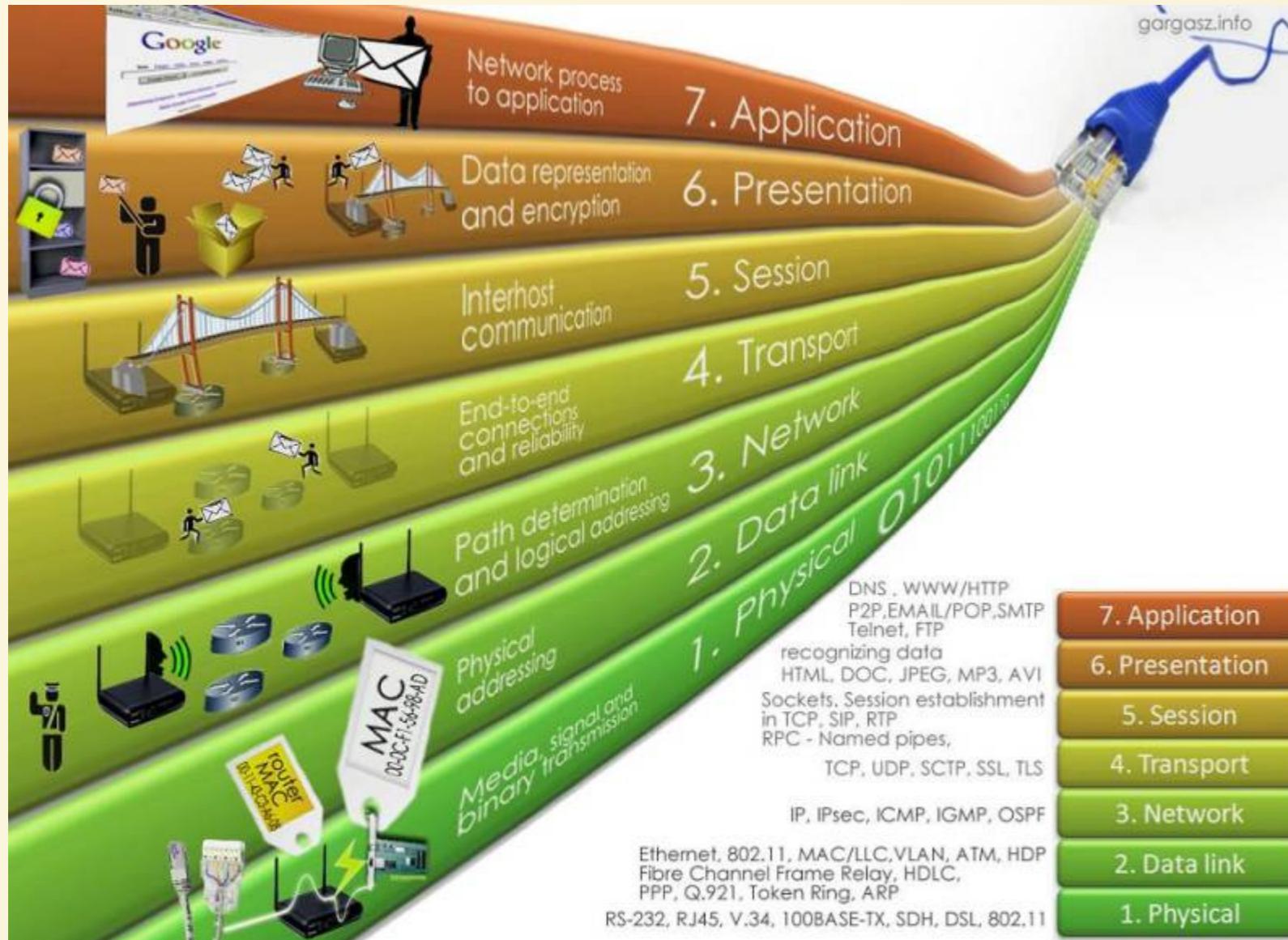


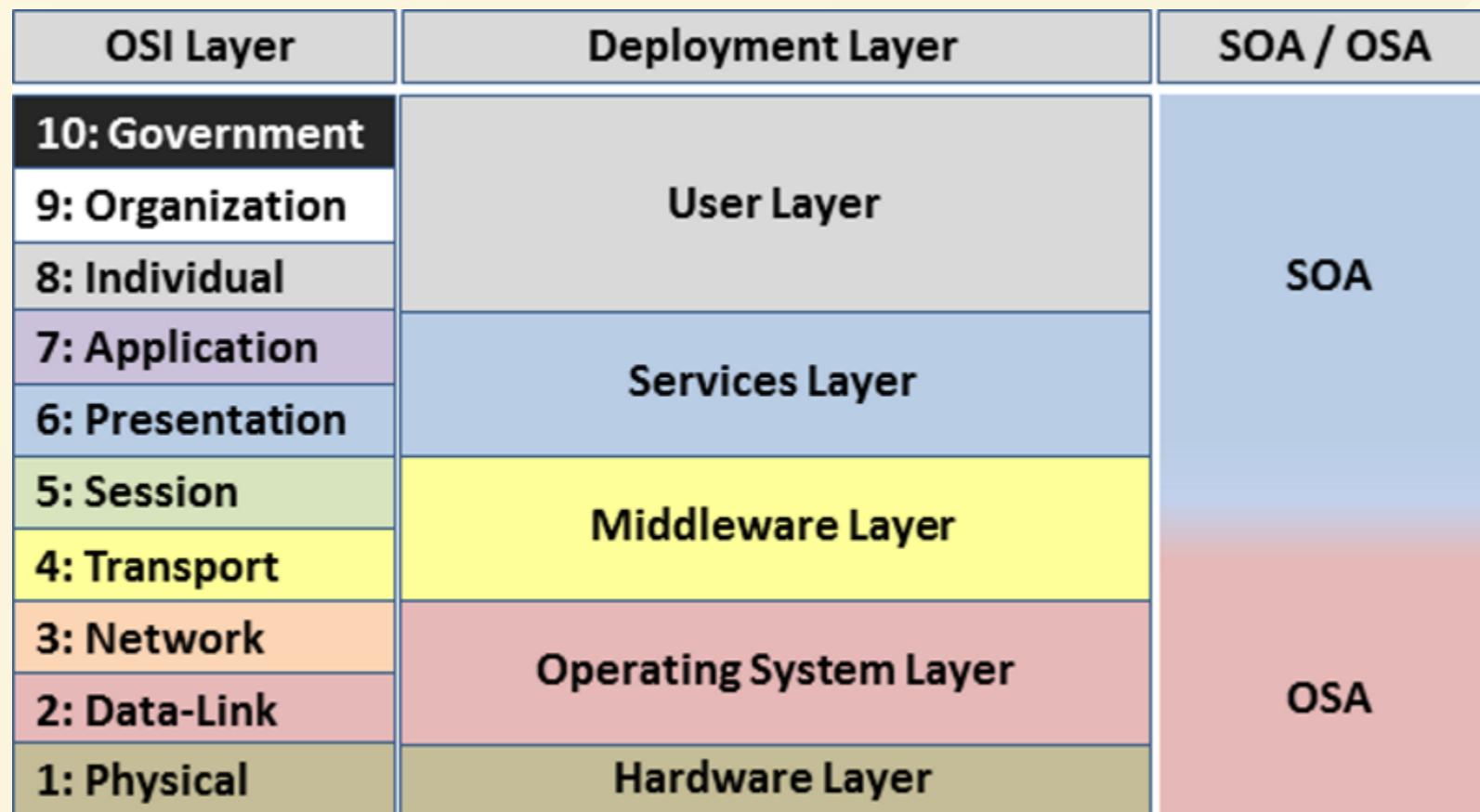
# Network Security

# OSI Network Layer Model

(repetition from Technische Grundlagen der Informatik 2)



# OSI User Layers



# Wireshark

“ Wireshark is the world's foremost and widely-used network protocol analyzer. It lets you see what's happening on your network at a microscopic level and is the de facto (and often de jure) standard across many commercial and non-profit enterprises, government agencies, and educational institutions. Wireshark development thrives thanks to the volunteer contributions of networking experts around the globe and is the continuation of a project started by Gerald Combs in 1998.

