TARGET PRELIMS 2024
BOOKLET-7; S&T-7
COMPUTER & IT - 4

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2. VARIOUS GENERATION OF CELLULAR WIRELESS COMMUNICATION TECHNOLOGY

1) DIFFERENCE BETWEEN 1G, 2G, 3G, 4G, AND 5G

- **G** in terms like 1G, 2G, 3G, 4G etc. refers to a generation of **cellular wireless communication technology**.
- When there is a change in generation, there is a change in:
  - The fundamental nature of service
  - Non-backwards compatible transmission technology
  - New Frequency bands.

- **Different Generations, key differences**:

Features	**1G**	**2G**	**3G**	**4G**	**5G**
Year of introduction	1980s	1990s	Early 2000s	Late 2000s	Late 2010s
Core technology	Analog	Digital (CDMA , GSM)	CDMA2000	LTE	NR (New Radio)
Services	Voice calls	Voice calls, SMS, Basic mobile Internet;	Integrated high-quality audio, video and data	Dynamic information access, variable devices	Dynamic information access, variable devices with all capabilities
IP Protocol	N/A	Supported	Supported	Fully Supported	Fully Supported
Data Speed		Upto 384 Kbps	Several Mbps	100 Mbps to 1 Gbps	Upto 20 Gbps
MIMO technology	N/A	No	Yes	Yes	Yes

Note: **Security** keeps on improving with every generation; **Latency** keeps on decreasing with every generation; **Data Speed** keeps on improving with every generation.
MIMO Technology: (Multiple Input Multiple Output) (MIMO) is a wireless technology that uses multiple transmitters and receivers to transfer more data at the same time.

Note: Legacy wireless streams used **Single-Input Single Output** (SISO) technology. They can only send and receive only one spatial stream at a time.

2) VARIOUS 4G TECHNOLOGIES

- **4G phones are supposed to be faster, but there are many technologies and speed varies.**

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- The International Telecommunication Union (ITU), a standards body, tried to issue requirements to call a network 4G but they were ignored by carriers, and eventually the ITU backed down.
- 4G technologies include.
    1. **HSPA+ 21/42**
    2. **WiMAX (now obsolete**)
    3. **LTE (Long Term Evolution)**

A) LTE

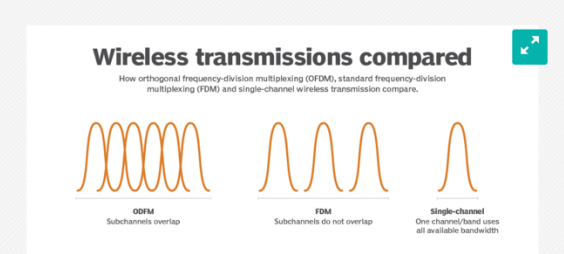
» LTE is the most popular 4G tech. Some people consider it the only true 4G tech of the bunch and some others say that none of them are fast enough to be called 4G. The **key difference** between 4G LTE and other "4G" technologies is the upload speed.

» **Other Details about LTE:** LTE only allows transmission of data. **Voice calls** are routed through telecom networks' older 2G and 3G networks. Therefore, under LTE, we can't access 4G data and services while on a call.

» **Key Features of LTE:**

- **Orthogonal Frequency Division Multiplexing (OFDM)**: It allows high data bandwidth to be transmitted efficiently while still providing a high degree of resilience to reflection and interference.

In a traditional single-channel modulation scheme, each data bit is sent serially or sequentially one after another. In OFDM, several bits can be sent in parallel, or at the same time, in separate substream channels. This enables each substream's data rate to be lower than would be required by a single stream of similar bandwidth. This makes the system less susceptible to interference and enables more efficient data bandwidth.



Multiple Input, Multiple Output: LTE-A uses MIMO antenna technology. MIMO and OFDM ensure a higher signal to noise ratio at the receiver ensuring good services even in dense regions.

B) VOICE OVER LTE (VOLTE)

- Voice over LTE is a **digital packet technology** that **uses 4G LTE to route voice traffic** and **transmit data**. VoLTE provides higher quality calls, better service, and the **ability to simultaneously use voice and data**.

