Network Attacks

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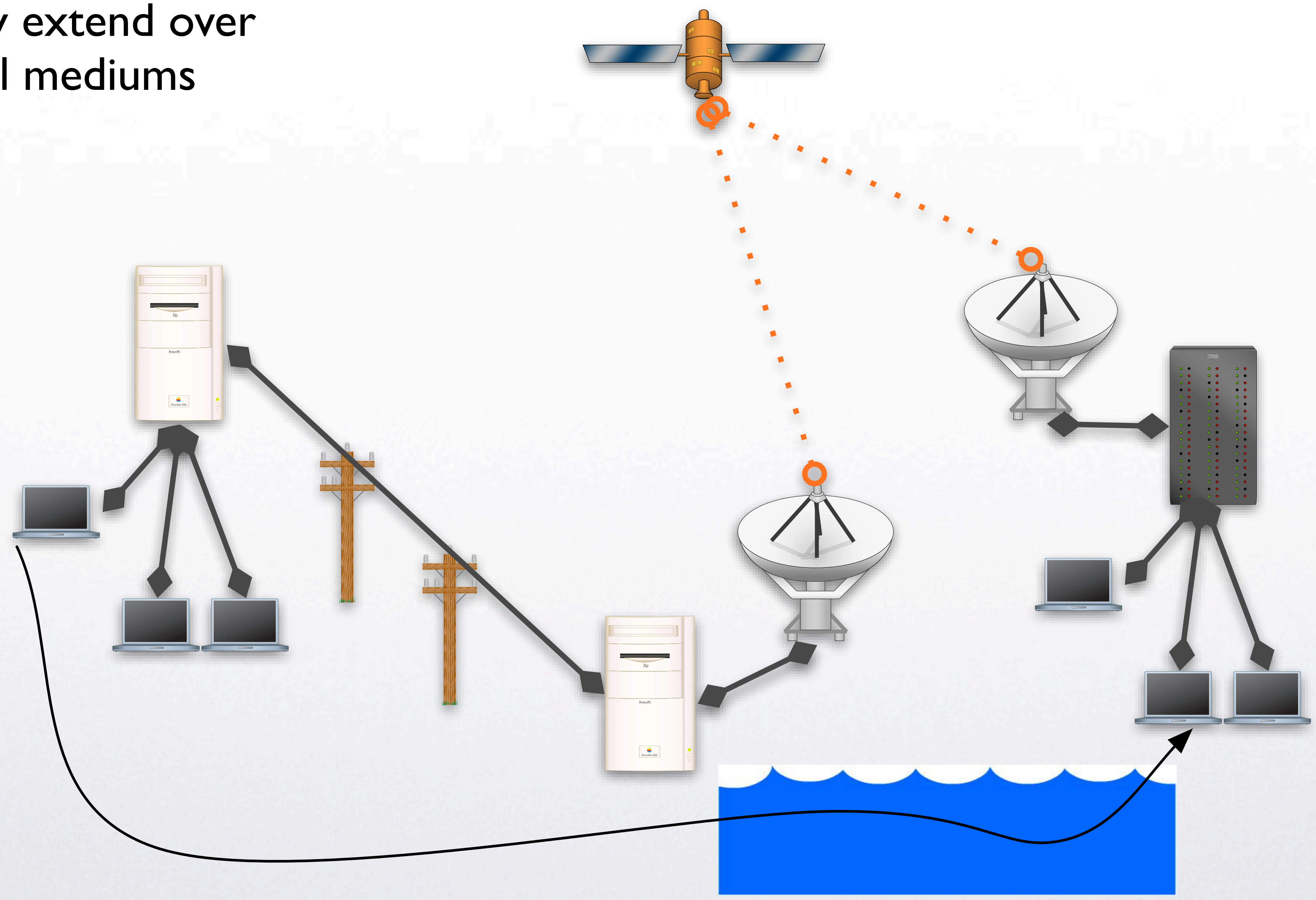
Networks...

- Computers connected to each other.
- Each machine has a unique address.
- Each message from the sender to receiver may stop at many intermediate hops till it reaches its destination. (networks are not complete graphs ...routing...)

Networks

A network may extend over various physical mediums



Communication Media

- Wire (copper wire: *cheap, slow*) 10 Mbps, ~100m. Carries electrical signal.
- Coax Cable (wire+insulation jacket) 100Mbps ~500m.
- Optical fiber (thin strand of glass). Carries pulses of light. 1000Mbps. ~4km.
- Wireless: WiFi, Radio signals.
- infrared, satellite etc...

OSI Model

- Open Systems Interconnection Model

7	Application	User-level data
6	Presentation	Data format (ascii etc.)
5	Session	Sequencing
4	Transport	Flow control (acks, retransmissions errors)
3	Network	Routing (where to send)
2	Data Link	Local delivery
1	Physical	Bit level representation

Example : e-mail

7	Application	e-mail composition
6	Presentation	text based transliteration, compression
5	Session	-
4	Transport	error-correcting codes, logical connection
3	Network	chop in packets - put addresses
2	Data Link	chop in frames - add MAC addresses
1	Physical	chop in bits - transmit

TCP/IP

- Transmission Control Protocol/ Internet Protocol.
- Four layers:
  - Application.
  - Host-to-Host Transport.
  - Internet.
  - Physical.

TCP/IP

Application Layer	Prepare messages from user	Addressing/ Interaction
Transport Layer (e.g., TCP)	Packets are made	Sequencing, Reliability Error Correction
Network Layer (IP)	Into Datagrams	Routing
Data Link Layer	Connection between adjacent hosts - Bits	
Physical	Bit representation	e.g. radio modulation

Data Link Layer Frames

- Source and destination Physical Addresses
- Encoding of bits
- Physical layer aspects (e.g., modulation).

IP Datagrams

- Contain *time to live (TTL)* information (# of hops).
- Source and Destination IP addresses.
- Information about the encapsulated protocol.

TCP Packets

- Source / Destination ports.
- Acknowledgment number for connecting packets of a session.
- Sequence numbers.
- Integrity (checksums).

