Application Layer
Part I

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Case / ICSI

EECS 325/425
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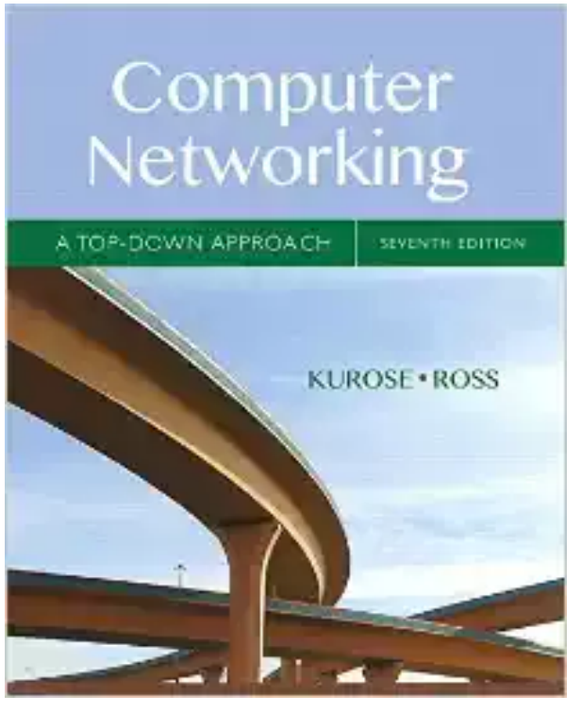
"All this energy callin' me, back where it comes from;
It's such a crude attitude, back where it belongs"

Many of these slides are more-or-less directly from the slide set developed by Jim Kurose and Keith Ross for their book “Computer Networking: A Top Down Approach, 5th edition”.

The slides have been lightly adapted for Mark Allman’s EECS 325/425 Computer Networks class at Case Western Reserve University.

Reading Along ...

- The application layer is covered in Chapter 2 of the book
- Read for re-inforcement and depth of understanding



Chapter 2: Application Layer

Our goals:

- conceptual and implementation aspects of network application protocols
  - transport-layer service models
  - client-server paradigm
  - peer-to-peer paradigm
- learn about protocols by examining popular application-level protocols
  - HTTP
  - SMTP / POP3 / IMAP
- programming network applications
  - socket API

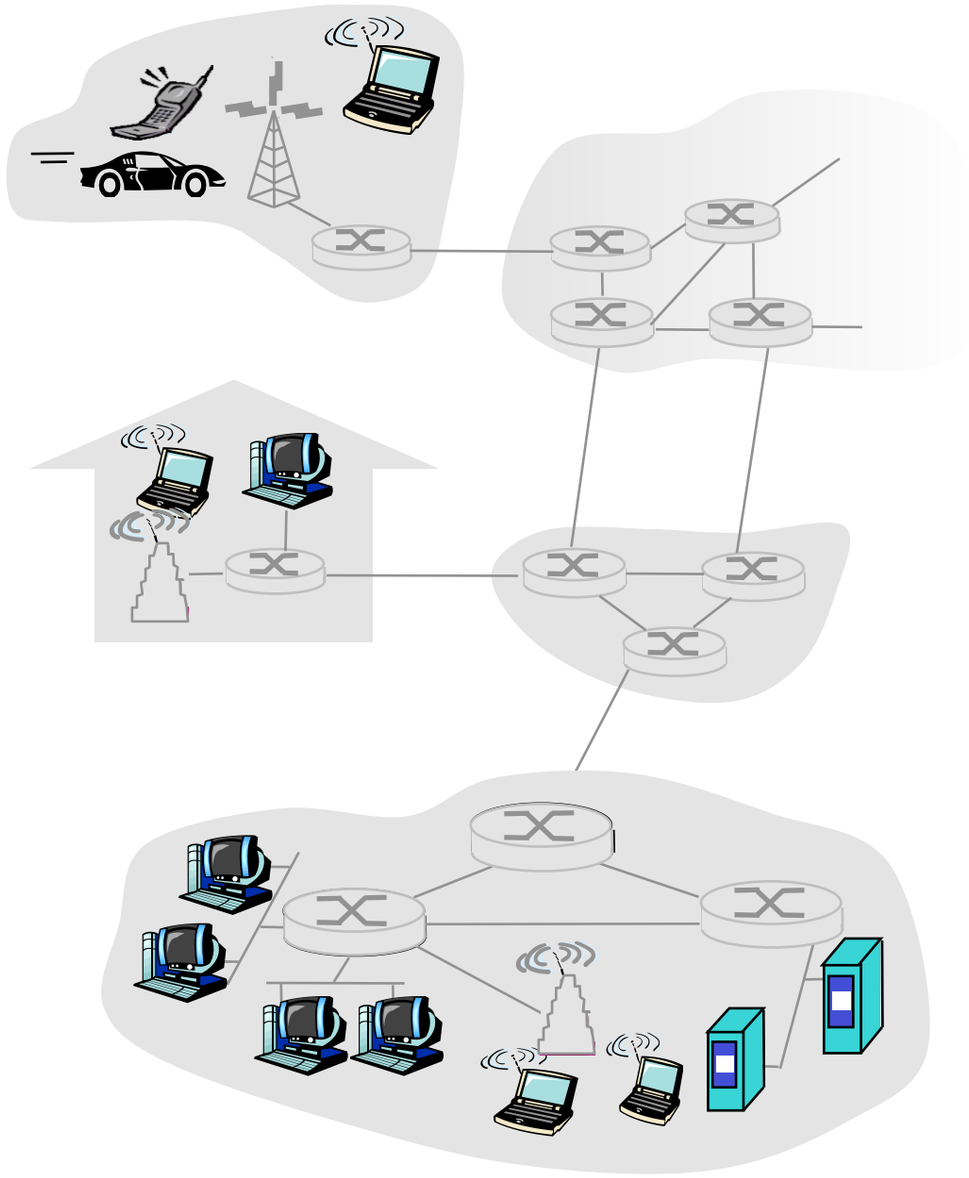
Some network apps

- e-mail
- web
- instant messaging
- remote login
- P2P file sharing
- multi-user network games
- streaming stored video (YouTube)
- voice over IP
- real-time video conferencing
- cloud computing
- …
- …
-

Creating a network app

write programs that

- run on (different) end systems
- communicate over network
- e.g., web server software communicates with browser software



No need to write software for network-core devices

- network-core devices do not run user applications
- applications on end systems allows for rapid app development, propagation

