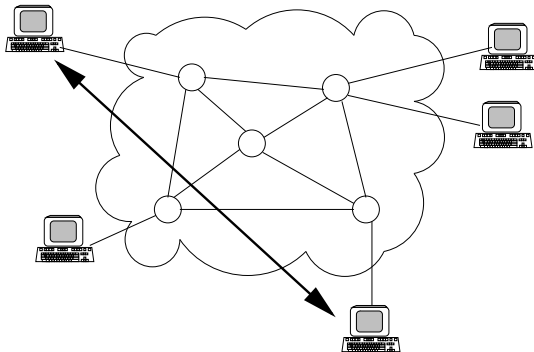


# Review: ARQ Protocols



**Reliable Data Transfer?**

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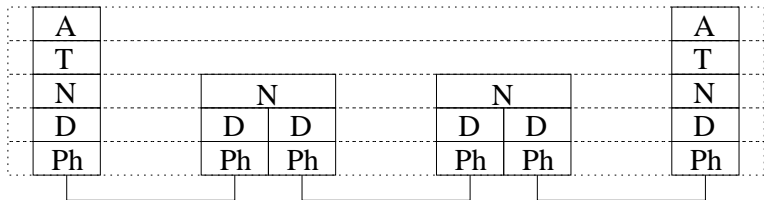
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# Review: ARQ Protocols



Does it make sense to implement ARQ in more than one layer?

# Where are we in the Course?

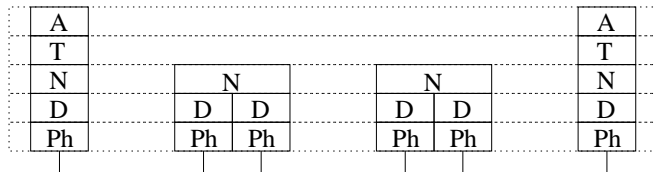
## Basics:

- Network Types (“Hardware”)
- Layered Network Architecture (“Software”)
- Reliable Data Transfer
- Tools for Performance Analysis

## Implementation:

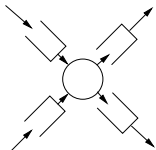
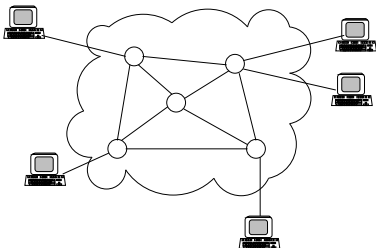
- Design of Protocols
- Analysis of the Service provided by Protocols

- Delay

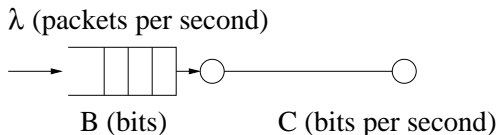


- Processing Delay
- Queueing Delay
- Transmission Delay
- Propagation Delay

# Queueing Delay



# Queueing Delay



Delay depends on  $B$ ,  $C$ , and  $\lambda$

Maximal delay is equal to

Loss depends on  $B$ ,  $C$ , and  $\lambda$



# Design Objectives

- Given network resources and a Quality of Service (QoS) requirement, what is the maximal traffic load that we can support?
- Given network resources and a traffic load, what QoS do we obtain?
- Given a QoS requirement and a traffic load, what are the network resources that we need?

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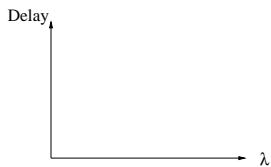
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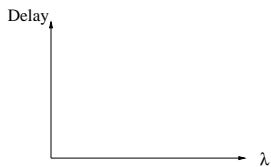
**These questions are difficult to answer!**

- Simple Models
- More Qualitative than Quantitative Analysis (Insight !)
- However, sometimes these models work quite well !

# Relation between Traffic Load and Delay



# Relation between Traffic Load and Delay



Simple Model



# Other Questions

- Average Delay?
- Expected Number of Packets in the Buffer?
- Probability that a Packet is lost?

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**We need a Probabilistic Model**

## Models

- Packet Arrivals: Poisson Process
- Packet Length: Exponential Distribution
- System: Queueing Theory