Review Question

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Emerging Trends in Networking

ICT169

Foundations of Data Communications

Admin

- Practical Exam will run **next week** during your regular lab session
    - **Must** attend the lab session you are enrolled in
    - 100 minute LMS-based test; no extra time if you are late
    - No aids allowed except note paper and command reference (provided)
- Please tell us how we're doing in the Unit and Teaching surveys
- Responses to participation quizzes
    - Need to be at least 50 words **and** clearly attempt to address all parts of the question

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Admin (cont.)

- PASS will be running an exam preparation session in **Week 15**
    - Thursday, 8 November 12:30—2:30PM
    - Running in 235.4.008

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Practical Exam

- Runs during Session 12 (Week 14) during lab times, you **must** attend the lab you are enrolled in
- Online (LMS-based) test, 100 minutes
- Use Packet Tracer for your implementation
- You will need to be able to:
  - Design an IP addressing scheme (subnet)
  - Build a network topology in Packet Tracer
  - Configure router interfaces and routing via CLI
  - Troubleshoot
- Contributes 25% of your final grade

Last Week

- A brief introduction to cybersecurity, looking at:
  - Motivations for cyberattacks
  - Different classes of cyberattacks and enabling techniques
  - Approaches to securing devices and networks
  - *Notable cyberattacks in recent history*

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https://hackaday.com/2017/04/01/ask-hackaday-which-balaclava-is-best-for-hacking/

Lecture Overview

- A look ahead at current and (possible) future trends in networking
- Software-Defined Networks
- Whitebox network hardware
- Network orchestration
- Internet of Things and Smart Cities

https://medium.com/thrive-global/use-technology-in-a-thoughtful-way-that-improves-your-life-3e22fb3372a4

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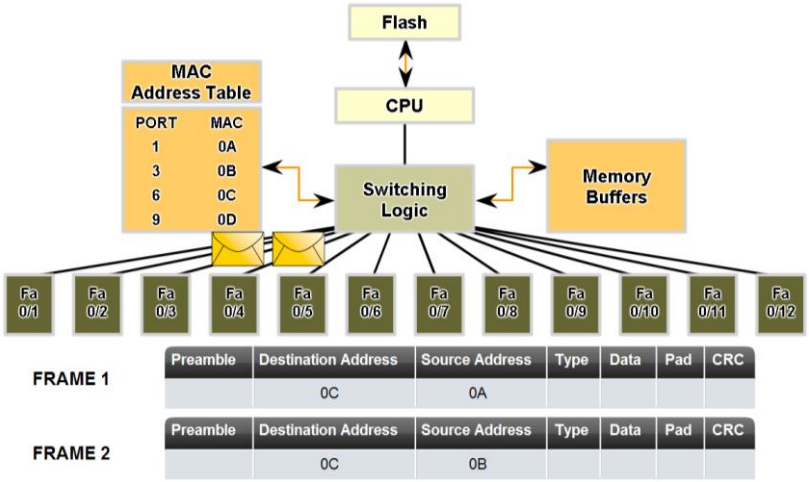
Ethernet Switching Revisited

- Remember that Ethernet switches forward frames only to the intended recipient (identified using MAC addresses)
- Stores MAC addresses in a **MAC address table** which maps addresses of connected devices to ports on the switch
- Mappings are usually created based on the source address of received frames
- If a frame is received for an unrecognized host, it will be flooded out all but the incoming port instead



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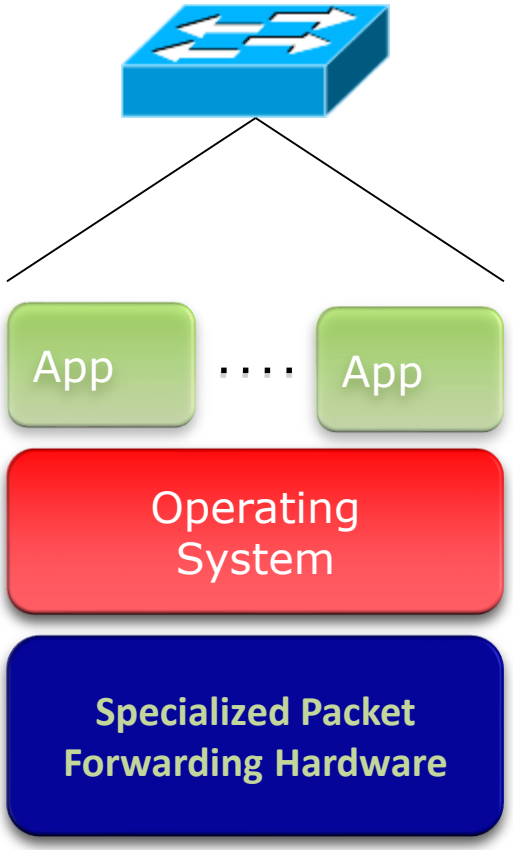
Traditional Switching Architecture

- Forwarding decisions are made on-device based on source and destination MAC address
- Can be thought of as two components:
- The **control plane** makes decisions about where how traffic is to be forwarded
- The **data plane** handles the incoming traffic and forwards it based on decisions by the control plane



OpenFlow/SDN tutorial, Srini Seetharaman, Deutsche Telekom, Silicon Valley Innovation Center

