Advanced Computer Networks (ACNs)

Topics Covered

- Internet routing characterization
- Routing security
- Internet of things (IoT)
- ISP traffic engineering
- Critical network infrastructure services
- Network security: IDS, worms, and honeypots
- CDNs, Peer to peer and overlay networks
- Wireless networking
- Sensor networking
- Network measurements
- Network security
- Network models

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What Do You Need To Do?

. **A research-oriented class project**

- Paper Reviews
- Lead one class discussion
- 2-3 design assignments

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Paper Reviews

Goal: synthesize main ideas and concepts in the papers

- **Length of your report:** no more than half page per paper
- **Content of your report:**

- Main points intended by the author
- Points you particularly liked/disliked
- Other comments (such as answering questions asked…)

- **Submission:**

- Submit each review via on lecture day in class

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Grading:

- **40%** for Projects I, II and III
- **45%** for Final exam
- **15%** for Homework and paper reviews.

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Self Introduction:

who is your lecturer?

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Student introduction

- **Please introduce yourself: name, standing, research area if any?**
- **Say a few words about what you think you would like to learn about computer networks**
- **Or what you think are "unsolved" problems in computer networks**

شبکه های کامپیوتری

رویکرد از فـراز به فـرود

ویراست ششم

دکترحسین حاج رسولیهـا

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شبکه های کامپیوتری

رویکرد از فـراز به فـرود

ویراست ششم

KUROSE

ROSS

نیازدانش

تازه های انتشارات نیاز دانش

شبکه های کامپیوتری به عنوان یک متن درسی دانشگاهی از جمله آثاری است که ویژه ی یادگیری اصول شبکه به شمار می آید. استادان جیم کراس و کیت راس ارایه ی عناوین مربوط به شبکه را در یک چارچوب فراگیر با بهره گیری از رویکرد از فراز به فرود ارائه داده اند. این رویکرد سبب پوشش موضوعات شبکه و اینترنت شده است. ویراست ششم مانند نسخه های پیشین خود تاکید بر لایه ی کاربرد، برنامه نویسی کاربردی و پروتکل های لایه های بالاتر را سر لوحه ی اهداف خود قرار داده است تا تجربه آموزی با اصول شبکه و پروتکل ها را برای دانش پژوهان علاقه مند فراهم نماید.

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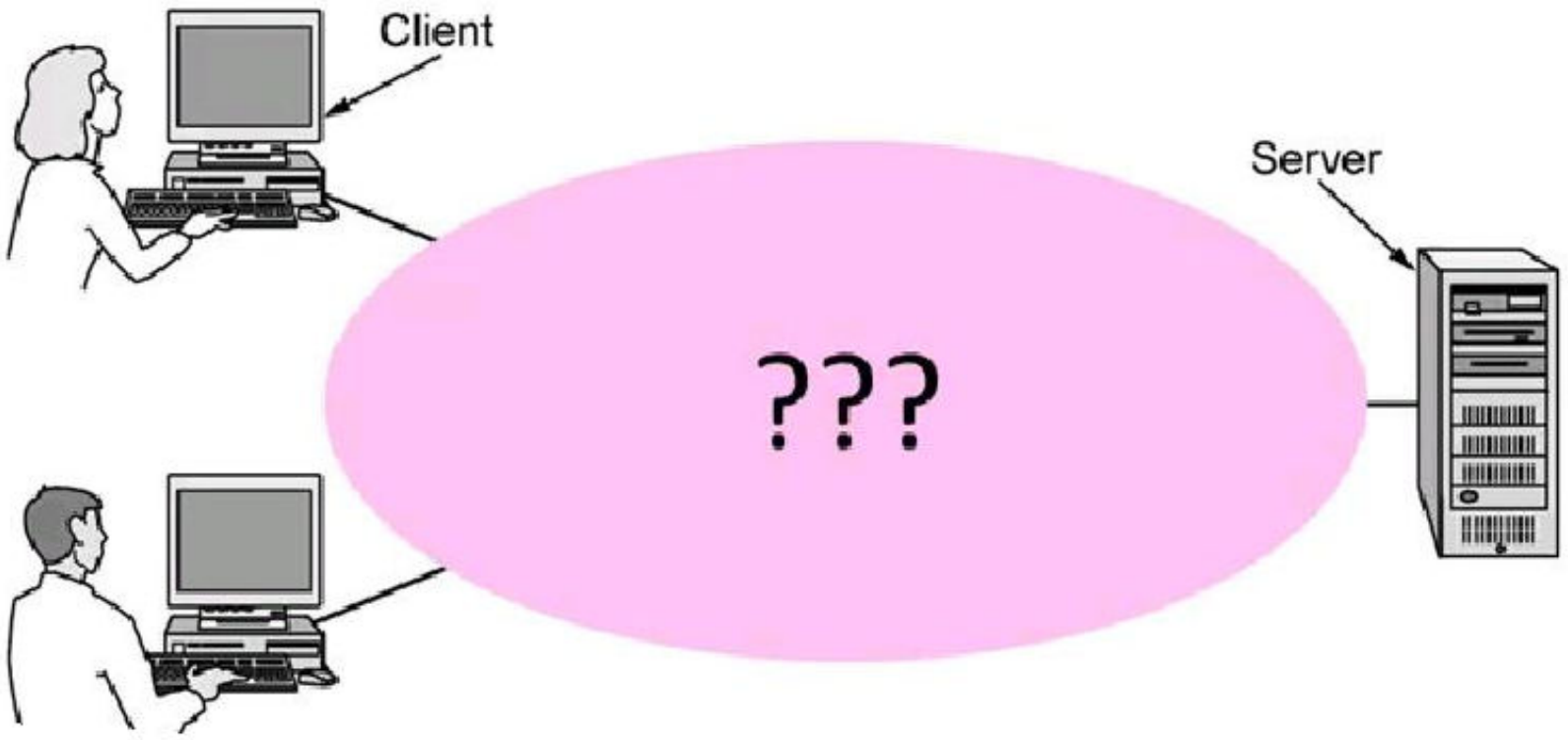
نیازدانش