- **NEED:** Why is VoLTE necessary?
    - » The technology is necessary because **LTE is a data-only networking technology**.
        - **Previous cellular networks** such as 2G and 3G, were designed to carry voice calls – services added cellular data support later through methods that basically "tunneled" data inside of voice-call connections.

- **LTE turns the network around** and uses Internet Protocol Packets for all communications. As such **it doesn't support traditional voice call technology**, so a new protocol and applications for voice over LTE are needed.

- **How does VoLTE work?**
  - It is based on the **IP Multimedia Subsystem (IMS) framework**. This allows the service to deliver multimedia as data flows using a common IP interface.

- **Advantages of VoLTE**
  - **VoLTE** uses the **spectrum more efficiently** than traditional voice calls. It uses **less bandwidth** because VOLTE's packet headers are smaller than those of unoptimized VoIP/LTE.
  - It provides for increased battery life when compared to VoIP.
  - Provides superior audio quality and a clearer calling experience.
  - **Ends dependency** on the **legacy circuit switched voice network** to be maintained.
  - Allows up to **six-way conference calls**.
  - Ability to **simultaneously use voice** and **Data.** Eliminates the need to have voice on one network and data on another.

- **Limitations**
  - Need volte capable smart phones
  - **Strong 4G coverage** to make and receive calls over 4G network.
  - For VoLTE call, both devices involved in communication must be compatible with VoLTE.

- **Services in India**

  Reliance Jio and Airtel are the leading operator providing the VoLTE. Reliance Jio doesn't have spectrum in 2G or 3G and thus it places all its calls using 4G LTE only (unlike other operators which drop to 2G or 3G for sending and receiving calls).

