CS4450

Computer Networks:
Architecture and Protocols

Lecture 5
- Design Goals

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Announcements

- **Course webpage is your one-stop shop**
- **Office hours have been announced**
    - We start immediately (starting today)
- **My office hours tomorrow will be covered by someone**
    - This week is extremely busy for me
    - Sorry if my responses to your emails or piazza posts are delayed
    - I will be back in full swing starting next week
- **Problem Set 1 solutions will be released today**

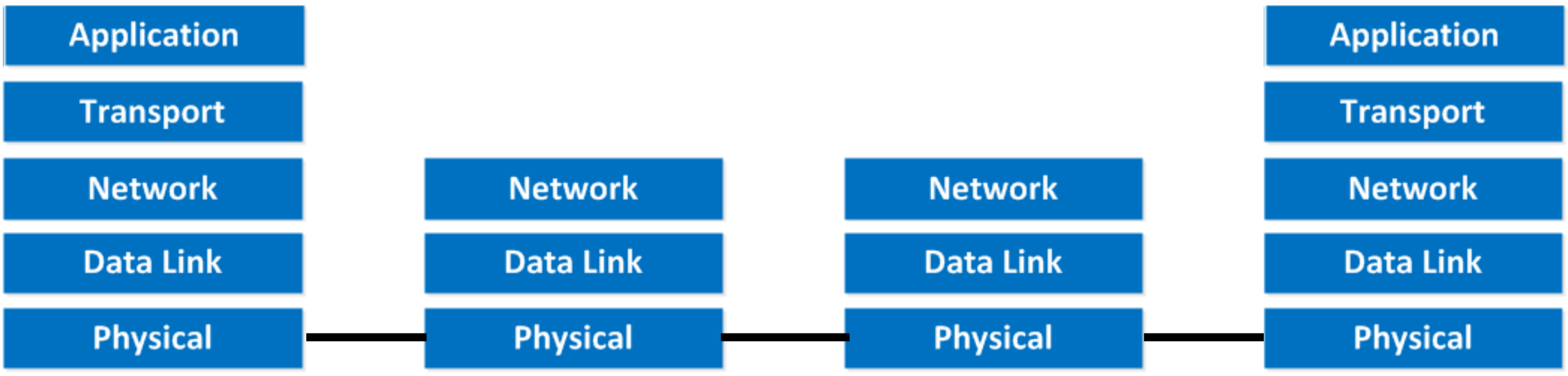
Context for Today's Lecture

- **Solving problems related to propagation and transmission delays**
    - Some in-class exercises
    - We will solve them together

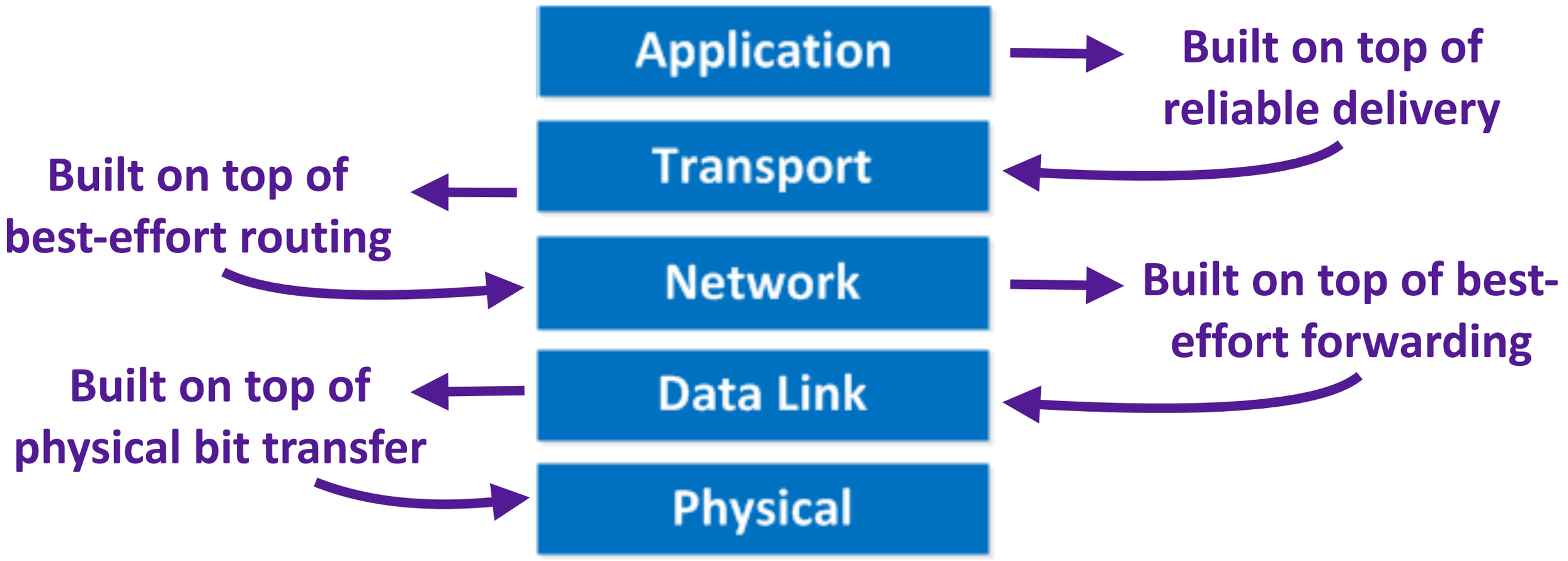
- **Why was the Internet designed the way it was?**

