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Security Issues, Challenges, and Opportunities in the IoT and 5G Networks

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Outline

- 5G Applications
- The 5G Testbeds and Trials Programme
- 4G and 5G network structure
- SDN AND NFV
- The IoT
- Benefits and Drawbacks of the IoT
- Cyber Attacks
- 5G Security Challenges
- What do we want to protect with 5G

What is 5G ?

5G is a new global wireless standard after 1G, 2G, 3G, and 4G networks.

1G -> 2G -> 3G -> 4G -> 5G

5G networks are cellular networks that divide the service area into small geographical areas known as cells.

greater data capacity and transmission speeds

100x faster speeds compared to 4G/LTE

5G provides universal ultra-high bandwidth and low latency connectivity for individual users and connected devices.

5G promises mobile data speeds significantly faster than ultra-high-speed home broadband

5G offers a new type of network capable of connecting nearly everyone and everything

5G will connect more devices than ever before

5G is meant to deliver the following

- higher multi-Gbps peak data speeds,
- ultra low latency
- more reliability
- massive network capacity
- increased availability

Cellular Technology Evolution

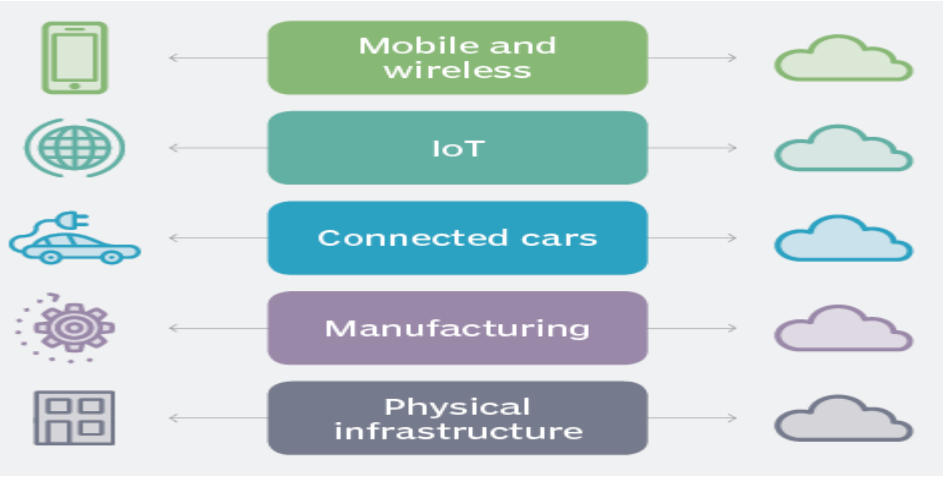
Technology	1G	2G	3G	4G	5G
Requirements	No official requirements, analog technology	No official requirements, digital technology	ITU's IMT-2000 required 144 Kbps mobile, 384 Kbps pedestrian, 2 Mbps indoors	ITU's IMT advanced requirements include ability to operate in up to 40 MHz radio channels and very high speed spectral efficiency	At least 1 GB/s or more data rates to support ultra-high definition video and virtual reality applications; 10 GB/s data rates to support mobile cloud service
Data bandwidth	1.9 Kbps	14.4 Kbps to 384 Kbps	2 Mbps	2 Mbps to 1 Gbps	1 Gbps and higher
Core network	PSTN	PSTN packet network	Packet network	All IP network	Flatter IP network and 5G network interfacing (5G-NI)
Service	Analog voice	Digital voice Higher capacity, packetized data	Integrated high quality audio, video and data	Dynamic information access, wearable devices, HD streaming; global roaming	Dynamic information access, wearable devices, HD streaming; any demand of users; upcoming all technologies; global roaming smoothly
Standards	NMT, AMPS, Hicap, CDPD, TACS, ETACS	GSM, GPRS, EDGE, etc.	WCDMA, CDMA 2000	All access convergence including: OFMDA, MC-CDMA, Network-LMPS	CDMA and BDMA
Multiple access	FDMA	TDMA CDMA	CDMA	CDMA	CDMA and BDMA

Benefits of 5G Technology

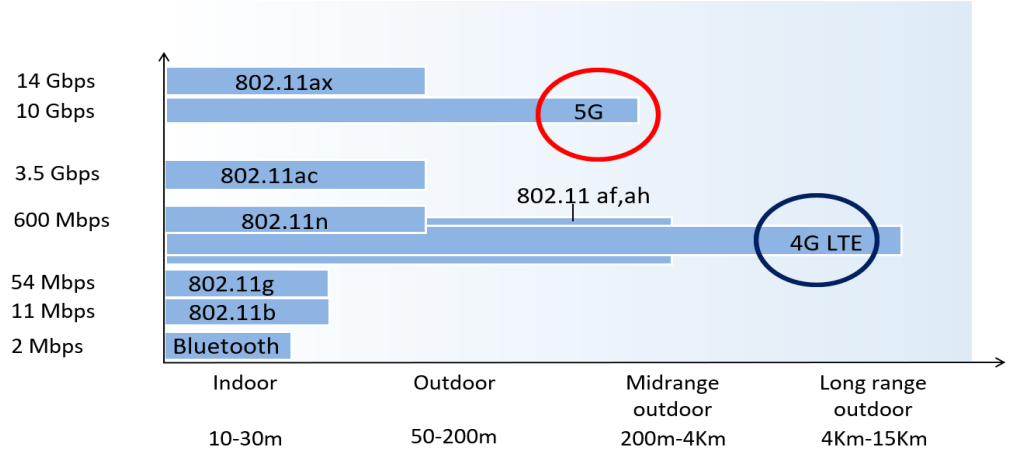
5G Capabilities	Description
• Provides a faster network with higher capacity	Higher capacity with faster processing can better serve the connectivity needs of the IoT ecosystem. The increased speed and capacity can eliminate lags in transmitting data across the network. 5G's extremely fast speeds provide latency of a mere 1 millisecond. The faster 5G speed means one could download an HD film in seconds compared to the longer time it currently takes to download such a film via devices running on a 4G network.
• Supports many static and mobile IoT devices	5G technology's flexibility provides a diverse range of: • Speeds • Bandwidth • Quality of service requirements
• Decreases network energy usage	5G technology can reduce network energy usage by 90% and provide up to 10 years' worth of battery life for low-powered IoT devices.

Source : Violino, B; "What 5G promises for IoT," Network World, 12 October 2020, www.networkworld.com/article/3584385/what-5g-brings-to-iot-today-andtomorrow.html

5G Network slicing



Characteristics of wireless links



5G Applications

- smart cities: improving quality of life with applications such as traffic management, streetlight control, trash management, and smart grids;
- education: Augmented and virtual reality applications may help students to study in entirely new ways by making classes more interactive;
- industrial predictive maintenance: assisting in the reduction of operating expenses by warning of potential equipment faults;
- retail logistics: fleets of connected/driverless lorries and vans moving products;
- agri-tech: farming that is becoming more precise and efficient in order to address the difficulties of a sustainable agricultural sector;
- augmented or virtual reality: providing new 'ultra-realistic' gaming applications or allowing sports fans to 'play' with their favorite athletes.
- Global data usage is anticipated to increase from **12 exabytes of mobile data traffic per month in 2017 to over 5 000 exabytes by 2030** - ***Special Report on 5G roll-out in the EU, March 2022***

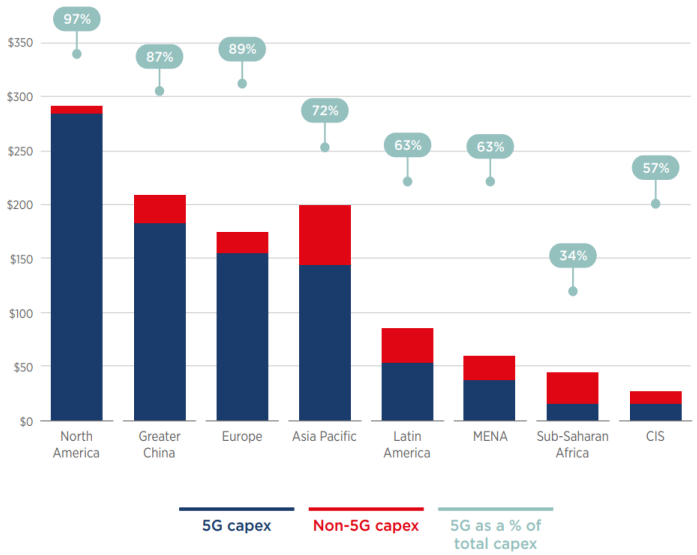
5G innovations will transform people's life.

