CHAPTER 1

INTRODUCTION TO MOBILE APPLICATION DEVELOPMENT AND SMART PHONE HARDWARE ARCHITECTURE

CHAPTER OUTLINE

1.1 MOBILE DEVICE

A **mobile device** is a portable electronic device that is designed to be easily carried and used by an individual. It is a handheld computing device which is small enough to hold and operate in the hand.It typically includes a computing platform, a display screen, and an input method, such as a touch screen or keyboard. Examples of mobile devices include smartphones, tablets, and wearables such as smartwatches.

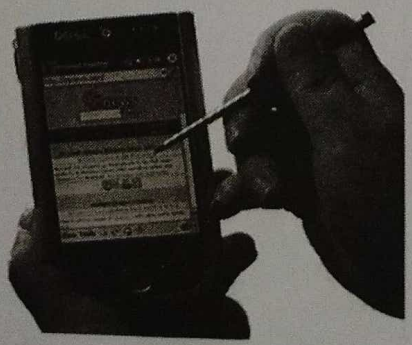
These devices typically have a variety of built-in features, such as internet connectivity, cameras, GPS, and sensors, and they can also run a wide range of third-party applications. Mobile devices allow users to communicate, access information, and perform various tasks on the go. They are widely used for activities such as making phone calls, sending text messages and emails, browsing the internet, integrated cameras, digital media players, Global Positioning System (GPS) capabilities, social networking, and playing video games.Mobile devices may run ***mobile operating systems*** that allow third-party applications to be installed and run on mobile device.

Mobile devices are commonly used for communication, entertainment, and productivity, and they often have a variety of built-in sensors, such as cameras, microphones, and accelerometers. With the help of mobile devices, people can access the internet, make phone calls, send messages, and use a variety of apps and software.Mobile devices may provide biometric user authentication such as face recognition or fingerprint recognition.

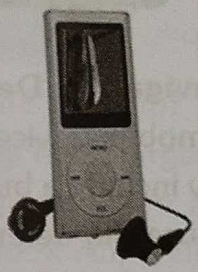
1.2 DIFFERENT TYPES OF MOBILE DEVICES

There are many kinds of mobile devices, designed for different applications. This includes :

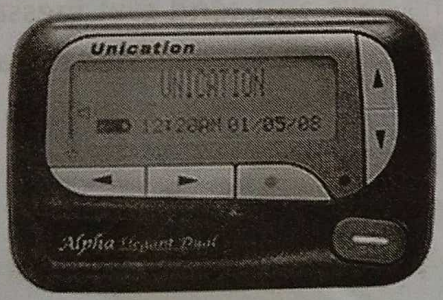
- **Personal Digital Assistants :** A personal digital assistant (PDA) is a handheld device that can be used for a variety of tasks, such as scheduling appointments, maintaining an address book, and sending and receiving email. PDAs typically include a touch screen or stylus for input, and may also have a small keyboard. They can also be used to browse the internet, listen to music, and play games. PDAs were popular in the early 2000s, but have since been largely replaced by smartphones, which offer many of the same features and more.

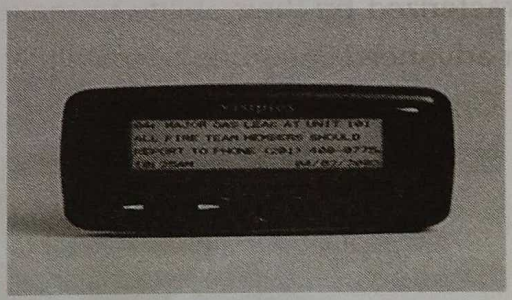


- **Portable Media Players :** A portable media player (PMP) is a handheld device that is used for storing and playing back digital media files such as music, videos, and pictures. PMPs typically have a small screen for viewing video and a set of controls for navigating through and playing back media files. They often have built-in storage for storing media files, and can also accept removable memory cards for additional storage. Some PMPs also have the ability to connect to the internet to download and stream media files. They were also popular in the early 2000s.



- **Pagers :** A pager, also known as a beeper, is a wireless telecommunications device that receives and displays alphanumeric or voice messages. Pagers were originally developed for use in emergency medical services and other critical industries, but they were also commonly used by individuals as a means of communication in the 1990s and early 2000s. The messages were usually sent by telephone or a computer, and were then transmitted via a radio or cellular network to the pager. Pagers had a small display that showed the phone number or message of the sender. Examples of pagers include Motorola Bravo, Motorola Elite, and the Motorola Advisor.





- **Feature Phones :** Feature phones, also known as basic phones or feature-rich mobile phones, are a type of mobile device that are designed to provide basic communication and messaging capabilities. They are typically less expensive and less complex than smartphones, and they often have a longer battery life and a more durable design.

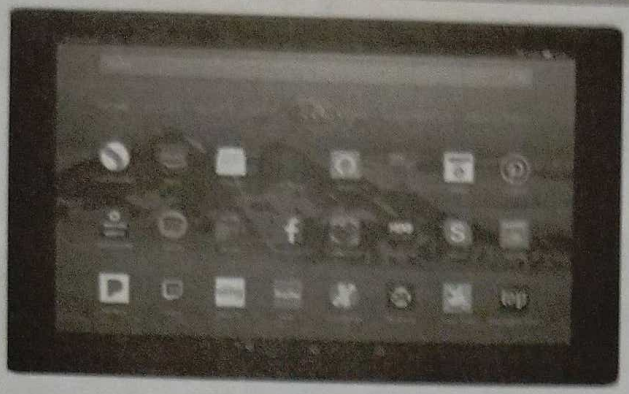
  Feature phones typically include a keypad or numeric keypad for making calls and sending text messages, a small display screen, and basic features such as a calendar, alarm clock, and contacts list. They may also include basic camera, media player and built-in FM radio. Some feature phones also include built-in games, torchlight and

even some basic internet capabilities such as WAP or GPRS.Examples of feature phones include Nokia 3310, Samsung Guru, Motorola W230, JioPhone etc.

- **Personal Navigation Devices :** Personal navigation devices, also known as GPS devices, are mobile devices specifically designed for navigation and location tracking. They typically include a built-in GPS receiver, a display screen, and mapping software. They can be used to determine a user's current location, plan routes to a destination, and provide turn-by-turn directions. Examples of personal navigation devices include the TomTom Go, the Garmin Nuvi, and the Magellan RoadMate.

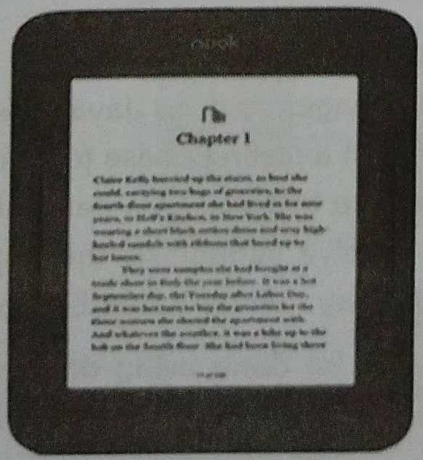
- **Smartphones :** These are the most common type of mobile devices and are characterized by their ability to make phone calls and send text messages, as well as their advanced computing capabilities. Examples include the iPhone, Samsung Galaxy, and Google Pixel etc.

- **Tablets :** These are larger than smartphones, with bigger screens and more powerful processors. They are designed for media consumption and entertainment, as well as for productivity tasks such as web browsing and document editing. Examples include the iPad, Samsung Galaxy Tab etc.