”



# Wireshark Features (Excerpt)

- “
- Deep inspection of hundreds of protocols
  - Live capture and offline analysis
  - Rich VoIP analysis
  - Live data can be read from Ethernet, IEEE 802.11, PPP/HDLC, ATM, Bluetooth, USB, Token Ring, Frame Relay, FDDI, and others (depending on your platform)
  - Decryption support for many protocols, including IPsec, ISAKMP, Kerberos, SNMPv3, SSL/TLS, WEP, and WPA/WPA2
- ”

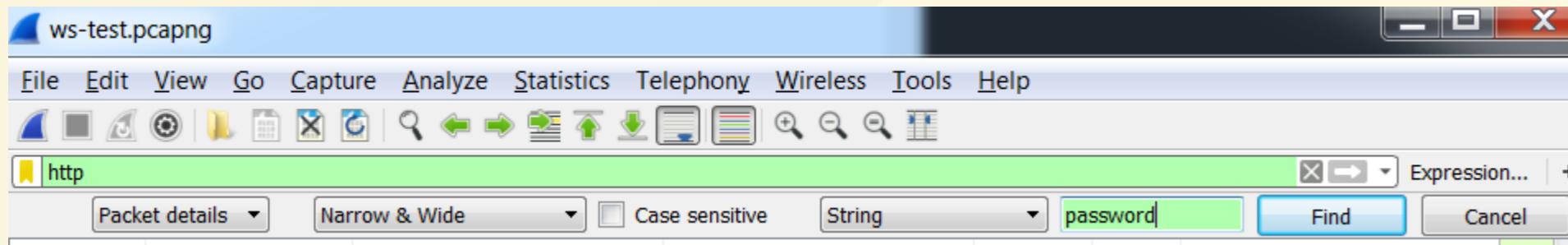
# Exercise 4.1

1. Install Wireshark from <https://www.wireshark.org/#download>
2. Click *Start capturing packets*
3. Spend a few minutes surfing the Internet (the way you usually do)
4. Click *Stop capturing packets*
5. Use *File > Save as...* to save your captured network traffic

**i** *You might be better off performing this exercise on a privately owned laptop, because campus computers might not allow installation of Wireshark.*

# Exercise 4.2

1. Open your previously saved `.pcapng` file
2. Set `http` as a filter
3. Use *Find a packet* to search for the *String* `password` within the *Packet details* (see screenshot below)



ws-test.pcapng

File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help

http

Packet details Narrow & Wide Case sensitive String password Find Cancel

No.	Time	Source	Destination	Protocol	Length	Info
9795	18.905148	10.50.241.73	185.46.212.97	TLSv1.2	61	Alert (Level: Fatal, Description: Bad Certificate)
9886	28.506789	10.50.241.73	185.46.212.97	HTTP	647	GET http://juice-shop.herokuapp.com/rest/user/whoami HTTP/1.1
9889	28.507888	10.50.241.73	185.46.212.97	HTTP	791	POST http://juice-shop.herokuapp.com/rest/user/login HTTP/1.1 (application/json)
9893	28.622371	185.46.212.97	10.50.241.73	HTTP	402	HTTP/1.1 200 OK (application/json)
9894	28.636735	185.46.212.97	10.50.241.73	HTTP	1092	HTTP/1.1 200 OK (application/json)

[HTTP request 1/3]  
[Response in frame: 9894]  
[Next request in frame: 9896]

File Data: 51 bytes

JavaScript Object Notation: application/json

- Object
  - Member Key: email
    - String value: admin@juice-shop
    - Key: email
  - Member Key: password
    - String value: admin123

0260	20	63	6f	6e	74	69	6e	75	65	43	6f	64	65	3d	51	33	continu eCode=Q3
0270	6c	45	37	39	4c	6b	79	77	67	6d	71	61	6a	34	7a	59	1E79Lkyw gmqaj4zY
0280	32	64	35	38	48	56	75	77	68	36	49	50	69	36	75	58	2d58HVuw h6IPi6uX
0290	63	4a	43	52	43	4e	50	41	62	57	4a	4d	44	72	6f	78	cJCRCNPA bWJMDrox
02a0	42	35	70	4e	4f	56	31	36	52	5a	3b	20	5f	73	6d	5f	B5pNOV16 RZ; _sm_
02b0	61	75	5f	63	3d	69	71	48	6e	50	76	76	36	36	72	53	au_c=iqH nPvv66rS
02c0	50	30	72	33	4e	31	38	3b	20	69	6f	3d	67	6c	73	6b	P0r3N18; io=glsk
02d0	6a	34	76	4f	66	4d	45	52	42	52	67	34	41	41	41	33	j4vOfMER BRg4AAA3
02e0	0d	0a	0d	0a	7b	22	65	6d	61	69	6c	22	3a	22	61	64	....{"em ail":"ad
02f0	6d	69	6e	40	6a	75	69	63	65	2d	73	68	2e	6f	70	22	min@juic e-sh.op"
0300	2c	22	70	61	73	73	77	6f	72	64	22	3a	22	61	64	6d	, "passwo rd":"adm
0310	69	6e	31	32	33	22	7d										in123"}

Bytes 780-789: String value (json.value.string) || Packets: 10094 · Displayed: 1087 (10.8%) · Dropped: 0 (0.0%) || Profile: Default

# **VPN**

## **(Virtual Private Network)**

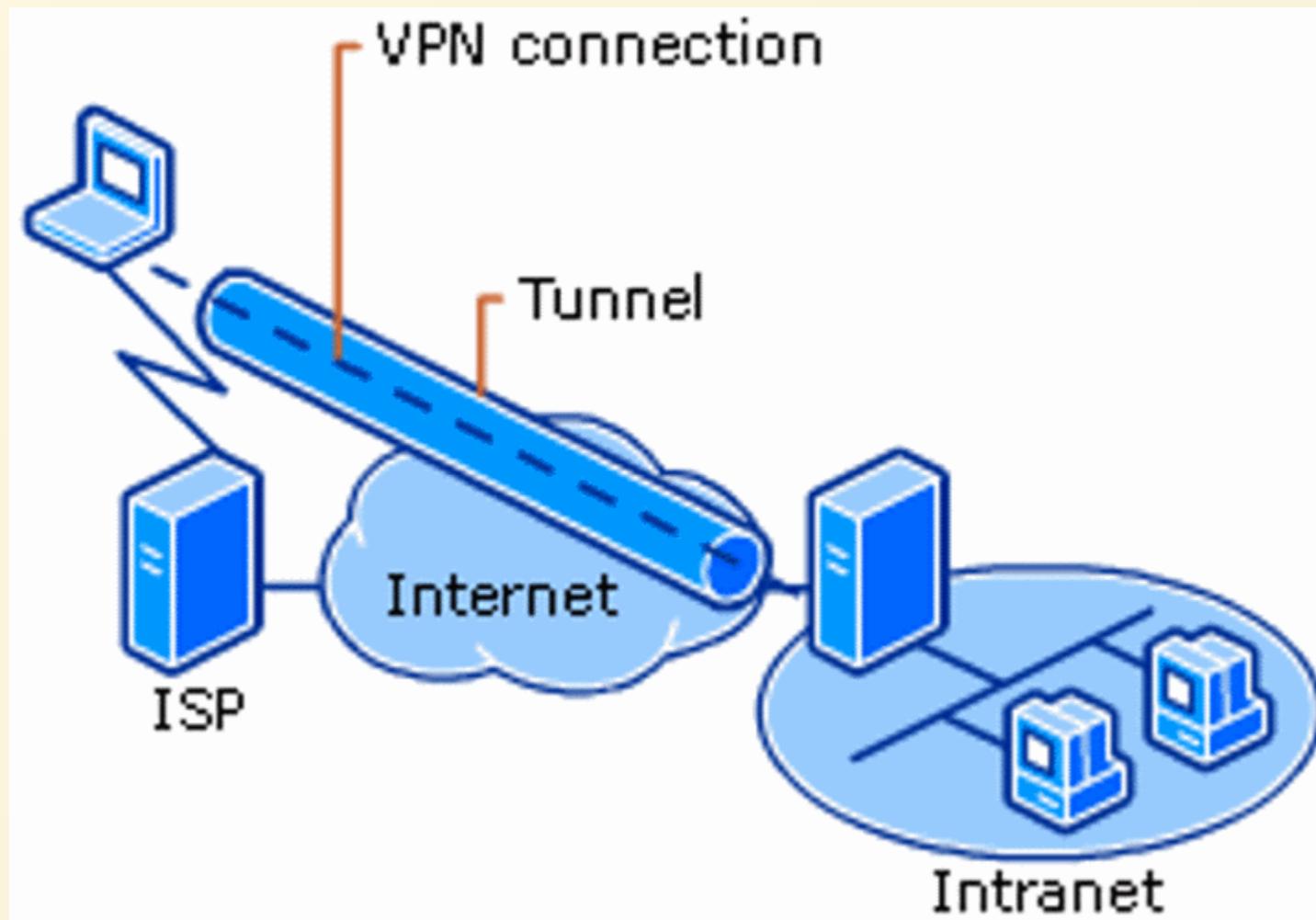
# VPN Architecture

“ Using VPNs, an organization can help **secure private network traffic over an unsecured network**, such as the Internet. VPN helps provide a secure mechanism for encrypting and encapsulating private network traffic and moving it through an intermediate network. **Data is encrypted for confidentiality**, and **packets** that might be intercepted on the shared or public network **are indecipherable** without the correct encryption keys. Data is also encapsulated, or wrapped, with an IP header containing routing information. [[^1](#)] ”

# VPN Scenarios

- **Remote Access VPN:** [...] Single computer user who connects to a private network from a remote location. The VPN server provides access to the resources of the network to which the VPN server is connected.
- **Site-to-Site VPN:** [...] Connects two portions of a private network or two private networks. [...] Allows an organization to have routed connections with separate offices, or with other organizations, over the Internet. [...] The VPN server provides a routed connection to the network to which the VPN server is attached. [[^1](#)]

