2550 Intro to cybersecurity

L26: DDOS and Review

abhi shelat

Today's plan

Crimeware

Malware, Spyware, Adware, Ransomware, Trojans, RATs, Bots…

Botnets

The backbone of the underground

Structure of the Underground

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Common Methods of Compromise

1. Malware email attachments
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3. Exploiting browser bugs
   - Known as drive-by exploits or drive-by downloads
   - Get the victim to visit a webpage containing exploits

Malware Attachments

Send spam containing malicious attachments

Use social engineering to trick users into downloading & opening the attachments
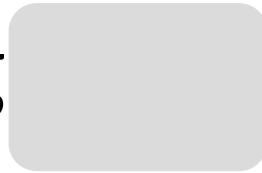
Malware Attachments

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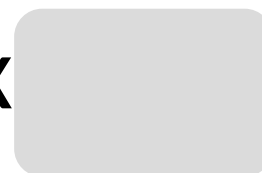Use social engineering to trick users into downloading & opening the attachments

Misleading Icons and File Extensions

funny.jpg.exe

contract.docx.exe

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Misleading Icons and File Extensions   **Scripting Languages**

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VisualBasic script macros

Flash and JavaScript

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Misleading Icons and File Extensions

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Scripting Languages

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Exploitable Vulnerabilities

Any complex file format can potentially trigger exploitable bugs and contain shellcode

From Crimeware to Botnets

Infected machines are a fundamentally valuable resource

- Unique IP addresses for spamming
- Bandwidth for DDoS
- CPU cycles for bitcoin mining
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Early malware monetized these resources directly

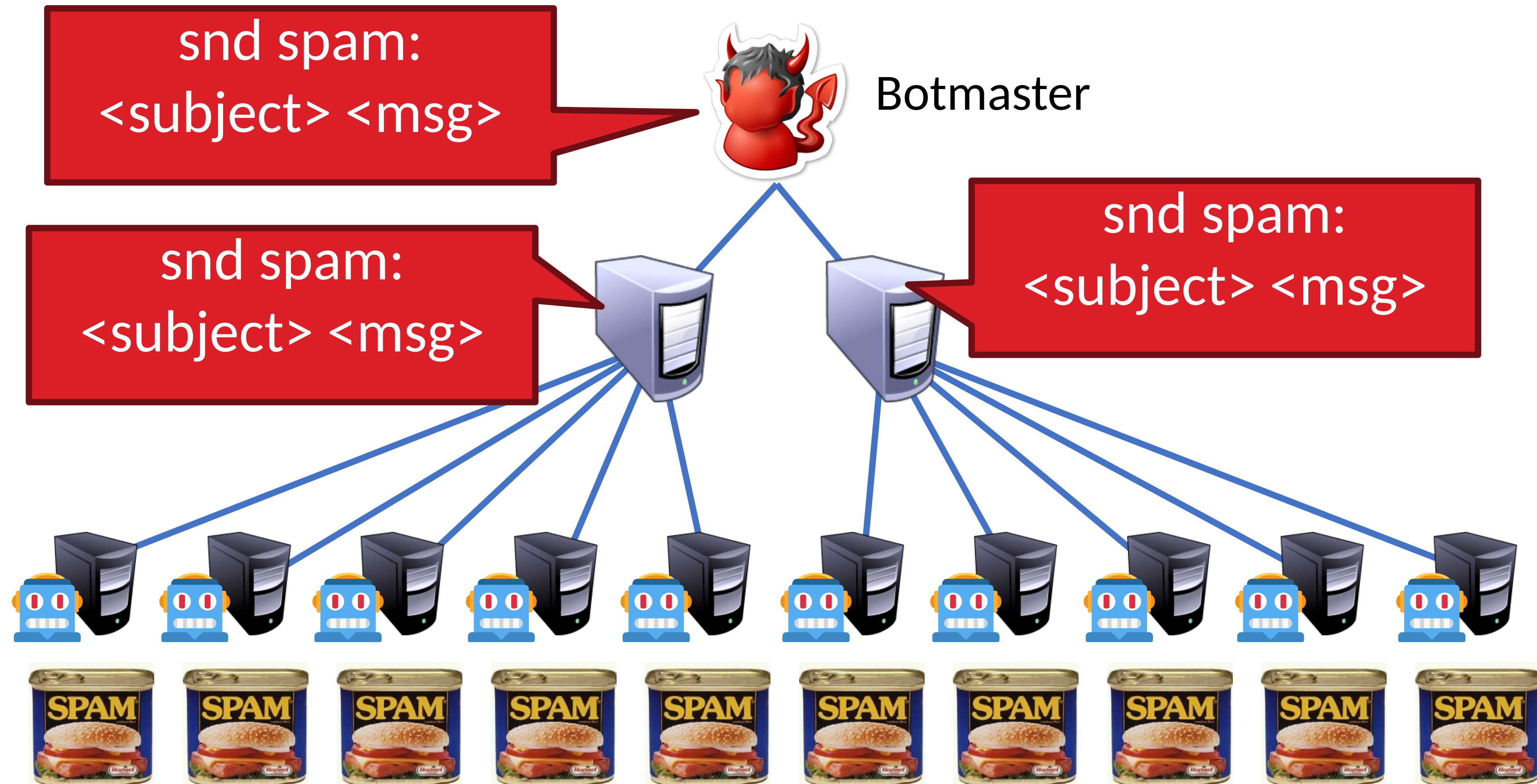- Infection and monetization were tightly coupled

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Early malware monetized these resources directly
- Infection and monetization were tightly coupled

Botnets allow criminals to rent access to infected hosts
- Infrastructure as a service, i.e. the cloud for criminals
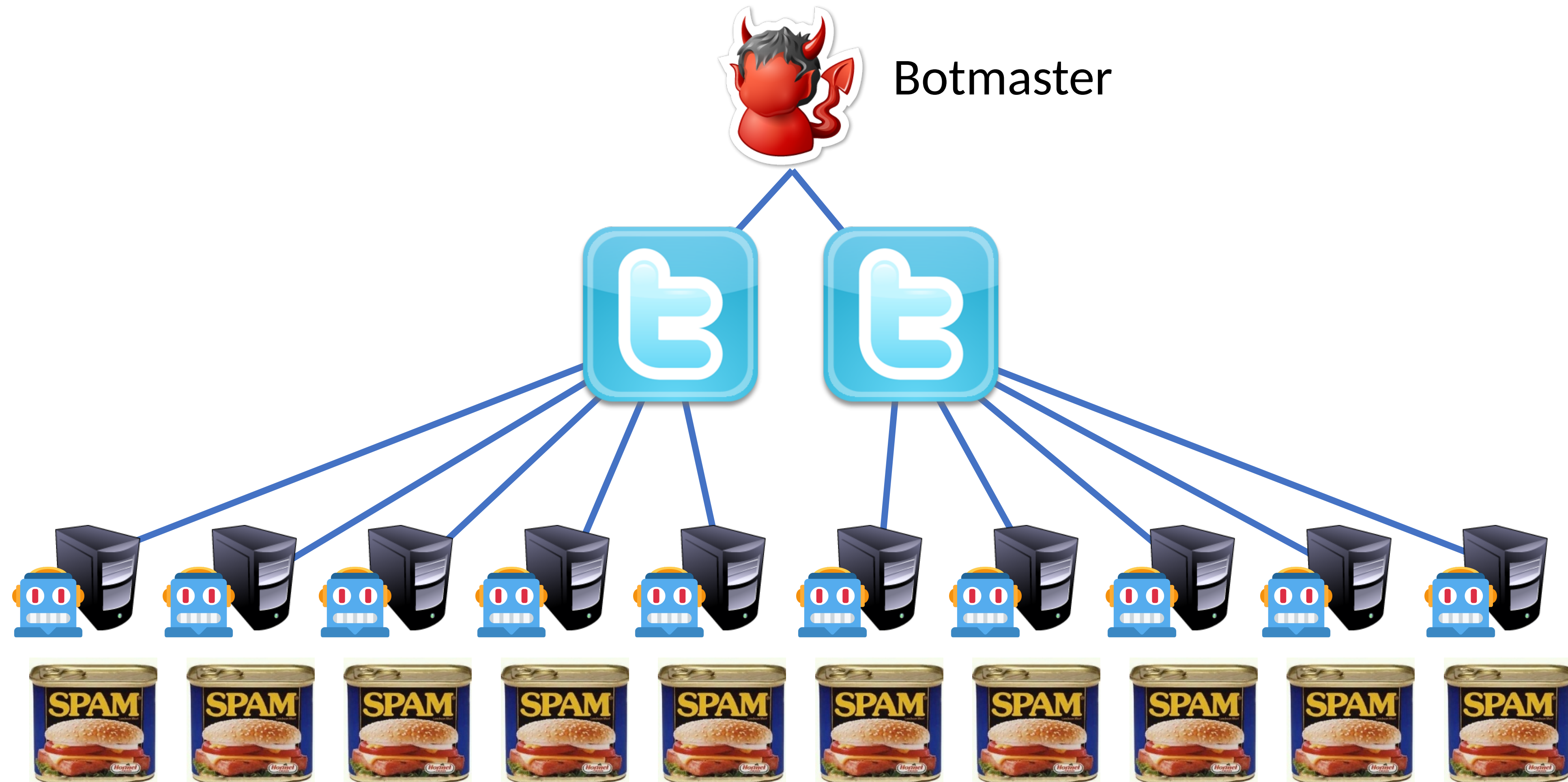- Command and Control (C&C) infrastructure for controlling bots
- Enables huge-scale criminal campaigns

Old-School C&C: IRC Channels
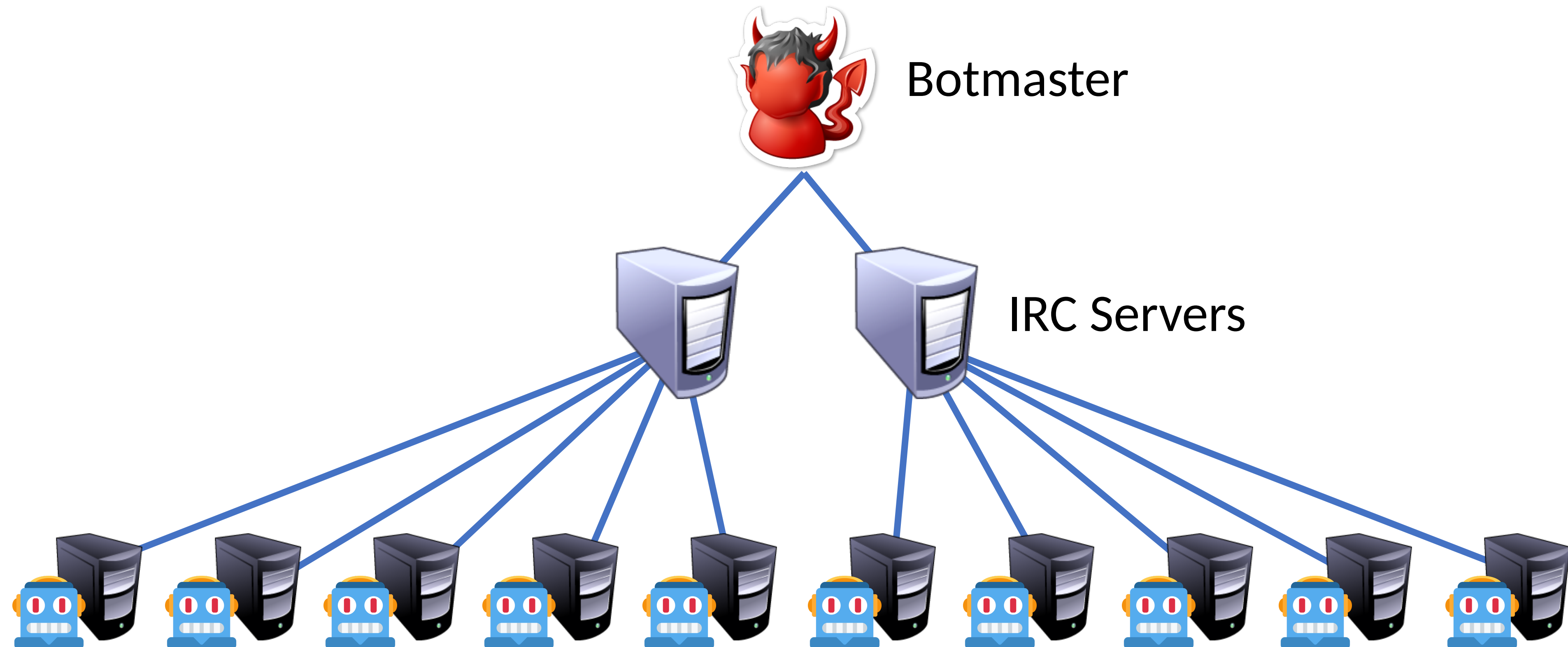
Old-School C&C: IRC Channels

snd spam:
<subject> <msg>

Botmaster

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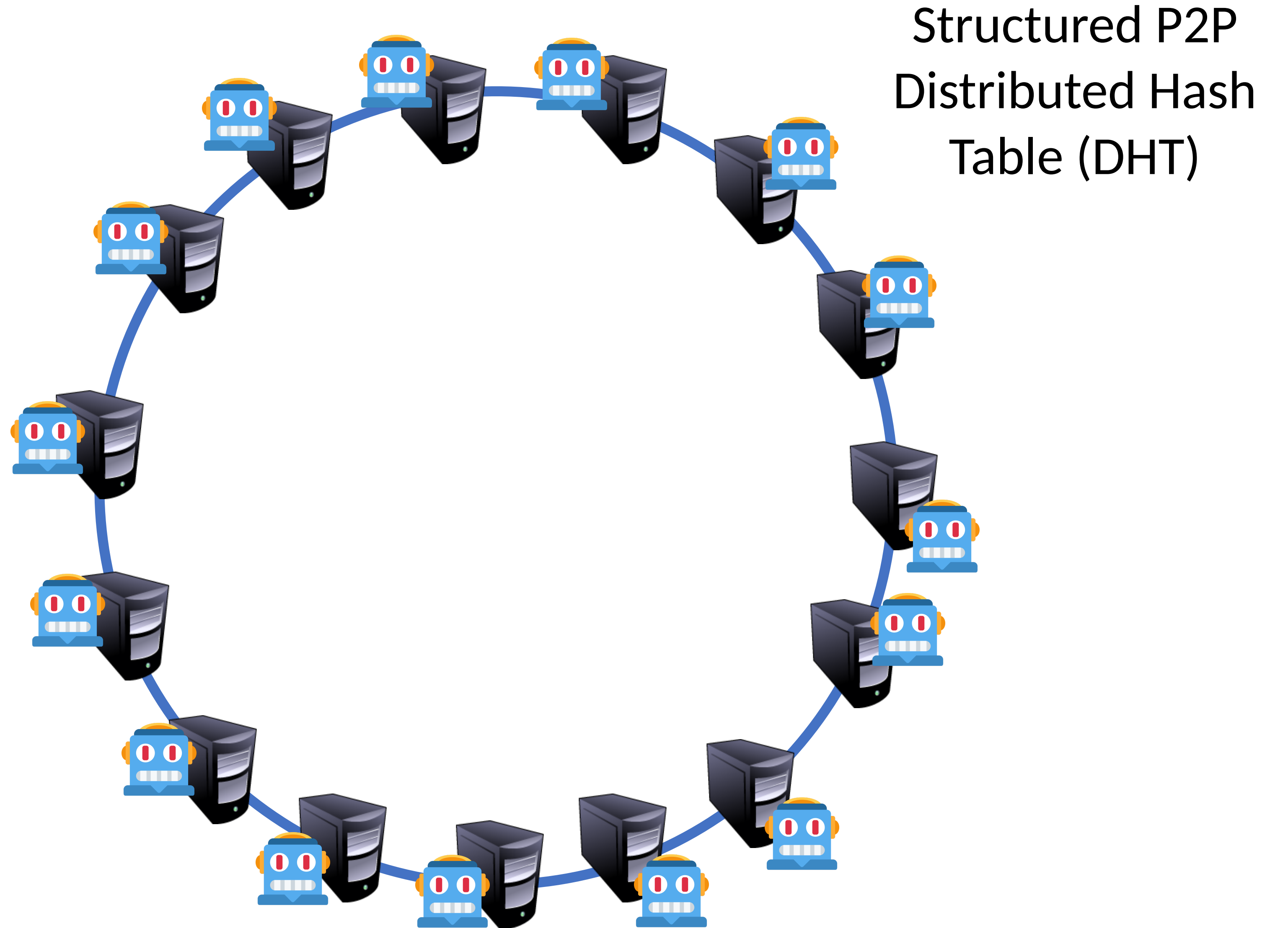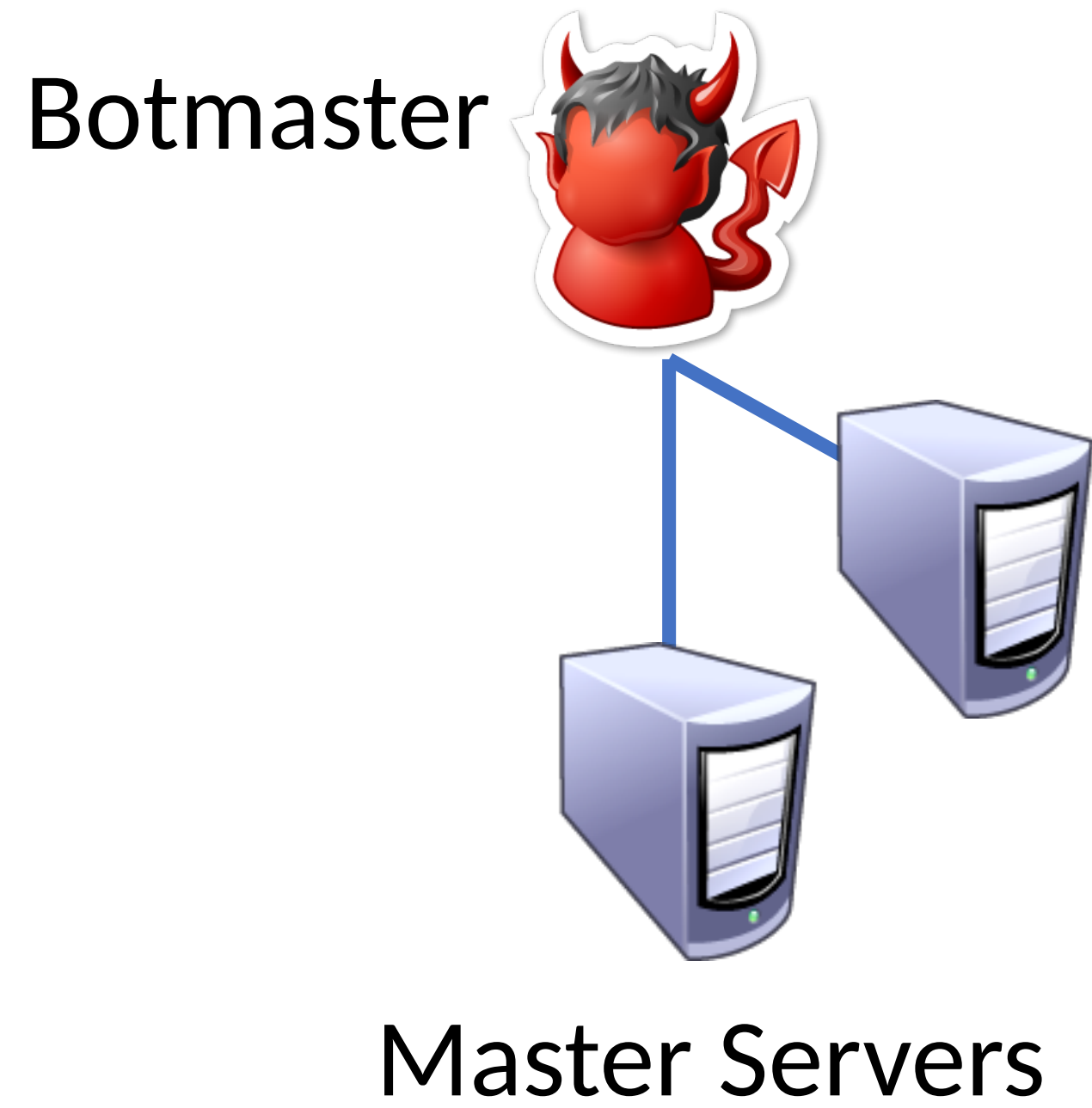<subject> <msg>

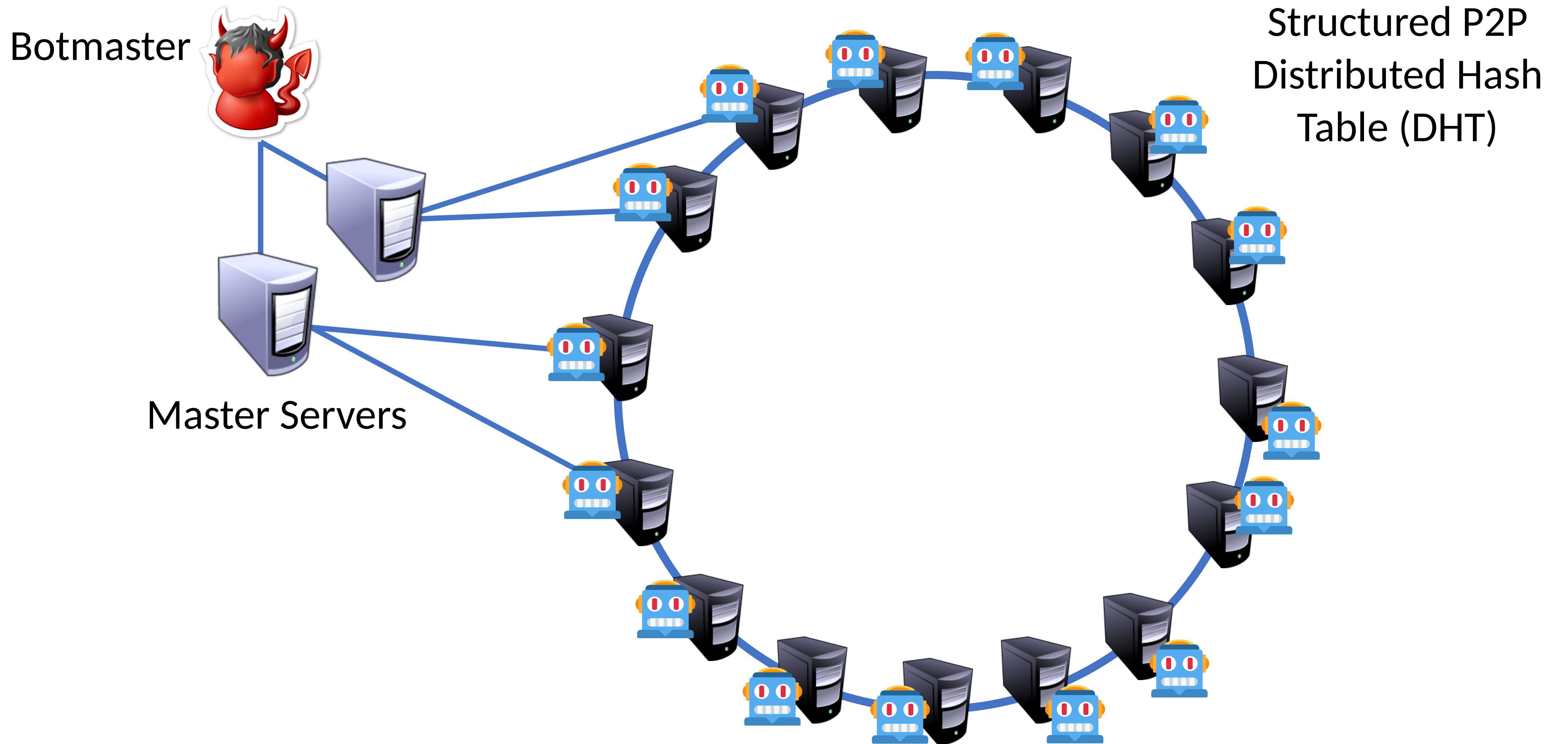# Old-School C&C: IRC Channels

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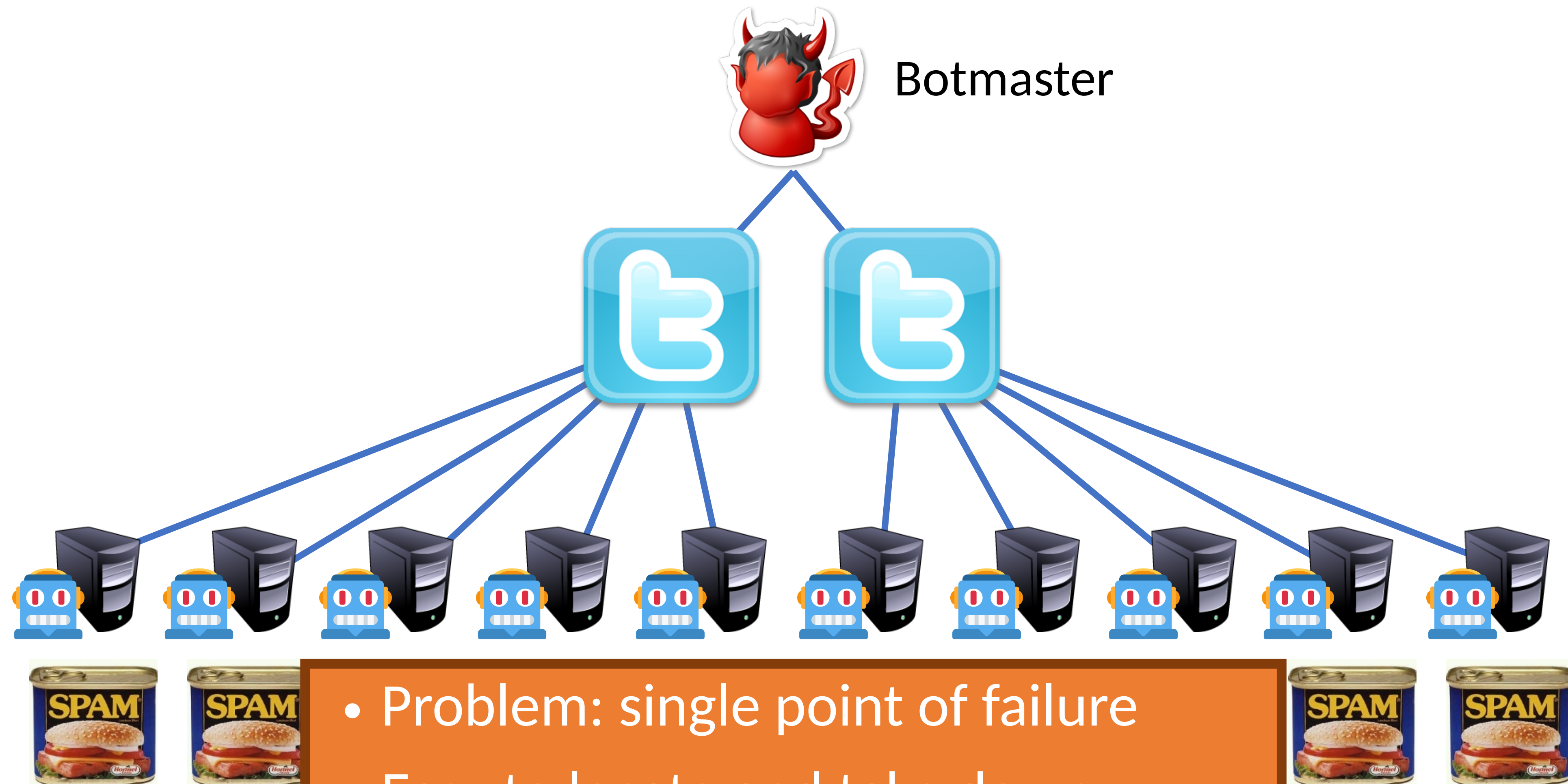
- Problem: single point of failure
- Easy to locate and take down

P2P Botnets

Botmaster

Master Servers

Structured P2P
Distributed Hash
Table (DHT)

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Get commands from the DHT

Fast Flux DNS

Botmaster

HTTP Servers

12.34.56.78   6.4.2.0   31.64.7.22   245.9.1.43   98.102.8.1

www.my-botnet.com

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But: ISPs can blacklist the rendezvous domain
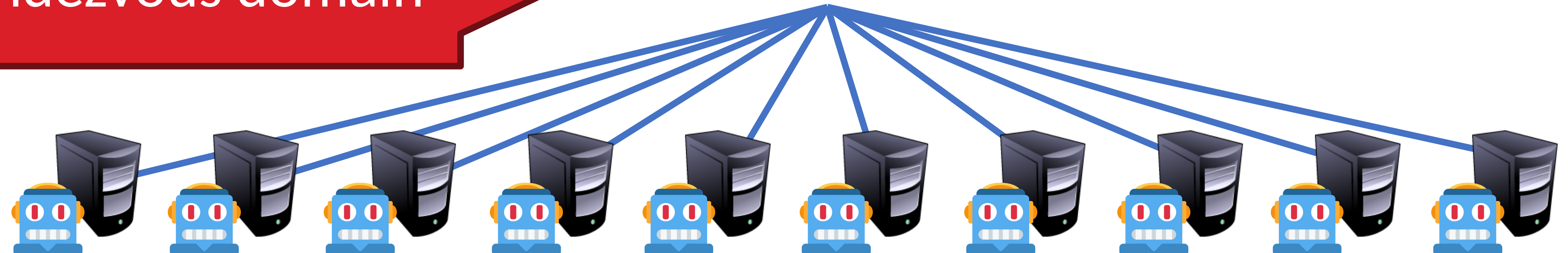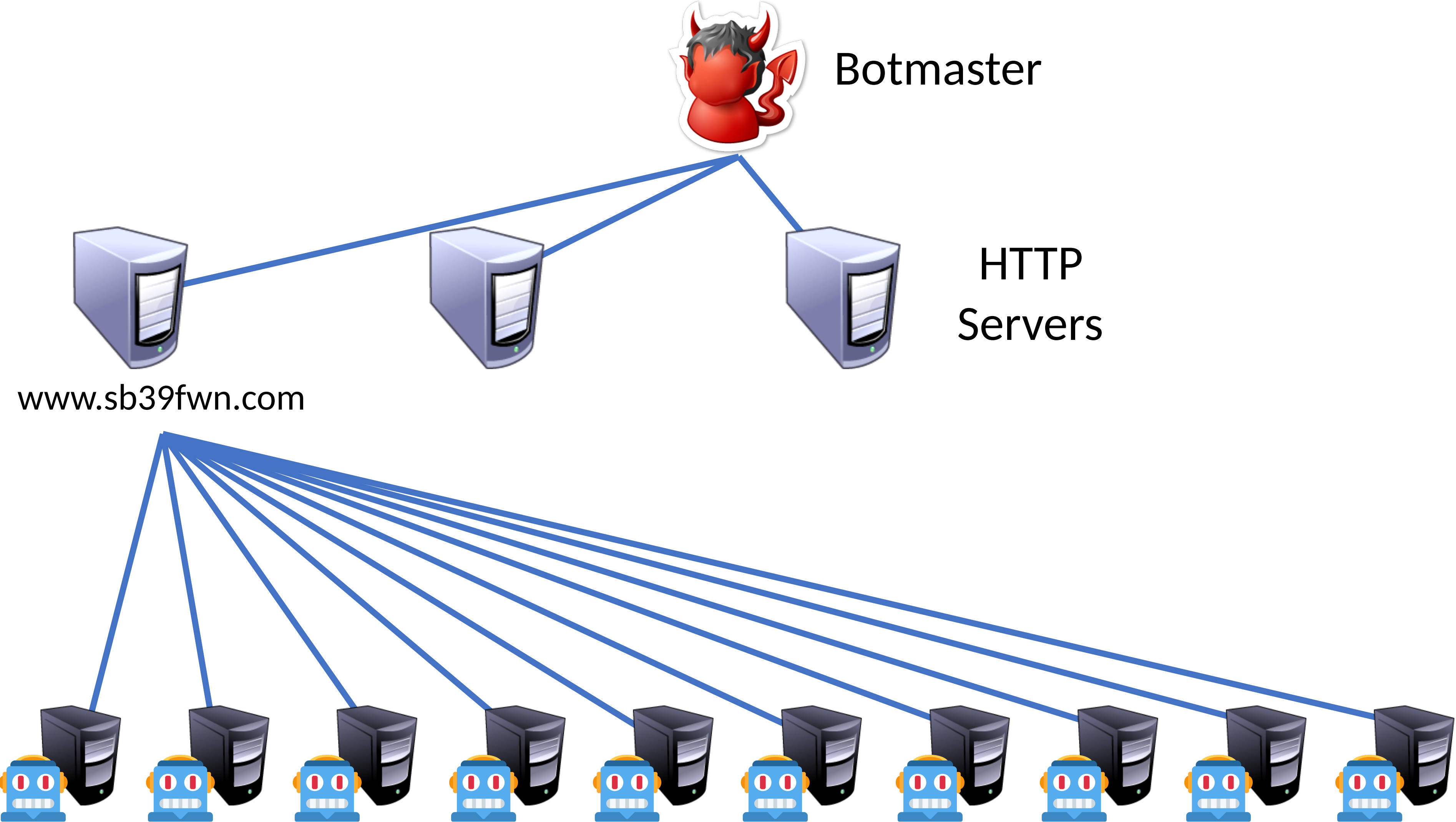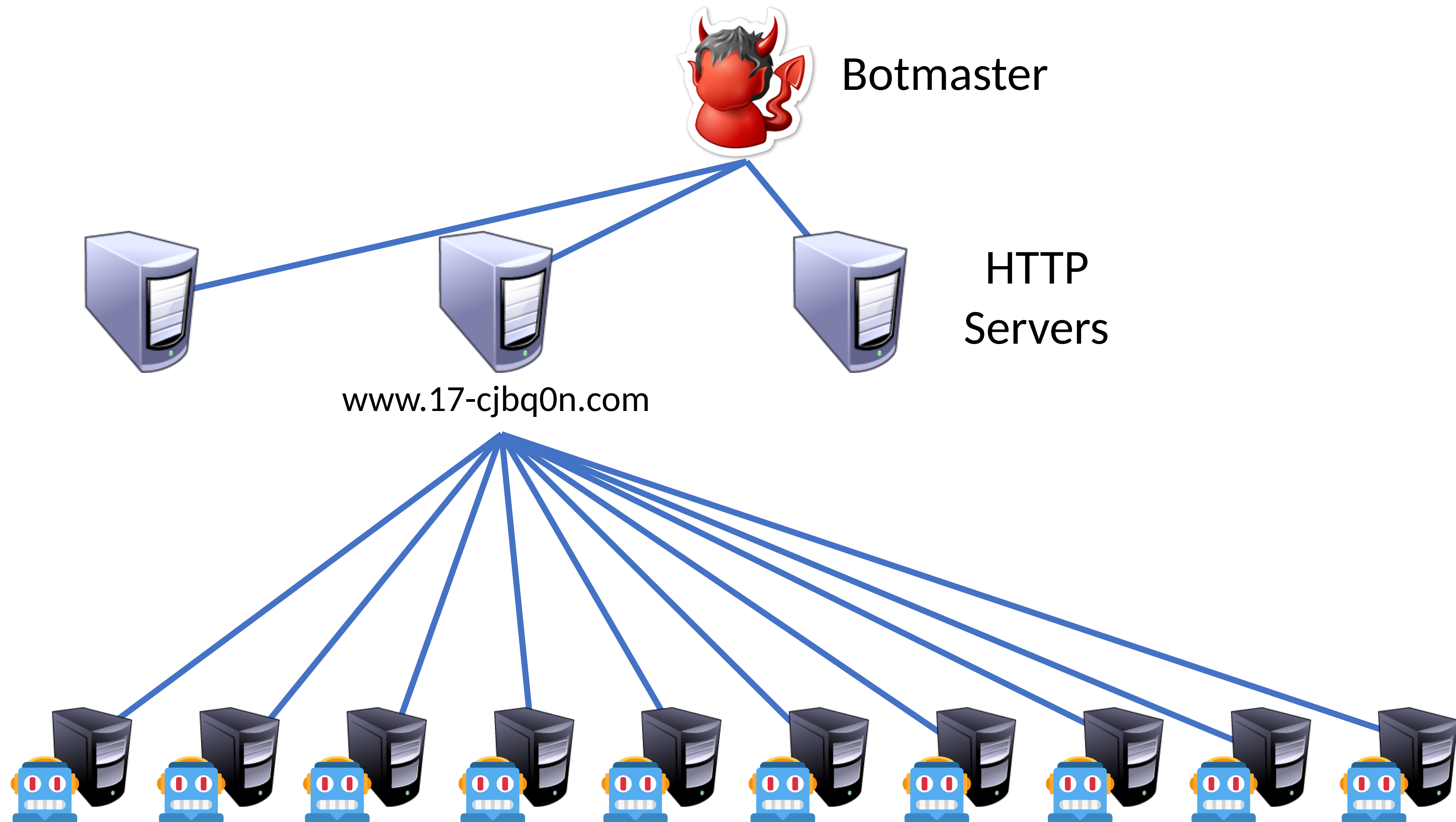
Domain Name Generation (DGA)

