Introduction to Telecommunications Networks

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Outline of talk

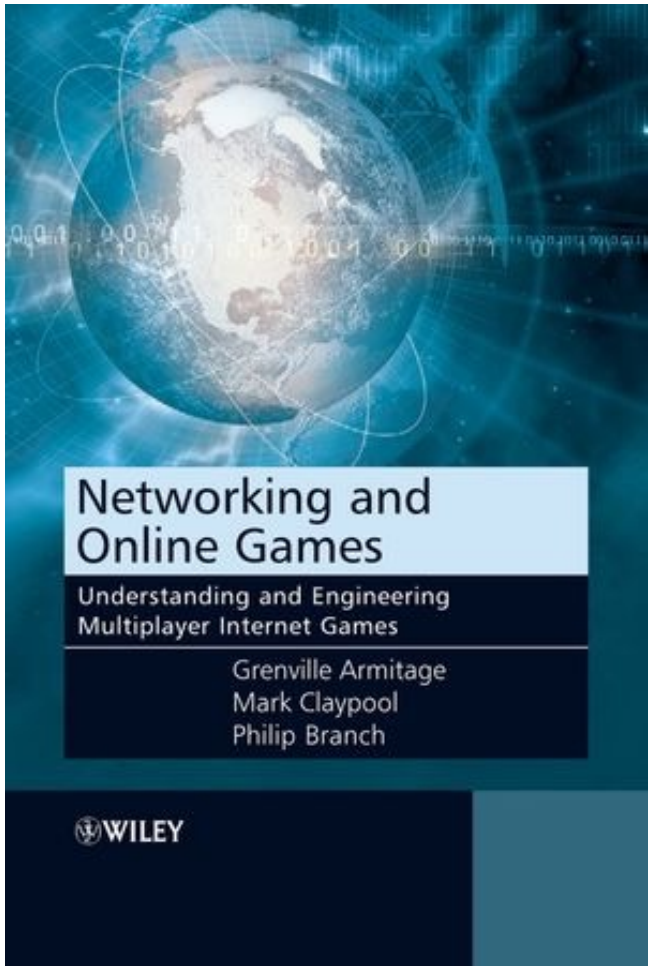
- Why engineers and software developers need to know comms
- Network requirements for different applications
- General network characteristics
- Core networks
- Access networks
- Review of network types

But first… Why do you need to know about Telecommunications and Networks

- Engineers:
  - Electrical Engineers may actually end up working for a telco and electrical systems often centrally monitored and controlled
  - Smart grid relies on communications to transfer or store energy
  - Mechanical, Electrical and Civil engineering equipment now connected to remote controllers
  - Civil engineering use sensors for building and bridge stress and movement, mining for wall deformation
  - Biomedical Engineers have many body sensor devices moving to wireless and remote access
  - Computer Systems Engineers work with multiple devices that need to communicate

But first… Why do you need to know about Telecommunications and Networks

- Computer scientists:
  - Most systems distributed
- Game Developers:
  - Game performance depends on underlying network infrastructure



Requirements of different applications of communications networks

- Different applications need different things from a network
- Voice
  - Low bit rate, can tolerate some loss but very intolerant of delay
- Video conferencing
  - Similar to voice (tolerant of some loss, intolerant of delay) but higher bit rates needed
- Video streaming
  - Can be buffered to deal with delay but very high bit rates
  - Ultra-High Definition Television can be encoded at up to 91 Mbps
  - Netflix 4k is encoded at 15.4 Mbps but Netflix recommend minimum 25 Mbps
- Data services such as eCommerce, online banking, web pages, emails..
  - Can tolerate delay and usually low bit rates but cannot tolerate errors

Network Characteristics

- Some networks are less reliable than others
  - Wireless for example
  - But can be made reliable at the cost of delay and delay variation
  - Protocols such as TCP include error checking and correction
- Some have much lower bit rates than others
  - Internet of Things technologies such as LoRa, NB-IoT, LTE-M have much lower bit rates than WiFi, LTE and Ethernet for example
- Some have less coverage than others
  - WiFi about 100 metres while LTE (4G cellular) has up to 30 kms
- Some are much more expensive than others
  - Satellite much more expensive than WiFi
- Some are more readily available than others
  - Satellite available most places while cellular much less available outside population centres