# Remote Client to a Private Intranet

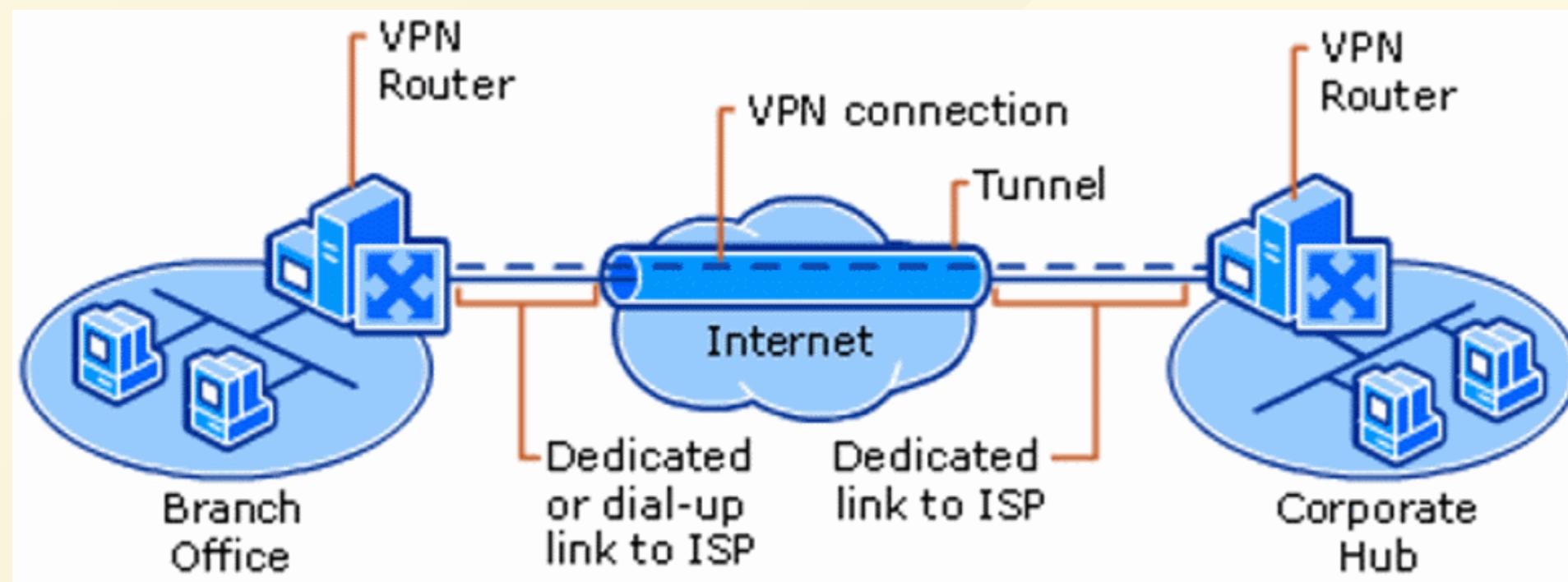


# Remote Client to a Private Intranet

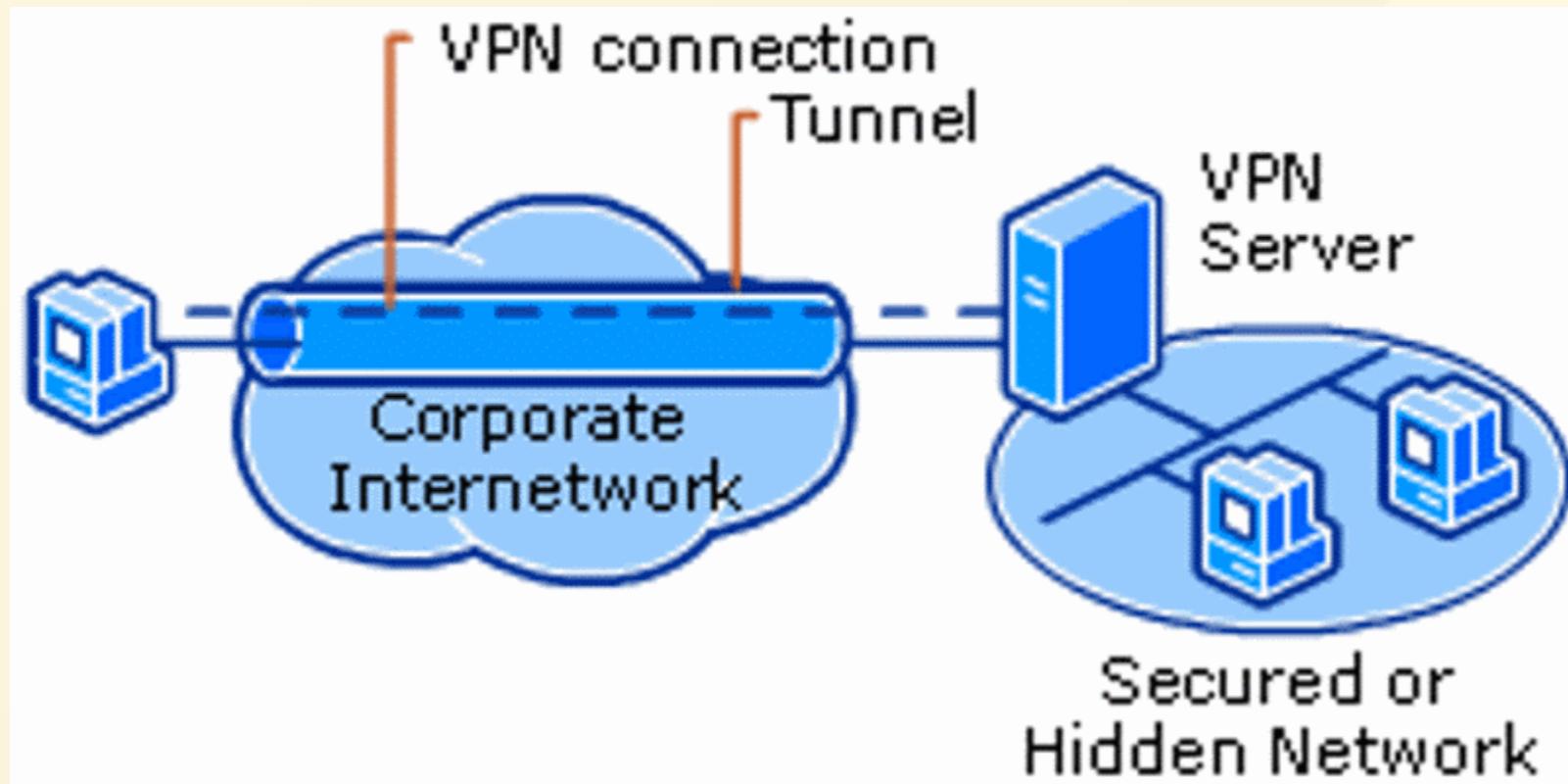
“ A remote access VPN connection over the Internet enables a remote access client to initiate a dial-up connection to a local ISP instead of connecting to a corporate or outsourced network access server (NAS). By using the established physical connection to the local ISP, the remote access client initiates a VPN connection across the Internet to the organization’s VPN server. When the VPN connection is created, the remote access client can access the resources of the private intranet. [...] [[^1](#)] ”

# Two Remote Sites Across the Internet

“ When networks are connected over the Internet, as shown in the following figure, a router forwards packets to another router across a VPN connection. To the routers, the VPN connection operates as a data-link layer link. [[^1](#)] ”



