OSI Security Model

The OSI Layers

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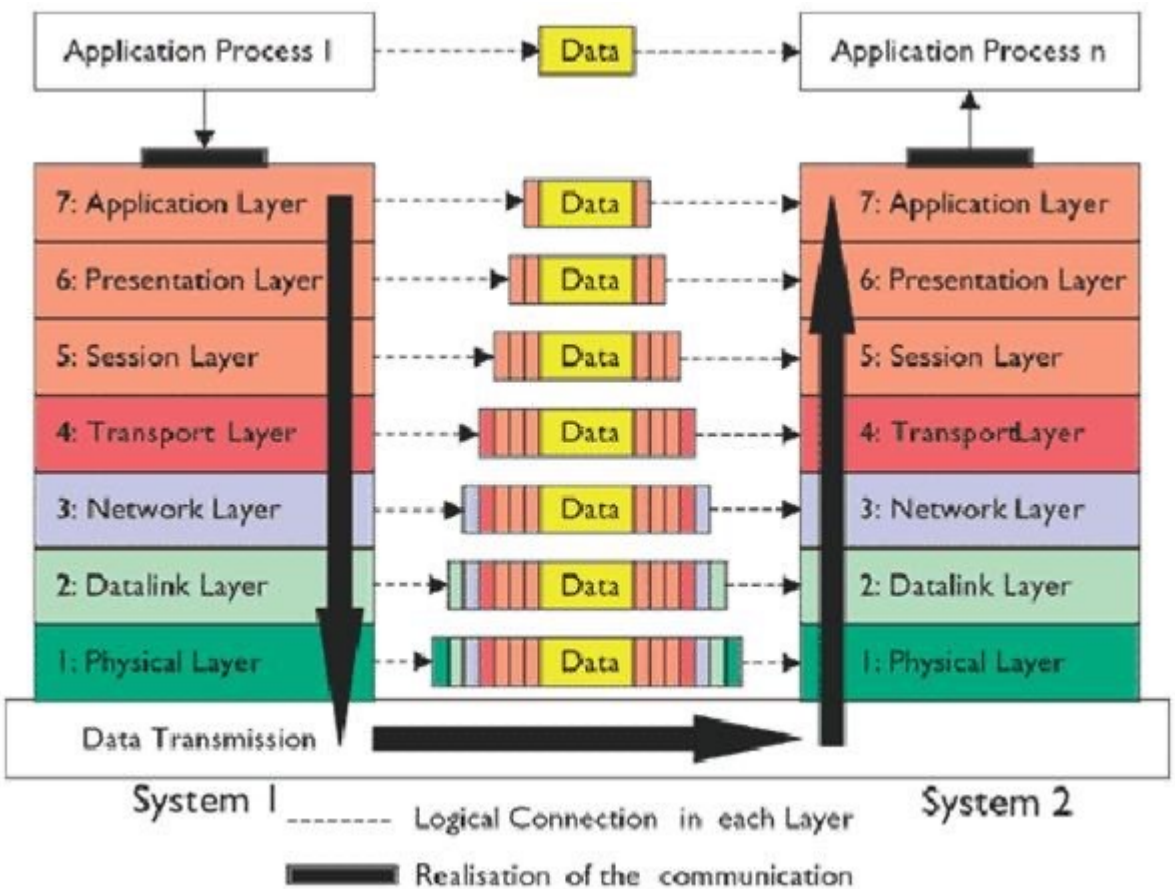
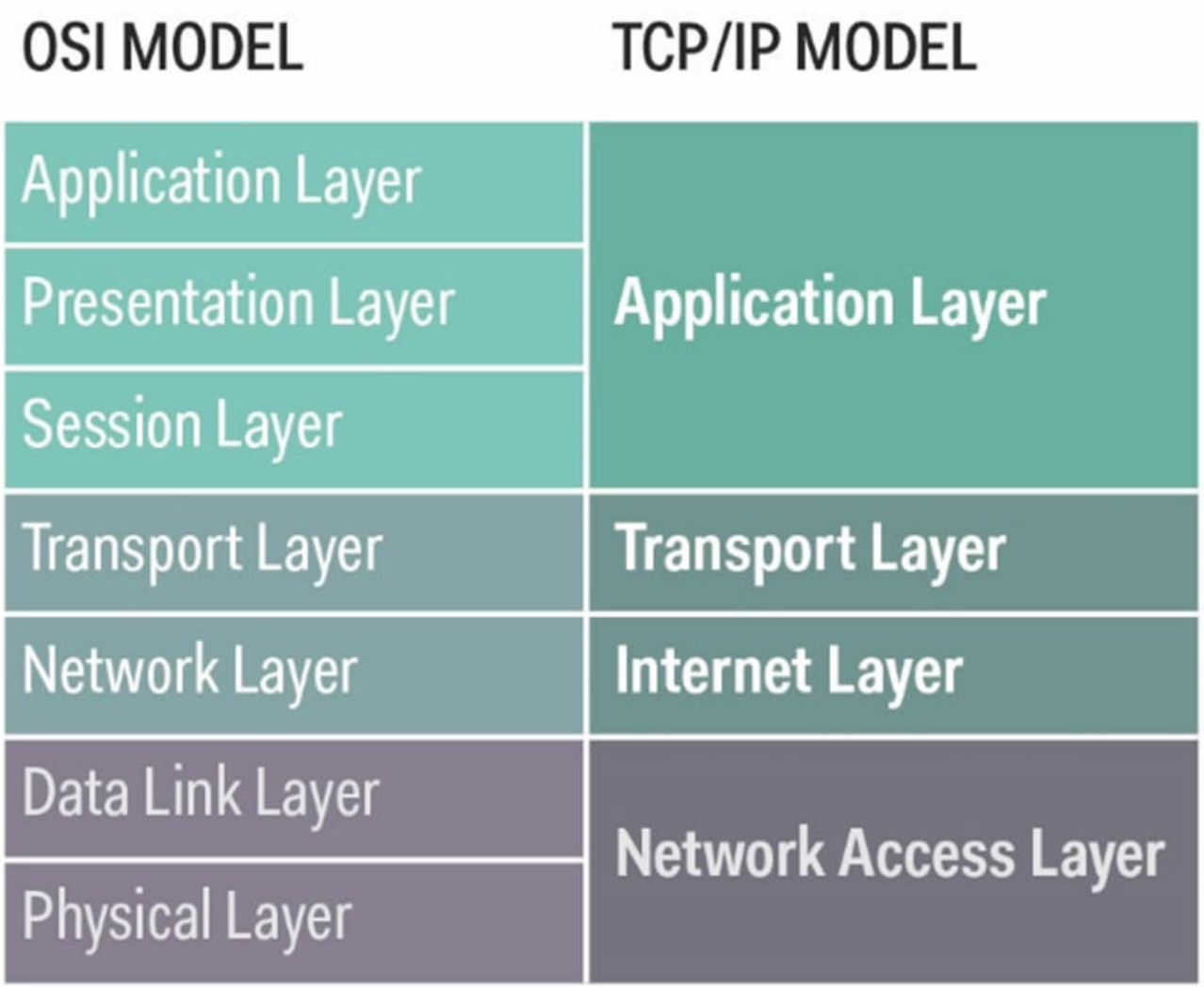
The OSI Layers