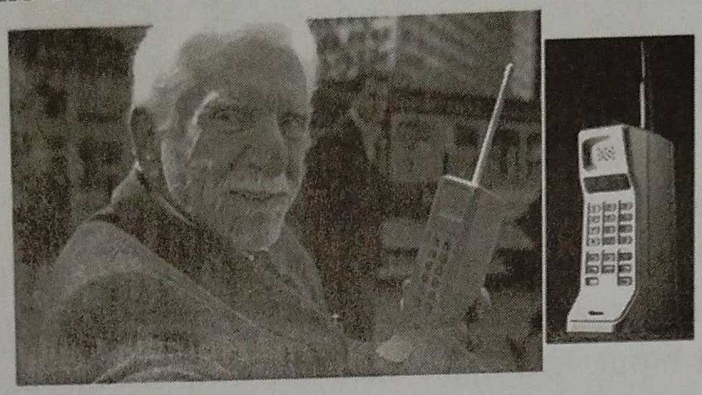
- **Laptops :** These are portable computers that can be used for tasks such as word processing, web browsing, and video playback. They have larger screens and more powerful processors than tablets and smartphones, and often include a keyboard and trackpad for input. Examples include the MacBook Air, Dell XPS, and Lenovo ThinkPad etc.
- **Wearables :** These are small, portable devices that can be worn on the body, such as smartwatches and fitness trackers. They are designed to provide quick and easy access to information, such as notifications and fitness data, and often have touch screens or voice-controlled interfaces. Examples include the Apple Watch, Samsung Galaxy Watch, and Fitbit etc.

- **E-readers :** These devices are designed specifically for reading digital books, magazines, and newspapers. They typically have black-and-white screens that are easy to read in direct sunlight and have long battery life. Examples include Kindle, Kobo, and Nook etc.



- **Gaming Devices :** These devices are specifically designed for gaming, usually have the capability to connect to a TV for large screen gaming. Examples include Nintendo Switch, Sony PS Vita and Xbox portable.

Evolution of Mobile Phones : In 1973 the first phone call was made by this man.



Martin Cooper, the former Motorola vice president and division manager made the call on the company's **DynaTAC** phone.

https://www.youtube.com/watch?v=xnobktms0TM

How mobile phone works → **https://www.youtube.com/watch?v=RNN50YmeUNM**

1.3 MOBILE APPLICATION DEVELOPMENT

Mobile application development is the process of creating software applications that run on mobile devices such as smartphones and tablets. These applications, also known as **"apps,"** can be used for a wide variety of purposes, including entertainment, social networking, productivity, and more.

The process of mobile application development typically involves several stages, including concept development, design, coding, testing, and deployment. The first stage, concept development, involves creating an idea for the app and determining its overall purpose and functionality.Once the concept is developed, the design stage begins. This involves creating the visual elements of the app, such as its layout, user interface, and graphics.

Once the design is complete, the coding stage begins. This is where the app is actually built using programming languages such as Java, Swift, and C#. After the coding is complete, the app goes through a testing phase to ensure it works properly and is free of bugs. Once the app has been tested and is determined to be functional, it is ready for deployment. This can involve submitting the app to an app store, such as the Apple App Store or Google Play, where it can be downloaded by users.

Mobile app development can be done using different frameworks, languages, and tools. Some popular frameworks include React Native, Xamarin, and Flutter, they

allow developers to create apps that can run on multiple platforms (iOS and Android), with a single codebase.

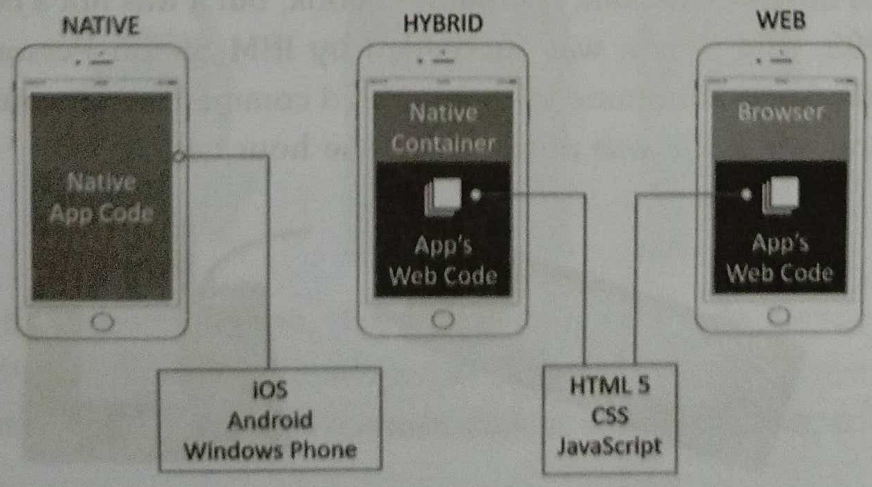
1.4 CLASSIFY MOBILE APPLICATION DEVELOPMENT APPLICATIONS, NATIVE, WEB AND HYBRID

Mobile application development can be classified into three main categories: Native, Web, and Hybrid.

Native Mobile Application Development involves creating apps that are specifically designed to run on a particular mobile platform, such as iOS or Android. These apps are typically developed using a programming language that is specific to the platform, such as Swift for iOS or Java for Android. Native apps have access to all the features and capabilities of the mobile device, such as the camera, GPS, and accelerometer, and generally have the best performance and user experience.

Web Mobile Application Development, also known as mobile web development, involves creating apps that are accessed through a web browser on a mobile device. These apps are typically written in HTML, CSS, JavaScript, and JQuery, and are designed to be accessed through a web browser, rather than downloaded from an app store. Web apps do not have access to all the features of a mobile device and typically have less features than native apps, but they are platform-independent, meaning that they can run on any device with a web browser.

Hybrid Mobile Application Development is a combination of both native and web app development. Hybrid apps are built using web technologies such as HTML, CSS,Javascript,JQuery,Mobile JavaScript frameworks, Cordova/PhoneGap, but they are wrapped in a native container, which allows them to access the device's hardware and software features. Hybrid apps are platform-independent, meaning they can run on multiple operating systems with a single codebase.



1.5 SMARTPHONE

A **Smartphone** is a type of mobile phone that combines advanced computing and connectivity capabilities with the functionality of a traditional mobile phone. Smartphones typically run on operating systems such as iOS, Android, and Windows Mobile, and have a wide range of features and capabilities, including the ability to make phone calls, send text messages, access the internet, and use a variety of mobile applications (apps).

A Smartphone typically has a larger screen than a traditional mobile phone, and its interface is usually based on a touch screen. It also has advanced features like camera, GPS, accelerometer, compass and a wide range of sensors. It also has powerful processor and more memory compared to a traditional mobile phone, which allows for more advanced apps and services, such as streaming video and music, and video conferencing.

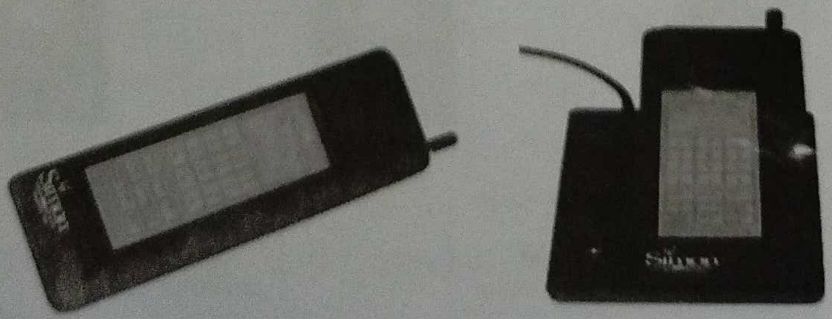
In addition to the standard features of a mobile phone, smartphones also have various connectivity options, such as Wi-Fi, Bluetooth, and cellular data, which allow them to connect to the internet, other devices, and networks. This allows users to access a wide range of information and services, such as email, social media, and online shopping, as well as various location-based services, such as maps and navigation.

