WILLIAM & MARY

CHARTERED 1693

CSCI 667: Concepts of Computer Security

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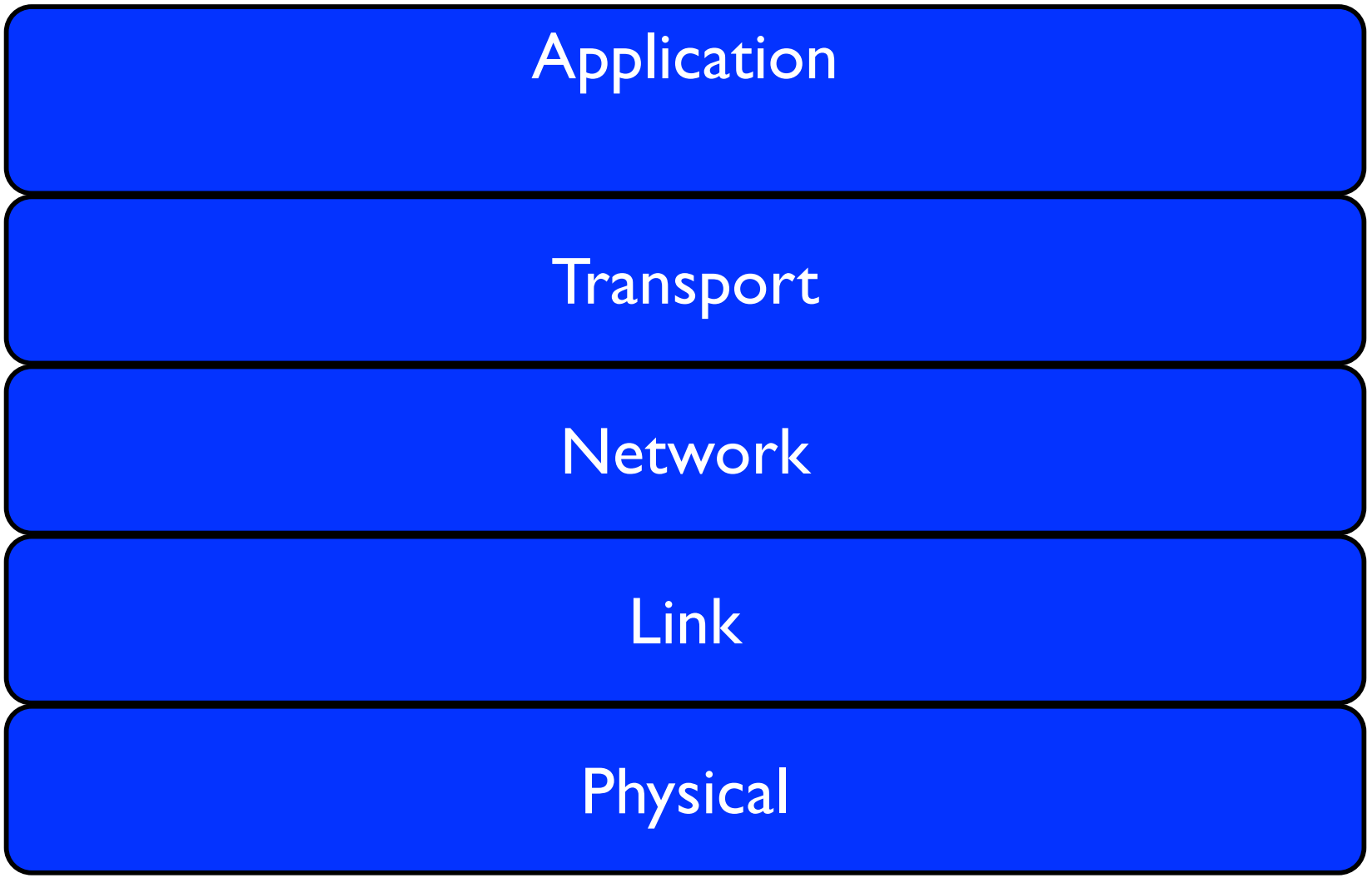
Derived from slides by William Enck and Micah Sherr

Project Presentations

- *4 presenters, room for 2 more (by 11am today)*
- *15 min: 10 minute presentations, 5 mins questions*
- Must contain (in no specific order, whatever flow makes sense):
  - Area and Motivation
  - Problem
  - Proposed Methodology
  - Expected Results
  - Project Status
    - Completed Tasks and Preliminary results.
    - Remaining Tasks

TCP/IP security
(read the Bellovin paper!)

