MONASH University

Information Technology

FIT5183: Mobile and Distributed Computing Systems (MDCS)

Lecture 8B
Enabling Wireless Networks and Technologies

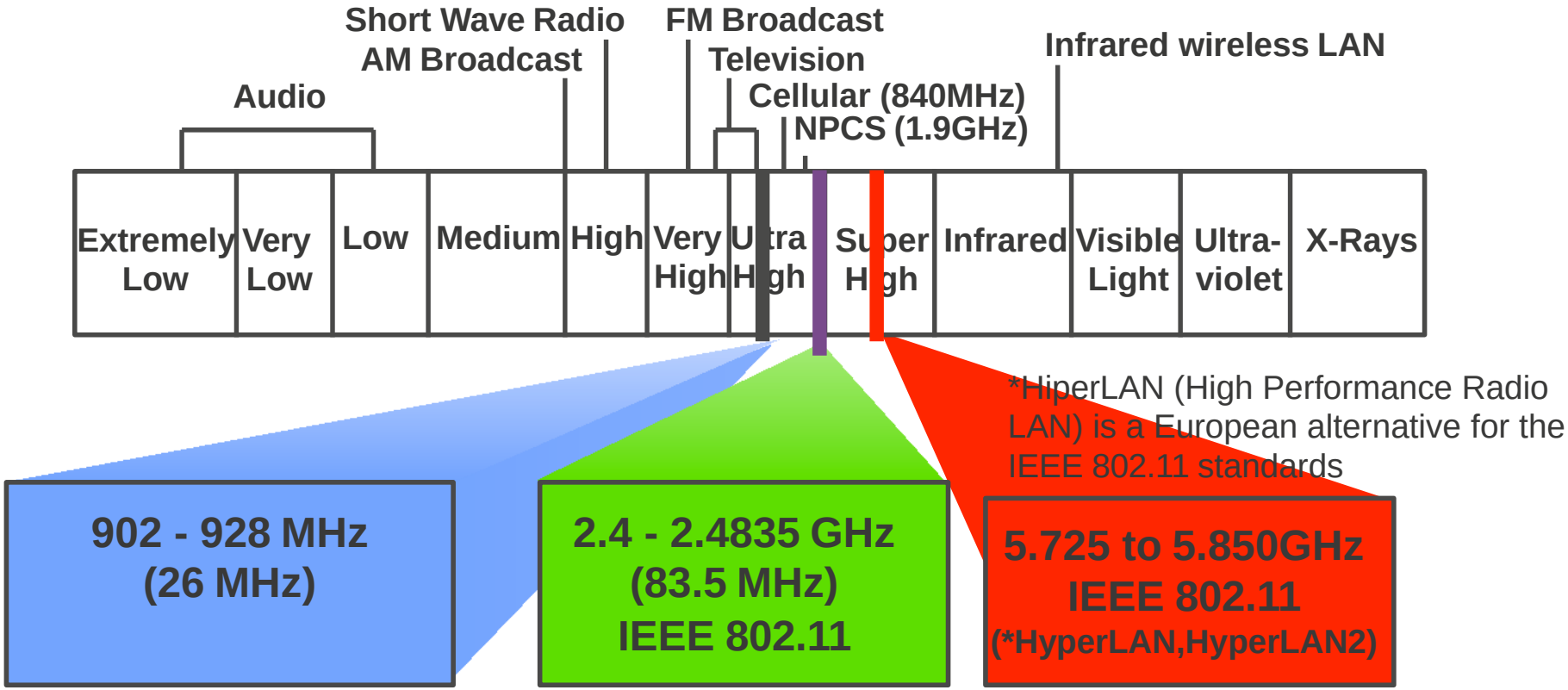
First.. Let's take stock of the Assignments

- Assignment 1
  - They have been marked – please check that you can see grades and my detailed feedback comments to each group
  - Good points and not so good points in the submitted reports
  - Technical points: e.g.: PK/FK, ER Relations, Triggers and JSON
- Assignment 2
  - Expectations for the Code Development, Reporting and Demos
  - Timeframe for completion over Semester Break
- Assignment 3
  - Prepare your power point presentation based on the works you have done in Phase I & II assignments
  - All students in each group must do individual presentation which are integral parts of the group final presentation. Peer assessment of presentation will be implementated.

Overview

- Unlicensed ISM band and U-NII unlicensed bands
- Brief look at IEEE 802.11 standards and WiFi
- WiMax and LTE
- Bluetooth
- ZigBee
- Radio Frequency ID (RFID)
- Near Field Communication (NFC)

The Industrial, Scientific and Medical (ISM) Bands

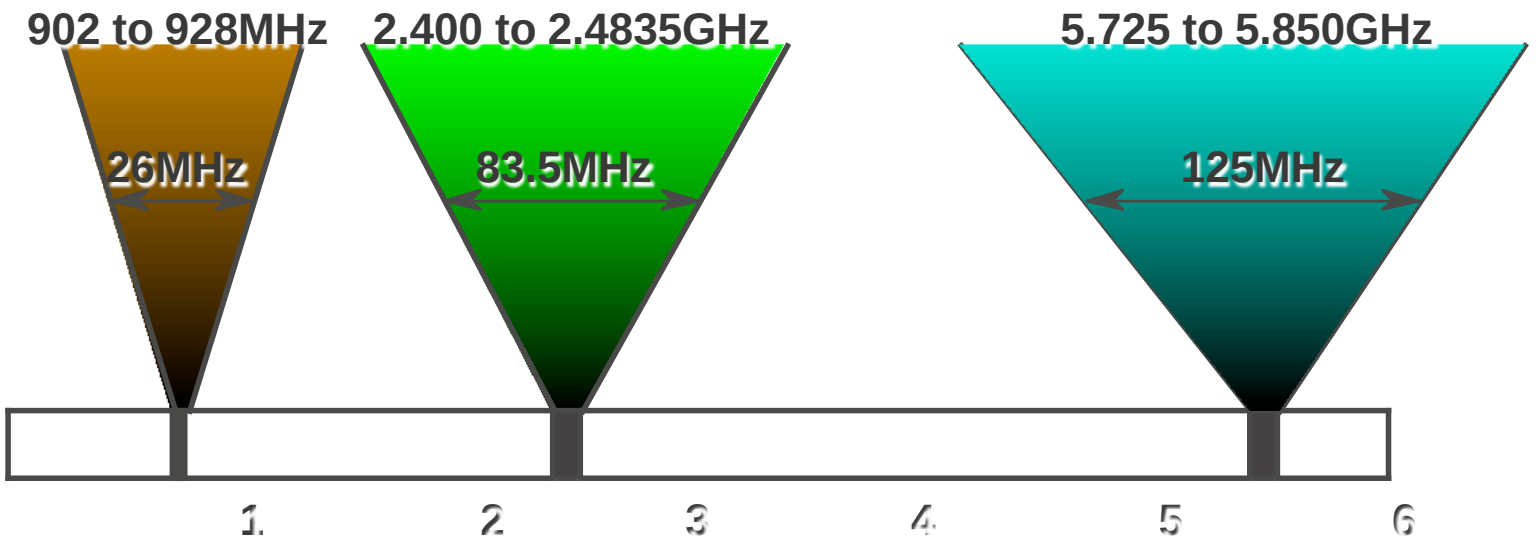


- **The Industrial, Scientific and Medical (ISM)** include the radio bands internationally reserved and can be used without a license

ISM band

- The ISM bands were introduced in 1947 by ITU (The International Telecommunication Union)
- The ISM bands were initially used for machines that emitted radio frequencies for industrial, scientific and medical purposes (not for radio communications)
  - E.g. RF welders, industrial heaters , microwave ovens, and medical diathermy machines
- In 1985, the FCC (Federal Communications Commission) allowed the ISM bands to be used for Wireless LAN
- Many other countries followed similar regulation but some countries apply a different regulation

ISM Bands



- FREQUENCY (GHz)902-928 MHz: cordless phones (1993), amateur radio
- 2.4-2.4835 GHz: WiFi (802.11b/g), Bluetooth, microwave ovens, baby monitors, cordless phones (1998)
- Very crowded and saturated due to a large number of devices operating in this band
- 5 GHz: cordless phones (2003), WiFi – 802.11a/n

U-NII

- FCC introduced new UNII bands in the 5 GHz range to provide high data rate communication
  - UNII (**Unlicensed National Information Infrastructure**)

- Each band is 100MHz wide and divided into channels

UNII-1

Freq. range: 5.15-5.25 GHz

UNII-2

Freq. range: 5.25-5.35 GHz

UNII-2 Extended

Freq. range: 5.47 to 5.725 GHz

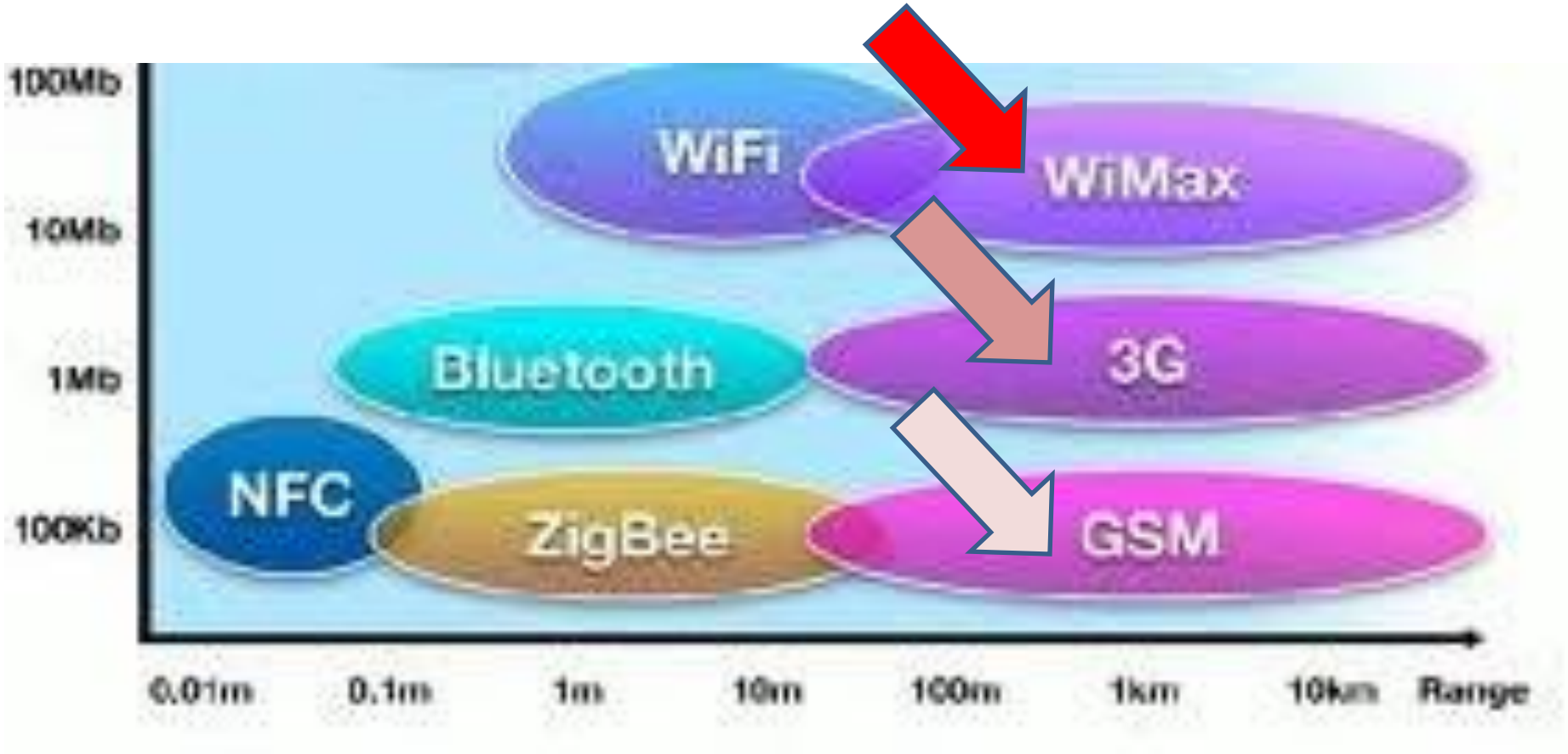
UNII-3

Freq. range: 5.725-5.825 GHz

Radio Frequency Ranges

- The **frequency** range directly affects the **data rates** to be transmitted
- The higher the **frequency** range (called bandwidth), the greater the **capacity** of the wireless circuit, allowing the signal to carry more data and faster
- Higher **frequencies** suffer **attenuation** more quickly than lower frequencies
- The higher the **frequency** of a wireless signal, the shorter its **range.** Thus the 2.4 GHz range signals can travel farther compared to the 5 GHz range transmission

Wireless Technology
Bit-rates versus Range Graph: *2G, 3G, ...*

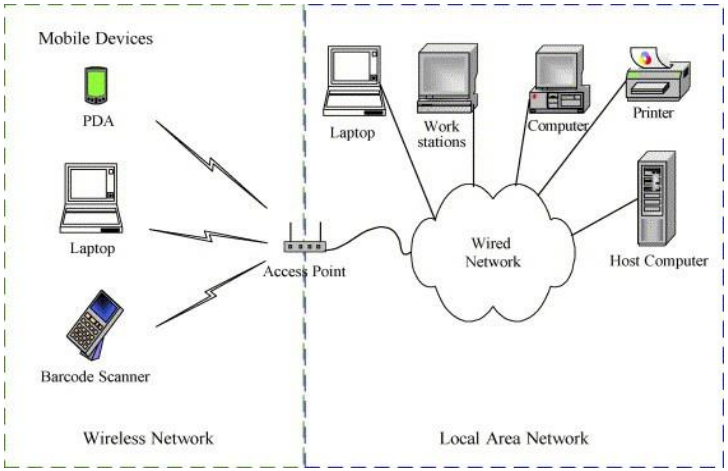


WLAN: Wireless LAN Extension

- Early wireless LAN products introduced in the late 1980s

  Motivations:

  - To save costs of cabling and easing the problems with relocation and modification to the network
  - In buildings with large open areas like manufacturing plants
  - Historical/old building with no cabling support
  - Mobility
- In most of the cases, wireless LAN linked into a wired network