Application Data

- Depends on the application layer protocol used.
- Example:

Example

Physical Layer: eth
the 2 MAC addresses
+ IP indication

Network Layer: IP
IP addresses, TTL,
checksum, fragmentation

```
0000  00 0f db 4d 77 95 00 0d 93 b0 a3 24 08 00 45 00   ...Mw......$..E.
0010  01 75 c8 de 40 00 40 06 44 dd c0 a8 01 2e 40 ec   .u..@.@.D.....@.
0020  29 05 e6 10 00 50 15 86 10 4d 25 b6 67 ed 80 18   )....P...M%.g...
0030  ff ff 2d 2f 00 00 01 01 08 0a 2f 41 cf 64 62 38   ..-/....../A.db8
0040  81 9a 47 45 54 20 2f 63 6e 6e 2f 32 30 30 36 2f   ..GET /cnn/2006/
0050  55 53 2f 30 32 2f 32 37 2f 6b 61 74 72 69 6e 61   US/02/27/katrina
0060  2e 70 6f 6c 6c 2f 74 31 2e 32 31 33 35 2e 6d 6f   .poll/t1.2135.mo
0070  6e 2e 62 65 61 64 73 2e 61 70 2e 6a 70 67 20 48   n.beads.ap.jpg H
0080  54 54 50 2f 31 2e 31 0d 0a 41 63 63 65 70 74 3a   TTP/1.1..Accept:
0090  20 2a 2f 2a 0d 0a 41 63 63 65 70 74 2d 4c 61 6e    */*..Accept-Lan
00a0  67 75 61 67 65 3a 20 65 6e 0d 0a 41 63 63 65 70   guage: en..Accep
00b0  74 2d 45 6e 63 6f 64 69 6e 67 3a 20 67 7a 69 70   t-Encoding: gzip
00c0  2c 20 64 65 66 6c 61 74 65 0d 0a 52 65 66 65 72   , deflate..Refer
00d0  65 72 3a 20 68 74 74 70 3a 2f 2f 77 77 77 2e 63   er: http://www.c
00e0  6e 6e 2e 63 6f 6d 2f 0d 0a 55 73 65 72 2d 41 67   nn.com/..User-Ag
00f0  65 6e 74 3a 20 4d 6f 7a 69 6c 6c 61 2f 35 2e 30   ent: Mozilla/5.0
0100  20 28 4d 61 63 69 6e 74 6f 73 68 3b 20 55 3b 20    (Macintosh; U;
0110  50 50 43 20 4d 61 63 20 4f 53 20 58 3b 20 65 6e   PPC Mac OS X; en
0120  29 20 41 70 70 6c 65 57 65 62 4b 69 74 2f 34 31   ) AppleWebKit/41
0130  37 2e 39 20 28 4b 48 54 4d 4c 2c 20 6c 69 6b 65   7.9 (KHTML, like
0140  20 47 65 63 6b 6f 29 20 53 61 66 61 72 69 2f 34    Gecko) Safari/4
0150  31 37 2e 38 0d 0a 43 6f 6e 6e 65 63 74 69 6f 6e   17.8..Connection
0160  3a 20 6b 65 65 70 2d 61 6c 69 76 65 0d 0a 48 6f   : keep-alive..Ho
0170  73 74 3a 20 69 2e 61 2e 63 6e 6e 2e 6e 65 74 0d   st: i.a.cnn.net.
0180  0a 0d 0a                                          ...
```

Transport Layer: TCP
Ports, Seq Ack numbers,
checksum, timestamps

Application Layer: HTTP
Request: GET
Request URI
Referrer
User-agent info
Connection info

Internet Protocols

- Data link Layer: ethernet, wi-fi etc.
- Network Layer: ICMP (Internet control message), IP etc.
- Transport Layer: UDP (user datagram protocol), TCP etc.
- Application Layer: Finger, FTP (file transfer), HTTP (hypertext transfer), IMAP (internet message access), IRC (internet relay chat), POP (post office), SMTP (simple mail transfer), TELNET (terminal emulation), X-window, etc.

UDP Protocol

- user datagram protocol.
- lightweight alternative to TCP.
- Faster, lighter - adds 8 bytes for control.
- stateless sending and no ordering.
- used for application layer protocols as SNMP (simple network monitoring), Syslog (system audit log), Time etc.

How does data find its way?

- *Application.* HTTP request to www.website.com (DNS resolution)
- *Transport.* which in turn will result to some packets directed to a certain **port #**.
- *Internet.* which in turn will result to some frames directed to a **IP address.**
- *Physical.* which in turn will result to some actual bits being sent to **MAC address**

Addressing

- Two mappings are necessary:
  - From host name to IP address.
  - From IP address to MAC address.
- Host name will be mapped to an IP address through a protocol called DNS
- MAC address will be obtained from an address resolution table. (ARP)

Transmitting a packet

- A packet needs to be directed to a certain IP address.
- To figure out where to send it next, a routing table is consulted. Example:

```
Routing table:
Destination        Gateway            Flags     Refs      Use   Netif Expire
default            137.99.11.1        UGSc        16     1863     en0
...
```

Transmitting a packet, II

- Once the (intermediate hop) IP address is determined the packet must be split into frames and directed to the right MAC address.

- Internet to Ethernet address translation:

Address	HWtype	HWaddress	Flags Mask	Iface
137.99.11.1	ether	00:0B:46:9A:1B:3F	C	eth0

Receiving a packet

- Keep it or forward it.
- Based on destination address (and perhaps other parameters).
- Forward it using the routing table as before.
- Routing and Address Resolution tables are dynamically updated.

IP Addresses and DNS

- 32-bit (IPv6 offers 128-bits).
- IP addresses are assigned to names according to Domain Name Service (DNS).
- Given a certain name at the application layer a query will be transmitted to a *Name Server* to resolve it for the corresponding IP address.