Network Stack, yet again



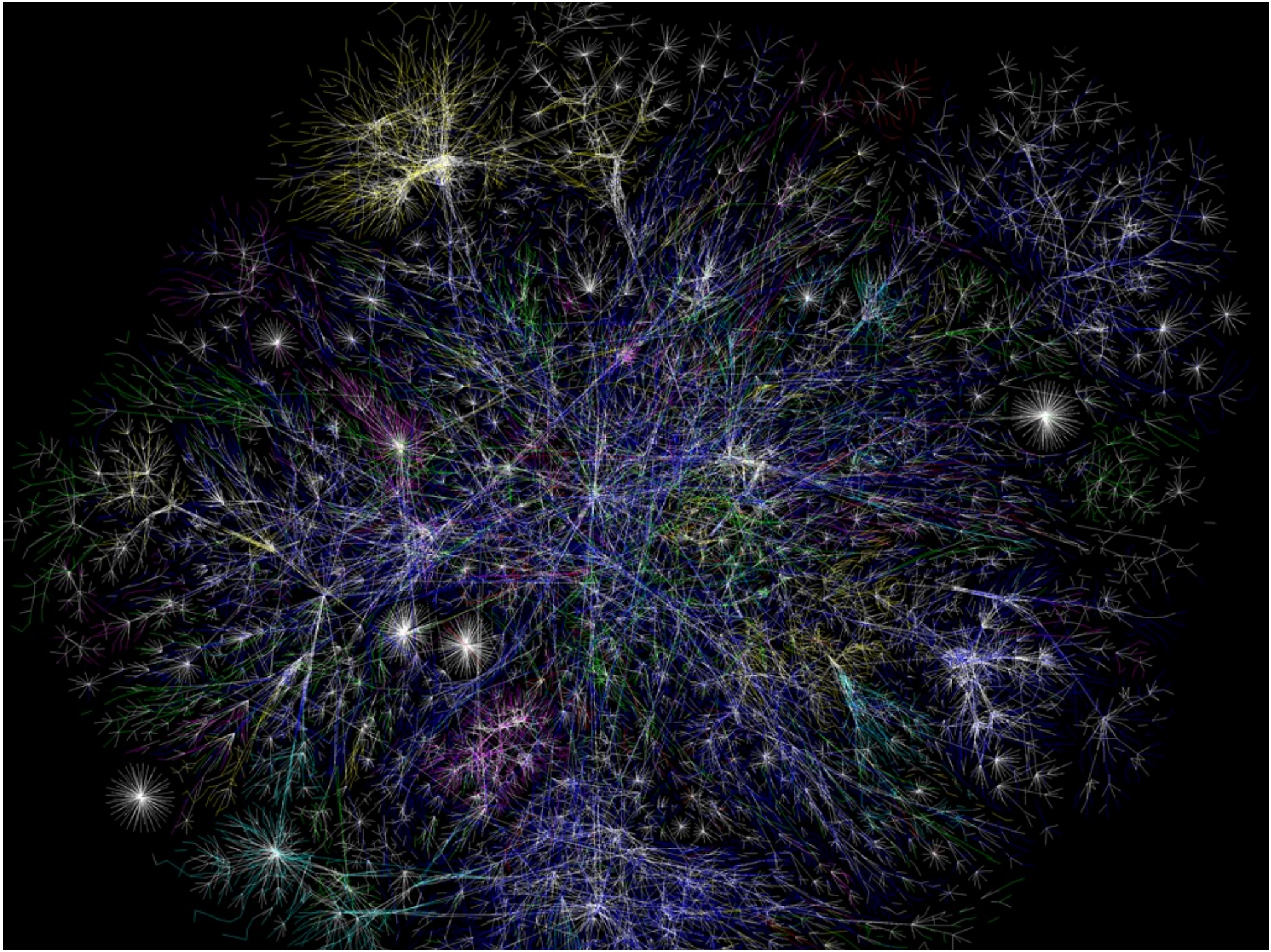
Networking

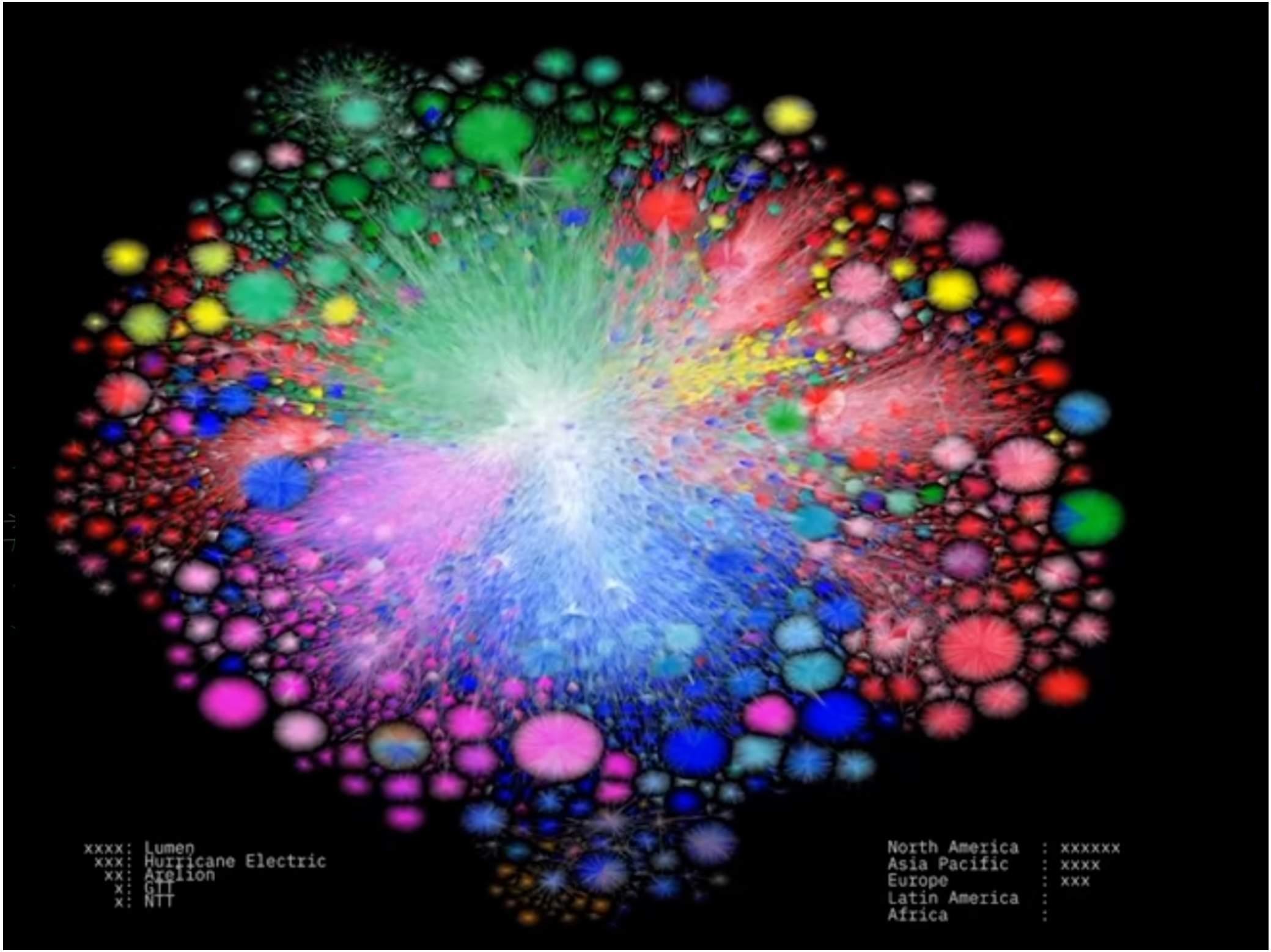
- Fundamentally about transmitting information between two devices
- Communication is now possible between any two devices anywhere (just about)
  - Lots of abstraction involved (see previous slide)
  - Lots of network components (routers)
  - Standard protocols (e.g., IP, TCP, UDP)
  - Wired and wireless
- What about ensuring *security*?

