CHAPTER 6

EVOLUTIONARY APPROACH TO NEXT GENERATION WIRELESS AND CELLULAR NETWORKS

6.1 Introduction

The wireless network provides the portability in the communication technology the wireless communication provides good medium to provide various networking, in recent days we cell phones to audio communication as well as check mails, surf the net therefore the mobile phones are not restricted for audio data its used for multimedia data audio, video, web applications, entertainment etc. Therefore, the goal of the cellular network providers is to speed up the network. To accommodate our growing needs for increased transmissions, cellular networks have gone through various generations through evolutionary stages such as 1G, 2G, 3G, 4G, etc. (Lawton George, 2005).
6.2 First Generation (1G) Cellular Network

The first generation refers to the analog communication, especially with telephony systems, which come under first generation technology. The normal speed at which the first generation operates is 2.4 kbps at that time, and only analog systems support in the system. The first generation era heavily depended on the analog-based system with very low speed. (Nicopolitidis P. et al., 2010):

**The Advanced Mobile Phone Systems (AMPS):** AMPS is an advanced mobile phone system that is considered to be an advanced form of the telephone system with high-speed speech communication. The idea here is to divide the 3 kHz channels of various frequency spectrum, several such channels are divided in the AMPS system. The modulation technique used here is FM and BFSK, which works at the rate of 10 kbps. Speech channel uses Frequency Modulation (FM) technique while Binary Frequency Shift Keying (BFSK) which works at a rate of 10 kbps is used by control channel. Both frequency tones and data messages are used for AMPS control signaling and two operators can be collocated in the same geographical area.
6.3 Second Generation (2G) Cellular Networks

The second generation 2G systems are based on the digital system, the era of digital technology is the major focus in the 2G system, the drawbacks of 1G systems also addressed and overcome in the 2G systems, the digital technology network system was the main attraction in the 2G systems, the early mobile phones is the major successful 2G systems which is used for only speech communication and operate at low speed but sufficient for the audio communication, the data part was still missing in the 2G system, the evolution of technology has enabled the industry to move to Second Generation (2G) cellular networks, a successor of 1G cellular network. 2G is based on digital technology and network infrastructure. Many of the deficiencies of 1G system are overcome by 2G cellular network. The increased capabilities of 2G cellular networks are because it is completely digital. 2G cellular networks have following advantages over the 1G system:

- **Encryption:** The 1G system is suppose to be not secure and privacy also not that much high the 2G system provides the security and privacy as a priority component in the system, digitized traffic can be easily encrypted. Encrypted signals cannot be overheard and encrypted by unauthorized parties. Contrary to it, the signal is suitable for encryption in the networks therefore the security is suppose to be low in the 1G system but in 2G because of the encryption the security can be much higher. Therefore, 2G cellular network, a fully digital system.

- **Error handling mechanism:** 2G provides the effective mechanism to deals with the errors; the 2G uses some kind of error detection and correction techniques to the user traffic in a digital system applying these many form of error detection and correction mechanism one can easily deals with error as the system should capable to detect and correct errors in the system because of this the overall quality of the speech improves in the 2G systems.

- **Enhanced Digital services:** The 2G systems provides the limited data based services which is the central attraction of the 2G systems, for example the Short Messaging Services SMS with limited characters message which can be send and receive in the system is the main data based services which is the
main value added service other than traditional voice service only, later in the further development in the 2G like 2.5 G the data services further enhanced with multimedia services like MMS and other important services like voice over Internet Protocol VOIP which is further enhance in the system.

**Example of 2G system:**

There are several 2G system build which is based on digital audio communication, the main systems includes DAMPS, CDMA and 2.5 G supported GSM, here we will discuss the two major system of 2G

**CDMA Code Division Multiple Access**

The code division multiple access is the major 2G wireless voice based systems, the CDMA based on the code division technique for voice communication, this system provides very flexible environment for the low volume wireless communication system.

