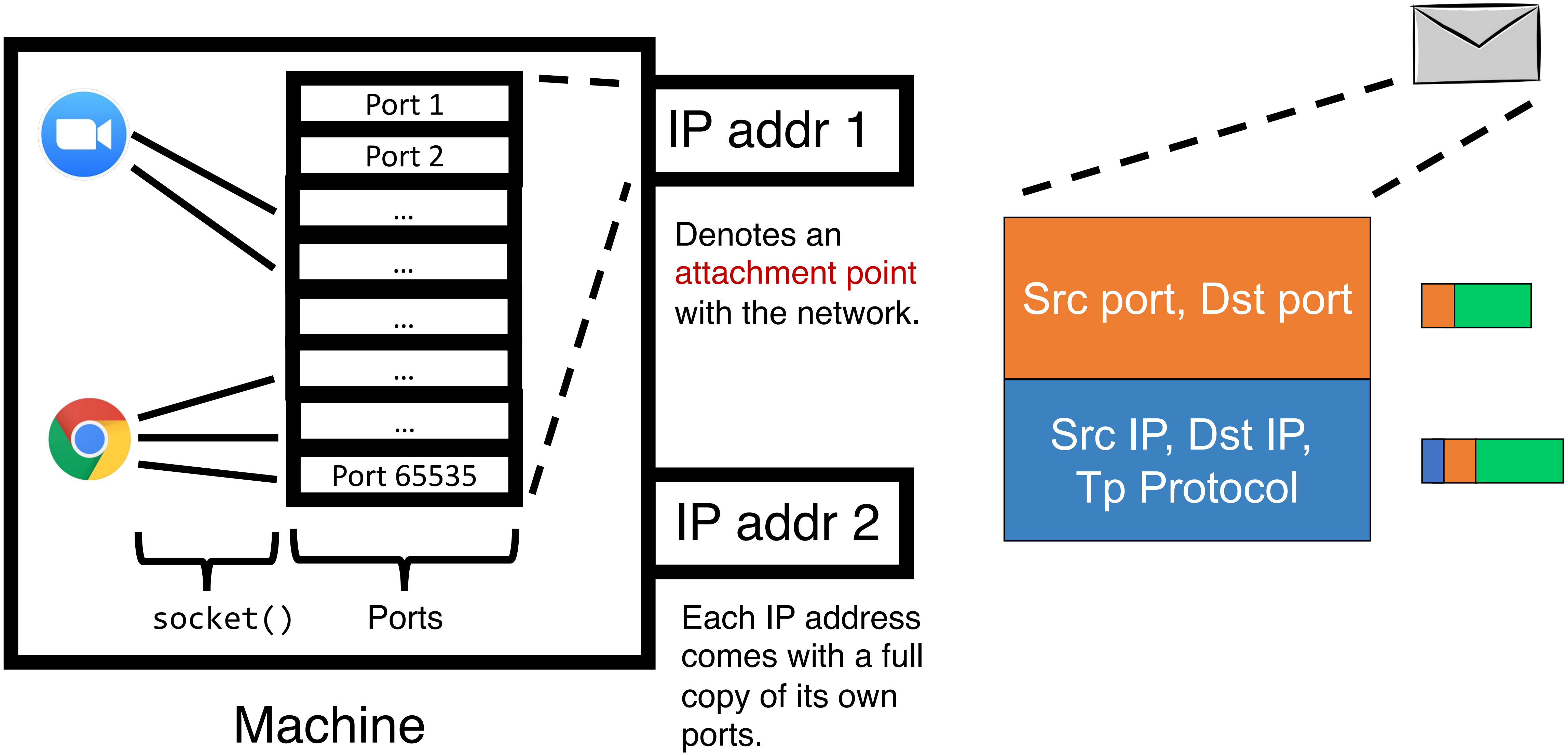
Machine



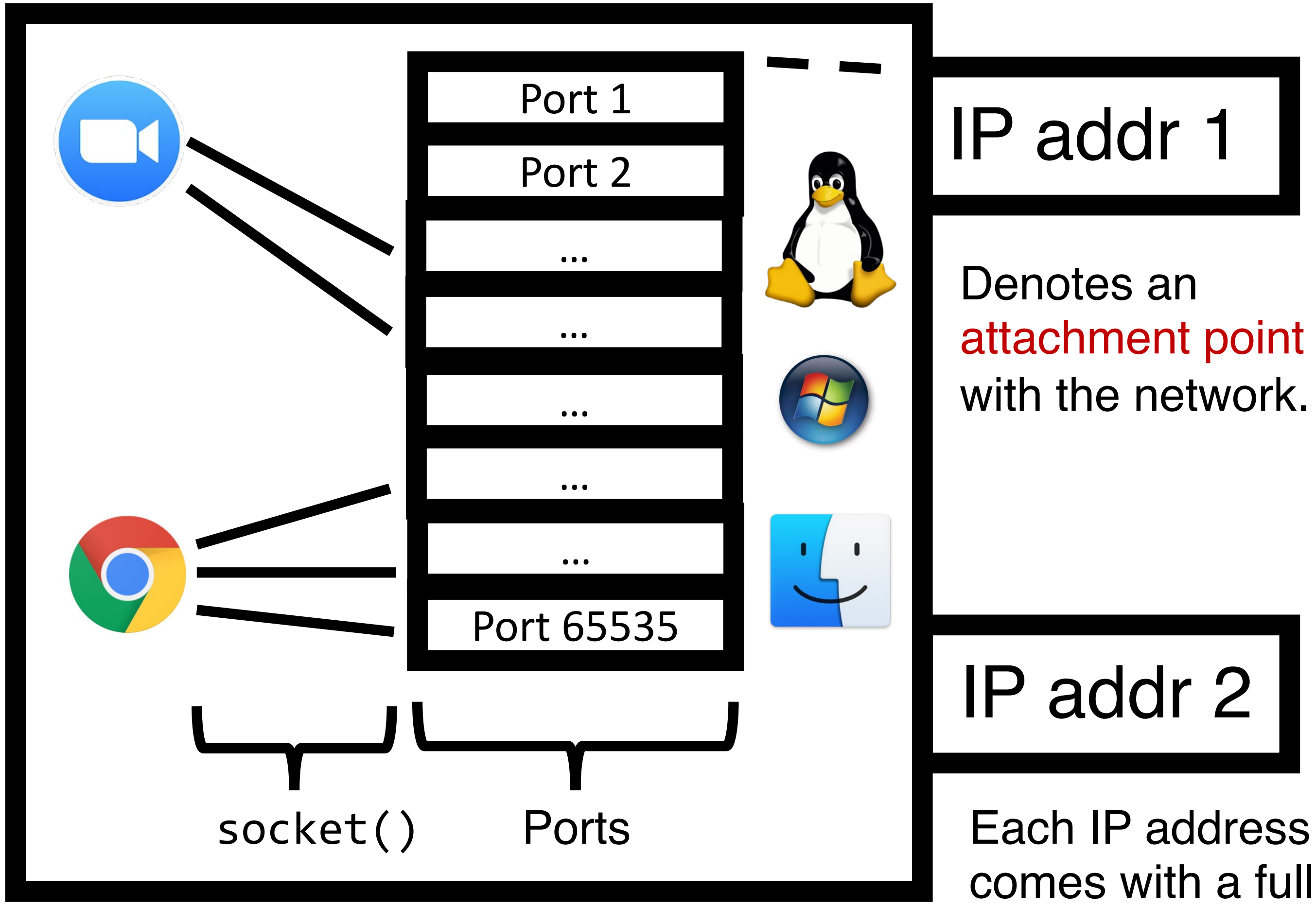
Demultiplexing



Demultiplexing



Demultiplexing