Network Security

- Every machine is connected
  - No barrier to entry
  - Not just limited to dogs as users

"On the Internet, nobody knows you're a dog."




xxxx: Lumen
xxx: Hurricane Electric
xx: Arelion
x: GTT
x: NTT
North America : xxxxxx
Asia Pacific : xxxx
Europe : xxx
Latin America :
Africa :

Exploiting the network

- The Internet is extremely vulnerable to attack
  - it is a huge open system ...
  - which adheres to the end-to-end principle
    - *smart end-points, dumb network*
- Can you think of any large-scale attacks that would be enabled by this setup?

Network Security: The high bits

- The network is …
  - … a collection of interconnected computers
  - … with resources that must be protected
  - … from unwanted inspection or modification
  - … while maintaining adequate quality of service.

Network Security: The high bits

- Network Security (one of many possible definitions):
  - Securing the network infrastructure such that the integrity, confidentiality, and availability of the resources is maintained.

Steven Bellovin's Security Problems in the TCP/IP Protocol Suite

- Bellovin's observations about security problems in IP
  - Not really a study of how IP is misused (e.g., IP addresses for authentication), but rather what is inherently bad about the way in which IP is set up
- A really, really nice overview of the basic ways in which security and the IP design is at odds

TCP Sequence Numbers

SYN(ISN$_A$)

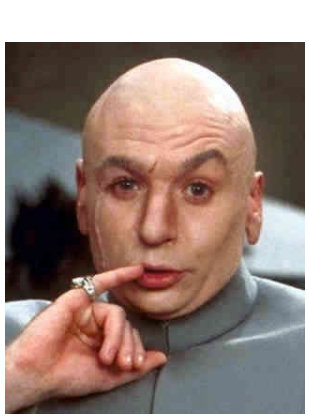
SYN(ISN$_B$),ACK(ISN$_A$)

ACK(ISN$_B$)

Bob Barker

- TCP's "three-way handshake":
  - each party selects Initial Sequence Number (ISN)
  - shows both parties are capable of receiving data
  - offers some protection against forgery -- **WHY?**

TCP Sequence Numbers



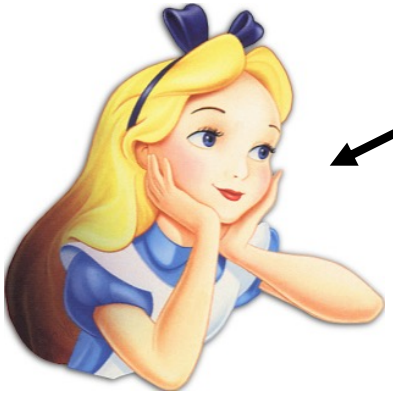
SYN(ISN$_A$), SRC=A

Bob Barker

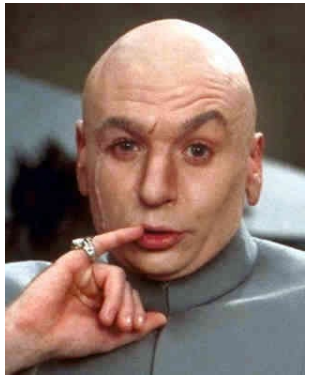
K(ISN???)