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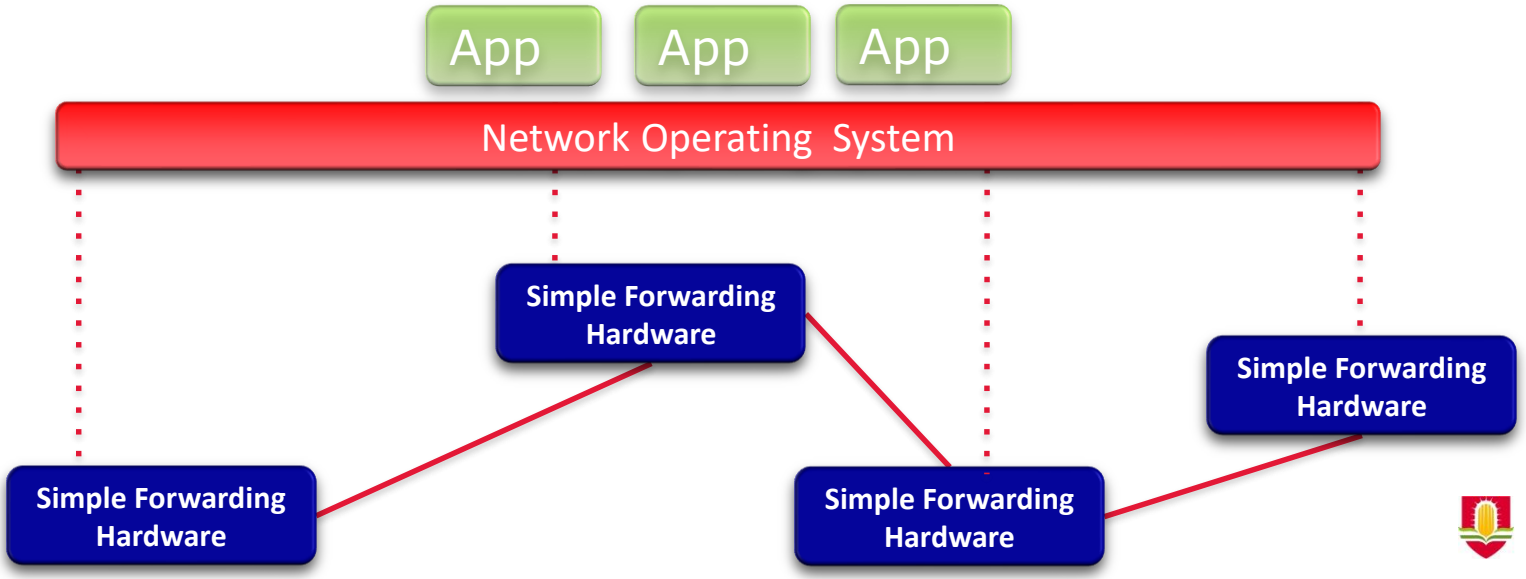
Software-Defined Networking

- De-couple the data and control planes
  - Software-based controller run on general purpose hardware centralises the control plane
- Commodity networking hardware can be used in place of expensive switches and routers
- Data plane can be centrally programmed and controlled



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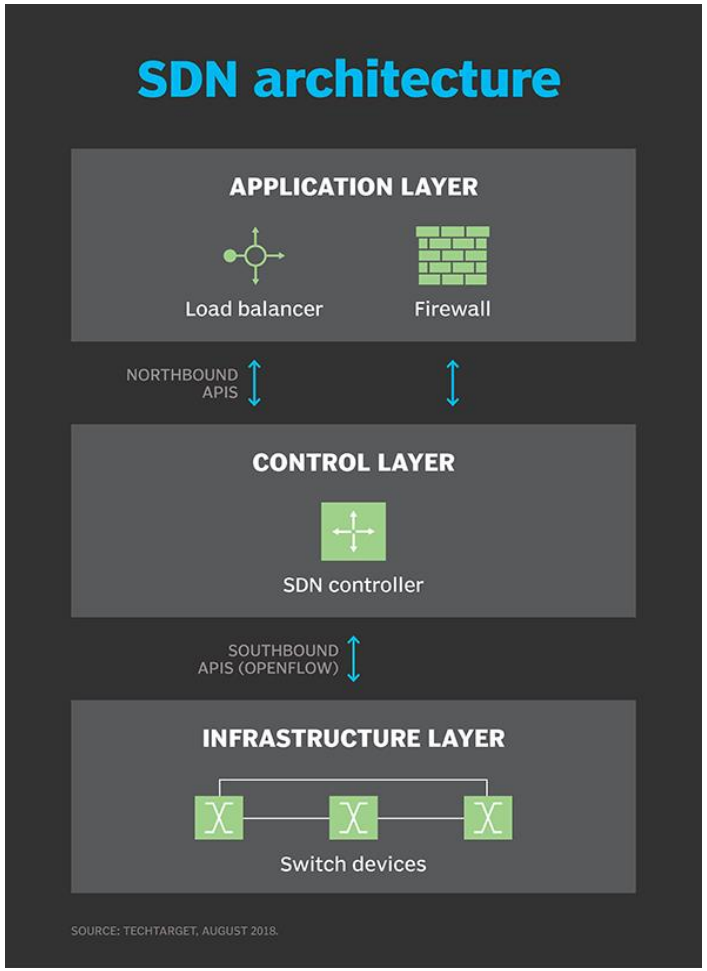
Adapted from OpenFlow/SDN tutorial, Srini Seetharaman, Deutsche Telekom, Silicon Valley Innovation Center

Application-Centric Networking

- Use knowledge of the network configuration to change routing decisions
- Load-balancing and performance optimisation can be modified in response to changes in network usage
- Policies implemented on a per-application basis

SDN Architecture and Terminology

- Usually divided into three layers or planes
- Application layer
  - Communicates with the SDN controller via a **northbound application programming interface (API)**
- Control layer (plane) manages policies and network traffic
  - Connects to network devices using a **southbound API**
- Infrastructure layer (data plane) includes the switches



