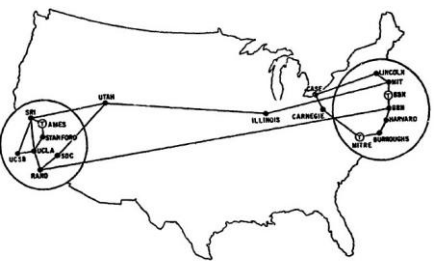


Digging Down Under the Surface of the Internet

Ping Ji

PhD in Computer Science

Professor, Executive Director



World Wide Web



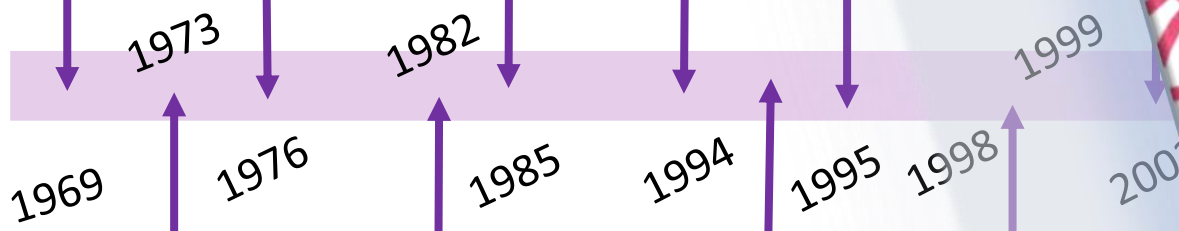
ARPANET

ETHERNET

802.11

Aol.

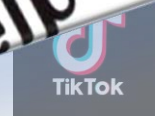
Java
eBay



TCP/IP, FTP

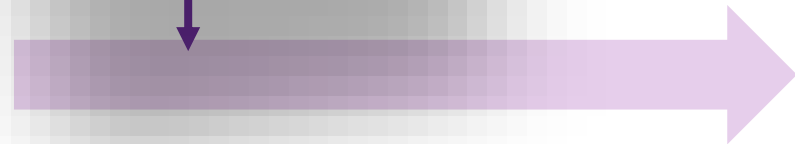
INTERNET

Netscape
amazon
YAHOO!





ChatGPT!!



2022

2023



- 5+ Billion People Online
- 4+ Billion Smart phone users

What about the Smart Devices?

Internet of Things!!

- 10s Millions Apps
- 100s Billions App Downloads

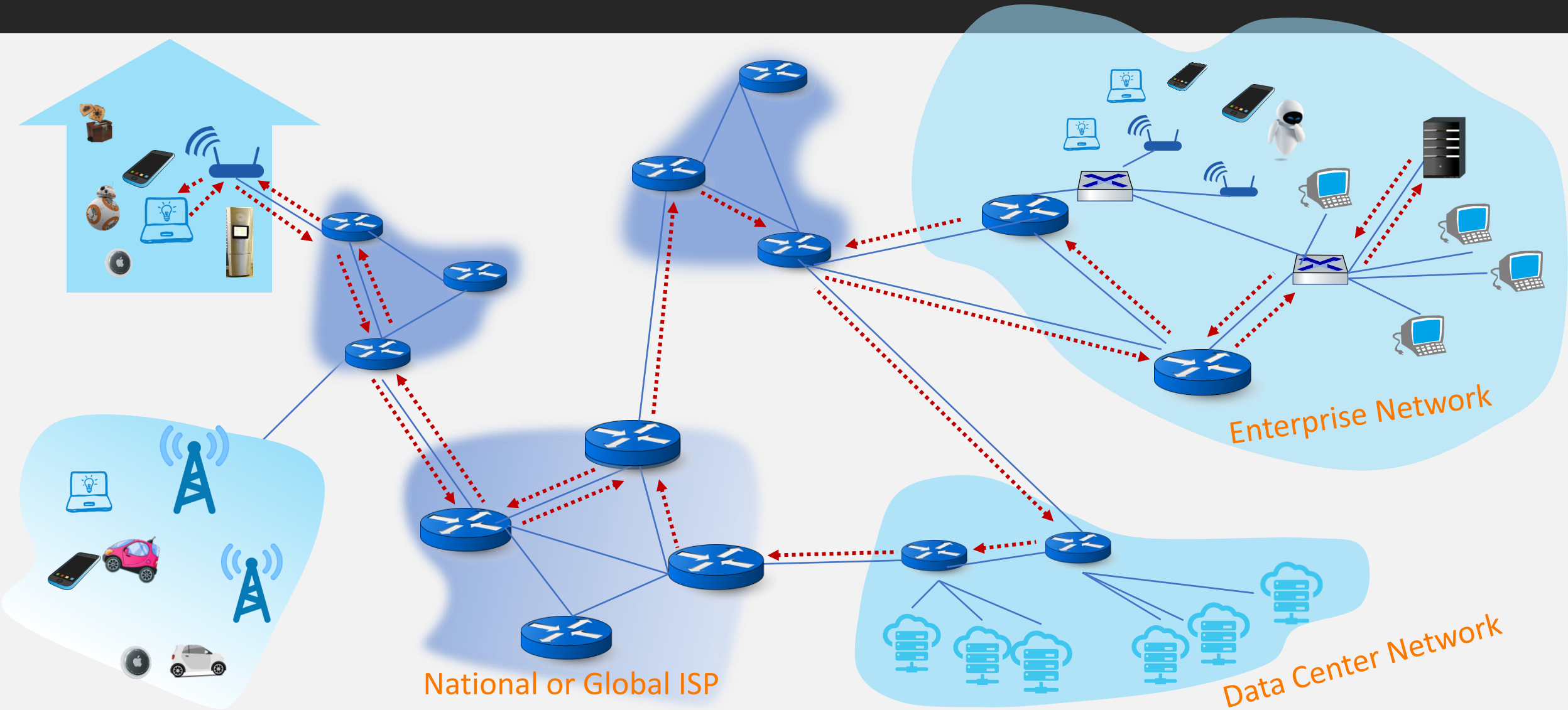
How Does the Internet Work?