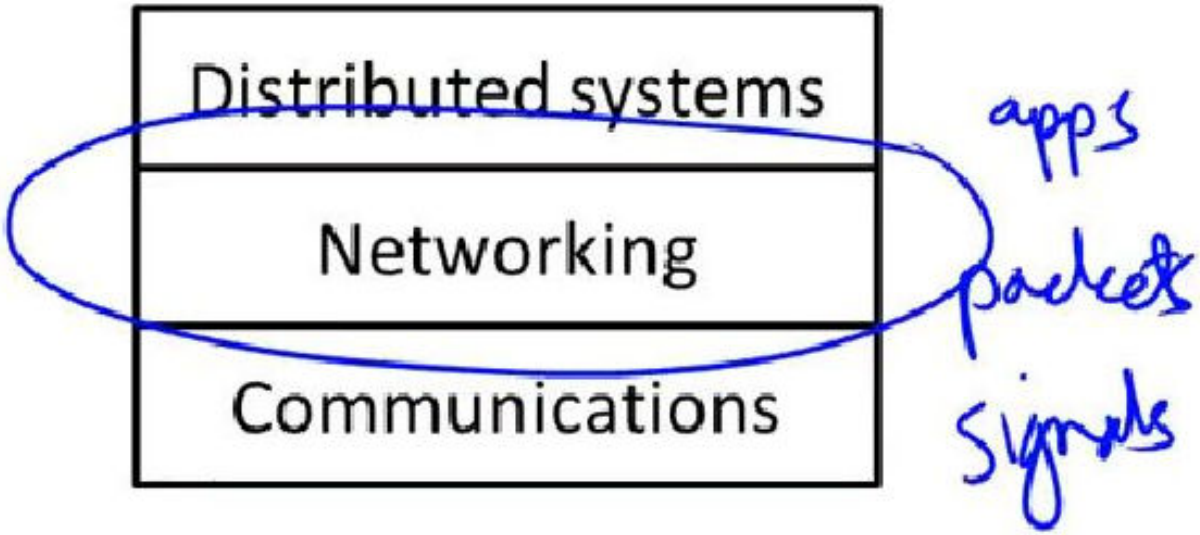
ACN Lecture 1

Focus of the course



Focus of the course (2)

- Three "networking" topics:



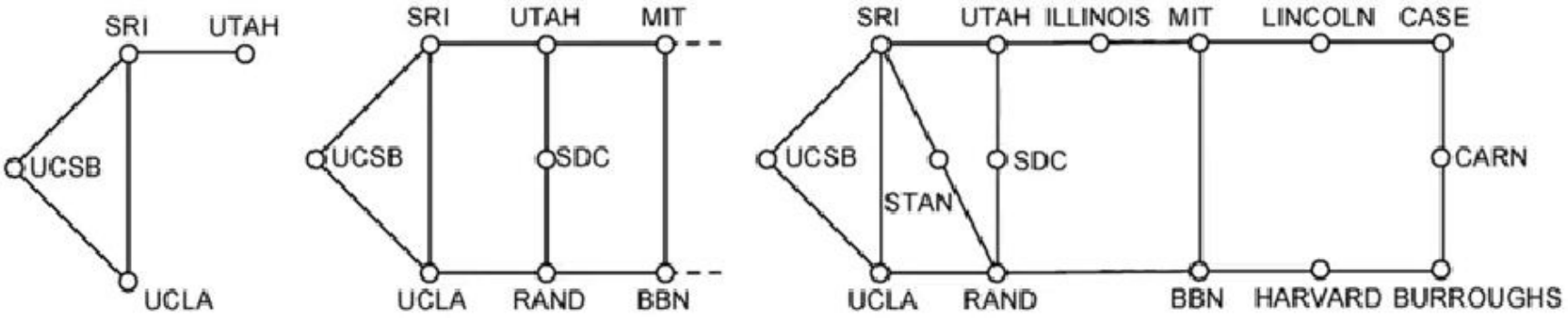
- We're in the middle

Why learn about the Internet?

1. Curiosity »
2. Impact on our world »
3. Job prospects!

From this experimental network …

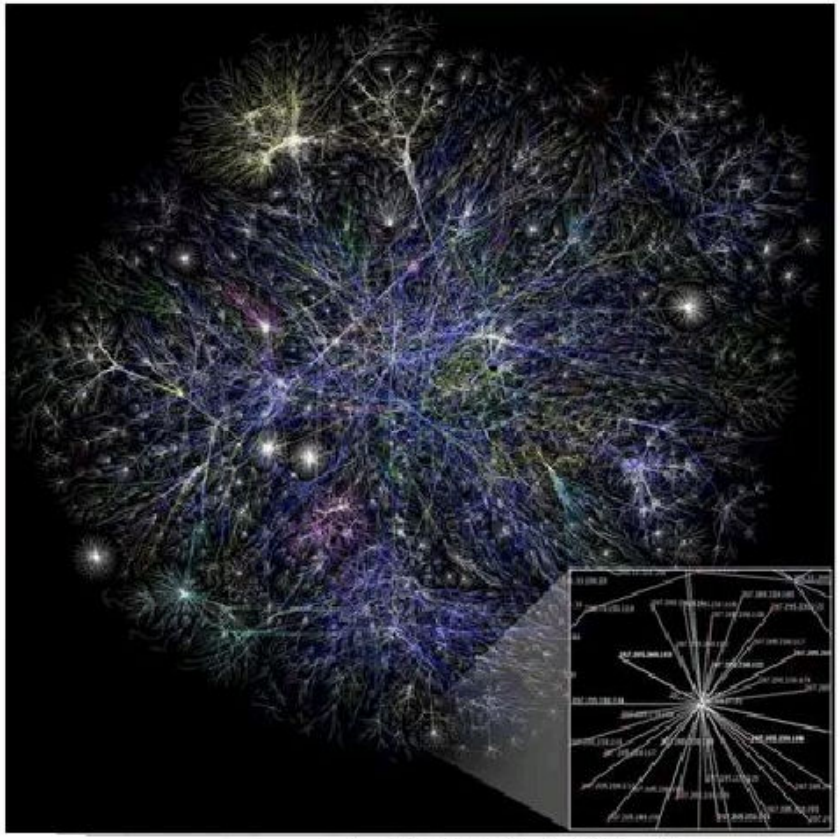
ARPANET ~1970



(a) Dec. 1969. (b) July 1970. (c) March 1971.