Botmaster

HTTP
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www.sb39fwn.com

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HTTP Servers

www.17-cjbq0n.com

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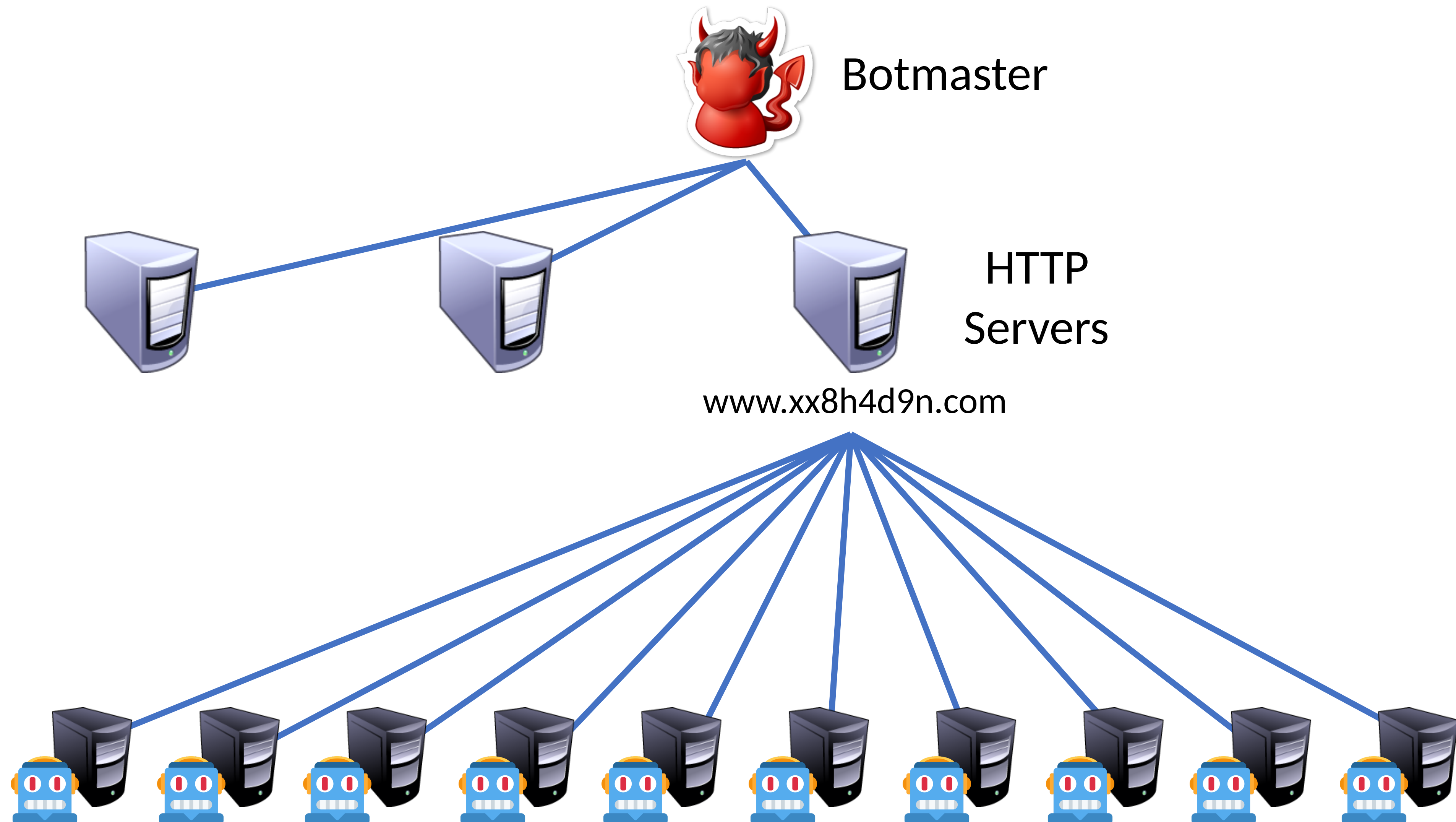
www.xx8h4d9n.com

Domain Name Generation (DGA)

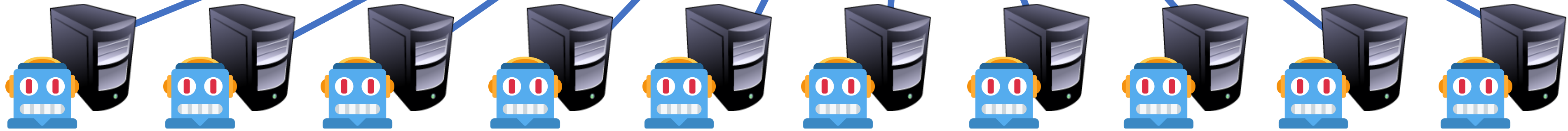...But the Botmaster only needs to register a few

Botmaster

Bots generate many possible domains each day

HTTP Servers

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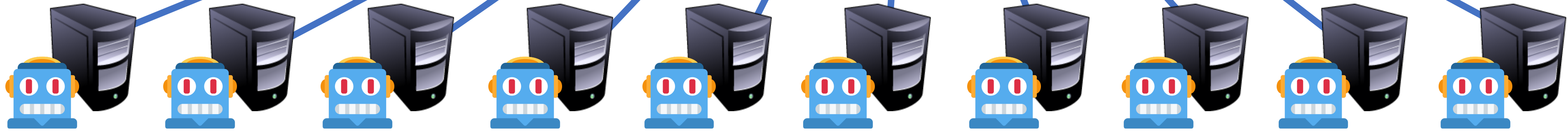...But the Botmaster only needs to register a few

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Can be combined with fast flux

"Your Botnet is My Botnet"

Takeover of the Torpig botnet

- Random domain generation + fast flux
- Team reverse engineered domain generation algorithm
- Registered 30 days of domains before the botmaster!
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- Researchers gathered all this data

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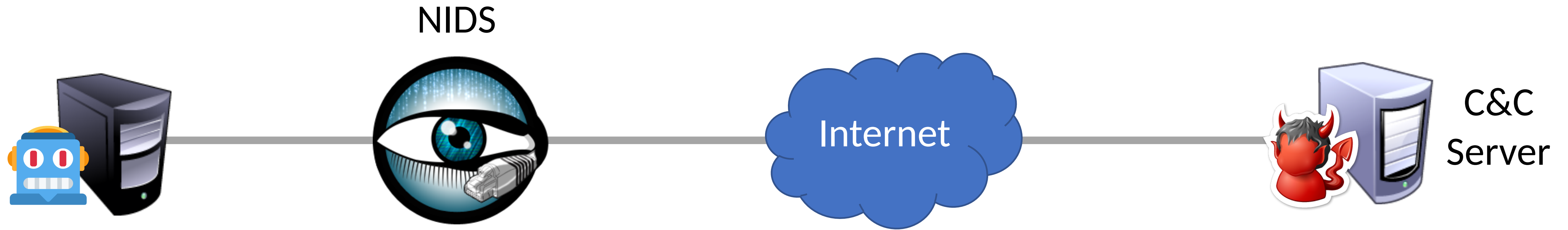Other novel point: accurate estimation of botnet size

Stopping Botnets

Individual perspective: ridding your network of bots

- Anti-virus and anti-malware
- Intrusion and anomaly detection to identify infections, block traffic
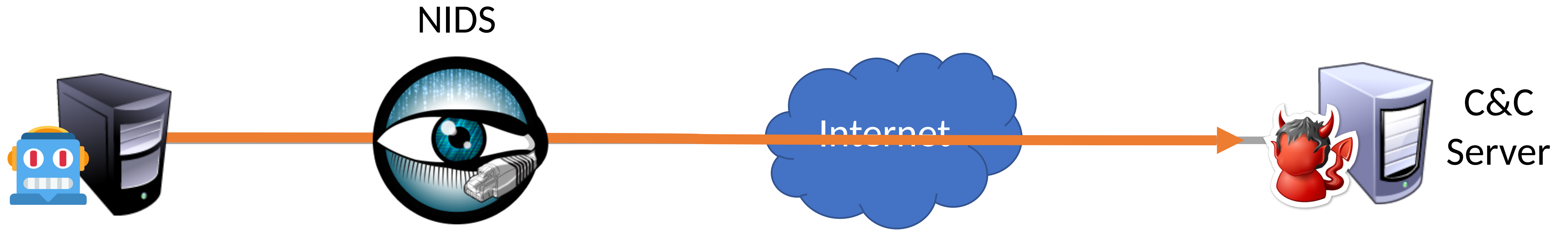
Global perspective: takedowns and arrests

- Create a sinkhole (fake C&C server)
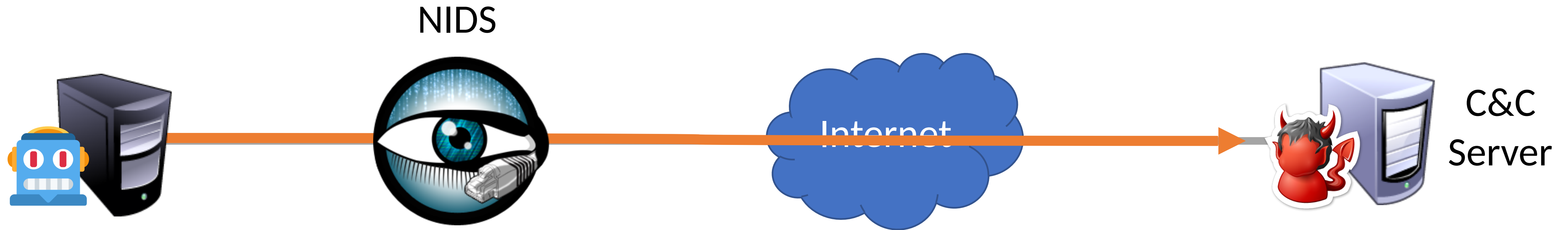- Track down and arrest the perpetrators

Classic Detection of Bots

NIDS

Internet

C&C
Server

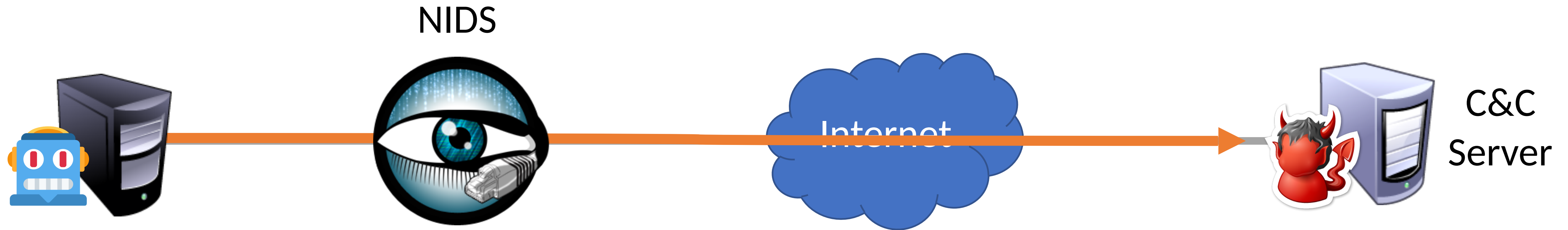# Classic Detection of Bots
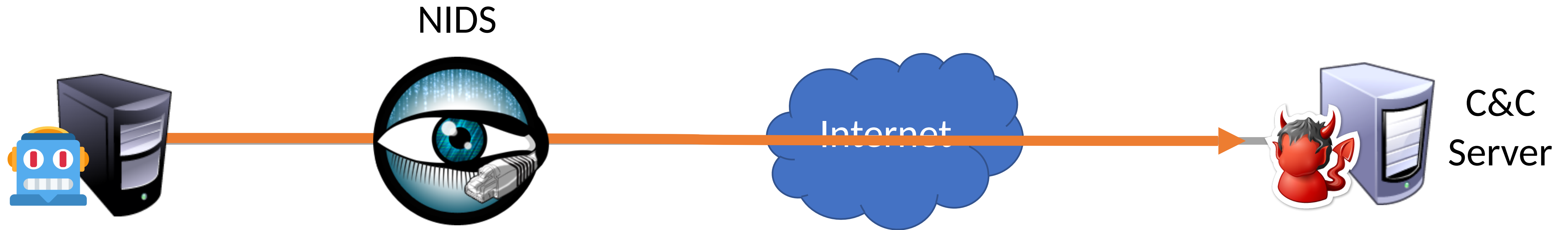
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- Unusual ports or protocols
  - IRC port 6667

- Message signatures
  - "cmd=spam; target=..."

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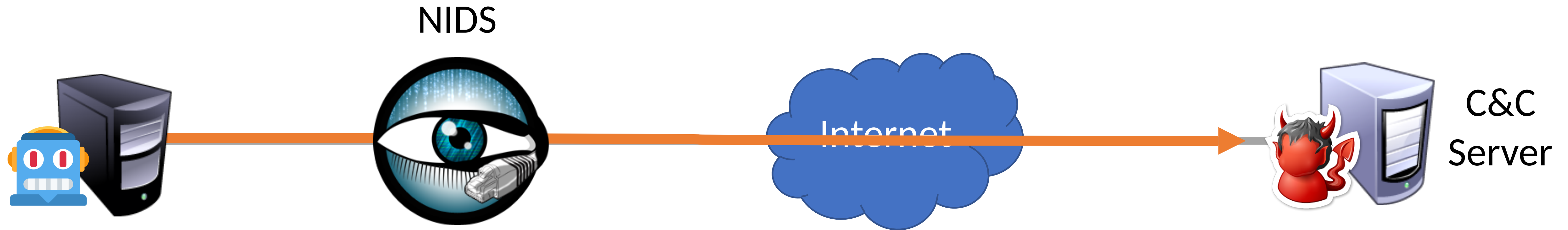
C&C Server

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- Defeated by using standard ports
  - HTTP(S) ports 80/443

Classic Detection of Bots

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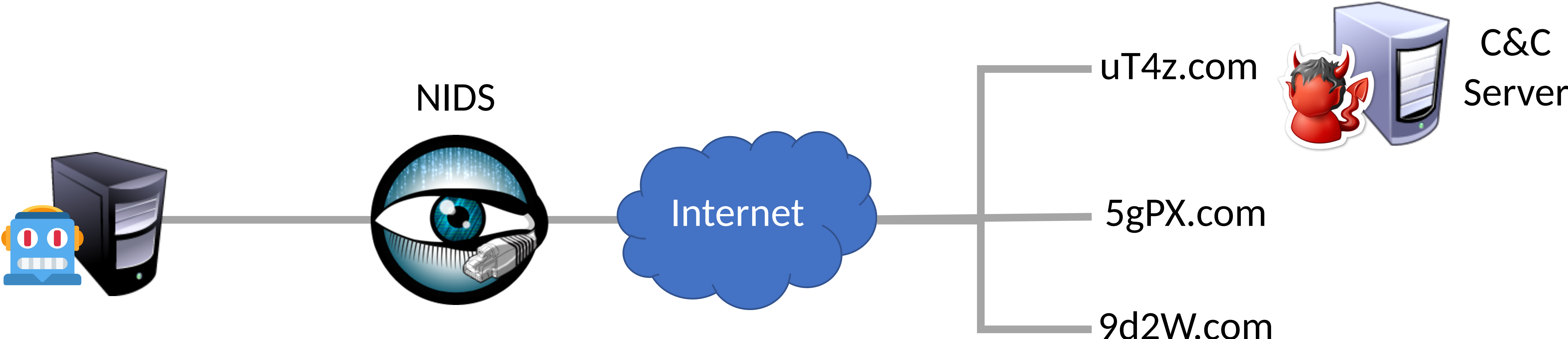❌ **Message signatures**
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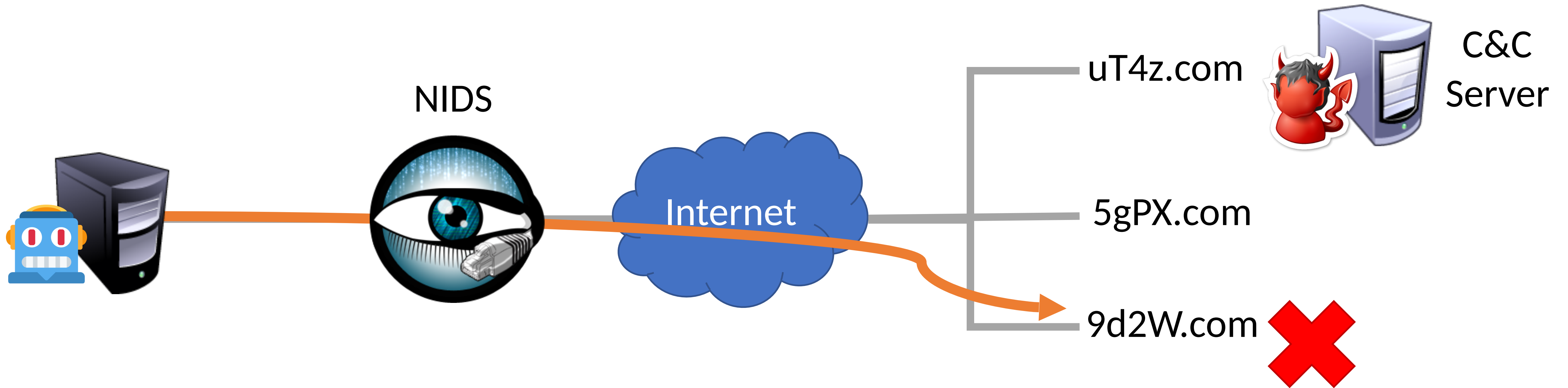
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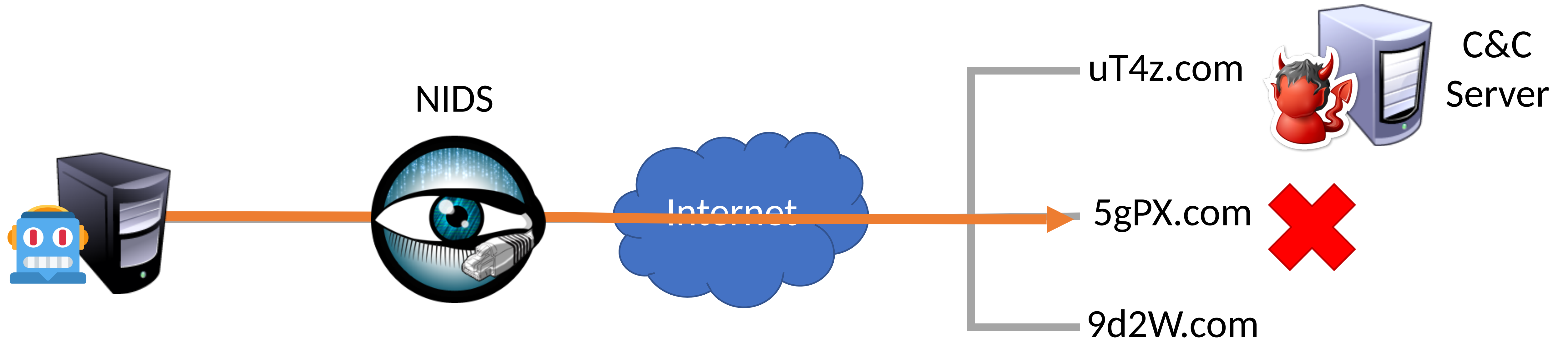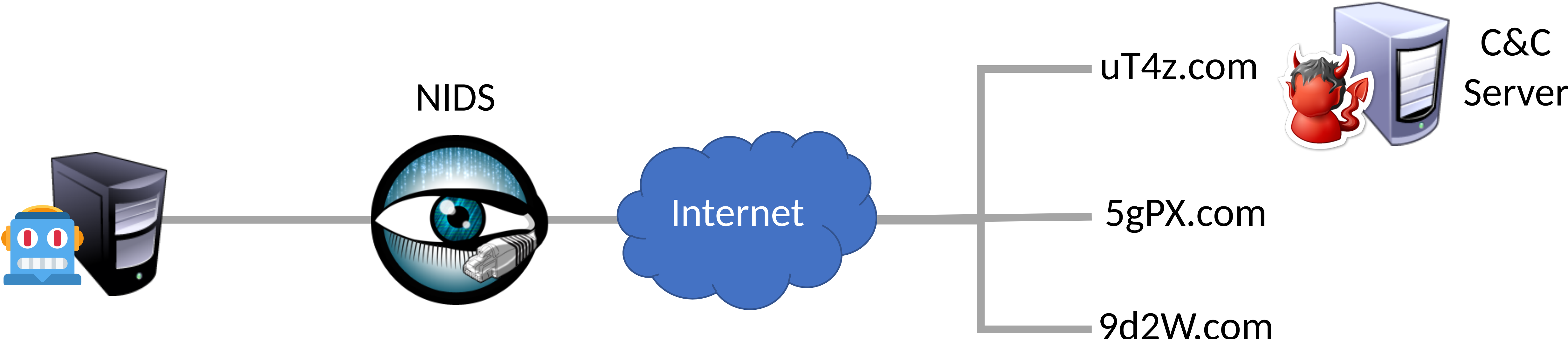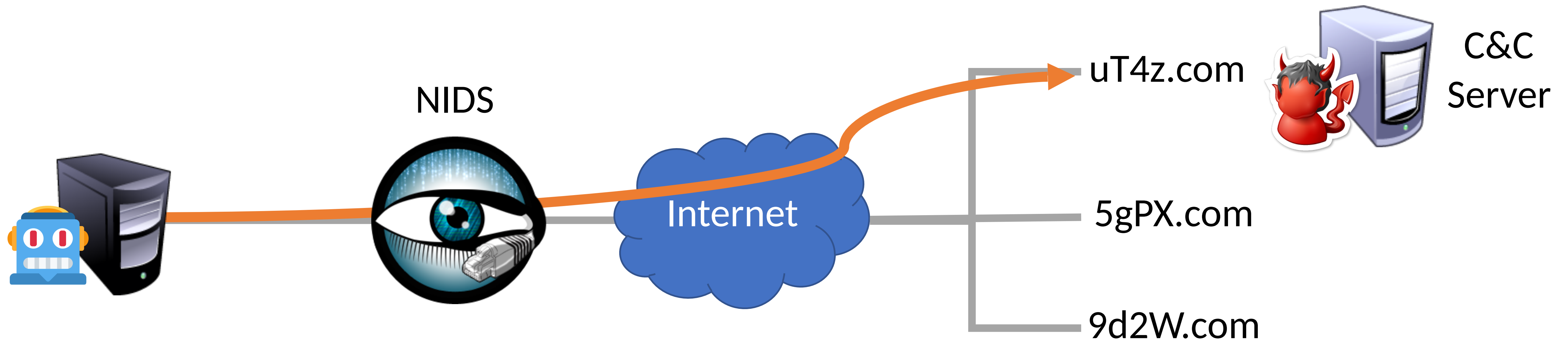 - HTTP(S) ports 80/443
- Defeated by encryption

Detection of DGA and Fast Flux

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NIDS

Internet

uT4z.com

5gPX.com

9d2W.com

C&C Server

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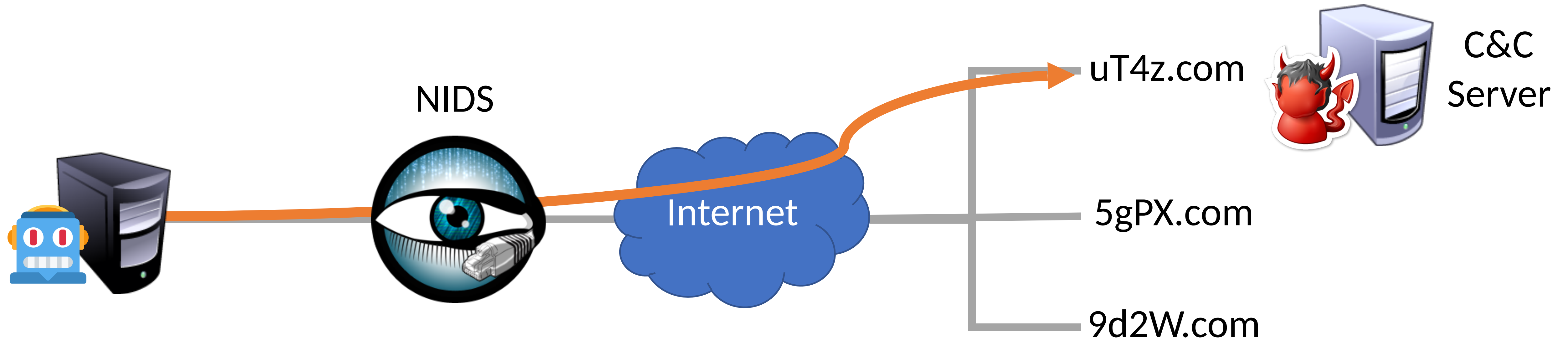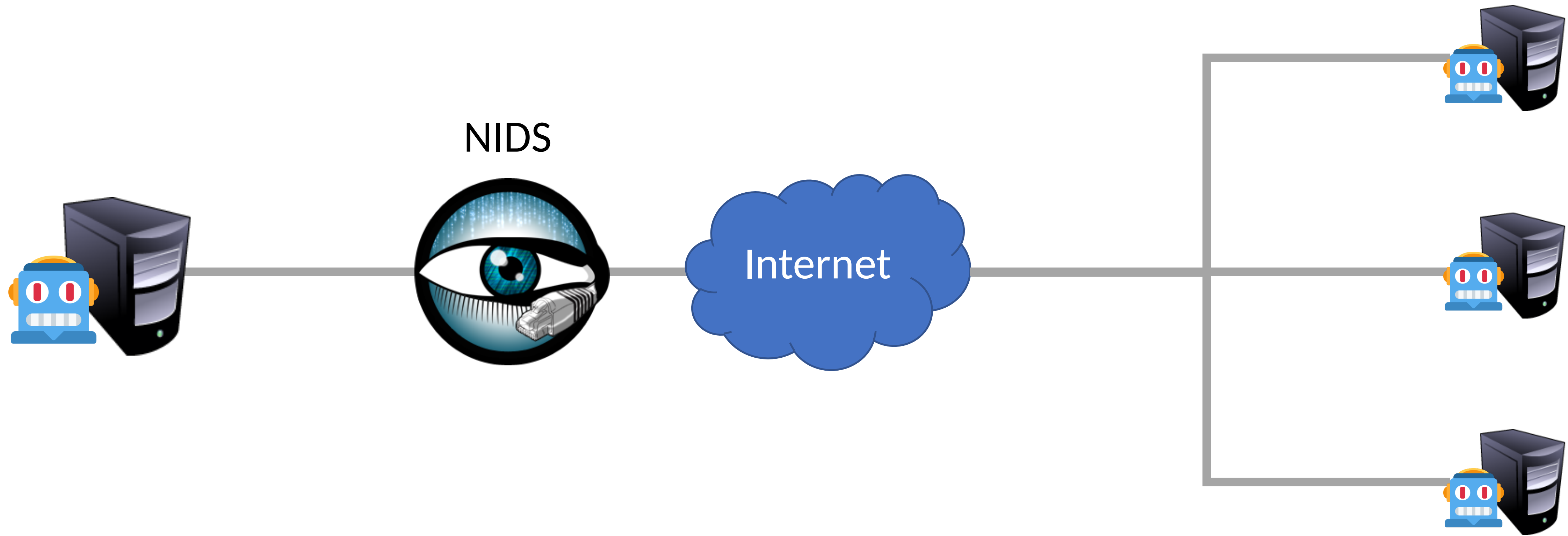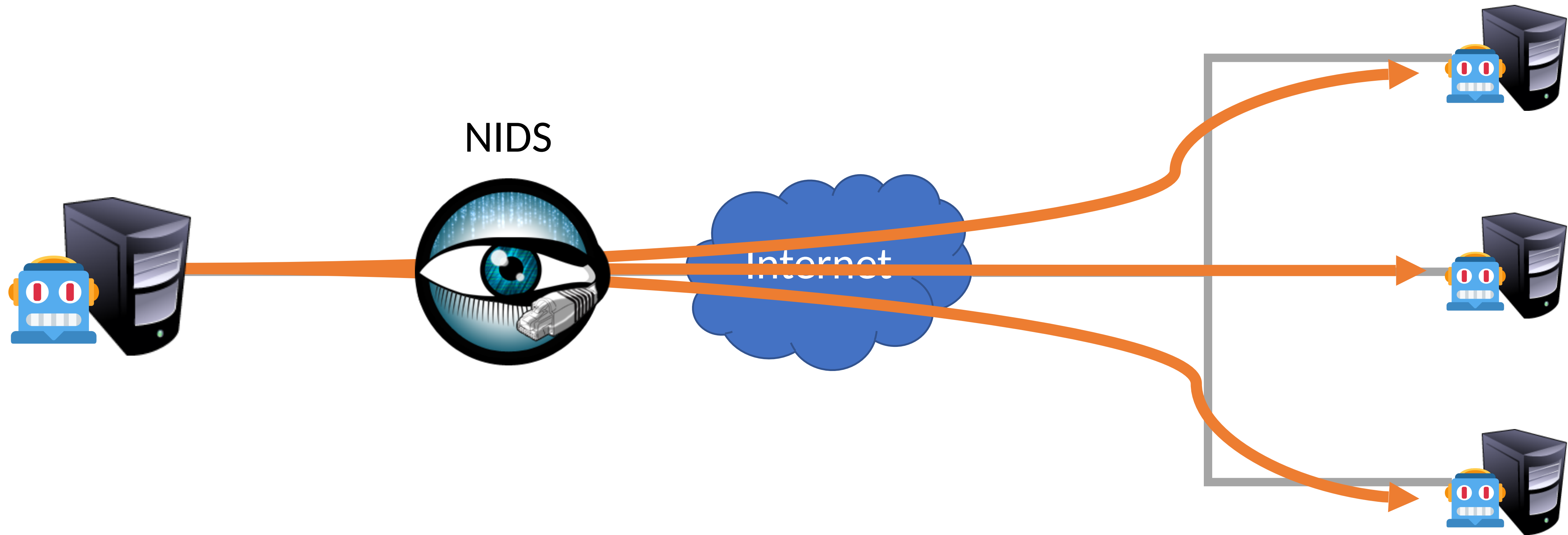
- For DGA: many failed DNS lookups
- For fast flux: multiple DNS lookups for one name, response has short TTL
  - 10 seconds – 10 minutes
  - Most DNS names have TTL of hours or days

Detection of P2P

NIDS

Internet

Detection of P2P

- Many connections to seemingly random hosts
  - Bursty traffic patterns
  - Unexpected geographic patterns (connections to hosts in other countries)

Infamous Takedowns

Botnet Name	Timeframe	Estimated Size	Taken Down by…
DNS Changer	2006-2011	4M	FBI, Trend Micro
Rustock	2006-2011	150K-2.4M	FBI, Microsoft, Fireeye, Univ. of Washington
Grum	2008-2012	560K-840K	Fireeye, Spamhaus
Conficker	2008-2009	4M-13M	FBI, Microsoft, Symantec, ICANN
Citadel	2011-2013		FBI, Microsoft
Gameover Zeus/Cryptolocker	2012-2014		DoJ, FBI, Europol, Dell, Microsoft, Level3, McAfee, Symantec, Sophos, Trend Micro, Carnegie Mellon, Georgia Tech, etc.
SIMDA	2011-2015	770K	INTERPOL, Trend Micro, Microsoft, Kaspersky Lab
DRIDEX	2014-2015		FBI, Trend Micro
Avalanche	2009-2016	500K	FBI, Symantec, Fraunhofer