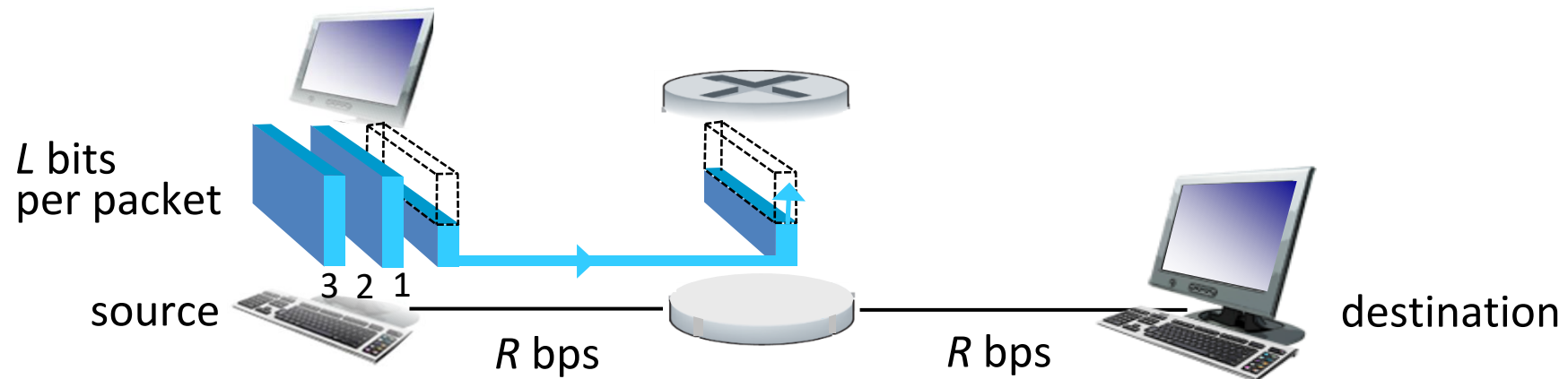
Computing Devices



Network Edge vs Network Core

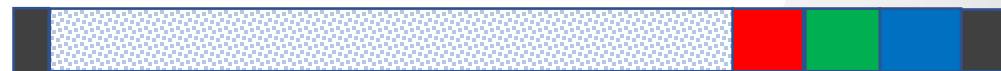
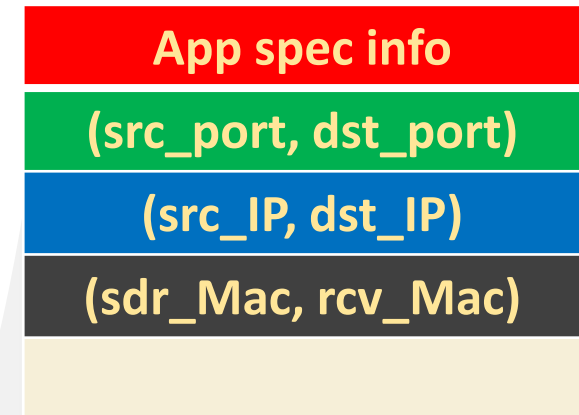
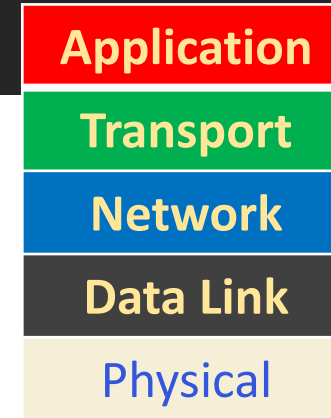
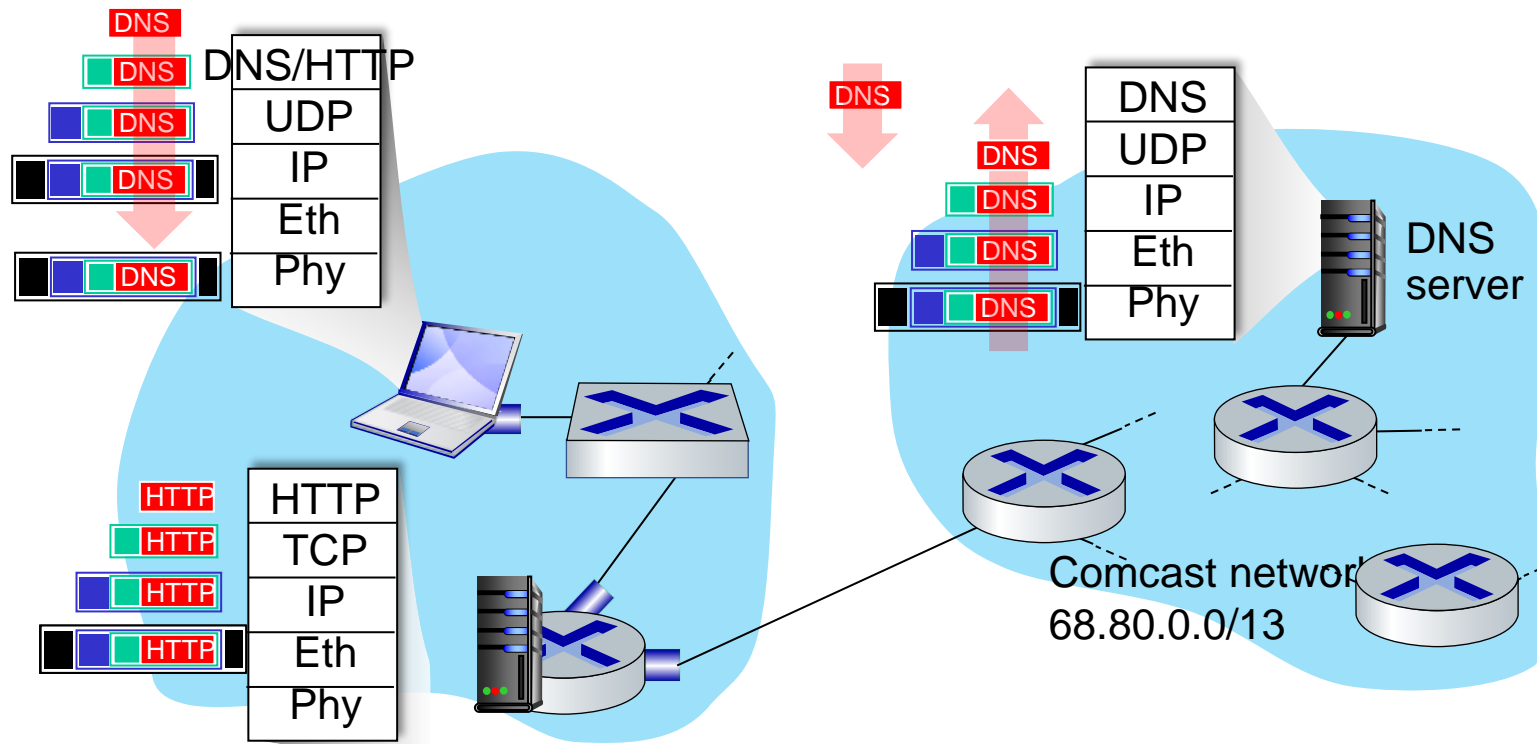


Packet Switching



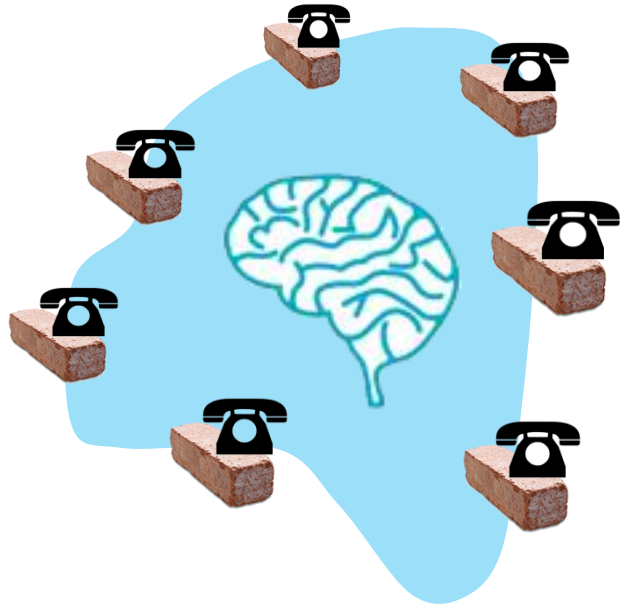