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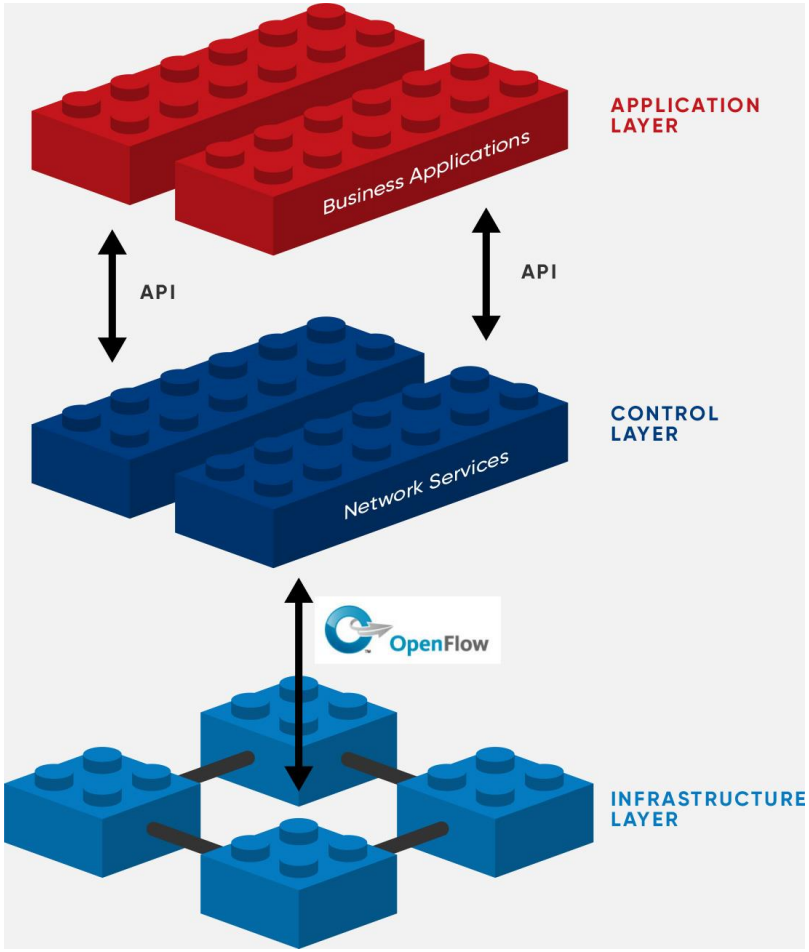
https://searchsdn.techtarget.com/definition/software-defined-networking-SDN

OpenFlow

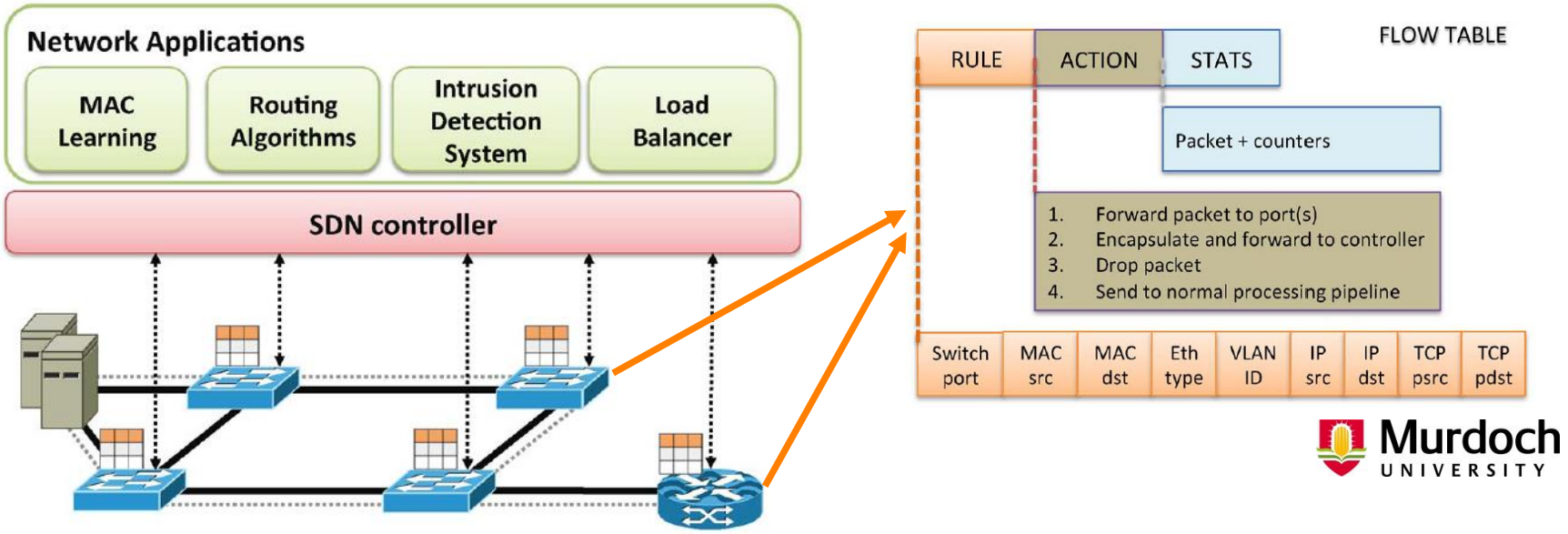
- First standard for SDN that emerged around 2008—2009
  - Southbound API for communication between control and data planes
- Now managed by the Open Networking Foundation (ONF)
- Link layer protocol specifying:
  - Separation between control and data planes
  - Interface between switches and network OS
  - Makes use of existing structures (routing and forwarding tables) in hardware



https://www.opennetworking.org/sdn-definition/

OpenFlow Operation

- Each device in the network maintains a flow table
- The flow table contains a list of rules that dictate how packets are handled
    - Entries for hosts (similar to the MAC address table for switches)
    - Actions to be applied to matching traffic



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OpenFlow Operation (cont.)

