CIS 5530: Networked Systems

Design Goals

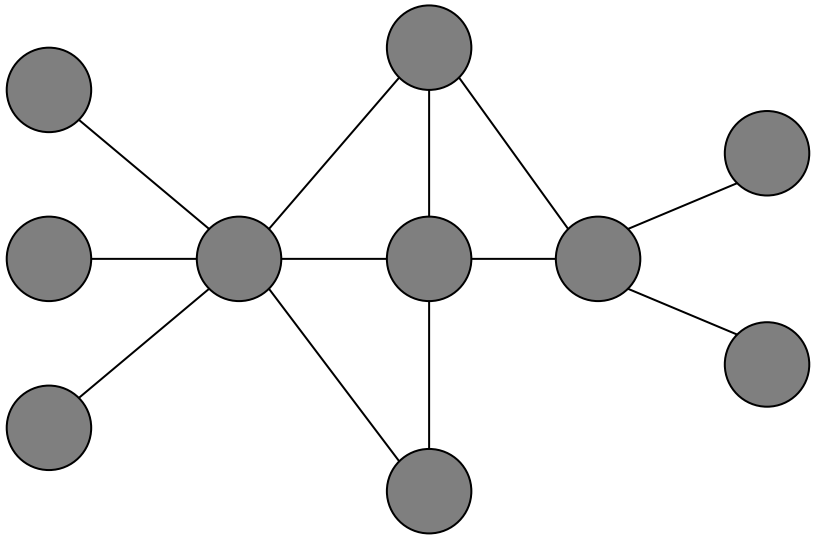
September 6, 2023

Agenda

- History of the Internet
- Networking Basics NEXT
- Design goals of the Internet
  - Taxonomy of networks
  - Design goals (Clark '88)
  - Layering and the end-to-end principle

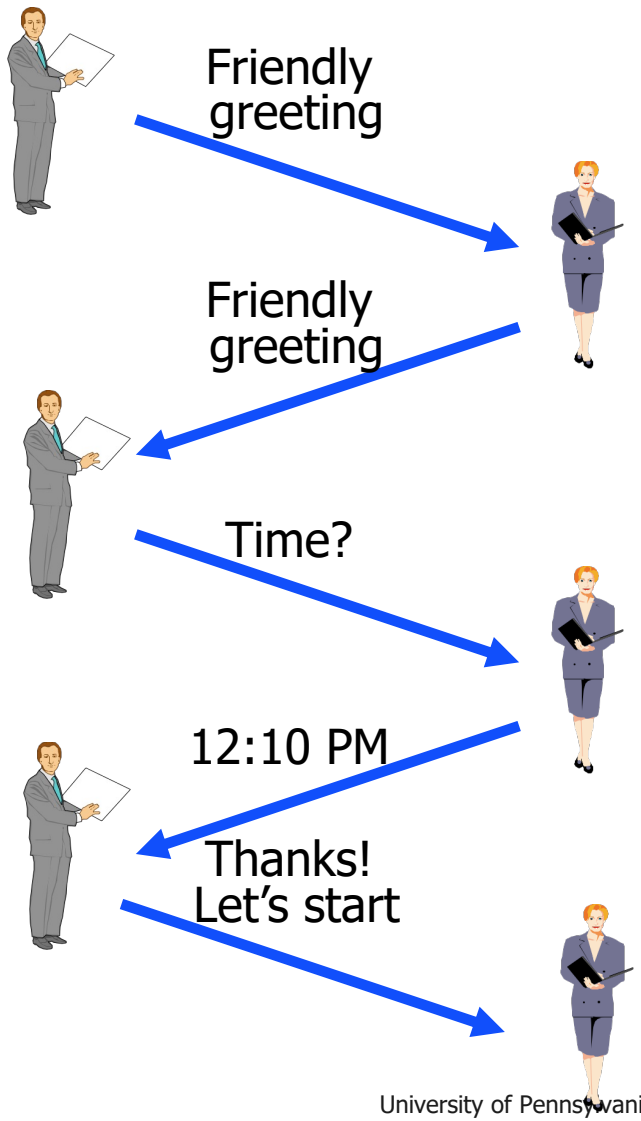
Networked Systems

- Study of systems of links that interconnect computers in order to move data



- More simply: How computers communicate with one another

How do <u>we</u> communicate?



What is required to make this work?

Protocols

- An agreement between parties on how to communicate
- Defines the syntax of communication
  - The sound will be broken up into English sentences
  - The sentences will be broken up into words
  - I will pause slightly between words
  - …