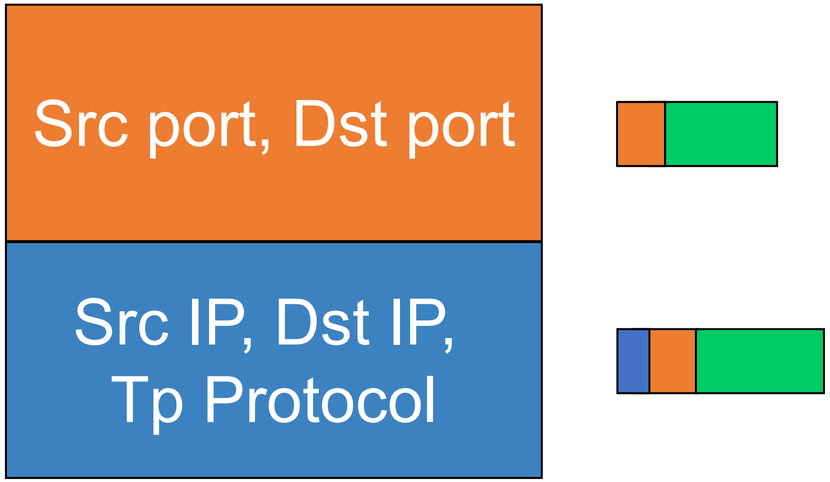


Machine

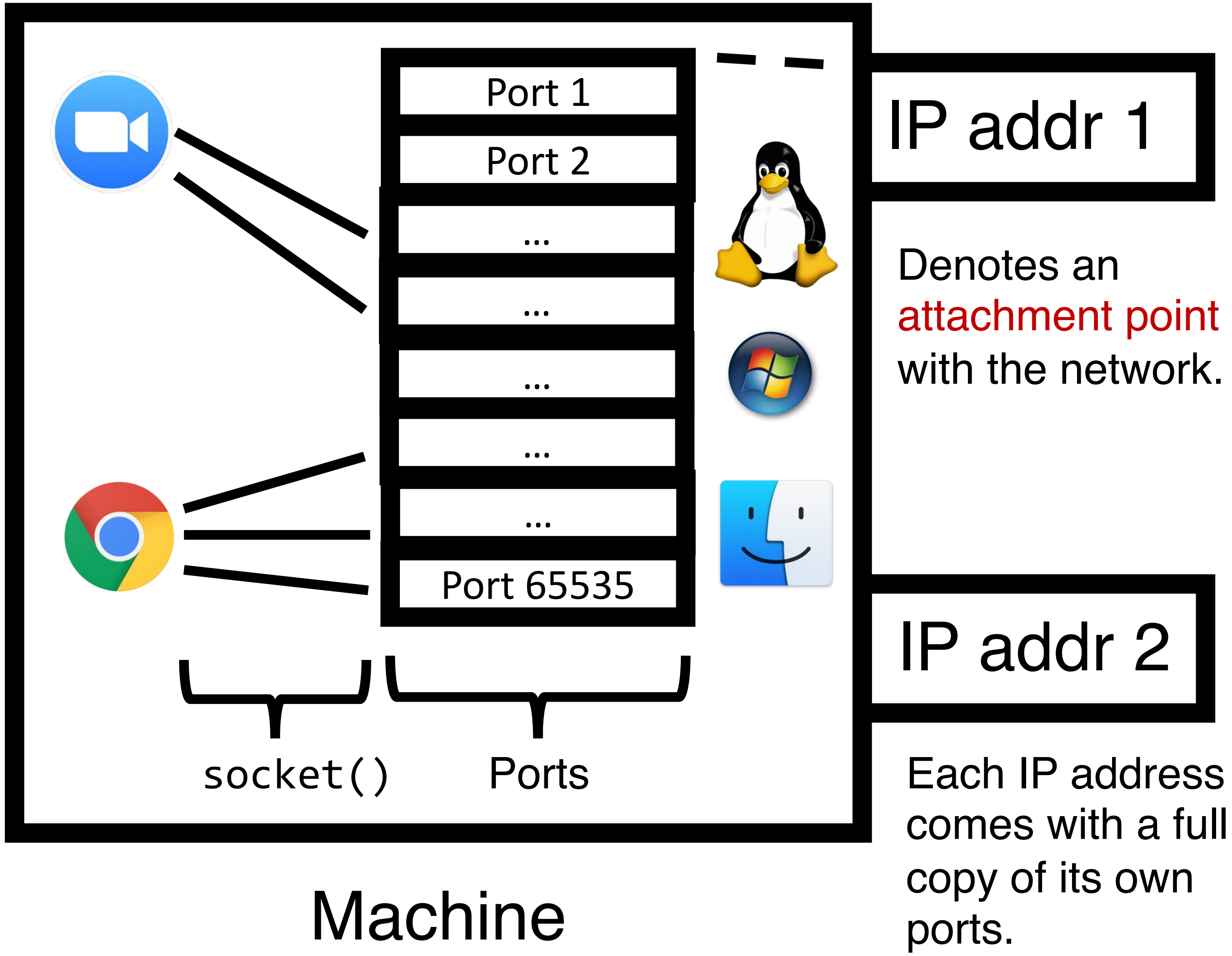
Denotes an attachment point with the network.