- Firstly, switches will try to find a matching flow table based on the **rule**
    - Rules can specify header fields to match (eg. source IP) or receiving interface
- If a match is found, the specified action will be performed and counters updated

Port	Src MAC	Dst MAC	VLAN ID	Priority	EtherType	Src IP	Dst IP	IP Proto	IP ToS	Src L4 Port ICMP Type	Dst L4 Port ICMP Code	Action	Counter
*	*	0A:C8:*	*	*	*	*	*	*	*	*	*	Port 1	102
*	*	*	*	*	*	*	192.168.*.*	*	*	*	*	Port 2	202
*	*	*	*	*	*	*	*	*	*	21	21	Drop	420
*	*	*	*	*	*	*	*	0x806	*	*	*	Local	444
*	*	*	*	*	*	*	*	0x1*	*	*	*	Controller	1

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OpenFlow Operation (cont.)

- If packet doesn't match a flow table entry, switch will fall-back to the table-miss action
- Table-miss action will usually specify the switch forward the non-matching packets (or packet headers) to the controller or drop them

Port	Src MAC	Dst MAC	VLAN ID	Priority	EtherType	Src IP	Dst IP	IP Proto	IP ToS	Src L4 Port ICMP Type	Dst L4 Port ICMP Code	Action	Counter
*	*	0A:C8:*	*	*	*	*	*	*	*	*	*	Port 1	102
*	*	*	*	*	*	*	192.168.*.*	*	*	*	*	Port 2	202
*	*	*	*	*	*	*	*	*	*	21	21	Drop	420
*	*	*	*	*	*	*	*	0x806	*	*	*	Local	444
*	*	*	*	*	*	*	*	0x1*	*	*	*	Controller	1

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Drawbacks to the Centralised Control Plane

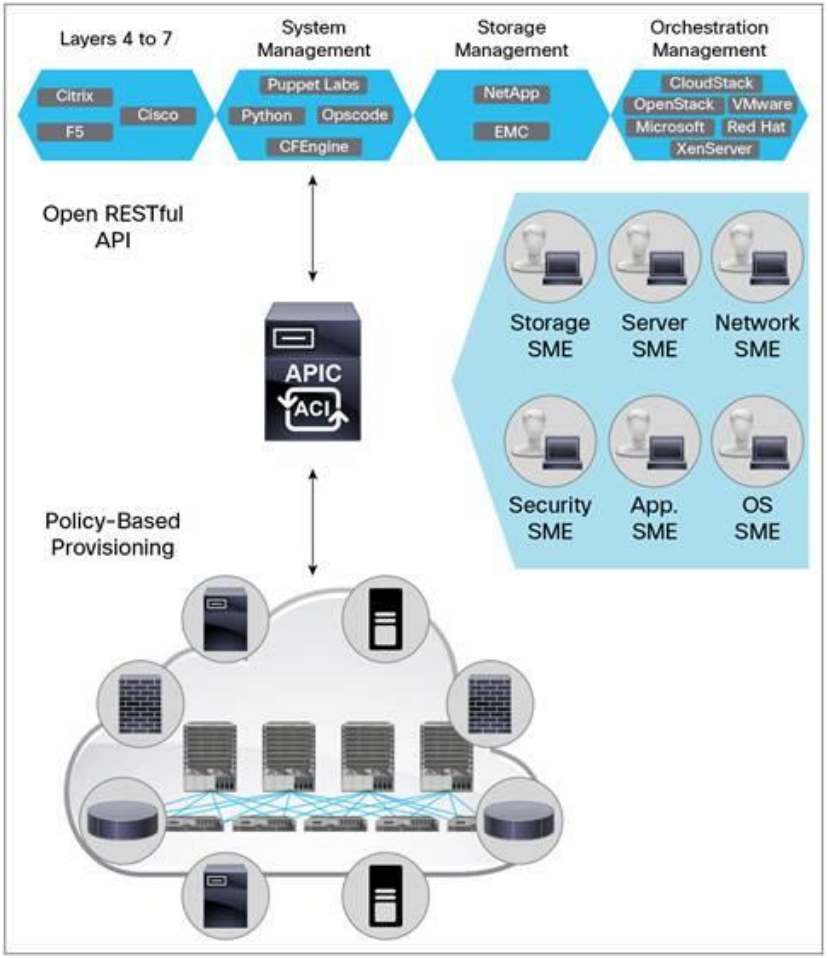
- So what happens to a Software-Defined Network when the controller fails?
    - Early implementations of OpenFlow would simply cease to operate without a controller
    - Network may be able to continue to operate under the previous known state but no new rules can be specified
- Heavy reliance on the SDN controller can also add latency to traffic; switches must wait for controller to provide them with instructions
- One approach is to introduce redundancy in controllers

The Hybrid Approach

- Some approaches to SDN have largely moved the control plane back to the switches
- Controller specifies and propagates policies to switches
    - Failure means no changes can be made to the network, but no consequences otherwise
    - Reduce latency by no longer being reliant on the controller for forwarding decisions

The Hybrid Approach – An Example

- Cisco Application Centric Infrastructure (ACI) is an example of this hybrid approach
- Architecture should look familiar (refer to regular SDN architecture)
- APIC acts as a controller, but only to propagate policy to switches
- Published API available to allow multi-vendor support



https://www.cisco.com/c/en/us/solutions/collateral/data-center-virtualization/application-centric-infrastructure/white-paper-c11-733456.html

Whitebox Switches – Commodity Switching Hardware

- Moving the control plane away from individual switches meant switch hardware became simpler
    - Reduced the reliance on custom Application-specific Integrated Circuits (ASICs) for hardware acceleration
- Switches could now be built out of off-the-shelf parts
- Lower cost than existing vendors like Cisco and Juniper
- Purchase with or without an operating system (install your own)

https://store.netgate.com/Pica8/P-3297.aspx

https://www.dell.com/en-au/work/shop/povw/networking-z-series

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Whitebox Switch Operating Systems

- Several options for operating systems available with different feature sets
- Some support traditional switching architecture while others are designed for SDN

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Network Management

- By centralising the control plane, SDN also made it easier to manage networks at scale
- Configuration changes made on the controller are propagated throughout the network
    - Same process for the hybrid approach; main purpose of the controller in this model
- Configuration management tools have been developed that allow similar management of SDN and traditional network infrastructure alike
- This approach is sometimes referred to as **orchestration**