Protocols

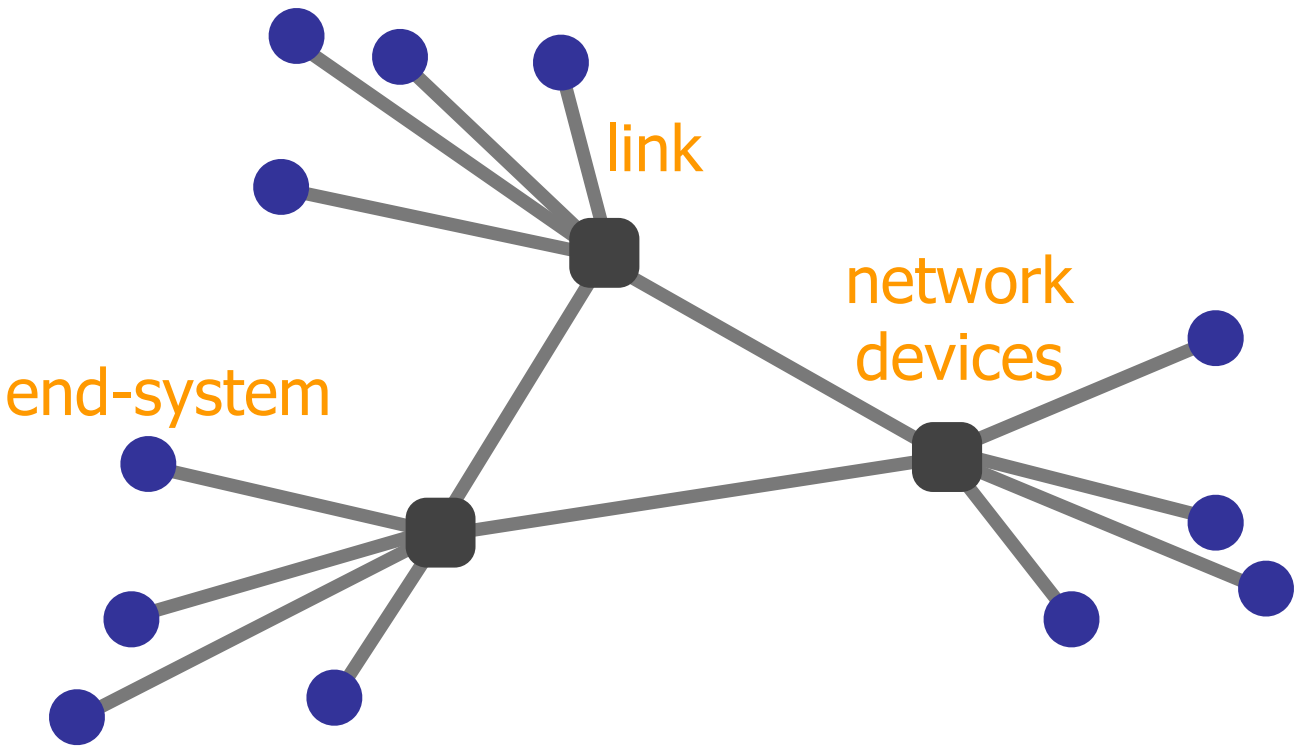
- An agreement between parties on how to communicate
- Defines the syntax of communication
- And semantics
  - "First a hello, then a request…"
- We will study many protocols
  - Exist at many levels (e.g., hardware and software)
  - Exist for many purposes (e.g., data transfer and routing control)
  - Defined by standards bodies like IETF, IEEE, ITU

Designing the Postal Service

- What is the syntax?
- How do I know where its going?
- How does it get there?

The Internet shares similarities to the Postal Service

Header	Payload	(Trailer)



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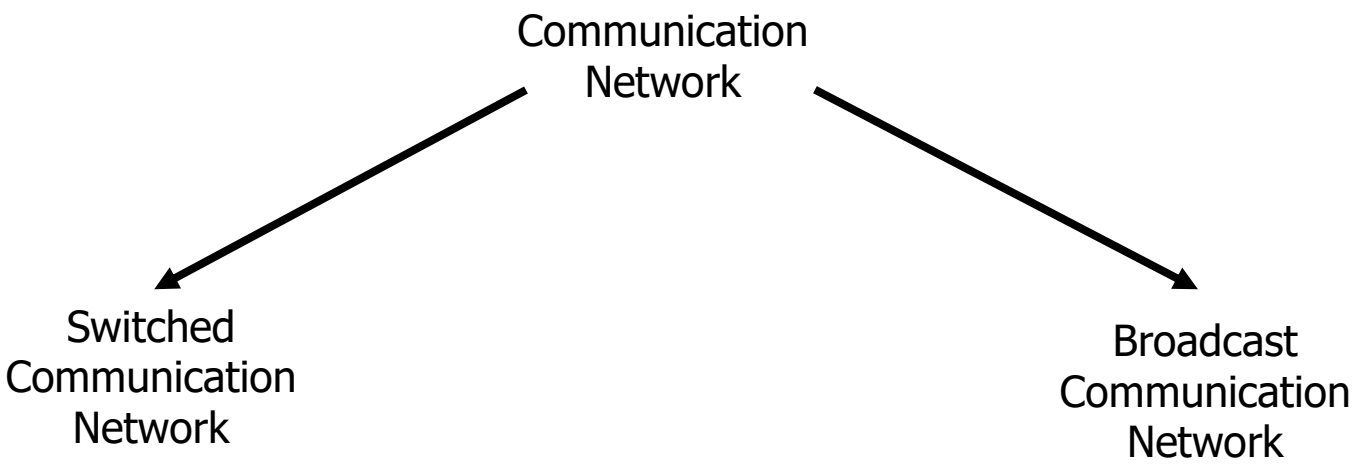
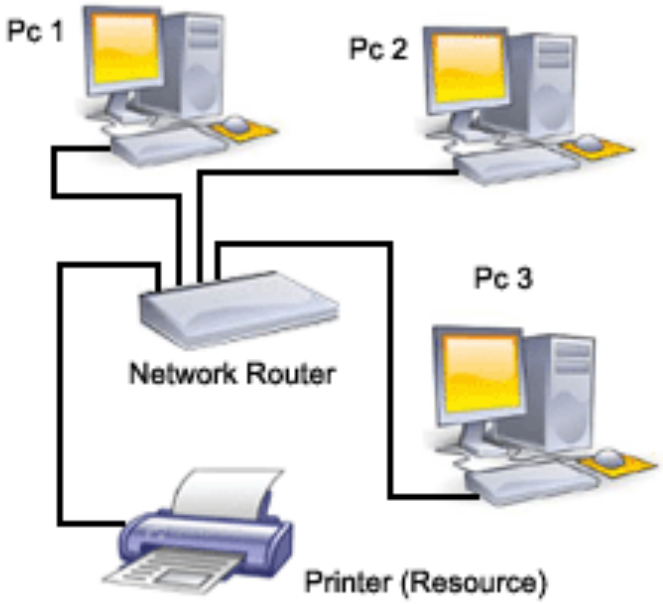
Taxonomy of Communication Networks