- Open System Interconnection or OSI layers
- Reference model for how information from software in one device moves to an application on another computer



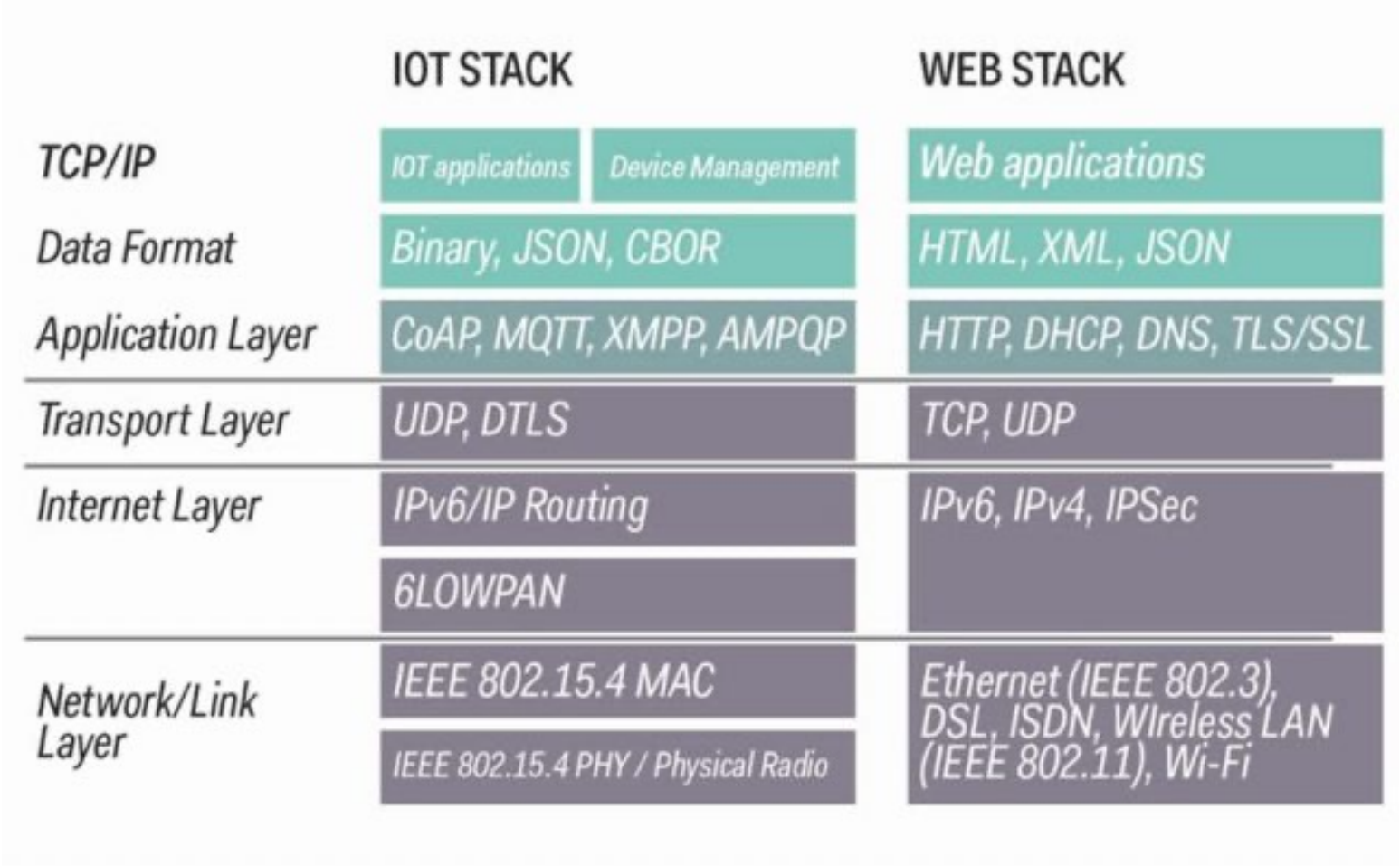
The OSI Layers

- Maps to various implementations
- TCP/IP architecture for example



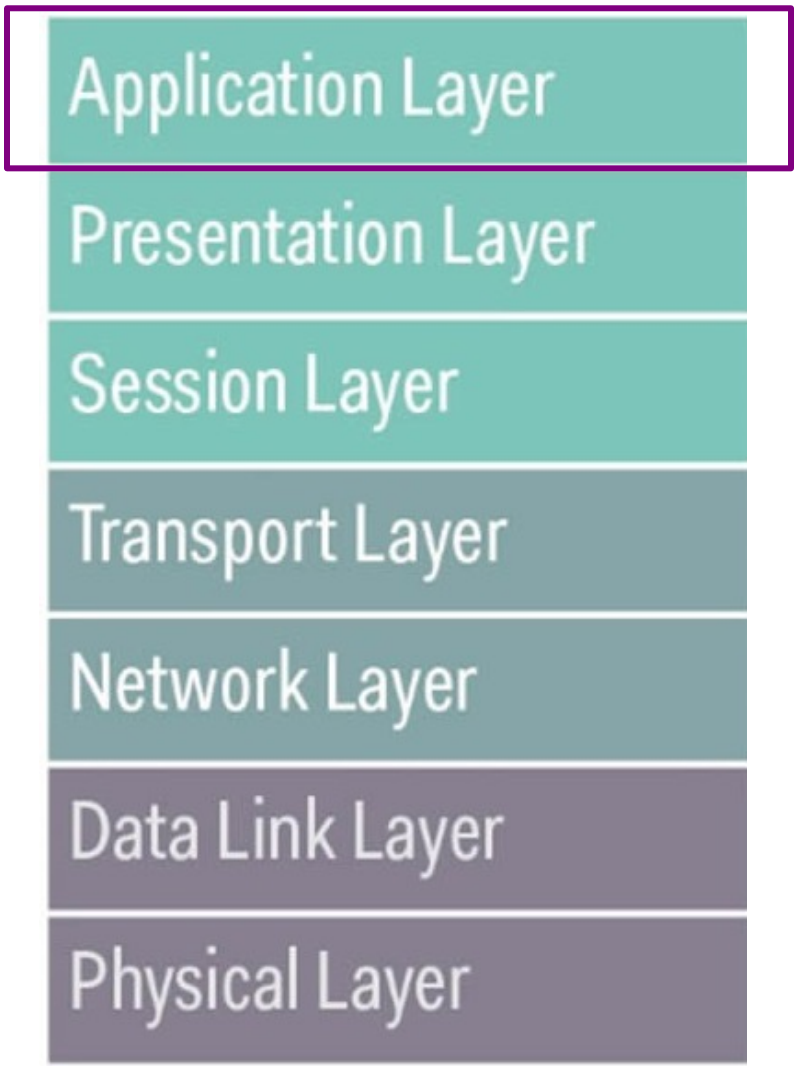
The OSI and IoT

- OSI maps to different protocols and standards for web and IoT worlds



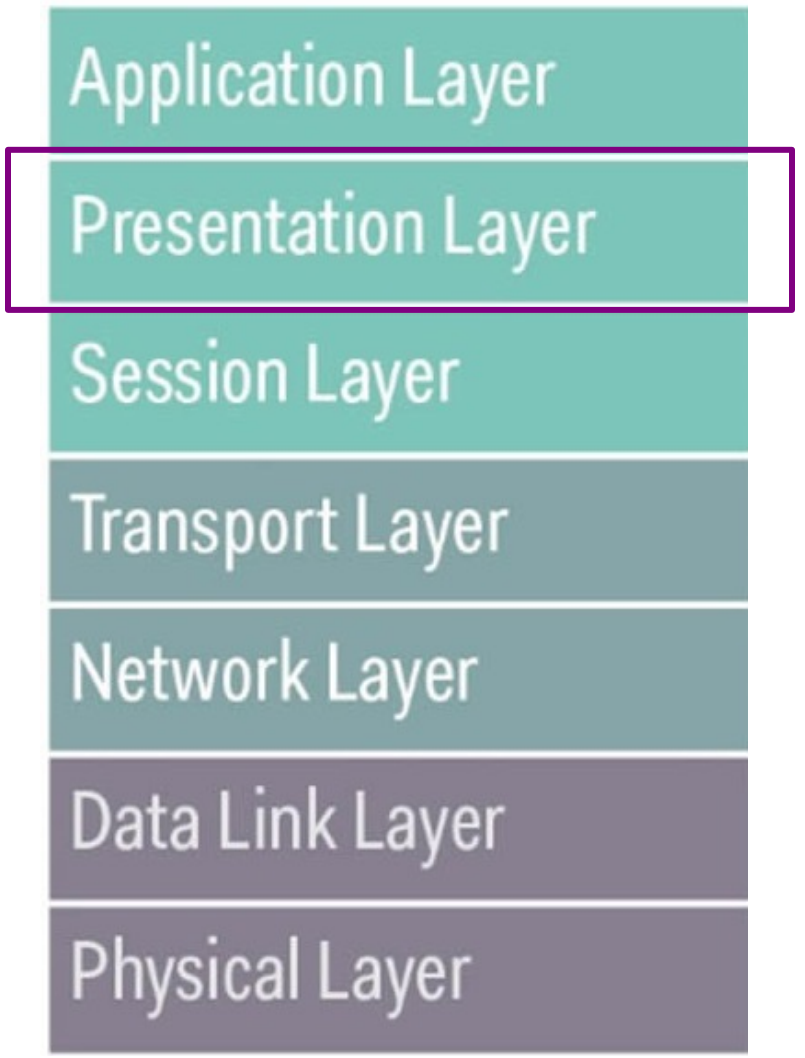
Application Layer