Trace route

```
 1  192.168.63.11 (192.168.63.11)  3.896 ms  2.122 ms  1.511 ms
 2  195.134.67.1 (195.134.67.1)  1.794 ms  2.839 ms  1.784 ms
 3  grnetRouter.L1.uoa.athens-3.access-link.grnet.gr (194.177.209.97)  1.984 ms  2.262 ms  3.360 ms
 4  eie2-to-koletti1.backbone.grnet.gr (195.251.27.46)  2.196 ms  4.345 ms  3.539 ms
 5  core1.ams.net.google.com (195.69.144.247)  72.084 ms  72.003 ms  72.743 ms
 6  209.85.248.88 (209.85.248.88)  74.182 ms *  74.916 ms
 7  64.233.175.246 (64.233.175.246)  75.377 ms  75.800 ms  74.950 ms
 8  209.85.255.143 (209.85.255.143)  77.161 ms 72.14.239.197 (72.14.239.197)  79.314 ms 209.85.255.166
(209.85.255.166)  90.792 ms
 9  72.14.232.37 (72.14.232.37)  81.473 ms 72.14.232.41 (72.14.232.41)  84.950 ms 72.14.232.37
(72.14.232.37)  84.960 ms
10  ez-in-f104.1e100.net (66.102.13.104)  79.149 ms  78.015 ms  76.316 ms
```

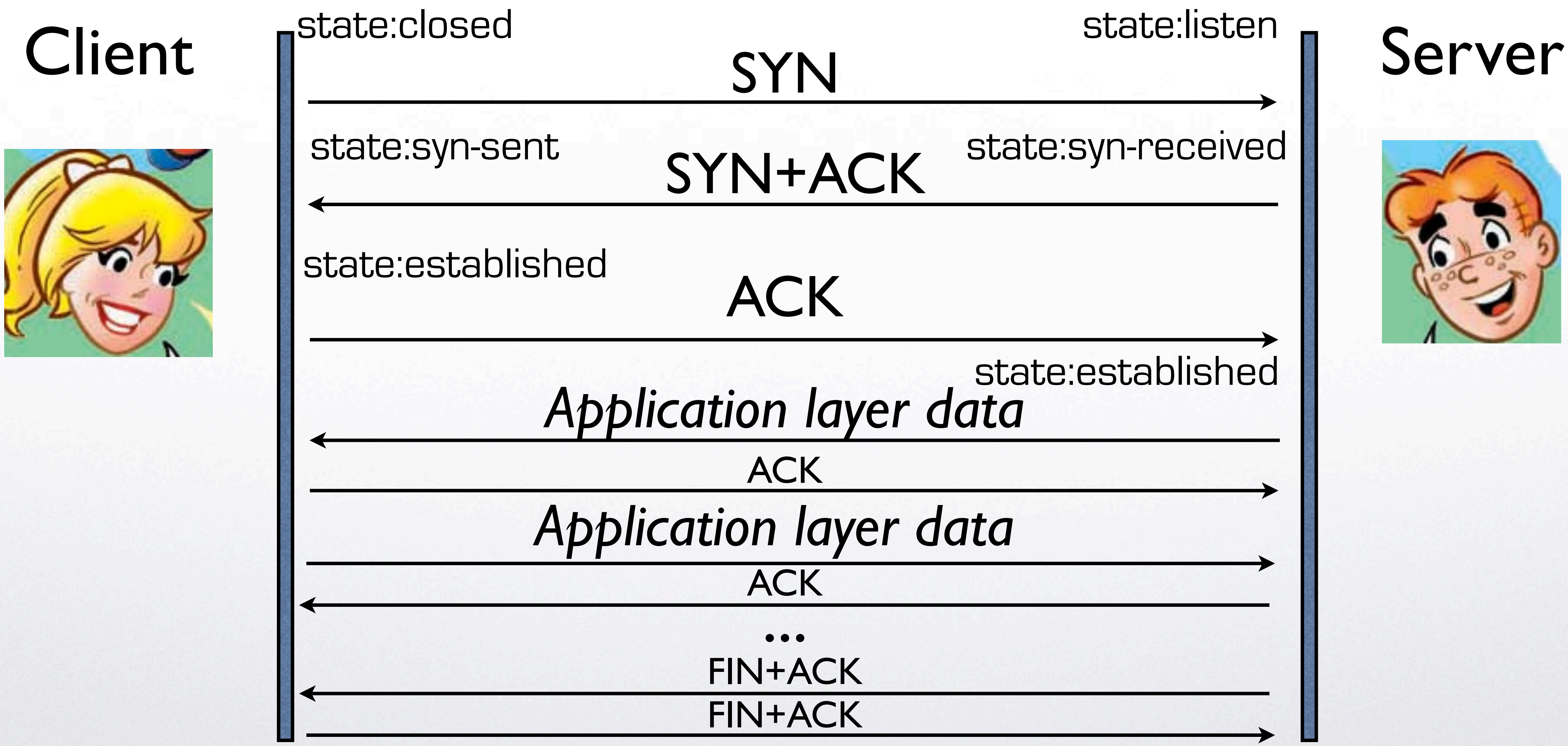
How traceroute works

- Using a special IP header filed called TTL : time to live.
- TTL = number of hops a packet is allowed to make. Each router decreases by one.
- When TTL reaches 0 then a router discards the packet and notifies originator.
- For traceroute: send repeatedly packets and calibrate TTL as 1, 2, 3, 4, 5, ...
- not all routers necessarily respond (* * *)

Client Server Model

- Application protocols, FTP, HTTP, Telnet etc.
- Server listens to port for client requests.
- Client initiates protocol

Talking over TCP/IP



Packet Sniffing

- Every computer in the Internet sends and receives packets.
- Anyone with the appropriate privileges in a certain host can "sniff" the packets that are being forwarded by the host (and not only the packets that are directed to the host).
- In this case the host is said to be in promiscuous mode.

Packet Sniffing, II

- If you have privileges for promiscuous mode then you can capture all traffic within the sub-network the host belongs to.
- You cannot capture traffic outside your sub-network (e.g., traffic that is not directed towards your gateway).
- When you use your computer do always ponder what is your sub-network (consider: sitting at a cafe connected to a wireless access point)

Wireshark

- Wireshark is a powerful “network protocol analyzer”
- It not only sniffs data when put on promiscuous mode but also “knows” the protocols and structures the packets in the appropriate format.