- ✓ Data are truncated into digital packets
- ✓ Data packets are transmitted *hop-by-hop*
- ✓ Packets for different sender/receiver pairs share physical media (queuing)

Communication Protocols



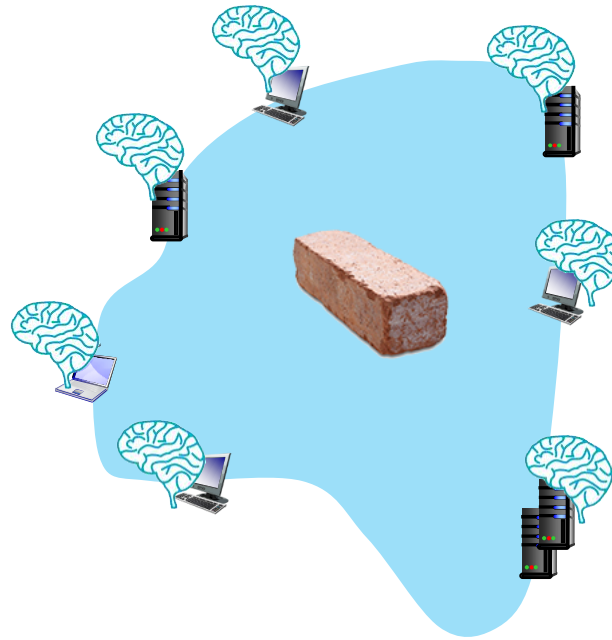
- ✓ Layered Structure
- ✓ Data packets carry header information for each layer

Where is the Intelligence?