SYN(ISN$_B$),A

SN$_A$)



TCP Sequence Numbers



Bob Barker

SYN(ISN$_E$)

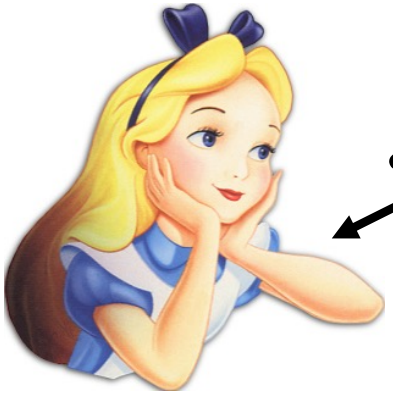
SYN(ISN$_{B1}$),ACK(ISN$_E$)

SYN(ISN$_A$),SRC=A

ACK(ISN$_{B1+\delta}$), SRC=A

EVIL DATA, SRC=A

SYN(ISN$_{B2}$),ACK(ISN$_A$)



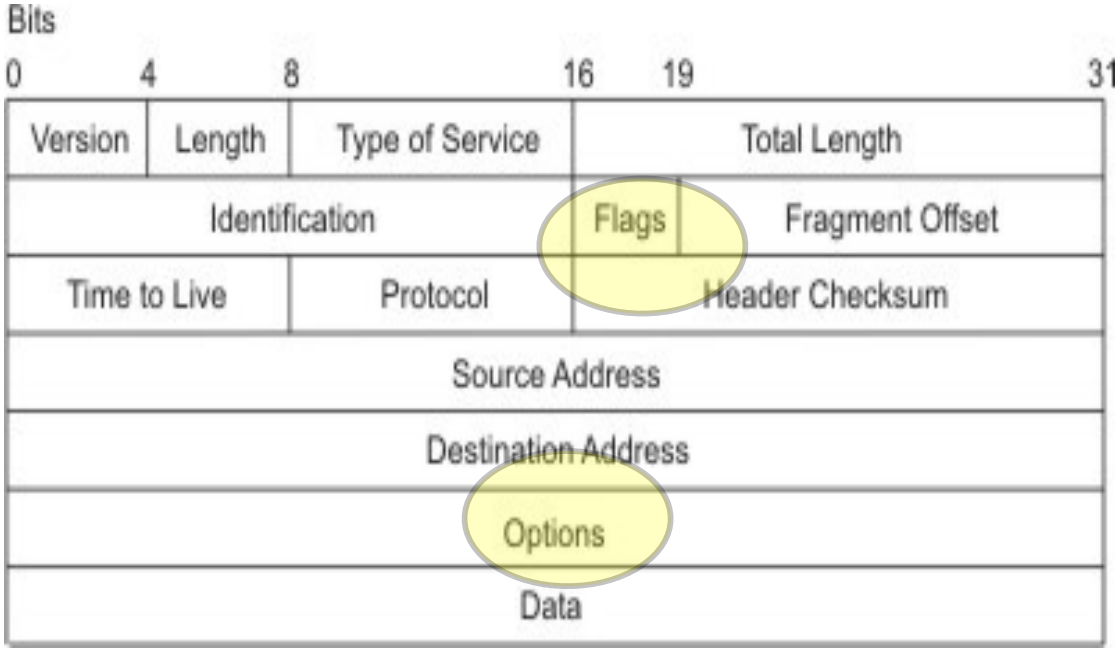
In many TCP implementations, ISNs are predictable -- based on time (e.g,. ++ each 1/128 sec)

How do we fix this?