Wireshark, II

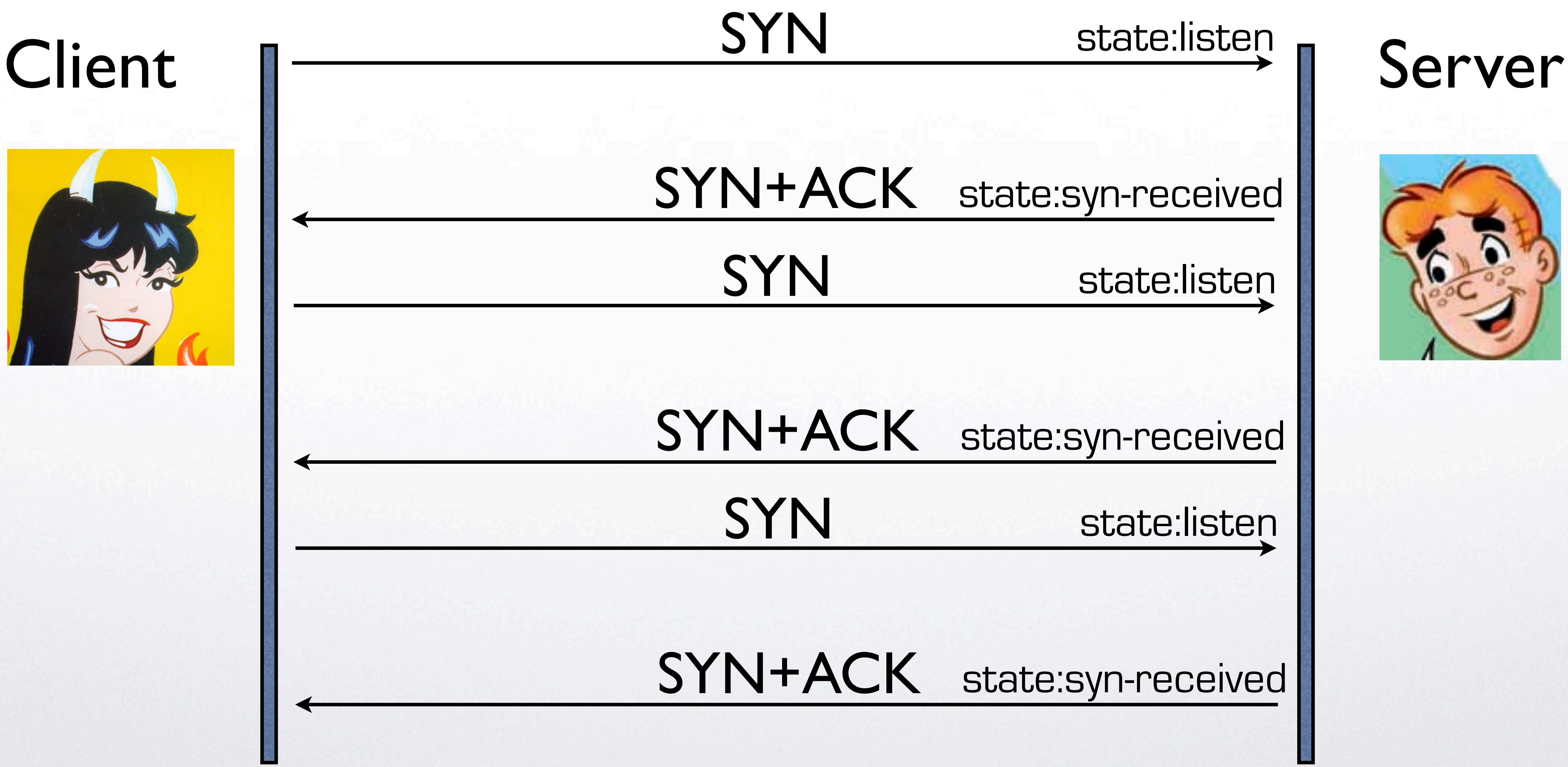
screen dump of capture window after an FTP connection

No.	Time	Source	Destination	Protocol	Info
1	0.000000	192.168.1.46	192.168.1.1	DNS	Standard query A ftp.debian.org
2	0.156872	192.168.1.1	192.168.1.46	DNS	Standard query response A 128.101.240.212
3	0.203708	192.168.1.46	128.101.240.212	TCP	58408 > ftp [SYN] Seq=0 Ack=0 Win=65535 Len=0 MSS=1
4	0.311009	128.101.240.212	192.168.1.46	TCP	ftp > 58408 [SYN, ACK] Seq=0 Ack=1 Win=5792 Len=0 M
5	0.311128	192.168.1.46	128.101.240.212	TCP	58408 > ftp [ACK] Seq=1 Ack=1 Win=65535 Len=0 TSV=7
6	0.427572	128.101.240.212	192.168.1.46	FTP	Response: 220 saens.debian.org FTP server (vsftpd)
7	0.457218	192.168.1.46	128.101.240.212	TCP	58408 > ftp [ACK] Seq=1 Ack=43 Win=65535 Len=0 TSV=
8	3.908879	192.168.1.46	128.101.240.212	FTP	Request: USER anonymous
9	3.995051	128.101.240.212	192.168.1.46	TCP	ftp > 58408 [ACK] Seq=43 Ack=17 Win=6144 Len=0 TSV=
10	3.995621	128.101.240.212	192.168.1.46	FTP	Response: 331 Please specify the password.
11	4.058261	192.168.1.46	128.101.240.212	TCP	58408 > ftp [ACK] Seq=17 Ack=77 Win=65535 Len=0 TSV=
12	8.388059	192.168.1.46	128.101.240.212	FTP	Request: PASS ak@ak.org
13	8.473188	128.101.240.212	192.168.1.46	FTP	Response: 230-
14	8.473824	128.101.240.212	192.168.1.46	FTP	Response: 230-This site is just another one in a worldwid
15	8.659296	192.168.1.46	128.101.240.212	TCP	58408 > ftp [ACK] Seq=33 Ack=158 Win=65535 Len=0 TSV
16	8.751453	128.101.240.212	192.168.1.46	FTP	Response: 230-It is not the "primary Debian FTP site" – it
17	8.758911	192.168.1.46	128.101.240.212	FTP	Request: SYST