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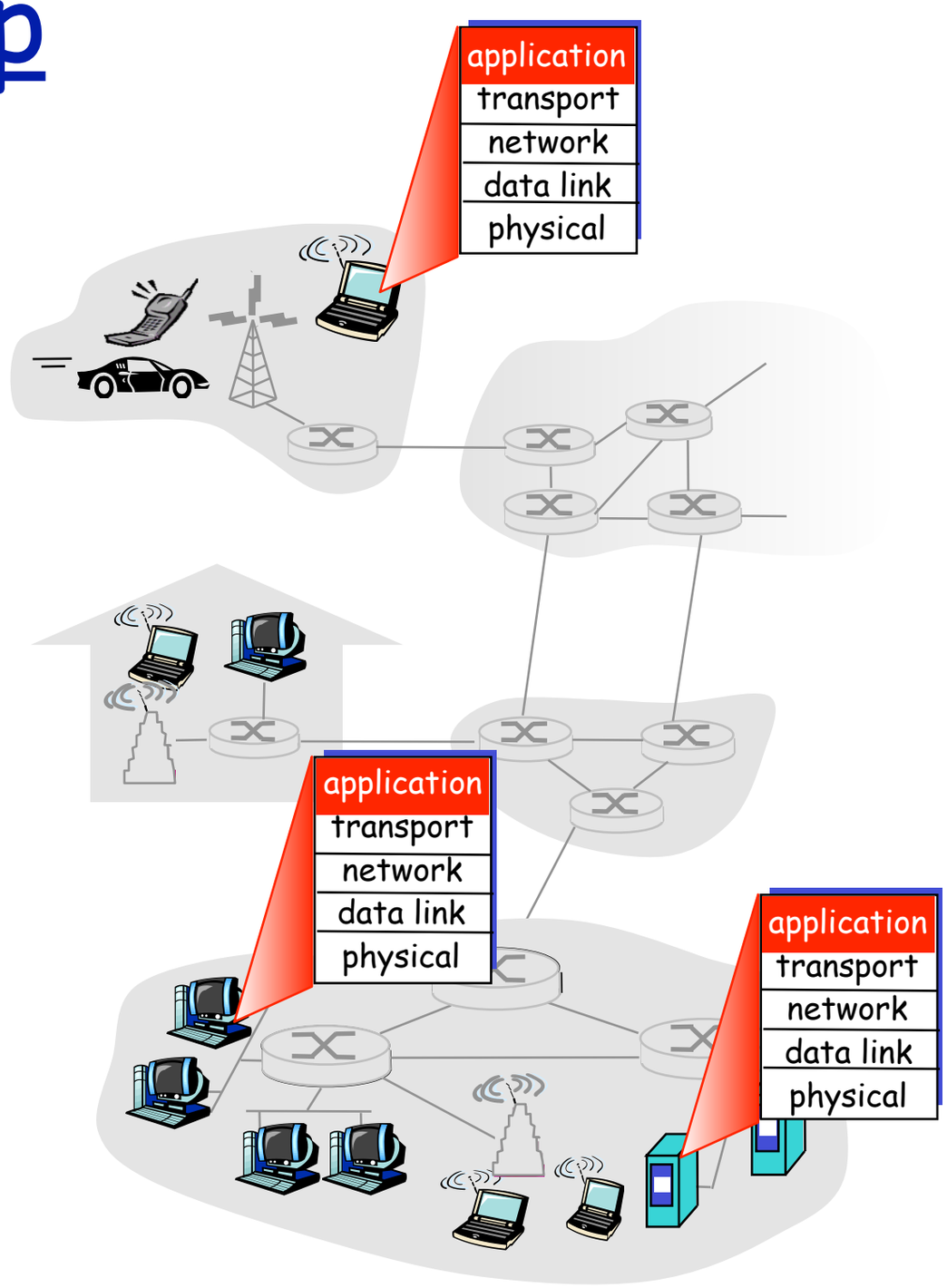

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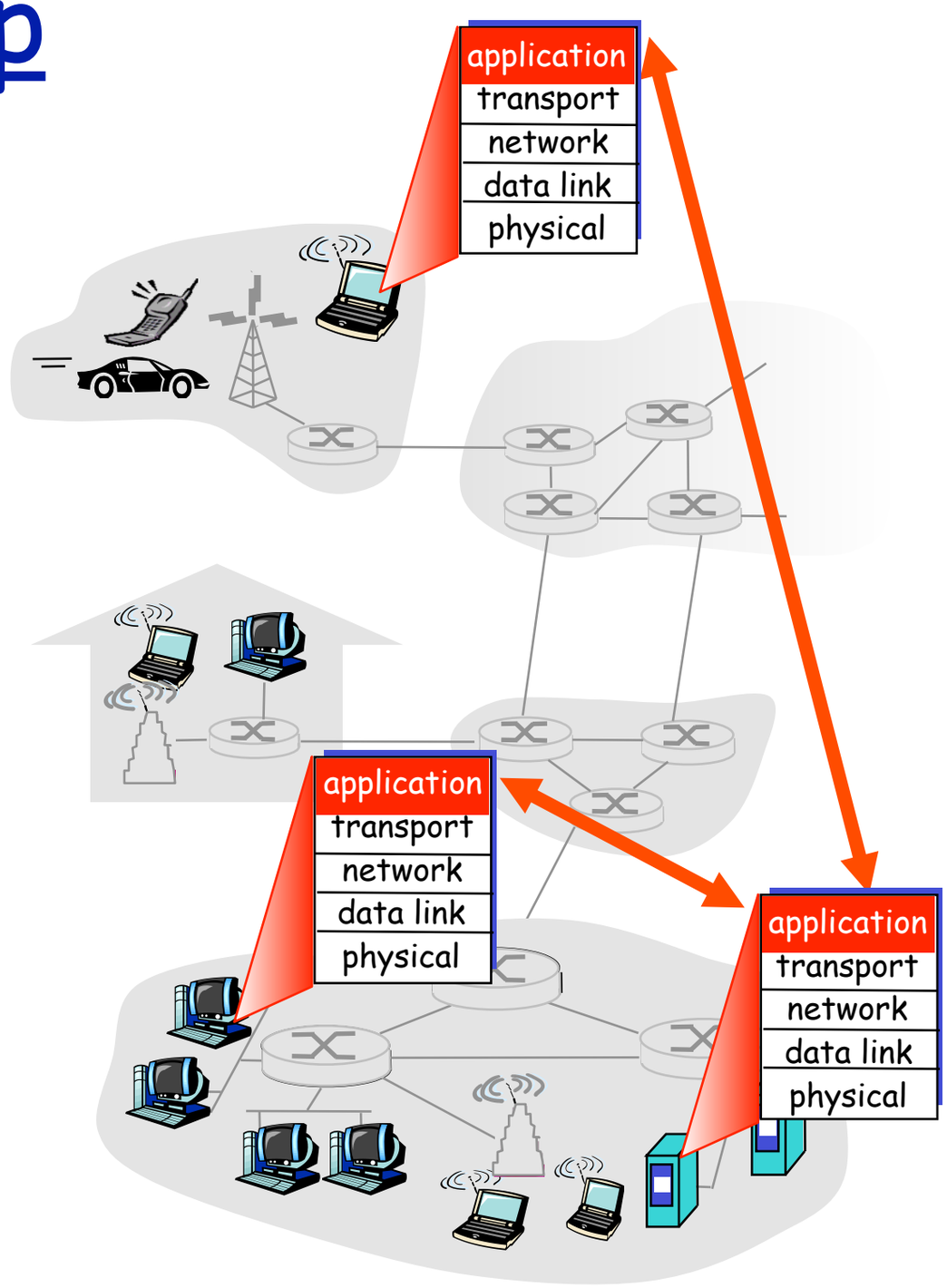

