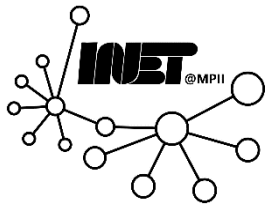
# Data Networks

## Introduction



# Introduction

## *Goals:*

- Get "feel" & terminology
- More depth, detail *later* in course
- Approach:
  - Use Internet as example

## *Overview*:

- What's the Internet?
- What's a protocol?
- Network edge:
  - *End-systems, access net, physical media*
- Network core:
  - *Packet/circuit switching, Network structure*
- Performance: *Delay, loss, throughput*
- **Protocol layers, service models**
- Networks under attack: Security
- History

# Protocol “layers”

*Networks are complex, with many “pieces”:*

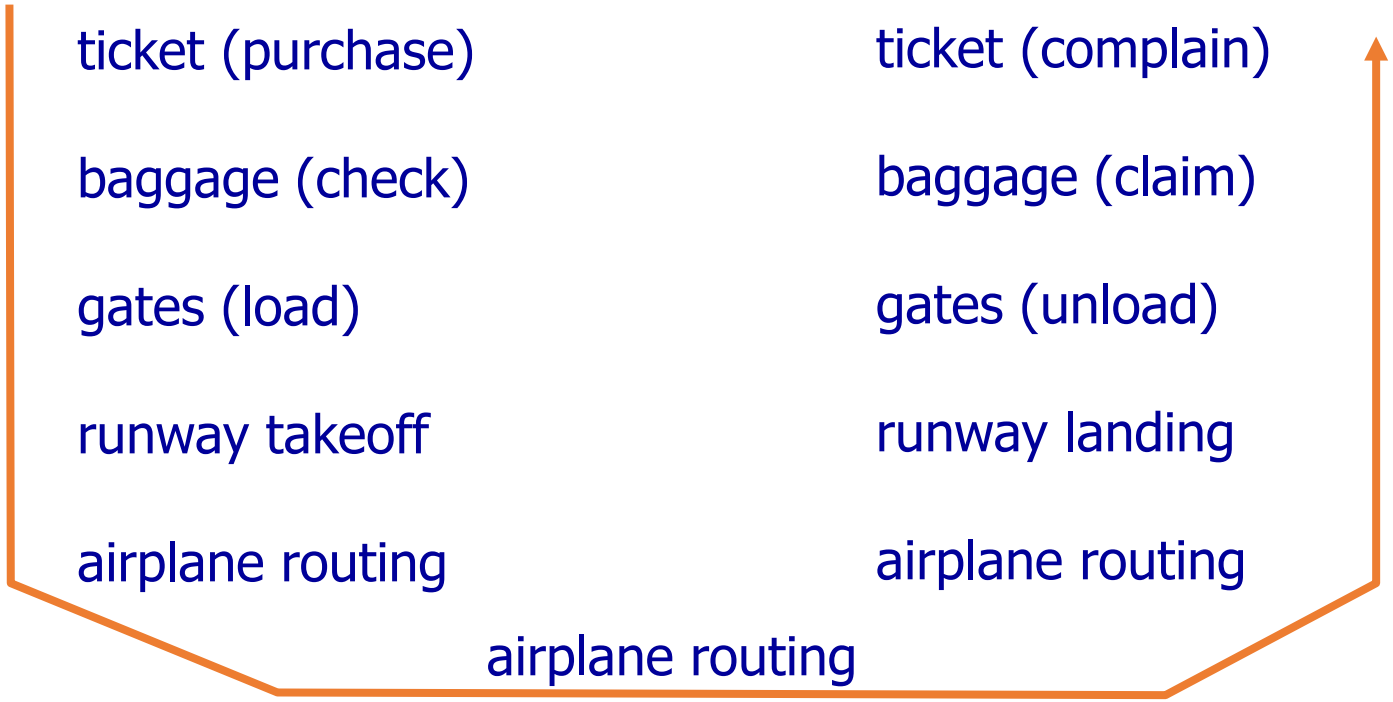
- Hosts
- Routers
- Links of various media
- Applications
- Protocols
- Hardware, software

*Question:*

Is there any hope of *organizing* structure of network?