3) 5G

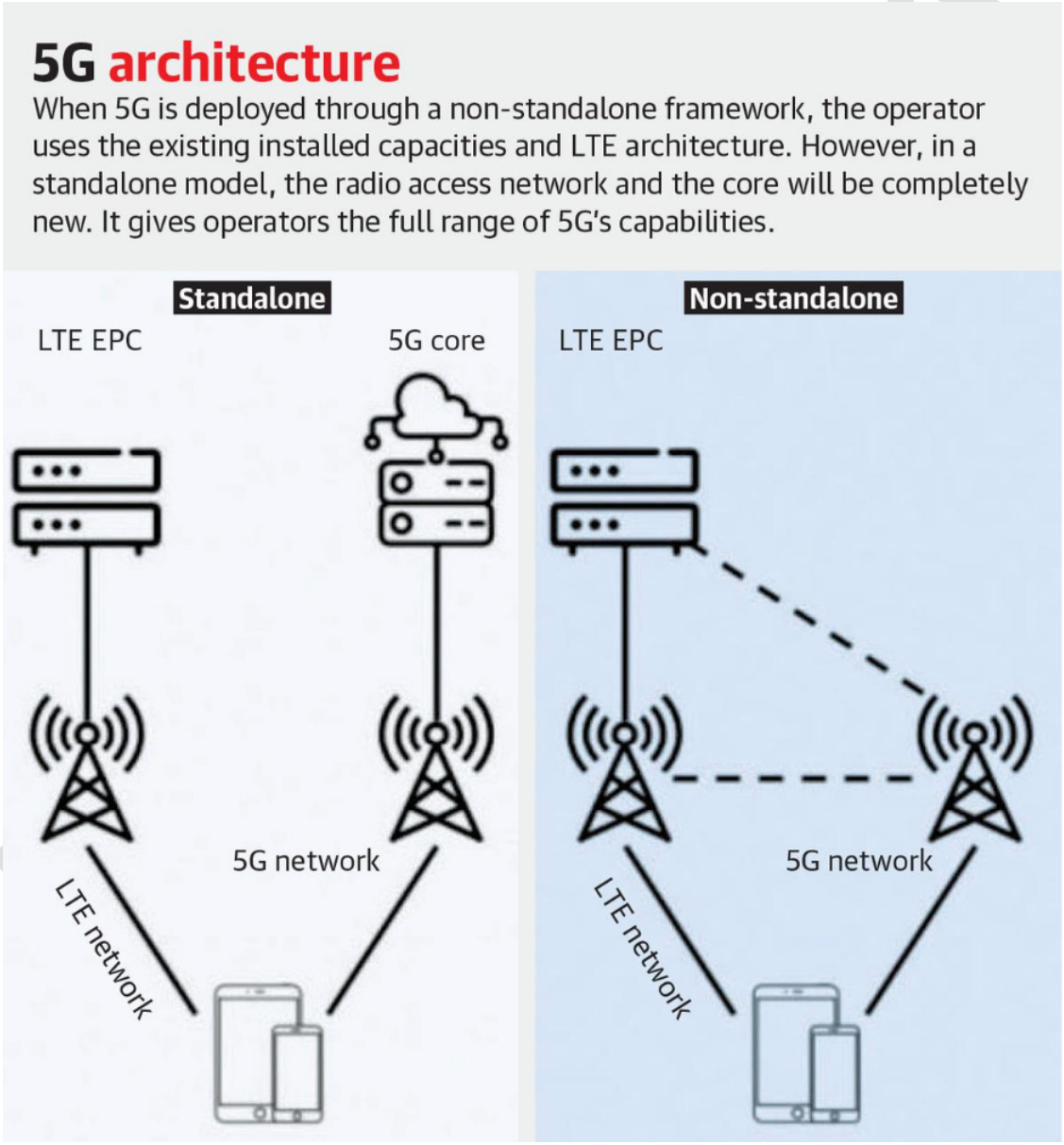
- 5G refers to **the fifth generation of cellular wireless communication technologies**.
- **Key features of 5G technology are**:
  - **Higher speed**; **Lower latency; Greater network stability**.
  - **Device Intelligence:** Unlike 4G, 5G has the capability to **differentiate between fixed and mobile devices**. It uses **cognitive radio techniques** to identify each device and offer the most appropriate delivery channel. This will allow a much more customized internet connection – according to device capability and local reception environment.
  - **Other technical features of 5G**
    - 5G will use **higher frequencies** of wireless spectrum (~ **30 GHz to 300 GHz**) range when compared to 4G which uses frequencies below 6 GHz.
      - **Higher Frequency** -> Huge quantity of data; Shorter Wavelength -> smaller antenna sizes.
    - Building on the multiplexing technology of its predecessor, 5G ushers in a new standard called **5G New Radio (NR),** which uses the best capabilities of LTE. **5G NR** will enable **increased energy savings for connected** devices and enhance connectivity.
    - These frequencies are **highly directional** and thus can be used right next to other wireless signals without causing interference.

- Several hundreds of thousands of simultaneous connections for wireless sensors
- Spectral efficiency significantly enhanced compared to 4G
- Improved Coverage
- Enhanced signal efficiency

C) STANDALONE AND NON-STANDALONE 5G

- 5G networks are deployed on two modes: **standalone** and **non-standalone**.

- Each architecture has its advantage and disadvantages. The method used by the operators primarily reflect their view of the market for the new technology, and consequent rollout strategy.



- **Standalone Mode**: In this mode, the 5G network operates with dedicated equipment and runs parallel to the existing 4G network. In this architecture, Radio Access Network (RAN) and the core are

completely new, and there will be a clear separation of different network functions in line with the 3GPP recommendations.

- Jio has chosen this method. It has committed an investment of Rs 2 lakh crore for its standalone 5G network.
- **Advantages:** Provides full 5G capabilities and new network functionalities such as slicing that provides greater flexibility to operators to efficiently use their spectrum holding; Simplify network operations; much faster than NSA 5G -> improved user experience; Long term solution.
- **Limitations**: High Initial Investment

- **Non-Standalone Mode (NSA)**: It this, the 5G network is supported by the 4G Core infrastructure. The operators can use their existing capacities and LTE architecture to deploy 5G services while implementing a new radio access network (RAN). The operations in the core network will be supported by the existing evolved packed (EPC) from LTE. **Germany** for e.g., used the NSA model to roll out 5G services in 2019.