Broadcast Networks

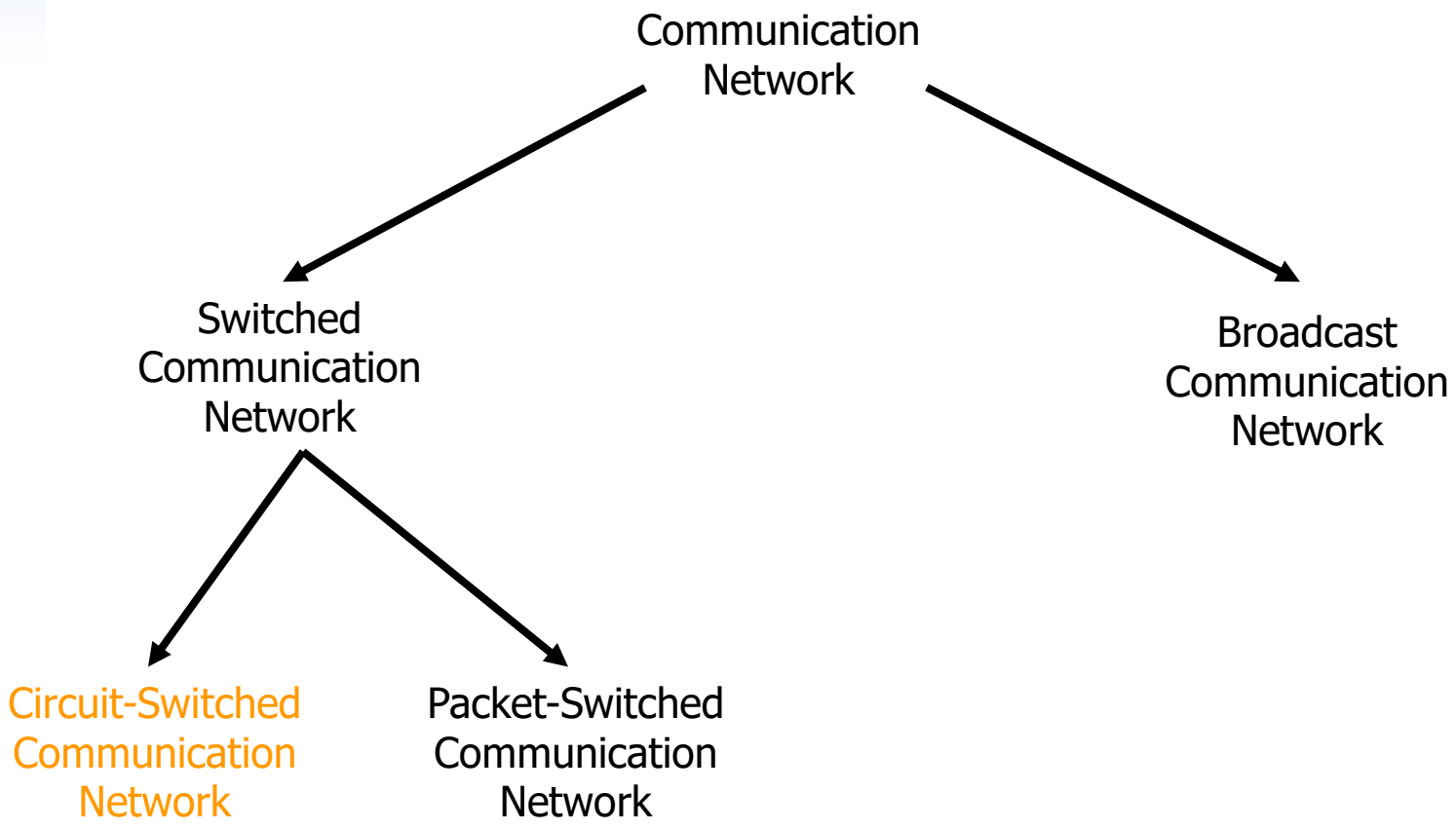
Switched Networks



- Nodes share a common channel
- Everyone can hear everyone else

- Information is transmitted to a small subset (usually one) of the nodes

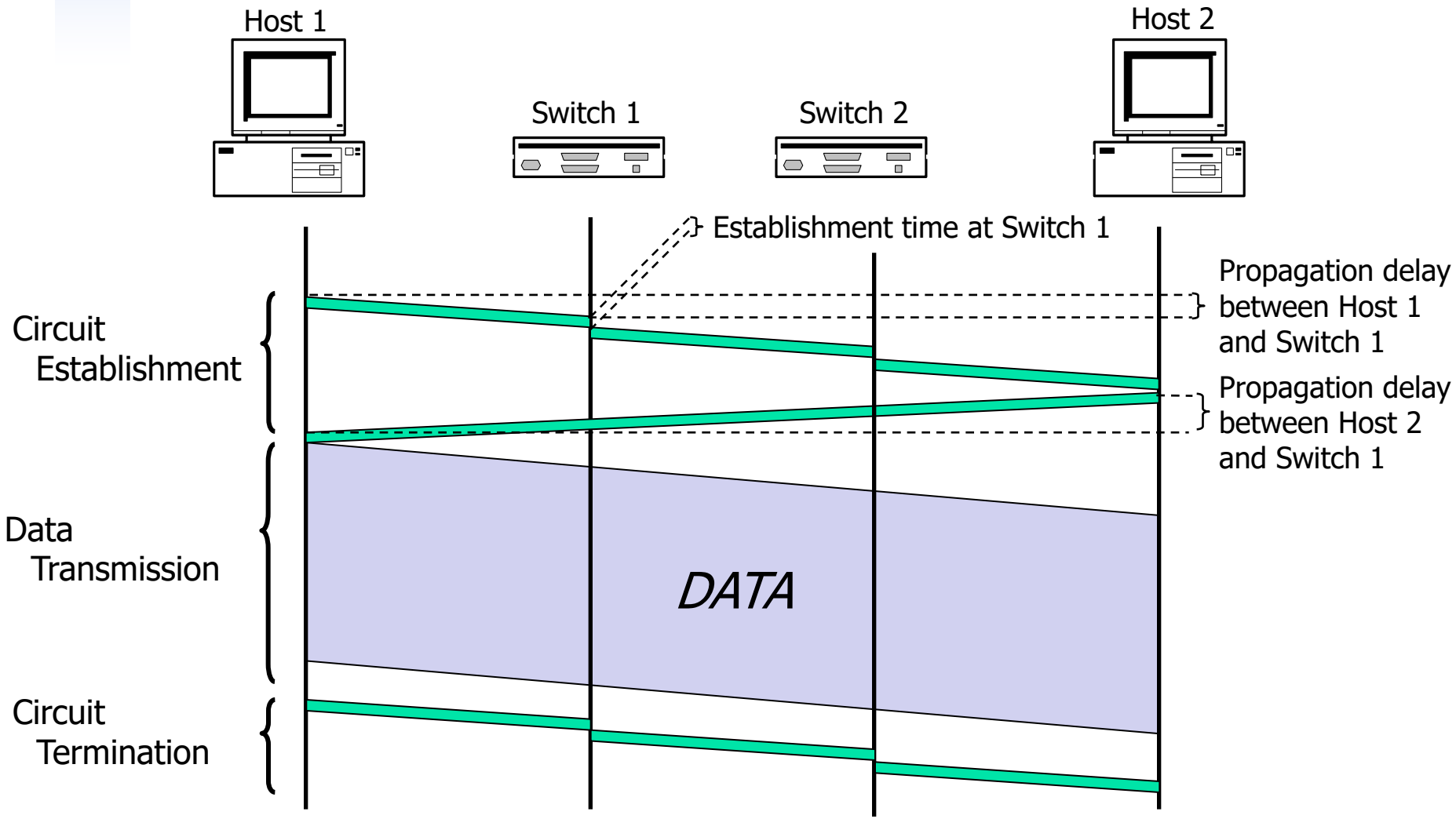
Taxonomy of Communication Networks



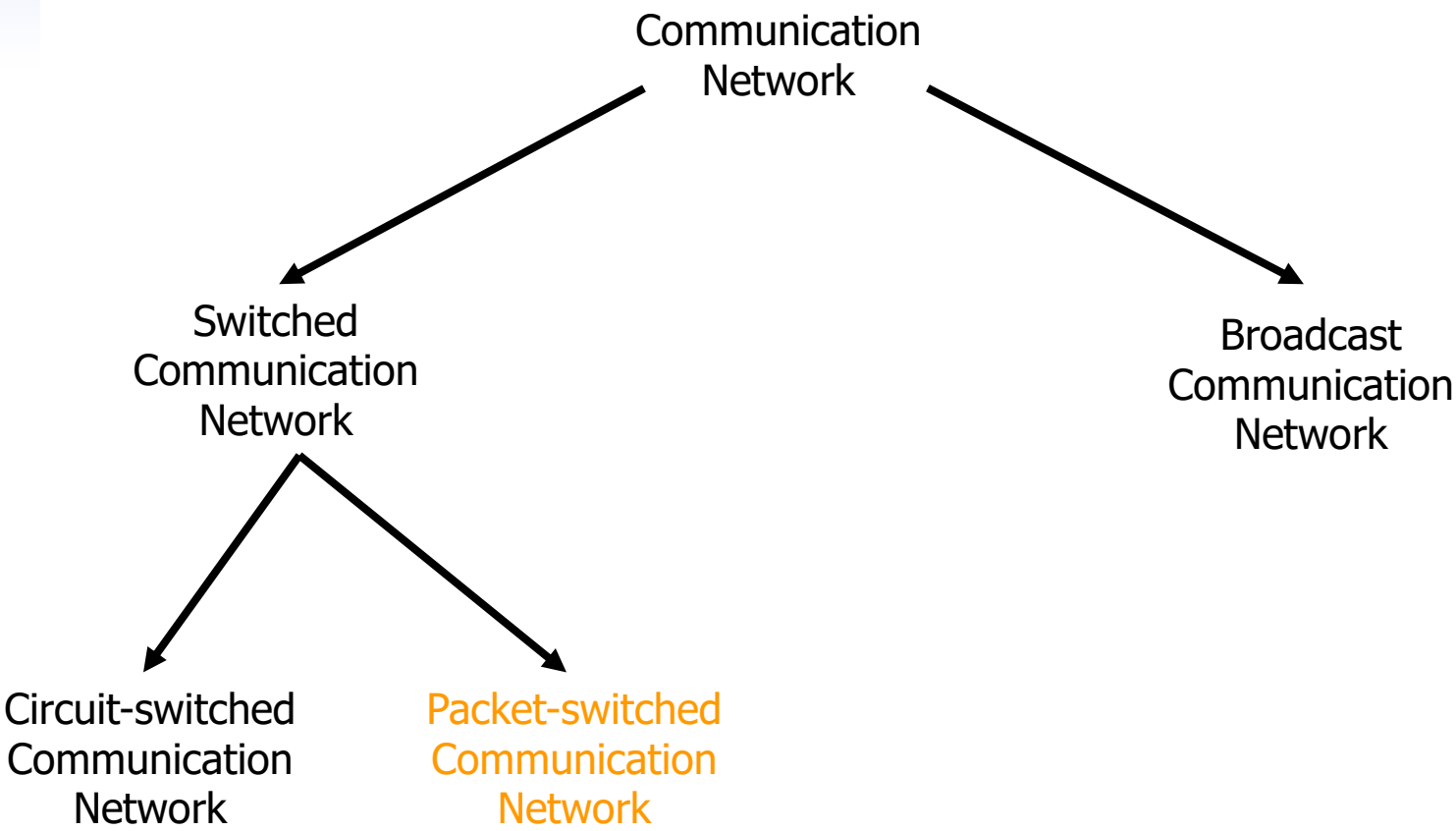
