Mobile Computing:
Principles, Devices and Operating Systems

Masoud Nosrati *
Dept of Computer Engineering
Shaneh Branch,
Islamic Azad University,
Shaneh, Iran.
minibigs_m@yahoo.co.uk

Ronak Karimi
Dept of Computer Engineering
Shaneh Branch,
Islamic Azad University,
Shaneh, Iran.
rk RESPINA_67@yahoo.com

Hojat Allah Hasanvand
Department of Graphic Engineering
Shaneh Branch,
Islamic Azad University,
Shaneh, Iran.
hasanvand_6@yahoo.com

Abstract: This paper will have a survey on mobile computing. It involves software, hardware and mobile communication. Due to this, different types of mobile devices are talked and they are investigated in details. Then, existing operation systems that are most popular for mentioned devices are talked. Limitations of mobile computing is another issue that is concerning in this study.

Key word: Mobile computing, mobile devices, mobile operating systems

I. INTRODUCTION

Mobile computing is an interaction between human and computer by which a computer is expected to be motivating during normal usage. Mobile computing involves software, hardware and mobile communication. Respectively, mobile software deals with the requirements of mobile applications. Also, hardware includes the components and devices which are needed for mobility. Communication issues include ad-hoc and infrastructure networks, protocols, communication properties, data encryption and concrete technologies. Mobile computing means being able to use a computing device while changing location properties. Portability is one aspect of mobile computing [1]. Also, it is referred as the ability to use computing capability without a pre-defined location and/or connection to a network to for engaging data and information.

II. MOBILE COMPUTING DEVICES

Many types of mobile computers have been introduced since the 1990s including the: personal digital assistant/enterprise digital assistant, smart phone, tablet computer, ultra-mobile PC, and wearable computer.

II.1. Personal Digital Assistant (PDA)

A personal digital assistant (PDA), also known as a palmtop computer, or personal data assistant [2][3], is a mobile device that functions as a personal information manager. PDAs are largely considered obsolete with the widespread adoption of smart phones [4]. Figure 1 shows a sample PDA.

Commonly current PDAs are able to connect to the Internet. A PDA has all requirements of connecting to internet such as : an electronic visual display, enabling it to include a web browser, audio capabilities enabling use as a portable media player. Most PDAs can access the Internet, intranets or extranets via wireless methods like Wi-Fi or Wireless Wide Area Networks. Most PDAs uses touchscreen technology.

In 1984 Psion released the first “PDA”, Organizer II. In 1991 followed by Psion’s Series 3, which began to resemble the more familiar PDA style. It also had a full keyboard [5].

The term PDA was first used on January 7, 1992 by Apple Computer CEO John Sculley at the Consumer Electronics Show in Las Vegas, Nevada, referring to the Apple Newton [6].
II.2. Smartphone

A smartphone is a mobile phone built on a mobile operating system, with more advanced computing capability and connectivity than a feature phone [7][8][9]. Figure 2 indicated a sample smartphone.

The first smartphones was a combination of a personal digital assistant (PDA) and a mobile phone functionally. Some functions were added in later models like portable media players, low-end compact digital cameras, pocket video cameras, and GPS navigation units to form one multi-use device, high-resolution touchscreens and web browsers for displaying standard web sites and mobile-optimized pages. Also, Wi-Fi provided high-speed data access and mobile broadband.

The most usual mobile operating systems (OS) used by modern smartphones include Google's Android, Apple's iOS, Nokia's Symbian, RIM's BlackBerry OS, Samsung's Bada, and Microsoft's Windows Phone. Such operating systems are able to adjust with many different phone models. Also, typically each device can have multiple OS installed over its lifetime.

II.3. Tablet computer

Tablet computers are larger than a mobile phone or personal digital assistant. They are a type of mobile devices integrated into a flat touch screen and primarily operated by touching the screen. No physical keyboard is placed in them. It often uses an onscreen virtual keyboard, a passive stylus pen, or a digital pen [10][11][12]. Normally, tablet does not have an integrated keyboard but they can be connected to a wireless or a USB keyboard, while notebook computers have an integrated keyboard that can be hidden by a slide joint. In hybrid models a detachable keyboard is
included so that the touch screen can be used as a stand-alone tablet. Booklets include dual-touchscreens. One of them is used as a virtual keyboard. Figure 3 shows a sample tablet computer.