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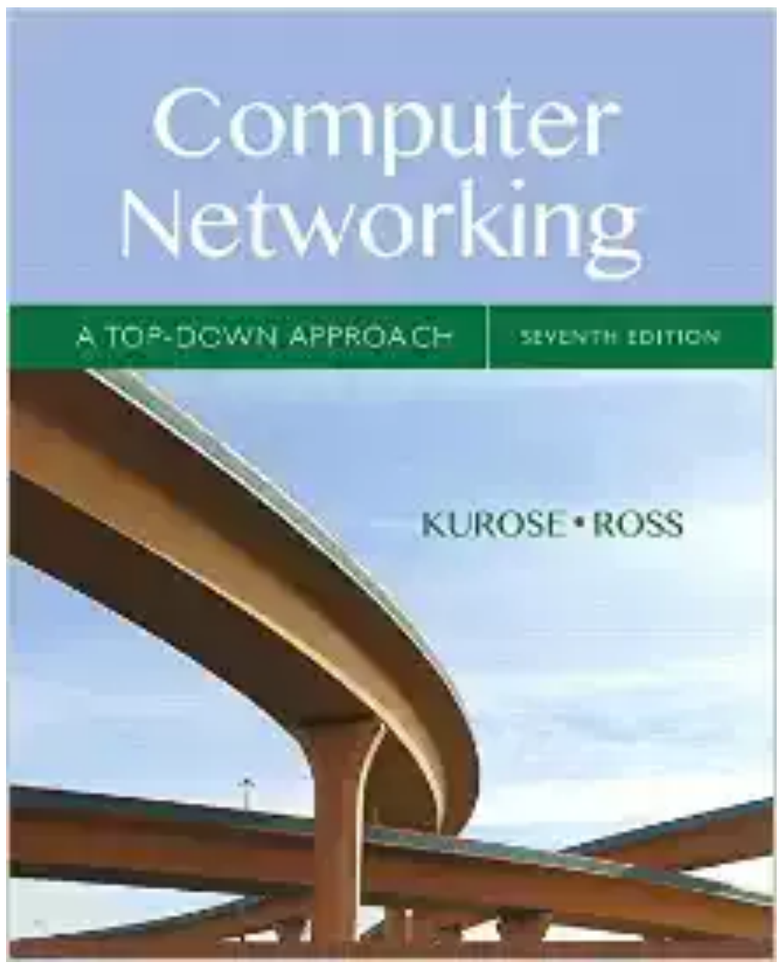
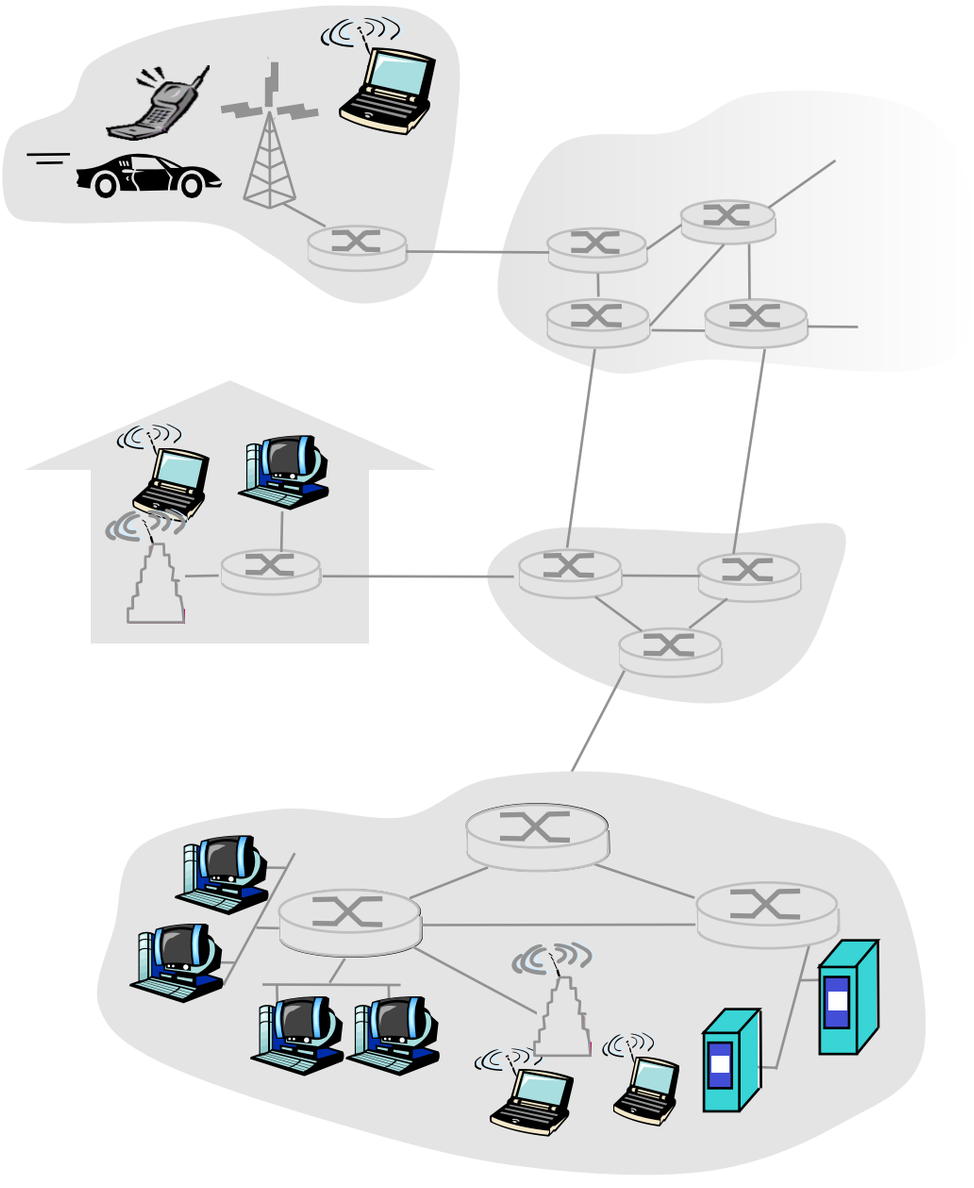


- 2.1: Principles of network applications

Application architectures

- client-server
- peer-to-peer (P2P)
- hybrid of client-server and P2P

Client-server architecture



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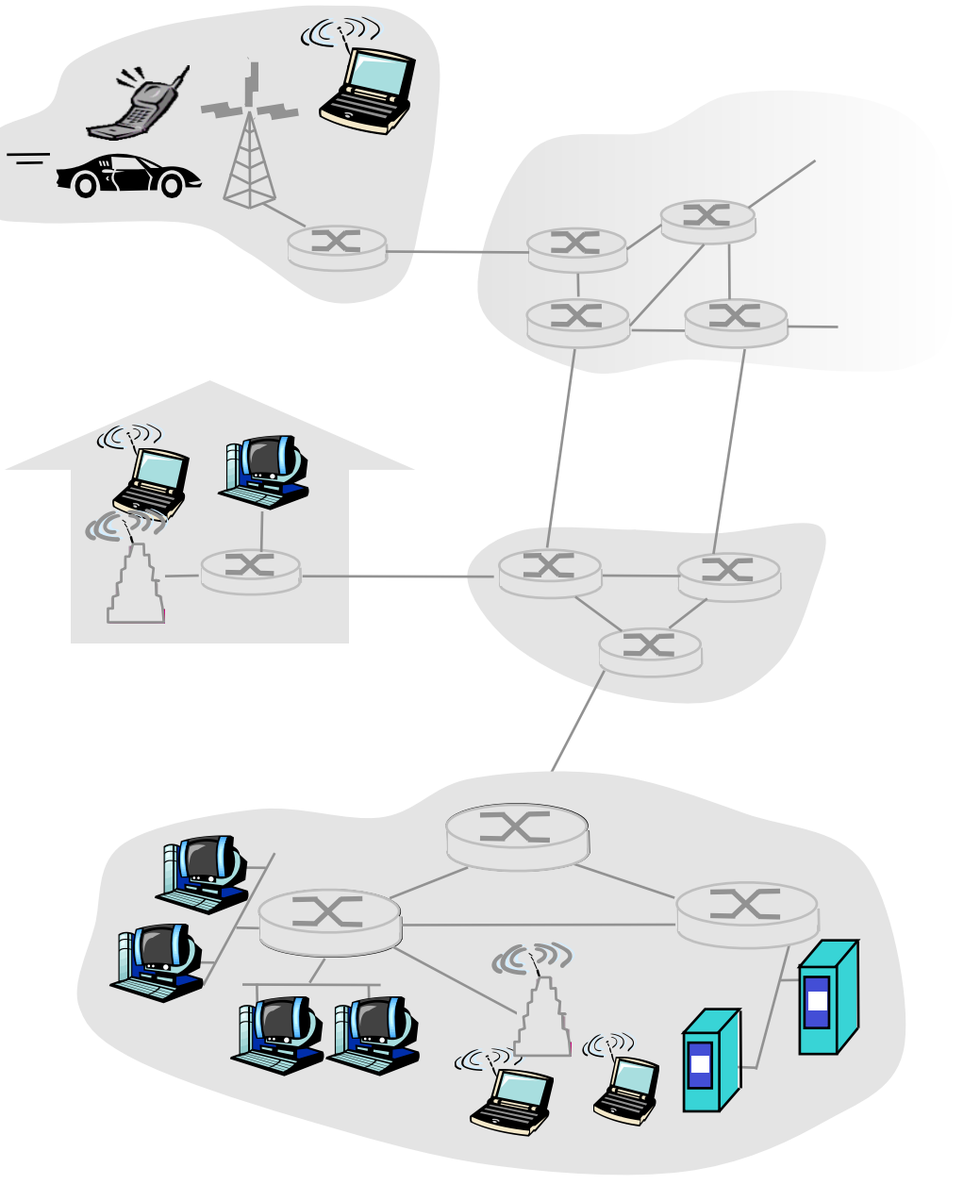