Appropriate Network Technologies

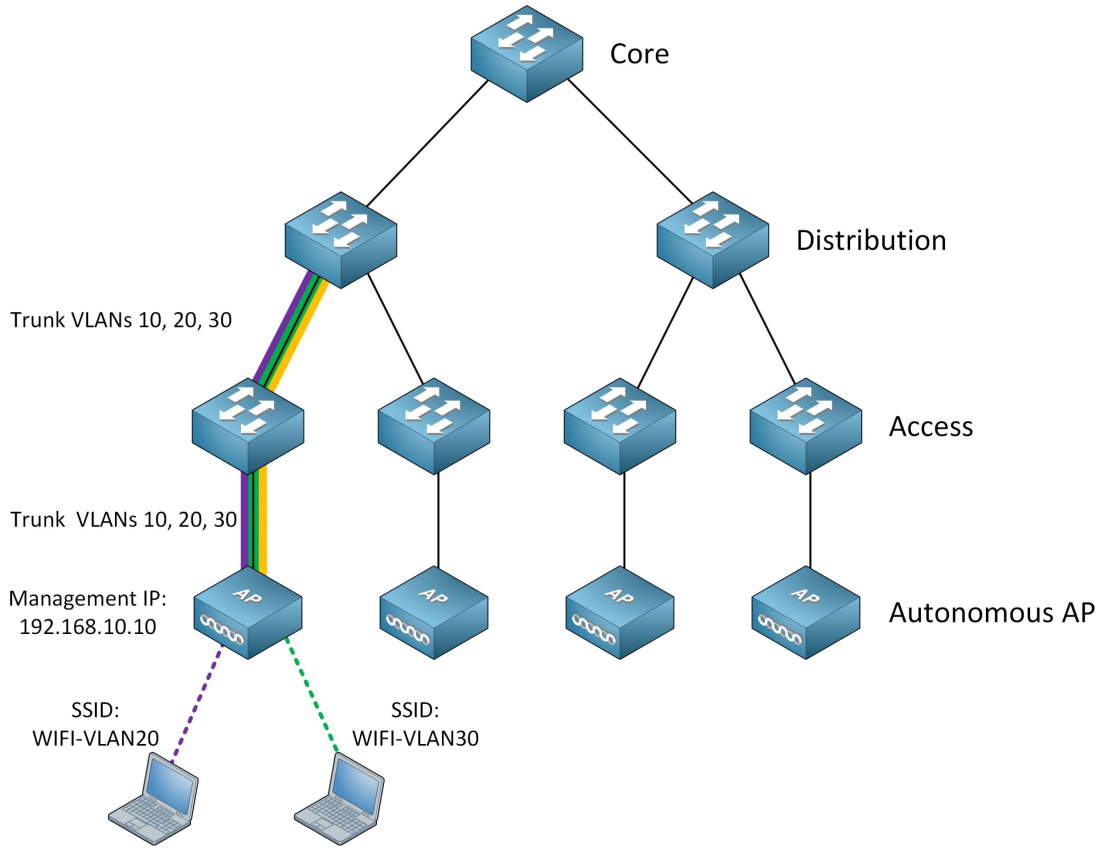
- The appropriate network technology for a particular client or clients will depend on many things
  - Cost, number of users, distribution of users, available infrastructure, purpose of the network…
- It may be appropriate to implement a mix of technologies
  - Fixed wireless or ADSL for distances of up to two or three km and a satellite uplink for example
- There will usually be many possible mixes of technologies for any particular situation….

Communications Technologies

- Many ways to classify network technologies
  - Topological location: Core / Distribution / Access
  - Medium: Wireless / Copper / Fibre
  - Ownership: Public / Corporate / Home
  - Coverage: PAN / LAN / MAN / WAN
  - Capacity: 1000Ethernet / Cable Modem / ADSL2
  - Purpose: IoT, Voice, Data