5G Applications II

- 5G will likely place a greater emphasis on commercial and other large enterprise applications.
- 5G Technology will foster development of innovation in communication technologies
- 5G will empower flexible working
  - Faster, more reliable 5G mobile connections let you and your team work flexibly and efficiently.
- 5G Technology will enhance innovations in Supply Chains
- 5G Technology will drive Digital Marketplace developments.
- 5G can transform customer experience
  - 5G networks improve offline and online consumer experiences for small businesses.
- 5G for Police Services
  - Officers can get needed information from anywhere.
- 5G Security Solutions
- 5G for Public Sector
  - Flexible working, cooperation, and new company models save money.
- 5G for Healthcare

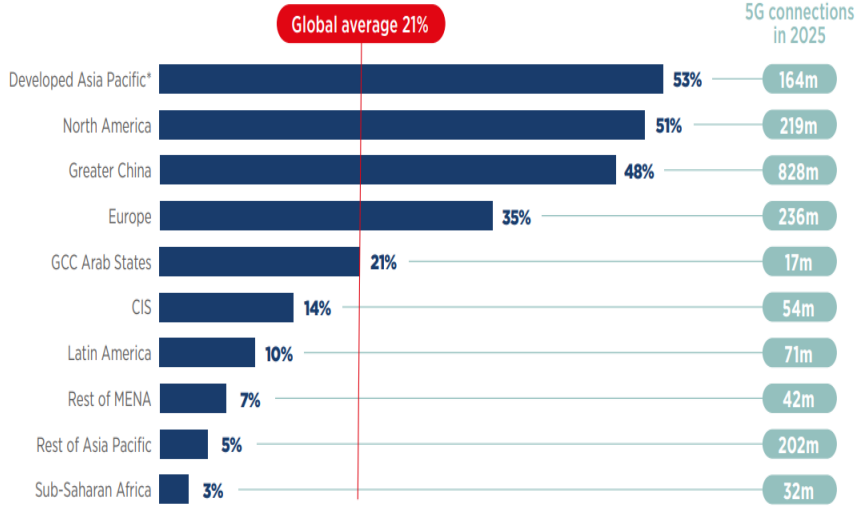
Mobile operators will invest $900 billion in their networks over the period to 2025, of which more than 80% will be on 5G

Capex (billion), 2021–2025



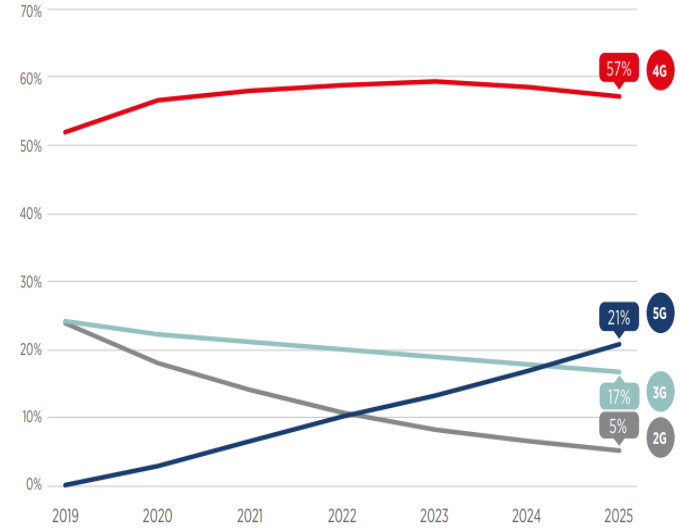
China alone will account for nearly half of total 5G connections by 2025, while adoption will be highest in developed Asia Pacific and North America

5G adoption in 2025 (percentage of connections)



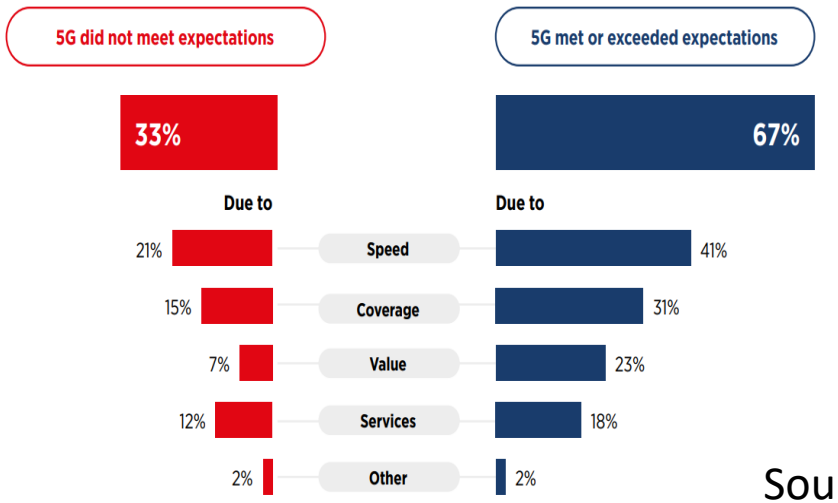
Nearly three in five connections are based on 4G; the momentum behind 5G is growing

Percentage of connections (excluding licensed cellular IoT)

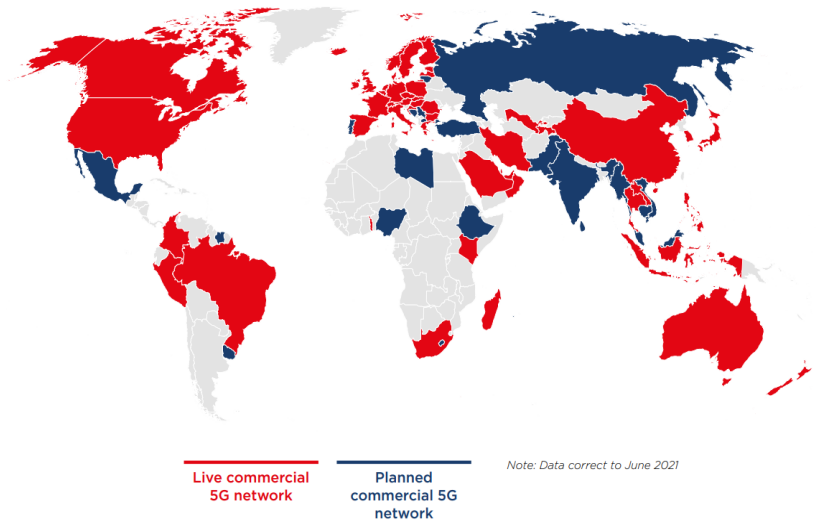


Feedback on the 5G experience is overwhelmingly positive; users are impressed by the speeds on offer, but also highlight the limited number of services available

Which of the following statements best describe your experience with your 5G networks?
Why has 5G met/not met your expectations?
(Percentage of respondents)

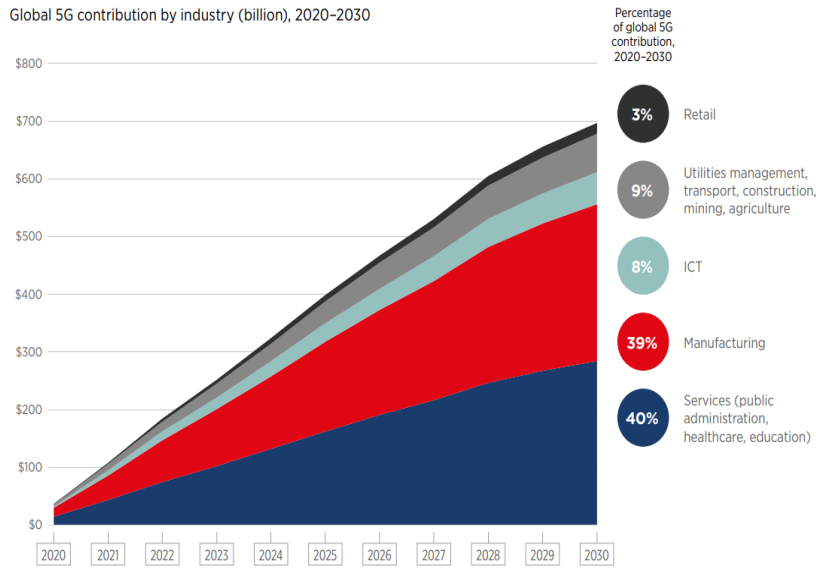


5G is now available in every region, making it a truly global technology



5G is expected to benefit all economic sectors; some industries will benefit more than others due to their ability to incorporate 5G use cases

Global 5G contribution by industry (billion), 2020–2030



Source: GSMA. The Mobile Economy 2021.

The 5G Testbeds and Trials Programme (5GTT)

In 2018, the 5GTT financed the 5GUK Test Networks testbeds.

University of Surrey, King's College London, and University of Bristol) to create the United Kingdom's first end-to-end 5G network.

The Liverpool 5G project established the largest 5G mmWave mesh network in the UK and the second largest in the world

Thanks to 5G's low latency capabilities, the University of Bristol's Smart Internet Lab was able to deliver the world's first 5G music class, connecting musicians in London and Bristol to play together.

In 2019, four mobile network operators launched 5G networks in the United Kingdom.

the Department for Digital, Culture, Media & Sport (DCMS)

6 April 2022

Water pipes in Yorkshire to deliver high-speed broadband in new trial

Fast broadband will run through water pipes in parts of South Yorkshire as part of plans to get better internet access to people quicker

8 February 2022

New plans to slash red tape from 5G roll out and improve mobile phone connectivity

Street lights, bus shelters and traffic lights will host more mobile network equipment to help boost mobile coverage as part of a new scheme to cut red tape and install more 4G and 5G kit.

8 December 2021

New measures to boost UK telecoms security

2G and 3G will be phased out by 2033 under plans to help bring in new telecoms suppliers to build the UK's 5G networks.

2 July 2021

New £30 million competition to make UK a pioneer in building 5G networks

A £30 million competition to turn the UK into a leading global destination for developing the next generation of 5G networks has been launched.

13 January 2021

£28 million to trial innovative new uses of 5G to improve people's lives

The joint investment from government and businesses will fund nine UK-wide projects that will seize the benefits of 5G and help British industries.

13 July 2020

Funding boost for UK tech innovators to seize opportunities of 5G technology

The next wave of government-funded research and development projects aiming to put Britain at the forefront of 5G technology have been announced.