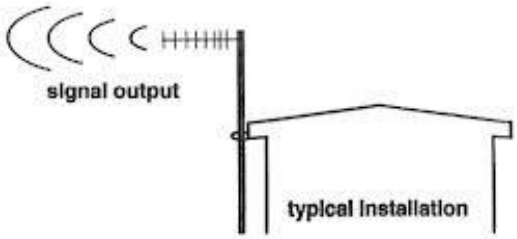


Wireless LAN Components

1. Communication medium
   - a set of radio frequencies replacing cables for data transmission
2. A wireless network adapter/card (radio card)
3. An antenna (usually internal)
4. Radio Transceiver that sends and receives radio signals through a short range
5. A wireless Access Point (AP)
   - It enables connection between mobile devices/laptops
   - It can act also as a Repeater and Router

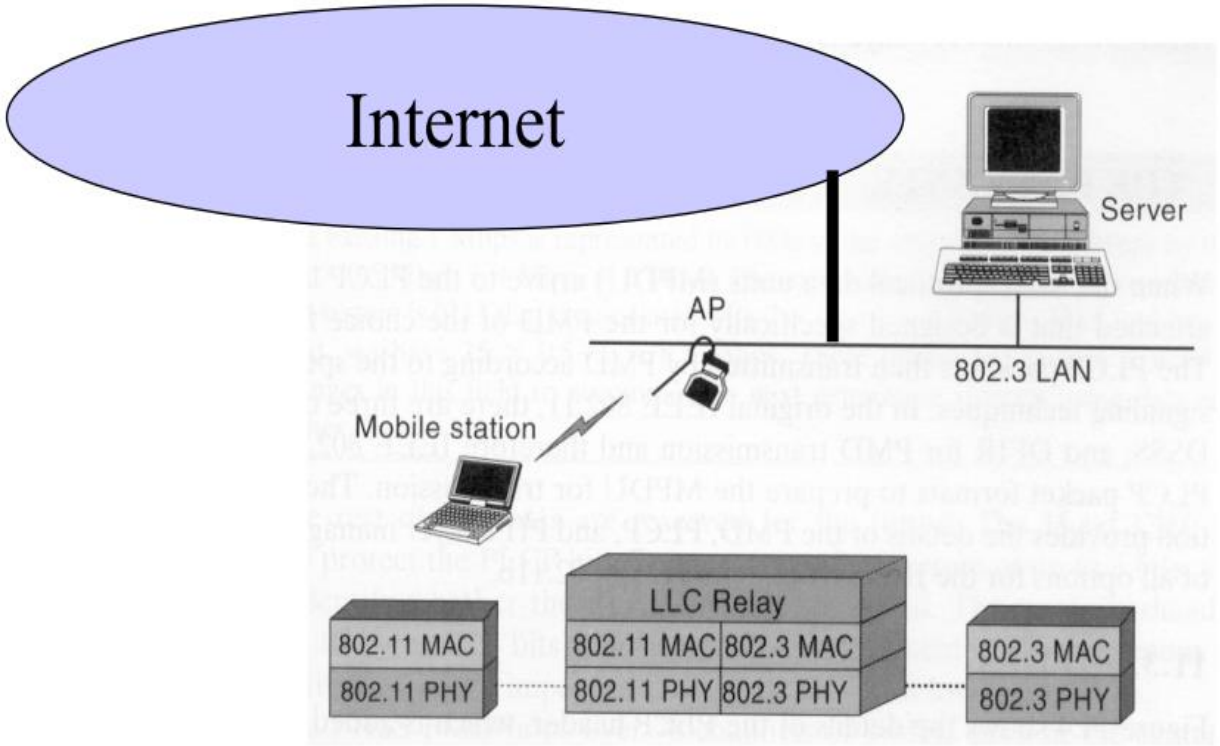
Antennas

- Two types
  - **Omnidirectional antenna** transmits in all directions simultaneously
  - **Directional antenna** transmits only on one direction
- Wireless Access Points (APs) have usually omnidirectional antennas
- To avoid transmission interference between close APs, usually each AP transmits on a different channel



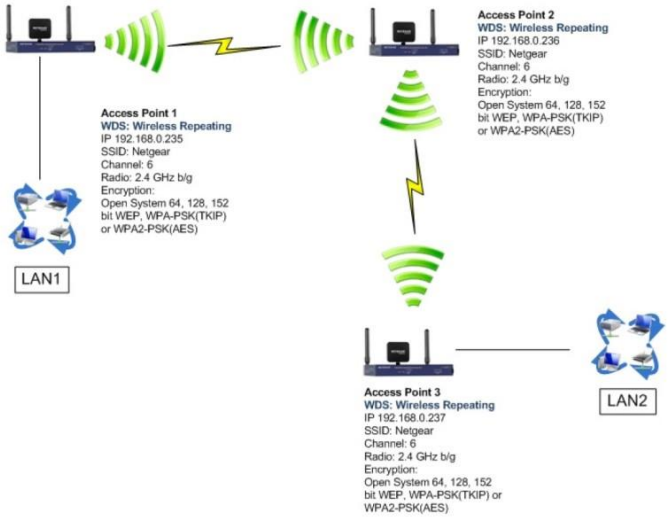
Wireless Access Point (WAP)

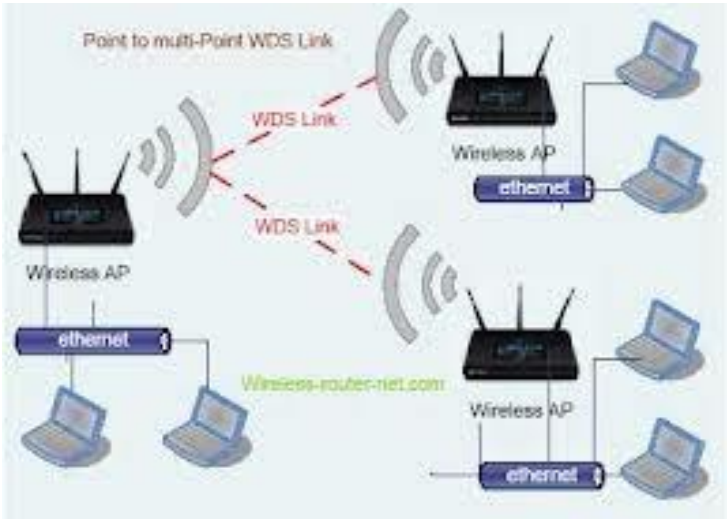
- A wireless AP can be connected to a wired LAN or backbone
- Wireless APs support Wireless LAN's infrastructure mode



Wireless Distribution System (WDS)

- WDS refers to two or more APs connecting wirelessly
- WDS offers two modes:
  - **Wireless Bridging** in which the APs communicate with each other and with other the wireless clients (as routers)
  - **Wireless Repeating** in which access points communicate only with each other (as repeaters), extending the wireless reach of an existing AP





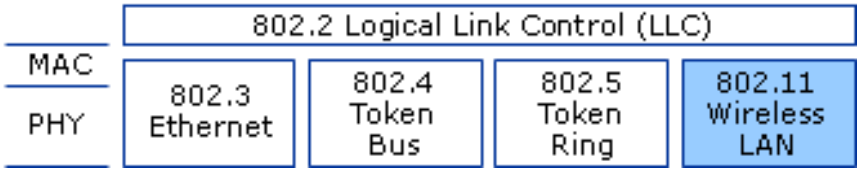
The IEEE 802 Standards and 802.11 – WiFi

(Overview only)

Wireless Technology
Bit-rates versus Range Graph: *WLAN/WiFi*

IEEE 802

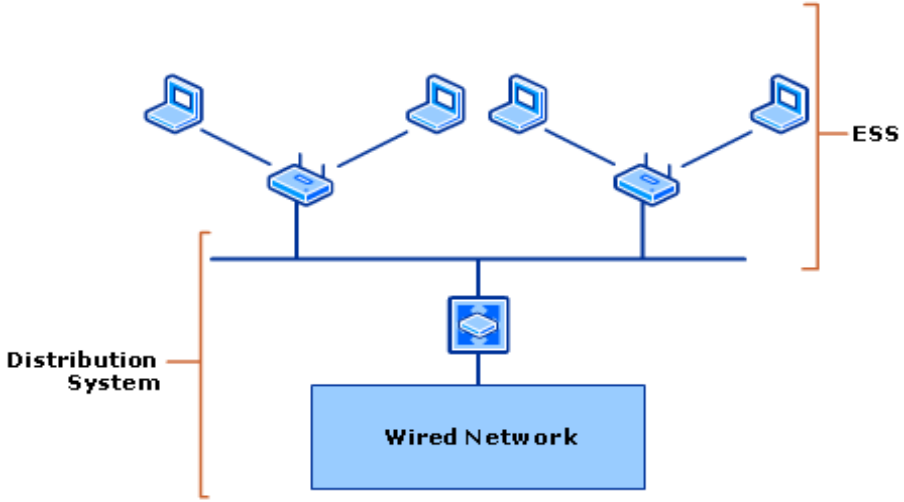
- IEEE 802 is responsible for the general administration of the LAN and MAN standard activities
- Defines 2 layers for the Data Link layer:
  - 802.2 Logical Link Control (LLC)
  - Media Access Control (MAC)
- IEEE 802.11 became a standard in July 1997
- IEEE 802.11 is **a set of standards** for implementing **wireless local area network (WLAN)** computer communication

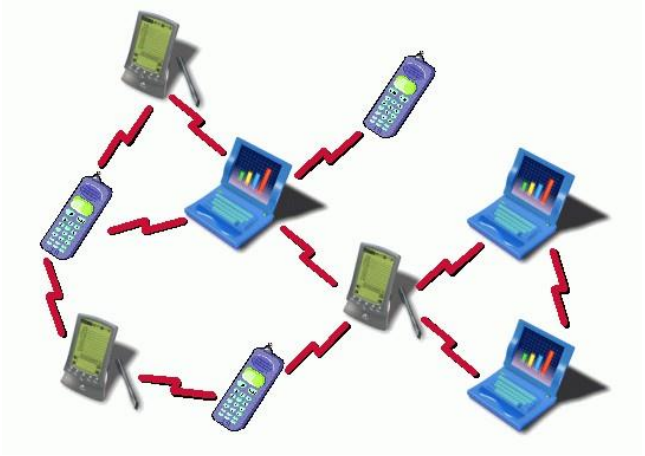


802.11 Operating Modes

- **Infrastructure Network**: wireless clients communicate with each other through a wireless AP
  - Includes one or more Access Points

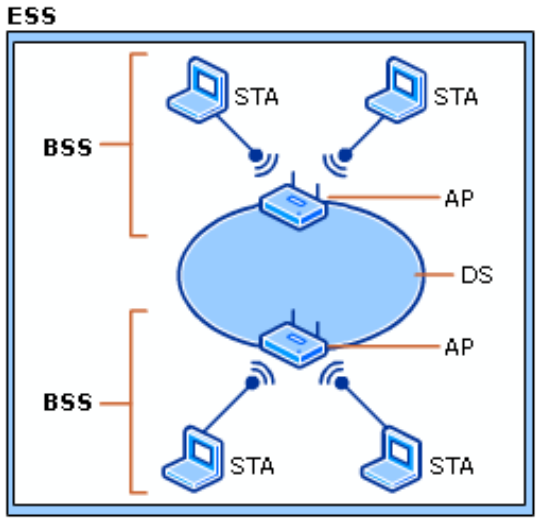
- **Ad Hoc Network**: decentralized type and peer to peer networks set up temporarily
  - E.g. during emergency situations like natural disasters or in a conference room between employees

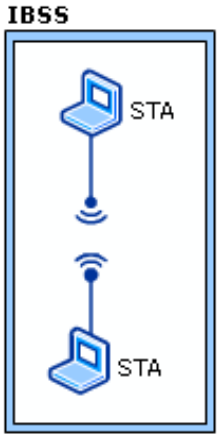




802.11 Architecture

- **Station (STA):** A laptop or mobile device with a wireless network interface
- **Access Point (AP):** acts as a relay point/bridge between STAs and the backbone
- **Basic Service Set (BSS):** consists of a single wireless AP supporting one or more STAs
  - In BSS client stations do not communicate directly with each other
- **Distribution System (DS):** provides distribution
  - services to allow the roaming of STAs between BSSs
- **Extended Service Set (ESS):** A set of two or more wireless APs connected to the same wired network
- **Independent basic service set (IBSS)**: stand- alone BSS
  - No AP involved and no connection to other BSSs





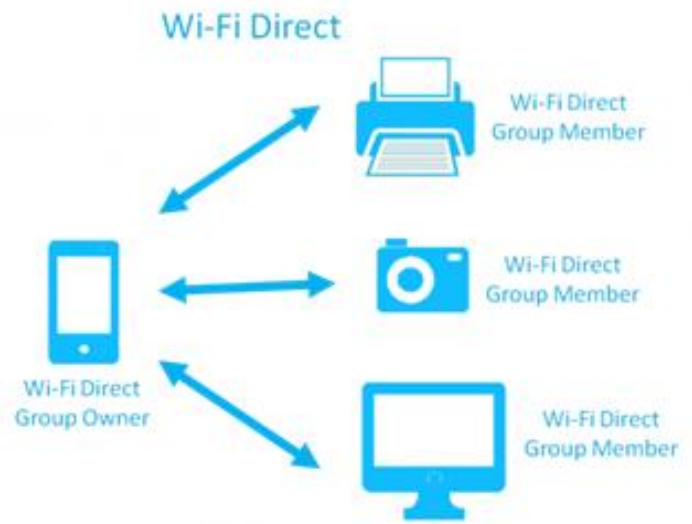
Wi-Fi

- Wi-Fi a trademark by WiFi Alliance
- Wi-Fi stands for Wireless Fidelity
- The Wi-Fi Alliance defines Wi-Fi as any "wireless local area network (WLAN) products that are based on the Institute of Electrical and Electronics Engineers' **(IEEE) 802.11** standards".
- WiFi Alliance is a trade association that promotes and certifies products conforming to certain standards of interoperability

Wi-Fi Direct

- A specification and certification mark by Wi-Fi Alliance
- To enable Wi-Fi devices to connect directly in a simple and convenient way without an access point

http://www.wi-fi.org/discover-wi-fi/wi-fi-direct



https://developer.tizen.org/development/training/native-application/creating-applications-connectivity-and-network/p2p-connections-wi-fi-direct%E2%84%A2#TDLS