![CDMA Users are Separated by Codes](image)

**Figure 6.1: Code Division Multiple Access- How CDMA works in wireless communication**

Code division multiple accesses provide effective 2G data and voice communication and provide the digital communication which is amongst the first wireless digital based communication the code is divided as shown in the figure in order to communicate the code of different colors shown in the figure the different color codes is mixed and at the receiver end the different color code is match and that demonstrate the working of CDMA. CDMA provides several benefits over the 1G traditional systems which mainly include the CDMA is completely a digital system as compare to the 1G analog systems, the second difference is the CDMA uses the code division
technique which very different than traditional Time Division Multiple Access and Frequency Division Multiple Access.

**Global System for Mobile Communication (GSM)**

GSM is the major 2G system introduced by European standard and widely spread in Europe and Asia, the GSM uses the both multiplexing techniques i.e. FDMA and TDMA so the time slot are divided mostly eight time slot are available in the GSM the various Frequency channels are uses one of the time slot in order to communicate with the base station in the system., There are four variants of GSM operating at 900 MHz, 1800 MHz, 1900 MHz and 450 MHz Its implementation is fully digital and manages channel access via a Time Division Duplex (TDD) mechanism that splits the available bandwidth in the time domain for separate sets of uplink and downlink transmissions. The resulting access method is actually a hierarchy of slots, frames, multiTframes, superframes, and hyper frames. In addition to voice services, GSM also offers data data transfer services at the rate of 9.6 kbps.

**GSM Architecture**

![GSM Architecture Diagram](image)

**Figure 6.2: GSM Architecture**

The GSM architecture is showing three major components in the system which is shown in the figure the mobile station i.e. your portable devise is refer as the end user interface which usually consists of SIM and mobile devise hardware with IMEI identification number to identify the devise, the second component in the
system is the Base station in which BTS base transceiver station and BSC this is generally perform paging process from the mobile devise the call is initiate between mobile station and base station and further process by the Mobile Base station. The various interfaces such as Um user interface and the air interface uses in the system, the main part of the system is the FDMA and TDMA combination uses in the system besides that several databases such as equipment database which stores all the Equipment Id i.e. IMEI and also customer database maintain in the system.

The GSM is most effective wireless mobile communication system which is used for speech and data communication, the text for of the communication like SMS uses effectively in the GSM based systems but the major problem is with the multimedia data especially the video data like MMS and internet connectivity was limited in the GSM system in order to enhance the internet speed in the GSM system the various technologies like EDGE, GPRS is introduces and those technology refers as 2.5 G system, the EDGE and GPRS are the most common examples of the 2.5 G systems as they just enhance the internet data connectivity in the GSM systems.

There are 2.5 G cellular networks such as HSCSD, GPRS and EDGE as described below. The classical data rate of GSM is 9.6 kbps. Using less FEC 14.4 kbps is available too. These data rates are achievable using a single time-slot per frame in a certain channel. But with today’s requirements, i.e., Web browsing, file download, or even intensive email exchange with attachments, this is not enough (Schiller). To enhance the data transmission capabilities of GSM, following three approaches are possible:

- **High Speed Circuit Switched Data (HSCSD)**
- **General Packet Radio Service (GPRS)**
- **Enhanced Data rates for Global (or GSM) Evolution (EDGE)**

**HSCSD (High-Speed Circuit Switched Data):**

As compare to the basic GSM working which is based on connection-oriented traffic channels (TCHs) with 9.6 kbps each (14.4 kbps with some providers), several traffic channels could be combined to increase bandwidths and thus data rates to get higher AIUR (Air Interface User Rate), e.g., 57.6 kbps using 4 slots of 14.4 kbps each. This
system is called HSCSD. In the GSM the Mobile station requests one or more Time Channels from the GSM network which allocates several Time Division Multiple Access slots within a Time Division Multiple Access frame but leaves coding untouched.

**Advantages:** ready to use, constant quality, simple.

**Disadvantages:** The major disadvantage as HSCSD rely on connection-oriented mechanism of GSM. Since the traffic is busy in nature the large file need the reserve channel and the most web application reserve the channel idle in most cases, the major drawback as channel reserve for the particular user then other user cannot use that particular channel even if that channel is idle for most of the time. Another problem associated with HSCSD is the battery life as system uses the HSCD it decrease battery life drastically.