- Represents processes on the level of applications and users, IoT and otherwise
- Links the business application access to network services
- Messaging protocols found at this layer CoAP, MQTT, XMPP, AMPQP and HTTP



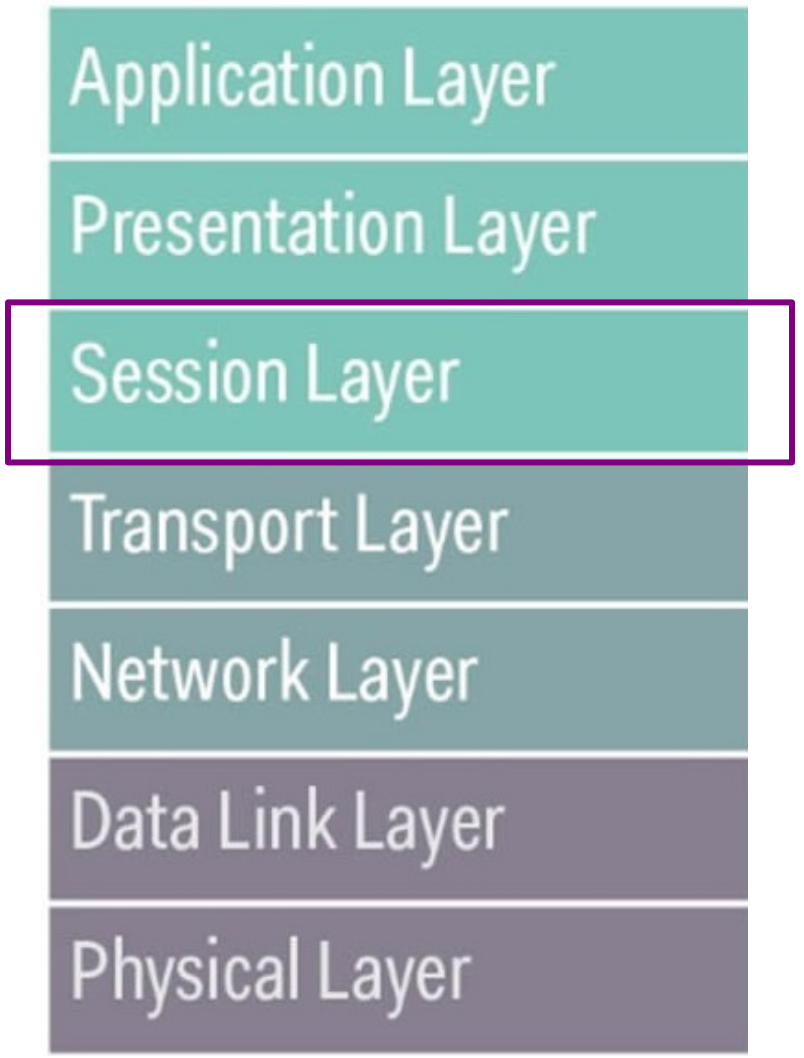
Presentation Layer

- Formats and encrypts data for communication.
- Resolves compatibility issues in the communication between the application and the network.
- For example, TLS class of cryptographic protocols