the three-way handshake

Observe the password and username

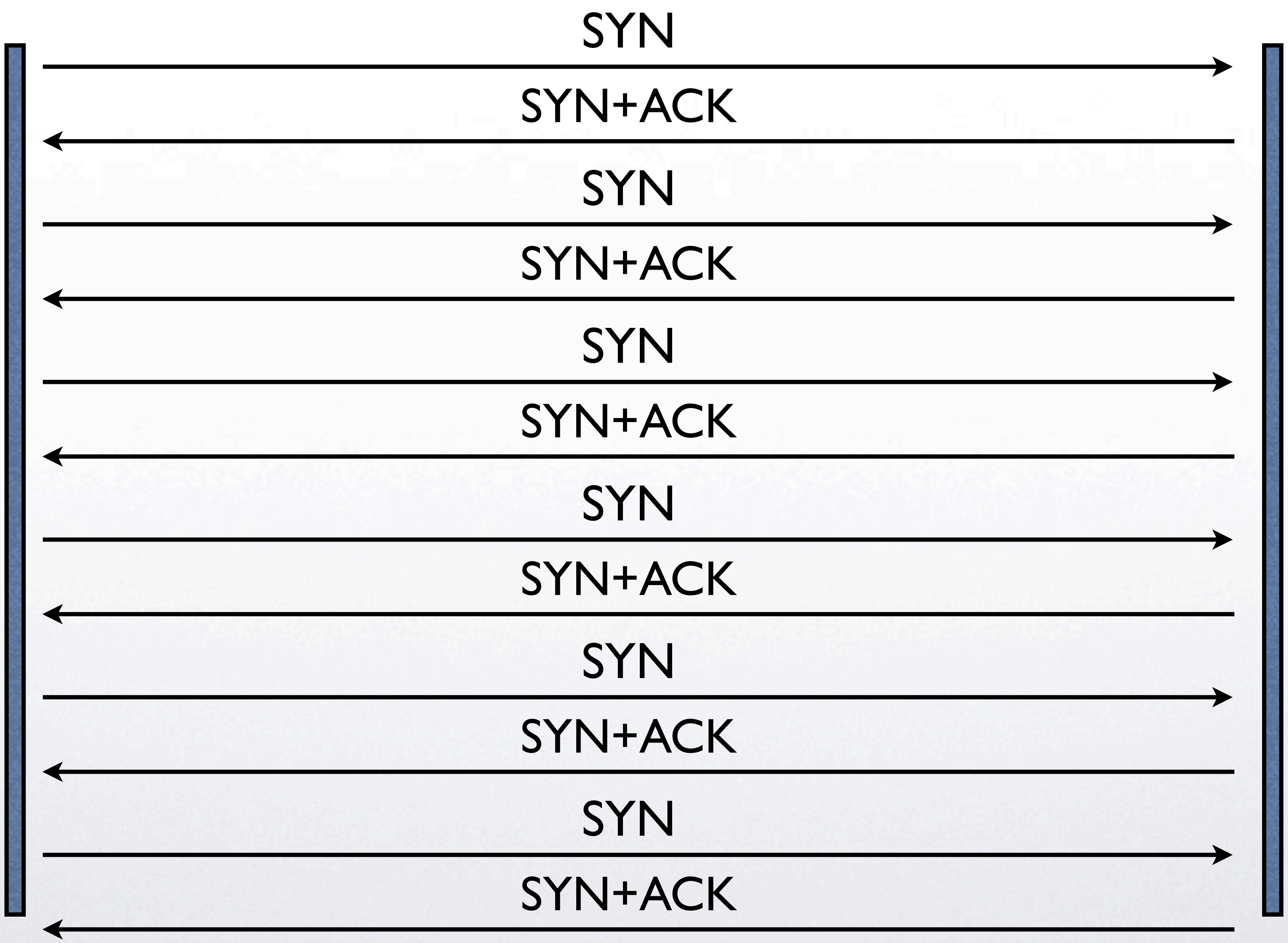
A malicious client



A malicious client, II

Client

IP
Spoofing



Server

SYN Flooding

- Client bombards Server with SYN packets that are never ACK'ed.
- *IP spoofing* can be used to make packets look like they are coming from other places.
- Physical limitation: *bandwidth*.
- If bandwidth on client is substantial compared to server there is serious potential for a *Denial of Service (DoS) Attack*

DoS Attacks

- Deplete / misconfigure / misallocate the resources on a target server host so that it cannot serve its clients.
  - resources:
    - bandwidth.
    - memory.
    - cpu.
    - ...

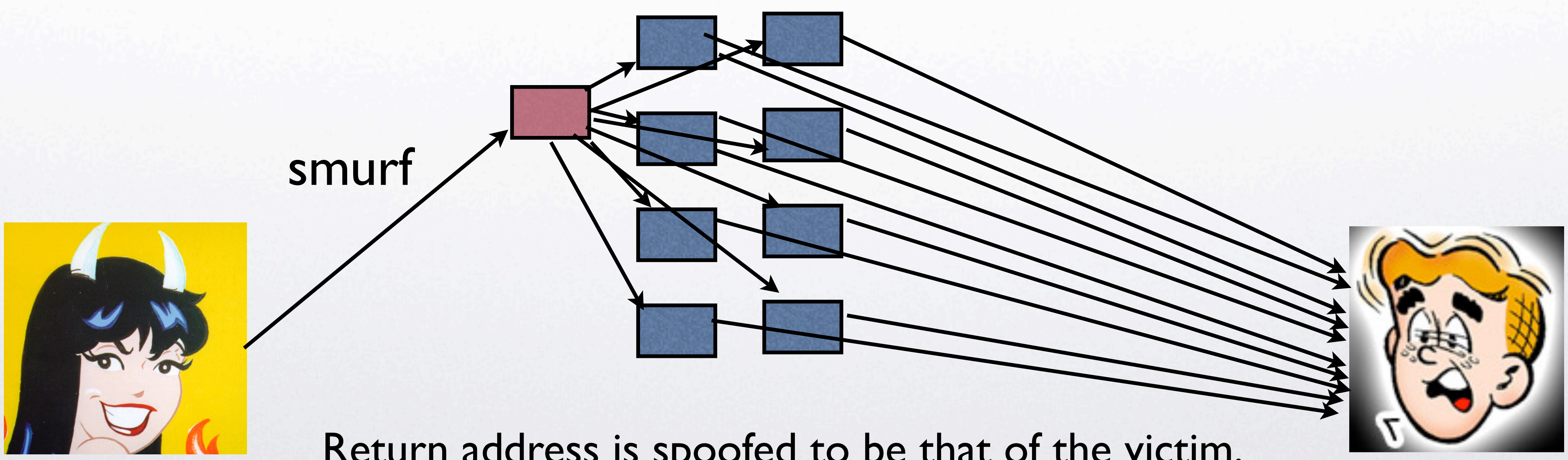
DoS By Flooding

- SYN Flooding - we just saw it.
- Ping Floods: this is a flooding of ICMP Echo Request packets.

```
aggelos@grub:~$ ping 192.168.1.1
PING 192.168.1.1 (192.168.1.1): 56 data bytes
64 bytes from 192.168.1.1: icmp_seq=0 ttl=64 time=0.686 ms
64 bytes from 192.168.1.1: icmp_seq=1 ttl=64 time=0.611 ms
64 bytes from 192.168.1.1: icmp_seq=2 ttl=64 time=0.617 ms
^C
--- 192.168.1.1 ping statistics ---
3 packets transmitted, 3 packets received, 0% packet loss
round-trip min/avg/max/stddev = 0.611/0.638/0.686/0.034 ms
```

