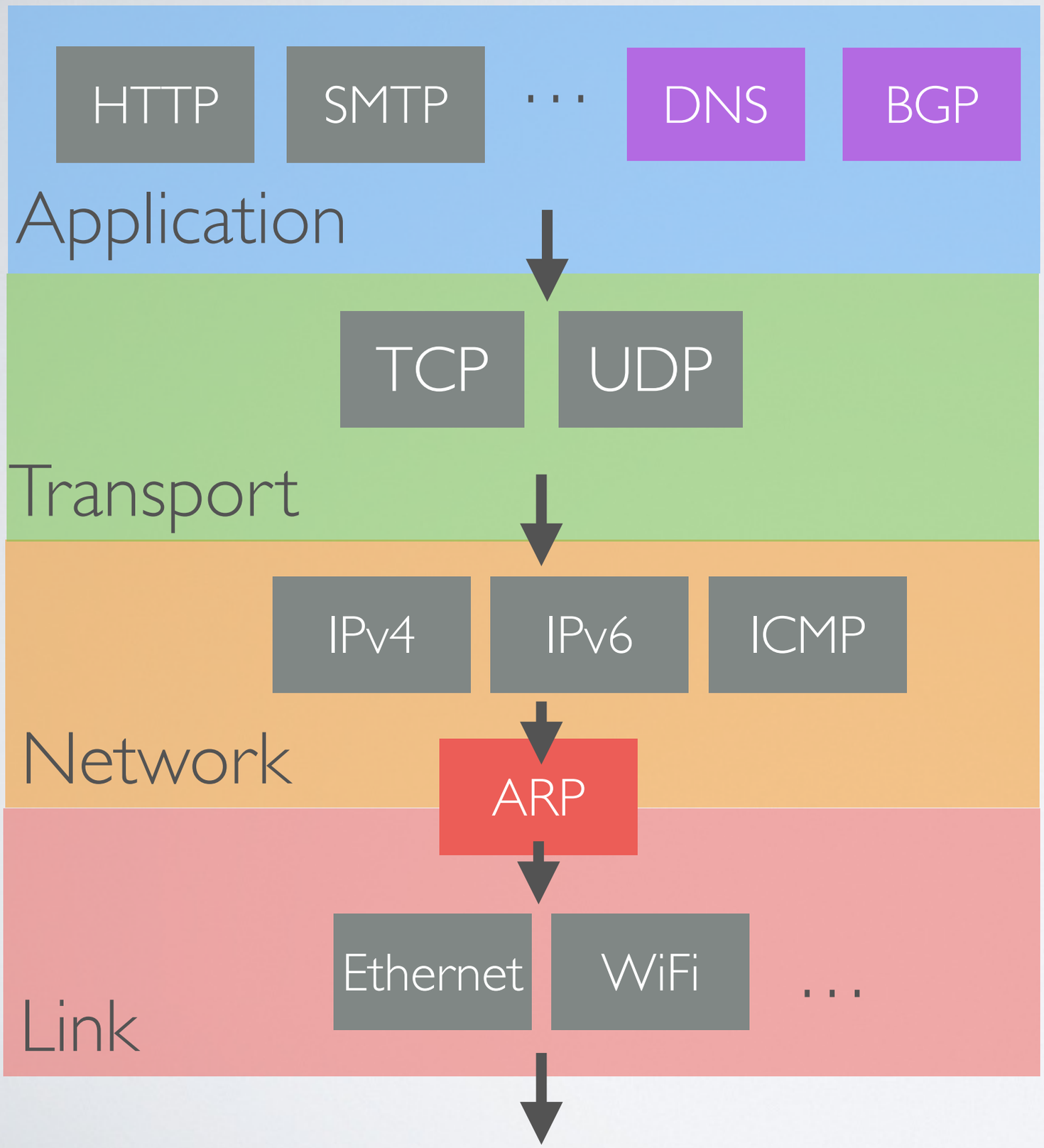
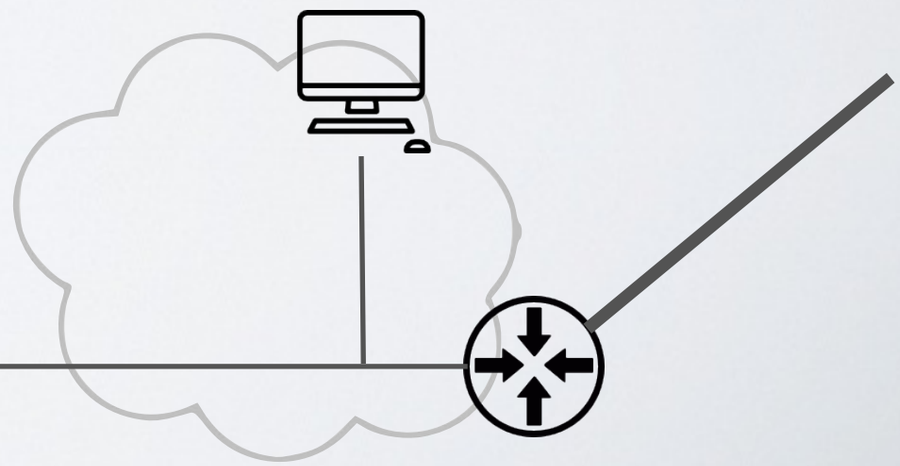
Network Security

Kc Udonsi

The Protocol Stack





The attacker is capable of …

confidentiality
integrity
availability

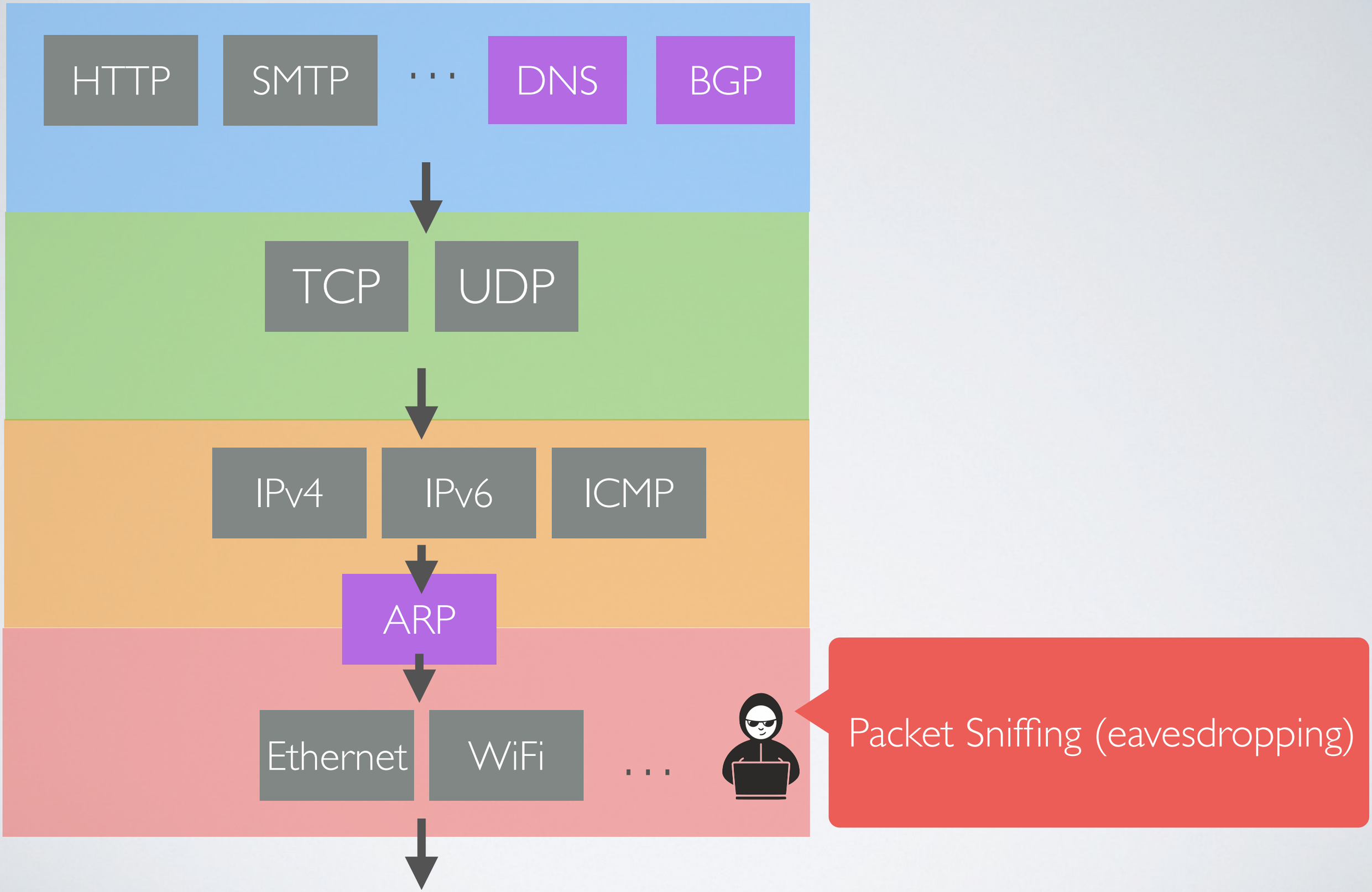
Scanning - survey the network and its hosts

Eavesdropping - read messages

Spoofing - forge illegitimate messages

DOS (Denial of Service) - disrupt the communications

➡ The attacker can target any layer in the network stack


HTTP
SMTP
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DNS
BGP
TCP
UDP
IPv4
IPv6
ICMP
ARP
Ethernet
WiFi
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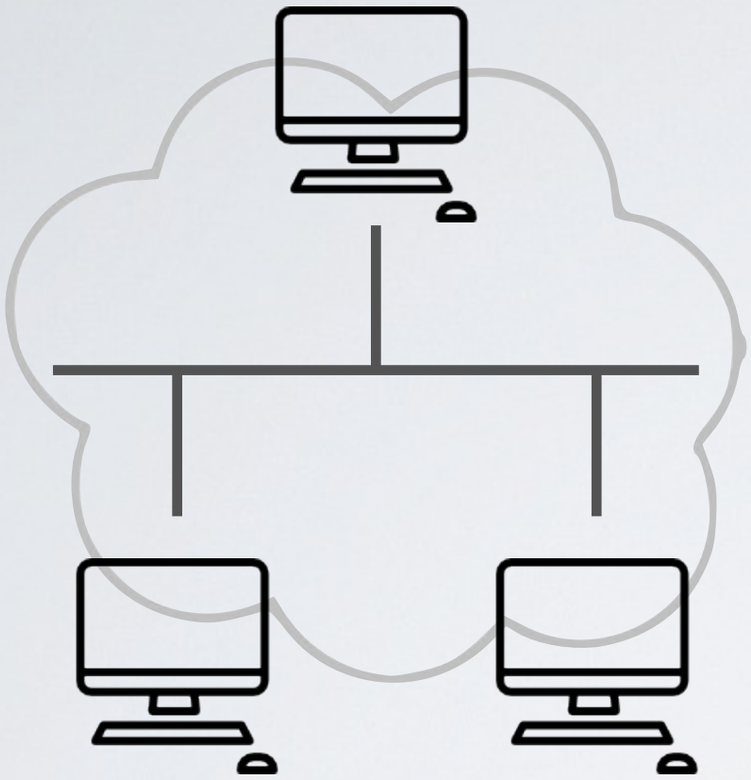
Packet Sniffing (eavesdropping)