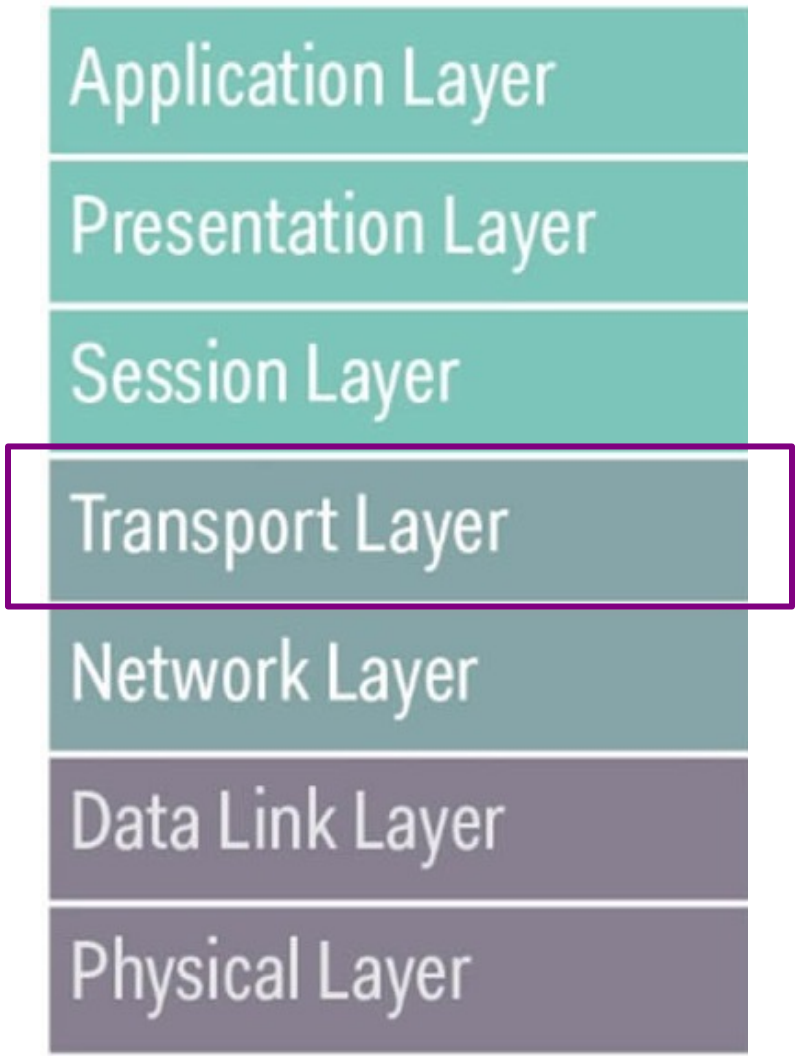
Session Layer

- Connections between local and remote applications are initiated, managed and terminated here
- Manages sessions over multiple devices on the same network



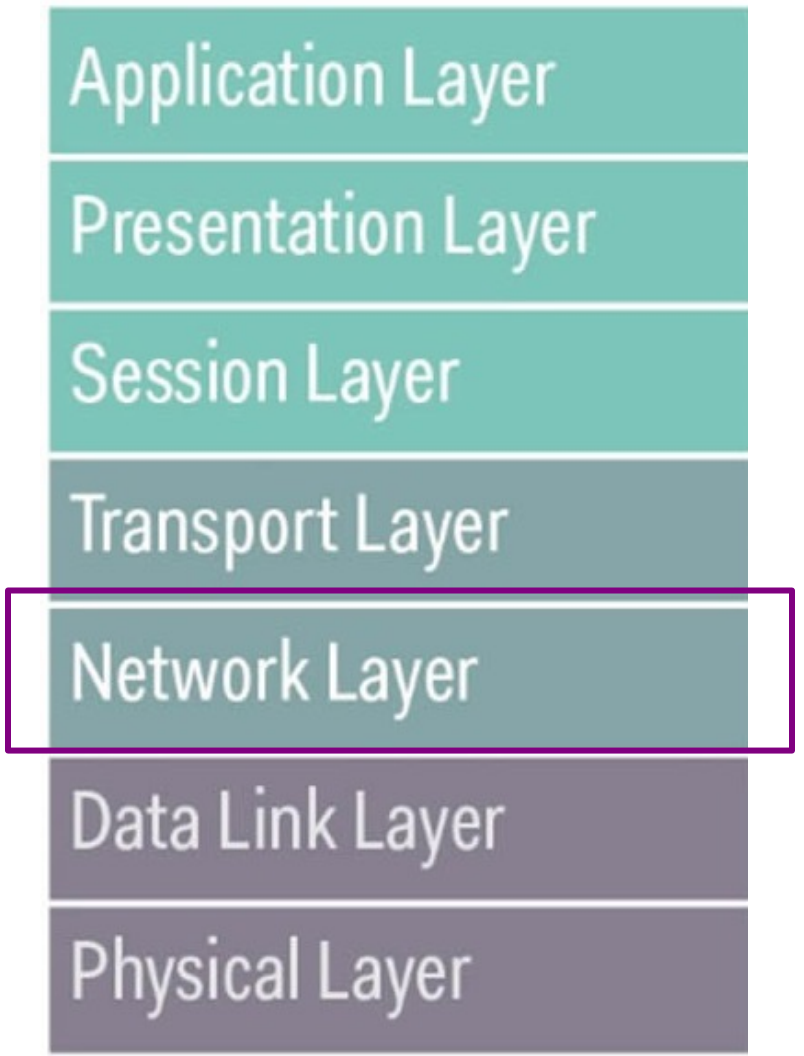
Transport Layer

- Manages the host-to-host data transmission
- Ensures that data transfers between hosts are completed.
- Manages error recovery and retransmission of lost data.
- TCP and UDP are two common protocols in this layer



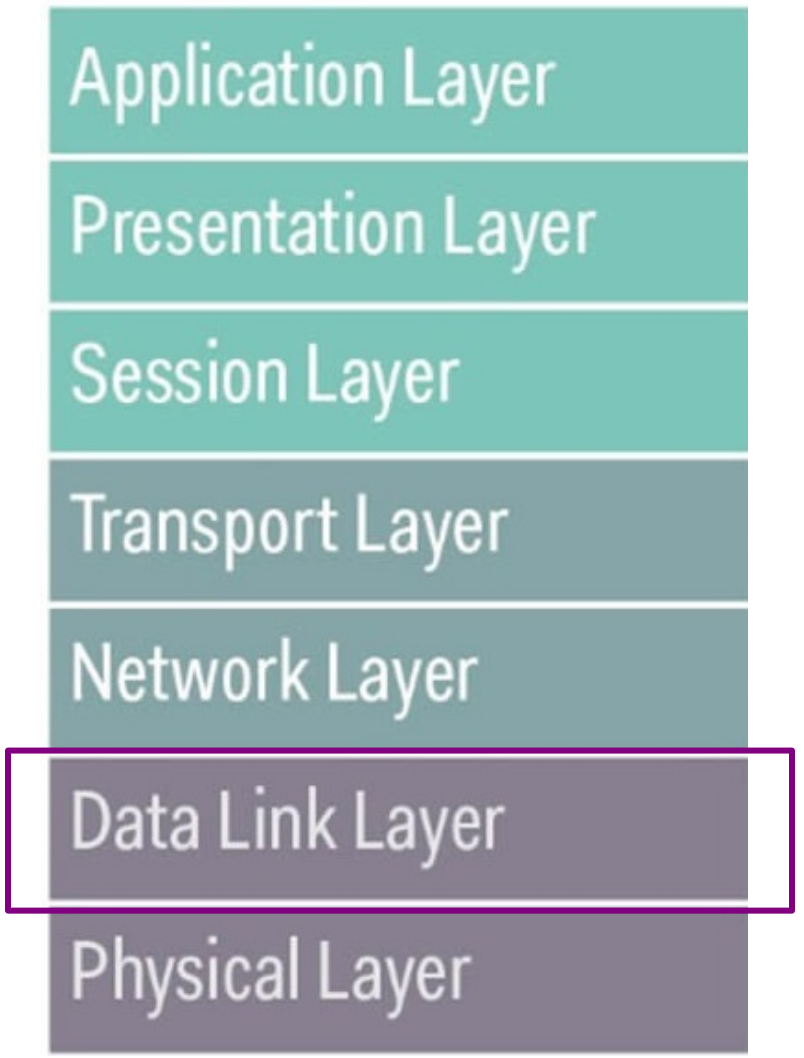
Network Layer

- Responsible for routing and transferring data packets between different nodes across various networks
- Includes the IP the Internet Protocol part of TCP/IP
- Of concern to IoT is that it also includes IPv4 and IPv6