Kelihos

Resilient, P2P botnet

- Successor to Waledac, which was originally distributed via Conficker
- Five variants, spanning 2009-2017
- Roughly 100K-200K infections at any given time
- Spam, credential theft, Bitcoin mining and wallet theft
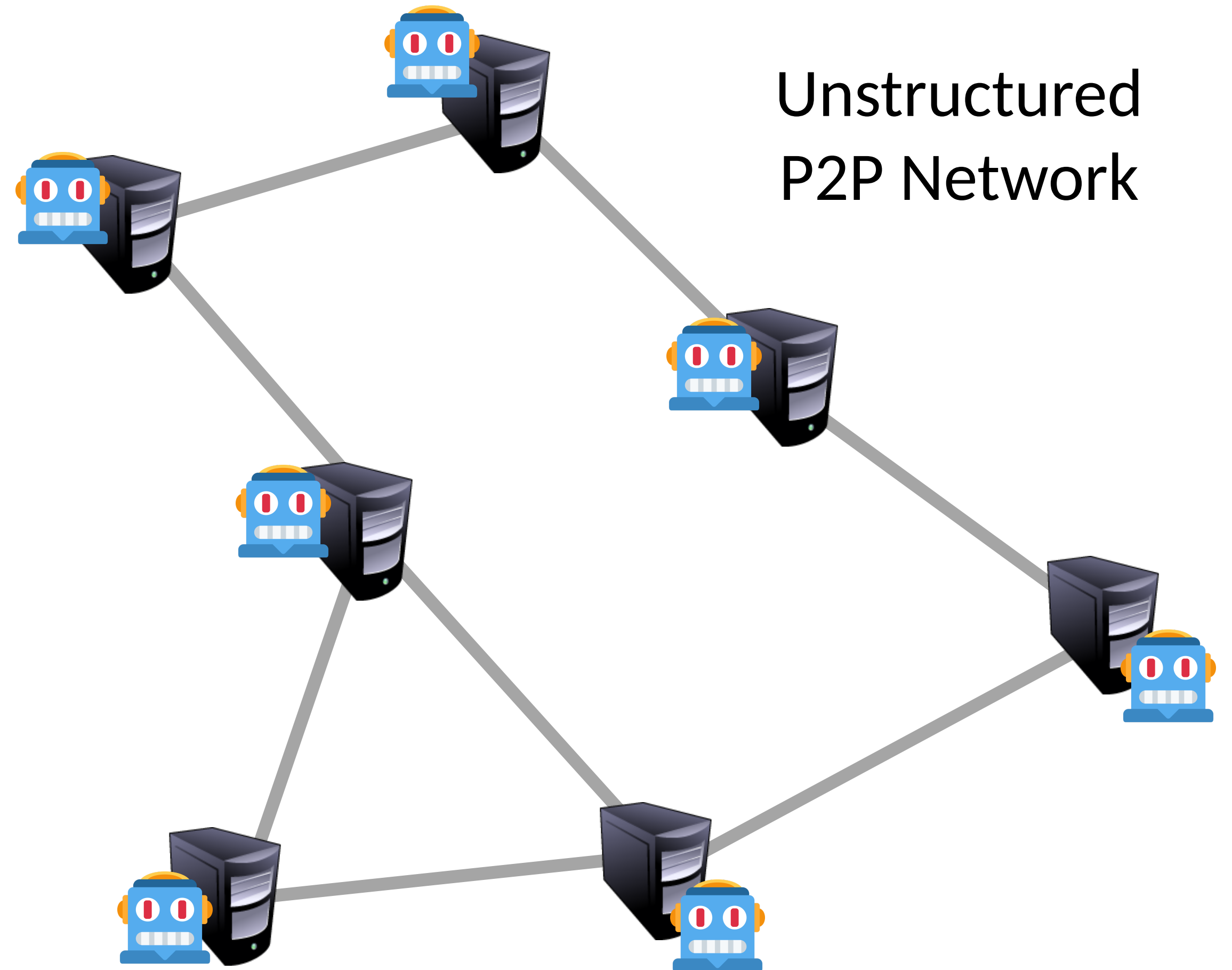
Taken down five times

- Four times: authors produced a new version, built a new botnot
- Fifth time: author arrested (2018)

Botmaster

Master
Server

Unstructured
P2P Network

Botmaster

Master Server

Unstructured P2P Network

Botmaster

Master Server

Unstructured P2P Network

Botmaster

Master
Server

Unstructured
P2P Network

List of Known,
"Good" Peers

Botmaster

Master
Server

Unstructured
P2P Network

Botmaster

Master
Server

Unstructured
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Botmaster

Master
Server

Unstructured
P2P Network

Botmaster

Master
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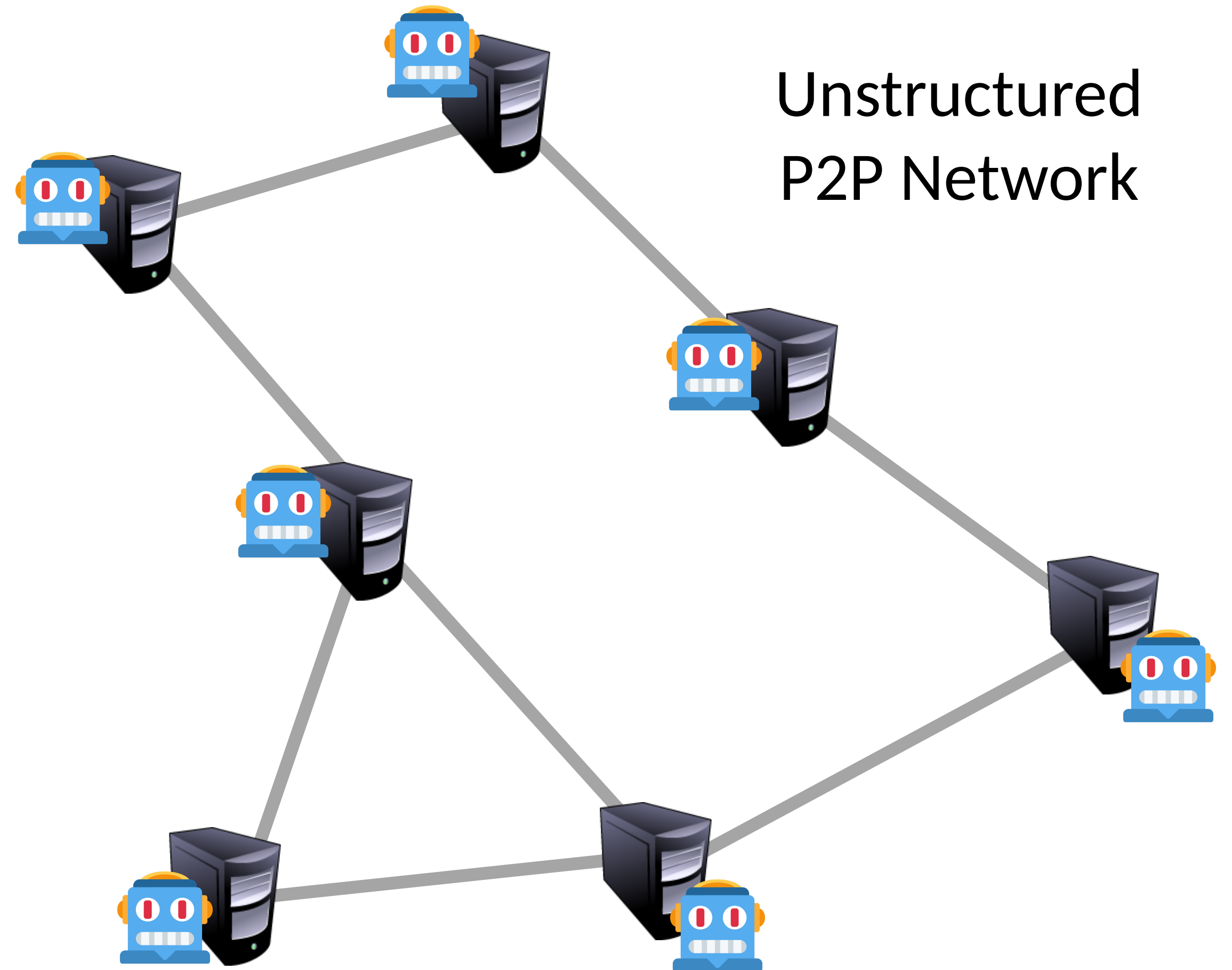Unstructured
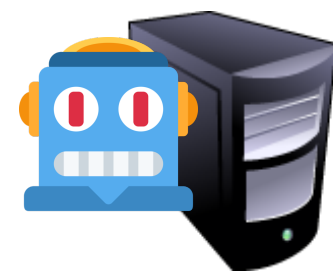P2P Network
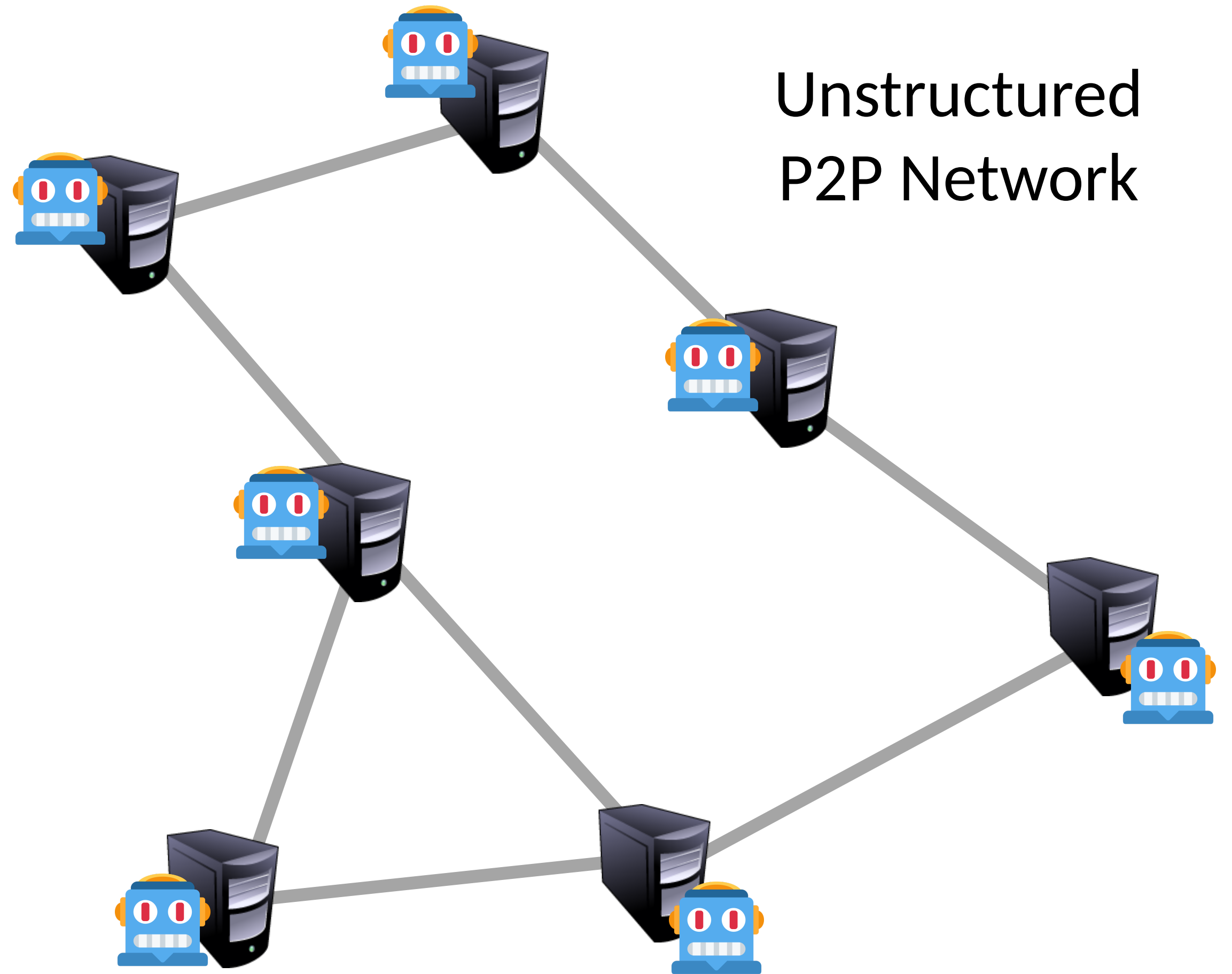
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Master Server

Unstructured P2P Network

FBI

Botmaster

Master
Server

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Botmaster

Master
Server ❌

Unstructured
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Master Server

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Master
Server

Master
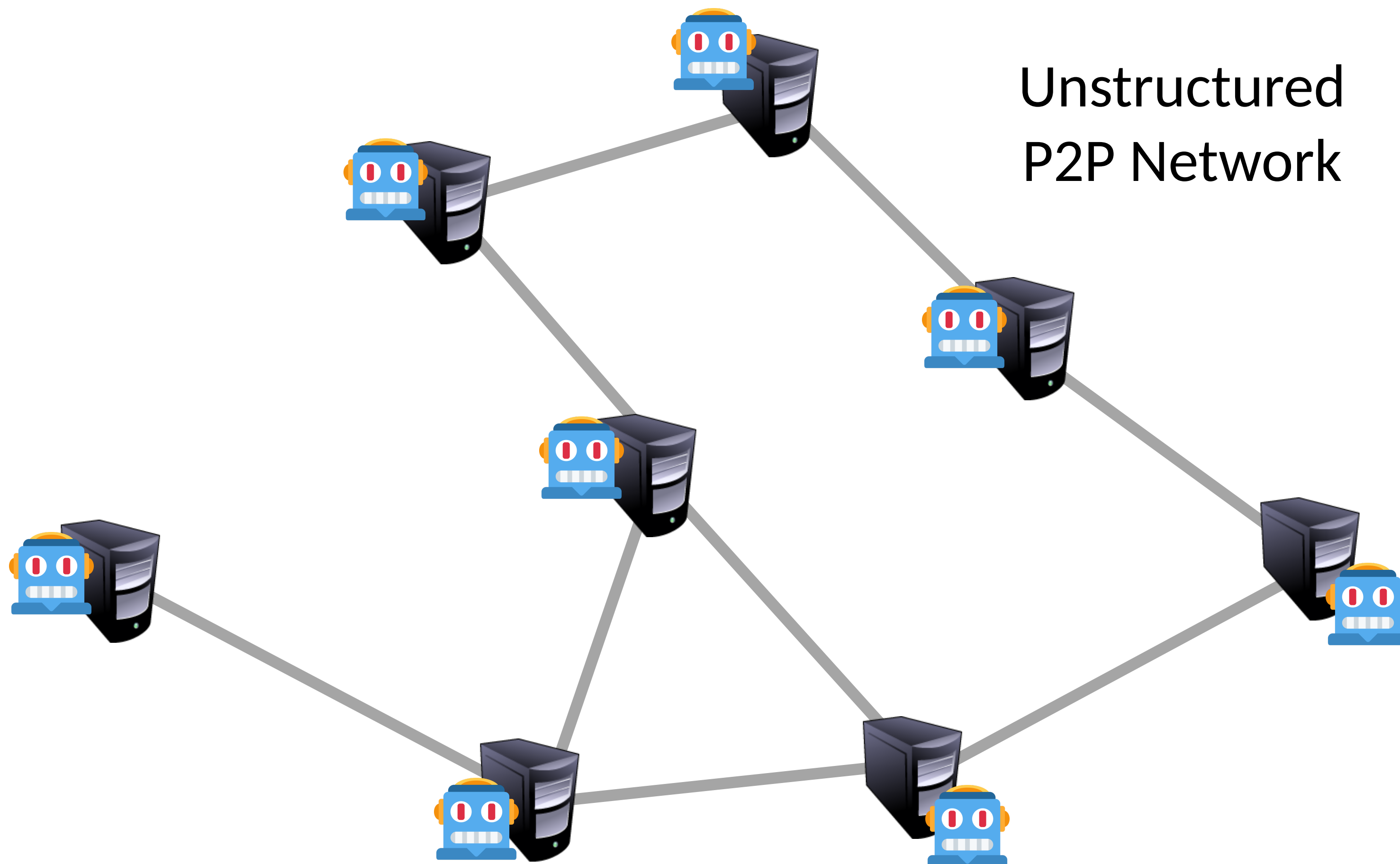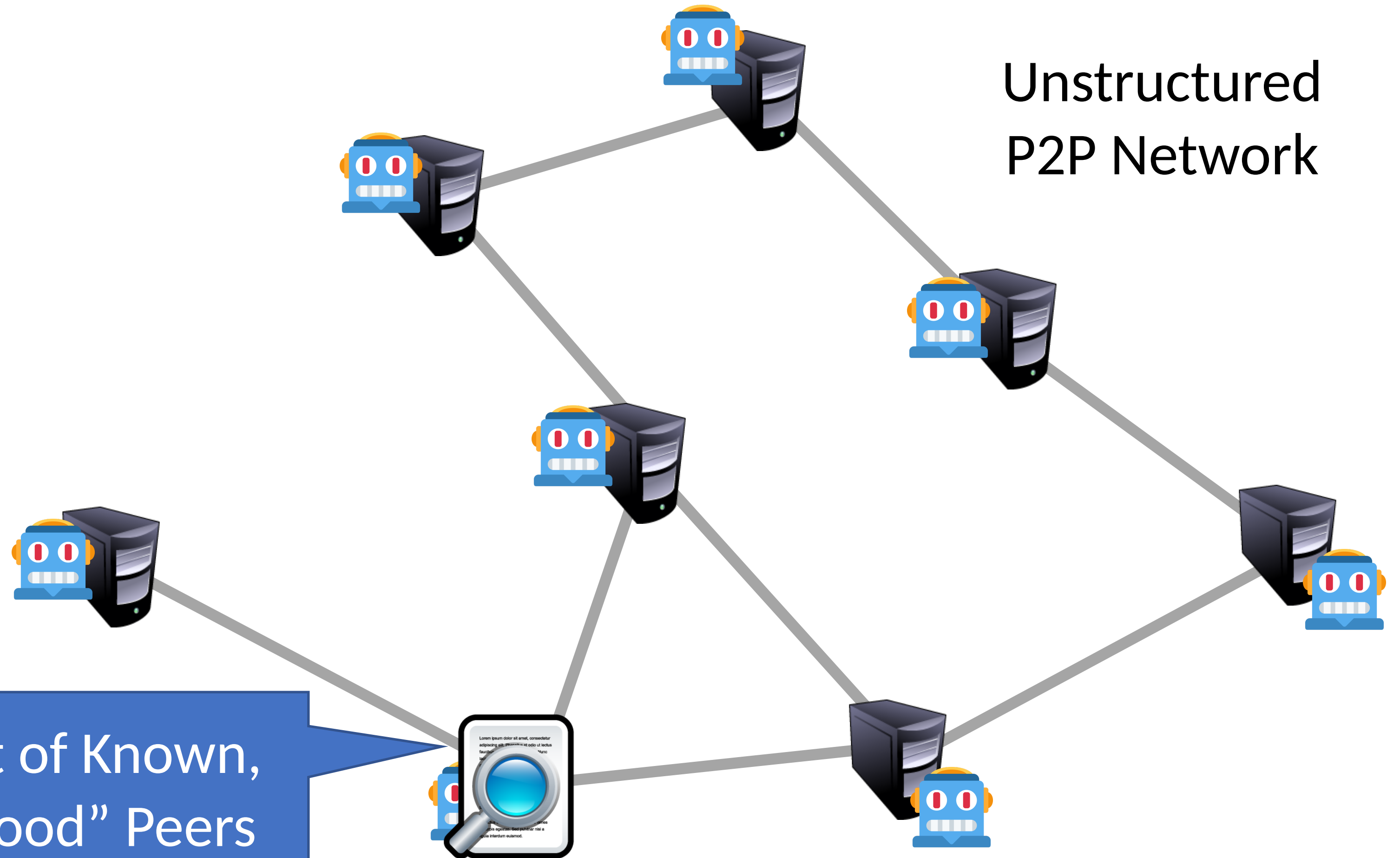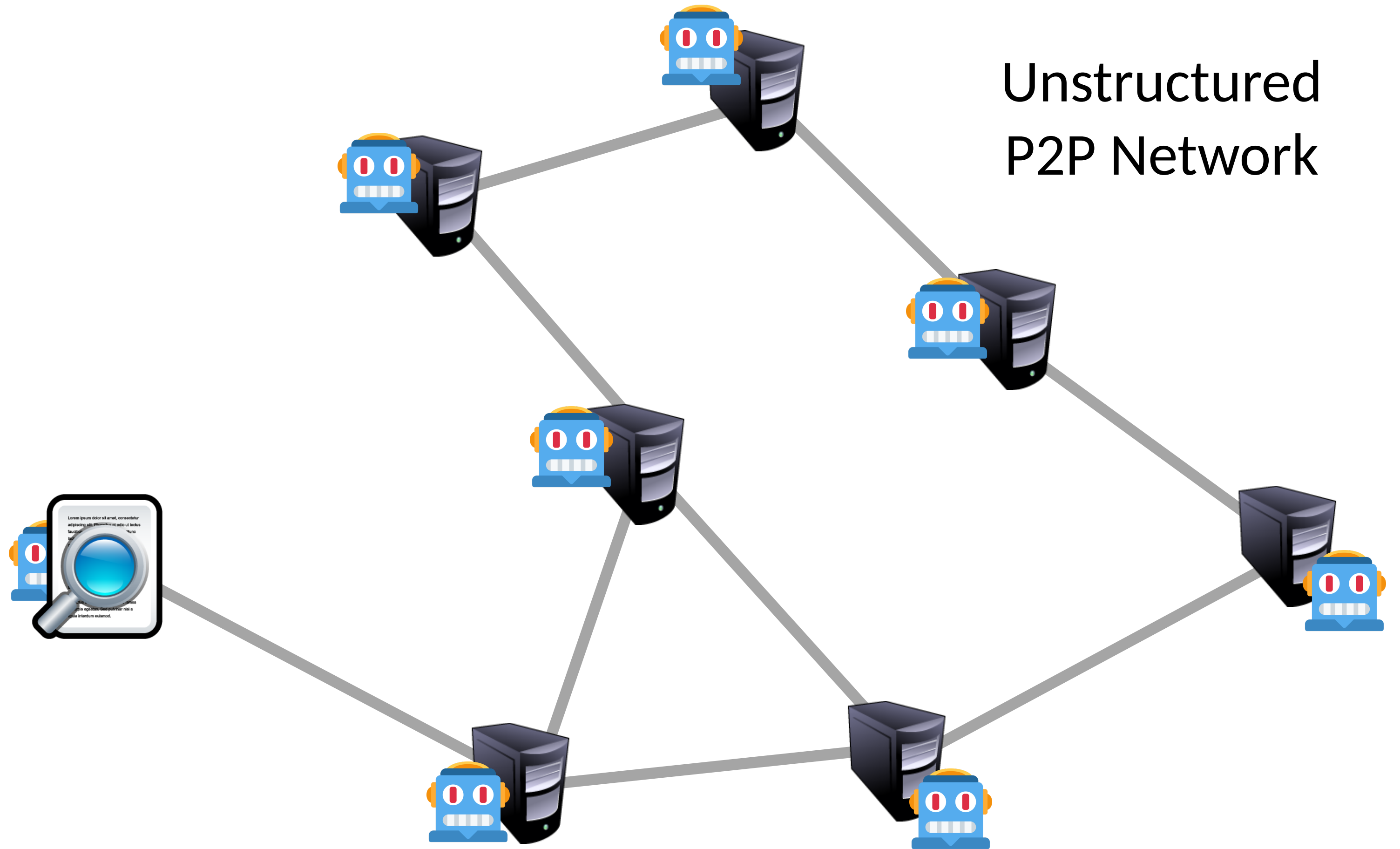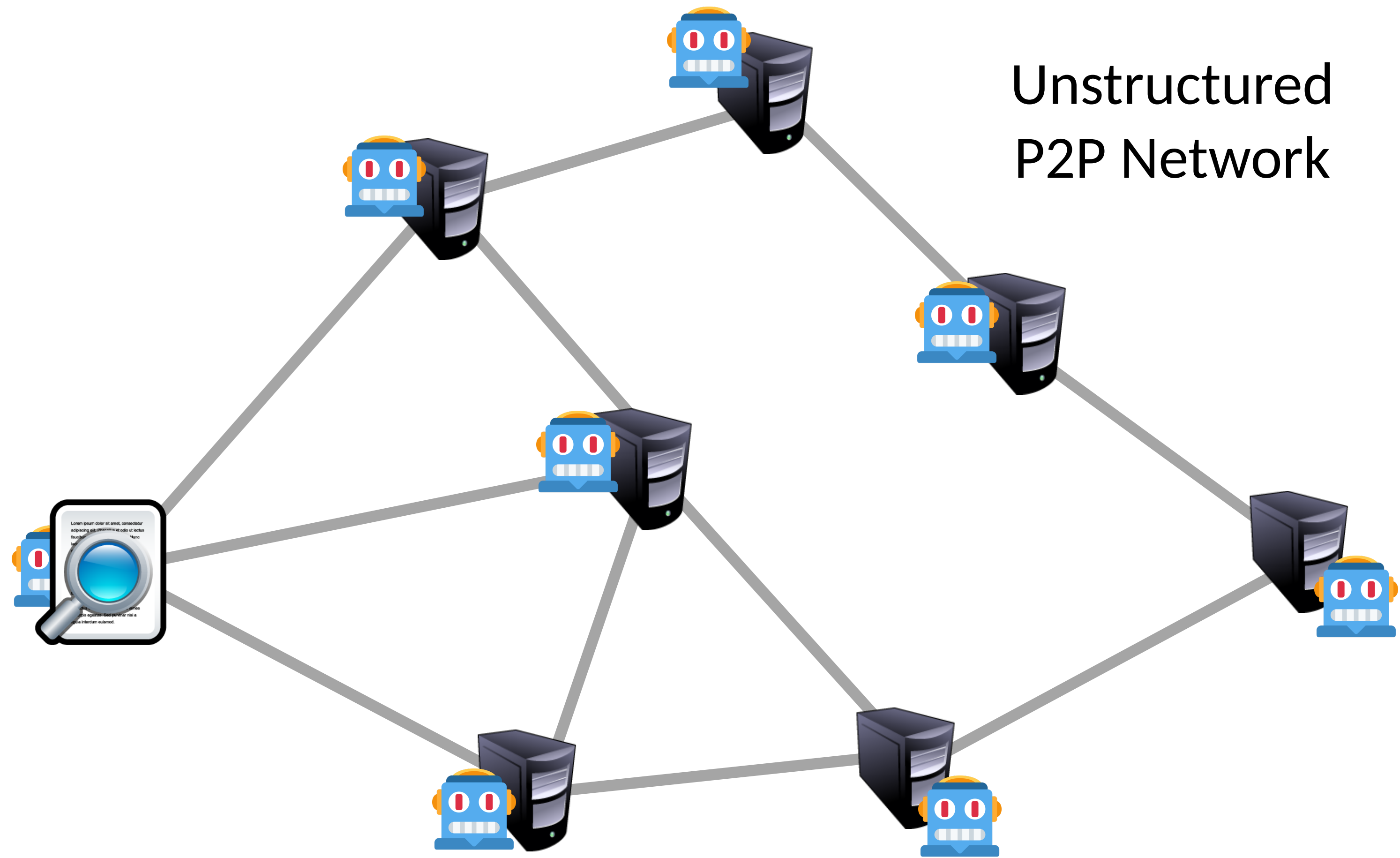Server

FBI

Unstructured
P2P Network

Botmaster

Master
Server

Unstructured
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FBI

Botmaster

Master Server

FBI

Unstructured P2P Network

Botmaster

Master Server

Unstructured P2P Network

FBI

Sinkhole

Botmaster

Master Server

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Unstructured P2P Network

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Sinkhole

Botmaster

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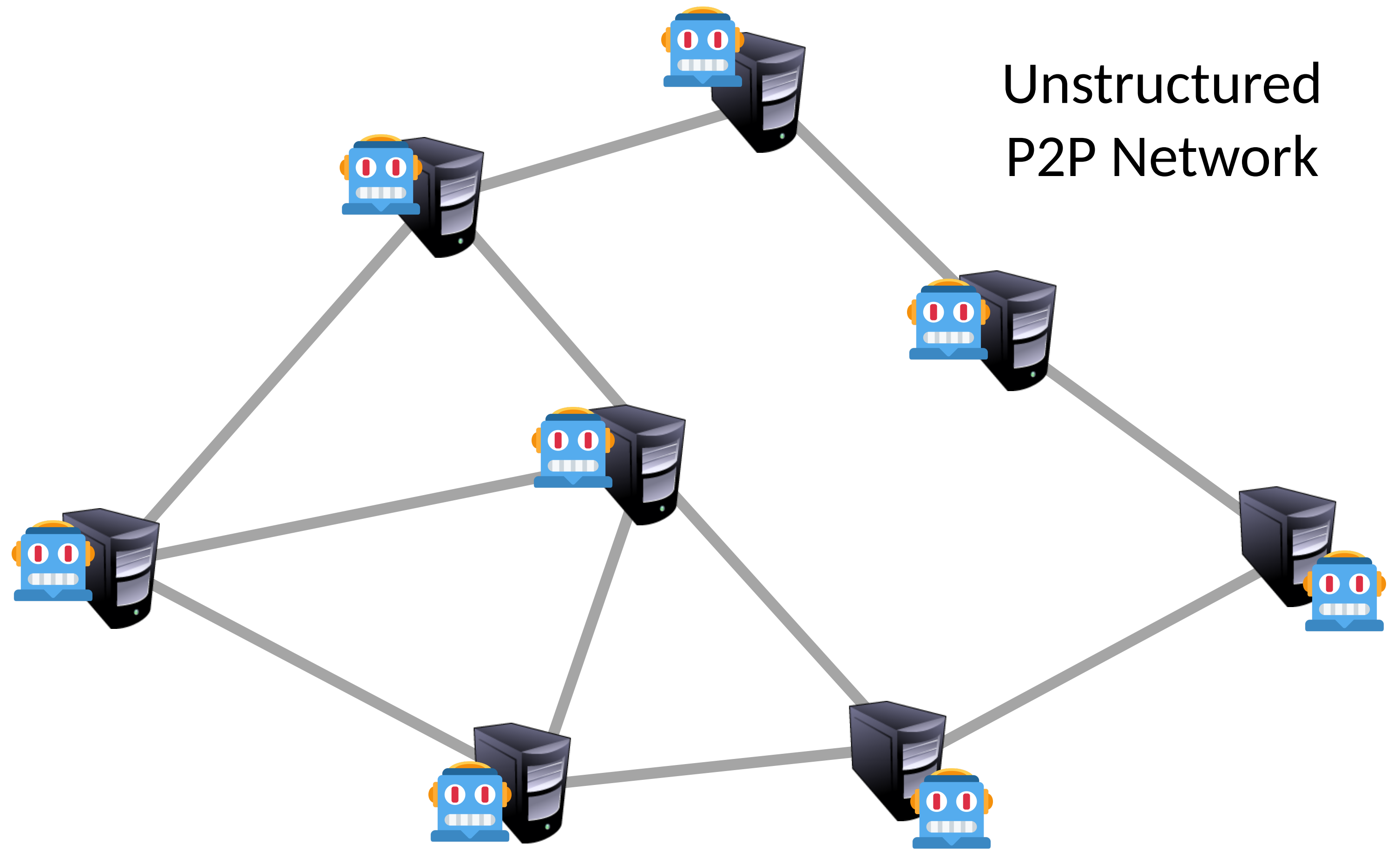Unstructured P2P Network

FBI

Sinkhole

Botmaster

Master Server

Unstructured P2P Network

FBI

Sinkhole

Denial of service

Ping of Death

```
$ ping —s 65535 66.66.0.255
```

Ping of Death

```
$ ping –s 65535 66.66.0.255
```

iOS Teluga Unicode Bug

- February 2018: iPhones and iPads crash if they receive text or email containing a specific symbol in Indian

- In some cases, reboot doesn't solve the issue
  - Apps reload bugged messages automatically on startup and crash again

- Device wipe is sometimes the only fix

Denial of Service (DoS)

- Prevent users from being able to access a specific computer, service, or piece of data

- In essence, an attack on availability

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- Often very easy to perform...