802.11 Standards (in brief)

IEEE 802.11a (1999)

- Operates in the 5 GHz band (5.3 GHz and 5.8 GHz)
- Due to higher frequency, more absorption of signals by walls and other physical obstructions
- Uses OFDM (Orthogonal Frequency Division Multiplexing) modulation technique

IEEE 802.11b (1999)

- Operates in the 2.4 GHz band
- Up to 11 Mbps data rate
- High Rate HR-DSSS based on DSSS using *complementary code keying*
- Compared to 802.11a, it suffers less attenuation and the signal has greater range

802.11 Standards (in brief, cont'd)

IEEE 802.11g (2003)

- Operates in the 2.4 GHz band, like the 802.11b standard
- Uses ERP-OFDM based on OFDM (Extended Rate Physical layer)
- Increased data rate (54 Mbps) compared to 802.11b

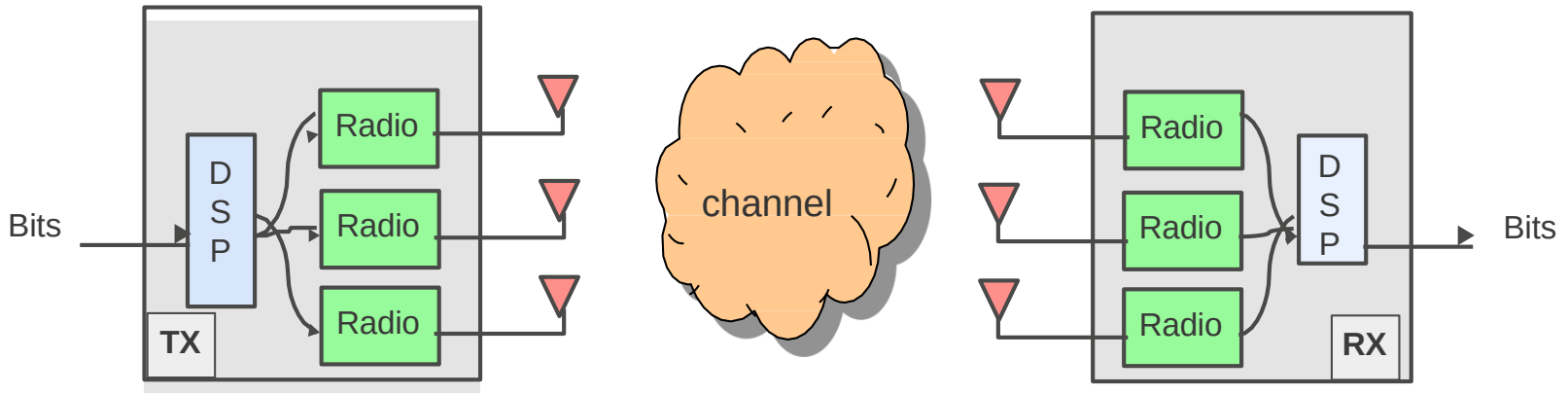
IEEE 802.11n (2009)

- Uses both 2.4 GHz and 5 GHz bands
  - Higher data rates (150-600 Mbps)
- Uses OFDM but using **MIMO** and **CB**

  - **MIMO (multiple input, multiple output antennas)** Capable of sending or receiving multiple streams of data
  - **CB (Channel Bonding)** Doubling the transmission rate by combining two 20 MHz channels to create a 40-MHz channel using OFDM

MIMO (Multiple Input Multiple Output)

- MIMO is a wireless technology using multiple antennas
- Transmit and receive more data simultaneously
- An example when 3 MIMO antennas used:
  - If 802.11n OFDM has a maximum data rate of 65 Mbps, multiplying that by the 3 MIMO antenna channels raises the data rate to 195 Mbps



DSP: Digital Signal Processors

http://www.intel.com/support/wireless/sb/cs-025345.htm

802.11 Standards (in brief, cont'd)

IEEE 802.11ac (2013)

- The 5 GHz band
- Wider channels up to 80 MHz (Wave 1) and 160 MHz (Wave 2)
- Data rates (433 Mbps to 7Gbps)
- Uses OFDM and MU-MIMO (Multi-User MIMO) Allows transmitting multiple streams to multiple clients simultaneously

IEEE 802.11 ad

- WiGig – ultra fast, short range technology in the 60Mhz band
- Difficulty in penetrating walls

IEEE 802.11 ah

- Operates in unlicensed 900MHz range
- Can easily penetrate walls..

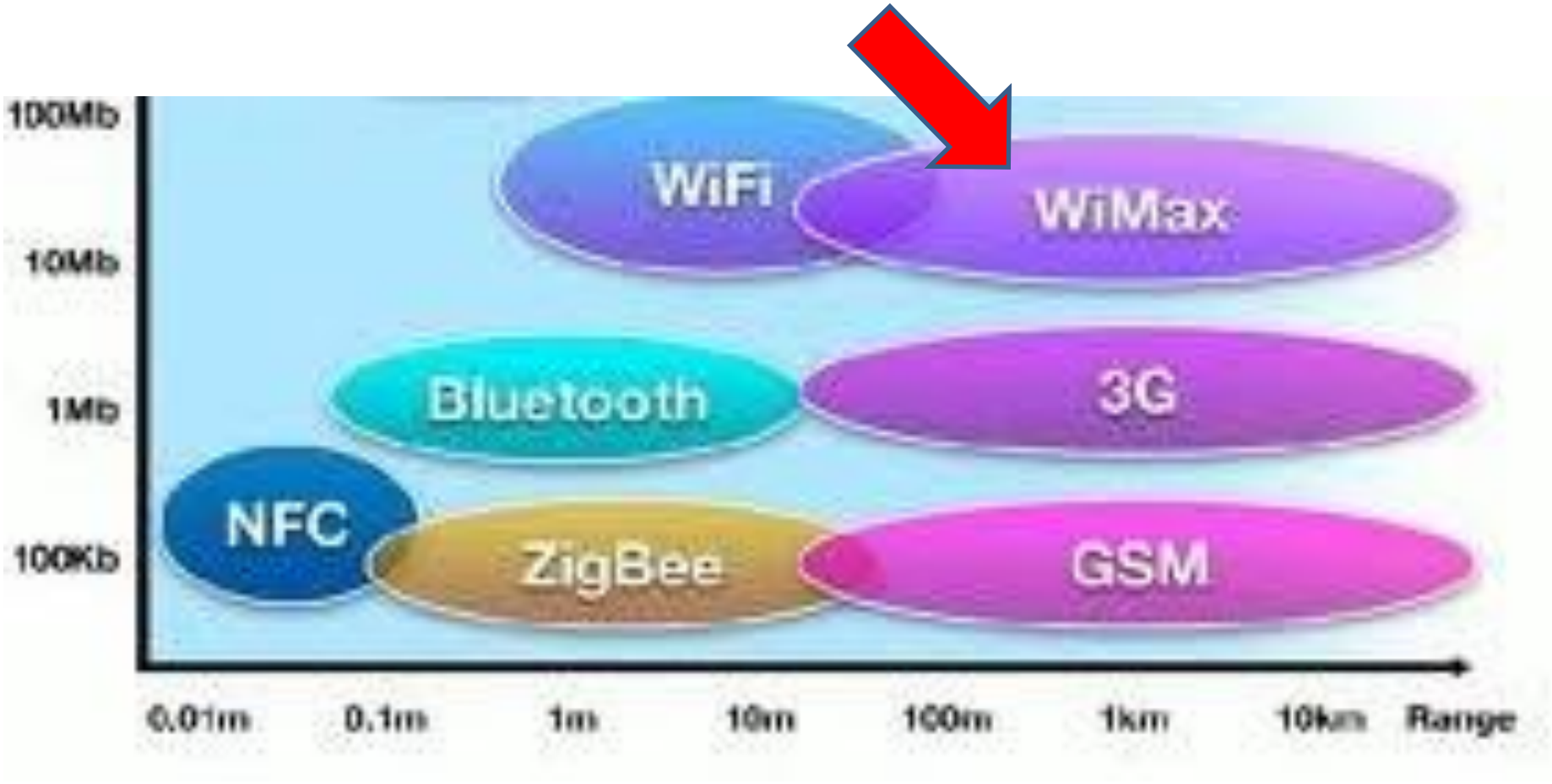
Future of WiFi:

IEEE 802.11ax

- The successor of IEEE 802.11 ac
- To increase data rates **4X**
- It will (still) use OFDMA

WiMAX (IEEE 802.16)

Wireless Technology
Bit-rates versus Range Graph: *WiMAX & LTE*



IEEE 802.16 and WiMAX

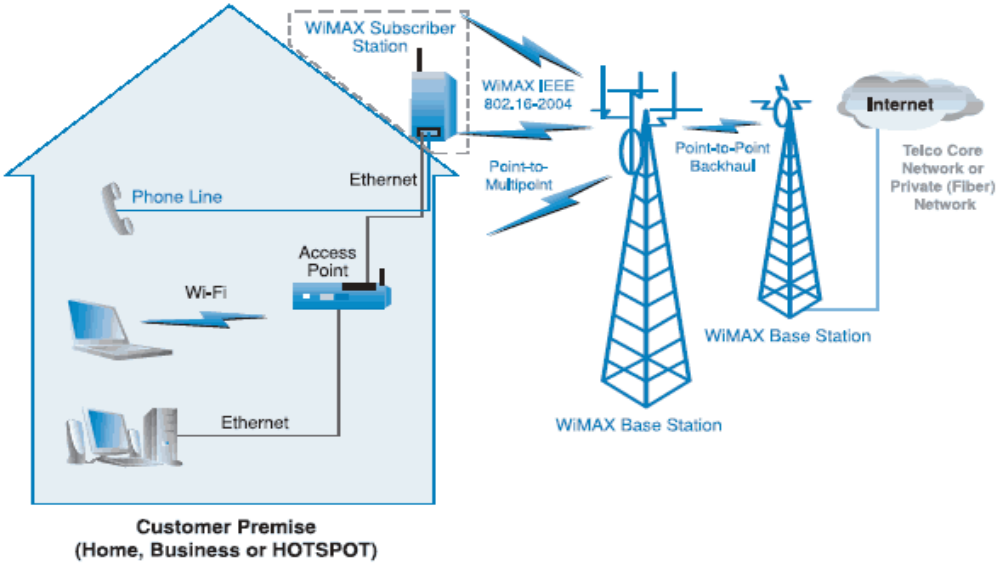
- IEEE 802.16 is **a family of standards** for WirelessMAN (Metropolitan Area Networks) for use in large, city-sized wireless networks
- The original 802.16 standard, published in December 2001
- About 25 standards (802-16-2001 to IEEE 802.16-2013) and most of them are superseded
- WiMAX (**Worldwide Interoperability for Microwave Access**)
  - Commercial name for IEEE 802.16 standards
- “WiMAX" supported by the WiMAX Forum industry alliance
- WiMAX also a competing technology used in 4G

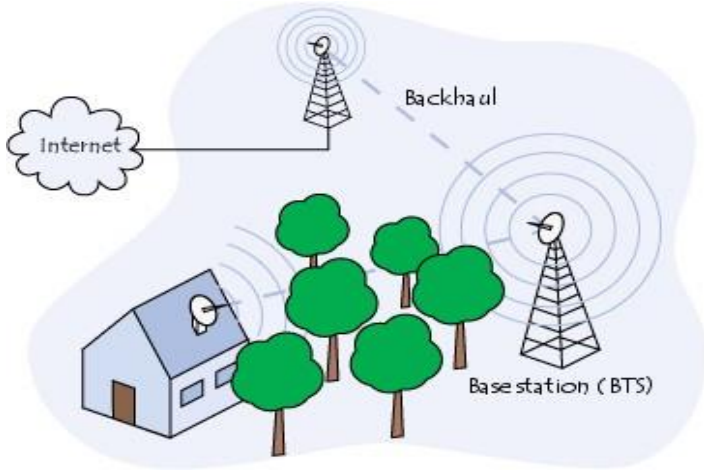
Fixed and Mobile WiMAX

- WiMAX operates the 2.3 GHz, 2.5 GHz, and 3.5 GHz frequency bands
- Based on OFDMA and OFDM
- The IEEE 802.16 standard **originally** aimed for a fixed wireless broadband access technique (Fixed WiMAX)
- **Fixed WiMAX** based on IEEE 802.16-2004
- Later mobility support was considered in **Mobile WiMAX**, a technology for wide area wireless networks

WiMAX Architecture (Fixed)

- WiMAX Base Station (**BS**): connected to a public network
- Subscriber Station (**SS**): usually serves a building
- WiMAX covers **the "last mile" area**, meaning providing high-speed Internet access to the areas which normal wired technologies do not cover