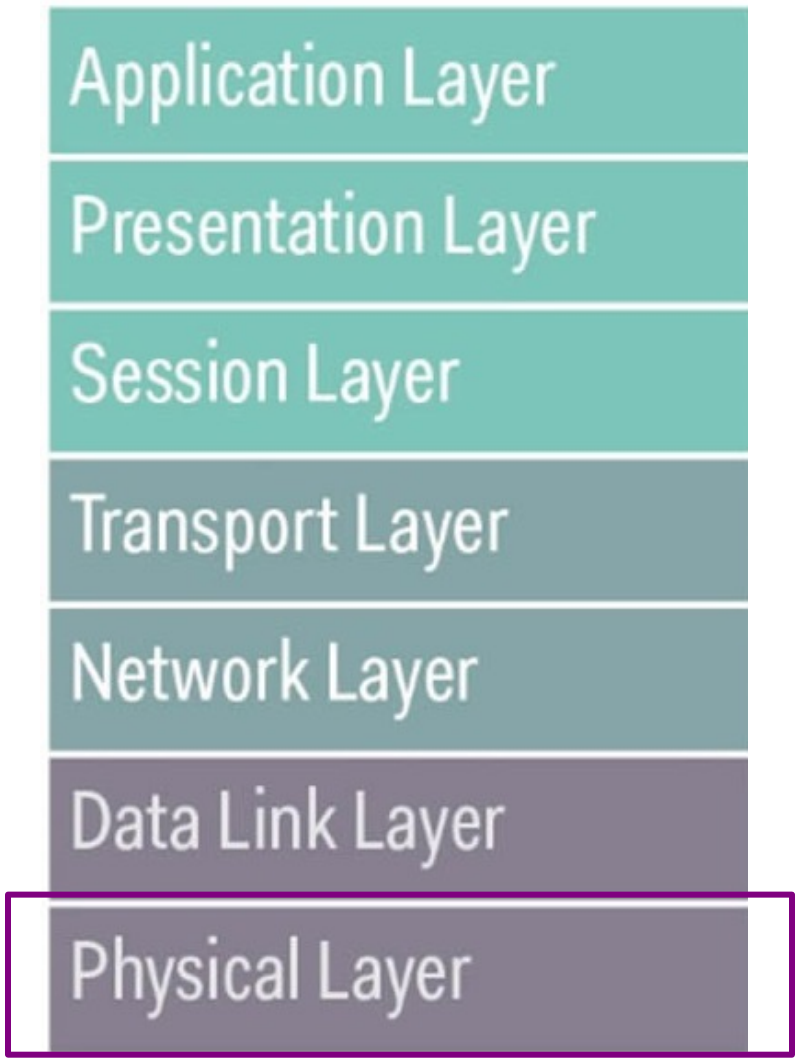
Data Link Layer

- Later where data transfer between two directly connected nodes in a network takes place
- Divided into two sub layers:
  - Medium access control layer (MAC layer)
  - Logical link control layer (LLC).
- Various IEEE 802 standards apply to this layer
  - IEEE 802.15.4 or low rate Wireless PAN for example



Physical Layer

- Layer where networks are organized
- Foundation of IoT and its connected
- Includes the essential physical structure needed to make the IoT possible
  - E.g., cables and radio frequency links
  - Essential transmission specifications, communication protocols and hardware on a device and data level.=



OST Intuitive Model

- Using OSI to figure out why an application isn't working
  - Layer 1: Physical
    - Is the network cable plugged in?
  - Layer 2: Data Link
    - Do you have a link light?
  - Layer 3: Network
    - Are you getting an IP?
  - Layer 4: Transport
    - Can you connect to your default gateway?
  - Layer 5: Session
    - Do you have DNS server information?
    - Can you ping 4.2.2.2 but not google.com?
  - Layers 6&7: Presentation & Application –
    - Can you browse to a site?

Common Attacks by Layer

OSI Security Model

Examples of Attacks at Each Level

Layer	Description	Attack
7	Application	Social Engineering, UserID/Password sniffing. Lack of role-based security for admin and support. Spoofing authentication credentials
6	Presentation	Phishing, TLS/SSL sniffing Breaking weak or faulty encryption
5	Session	Hacking – Telnet and FTP hacking Access to unsecured applications
4	Transport	TCP Sessions sniffing Port sniffing
3	Network	Man in the Middle Attacks Port sniffing
2	Data Link	Spoofing MAC/ARP sniffing
1	Physical	Sniffing, physical device compromise

Application Level Security

- Refers to the applications that support the end user functions
  - Applications at this layer include FTP, SMTP and other services
  - Supports user applications with that authentication and authorization
- Main security challenge for IIoT is unauthorized access to control systems
  - Entry point to introduce additional vectors – e.g, creating backdoors for future attacks
  - Common attack vector using social engineering, phishing and other deceptive exploits
- First line of defense is strong organizational procedures and policies on issuing, revoking and changing authentication credentials

Application Level Security

- UserID/Password is common authentication
  - Often implemented with weak account policy
  - Users suffer from password fatigue
    - Tend to use the same password across accounts
    - Tend to use short easy to guess passwords
    - Tend to not change their passwords
- Mitigations
  - Password policy requiring strong passwords and regular rotations
  - Use generated tokens instead of passwords
    - These have higher entropy and are harder to crack
    - Eliminates the problem of password reuse
  - MFA – multi-factor authentication
    - Requires authentication from two of three possible sources
      - What the user knows – password or token
      - Where the user is – specific IP address
      - Something the user has – mobile phone for a confirmation code