20 February 2020

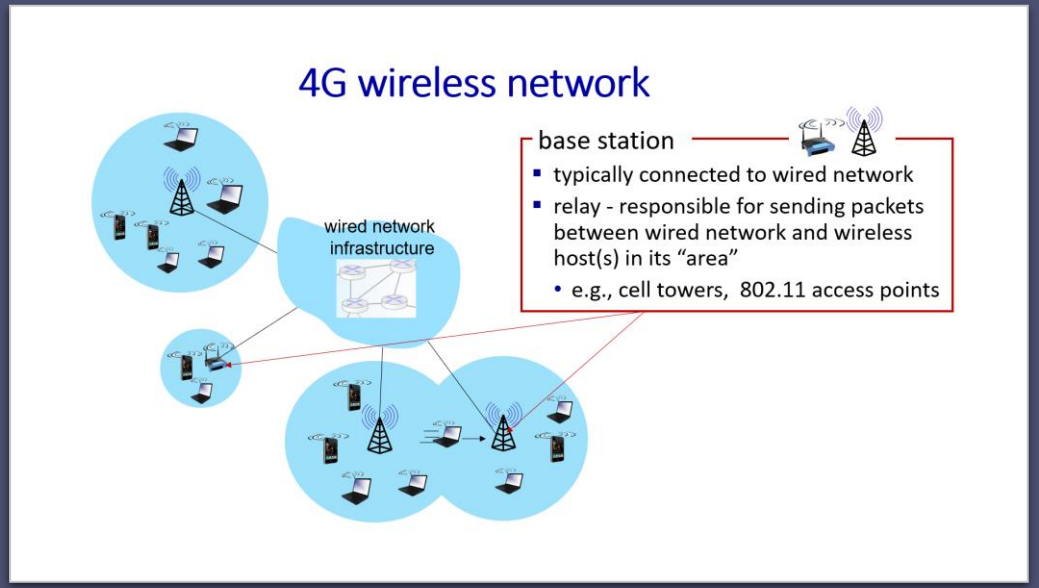
New £65 million package for 5G trials

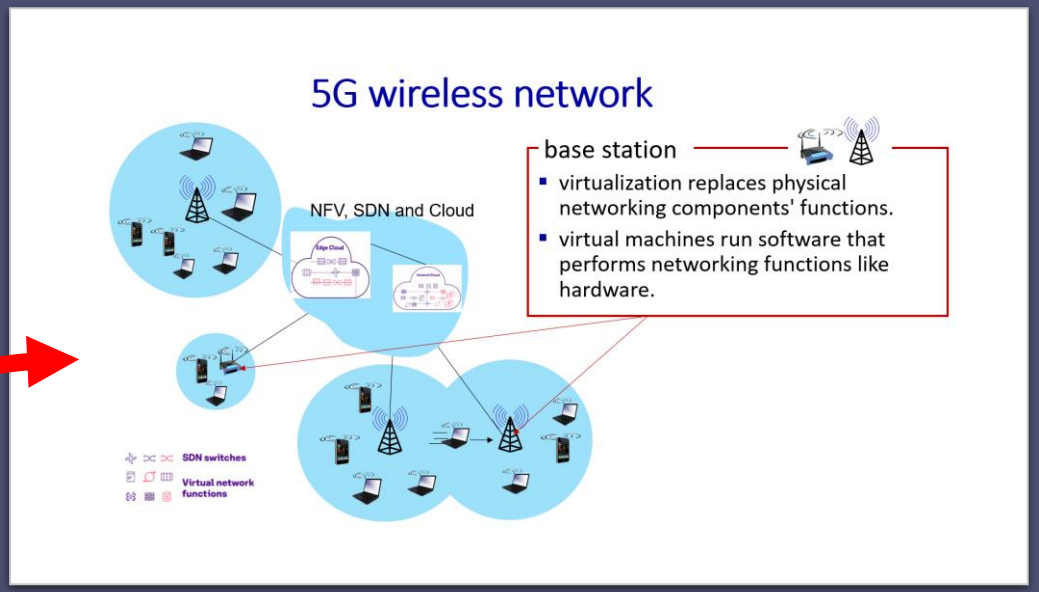
Winners of £35 million funding pot to help Britain unlock potential of 5G announced, and new £30 million 5G competition for sectors launched as part of government's continued commitment to level up infrastructure across the UK.

https://www.gov.uk/guidance/5g-testbeds-and-trials-programme

4G and 5G network structure

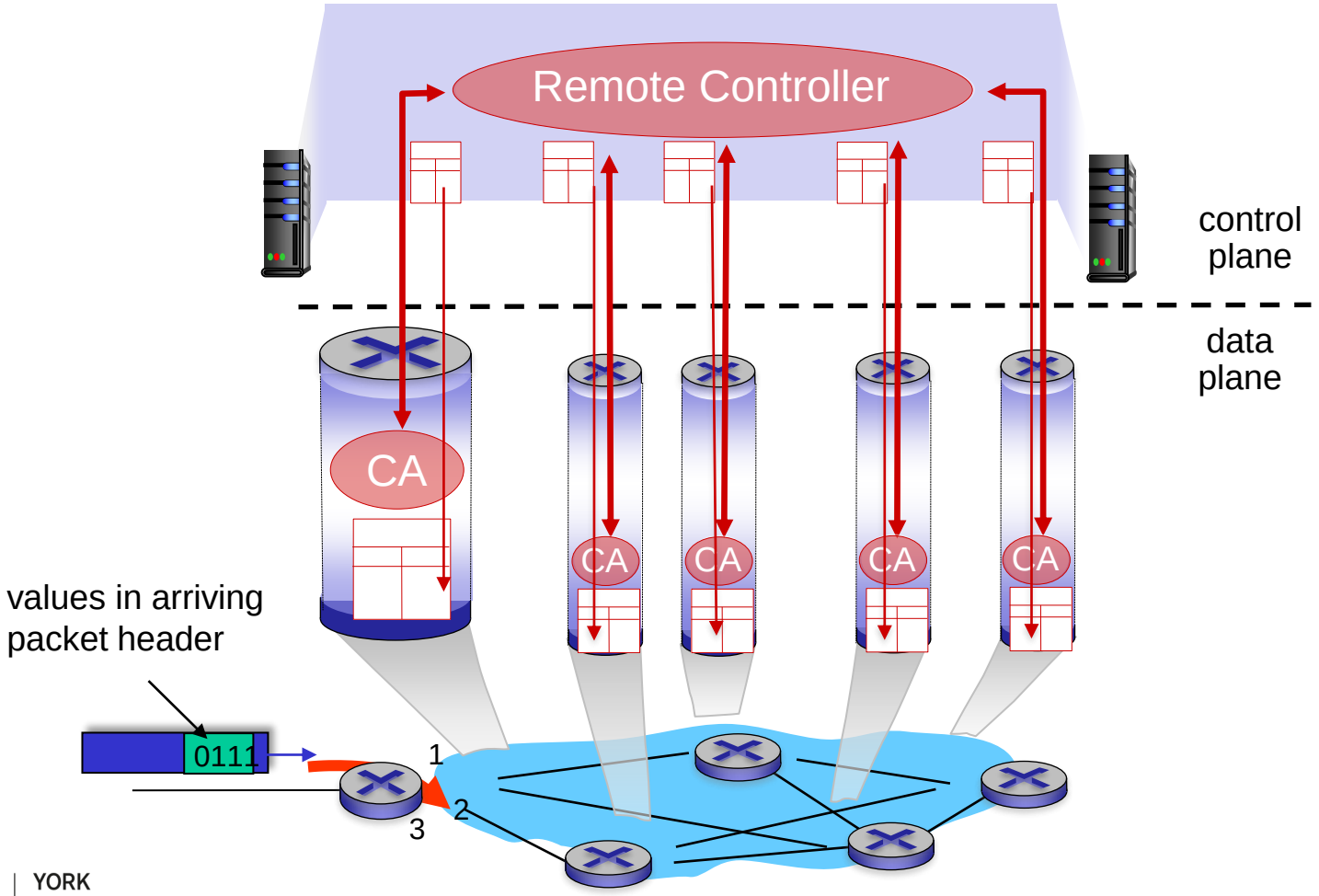
- **Security issues: NFV and SDN for 5G**
  - **NFV separates networking services from dedicated hardware appliances**
- **Physical security controls are not effective:** Virtualizing network components increases their vulnerability to new kinds of attacks compared to physical equipment that is locked in a data center.
- **Malware is difficult to isolate and contain:** It is easier for malware to travel among virtual components
- **Network traffic is less transparent**: NFV requires more fine-grained security solutions.





Software-Defined Networking (SDN) for 5G

The functionality of purpose-built network hardware like routers, switches and firewalls is being replaced by SDN and NFV

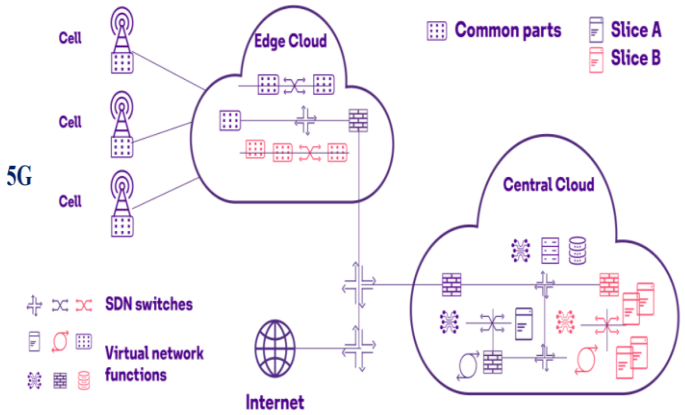


Kurose, J. and Ross, K., 2010. Computer networks: A top down approach featuring the internet.