1.6 EVOLUTION OF SMARTPHONES

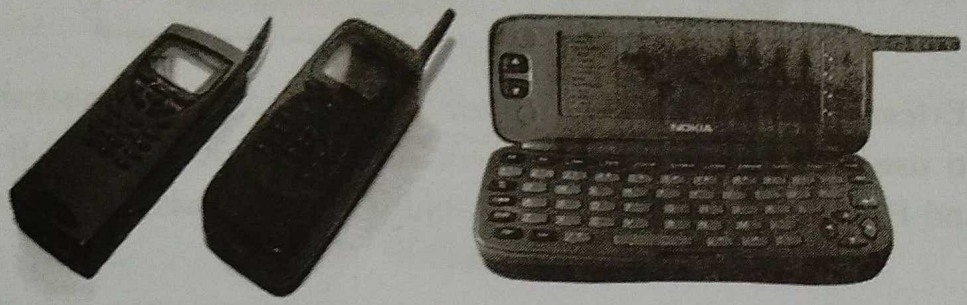
The **evolution of smartphones** has been a rapid and ongoing process since the first smartphone was invented in 1992. The first smartphones were large, bulky devices that were primarily used for making phone calls and sending text messages, but as technology advanced, smartphones have become smaller, more powerful, and increasingly versatile, with many new features and capabilities added over time.

Evolution of smartphones → https://www.youtube.com/watch?v=TedBqinR04o

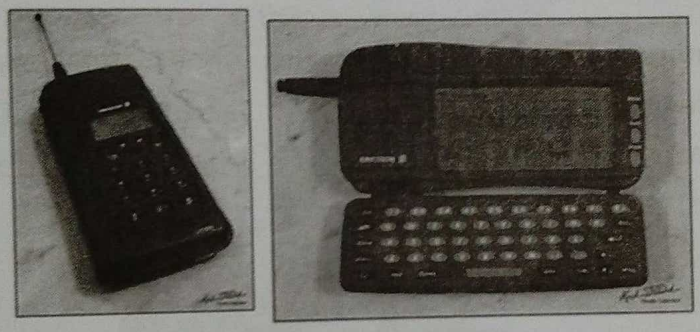
1993 - The first smartphones were **IBM Simon** which was released in 1992, it had a touch screen display, calendar, and address book, but it was not a commercial success. Then in 1993, IBM Simon was succeeded by IBM Simon Personal Communicator which was the first smartphone to be marketed commercially.It could take notes, send messages and e-mails. It was powered by one hour battery life.



1996 - The Nokia 9000 Communicator was a mobile phone and personal digital assistant (PDA) that was first released in 1996. It was one of the first devices to combine the functions of a phone and a PDA, and was considered to be an originator to modern smartphones. Its features are e-mail, short messaging, internet access, calendar, address book, calculator.

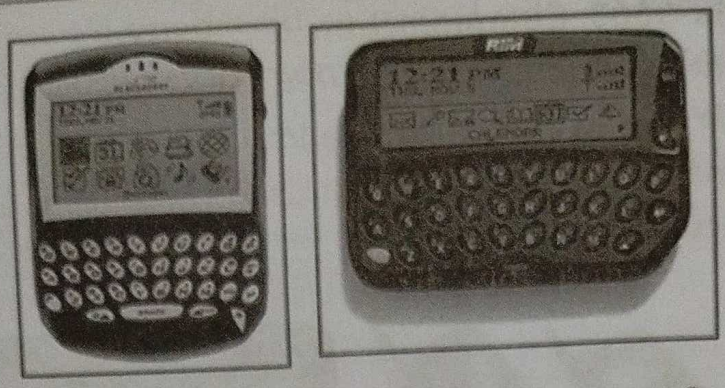


1997 - The Ericsson GS 88 Penelope was a mobile phone developed by Ericsson and was released in 1997. It was considered as one of the first smartphones as it had many features that are now common in modern smartphones.

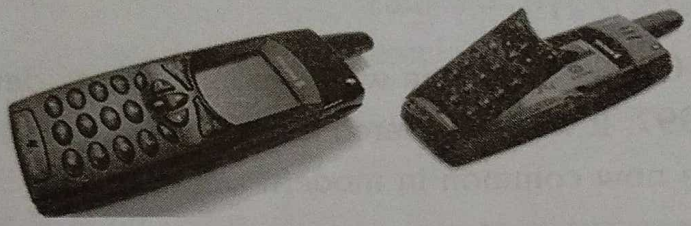


1999 - The Qualcomm pdQ Smartphone was a mobile phone developed by Qualcomm, released in 1999. It was considered to be a pioneer in the smartphone industry as it featured advanced capabilities for its time, such as the ability to access the internet and run third-party applications.

1999 - The BlackBerry phone, developed by Research In Motion (RIM), was first released in 1999. It was initially marketed as a two-way pager, but it eventually evolved into a smartphone with advanced features such as email, calendar, and a web browser.



2000 - Ericsson R380 is the first phone marketed as a Smartphone. It is the first device to use Symbian OS. It was with resistive touchscreen. It combined mobile phone and PDA functions and offered limited web browsing.



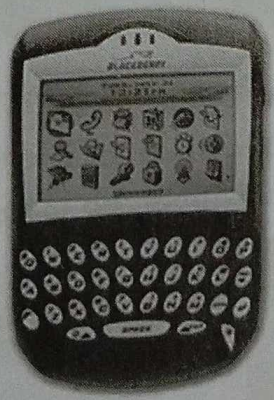
2001- The **Samsung SPH-1300**, also known as the Samsung Smartphone, was a mobile phone developed by Samsung and released in 2001. It was one of the early smartphones that ran on the Windows CE operating system and was considered as one of the first smartphones from Samsung.

2001 - Windows CE is a compact version of the Windows operating system designed for use on small devices such as mobile phones, PDAs, and embedded systems, was released in 2001.

2002 - BlackBerry OS, also known as BlackBerry Device Software or BlackBerry Handheld Software, was the operating system developed by Research In Motion (RIM) for the BlackBerry line of smartphones. The first version of BlackBerry OS, version 1.0, was released in 2002.

2003 - The BlackBerry 6210with scroll wheel was a mobile phone developed by Research In Motion (RIM), and was released in 2003. It was a successor of the BlackBerry 5810 and it was considered as one of the early smartphones that ran on the BlackBerry OS.

BlackBerry 7210 offered color screenand was released in 2004.

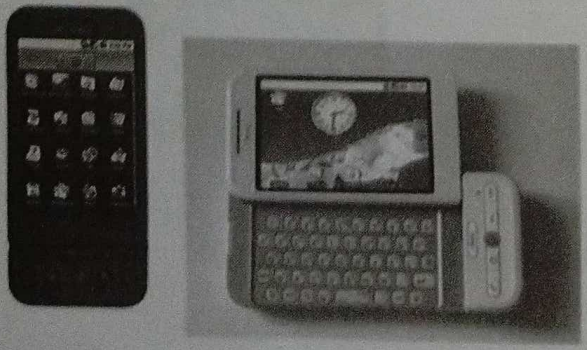


2006 - The BlackBerry Pearl 8100with Middle scroll wheel is a smartphone developed by BlackBerry, which was first released in 2006.

2007 - The **iPhone** is a line of smartphones designed and marketed by Apple Inc, first phone with multi-touch capabilities. The first iPhone was announced on January 9, 2007, and was later released on June 29, 2007.

2007 - The **Samsung F700**, also known as the Samsung Ultra Smart F700, is a smartphone developed by Samsung that was first released in 2007. It features a large, high-resolution touch screen display, a slide-out QWERTY keyboard, and a 5-megapixel camera. It runs on the Windows Mobile operating system. The F700 also has support for 3G connectivity and GPS.

2008 - The **T-Mobile G1**, also known as the **HTC Dream**, is a smartphone developed by HTC and released by T-Mobile in 2008. It is the first phone to run on the Android operating system, which was developed by Google.



In recent years, smartphones have become even more advanced, with features such as facial recognition, fingerprint sensors, and advanced AI capabilities. Additionally, 5G technology has brought about faster internet speeds and more reliable connectivity. With the advent of foldable and rollable displays, smartphones are becoming more versatile and adaptable to different use cases.