Early examples of the tablet concept originated in the 19th and 20th centuries mainly as prototypes and concept ideas. The first commercial portable electronic devices based on the concept appeared at the end of the 20th century.

Apple released the iPad with operating system and touchscreen technology in 2010 and became the first successful mobile computer tablet to achieve worldwide commercial purposes. This has sparked a new market for tablet computers and after this success many other manufacturers have produced versions of their own including Samsung, HTC, Motorola, RIM, Sony, Amazon, HP, Microsoft, Archos, etc. Between competing tablets, the main concentration in using OS was on iOS (Apple), Android (Google), Windows (Microsoft) and QNX (RIM) among producers.

In 2012 31% of USA Internet users were reported to have a tablet, which was used mainly for consuming published content such as video and news [13].

Typical functions of tablet computers in 2012 are:

- Wireless mobile browser functions (using 2G,3G,4G or WiFi)
- E-mail and social media devices (typically with integration apps to bring all feeds into the same view)
- Potential cell phone functions (Messaging, video calling, speakerphone or headset cellphone uses)
- GPS satellite navigation
- Still and video camera functions, photo and video viewing and editing
- E-book reading (including electronic versions of periodicals)
- Downloadable apps (games, education, utilities)
- Portable media player function
- Weigh around one or two pounds (0.5 - 1 kilogram)
- Battery life of three to twelve hours depending on usage pattern.

Figure 3. A sample tablet computer manufactured by Motorola

II.4. Ultra-Mobile PC

An ultra-mobile PC [14] (ultra-mobile personal computer or UMPC) is a small form factor version of a pen computer, a class of laptop whose specifications were launched by Microsoft and Intel in spring 2006. Sony with its Vaio U series had manufactured the first attempt in this direction in 2004, which was however only sold in Asia. UMPCs are smaller than subnotebooks operated like tablet PCs, with a TFT display measuring (diagonally) about 12.7 to 17.8 cm, and a touchscreen or a stylus. There is no distinct boundary between subnotebooks and ultra-mobile PCs.

The first-generation UMPCs were just simple PCs with Linux or an adapted version of Microsoft's tablet PC operating system. With the announcement of the UMPC, Microsoft dropped the licensing requirement that tablet PCs must support proximity sensing of the stylus, which Microsoft termed "hovering".
Second-generation UMPCs use less electricity and can therefore be used longer (up to five hours) and also support Windows Vista.

Originally codenamed Project Origami, the project was launched in 2006 as collaboration between Microsoft, Intel, Samsung, and a few others. Despite prediction of the demise of UMPC device category according to CNET [15] the UMPC category appears to continue to be in existence, however, it has largely been supplanted by tablet computers [16] as evidenced by the introduction of Apple iPad, Google Android, BlackBerry Tablet OS, and Nokia's upcoming MeeGo.

**II.5. Wearable computers**

Wearable computers, also known as body-borne computers are miniature electronic devices that are worn by the bearer under, with or on top of clothing [17]. This class of wearable technology has been developed for general or special purpose information technologies and media development. Wearable computers are especially useful for applications that require more complex computational support than just hardware coded logics. Figure 5 shows a wearable computer sample.

One of the main features of a wearable computer is consistency. There is a constant interaction between the computer and user, i.e. there is no need to turn the device on or off. Another feature is the ability to multi-task. It is not necessary to stop what you are doing to use the device; it is augmented into all other actions. These devices can be incorporated by the user to act like a prosthetic. It can therefore be an extension of the user’s mind and/or body.

Many issues are common to the wearable as with mobile computing, ambient intelligence and ubiquitous computing research communities, including power management and heat dissipation, software architectures, wireless and personal area networks.

The International Symposium on Wearable Computers is the longest-running academic conference on the subject of wearable computers.
III. MOBILE OPERATING SYSTEM

Mobile operating systems are talked in this section. This issue involves the most popular operating systems such as: Symbian, Windows, Palm OS, BlackBerry, iOS, Android, and Bada.

III.1. Symbian

Symbian is a mobile operating system designed for smartphones originally developed by Symbian Ltd. but currently maintained by Accenture.[18] The Symbian platform is the successor to Symbian OS and Nokia Series 60. The latest version, Symbian ver.3, was officially released in Q4 2010 and first used in the Nokia N8 [19].

The first Symbian phone the touchscreen Ericsson R380 Smartphone was released in 2000 [20] and was the first device to be marketed as a ‘smartphone’ [21]. It combined a PDA with a mobile phone [22].