Network Function Virtualization for 5G

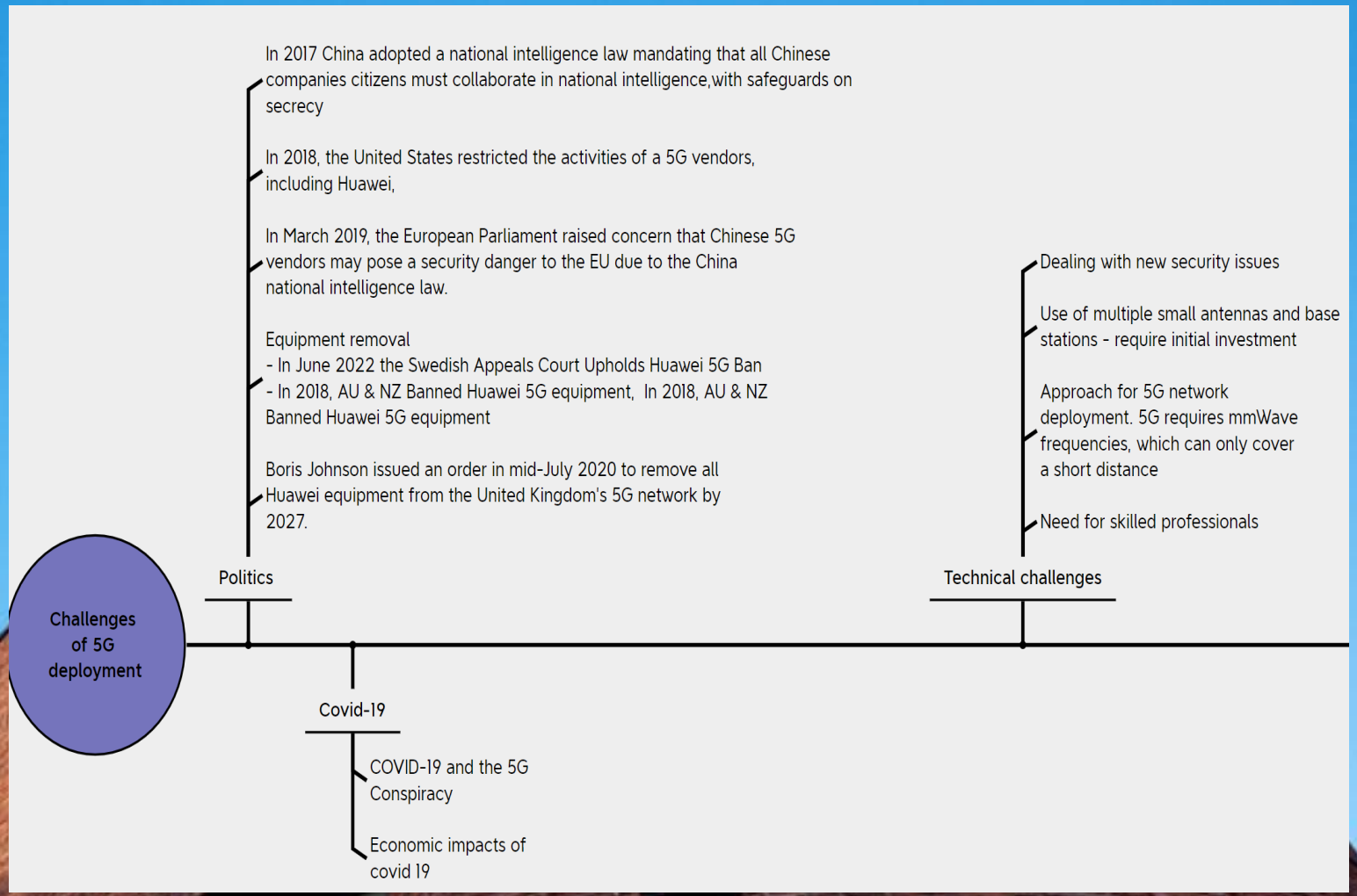
- Virtualization replaces physical networking components' functions.
- Virtual machines run software that performs networking functions like hardware.
- **Physical security controls are not effective:** Virtualizing network components increases their vulnerability to new kinds of attacks compared to physical equipment that is locked in a data center.
- **Malware is difficult to isolate and contain:** It is easier for malware to travel among virtual components
- Network traffic is less transparent: NFV requires more fine-grained security solutions.

Mobility Management Entity (MME)
Home Subscriber Server (HSS)
Packet Data Network



5G Deployment - Challenges

- 5G represents a paradigm shift in technology development, deployment, and application.
- However, the skills needed to reap the benefits of 5G are currently in short supply.
- Supporting, expanding, and driving innovation across the 5G ecosystem requires 5G expertise
    - Artificial Intelligence
    - Big Data analytics
    - the Internet of Things, and
    - Cyber Security



Alternatives?
Are there any other ways to meet 5G industry data transfer standards?

Edge Computing

Edge computing reduces latency and boosts bandwidth by processing networked data locally. This decongests the network, allowing for improved IoT data flow.

However, Edge Computing alone is not enough to match the demands of 5G.

Floating Topic

Fibre optics

Fibre optics could be an alternative to obtaining the high speeds offered by 5G. However, fiber-optic lines must be installed underground.

5G, on the other hand, employs network slicing, in which dedicated frequency bands are assigned to certain applications that must be highly reliable, such as emergency communication. Separate channels cannot, unfortunately, be carried across fibre optic connections.

Satellites

Satellites can extend 5G to hard-to-reach places. They improve mobile connectivity in rural places and integrate automobiles and planes.

But without other technologies they cannot improve the high bandwidth and low-latency demands of 5G.

4G and 6G

4G cannot compete with fifth generation because it lacks the bandwidth and low-latency requirements.

6G, on the other hand, is still a long way off, and research is still in its early stages.

5G Health Concerns

- Most current communication systems operate at frequencies below 6 GHz.

- Thus the spectrum below 6 GHz is already too saturated
- 5G technology will have to rely on additional bandwidths.

    - 5G requires ranges well above ultra-high frequencies (UHF), having wavelengths in the centimetre (3–30 GHz) and the millimetre ranges (30–300 GHz).

- **5G Masts needs to be situated closely together**

    - 5G antenna masts will be placed close together and will continue to operate alongside existing 2-4G towers for many years.

The researchers aim to know, among other things, if such high frequencies (6 - 100 GHz, millimetre waves, MMW) in combination with 2-4G radio frequency (RF) waves can harm human health and the environment.

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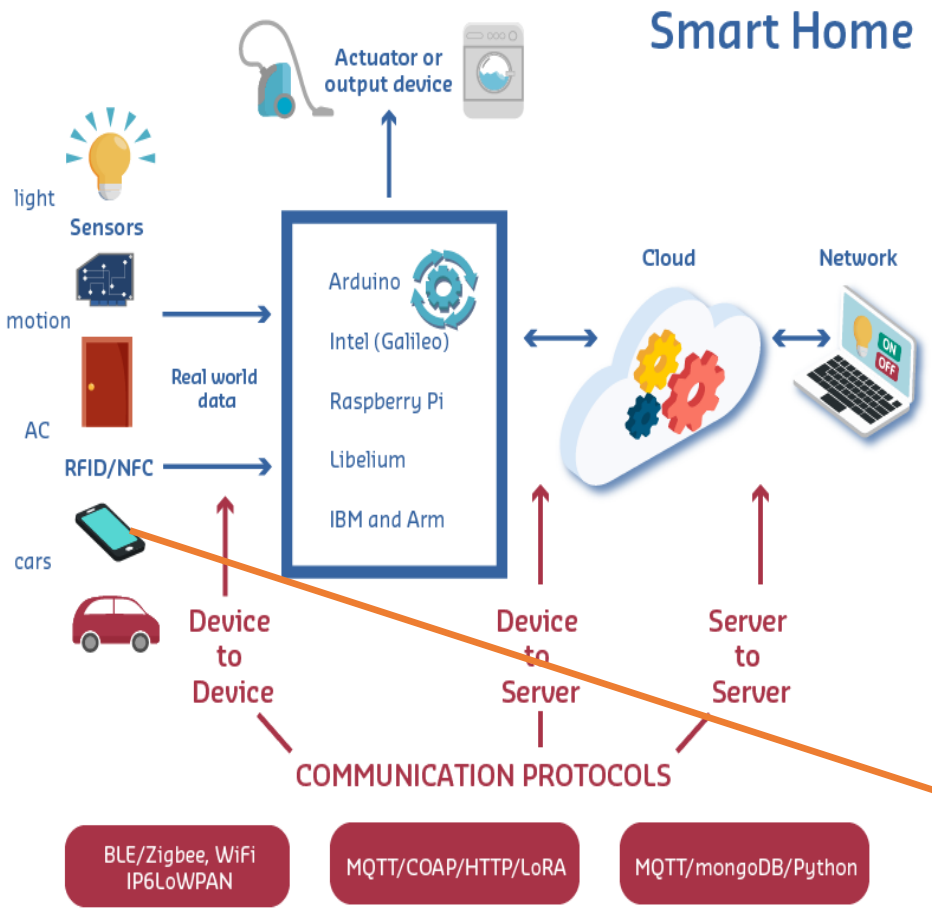
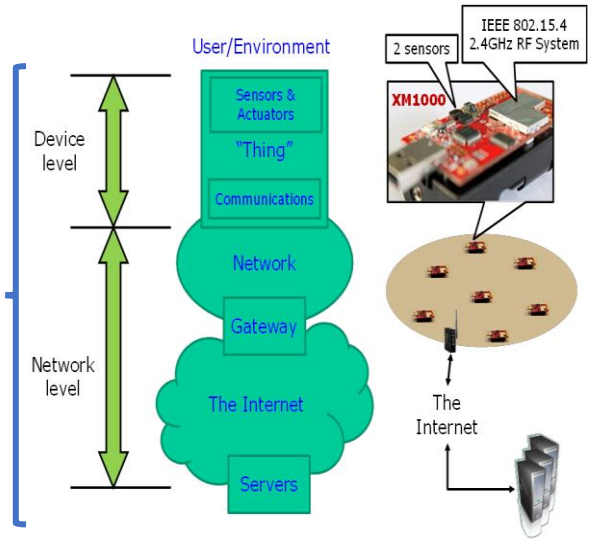
The IoT

- The IoT enables physical objects to see, hear, think, and perform jobs by having them “talk” to each other, share information, and coordinate decisions

- Definition!
  - The Internet of Things (IoT) is the network of physical devices, cars, and household appliances embedded with electronics, software, sensors, actuators, and connections that enables these things to communicate and exchange data.

  - Machine-2-Machine





Benefits and Drawbacks of the IoT

- IoT offers several benefits to organizations, enabling them to:
  - Building Innovative solutions
    - Efficient operation management
    - Better use of resources and assets
    - Cost-effective operation
    - Make better business decisions; and
    - Generate more revenue.
    - AI, Machine Learning applications requires massive amount of data
  - Autonomous vehicle communications
  - Smart grids
  - Highway/traffic sensors
  - Drone communications
  - Medical sensors and
  - AR/VR

- Drawbacks of IoT
  - Security flaws
  - Associated costs
  - Power supply dependence
  - Network dependence
  - **Handling complex device identities at scale**

- As the number of connected devices increases and more information is shared between devices, the potential that a hacker could steal confidential information also increases.

- Enterprises may eventually have to deal with massive numbers - maybe even million and collecting and managing the data from all those devices will be challenging.

- If there's a bug in the system, it's likely that every connected device will become corrupted.

