Handheld Technology Review

Report 2001-008-C-06

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Research Program C:
Delivery and Management of Built Assets

Project 2001-008-C:
Project Team Integration: Communication, Coordination and Decision Support

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PREFACE

The Cooperative Research Centre for Construction Innovation (CRCCI) research project 2001-008-C: *'Project Team Integration: Communication, Coordination and Decision Support'*, is supported by a number of Australian industry, government and university based project partners including: Queensland University of Technology (QUT); Commonwealth Scientific Industrial Research Organisation (CSIRO), University of Newcastle; Queensland Department of Public Works (QDPW); and the Queensland Department of Main Roads (QDMR).

Supporting the project's research aims and objectives, this report reviews the current state of Handheld technology across industry sectors. It also discusses the technology's current usage in the Construction Industry and looks at future prospects for currently available and future technological advances that may provide improvements for the Construction Industry.

EXECUTIVE SUMMARY

In order to focus this current research a Handheld device has been limited to devices which fit into one's pocket. In some cases they may be substantial pockets e.g. Tiqit "eighty-three" and Psion 7535 (Figure 3), however the authors felt that these devices should be included in any analysis due to their significance to the topic at hand. Larger devices such as Tablet PCs and Sub-notebooks have not been included, however, one must not disregard the impact these devices are having on the mobile workforce. Also dedicated mobile phones have not been included due to functionalities at present being mainly aimed at the personal use market. Once again one must not disregard the improvement in communications that mobile phones have made to particular sectors of the AEC industry, in particular, the Home Building industry.

There are in general four devices that have been investigated for this report, the traditional Handheld computer devices such as Personal Digital Assistant (PDA), the Portable Data Terminal (PDT), the Global Positioning System (GPS) and the Hybrid Integrated Mobile Phone/Handheld computers commonly referred to as Phone-pdas, pda-Phones, Smart-Phones or Communicators.

These devices range in size from the small wristwatch PDAs (e.g. by Fossil, Xircom) and credit card size organisers (e.g. Xircom Rex 5001) [Figure 2] to the larger PDT (e.g. Psion 7535) [Figure 3] and Windows XP operating system enabled devices (e.g Tiqit "eighty-three") [Figure 3].

From an Internet survey conducted in July of 2003 the following specifications are typical of the High-end of the Handheld device market:

- Processing Speed: 400 MHz
- ROM: 48MB
- RAM: 128MB
- Connectivity: GSM/GPRS, CDMA, Infrared, Bluetooth, Wi-Fi (802.11b), USB sync.
- Screen Resolution:
    - 320x320 and 320x480 for Palm OS);
    - 240x320 and 640x480 (Toshiba e805 & Tiqit "eighty-three") 800x480 (Sony Nexio S160) for Windows OS.

In general there is a trend to include all of the functionality into one fully integrated Handheld device. In the interim manufacturers of Handheld device equipment are providing full functionality through add-ons that can be either clipped-on and/or plugged-in to an existing device.

The most prevalent trend currently for Handheld devices is the integration of mobile phones with hand held computers. This convergence is happening from both sides of the market, where many alliances are being formed between traditional mobile phone and traditional Handheld computer manufacturers. In general there are mobile phone based integrated devices which initially have been targeted towards the personal use market as a replacement for a user's dedicated mobile phone (e.g. Kyocera 7135) [Figure 4]. There are also the Handheld computer based devices which are aimed more at the business user (e.g. Palm Tungsten W series) [Figure 4], although some would argue that these devices have limited use for business in their current form.

The advent of wireless connectivity is probably the single most important technological advance for Handheld devices currently, as this allows site-based personnel wireless access to the back or site office system with their Handheld device.

The ability for Handheld devices to connect to the internet wirelessly allows access to a large number and all levels of construction management software packages using a web browser. An emerging trend that is facilitating this wireless access to sophisticated software is the advent of Application Service Providers (ASPs). The ASP hosts the software and maintains the hardware, providing the service through various lease agreements. This allows SMEs to utilise sophisticated software packages without the capital outlay and maintenance that "self-hosting" of applications require. This means the client/user can be thin, thin meaning only requiring a web browser to utilise the software, without the need for sophisticated hardware or an on-device software version suitable for the current Handheld devices. However, until the communication networks (e.g. GPRS & 3G) become more affordable, using a Handheld device in a WAN environment for this type of application may not be viable.