# Remote Access to a Secured Network over an Intranet

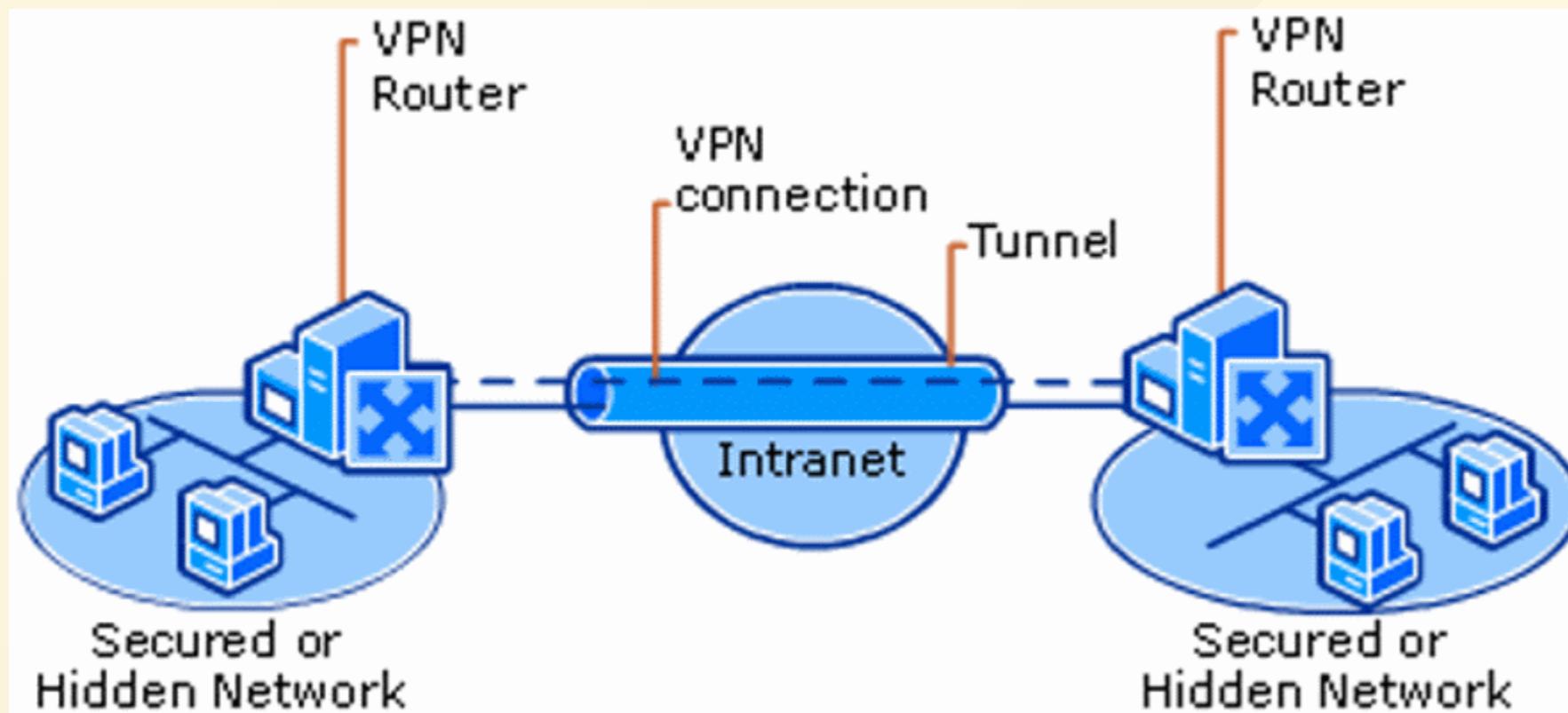


# Remote Access to a Secured Network over an Intranet

“ In some organization intranets, the data of a department, such as human resources, is so sensitive that the network segment of the department is physically disconnected from the rest of the intranet. While this protects the data of the human resources department, it creates information accessibility problems for authorized users not physically connected to the separate network segment.

VPN connections help provide the required security to enable the network segment of the human resources department to be physically connected to the intranet. [...] [^1]

# Connecting Two Networks over an Intranet



# Connecting Two Networks over an Intranet

“ Two networks can be connected over an intranet using a site-to-site VPN connection. This type of VPN connection might be necessary, for example, for two departments in separate locations, whose data is highly sensitive, to communicate with each other. For instance, the finance department might need to communicate with the human resources department to exchange payroll information.

The finance department and the human resources department are connected to the common intranet with computers that can act as VPN clients or VPN servers. [...] [[^1](#)]

# Exercise 4.3 (🏠)

1. Find out if your university (or company) is offering remote access via VPN and request access
2. Set up a VPN connection from your private computer (in your home network) and test the connection
3. Which protocols does your university (or company) VPN use for
  - Tunneling
  - Authentication
  - Encryption?
4. Elaborate how these protocols work together to provide a VPN (📝)

# Wireless Security

# "I'm never gonna move"



!? Why would anyone not agree with *Success Baby* on this?

# WLAN Security

“ [...] The original security standard was **Wired Equivalent Privacy (WEP)**. It was replaced by the original **Wi-Fi Protected Access (WPA)** in 2003 as an interim solution to the limited protection offered by WEP. The WPA program added support for **Temporal Key Integrity Protocol (TKIP)** encryption, an older form of security technology with some vulnerability to cryptographic attacks. WPA was replaced in 2004 with more advanced protocols of **WPA2**.

Though the threat of a security compromise is small, users should not purchase new equipment which supports only WPA with TKIP. Only devices supporting WPA2 and **WPA3** security should be purchased and used. [^4] ”

- *Details on each protocol will be covered in the Encryption lecture!*

# Exercise 4.4 (📌)

1. Read the BSides Perth 2018 presentation [What Your RF Signature Says About You](#)
2. Identify devices you own that could become a privacy risk
3. Consider changing some habits to reduce this risk, e.g. by following the [All Privacy Suggestions](#)

# Wardriving

“ Wardriving is the act of searching for Wi-Fi networks from a moving vehicle. It involves **slowly driving around an area with the goal of locating Wi-Fi signals**. This may be accomplished by an individual or by two or more people, with one person driving and others searching for wireless networks.

Wardriving may be as simple as searching for free Wi-Fi using a smartphone inside an automobile. However, the definition usually applies to a **hardware and software configuration specifically designed for locating and recording Wi-Fi networks**. [...]

"Warbiking," "warwalking," and "warrailing" are variations of wardriving. [[^2](#)]



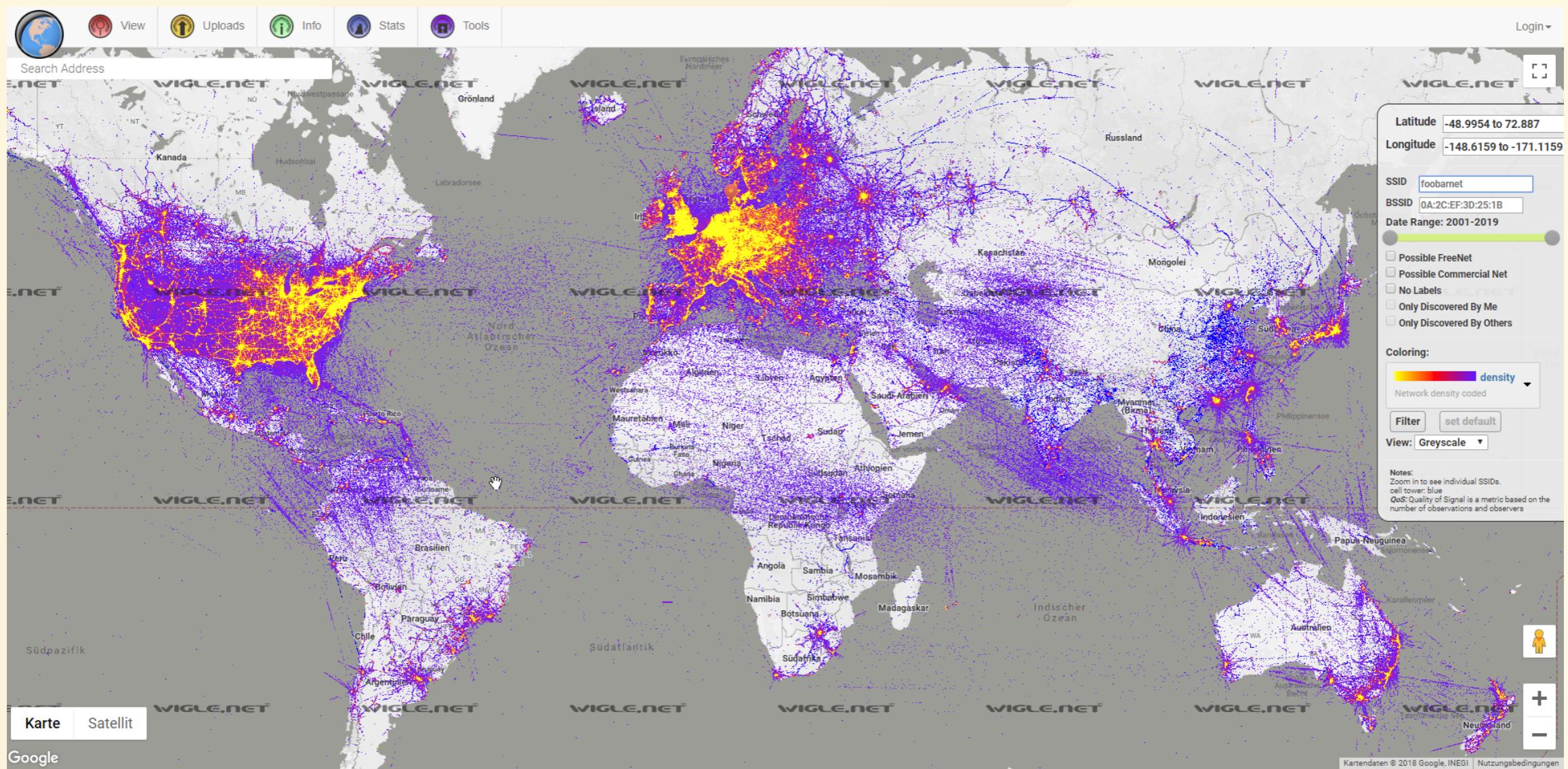
## WiGLE

“ WiGLE, or (Wireless Geographic Logging Engine), is a website for collecting information about the different wireless hotspots around the world. Users can register on the website and upload hotspot data like GPS coordinates, SSID, MAC address and the encryption type used on the hotspots discovered. In addition, cell tower data is uploaded and displayed.