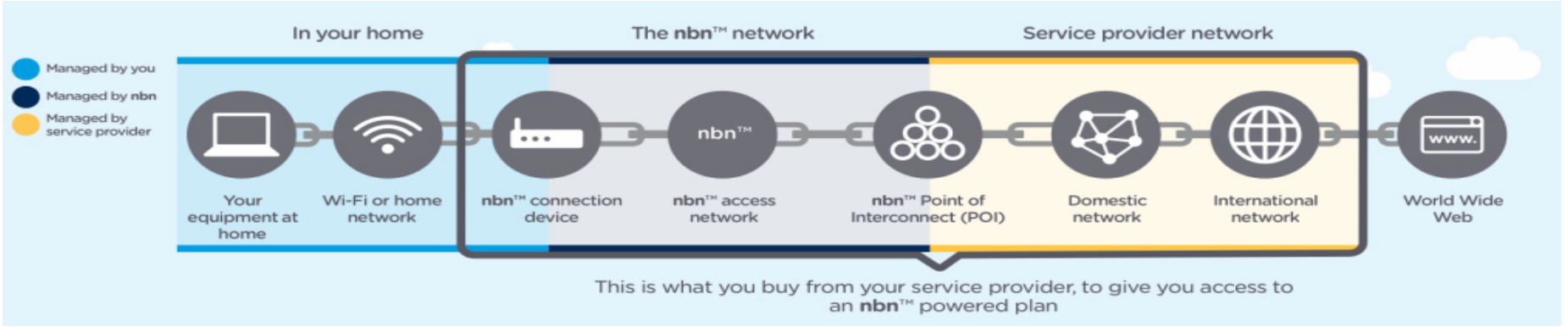
Access and Core Networks

- Access networks concerned with ‘last mile’ problem
  - Provide connectivity to a users
- Core networks shift large volumes of traffic between different nodes in the network which may be located vast distances apart
- Many different Access networks but only a few Core networks
  - appropriate Access network depends on many factors
    - population density of users to be connected
    - the distance to the nearest core network node (such as a telephone exchange or wireless base station)
    - existing installed network infrastructure
    - purpose of network



Core networks

- Sometimes “backhaul” network
- A few technologies
  - Satellite
  - Optic fiber
  - Microwave
- Uses SDH or Gigabit Ethernet along with ATM, TCP/IP…
- Used to connect different sites together
  - Exchanges, campuses, transmission towers…



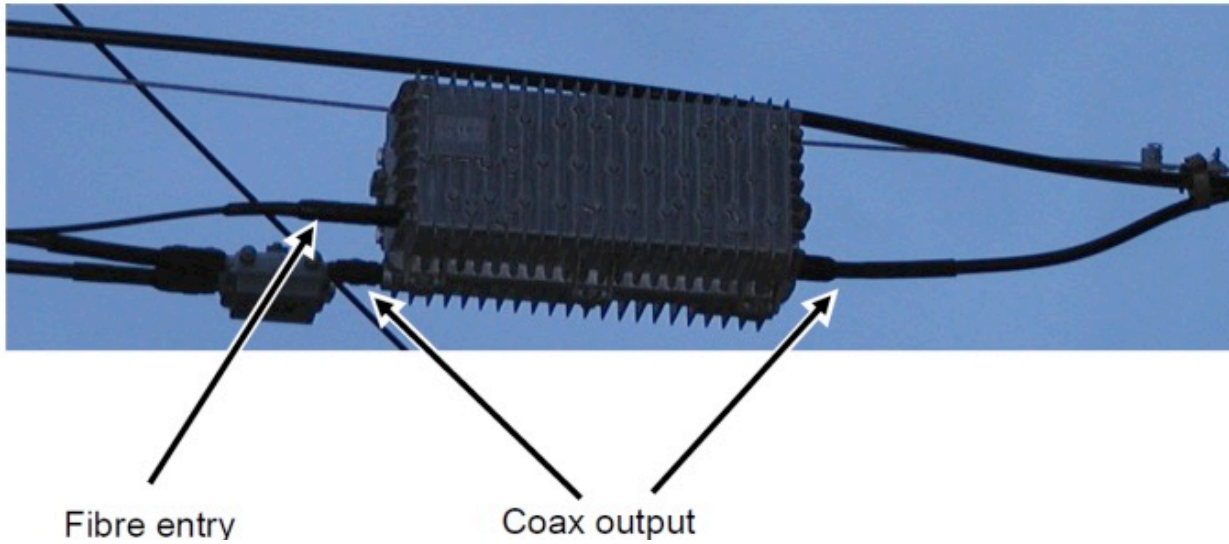
Access Networks

- Will review each of the following
  - Ethernet
  - Cable Modem
  - ADSL
  - Wireless LAN
  - LTE
  - 5G NR
  - GPON
  - FTTP
  - Fixed Wireless
  - Satellite
  - Internet of Things wireless networks