- ... and fiendishly difficult to mitigate

Attacker Goals and Threat Model

66.66.0.11

Internet

Servers
128.91.0.*
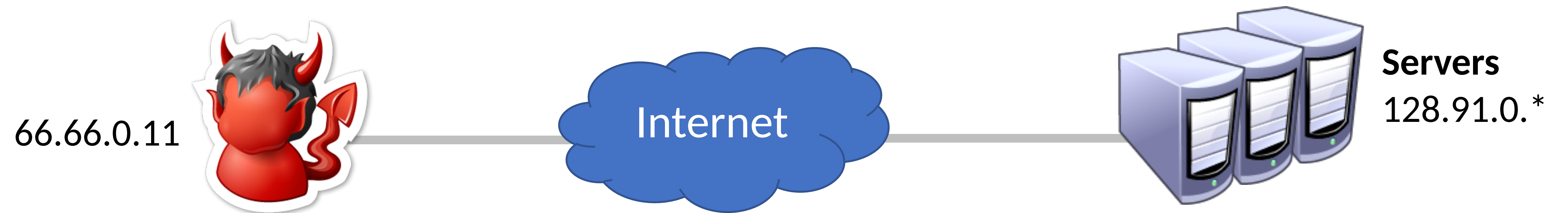
Attacker Goals and Threat Model
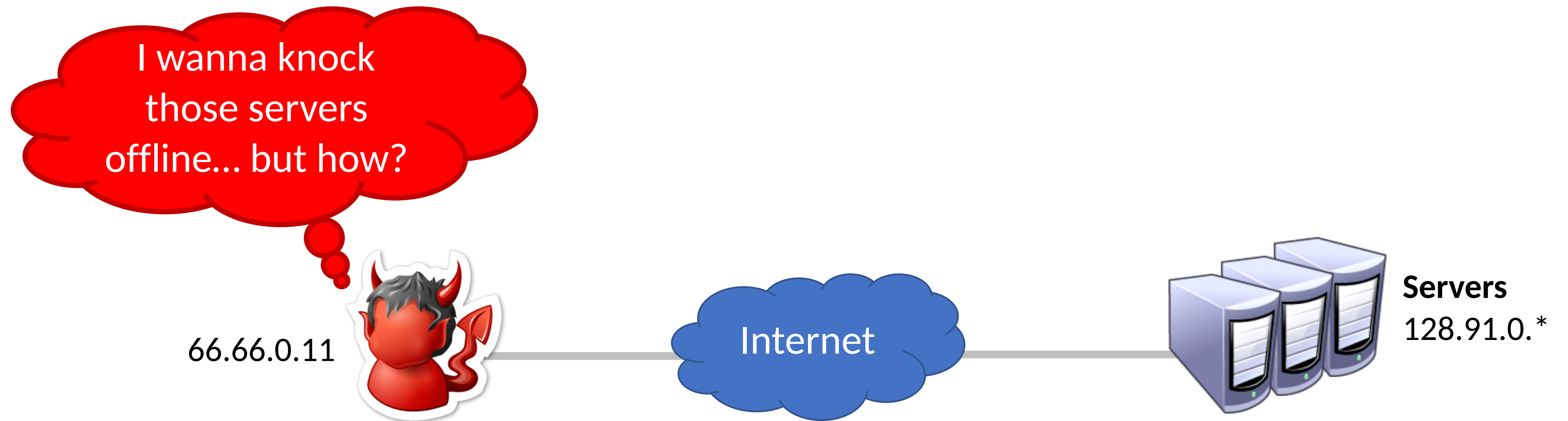
Attacker Goals and Threat Model

- Active attacker who may send arbitrary packets

- Goal is to reduce the availability of the victim
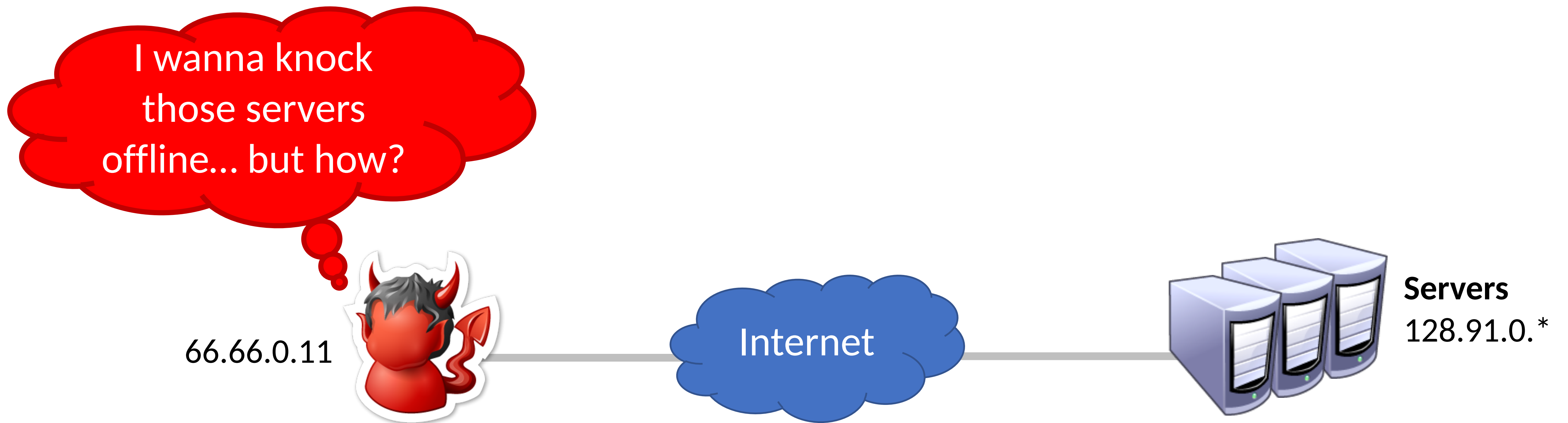
DoS Attack Parameters

1. How much bandwidth is available to the attacker?
   - Can be increased by controlling more resources…
   - Or tricking others into participating in the attack
2. What kind of packets do you send to victim?
   - Minimize effort and risk of detection for the attacker…
   - While also maximizing damage to the victim

Exploiting Asymmetry
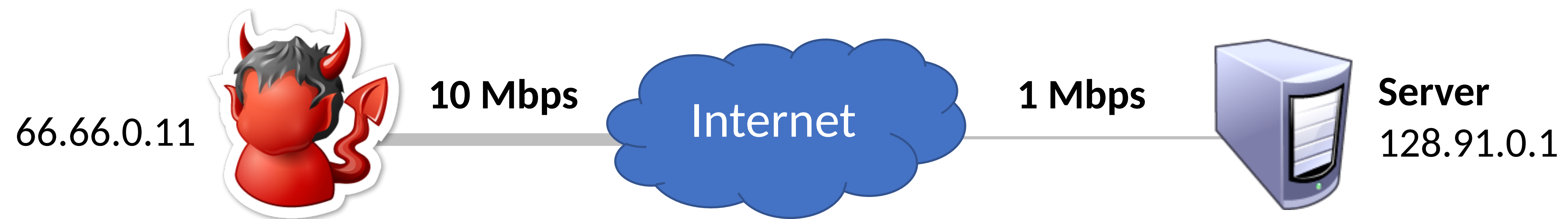
66.66.0.11 | 10 Mbps | Internet | 1 Mbps | **Server** 128.91.0.1

Exploiting Asymmetry

66.66.0.11

10 Mbps

Internet

1 Mbps

Server
128.91.0.1

Exploiting Asymmetry

66.66.0.11

10 Mbps

Internet

1 Mbps

Server
128.91.0.1

Exploiting Asymmetry

66.66.0.11 — 1 Mbps — Internet — 10 Mbps — **Server** 128.91.0.1

Exploiting Asymmetry

1 Mbps

Internet

10 Mbps

66.66.0.11

Server
128.91.0.1

Exploiting Asymmetry

66.66.0.11

1 Mbps

Internet

10 Mbps

Server
128.91.0.1

Exploiting Asymmetry

- Example of a Distributed Denial of Service Attack (DDoS)

66.66.0.11

1 Mbps

Internet

10 Mbps

Server
128.91.0.1

Exploiting Asymmetry

- Example of a Distributed Denial of Service Attack (DDoS)

- Some DDoS is fueled by volunteers
  - E.g. Anonymous and Low Orbit Ion Canon (LOIC)

66.66.0.11

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Internet

10 Mbps

Server
128.91.0.1
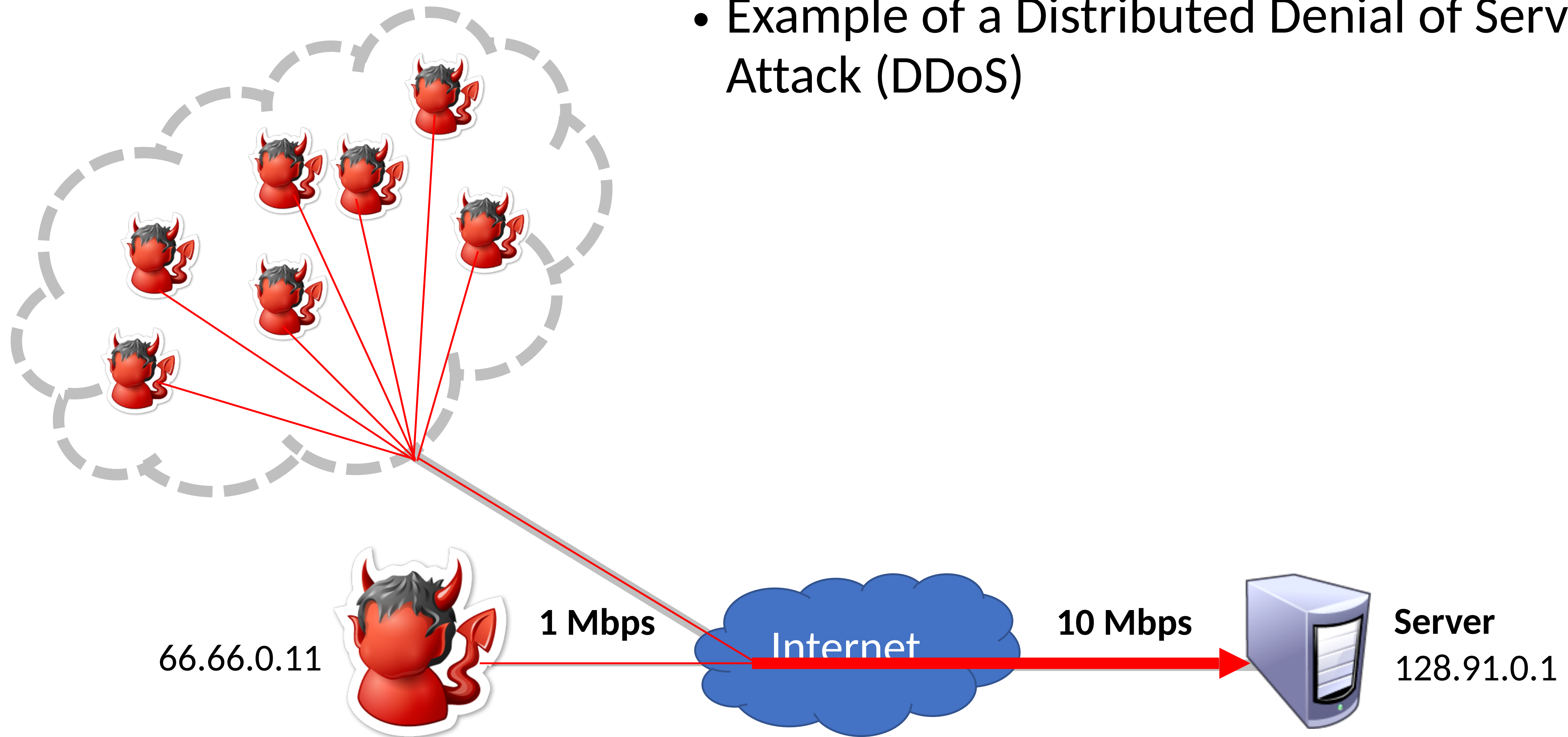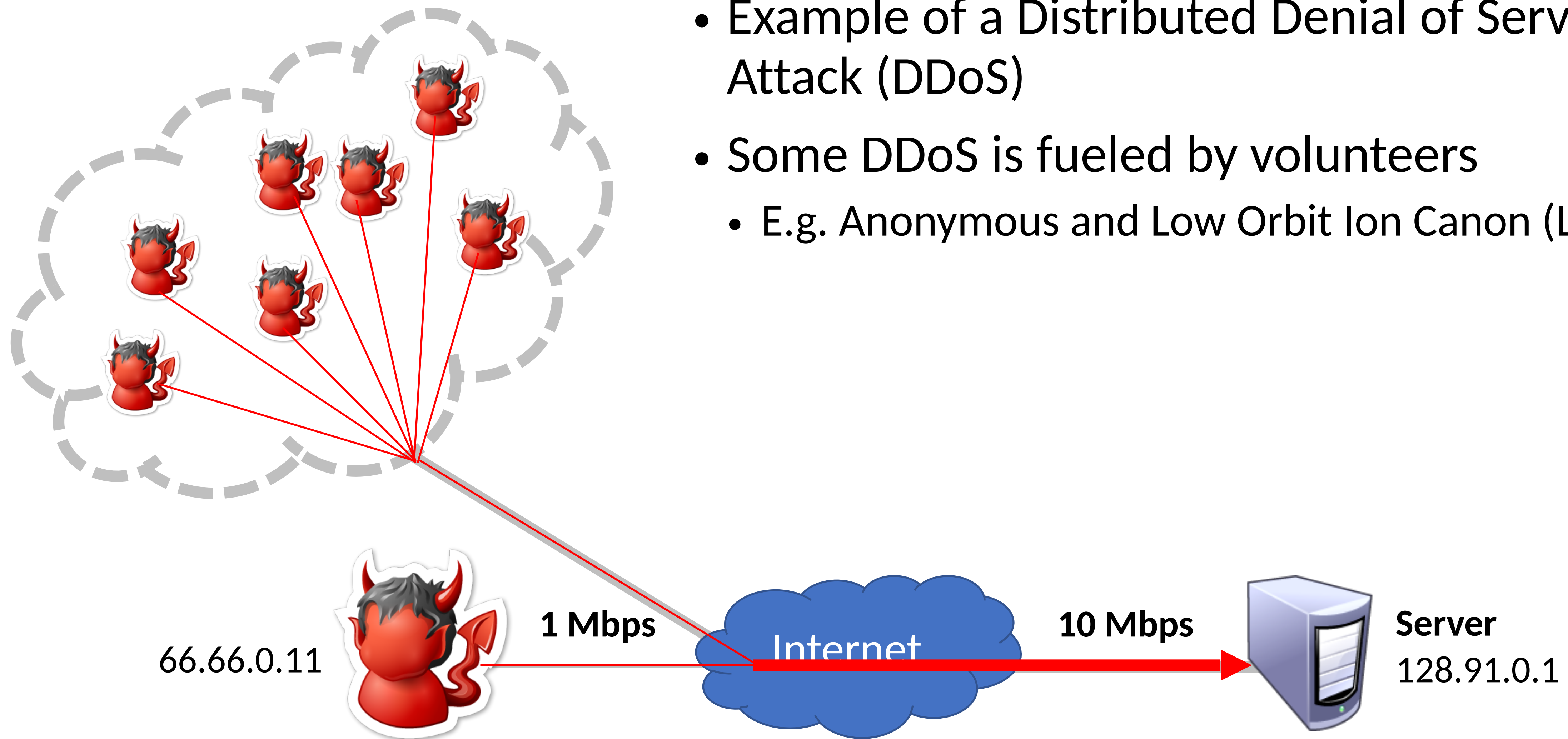
Exploiting Asymmetry

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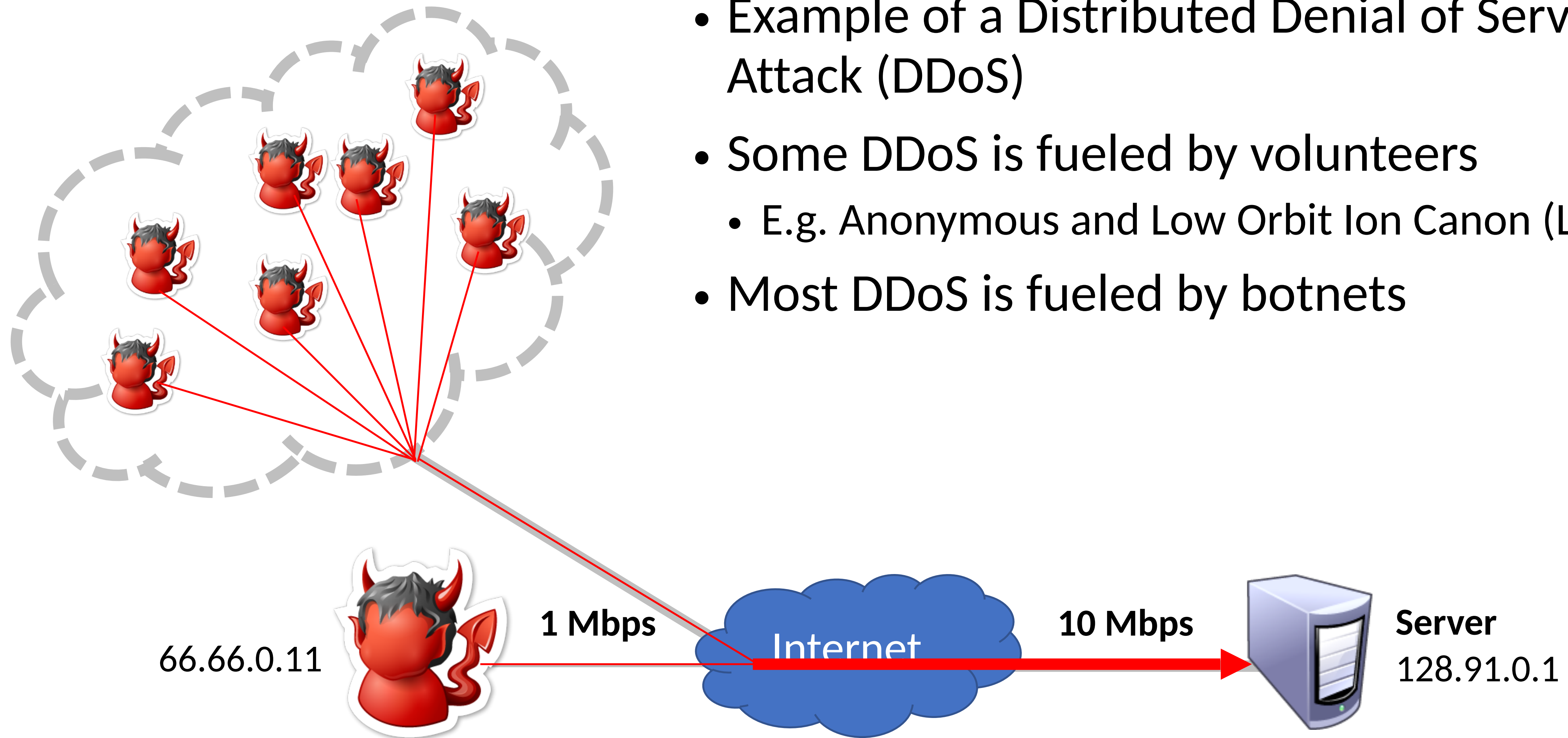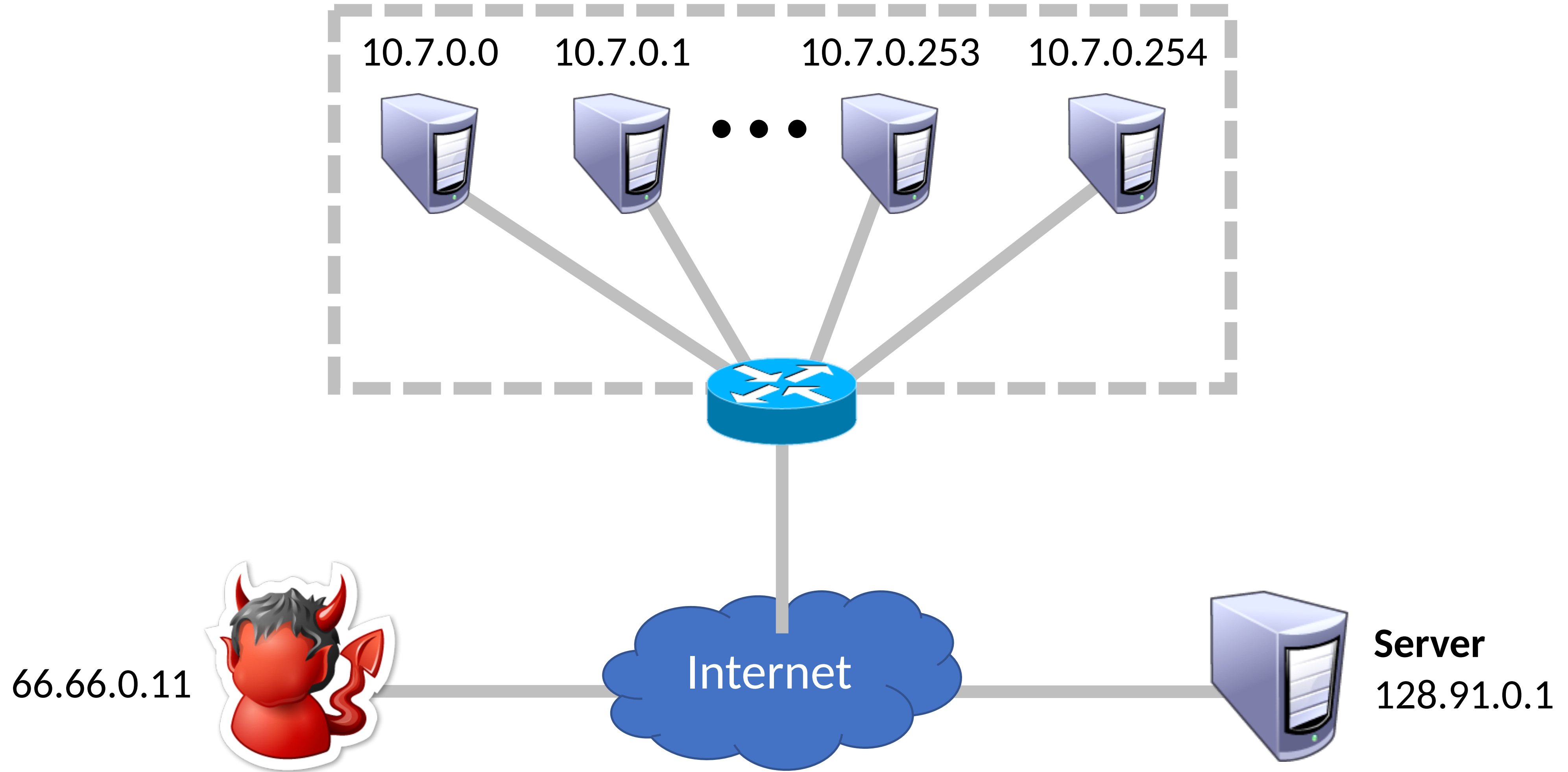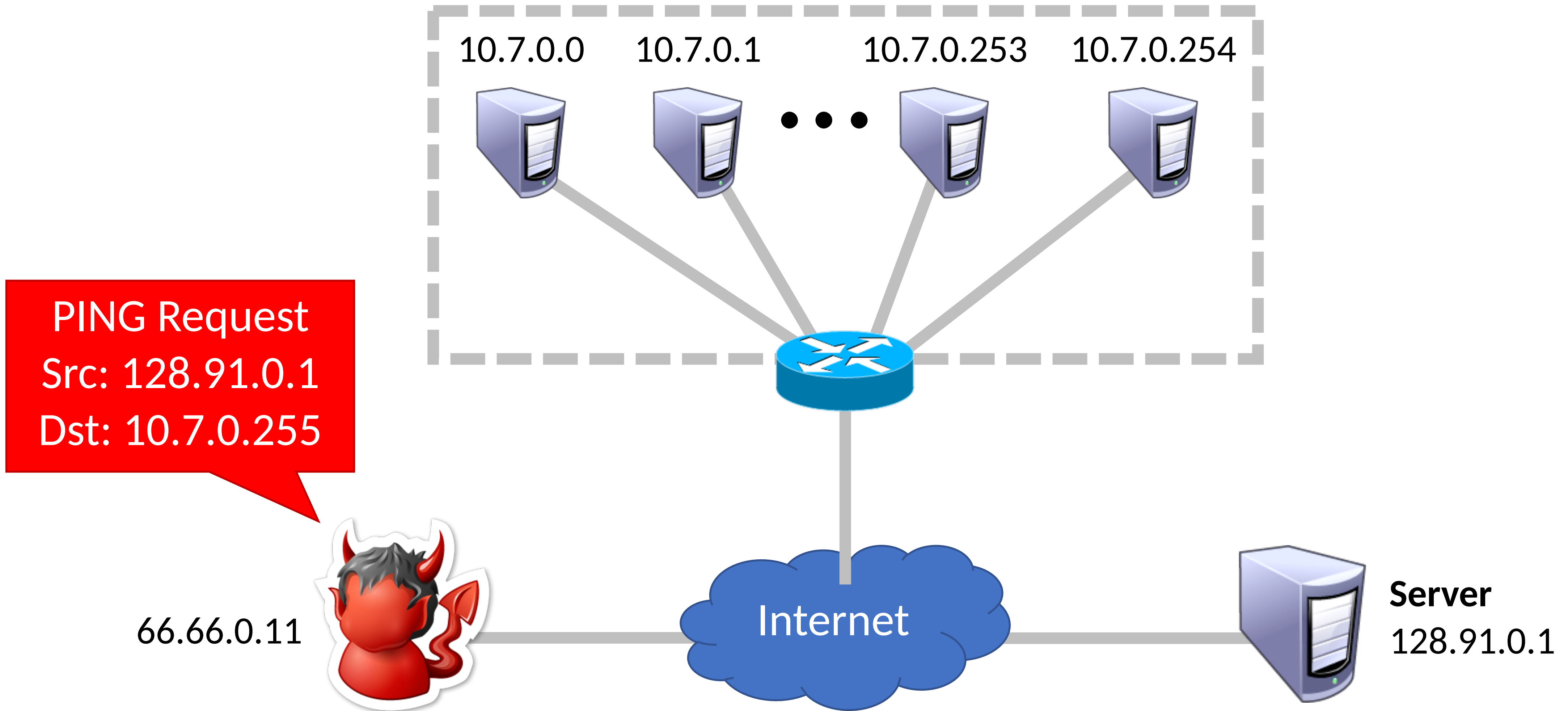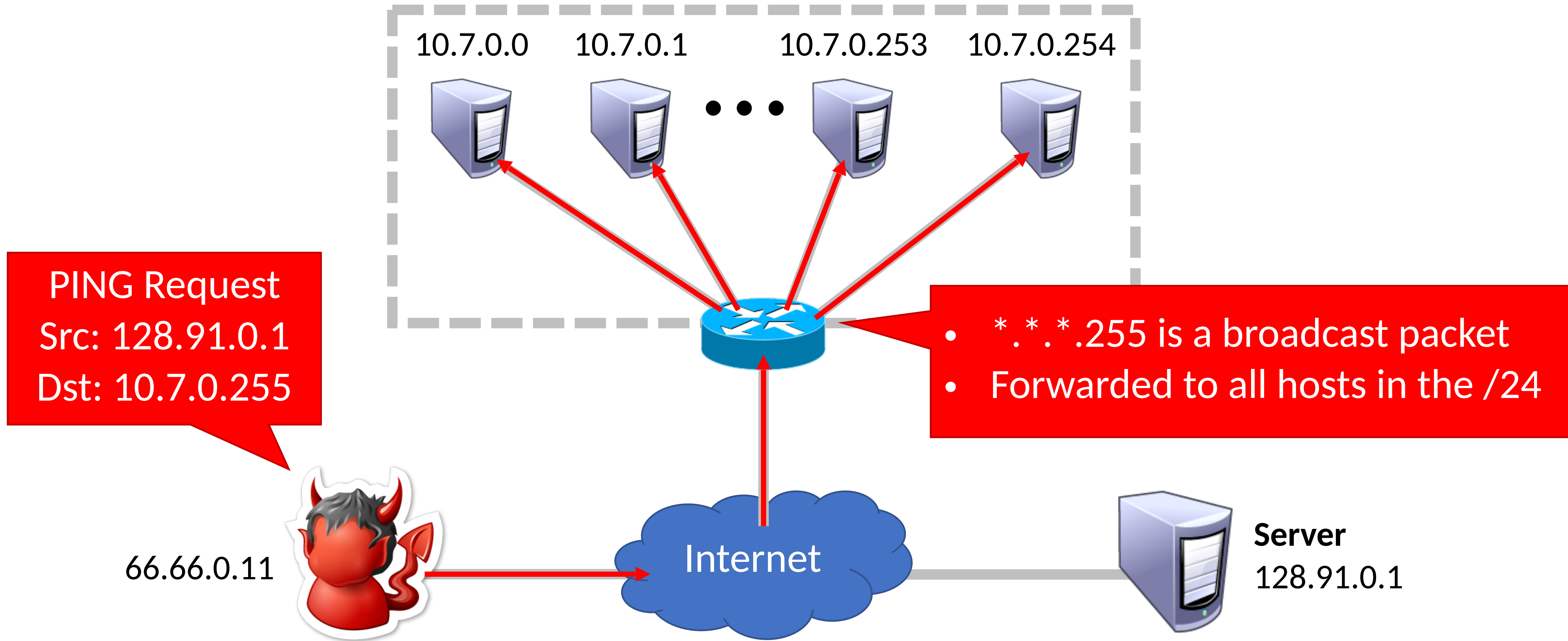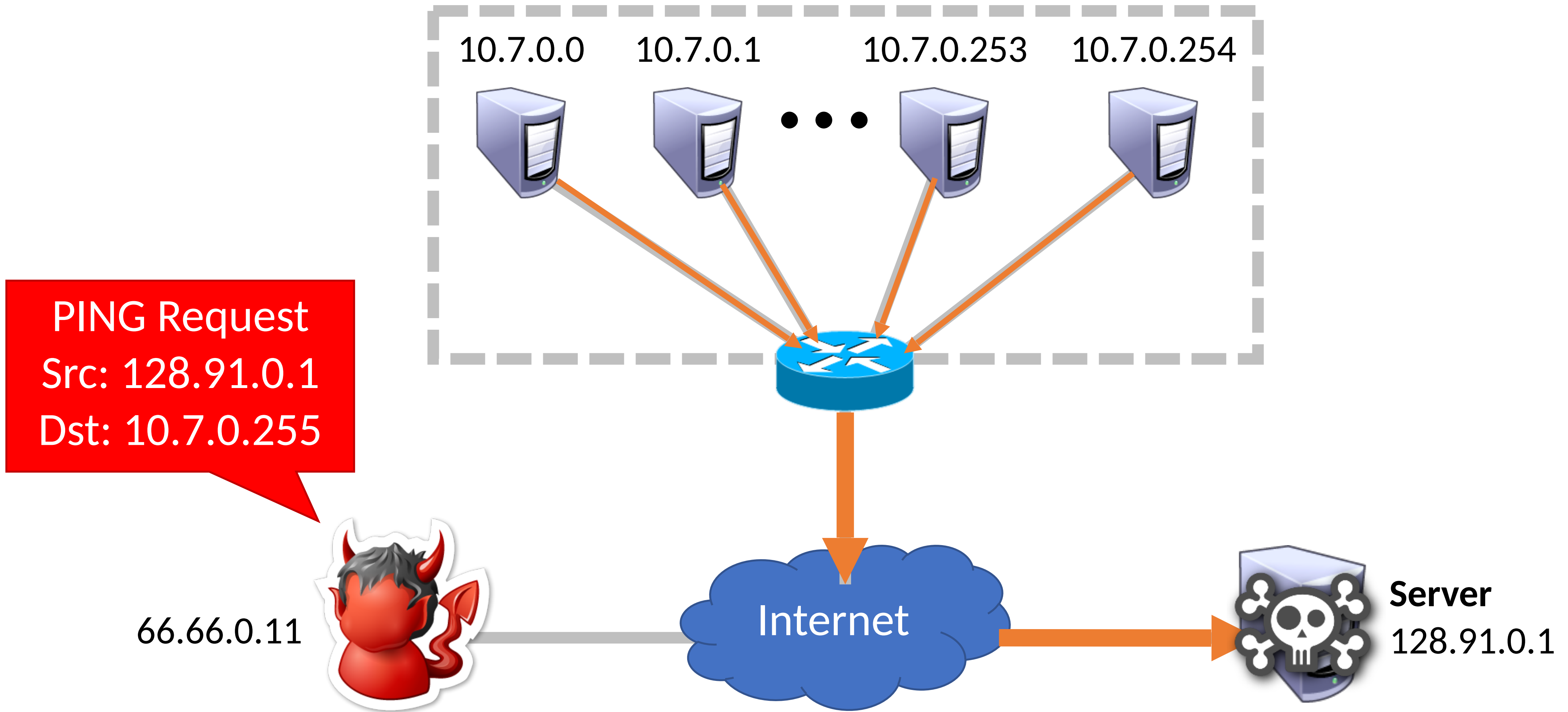
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1 Mbps

Internet

10 Mbps

Server
128.91.0.1

The Smurf Attack

10.7.0.0   10.7.0.1   10.7.0.253   10.7.0.254

Internet

66.66.0.11

Server
128.91.0.1

The Smurf Attack

10.7.0.0   10.7.0.1   10.7.0.253   10.7.0.254

● ● ●

PING Request
Src: 128.91.0.1
Dst: 10.7.0.255

66.66.0.11

Internet

Server
128.91.0.1

The Smurf Attack

10.7.0.0   10.7.0.1   10.7.0.253   10.7.0.254

PING Request
Src: 128.91.0.1
Dst: 10.7.0.255

- *.*.*.255 is a broadcast packet
- Forwarded to all hosts in the /24

Internet

66.66.0.11

Server
128.91.0.1

The Smurf Attack

10.7.0.0   10.7.0.1   10.7.0.253   10.7.0.254

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66.66.0.11

Internet

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Why Does Smurfing Work?

1. ICMP protocol does not include authentication

   - No connections
   - Receivers accept messages without verifying the source
   - Enables attackers to spoof the source of messages

Why Does Smurfing Work?

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2. Attacker benefits from an amplification factor

$$amp\ factor = \frac{total\ response\ size}{request\ size}$$

   - Smurf amp factor – *[number of servers that respond to the broadcast]:1*

Modern defense

`Router(config-if)# no ip directed-broadcast`[5]

Reflection/Amplification Attacks

- Smurfing is an example of a reflection or amplification DDoS attack

- Fraggle attack also relies on broadcasts for amplification
  - Send spoofed UDP packets to IP broadcast addresses on port 7 (*echo*) and 13 (*chargen*)
    - *echo* – 1500 bytes/pkt requests, equal size responses
    - *chargen* -- 28 bytes/pkt request, 10K-100K bytes of ASCII in response
  - Amp factor
    - *echo – [number of hosts responding to the broadcast]:1*
    - *chargen – [number of hosts responding to the broadcast]*360:1*

DNS Reflection Attack

- Spoof DNS requests to many **open** DNS resolvers
  - DNS is a UDP-based protocol, no authentication of requests
  - Open resolvers accept requests from any client
    - E.g. 8.8.8.8, 8.8.4.4, 1.1.1.1, 1.0.0.1
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- 64 byte DNS queries generate large responses
  - Old-school "A" record query →   maximum 512 byte response
  - EDNS0 extension "ANY" record query →   1000-6000 byte response
    - E.g. $ dig ANY isc.org
  - Amp factor – *180:1*

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  - Amp factor – *180:1*
- Attackers have been known to register their own domains and install very large records just to enable reflection attacks!