server:

- always-on host
- permanent IP address
- server farms for scaling

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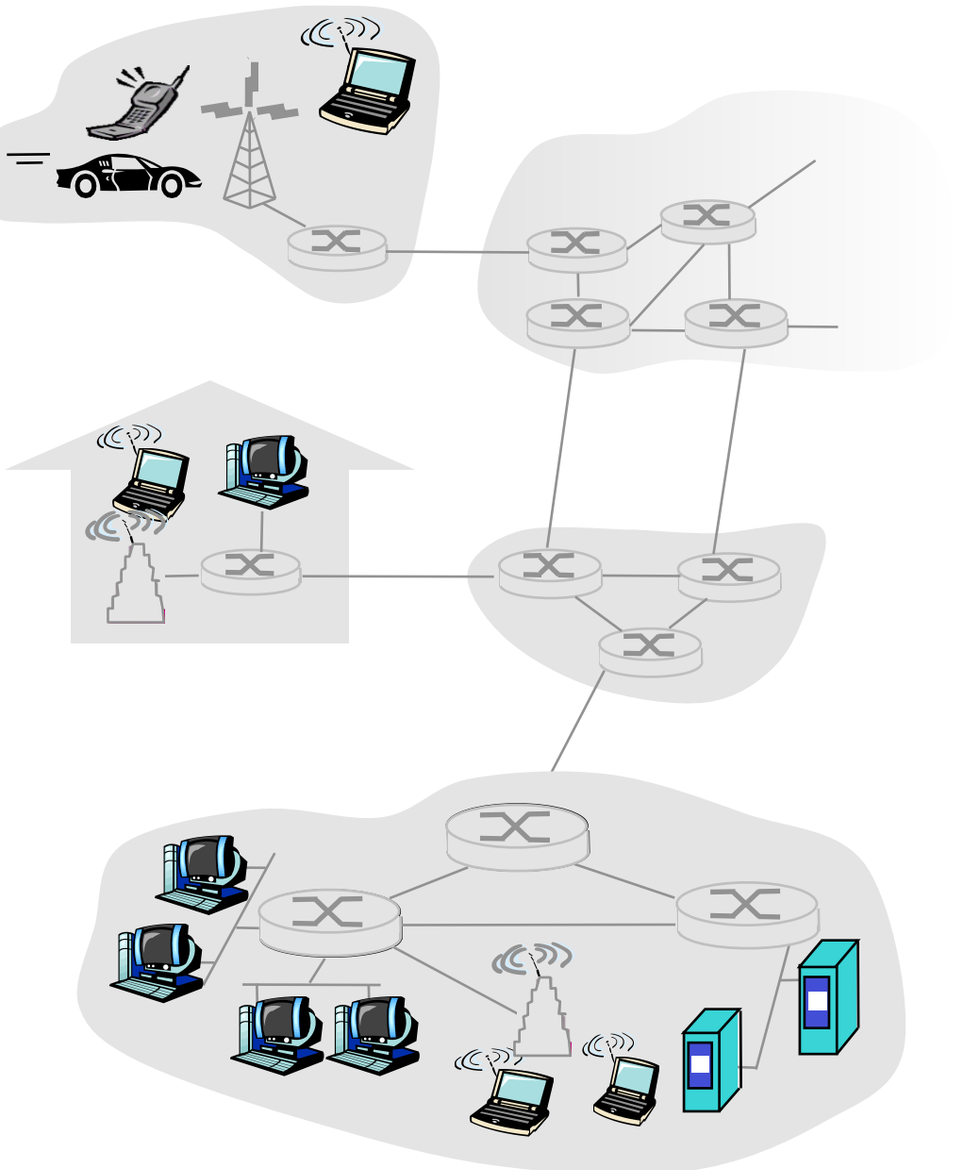

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- may have dynamic IP addresses
- do not communicate directly with each other

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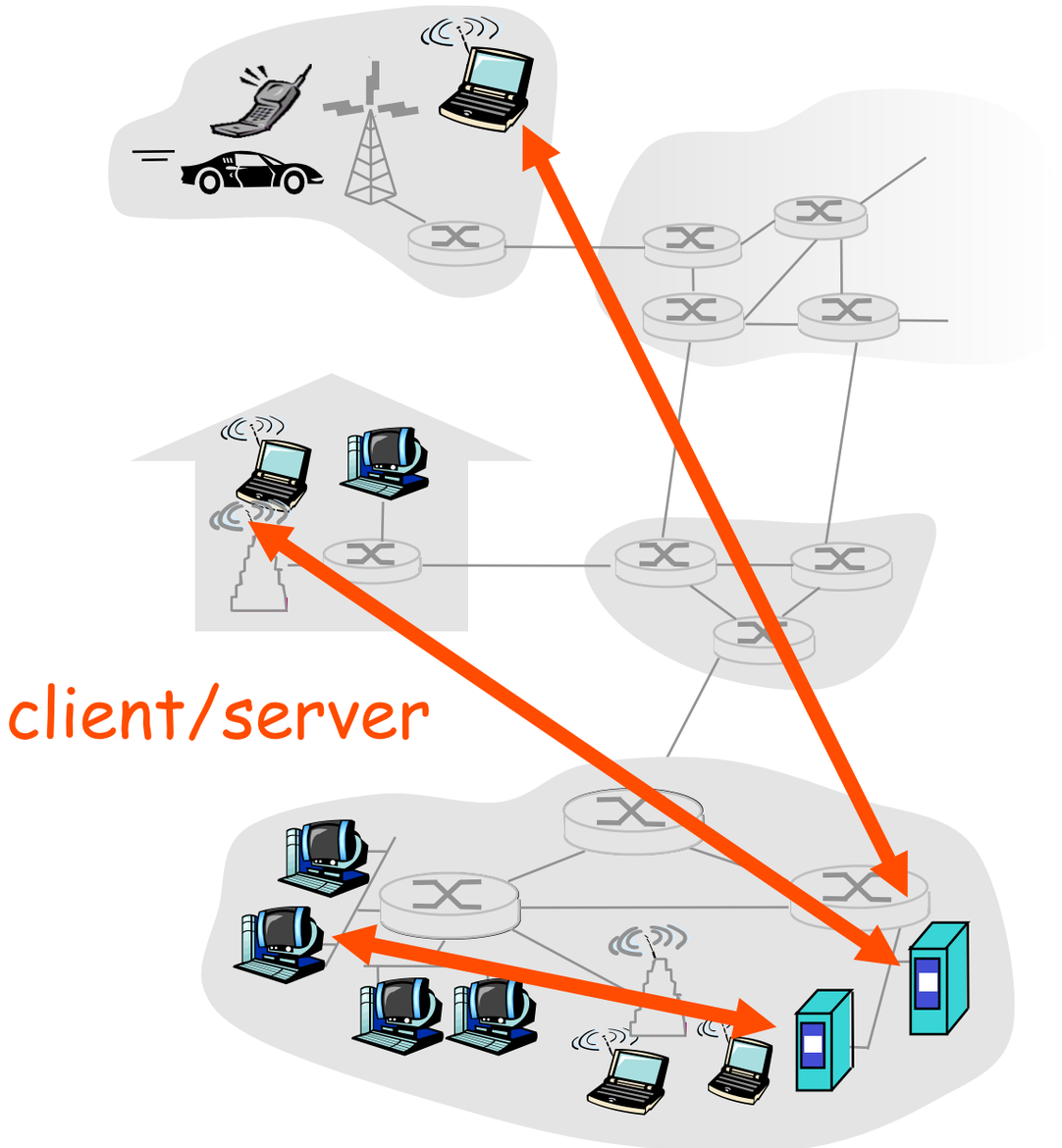