Circuit Switching

- Three phases
  1. Circuit establishment (from source to destination)
  2. Data transfer
  3. Circuit termination
- Guaranteed capacity until circuit termination
- If circuit not available: "Busy signal"
  - Even if no data is sent!

Circuit Switching Timeline



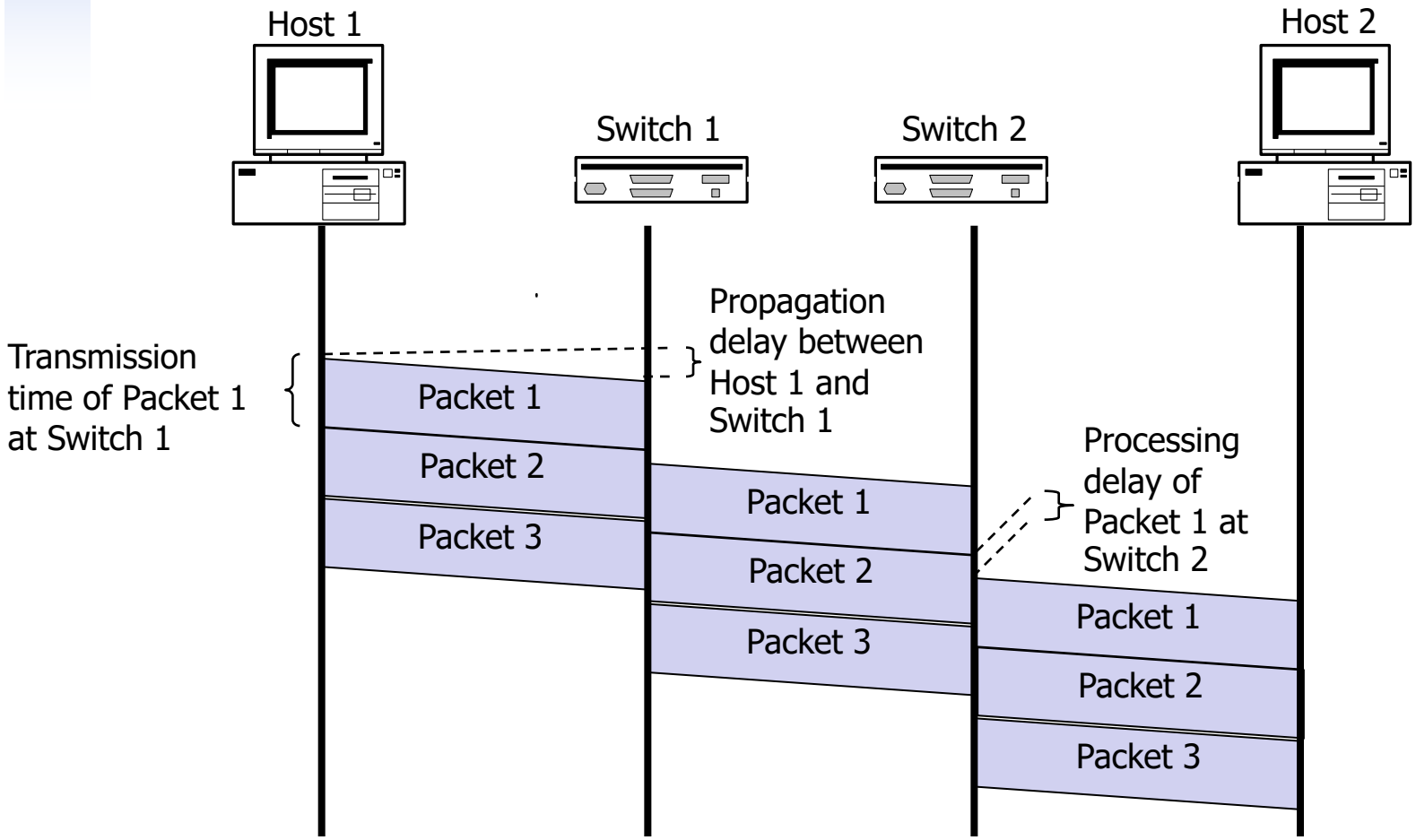
Taxonomy of Communication Networks



Datagram Packet Switching

- Each packet is independently switched
  - Each packet header contains destination address
  - Routing protocol is used to compute next hop
- No resources are pre-allocated (reserved) in advance

Packet Switching Timeline



What are the advantages/disadvantages of packet switching?