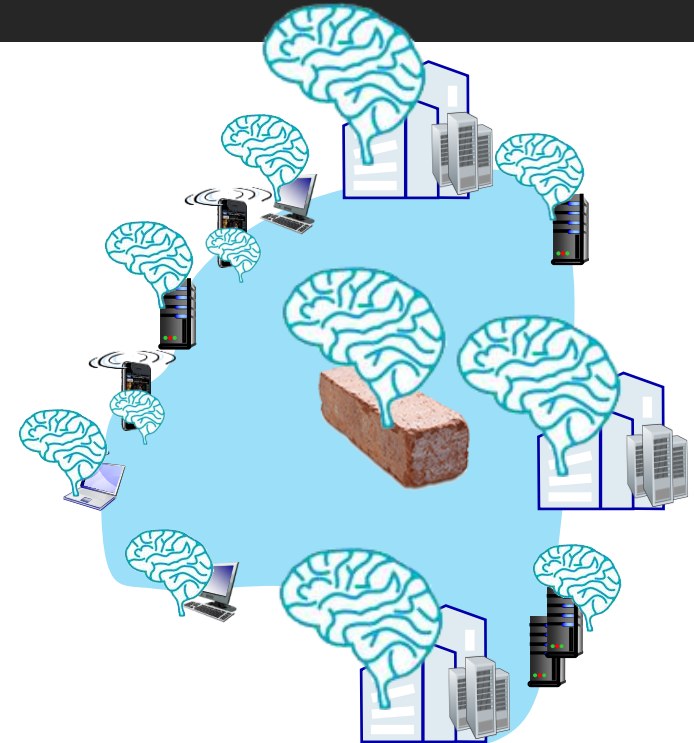
20th century phone net:

- intelligence/computing at network switches



Internet (pre-2005)

- intelligence, computing at edge



Internet (post-2005)

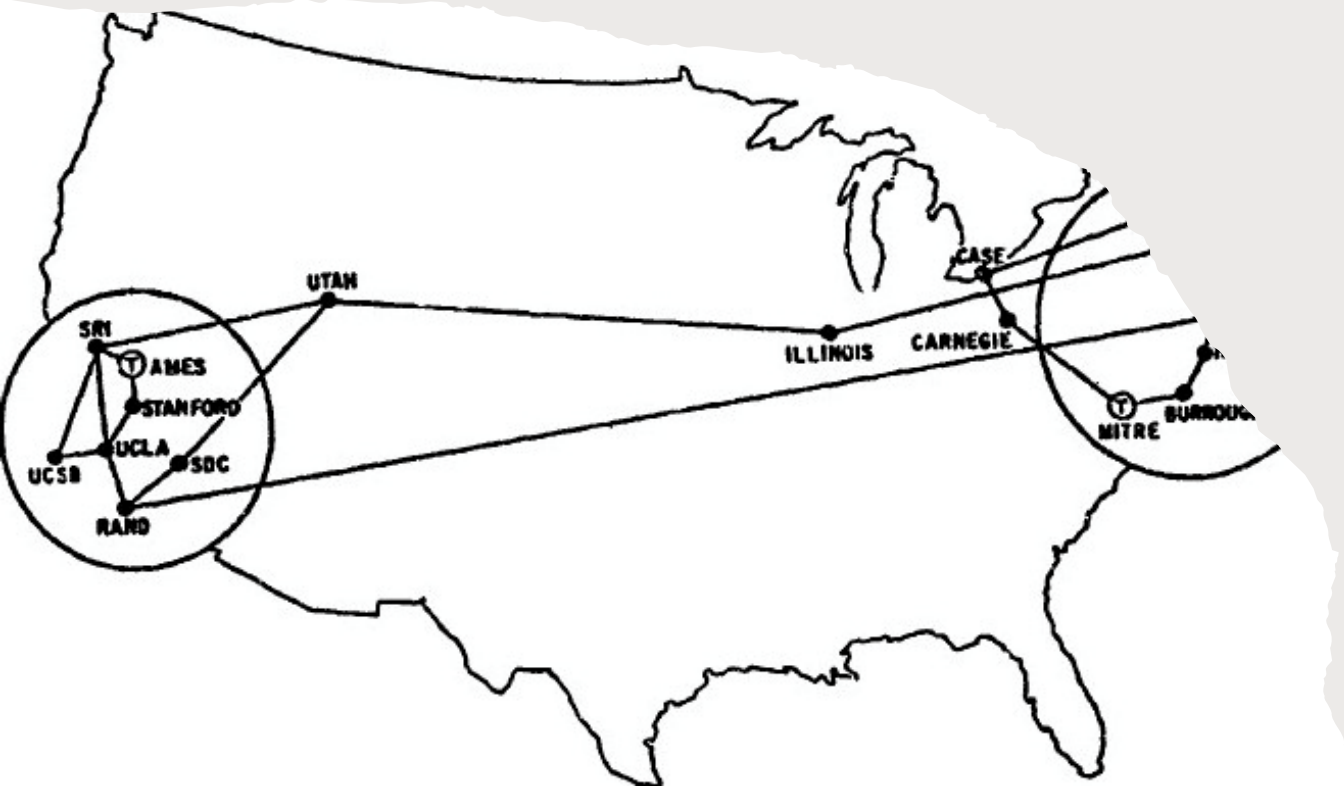
- programmable network devices
- intelligence, computing, massive application-level infrastructure at edge