Each IP address comes with a full copy of its own ports.

Connection lookup: The operating system does a lookup using these data to determine the right socket and app.



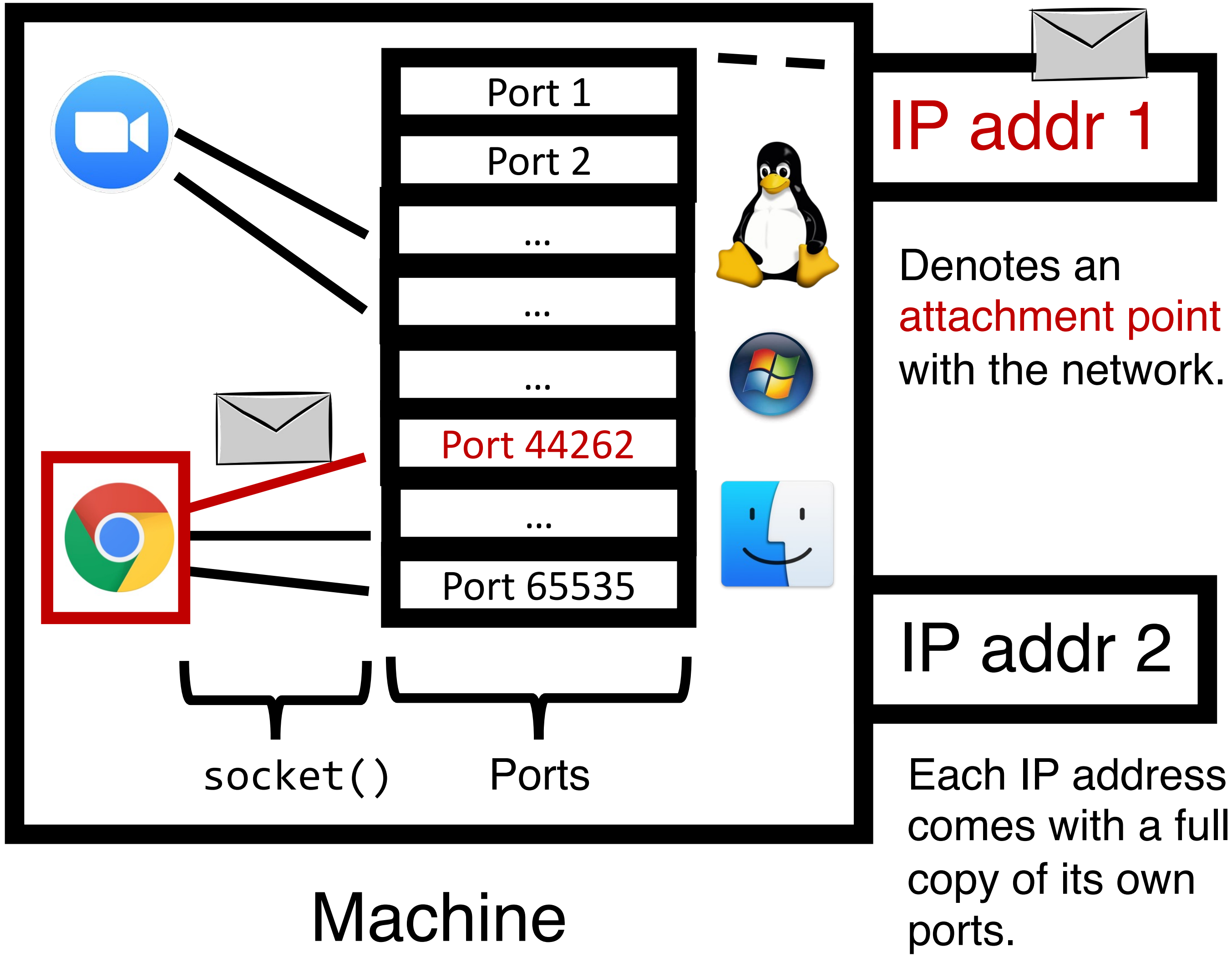
Demultiplexing



Connection lookup: The operating system does a lookup using these data to determine the right socket and app.