1.7 KEY FEATURES OF SMARTPHONE

Smartphones typically have a variety of features that make them useful and convenient for a wide range of tasks.

Some of the key features of smartphones include :

1. **Communication :** The ability to make phone calls and send text messages is a fundamental feature of smartphones. Many smartphones also include features such as voicemail, call forwarding, and conference calling.
2. **Internet Connectivity :** Smartphones have built-in cellular connectivity, allowing them to connect to the internet using 3G, 4G, or 5G networks. This feature enables users to access the internet, check email, and use various internet-based apps and services.
3. **Multimedia :** Smartphones include cameras, video recorders, and music players, enabling users to capture and share photos and videos, and listen to music.
4. **Camera :** Smartphones typically come equipped with at least one built-in camera, and many have multiple cameras for capturing still images and videos.
5. **GPS :** Many smartphones include GPS technology, which allows them to determine their location and be used for location-based services.
6. **Touchscreen display :** Most smartphones feature a touch-sensitive display, which allows users to interact with the device using gestures such as tapping, swiping, and pinch-to-zoom, typing, and interacting with apps.
7. **App Store :** Smartphones have access to app stores, where users can download and install various apps, such as games, social networking apps, productivity apps, and more.
8. **Personal Assistant :** Smartphones have virtual personal assistants like Siri, Alexa, Google Assistant, and Bixby which can be used for various tasks like scheduling, weather forecast, setting reminders, and more.
9. **Security :** Smartphones have various security features such as fingerprint scanners, facial recognition, and password protection to keep the device and user's data secure.
10. **Calendar :** With calendar/scheduler all our appointments can be entered and edited directly on the Smartphone.

11. **Address Book (Contacts)** : With a Smartphone, all your contacts can be added, deleted and edited. A Smartphone can even prompt you to automatically create a new contact in your Address Book after communicating with a new person/number.
12. **Bluetooth** : Bluetooth is a wireless connection technology used to connect Bluetooth-capable hardware over short distances.
13. **Processing Power** : Smartphones have advanced processors that allow them to run complex apps and perform other tasks quickly and efficiently.
14. **Storage**: Smartphones come with varying amounts of internal storage, allowing users to store apps, music, photos, videos, and other types of data.
15. **Operating System** : Smartphones run on different operating systems such as iOS, Android, Windows and Blackberry.
16. **Multi-tasking** : smartphones have the ability to run multiple apps at the same time.
17. **Battery Life**: Battery life is an important aspect of smartphones, as users rely on their devices for a variety of tasks throughout the day.
18. **Biometric Security** : Many smartphones come with features such as fingerprint scanners, facial recognition and iris scanner for additional security.
19. **Additional Features** : Some smartphones come with additional features such as water resistance, wireless charging, and expandable storage.

1.8 SYSTEM ON CHIP (SOC)

A **System on Chip (SoC)** is an integrated circuit (IC) that integrates all components of a computer or electronic system into a single chip. It is a combination of different components like a microprocessor, memory interface, secondary storage, input/output interfaces, and other peripherals, all integrated onto a single piece of silicon.

SoCs are commonly used in mobile devices, such as smartphones and tablets, as well as in other portable electronic devices like digital cameras and gaming consoles. They are also used in embedded systems and the Internet of Things (IoT) devices.

The main advantage of SoCs is their small size and low power consumption, which allows for more compact and portable electronic devices. Additionally, SoCs can also improve performance and reduce costs by integrating multiple components onto a single chip, rather than having to use multiple separate components.

SoCs found in many consumer products, from modems, wireless routers, smart watches, mobile phones, DVD players, televisions and iPODs.

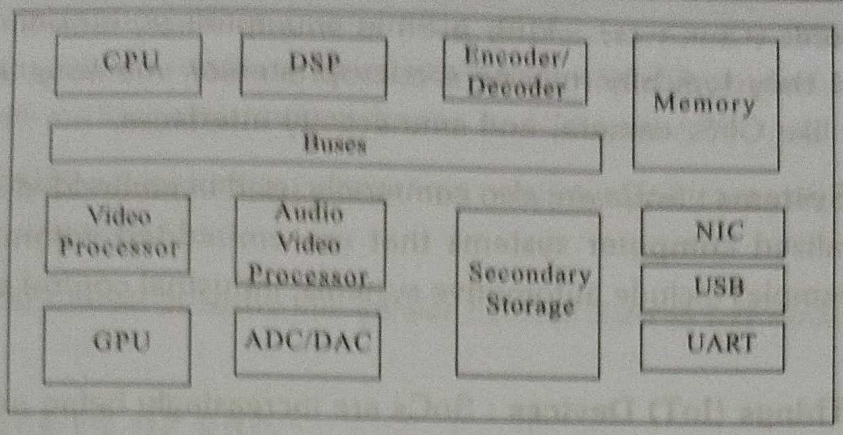


FIG 1.1 : Basic System-on-Chip Model

The top SoC (System on Chip) manufacturers in the industry are:

1. **Qualcomm :** Qualcomm is a leading manufacturer of mobile SoCs, with a strong presence in the smartphone market. Its Snapdragon line of SoCs is widely used in high-end and mid-range smartphones, and also in some laptops.
2. **Samsung :** Samsung is a major player in the SoC market, and produces a wide range of SoCs for mobile devices, including its Exynos line of SoCs for its own devices and also for other brands.
3. **MediaTek:** MediaTek is a Taiwan-based SoC manufacturer that is known for producing SoCs for budget and mid-range mobile devices.
4. **Apple :** Apple designs and manufactures its own SoCs, known as A-series, for its iPhone and iPad devices, which are known for their high performance and power efficiency.
5. **Huawei :** Huawei, a Chinese multinational technology company, designs and manufactures its own SoCs, known as HiSilicon, which are used in its smartphones, tablets, and other devices.
6. **Intel :** Intel is a major player in the computer processor market and also produces SoCs for mobile devices and IoT devices.
7. **Broadcom :** Broadcom designs and manufactures SoCs for a wide range of applications, including mobile devices, networking equipments, and set-top boxes.
8. **NVIDIA :** NVIDIA is a major player in the graphics processing unit (GPU) market and also produces SoCs for AI and autonomous vehicles applications.

Typical Applications of SOC : System on Chip (SoC) technology is widely used in a variety of applications, including :

1. **Mobile Devices :** SoCs are widely used in smartphones, tablets, and other mobile devices, and they typically include a microprocessor, memory, and various other components like GPS, camera, and connectivity interfaces.
2. **Embedded Systems :** SoCs are also commonly used in embedded systems, which are small, specialized computer systems that are embedded within other devices or products. Examples include automotive systems, industrial control systems, and home appliances.
3. **Internet of Things (IoT) Devices :** SoCs are increasingly being used in IoT devices, such as smart home devices, wearable devices, and industrial sensors. These devices often require low power consumption and small size, which makes SoCs an ideal solution.
4. **Digital Cameras :** SoCs are used in digital cameras, for image processing and management. They are also used in other imaging applications, such as medical imaging, surveillance, and industrial inspection.
5. **Gaming Consoles :** SoCs are also used in gaming consoles, like the Playstation or Xbox. These SoCs are specially designed to handle the high-performance requirements of video games.
6. **Automotive :** SoCs are used in automotive applications, such as infotainment systems, driver assistance systems, and autonomous vehicle systems.
7. **Networking :** SoCs are also used in networking equipment, such as routers, switches, and wireless access points.
8. **Television and Set-top Boxes :** SoCs are used in television sets and set-top boxes, for decoding and displaying video, as well as providing other features like internet connectivity and streaming.