To this!
Internet ~2005

- An everyday institution used at work, home, and on-the-go
- Visualization contains millions of links



Internet – Societal Impact

- An enabler of societal change
  - Easy access to knowledge
  - Electronic commerce
  - Personal relationships
  - Discussion without censorship

PayPal

match.com

Tor

Internet – Economic impact

- An engine of economic growth
  - Advertising-sponsored search
  - "Long tail" online stores
  - Online marketplaces
  - Crowdsourcing

The Main Point (2)

1. To learn how the Internet works
2. To learn the fundamentals of computer networks
   - What hard problems must they solve?
   - What design strategies have proven valuable?

Why learn the Fundamentals?

1. Apply to all computer networks
2. Intellectual interest »
3. Change / reinvention »

Fundamentals – Intellectual Interest

- Example key problem: Reliability!
  - Any part of the Internet might fail
  - Messages might be corrupted
  - So how do we provide reliability?
- Reliability solutions
  - Codes to detect/correct errors
  - Routing around failures ...

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- Reliability solutions
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Fundamentals – Intellectual Interest (2)

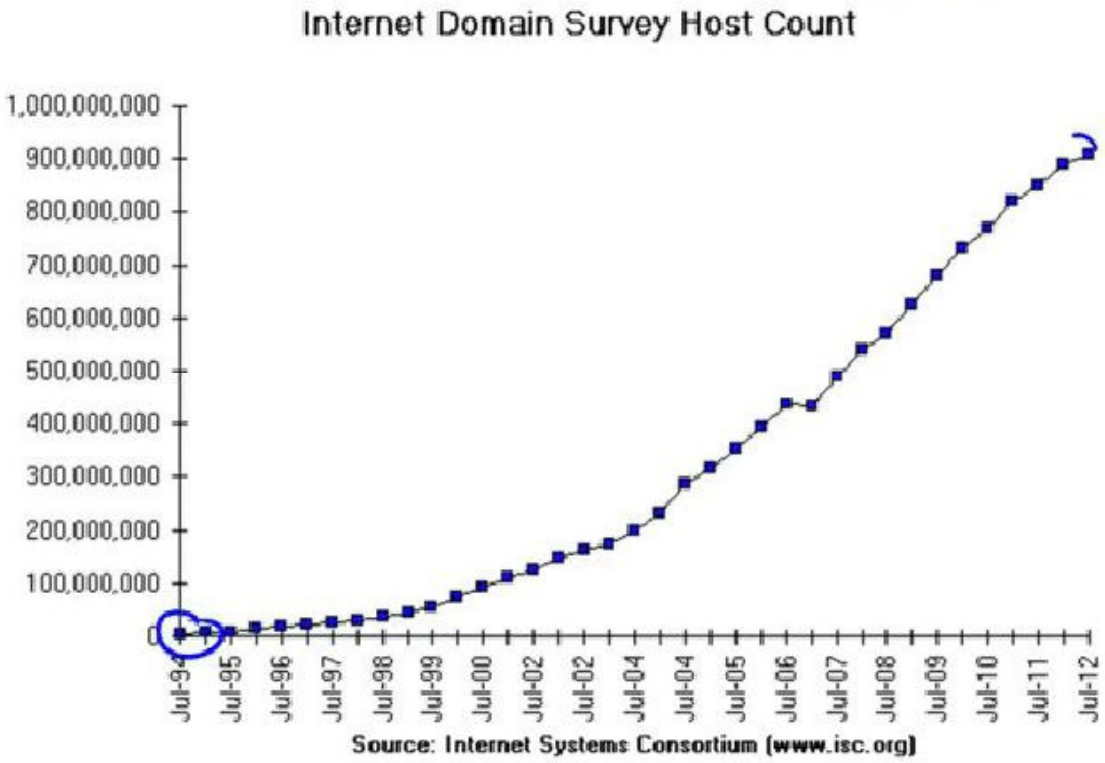
Key problem	Example solutions
Reliability despite failures	Codes for error detection/correction (§3.2, 3.3) Routing around failures (§5.2)
Network growth and evolution	Addressing (§5.6) and naming (§7.1) Protocol layering (§1.3)
Allocation of resources like bandwidth	Multiple access (§4.2) Congestion control (§5.3, 6.3)
Security against various threats	Confidentiality of messages (§8.2, 8.6) Authentication of communicating parties (§8.7)

Fundamentals – Reinvention

- The Internet is constantly being re-invented!
  - Growth over time and technology trends drive upheavals in Internet design and usage »
- Today's Internet is different from yesterday's
  - And tomorrow's will be different again
  - But the fundamentals remain the same

Fundamentals – Reinvention (2)