  - **Advantages:** Reduce initial cost/investment; Maximizes the utilization of existing network; Reduces time of deployment; first national coverage
  - **Limitation:** Only short term/medium term solution; Not as fast as pure 5G

- Given that the non-standalone networks are built on existing infrastructure, **the initial cost and rollout times are significantly lower**. It lets operators maximize the utilization of existing network infrastructure with relatively lower investment.

  Compatibility with existing device ecosystems: Most smartphones today have compatibility to connect to non-standalone 5G network – which are essentially 5G airwaves transmitted through 4G networks. It will require software updates by their OEMs to be able to connect to standalone networks.

D) CHALLENGES OF FIBERIZATION AHEAD OF INDIA'S 5G DEPLOYMENT (CLASS DISCUSSION)

E) 5G SPECTRUM (LOW BAND, MIDDLE BAND, HIGH BAND)

- **5G** differs from previous cell phone standards, in having much wider spectrum than before. It is capable of tuning in many more types of frequencies – and multiple types of frequencies at the same time.
  - **Low Band 5G (600 – 700 MHz)**: Low band tower can cover 100s of sq miles with 5G services that range in speed from **30 – 250 megabits** per second (Mbps). It is the blanket layer for nationwide coverage. It will provide a base and services will not get worse than this. It uses the same frequency (600 MHz) that was once used for analog TV broadcasts. This ensures coverage in far flung rural areas.
    - **Note:** Even low band services are faster than 4G services.

  - **Middle Band 5G (2.5-3.5 GHz):** Mid band tower can cover several mile radii with 5G service that range in speed from **100 – 900 Mbps**.
    - **Note:** Some carriers will be skipping low band 5G, so their middle band 5G services will be the base service.

- **Note:** Cellular industry is considering the mid band 5G as the sweet spot for 5G distance and performance.

- **High Band** (millimeter wave/24-39 GHz) tower covers a **one mile or lower radius** while delivering **superfast speeds** (roughly 1-3 gbps speeds). It will be deployed in areas with "**dense urban"** environments and public gathering places that frequently save huge number of people.
- Each of these tiers would improve in performance over time.

F) PRIVATE 5G

- It is a cellular network technology that provides 5G connectivity for a specific, closed user group within a limited geographic area.
- Unlike public 5G networks, which are operated by mobile carriers and accessible to anyone with compatible device and subscription, private 5G networks are owned and operated by private entities, such as businesses, governments, or universities. This gives owner full control over the network, including who can access it, how it is used, and the quality of service.
- **How does it work**?
  - Same tech as public 5G, but they operate on licensed or unlicensed spectrum.
- **Advantages:**
  - **Increased privacy and security:** It allows organizations to implement their own security measures.
  - Improved reliability and performance (since it can be tailored to specific needs of the users)
  - Greater control and flexibility
  - Reduced cost

G) AIRLINES VS 5G IN USA AND SOME OTHER COUNTRIES (CLASS DISCUSSION)

- **what were the problems caused by deployment of 5G 'C-Band' spectrum (3.7 GHz – 3.98 GHz)?**
  - The **C-band frequency range of 5G wireless technology** is very close to the 4.2 to 4.4 GHz range used by altimeters on all aircrafts, something that was established long back

4) 6G

Successor of 5G

Frequency Bands – 95 GHz to 3 THz

It seeks to use Tera Hz band frequency which is still unutilized. Tera Hz band fall between infrared and microwaves. Though the waves have very small wavelength, there is a huge amount of free spectrum which would allow us very fast data rates.

Data rate – Upto 1 TBPS (100 times faster than 6G)

Latency < 1 milli seconds

Application and Advantages (Similar points as 5G)

6G also envisions to enable new applications such as **holographic communication**, brain-computer interface, quantum internet, and artificial intelligence.

Challenges for India:

Low R&D investments

Terahertz communication are blocked easily by barriers and signal also attenuates easily

5) BHARAT 6G ALLIANCE (B6GA)

Why in news?