Examples of SoC :

1. **Qualcomm Snapdragon :** It is a popular SoC used in many high-end and mid-range smartphones. It includes a microprocessor, memory, and various other components.
2. **Samsung Exynos :** It is used in many Samsung smartphones and tablets.
3. **MediaTek Helio :** It is used in many budget and mid-range smartphones and tablets.
4. **Apple A-series :** Apple designs and manufactures its own A-series SoCs, which are used in its iPhone and iPad devices.
5. **Huawei HiSilicon :** It has its own HiSilicon SoCs, which are used in its smartphones, tablets, and other devices.

6. **NVIDIA Tegra :** It is used in gaming consoles, like the Nintendo Switch, and in many other applications like automotive, drones and AI systems.
7. **Broadcom BCM :** It is used in networking equipment, such as routers, switches, and wireless access points.
8. **Intel Atom :** It is used in many low-power devices such as IoT devices and embedded systems.

1.9 COMPONENTS OF SOC

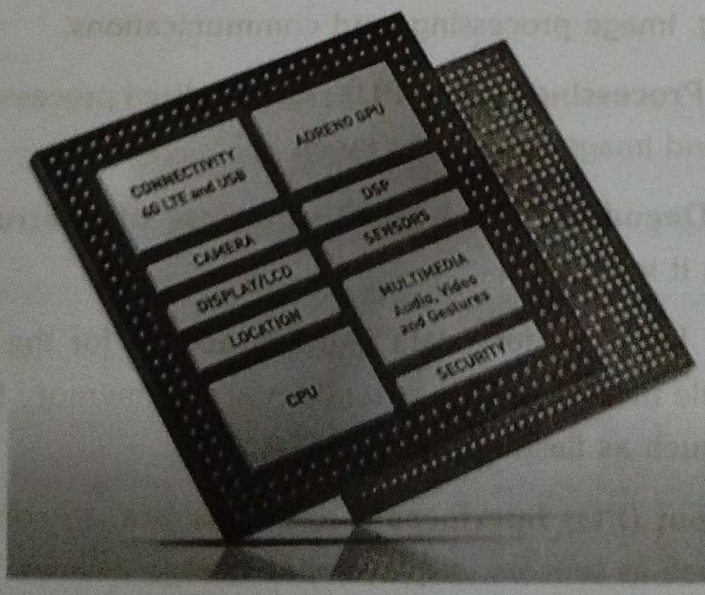
SoC is the short term for **System on a Chip**. A *System on a Chip* is an electronic integrated circuit that contains various electronic components designed to work together to achieve a common goal. The first part of the term - **System** - says that its all about a complex electronic assembly, while the last part - **Chip**- tells you that all the components of that system are squeezed together on a single integrated circuit.

A System on Chip (SoC) typically includes a variety of components that are integrated onto a single piece of silicon. These components may include :

1. **Processor :** It is the heart of SoC, usually SoC contains at least one or more than one coprocessor. It can be a microcontroller, microprocessor, or DSP. Most of the time DSP is used in every SoC as a processor.
2. **Microprocessor :** The microprocessor is the "brain" of the SoC and is responsible for executing instructions, performs calculations and controlling the other components of the SoC.
3. **DSP :** Digital Signal Processor, a specialized microprocessor designed for digital signal processing capabilities, which are used for tasks such as audio and video processing, image processing, and communications.
4. **Graphics Processing Unit (GPU) :** A specialized processor designed for handling graphics and image processing tasks.
5. **Encoder/Decoder :** Used for the purpose of interrupting information and converting it into codes.
6. **Memory :** Used to store data and instructions for the CPU. This can include both volatile memory, such as random access memory (RAM), and non-volatile memory, such as flash memory.
7. **Input/Output (I/O) Interfaces :** Allows the SoC to communicate with external devices, such as sensors, displays, and storage devices.

8. **Communication Interfaces :** Allows the SoC to communicate with other devices, such as other SoCs or networks. Examples include Ethernet, Wi-Fi, and Bluetooth.
9. **Analog-to-Digital and Digital-to-Analog Converters (ADC/DAC) :** Used to convert analog signals to digital and vice-versa.
10. **Peripherals :** SoCs can include a wide range of peripherals, such as cameras, GPS modules, accelerometers, and touchscreens, which are used for various functions like image capturing, navigation, motion sensing, and touch interactions.
11. **Power Management :** SoCs include power management components, such as voltage regulators and clock generators, which are used to control the power consumption and clock frequency of the SoC.
12. **Wireless Connectivity :** SoCs can include wireless connectivity interfaces, such as Wi-Fi, Bluetooth, and cellular, which allow the device to connect to wireless networks and other devices.
13. **Network Interface Card :** the Network interface card provides a connection of the network to system.
14. **Security :** SoCs may include security features like encryption, secure boot, and secure key storage, which are used to protect the device from unauthorized access and malware.
15. **UART :** Universal Asynchronous Receiver Transmitter is included in SoC which is used to transmit or receive serial data. Voltage regulators, Oscillators, clocks are also part of SoC.

Here's an illustration of what components Snapdragon 410 *System on a Chip* from Qualcomm includes :



1.10 ADVANTAGES AND DISADVANTAGES OF SOC

1.10.1 ADVANTAGES OF SYSTEM ON A CHIP (SOC)

1. **Reduced Size and Complexity** : SoCs integrate multiple components into a single chip, which reduces the overall size and complexity of a device.
2. **Increased Efficiency** : SoCs can lead to increased efficiency in terms of power consumption and performance, as components can be optimized to work together.
3. **Lower Cost** : SoCs can reduce the overall cost of a device, as they require fewer components and less Printed Circuit Board space.
4. **Increased Functionality** : SoCs can include a wide range of components, such as microprocessors, memory, and peripheral interfaces, which can increase the functionality of a device.

1.10.2 DISADVANTAGES OF SYSTEM ON A CHIP (SOC)

1. **Limited Flexibility** : SoCs are designed to work together and may not be easily replaceable or upgradeable.
2. **Higher Development Costs** : Developing SoC can be more expensive than developing individual components, as it requires more specialized expertise.
3. **Limited Scalability** : SoCs are designed to work within a specific device or application, and may not be easily scalable to other products or applications.
4. **Possibility of Single Point of Failure** : If one component of a SoC fails, the entire chip may become inoperable.

1.11 DIGITAL SIGNAL PROCESSOR (DSP)

A **Digital Signal Processor (DSP)** is a specialized microprocessor that is designed to efficiently process digital signals, such as audio and video. In a system-on-a-chip (SOC), a DSP is integrated along with other components, such as memory and communication interfaces, to form a single, compact device.

DSP is a technique of performing the mathematical operations on the signals in digital domain. As real time signals are analog in nature we need first convert the analog signal to digital, then we have to process the signal in digital domain and again converting back to analog domain. Thus ADC is required at the input side whereas a DAC is required at the output end. A typical DSP system is shown in Fig. 1.2.

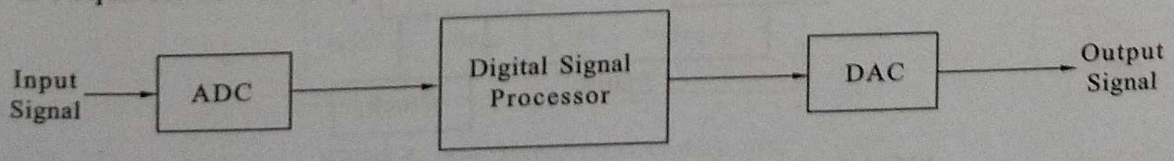


FIG 1.2 : A Typical DSP System

1.11.1 NEED OF DIGITAL SIGNAL POCESSOR (DSP)

There are several reasons why a digital signal processor (DSP) is needed in a system-on-a-chip (SOC) :

1. **High Computational Power :** DSPs are specifically designed to handle complex mathematical operations required for digital signal processing. SOCs that incorporate a DSP can perform these operations much more efficiently than general-purpose microprocessors.
2. **Real-time Processing :** Many applications such as audio and video require real-time processing, which DSPs are well-suited for.
3. **Low Power Consumption :** DSPs are optimized for low power consumption, which is important for mobile and battery-powered devices.
4. **Cost-Effective :** Integrating a DSP into an SOC can reduce the overall cost and size of a device, as it eliminates the need for separate DSP and microcontroller chips.
5. **Machine Learning Capabilities :** DSPs are also designed to handle matrix operations, which are required for many machine learning algorithms such as convolutional neural networks. So, DSPs can be used to perform AI-related tasks in SOCs.