**GPRS:**

General public Radio Service is very efficient technology used in the 2G and 3G particularly to enhance data support in the 2G system, as the internet speed is limited in the 2G there is a need to boost the system, GPRS provide that booster capabilities in the 2G system, GPRS uses packet switched network with enhance speed then HSCSD, GPRS can dynamically manages several time slots, GPRS provides quality of support and guarantee of the good network services in the system, because of the good QoS factor GPRS is the very popular choice of service providers in the data service in the 2G systems.

**EDGE:** One initial enhancement of GSM toward UMTS (3G cellular network) was EDGE, which uses enhanced modulation scheme (8 PSK) in addition to GSM's GMSK, which offers even higher data rates of up to 384 kbps using the same 200 KHz wide carrier and the same frequencies as the GSM (a data rate of 48 kbps per time slot is available) under good propagation conditions. EDGE can be introduced incrementally offering some channels with EDGE enhancement that can switch between EDGE and GSM.

**CdmaTwo:** It is an upgrade of CdmaOne that lets a mobile station use up to eight (8) spreading codes which is equivalent to performing more than one CDMA transmission, thus resulting in speeds up to 115.2 kbps.
- **IS-94** is actually not a 2G standard but rather a protocol that operates on the network side of North American cellular networks.

- The **Digital European Cordless Telecommunications (DECT)** standard, a fully digital system for cordless voice and data transmission.

- **Personal Handyphone System (PHS)**, a 2G system for cordless telephony.
6.4 Third Generation (3G) Cellular Networks

The 2G enhances the mobile networks with enhance data rate to operate internet however the speed at which 2G working is not enough to handle the high speed user requirements especially to handle large multimedia data services, the new technological services which required data rate is still need a enhance the speed and the data services, the 3G is the basically provides the high speed data network which provides the good speed the 3G provides good multimedia support in the mobile based systems, the issues related to large multimedia is addressed in the 3G systems (Chaudhury P., 1999). In the near future, there will be demand on mobile platforms for a variety of services, now a days mobile phone uses wide range of mobile services for example voice services, video call, web browsing etc, the main aim of 3G cellular network is to provide efficient support for both voice and high bit rate data services, ranging from 144 kbps to 2Mbps. 3G cellular networks fulfil the demands of future services and will offer global mobile multimedia communication capabilities in an efficient and seamless manner. In order to enjoy a wide variety of applications, users will be able to use a single device, irrespective of their location. Main features and characteristics of 3G mobile phone systems are (Nilsson T., 1998):

- operation at 2 GHz.
- Higher and more flexible data rates,
- usage of CDMA (in almost all systems),
- packet-switched and circuit-switched services support, such as Internet (IP) traffic and high performance voice services
- better voice quality due to new codecs,
- support for both symmetric and asymmetric traffic
- support for running several services over the same terminal simultaneously
- support for roaming
•backward compatibility and system operability

•more powerful modulation schemes,

•CDMA as additional multiplexing scheme, and

•more powerful devices (more precise power adaptation, utilisation of multipath propagation

The International Telecommunication Union-Telecommunications (ITU-T) initiated standardization for 3G in 1992. The outcome of the standardization effort comprises a number of different 3G standards, called International Mobile Telecommunications 2000 (IMT-2000). Each of these standards was submitted by one or more national Standard Developing Organizations (SDOs). The goal of these standards is to achieve smooth introduction of 3G systems in order to maintain backward compatibility with existing 2G standards. Several International projects such as the Third Generation Partnership Proposal (3GPP), and 3GPP2 were created in order to facilitate the development of a smaller set of compatible 3G standards. In an effort to provide backward compatibility with existing legacy 2G systems and conform to the country's spectrum regulation issues, a suitable radio access standard, also known as the air interface, is to be deployed by each country.

The number 2000 in IMT-2000 should indicate the start of the system (year 2000 + x) and the spectrum used (around 2000 MHz). IMT-2000 includes different environments such as indoor use, vehicles, satellites and pedestrians. The original plan of IMT-2000 was to have a common global system but later on this idea was dropped and a so-called family of 3G standard was adopted. ITU-T standardized five groups of 3G radio access technologies as given in figure 6.1.
Figure 6.3: The IMT- 2000 family.

- **1IMT-FT**: As frequency time technology, an enhanced version of the cordless telephone standard DECT has also been selected for applications that do not require high mobility. ETSI is responsible for the standardization of DECT.