DoT launches Bharat 6G Alliance to drive innovation and collaboration in Next-Generation Wireless Technology (July 2023)

Details about **B6GA**:

It is a collaborative platform consisting of public and private companies, academia, research institutions and standards development organization. It will forge coalition and synergies with other 6G Global Alliances, fostering international collaboration and knowledge network.

The **primary objective** of the B6GA is to facilitate market access for Indian telecom technology products and services, enabling the country to emerge as a **global leader in 6G technology**.

It aims to bring together Indian startups, companies, and the manufacturing ecosystem to establish consortia that drive the design, development and deployment of 6G technologies in India.

It also focuses upon accelerating standard related patent creation within the country and actively contributing to international standardization organizations such as 3GPP and ITU.

6) BHARAT 6G MISSION

- Aim of 6G service rollout by **2030.**
- India has also launched a development test bed.
- **More about the Vision document**
  - » **Prepared** by the Technology Innovation Group on 6G (TIG) which was set up by Department of Telecommunication in 2021.
  - » **Mission divided into two phases**:
    - **Phase 1** (2023-2025): Ideation phase – understand various potentials and risks; test proof the concept
    - **Phase 2** (2025-2030): Delivering the potential technology solution
  - » **Constitution of an apex body** to oversee the mission and approve the budget of the mission
- **Significance** of the document:
  - » Assuming leadership in setting the 6G standards
  - » Not delaying adoption (as has happened in previous generations)
  - » Ensuring latest technology coming to India in the fastest way possible.

3. E-SIM

- **What is an eSIM (embedded Sim)?**
  - » An eSIM is a programmable chip that is built (embedded) into smartphones, tablets or other devices. An eSIM is a digital SIM that allows you to use a cellular plan from your carrier without having to use a

physical nano-SIM. The pre-installed (embedded) simcard is activated by installing the "**eSIM profile"** of a new operator.

» **Technical Name:** The eSIM is called by its technical name, **eUICC** (Embedded Universal Circuit Card) or virtual SIM.

- **Advantages:**
  - » This has very **small physical footprint**, even smaller than the nano sims available since 2012. Not having a removable sim slot also saves a lot of space. This is especially useful for smaller electronics like smartwatches. Further, not having the sim tray increases the scope of making the **device water resistant**.
  - » It serves the same purpose as a physical SIM, but it is **carrier independent** and can be programmed via software instead.
  - » **Same eSIM profile** can be activated on multiple device (e.g. phone, smart watches etc.) (traditionally, one physical sim card could be used only in one device)
  - » **Switching providers is very easy**: Instead of getting a new physical SIM card, all you have to obtain is a configuration file and activate it on the device. Providers generally refer to it as an eSIM profile and offer it as a QR code that you can scan and download.
  - » Further, eSIM allows **storage of multiple carrier profiles** on the smartphones and carrier can be switched between on the fly.
  - » **Carriers also benefit** as they don't have to manufacture and provide a physical sim card thus reducing the cost.
  - » **Environment friendly** – extra packaging of physical sim card, plastic waste, e-waste etc. could all be reduced.

- **Disadvantages/Limitations:**
  - » **Not supported by all carriers yet**.

- In India, **Jio, Airtel, and Vi** all support eSIM. You need to send a message to the carrier asking them to activate eSIM and they usually send a code which has to be scanned via the device on which you intend to use the eSIM. Once done, the eSIM should work.

4. RFID COMMUNICATION

- RFID (radio frequency identification) is automatic recognition technology that uses wireless communication. Here, data is encoded in an RFID tag which might be read by the reader.
- **What is the most important advantage of RFID?**
  - » Electronic devices generally need a power source. But, RFID tags use a mechanism where we can send power to device, whenever the device needs it. (Electromagnetic field coupling)
  - » We don't need a power source on RFID tags.

- **Kinds of RFID: Passive and Active**
  - » **Passive RFID:** RFID tags have neither an electric plug nor a battery. Instead, all of the energy needed to operate them is supplied in the form of radio waves by RFID readers. This technology is called passive RFID.
  - » **Active RFID:** Here, there is a power source on the tag.