Preventing eavesdropping attacks

Preventing packet sniffing over Ethernet



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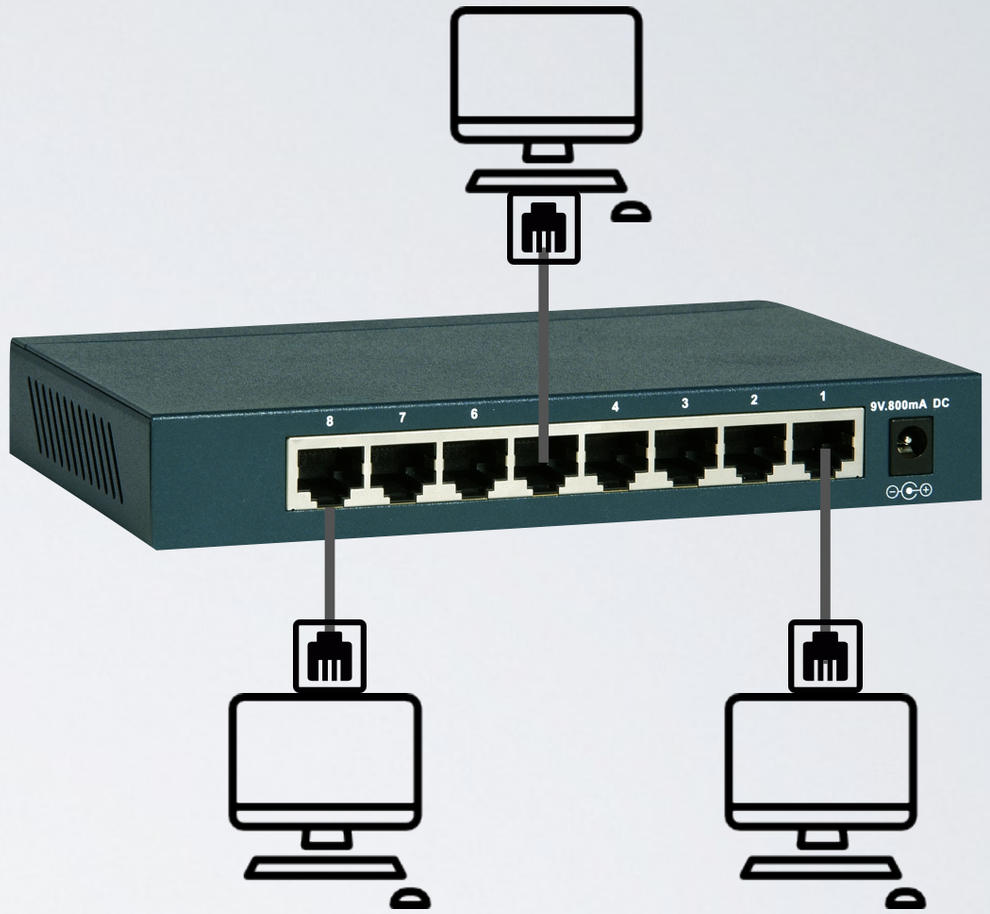


Hub : broadcast all messages on all ports

Switch : (smart HUB) forward messages on specific port based on their MAC addresses

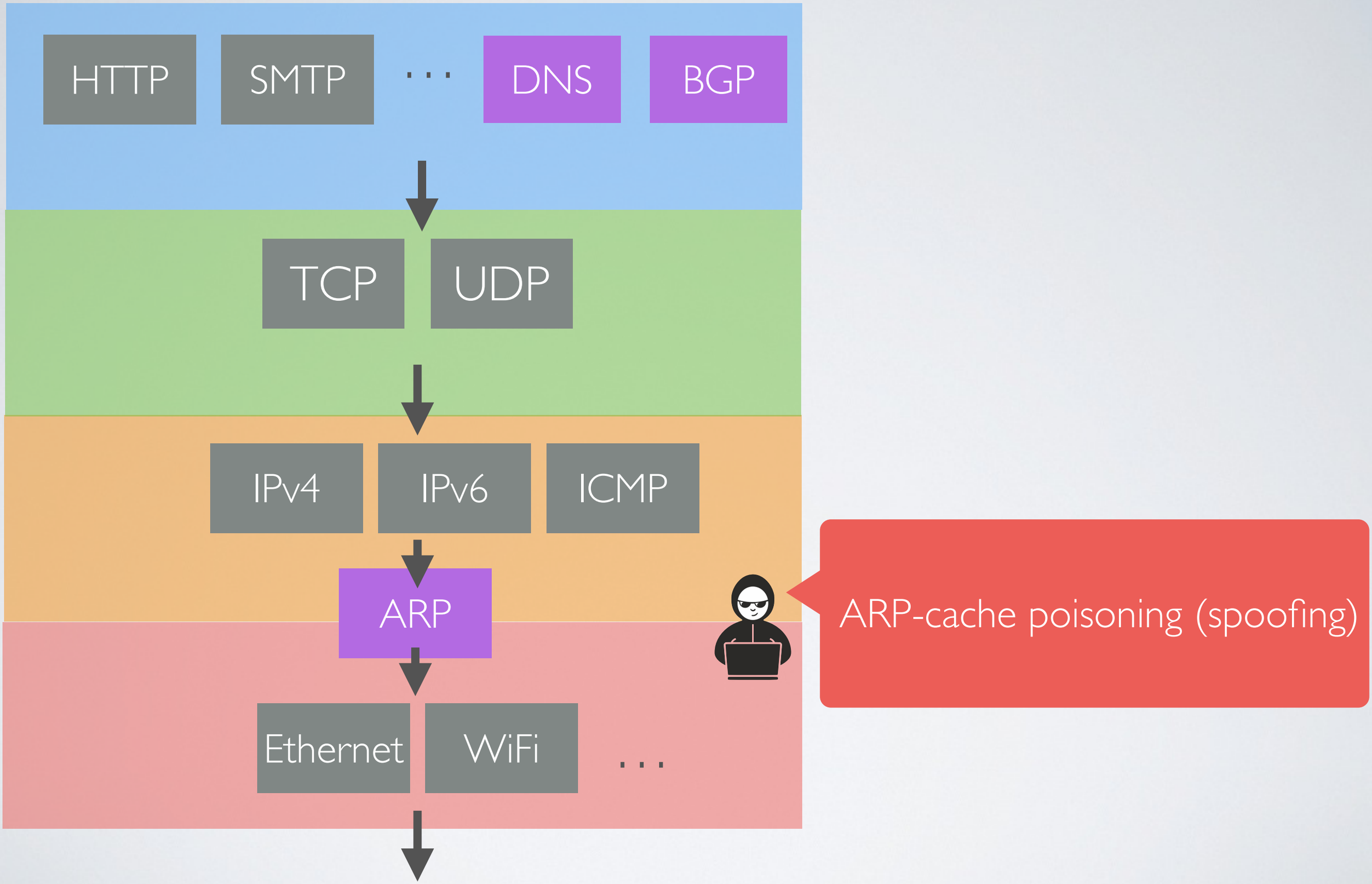
➡ isolate Ethernet traffics (no straightforward packet sniffing)

Packet sniffing over a wireless network

➡ Encrypt message before sending them over the air

◉ WEP is obsolete

Wireless Security	WPA	WPA2		WPA3	
		Personal	Enterprise	Personal	Enterprise
Authentication	Shared Key	Shared Key	RADIUS Server	Shared Key	RADIUS Server
Cryptography	TKIP and RC4	CCMP and AES		128-bit CCMP and AES	192-bit CCMP and AES
Security	Broken	External attackers only	Good	Better, Simultaneous Authentication of Equals	
Year	2003	2004		2018	


HTTP
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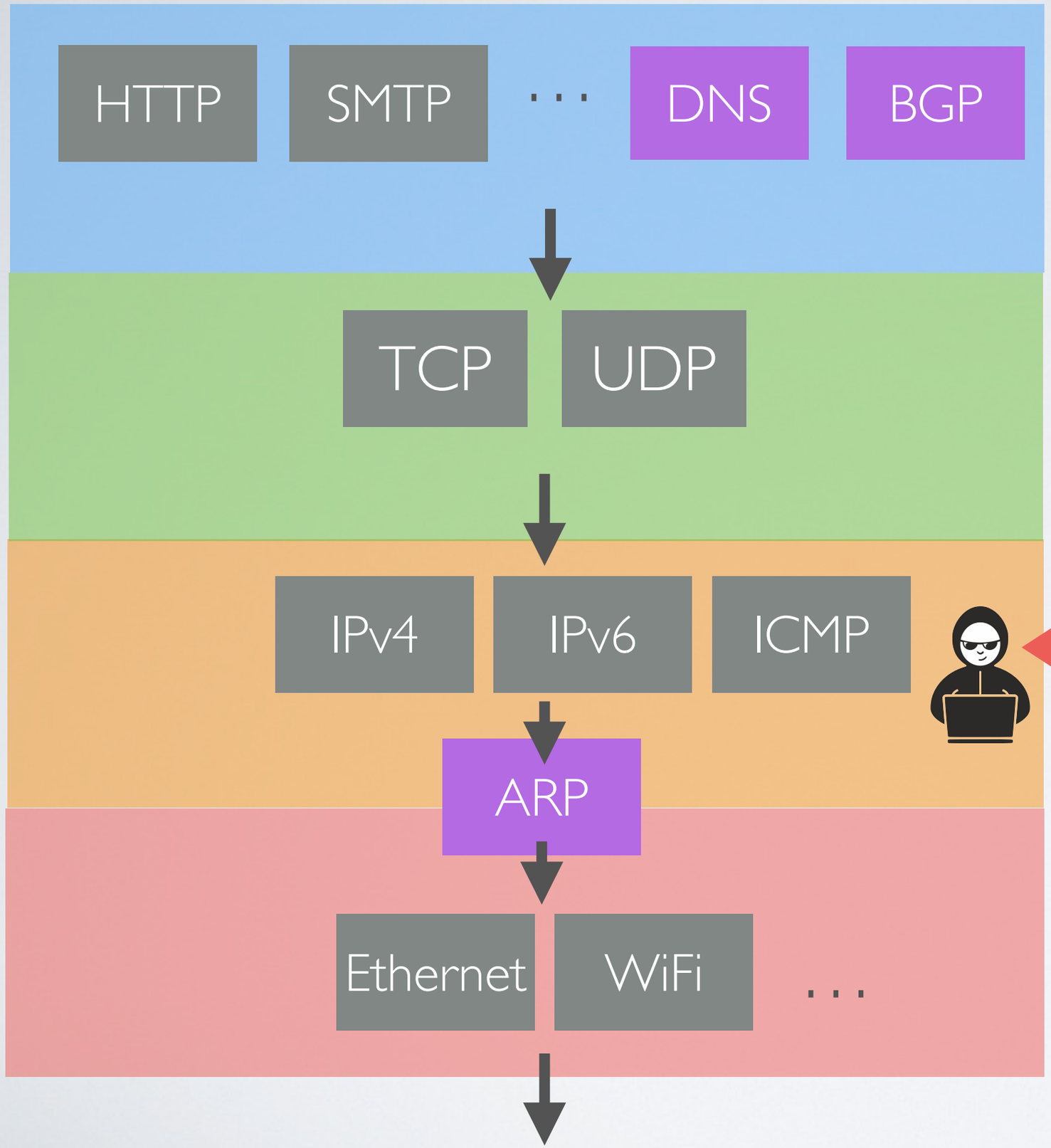
. . .
ARP-cache poisoning (spoofing)