An emerging trend is towards technologies or applications that allow different devices to communicate with each other. One of these is BlueTooth. Other device-to-device enabling technologies include Jini (Sun), ChaiServer (Hewlett-Packard), Inferno (Lucent Technologies) and Universal Plug and Play (Microsoft). The beauty of these technologies is that they impose a small footprint, making them suitable for Handheld devices.

Automatic Data Collection technologies appear to provide the greatest potential for Handheld devices for the AEC industry in the near future. These technologies include Speech Technologies, Bar Code Reading, Radio Frequency Identification (RFID) and Biometric Security including speaker verification and fingerprint sensors. All of these technologies provide improved productivity and quality for data collection activities through the automation and reduction of slow manual multiple data entries. The most obvious application for the construction industry would be in the materials management area using Bar Code readers and RFID tags to track materials throughout the delivery and construction process. For PPP type projects, where traditional construction companies take on an asset /facility management role, the ability to track asset components throughout their lifecycle using RFID technologies provides huge potential for efficiency and quality improvements. Data collection through digital camera capability is provided either built-in or as an add-on. However, at this point in time their functionality is limited for business applications.

Several case studies looking at the use of Handheld devices on construction projects has been conducted (Saidi et al, 2002; Robolj et al, 2000; Bowden et al, 2002). The results indicate in general that reductions in activity times and costs can be achieved through the use of Handheld devices. On the other side of the coin, it is commonly agreed that current Handheld devices have several drawbacks mainly relating to their technological limitations including: screen size, screen resolution affecting viewing in direct sunlight, cumbersome data entry and screen navigation.

In order to address these problems there are several technologies specifically aimed at improving current Handheld devices. As far as screen size and resolution is concerned, a recent addition to the add-on capabilities of Handheld devices is a plug-in expansion Near Eye display. This add-on provides the illusion of a full VGA 15" screen at 2 feet from the users eye. In order to deal with the inherent cumbersome navigation that a small screen permits, Innoventions Inc. has developed a new navigation system called RotoView. During navigation mode, the Handheld small display navigates the large stored virtual display in response to changes in orientation at which the device is held. It allows the web browser to navigate a large display in all directions.

One problem for Handheld devices is that functionality is proportional to power drain. This is highlighted by the current higher-end Windows OS devices, which if used continuously, require charging almost on a daily basis. There are several future power source technologies looking to address this problem including: Fuel Cells, Silver Polymer Batteries, Photovoltaic & Hydrogen Fuel Cells and Micro-engines. Fuel cells create power by converting methanol into water. Direct methanol fuel cells provide five times higher energy

density than rechargeable lithium-ion batteries widely used on the current crop of Handheld devices. Silver Polymer battery prototypes have achieved over 2 kilowatts per litre, which is several times the power level of lithium-ion batteries. A prototype combination of photovoltaic and hydrogen fuel cells has been developed for the cover of a Casio Handheld device. The output from this technology is 35 milliamps per square centimetre in direct sunlight. Alternatively, researchers at Birmingham University are developing tiny motors or micro-engines which are a couple of millimetres in size but are able to generate up to 300 times as much energy as an ordinary battery.

The most likely future technological advance that will facilitate the uptake of Handheld devices in the AEC industry is the broadening of communication networks through future generation communication technologies (i.e. 4G) and beyond. The increased bandwidth has the potential to greatly improve efficiencies through faster download rates, which is one of the barriers to using the currently available WAN communication systems. As with all new technologies another barrier is the cost, which should decrease with time, making this form of communication the norm in the future.

Looking ahead it appears that Handheld devices will be competing with wearable computers in the long term. This seems to be a natural progression for mobile technologies to take, where in the first instance mobile Handheld computers are being used to improve the capability and efficiency of the mobile workforce. Wearable computers offer much greater potential benefit to the mobile worker through the greater efficiencies provided by increased automation as well as human computer indirect interaction. The main objective of wearable computers is for the computer to carry out the users required tasks without any direct user interaction. In a sense the Handheld devices of the current and near future are a testing ground for some of the technologies slated for wearable computers in the more distant future.