- **2IMT-SC**: The enhancement of the US TDMA systems, UWC-136, is a single carrier technology originally promoted by the Universal Wireless Communications Consortium (UWCC). It is now integrated into the 3GPP efforts. This technology applies EDGE, among others, to enhance the 2G IS-136 standard.

- **3IMT-MC**: cdma2000 is a multi-carrier technology standardized by 3GPP2 (Third generation partnership project 2, 3GPP2, 2002). Version cdma2000 EV-DO has been accepted as the 3G standard.

- **4IMT-TC**: Initially, this family member, called time code, contained only the UTRA-TDD system which uses time-division CDMA (TD-CDMA). Later on, the Chinese proposal, TD-synchronous CDMA (TD-SCDMA) was added.
• **IMT-DS:** The **direct spread** technology comprises wideband CDMA (WCDMA) systems. ETSI called it UTRA-FDD in the UMTS context and used by all European providers and the Japanese NTT DoCoMo for 3G wide area services. To avoid complete confusion ITU’s name for the technology is IMT-DS. Today, standardization of this technology takes place in 3GPP (Third generation partnership project, 3GPP, 2002a).

Figure 6.3 shows more than just the radio access technologies. One idea of IMT-2000 is the flexible assignment of a core network to a radio access system. The classical core network uses SS7 for signalling which is enhanced by ANSI-41 (cdmaOne, cdma2000, TDMA) or MAP (GSM) to enable roaming between different operators. The **evolution toward 4G system** is indicated by the use of all-IP core networks. Internet-working functions have to be provided to enable cross-system data transfer, roaming, billing etc.

**6.4.1 Fixed Network Evolution**

2G systems deployed throughout the world will form the basis for the evolution and migration towards 3G systems (Chaudhury P., 1999). In an effort to provide seamless migration from 2G to 3G cellular networks and lower the accompanying cost, the aim is to reuse as much of the fixed network infrastructure as possible.

As a reference architecture, a version of Universal Mobile Telecommunication System (UMTS) Release ’99 (Jochen Schiller, 2002), a 3G successor of 2G GSM, is taken for discussion. This architecture is illustrated in Figure 6.2 and besides the air interface between the base stations and mobiles, it also comprises the following parts.

- 3G capable base stations.
- **Radio network Controller (RNC)** which corresponds to **Base Station Controller (BSC)** of GSM.
- The 3G capable base stations and RNCs form the **Radio Access Network (RAN)**, also called **UMTS terrestrial RAN (UTRAN)**, which correspond to the base station subsystem (BSS) of GSM.
Figure 6.4: UMTS core network together with a 3G RNS and a 2G BSS

Figure 6.4 shows the UMTS release 99 core network architecture together with UTRAN RNC and a GSM BSS.

UTRAN consists of several radio network subsystems (RNS). Each RNS is controlled by a radio network controller (RNC) and comprises several components that are called node B. An RNC in UMTS can be compared with the Base Station Controller (BSC); a node B is similar to a Base Transceiver Station (BTS). Each node B can control several antennas which make a radio cell. The mobile device, User Equipment (UE), can be connected to one or more antennas. Each RNC is connected with the core network (CN) over the interface Iu (similar to the role of the A interface in GSM) and with a node B over the interface Iub. A new interface, which has no counterpart in GSM, is the interface Iur connecting two RNCs with each other. The Iur interface supports handover functionality.

The core network (CN) shown here is basically the same as in the context of GSM and GPRS. The circuit switched domain (CSD) comprises the classical circuit switched services including signalling. Resources are reserved at connection setup and the GSM components Mobile services Switching Center (MSC), Gateway MSC (GMSC), and Visitor Location Register (VLR) are used. The CSD connects to the
RNS via a part of the Iu interface called **IuCS**. The CSD components can still be part of a classical GSM network connected to a BSS but need additional functionalities (new protocols etc.).