Reflection Example
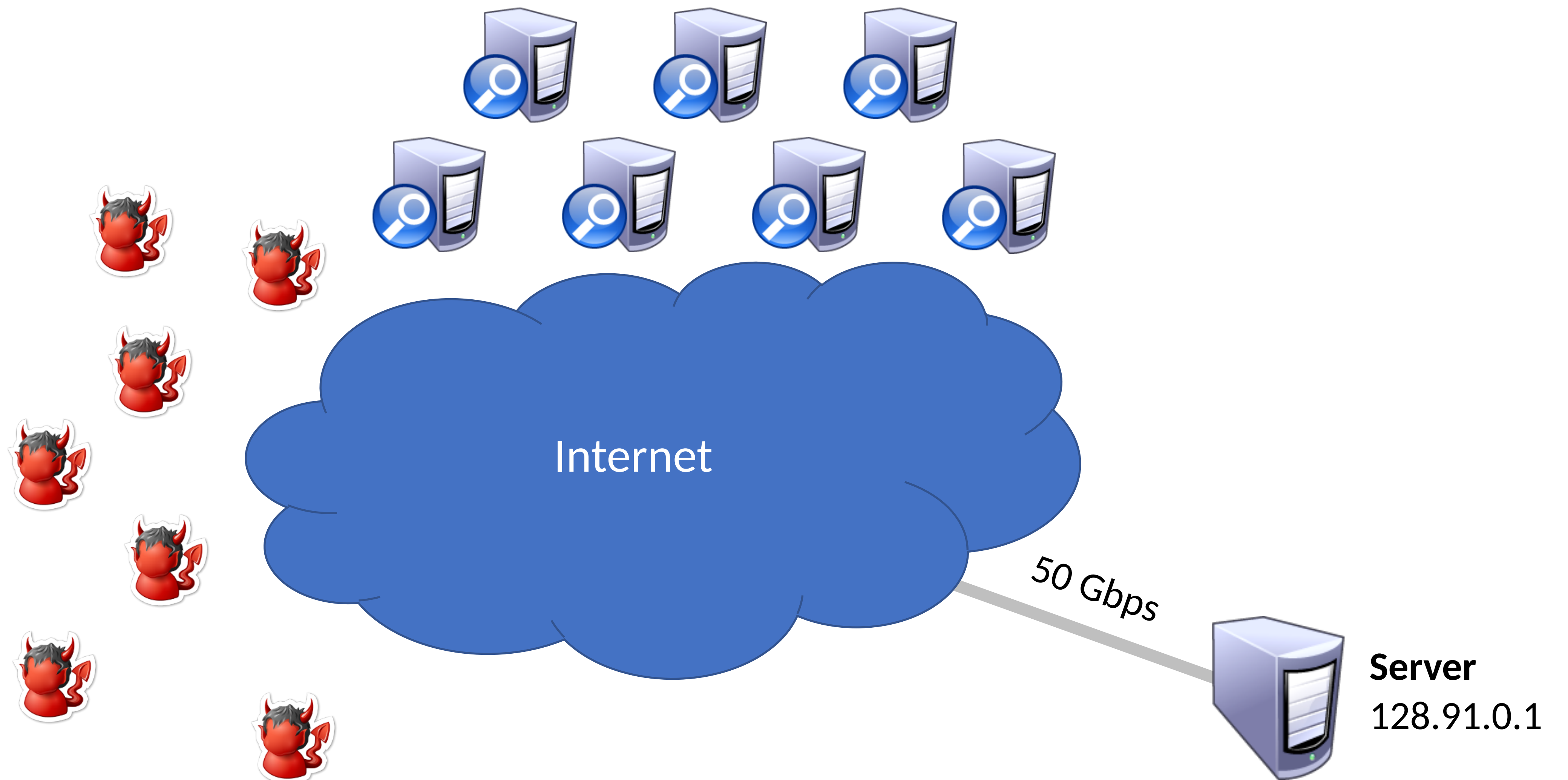
Internet

50 Gbps

Server
128.91.0.1

Reflection Example

Internet

50 Gbps

5 Gbps

Server
128.91.0.1

Reflection Example

Internet

50 Gbps

Server
128.91.0.1

Reflection Example

DNS Request
Src: 128.91.0.1
Dst: whatever

Internet

50 Gbps

Server
128.91.0.1

Reflection Example

DNS Request
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Internet

50 Gbps

100 Gbps
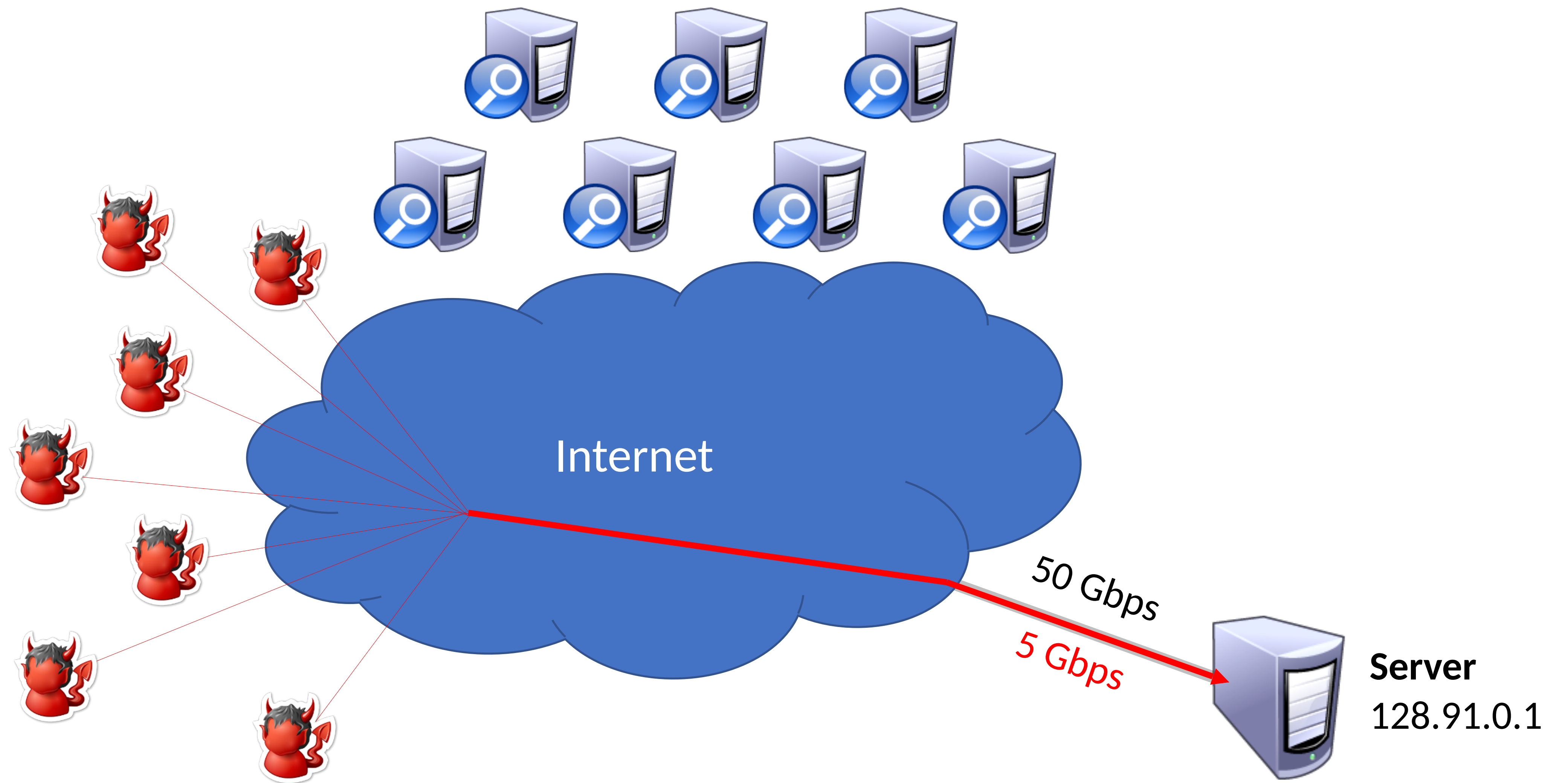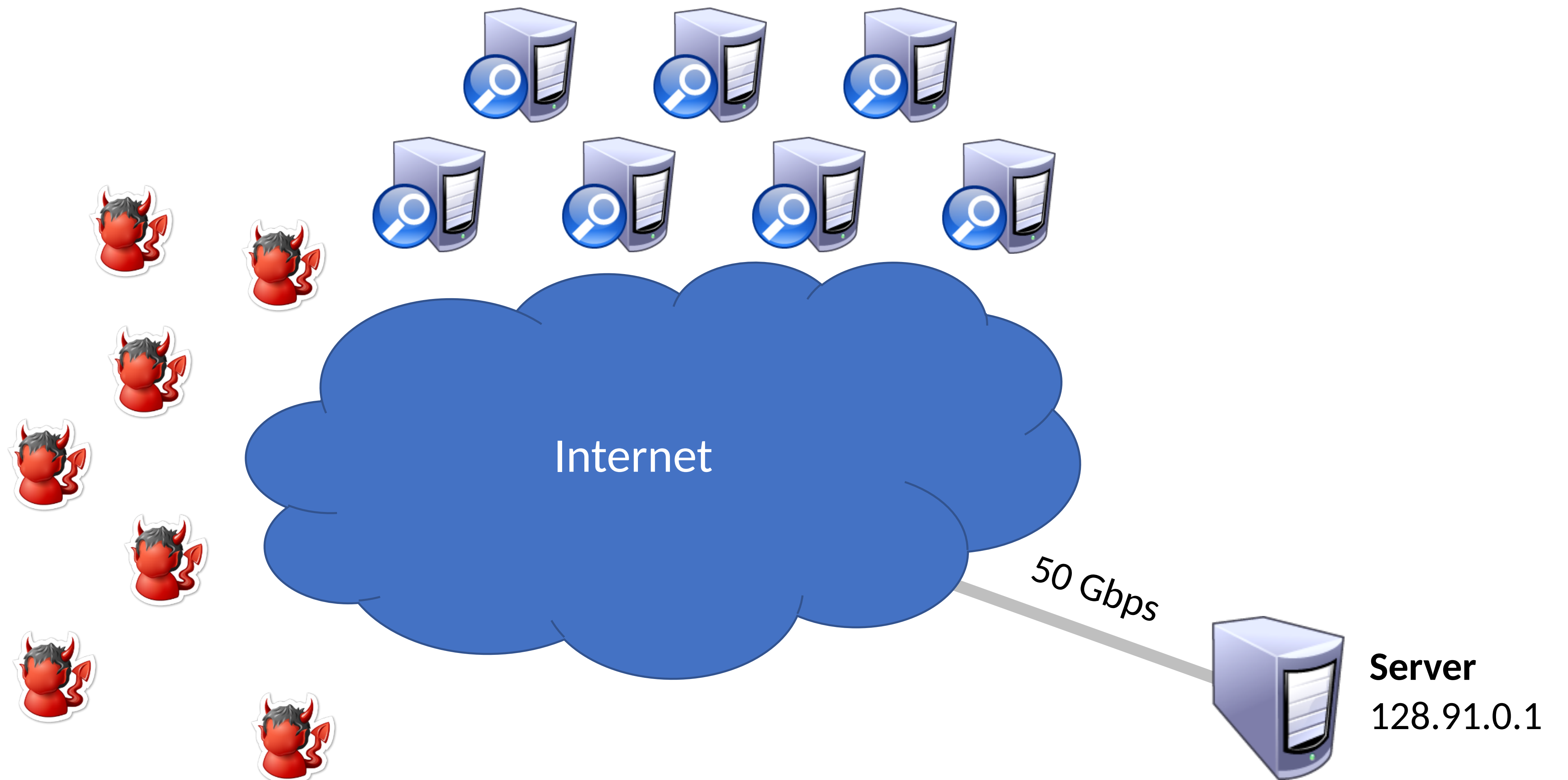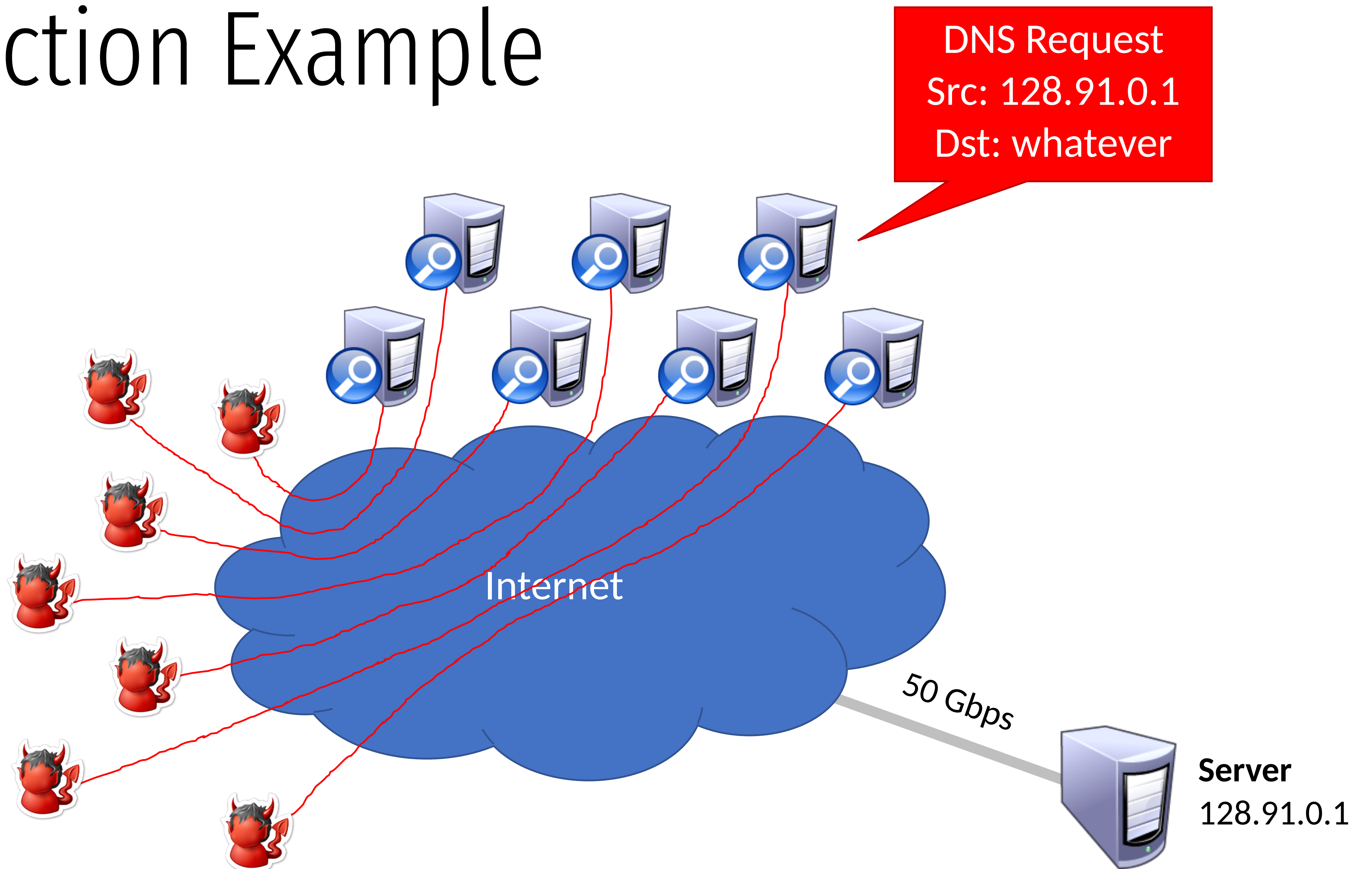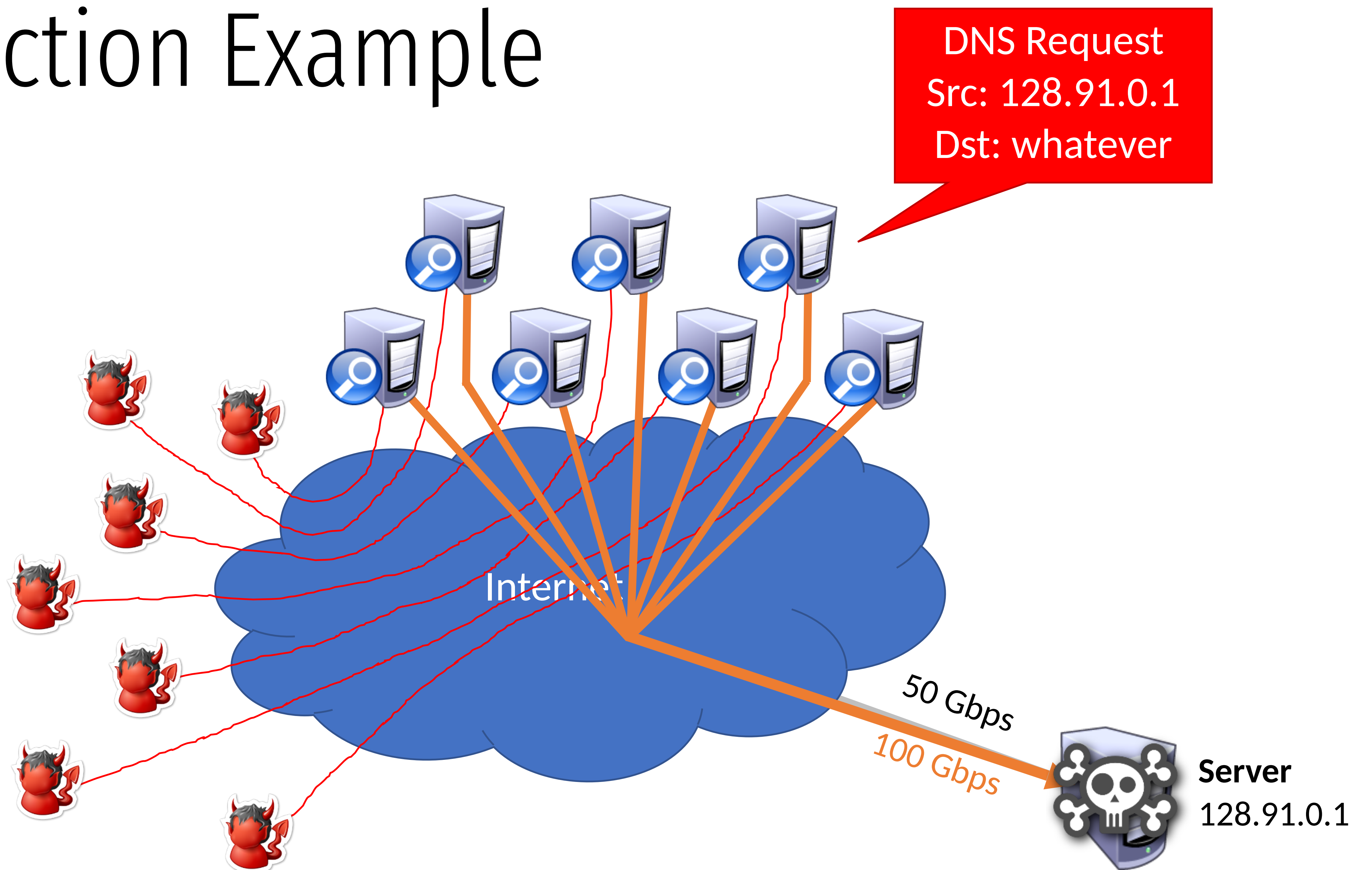
Server
128.91.0.1

NTP Reflection Attack

- Spoof requests to open Network Time Protocol (NTP) servers
  - NTP is a UDP-based protocol, no authentication of requests
  - May 2014 – 2.2 million open NTP servers on the internet
- 234 byte queries generate large responses
  - *monlist* query: server returns a list of all recent connections
  - Other queries are possible, i.e. *version* and *showpeers*
  - Amp factor – from *10:1* to *560:1*

LI	VN	Mode	Strat	Poll	Prec
Root Delay					
Root Dispersion					
Reference ID					
Reference Timestamp (64)					
Origin Timestamp (64)					
Receive Timestamp (64)					
Transmit Timestamp (64)					
MAC (optional 160)					

memcached Reflection Attack

- Spoof requests to open memcached servers
  - Popular <key:value> server used to cache web objects
  - memcached uses a UDP-based protocol, no authentication of requests
  - February 2018 – 50k open memcached servers on the internet
- 1460 byte queries generate large responses
  - A single query can request multiple 1MB <key:value> pairs from the database
  - Amp factor – up to *50000:1*

Reflection Amplification

Protocol	Amplification Factor
memcached	50000
NTP	557
chargen	359
DNS	179
QOTD	140
BitTorrent	54
SSDP	31
SNMPv2	6
Steam	6
NetBIOS	4

Infamous DDoS Attacks

When	Against Who	Size	How
March 2013	Spamhaus	120 Gbps	Botnet + DNS reflection
February 2014	Cloudflare	400 Gbps	Botnet + NTP reflection
September 2016	Krebs	620 Gbps	Mirai
October 2016	Dyn (major DNS provider)	1.2 Tbps	Mirai
March 2018	Github	1.35 Tbps	Botnet + memcached refection

Denial of Service as a Service

- Booters and Stressors
- Websites that claim to "test" a website for resilience against DDoS
  - Send huge amounts of traffic to a target for a fee
  - $10-$100 depending on the amount of traffic and duration of the "test"

Denial of Service as a Service

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- Obvious front for criminal DDoS attacks
  - Users can "test", i.e. attack, any website they want for a fee
  - Attack bandwidth drawn from botnets and bulletproof hosts

- Many, many stressor services operating out in the open

How do I purchase a vDos plan?

Purchasing a booter plan is easy and only takes a few minutes, we accept the following payment methods, based on your billing country/region and the currency in which you want to pay to make it an easy, secure and a quick shopping experience for you.

₿ Bitcoin, we believe in the huge potential of this new digital currency.
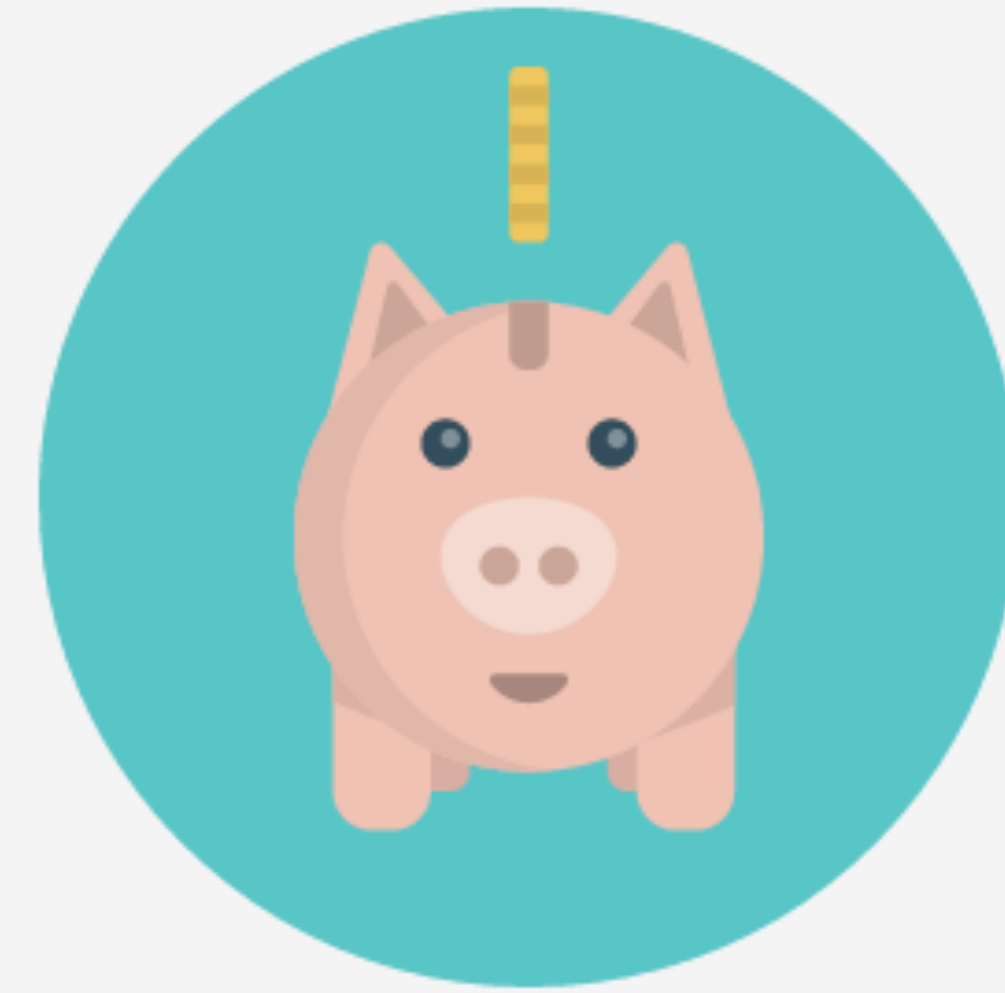
Pricing Lists

Select the best package based on your usage needs and size of business.

Bronze	Silver	Gold	VIP
$19.99 /monthly	$29.99 /monthly	$39.99 /monthly	$199.99 /monthly
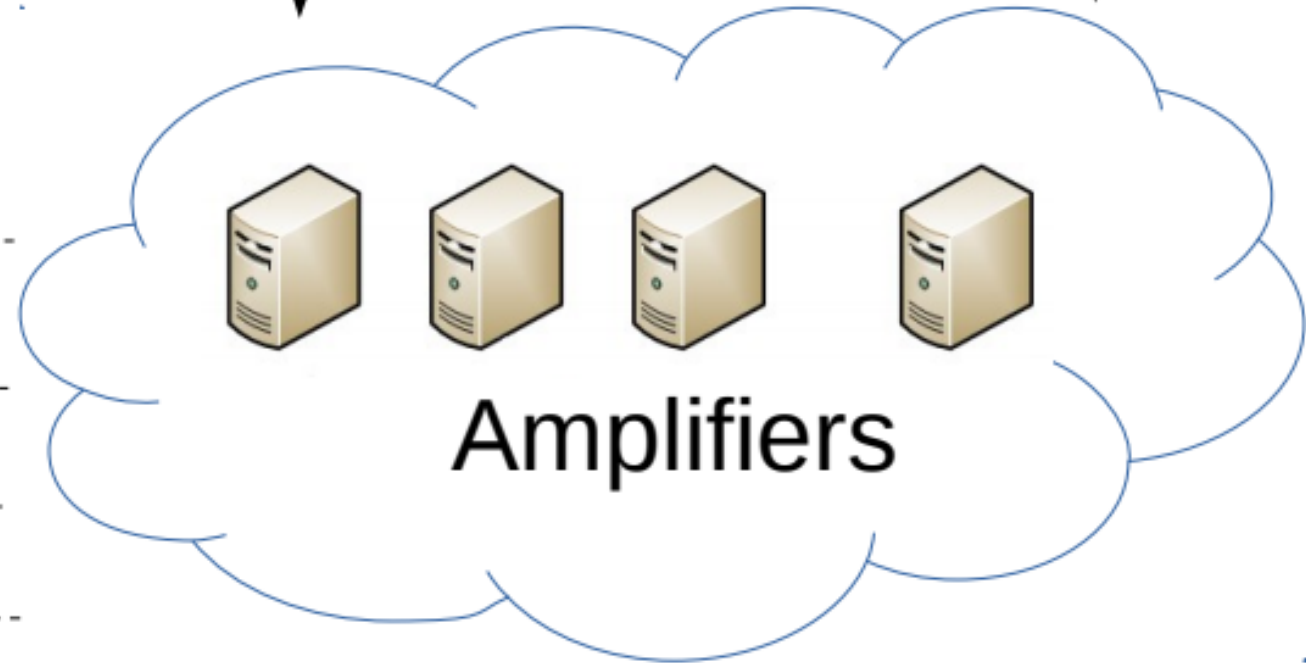
Posts Tagged: booter

DDoS-for-Hire / Ne'er-Do-Well News — 37 Comments

1 250 Webstresser Users to Face Legal Action
FEB 19

More than 250 customers of a popular and powerful online attack-for-hire service that was dismantled by authorities in 2018 are expected to face legal action for the damage they caused, according to **Europol**, the European Union's law enforcement agency.

In April 2018, investigators in the U.S., U.K. and the Netherlands took down attack-for-hire service **WebStresser[.]org** and arrested its alleged administrators. Prior to the takedown, the service had more than 151,000 registered users and was responsible for launching some four million attacks over three years. Now, those same authorities are targeting people who paid the service to conduct attacks.
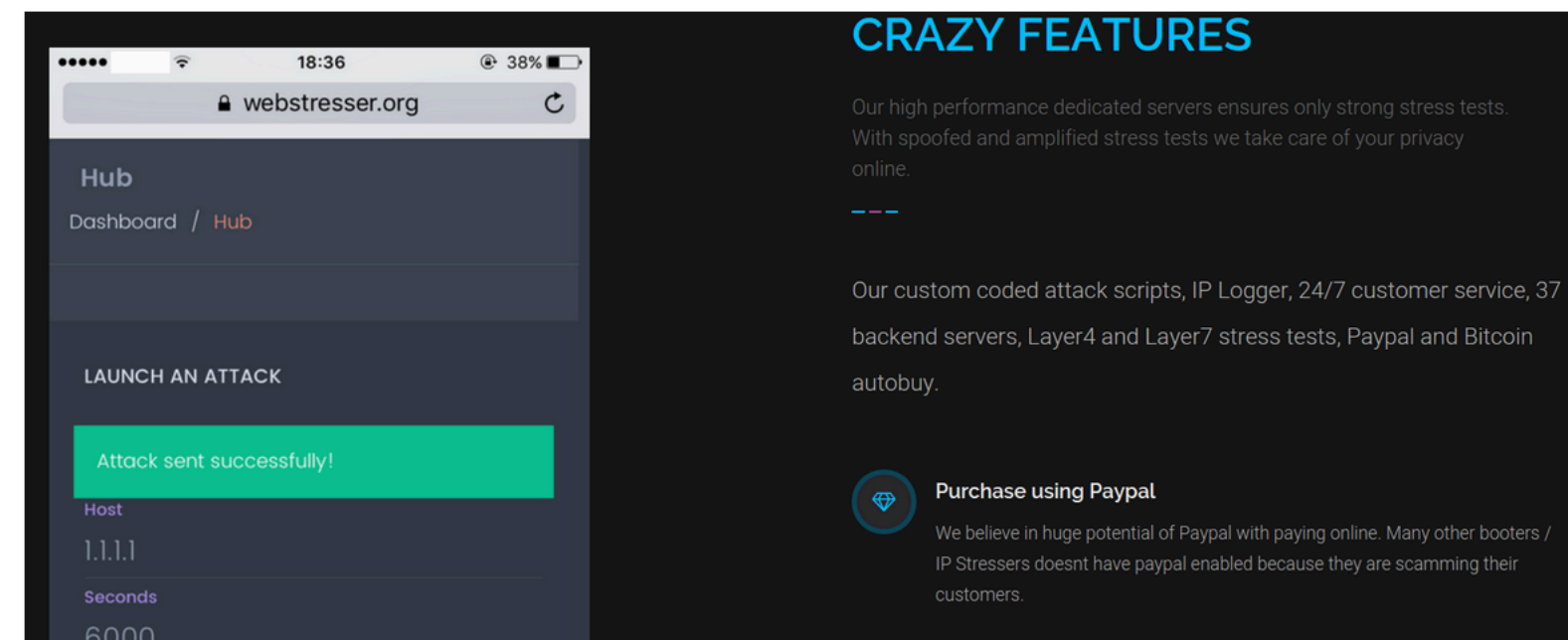
booter website

| Web | Images | Videos | News |

Any time ⌄   Advanced

Web Results

Best IP Stresser / DDOS Booter 2020 - Synstresser.to
https://synstresser.to/   Anonymous View

Synstresser is the best web stresser or ip booter of 2020. ... Attack that generates a huge amount of fake visitors to take down a website capable of bypassing ...

StressThem.to - The next generation IP Stresser
https://www.stressthem.to/   Anonymous View

StressThem is the strongest Booter on the market with a total capacity of 1000Gbit/s. Sign up and receive a free plan.

Str3ssed Booter/ IP Stresser - 6 Years Running!
https://str3ssed.co/   Anonymous View

Str3ssed Booter/IP Stresser is the hardest hitting, strongest and most effective ip ... Our website has changed its looks recently and detailed information can be ...