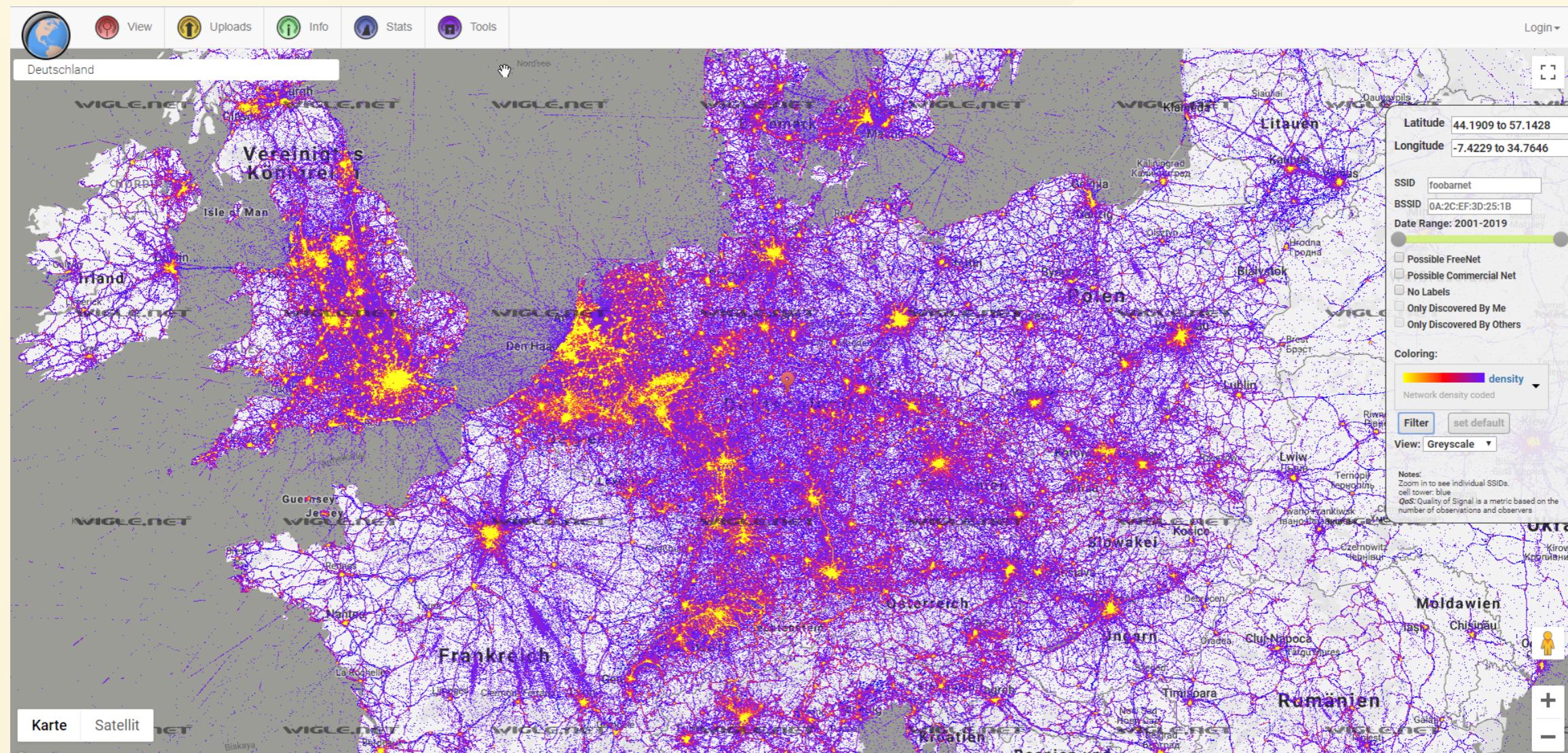
By obtaining information about the encryption of the different hotspots, WiGLE tries to create an awareness of the need for security by running a wireless network. [^3]

”

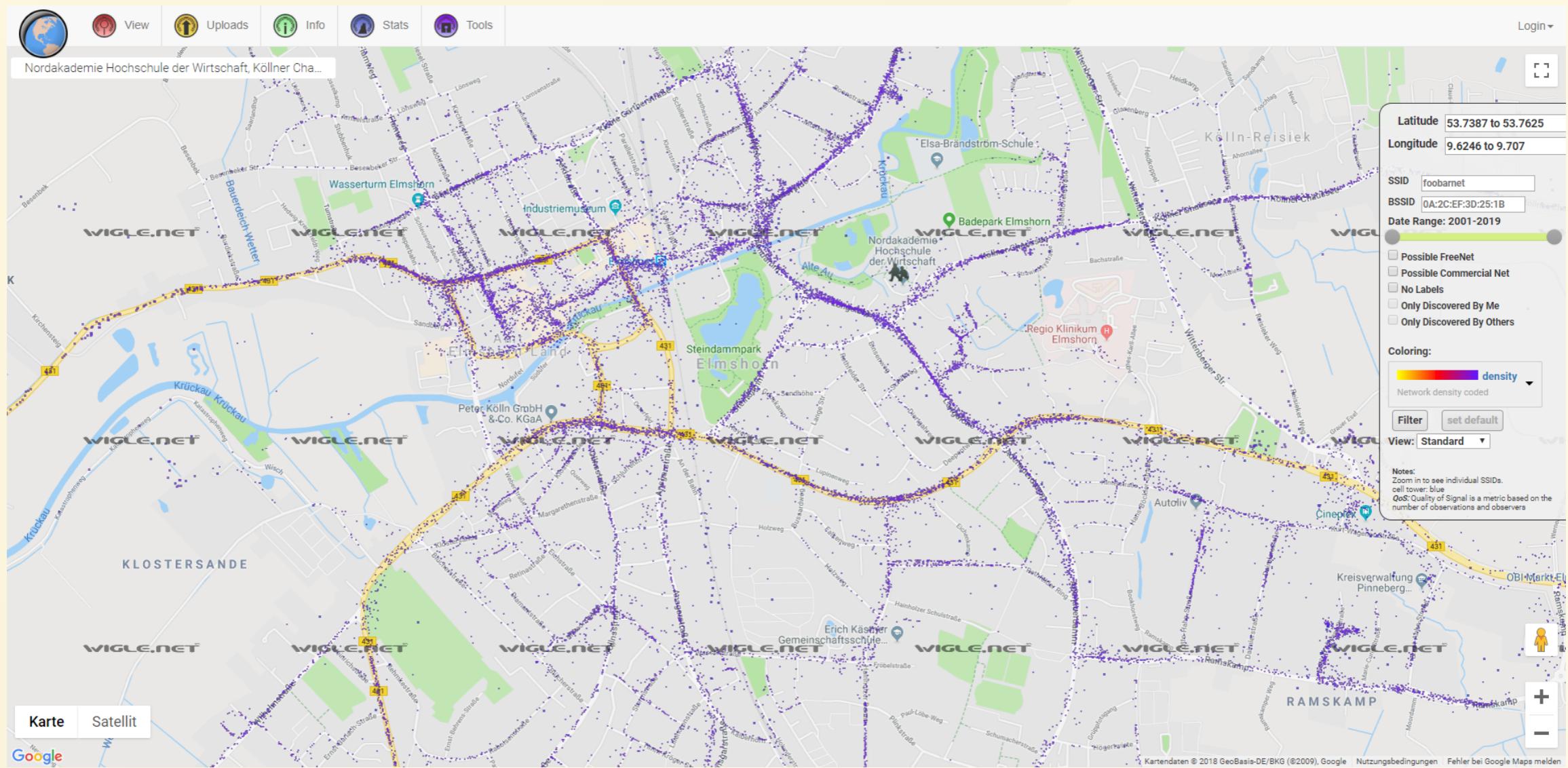
# WiGLE Map (World)