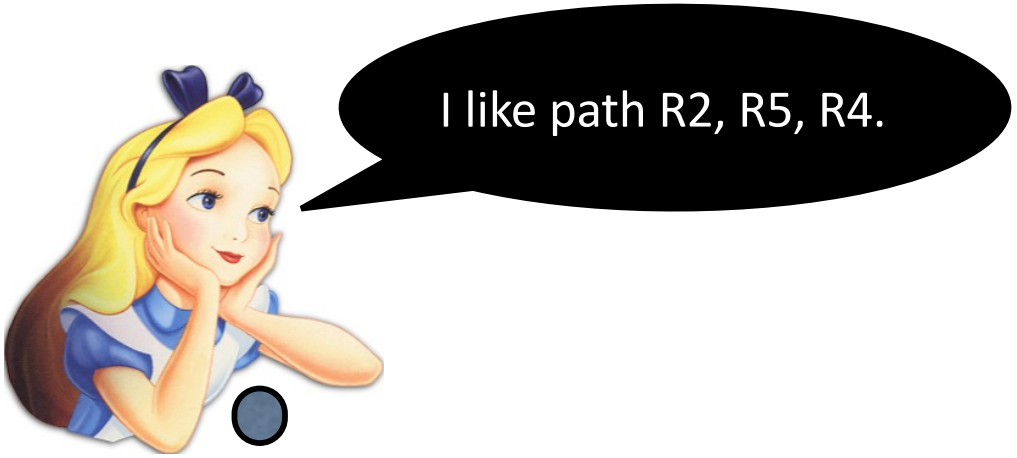
- Randomize ISNs
  - How?

Source Routing

- Standard IP Packet Format (RFC791)
- Source Routing allows sender to specify route
  - Set flag in *Flags* field
  - Specify routes in *Options* field



Source Routing




Bob Barker

R2

R4

R5

Source Routing

- Q: What are the security implications of Source Routing?
  - Access control?
  - DoS?

- Q: What are the possible defenses?
  - A: Block packets with source-routing flag

Routing Manipulation

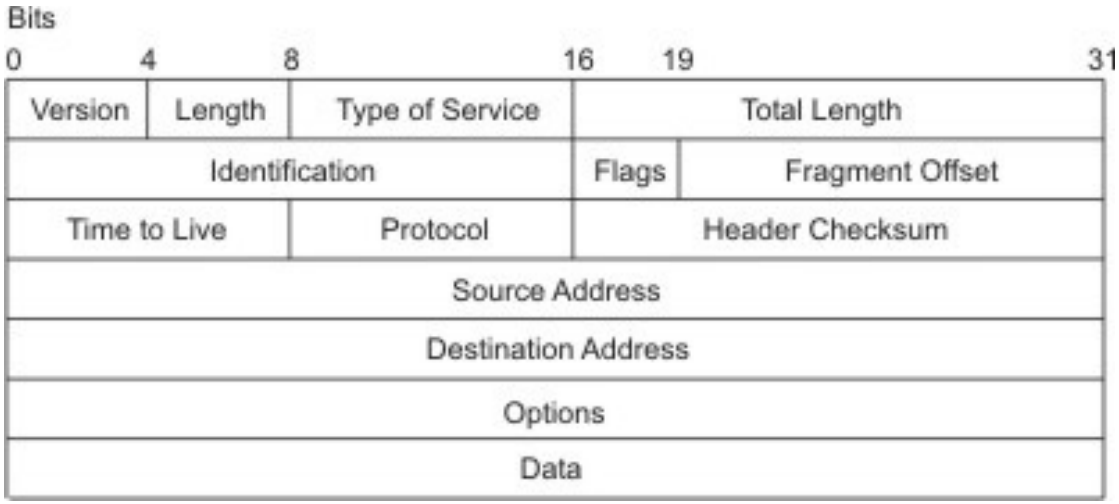
- RIP - Routing Information Protocol
  - Distance vector routing protocol used for the local network
  - Routers exchange reachability and "distance" vectors for all the sub-networks within (a typically small) domain
  - Use vectors to decide which route is best
- **Problem:** Data (vectors) are not authenticated
  - Forge vectors to cause traffic to be routed through adversary
  - or cause DoS
- Solutions: ? (still an open problem)