Ethernet

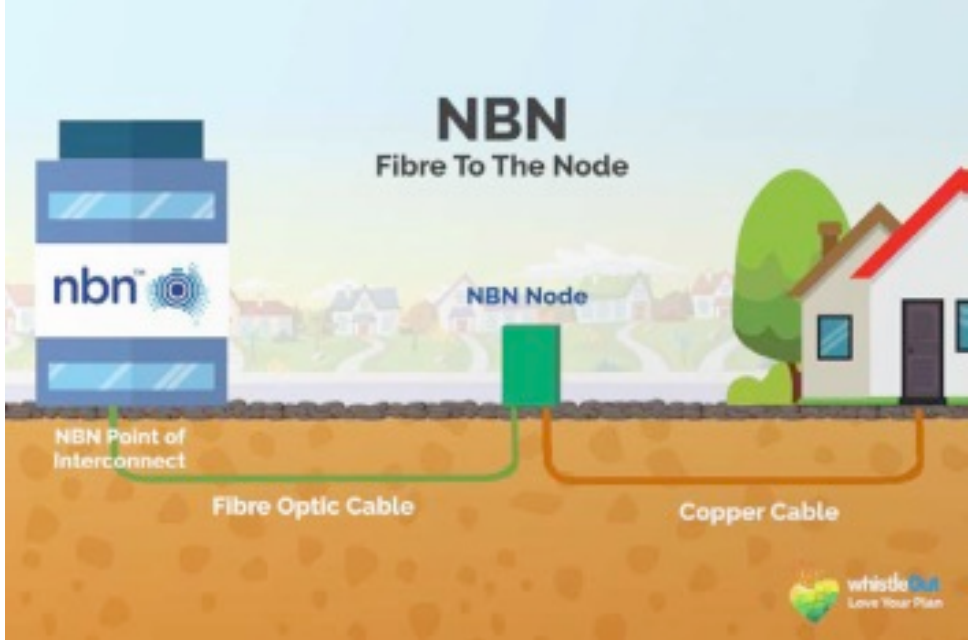
- Frame-based Local Area Network (LAN) technology
- Defines frame formats, Medium Access Controls
  - Mostly standardised by IEEE 802.3
- Short distances but can be linked to form large-ish networks
- Widely used Access network

Cable Modem networks



- Cable Television based
  - Use CATV infrastructure for data networking
  - Hybrid Fiber Coaxial Network
- Implemented as an inverted tree
  - root of the tree referred to as the ‘head-end’
- An analog medium
  - 6 MHz broadcast channels
  - data from multiple users is modulated onto multiple 6MHz channels
- Usually an asymmetric network
  - high bit rate forward link
  - low in reverse link

ADSL and VDSL



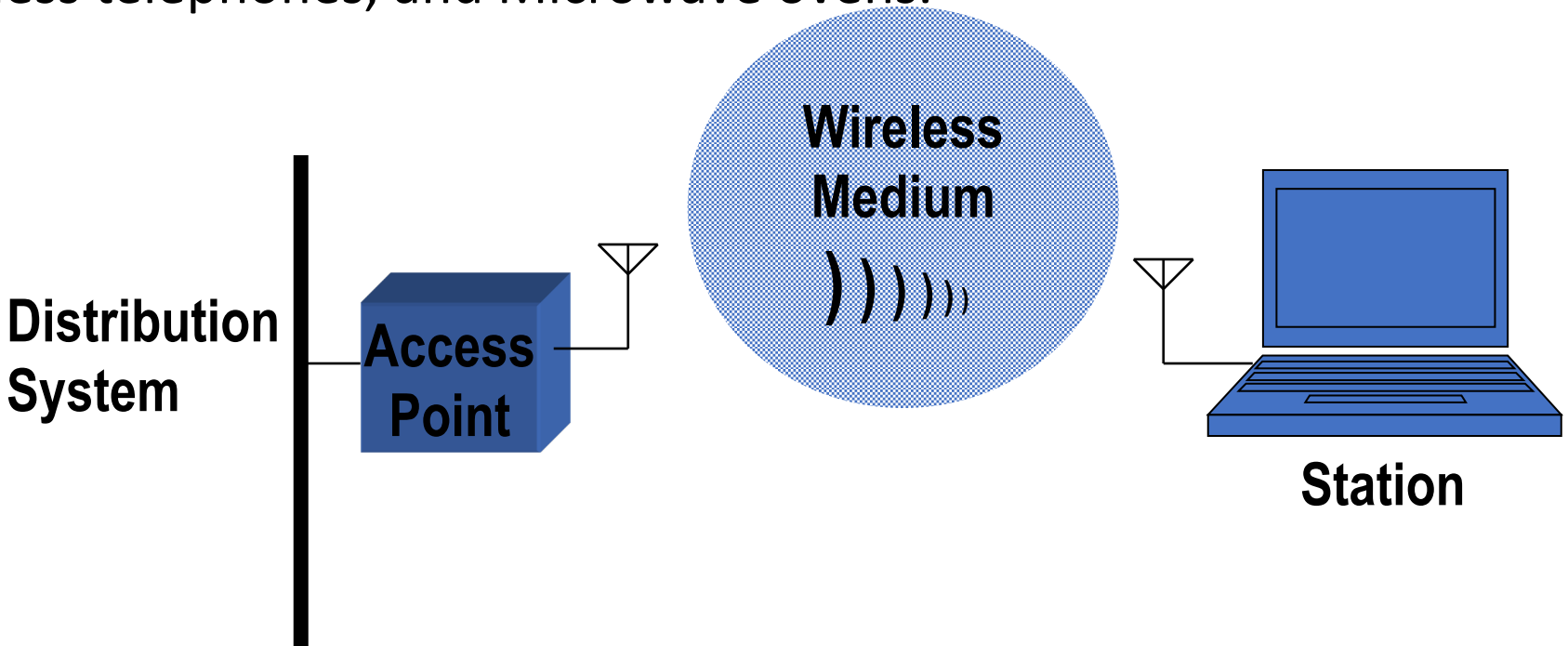
- Digital Subscriber Line technologies leverage existing telephone networks to provide broadband access.
- First major one was ISDN
- The most important of these technologies now are xDSL family
  - xDSL is a family of subscriber link technologies including Asymmetric DSL, High-speed DSL (HDSL), Very high speed DSL (VDSL) and variations of each
  - xDSL uses the existing PSTN twisted pair copper loop otherwise used for standard telephony.
  - Operates in parallel with the existing telephone service but independently and without affecting it.
    - Uses different frequencies to that of standard telephony