Network Management Approaches

- Before talking about how orchestration works, we need an understanding of network management
- Two approaches to configuring individual networking devices
- **In-band management** uses the existing data network for managing devices
    - Use protocols like Telnet, SSH, SNMP
- **Out-of-band management** refers to the use of a dedicated connection
    - Connect via a serial cable (eg. Console)

Configuration Management Tools

- Originally developed for client / server operating system and application management
- Adapted to manage network infrastructure as well
- Uses existing in-band management tools (usually SSH) to connect to devices
- Allows configuration to be checked and altered using simplified syntax

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Configuration Management Tools – An Example

Configuring OSPF via IOS Command Line (for each router)

```
Router(config)# router ospf 1
Router(config)# interface gi0/0
Router(config-if)# ip ospf 1 area 0
```

Configuring OSPF via Puppet

```
cisco_interface_ospf {"Gi0/0 Sample":
    ensure => present
    area => 0
}
```

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Break

When we return: The Internet of Things

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Introducing the Internet of Things

- The Internet has historically been used for connecting devices like computers, laptops, smartphones
- Recent shift towards connecting other physical devices and objects to the Internet for information sharing
    - Home appliances (fridges, toasters, microwaves)
    - Buildings (sensors, door locks, air conditioners)
    - Vehicles (autonomous vehicles)
    - Clothing (watches, jackets)
    - Medical devices (blood pressure monitors, activity monitors, scales)
- Related Terms: The Internet of Everything, quantified self, connected home, smart buildings, smart cities

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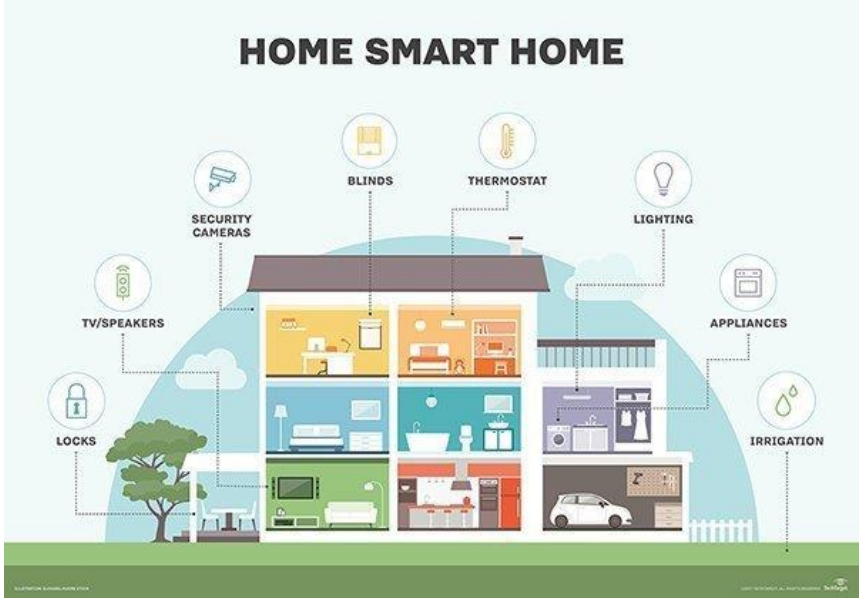
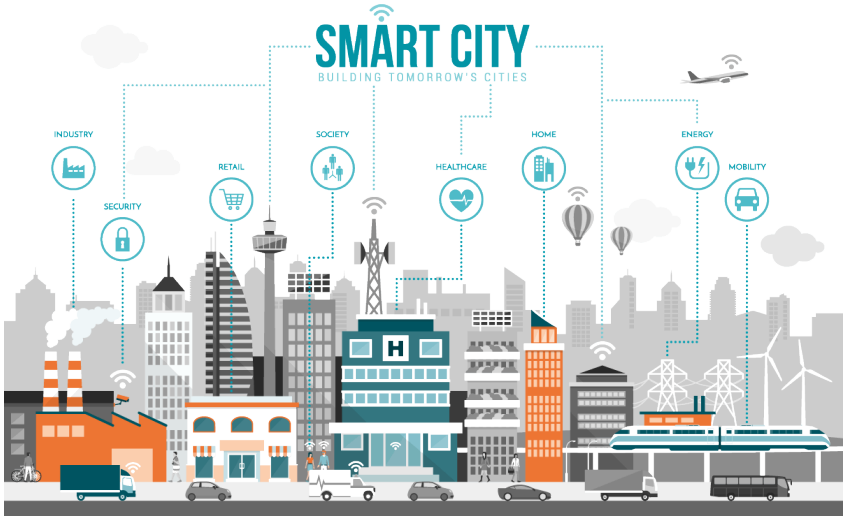
The Internet of Things

- Enabled by proliferation smart phones, high speed Internet connections, and wireless networking technologies
- Reduced cost of sensors and hubs also contributed
- Connected devices will change the way we interact with our surroundings



https://www.kalka.com.au/blog/building-an-automated-smart-home



https://www.arcweb.com/industries/smart-cities

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Internet of Things in Health and Fitness

- Monitor individual health and fitness through sensing data
    - Gather additional information to assist practitioners
    - Get customised fitness advice based on activity
    - Alert emergency services in case of accident
- Measure performance in a specific activity (eg. tennis) and compete with friends and / or improve your game
- Pictured: Fitbit Charge 3, Polar H10, Apple Watch, Babolat Smart Racquet