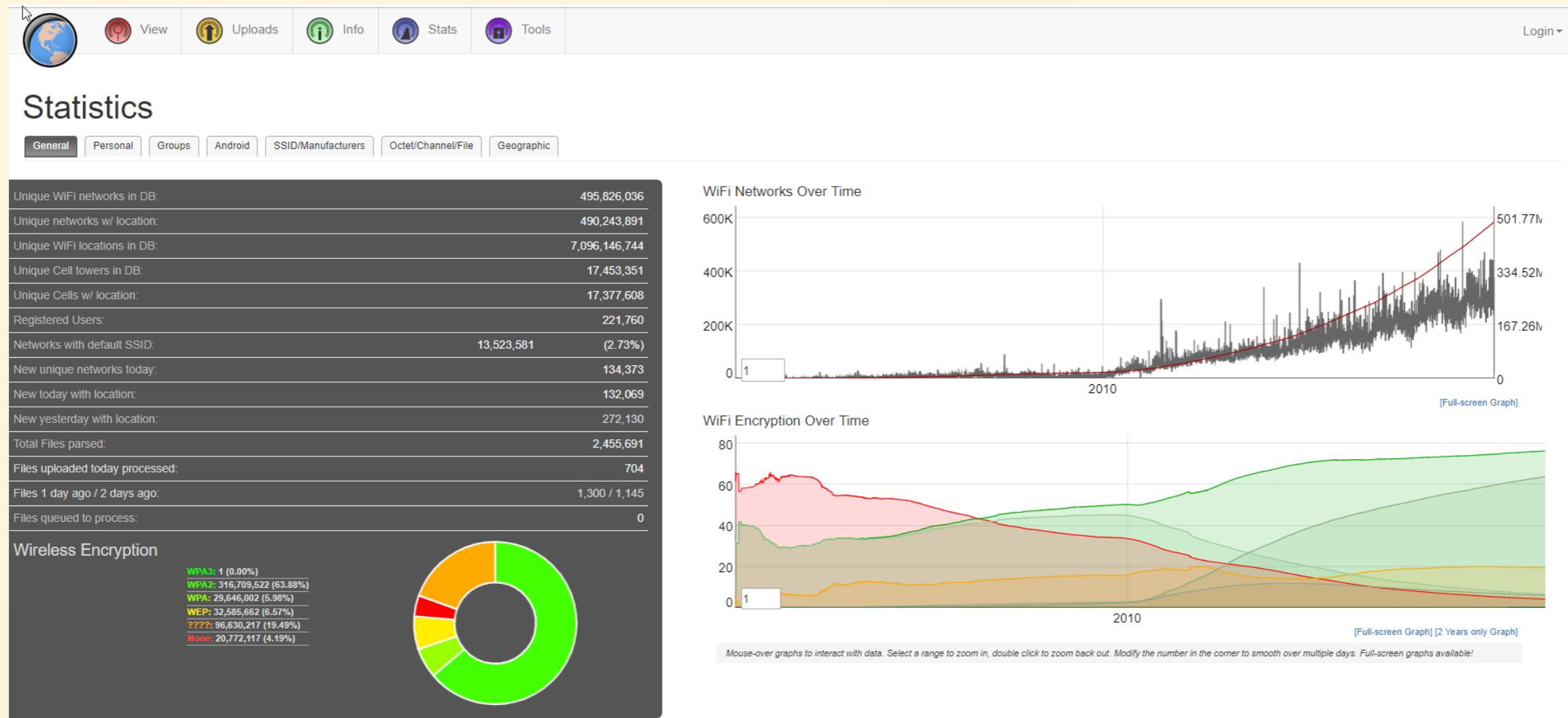
# WiGLE Map (Germany)



# WiGLE Map (Elmshorn, Germany)



# WiGLE Statistics

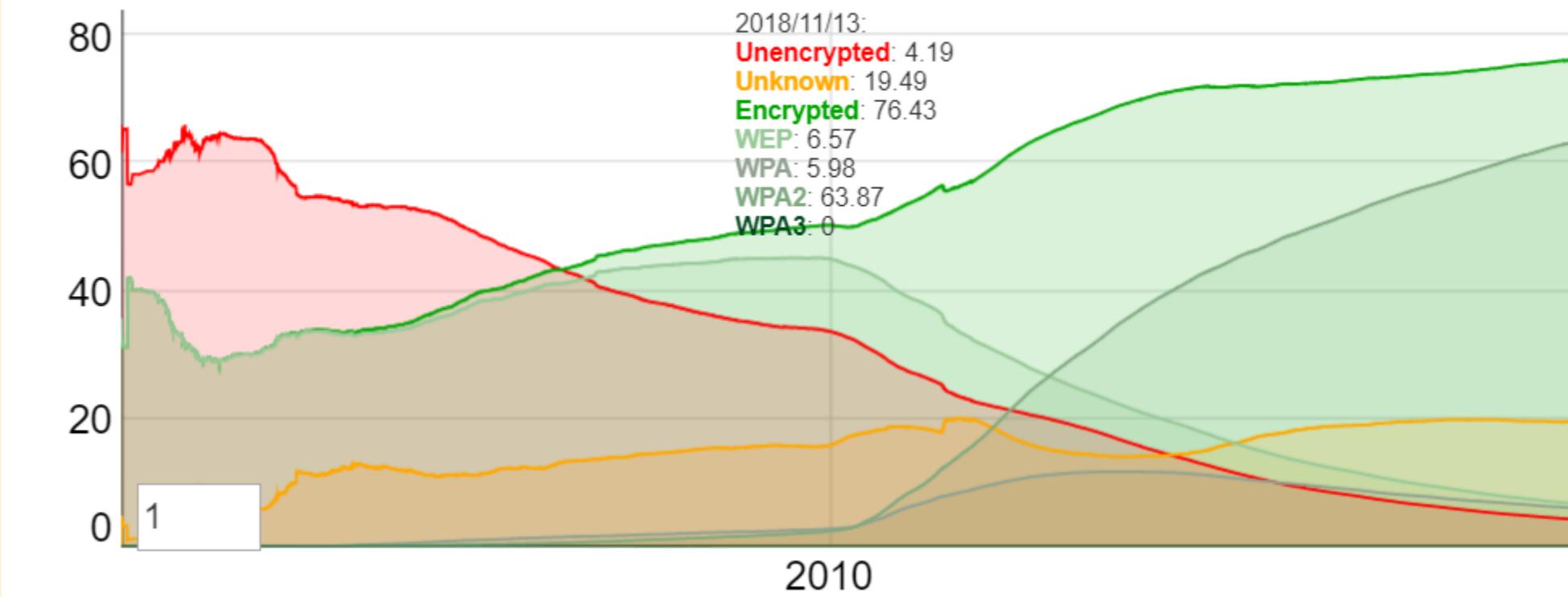


## Wireless Encryption

**WPA3:** 1 (0.00%)  
**WPA2:** 316,712,156 (63.88%)  
**WPA:** 29,646,012 (5.98%)  
**WEP:** 32,585,685 (6.57%)  
**????:** 96,630,507 (19.49%)  
**None:** 20,772,126 (4.19%)



## WiFi Encryption Over Time



# Exercise 4.5 ( optional for iPhone users)

1. Install [Wigle WiFi Wardriving](#) app for Android
2. Let the app scan for networks on your way home
3. How many unencrypted networks did you encounter?
4. Did you encounter any WEP encrypted networks? How many?

**i** *The Android app is Open Source: <https://github.com/wiglenet/wigle-wifi-wardriving>. Unfortunately, there are no war-driving tools for non-jailbroken iOS devices at this time, since Apple has disallowed them from their marketplace.*

# WiGLE Run from train station to university

## All Privacy Suggestions

- “ 1. Turn off phone WiFi when out
- 2. Forget old networks
- 3. Use a boring WiFi SSID (not your name)
- 4. Disable Wired to WiFi broadcasts
- 5. Migrate to 5GHz-only if possible
- 6. Wire your cameras
- 7. Pair Bluetooth devices at home
- 8. Put your cards in your wallet
- 9. Keep work logos and ID cards hidden [[^4](#)]

# Exercise 4.6 (🏠)

1. Install any popular NFC reader app on your smartphone
2. Scan a few of your credit cards, health insurance cards, ID cards etc. and document what personal information you can retrieve from each
3. Consider getting a Blocking Card or RFID-protected purse to prevent RFID skimming

# Data Center Security

# Network Firewall

“ A firewall is a system that provides network security by **filtering incoming and outgoing network traffic based on a set of user-defined rules**. In general, the purpose of a firewall is to **reduce or eliminate the occurrence of unwanted network communications** while allowing all legitimate communication to flow freely. In most server infrastructures, firewalls provide an essential layer of security that, combined with other measures, prevent attackers from accessing your servers in malicious ways. [[^5](#)] ”

# Types of Firewalls

- “
- **Packet filtering**, or stateless, **firewalls** work by inspecting individual packets in isolation. As such, they are unaware of connection state and can only allow or deny packets based on individual packet headers.
  - **Stateful firewalls** are able to determine the connection state of packets, which makes them much more flexible than stateless firewalls. They work by collecting related packets until the connection state can be determined before any firewall rules are applied to the traffic.
  - **Application firewalls** go one step further by analyzing the data being transmitted, which allows network traffic to be matched against firewall rules that are specific to individual services or applications. These are also known as proxy-based firewalls. [^5]
- ”

# Firewall Rules

A simple firewall could have rules defined like this:

- FROM *source* TO *destination* ALLOW|BLOCK *protocol* PORT *port(s)*

Example policy for incoming traffic using above rule syntax:

1. FROM *external* TO *internal* ALLOW *tcp* PORT 80/443
2. FROM *194.94.98.\** TO *internal* BLOCK *tcp* PORT 22
3. FROM *194.94.98.42* TO *internal* ALLOW *tcp* PORT 22
4. FROM *any* TO *any* BLOCK *any* PORT *any*