Preventing spoofing attacks

Preventing ARP-cache poisoning

- **Authenticating ARP messages** has been proposed (research) but never implemented
- **Static ARP** tables (not practical in dynamic environment)
- **Detection and correction** tools



- Host discovery (scanning)
- IP forgery (spoofing)
- ICMP Ping flooding (DOS)

Defending against IP forgery

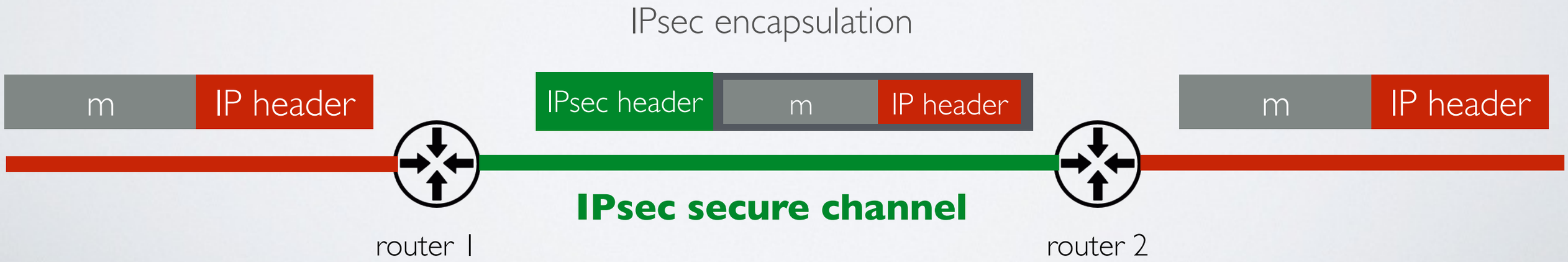
IPsec - Internet Protocol Security provides authentication (AH) (and optionally encryption (ESP)) of IP traffic

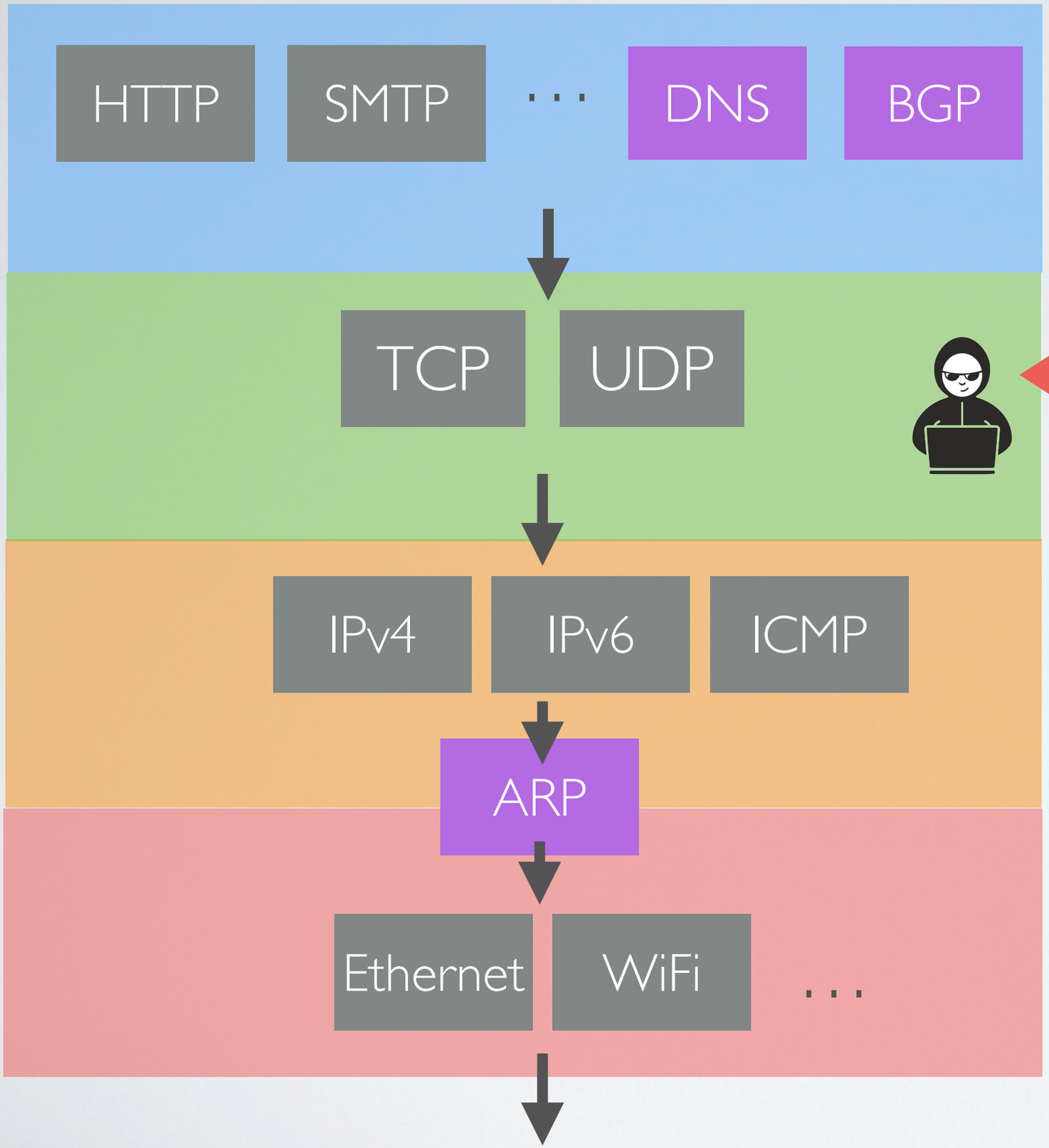
➡ Uses SHA2 and AES (previously SHA1 and 3DES)

➡ Built-in support in IPv6

➡ Transport mode and Tunnel mode (most common)

✓ Used usually between routers (link and network layers only)





- Port scanning (scanning)
- TCP forgery (spoofing, DOS)
- TCP-syn flooding (DOS)
- UDP flooding (DOS)

TLS - Transport Layer Security

TLS - Tranport Layer Protection

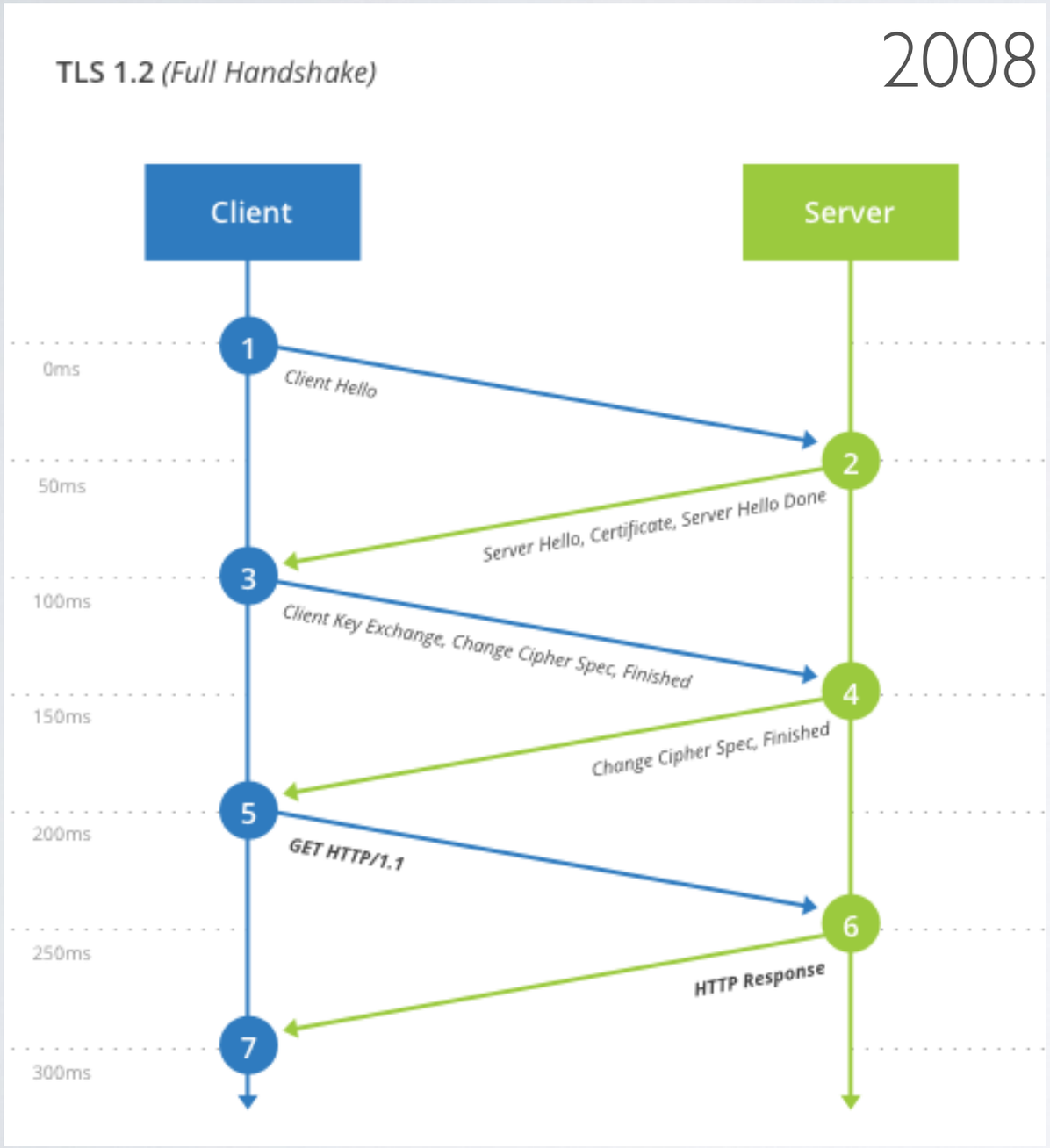
➡ Transport Layer Security (formerly SSL) provides