    - **Advantages:**

- Data can be read from longer distance. (for e.g., even if the tag is high, relatively inaccessible place) etc.
- Multiple tags can be read at once -> it obviates the need to hold item one by one in order to read the data.
- Data can also be read from outside the box unlike barcode/ QR code (without opening the box). It is also immune to things like dirt.
- A passive type RFID can be used semi-permanently without a battery.
- Since tag contains a memory, the data can be rewritten.

- **Applications**:
  - It enables efficient inventory count at logistics center, backyard, and storefront.
  - Incoming and outgoing record (e.g. FASTag at toll booths)
  - **Brand Protection**: It is a useful tool to prevent grey market and counterfeit products of luxury brands.
  - Tracking: Personnel, asset etc.
  - **Smart Keys** (for doors)

- **Disadvantages:**
  - It takes longer to program an RFID tag (compared to QRCode)
  - RFID can be intercepted easily, even if its encoded.
  - **Foil (2-3 layers of household foil)** can dam the radio waves
  - Privacy concerns: Anybody can access information about anything

5. NEAR FIELD COMMUNICATION

- **What is NFC and How does it work?**
  - It is a short-distance wireless communication technology. When two NFC enabled devices are very close to each other (around 4 cm), then they can communicate with each other using radio waves.
    - **Atleast one of the device should be active device** like smart phone, tablet, or post terminal. Please note that the active device would need an external power supply. The other device may be active of passive (for e.g. NFC tags). Passive device is powered by the electromagnetic field of the active device.

  - **NFC supports three modes of communications:**
    - **Peer to Peer communication mode**
      - E.g., when we share information between two smart phones.
      - In this mode, both devices are active devices. They can communicate with each other by generating radio waves alternatively. When one device transmits data, the other listens to it and vice-versa.

    - **Reader/Writer Mode:**
      - **E.g.** when we access data from smart phones using NFC tags.
      - This mode is **similar to RFID**. Here the active device like smartphones and tablets reads of writes the data on NFC tag using the principle of electromagnetic induction. A time varying electromagnetic field generates the voltage in this passive tag. This voltage powers up the chip in this NFC tag. Once powered up the tag responds with its own information.

    - **Card Emulation Mode**

- E.g. when smartphones are used for mobile payments.
- Both devices are active device. One device will be a smart phone and the second device is a payment terminal. Here, **smartphone acts like a passive smart card** and don't generate their own radio waves. They only respond back with the requested data by the payment terminal. Operating principle in this mode is similar to reader/writer mode.

- **Applications**
  - **File sharing**
  - **Contactless payments:** NFC is behind the cards that we have over card readers on shops
  - **Mobile payments**
  - **Pairing different devices**
  - **Information sharing using smart posters and business cards**
  - **Home automation**
    - NFC tech is present in new age speakers, household appliances, and other electronic devices that we monitor and control through our smartphones.
    - E.g. changing temperature of AC, ambient lighting etc.
    - Automatic closing of doors
  - **Healthcare:** NFC is used to monitor patients stats through NFC-enabled wristbands.
  - **Library systems**: Keeping tabs on library books
  - **Preventing Auto theft**
  - **Personal usage**
  - **Running unmanned toll booths**
  - **Wireless charging**

- **Advantages over other forms of communication**.
  - NFC vs Bluetooth: While Bluetooth provides for higher data rate sharing; But **NFC reduces the time required for pairing of devices**. In case of NFC the two devices can be set up in less than 0.1 seconds. Once the pairing between devices is done, for communications either Bluetooth or wifi can be used.
  - **NFC vs RFID**: NFC is derived from RFID standards and the working principles are quite similar to RFID. But RFID works on large band of frequencies (LF: 125 kHz or 134 kHz) HF: 13.56 MHz; UHF: 860-960 MHz). But **NFC works on a particular frequency band** i.e. 13.56 MHz band. In case of RFID, the reader sends the request to the RFID tag and in response the RFID tag replies back to the reader. So, in case of RFID there is only one way communication. While in case of **NFC peer to peer communication is possible**.