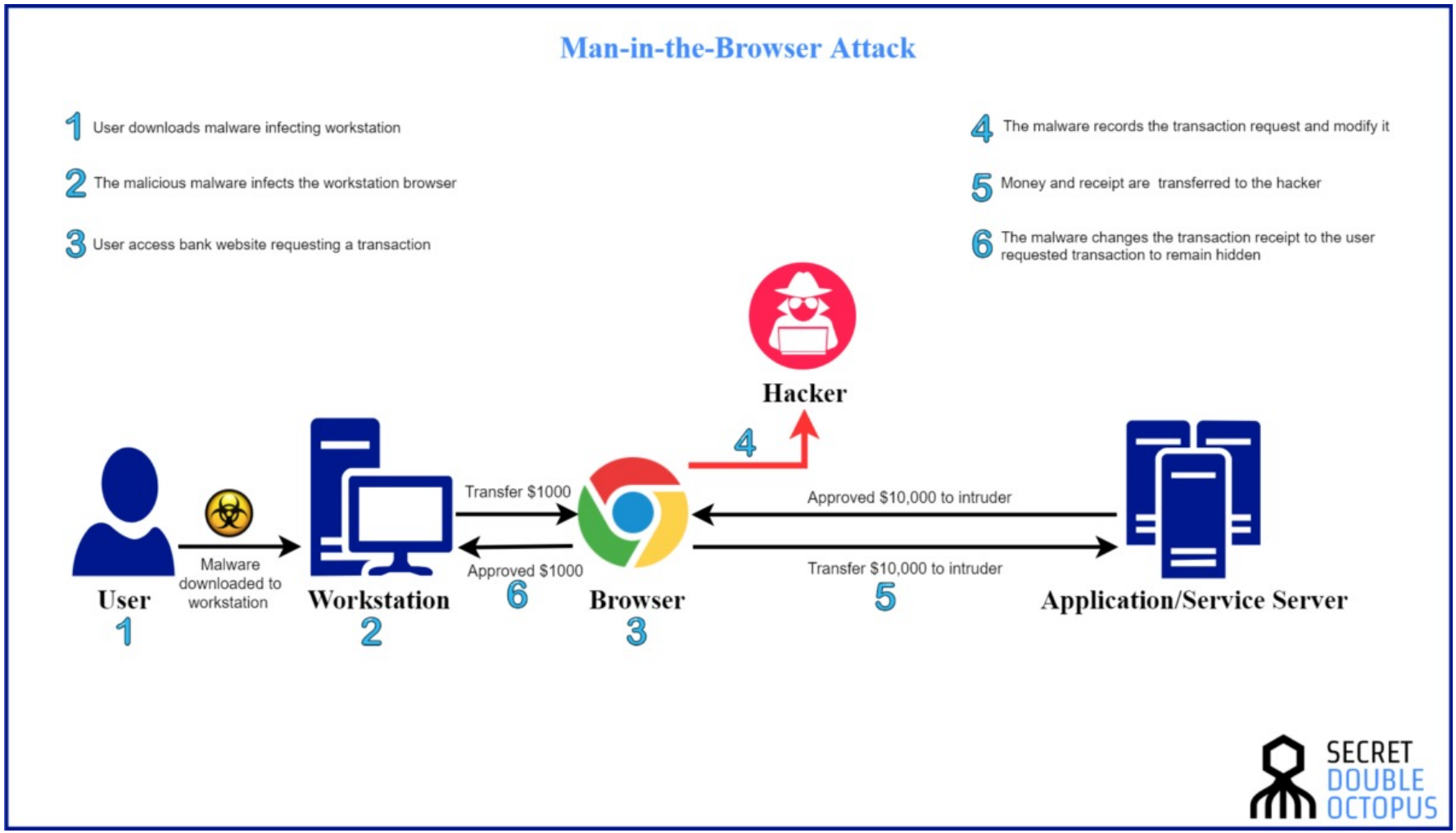
Presentation Level Security

- Encryption is performed at this layer
- Common attacks often involve weak or missing encryption
  - There must be both encryption for data in transit and encryption for data at rest
- Exploitable weaknesses can occur when:
  - An encryption standard is used that is too weak, one that has known weaknesses for example
  - Flawed implementation of the encryption such as:
    - Keys are too short
    - Salts are not used in digests allowing the use of rainbow tables to reverse engineer passwords
    - Using an encryption library that has not been fully vetted
    - Using a home-grown encryption library that is not full tested
  - Flawed application of an encryption application
    - Failure to encrypt data when it should be
    - Not encrypting some data that is accessible

Presentation Level Security

- Presentation level security can be subverted at the application level
- Called a Man in the Browser (MiTB) attack
  - Access is gained at the application level to steal or alter data before it become encrypted
- Often the result of human engineering
  - Compromised user installs malware
  - Or malware is installed from a phishing or other attack
- Can be mitigated to a degree by isolation
  - Applications used for systems control do not have access to other applications
  - No public access to the user control apps
  - Only the absolute minimum network access to private networks
- Ideally, control systems only connect to the system they control

Man in the Browser



Session Level Security

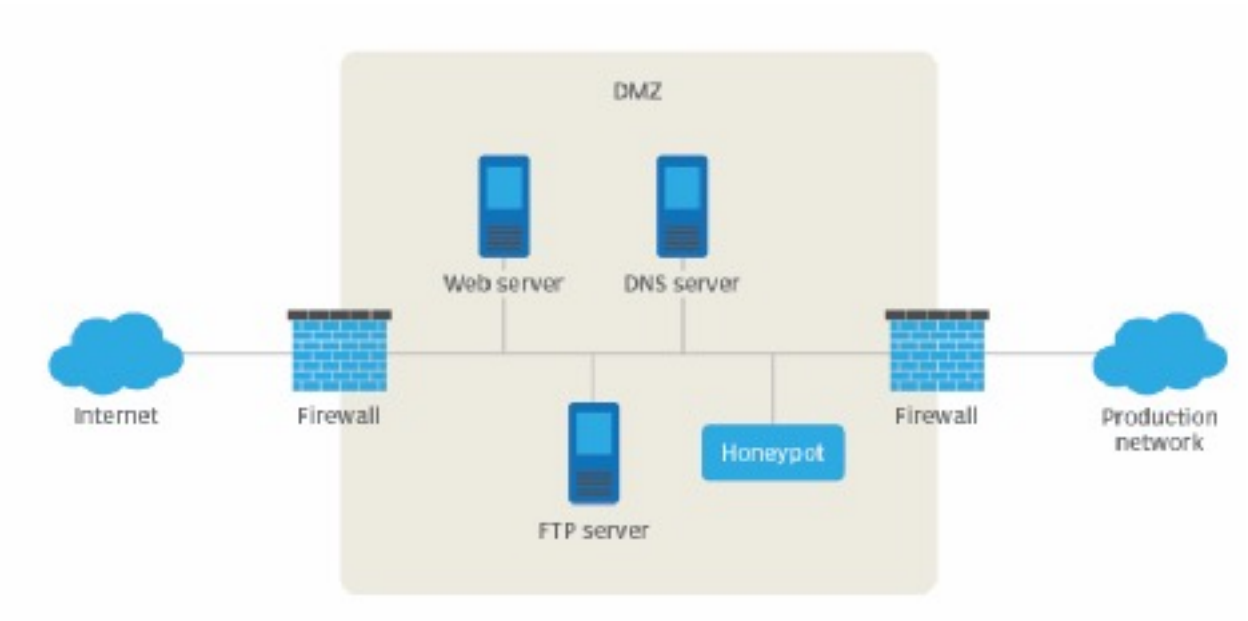
- The main attacks at this level deal with interfering with sessions or some sort of session hijack
- Man in the Middle (MiTD) attacks occur when an adversary can intercept communications between two parties in a session
- A main risk is that an adversary could take over an automated system by hijacking a session between the system and an operator
- Some potential exploits
  - Failure to use regular confirmation of identity of participant
    - Ignoring warning about expired TSL certificate for example
  - Failure to rotate credentials during a session
    - The longer a set of credentials is used, the more likely they are to be hacked
  - Failure to securely transmit session information
    - Often makes the session tokens or ids guessable by an adversary

Transport Level Security

- Internet based attacks probe for open ports
  - Can be used to inject malware
  - Malware often opens other ports as a backdoor
- Mitigations involve
  - Regular port scans
  - Use of non-standard ports to confound probing for commonly used ports
  - Firewalls to block access to most ports except those explicitly allowed on a whitelist
- Known or published IP addresses are potential targets
- Mitigations involve
  - Use of an API gateway to map external IP addresses to internal addresses
  - Use of filtering and firewalling on the gateway
  - Establishment of a DNZ