Later in 2000, the Nokia 9210 communicator was released, also with Symbian. The later 9500 was Nokia’s first camera phone and first Wi-Fi phone. The 9300 was smaller, and the E90 Communicator included GPS. In 2007, Nokia launched the Nokia N95 which integrated various multimedia features: GPS, a 5 megapixel camera with autofocus and LED flash, 3G and Wi-Fi connectivity and TV-out. In the next few years these features would become standard on high-end smartphones. The Nokia 6110 Navigator was a Symbian based dedicated GPS phone introduced in June 2007.

In 2010, Nokia released the Nokia N8 smartphone with a stylus-free capacitive touchscreen, the first device to use the new Symbian^3 OS [23]. Its megapixel camera able to record HD video in 720p [24]. It also featured a front-facing VGA camera for videoconferencing.

Some estimates indicate that the number of mobile devices shipped with the Symbian OS up to the end of Q2 2010 is 385 million [25]. Symbian was the number one smartphone platform by market share from 1996 until 2011 when it dropped to second place behind Google's Android OS.

In February 2011, Nokia announced that it would replace Symbian with Windows Phone as the operating system on all of its future smartphones [26]. This transition was completed in October 2011, when Nokia announced its first line of Windows Phone 7.5 smartphones, Nokia Lumia 710 and Nokia Lumia 800 [27]. Nokia committed to support its Symbian based smartphones until 2016, by releasing further OS improvements, like Nokia Belle and Nokia Belle FP1, and new devices, like the Nokia 808 PureView.

III.2. Windows

Microsoft Windows CE (now officially known as Windows Embedded Compact and previously also known as Windows Embedded CE [27], and sometimes abbreviated WinCE) is an operating system developed by Microsoft for embedded systems. Windows CE is a distinct operating system and kernel, rather than a trimmed-down version of desktop Windows [28]. It is not to be confused with Windows Embedded Standard which is an NT-based componentized version of desktop Microsoft Windows.

Microsoft licenses Windows CE to OEMs and device makers. The OEMs and device makers can modify and create their own user interfaces and experiences, with Windows CE providing the technical foundation to do so.

The current version of Windows Embedded Compact supports Intel x86 and compatibles, MIPS, and ARM processors.

III.3. Palm OS

Palm OS (also known as Garnet OS) is a mobile operating system initially developed by Palm, Inc., for personal digital assistants (PDAs) in 1996. Palm OS is designed for ease of use with a touchscreen-based graphical user interface. It is provided with a suite of basic applications for personal information management. Later versions of the
OS have been extended to support smartphones. Several other licensees have manufactured devices powered by Palm OS.

Following Palm’s purchase of the Palm trademark, the currently licensed version from ACCESS was renamed Garnet OS. In 2007, ACCESS introduced the successor to Garnet OS, called Access Linux Platform and in 2009, the main licensee of Palm OS, Palm, Inc., switched from Palm OS to webOS for their forthcoming devices [29].

Palm OS is a proprietary mobile operating system. Designed in 1996 for Palm Computing, Inc.’s new Pilot PDA, it has been implemented on a wide array of mobile devices, including smartphones, wrist watches, handheld gaming consoles, barcode readers and GPS devices.

Palm OS versions earlier than 5.0 run on Motorola/Freescale DragonBall processors. From version 5.0 onwards, Palm OS runs on ARM architecture-based processors.

The key features of the current Palm OS Garnet are:

- Simple, single-tasking environment to allow launching of full screen applications with a basic, common GUI set
- Monochrome or color screens with resolutions up to 480x320 pixel
- Handwriting recognition input system called Graffiti 2
- HotSync technology for data synchronization with desktop computers
- Sound playback and record capabilities
- Simple security model: Device can be locked by password, arbitrary application records can be made private
- TCP/IP network access
- Serial port/USB, infrared, Bluetooth and Wi-Fi connections
- Expansion memory card support
- Defined standard data format for personal information management applications to store calendar, address, and task and note entries, accessible by third-party applications.
- Included with the OS is also a set of standard applications, with the most relevant ones for the four mentioned PIM operations.

III.4. BlackBerry

BlackBerry is a line of phone devices developed and designed by Research In Motion (RIM). The first BlackBerry smartphone was released in 1999 [30][31]. The latest BlackBerry 7 devices were announced in the Summer of 2011.