Network Security VS Forensics
- *anonymity or accountability*

Internet was built for friends

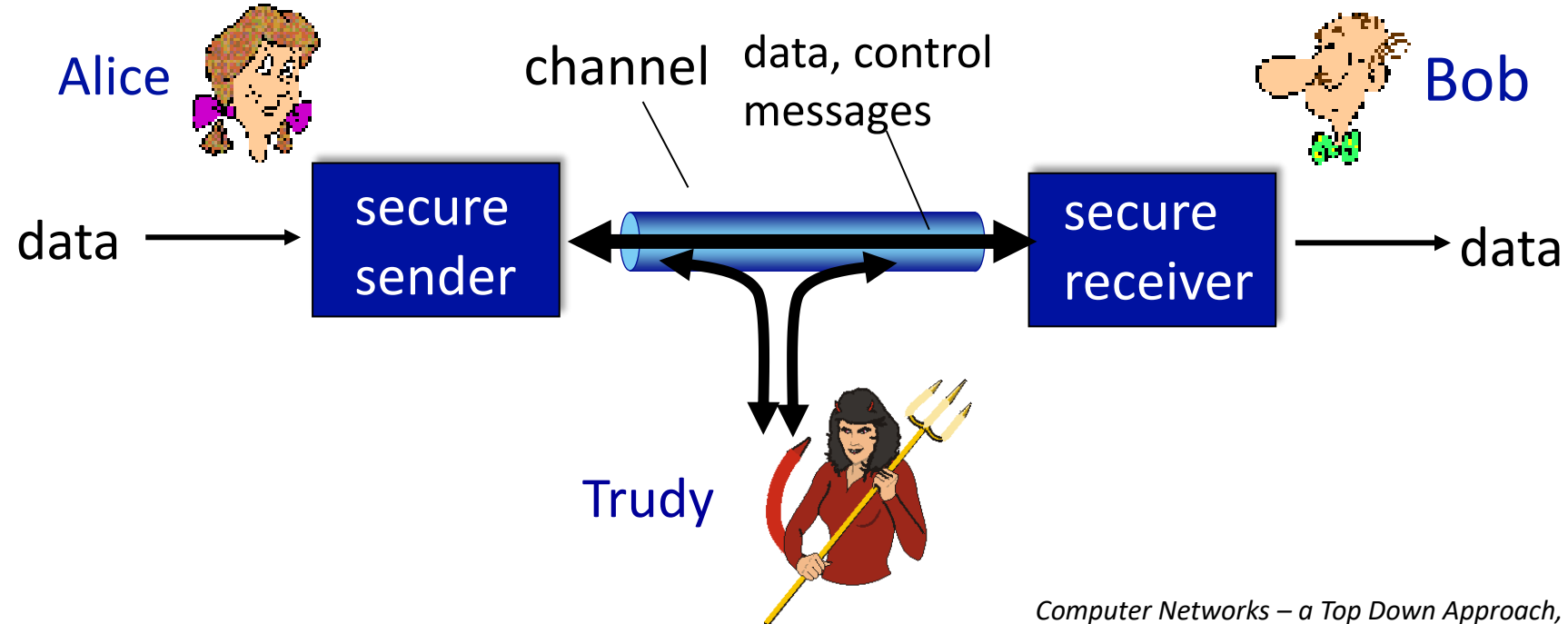
- A group of friendly users to share and exchange data remotely, assuming
 - No eavesdropping
 - No impersonation
 - No network/system hijacking
 - No wireless
 - No social media
 - Absolutely no mobility
 - ... it is a good world out there



Well, every baby grows up,
learning “life is not easy”!