client/server

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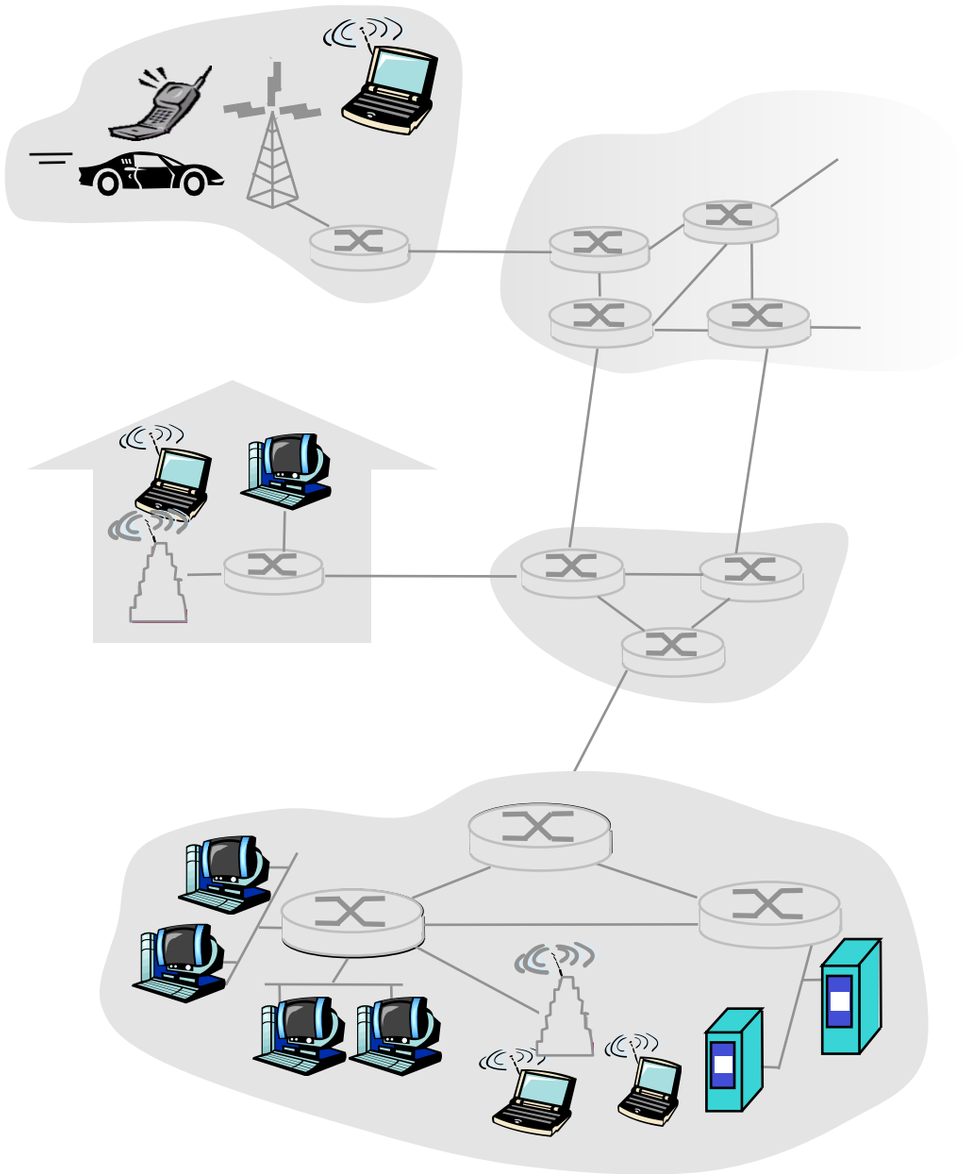

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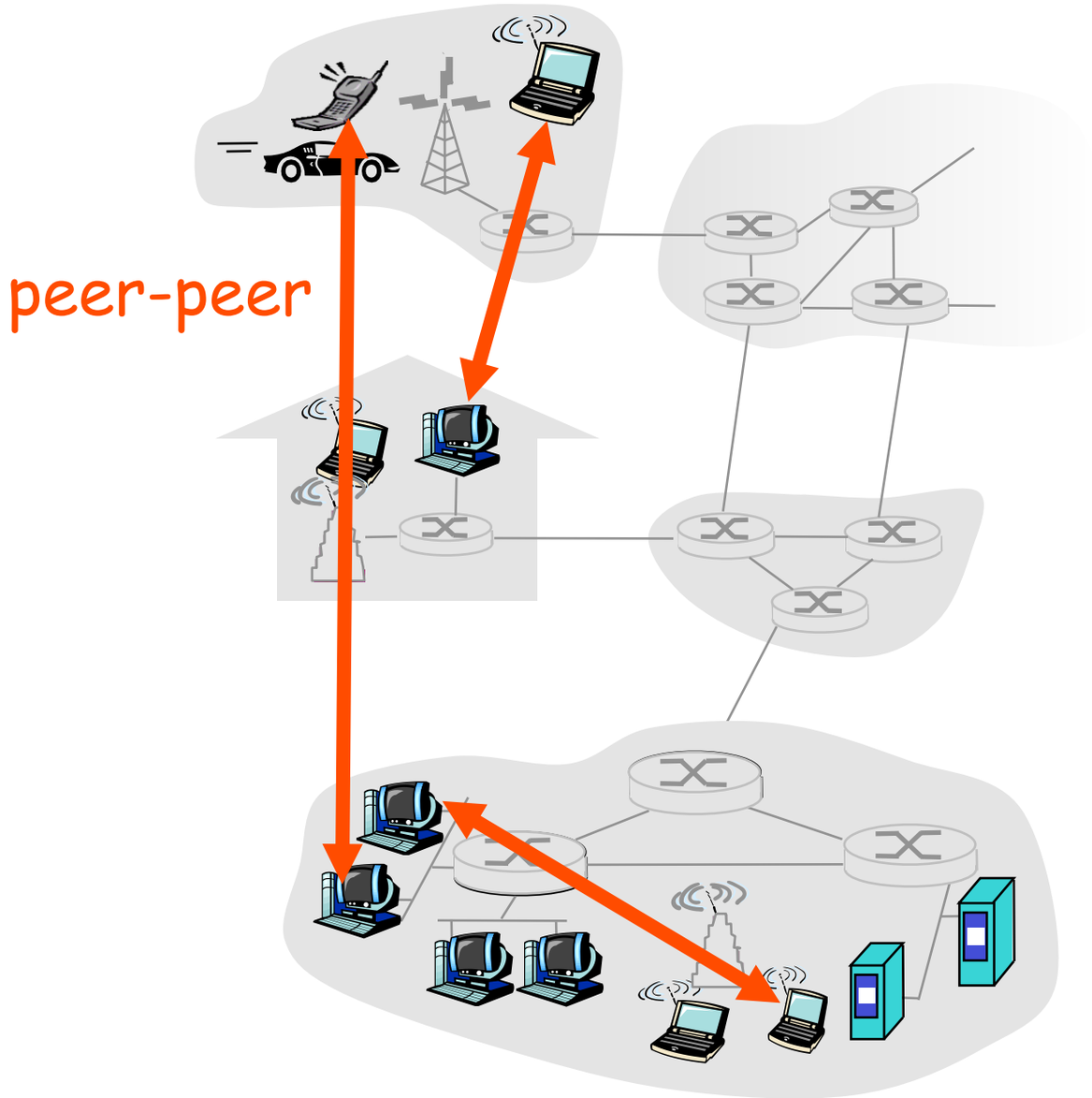