- At least a billion Internet hosts and growing …



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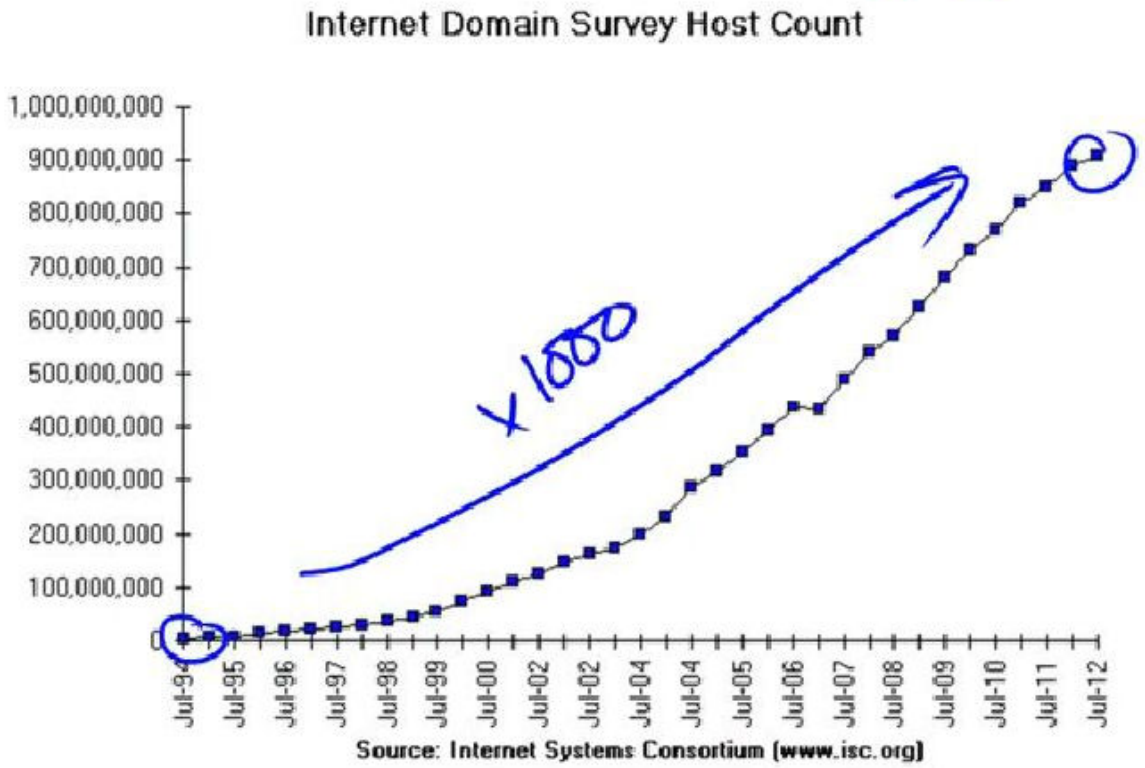

Fundamentals – Reinvention (3)

- Examples of upheavals in the past 1-2 decades

Growth / Tech Driver	Upheaval
Emergence of the web	Content Distribution Networks
Digital songs/videos	Peer-to-peer file sharing
Falling cost/bit	Voice-over-IP calling
Many Internet hosts	IPv6
Wireless advances	Mobile devices

And now today talk is about IoT

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Who is Who in the Internet ?

- **Internet Engineering Task Force (IETF): The IETF is the** protocol engineering and development arm of the Internet. Subdivided into many working groups, which specify RFCs or Request For Comments.
- **IRTF (Internet Research Task Force): The Internet** Research Task Force is a composed of a number of focused, long-term and small Research Groups.
- **Internet Architecture Board (IAB): The IAB is responsible** for defining the overall architecture of the Internet, providing guidance and broad direction to the IETF.
- **The Internet Engineering Steering Group (IESG): The** IESG is responsible for technical management of IETF activities and the Internet standards process. Standards. Composed of the Area Directors of the IETF working groups.

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Internet Standardization Process

- **All standards of the Internet are published as RFC (Request for Comments). But not all RFCs are Internet Standards !**

- RFCs are available @: http://www.ietf.org

- **A typical (but not only) way of standardization is:**

- Internet Drafts

- RFC

- Proposed Standard

- Draft Standard (requires 2 working implementation)

- Internet Standard (declared by IAB)

- **David Clark, MIT, 1992: "We reject: kings, presidents, and voting. We believe in: rough consensus and running code."**

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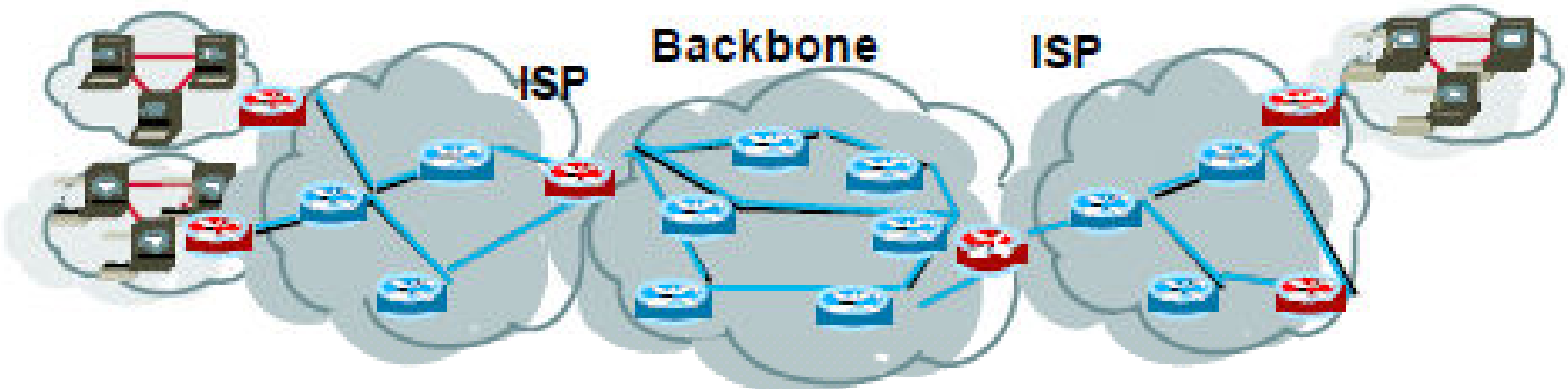
Internet Physical Infrastructure



- Residential Access
  - Modem
  - DSL
  - Cable modem
  - Satellite
- Enterprise/ISP access, Backbone transmission
  - T1/T3, DS-1 DS-3
  - OC-3, OC-12
  - ATM vs. SONET, vs. WDM
- Campus network
  - Ethernet, ATM
- Internet Service Providers
  - access, regional, backbone
  - Point of Presence (POP)
  - Network Access Point (NAP)

Uses of Networks:

- To built effective Computer Nets. We need to study USES of NETs.
- Uses of Networks are: At Home, Work, Mobile.
- Uses of Nets. Tells us Why we need to built networks.
- So we can say nets. Are for:

1) User Communications.
2) Resource Sharing.
3) Content Delivery.
4) Computer Communications.
5) Connecting Computer Systems to Physical World.

