# CS519: Computer Networks

Lecture 1: Jan 26, 2004

*Intro to Computer Networking*

## Lets start at the beginning…

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- What is a network for?
  - To allow two or more endpoints to communicate
- What is a network?
  - Nodes connected by links

## Lets start at the beginning…

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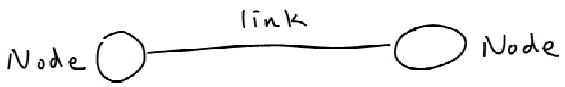
- Is this a network?




## Lets start at the beginning…

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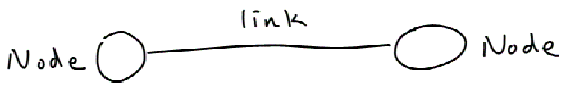
- Is this a network?




- Of course it is!
  - Just not very interesting

## Other “networks” (network topologies)

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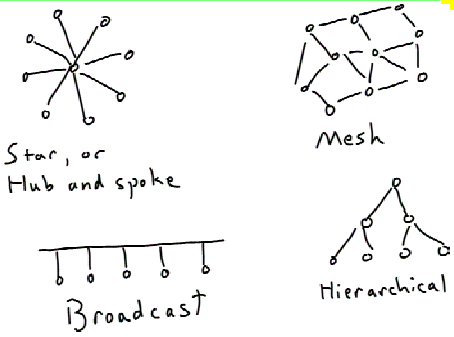


## What is a data network?

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- The answer is NOT “a network that carries data”
  - Cause you can send “data” (e.g. a fax) over the “voice network”
- “Data network” is often a euphemism for “packet network”
  - And “voice network” is often a euphemism for “circuit network”

## Packet network versus circuit network

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- Historically, a circuit network was a network that literally established a physical wired connection between two points
  - With relays, plus amplifiers and stuff
- Before computers, this was the only way to do networks

## Packet network versus circuit network

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- But these days voice is modulated and digitized in numerous ways as it works through the network
  - Very few physical circuits
- So nowadays we consider a circuit network one that appears to establish a fixed “pipe” (amount of bandwidth) between two points

## Types of circuits

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- Synchronous time-division multiplexing (STDM)
  - Each circuit is given a slice of time
- Frequency-division multiplexing (FDM)
  - Each circuit is given a transmission frequency

## Packet network versus circuit network

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- By contrast, a packet network allows small units of data (packets) to be individually sent to different destinations

## Packet network versus circuit network

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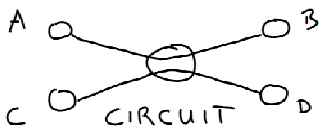
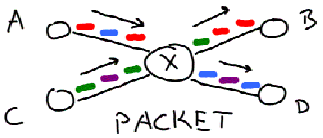



C can't talk to B while A is talking to B




A and C can both talk to B and D

## Packet network versus circuit network

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- So clearly packet switched is better than circuit switched, right?

## Packet network versus circuit network

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- So clearly packet switched is better than circuit switched, right?
- Well, as with so much in this world, *it depends*
- What if A and C try to talk exclusively to B at high speed at the same time?

## Delay and packet loss in packet networks

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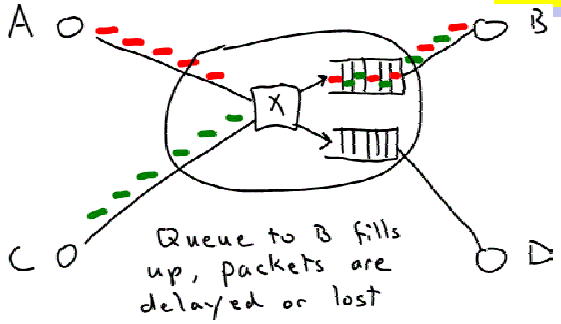


## Delay and packet loss in packet networks

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- Can happen any time multiple links feed into a single link
  - And incoming volume exceeds outgoing volume
- Larger queues can reduce packet loss at the expense of more delay
- Ultimately the sources have to slow down (congestion control)
- By contrast, circuit networks can block (busy tone)