BlackBerry devices are smartphones, which are designed to function as personal digital assistants, portable media players, internet browsers, gaming devices, cameras and much more. They are primarily known for their ability to send and receive push email and instant messages while maintaining a high level of security through on-device message encryption. BlackBerry devices support a large variety of instant messaging features, with the most popular being the proprietary BlackBerry Messenger service.

BlackBerry accounts for 3% of mobile device sales worldwide in 2011, making its manufacturer RIM the sixth most popular device maker (25% of mobile device sales are smartphones) [32]. The consumer BlackBerry Internet Service is available in 91 countries worldwide on over 500 mobile service operators using various mobile technologies [33]. As of October 2011, there were seventy million subscribers worldwide to BlackBerry [34]. In 2011 the Caribbean and Latin America, had the highest penetrations of BlackBerry smartphones worldwide – with up to about 45 per cent in the region having a RIM device [35].

Modern GSM-based BlackBerry handsets incorporate an ARM 7, 9 or ARM 11 processor [36], while older BlackBerry 950 and 957 handsets used Intel 80386 processors. The latest BlackBerry models called "Torch" (Torch 9850/9860, Torch 9810, and Bold 9900/9930) have a 1.2 GHz MSM8255 Snapdragon processor, 768 MB system memory, and 8 GB of on-board storage [37][38]. All BlackBerry smartphones after OS 5 support up to 32 GB microSD cards.
III.5. iOS

iOS (previously iPhone OS) is a mobile operating system developed and distributed by Apple Inc. Originally released in 2007 for the iPhone and iPod Touch, it has been extended to support other Apple devices such as the iPad and Apple TV. Unlike Microsoft's Windows CE (Windows Phone) and Google's Android, Apple does not license iOS for installation on non-Apple hardware. As of 2012 Apple's App Store contained more than 700,000 iOS applications, which have collectively been downloaded more than 30 billion times [39].

The user interface of iOS is based on the concept of direct manipulation, using multi-touch gestures. Interface control elements consist of sliders, switches, and buttons. The response to user input is immediate and provides a fluid interface. Interaction with the OS includes gestures such as swipe, tap, pinch, and reverse pinch, all of which have specific definitions within the context of the iOS operating system and its multi-touch interface. Internal accelerometers are used by some applications to respond to shaking the device (one common result is the undo command) or rotating it in three dimensions (one common result is switching from portrait to landscape mode).

iOS is derived from OS X, with which it shares the Darwin foundation, and is therefore a Unix operating system. iOS is Apple's mobile version of the OS X operating system used on Apple computers.

In iOS, there are four abstraction layers: the Core OS layer, the Core Services layer, the Media layer, and the Cocoa Touch layer. The current version of the operating system (iOS 5.1.1) dedicates 1-1.5 GB of the device's flash memory for the system partition, using roughly 800 MB of that partition (varying by model) for iOS itself [40].

III.6. Android

Android is a Linux-based operating system designed primarily for touchscreen mobile devices such as smartphones and tablet computers, developed by Google in conjunction with the Open Handset Alliance [41]. Initially developed by Android Inc., whom Google financially backed and later purchased in 2005 [42], Android was unveiled in 2007 along with the founding of the Open Handset Alliance, a consortium of 86 hardware, software, and telecommunication companies devoted to advancing open standards for mobile devices [43].

Google releases the Android code as open-source, under the Apache License [44]. The Android Open Source Project (AOSP), lead by Google, is tasked with the maintenance and further development of Android [45]. Additionally, Android has a large community of developers writing applications (“apps”) that extend the functionality of devices. Developers write primarily in a customized version of Java [46], and apps can be downloaded from online stores such as Google Play (formerly Android Market), the app store run by Google, or third-party sites. In June 2012, there were more than 600,000 apps available for Android, and the estimated number of applications downloaded from Google Play was 20 billion [47].

The first Android-powered phone was sold in October 2008 [48], and by the end of 2010 Android had become the world’s leading smartphone platform [49]. It had a worldwide smartphone market share of 59% at the beginning of 2012 [50].

III.7. Bada

Bada is an operating system for mobile devices such as smartphones and tablet computers. It is developed by Samsung Electronics. Its name is derived from bada, meaning “ocean” or “sea” in Korean. It ranges from mid-range to high-end smartphones [51].

To foster adoption of Bada OS, Samsung is reportedly considering releasing the source code under an open-source license, and expanding device support to include Smart TVs [52]. Samsung announced in June 2012 it may merge Bada into the Tizen project, but it is not confirmed [53][54]. Samsung is using its own Bada operating system, in parallel with Android OS and Windows Phone, for smartphones they develop.