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?

#1 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

#2 For Resource Sharing

- Many users may access the same underlying resource
  - E.g., 3D printer, search index, machines in the cloud

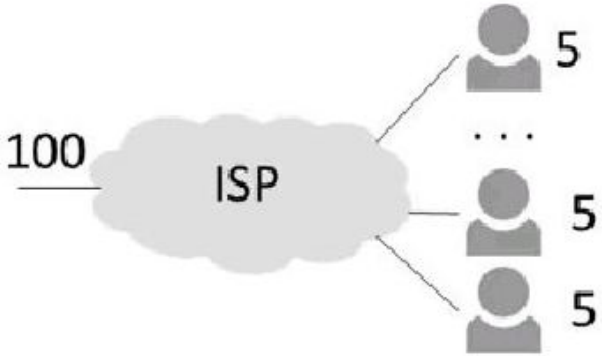
→ More cost effective than dedicated resources per user
  - Even network links are shared via statistical multiplexing »

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:
  - Probability all bandwidth is used:
    (assuming independent users)



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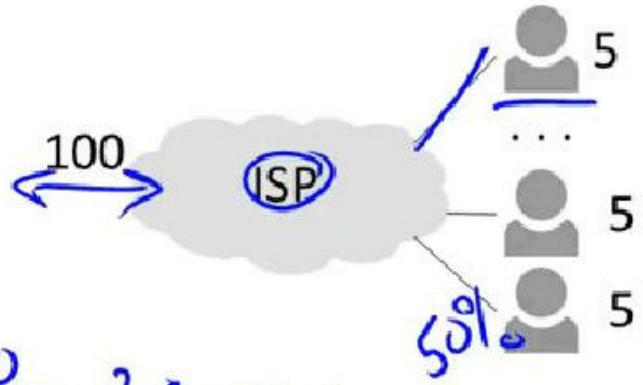


- How many users can the ISP support?
  - With dedicated bandwidth for each user: $\frac{100}{5} = 20$ users
  - Probability all bandwidth is used: $\frac{1}{2} \times \frac{1}{2} \times \ldots \ldots \frac{1}{2} = \left(\frac{1}{2}\right)^{20}$ (assuming independent users)

Binomial Distribution:

$$Prob\ of(n = k) = \binom{n}{k} p^k\ (1-p)^{n-k}$$

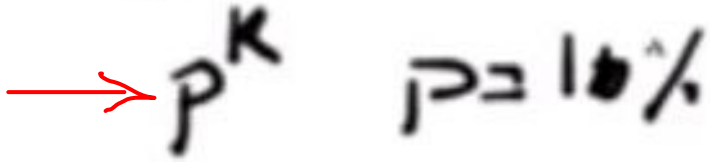
n= number of intended users.

p= probability of using all the assigned BW by a user.

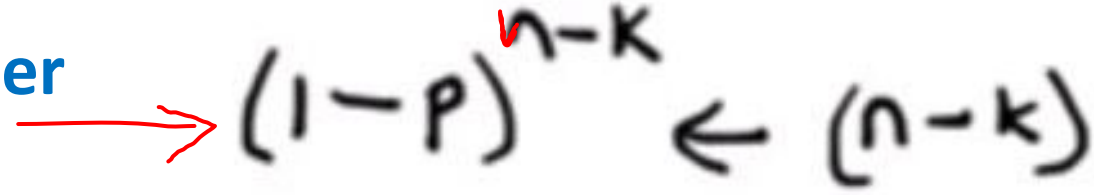
k = number of active users.

- The combination of 10 users out of 35.

- Probability of k active users



- Probability that (n-k) user are NOT active



$$Prob\ of(n = k) = \binom{n}{k} p^k (1-p)^{n-k}$$

With:

- $n=35$
- $k=10$
- $P\text{^}k=10\%$

Then:

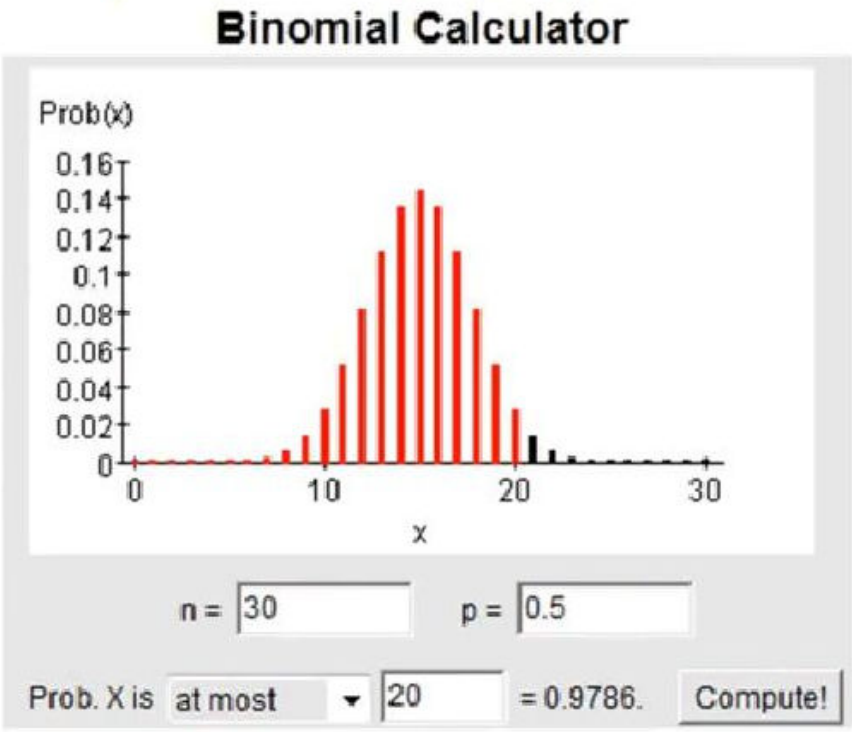
$$P(n = k) = 0.0004$$

The probability of 10 users being active.