1 INTRODUCTION

It is well documented that the quality of communication and document mangagement has great impact on the outcome of construction projects (Kajewski & Weippert, 2002). In recent times mobile workforces have been provided with new technologies to help improve their communication and document management performance.

Laptop computers provide an electronic mobile device capable of carrying large amounts of documentation and having the ability to access back-office systems through the phone-line and more recently through various wireless technologies.

This addressed a small portion of the workforce that are typically site office based personnel. More recently mobile workforces at the coalface have been given Handheld computing devices providing a much greater proportion of the construction team the ability to record data and talk to site and back office systems. This greater proportion should transfer into greater improvements in communication and document management quality, and hence, an improved bottom-line.

In light of this new and emerging technology this report investigates the current and possible future state of Handheld Technology including:

- The types of hardware and software available at this point in time including a comprehensive list of available hardware and software found in Appendix A and Appendix B respectively;

- The benefits of using Handheld devices on construction projects, as well as the drawbacks of the current Handheld technologies;

- A discussion on various technologies which are looking to address the aforementioned drawbacks is provided; and

- Finally a look in to the possible future technologies that Handheld devices will incorporate including discussions on those identified with potential construction industry applications.

2 CURRENT STATE OF HANDHELD TECHNOLOGY

This section investigates the current state of play for Handheld technology and includes a look at the different types of Hardware available today, which is considered relevant in a business/construction environment. The main operating systems and their typical characteristics as well a list of the main types of software systems on the market today is discussed. A comprehensive list of all of the types of software available on Handheld devices is also presented. The emergence and types of wireless technologies that enable the mobile workforce connectivity to back office and site office systems through their Handheld devices, is discussed. There is also a brief look at several technologies which are allowing unencumbered device-to-device communication. Finally a look at automatic data collection technologies that are currently enabling productivity improvements in other industries and which provide huge potential for similar improvements in the construction industry.

2.1 Hardware Overview: What's Available in General

This section looks at what is available in the way of handheld devices in the marketplace at the current point in time (July 2003). One of the difficulties in conducting this type of research is defining what is a Handheld. For the purpose of this report a Handheld is something that can fit in one's pocket. Therefore, devices such as tablet PCs and sub-notebooks have been excluded in general from the discussion. However, one must not disregard these devices and their current impact/importance on mobile workforces. The notable exclusion of stand-alone mobile phones is due to their roots being essentially in the personal use category, particularly at present. Having said this, it must not be forgotten the importance they have played in improving efficiencies in communication across a broad range of industries in the past and possibly the near future.

There are a plethora of device names that fall in to the handheld device bucket. These include Organisers, Personal Digital Assistants (PDAs), SmartPhones, pdaPhones, Portable Data Terminals (PDTs), Communicators, PocketViewers and Global Positioning System (GPS) terminals to name but a few. A survey of the Internet in July 2003 revealed that there is somewhere in the range of 100 manufacturers of hand held computing devices producing around 250 different devices of varying capabilities.

Table 1 Top five PDA manufacturers as measured by worldwide shipments in 2002 (Thomas, 2003)

Position	Company	Operating System	Units Sold
1	3COM/Palm	Palm	4 446 006
2	Hewlett-Packard	Windows	1 621 917
3	Sony	Windows	1 353 398
4	Handspring	Palm	662 540
5	Casio	Windows	468 140

Current typical standard specifications at the high end include:

- Processing Speed: 400 MHz;
- ROM: 48MB;
- RAM: 128MB;
- Connectivity: GSM/GPRS, CDMA, Infrared, Bluetooth, Wi-Fi (802.11b), USB sync; and
- Screen Resolution: 320x320 (Palm OS); 240x320 and 640x480 (Tiqit eighty three & Toshiba e805) 800x480 (Sony Nexio S160, Figure 1) [Windows OS].

Figure 1 Sony Nexio S160 high end device (http://www.dynamism.com/nexio/index.shtml)

Typical applications for Handheld computers across a range of industries include (Comware Pty Ltd, 2003):

Retail

- Point-of-Sale ("POS") Terminal;
- Inventory (bar code reading);
- Shelf Price Verification;
- Planograms;
- Reordering; and
- Competitive Price Collection.