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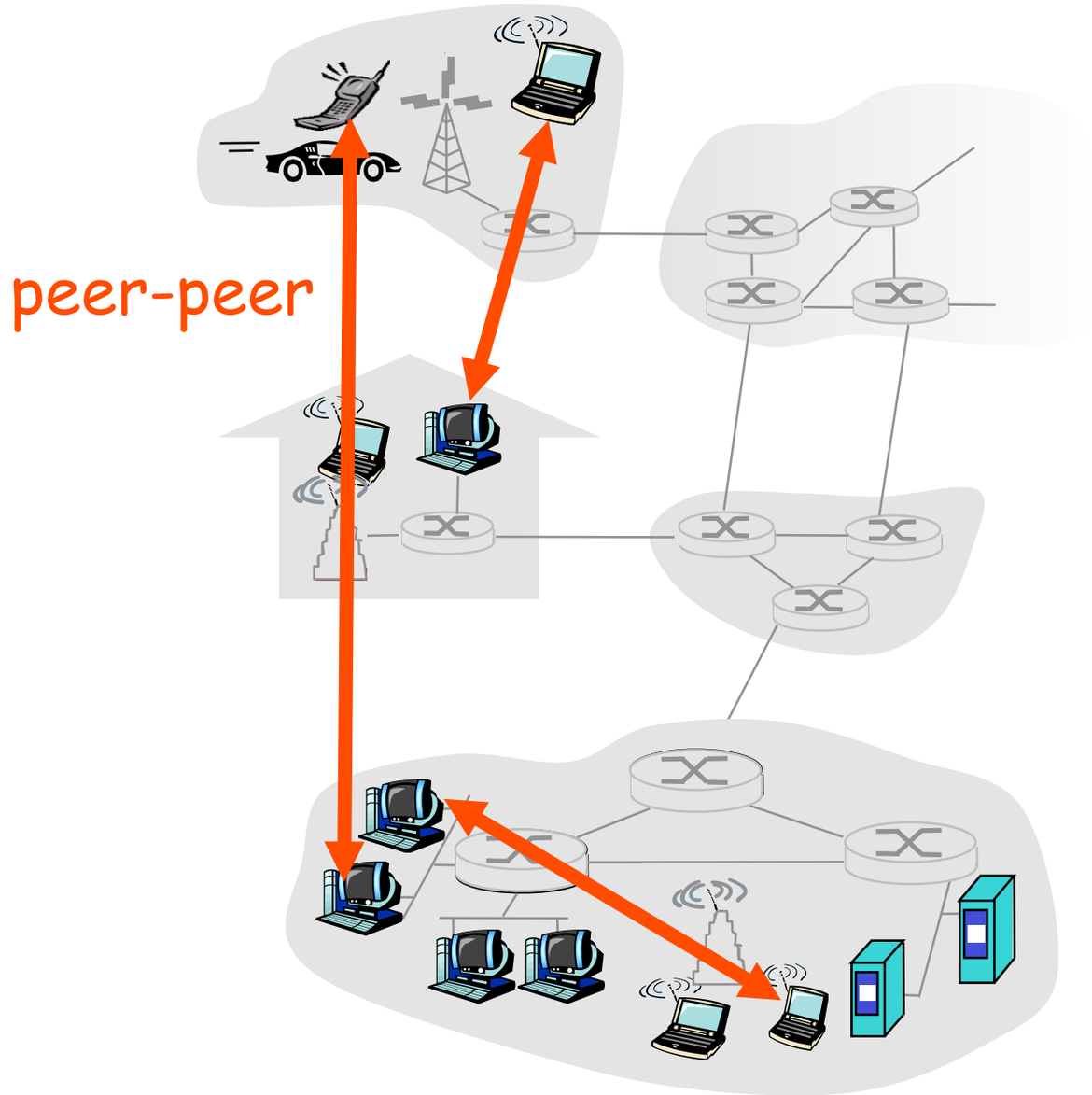

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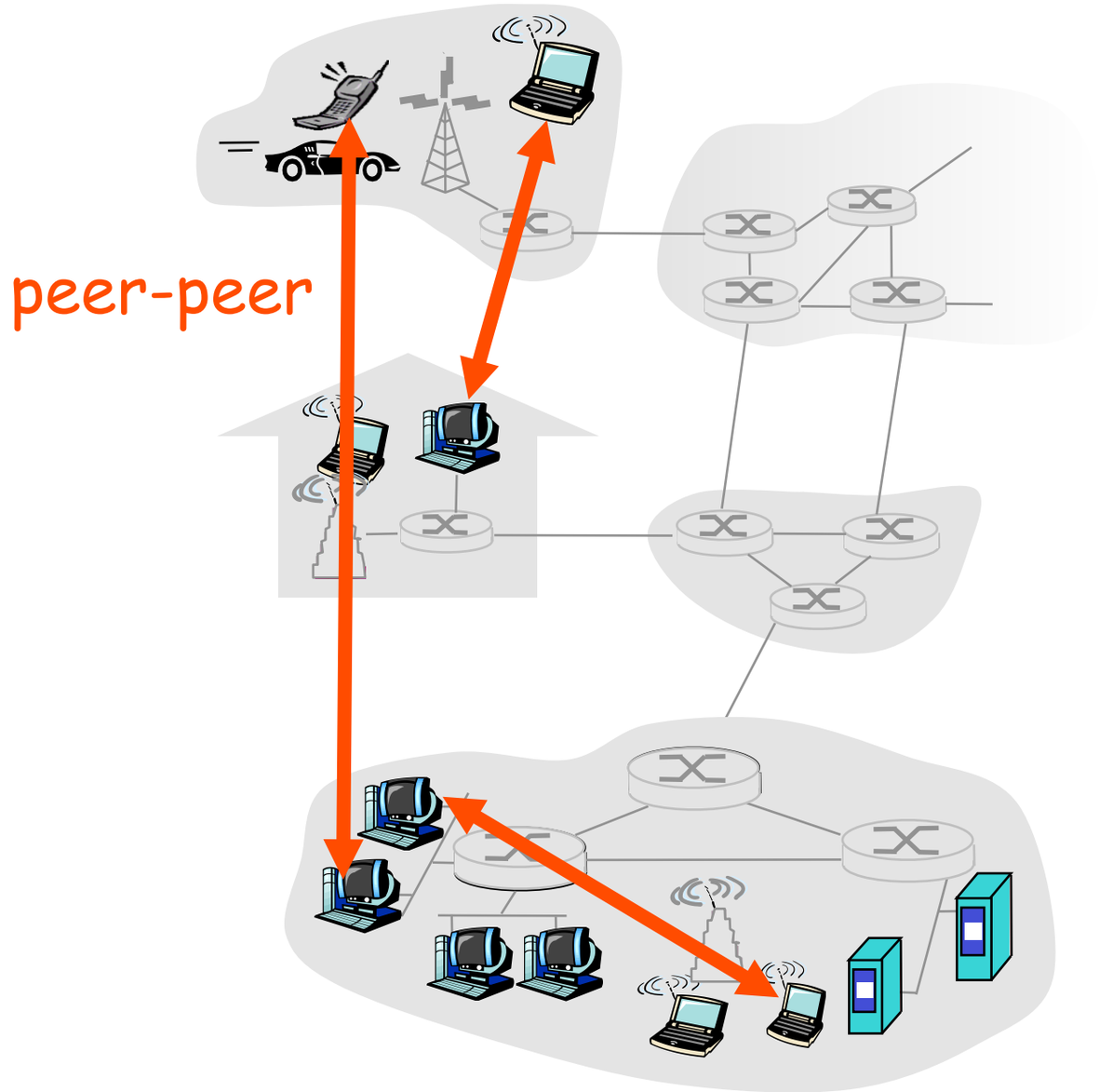