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



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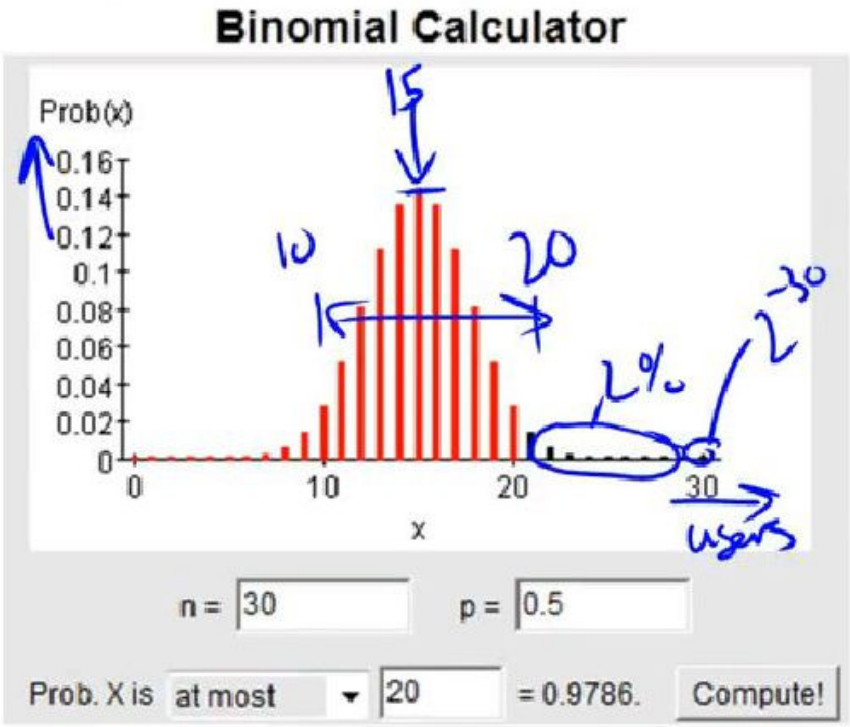