Hacked & Dumped Booter Services

Booter	Period	All Users	Subscribers	Revenue	Attacks	Targets
Asylum Stresser	10/2011-3/2013	26,075	3,963	$35,381.54	483,373	142,473
Lizard Stresser	12/2014-01/2015	12,935	176	$3,368 [†]	15,998	3,907
VDO[‡]	12/2014-2/2015	11,975	2,779	$52,773*	138,010	38,539
Total	-	50,985	6,918	$91,522.54	637,381	184,919

Hacked & Dumped Booter Services

99.4% via Paypal

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Booter Attack Characteristics

Booter	Chargen (#)	Chargen (%)	DNS (#)	DNS (%)	NTP (#)	NTP (%)	SSDP (#)	SSDP (%)
ANO	-	-	1,827	73%	-	-	-	-
BOO	370	65%	-	-	1,764	86%	-	-
CRA	-	-	43,864	56%	-	-	64,874	46%
GRI	-	-	-	-	1,701	72%	10,121	60%
HOR	-	-	-	-	8,551	58%	242,397	30%
INB	-	-	38,872	55%	4,538	92%	170,764	54%
IPS	1,636	44%	-	-	1,669	85%	90,100	29%
K-S	1,422	30%	-	-	-	-	5,982	76%
POW	-	-	-	-	-	-	1,424,099	11%
QUA	-	-	10,105	85%	-	-	39,804	67%
RES	-	-	2,260	82%	27	100%	-	-
SPE	2,358	38%	26,851	61%	6,309	35%	258,648	24%
STR	-	-	93,362	53%	-	-	7,126	74%
VDO	-	-	16,133	82%	6,325	82%	150,756	62%
XR8	-	-	44,976	52%	-	-	-	-
Total	4,565	23.46%	181,298	35.30%	17,599	42.31%	2,145,015	11.84%

Amplifier Locations

CC	%	AS	%
		Chargen	
CN	48.78%	4134 (Chinanet)	14.46%
US	12.51%	37963 (Hangzhou Alibaba Advertising)	10.47%
KR	5.50%	4837 (CNCGROUP China169 Backbone)	6.88%
RU	4.58%	17964 (Beijing Dian-Xin-Tong Network)	2.61%
IN	2.56%	7922 (Comcast Cable Communications)	2.61%
		DNS	
US	12.38%	4134 (Chinanet)	2.68%
RU	11.58%	3462 (Data Communication Business Group)	2.15%
BR	9.19%	18881 (Global Village Telecom)	1.46%
CN	6.84%	4837 (CNCGROUP China169 Backbone)	1.45%
JP	3.61%	7922 (Comcast Cable Communications)	1.27%
		NTP	
US	31.47%	3462 (Data Communication Business Group)	14.01%
TW	15.29%	46690 (Southern New England Telephone)	12.35%
CN	10.68%	7018 (AT&T Services)	4.84%
KR	5.50%	4134 (Chinanet)	3.58%
RU	4.74%	4837 (CNCGROUP China169 Backbone)	2.18%
		SSDP	
CN	36.26%	4837 (CNCGROUP China169 Backbone)	18.98%
US	19.37%	4134 (Chinanet)	11.16%
EG	6.83%	8452 (TE Data)	6.61%
AR	5.37%	22927 (Telefonica de Argentina)	5.13%
CA	5.36%	7922 (Comcast Cable Communications)	4.60%

Payment Interventions
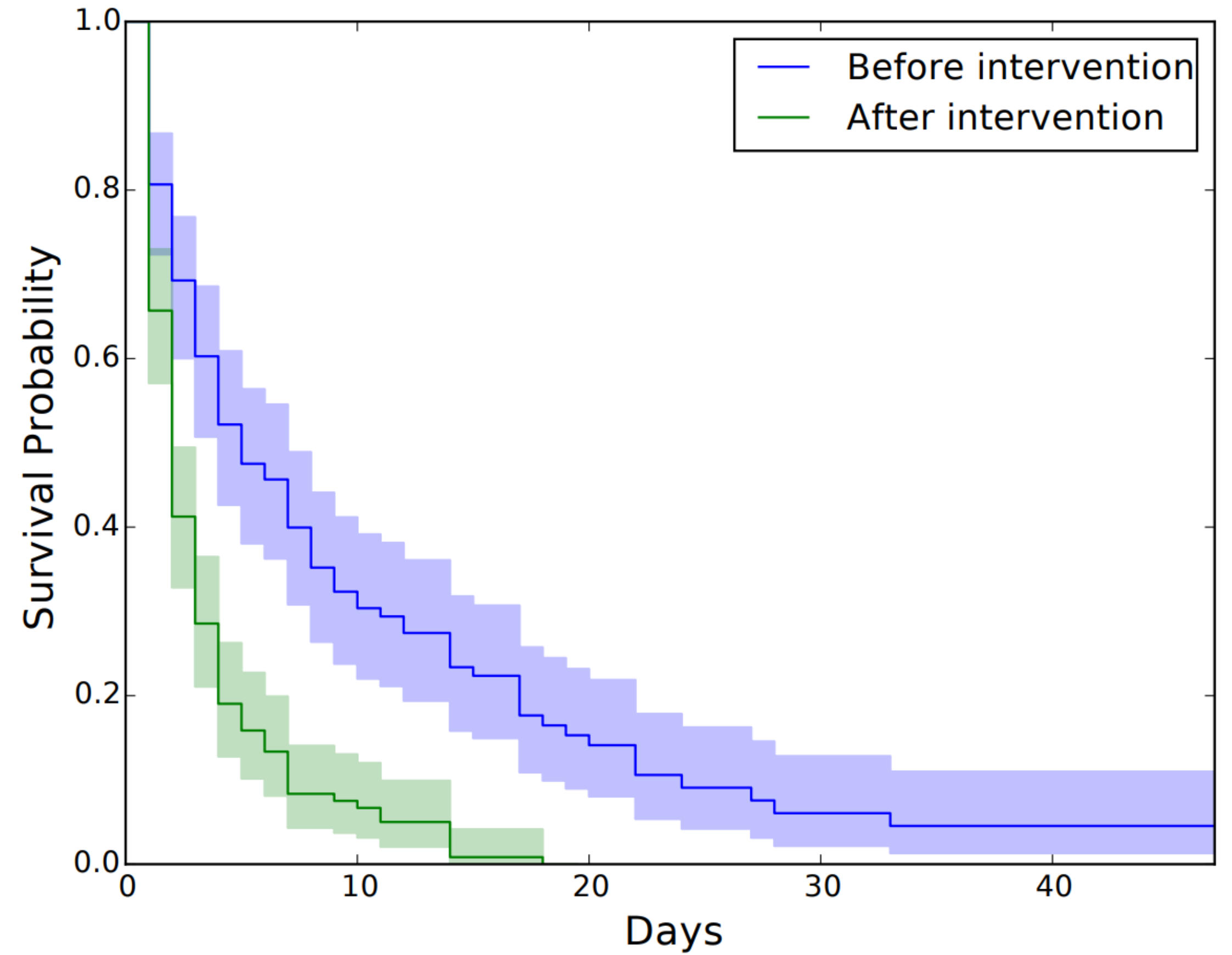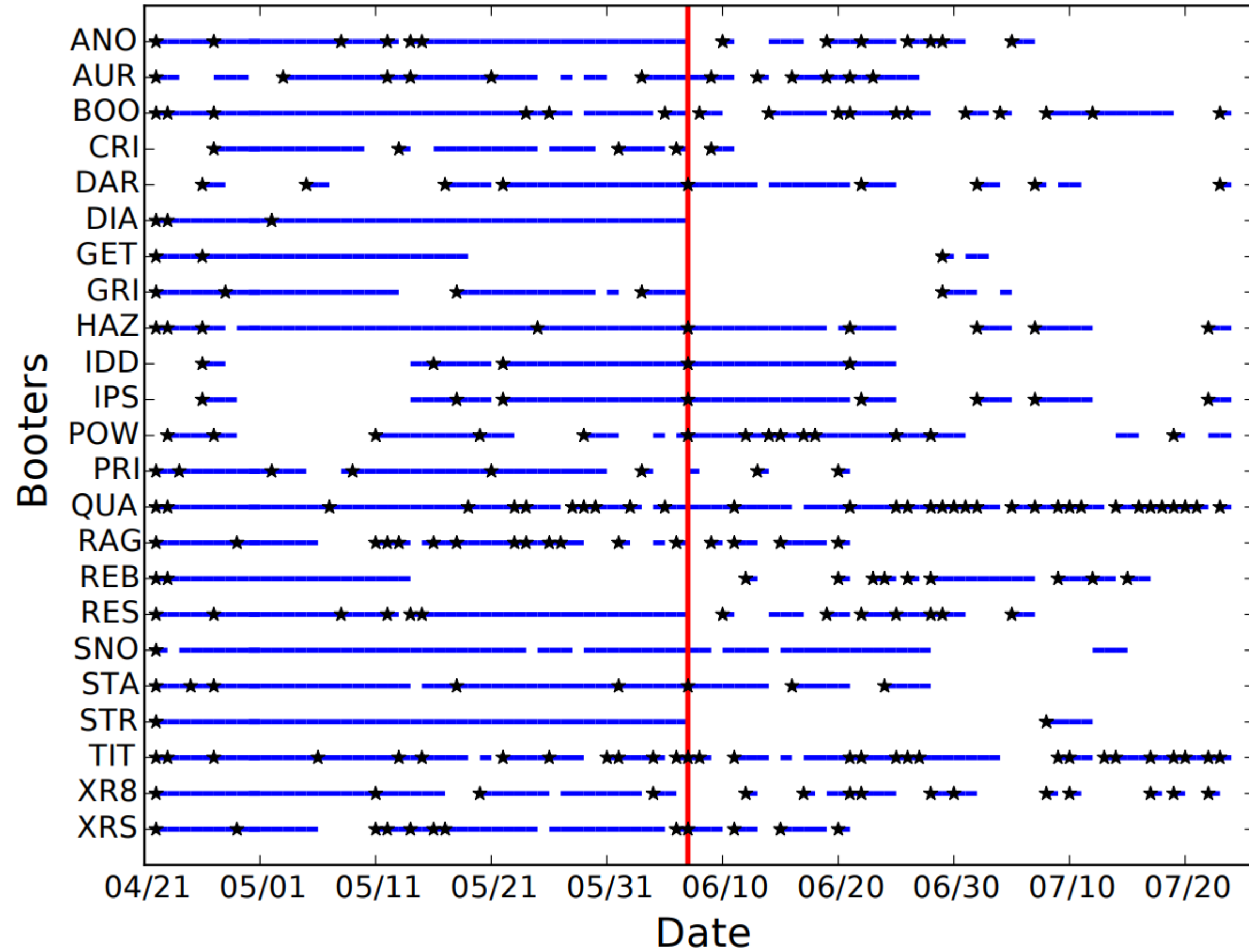
Mitigations

Anti-amplification

Filters

Anti-spoofing

CDNs

Avoid Becoming an Amplifier

- Filter ingress IP broadcasts at the gateway router
  - i.e. drop anything destined to *.*.*.255

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- If you write a UDP service, authenticate the sources of packets
  - TCP is connection-oriented, and thus much less vulnerable
- **Don't be part of the problem!**
  - The behavior of your software and network impacts the well-being of others

Outreach

- Researchers are trying to clean up amplifiers
  - Scan for servers with open services that are possible amplifiers
  - Manually contact server owners, ISPs, and ASs
  - Issue public advisories
  - Get vendors to issue patches that disable services or features by default

Example: NTP *monlist* Cleanup
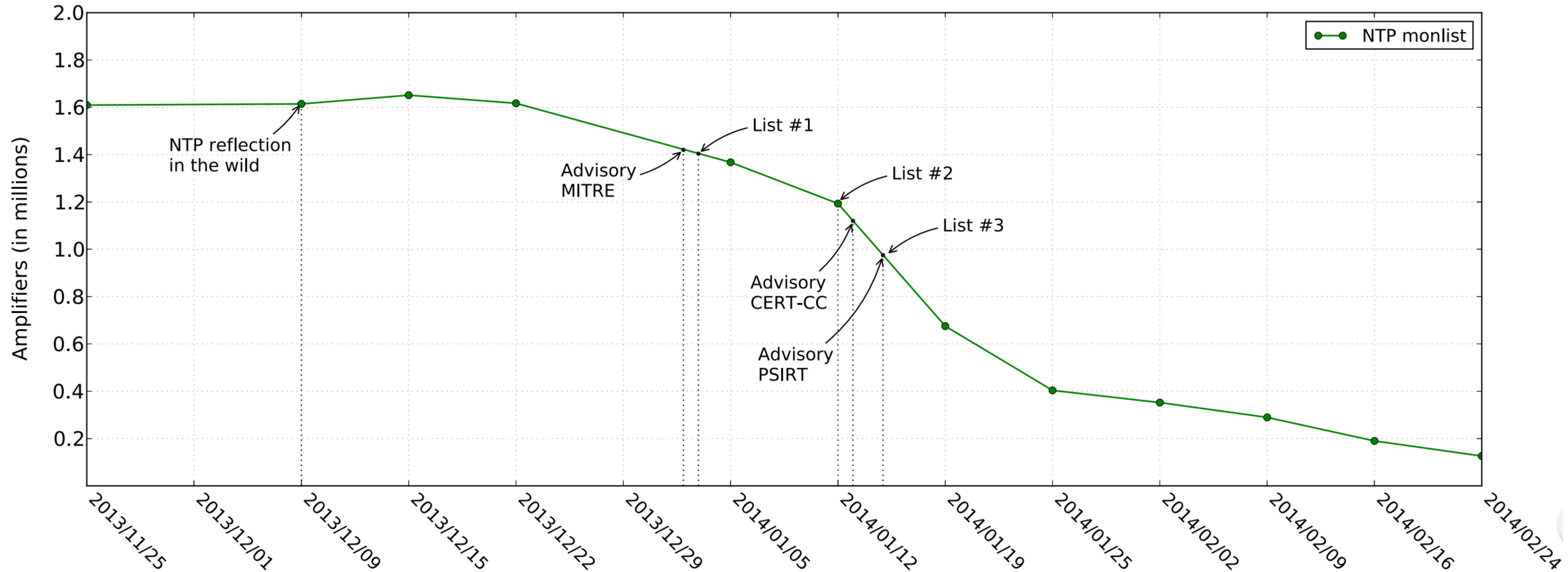
What About Filtering?
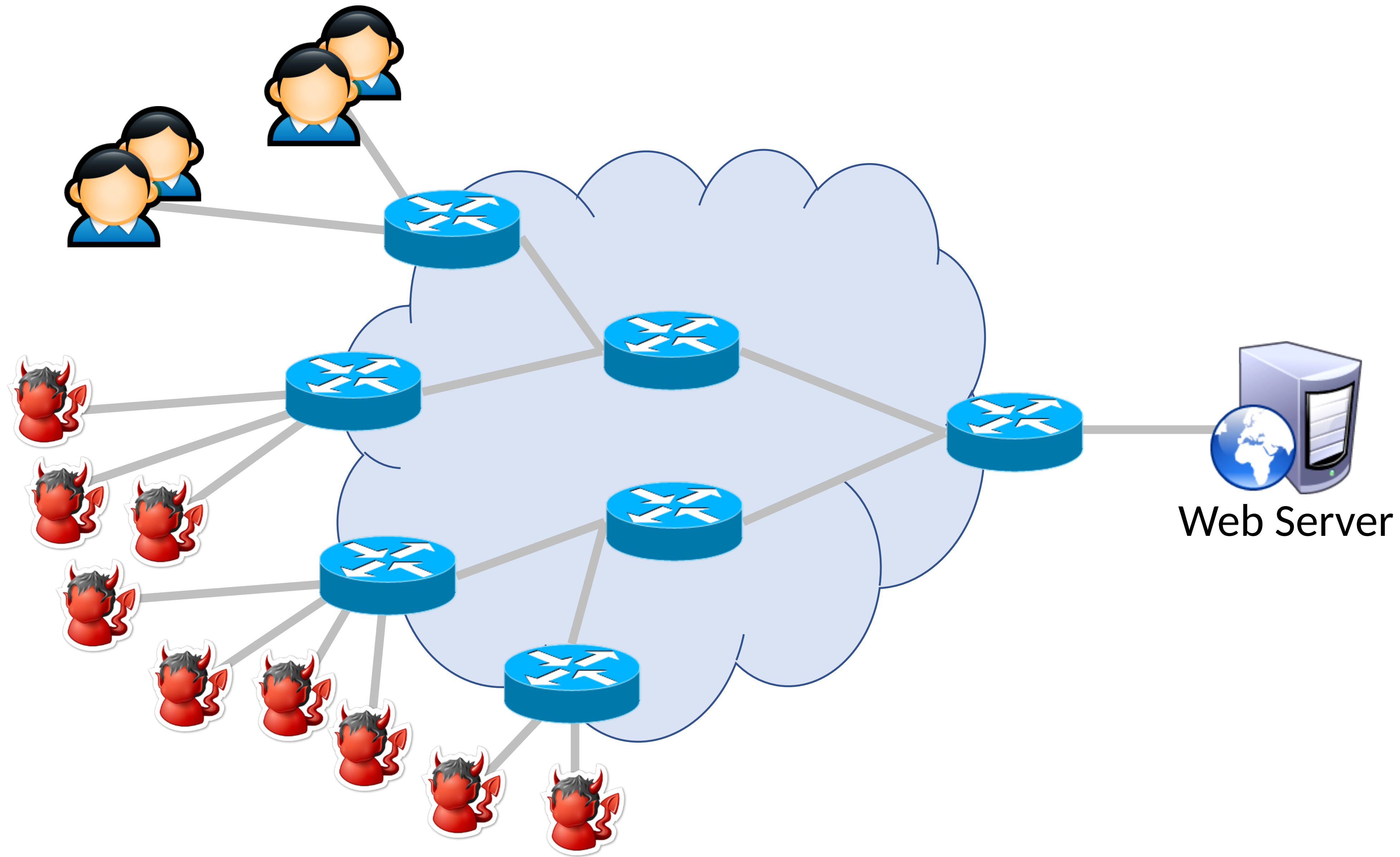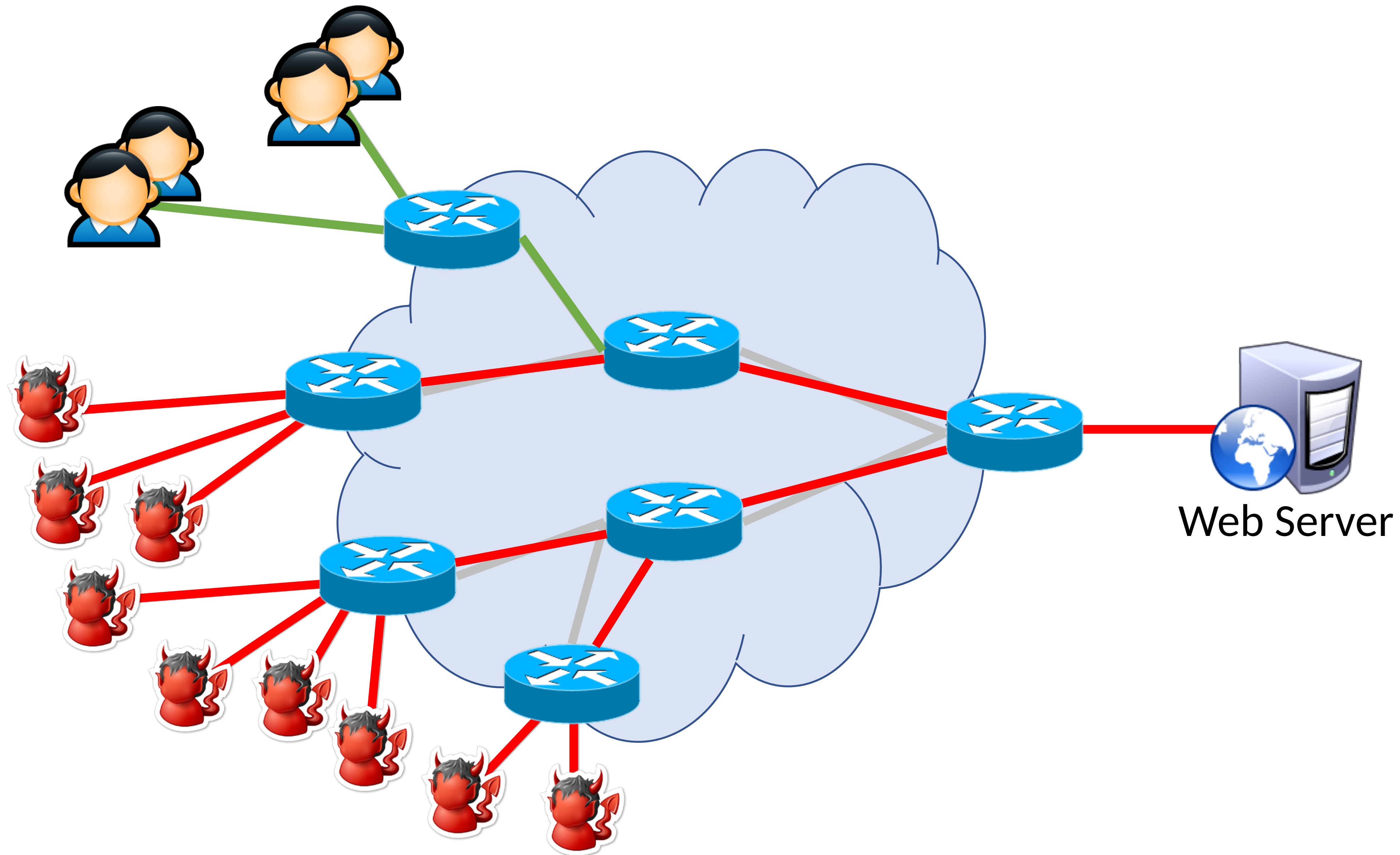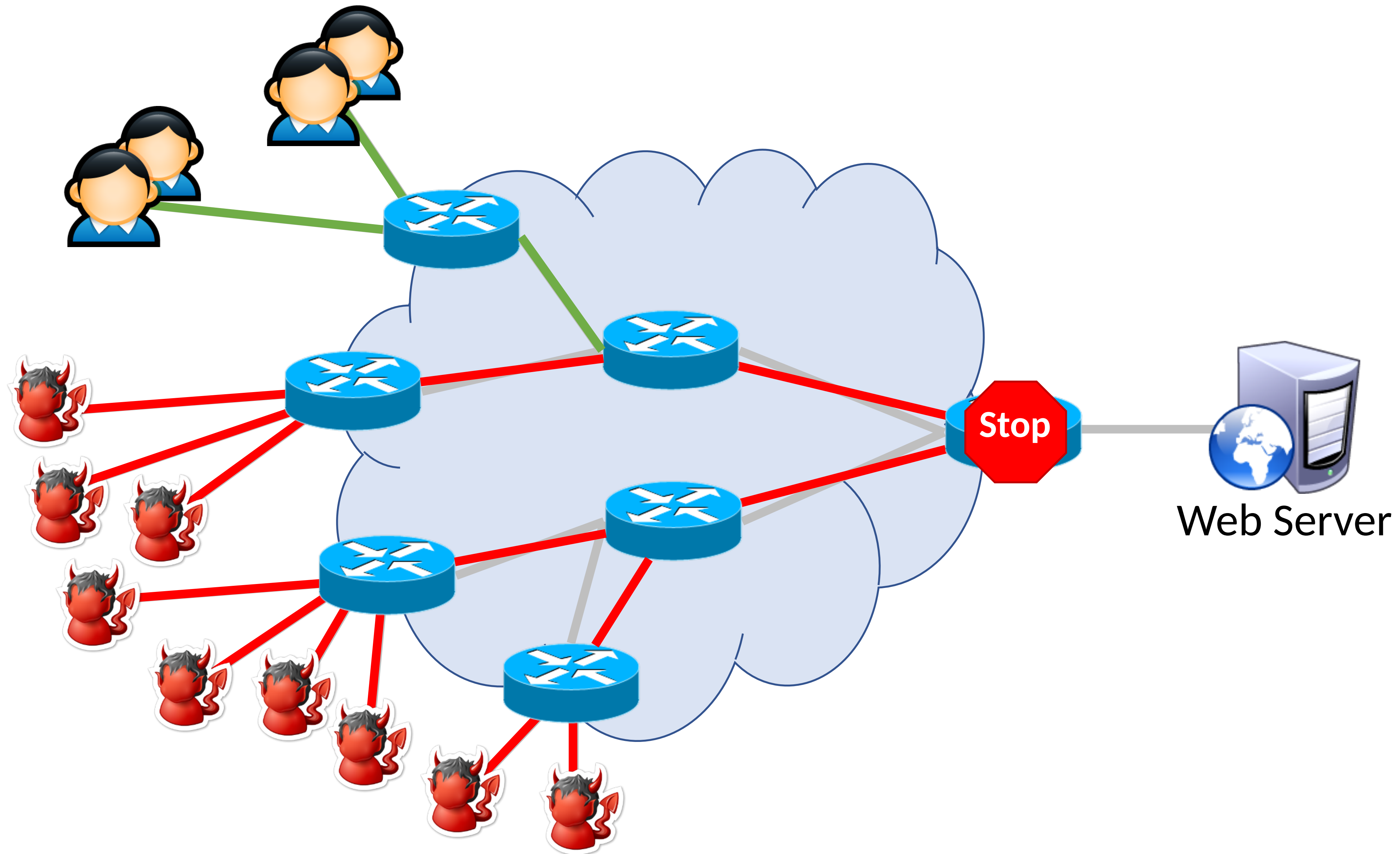
Web Server

What About Filtering?

Web Server

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What About Filtering?

Problems:
1. The ingress links are still saturated
2. No idea where the attack is coming from

Stop

Web Server

What About Filtering?

What About Filtering?

Web Server
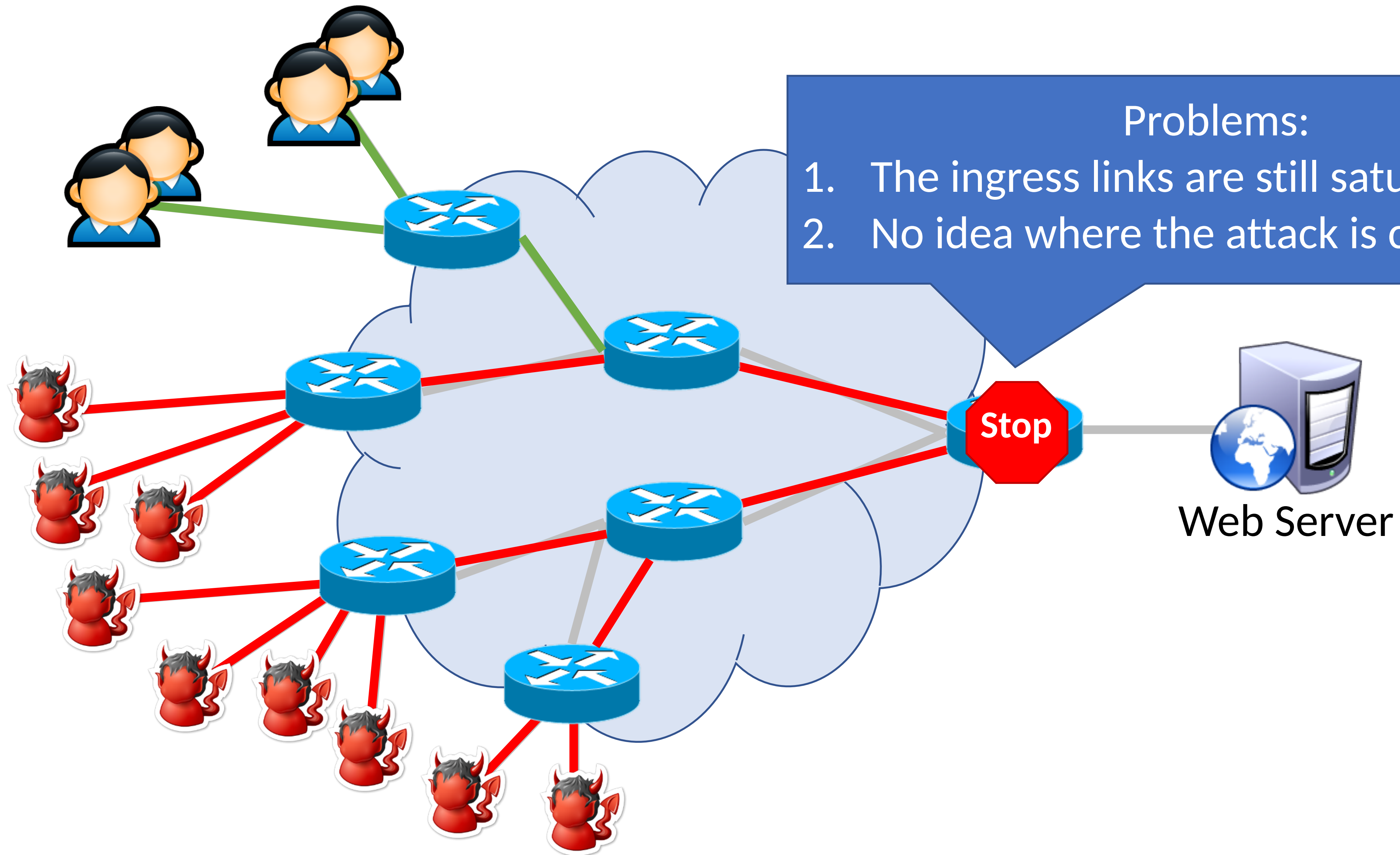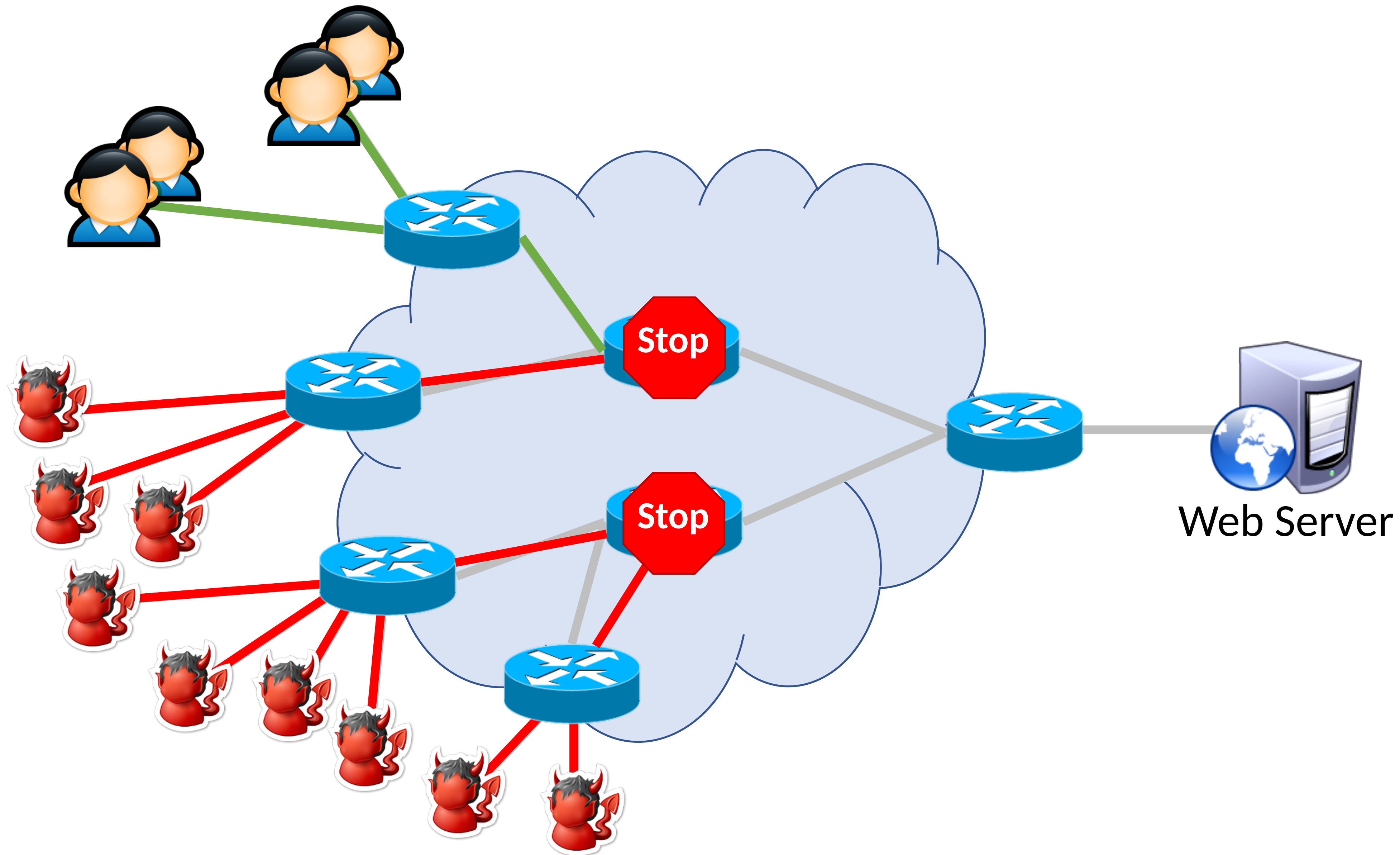
Success! Some of the attack is halted
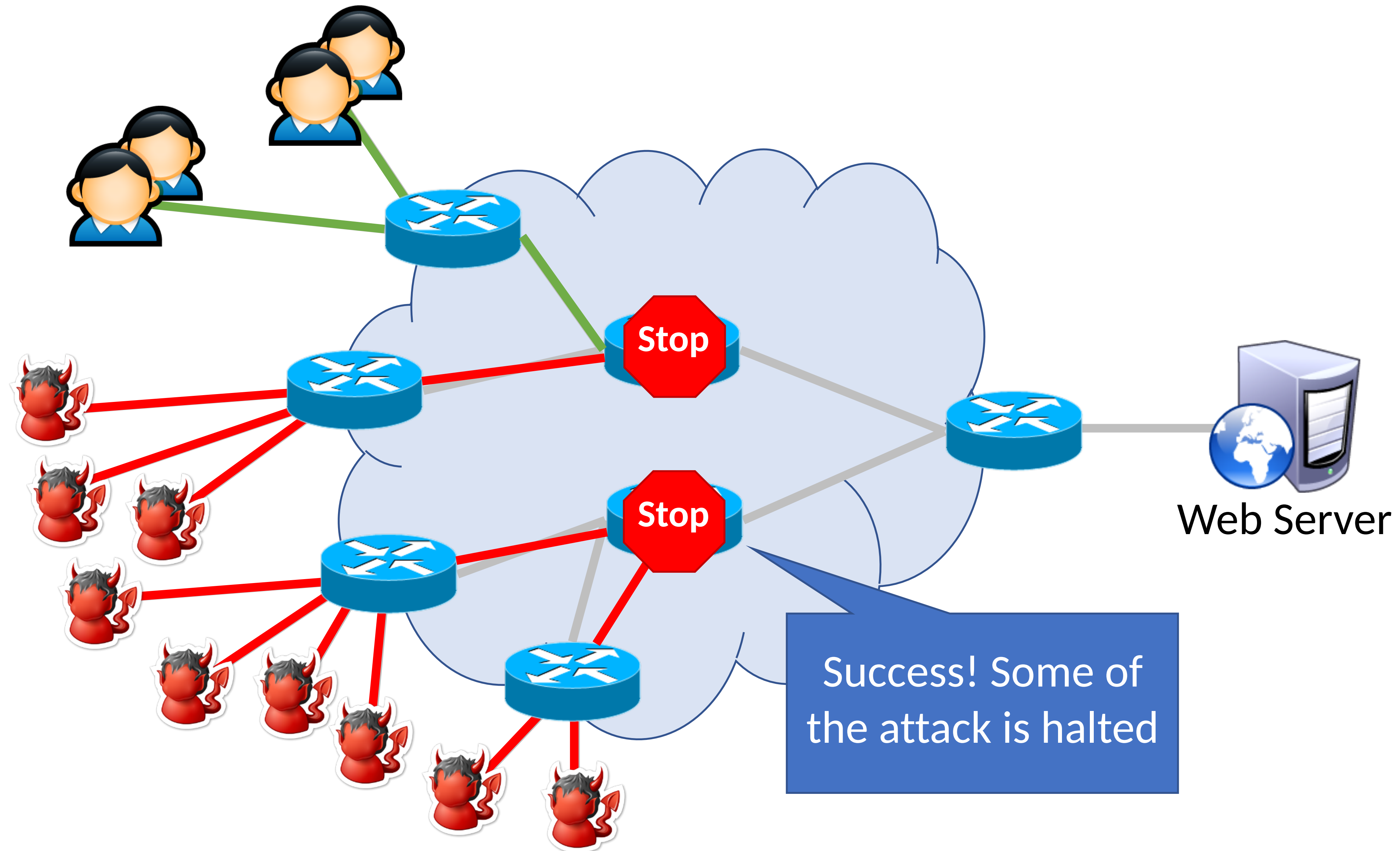
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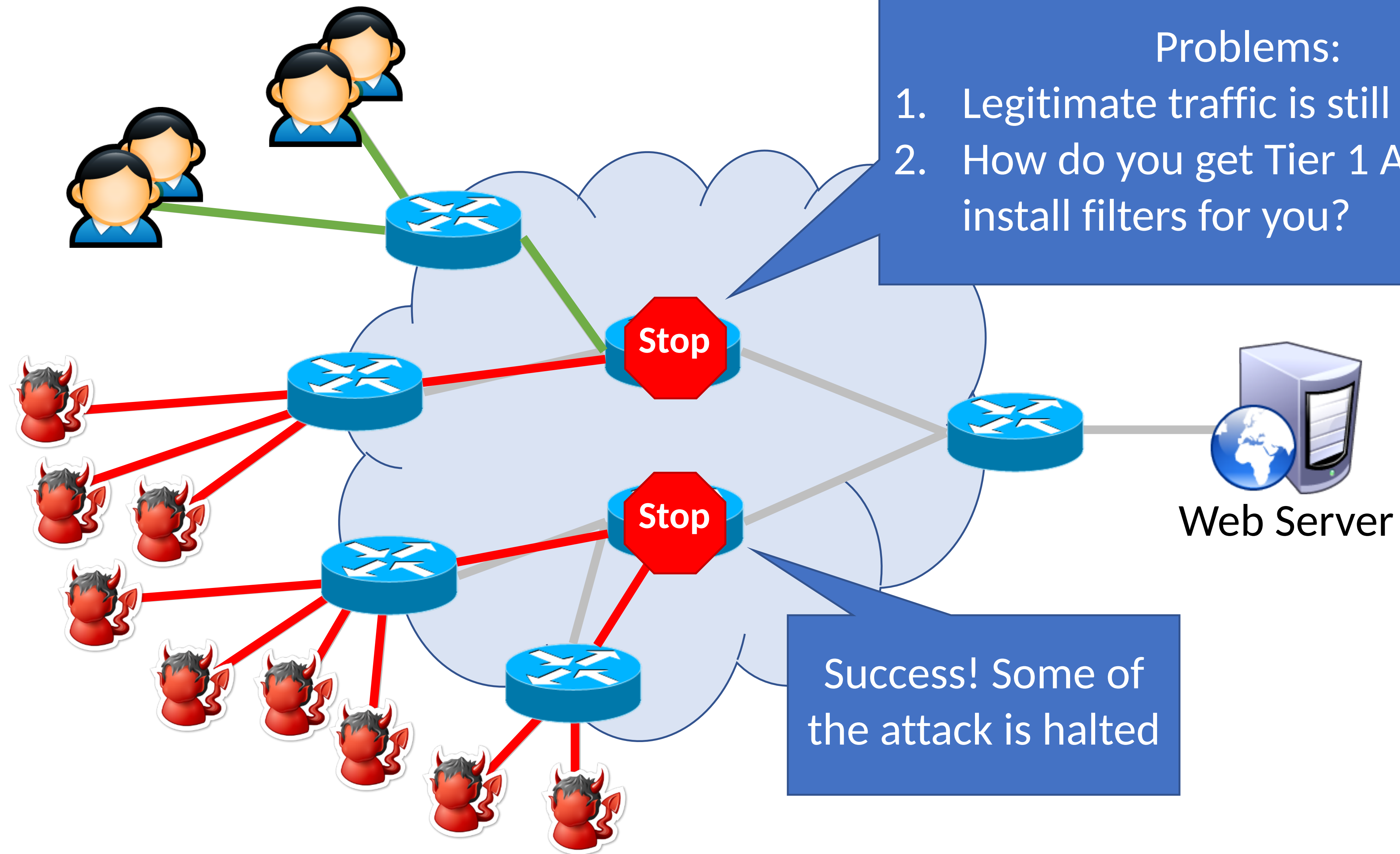
Problems:
1. Legitimate traffic is still blocked
2. How do you get Tier 1 ASs to install filters for you?