TCP sockets:
(src IP, dst IP, src port, dst port)
➔
Socket ID

Demultiplexing



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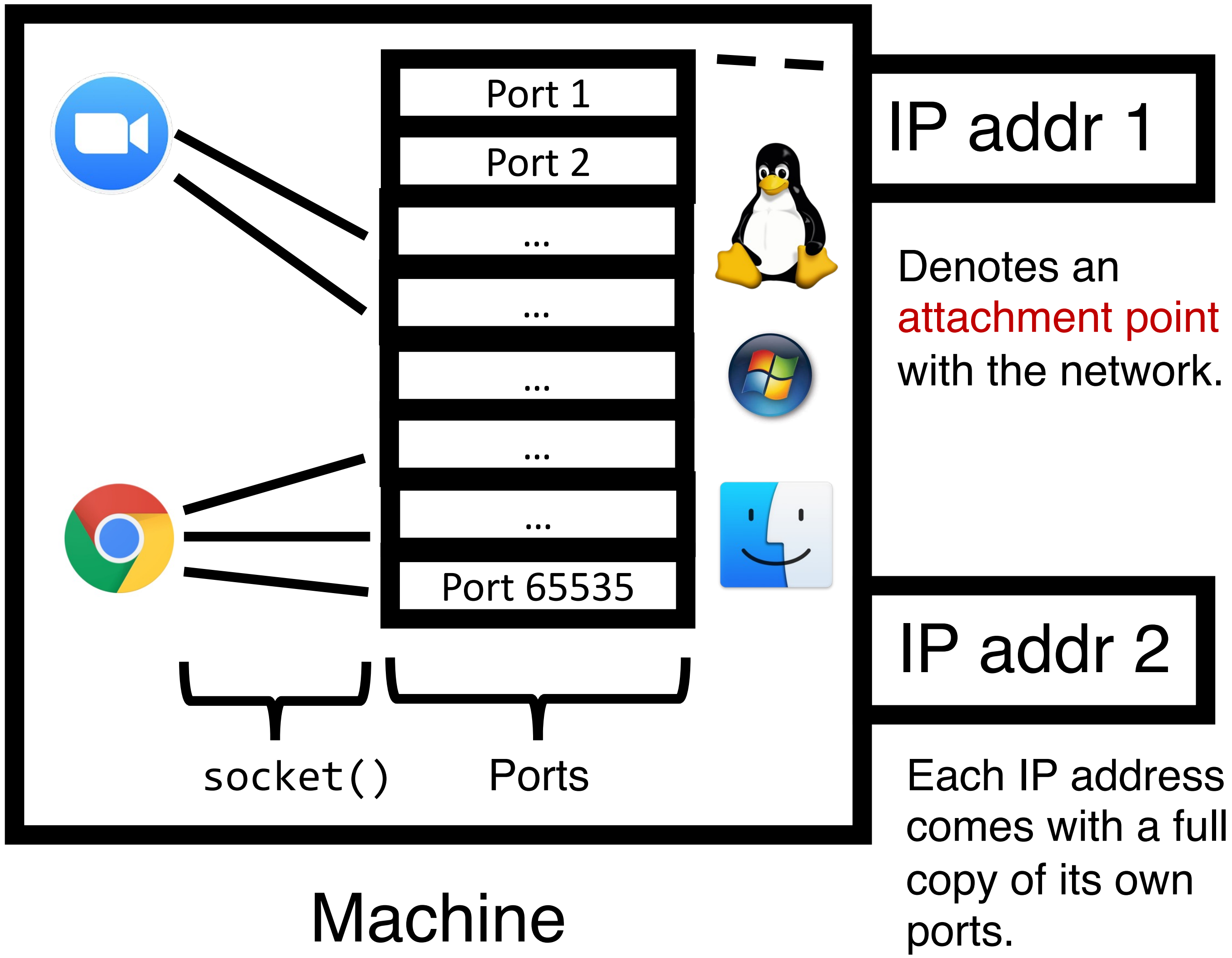
Socket ID

(Our familiar 4-tuple)

Demultiplexing



Connection lookup: The operating system does a lookup using these data to determine the right socket and app.