All Bada-powered devices are branded under the Wave name; similar to how Samsung’s Android-powered devices are branded under the name Galaxy.
Bada, as Samsung defines it, is not an operating system itself, but a platform with a kernel configurable architecture, which allows using either a proprietary real-time operating system hybrid (RTOS) kernel and Linux kernel [55]. According to copyrights displayed by Samsung Wave S8500, it uses code from FreeBSD, NetBSD and OpenBSD. Despite numerous suggestions, there is no known bada device to date that is running the Linux kernel. Similarly, there is no evidence that bada uses the same or similar graphics stack as the Tizen OS, in particular EFL.

In architecture of Bada the device layer provides core functions such as graphics, protocols, telephony and security. The service layer provides more service-centric features such as SMS, mapping and in-app-purchasing. To provide such features there is a so-called bada Server. The top layer, the framework layer provides an application programming interface (API) in C++ for application developers to use.

Bada provides various UI controls to developers: It provides assorted basic UI controls such as Listbox, Color Picker and Tab, has a web browser control based on the open-source WebKit, and features Adobe Flash, supporting Flash 9, 10 or 11 (Flash Lite 4 with ActionScript 3.0 support) in Bada 2.0. Both the WebKit and Flash can be embedded inside native Bada applications. Bada supports OpenGL ES 2.0 3D graphics API and offers interactive mapping with point of interest (POI) features, which can also be embedded inside native applications [56]. It supports pinch-to-zoom, tabbed browsing and cut, copy, and paste features [57].

Bada supports various mechanisms to enhance interaction, which can be incorporated into applications. These include various sensors such as motion sensing, vibration control, face detection, accelerometer, magnetometer, tilt, Global Positioning System (GPS), and multi-touch [58].

Native applications are developed in C++ with the Bada SDK, and the Eclipse based integrated development environment (IDE). GNU-based tool chains are used for building and debugging applications. The IDE also contains UI Builder, with which developers can easily design the interface of their applications by dragging and dropping UI controls into forms. For testing and debugging, the IDE contains an emulator which can run apps.

IV. LIMITATIONS OF MOBILE COMPUTING

There are some general limitations for mobile computing devices. They are nominated and described in brief in follow:

- **Insufficient bandwidth**: Mobile Internet access is generally slower than direct cable connections, using technologies such as GPRS and EDGE, and more recently HSDPA and HSUPA 3G networks. These networks are usually available within range of commercial cell phone towers. Higher speed wireless LANs are inexpensive but have very limited range.
- **Security standards**: When working mobile, one is dependent on public networks, requiring careful use of VPN. Security is a major concern while concerning the mobile computing standards on the fleet. One can easily attack the VPN through a huge number of networks interconnected through the line.
- **Power consumption**: When a power outlet or portable generator is not available, mobile computers must rely entirely on battery power. Combined with the compact size of many mobile devices, this often means unusually expensive batteries must be used to obtain the necessary battery life.
- **Transmission interferences**: Weather, terrain, and the range from the nearest signal point can all interfere with signal reception. Reception in tunnels, some buildings, and rural areas is often poor.
- **Potential health hazards**: People who use mobile devices while driving are often distracted from driving and are thus assumed more likely to be involved in traffic accidents [59]. (While this may seem obvious, there is considerable discussion about whether banning mobile device use while driving reduces accidents or not [60][61].) Cell phones may interfere with sensitive medical devices. Questions concerning mobile phone radiation and health have been raised.
- **Human interface with device**: Screens and keyboards tend to be small, which may make them hard to use. Alternate input methods such as speech or handwriting recognition require training.
A comprehensive introduction of mobile computing is presented in this paper. Devices including personal digital assistant (PDA), smartphone, tablet computer, ultra-mobile PC, and wearable computers are talked. Also, operating systems such as Symbian, Windows, Palm OS, BlackBerry, iOS, Android, and Bada are got into. At the end, the limitations of mobile computing are subjected.

REFERENCES

[6] Newton, Reconsidered - Time magazine, June 1, 2012
[14] Spelled lower case because it's a type of computer, not a specific product, see Microsoft's description.
[15] Sony PSP Go (2009) - The decade's 30 biggest tech flops (photos) - CNET Reviews

V. CONCLUSION


[52] Study: Distractions, not phones, cause car crashes. Signal Strength - CNET News