Warehousing and Distribution

- Displaying warehouse diagram/layout for faster identification of bin location;
- "Signing" electronic shipping and receiving forms;
- Manufacturing;
- Shop Floor Data Capture;
- Machine Maintenance;
- Work Order Management; and
- Time and Attendance.

Agriculture

- Crop Management;
- Pest Control Monitoring; and
- Farm Equipment Maintenance and Inventory.

Recreation

- Ski Resort Management;
- Theme Park Management;
- Cruise Ship Point of Sale; and
- In-flight Duty Free Sales.

Healthcare

- Point-of-Care;
- Meds Dispensing;
- Respiratory Therapy;
- Emergency Medicine;
- Equipment/Instrument Inventory;
- Records Management;
- Display of X-rays and other photographic information; and
- "Signing" electronic forms and authorizations.

Quality Control, Maintenance, and Inspection Applications

- Interacting with Checklists;
- Accessing Repair Procedures;
- Presentation of Illustrated Parts Breakdown ("IPB") Diagrams;
- Display of Engineering Drawings and Electrical Schematics;
- Depiction of plant/facility layouts for security personnel Sketching damaged areas;
- Taking photographs of parts and assemblies with a digital camera; and
- "Signing" electronic forms and certifications.

Food Service

- Restaurant Order Taking; and
- Inventory.

Car Rental

- Check-in;
- Maintenance;
- Lot Inventory; and
- Supplies Inventory.

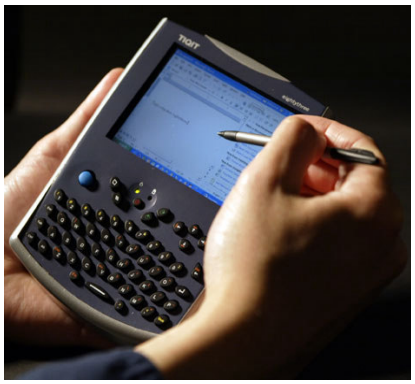
The physical dimensions of the devices range from the small (Figure 2) e.g. wristwatch computers and credit card size organisers (e.g. Xircom Rex 5001) to the larger (Figure 3) PDT (e.g. Psion 7535) and PC operating system (e.g. Tiqit “eighty-three”), which just scraps in regarding physical dimensions as a hand held device.

Fossil FX2005 Wristwatch PDA

Xircom Rex 5001 MicroPDA

Figure 2 Small-end Handheld Devices Fossil (http://www.fossil.com) & Xircom (http://geek.com)

Psion 7535 PDT based device



Tiqit “eighty-three” with XP operating system

Figure 3 Large-end Handheld devices Psion (http://www.rfid.it/Prodotti/Terminale_Palmare_Psion_7535-RFID.htm) & Tiqit (http://www.tiqit.com/gallery.shtml)

The following is an attempt at categorising these according to their level of sophistication and functionality. One must remember that this is an area that has no distinct boundaries having many situations of overlapping functionalities and levels of sophistication as well as integration.

The Organisers, Pocket Viewers, PDAs are handheld computing devices with varying degrees of functionality and sophistication. They range from the lower level devices aimed at the personal user with limited functionality to the higher level more sophisticated devices aimed at the business user having greater functionality.

The Communicators, SmartPhones or pdaPhones are a combination of Mobile Phone and Handheld Computer, where some are more a Handheld Computer with built-in phone capabilities (e.g. Palm Tungsten W, Figure 4) and others area more a Mobile Phone with built-in Hand held computer capabilities (e.g. Kyocera 7135, Figure 4). At this point in time it appears the combination device market is aiming more at personal use than business use, particularly with the more phone-based devices. This is inferred through the inclusion of entertainment software and the like as standard inclusions.