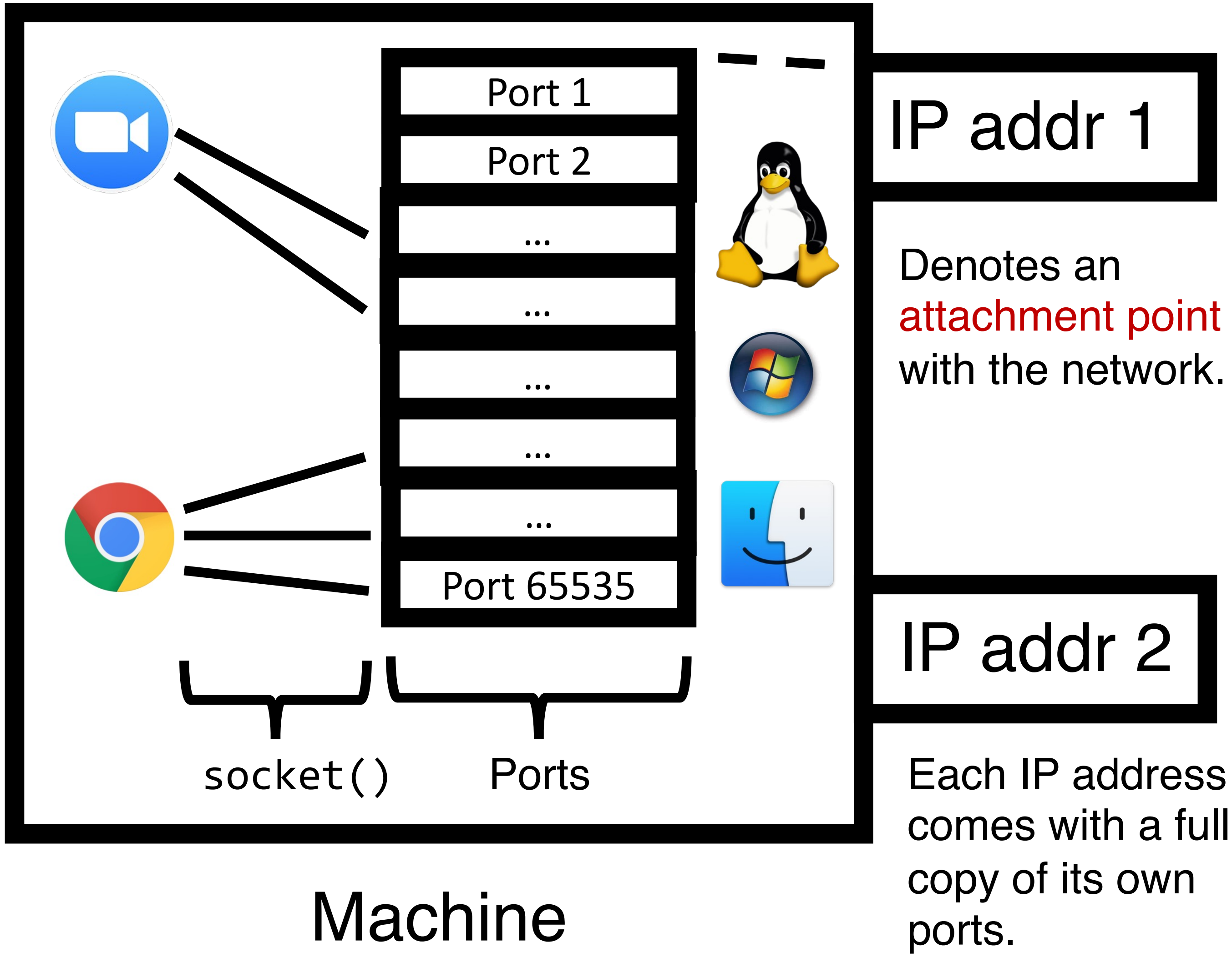
TCP sockets:
(src IP, dst IP, src port, dst port)
➔
Socket ID

(Our familiar 4-tuple)

UDP sockets:
(dst IP, dst port)
➔
Socket ID

Connectionless: the socket is shared across all sources!

Demultiplexing



Denotes an attachment point with the network.

Each IP address comes with a full copy of its own ports.

Connection lookup: The operating system does a lookup using these data to determine the right socket and app.

TCP sockets** Some caveats!

(src IP, dst IP, src port, dst port)

➔

Socket ID

(Our familiar 4-tuple)

UDP sockets:

(dst IP, dst port)

➔

Socket ID

Connectionless: the socket is shared across all sources!

TCP sockets of different types

Listening (bound but unconnected)

```
# On server side
ss = socket(AF_INET, SOCK_STREAM)
ss.bind(serv_ip, serv_port)
ss.listen() # no accept() yet
```

Connected (Established)

```
# On server side
csockid, addr = ss.accept()

# On client side
cs.connect(serv_ip, serv_port)
```

(src IP, dst IP, src port, dst port)

➔

Socket (`csockid NOT ss`)

TCP sockets of different types

Listening (bound but unconnected)

```
# On server side
ss = socket(AF_INET, SOCK_STREAM)
ss.bind(serv_ip, serv_port)
ss.listen() # no accept() yet
```

(dst IP, dst port)

➔

Socket (ss)

Enables new connections to be demultiplexed correctly

Connected (Established)

```
# On server side
csockid, addr = ss.accept()

# On client side
cs.connect(serv_ip, serv_port)
```

accept() creates a new socket with the 4-tuple (established) mapping

(src IP, dst IP, src port, dst port)

➔

Socket (csockid NOT ss)

Enables existing connections to be demultiplexed correctly

TCP demultiplexing

- When a TCP packet comes in, the operating system:

- Looks up table of existing connections using 4-tuple
    - If success, send to corresponding (established) socket

- If fail (no table entry), look up table of listening connections using just (dst IP, dst port)
    - If success, send to corresponding (listening) socket

- If fail again (no table entry), send error to client
    - Connection refused

UDP demultiplexing

- When a UDP packet comes in, the operating system:

- Looks up table of listening UDP sockets using (dst IP, dst port)
  - If success, send packet to corresponding socket
  - There are no established UDP sockets; they're all "unconnected"

- If fail (no table entry), send error to client
  - Port unreachable

Listing sockets and connections

- `ss`
- `iperf –s` and `iperf –s -u`

Why does it matter?

- Connection lookup and multiplexing determines which process the message goes to
  - If you restart `server`, port to socket mapping changes
- Help understand when lookup tables can be full or lookup can be slow (e.g., attacks, CDN servers, etc.)