Stop

Stop

Web Server

Success! Some of the attack is halted

What About Filtering?

Web Server
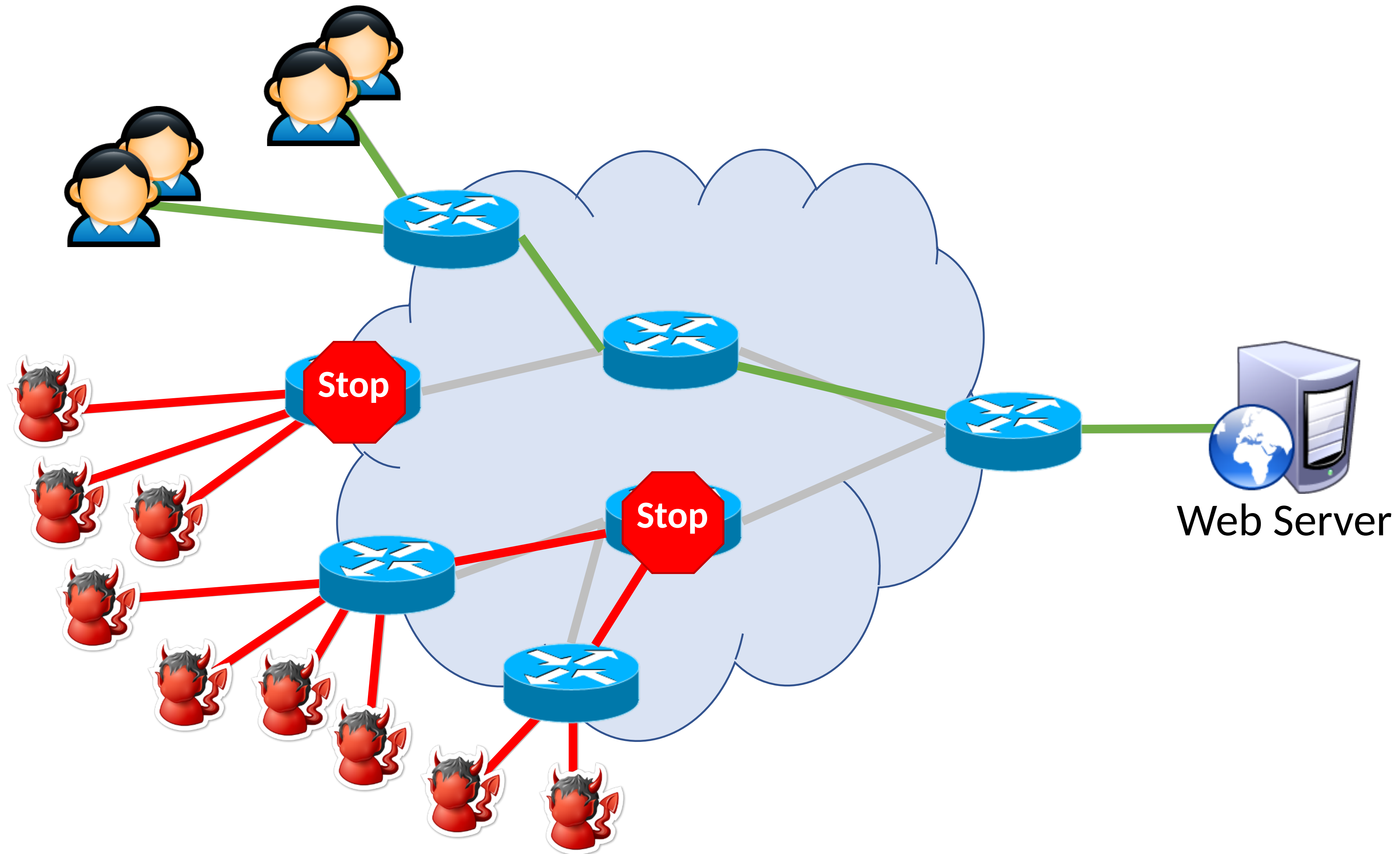
Problems With Filters

- Packet filtering is not a viable solution

- If you install a local filter:
  - Ingress links are still saturated
  - Very hard to distinguish DDoS packets from legitimate requests, since sources are spoofed

- Remote filters work better, but:
  - You still need to track down the source of the attack
  - You have no ability to force ISPs and ASs to install filters on your behalf

In-Network Defenses

- Why don't ISPs/ASs drop spoofed packets?

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- Unicast Reverse Path Forwarding (uRPF)
  - Routers validate the source IP addresses against routing tables
  - "Unlikely" source addresses are dropped

- uRPF modes:
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  - Feasible – may accept spoofed traffic (false negatives)
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- Most ISPs/ASs don't implement uRPF
  - Unwilling to risk false positives from strict mode
  - No incentive to implement security measures

Content Delivery Networks (CDNs)

- CDNs help companies scale-up their websites
  - Cache customer content on many replica servers
  - Users access the website via the replicas
- Examples: Akamai, Cloudflare, Rackspace, Amazon Cloudfront, etc.

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  - Users access the website via the replicas
- Examples: Akamai, Cloudflare, Rackspace, Amazon Cloudfront, etc.
- Side-benefit: DDoS protection
  - CDNs have many servers, and a huge amount of bandwidth
  - Difficult to knock all the replicas offline
  - Difficult to saturate all available bandwidth
  - No direct access to the master server
- Cloudflare: 15 Tbps of bandwidth over 149 data centers
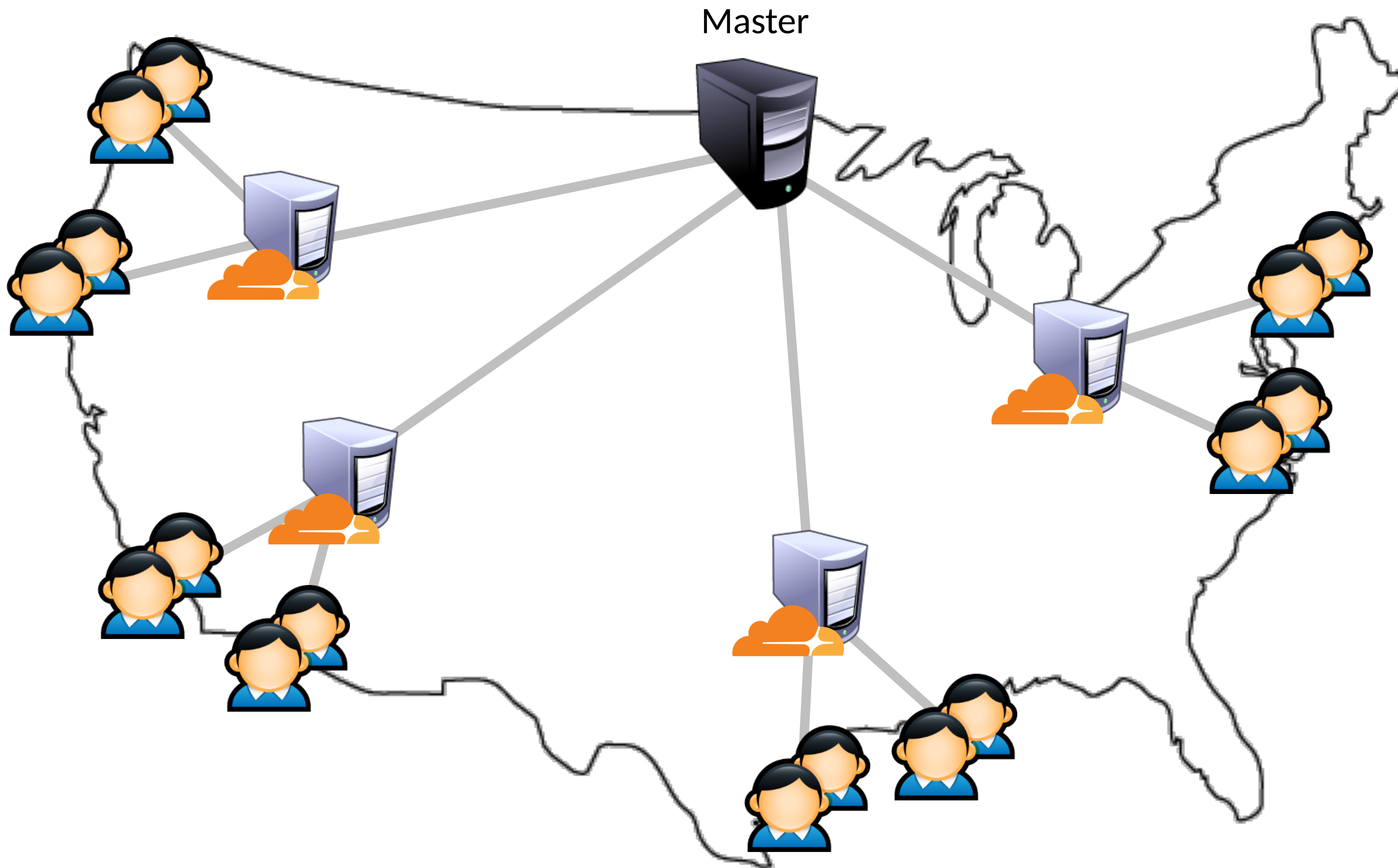
CDN Basics

CDN Basics

Master

Website content and database is here

CDN Basics

Master

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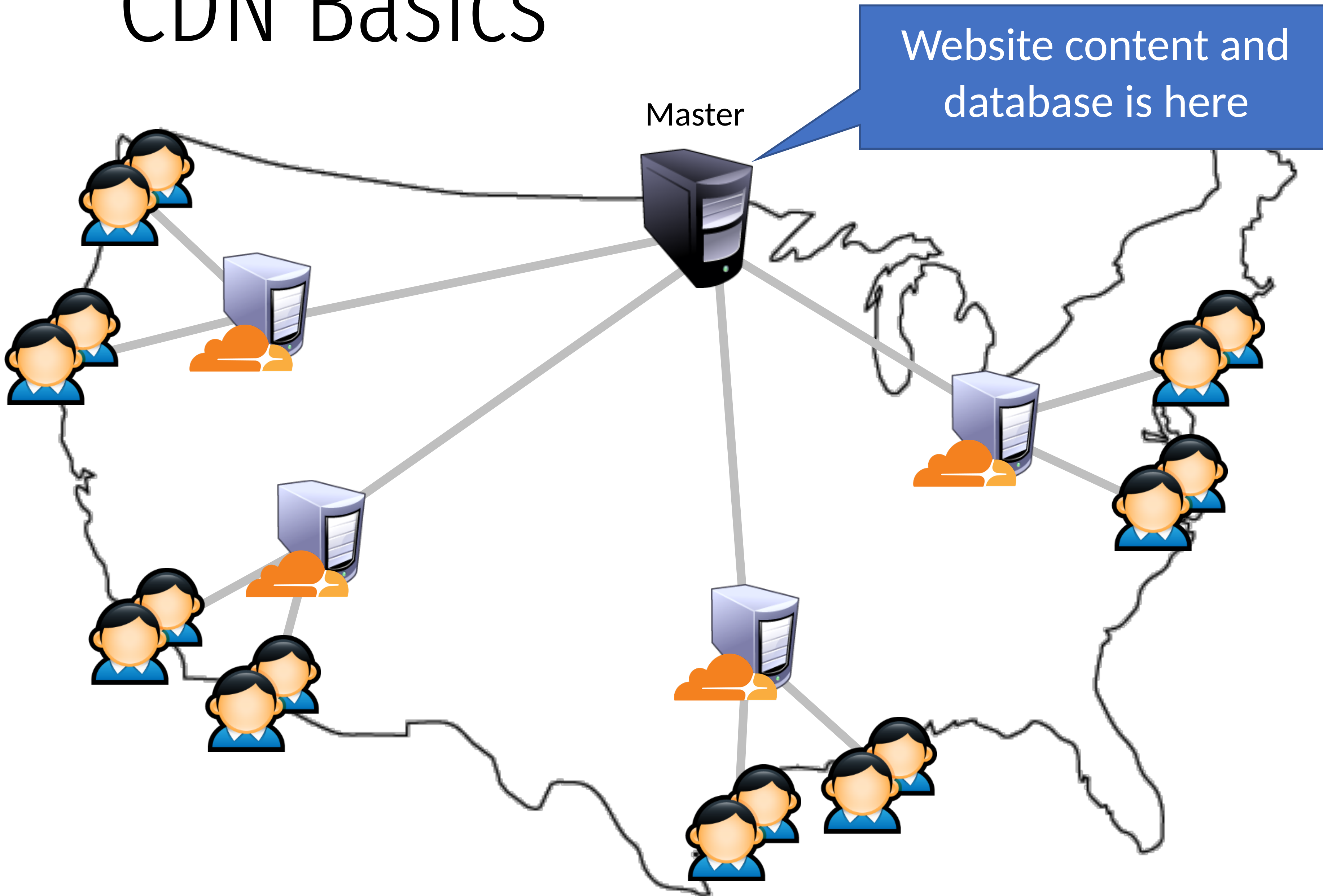
Content is cached in the replicas
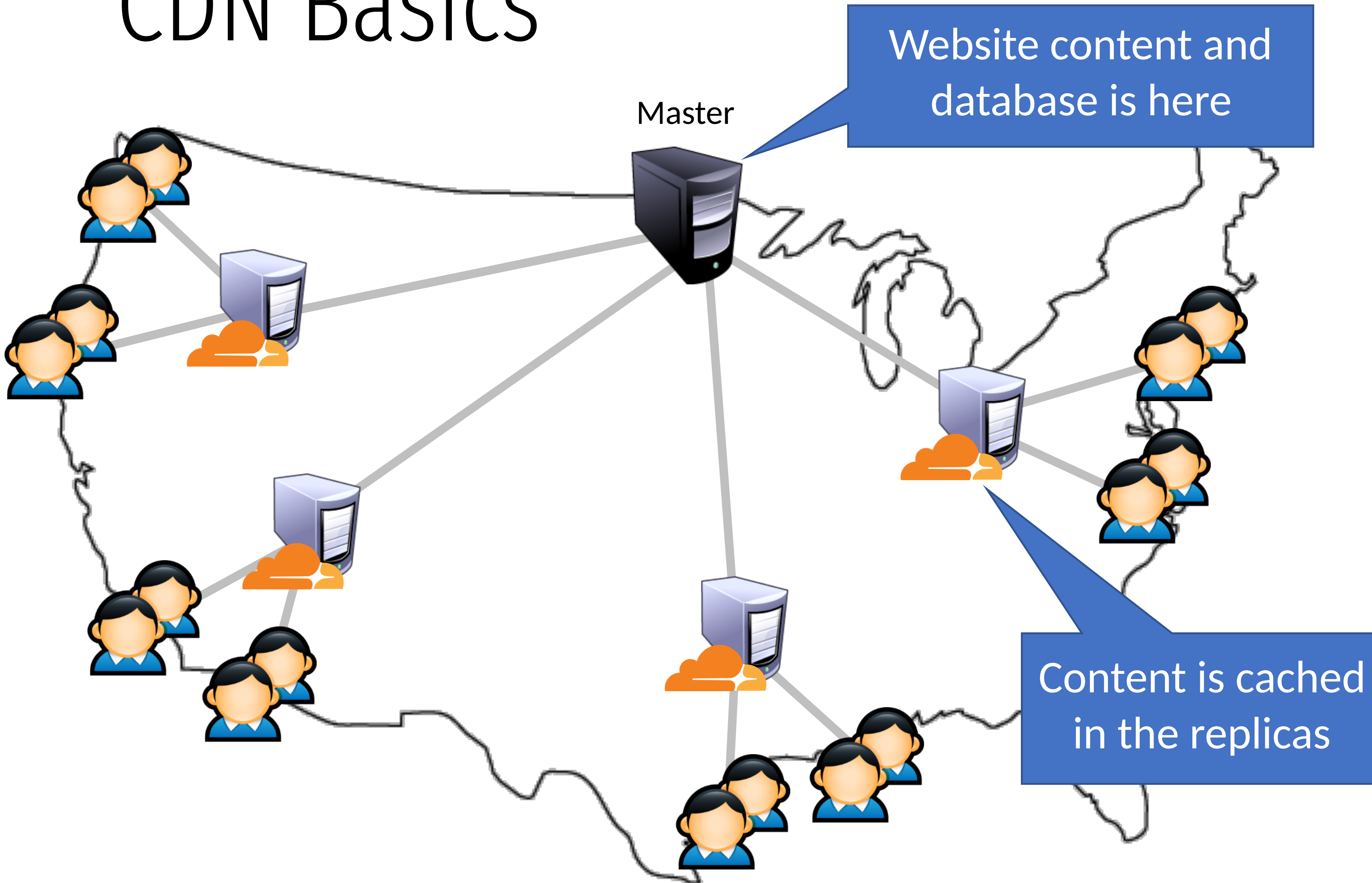
CDN Basics
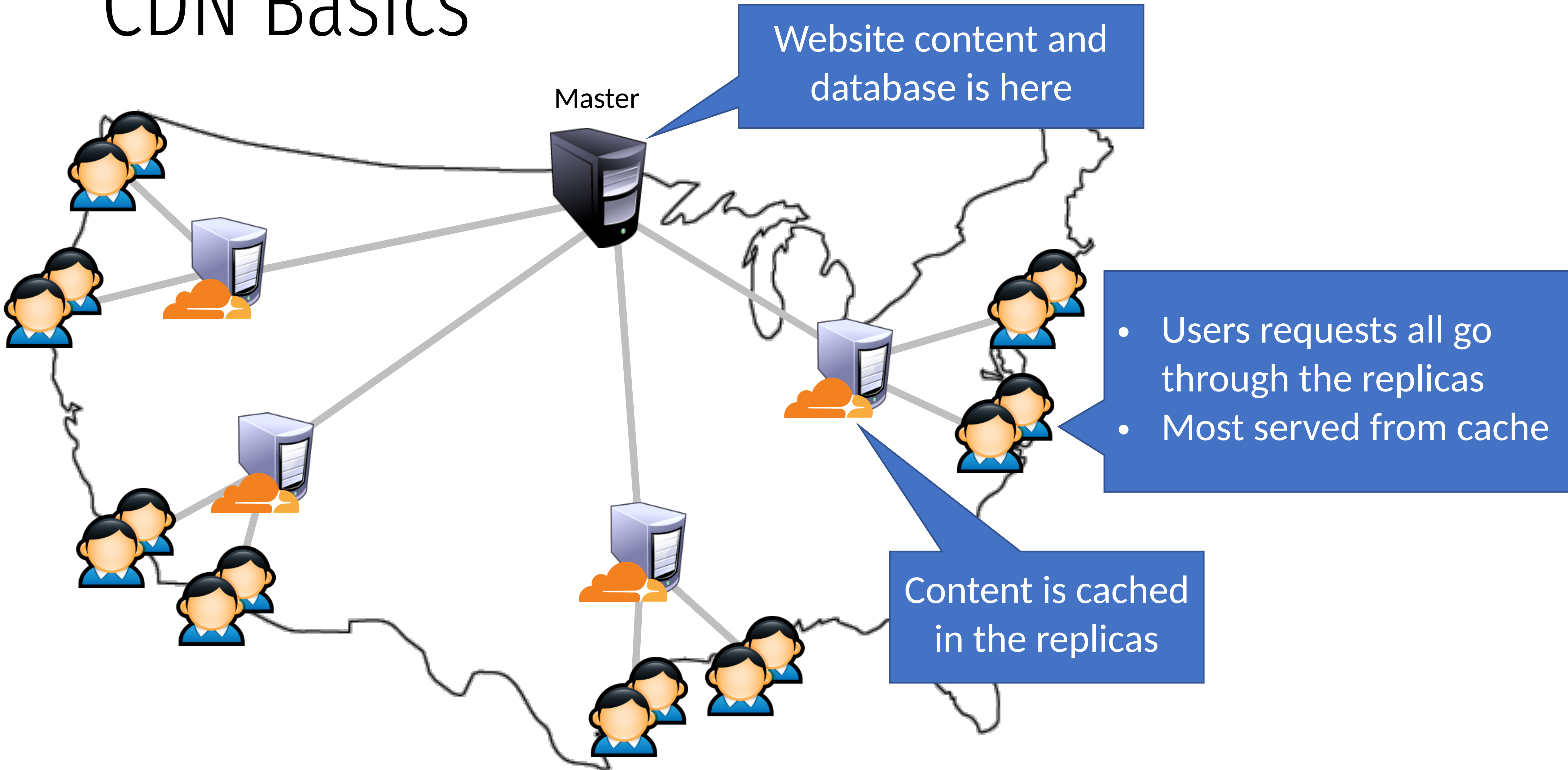
DDoS Defense via CDNs
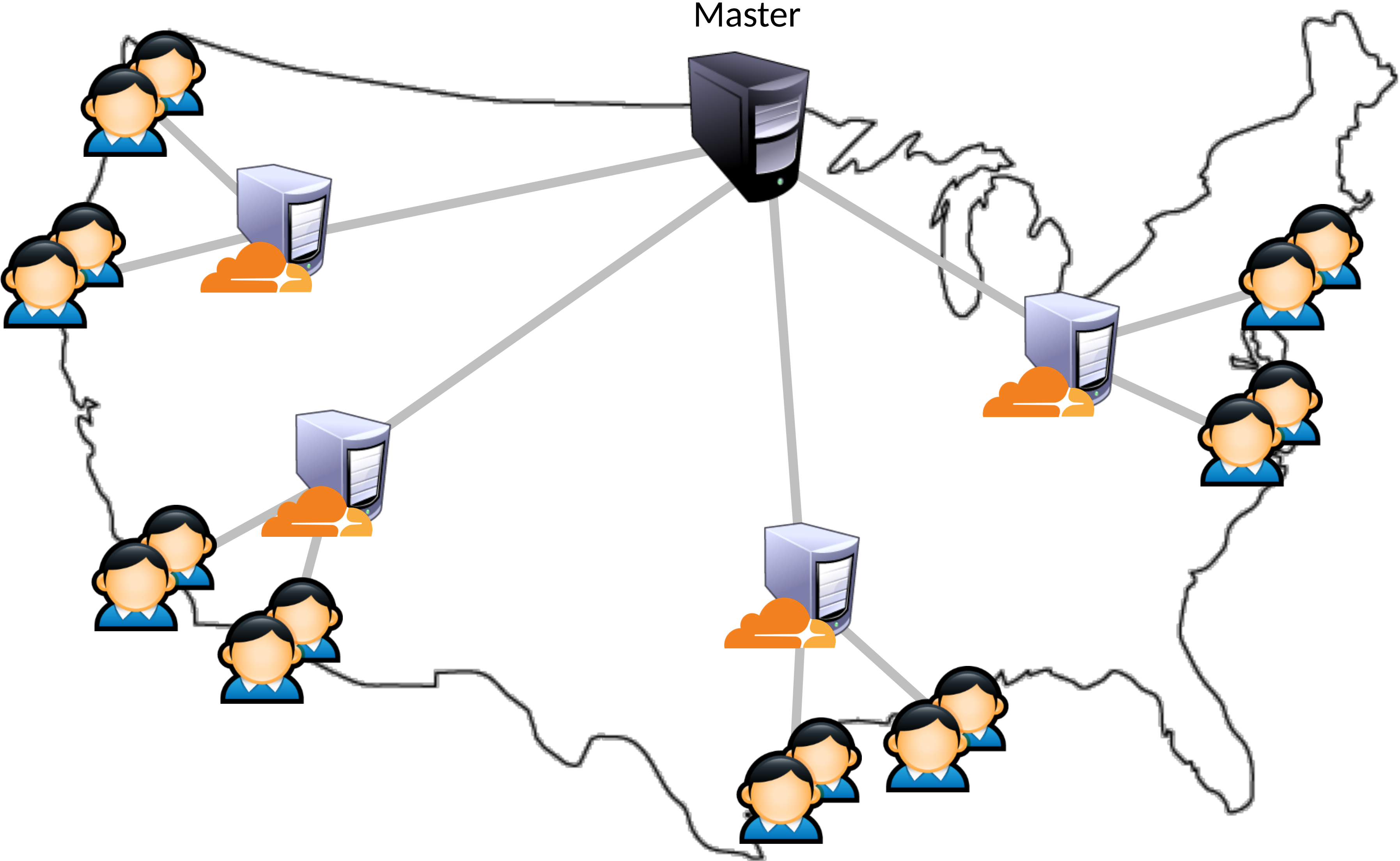
DDoS Defense via CDNs
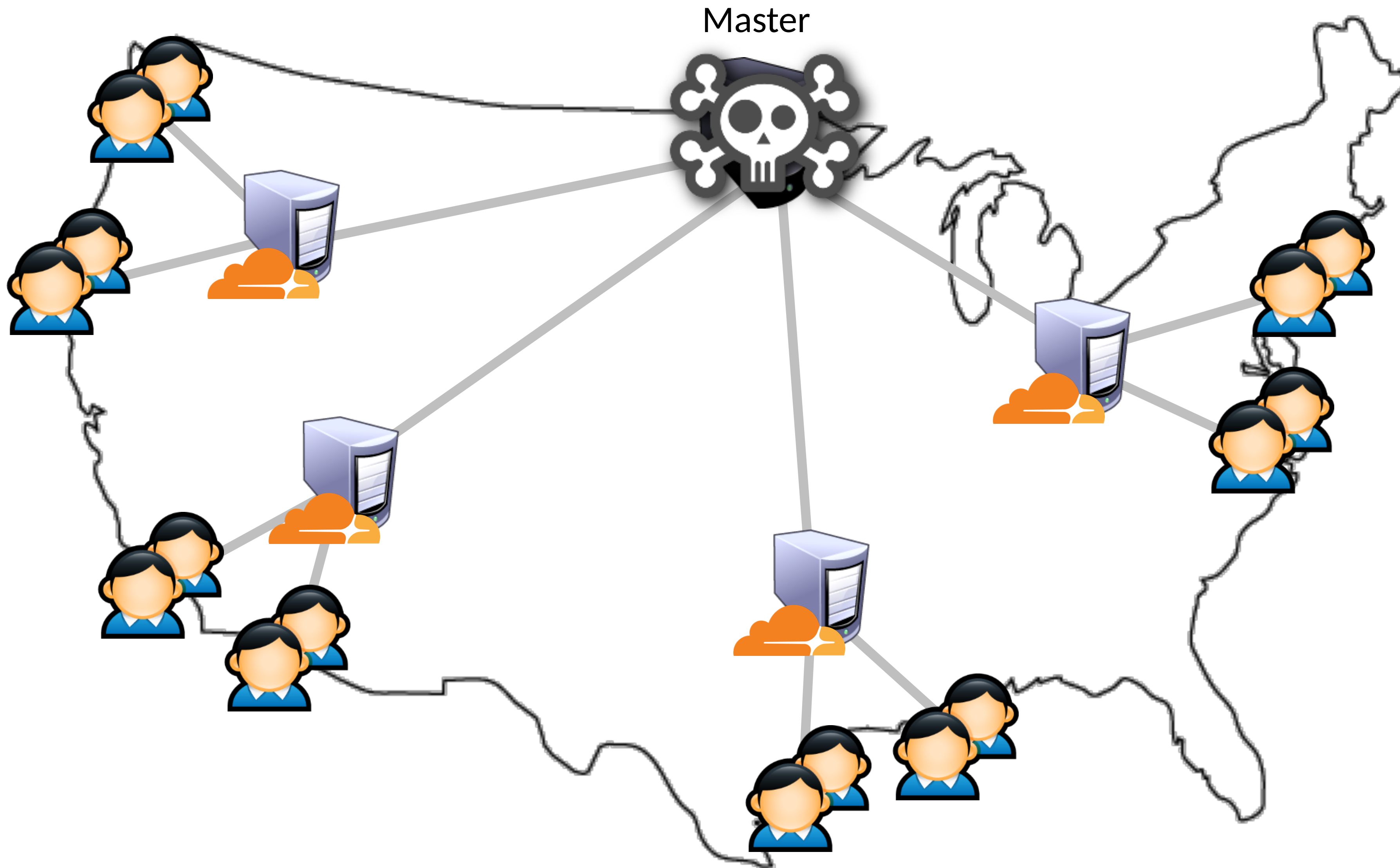
Master

- What if you DDoS the master replica?

DDoS Defense via CDNs
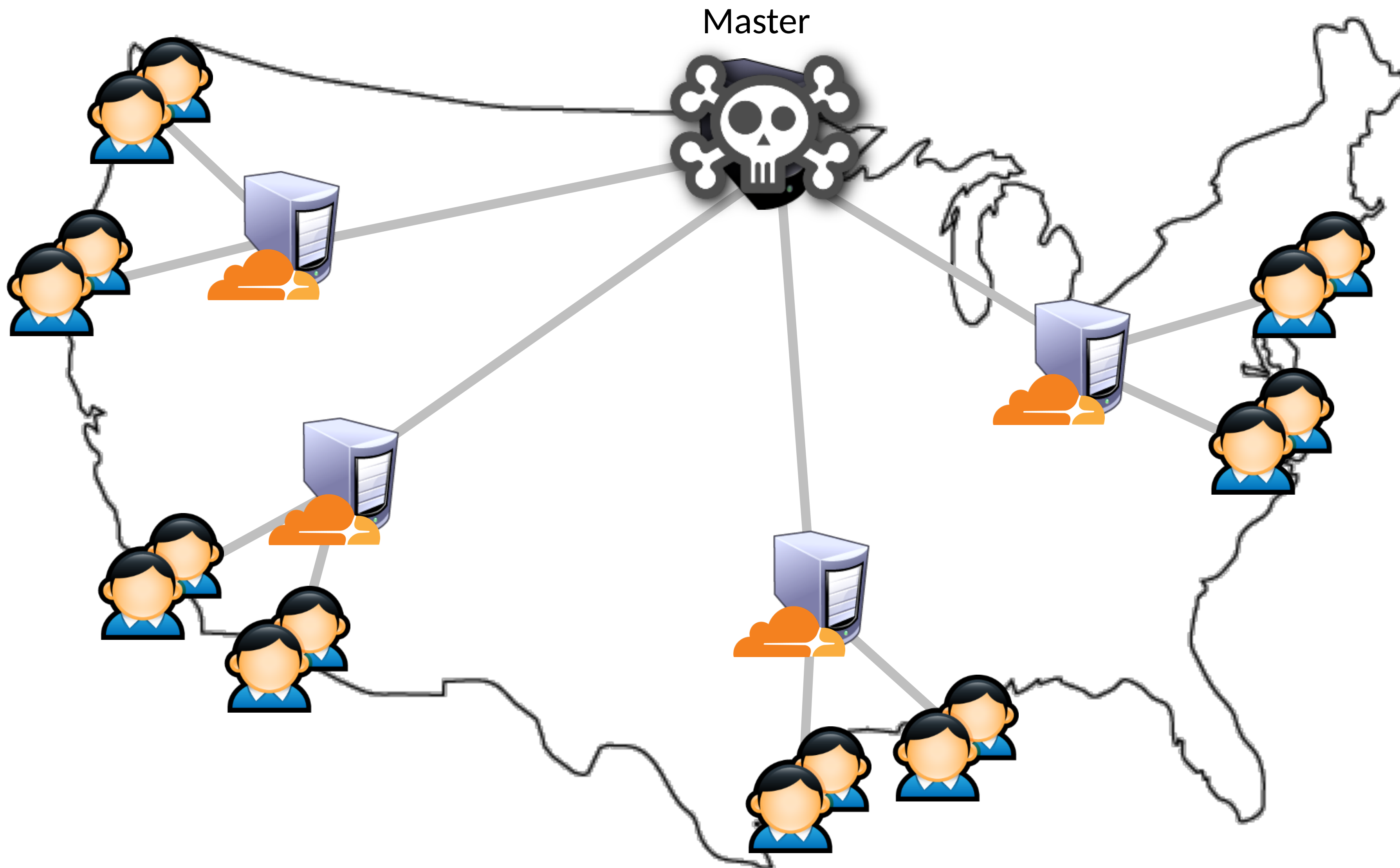
Master

- What if you DDoS the master replica?
  - Cached copies in the CDN still available
  - Easy to do ingress filtering at the master

DDoS Defense via CDNs
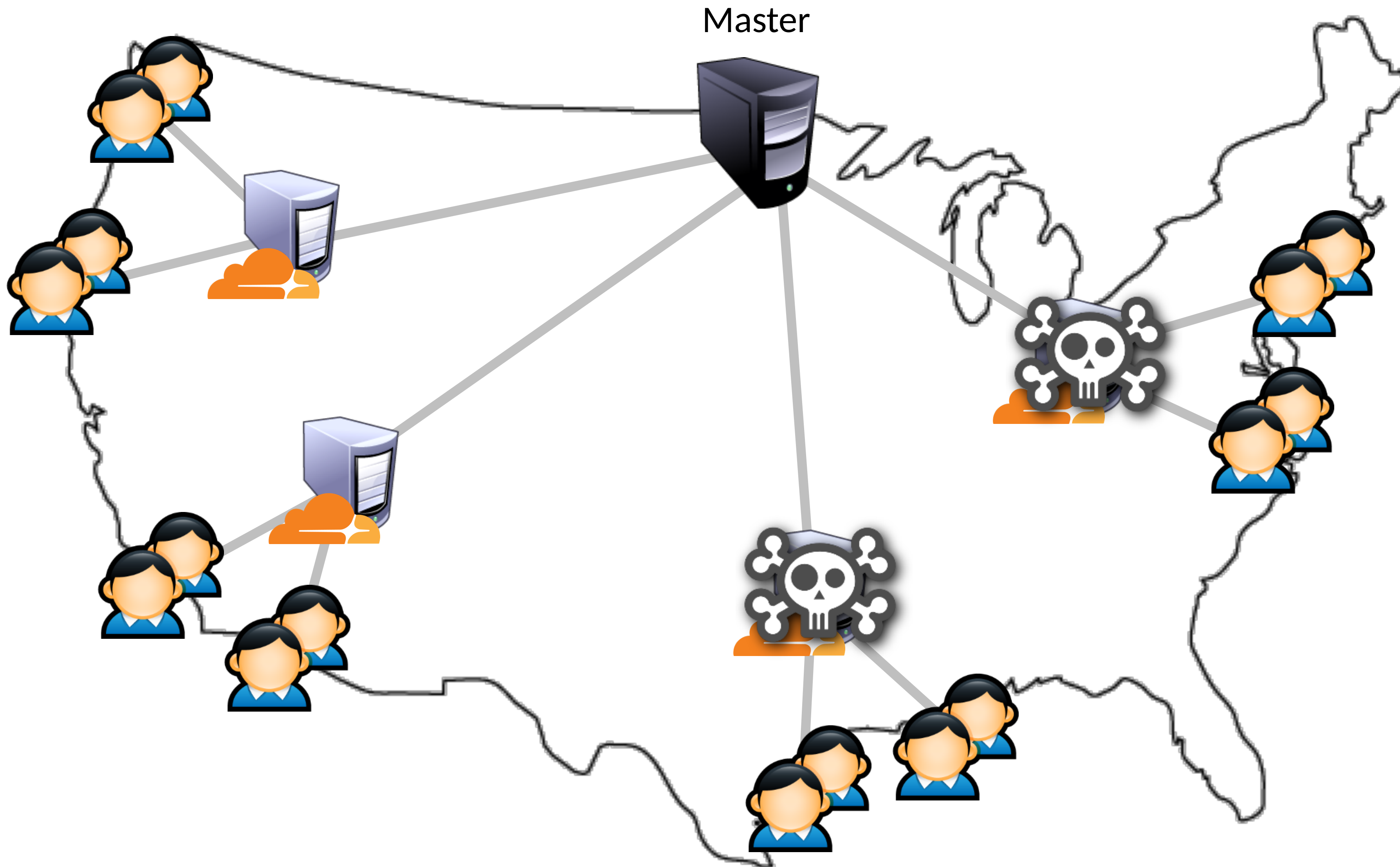
Master

- What if you DDoS the master replica?
  - Cached copies in the CDN still available
  - Easy to do ingress filtering at the master
- What if you DDoS the replicas?