Smurf Attack

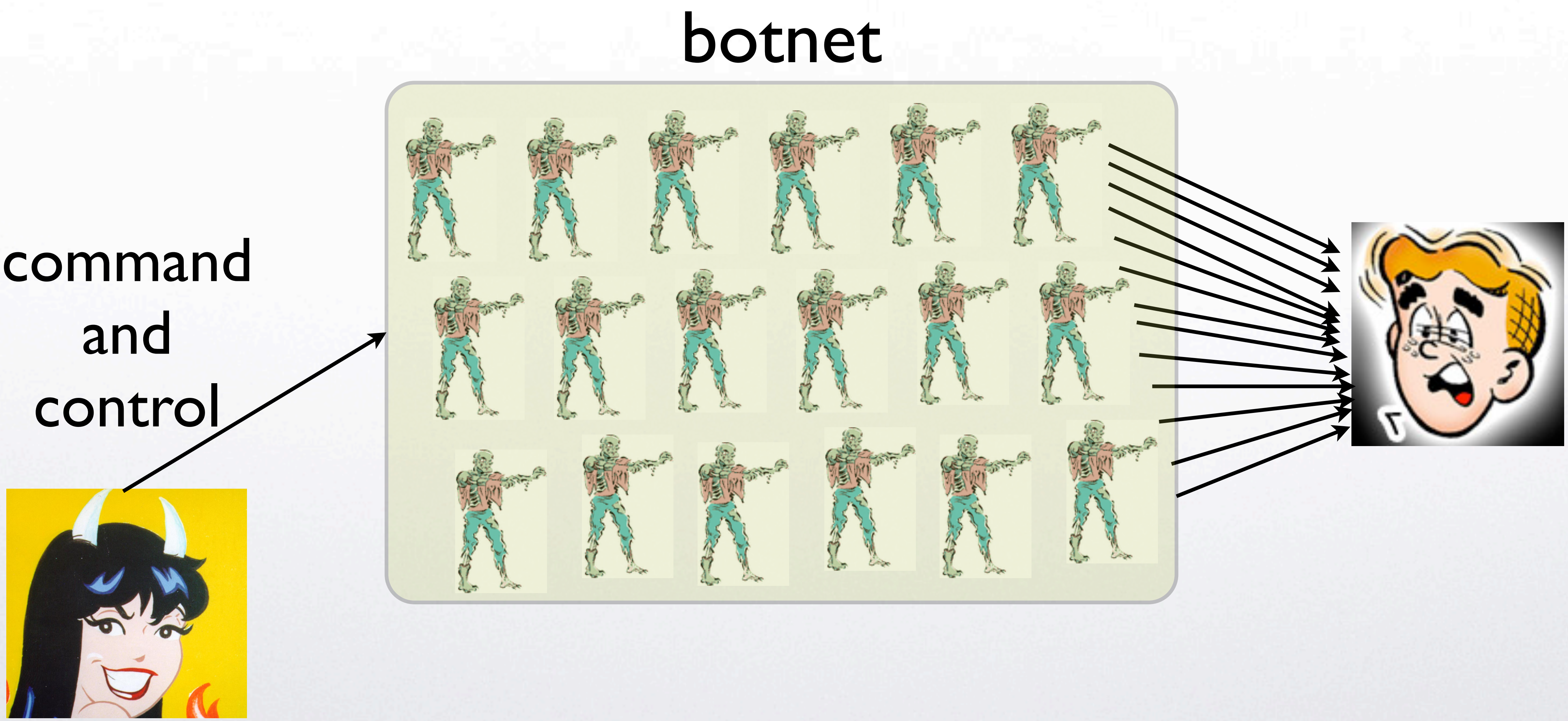
- An enhanced Ping flood attack that utilizes IP Broadcast:
  - it is possible to specify the destination IP address as a broadcast to all hosts in a subnetwork.



Return address is spoofed to be that of the victim.

Distributed DoS

- The real deal!



Botnet Creation

- Host compromised by virus, worm, trojan.
- Runs rootkit remote administration tool.
- When commanded it launches DoS attack against victim.
- Attack seems to be coming from everywhere!

Current Botnet Uses

- The convenience of separation between 'hacking a computer' and 'committing a crime.'
- Sending Spam.
- Click-Fraud.
- Identity Theft.
- Stealing files: e.g., game Diablo-2 items were stolen and sold on EBay...

Botnet Design Challenges

- Choosing botnet topology. (centralized, hierarchical, P2P).
- Command&Control flow (pull, push, ongoing).
- Command&Control protocols (old-use: IRC, IM, HTTP, specialized protocols).

Rallying Mechanism

- Botnet assembly:
  - hardcoded IP addresses.
  - list of DNS names.
  - Distributed DNS services implemented by the botnet itself.
  - DNS Fast Flux

Design challenges

- Bot should try to avoid being detected due its C&C communication or O/S *footprint*.
- Botnet may experience *Bot loss*.
- Botnet may experience *Bot stealing*.
- Botnet should detect fake bots that try to infiltrate.

Other DoS attacks

- The Fork Bomb: any program that constantly forks by creating child processes that do the same.
- Any time a process is called the O/S allocates memory for the process's requirements and enters the process specifics in a data structure.