Recap: Three design principles

- How to break system into modules
    - **Layering**
- Where are modules implemented
    - **End-to-End Principle**
- Where is state stored?
    - **Fate-Sharing**



Recap: Layering



- **A kind of modularity**
  - Functionality separated into layers
  - Layer n **interfaces with only layer n-1 and layer n+1**
    - Hides complexity of surrounding layers

Recap: End-to-end Principle (Interpretation)

Assume the condition (IF) holds. Then,

- **End-to-end implementation**
  - Correct
  - Generalized, and simplifies lower layers
- **In-network implementation**
  - Insufficient
  - May help — or hurt — performance

Recap: Fate-Sharing

- When storing state in a distributed system, colocate it with entities that rely on that state

- Only way failure can cause loss of the critical state is if the entity that cares about it also fails …
  - … in which case it doesn't matter

- Often argues for keeping state at end hosts rather than inside routers
  - E.g., packet switching rather than circuit switching

Recap: Decisions and their Principles

- How to break system into modules
    - **Dictated by layering**

- Where modules are implemented
    - **Dictated by End-to-End Principle**

- Where state is stored
    - **Dictated by Fate Sharing**

Questions?

From Architecture to Design:

Design Goals

David Clark

- Wrote a paper in 1988 that tried to capture why the Internet turned out as it did
- It described an ordered list of priorities that informed the decision
- What do you think those priorities were?

Internet Design Goals (Clark ’88)

- **Connect existing networks**
- Robust in face of failures
- Support multiple types of delivery services
- Accommodate a variety of networks
- Allow distributed management
- Easy host attachment
- Cost effective
- Allow resource accountability

#1: Connect Existing Networks

Want one protocol that could be used to connect any pair of (existing) networks

- Different networks may have different needs
    - For some: reliable delivery more important
    - For others: performance more important
    - **But there is one need that every network has: connectivity**

- The Internet Protocol (IP) is that unifying protocol
    - All (existing) networks must be able to implement it

#2: Robust in Face of Failures

As long as network is not partitioned, two hosts should be able to communicate (eventually)

- Must **eventually recover** from failures

- Very successful in the past; unclear how relevant now
    - **Availability** is becoming increasingly important than **recovery**

#3: Support Multiple Types of Delivery Services

Different delivery services (applications) should be able to co-exist

- Already implies an application-neutral framework

- Build lowest common denominator service
    - **Again: connectivity**
    - Applications that need reliability may use it
    - Applications that do not need reliability can ignore it

- **This isn't as obvious as it seems…**
    - What would applications in 2050 need?

Questions?

#4: Variety of Networks

Must be able to support different networks with different hardware

- **Incredibly successful!**
    - Minimal requirements on networks
    - No need for reliability, in-order, fixed size packets, etc.
    - A result of aiming for lowest common denominator

- **Again: Focus on connectivity**
    - Let networks do specific implementations for other functionalities
    - Automatically adapt: WiFi, LTE, 3G, 4G, 5G ….

#5: Decentralized Management

No need to have a single “vantage” point to manage networks

- Both a curse and a blessing
    - Important for easy deployment
    - Makes management hard today

- Recent efforts have improved management of individual networks
    - But no attempt to manage the Internet as a whole…
    - What might make this complex?

#6: Easy Host Attachment

The mechanism that allows hosts to attach to networks must be made as easy as possible, but no easier

- Clark observes that cost of host attachment may be higher because hosts had to be smart

- But the administrative cost of adding hosts is very low, which is probably more important
    - Plug-and-play kind of behavior…

- And now most hosts are smart for other reasons
    - So the cost is actually minimal…

#7: Cost Effective

Make networks as cheap as possible, but no cheaper

- Cheaper than circuit switching at low end
- More expensive than circuit switching at high end
- Not a bad compromise:
  - Cheap where it counts (low-end)
  - More expensive for those who can pay…

#8: Resource Accountability

Each network element must be made accountable for its resource usage

- Failure!

Real Goals

- **Build something that works**
- Connect existing networks
- Robust in face of failures
- Support multiple types of delivery service
- Accommodate a variety of networks
- Allow distributed management
- Easy host attachment
- Cost effective
- Allow resource accountability

Questions to think about

- What goals are missing from this list?
    - **Suggestions?**

- What would the resulting design look like?

Some of the missing issues

- **Performance**

- Security
    - Resilience to attacks (denial-of-service)
    - Endpoint security
    - Tracking down misbehaving users
- Privacy
- Availability
- Resource sharing (fairness, etc.)
- ISP-level concerns
    - Economic issues of interconnection

Questions?

Next lecture

- Beginning of “Design of computer networks”

- Start with Layer 1 and Layer 2
    - Physical bits (very little)
    - Local best-effort forwarding
    - Lots of interesting aspects
    - Lots of group activities
    - …