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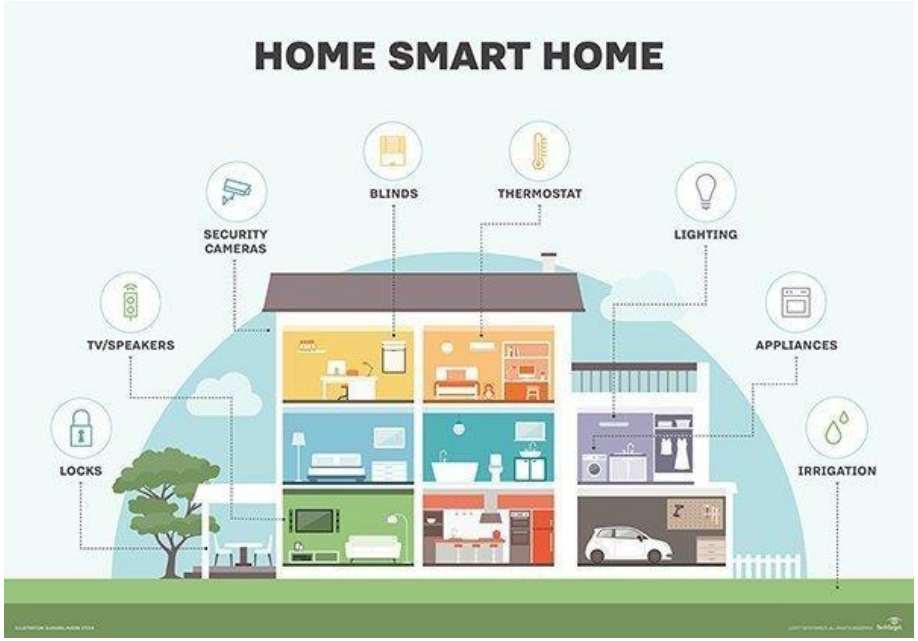
Internet of Things at Home

- Connected devices and appliances in the home can be used for convenience (eg. controlling appliances remotely)
- May also provide other benefits like improved security or energy savings



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Smart Home Hubs

- Smart homes usually require some sort of controller
- Often a speaker with voice assistant capability (eg. Amazon Echo, Google Home)
- Sometimes just a network-connected device
- Communicate with other devices via WiFi, Zigbee, Z-Wave, Thread

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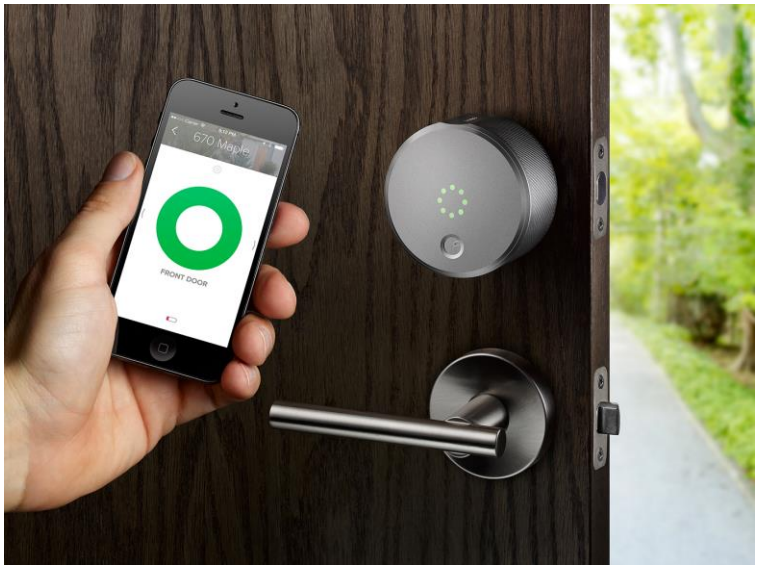
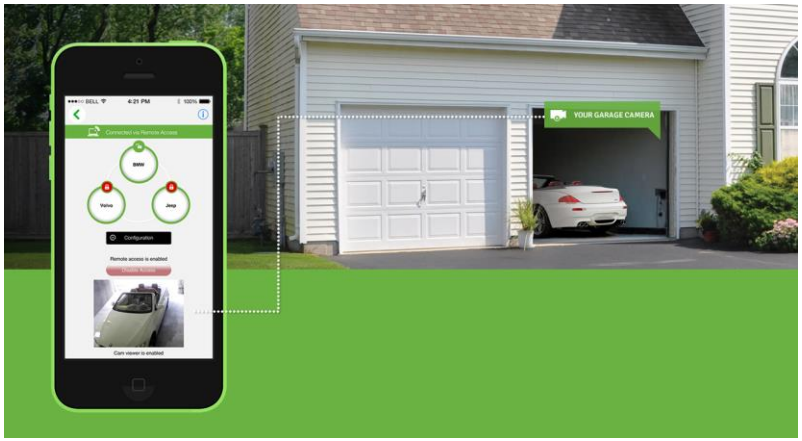
Smart Locks and Doorbells

- Lock or unlock door(s) and garage doors using your smartphone
- Answer the door from your phone (from anywhere in the world)
- Pictured: August Smart Lock, Ring Video Doorbell, Gogogate





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Connected Lightbulbs and Switches

- Control light fixtures and power to appliances via smartphones, voice assistants, or sensors
- Power saving benefits; doesn't matter if you forget to turn the lights off before leaving the house
- Pictured: Phillips Hue, Leviton Decora, Clipsal Iconic

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Environmental Control

- Household heating and cooling can be controlled remotely or automatically
- Temperature sensors used to monitor rooms
- Intelligent thermostats may adjust room temperature automatically depending on time of day and occupancy
- Pictured: Advantage Air myAir 5, Nest Learning Thermostat, Nest temperature sensor