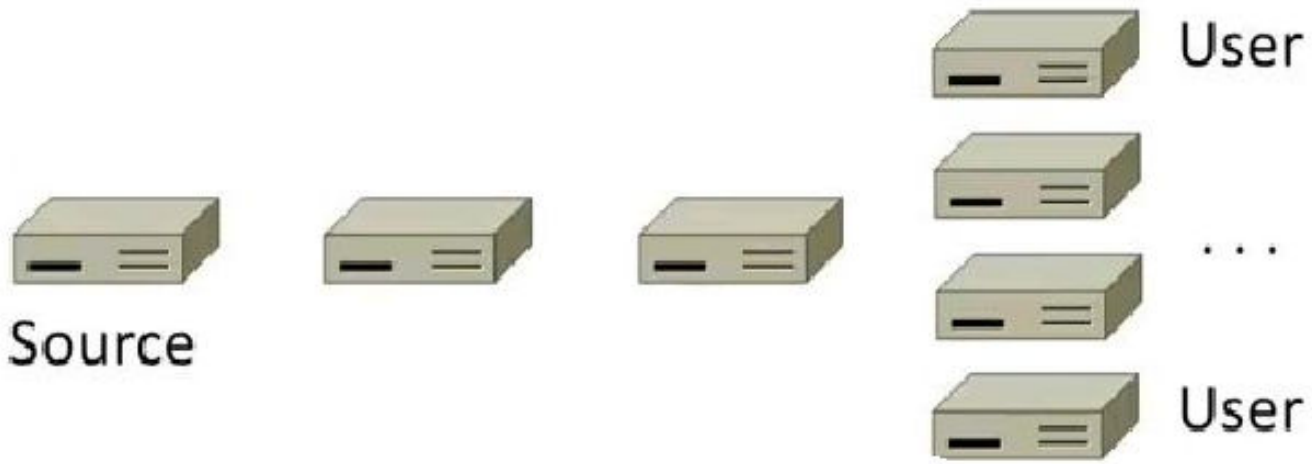
#3 For Content Delivery

- 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



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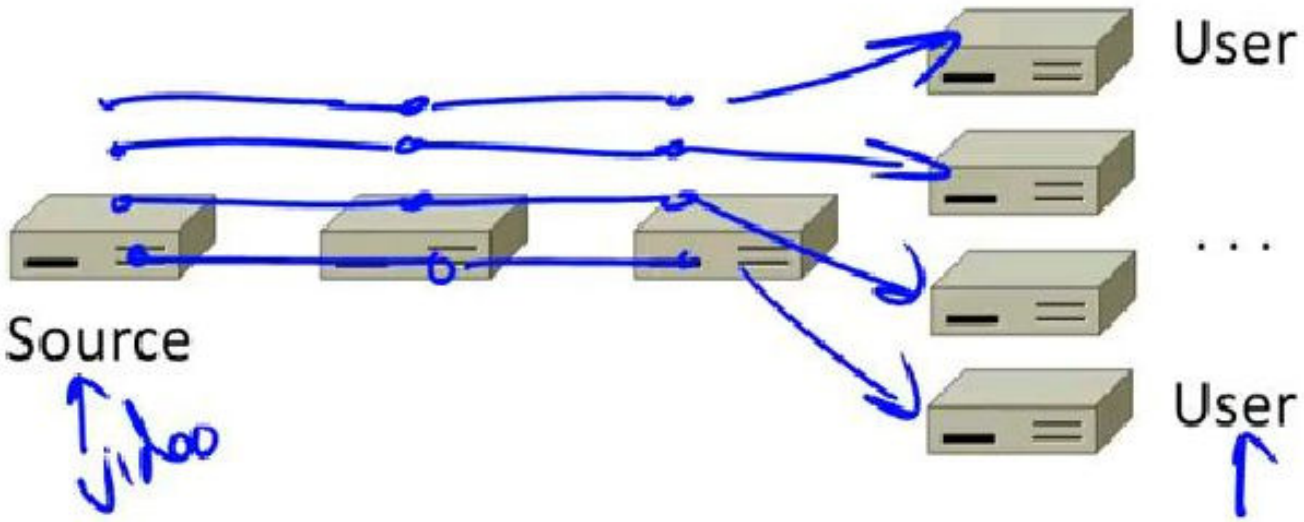
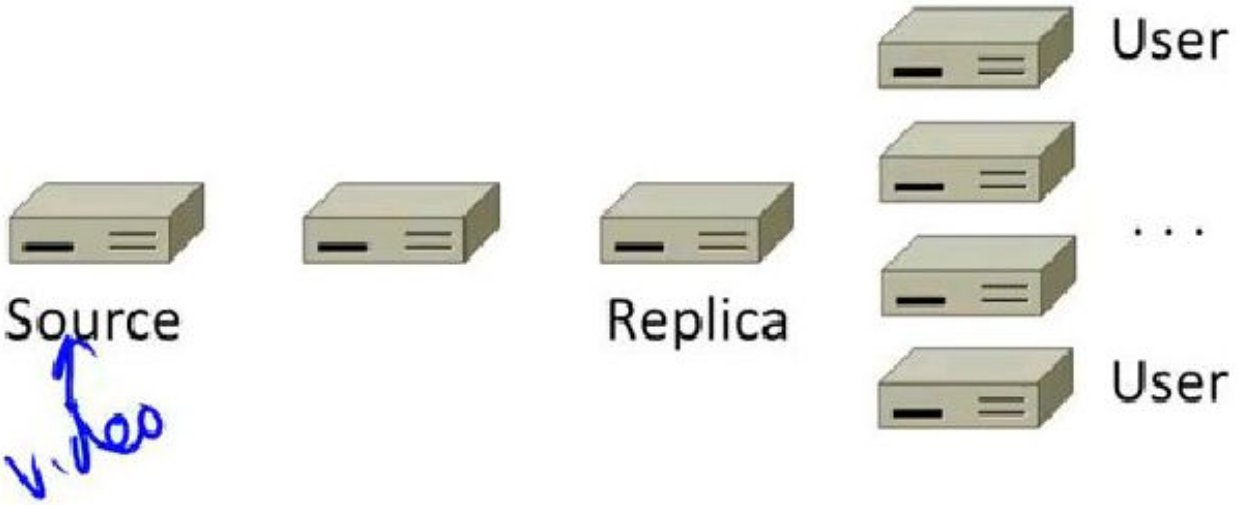


Content Delivery (3)

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



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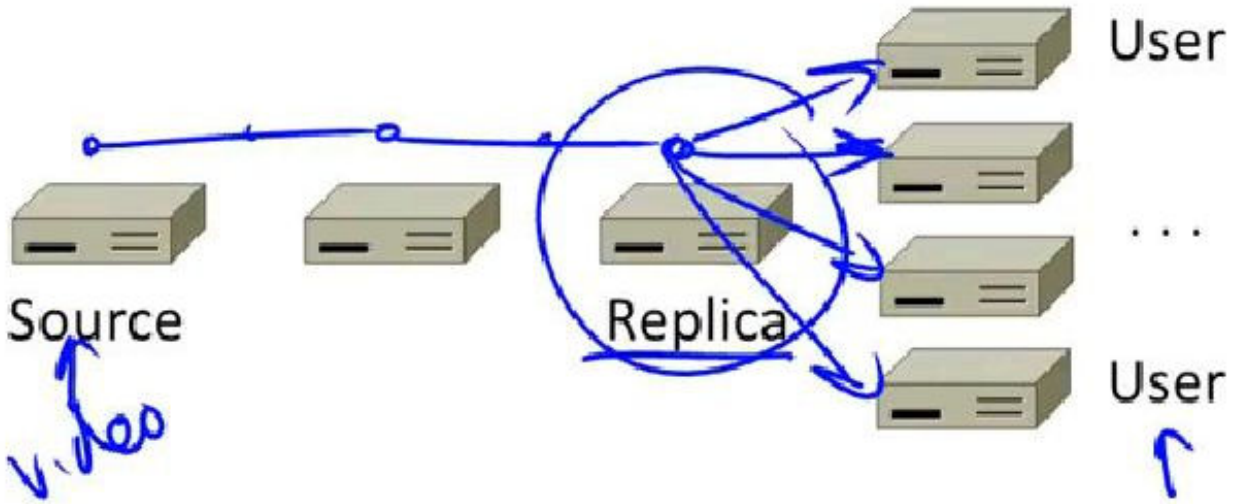


#4

For Computer Communication

- To let computers interact with other computers
  - E.g., e-commerce, reservations