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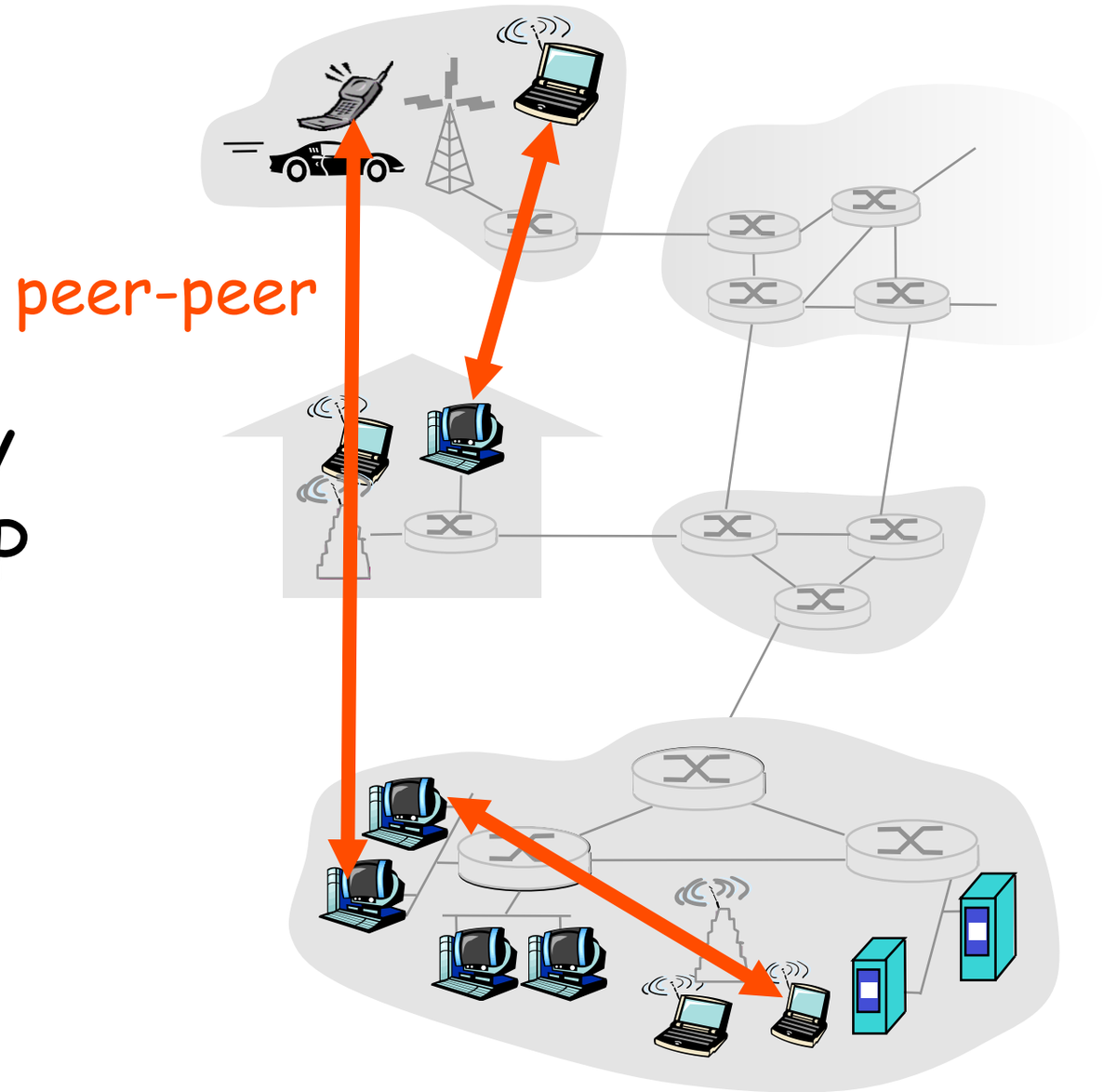

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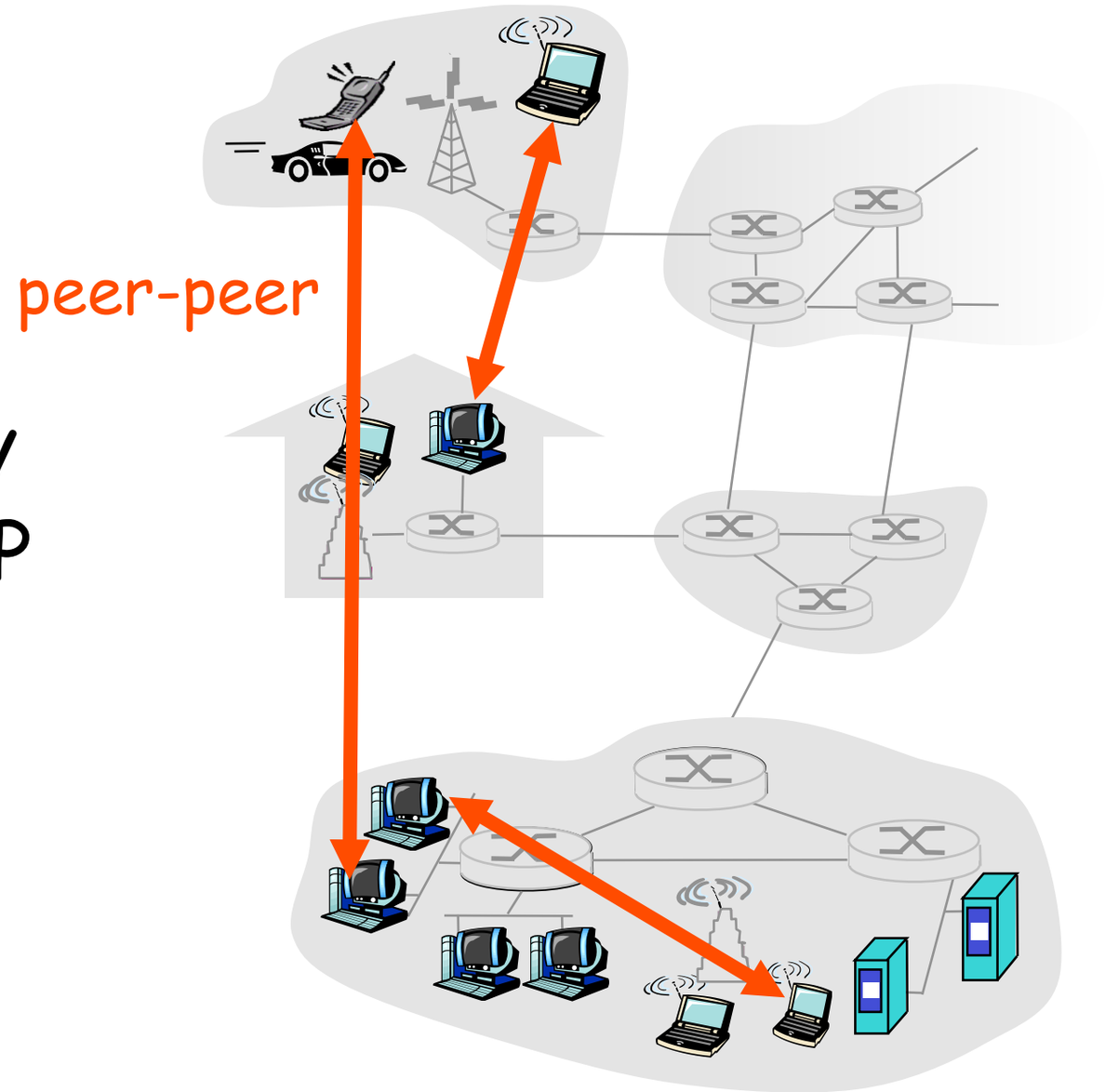