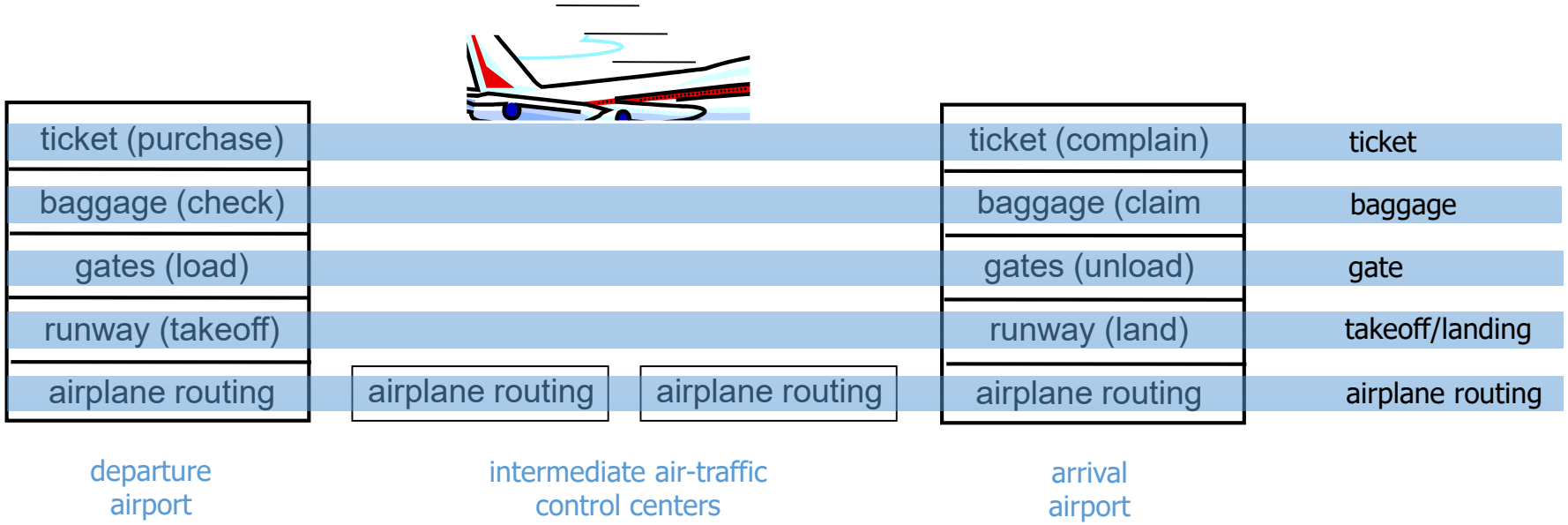
…. or at least our discussion of networks?

# Lets take a look at air travel




A series of steps

# Air travel "layering"




*Layers:* Each "layer" implements a service

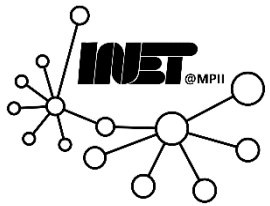
- Via its own internal-layer actions
- Relying on services provided by layer below

# Why layering?

To handle complex systems:

- Explicit structure allows identification, relationship of complex system's pieces
  - Layered *reference model* for discussion
- Modularization eases maintenance, updating of system
  - Change of implementation of layer's service transparent to rest of system
  - E.g., change in gate procedure doesn't affect rest of system

Layering is often also considered harmful?