Wireless LANs

- Wireless LANs protocols defined by the IEEE 802.11 work group for the ISM band
- All 802.11 networks use a common MAC layer, but vary in the physical layer details.
  - Most commonly used is the 802.11g and 802.11n standard operating in the 2.4 GHz Industrial, Scientific and Medical band (ISM).
  - 802.11n takes advantage of developments in transmitter receiver design (MIMO)
  - 802.11ac up to 7 Gbps (depending on configuration)

Wireless LANs

- Wireless LANs operate in the ISM band
  - An area of spectrum that is minimally regulated in which anyone may operate radio equipment subject to a minimal set of restraints, primarily on power levels
  - 802.11 is subject to interference from Bluetooth communications devices, some cordless telephones, and Microwave ovens.



Long Term Evolution (LTE)

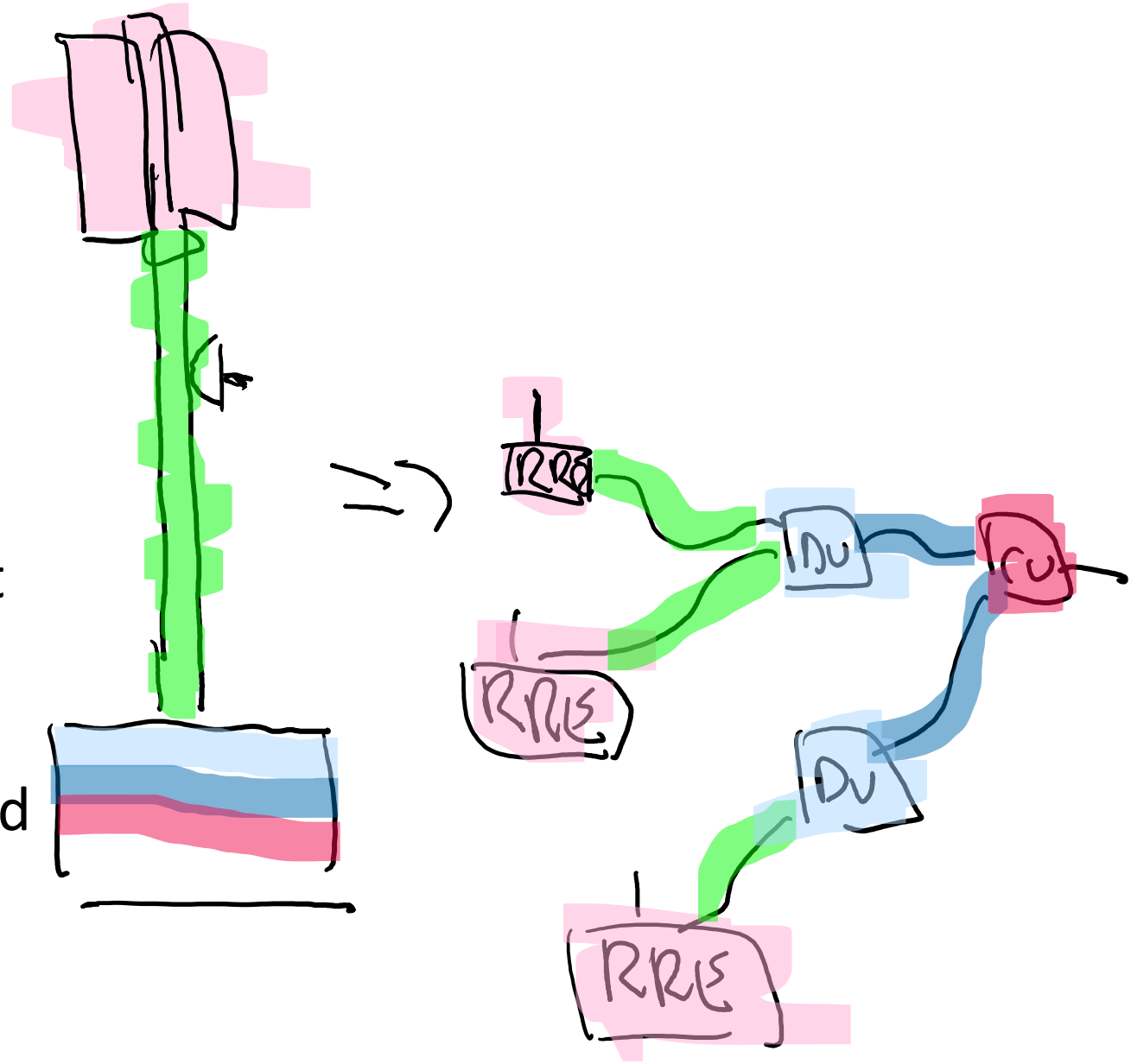
- Wireless cellular network
- Sometimes “4G”
- From the fourth generation cellular onwards the core and radio network were separated with the intention of allowing them to develop separately
  - LTE is the radio access network and Evolved Packet System (EPS) is the network core
- LTE and EPS build on successful history of security of other cellular networks
- Flexible security architecture allowing for implementation of developments in cryptography