User Datagram Protocol

UDP: User Datagram Protocol [RFC 768]

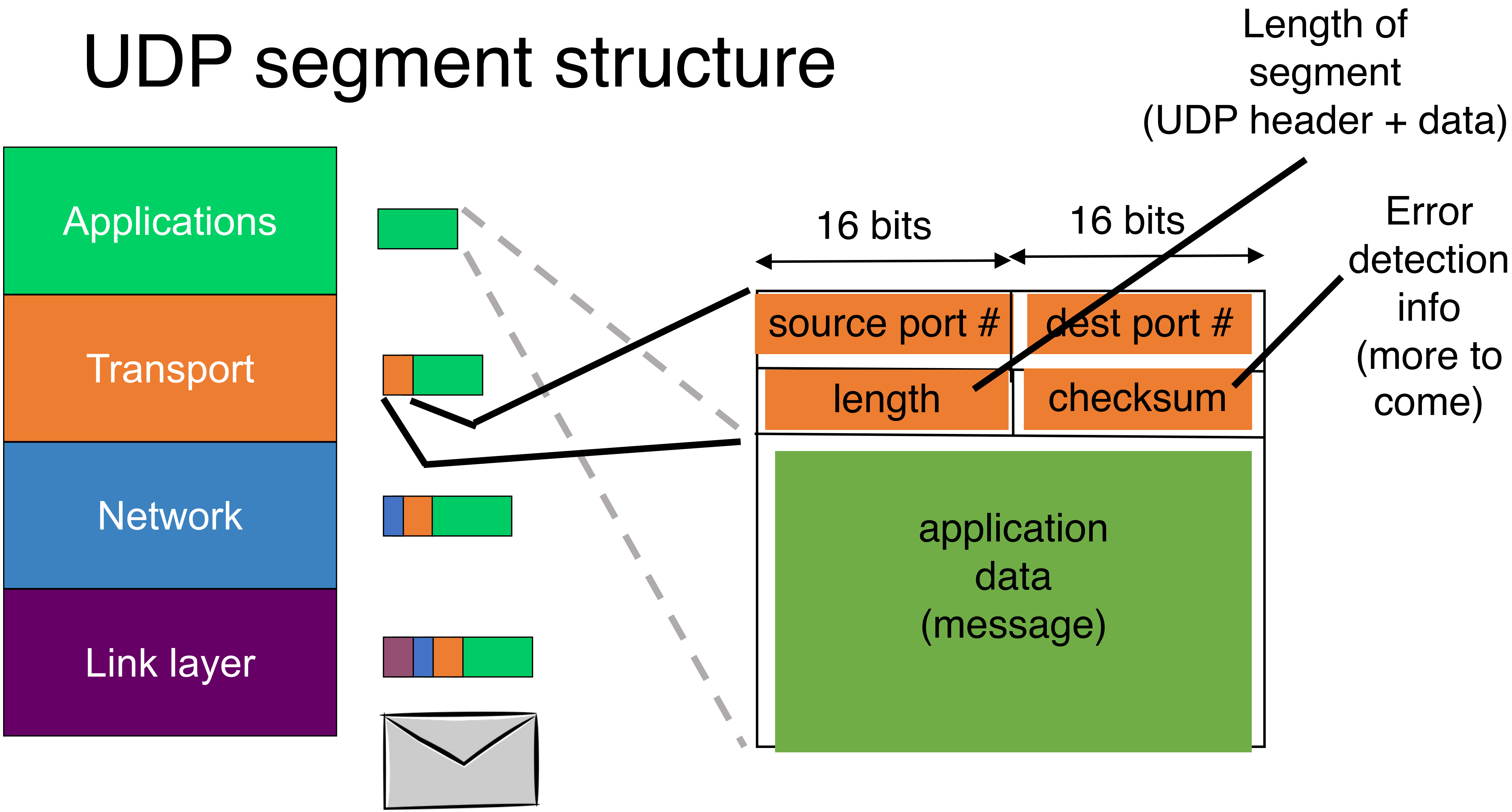
- Best effort service
  - UDP segments may be lost, corrupted, reordered
- UDP is connectionless
  - Each UDP segment handled independently of others (i.e. no "memory" across packets)
- Suitable for one-off req/resp
  - E.g., DNS uses UDP
- Loss-tolerant delay-sensitive apps. (e.g., VoIP & conf video)

Why are UDP's guarantees even okay?

