Computer Networks

Uses of Networks (§1.1)

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Example Uses of Networks

- Work:
  - Email, file sharing, printing, …
- Home:
  - Movies / songs, news, calls / video / messaging, e-commerce, …
- Mobile:
  - Calls / texts, games, videos, maps, information access …

Example Uses of Networks

- Work:
  - Email, file sharing, printing, …
- Hom
  - M s / video / , …
- Mobile:
  - Calls / texts, games, videos, maps, information access …

What do these uses tell us about why we build networks?

For User Communication

- From the telephone onwards:
  - VoIP (voice-over-IP)
  - Video conferencing
  - Instant messaging
  - Social networking

→ Enables remote communication
  - Need low latency for interactivity

For Resource Sharing

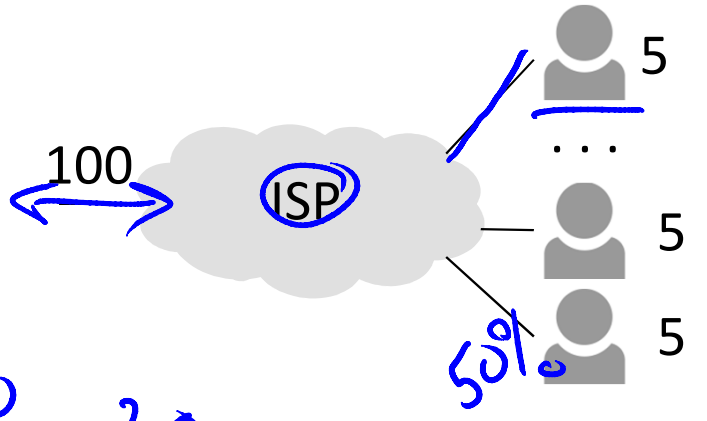
- Many users may access the same underlying resource
  - E.g., 3D printer, search index, machines in the cloud
- More cost effective than dedicated resources per user
  - Even network links are shared via statistical multiplexing »

Statistical Multiplexing

- Sharing of network bandwidth between users according to the statistics of their demand
  - (Multiplexing just means sharing)
  - Useful because users are mostly idle and their traffic is bursty
- Key question:
  - How much does it help?

Statistical Multiplexing (2)

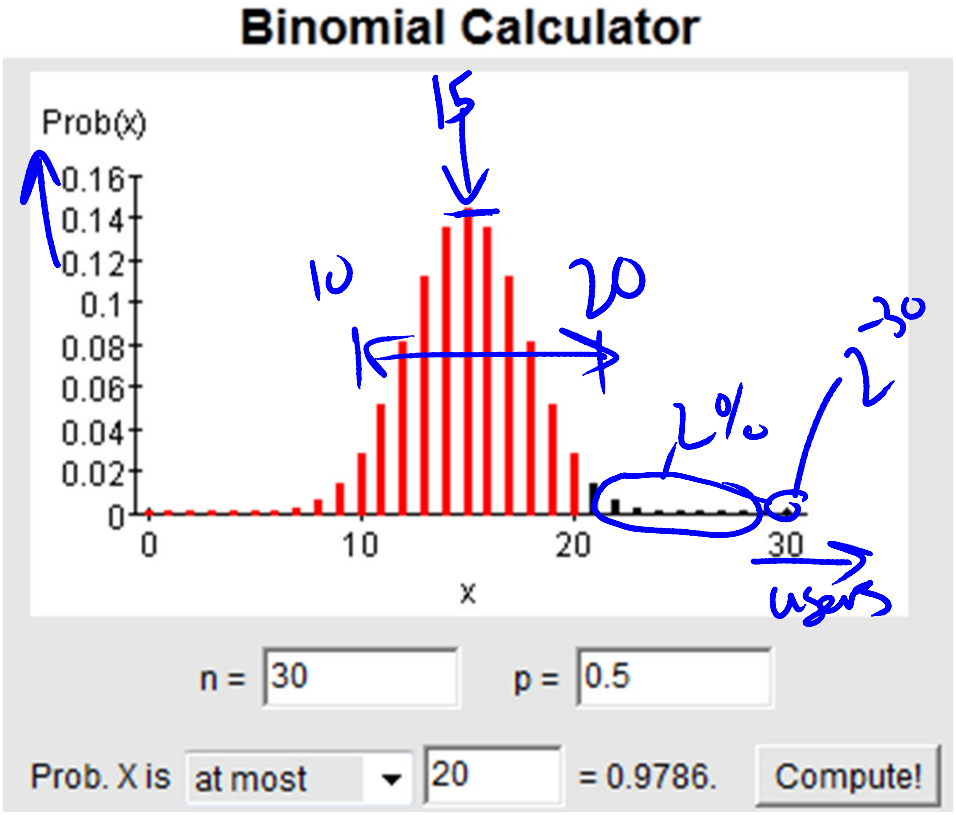
- Example: Users in an ISP network
  - Network has 100 Mbps (units of bandwidth)
  - Each user subscribes to 5 Mbps, for videos
  - But a user is active only 50% of the time …