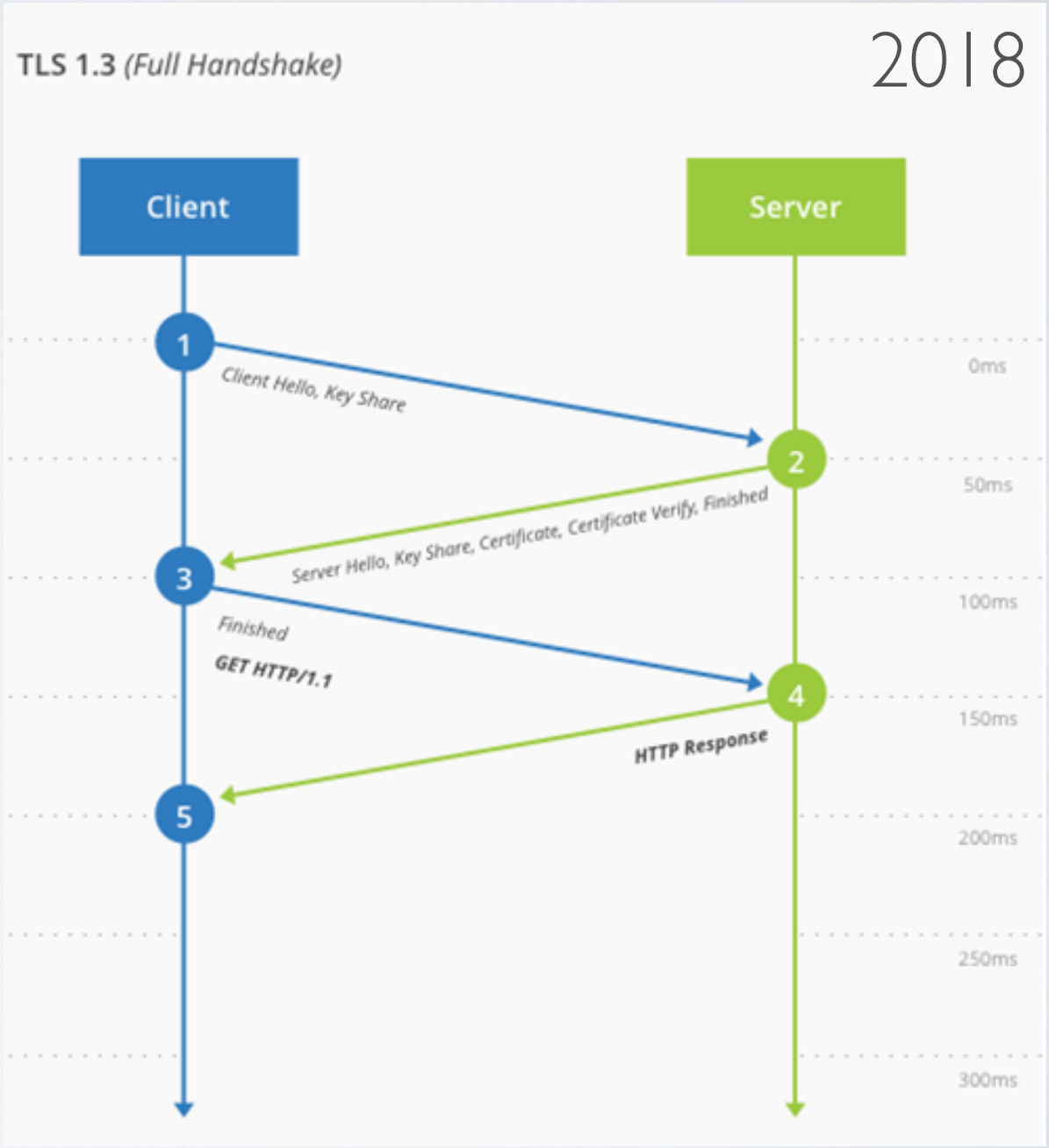
- **integrity:** authentication handshake
- **confidentiality:** end-to-end secure channel

✓ Prevents all kinds of eavesdropping and spoofing for application protocols e.g HTTP + TLS = HTTPS

◉ 2-10 times slower than an insecure TCP connection

TLS Authentication Handshake 1.2 vs 1.3



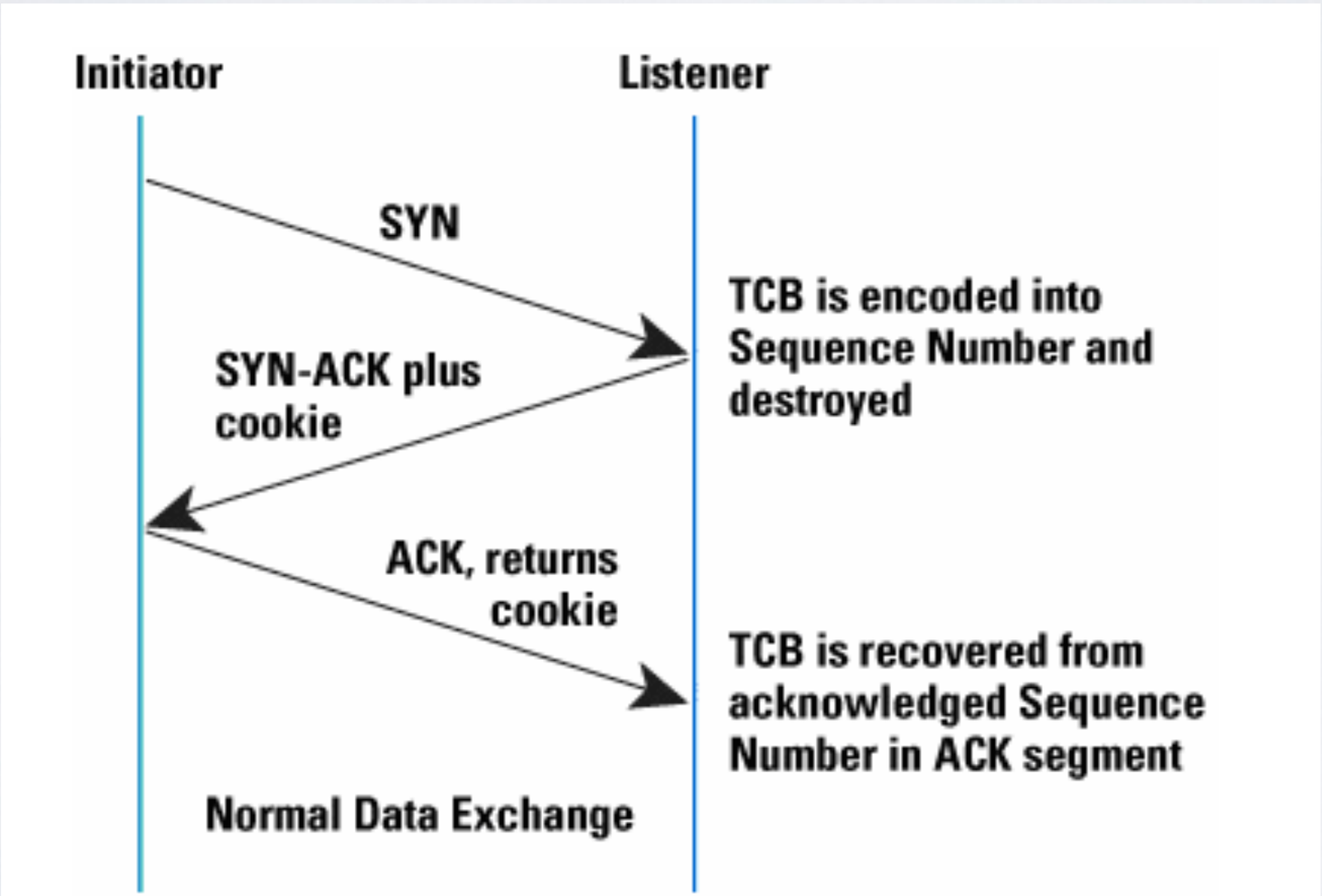


source https://www.cloudflare.com/learning-resources/tls-1-3/

Preventing DOS attacks

Preventing TCP-syn flooding

TCP-syn cookie prevents from maintaining a queue of half-opened TCP connections



Preventing Transport Layer DOS and DDOS attacks in general

Network Ingress Filtering (a.k.a BCP 38)

Best Current Practice to limit the impact of DOS and DDOS

1. Deny packets with spoofed addresses from leaving the router
2. Ensure that traffic is traceable to its correct source network

➡ Implemented by ISPs (Internet Service Providers)

Preventing scanning attacks (and beyond)

Preventing host discovery and port-scanning

Host discovery uses **`ICMP ping echo`** message

➡ ICMP can be disabled or reserved to hosts on the same network

Port Scanning uses **`TCP-syn`** messages

➡ TCP connections can be rejected if a source attempts to initiate multiple connections on multiple ports simultaneously

➡ **Packet filtering** can prevent these two scanning techniques

Limitation of a host-by-host packet filtering solution

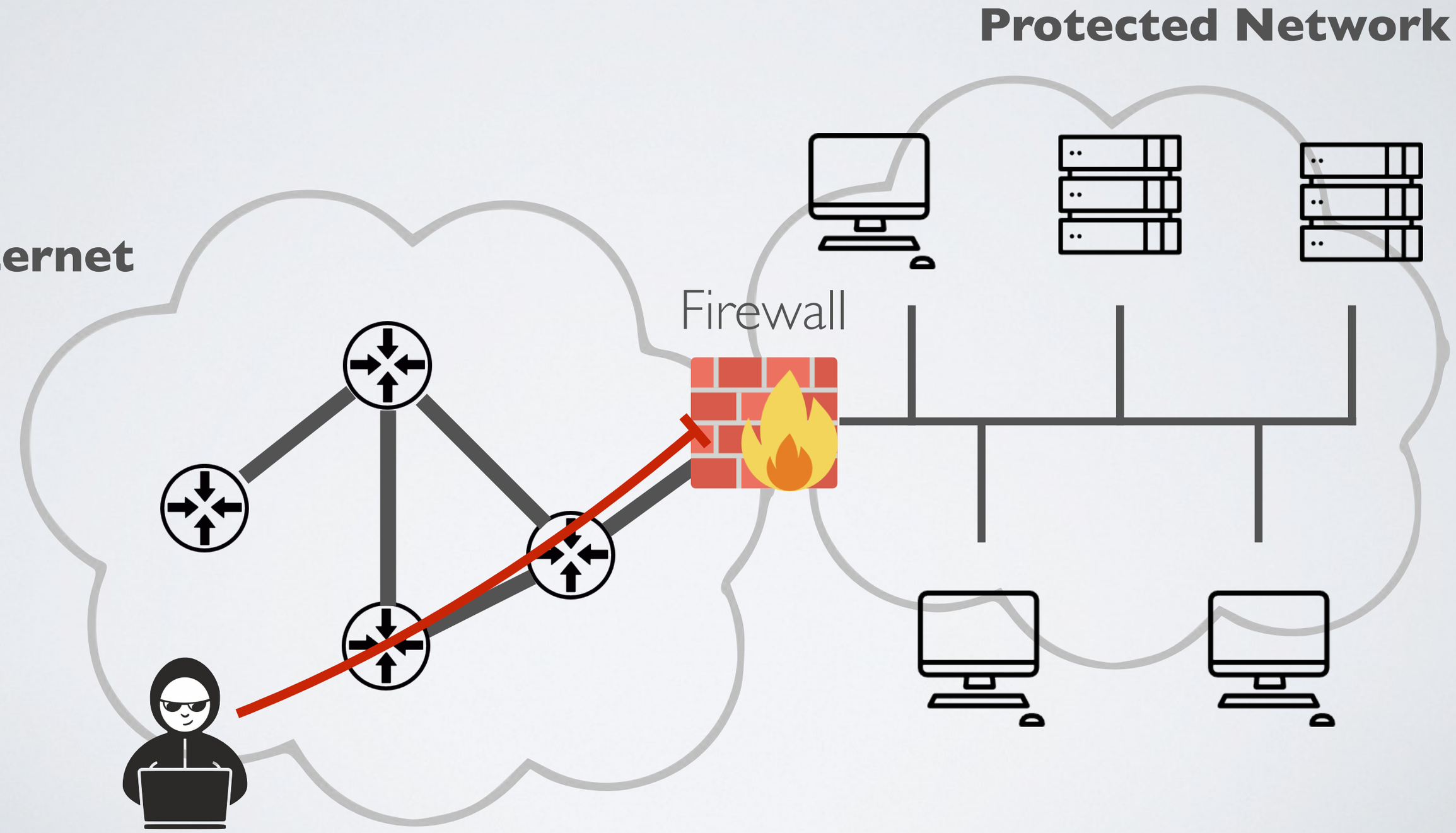
How to enable packet filtering on every host on the network?