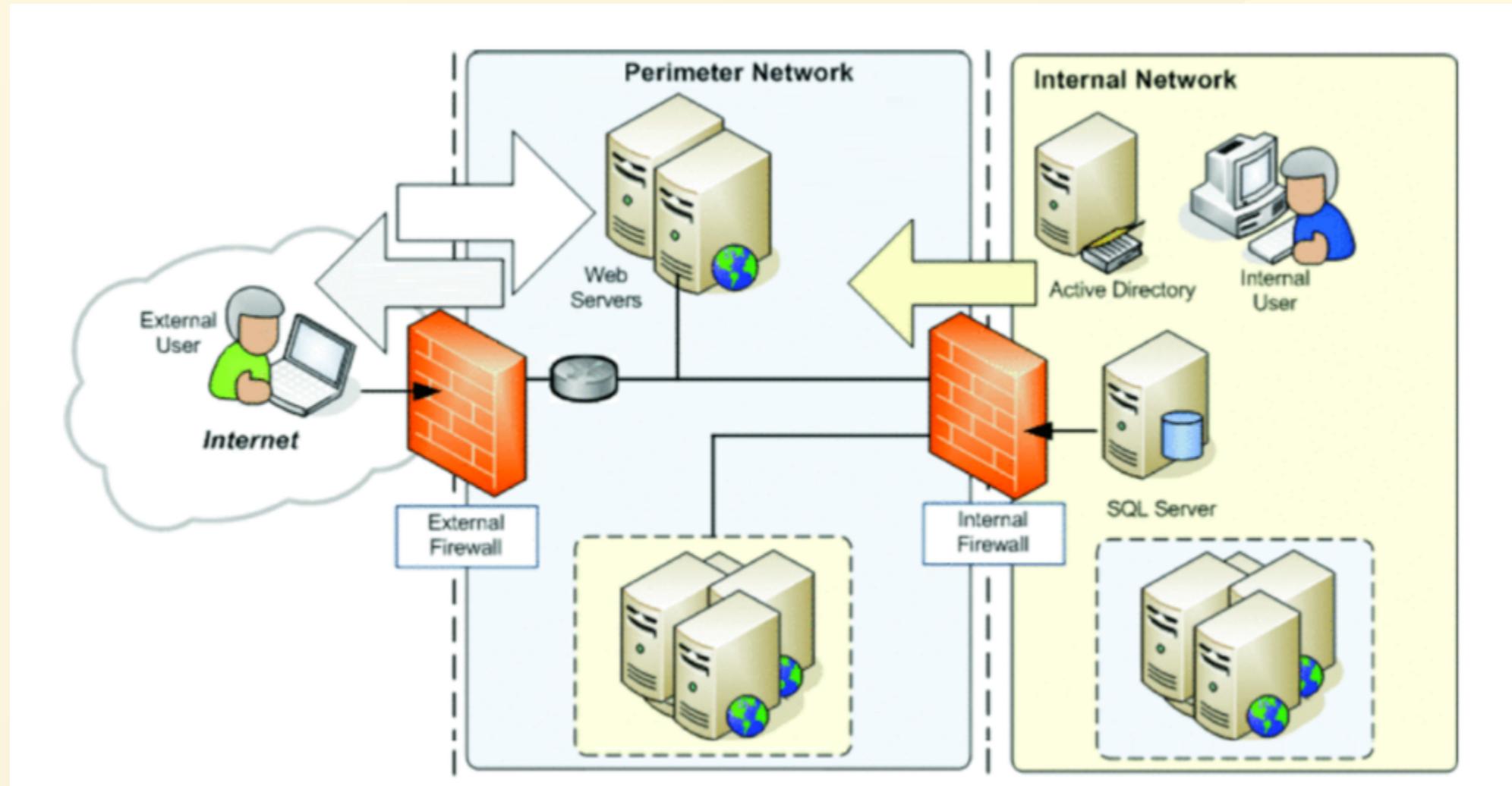
# Default Policy

To keep configuration effort and complexity low, Firewalls fall back to a default policy when no explicitly defined rule matches the traffic.

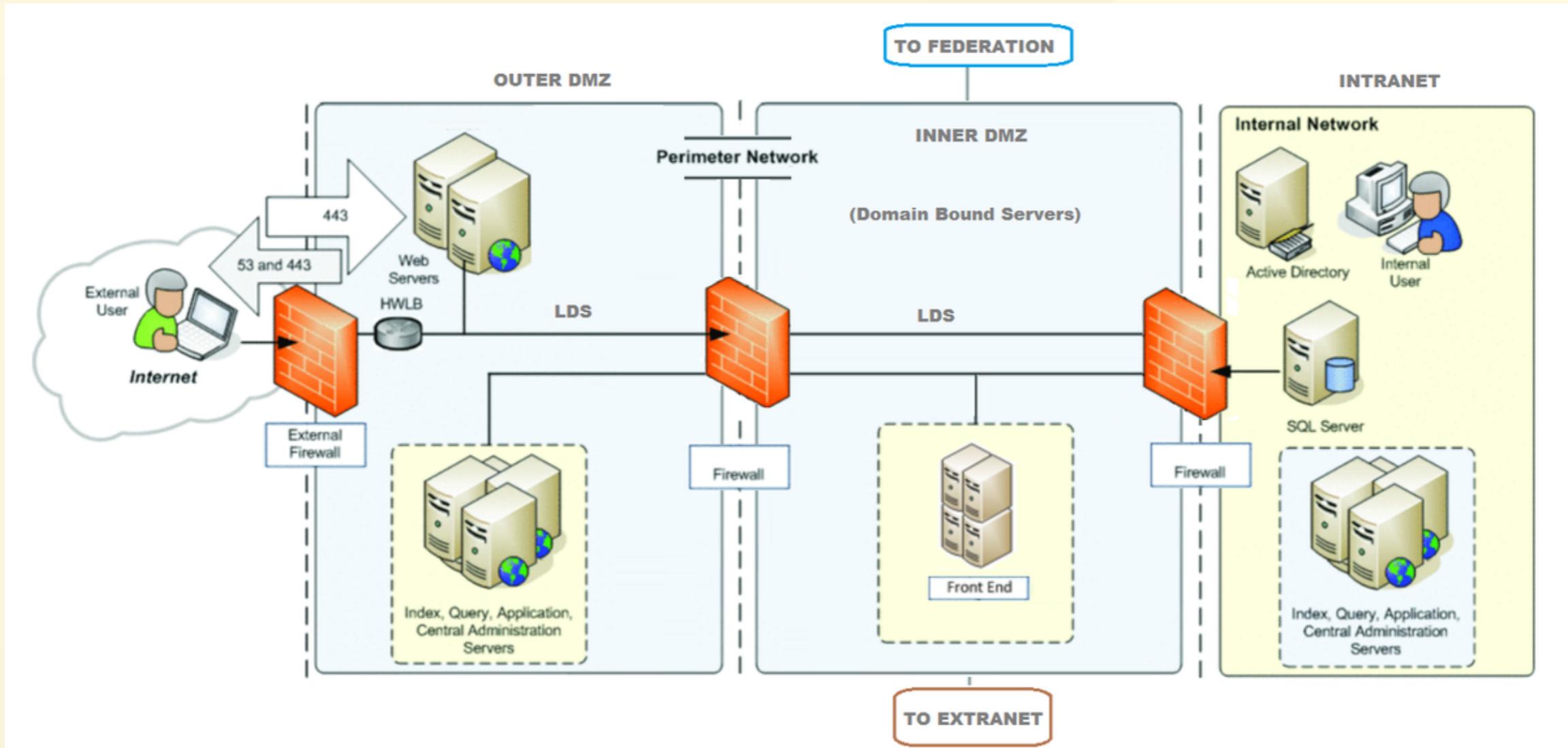
- `FROM any TO any BLOCK any PORT any`  
= Block everything by default ("White List")
- `FROM any TO any ALLOW any PORT any`  
= Allow everything by default ("Black List")

**i** For all incoming traffic a White List is recommended to maximize security. A Black List would suffice for outgoing traffic adding blocks only for some sites, e.g. `FROM 194.94.98.* TO youtube.* BLOCK tcp PORT 80/443`