IoT Applications & Data Analytics

IoT Analytics

Real-time analytics

- Real-time analytics refers to the automatic data analysis of information collected from various sensors done by AI-driven systems in real-time.
- It allows companies to keep track of various company processes as well as immediately respond to potential failures.

Descriptive analytics

- *Descriptive analytics is focused on the current situation and is based on the monitoring of IoT devices, operational processes, and assets conditions.*
- Mostly, descriptive analytics can provide information to IoT dashboards that are filled with graphs, charts, maps and tables. It helps to easily visualize and display all the data received from IoT devices.

Diagnostic analytics

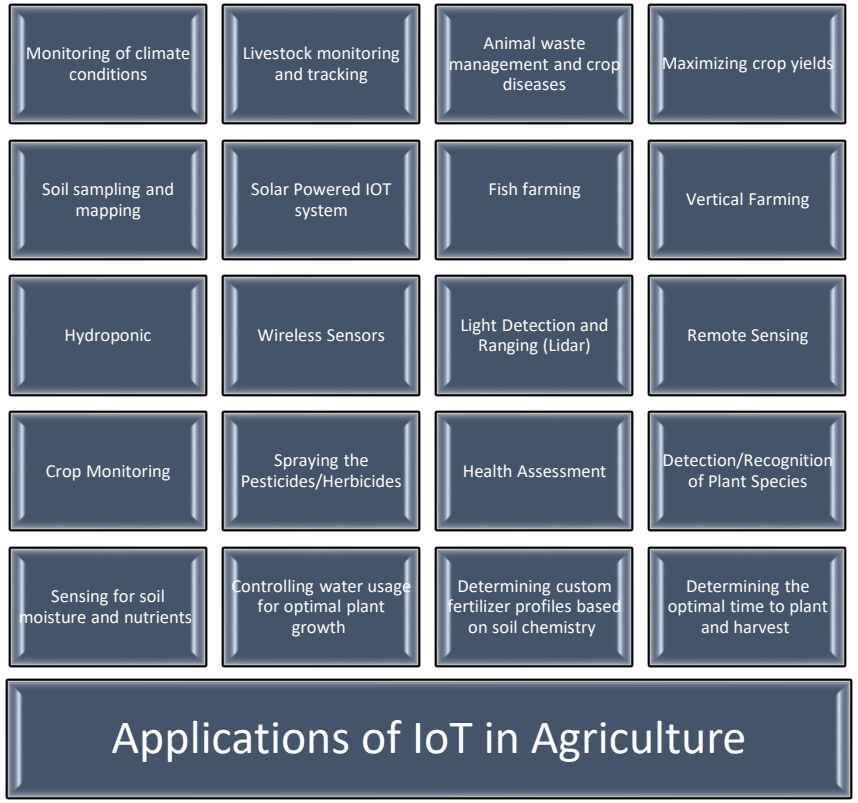
- Diagnostic analytics identifies inefficient areas and core problems and makes recommendations on how to fix or avoid them.

Predictive analytics

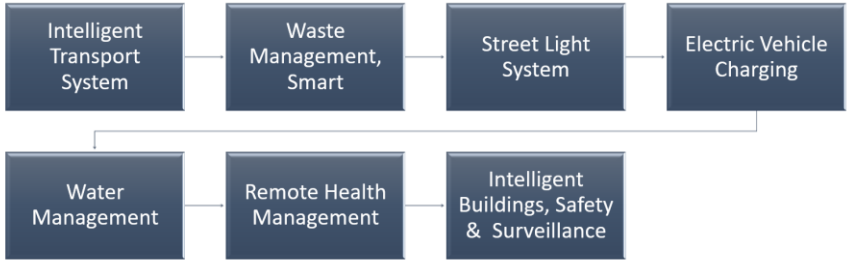
- Using IoT app analytics allows companies to make more accurate predictions and drive improved performances.
- Predictive Analytics-powered systems analyse huge amounts of data from various sources inside and outside the organization. It allows making forecasts based on the analysed information.

Historical analytics

- Historical analytics is focused on analysing stored data from the past in order to identify particular trends, correlations, and patterns that may provide valuable insights into company performances.
- Its application to real-time parameters helps to detect tendencies and forecast conditions and events that may occur at a specific time.



IoT Applications for Smart City



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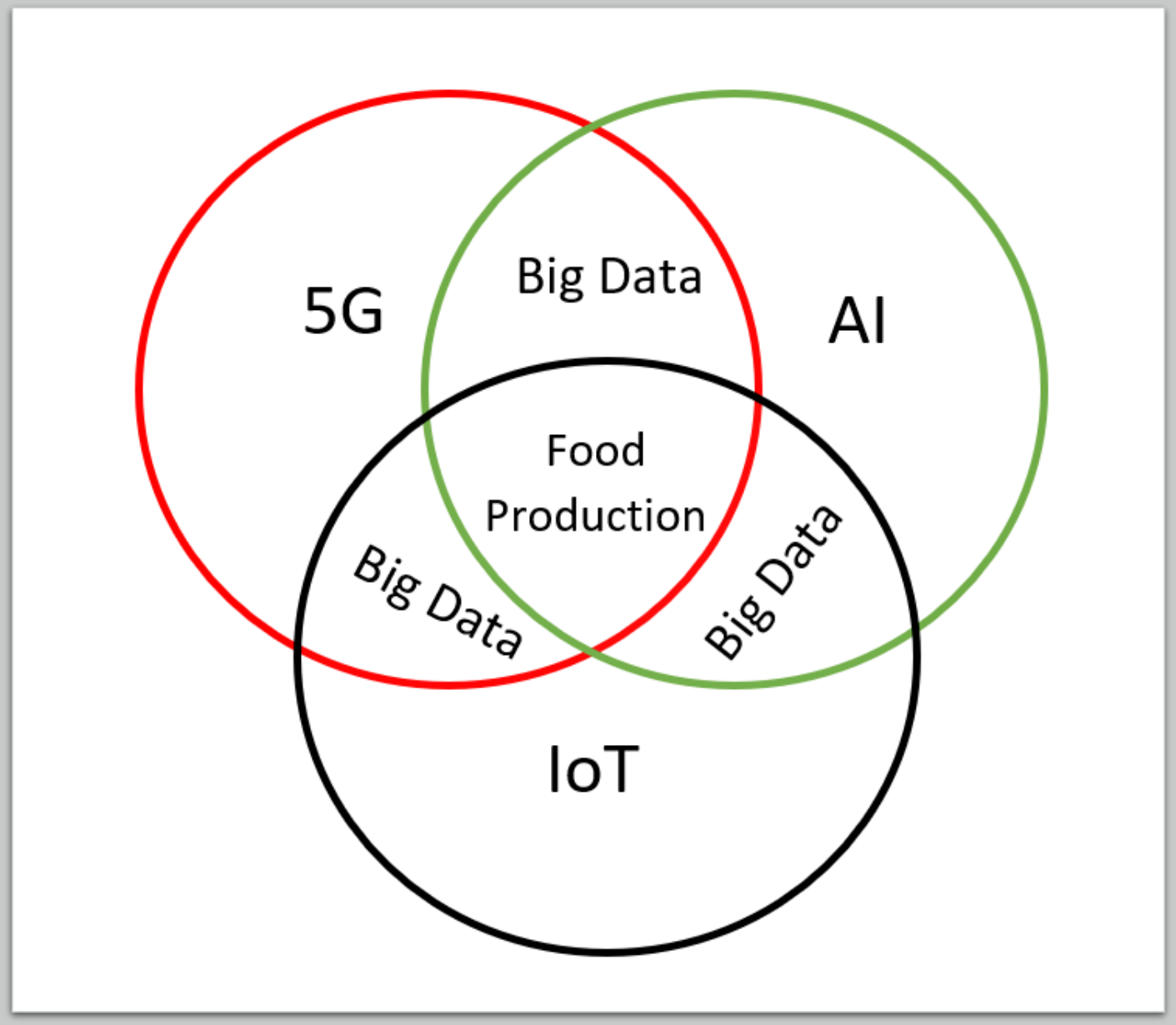
Unlocking the potentials of IoT, 5G and AI for Food Production

- 5G is a key part of the future Agricultural ecosystem's ability to support, grow, and drive innovation
- 5G networks will be able to connect billions of IoT devices, producing big data, necessitating the deployment of artificial intelligence to make sense of it
- Link