Example:

```
int main(void)
{
  while(1) {
    fork();
  }
  return 0;
}
```

this little program may crash your PC

You can write fork-bombs for all major languages.

bash example `:(){ :|:& };:`

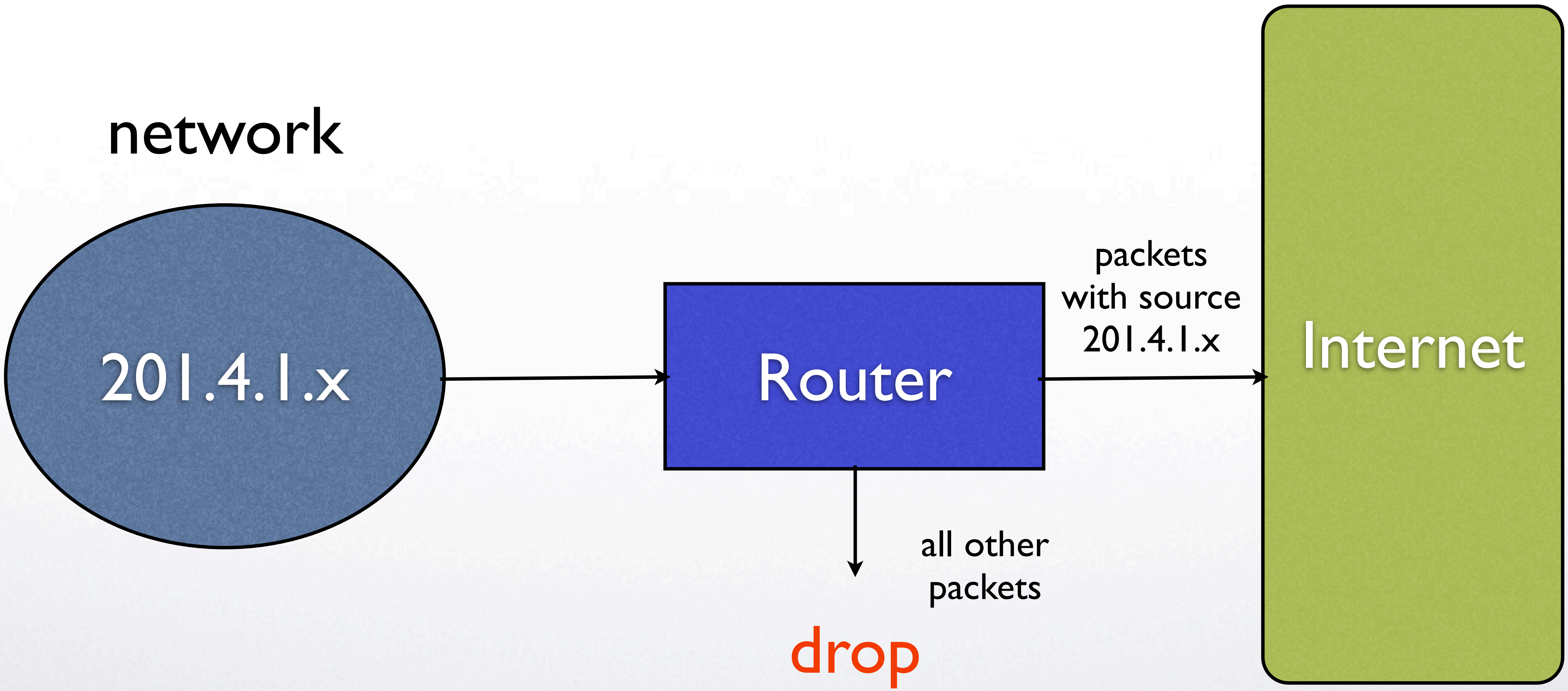
Defending against DOS

- Attacks like Smurf, Fork Bombs etc. result from the ability of an entity to allocate more resources than necessary in normal operation.
- Restricting such capability will thwart the related attack, e.g.,
  - restrict the use of IP broadcasting.
  - restrict the number of processes a user may create.

IP Throttling

- Any IP address that issues a big upstream will have its incoming packets being dropped at a certain rate.
  - Advantage: can be configured in your router. No need to modify client/server.
  - Disadvantage: what are the right settings?

Ingress Filtering



http://www.faqs.org/rfcs/rfc2827.html

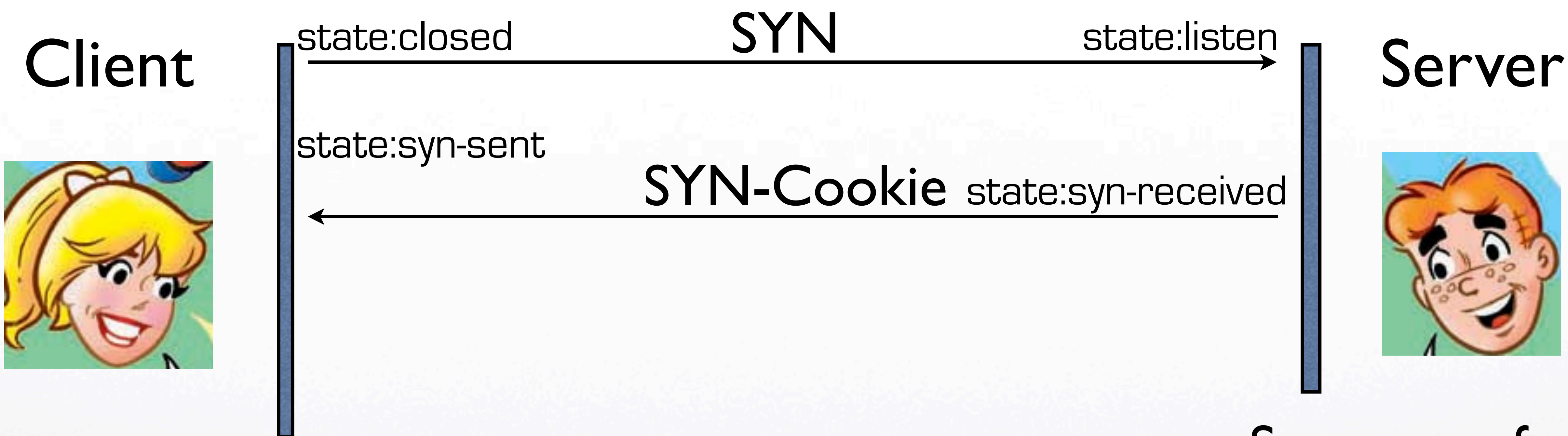
Defending against DDoS

- Harder since an attack may look as quite legitimate traffic: (e.g., HTTP)
- Challenge: distinguish between good traffic and DDoS traffic.
- We will examine some general approaches for DDoS defense next.