## Also Jitter

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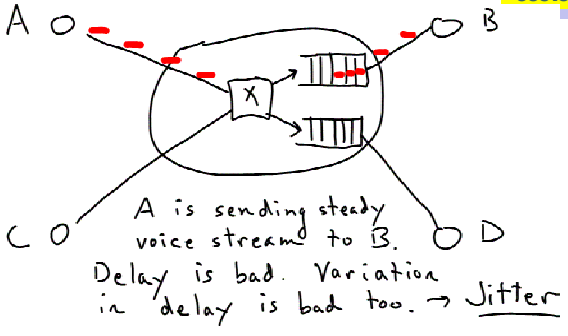

## Also Jitter

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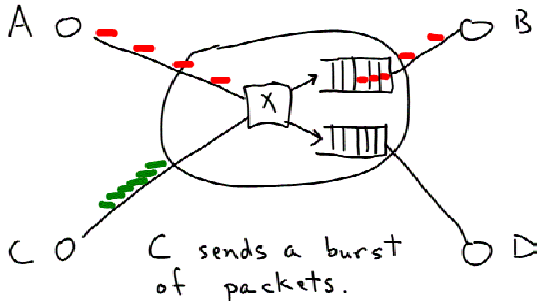


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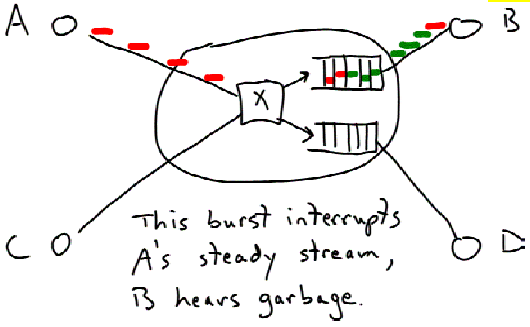


## Circuits versus packets

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- Circuits are an all or nothing proposition
  - Give good quality, if you can get yourself a circuit in the first place
  - Efficient only if the application keeps the circuit full (I.e. a voice stream)
- Packets are more flexible
  - Can send a little or a lot
  - But other traffic can interfere at any time
  - More efficient when traffic is bursty

## Can a packet network emulate a circuit?

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- After all, our STDM circuit sent data over the wire in “chunks”

## Can a packet network emulate a circuit?

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- After all, our STDM circuit sent data over the wire in “chunks”
- The answer is yes, it can
- And indeed, the first packet networks offered “services” that very much emulated circuits

## One way to do it

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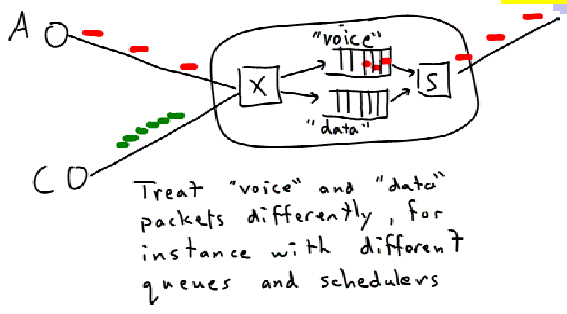


Treat "voice" and "data" packets differently, for instance with different queues and schedulers

## One way to do it

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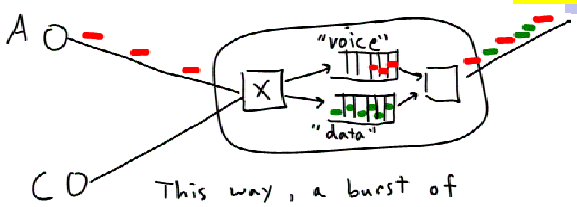


This way, a burst of data doesn't add jitter to the voice, but rather gets delayed itself

## But this has complications too

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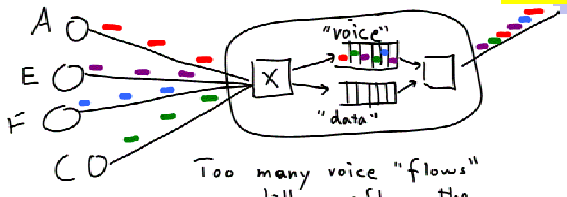


Too many voice "flows" can still overflow the queue. Must be a way to reserve queuing resources ("call setup")

## "Datagram" versus "virtual circuit" networks

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- Both are packet networks
  - (We won't discuss pure circuit networks any more in this course)
- Virtual circuit networks have the notion of call setup and blocking
  - But much more complex traffic models than our simple two-queue example
- Datagram networks is how the Internet ultimately got built!