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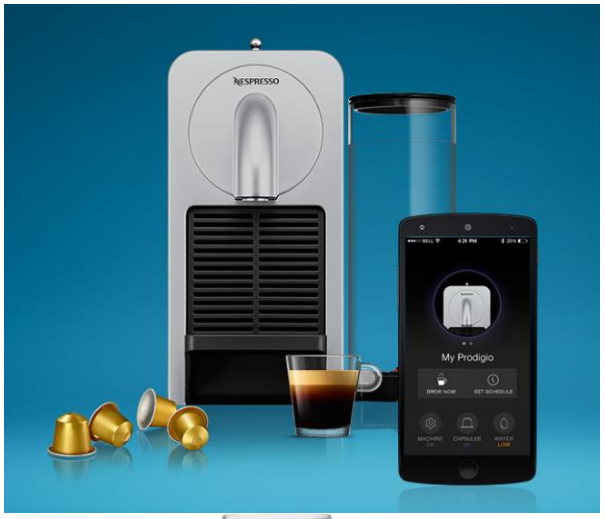
Kitchen Appliances

- Kitchen appliances can be controlled remotely for convenience
- Provide assistance or suggestions preparing meals and drinks (eg. recipes, step-by-step instructions)
- Pictured: June Oven, Nespresso Prodigio, Nutribullet Balance



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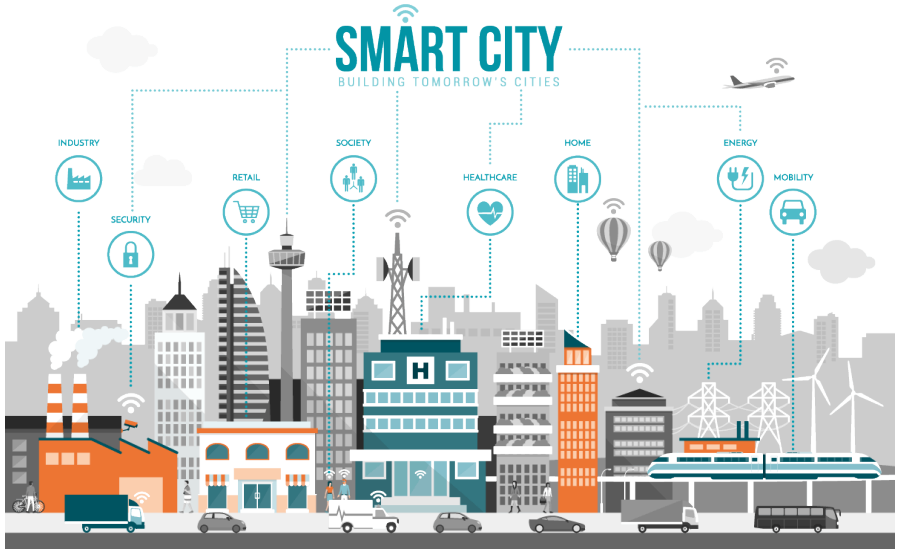
Internet of Things in Public Spaces

- Usually a greater focus on optimising service delivery and infrastructure use
    - Traffic flow monitoring and parking usage
- Aggregate data from numerous sensors for analysis
- Amsterdam and Barcelona (among others) have already begun the process



https://www.arcweb.com/industries/smart-cities

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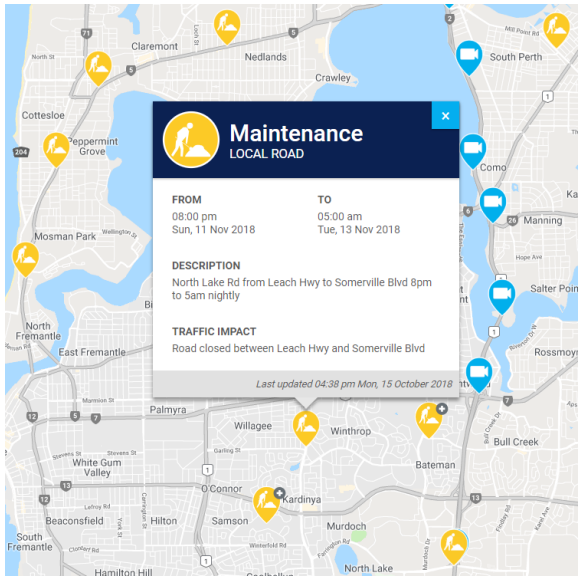
Traffic Management

- Monitor traffic flow through sensors installed on traffic lights and surveillance cameras
- Report congestion in real-time (road users can avoid these areas)
- Modify traffic signals based on occupancy, rather than timing-based

https://www.toronto.com/news-story/7961695-toronto-s-first-smart-traffic-control-signal-switches-on-in-north-york/



https://travelmap.mainroads.wa.gov.au/Home/Map

Waste Management

- Install sensors in garbage bins to optimise bin emptying schedule
- Notify operator when bins are full (and requiring emptying)
- Reduce time and fuel spent on emptying partially full bins
- Less traffic congestion from garbage collection trucks

https://www.cleantech.com/the-internet-of-waste-bins-interview-with-the-co-founder-of-enevo/

http://www.bigbelly.com

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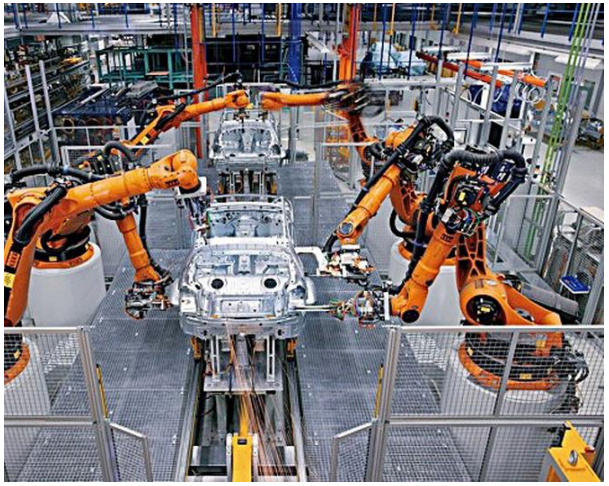
Internet of Things in Industrial Applications