1. Each host needs to have **packet filtering capability** across different hardware, OS and versions
2. The admin needs to have **administrative privilege on every host** to push the packet filtering policy

➡ Impossible in practice

Firewall

Network Firewall



Network Firewall

A firewall defines a logical defence parameter
and acts an access control between two networks

➡ Packet filtering based on IP addresses (TCP filtering)

- inbound traffic from the Internet trying to get into the protected network
- outbound traffic going the other way

✓ For the most part, we trust* the outbound
but not the inbound

Widely used in practice

Assuming the attacks comes from outside, a firewall can prevent

- Most scanning attacks
- Some spoofing attacks
- Some flooding attacks (as long as it can handle the load)
- Anomalous messages e.g smurf attack
- and others

➡ But more generally, it can restrict access to protected hosts

Two type of firewalls

Stateless packet filtering

is purely based on the IP address and the port

Stateful packet filtering

tracks the status of every connection (TCP 3 way handshake)

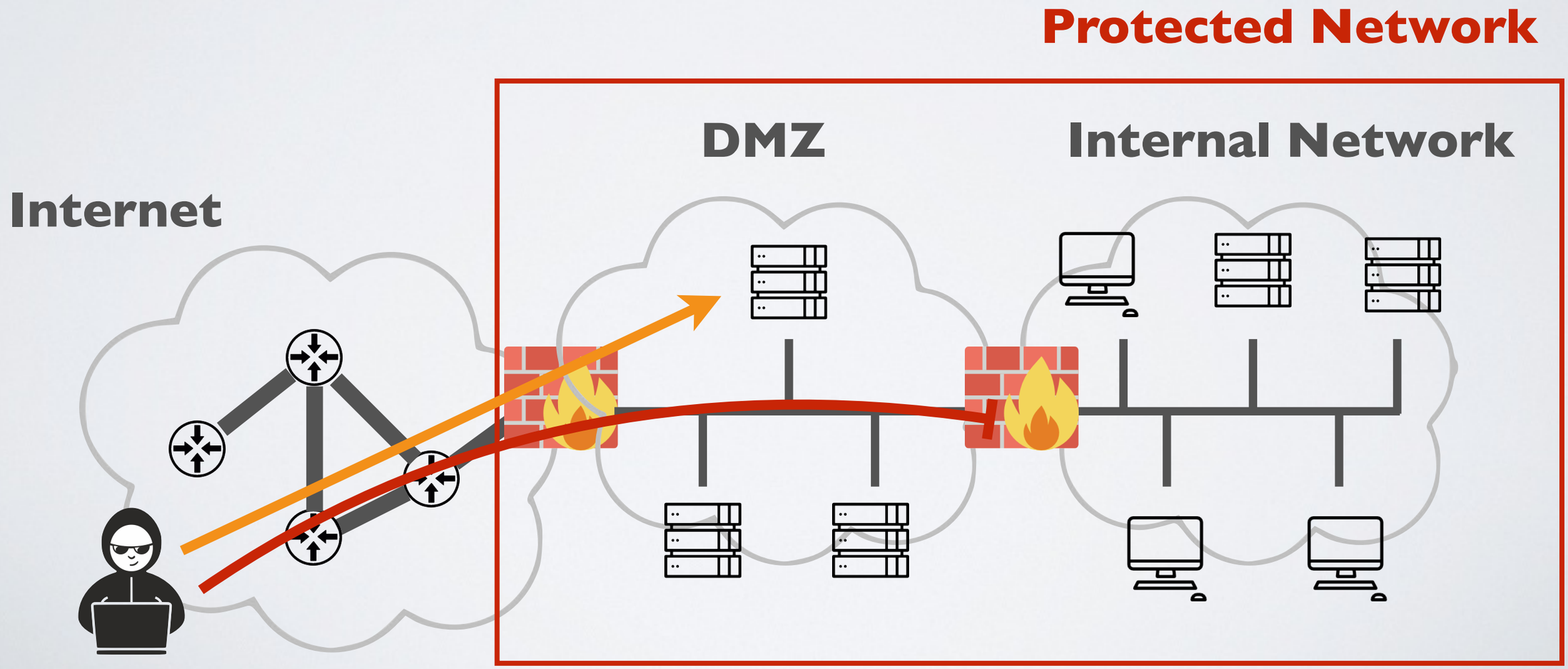
Example of a stateful firewall policy

ACL - Access Control Lists

action	protocol	IP src	port src	IP dst	port dst	state
allow	TCP	222.22/16	>1023	! 222.22/16	80	any
allow	TCP	! 222.22/16	80	222.22/16	>1023	ack
allow	UDP	222.22/16	>1023	! 222.22/16	53	-
allow	UDP	! 222.22/16	53	222.22/16	>1023	-
deny	all	all	all	all	all	all

Concept of DMZ

DMZ - DeMilitarized Zone isolates exposed public servers e.g web, mail, database and so on



Intrusion Detection

Two approaches to build an IDS

Signature-based IDS

Have pre-defined malicious message pattern

➡ Relies on a signature database

Heuristic-based

Builds a model of acceptable message exchange patterns

➡ Relies on machine learning

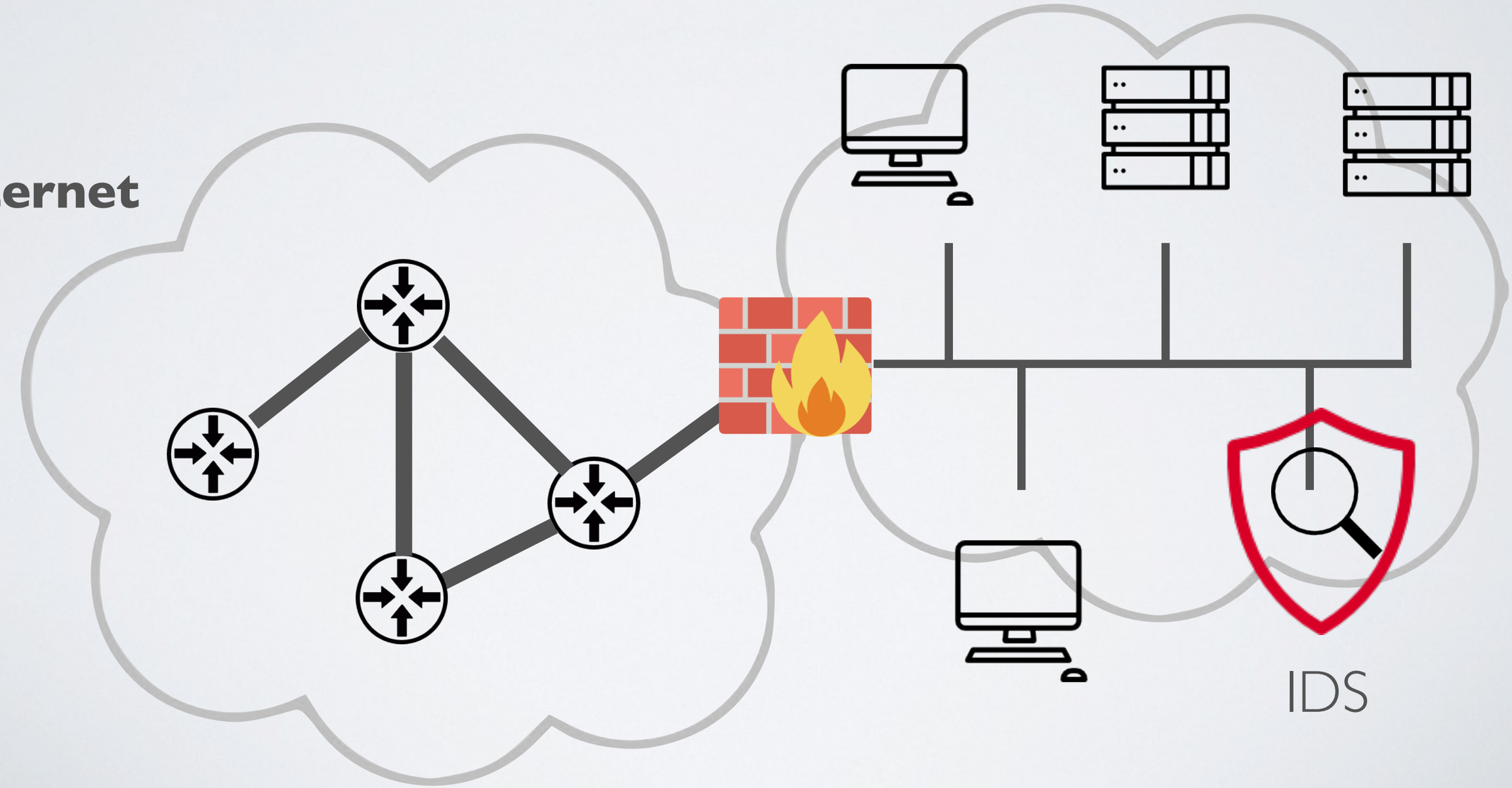
(Network) Intrusion Detection Systems

IDS - Intrusion detection systems performs deep packet inspection

- Looks at the headers
- Look at packet contents (payload)
- Looks at the packet fragmentation