Mobile WiMAX

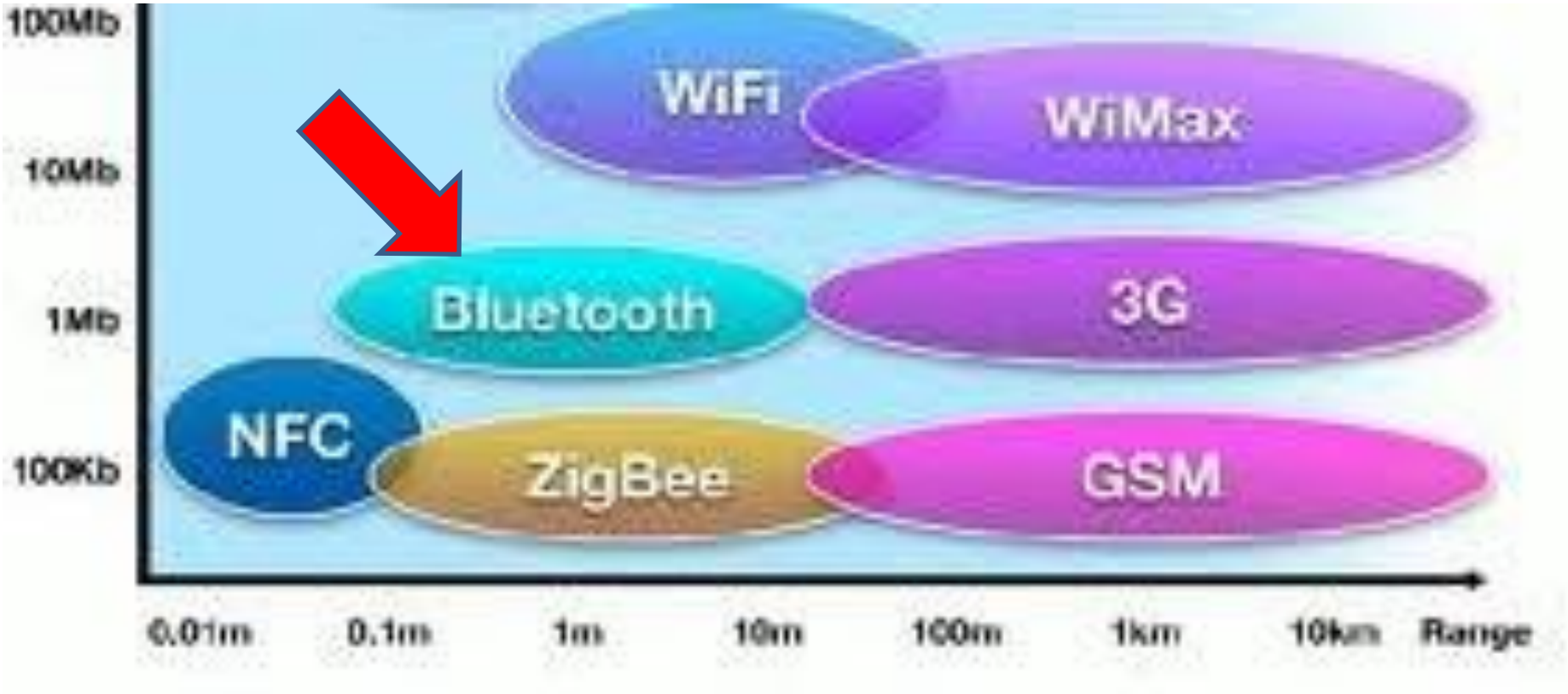
- Mobile WiMAX
  - Started with 802.16e-2005, then 802.16m-2011 (both superseded)
  - 802.16-2012: Air Interface for Broadband Wireless Access Systems

WiMAX and LTE

- WiMAX and LTE (Long-Term Evolution) are the two key 4G mobile broadband technologies
  - LTE standard by 3GPP (Third-Generation Partnership Project) and WiMAX an IEEE standard
  - Examples in Australia
    - Telstra 4G (LTE)
    - Vividwireless 4G (WiMAX), Melbourne coverage
- WiMAX was introduced to deal with the **last mile issue** and does not descend from cellular technologies
- LTE originally created for cellular networks
- **LTE "better integrated with other cellular technologies, making for smoother transitions between 3G and 4G"**

Bluetooth (IEEE 802.15.1)

Wireless Technology
Bit-rates versus Range Graph: *Bluetooth*



IEEE 802.15

- IEEE 802.15: a family of communication specifications for **Wireless Personal Area Networks** (**WPAN**s) managed by IEEE 802.15 Task Group
- Task group 1: **IEEE 802.15.1 (Bluetooth)**
- Task group 2: **IEEE 802.15.2-2003**
  - Provide interoperability and addresses the problem of coexistence of WPAN and WLAN
- Task group 3: **IEEE 802.15.3 (High Rate WPAN)**
  - Supporting the real-time video and music, better power management
- Task group 4: **IEEE 802.15.4 (Low Rate WPAN)**
  - For Low-Rate WPAN: very low-bandwidth low-energy communication at home (e.g. remote controls, alarms), WSN
- Basis for **ZigBee**

IEEE 802.15 Working Group

- Task group 5: **IEEE 802.15.5 (Mesh Networking)**
- Task group 6: **IEEE 802.15.6 (BAN: Body Area Networks)**
- Task group 7: **IEEE 802.15.7 (VLC: visible light communication)**
  - uses light to transmit data for wireless LAN and to create indoor positioning systems

- **Video**

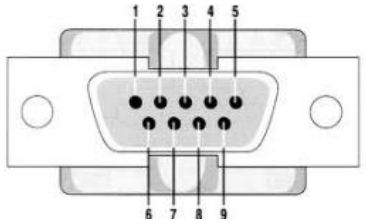
li-fi

IEEE 802.15

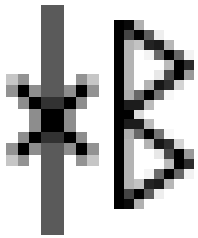
- A communication specification for **Wireless Personal Area Networks** (**WPAN**s)
- Technologies used for WPAN:
  - Wireless USB
  - ZigBee

Bluetooth

- A short-range wireless communication technology and standard
- Standardised in 2002 as IEEE 802.15.1
- Short range, low power and efficient
- Operates in the ISM unlicensed band
- Originally aimed to be a wireless replacement to RS-232
- No line of sight issues compared to Infrared (IrDA)
- Bluetooth SIG (Special Interest Group) oversees Bluetooth standards



Bluetooth®
SPECIAL INTEREST GROUP



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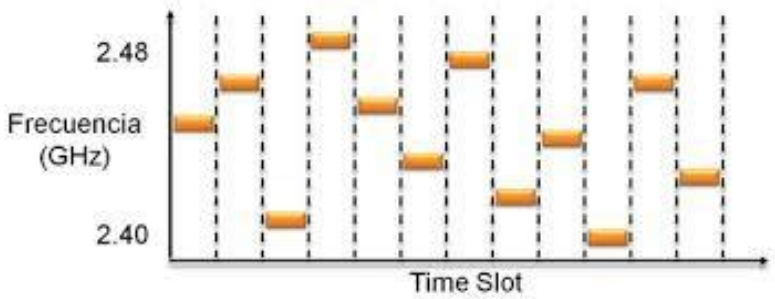
Bluetooth Technology

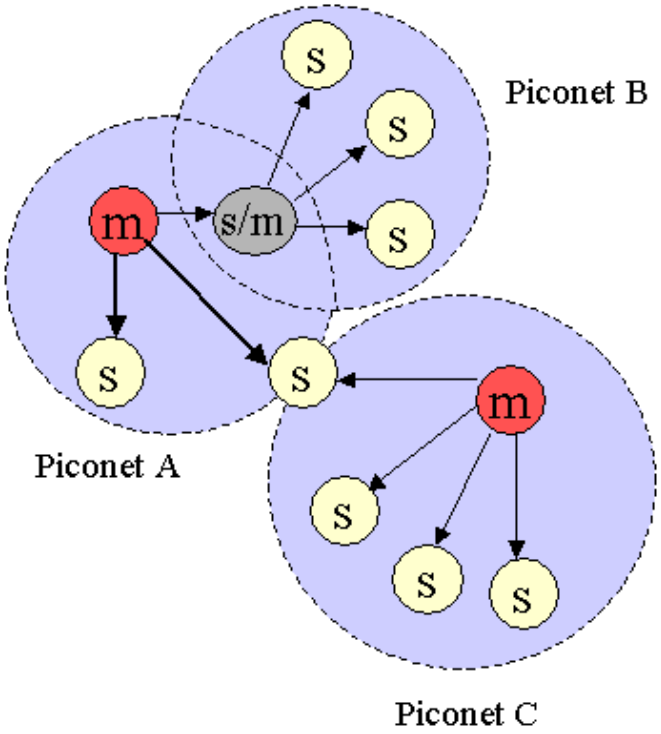
- IEEE 802.15.1
- Short range, low power and efficient
- No line of sight issues compared to IrDA
- Uses the 2.4 GHz ISM band (2402-2480 MHz)
- Uses FHSS (Frequency Hopping Spread Spectrum) technique

  - 79 1-MHz channels (sub-bands)
  - 1600 hops per second



Piconets

- Bluetooth enables wireless communication between nodes
- Nodes dynamically paired with no prior knowledge
- **Master**: the initiating node and controlling the use of the channel
- **Slave**: the other connecting node
- Piconet consists of **one master** and **up to 7 slaves**
- Nodes in more than one piconet act as a **bridge**
- A device can act as both master and slave



Bluetooth Applications

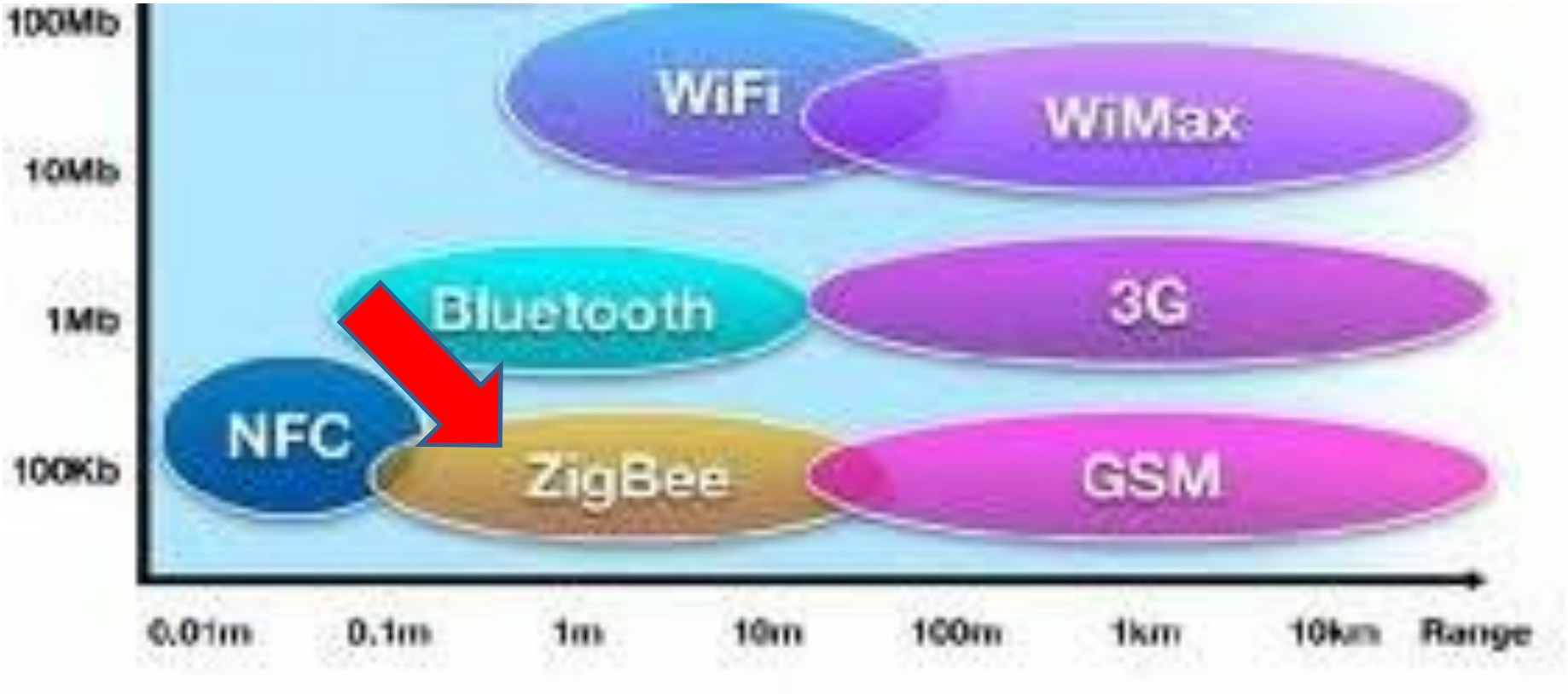
- **Sensors**
  - Sports and fitness
  - Mobile healthcare
  - Smart homes
  - Cars
- **Peripheral devices connected via Bluetooth**
  - Audio: headsets
  - Human Interface Devices
  - Network adapters & modems
  - Using Mobile phones as a remote control
  - Imaging: printers and cameras

Bluetooth Versions

- Version 1.x
- Version 2.x
- Version 3.0
- Version 4.x
  - Bluetooth low energy (BLE) aka Bluetooth Smart
  - More energy efficient
- Version 5 (Bluetooth 5)
  - Longer range, and higher broadcasting capacity and speed
  - Support for IoT

ZigBee (IEEE 802.15.4)

Wireless Technology
Bit-rates versus Range Graph: *ZigBee*



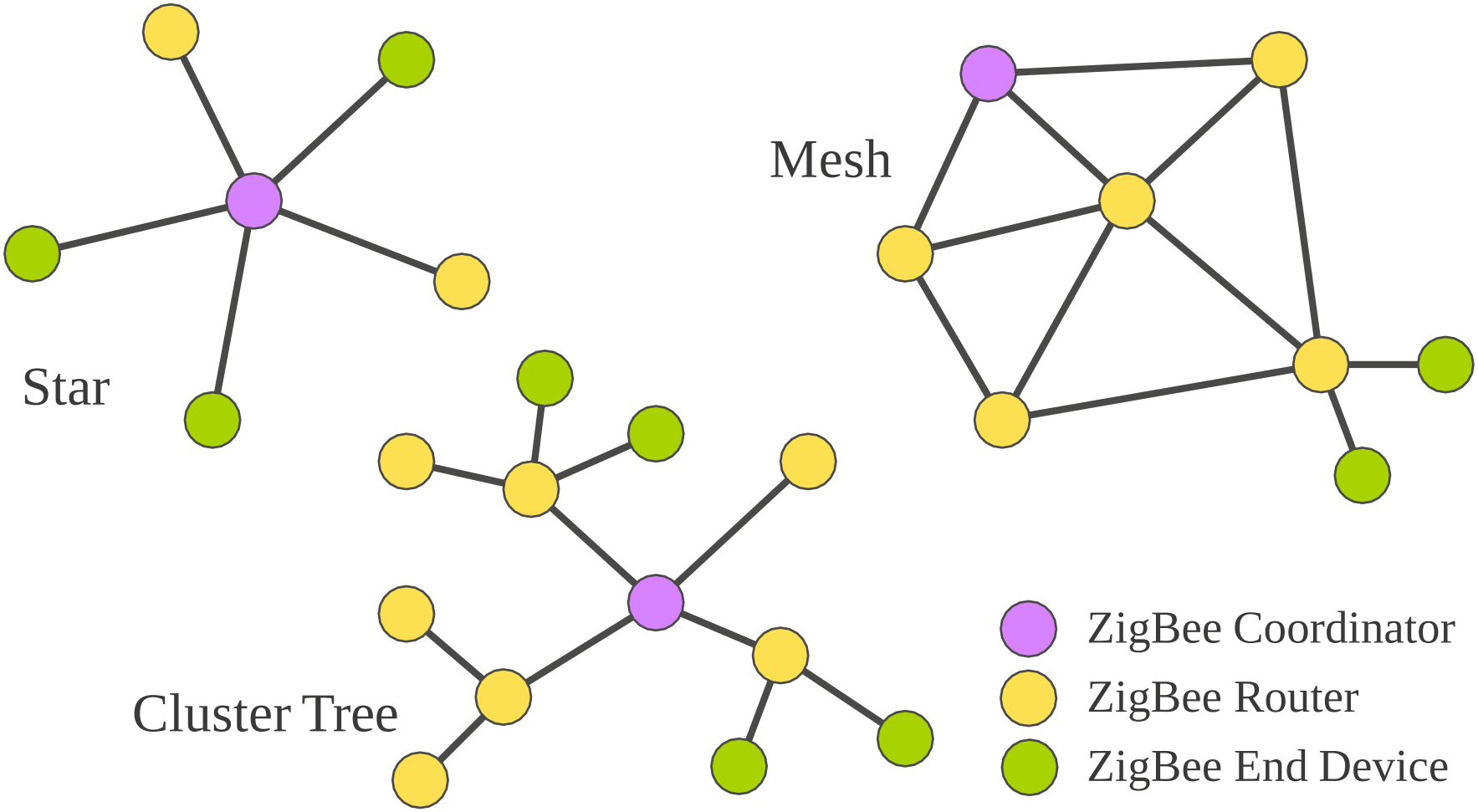
ZigBee

- Based on IEEE standard 802.15.4
- For **low-rate** WPANs (Wireless Personal Area Networks)
- Operates in the ISM unlicensed band
- Uses mesh networking which is flexible, self-forming and self-healing
- ZigBee benefits:
  - Easy to setup and maintain (mesh, self-organizing)
  - Reliability (self-healing)
  - Ability to scale to thousands of devices (nodes)
  - Long battery life
  - Low cost