1.12 DIGITAL SIGNAL PROCESSOR ARCHITECTURES

There are different architectures that can be used in Digital Signal Processors (DSPs), each with its own strengths and weaknesses. Some of the most common DSP architectures include :

1.12.1 TRADITIONAL DSP (DIGITAL SIGNAL PROCESSOR) ARCHITECTURES

Harvard Architecture : In this architecture, the instruction memory and data memory are separated, allowing for faster execution of instructions. It is often used in DSPs that need to perform a high number of mathematical operations.

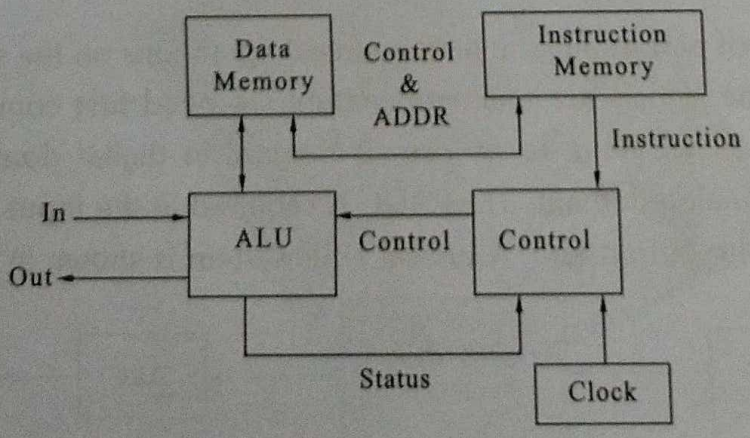


FIG 1.3 : Traditional DSP Architecture (Harvard Architecture)

Von Neumann architecture: This architecture is similar to the architecture used in general-purpose microprocessors, with a single memory space for both instructions and data. It is often used in DSPs that need to perform a high number of memory accesses.

1.12.2 MODERN DSP ARCHITECTURES

Modern DSP (Digital Signal Processor) architectures in mobile devices have evolved to meet the increasing demands for computational power and power efficiency.

Some of the most common modern DSP architectures in mobile devices include :

ARM Cortex-M Series : ARM Cortex-M series DSPs are widely used in mobile devices, they offer a balance of performance, power efficiency and cost. They are also designed to be highly configurable and can be tailored to specific applications.

Qualcomm Hexagon DSP : Qualcomm Hexagon DSP is a proprietary DSP architecture used in Qualcomm Snapdragon mobile processors. It is designed to handle a wide range of tasks, including multimedia processing, artificial intelligence, and sensor processing.

MediaTek Helio P-series : MediaTek Helio P-series DSPs are designed for mobile devices and offer a balance of performance, power efficiency, and cost. They are specifically optimized for multimedia processing, camera control, and other image-related tasks.

Apple's A-series DSP : Apple's A-series DSP is used in their custom-designed mobile processors, it is specifically optimized for their iOS devices and is used for tasks such as multimedia processing, machine learning, and augmented reality.

System on Chip (SoC) Based DSP Architectures : DSP (Digital Signal Processing) architectures in SoCs are designed to handle the specific computational demands of digital signal processing and are optimized for low power consumption. Some of the most common SoC-based DSP architectures include :

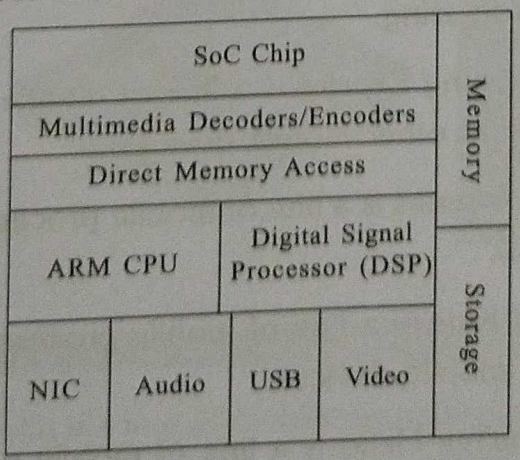


FIG 1.4 : SoC Based DSP Architecture

Multi-core DSPs : Multi-core DSPs are SoCs that integrate multiple DSP cores onto a single chip. This allows for parallel processing and improves the performance of the DSP. These DSPs are commonly used in applications such as multimedia processing, wireless communications, and artificial intelligence.

Application-Specific SoCs (ASICs) : ASICs are SoCs that are specifically designed for a particular application, such as video processing or audio processing. These SoCs are optimized for the specific computational demands of the application and can offer a high degree of performance and power efficiency.

Programmable SoCs : Programmable SoCs are SoCs that can be configured to meet the specific needs of different applications.

Heterogeneous SoCs : Heterogeneous SoCs are SoCs that integrate different types of processors, such as DSPs and general-purpose microprocessors, onto a single chip. This allows for a balance of performance and power efficiency, as different types of processing tasks can be handled by the appropriate processor.

Hybrid DSP SoCs : These SoCs combines the power of multi-core DSPs with a general purpose microcontroller to handle both digital signal processing and control tasks. They are commonly used in control systems, embedded systems and IoT devices.

1.13 CONTEMPORARY PROCESSORS IN SMART PHONES

Contemporary mobile phone processors are designed to meet the increasing demands for computational power, power efficiency, and connectivity in mobile devices. Some of the most common contemporary mobile phone processors include :

1. **Qualcomm Snapdragon :** Qualcomm Snapdragon is a line of mobile processors that are widely used in smartphones and other mobile devices. These processors are designed to handle a wide range of tasks, including multimedia processing, artificial intelligence, and wireless communications. They also include a Qualcomm Hexagon DSP for digital signal processing.
2. **Samsung Exynos :** Samsung Exynos is a line of mobile processors that are used in Samsung smartphones and other mobile devices.
3. **Apple A-series :** Apple A-series is a line of mobile processors that are used in Apple's iPhone and iPad devices.
4. **Huawei Kirin :** Huawei Kirin is a line of mobile processors that are used in Huawei smartphones and other mobile devices.
5. **MediaTek Helio :** MediaTek Helio is a line of mobile processors that are used in a wide range of mobile devices.

Apart from above ARM Cortex, Qualcomm Snapdragon, Nvidia Tegra is the most widely used mobile processors.

1.13.1 ARM CORTEX PROCESSORS

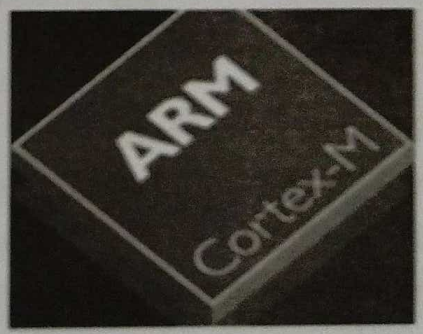
ARM Cortex processors are a series of microprocessors designed by ARM Holdings, a British multinational company that designs and licenses processor architectures. These processors are based on the ARM architecture, which is known for its low power consumption and high performance.

The Cortex series of processors are used in a wide range of devices, including smartphones, tablets, embedded systems, and the Internet of Things (IoT) devices. They are available in different configurations and can be tailored to meet the specific requirements of different devices.

The **Cortex-A series** processors are designed for use in high-performance applications such as smartphones and tablets. These processors feature a high-performance CPU, a GPU, and a memory controller. Some popular Cortex-A series processors include the Cortex-A53, Cortex-A57 and Cortex-A72.