- Heavy focus on sensing and automation for safety and cost efficiency
    - Preventative maintenance of equipment
    - Supporting or controlling automated equipment and vehicles
    - Environmental sensing and control
- Sometimes referred to as operational technologies or digitisation / digital



http://www.aptinex.com/services/industrial-automation/

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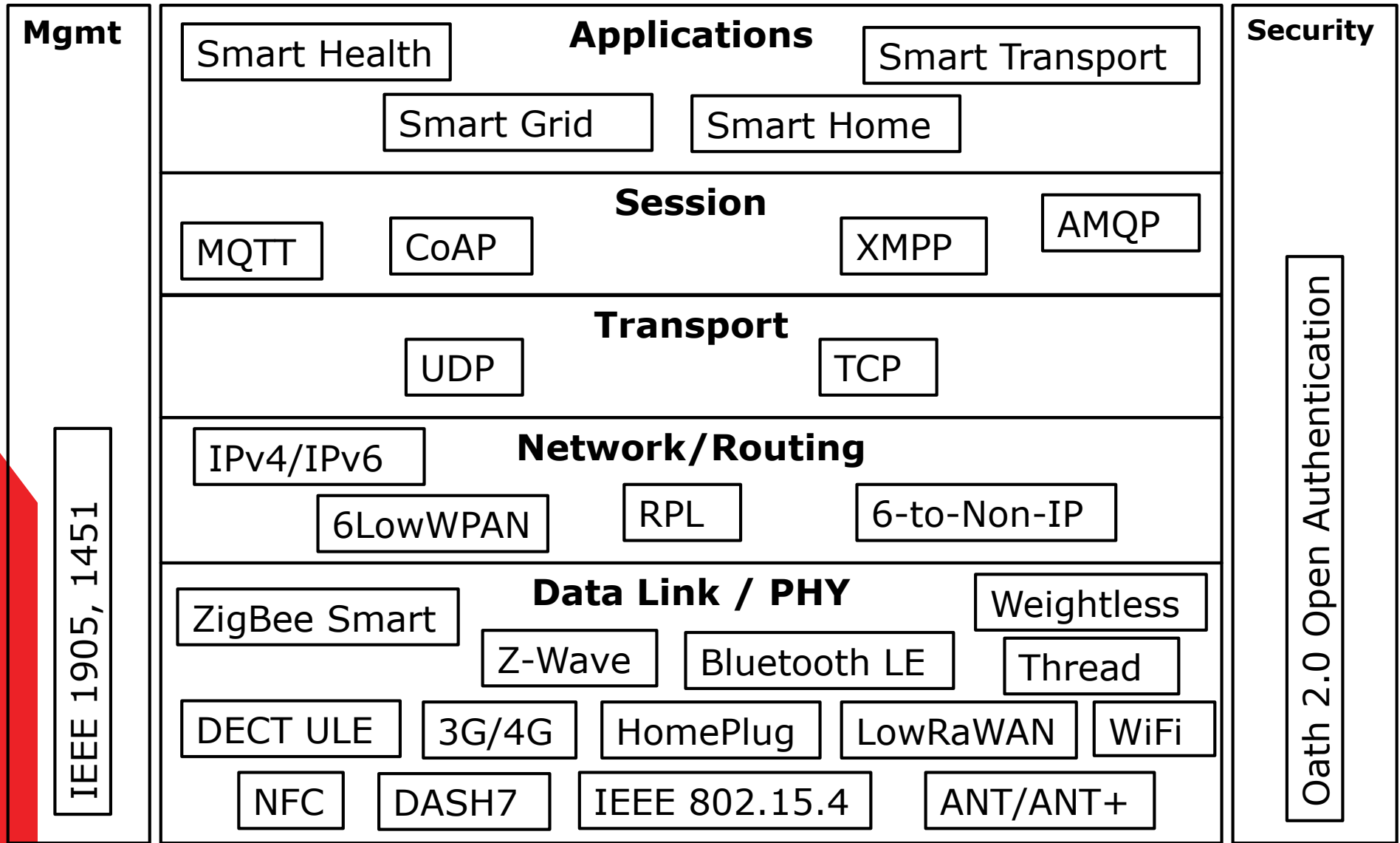
Protocols Enabling the Internet of Things



Challenges with IoT – Interoperability

- Technology is still developing with many competing systems and standards
- Appliances are usually only compatible with a single system
- Each system requires a hub device; multiple hubs could be required in a single home

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The Internet of Insecure Things

- Security is a difficult problem for traditional computing devices (eg. desktops, smartphones, etc)
- Connected devices can provide a clear picture about how habits and lifestyles
    - What could an attacker do with access to a connected speaker or CCTV cameras?
    - What about health data?
- Security may not be a high priority (or one at all) for low cost devices
    - Mirai botnet exploited default login credentials burned in to firmware to compromise CCTV cameras, video recorders, amongst other IoT devices

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The Internet of Insecure Things (cont.)

- Risks are much higher when industrial systems are targeted
    - NotPetya ransomware caused Cadbury and Merck production lines in 2017
    - BlackEnergy shut down the Ukrainian power grid in 2015
- Likely to increase as we become more reliant on IoT

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Challenges with IoT – Privacy

- Related to (but not the same as) security concerns about the data collected by connected devices
- Limited control over how vendors use collected data
- Data can be used benignly (or even for benefits)
    - Optimising healthcare or traffic management
    - Convenience of remotely controlling household appliances
- Concerns surrounding more intrusive uses
    - Fitness tracking for insurance purposes
    - Remotely controlling appliances in domestic violence

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Lecture Summary and the Week Ahead

- We've looked at some current trends in networking and networking applications
- Specifically, Software-Defined Networks, Whiteboxes, Orchestration, and the Internet of Things
- Readings for this week are listed on LMS
- In the labs: implementing the Internet of (one) Thing

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Next Week

- All good things must end.. a look back at the topics covered in ICT169
- Information regarding the Final Exam
- Practical Exam during the labs, don’t forget to study!

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