IDS in the protected network

➡ IDSs often operate in stealth mode

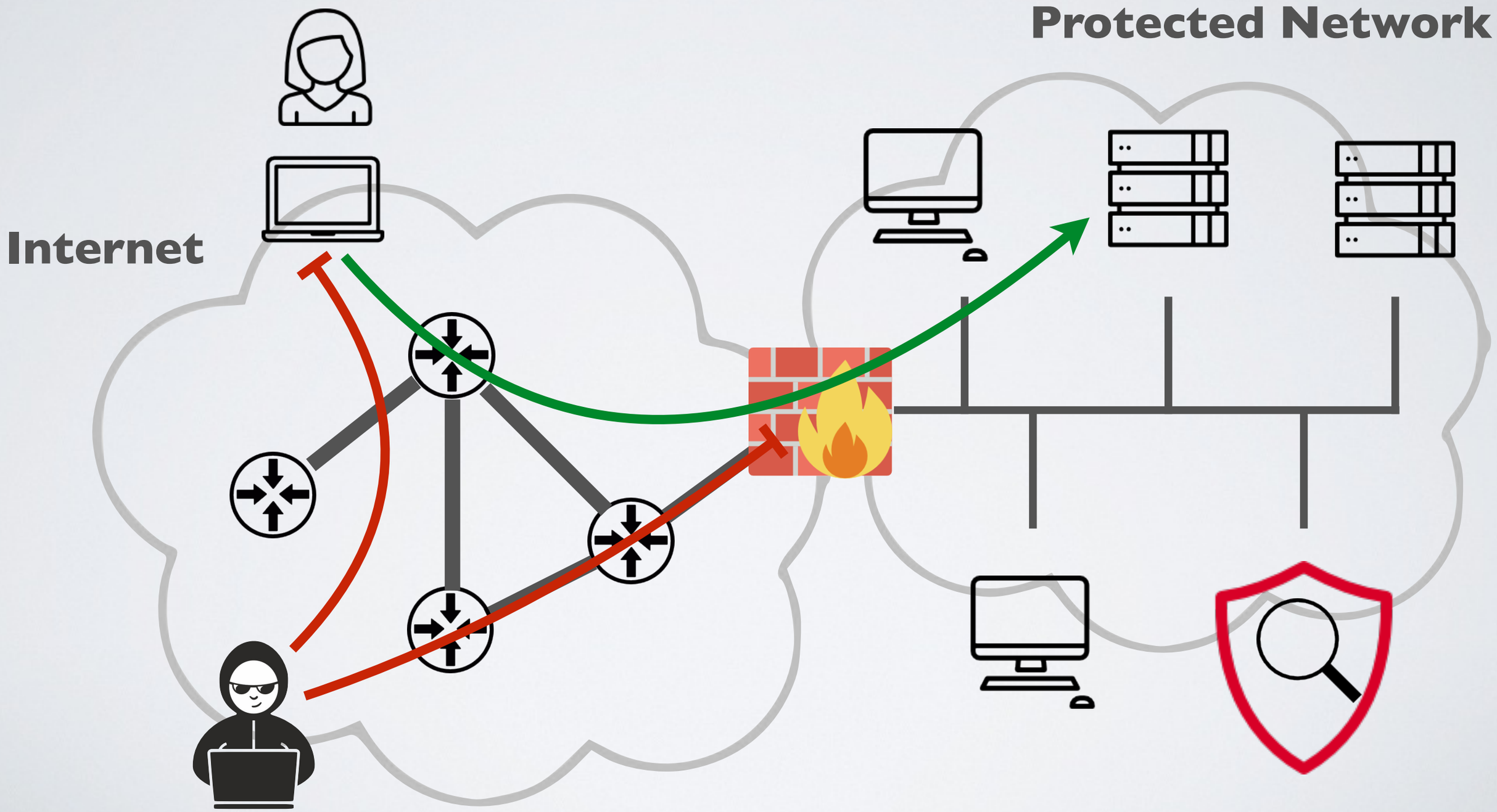


IPS - Intrusion Prevention system

IPS = IDS + Firewall

➡ IP addresses sending malicious packets can be filtered

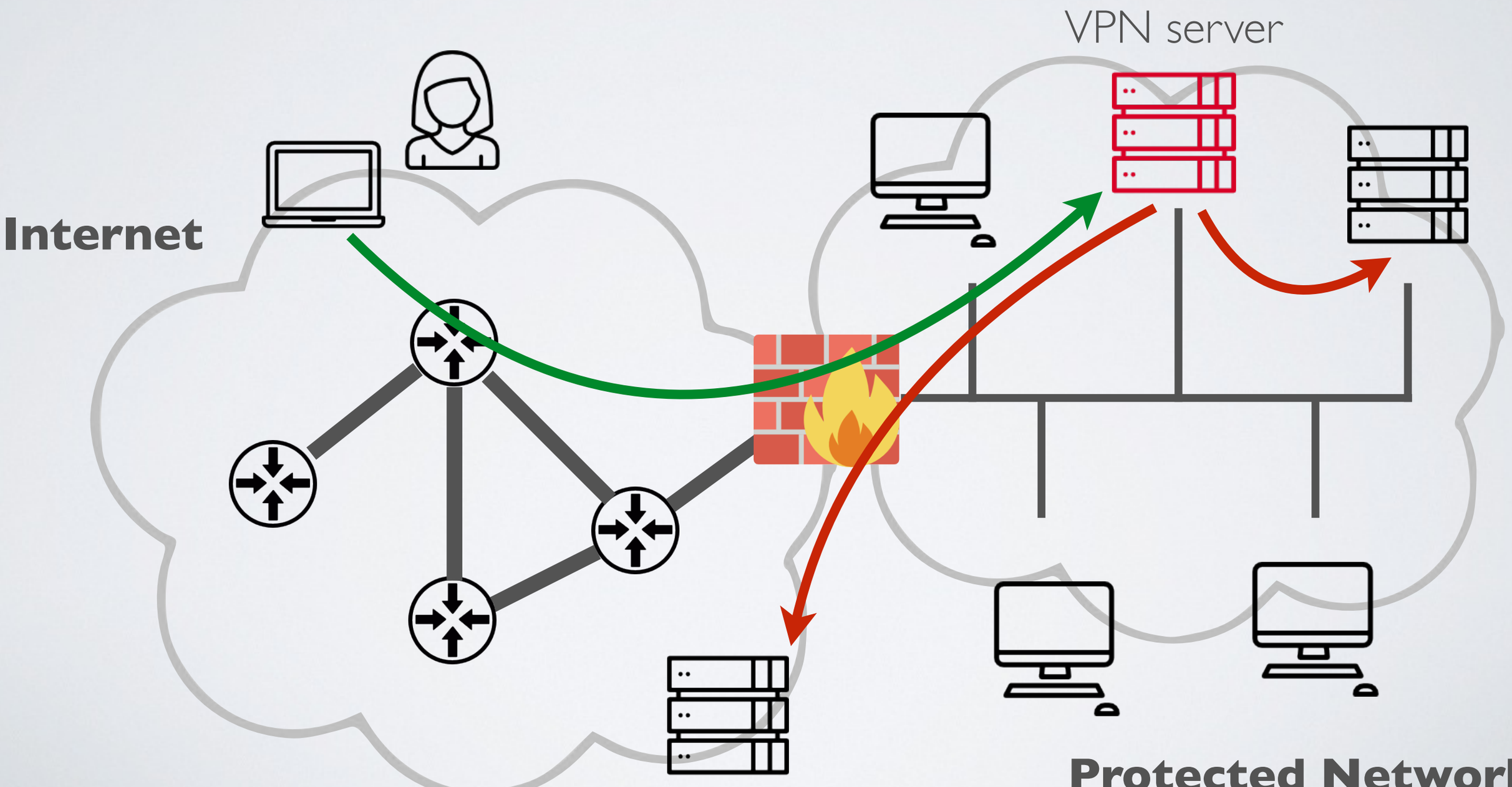
Problem with nomad hosts



VPN - Virtual Private Network

VPN - Virtual Private Network

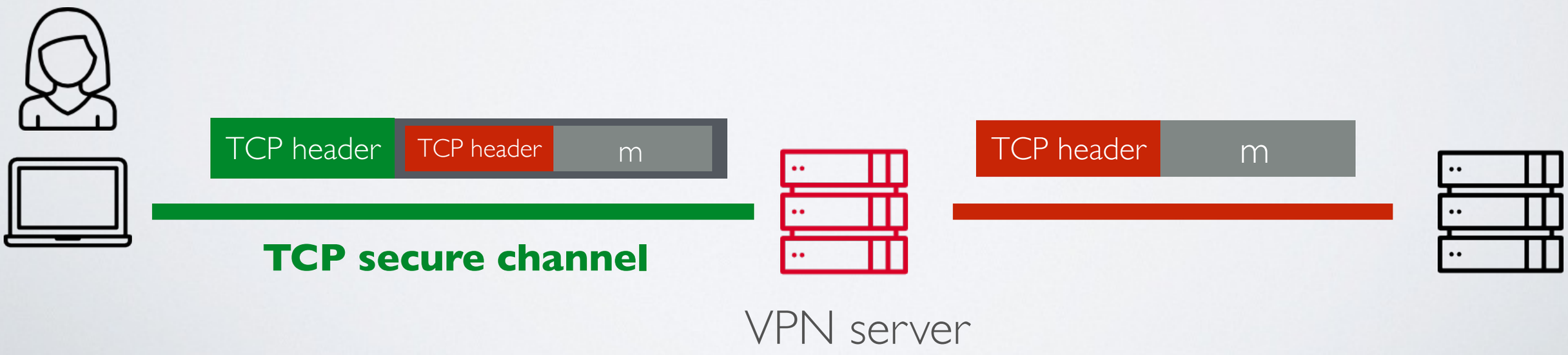
VPN protected nomad hosts outside the protected network



Tunneling protocol

1. Alice's message is encapsulated and sent to the VPN server
2. The VPN extract this traffic and send it to the destination
3. Same thing on the way back

➡ Provides anonymity (from the IP perspective at least)



Different type of VPNs

VPN can be built using different technology e.g.