# DMZ with two Firewalls



# Two-Layer DMZ with three Firewalls



# **IDS/IPS**

## **(Intrusion Detection / Prevention System)**

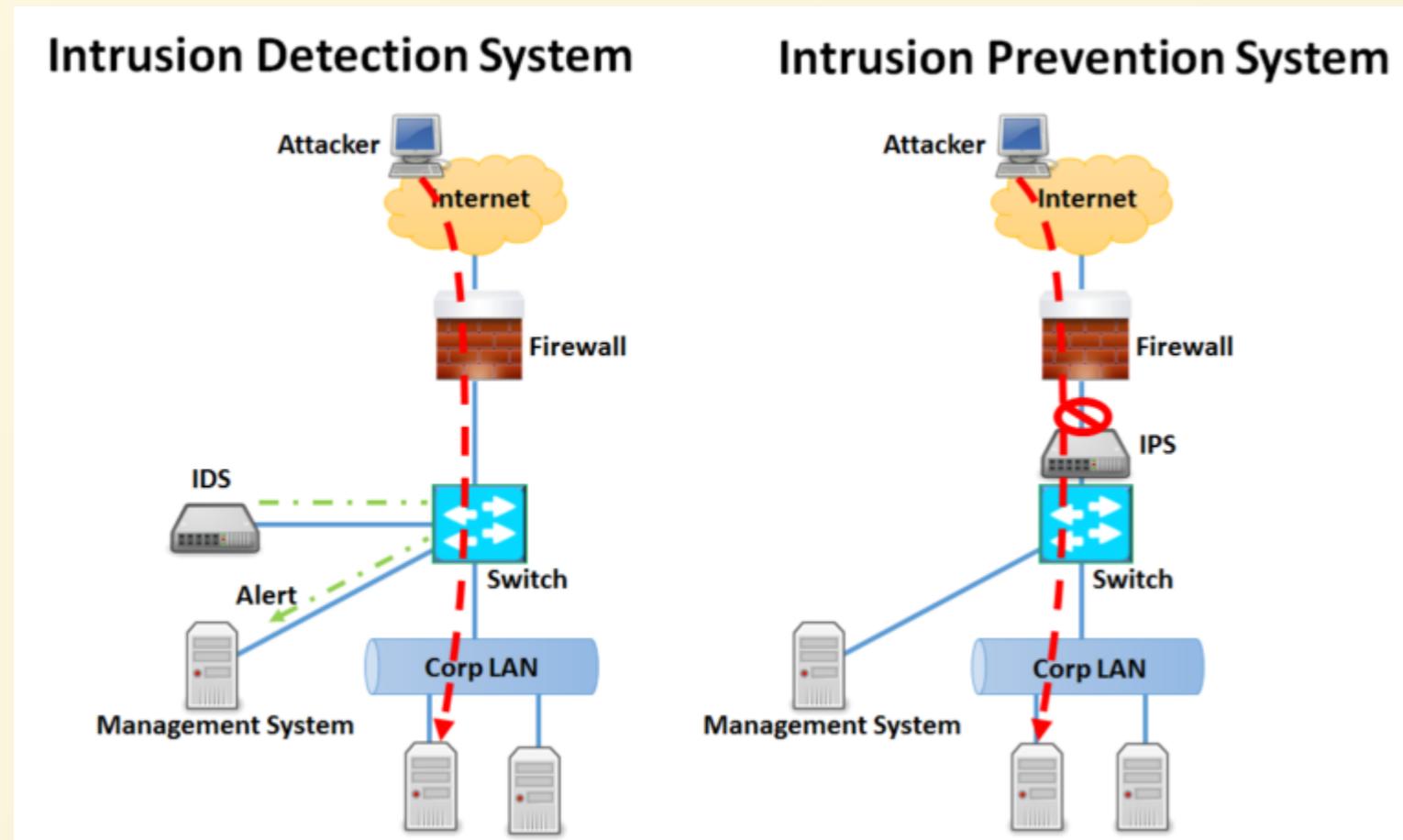
# Definition

- “ An **intrusion detection system (IDS)** is a device or software application that **monitors a network or systems for malicious activity or policy violations**. Any malicious activity or violation is typically **reported either to an administrator or collected centrally** [...]. ”
- “ **Intrusion prevention systems** are considered extensions of intrusion detection systems because they both monitor network traffic and/or system activities for malicious activity. The main differences are, unlike intrusion detection systems, **intrusion prevention systems are placed in-line and are able to actively prevent or block intrusions** that are detected. [^6] ”

# Network-based IDS

“ Network intrusion detection systems (NIDS) are placed at a strategic point or points within the network to monitor traffic to and from all devices on the network. It performs an analysis of passing traffic on the entire subnet, and matches the traffic that is passed on the subnets to the library of known attacks. Once an attack is identified, or abnormal behavior is sensed, the alert can be sent to the administrator. [^6] ”

# IDS vs. IPS (both Network-based)



# Limitations

- Noise (e.g. from software bugs or corrupt DNS data) can severely limit an intrusion detection system's effectiveness
- Number of real attacks is often so far below the number of false-alarms that the real attacks are often missed and ignored
- Lag between a new threat discovery and its signature being applied to the IDS
- Cannot compensate for weak identification and authentication mechanisms or for weaknesses in network protocols
- Encrypted packets are not processed by most intrusion detection devices [[^6](#)]

# Host-based IDS

“ Host intrusion detection systems (HIDS) run on individual hosts or devices on the network. A HIDS **monitors the inbound and outbound packets from the device only** and will alert the user or administrator if suspicious activity is detected. It **takes a snapshot of existing system files and matches it to the previous snapshot**. If the critical system files were modified or deleted, an alert is sent to the administrator to investigate. An example of HIDS usage can be seen on mission critical machines, which are not expected to change their configurations. [^6] ”

# **WAF**

## **(Web Application Firewall)**

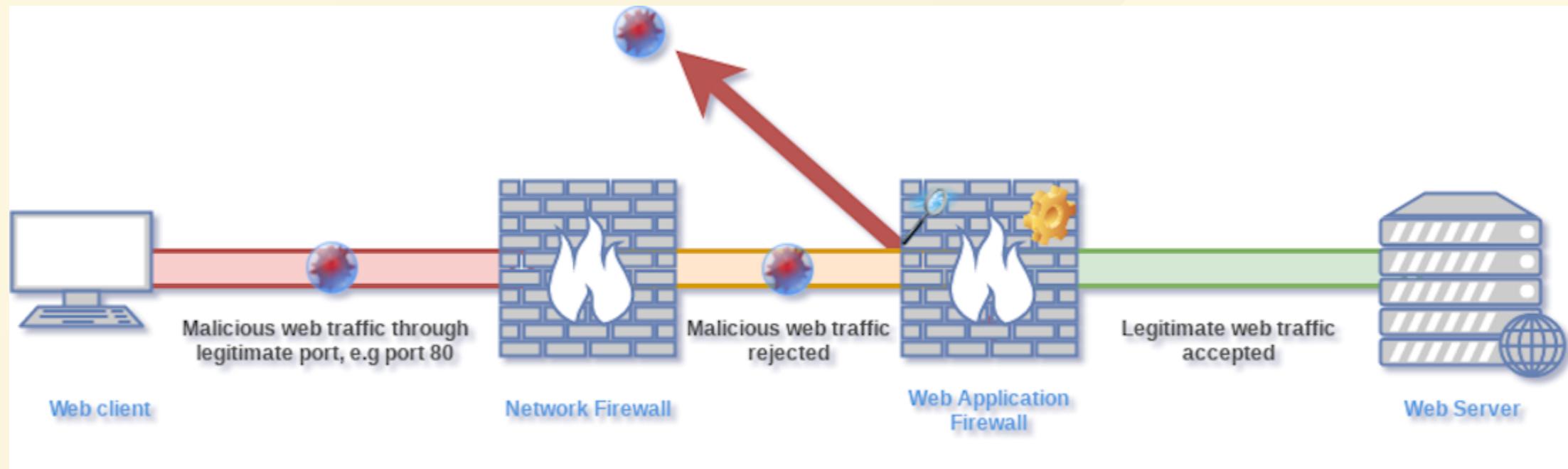
# Web Application Firewall

“ A web application firewall (WAF) is an application firewall for HTTP applications. It applies a set of rules to an HTTP conversation. Generally, these rules cover common attacks such as cross-site scripting (XSS) and SQL injection.

While proxies generally protect clients, WAFs protect servers. A WAF is deployed to protect a specific web application or set of web applications. A WAF can be considered a reverse proxy.

WAFs may come in the form of an appliance, server plugin, or filter, and may be customized to an application. The effort to perform this customization can be significant and needs to be maintained as the application is modified. [^7]

# WAF Deployment in the Network



💡 An application should be able to protect itself! Use a WAF only as a secondary defense mechanism to achieve Defense in Depth! For legacy systems (with no feasible way to patch directly) a WAF can be the main protection mechanism.

## Risk in the use of WAFs

- "Yet-another-proxy" (increased complexity of the IT infrastructure)
- Organisational tasks
- Training the WAF on each new release of the web application
- Testing
- False positives (which may have a significant business impact)
- More complex troubleshooting
- WAFs also have/generate errors
- Responsibility for system-wide error situations
- Cost-effectiveness

# WAF Modes

- **Blocking Mode:** Normal operational mode where the WAF blocks requests it identified as malicious.
- **Monitoring Mode:** The WAF logs alerts but does not block the corresponding requests.
- **Learning Mode:** The WAF learns from good traffic (e.g. by whitelisted IPs) what the normal use cases and input are.

 *Learning Mode might lead to false positives on new application releases when the WAF did not learn any traffic for new functionality.*

# Exercise 4.7 (🏠)

1. Find out if your university uses a Web Application Firewall
2. Find out which product/vendor is being used
3. Find out the number of web applications in your university
  - in total
  - accessible from public Internet (i.e. without VPN)
  - protected by a WAF
4. Repeat steps 1-3 for the company you work at (if applicable)

➡ SOON *Web Application Security will make up most of next semester's curriculum!*