Demilitarized Zone and Honey Pots

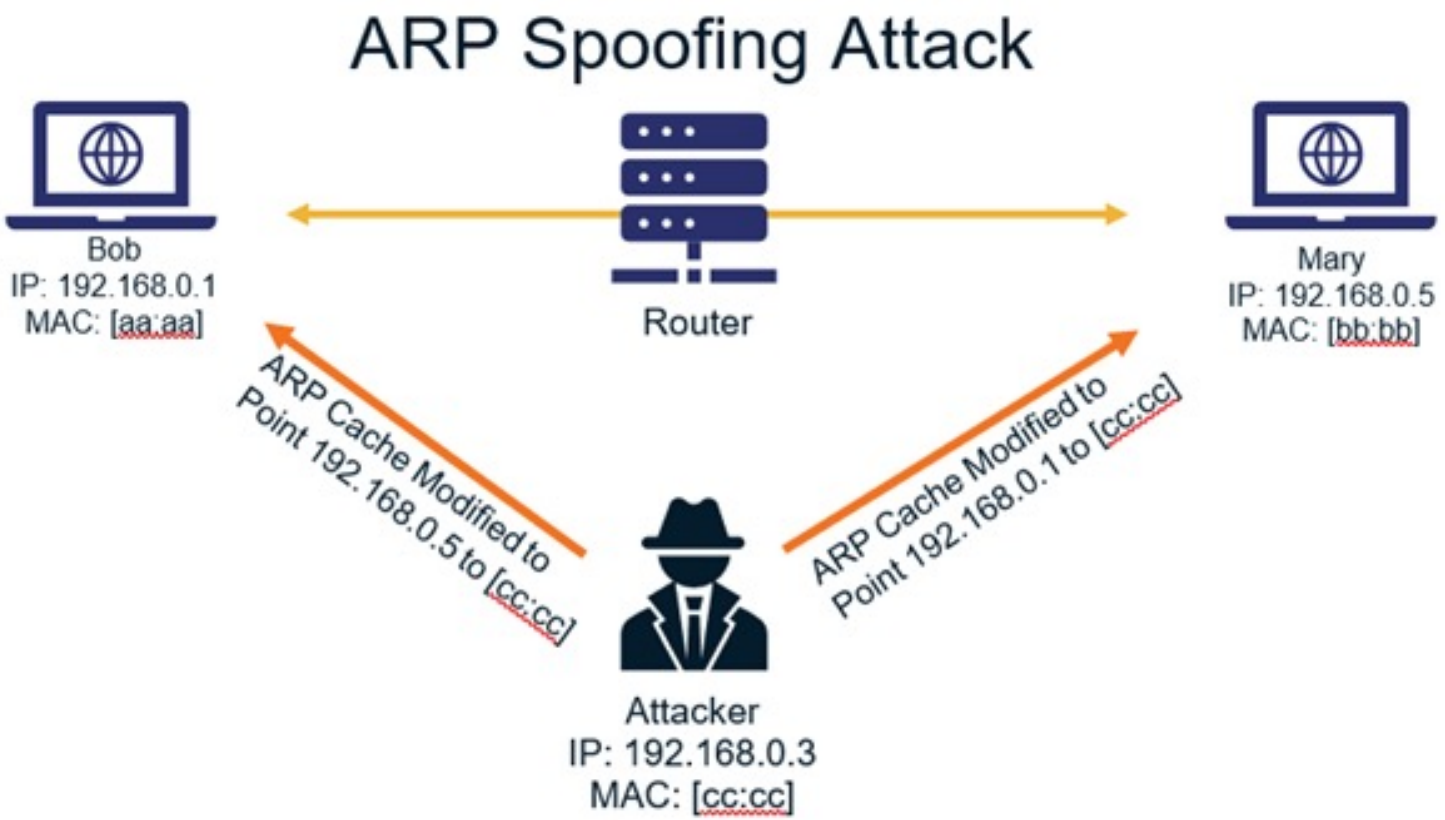
– DMZs connect internal networks to the outside world
  - Internal networks cannot be accessed directly
  - Must go through the DMZ
  - Including standard application-level attacks
– Honeypots are fake networks
  - Designed to distract attackers
  - They wind up attacking the honeypot instead of the industrial system



Network Layer Security

- Level at which most network hardware operates
  - Switches, routers, firewalls, etc.
- Attacker can reroute traffic via a compromised router
  - Many commercial routers have security flaws
- Malware insertion into network devices is a common attack
  - Used by the NSA as part of their Tailored Access Operations (TAO)
  - Network devices are physically intercepted during shipment
  - Malware is installed to create backdoors
- Security analyses often overlook off the shelf hardware

ARP Spoofing Attack



Network Layer Security

- Mitigations involve
  - Using NAT and other address translation strategies
  - Physically secure network equipment
  - Breeches at this layer commonly occur inside the organization
  - The use of VPNs where possible
  - However, this does add a layer of latency and complexity
  - Full security audits of all network equipment

Data Link Layer Security

- This layer works on the MAC address and packet layer
- Common attack is to force a Network Interface Controller (NIC) into promiscuous mode
  - This allows it to absorb traffic intended for other machines
- This is also the layer where attackers may spoof a MAC address
- Mitigation
  - A common mitigation is to create separate virtual LANS (VLANs) on a single physical LAN
  - Access control lists can then be applied to the different VLANs
  - Disabling unused ports also helps at this layer too

Physical Layer Security

- Most common attack is compromised physical devices
  - Access to the devices creates opportunities for insertion of malware or physical taps or attacks
- First line of defense
  - Physically isolate and lock up all the equipment
  - Allow access only to vetted people who need access
  - Use the lowest level of access needed
- Social engineering attacks try to convince staff to allow access to bad actors
  - Mitigation is to have strongly enforced security measures
  - “We will not open the server room for anyone who claims to have lost their keycard.”
- Physical interception is done by accessing cables and other devices – data taps for example
  - Also done by monitoring EM signals from monitors and other devices