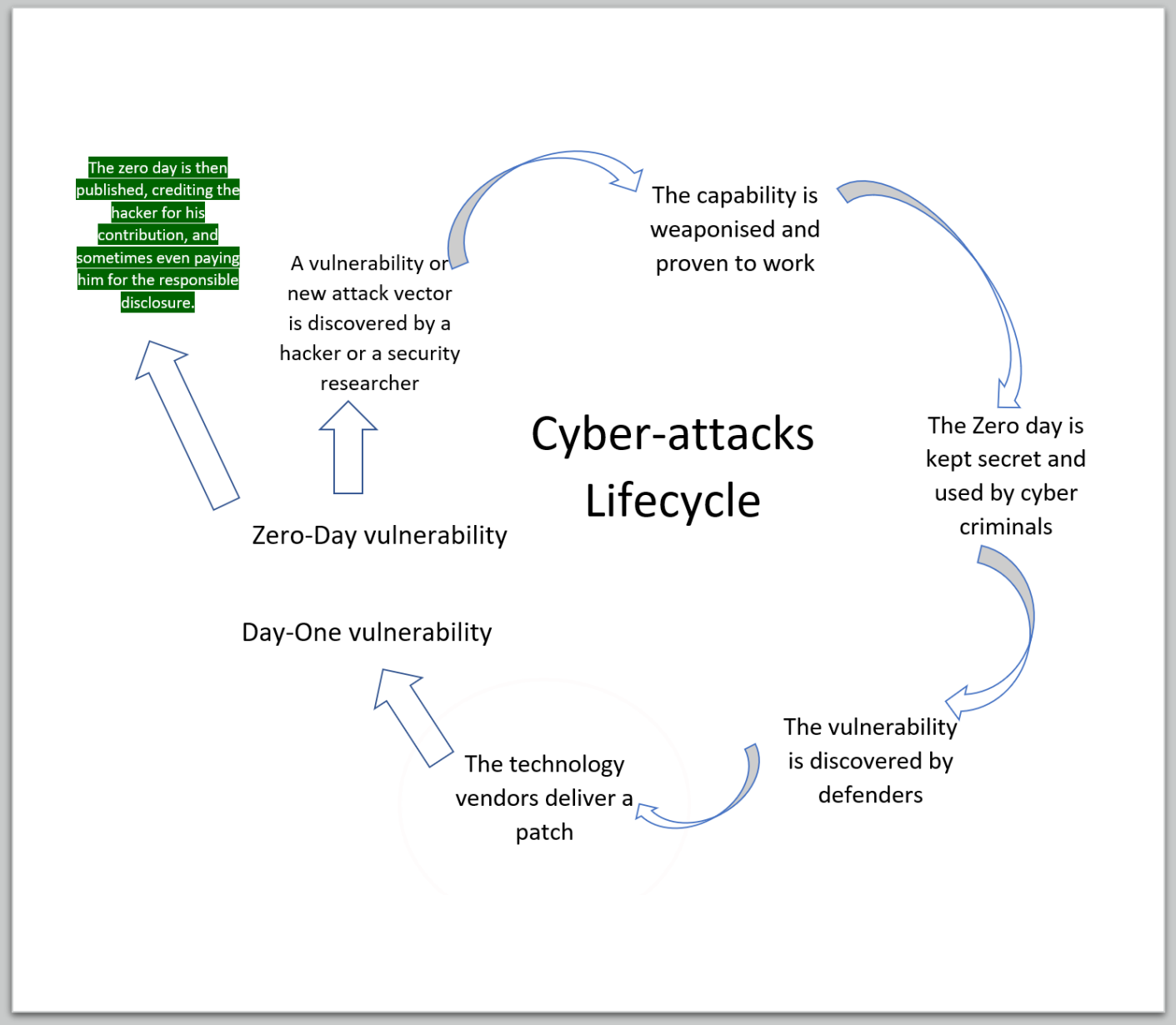


Two types of cyber attacks

- Zero-day attacks
- Day-one attacks

- Many of the “things” that make up the IoT landscape have zero-day vulnerabilities

- The 5G evolution means billions of these things, collectively referred to as MIoT, will be using the 5G Radio Access Network (RAN)



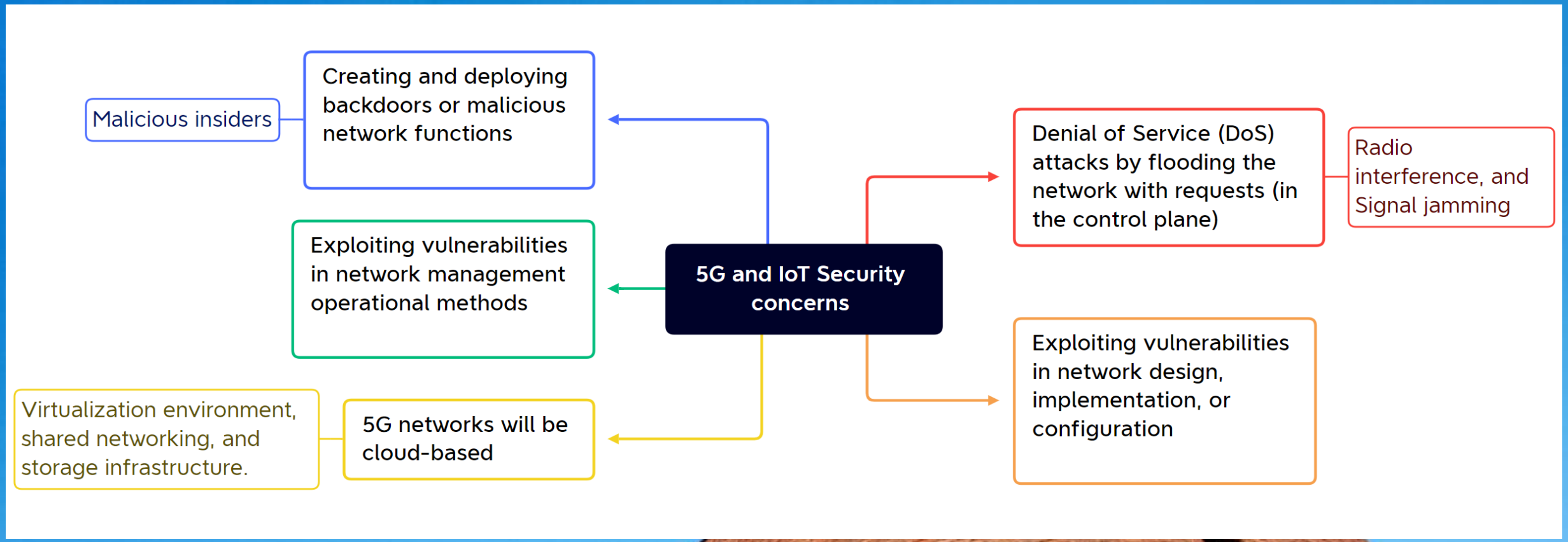
5G Security Standards

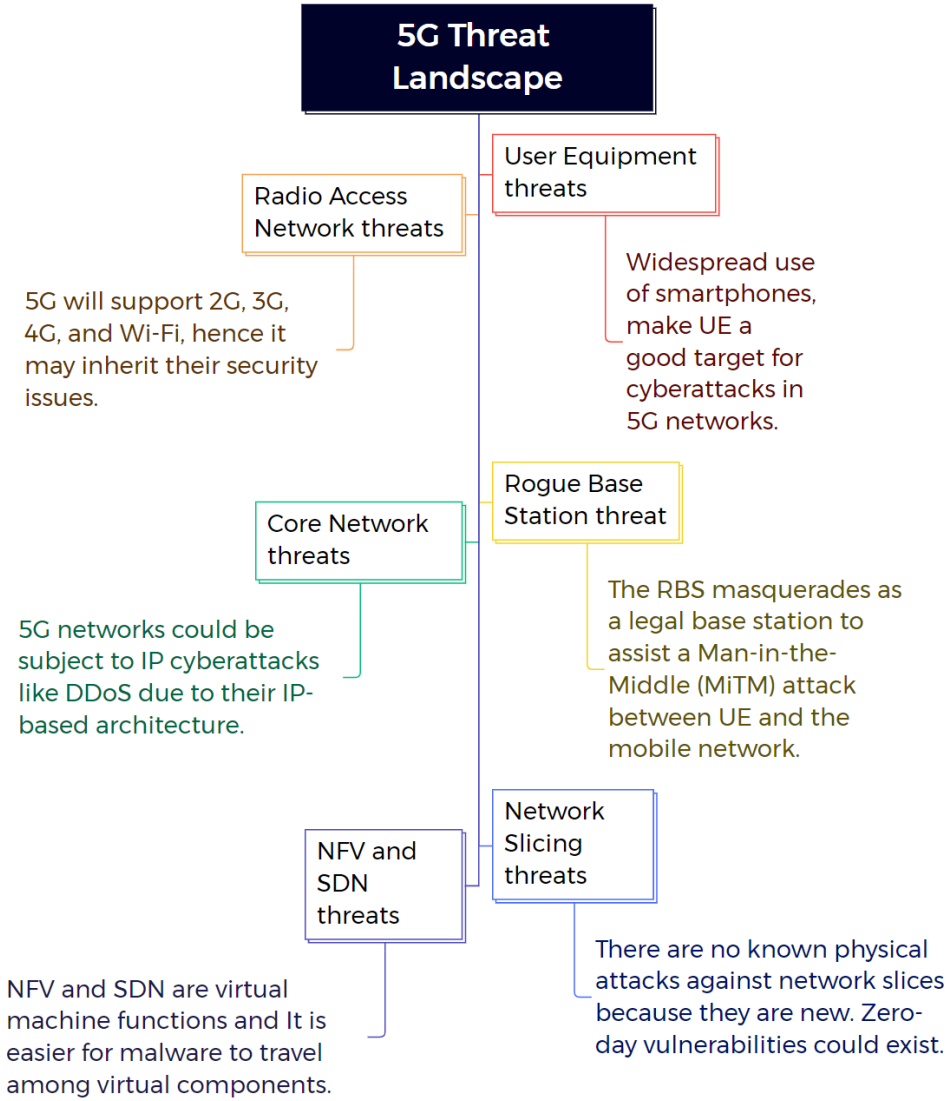
- 3GPP TS 33.501 V15.1.0 (2018-06) is the latest specification published by SA3 for 5G security
- defines the security architecture:
    - security features and processes for the 5G system and the 5G core and the 5G New Radio (NR)

- Increased the security of Home control
    - Vulnerabilities in 3G and 4G for home control authentication have been fixed
- Security Edge Protection Proxy (SEPP)
    - For all 5G interconnect roaming messages, the SEPP ensures end-to-end secrecy and/or integrity between the source and destination networks
- Security Anchor Function (SEAF)
    - The concept of an anchor key is introduced in 5G. The SEAF enables the device to be re-authenticated when it switches between access networks
- Secure Steering of Roaming
    - 3GPP Release 15 of the 5G standard added native support for a secure Steering of Roaming (SoR) solution

5G Security Challenges

- **Network traffic:** There will be a high number of end-user devices and new things (IoT)
- **Security of radio interfaces:** Radio interface encryption keys are sent over insecure channels
- Virtualization
  - Functions outside the operator network, such as the cloud, may be used to carry out the core network activities.
- Mobile IoT
  - Attacks on the devices (endpoints)
  - Attacks on service platforms (i.e., the cloud)
  - Attacks on the communications links (e.g. Cellular, WLAN, BLE air interface etc.)
- Artificial Intelligence (AI)
  - AI is expected to be widely employed in 5G networks and should benefit security.
- However, this technology is also available to the attacker and AI-driven attacks are anticipated.