# Internet protocol stack

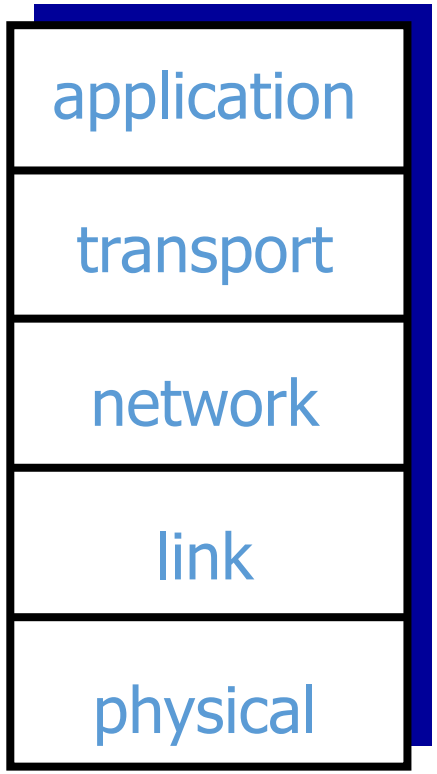
*Application:* Network applications
- FTP, SMTP, HTTP

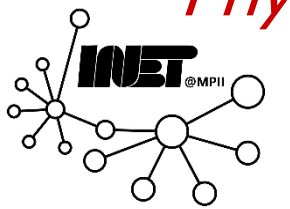
*Transport:* Process-process data transfer
- TCP, UDP

*Network:* Routing of datagrams from source to destination
- IP, routing protocols

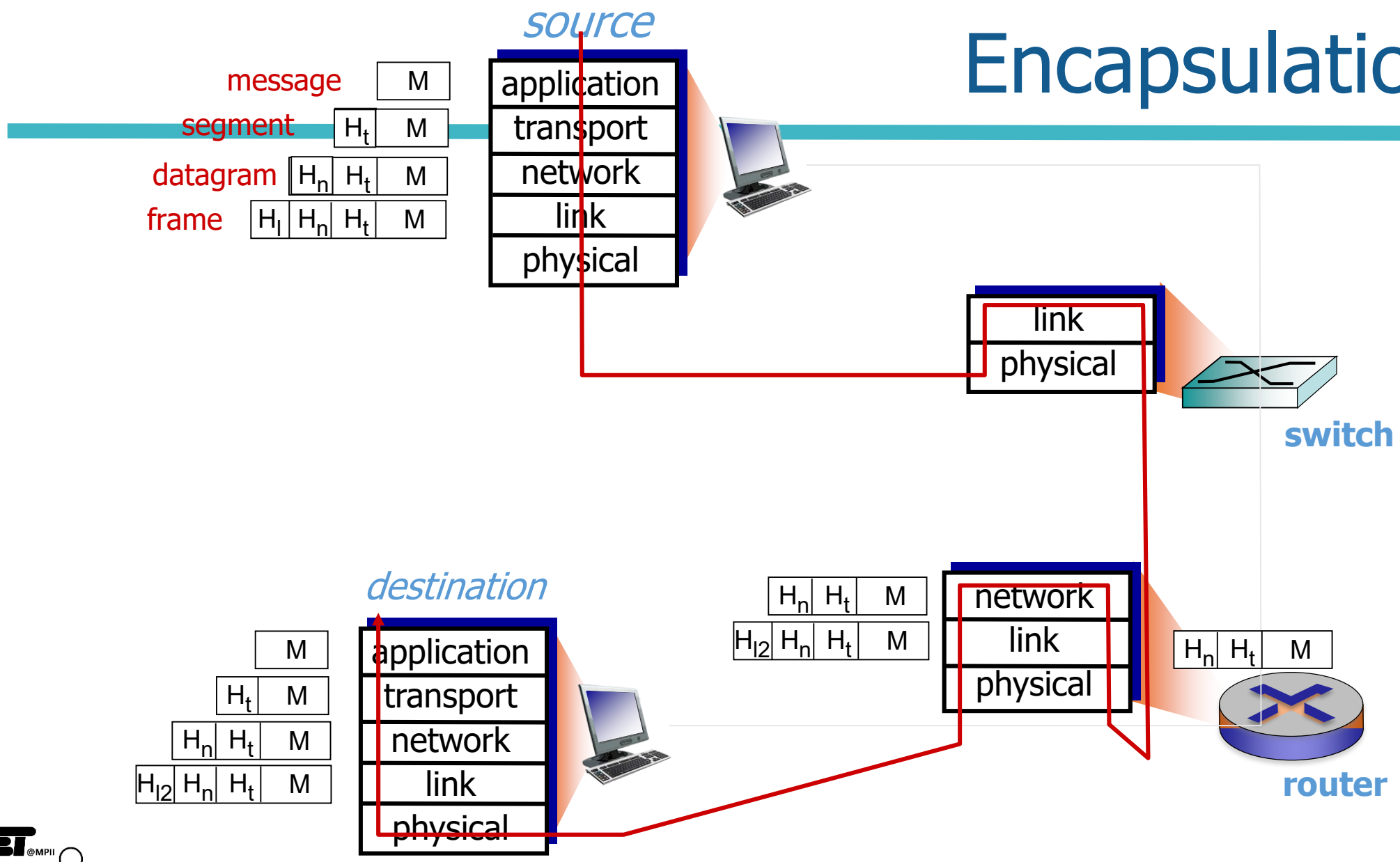
*Link:* Data transfer between neighboring network elements
- Ethernet, 802.111 (WiFi), PPP