Packet switching vs Circuit switching

- Advantages:
  - No connection state required
  - Easy to recover from errors
  - Minimal network assumptions
- Disadvantages:
  - No guarantees
  - Slower when transmitting a lot of data

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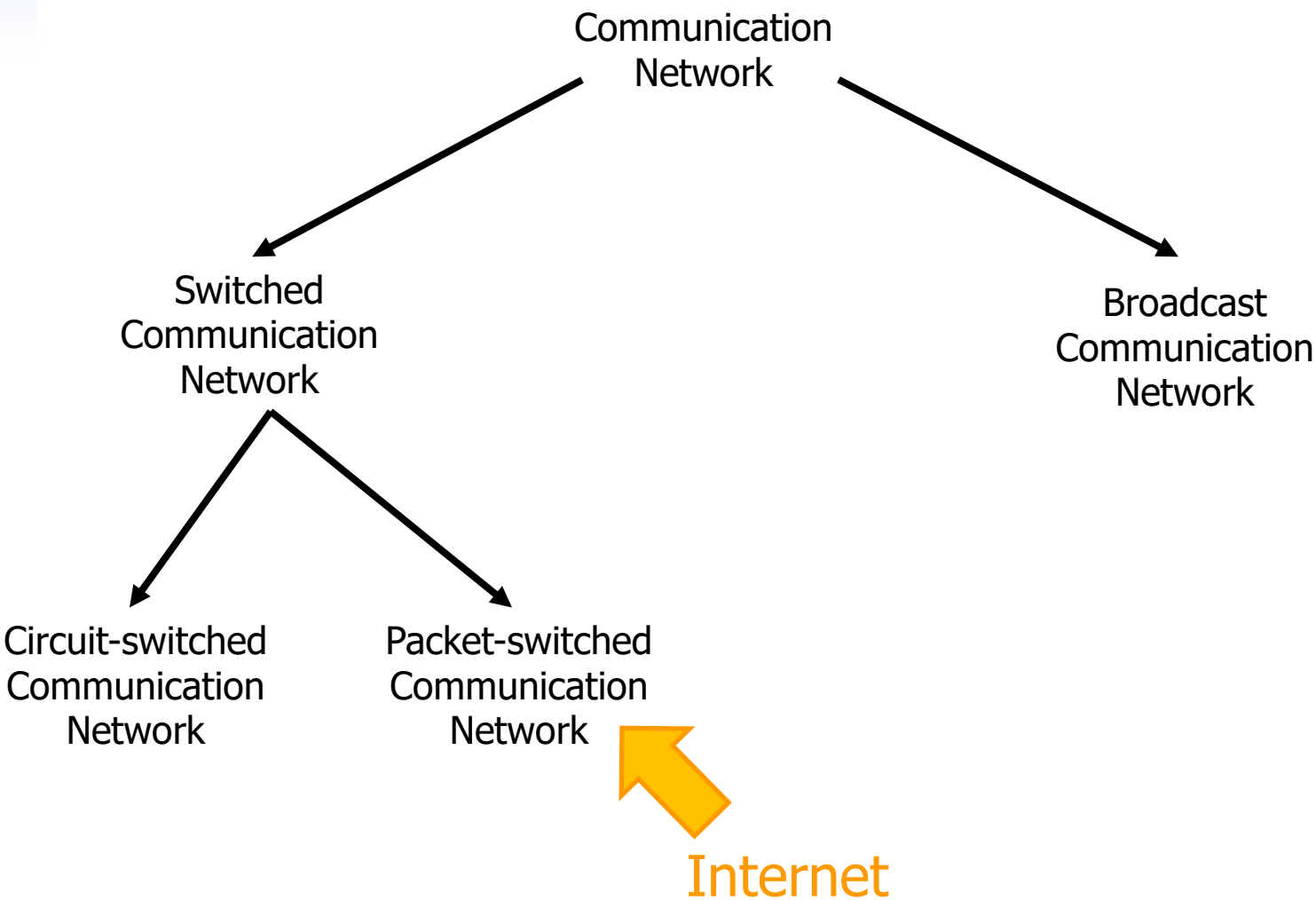
Taxonomy of Communication Networks



The fundamental goal of the Internet

- An inter-network:

  "technique for **multiplexed utilization** of **existing interconnected networks**"

- **Multiplexing** (sharing)
  - Shared use of a single communications channel

- **Existing networks** (interconnection)

The goals of the Internet

http://ccr.sigcomm.org/archive/1995/jan95/ccr-9501-clark.pdf

"technique for multiplexed utilization of existing interconnected networks"

- Second-level goals:
  - Resilience/survivability
  - Heterogeneity
    - Different types of services
    - Different types of netwo
  - Distributed managemen
  - Cost effectiveness
  - Easy host attachment
  - Resource accountability

"This set of goals might seem to be nothing more than a checklist of all the desirable network features. It is important to understand that these goals are in order of importance, and an entirely different network architecture would result if the order were changed."