5G and IoT Security concerns
Malicious insiders
Creating and deploying backdoors or malicious network functions
Exploiting vulnerabilities in network management operational methods
Virtualization environment, shared networking, and storage infrastructure.
5G networks will be cloud-based
Denial of Service (DoS) attacks by flooding the network with requests (in the control plane)
Radio interference, and Signal jamming
Exploiting vulnerabilities in network design, implementation, or configuration

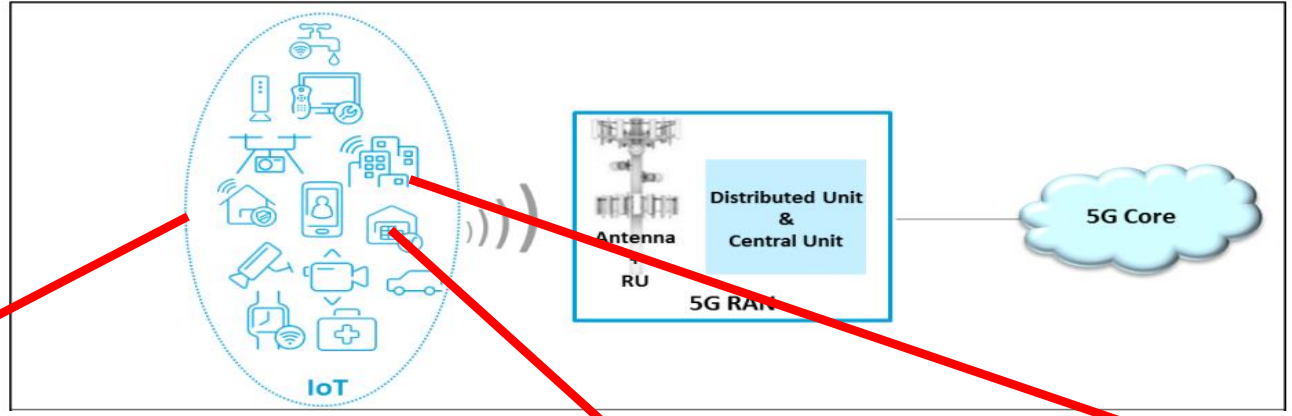


Examples

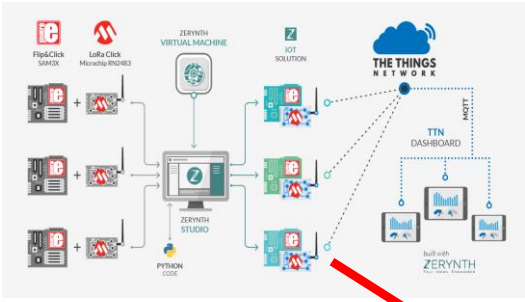
- **Rogue Base station threats**
  - [Creating a Rogue Wi-Fi Access Point]
- **Core Network threats**
  - [Network attacks using specialized tools]

IoT DDoS scenario

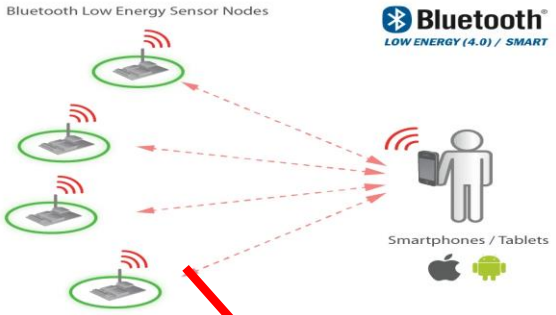
- *Hackers discover zero-day vulnerabilities and utilise them to build a botnet.*
- *The hackers then direct the software to simultaneously reset all devices in a selected or targeted 5G coverage area. This results in excessive malicious "attack requests," resulting in a signaling storm that overloads the 5G RAN resources. This DDoS attack renders the RAN inoperable for legitimate subscriber use.*



IoT Network using LoRaWAN Protocol



IoT Network using Bluetooth Protocol



IoT Network using Zigbee Protocol

IoT Network using RFID

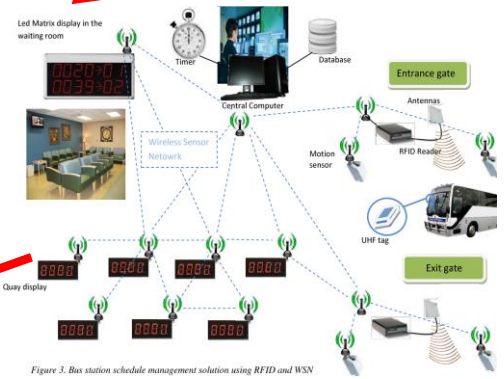
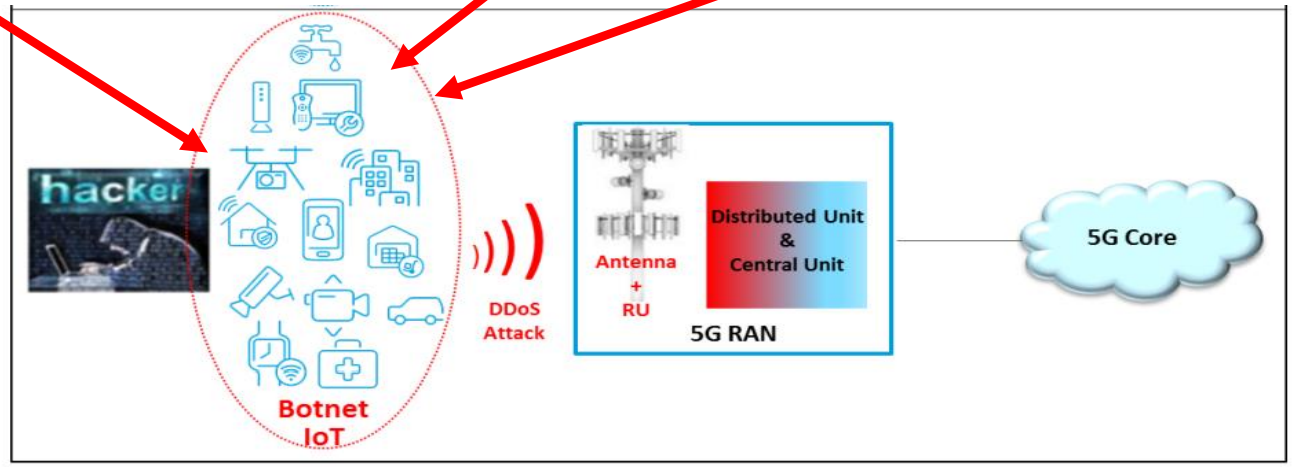


Figure 3. Bus station schedule management solution using RFID and WSN



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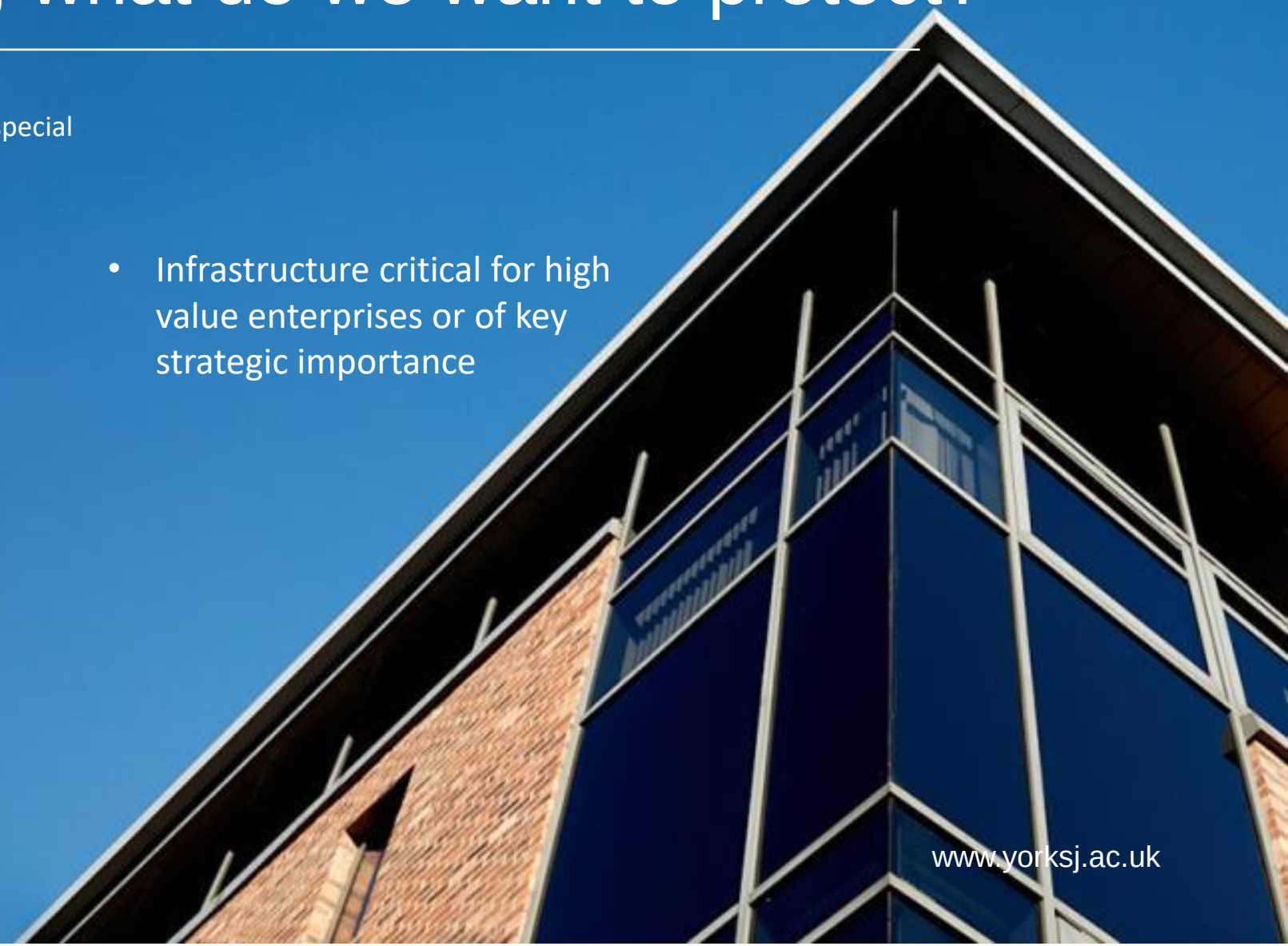
With 5G and IoT, what do we want to protect?