Friends and Enemies: Alice, Bob, Trudy

- well-known in network security world
- Bob, Alice (lovers!) want to communicate “securely”
- Trudy (intruder) may intercept, delete, add messages



BASIC Network Security Tasks

confidentiality: only sender, intended receiver should “understand” message contents

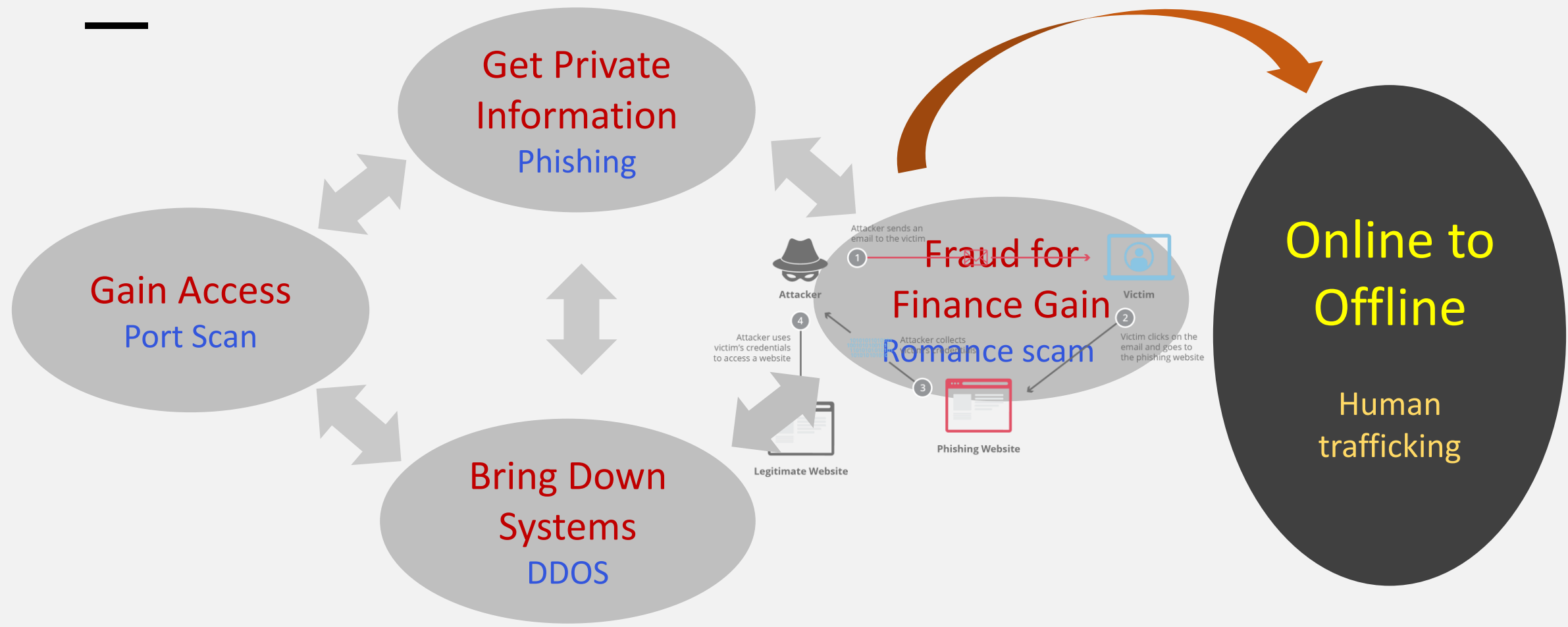
- sender encrypts message
- receiver decrypts message

authentication: sender, receiver want to confirm identity of each other

message integrity: sender, receiver want to ensure message not altered (in transit, or afterwards) without detection