These goals were prioritized for a military network. Should priorities change as the network evolves?

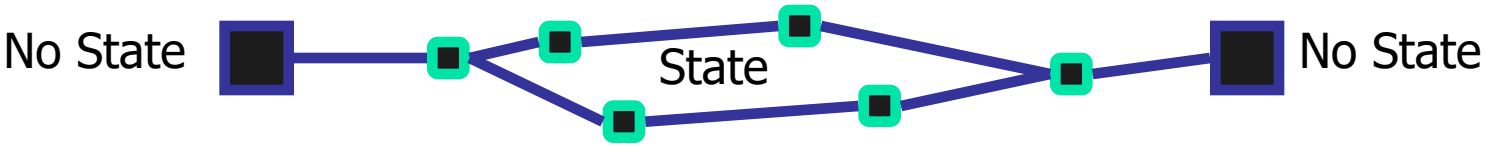
Goal #2: Survivability

- If a device between you and your destination fails
- Goal: End-hosts should be able to continue communicating
  - Reconfigure to mask transient failures
  - Only stop working if there is a complete partition
- Key issue: how to deal with state
  - Ex: Information on location, authentication, what types of messages I'm allowed to send, how fast I'm allowed to send, etc.
  - Replication vs Fate-sharing

Replication

- The network keeps the state for you

- To protect from information loss, must be replicated
- Fault tolerance limited by the number of replicas
  - More failures will still wipe out the state
- Hard to engineer
  - End host and network need to deal with a lot of corner cases



Fate-sharing (chosen by the Internet)

- End hosts are responsible for their own state
- Lose information for a host if (and only if?) the host itself goes down, in which case it doesn't care
- Easy to engineer
  - Protects against any number of failures
  - Network devices are (mostly) stateless
  - More trust placed at end-hosts

Tradeoff: performance.
But mostly works.

Goal #3: Heterogeneous services/networks

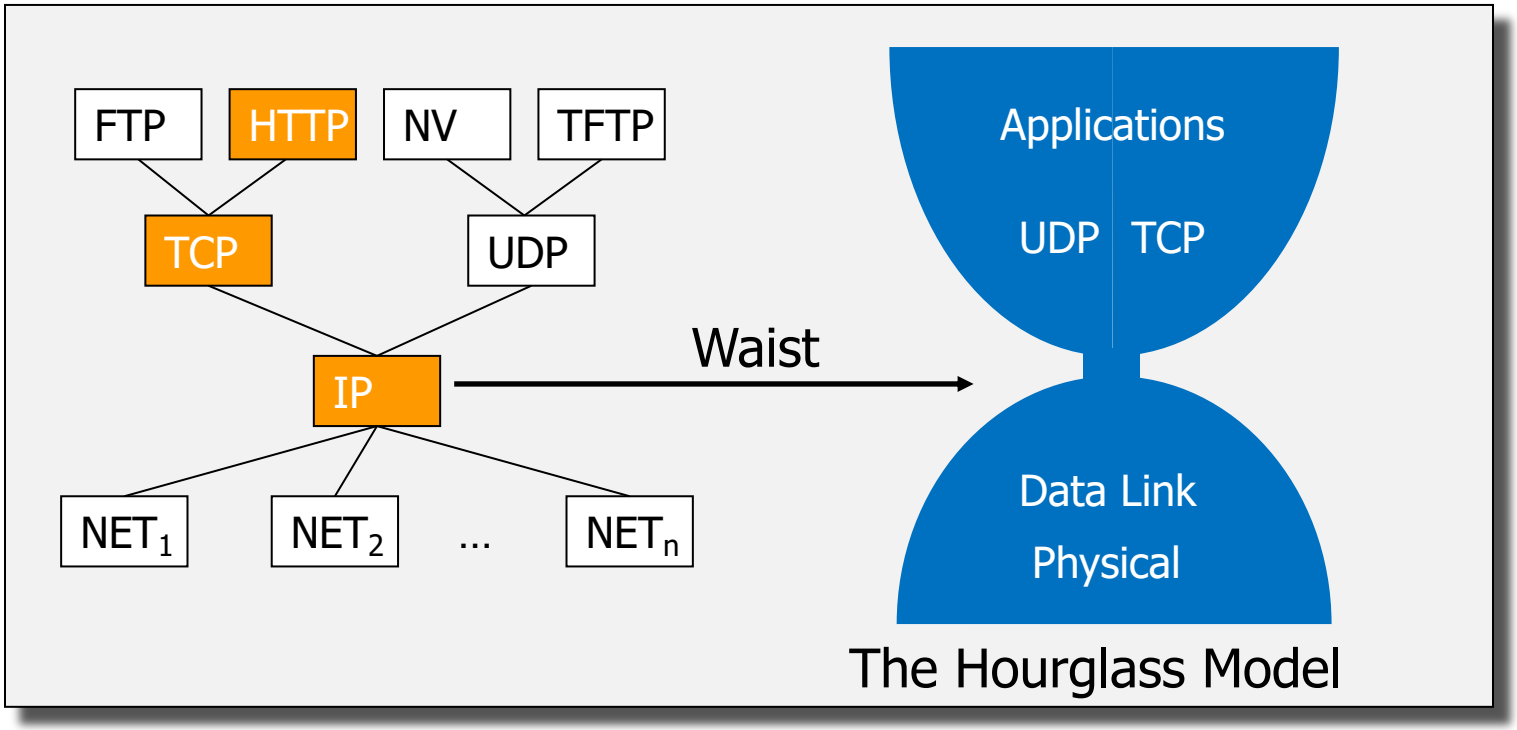
- May require and provide different interfaces
  - Example: Voice vs Video
  - Example: Wi-Fi vs Backbone network

- Abstraction through layering
  - (We'll talk more about this later)
  - Can swap out individual layers, e.g., backbone for Wi-Fi
- "Best effort" service model
  - If you give me a message, I'll "try my best" to deliver it
  - Don't guarantee anything so that

Tradeoff: No assumptions, no guarantees.
Also mostly works, but not in the way we expected.