highly scalable but
difficult to manage

Hybrid of client-server and P2P

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Skype

- voice-over-IP P2P application
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Instant messaging

- chatting between two users is P2P
- centralized service: client presence detection/ location
  - user registers its IP address with central server when it comes online
  - user contacts central server to find IP addresses of buddies

Processes communicating

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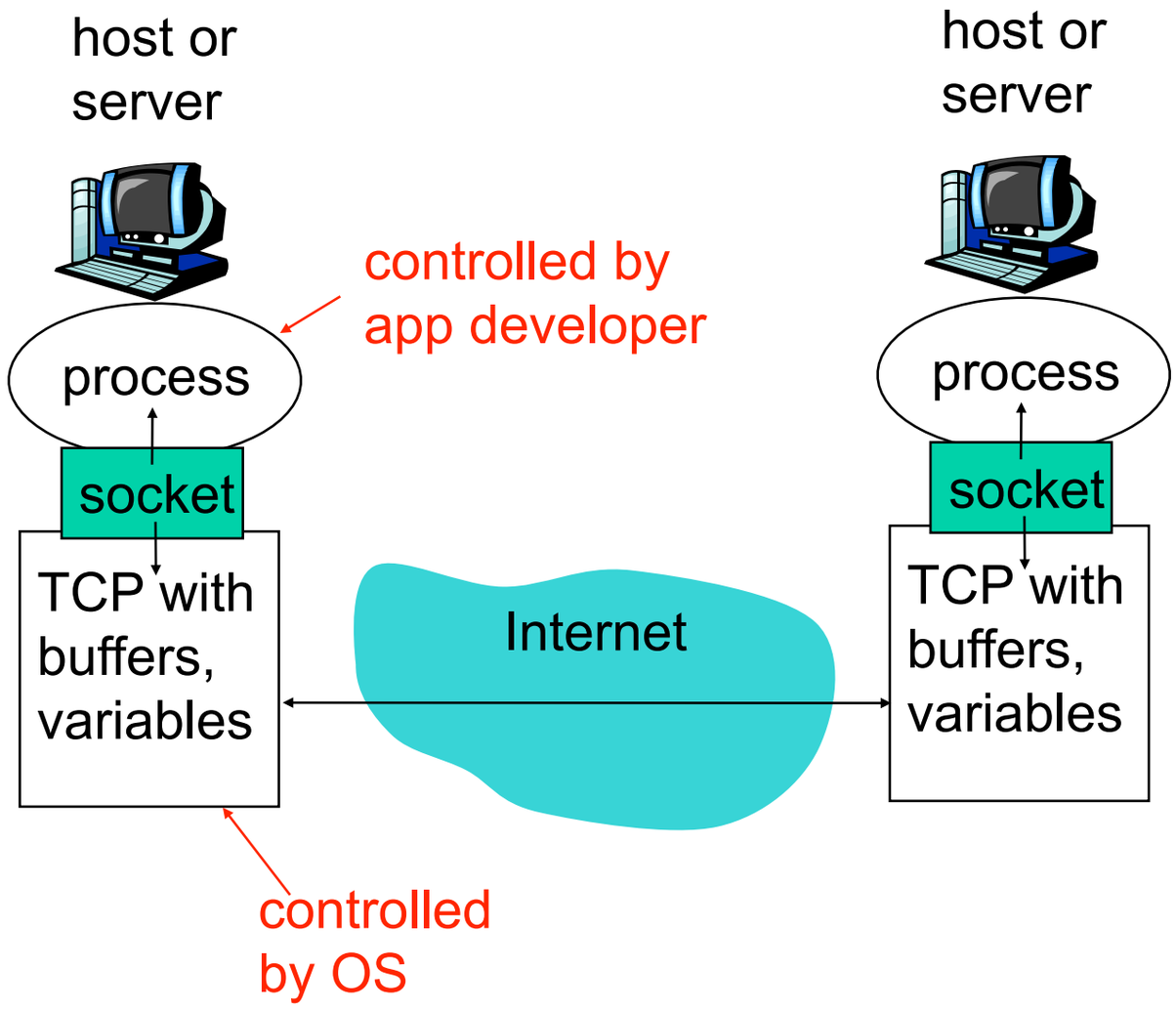
- aside: applications with P2P architectures have client processes & server processes

Sockets

- process sends/receives messages to/from its socket
- socket analogous to door
  - sending process shoves message out door
  - sending process relies on transport infrastructure on other side of door which brings message to socket at receiving process



- API: (1) choice of transport protocol; (2) ability to fix a few parameters (lots more on this later)

Addressing processes

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- host device has unique 32-bit IP address
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  - A: No, many processes can be running on same host
- identifier includes both IP address and port numbers associated with process on host.
- example port numbers:
  - HTTP server: 80
  - Mail server: 25
- to send HTTP message to www.icir.org web server:
  - IP address: 192.150.187.12
  - Port number: 80

App-layer protocol defines

- types of messages exchanged,
  - e.g., request, response
- message syntax:
  - what fields in messages & how fields are delineated
- message semantics
  - meaning of information in fields
- rules for when and how processes send & respond to messages

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public-domain protocols:

- defined in RFCs
- allows for interoperability
- e.g., HTTP, SMTP

proprietary protocols:

- e.g., Skype

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Security

- encryption, data integrity, …

Transport service requirements of common apps

Application	Data loss	Throughput	Time Sensitive
file transfer	no loss	elastic	no
e-mail	no loss	elastic	no
Web documents	no loss	elastic	no
real-time audio/video	loss-tolerant	audio: 5kbps-1Mbps video:10kbps-5Mbps	yes, 100's msec
stored audio/video	loss-tolerant	same as above	yes, few secs
interactive games	loss-tolerant	few kbps up	yes, 100's msec
instant messaging	no loss	elastic	yes and no

Internet transport protocols services

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TCP service:

- connection-oriented: setup required between client and server processes
- reliable transport between sending and receiving process
- flow control: sender won't overwhelm receiver
- congestion control: throttle sender when network overloaded
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Q: why bother? Why is there a UDP?

Internet apps: application, transport protocols

Application	Application layer protocol	Underlying transport protocol
e-mail	SMTP [RFC 2821]	TCP
remote terminal access	Telnet [RFC 854], ssh	TCP
Web	HTTP [RFC 2616]	TCP
file transfer	FTP [RFC 959]	TCP
streaming multimedia	HTTP (e.g., YouTube), RTP [RFC 1889]	TCP or UDP
Internet telephony	SIP, RTP, proprietary (e.g., Skype)	typically UDP