access and availability: services must be accessible and available to users

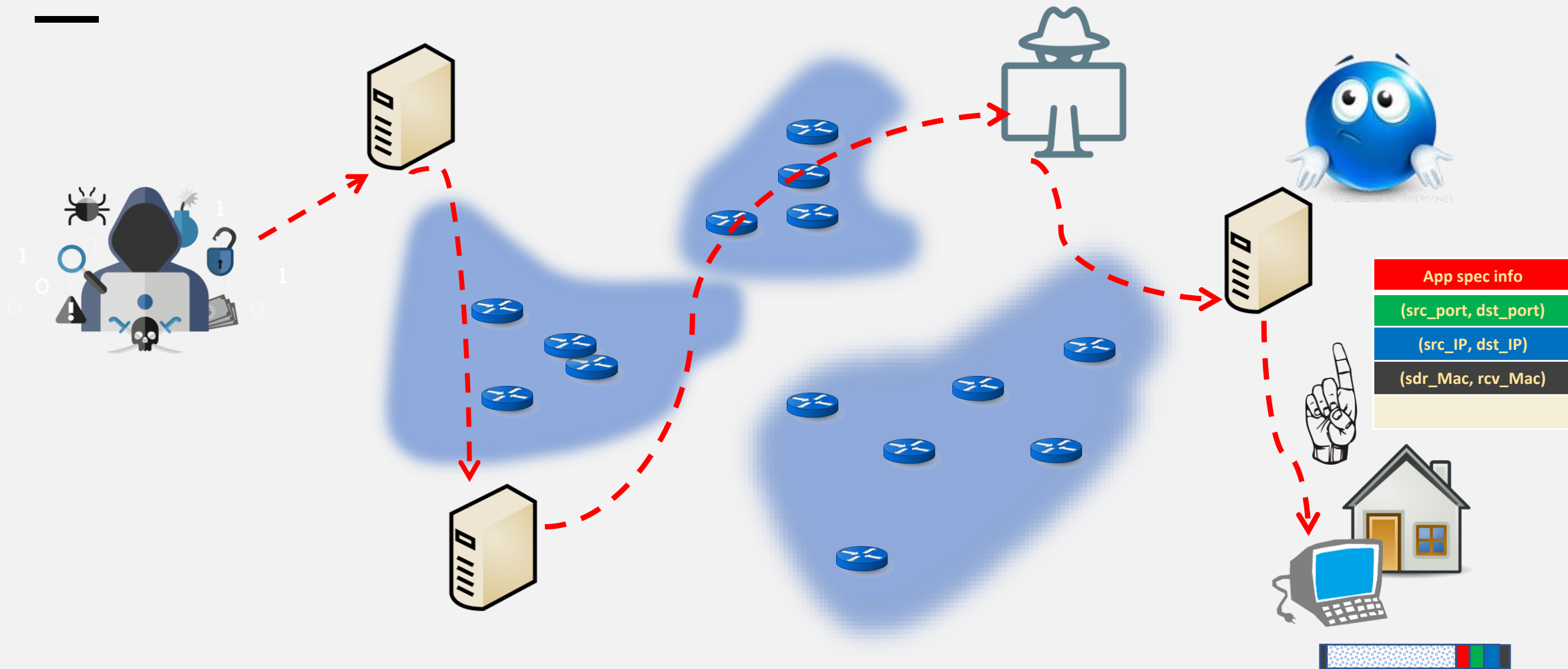
Persisting Goals of Network Attacks



- Every attacker (criminal) wants to hide their traces!!
- Internet is a happy playground for Anonymity!



Anonymity Tactics – Steppingstone



Anonymity Tactics –



-
- The Onion Router (routing) - TOR
 - Public Key Cryptography
 - Network tunneling built among TOR routers
 - Routing path initiated randomly

Cryptography Basics



Encryption algorithm

$E(\text{plaintext}, \text{key}) = \text{ciphertext}$

$D(\text{ciphertext}, \text{key}) = \text{plaintext}$



Symmetric (shared) key
cryptography

A single key is used is used

$D(E(p, k1), k1) = p$



Management of keys determines who has access to content

Public Key Cryptography

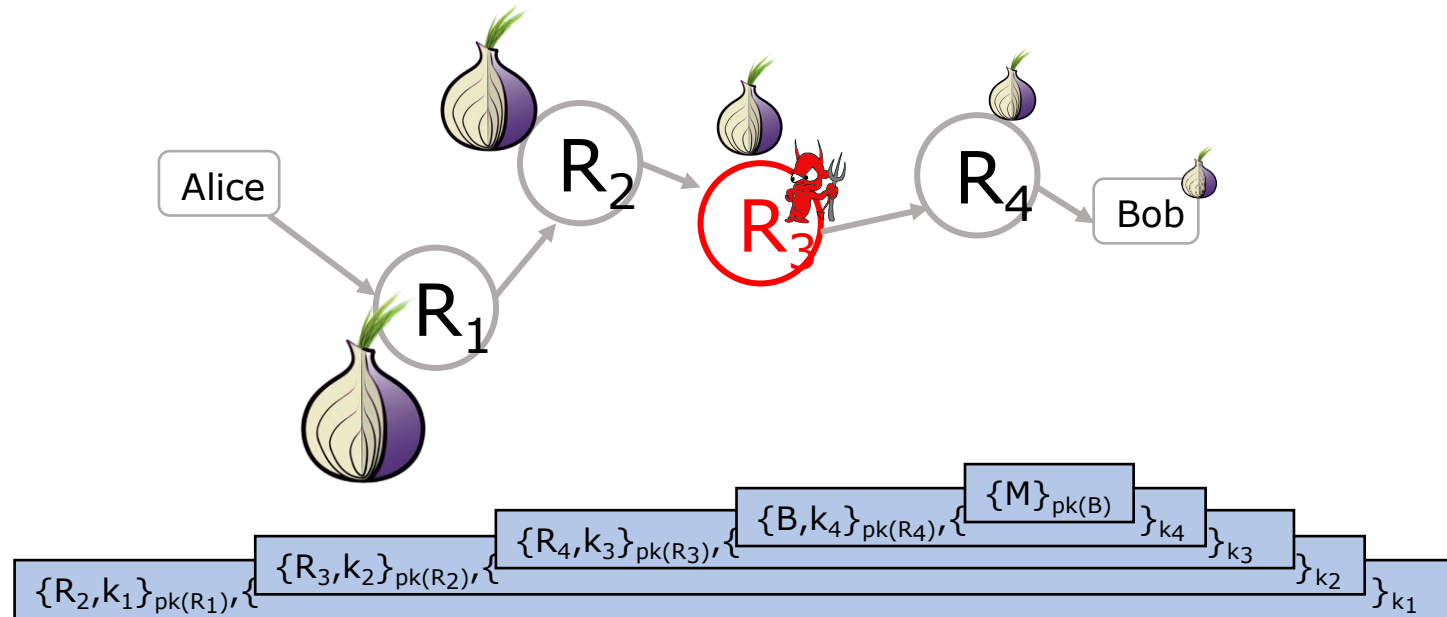
Public Key cryptography

- Each *key pair* consists of a public and private component: k^+ (public key), k^- (private key)
- $D(E(p, k^+), k^-) = p$
- $D(E(p, k^-), k^+) = p$