5G NR

- "Fifth Generation New Radio"
  - Fifth generation of cellular
- Three broad areas of activity defined by use cases
  - eMBB Enhanced Mobile Broadband
  - mMTC Massive Machine Type Communication
  - URLLC Ultra Reliable and Low Latency Communications
- These define what the network will do, not how they will do it
- But we can say a few things about implementation
  - eMBB is a straightforward evolution of LTE
  - mMTC will adapt existing cellular network technologies intended for IoT mainly NB-IoT and LTE-M
  - URLLC is the interesting one

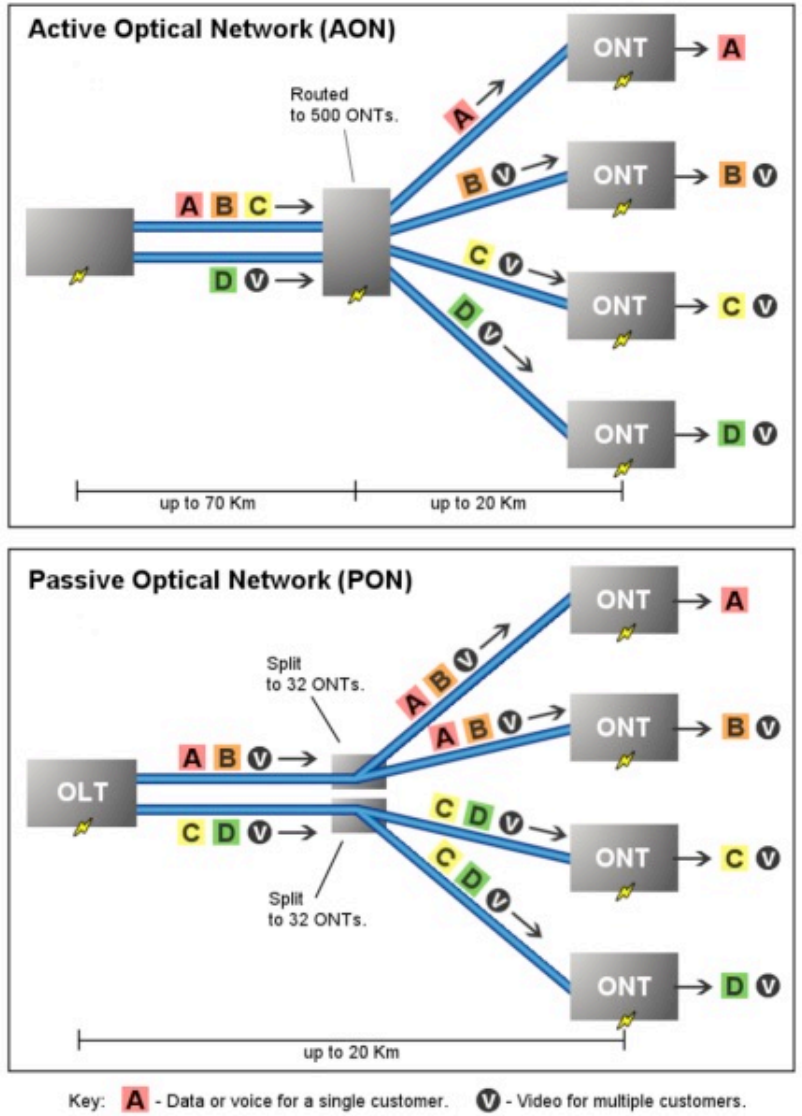
5G NR

- Most significant change with 5G NR is that the base station is distributed
- Introduces a Fronthaul and Midhaul network
- Front haul connects low cost transmitters (Remote Radio Equipment or RRE) and receivers to a “Distributed Unit (DU)”
- Mid haul connects a DU to a Centralised Unit (CU)
- Makes 5G NR look like a carrier grade WiFi network