Physical Layer Security

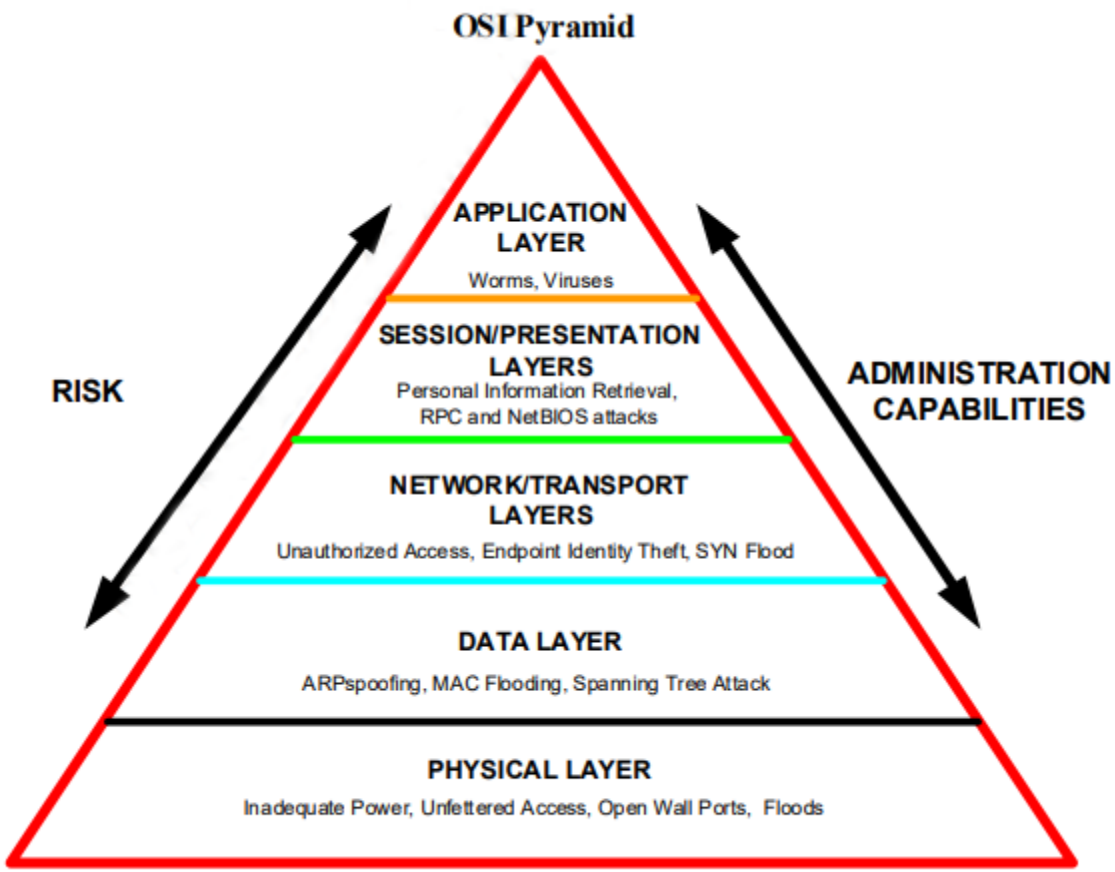
- Common vector to disable physical devices
  - Power overloads
  - EM pulses or physical damage
- Mitigations
  - Any device, cable or other “thing” connected to the network is vulnerable
  - Use proper shielding and physical isolation when necessary
  - Have a good disaster recover plan for loss of physical assets

Defense in Depth

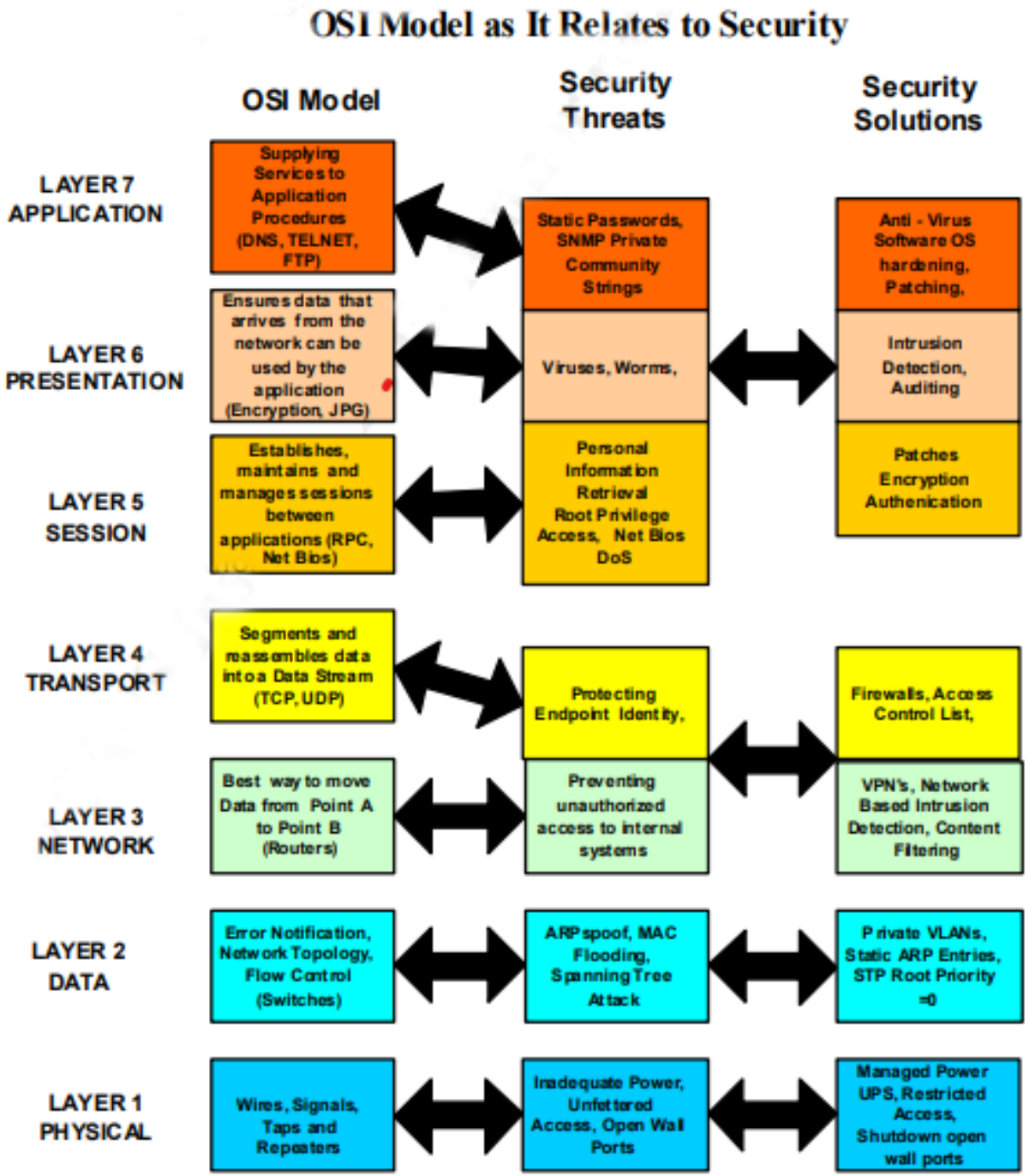
OSI Security Model

Defense in Depth

- Any IoT security solution must include a security model and plan for each of the OSI levels or their equivalent
- Any deployed system is as insecure as the security at its weakest level



OSI mitigations



Layer One Attacks

- Traditional cybersecurity improvements push attackers toward alternative paths
  - The physical layer has become a fertile ground for attacks
  - Effectively, the soft underbelly of cybersecurity
- Can take the form of a compromised employee planting a device on the network
- Rogue and insecure hardware is often missed during security audits
  - Legitimate hardware can be altered to provide insecure access
- Zero-trust network security causes attackers to look at physical access via hardware exploits
  - Even air-gapping is not an effective solution
  - For example, STUXNET

Hardware Security Challenges

- Firmware can be updated with compromised versions
  - Often overlooked in security testing
- Recommended mitigation
  - automated security validation tools that can scan for configuration anomalies within their platform and evaluate security-sensitive bits within their firmware
- Hardware uses multiple components from different manufacturers, each using a different supply chain
  - Security has to be enforced across the supply chain
- Problem made more urgent by the increased use of systems on chips (SoCs)
  - SoCs consolidate multiple traditional components on a single chip
  - Bypasses the more traditional network security analysis