*Physical:* Bits “on the wire”



# Encapsulation



# Introduction: Roadmap

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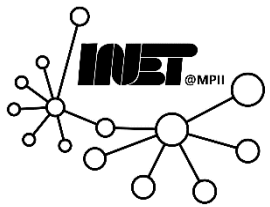
# Network security

## Field of network security:

- How bad guys can attack computer networks
- How we can defend networks against attacks
- How to design architectures that are immune to attacks

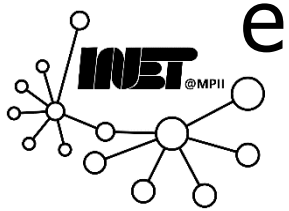
## Internet originally designed without (much) security in mind

- *Original vision:* "A group of mutually trusting users attached to a transparent network" ☺
- Internet protocol designers playing "catch-up"
- Security needed in all layers!



# Bad guys: Malware

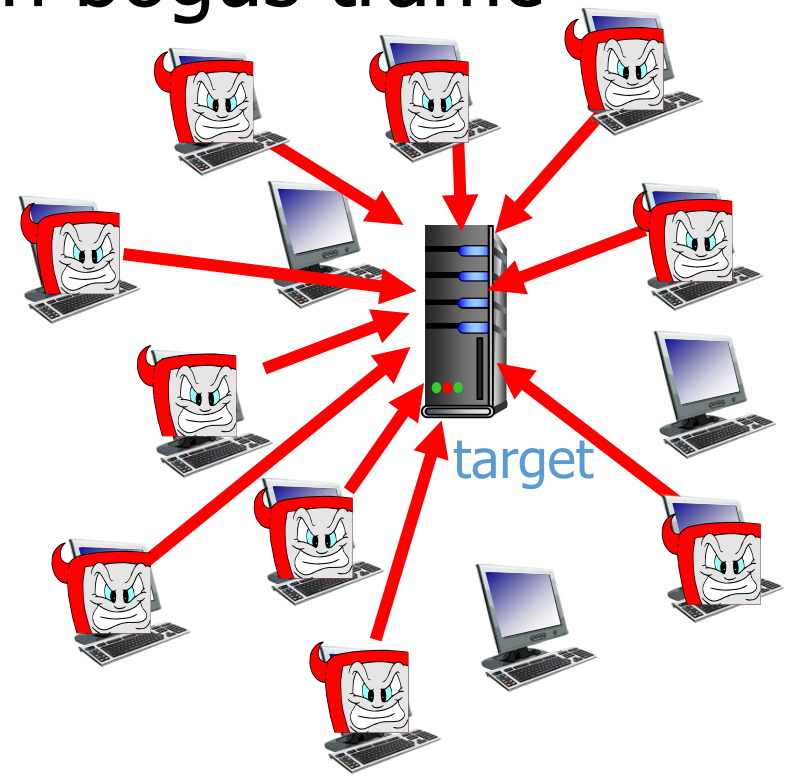
- Malware can get in host from:
  - *Virus:* Infection by receiving/executing object (e.g., e-mail attachment)
  - *Worm:* Self-replicating infection by passively receiving object that gets itself executed
- Spyware malware can record keystrokes, web sites visited, upload info to collection site
- Infected host are often enrolled in botnets, used, e.g., for spam, DDoS attacks