Simple Measures

- Try to use various parameters to make a system understand it is being attacked:
  - counting number of half-open connections (syn-rcvd).
  - counting number of connections refused.
- Once some red-flags are observed the system may shorten the time that it keeps half-open connections active.

SYN Cookies



A SYN-Cookie contains info derived by the source-address port, destination address and port etc.

Server can forget everything about the client till the ACK message that will include the SYN-Cookie

outsourcing the server state to the client

Proofs of Work

- Client is requested to solve a puzzle in order to establish a connection.
  - Pros: works in any client-server system. can be tuned to slow down malicious systems.
  - Cons: needs changes in the basic infrastructure (e.g., changes in both client and server). Will not eliminate bandwidth emaciation.

Example.

From Juels/Brainard (RSA)

Hash function

$$\mathcal{H} : \{0,1\}^* \rightarrow \{0,1\}^k$$

r = secret || time || client request

$$r \downarrow$$

$$x = \mathcal{H}(r)$$

$$\mathcal{H} \longrightarrow x \in \{0,1\}^k \overset{\text{trunc}}{\rightarrow} x' \in \{0,1\}^{k-w}$$

Server to client: sends $x', y = \mathcal{H}(x)$ stores (x, y)

Client needs to respond with $x'' : \mathcal{H}(x'||x'') = y$

$$x'' \in \{0,1\}^w$$

IP Traceback

- A “forensic” technique:
  - try to identify the real path of a packet.
  - Have routers mark packets with their IP address. => problem: not enough space in a packet.

Edge Marking.

- With some low probability q a router marks a packet. Marking is defined as:
  - IF packet unmarked:
    - enter your IP address as the start IP address of the edge. Set distance = 0
  - ELSE: If distance = 0, enter your IP address as the end IP address of the edge. increment the distance.
- Otherwise increase the distance.

Encoding IP addresses

- Use only the 16 bits of the IP identification field used for fragmentation.
- How to pack 64+5 bit information into 16 bits?

$$\mathcal{H}_1, \mathcal{H}_2 : \{0,1\}^{32} \rightarrow \{0,1\}^{11}$$

- Use

first router

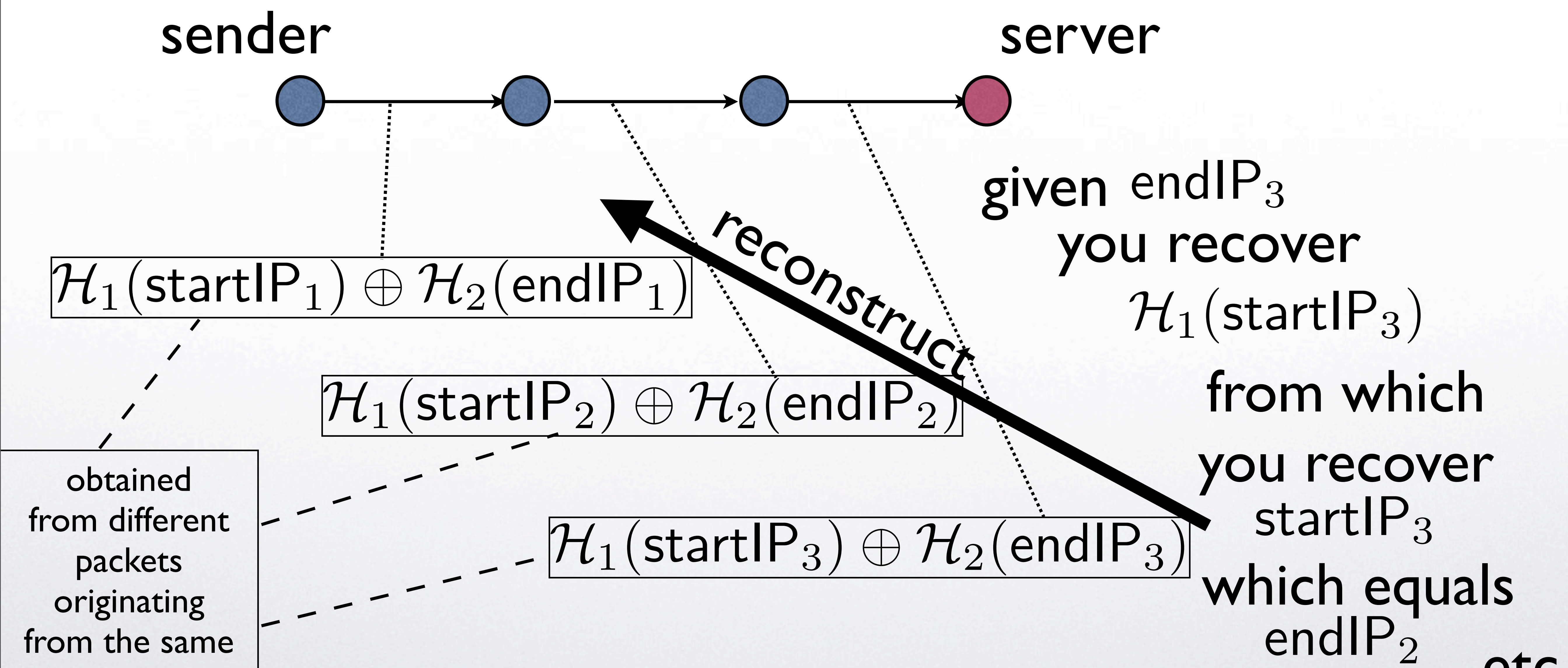
$\mathcal{H}_1(\text{startIP})$

second router

$\mathcal{H}_1(\text{startIP}) \oplus \mathcal{H}_2(\text{endIP})$

birthday paradox says that there will be 50/50 odds of a collision at around sqrt(2^11) which is about 2^6 = 64 hops. This means that we are only able to hash from 32 bit IPs down to about 11 bits before noise overwhelms the hashing

Reconstruct Path



http://www.ece.cmu.edu/~dawnsong/papers/iptrace.ps