- How many users can the ISP support?
  - With dedicated bandwidth for each user: $\frac{100}{5} = 20$ users
  - Probability all bandwidth is used: (assuming independent users) $\frac{1}{2} \times \frac{1}{2} \times \ldots \ldots \frac{1}{2} = \left(\frac{1}{2}\right)^{20}$ ← 1 in 1 million

Statistical Multiplexing (3)

- With 30 independent users, still unlikely (2% chance) to need more than 100 Mbps!
  - Binomial probabilities
- Can serve more users with the same size network
  - Statistical multiplexing gain is 30/20 or 1.5X
  - But may get unlucky; users will have degraded service

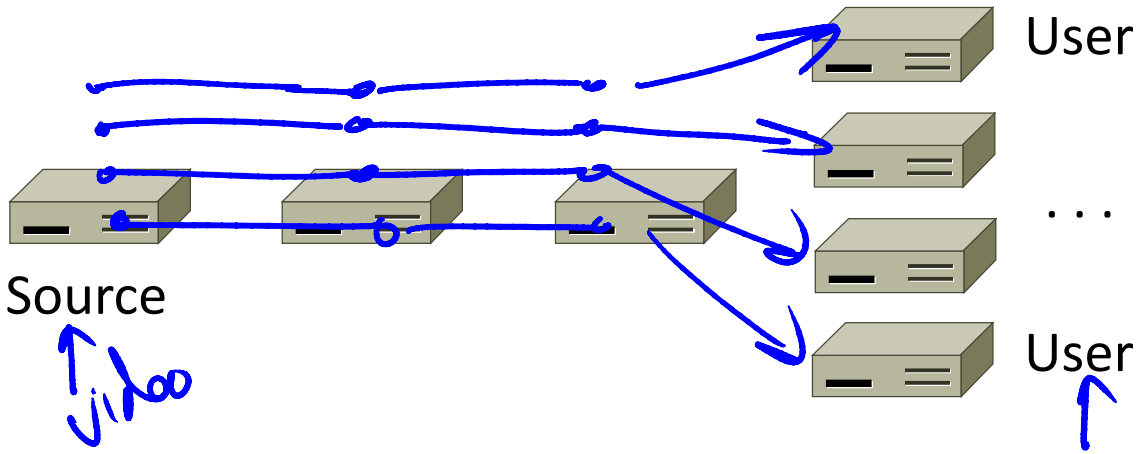


For Content Delivery

- Same content is delivered to many users
  - Videos (large), songs, apps and upgrades, web pages, …
- More efficient than sending a copy all the way to each user
  - Uses replicas in the network »

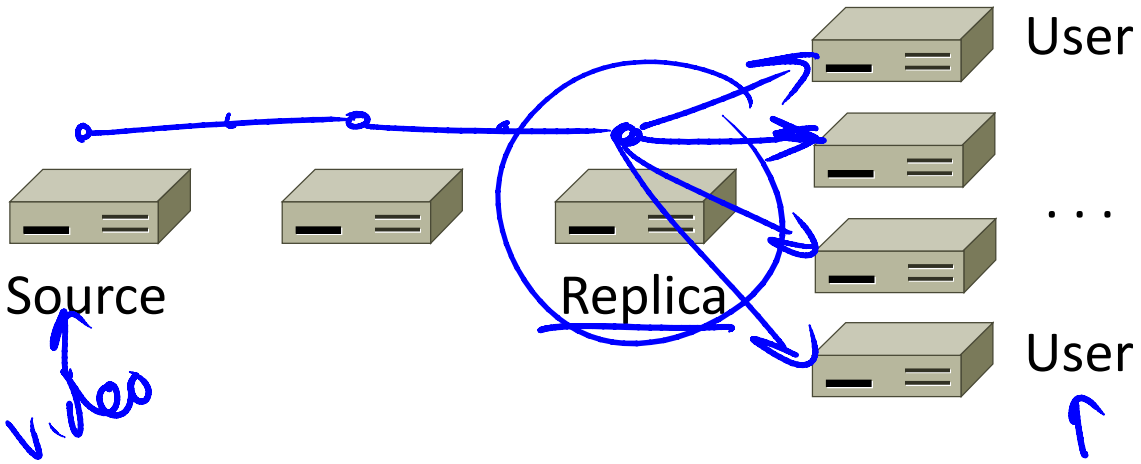
Content Delivery (2)