→ Enables automated information processing across different parties

#5

To Connect Computers to the Physical World

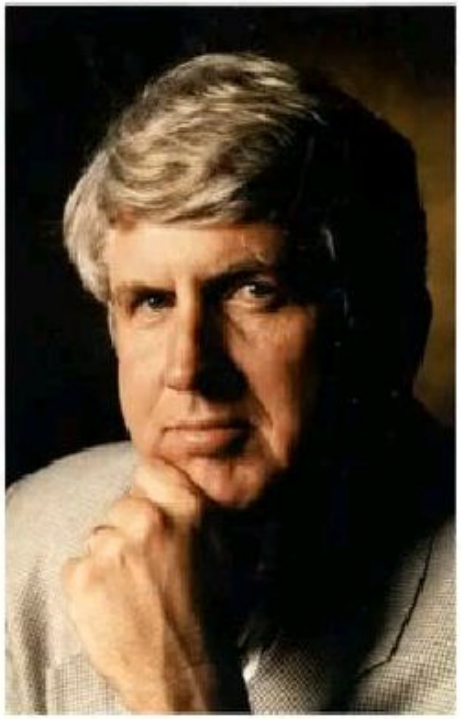
- For gathering sensor data, and for manipulating the world
  - E.g., webcams, location on mobile phones, door locks, …
- This is a rich, emerging usage

#6 network value

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



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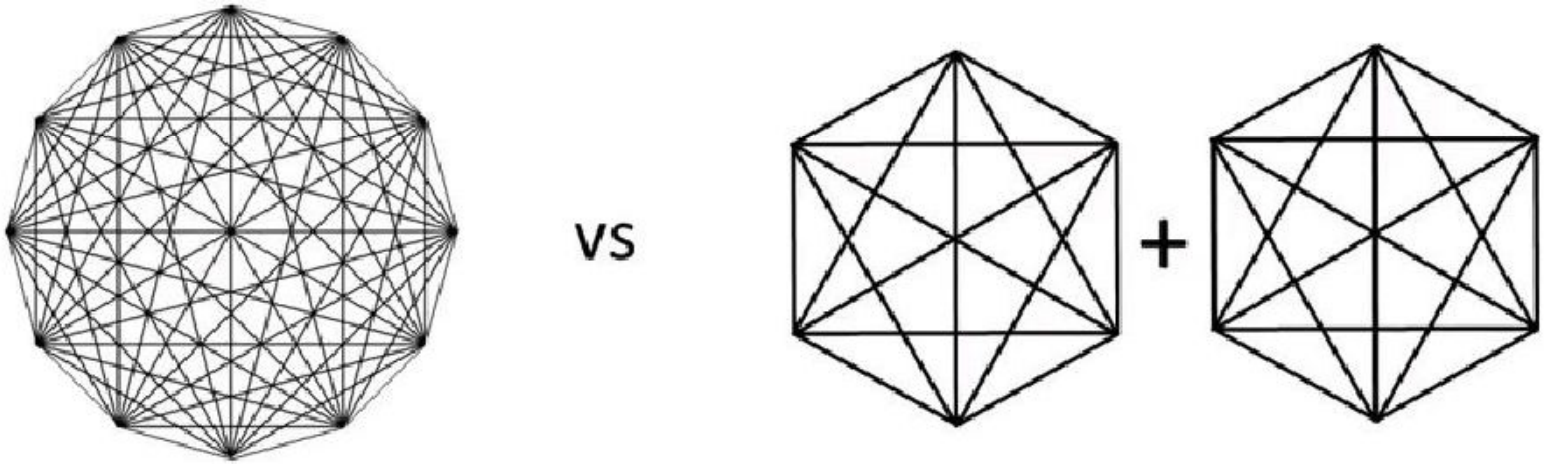
The Value of Connectivity (2)

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



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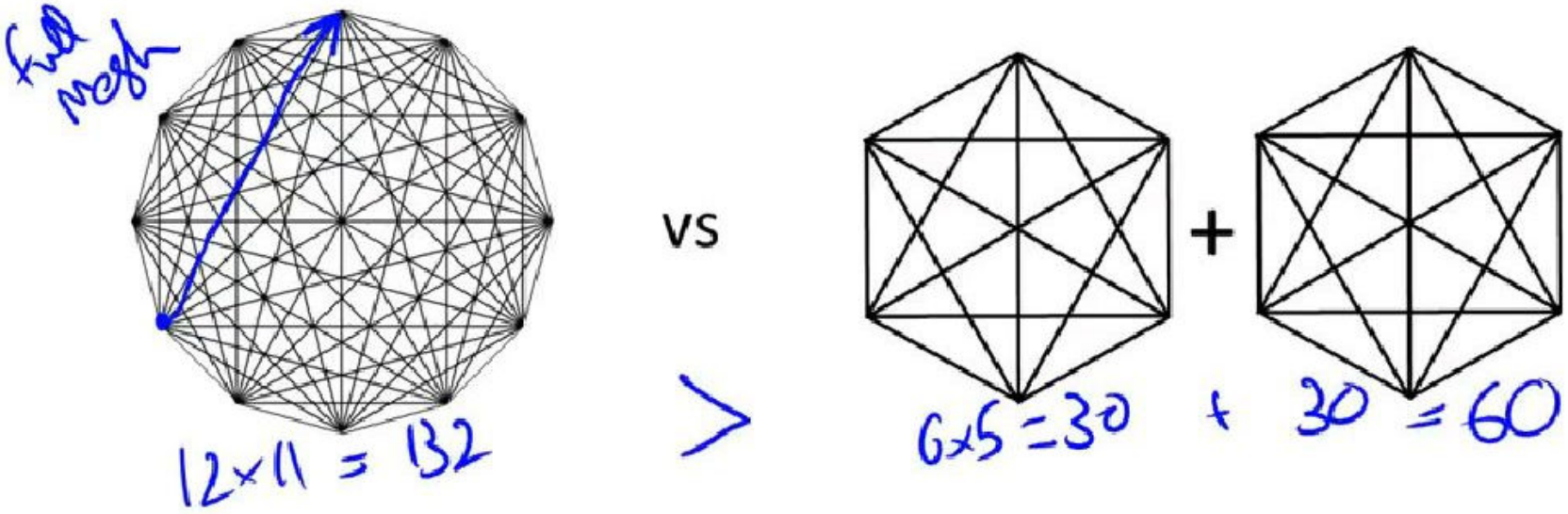

End of Lecture 1