  - **NFC vs QR Codes**: In case of QR codes, scanning if required to access the information. In case of NFC, just by tapping mobile to NFC tag, information can be easily accessed. Therefore, access time required in case of NFC is less than that of QR code. Further NFC is more secure than the QR code. Because in case of QR code, wrong information may be provided by putting another QR code on top of the 1st QR code, while in case of NFC, if someone puts another NFC tag on top of the first one, then neither of the tags would be accessed. Thus, NFC tech is more secure than the QR code technology.

- **How secure is this tech?**
  - Since NFC works at very close distance, it makes it difficult for attackers to record or communication between the devices compared to other wireless technologies.
  - The user of the NFC-enabled device determines by the touch gesture which entity the NFC communication should take place with, making it more difficult for the attacker to get connected.

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- Peer to Peer communication provides a mechanism to cipher all exchanged data to avoid external interpretation of recorded communication.

- **When did NFC tech start?**
- In 2004, consumer electronics companies, Nokia, Philips, and Sony together formed the NFC forum, which outlined the architecture for NFC technology to create powerful new consumer driven products.

A) 'TAP TO PAY' FOR UPI LAUNCHED BY GOOGLE PAY

- Google has recently launched a new feature in India, '**Tap to pay for UPI'**, in collaboration with Pine Labs. The feature makes use of Near Field Communication (NFC) technology.
- The functionality would allow users with NFC-enabled Android Smartphones and UPI accounts linked to Google Pay to carry out transactions just by tapping their phone on any Pine Labs Android point-of-sale (POS) terminal across the country. **Till now, TAP to pay was only available for cards**.
- Google Pay has been the first among UPI apps to bring Tap to Pay feature working on POS terminals.

- **How will this work?**
  - Once the users tap their phones on the POS terminal, it will automatically open the Google pay app with the payment amount pre-filled. Users can then verify the amount and merchant name and authenticate the payment, using their UPI PIN.
  - They will be notified when the payment is successful.
  - **Advantage:** The process is much faster compared to scanning a QR code or entering UPI-linked mobile number which has been the conventional way till now.
- **Are other companies using NFC tech for payments using smartphones?**
  - In Feb 2022, Apple introduced Tap to Pay on the iPhone. It will allow merchants across the US to use their iPhone to accept Apple Pay, contactless credit and debit cards, and other digital wallets through a tap on their iPhone without the need of any additional hardware or payment terminal.

At checkout, a customer just needs to hold their iphone or apple watch to pay with Apple Pay, their contactless credit or debit card, or other digital wallet near the Merchant's iphone to complete the payment using NFC technology.

6. BLUETOOTH COMMUNICATION

- Bluetooth is a wireless communication technology that can be used for close range of data transmission from one digital device to another. It relies on short-range radio frequency, and any device that incorporates the technology can communicate as long as it is withing the required distance.
- It is essentially a one-to-one wireless connection that uses 2.4 GHz band radio waves. This is the same frequency which other wireless technologies in the home or office, such as cordless phones and WiFi routers use.
- Bluetooth creates a 10 meter (33 foot) radius wireless network, called a personal area network (PAN) or **piconet**, which can network between 2 to 8 devices.
- It is an electronics "standard", which means that manufacturers that want to include this feature have to incorporate specific requirements into their electronic device.

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These specifications ensure that the devices can recognize and interact with other devices that use Bluetooth technology.

The "Bluetooth" name is taken from a 10th-century Danish king named Harald Bluetooth, who was said to unite disparate, warring regional factions. Like its namesake, Bluetooth technology brings together a broad range of devices across many different industries through a unifying communication standard.

- **Advantages:**
  - Bluetooth offers a uniform structure for a wide range of devices to connect and communicate with each other.
  - It has achieved global acceptance and almost any Bluetooth enabled device, anywhere in the world can connect to another Bluetooth enabled device nearby.
  - Low power consumption when compared to wifi and other such wireless systems.
  - It also costs much less to implement.

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