The Internet Protocol Suite

Eventually, different networks had to agree on *something*
That something was IP*
*now IP/TCP/HTTP



Led to something called the "Curse of the Narrow Waist"

Goal #4: Distributed Management

- Today's Internet is decentralized
  - 10s of thousands of ISPs across almost every country
- Autonomous systems exchange routes with each other
- Each autonomous system can manage their Internal networks, connect to whomever they want

Allows for organic growth, scalable management.
Tradeoff: No one party has visibility/control.

No Owner, No Responsible Party

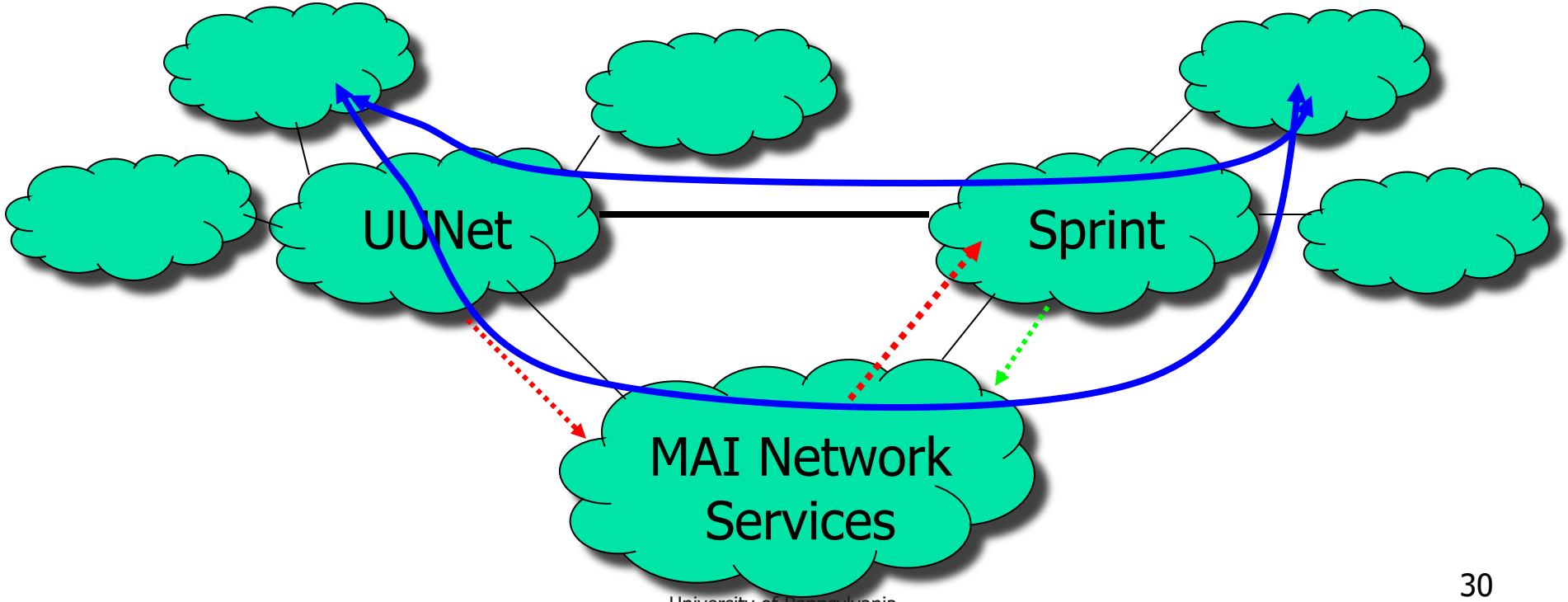
"Some of the most significant problems with the Internet today relate to lack of sufficient tools for distributed management, especially in the area of routing."

- Hard to figure out who/what's causing a problem
- Worse yet, local actions have global effects…

Local Actions, Global Consequences

"…a glitch at a small ISP… triggered a major outage in Internet access across the country. The problem started when MAI Network Services...passed bad router information from one of its customers onto Sprint."

-- *news.com*, April 25, 1997



The goals that started to fall by the wayside

Goal #5: Cost Effectiveness

- Many inefficiencies in the Internet
  - For small packets, headers introduce high overhead
  - End-to-end retransmission of lost packets leads to wasted bandwidth
- Arguably a good tradeoff as network speeds have grown rapidly
- Exception is wireless, where they try to correct for some of this

Goal #6: Ease of Attachment

- Anything with an IP stack can connect (hourglass model)
- Some amount of burden on end systems and programmers

- But once you get a working network stack…
  - A huge success!!

The "last" Goal #7: Resource Accountability

- Not prioritized at all
- Datagram networks make accounting tricky
  - The phone network has had an easier time figuring out billing
  - Payments/billing on the Internet is much less precise

- Convoluted business relationships
- Hot potato routing

What's Missing?

- Security
- Availability
- Accountability (the other kind)
- Support for disconnected/intermittent operation
- Mobility
- …