Public certificates

- Anyone can communicate secretly with you if they have your certificate

Onion Routing




- Routing info for each link encrypted with router's public key
- Each router learns only the identity of the next router
- <http://www.torproject.org/>

Dilemma of Tor Network

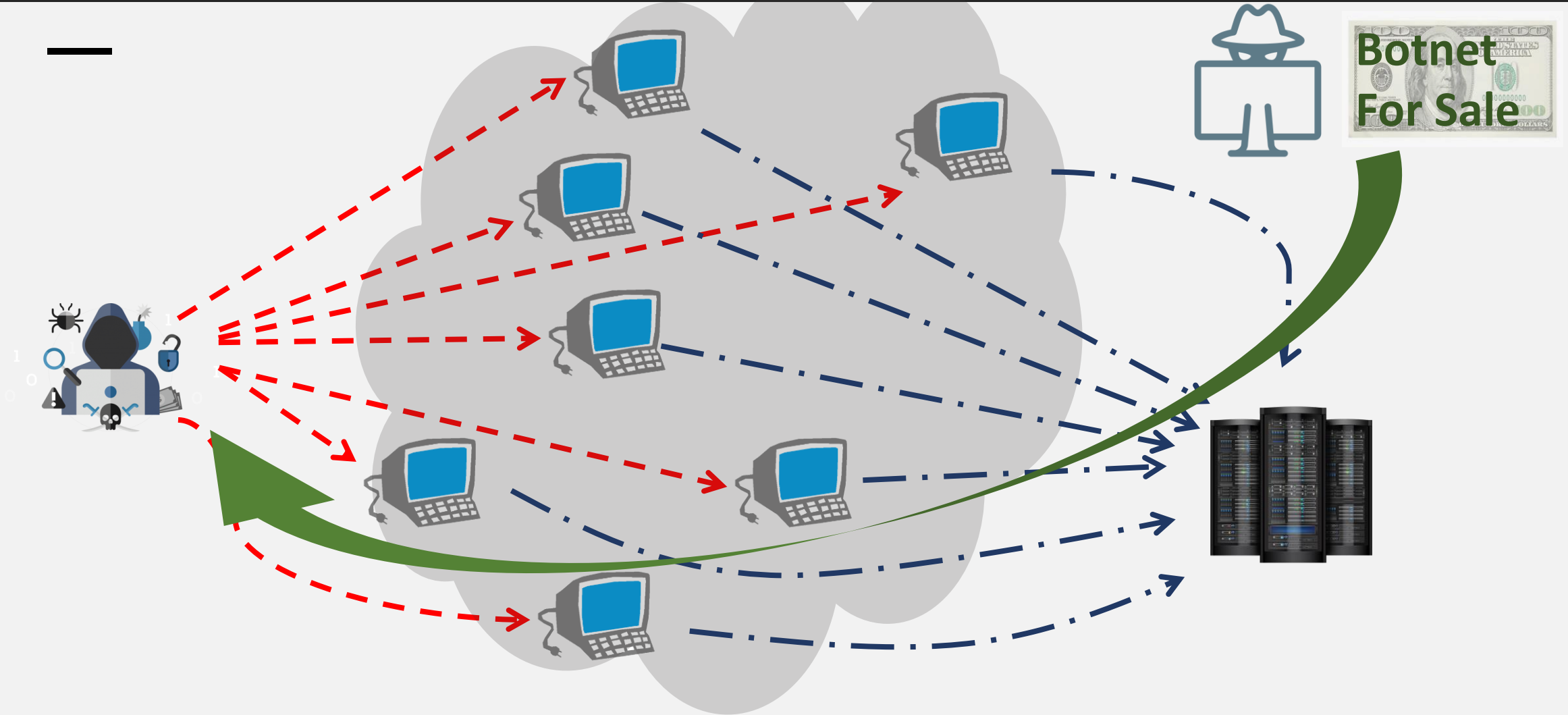


Designed to
protect privacy,
prevent
censorship



Used by hackers,
criminals, darknet

Anonymity Tactics - Botnets



Network Forensics Tools



IP Traceback



Timing Fingerprint



Flow Correlation,



Biggest Challenge: **Lack of Data!!**



Computer Networks Research

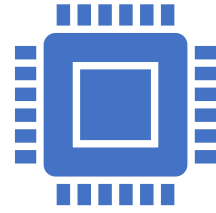
Classics

-
- Network Performance
 - Protocol Design
 - Signaling, States, Randomization
 - Measurement
 - Security & Privacy
 - Wireless & Mobility

Emerging

- Sensor & IoT Networks
- Adhoc Networks
- Content Distribution Networks
- Software Defined Networks
- Quantum Networks
-
- Network Forensics
- Mis/Dis-information Detection
- Ethics

Take Aways!



Computer Networking is an exciting field!

- Provide fundamental infrastructure for modern information boom, making AI more powerful
- New software and hardware are added to the Internet without speed breakers
- A LOT of challenging problems to solve



Ethics & Social Science will be crucial

- After all, it's a virtual world with virtual (artificial) human minds (intelligence)
- How laws, regulations, legislations should be set up, while protecting the diversity, equity and inclusion naturally brought by the anonymity of the Internet?



Questions?