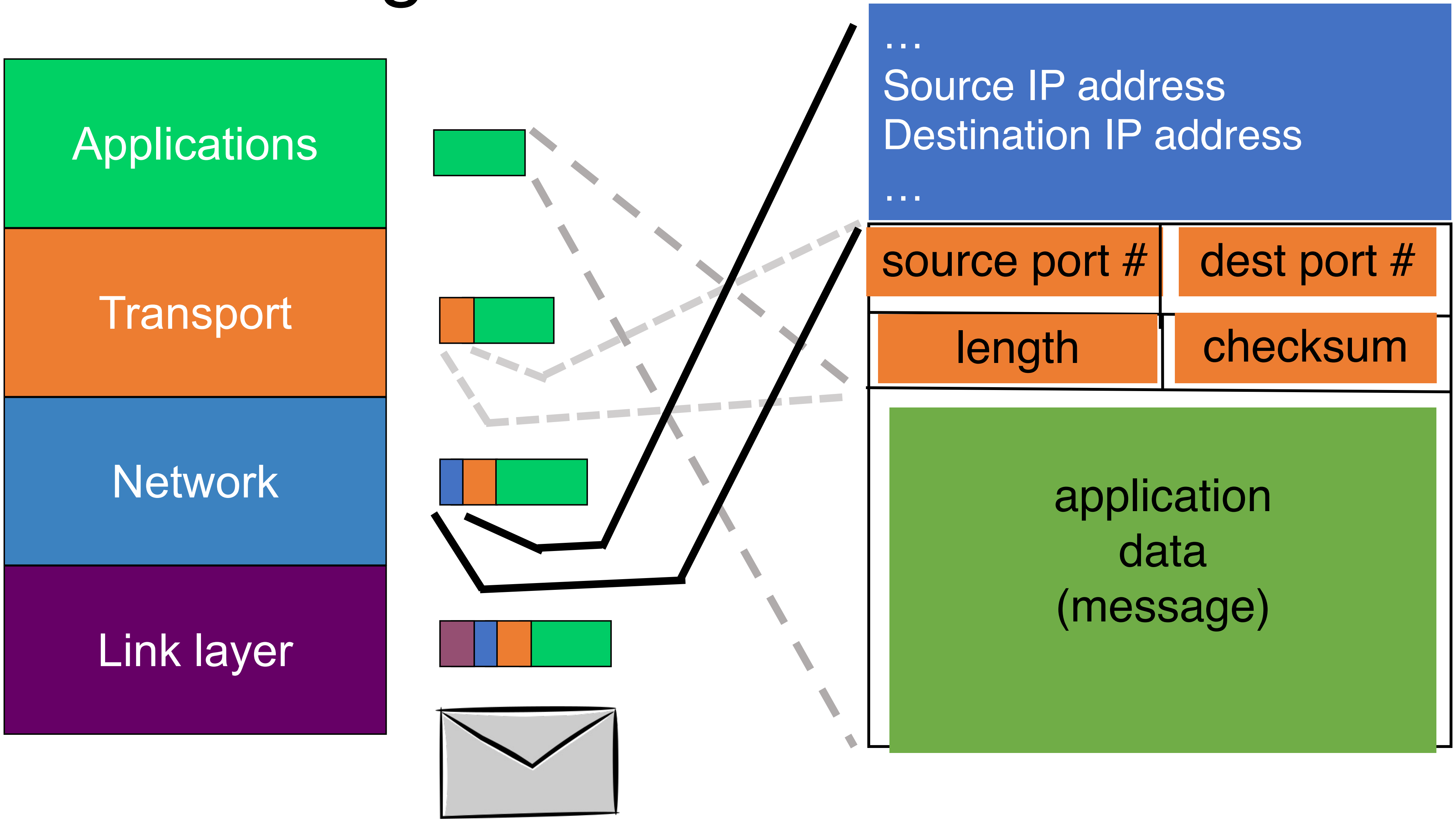
Simple & low overhead compared to TCP:

- No delays due to "connection establishment" (which TCP does)
  - UDP can send a packet immediately
- Small segment header (TCP's is larger)
- UDP can blast data without control
  - TCP is more balanced and measured
- Less memory for connection "state" at sender & receiver relative to TCP