The **Cortex-M series** processors are designed for use in microcontroller-based applications such as embedded systems and IoT devices. These processors feature a low-power CPU, a small amount of on-board memory, and a variety of peripheral interfaces. Some popular Cortex-M series processors include the Cortex-M0, Cortex-M3 and Cortex-M4.

Cortex-R series processors are designed for real-time applications such as industrial control, automotive and storage systems. These processors feature high-performance CPU, large memory and have fault tolerant features.



1.13.2 QUALCOMM SNAPDRAGONPROCESSORS

The Qualcomm Snapdragon is a line of mobile processors designed and manufactured by Qualcomm, a major American multinational semiconductor and telecommunications equipment company. These processors are used in a wide range

of mobile devices, including smartphones, tablets, and portable computers, and are known for their high performance and power efficiency.

The Snapdragon processors are based on the ARM Cortex architecture and are available in different configurations to meet the specific requirements of different devices. They typically include a central processing unit (CPU), graphics processing unit (GPU), memory, and other components such as a digital signal processor (DSP) and a cellular modem.

One of the most popular Snapdragon processors is the **Snapdragon 865**, which was released in December 2019. It is based on 7nm process technology and features an octa-core CPU with a maximum clock speed of 3.1GHz, an Adreno 650 GPU, and a X55 5G modem. This processor is used in many of the most recent smartphones and is known for its high performance and power efficiency.

Another popular Snapdragon processor is the **Snapdragon 765**, which was released in December 2019 as well. It is based on 7nm process technology and features an octa-core CPU with a maximum clock speed of 2.4GHz, an Adreno 620 GPU, and a X52 5G modem. This processor is used in many of the high-midrange smartphones and is known for its high performance and power efficiency.

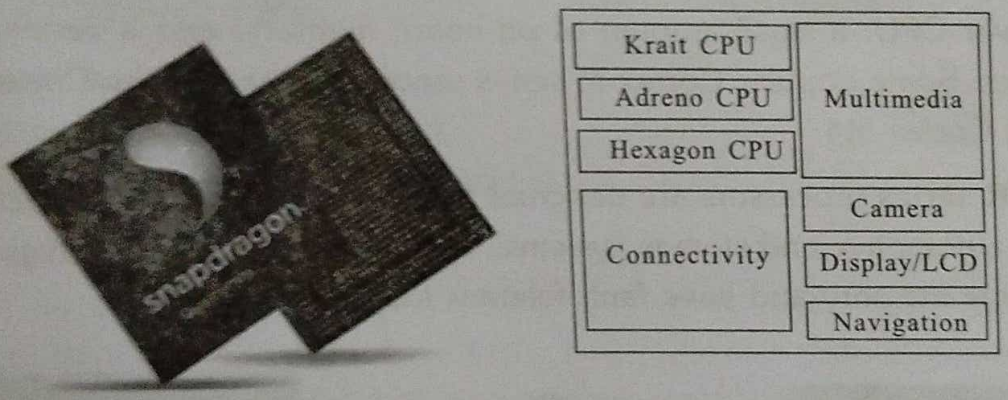


FIG 1.5 : Qualcomm Snapdragon 800 Processor Architecture

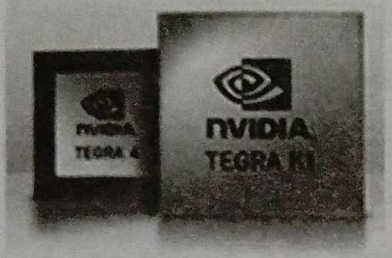
Nvidia Tegra Processors : Nvidia Tegra is a line of mobile processors designed and manufactured by Nvidia, an American multinational technology company known for its graphics processing units (GPUs) and other computer hardware. The Tegra processors are based on the ARM Cortex architecture and are available in different configurations to meet the specific requirements of different devices.

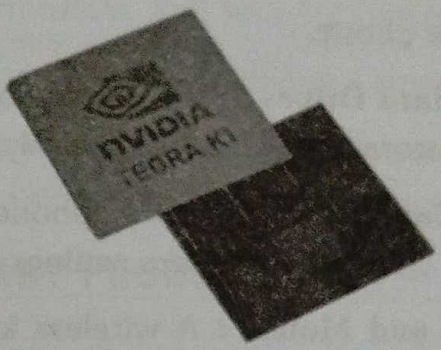
One of the most popular Tegra processors is the **Tegra 4**, which was released in 2013. It features a quad-core Cortex-A15 CPU, a 72-core GeForce GPU, and a fifth battery-saver core. It was used in devices such as the Microsoft Surface 2 and the Nvidia Shield.

Another popular Tegra processor is the **Tegra X1**, which was released in 2015. It features a 64-bit 8-core CPU, 256 Maxwell GPU cores and support for 4K video. It was used in devices such as Google's Project Tango tablet and the Nvidia Shield TV.

The most recent Tegra processor is the **Tegra X2** which was released in 2016, It features a Dual-core 64-bit ARM Cortex-A57 and quad-core 64-bit ARM Cortex-A53 CPU, 256 Maxwell GPU cores, and support for 4K video at 60fps and 1080p video at 120fps.

Nvidia has recently launched next generation mobile processor, **Tegra K1**. *Tegra K1* is Nvidias next generation mobile processor with 192 graphics cores for mobile gaming applications.





1.14 DIFFERENT PERIPHERAL DEVICES IN A SMART PHONE

1. **Display Screen :** The main display screen allows the user to interact with the device and view content such as text, images, and videos.
2. **Touch Screen :** A touchscreen allows the user to interact with the device by touching the display screen, rather than using physical buttons.
3. **Camera (Front & Rear) :** Smartphones typically include one or more cameras, which can be used to take photos and videos.
4. **Microphone :** A microphone allows the user to make phone calls, record audio, and use voice commands.
5. **Speaker :** A speaker allows the user to hear audio from the device, such as music, phone calls, and notifications.
6. **Accelerometer :** An accelerometer is used to detect the device's orientation and movement.
7. **GPS :** A GPS receiver is used to determine the device's location.
8. **Sensors :** Smartphones come with other sensors such as gyroscope, proximity sensor, barometer, ambient light sensor, and others.
9. **Battery :** A battery provides power to the device, allowing it to function.
10. **Connectivity Ports :** Such as USB, Bluetooth, NFC, etc.
11. **Memory Card Reader :** Used for expanding the device's storage capacity.

12. **Charging Port :** A charging port allows the user to charge the device's battery.
13. **SIM Card Tray :** A SIM card tray holds the SIM card, which is used to connect to a cellular network.
14. **Headphone Jack :** A headphone jack allows the user to connect headphones or speakers to the device.

There are several other peripheral devices that can be externally connected to a smartphone, including :