ZigBee Alliance

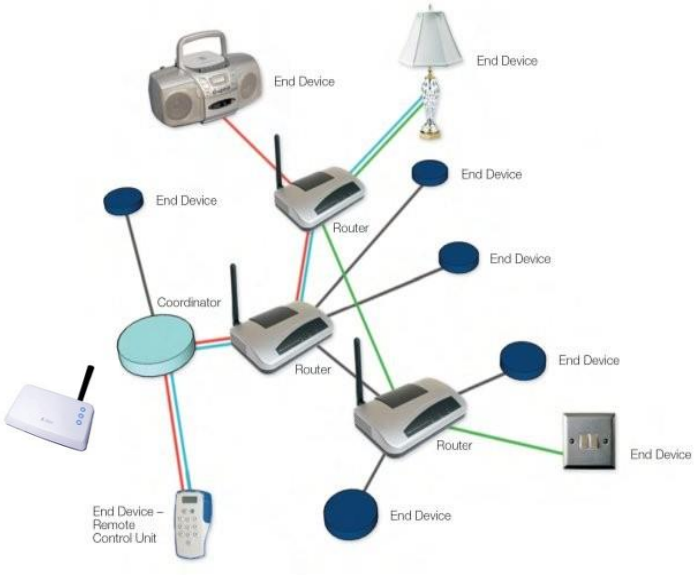
- ZigBee developed by ZigBee Alliance
- An open, non-profit association of members
- Established in 2002
- Supported by 400+ companies around the world

ZigBee Network Topologies



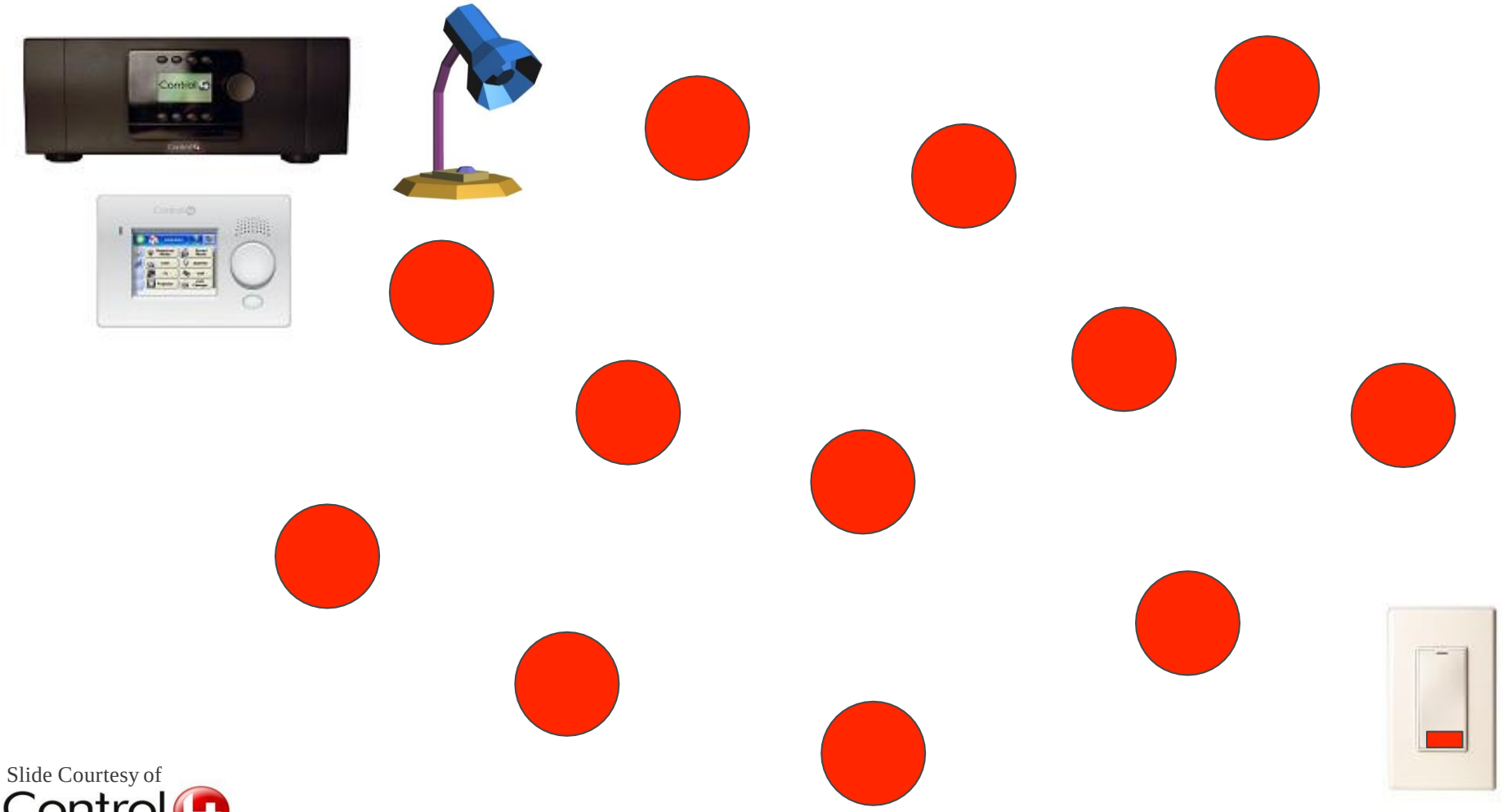
Network Components

- **Coordinator**
  - All networks need one
  - Starts the network and selects the frequency channels
- **End Device**
  - Send and receive messages
  - Perimeter or leaf nodes
  - Often battery powered and sleep when not operating
- **Router**
  - Relays and passes messages from one node to another
  - Allows sub-nodes to connect to it



http://www.mitscomponent.com/product_50_Jennic%20Product.html

ZigBee Mesh Networking



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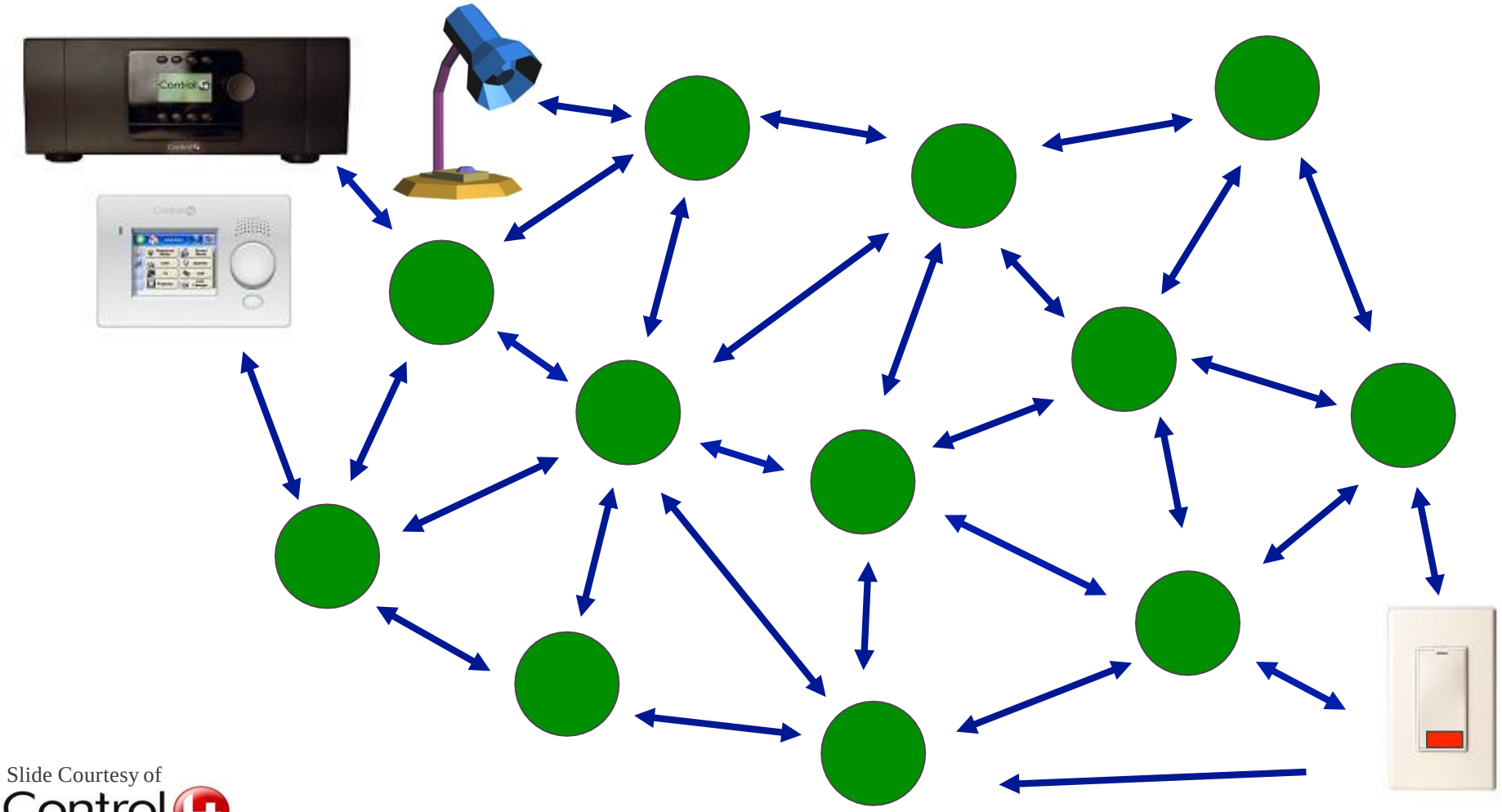
ZigBee Mesh Networking



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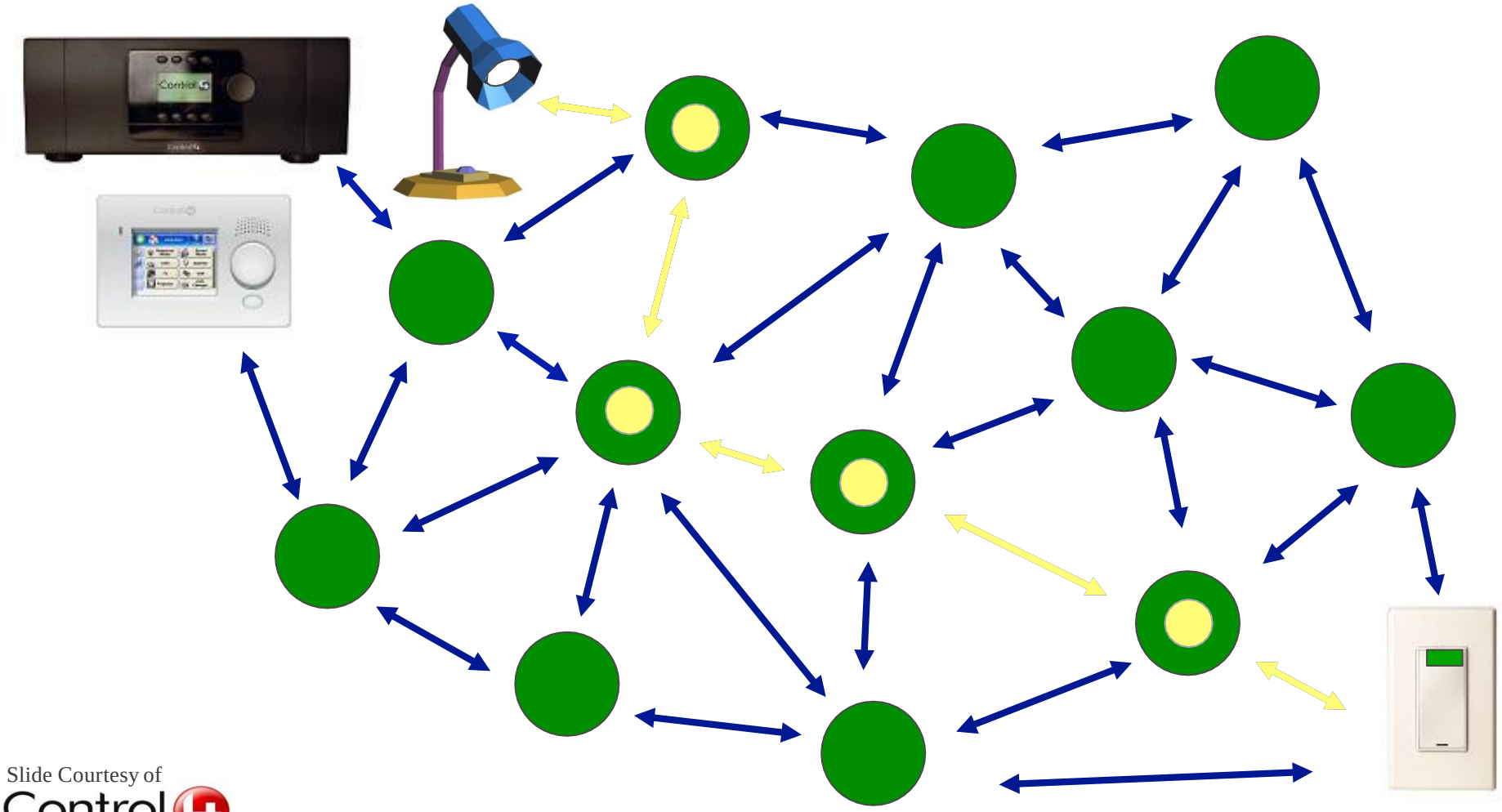
ZigBee Mesh Networking