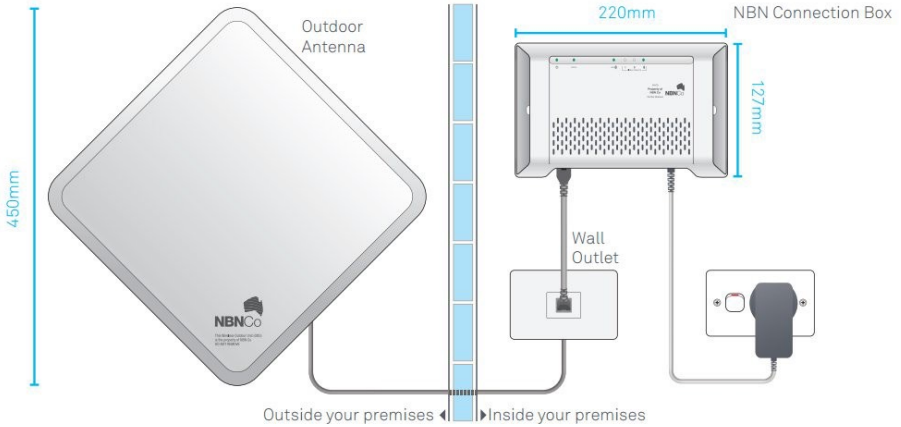
Gigabit Passive Optical Network (GPON)

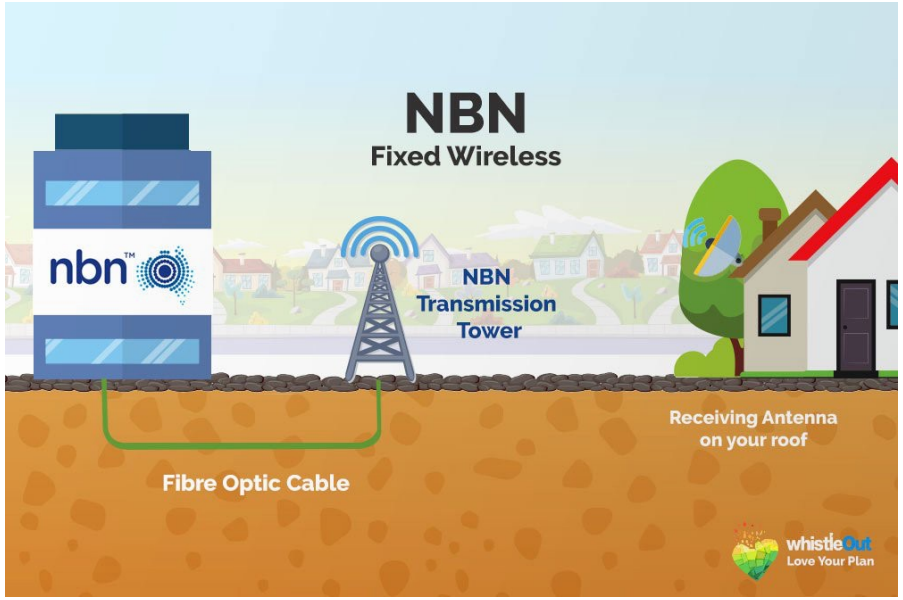
- Enables a single fibre to serve multiple users
- Unpowered (passive) Fibre Optic Splitters transmit the optic signal to multiple fibres, each terminating at a single residence
- Each end user receives the full signal but decodes only their component
- Much simpler than Active Optical Networking