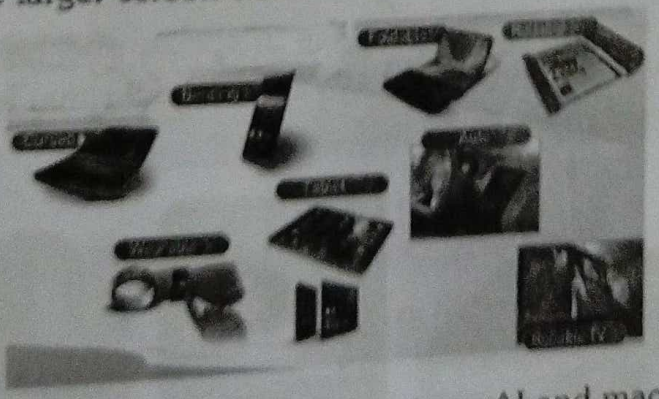
1. **External Storage Devices :** Such as USB flash drives or SD cards, for storing additional data on the phone.
2. **External Hard Drives :** An external hard drive can be connected to a smartphone to expand its storage capacity or to easily transfer large files.
3. **External Cameras :** Some smartphones can connect to external cameras via USB or wireless to control the camera settings and transfer the pictures.
4. **Keyboard and Mouse :** A wireless keyboard and mouse can be connected to a smartphone via Bluetooth to make it easier to type or navigate.
5. **Headphones or Earphones :** A pair of wired or wireless headphones can be connected to a smartphone to listen to music, podcasts, or make phone calls.
6. **Bluetooth Speakers :** A Bluetooth speaker can be connected to a smartphone to play music and other audio.
7. **Game Controllers :** A game controller can be connected to a smartphone to play games with more precision and control.
8. **Fitness Trackers :** These can be connected to a smartphone via Bluetooth to track the user's fitness activity (tracking steps, sleep patterns etc.)and sync data to monitor health data.
9. **Smart Watches :** These can be connected to a smartphone via Bluetooth to receive notifications, control music, make phone calls, track fitness data, and control the phone's functions remotely.
10. **Point of Sale (POS) Terminals :** Some smartphones have the capability to connect to POS terminals via NFC or Bluetooth to process payments.
11. **OBD-II Scanner :** A smartphone can be connected to an OBD-II scanner to diagnose and troubleshoot issues with a car.
12. **Virtual Reality (VR) Headset :** Some smartphones can be connected to VR headsets via USB or wireless for immersive gaming or viewing experiences of VR content.

13. **Printers :** Some smartphones can connect to printers via Bluetooth or wireless to print documents or photos.
14. **Projectors :** A smartphone can be connected to a projector to display content on a larger screen.
15. **USB-C Hubs :** Some smartphones can connect to USB-C hubs to expand their capabilities such as extra USB ports, HDMI, and Ethernet.
16. **Smart Home Devices :** A smartphone can be used to control and monitor smart home devices such as smart lights, thermostats, and security cameras.
17. **Portable Chargers :** Portable chargers can be used to charge a smartphone on the go.
18. **Medical Devices :** Some medical devices like blood glucose meters, blood pressure monitors, ECG, etc. can be connected to a smartphone to collect data and monitor health.

1.15 FUTURE TECHNOLOGY IN SMART PHONES

There are several technologies that are expected to be integrated into smartphones in the future, including :

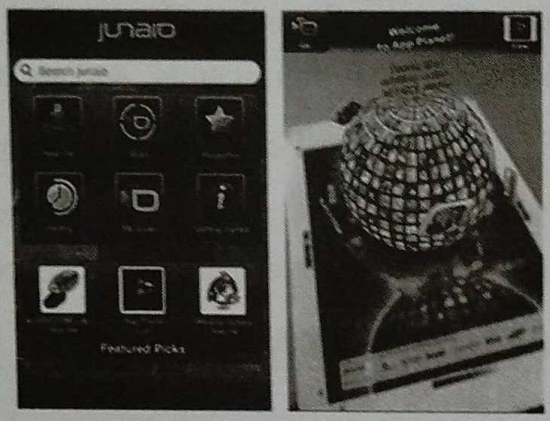
1. **5G Connectivity :** 5G is the latest generation of cellular networks, offering faster download and upload speeds, lower latency, and improved reliability. This technology is expected to be integrated into smartphones in the future, allowing for faster and more reliable internet connectivity.
2. **Foldable and Rollable Displays :** Foldable smartphones with flexible displays that can be folded and unfolded are becoming increasingly popular. These displays can be used to create larger screen sizes or to make the device more compact.



3. **Artificial Intelligence and Machine Learning :** AI and machine learning could allow smartphones to become more personalized and more efficient, such as by optimizing battery life, providing personalized recommendations, voice assistants, and enabling more advanced photography features.

4. **Augmented Reality (AR) and Virtual Reality (VR) :** Smartphones are expected to become more powerful in terms of processing power, graphics capabilities and sensors which will allow them to support high-quality AR and VR experiences.

   Junaio is an augmented reality (AR) browser application developed by Metaio, a company that was acquired by Apple in 2015. The app allows users to access and view AR content, such as 3D models, videos, and animations, by holding their iPhone or iPad camera up to real-world objects or locations.



5. **Camera :** Advancements in camera technology such as multi-lens cameras, 3D sensing, and improved image processing algorithms will allow smartphones to capture higher quality photos and videos.

6. **In-display Fingerprint Scanners :** In-display fingerprint scanners could replace traditional fingerprint scanners, allowing for a more seamless design and improved security.

7. **In-Built Projector :** In-built projectors in smartphones are a potential future technology that could be integrated into smartphones, allowing users to project images, videos and other content onto a larger screen or surface.

   Samsung Galaxy Beam was released back in the second half of 2010. It features a built-in DLP (Digital Light Projection) WVGA projector that is able to project future features-smart-phones/ at up to 50 inches in size.

8. **Quantum Computing :** With the development of quantum computing, smartphones could become more powerful and capable of handling more complex tasks.

9. **Advanced Biometric Authentication :** Smartphones could include more advanced biometric authentication methods such as facial recognition, iris scanning, and voice recognition.

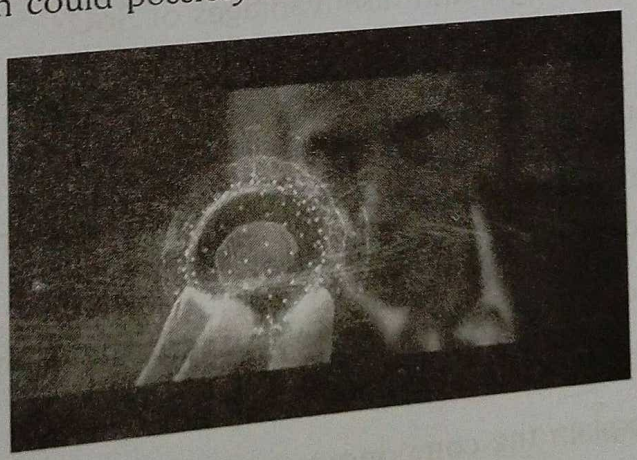
10. **Battery and Charging :** With the increasing power and capabilities of smartphones, battery life and charging time have become a concern.Battery technology will advance to allow for longer battery life, fast charging, and even wireless charging.

11. **Internet of Things (IoT) :** Smartphones are expected to play a key role in the growth of the Internet of Things, as they can be used to control and monitor IoT devices, and as a hub for data collected from IoT devices.

12. **Blockchain Technology :** Blockchain technology could be used in smartphones to improve security and privacy, and to enable new use cases such as digital payments and secure storage for personal data.

13. **3D Screens & Holograms** : Mobile companies are now **moving from 2D to 3D smart phone screen.** At present, we have few 3D smartphones such as, Samsung AMOLED 3D LG Optimus 3D, Motorola MT810.

    After 3D the next path could possibly be **holographic projections.**



REVIEW QUESTIONS

Short Answer Questions :

1. What is a mobile device?
2. List different type of mobile devices.
3. What is mobile application development?
4. Classify mobile application development applications.
5. What is a smartphone?
6. What is Dalvik Virtual Machine (DVM)?
7. What are the key features of a smartphone?
8. Write the uses of a) Accelerometer b) Gyroscope in smartphones.
9. Define SoC.
10. Name the components of SoC.
11. Define Digital Signal Processor (DSP).

Essay Type Questions :

1. Classify mobile application development applications and provide examples for eac category.
2. What are the advantages and disadvantages of SoC?
3. List 3 types of contemporary processors used in mobile devices.
4. List the different types of DSP architectures.
5. Briefly describe the features of Traditional DSP Architecture, Modern DSP Architecture and SoC-based architecture.
6. List different peripheral devices connected to a smart phone.
7. Explain the evolution of smart phones.
8. Define SOC. Explain the components of SOC.
9. Explain in detail about Traditional DSP Architecture.
10. Explain in detail about Modern DSP Architecture.
11. Explain SOC based architecture.
12. Explain different contemporary processors.
13. Explain about future technology in smart phones.