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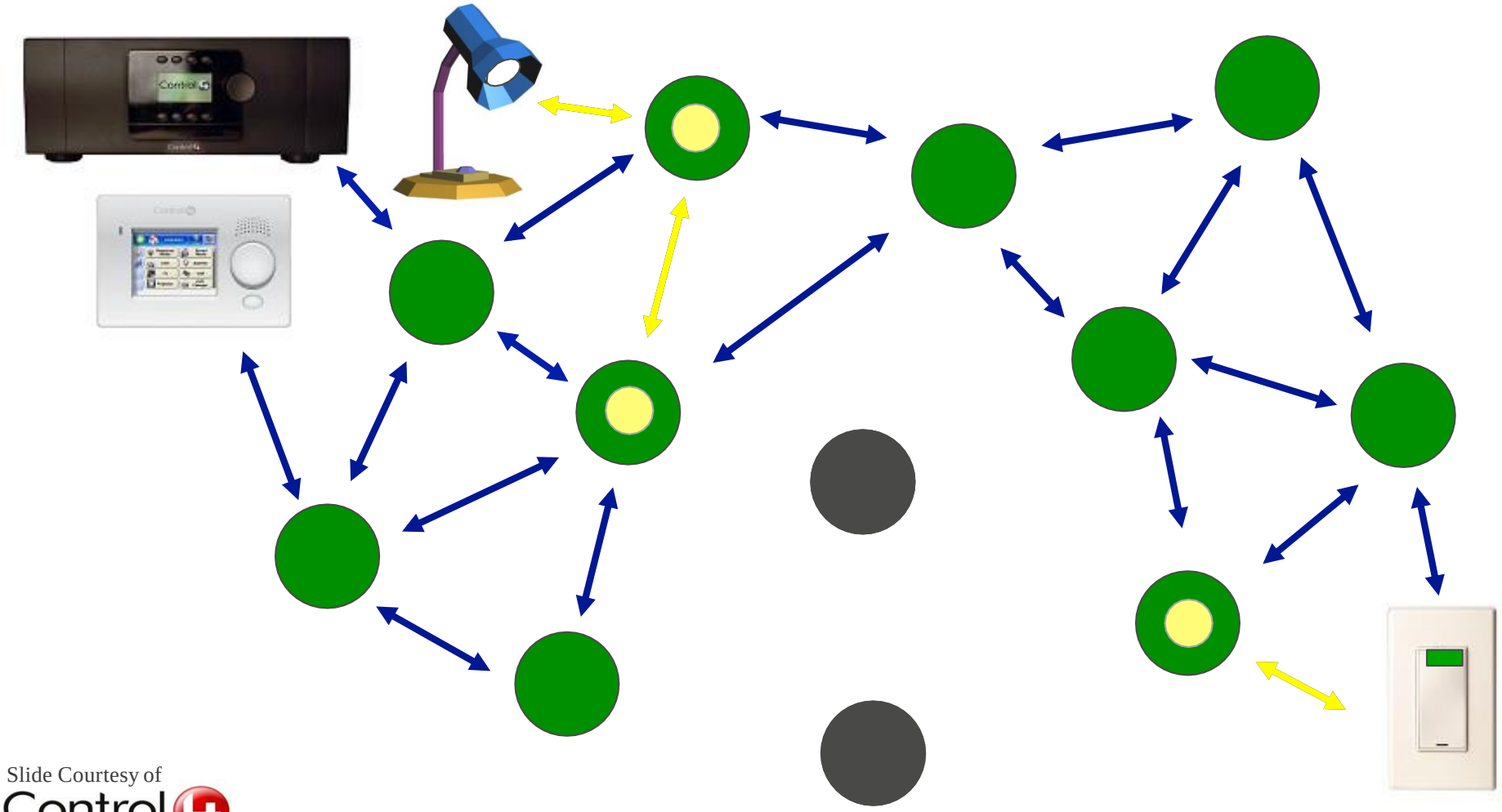
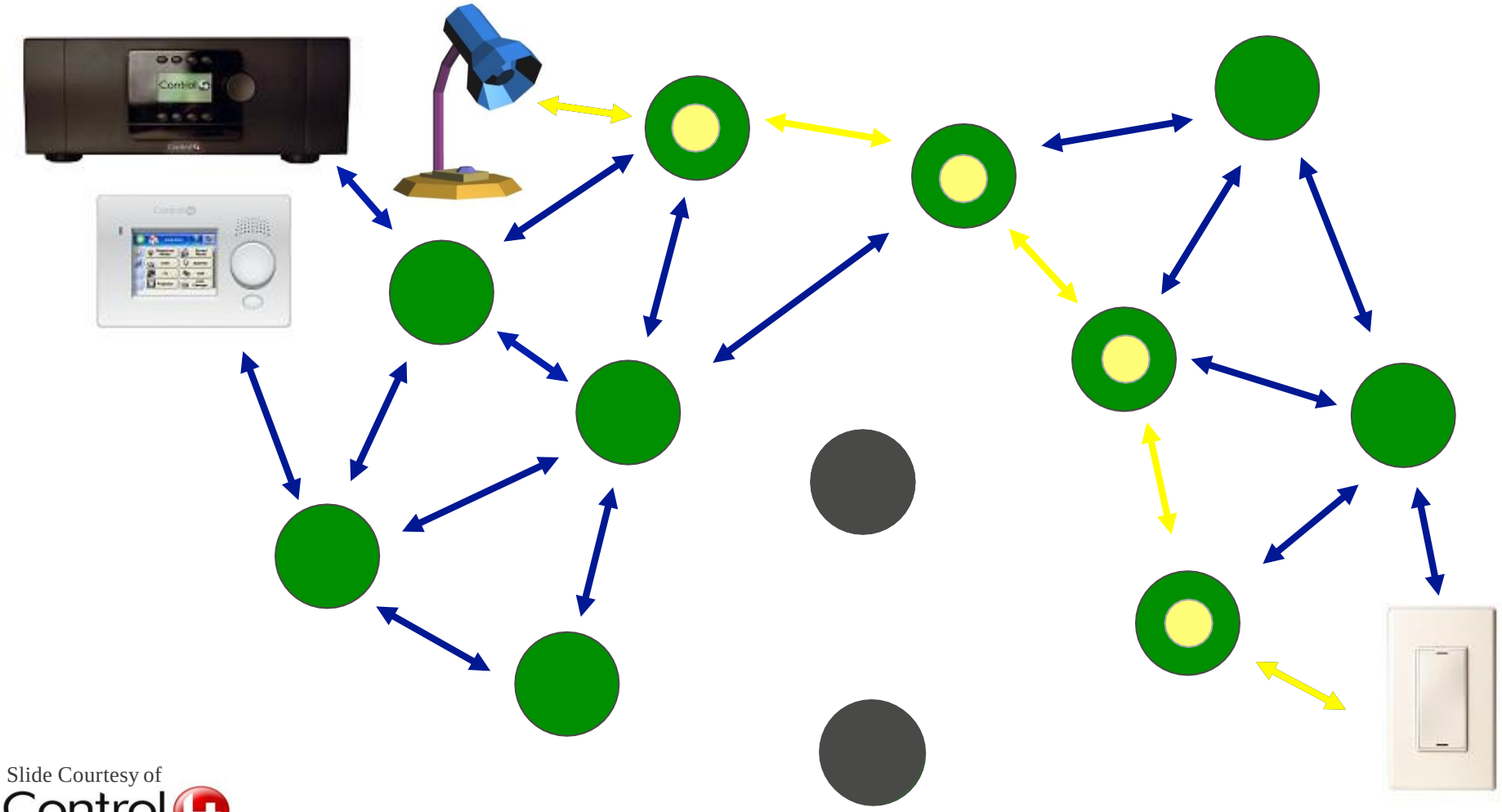
ZigBee Mesh Networking



Slide Courtesy of Control 4

ZigBee Mesh Networking



Slide Courtesy of Control 4

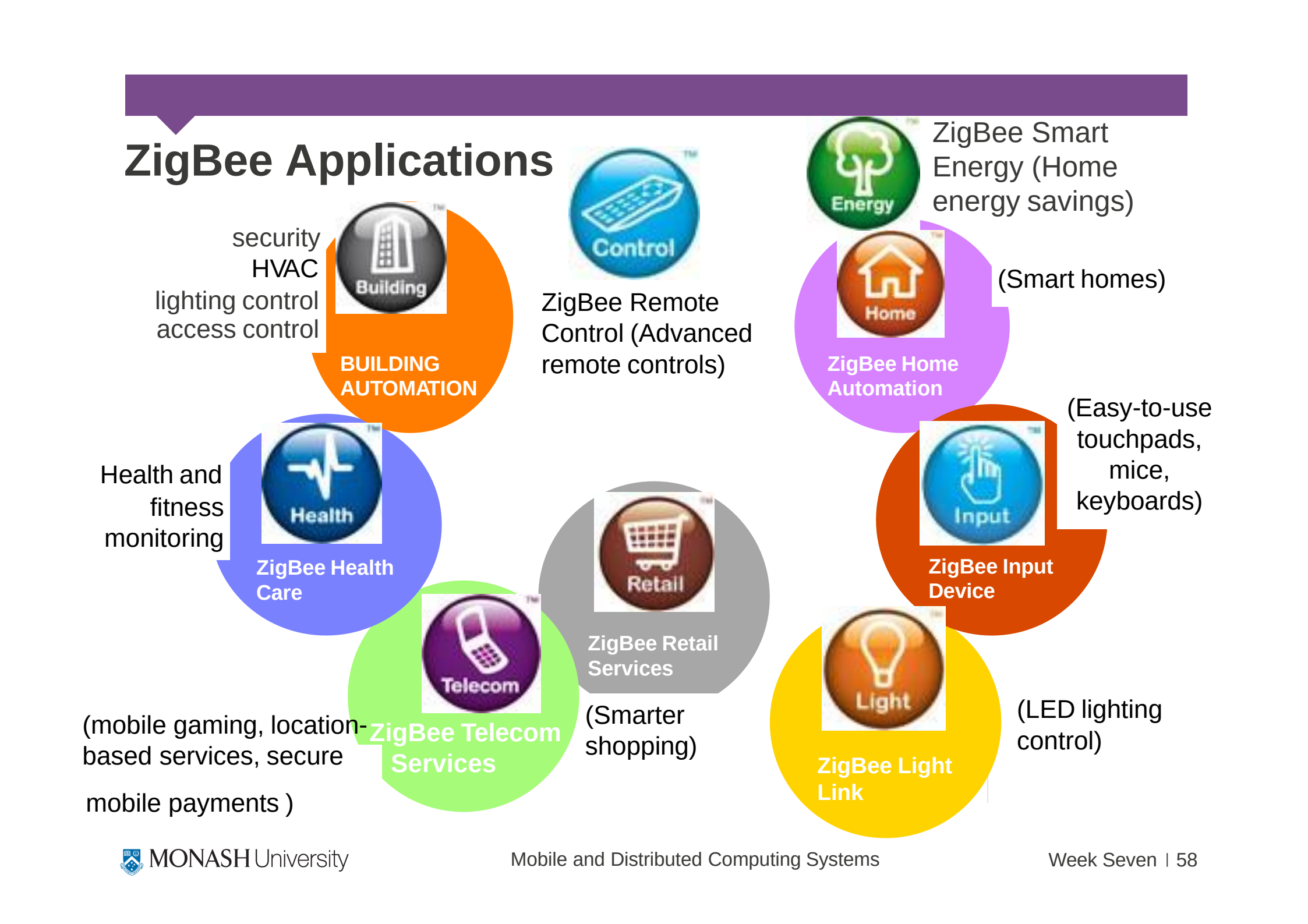
ZigBee – Highly Reliable

- Mesh network is self forming and self-healing
- If a device fails the others can rejoin and re-connect through the remaining nodes
- Automatic retries and acknowledgements

ZigBee – Security

- Utilizes AES (**Advanced Encryption Standard**) encryption
- The encryption algorithm is associated with keys

ZigBee Applications



Comparison of main Wireless Technologies

WiMAX vs WiFi

- WiFi for wireless LAN but WiMAX for more user and larger areas (MAN and WAN)
- WiMAX supports higher data rates
- WiMAX is a long range system
- There are some implementations of WiMAX for unlicensed spectrum but mainly WiMAX is licensed and WiFi is unlicensed