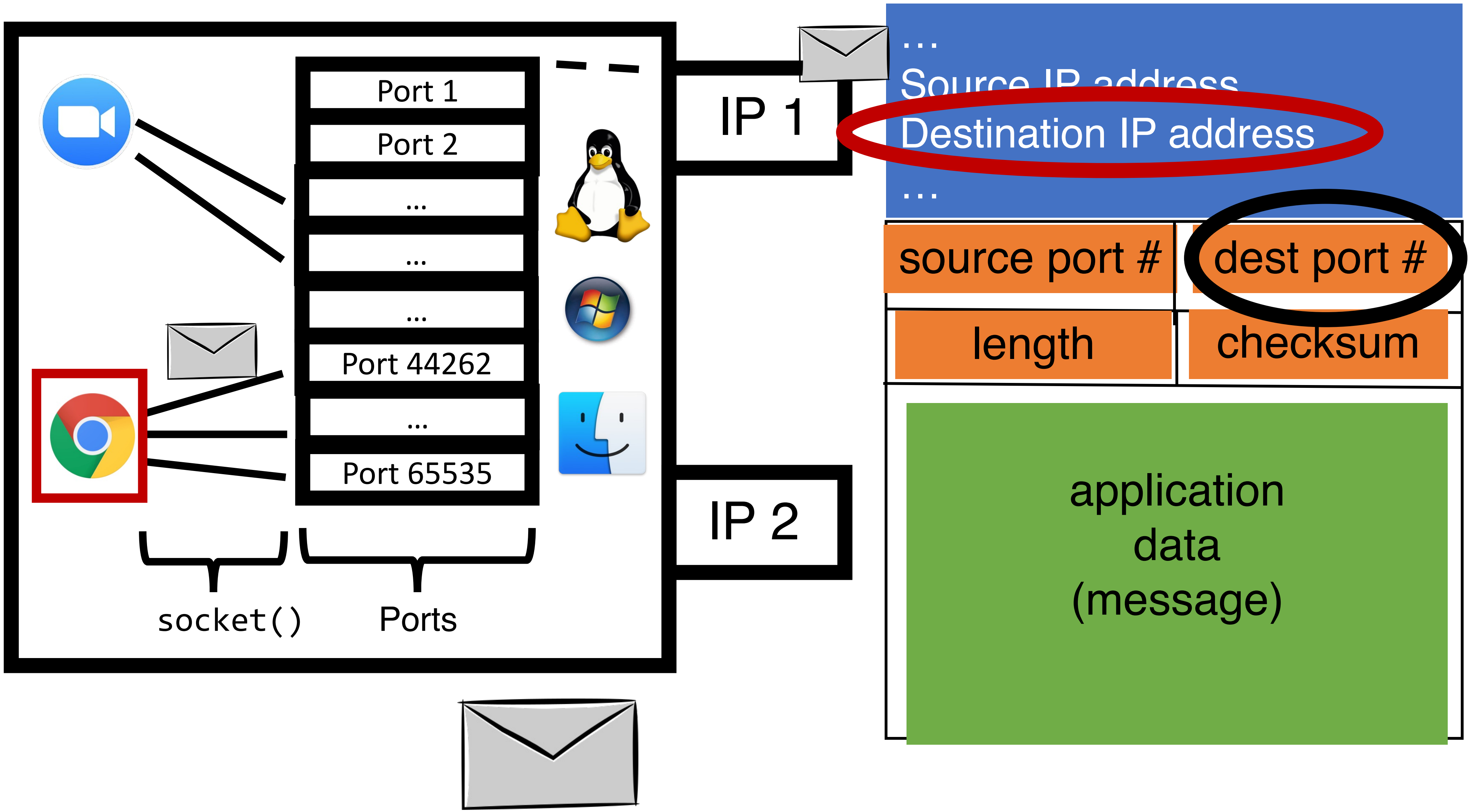
UDP segment structure



UDP segment structure



Review: UDP demultiplexing



Seeing UDP packets in action

- How to craft and send (UDP) packets?
  - It's simpler than you think!

- `sudo tcpdump -i lo udp –XAvvv # observe packets`
- `sudo scapy # tool used to send crafted packets`
- Example: `send(IP(dst="127.0.0.1")/UDP(sport=1024, dport=2048)/"hello world”, iface="lo")`
- See other fields of UDP using `UDP().fields_desc`
- Scapy can send and receive crafted packets!
  - However, it requires sudo (superuser privileges)

Error Detection

Why error detection?

- Network provides best effort service
- UDP is a simple and low overhead transport
  - Data may be lost
  - Data may be corrupted along the way (e.g., 1 -> 0)
  - Data may be reordered

- However, simple error detection is possible!
  - Was the data I received the same data the remote machine sent?

- Error detection is a useful feature for all transport protocols including TCP

Error Detection in UDP and TCP

- Key idea: have sender compute a function over the data
  - Store the result in the packet
  - Receiver can check the function's value in received packet

- An analogy: you're sending a package of goodies and want your recipient to know if goodies were leaked along the way

- Your idea: weigh the package; stamp the weight on the package
  - Have the recipient weigh the package and cross-check the weight with the stamped value

Requirements on error detection function

- Function must be easy to compute
- Function must capture the likely changes to the packet
  - If the packet was corrupted through these likely changes, the function value must change
- Function must be easy to verify

- UDP and TCP use a class of function called a checksum
  - Very common idea: used in multiple parts of networks and computer systems

UDP & TCP's Checksum function

Sender:

- treat segment contents as sequence of 16-bit integers
- checksum: addition (1's complement sum) of segment contents
- sender puts checksum value into UDP checksum field

Receiver:

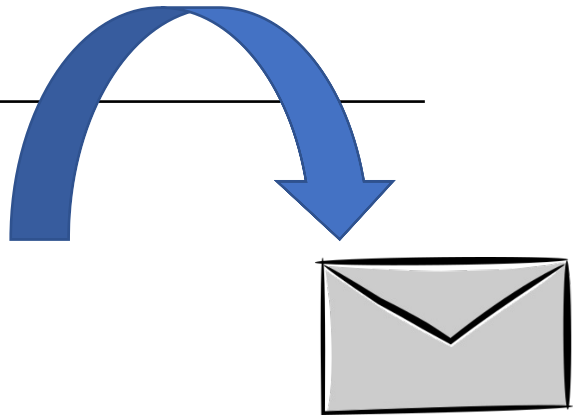
- compute a checksum of the received segment, including the checksum in packet itself
- check if the resulting (computed) checksum is 0
- NO – an error is detected
- YES – *assume* no error

Computing 1's complement sum

- Very similar to regular (unsigned) binary addition.
- However, when adding numbers, a carryout from the most significant bit needs to be added to the result

- Example: add two 16-bit integers

		1	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0
		1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
wraparound	1	1	0	1	1	1	0	1	1	1	0	1	1	1	0	1	1
sum		1	0	1	1	1	0	1	1	1	0	1	1	1	1	0	0
checksum		0	1	0	0	0	1	0	0	0	1	0	0	0	0	1	1



From the UDP specification (RFC 768)

- Checksum is the 16-bit one's complement of the one's complement sum of a pseudo header of information from the IP header, the UDP header, and the data, padded with zero octets at the end (if necessary) to make a multiple of two octets.

- The pseudo header conceptually prefixed to the UDP header contains the source address, the destination address, the protocol, and the UDP length.

Some observations on checksums

- Checksums don't detect all bit errors
  - Consider (x, y) vs. (x – 1, y + 1) as adjacent 16-bit values in packet
  - Analogy: you can't assume the package hasn't been meddled with if its weight matches the one on the stamp. More smarts needed for that. ☺
  - But it's a lightweight method that works well in many cases

- Checksums are part of the packet; they can get corrupted too
  - The receiver will just declare an error if it finds an error
  - However, checksums don't enable the receiver to detect where the error lies or correct the error(s)
  - Checksum is an error detection mechanism; not a correction mechanism.

Some observations on checksums

- Checksums are insufficient for reliable data delivery
  - If a packet is lost, so is its checksum

- UDP and TCP use the same checksum function
  - TCP also uses the lightweight error detection capability
  - However, TCP has more mature mechanisms for reliable data delivery (more to come on this)

Playing with checksums

- Can you create two UDP packets with the same checksum?

Summary of UDP

- UDP is a thin shim around network layer's best-effort delivery
  - One-off request/response messages
  - Lightweight transport for loss-tolerant delay-sensitive applications

- Provides basic multiplexing/demultiplexing for application
- No reliability, performance, or ordering guarantees
- Can do basic error detection (bit flips) using checksums
  - Error detection is necessary to deliver data reliably, but it is insufficient