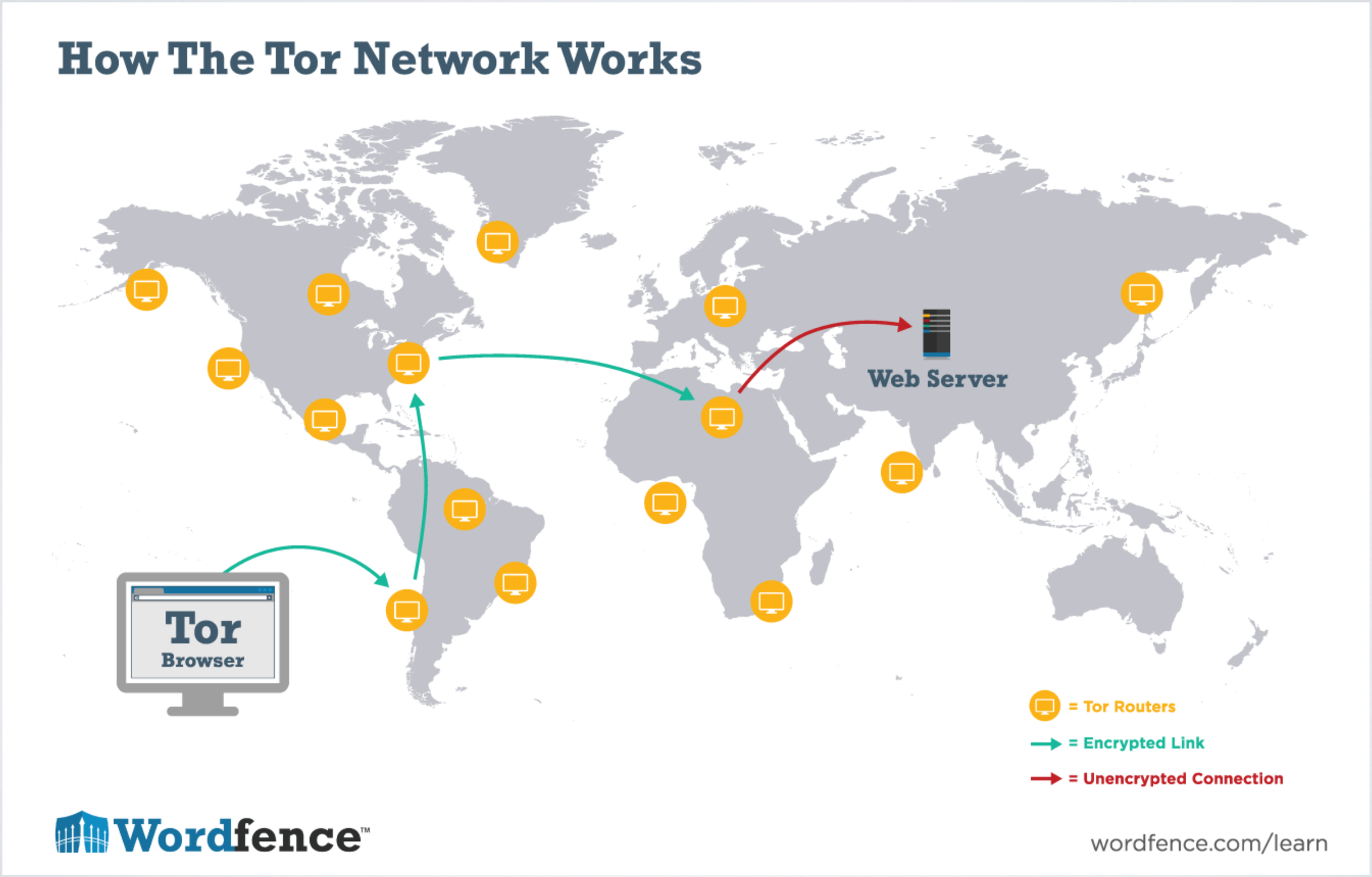
- IPsec
- TLS (e.g openVPN)
- SSH

VPN to enforce security … or evade it :)

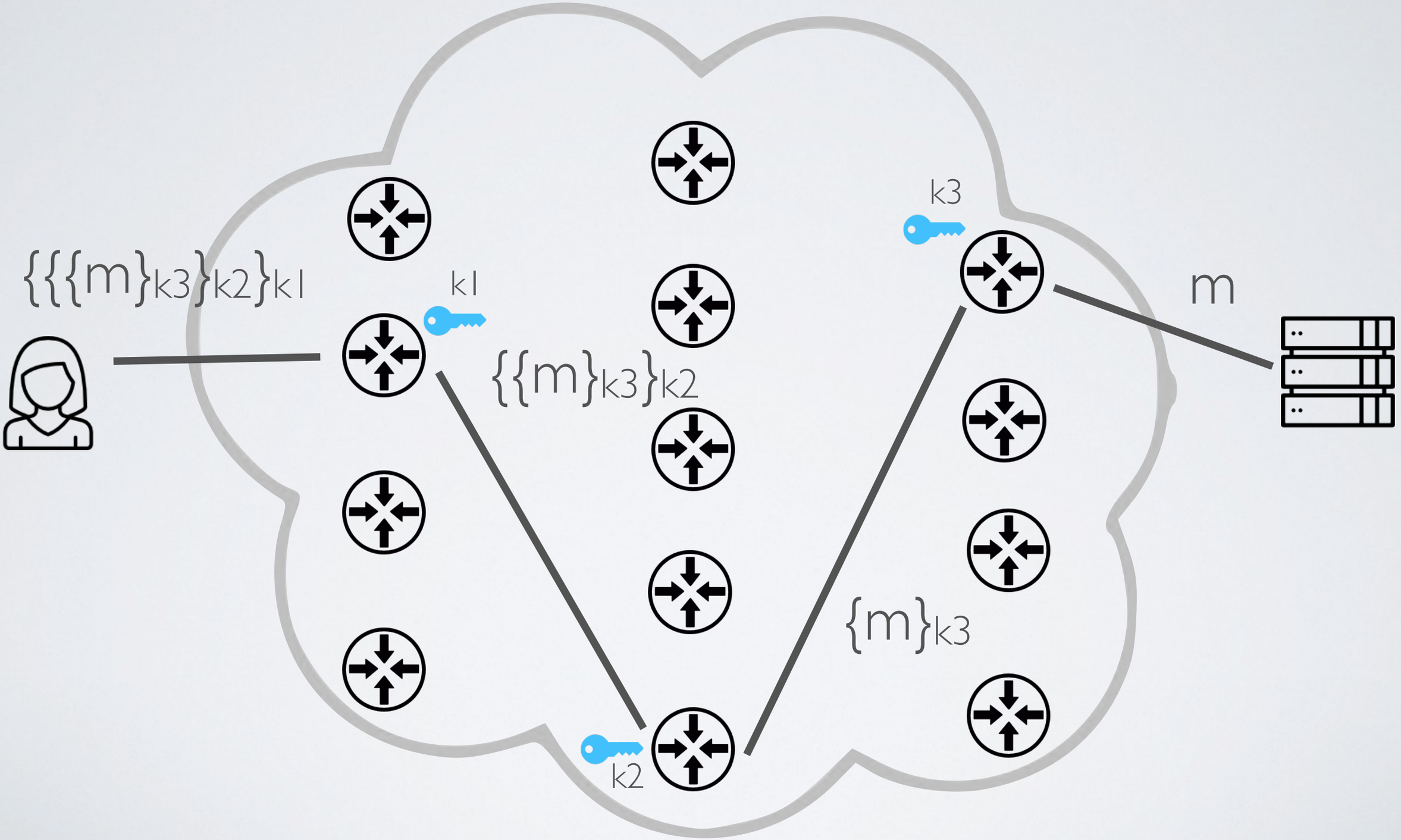
➡ Protect privacy, evade censorship and geo-restrictions by masking the real IP address

TOR - The Onion Router

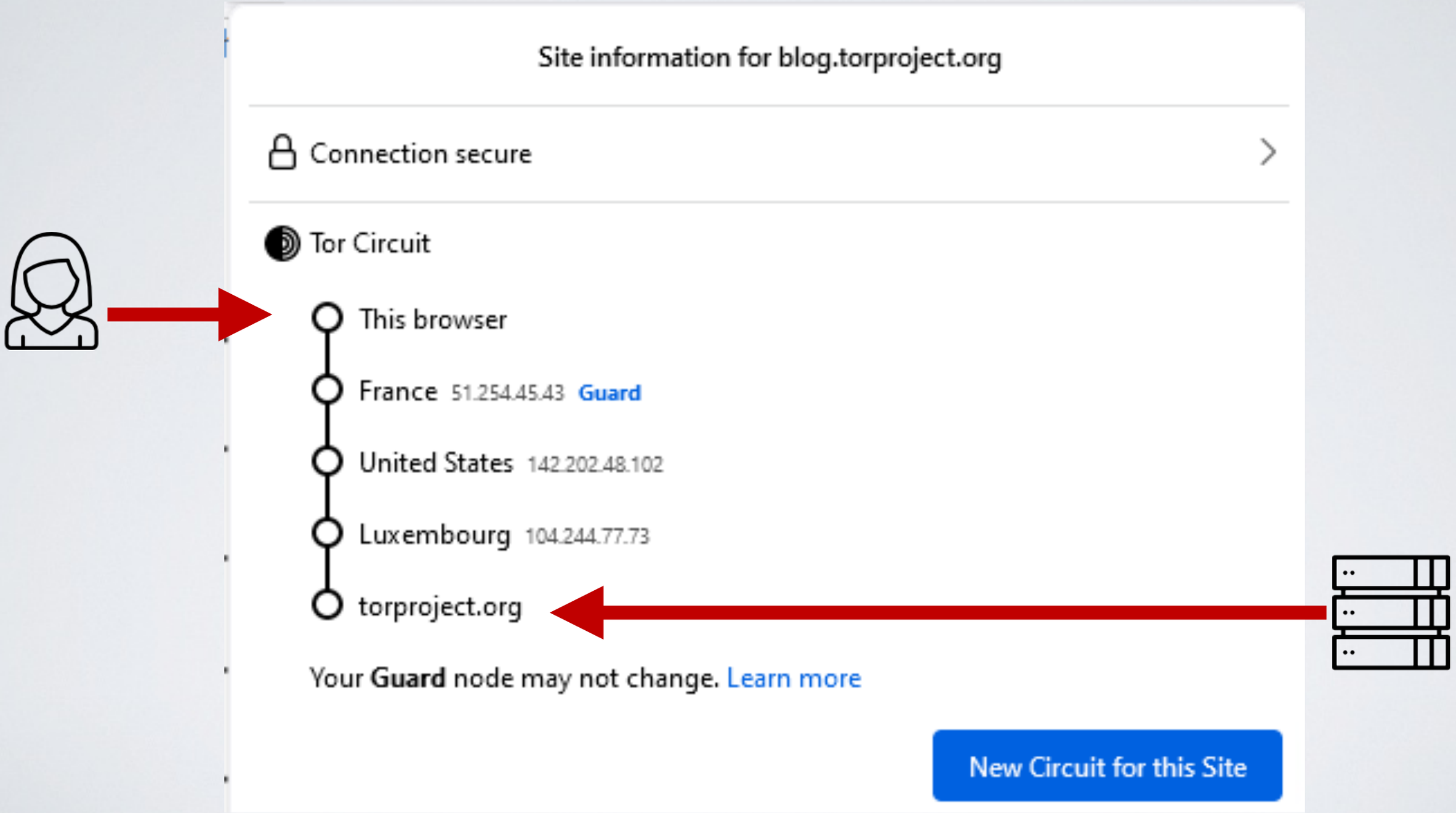
The TOR network a.k.a Onion Routing



Hiding Alice behind TOR



Hiding Alice behind TOR



	knows about
TOR #1 (guard node)	Alice's and TOR #2 IP addresses
TOR #2 Middle Node)	TOR #1 and TOR #3 IP addresses
TOR #3 (Exit node)	TOR #2 and Bob's IP addresses and Alice's content (but not Alice's IP)
Bob	TOR #3 IP address and Alice's content (but not Alice's IP)

➡ Nobody knows about Alice'IP and Alice's content at once

✓ The more TOR node are available in the TOR network
The more secure it is

The exit node

- Whatever Alice does illegally on the Internet
  the exit node might be blamed for it

➡ Tips for running an exit node (from "TOR blog")
https://blog.torproject.org/tips-running-exit-node