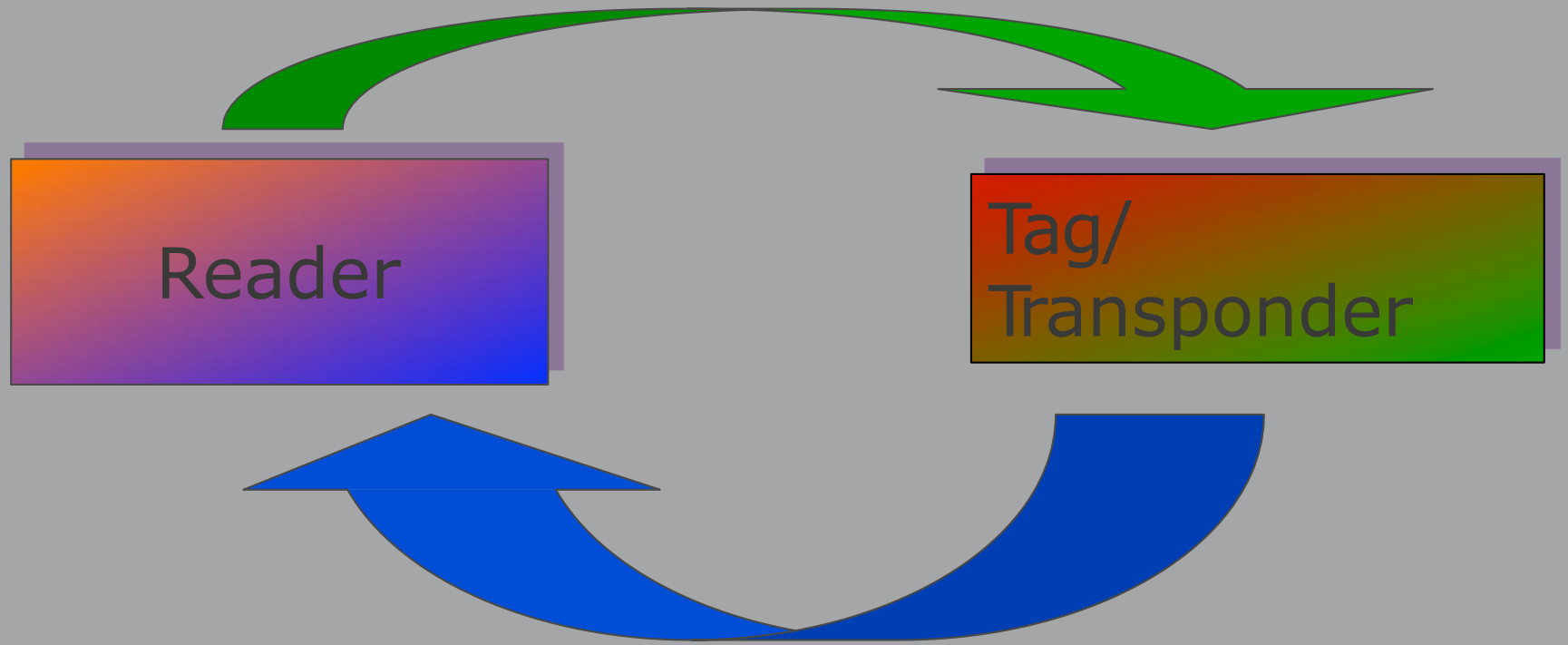
WiFi vs Bluetooth

- Both share 2.4 GHz band but WiFi also uses other bands like 5GHz
- WiFi aimed to achieve wireless LAN
- Bluetooth aimed to be a wireless replacement to RS-232 and cabling in personal applications
- WiFi has higher bandwidth and higher data transfer rates than Bluetooth
- Wifi has a longer range
- WiFi has better security
- WiFi has higher power consumption

Bluetooth vs ZigBee

- ZigBee operates in the 868 MHz, 915 (900-928) MHz and 4 GHz ISM bands
  - Bluetooth operates in 2.4 GHz
- Uses Direct Sequence Spread Spectrum (DSSS)
  - Bluetooth uses FHSS
- Network speed up to 250 kbps
  - Bluetooth up to 1-3Mbps
- ZigBee Alliance
  - Bluetooth SIG

Radio Frequency Identification (RFID)

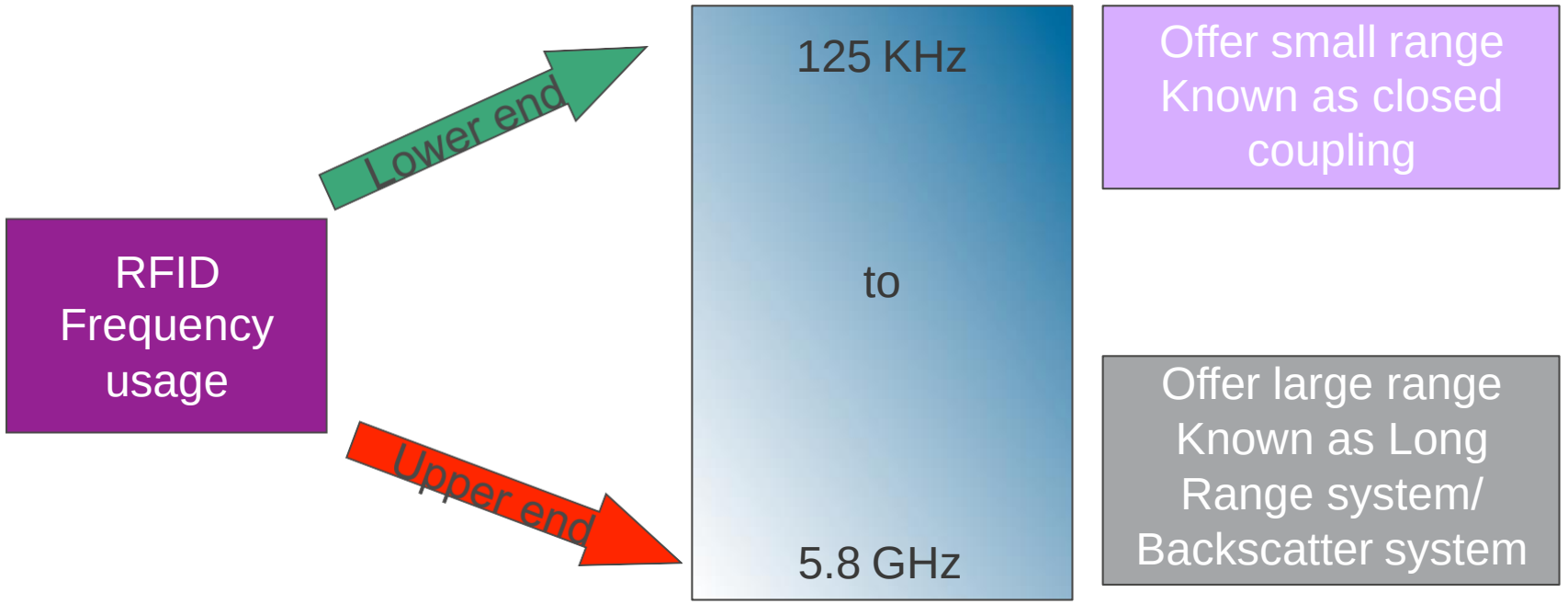


What is RFID?

- RFID (Radio Frequency Identification) is an electronic tagging/identification technology which facilitates automatic identification
  - Without any contact
  - Without the line of sight
  - By exchange of electromagnetic signals between readers and tags

Frequency spectrum

Electric, magnetic and electromagnetic field are used as physical coupling



- However, RFID system may not be limited by 125 KHz and 5.8 GHz. Systems are also being developed for frequencies outside this range.

Early history and evolution

- Ideas about RFID can be traced back to World war II. **Radar** sends a radio wave and detects the reflected signal back from the object.
- Germans discovered that if a plane rolled over it changed the reflected frequency back to base, allowing for crude identification.
- British improved on this by placing a transponder beneath aircraft to identify friendly planes. RFID works on similar principle.

Types of Transponders/Tags:

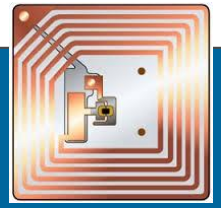
1. **Passive**
2. **Semi-passive**
3. **Active**

RFID Demystified

- A RFID system in its basic form contains the following:

Reader

Radio frequency Generated by reader



Device with silicon chip, Coiled Antenna

Tag/transponder

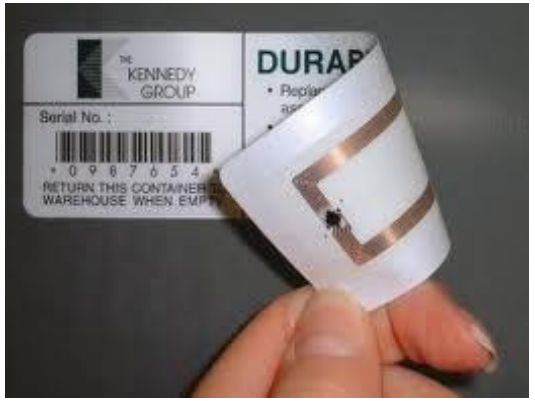
A microcontroller based Unit

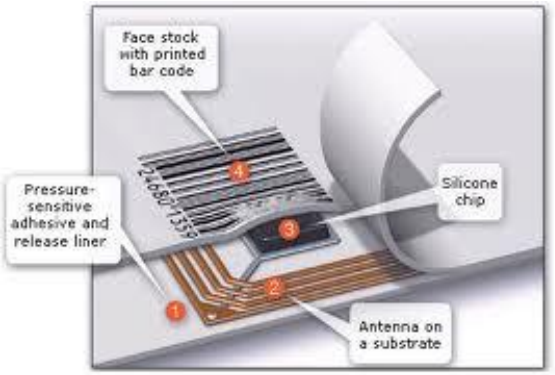
Transmits radio signals to Tags and receives signal back from tags

- Reader sends a weak signal which is a form of energy and it is used to power/wake up the tag. The tag then transmits the information on its microchip back to the Reader.

Passive Tags

- No internal power source
- They draw their power from the electromagnetic field generated by the RFID reader
- When radio waves from the reader are encountered by a passive RFID tag, the coiled antenna forms a very small magnetic field
- The tag draws power from this field, energizing the circuits in the tag
- The tag then sends the information encoded in the tag's memory to the reader
- The information can be a single binary bit or arrays of bits like an identity code



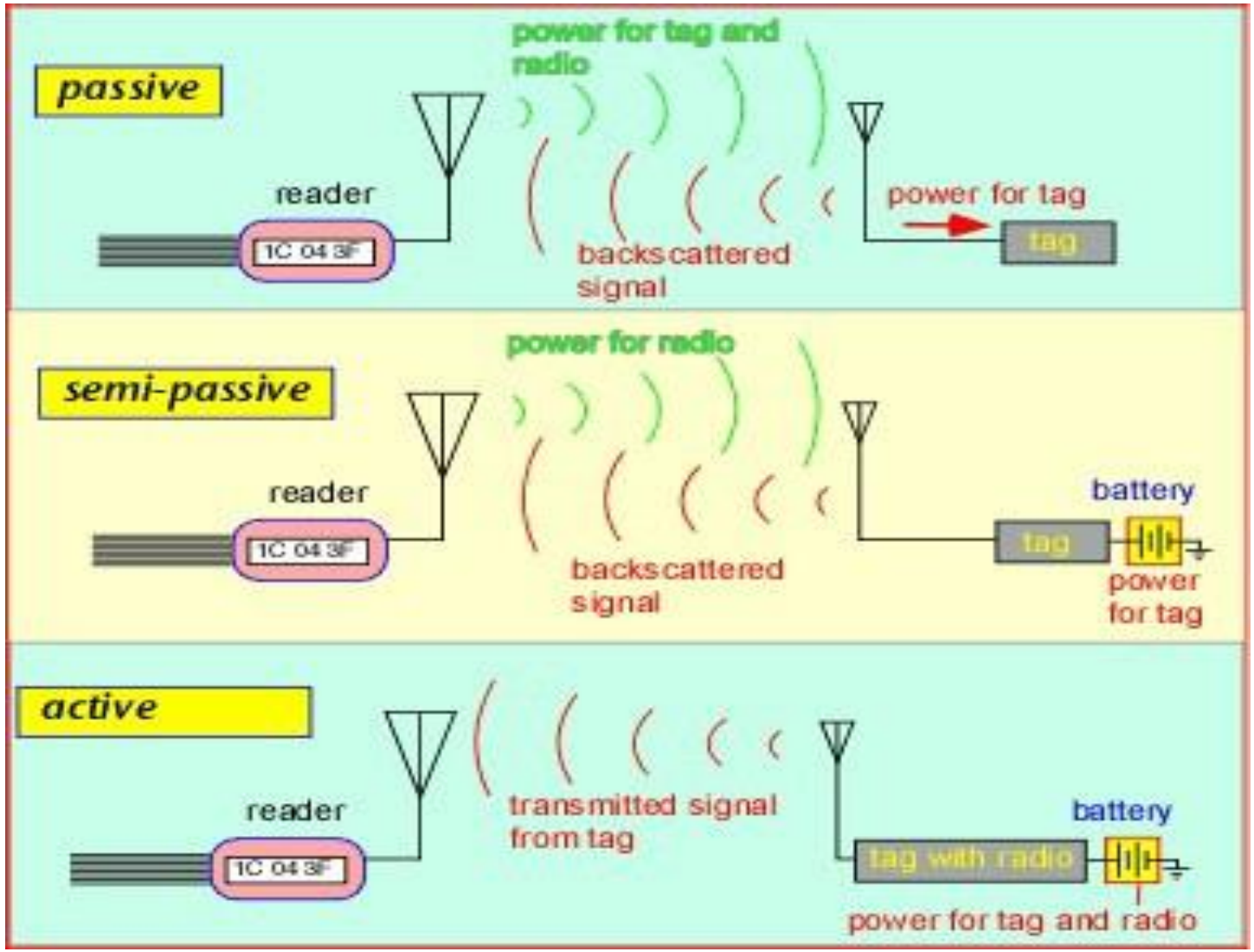


Semi-active or semi-passive tags

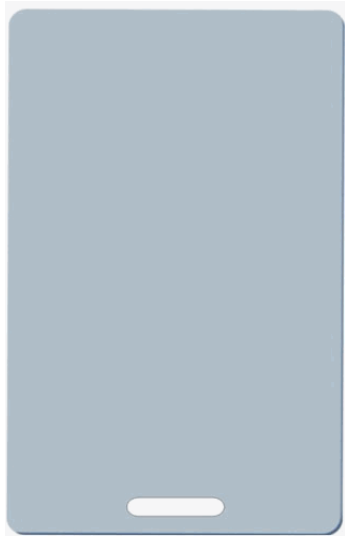
- Semi-Passive Transponders have their own power source (a small battery) that powers the microchip only
- The battery is needed only for the tag's operation (not for transmitting signal back to the reader)
- Like passive tags, they have no transmitter
- They can act faster than the passive tags
- The read range for a semi-active tag can be up to ~6-30 meters

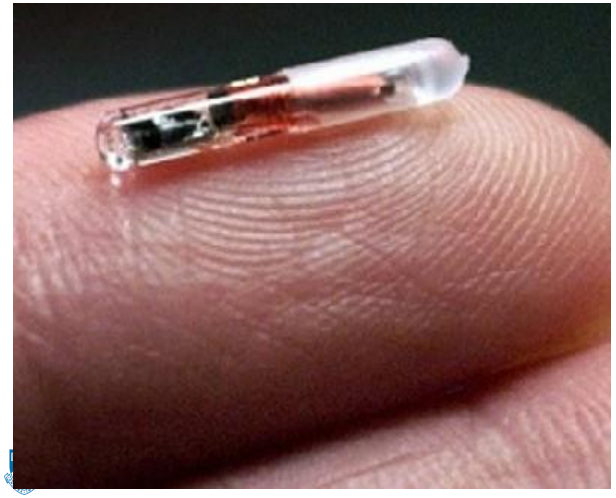
Active tags

- They have transmitters and internal power (on-board battery) to power up the microchip and transmit signals to a reader
- The read range is much greater than Passive ones, up to100 meters
- Very expensive compared to passive tags and bigger in size
- Operates in high frequency range: e.g. 455 MHz, 2.45 GHz or 5.8 GHz
- Used for tracking expensive assets over a large area or vehicles (military, shipping or mining industries)


passive
power for tag and radio
reader
power for tag
tag
backscattered signal
semi-passive
power for radio
reader
battery
tag
backscattered signal
power for tag
active
reader
transmitted signal from tag
battery
tag with radio
power for tag and radio

RFID Tags





Reading and Writing to RFID Tags

Read only (RO) tags

- The manufacturers of tags burn permanently data for the tag onto the microchip.
- It is also referred to as factory programmed tag.