- Sending content from the source to 4 users takes 4 x 3 = 12 “network hops” in the example



Content Delivery (3)

- But sending content via replicas takes only 4 + 2 = 6 “network hops”



For Computer Communication

- To let computers interact with other computers
  - E.g., e-commerce, reservations
- Enables automated information processing across different parties

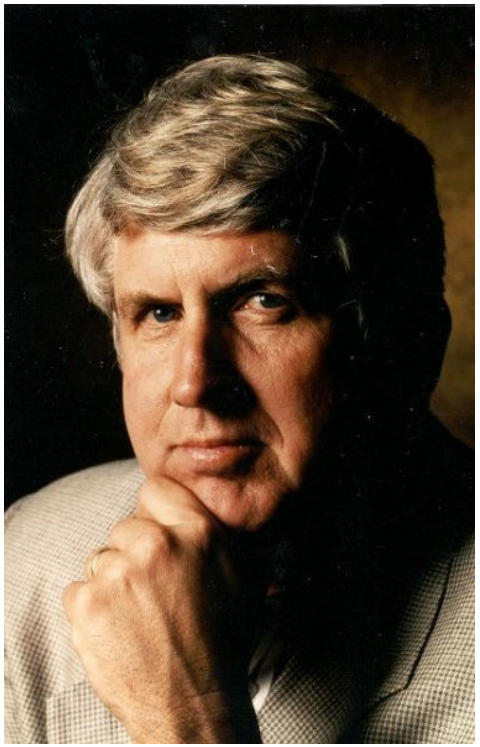
To Connect Computers to the Physical World

- For gathering sensor data, and for manipulating the world
  - E.g., webcams, location on mobile phones, door locks, …
- This is a rich, emerging usage

The Value of Connectivity

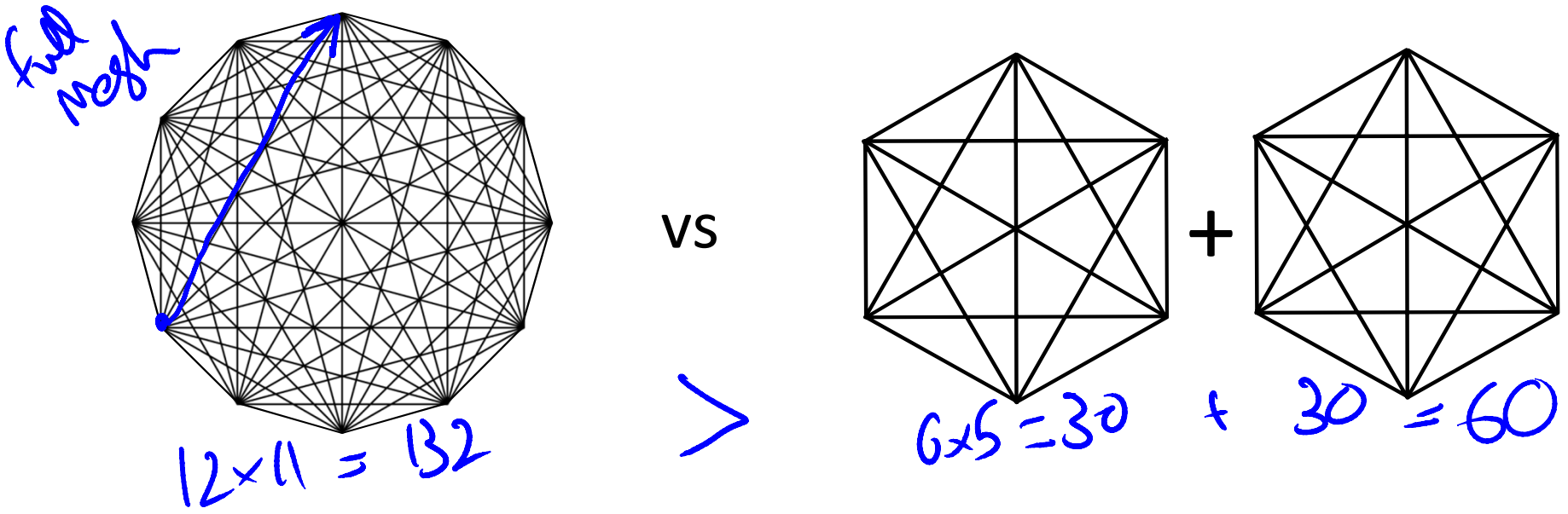
- "Metcalfe's Law" ~1980:
  - The value of a network of N nodes is proportional to N^2
  - Large networks are relatively more valuable than small ones

Bob Metcalfe



The Value of Connectivity (2)

- Example: both sides have 12 nodes, but the left network has more connectivity



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