## But virtual circuit networks still important

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- We don't see virtual circuit networks to our desktop
  - Though this was the vision for many folks
- But virtual circuit networks formed the unpinning of the Internet
  - Something called ATM
  - Though this is fading

## This class focuses on the Internet

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- Which is a datagram network
- One big topic will be how queues in the Internet manage not to become hopelessly overloaded
  - Many of you know, the answer is TCP, but we'll look at this in detail

## Some terms introduced so far

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- Network, node, link, queue
- Circuit and packet networks
  - a.k.a. data and voice networks
- Virtual circuit and datagram networks
- Delay, latency, loss, drop, jitter, blocking

## Bandwidth and Latency

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- We looked at delay due to queuing
- But there are three main components to delay:
  - Propagation delay
  - Transmit delay
  - Queuing delay

## Queuing, transmit, and propagation delays

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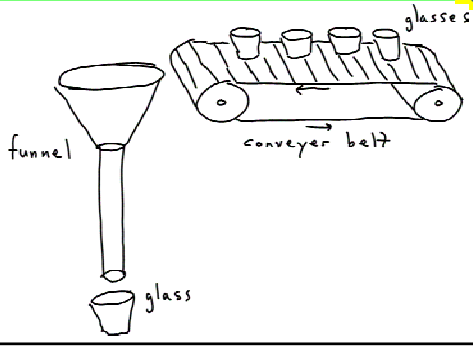


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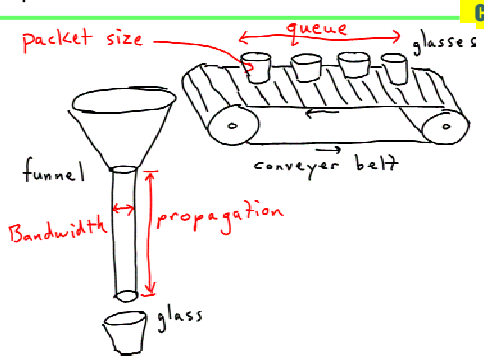


## Total latency

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- Total latency =
  - Propagation + Transmit + Queue
- Propagation =
  - Distance / Speed of light
- Transmit =
  - Packet size / Bandwidth

## Delay x Bandwidth Product

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- Refers to the number of bits you can have "in the pipe" at the same time
  - Or, how many bits you can stuff in the pipe before the first bit comes out the other end
  - Like hot water getting from the water heater to your shower!
- As bandwidth increases (and distance doesn't change) this is becoming an issue

## An extreme (but realistic) Delay x Bandwidth Example

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- Coast-to-coast propagation delay = 15ms
- OC192 link = 10 Gbps
- 10 Gbps x 15ms = 150,000,000 bits = 19 Mbytes = 7 songs (MP3 files)
- You could stuff 7 songs into an OC192 pipe at Boston before the first song starting arriving in LA!!!

## A more common Delay x Bandwidth Example

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- 50ms coast to coast delay (mainly from queuing)
- 100 Mbps Ethernet
- This is about 600Kbytes…still a decent sized file
- Delay x Bandwidth is starting to dominate our thinking about protocol performance

## Common provider bandwidth units

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- DSO = 64 Kbps
- DS1 = 1.544 Mbps
- DS3 = 44.736 Mbps
- OC3 = 155.52 Mbps
- OC12 = 622.08 Mbps
- OC48 = 2.488 Gbps
- OC192 = 9.953 Gbps
- OC768 = 39.813 Gbps

# Bandwidth and throughput and goodput

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- Bandwidth is the maximum theoretical speed of a pipe
- Throughput is the actual measured speed
  - Vague term because depends on where you measure
- Goodput is the throughput seen by the application
  - Throughput over the pipe can be more than goodput because of dropped and retransmitted packets, control packets, and headers