DDoS Defense via CDNs
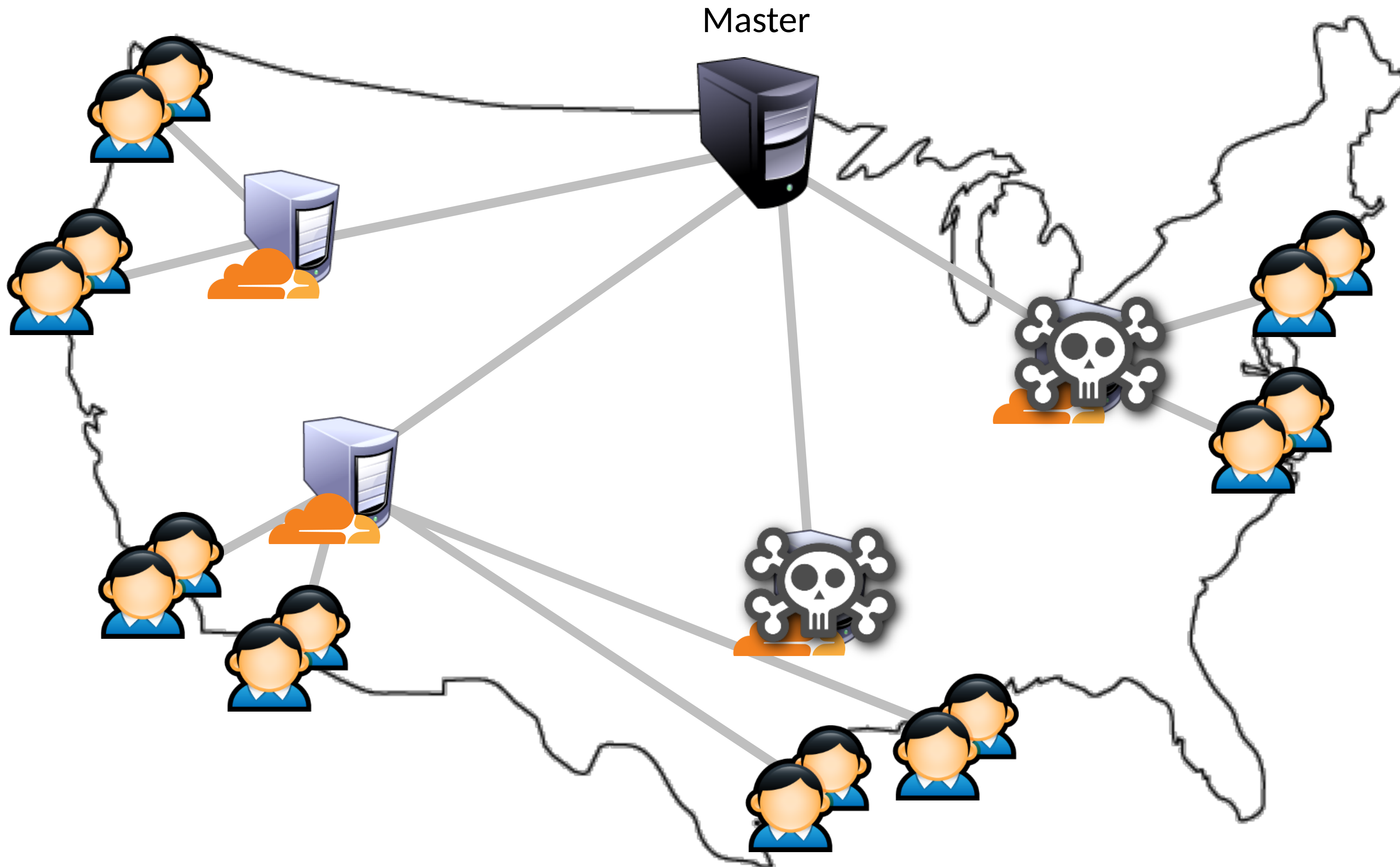
Master

- What if you DDoS the master replica?
  - Cached copies in the CDN still available
  - Easy to do ingress filtering at the master
- What if you DDoS the replicas?
  - Difficult to kill them all
  - Dynamic DNS can redirect users to live replicas

Sources

Stress Testing the Booters: Understanding and Undermining the Business of DDoS Services -- https://dl.acm.org/citation.cfm?id=2883004

Taming the 800 Pound Gorilla: The Rise and Decline of NTP DDoS Attacks -- https://dl.acm.org/citation.cfm?id=2663717

Exit from Hell? Reducing the Impact of Amplification DDoS Attacks -- https://www.usenix.org/system/files/conference/usenixsecurity14/sec14-paper-kuhrer.pdf

Review

Our main topics

Cryptography

Authentication, passwords

Authorization

Ethics and cyberlaw

Social engineering

Systems security

Exploits:

Crimeware, Botnets:

Cryptography

Privacy:

Authenticity:

Hashing:

Passwords and Authentication

What is authentication?

Classes of secrets?

Methods and attacks against passwords?

Authorization

Basics of an access control check

Access Control Check

- Given an access request from a subject, on behalf of a principal, for an object, return an access control decision based on the policy

Authorization

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Object

Allow

Principal   Subject

Deny
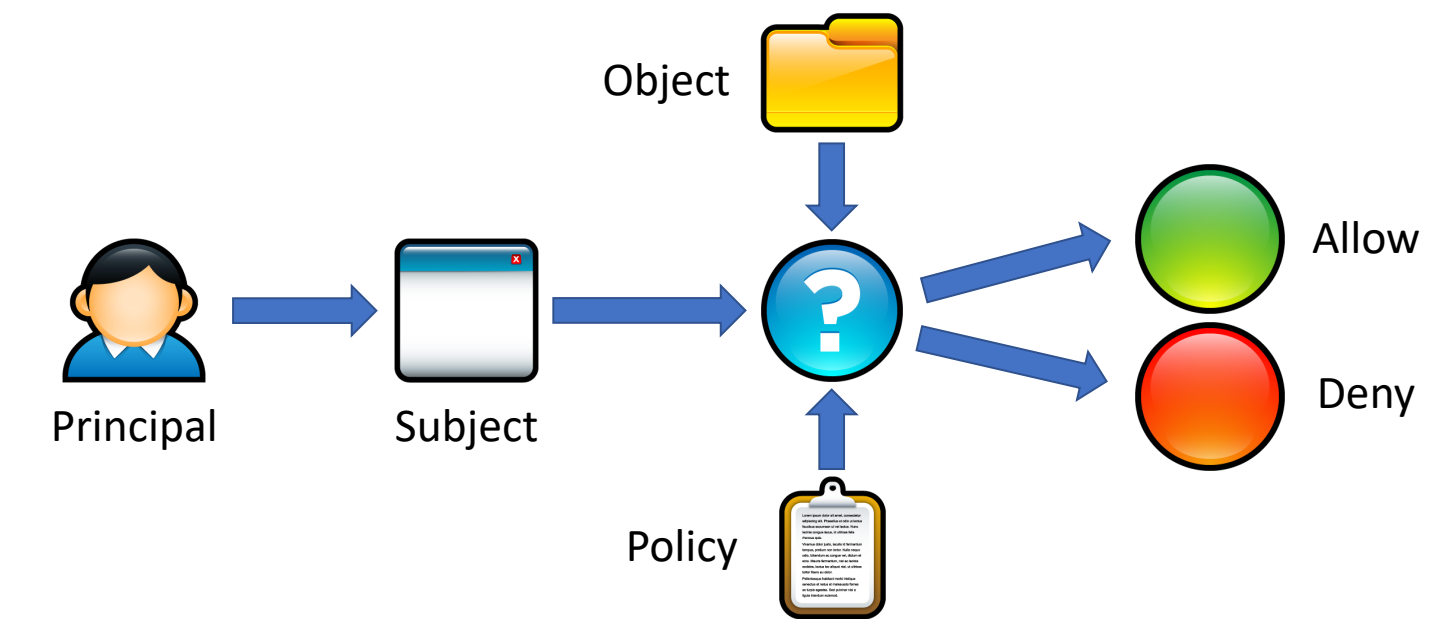
Policy
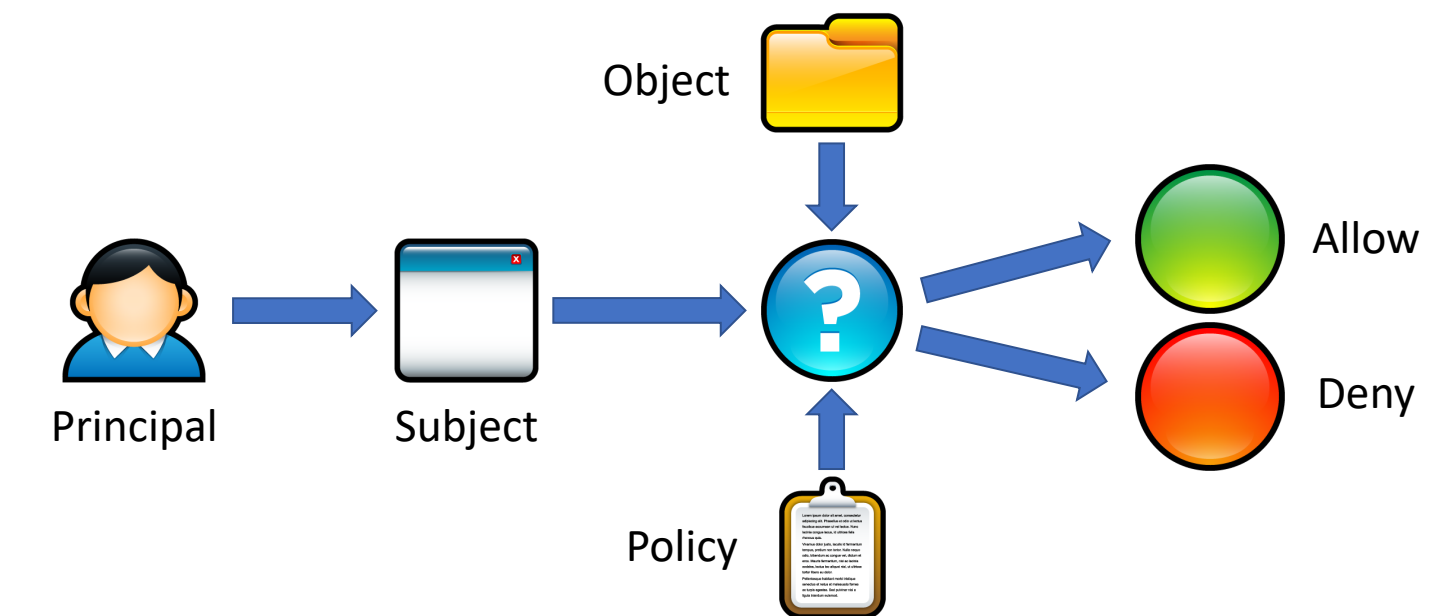
Two types

Access Control Models

- Discretionary Access Control (DAC)
  - The kind of access control you are familiar with
  - Access rights propagate and may be changed at subject's discretion
  - Implemented in Windows and Linux
  - Main issues:
    - Ambient authority (subjects inherit all permissions of principals)
    - Confused deputies (subject doesn't know which principal it serves); setuid

- Mandatory Access Control (MAC)
  - Access of subjects to objects is based on a system-wide policy managed by admin ∂
  - Denies users full control over resources they create
  - Bell-LaPadula: MAC for confidentiality (uses Multi Level Security)
  - Biba: MAC for integrity
  - Main issues:
    - Inflexible and complicated to manage
    - Do not prevent side channel attacks

Cybersecurity and Ethics

- Many laws govern cybersecurity
  - Designed to help prosecute criminals
  - Discourage destructive or fraudulent activities
- However, these laws are broad and often vague
  - Easy to violate these laws accidentally
  - Security professionals must be cautious and protect themselves

- Cybersecurity raises complex ethical questions
  - When and how to disclose vulnerabilities
  - How to handle leaked data
  - Line between observing and enabling crime
  - Balancing security vs. autonomy
- Ethical norms must be respected
  - Rights and expectations of individuals and companies
  - Community best-practices

Social Engineering

1. Cognitive vulnerabilities
    - Subconscious decisions may be made before you are consciously aware
    - Behavioral, social, memory biases

2. Social engineering tactics
    - Weaponizing cognitive vulnerabilities
    - Pretexting and framing
    - Elicitation and persuasion

3. Social engineering attacks
    - Baiting, Tailgating
    - Phishing, spear phishing
    - CEO fraud
    - Scareware

System Security: Attack Surfaces

- Steal the device and use it

- Social Engineering
  - Trick the user into installing malicious software
  - Spear phishing

- OS-level attacks
  - Backdoor the OS
  - Direct connection via USB
  - Exploit vulnerabilities in the OS or apps (e.g. email clients, web browsers)

- Network-level attacks
  - Passive eavesdropping on the network
  - Active network attacks (e.g. man-in-the-middle)

Modern defense: Isolation

Rings:

Most modern CPUs support protected mode

x86 CPUs support three rings with different privileges
- Ring 0: Operating System
  - Code in this ring may directly access any device
- Ring 1, 2: device drivers
  - Code in these rings may directly access some devices
  - May not change the protection level of the CPU
- Ring 3: userland
  - Code in this ring may not directly access devices
  - All device access must be via OS APIs
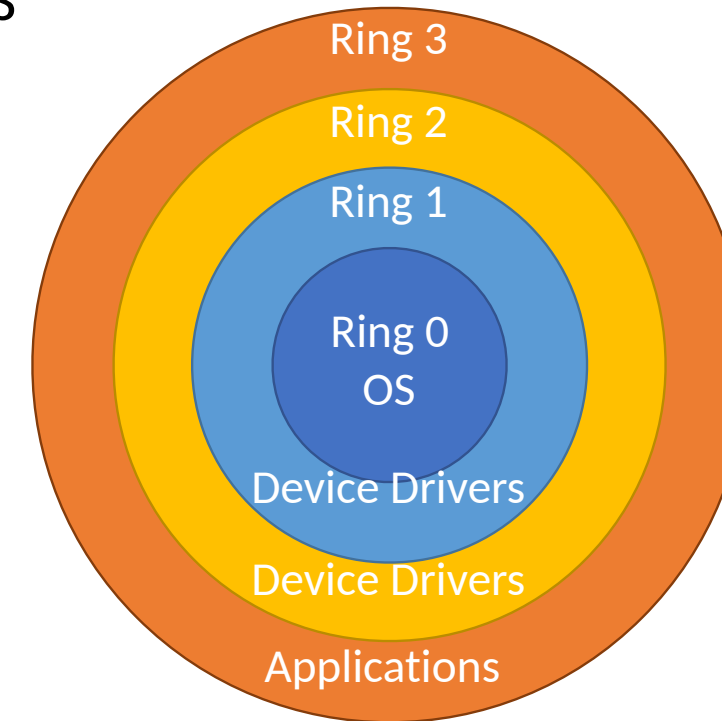 - May not change the protection level of the CPU

Modern defense: Isolation

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Ring 3
Ring 2
Ring 1
Ring 0
OS
Device Drivers
Device Drivers
Applications

Virtual Memory:

Physical Memory   Virtual Memory Process 1   Virtual Memory Process 2

4 GB   4 GB   4 GB

OS

Chrome believes it is the only thing in memory

Skype believes it is the only thing in memory

0   0   0
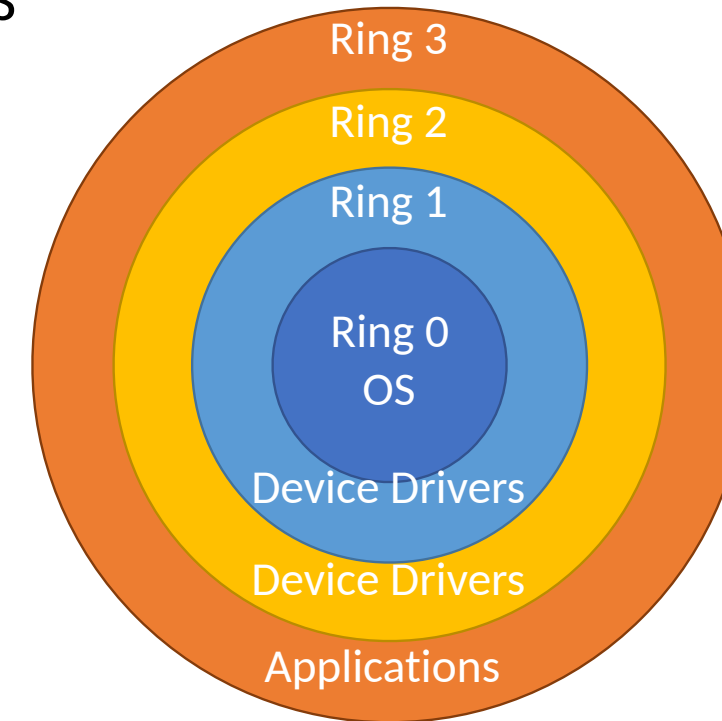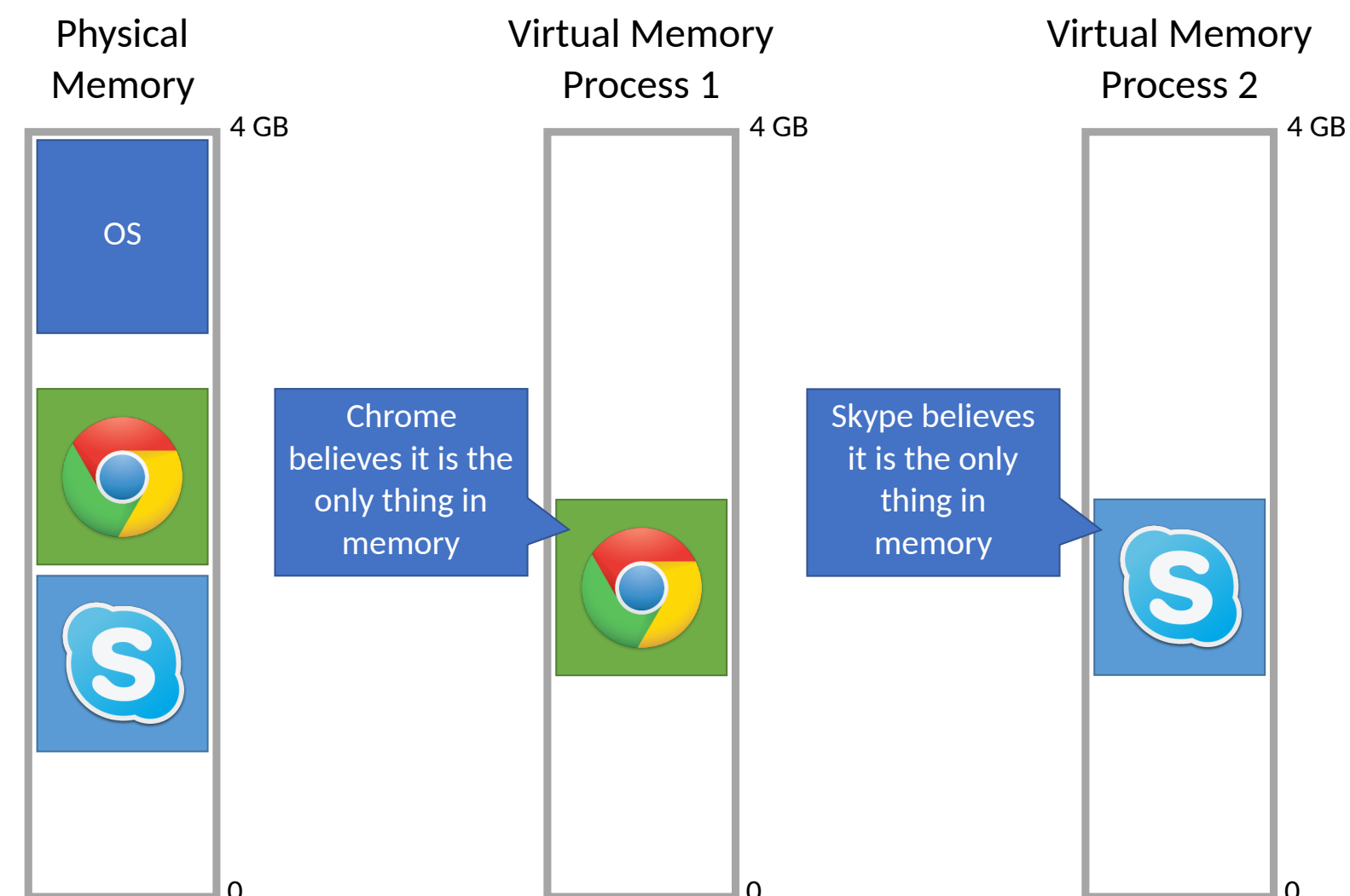
Basis for tools

Security Technologies

Authentication
- Physical and remote access is restricted

Access control
- Processes cannot read/write any file
- Users may not read/write each other's files arbitrarily
- Modifying the OS and installing software requires elevated privileges

Firewall
- Unsolicited communications from the internet are blocked
- Only authorized processes may send/receive messages from the internet

Anti-virus
- All files are scanned to identify and quarantine known malicious code

Logging
- All changes to the system are recorded
- Sensitive applications may also log their activity in the secure system log

Systems Security Principles

Defense in Depth

1. Fail-safe Defaults
2. Separation of Privilege
3. Least Privilege
4. Open Design
5. Economy of Mechanism
6. Complete Mediation
7. Compromise Recording
8. Work Factor
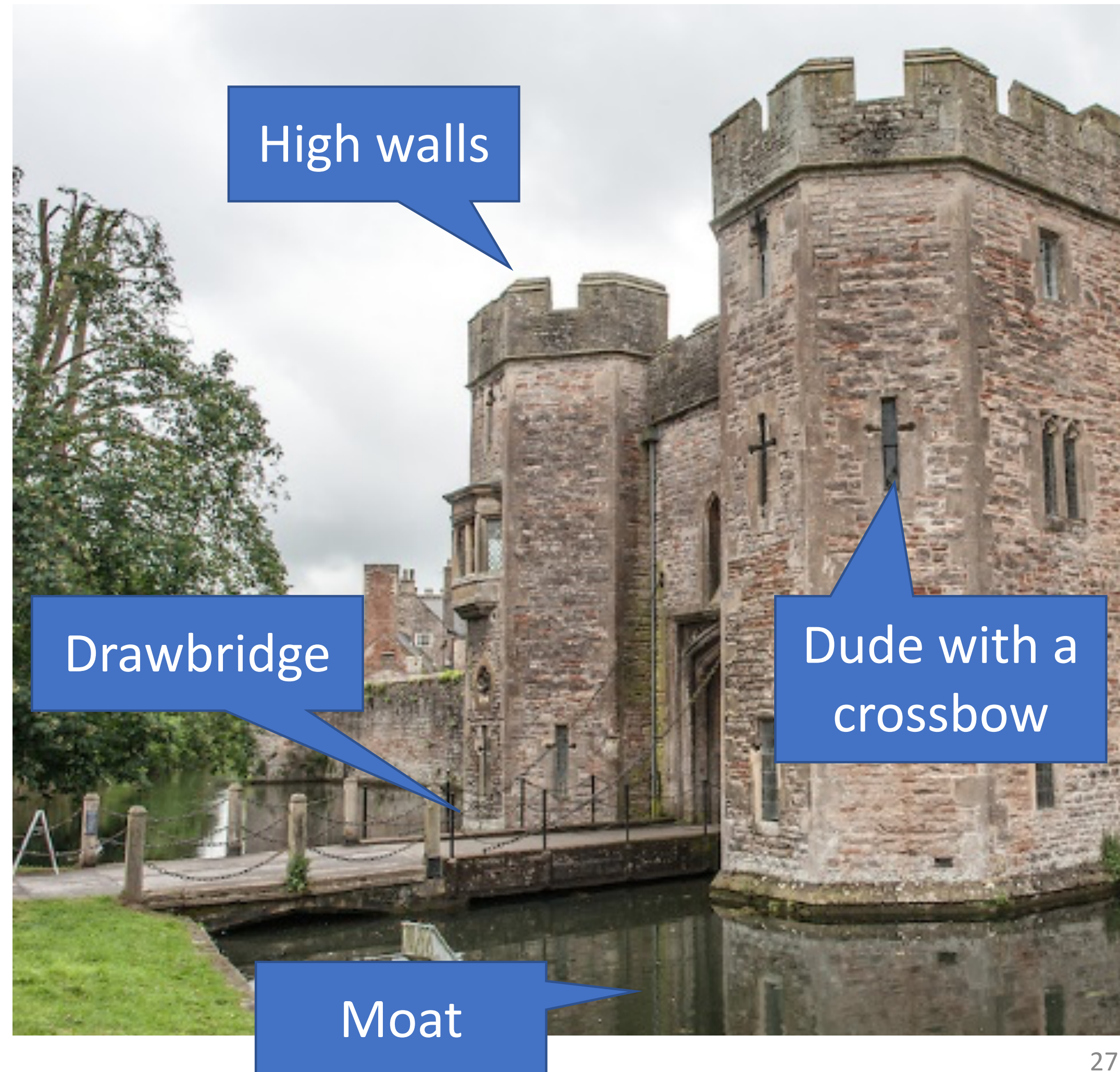
Exploits

Anatomy of an exploit

Program Crash

Saved IP is destroyed!
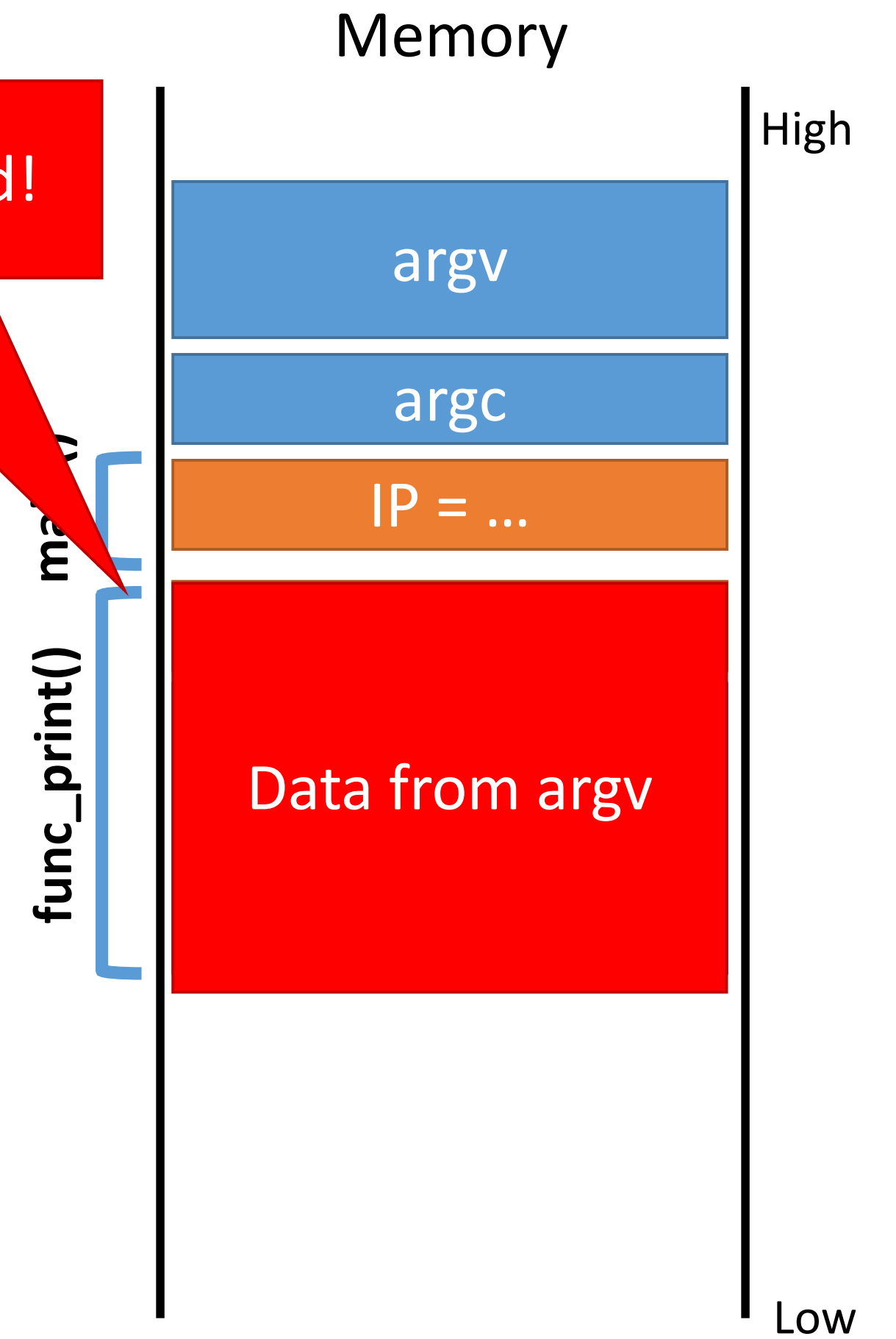
```
0:   void func_print(char s[]) {
         // only holds 32 characters, max
         char buffer[32];
1:       strcpy(buffer, s);
2:       printf("%s\n",buffer);
3:   }

4:   void main(i
5:       for (int i=1; i < argc; i++) {
6:           func_print(argv[i]);
7:       }
8:   }
```

Program crashes :(

IP

Memory

High

argv

argc

IP = ...

func_print()   ma

Data from argv

Low
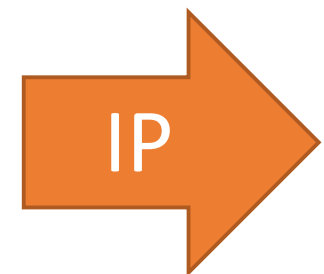
Mitigations

- **Stack canaries**
  - Compiler adds special sentinel values onto the stack before each saved IP
  - Canary is set to a random value in each frame
  - At function exit, canary is checked
  - If expected number isn't found, program closes with an error

- **Non-executable stacks**
  - Modern CPUs set stack memory as read/write, but no eXecute
  - Prevents shellcode from being placed on the stack

- **Address space layout randomization**
  - Operating system feature
  - Randomizes the location of program and data memory each time a program executes

SQL Injection

`'SELECT * FROM user_tbl WHERE user="%s" AND pw="%s";'`

form['username']	form['password']	Resulting query
alice	123456	'… WHERE user="alice" AND pw="123456";'
bob	qwerty1#	'… WHERE user="bob" AND pw="qwery1#";'
goofy	a"bc	'… WHERE user="goofy" AND pw="a"bc";'
weird	abc" or pw="123	'… WHERE user="weird" AND pw="abc" or pw="123";'
eve	" or 1=1; --	'… WHERE user="eve" AND pw="" or 1=1; --";'
mallory"; --		'… WHERE user="mallory"; --" AND pw="";'

5 Lessons of fight club

verify assumption about input, reject bad/unforseen inputs

Lesson 1:
Never trust input from the user

Lesson 2:
^ XOR
Never mix code and data

NXS
W²X . "write a page or execute a page"

Lesson 3:
Use the best tools at your disposal

X PWF

Lesson 4:
(Get this in 2550)
Awareness and Vigilance

Lesson 5:
Patch!

Topics we did not cover

- Post-quantum cryptography
- Crypto currencies and smart contracts
- Protocol Security (TLS, wireless, SDN)
- Side channel attacks
- Secure Hardware Technologies (TPM, TXT)
- Distributed System Security and Resilience
- Privacy and regulations
- Fuzzing and software testing
- Formal verification
- Mobile and IoT security
- Machine Learning for Security
- Adversarial Machine Learning

TAs deserve thanks!

Byron, Donald, Fiona, Kate, Martin, Matthew, Rahul, Samir, Simon

Please submit a TRACE course review