Internet Control Message Protocol (ICMP)

- ICMP is used as a control plane for IP messages
  - Ping (connectivity probe)
  - Destination unreachable (error notification)
  - Time-to-live exceeded (error notification)
- ICMP messages are easy to spoof: no handshake
- Some ICMP messages cause clients to alter behavior
  - e.g., TCP RSTs on destination unreachable or TTL-exceeded
- Enables attacker to remotely reset others' connections
- Solution:
  - Verify/sanity check sources and content
  - Filter most of ICMP

Ping-of-Death: Background: IP Fragmentation

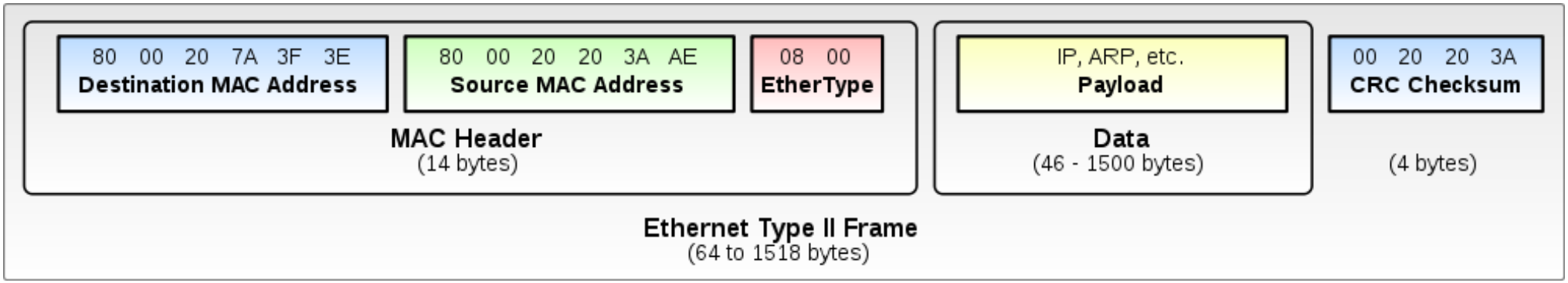
- 16-bit "Total Length" field allows 2^{16}-1=65,535 byte packets
- Data link (layer 2) often imposes significantly smaller **Maximum Transmission Unit** (MTU) (normally 1500 bytes)
- Fragmentation supports packet sizes greater than MTU and less than 2^{16}
- 13-bit Fragment Offset specifies offset of fragmented packet, in units of 8 bytes
- Receiver reconstructs IP packet from fragments, and delivers it to Transport Layer (layer 4) after reassembly



Ping-of-Death

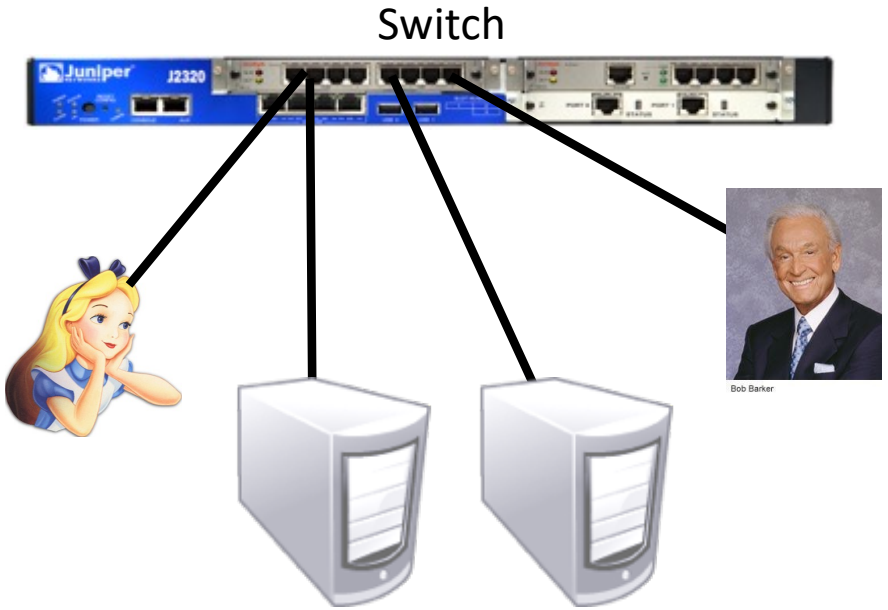
- Maximum packet size: 65,535 bytes
- Maximum 13-bit offset is $(2^{13} - 1) * 8 = 65,528$
- In 1996, someone discovered that many operating systems, routers, etc. could be crash/rebooted by sending a **single** malformed packet
  - If packet with maximum possible offset has more than 7 bytes, IP buffers allocated with 65,535 bytes will be overflowed (65535-65528 = 7)
  - ...causing crashes and reboots
- Not really ICMP specific, but easy
  - % ping -s 65510 your.host.ip.address
- Most OSes and firewalls have been hardened against PODs
- This was a popular pastime of early hackers