# Bad guys: May attack infrastructure, hosts, …

- *Denial of Service (DoS):* Attackers make resources (server, bandwidth) unavailable to legitimate traffic by overwhelming resource with bogus traffic

1. Select target
2. Break into hosts around the network (see botnet)
3. Send packets to target from compromised hosts



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# Internet History

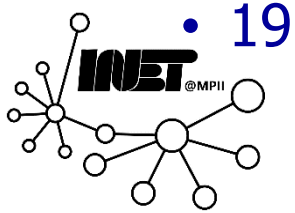
## *1972-1980: Internetworking, new and proprietary nets*

- 1970: ALOHAnet satellite network in Hawaii
- 1974: Cerf and Kahn - architecture for interconnecting networks
- 1976: Ethernet at Xerox PARC
- Late 70's: Proprietary architectures: DECnet, SNA, XNA
- Late 70's: Switching fixed length packets (ATM precursor)
- 1979: ARPAnet has 200 nodes

Cerf and Kahn's internetworking principles:

- Minimalism, autonomy - no internal changes required to interconnect networks
- Best effort service model
- Stateless routers
- Decentralized control

Defines today's Internet architecture



# Internet history

*1980-1990: New protocols, a proliferation of networks*

- 1983: Deployment of TCP/IP
- 1982: SMTP e-mail protocol defined
- 1983: DNS defined for name-to-IP-address translation
- 1985: FTP protocol defined
- 1988: TCP congestion control

- New national networks: CSnet, BITnet, NSFnet, Minitel
- 100,000 hosts connected to confederation of networks

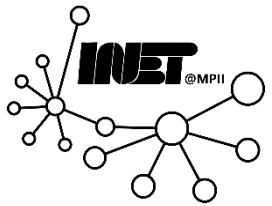
# Internet history

*1990, 2000's: Commercialization, the Web, new apps*

- Early 1990's: ARPAnet decommissioned
- 1991: NSF lifts restrictions on commercial use of NSFnet (decommissioned, 1995)
- Early 1990s: Web
  - hypertext [Bush 1945, Nelson 1960's]
  - HTML, HTTP: Berners-Lee
  - 1994: Mosaic, later Netscape
  - late 1990's: Commercialization of the Web

Late 1990's – 2000's:

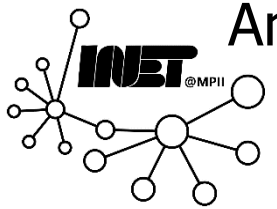
- More "killer" apps: instant messaging, P2P file sharing
- Network security to forefront
- Est. 50 million host, 100 million+ users
- Backbone links running at Gbps



# Internet history

## *2005-present*

- ~5B devices attached to Internet (2016)
  - Smartphones and tablets
- Aggressive deployment of broadband access
- Increasing ubiquity of high-speed wireless access
- Emergence of online social networks:
  - Facebook: ~ one billion users
- Service providers (Google, Microsoft) create their own networks
  - Bypass  Internet, providing “instantaneous” access to search, video content, email, etc.
- E-commerce, universities, enterprises running their services in “cloud” (e.g., Amazon EC2)



# Introduction: Summary

*Covered a "ton" of material!*

- Internet overview
- What's a protocol?
- Network edge, core, access network
- Packet-switching versus circuit-switching
- Internet structure
- Performance: Loss, delay, throughput
- Layering
- Security
- History

*You should now have:*

- Context, overview, "feel" of networking
- More depth, detail *to follow!*