Write-once, read many (WORM)

- This kind of tags enables the users to modify or update the tag's information. Security-wise these are better than RW tag.
- These are also available at a lower cost.

Read write (RW)

- Here the reader can be used to modify data in the tags.
- This kind of tags is also known as field programmable or re-programmable.

RFID Classes

EPC Class Type	Features	Tag Type
Class 0	Read Only	Passive (64 bit only)
Class 1	Write Once, Read Many (WORM)	Passive (96 bit min.)
Class 2 (Gen2)	Read/ Write	Passive (96 bit min.)
Class 3	Read/Write with battery power to enhance range	Semi-Active
Class 4	Read/Write active transmitter	Active

TABLE I

RFID FREQUENCY RANGES, STANDARDS AND THEIR KEY APPLICATIONS

RFID	KEY APPLICATIONS	STANDARD
125 kHz (LF)	Inexpensive passive RFID tags for identifying animals	ISO 18000-2
13.56 MHz (HF)	Inexpensive passive RFID tags for identifying objects, e.g., library books identification, clothes identification, etc.	ISO 14443
400 MHz	For remote control for vehicle centre locking systems	ISO 18000-7*
868 MHz, 915 MHz & 922 MHz (UHF)	For active and passive RFID tags for logistics in Europe, United States & Australia, respectively	Auto-ID Class 0 Auto-ID Class 1 ISO 18000-6
2.45 GHz (microwave)	An ISM band, used for active & passive RFID tags, e.g., with temperature sensors or GPS localization	ISO 18000-4
5.8 GHz (microwave)	Used for long read range passive and active RFID tags for vehicle identification, highway toll collection	ISO 18000-5

RFID Application Areas

- Proximity access control (cards and key fobs)
- Passports
- Toll collection
- Transportation and logistics
- Hospitals and healthcare
- Livestock and wild animal tracking

Source: https://www.corporatetravelsafety.com/

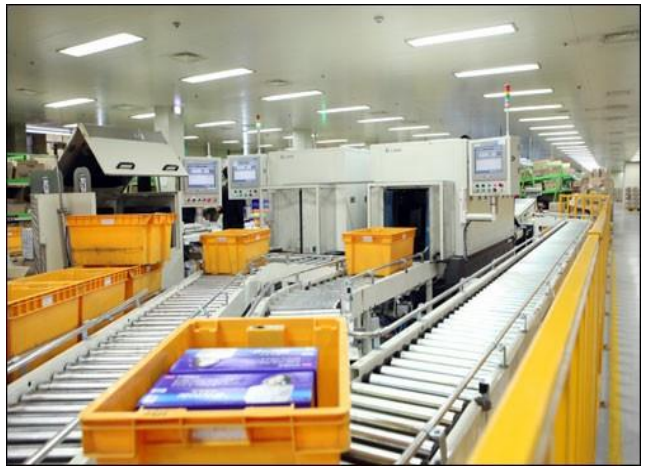
Source www.rfidtagsandreader.com

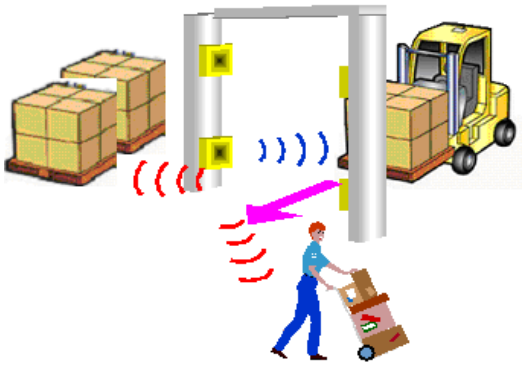
Source http://www.ijser.org

Source www.secureidnews.com

RFID Applications Areas (Cont'd)

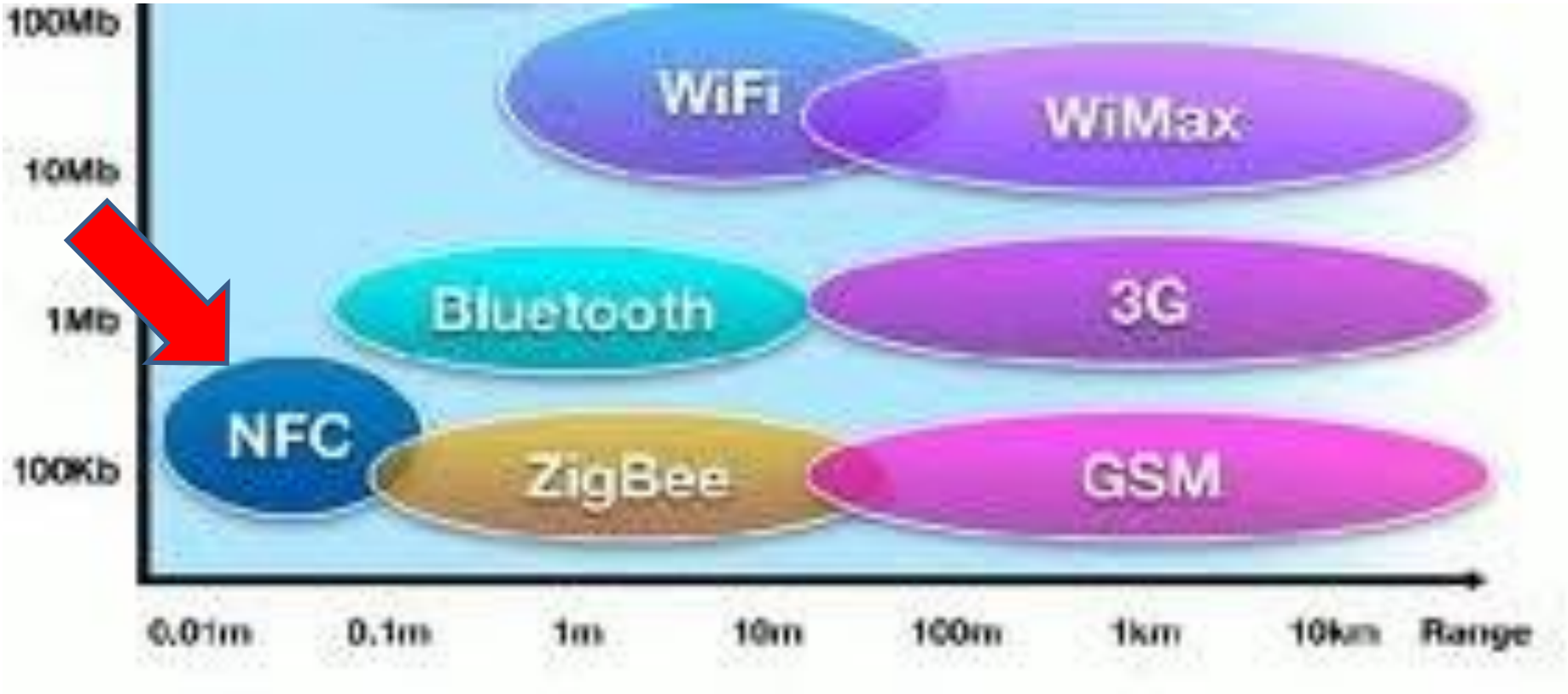
- Retail
- Supply Chain Management
- Asset tracking and Logistics
- Inventory systems





Near Field Communication (NFC)

Wireless Technology
Bit-rates versus Range Graph: *NFC*

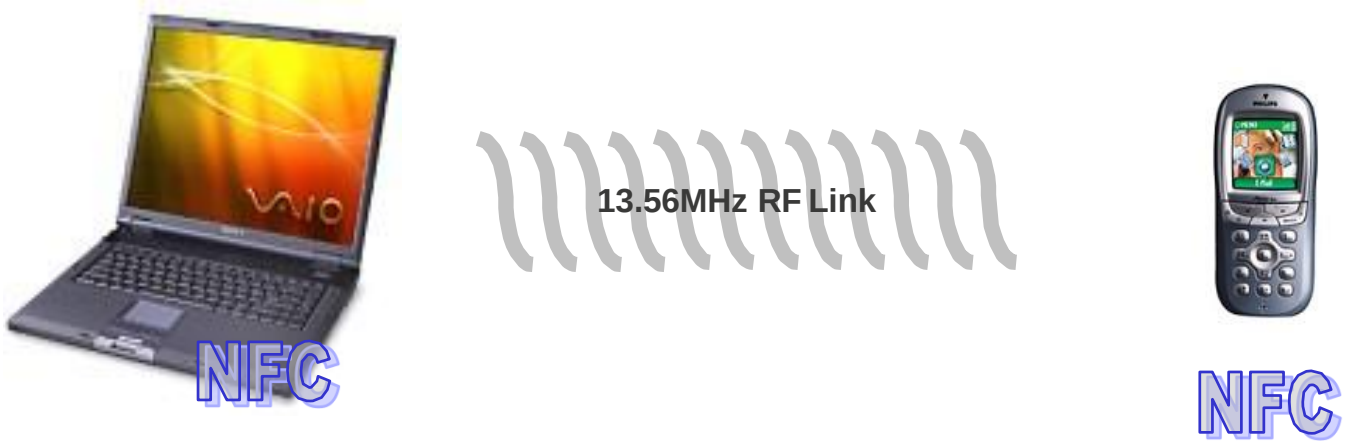


What is NFC (Near Field Communication)

- A very **short range** wireless radio communication technology between devices like smartphones or tablets
- Based on RFID technology

NFC - Technical Basics

- Operating at the **13.56 MHz** frequency and distance up to **10-20 cm**
- Compatible with the RFID technology



NFC Forum

- Developed and promoted by the NFC Forum
  - Founded in 2004 by Sony, Nokia, and Philips
- Collaboration with groups such as the Bluetooth SIG (Special Interest Group)
  - *Bluetooth Secure Simple Pairing Using NFC*
    - Provides developers with even more design options for connecting Bluetooth devices
    - Pairing devices with little or no user interface to smartphones

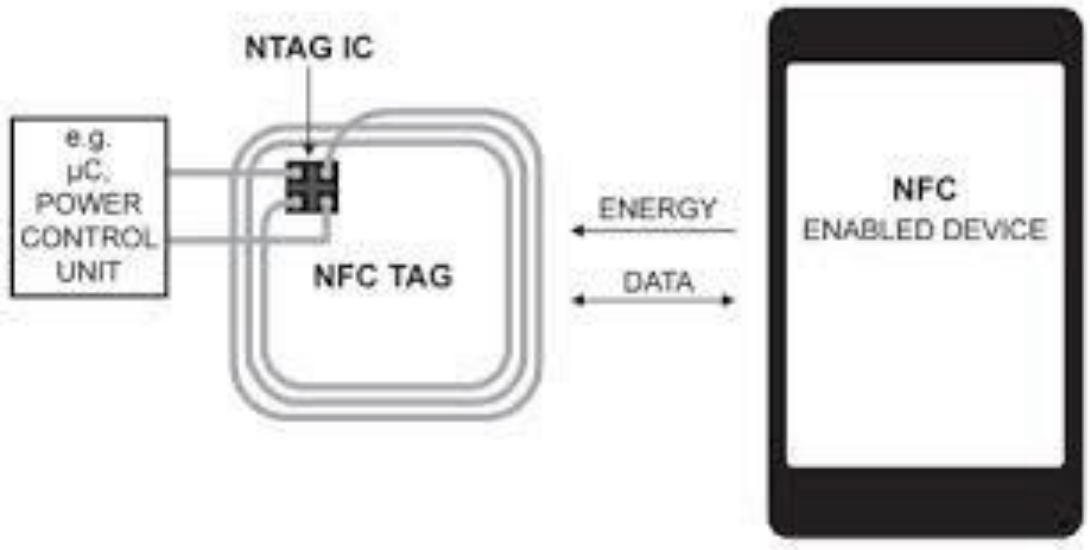
Types of Data Exchange

- **Passive mode (between NFC device and tag):**
  - A passive device (such as an NFC tag) stores information that other NFC devices can read but it cannot read any information itself
  - E.g. a sign on a wall
- **Active mode (between two NFC devices):**
  - Both devices can be NFC readers and tags
  - Like a smartphone that is able to collect information from NFC tags and also to store and exchange information with other compatible phones/devices
  - **Peer-to-peer communication** through two active, allowing both devices to send and receive information

techwikasta.com

How does NFC work?

- NFC allows a device (a reader) to create a radio frequency current that communicates with a small NFC tag holding the information
- NFC utilizes electromagnetic radio fields for mobile communication and data exchange between devices



NFC Applications

- Credit cards, debit cards and tickets, or e-cards
- Uses a secure channel and encryption for exchanging sensitive information

Figure source subhb.org

http://www.pearls.com/pages/momento-pearls-pearl-jewelry-that-speaks

ANZ Android Pay™

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