The **packet switched domain (PSD)** uses the GPRS components Serving GPRS Support Nodes (SGSN) and Gateway GPRS Support Nodes (GGSN) and connects to the RNS via the **IuPS** part of the Iu interface. Both domains need the data-bases EIR for equipment identification and Home Location Register (HLR) for location management (including the **AuC** for authentication and **GR** for user specific GPRS data).
6.5 Fourth Generation (4G) Cellular Networks

Fourth generation cellular network technologies is committed to provide high speed data services then 3G, the modern application requires the high speed data connection to provide the multimedia services in the modern cellular network, the main application areas in 4G includes high speed web access, HD TV, video conferencing, IP Telephone, cloud computing and video conferencing etc, the 4G is successfully implemented system as Long Term Evolution standard LTE used in european country in 2009, the international standard set by the ITU-T is 100 Mbps speed data rate network with high mobility speed.

A comparison of 3G and 4G cellular networks are given in table 5.1 (Li Z et al., 2009).

Table 6.1: Comparison of 3G and 4G Cellular networks

<table>
<thead>
<tr>
<th>Items</th>
<th>3G</th>
<th>4G</th>
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<tbody>
<tr>
<td>Speed</td>
<td>Up to 2Mbps</td>
<td>Full-mobility: up to 100Mbps</td>
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<tr>
<td></td>
<td>Difficulty of global roaming</td>
<td>Low-mobility: up to 1Gbps</td>
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<tr>
<td>Services</td>
<td></td>
<td>Roaming smoothly</td>
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<tr>
<td>Core Network</td>
<td>Wide-area concept Circuit</td>
<td>Broadband, Entirely IP-based</td>
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<td></td>
<td>and packet</td>
<td>packet switching</td>
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<td></td>
<td>switching</td>
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<tr>
<td>Technologies</td>
<td>WCDM, CDMA2000, TD-SCDMA</td>
<td>All access convergence</td>
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<tr>
<td></td>
<td></td>
<td>including: OFDM, MC-CDMA,</td>
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<td></td>
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<td>LAS-CDMA, Network-LMPS</td>
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6.6 Fifth Generation (5G) Cellular Networks

The 5G cellular networks will be supported by LAS-CDMA, OFDM, MC-CDMA, UWB, Network-LMDS and IPv6 ((Li Z et al., 2009) where IPv6 shall be the main protocol for running on both 4G and 5G. Since IPv6 assigns any IP address to any mobile node based on location management, therefore, its use in 5G network may create problem because 5G cellular network is designed for World Wide Wireless Web (WWWW) to mobile users based on network access management. This will waste resource. This will cause 5G cellular network resources to be wasted. To solve this problem, the bandwidth optimization control protocol (BOCP) and the mixed bandwidth data path for future 5G cellular and wireless networks is proposed in (Salleh R. et al., 2008). The BOPC is implemented in between Media Access Control (MAC) layer and TCP/IP layer which is used to establish the mix bandwidth (Figure 6.3).
Figure 6.5: Mix-bandwidth Data Path.

(Source: Li X. et al., 2008)
6.7 Sixth Generation (6G) Cellular Networks

As shown in Figure 5.3 (Li Z et al., 2009), 6G cellular networks integrates 5G wireless and cellular networks and satellite communications network for global coverage. Satellite communications networks comprises of telecommunication satellites networks, navigation satellites networks and earth imaging satellites networks (Psiaki M. L., 20010).

![Integration of satellite networks in 6G.](image)

Figure 6.6: Integration of satellite networks in 6G.

Development of Global navigation Satellite Systems (GNSS) has been announced by five countries - Global positioning System (GPS) by USA, Galileo of European countries, COMPASS of Chinese, and Russian GLONASS, have been developed and deployed.
6.8 Seventh Generation (7G) Cellular Networks

6G which is migrated from 5G, is based on MC-CDMA standard. Thus, integration of 6G with 5G with these four satellite networks will force 6G to have four standards, i.e., 6G will have four technologies, networks and systems. Roaming and handoff must happen in space between any two networks and systems and technologies. This gives rise to Seventh Generation (7G) cellular mobile network.