Limitation of TOR

✓ TOR prevents people from identifying you based on your IP address

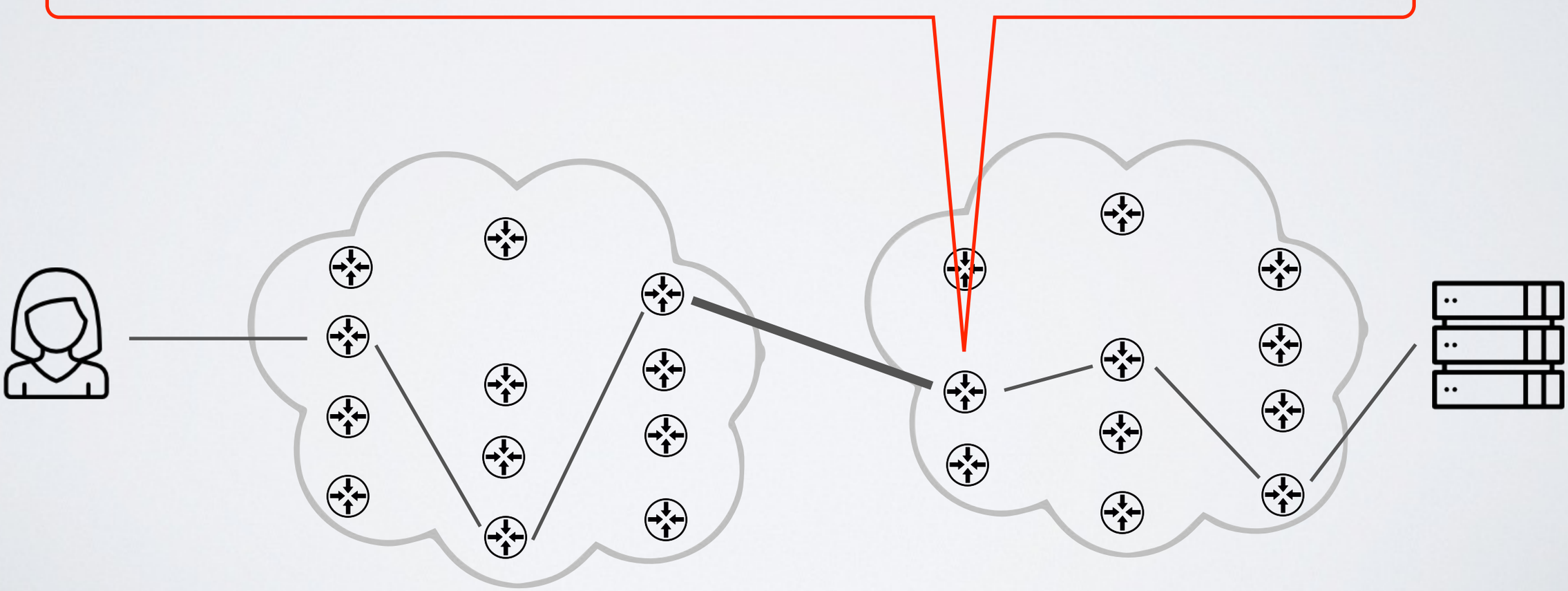
◉ TOR does not prevent you from be identified based on application identify information (e.g web tracking)

➡ TOR should be used with the TOR browser that deactivates scripts and other tracking mechanisms

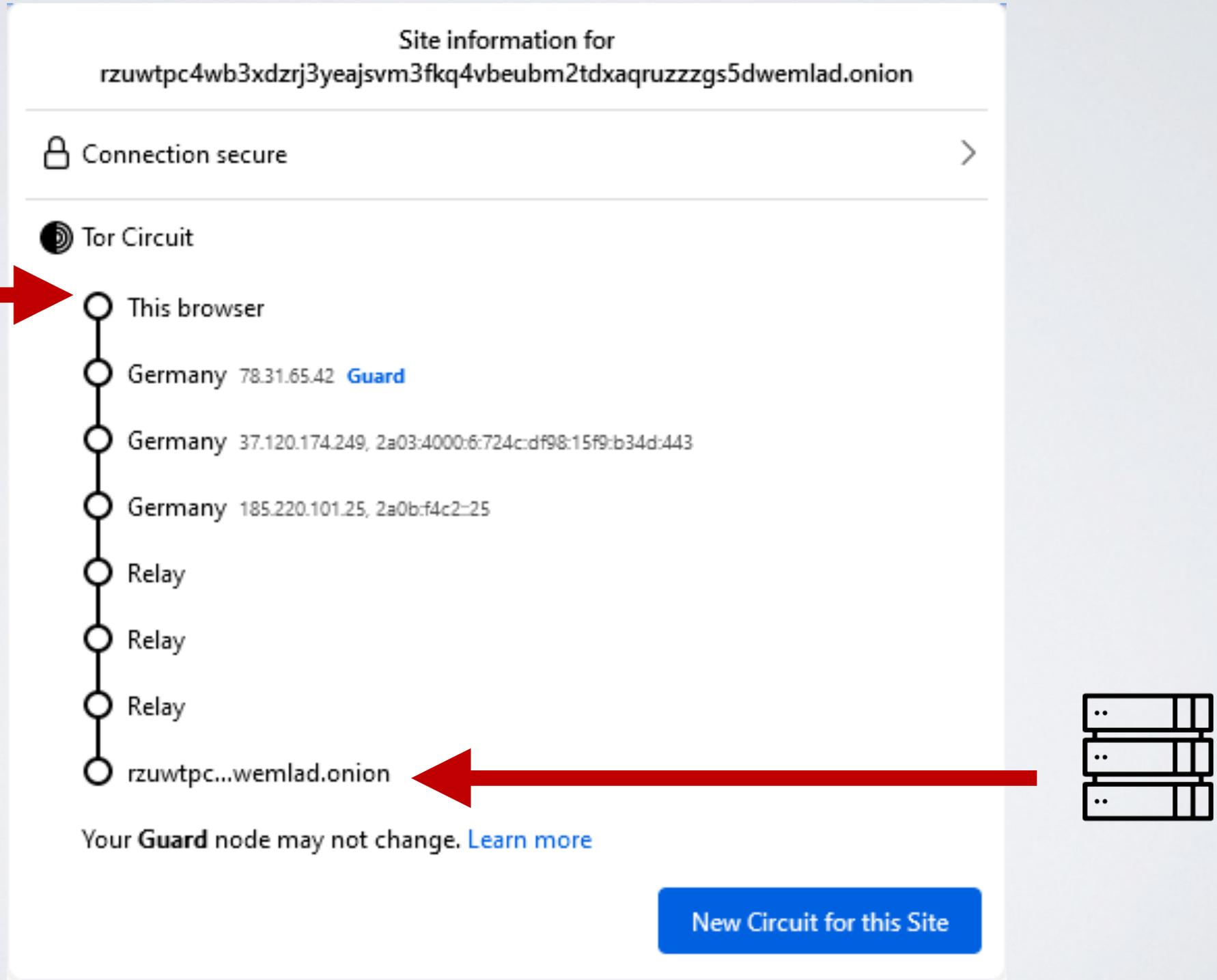
Hiding Bob behind TOR (a.k.a `.onion` server)

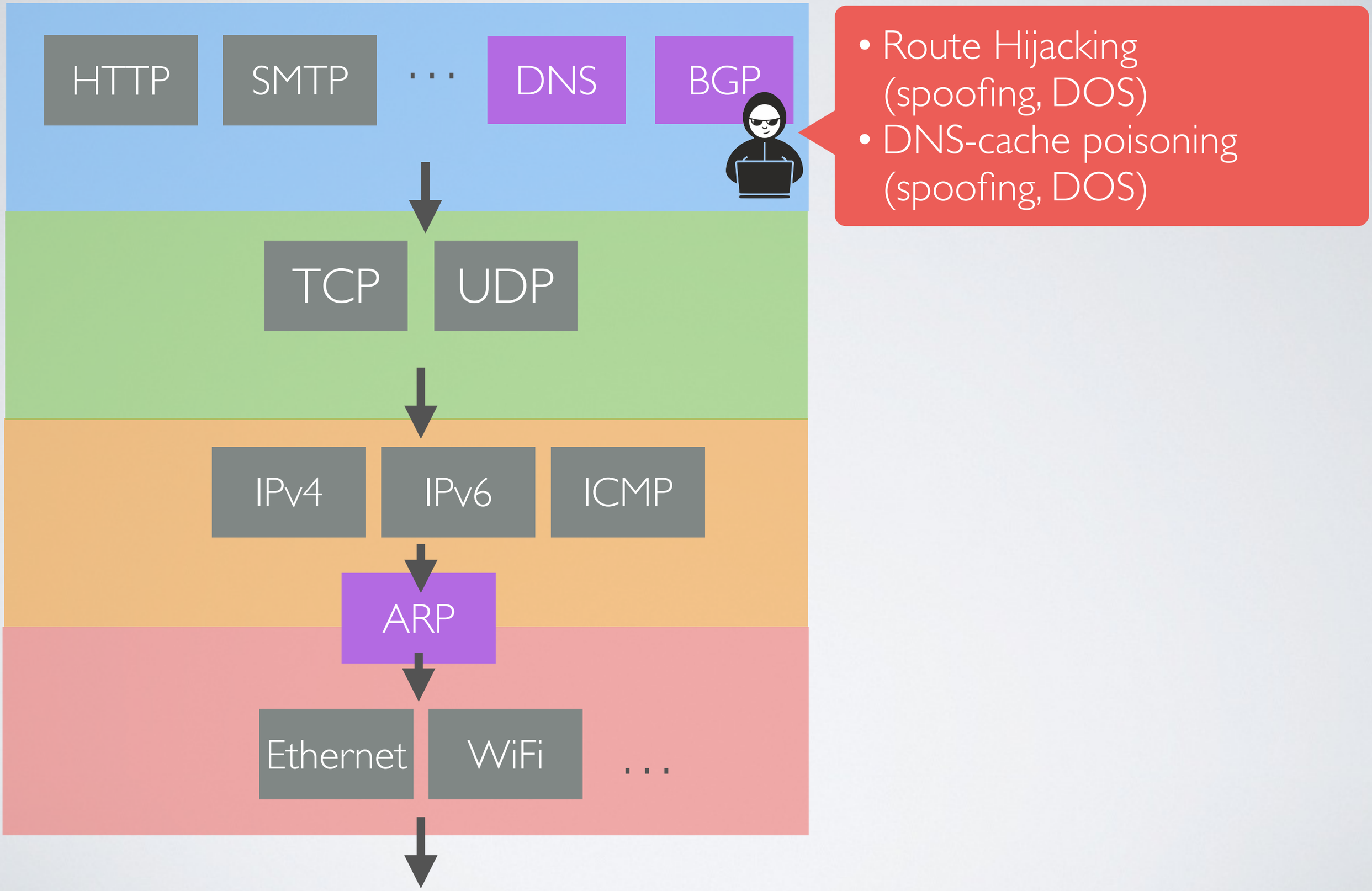
For `http://8t3D0lPwqN5fap4n.onion`

meet me at that RP node (Rendez-vous Point)



Hiding Bob behind TOR (a.k.a .onion server)




HTTP
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• Route Hijacking (spoofing, DOS)
• DNS-cache poisoning (spoofing, DOS)

Preventing DNS spoofing

DNSSEC - Domain Name System Security Extensions provides authentication (but not encryption) between DNS servers

- Not widely deployed

DNS over HTTPS (since 2018)
provides authentication and encryption between client/server and server/server

- Pushed by Google and Mozilla

Preventing route hijacking (BGP)

Bogon Filtering

Best Current Practice to limit fake route advertisement

Deny route advertised by hosts with spoofed addresses

➡ Implemented by ISPs (Internet Service Providers)

Specific attacks of HTTPS

Webpages can be delivered either with HTTPS or HTTP

➡ The browser can automatically switch between HTTP and HTTPS

Sometime within the same webpage (mixed-content)
e.g the main page loads over HTTPS
but images, scripts or css load with HTTP

An attacker can do a MitM attack and remove the SSL protection

➡ **SSLStripping** attack (challenge coming next)