Fixed Wireless

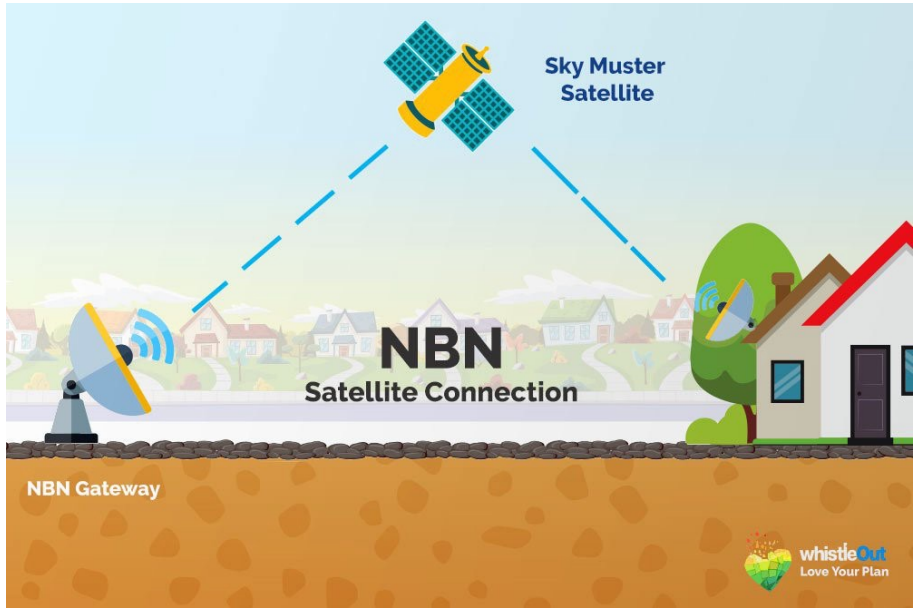
- Used in rural and remote areas where other options not feasible
- Uses same technology as cellular 4G but with fixed antennae
  - Technology is usually referred to as LTE (Long Term Evolution)
- Operates in 2.3 GHz range. Cf regular 4G usually 700 MHz and 1800 MHz
- Bit rates up to 50 Mbps downstream and 20 Mbps upstream





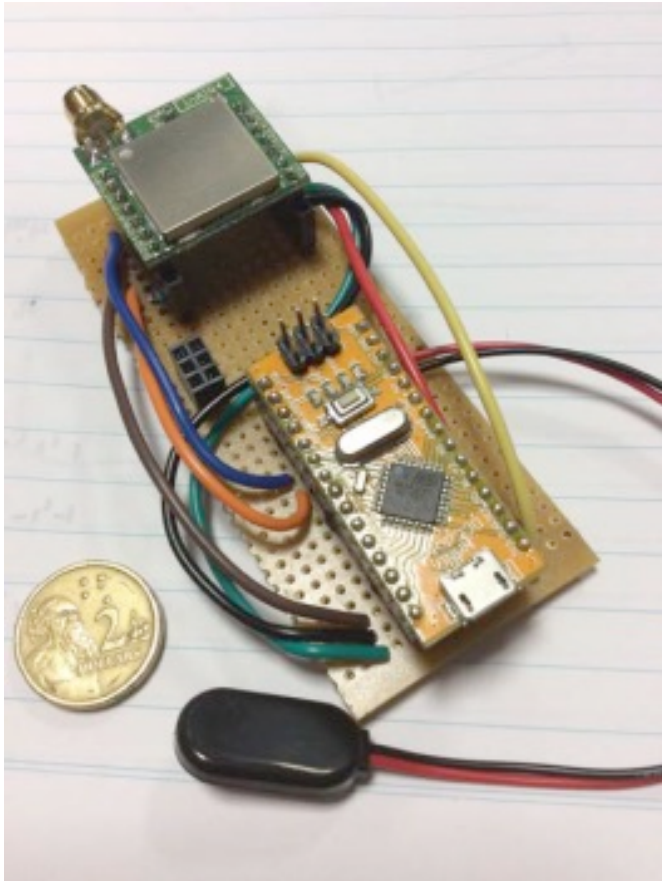
Satellite

- Intended for regional and remote areas
- Geosynchronous Earth Orbit adds delay of 240 ms per hop (up and down)
- Service maybe 3% of the population
- Bit rates up to 25 Mbps downstream and 5 Mbps upstream
- Operates in Ka Band 26.5–40 GHz
- Emerging low cost “CubeSat” technology
- Star Link said to be available with about 100 Mbps. Expensive though
- NBN Sky Muster a bit more affordable but slower



Many emerging Internet of Things network technologies

- General
  - LoraWAN, Bluetooth Low Energy, Bluetooth Mesh, 6LoWPAN
- Personal
  - ANT and ANT+
- Home automation
  - ZigBee integrated with IP
- Cellular
  - SigFox, NB-IoT, LTE- M (LTE for Machines)
- Industrial Internet of Things
  - PROFINET, TSN, UA, OPC



Conclusion

- Many network technologies
- Many tradeoffs need to be considered when deciding the most appropriate network or networks for a particular client
- Will usually not just be one network technology