Palm Tungsten W PDA Based

Kyocera 7135 Phone Based

Figure 4 Currently available pdaPhone examples. Palm (http://www.Palm.com) & Kyocera (http://www.mobilenetwork.com.au/pages/mobilepages/7135.asp)

PDTs are typically aimed at Horizontal service industries for the collection of data. They are essentially hand held bar code scanner terminals with varying degrees of computer functionality and typically have a more ruggedised configuration than that of their PDA counterparts. However, there are several PDT based products such as the Intermec-700 series, Symbol Technologies-PPT 8800 and PSC-Falcon 4210 that are more PDA style in configuration and appearance (Figure 5). **Global Positioning System** (GPS) devices are in most cases ruggedised hand held terminals mainly aimed at the leisure market, however, have potentially a broad range of uses in the AEC industry. Figure 6 shows a Garmin integrated GPS/PDA device.

Intermec 700 series

Symbol PPT 8800

PSC Falcon 4210

Figure 5 PDA style PDT based product examples Intermec (http://www.intermec.com/), Symbol Technologies (http://www.symbol.com/) & PSC (http://www.pscnet.com/)

Garmin iQue 3600 PDA / GPS

Figure 6 Integrated PDA-GPS device Garmin (http://www.onlinemarine.com/)

The current trend in hardware, as emphasized by the integration of Mobile Phone and Handheld computer devices, is the integration of the separate devices functionality i.e. Mobile Phone (Wide Area Network-WAN), Handheld Computer, PDT and GPS terminal. There are numerous devices that include various combinations of the integrated functions, the GPS and scanning functionality having the lowest inclusion rates. Another trend is towards built-in Wireless Local Area Network (WLAN) capabilities through Wi-Fi 802.11b and Wireless Personal Area Network (WPAN) capabilities through BlueTooth. In the majority of

cases currently these built-in capabilities are only available in isolation i.e. either BlueTooth or Wi-Fi is built-in.

In the interim manufacturers are providing for full functionality through a capacity to accommodate add-ons in the form of clip-ons and/or plug-ins. The following section discusses the types of add-on devices available in the current market.

2.2 Add-ons and Expansions

This section looks at the various types of add-ons and expansions available in today's market. The Handheld devices accommodate these peripheral devices through various types of slot including:

- Secure Digital (SD)/MultiMediaCard (MMC) slot;
- Compact Flash Slot (CF)/Microdrive slot;
- Springboard Slot (Handspring);
- PC Slot; and
- Memory Stick slot.

As mentioned in the previous section increased functionality is provided to a particular device through the alibility to accommodate add-ons. This increased functionality is not limited to the main functions mentioned previously i.e. GPS, WAN, PAN, WLAN, Scanner. Table 2 provides a brief description of the types of add-ons available on the market today.

Table 2 Add-on capabilities available for Handheld devices.

Type	**Description**
Portable Keyboards	Folding keyboards
GPS Navigator Kits	Clip-on GPS devices
Memory Expansion	Plug-in additional memory: CF cards, Microdrives, SD cards MMC cards, Memory Sticks.
Printers	Clip-on printer
Modem Connectivity Kits	Clip-on modem for the Internet
Wireless Headsets	BlueTooth Headsets for voice communication
Car Lighter Sockets	12 Volt plug-in for car lighter sockets
Cameras	Digital clip-on cameras
WLAN Module	Clip-on Wi-Fi capability
Multimedia Expansion Jackets	Allows output to TV, Projector or VGA monitor
MP3 Audio Kits	Allows reading of MP3 files
Mobile Phone	Clip-on GSM phone capabilities for PDA.
PDA	Clip-on PDA functionality for mobile phones.
Digital Voice Recorder	Plug in Digital Voice Recorder.
Language Translator Cards	Expansion card for language translation.
Bluetooth sleds	Clip-on Bluetooth capabilities

Type	Description
WAN CF Card	CompactFlash Card enabling GSM/GPRS
Bar Code Module	Slip on plug-in Bar Code capability.
3G Card Modem	Card modem enabling UMTS.
Bar Code CF Card	CompactFlash Card enabling Bar Code Scanning capabilities (Wand Type)
Protective Cases	Clip-on cases that give dust, water etc. protection to devices in line with PDT type devices.
Orientation Driven Navigation	Expansion Card allows navigation of screen by orientation of device.
Power Charger	Solar powered battery charger
Eyewear Mounted Monitors	Plug-in full size virtual 15" VGA screen image