Critical telecom elements that should undergo special scrutiny

- Government networks and data centres
- Infrastructure used by providers of basic products and services including
  - Railways
  - Airports
  - Energy
  - Food
  - Banks
  - Internet exchanges
  - Water utilities
  - Hospitals, etc

- Infrastructure critical for high value enterprises or of key strategic importance



References

- Connectivity, Intelligent. "How The Combination Of 5g, Ai, Big Data [illegible] ng, Gsma, 2019."
- Statista, Number of internet of things (IoT) connected devices wo[illegible] 030.
- European Court of Auditors, Special Report, 5G roll-out in the EU[illegible] networks with security issues remaining unresolved, 2022
- Cisco Visual Networking Index: Global Mobile Data Traffic Forec[illegible] ruary 2019.
- ITU-R, IMT traffic estimates for the years 2020 to 2030.
- Shafi, M., Molisch, A.F., Smith, P.J., Haustein, T., Zhu, P., De Sil[illegible] ebbour, A. and Wunder, G., 2017. 5G: A tutorial overview of standards, trials, challenges, deployment, and practice. IEEE journal on selected areas in c[illegible] pp.1201-1221.
- European Commission, 2030 Digital Compass: the European [illegible] de, COM(2021) 118 final.
- Review 02/2019: Challenges to effective EU cybersecurity p[illegible] 020 Contact Committee Audit Compendium – Cybersecurity; and European Parliamentary Research Service – European Science-Media hub.
- NIS Cooperation Group, EU coordinated risk assessment of th[illegible] 5G networks, 9.10.2019. Point 3.4. 8 World Economic Forum, Wild Wide Web – Consequences of Digital Fragmentation, 2021.

Unlocking the potentials of IoT, 5G and AI for Food Production – a short review

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In recent years, we have witnessed amazing advancements in agricultural processes, from micro-farming to large-scale farming, while global food consumption continues to climb. By using the Internet of Things, Artificial Intelligence, and fast network connectivity (5G) for monitoring, managing, and analysing agricultural data and processes for an information-driven agricultural management system, smart farming will continue to lead the way to the required increase in food production.

The Internet of Things (IoT) provides a solid foundation for innovative agriculture solutions by using sensors to collect real-time agricultural data for analytics. When AI algorithms are applied to agricultural data, farmers can perform real-time descriptive, diagnostic, or predictive analytics to make sense of the data and farming automation.

IoT has aided in developing agricultural robots that can do various tasks that would otherwise require humans. The IoT devices and cloud services connected to the 5G network enable flexible and efficient smart farming solutions and the automated operation of numerous unmanned IoT devices, resulting in secure, dependable, environmentally friendly, and energy-efficient operations with low latency and high-speed broadband networks.

The installation of 5G networks is often done for proximity coverage, non-battery powered systems, and short-range access. As a result, other networking technologies like LoRaWAN, Ingenu, Sigfox, and NB-IoT are adopted for large-scale farming solutions and long-distance data transfer. Long-distance data transport is dominated by LoRaWAN so far. While 5G offers high network capacity, high spectral efficiency, and seamless connectivity between end devices, sensor devices are integrated with these LoRa-equipped transceivers to collect data and deliver it to gateways. These gateways then transport the data to the core 5G network. With 5G network Farmers can acquire real-time data from drones, such as high-definition video streams, as well as other crucial sensory data and telemetry, faster and more fluidly than with previous-generation mobile networks thanks to the 5G network. Because they make long-term investments, farmers are under pressure to select the most appropriate technology for their operations [1]. Concerning soil health, for instance, a farmer's investment considerations may include the deployment of sensors or smart farming technologies with an optimal network architecture that addresses the need to scale from thousands to millions of nodes, densely or sparsely populated IoT devices distribution, fixed or mobile operations depending on the geographical locations of the farms.

Nutrient monitoring in the soil can become difficult on a large field; manually taking samples around the area and testing them is labour-intensive. As a solution, IoT sensors are deployed into the ground to monitor the state of soil around the area in real-time for accurate information-gathering of soil’s qualities [2]. These sensors are deployed in-ground and connected to applications to receive real-time data on the soil, which can subsequently allow the implementation of AI algorithms that could map the sensors

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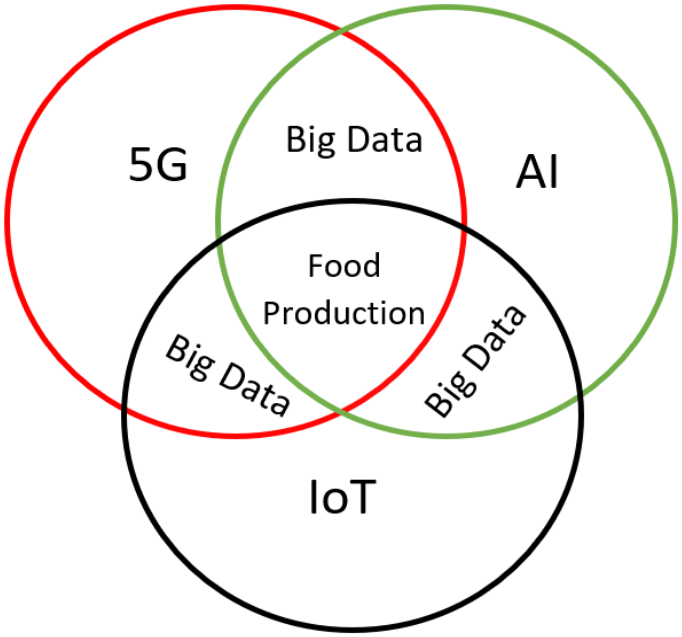
around the field and display visual maps and charts on the data collected or react to the occurrence of a certain event. To ensure plant fertility, the chemical composition of fertilizers and soil, such as the amounts of phosphorus, nitrogen, and potassium, is calculated using IoT-based devices. Farmers can apply the ideal amount of fertiliser to their crops without sacrificing the fertility of the soil by using sensor data on nutrient and weather levels [3].

Farmers often use single-based sensors that are vertically submerged into the ground to record the level of Soil moisture which can vary across the depth of the ground, but in a well-optimized system, these vertical sensors collect data at different points of its length. The soil moisture sensor helps to quickly detect soil water content and soil nutrients and convert them into a precise velum to display on a smartphone or programmable Board with an LCD screen. A suitable sensor layout around the field can create a sophisticated irrigation system, making sure the levels of moisture are recorded all around the field throughout the season, thus improving crop yield and reducing water waste. However, since different variables affect the soil around the area, the soil moisture or nutrient may not be completely uniform. Thus, the more sensors are deployed, the more accurate the data is provided about the soil.

With the ability to connect billions of the Internet of Things (IoT) devices, 5G networks will be able to create big data that will require the use of artificial intelligence to analyse.



Farmers are using more innovative livestock monitoring to boost productivity, improve livestock health, minimise waste, and save costs as they combat rising land costs and concerns about food hygiene caused by animal diseases. Implementing a data-driven agricultural system that makes use of technologies like the Internet of Things, 5G, and artificial intelligence to improve cattle health is imminent.

Sensors are being used to keep an eye on livestock from a distance, track where cattle are, and so on. For example, more and more farmers use health sensors every day, such as heart rate sensors, body temperature sensors, Glucometers (which measure the amount of glucose in the blood), and Sphygmomanometers (which measure blood pressure) to monitor animal health. [4] With the IoT sensor's readings and the animal's GPS data, predictions on the health state of the herd are being made in real-time [5].

Other applications of IoT in livestock include using sensors to learn how animals eat before, during, and after milking so that farmers can predict milk production or using motion sensors to measure cows' stress levels to find out if it affects how much milk they make. Another IoT application uses a heat detection sensor to track when the cows are in heat so that the cow's feed, mating schedule, and overall health can be adjusted in advance.

Further, AI and IoT sensors are being used to identify how much energy animals are getting in [6]. This is important for understanding and even predicting diseases like trace element deficiencies, lameness, and calving issues in animals. Anoestrus in animals, for example, can be caused by a number of factors, including postpartum illness and, more significantly, an inadequate energy intake that cannot support the needs of nursing. These solutions greatly aid the precision agricultural field as they smartly inform growers and farmers what crops or animals need particular attention at the correct time, saving money in the long run.

Conclusion

5G networks will be able to connect billions of IoT devices, producing big data, necessitating the deployment of artificial intelligence to make sense of it. 5G is a key part of the future Agricultural ecosystem's ability to support, grow, and drive innovation. Unlocking the potential of technologies like Artificial Intelligence (AI), the Internet of Things, and 5G could help develop new ideas for smart agriculture for global food production.

[1] Pergola, Maria, et al. "Composting: The way for a sustainable agriculture." Applied Soil Ecology 123 (2018): 744-750.

[2] Chamara, Nipuna, et al. "Ag-IoT for crop and environment monitoring: Past, present, and future." Agricultural Systems 203 (2022): 103497.

[3] Lavanya, G., Chellasamy Rani, and Pugalendhi GaneshKumar. "An automated low cost IoT based Fertilizer Intimation System for smart agriculture." Sustainable Computing: Informatics and Systems 28 (2020): 100300.

[4] Khatate, Prathamesh, Anagha Savkar, and C. Y. Patil. "Wearable smart health monitoring system for animals." 2018 2nd International Conference on Trends in Electronics and Informatics (ICOEI). IEEE, 2018.

[5] Buller, Henry, et al. "Animal welfare management in a digital world." Animals 10.10 (2020): 1779.

[6] Neethirajan, Suresh. "The role of sensors, big data and machine learning in modern animal farming." Sensing and Bio-Sensing Research 29 (2020): 100367.