ARP Spoofing:
Background: Ethernet Frames



ARP Spoofing: Background: ARP

- **Address Resolution Protocol (ARP):** Locates a host's link-layer (MAC) address
- Problem: How does Alice communicate with Bob over a LAN?
  - Assume Alice (10.0.0.1) knows Bob's (10.0.0.2) IP
  - LANs operate at layer 2 (there is no router inside of the LAN)
  - Messages are sent to the switch, and addressed by a host's link-layer (MAC) address
- Protocol:
  - Alice broadcasts: "Who has 10.0.0.2?"
  - Bob responses: "I do! And I'm at MAC f8:1e:df:ab:33:56."



ARP Spoofing

- Each ARP response overwrites the previous entry in ARP table -- **last response wins**!
- Attack: Forge ARP response
- Effects:
  - Man-in-the-Middle
  - Denial-of-service
- Also called **ARP Poisoning** or **ARP Flooding**

ARP Spoofing: Defenses

- Smart switches that remember MAC addresses
- Switches that assign hosts to specific ports

Legacy flawed protocols and services

- Finger user identity
  - host gives up who is logged in, existence of identities

```
ip-128-239-134-5:CSCI680 adwait$ finger adwait
Login: adwait                           Name: Adwait
Directory: /Users/adwait                Shell: /bin/bash
On since Wed Sep 27 10:27 (EDT) on console, idle 28 days 8:11 (messages off)
On since Wed Sep 27 13:56 (EDT) on ttys000, idle 14 days 3:48
On since Wed Oct 11 14:44 (EDT) on ttys001, idle 14 days 3:50
On since Thu Oct  5 12:32 (EDT) on ttys002, idle 14 days 1:07
On since Wed Oct 18 14:41 (EDT) on ttys003, idle 1 day 6:41
On since Wed Oct 25 18:35 (EDT) on ttys004
No Mail.
No Plan.

Login: adwaitnadkarni                   Name: Adwait Nadkarni
Directory: /Users/adwaitnadkarni        Shell: /bin/bash
Never logged in.
No Mail.
No Plan.
ip-128-239-134-5:CSCI680 adwait$
```

- This is horrible in a distributed environment
  - Privacy, privacy, privacy …
  - Lots of information to start a compromise of the user.

POP/SMTP/FTP

- Post office protocol - mail retrieval
  - Passwords passed in the clear
  - Solution: SSL, SSH, Kerberos
- Simple mail transport protocol (SMTP) - email
  - Nothing authenticated: SPAM
  - Nothing hidden: eavesdropping
  - Solution: ?
- File Transfer protocol - file retrieval
  - Passwords passed in the clear
  - Solution: SSL, SSH, Kerberos

Lessons Learned?

- The Internet was built for robust communication
- Smartness occurs at the end-hosts

  (see End-to-End Principle)
- Does this design support or hinder network security?

And if we had to start all over again, could we do better?