Integration of 6G cellular systems with the telecommunication satellite systems, the global navigation satellite systems, and the earth imaging satellite systems creates 7G cellular system. The voice and multimedia data for users' communication requirements can be supplied by the telecommunication systems. A user's position is determined by the global navigation satellite system. The weather information as an extra service for mobile users are contained in earth imaging satellite systems. While the 6G cellular network system may be a wireless local network supporting the local voice and multimedia data services. The roaming and handoff must happen between each satellite. Furthermore, any two different satellite systems are necessary for roaming and handoff when mobile users are moving from one country to another. This kind of roaming/handoff is called space handoff/roaming.
The time table for all generation’s cellular networks is shown in figure 6.5.

![Cellular Networks Generation Time Table](image)

Figure 6.7: Cellular Networks generation Time Table

**Mobile Wireless Application development**

The mobile application development is refer to develop a wireless application development along with the wireless technological development, the most important aspect here how the application development cope up with the technological development in terms of mobile application development, in general the mobile wireless application development is follow as

**WAP** Wireless Application Protocol to develop mobile application based on the markup language WML which can be create a markup based user interface for the mobile based application, the major disadvantages include limited programming capabilities and very limited Application Programming Interface for various purpose.
The figure shows the WAP architecture with the various services shown for wireless systems, the main services like Bearer services like SMS, USSD, CDMA etc are shown in figure. The layer wise division of WAP includes the HTML or java script as a programming part with the bottom layers includes various protocol services the TCP/IP and UDP/IP is the bottom layer protocol in the WAP system.

**Java Based J2ME Java 2 Micro Edition**

Java 2 Micro Edition is the java based application development environment for wireless small devise application development, this is first major Application Programming Interface API provided by the sun micro system in the form of sun wireless toolkit to create a wireless and embedded system, the J2ME program supports wide range of devise support and almost it support all the mobile devise which is not a Smartphone, the java provides a effective mechanism for the wireless application development platform the sun microsystem provides the detailed architecture in the form of J2ME for all types of wireless application development.

The major features in the wireless application development using J2ME is

- Wireless User Interface
- HTTP wireless Programming Support.
- Bluetooth Programming API Support,
- Wireless gaming API and 3D Support.
The main aim to provides the infrastructure for the wireless application support, the J2ME is based on the java programming therefore the java programmers gets good opportunity in the field of wireless development, the java coders easily code the wireless systems using J2ME which is completely based on the java platform.

The J2ME provides the support to integrate the other application to not only create wireless application or devise programming, it also supports the embedded programming for the wireless systems, the architecture provides other supports like card programming and xlets other that mobile wireless systems, the main aim of the J2ME is take care of all the infrastructure supports for the developer to build wireless systems and embedded systems which may be integrated in the wireless systems and secondly it is java based so that the platform in dependence issues is not that so that system can easily I targeted in the embedded environment.

The various issues that is since the wireless development is fast development area in the early 2000 with the introduction of Smartphone and the very fast and rapid growth of the smart phones the effective wireless development systems are build, the Apple IOS and Android is the mobile operating systems examples which is especially build for the Smartphone systems only, therefore the java enable J2ME is got the limitations as the devise is having the limitations, the major limitations in the java based small devises that it does not support the touch screen, the touch screen support is not in the java bases small devise and Smartphone provides good screen size with touch screen support for the users hence Smartphone is very popular and widely used despite of the fact that it is costly.
Figure 6.9: J2ME in the Java Picture

The figure shows the J2ME part in the whole java system, the J2ME includes the two important configuration architecture the first is CDC Connection Devise Configuration and second is CLDC Connection Limited Devise Configuration.

**J2ME Features**

- Wireless Programming Interface for Small Devises.
- Additional Support API for wireless devices programming.
- The support for Http, Database, RMI, Servlet, JSP in the wireless programming.
- Bluetooth and Gaming Support architectures.
J2ME Architecture

![J2ME Architecture Diagram]

Figure 6.10: J2ME Architecture
The figure shows the J2ME architecture the main part id CLDC which targeted the small devise wireless system programming, the MIDP is mobile information devise profile, the MIDP is set for the devise that is targeting for the wireless application development. The upper section is optional packages like http support package or Bluetooth or 3d gaming package.

The application created in the form of jar files the verification of the jar file is done the precertification is check the resources used by the system, the jar files can be tested in the emulator provided by the sun microsystem sun wireless system, once tested the jar can be directly deployed to the target devise this is simple wireless system development approach provided by the J2ME.