2.3 Integrated Phone & PDA: The Current trend

At current a major trend in the hand held device market appears to be the integration of mobile phones and Handheld computers. This has sparked a flourish of industry alliancing amongst traditional mobile phone manufacturers and their hand held computing manufacturer counterparts. As with most IT market sectors, it appears to be Microsoft Corporation vs the Rest. The major players in the integration game along with Microsoft Corporation and its' various partners are the Symbian Consortium and 3COM/Palm and their various partners. Windows based devices include O2 XDA, Audiovox Thera, Hitachi G1000 and Siemens SX56 (Figure 7). Symbian based devices include Sony Ericson P800, Nokia 9210 (Figure 8). Palm based devices include, Handspring Treo range, Kyocera 7035 and Samsung SPH i700 (Figure 9). Other manufacturers of hybrid PDA/Phone devices include Research In Motion (RIM) with its Blackberry OS range of devices, Invair Technologies with its Linux OS Filewalker Messenger (Figure 10).

Audiovox Thera

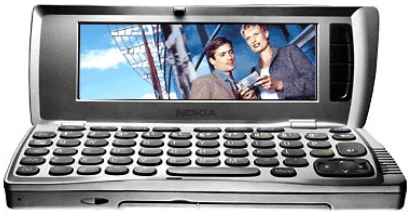
Siemens SX56

Hitachi G1000

02 XDA

Figure 7 Windows based pdaPhone device examples (http://pdaphonehome.com/).

Sony Ericsson P800



Nokia 9210

Figure 8 Symbian based pdaPhone device examples (http://pdaphonehome.com/).

Kyocera 7035

Samsung i700

Handspring Treo 270 & Treo 300

Figure 9 Palm based pdaPhone device examples (http://pdaphonehome.com/).

RIM Blackberry device

Invair Technologies Filewalker Messenger

Figure 10 Other operating system based pdaPhone integrated device examples RIM (http://resources.rimdev.com/) & Invair Technologies (http://www.invair.de/).

From a survey of the literature it appears the functionality of the phone based devices does not cut it in the business environment, where in the majority of cases the screen is relatively small and functionality is limited. From all accounts the more suitable devices for business use are the hybrid integrated devices that are more PDA based e.g. Palm Tungsten W and RIM Blackberry.

2.4 Software: What's Available in General

One of the main criterions to disseminate between the various brands of computer devices is the Operating System (OS) software. There are several manufacturers in the hand held computer market that run their own operating system e.g. 3COM with the Palm OS. Then there are the manufacturers (Original Equipment Manufacturer- OEM) that utilise an off-the-shelf OS through the formation of an alliance with an established OS manufacturer (Original Design Manufacturer -ODM).

The four main operating systems on hand held devices today are the Palm, Windows, Symbian (Formerly EPOC) and Linux. The Palm and Symbian systems are easily identified since they have maintained their names and changed versions through a numbering system e.g. Palm OS 4.1, Symbian 7.0. In contrast, the Windows Handheld systems include Pocket PC, CE, CE.Net, Smartphone and recently XP in the large Tiqit eighty-three device (Figure 3). The Linux system is based on the Unix OS, originally developed by AT&T Bell Laboratories in 1969. Linux is unique in the fact that it is being developed through a General Public License (GPL). This means that it is being developed in an uncoordinated fashion by many developers. However, some developer clusters exist e.g. Red Hat in the US. There are also several OSs in use today that are only referred to in the literature as proprietary. There appears to be a trend for OEMs to license a number of the operating systems for use in their devices i.e. they have optional OSs e.g. HNT Exilion 201 has Linux OS as standard and Windows CE OS as optional.

2.4.1 Palm OS

The Palm operating system has been developed specifically for hand held device applications and therefore has low memory and power requirements. It has been developed in C and more recently C++ programming languages. Lukmani (2002) commented that the Palm OS scores over the Symbian OS as Palm code, once compiled on the emulator and debugged, the code can be easily run on the real Palm OS not requiring it to be recompiled.
The Palm OS is organized in horizontal and vertical layers; the microkernel encapsulates the hardware specific functionality and keeps the vertical layers independent from the under lying hardware. The vertical layer provides application programming interfaces (APIs) for applications to access the operating system functionality. As shown below the different vertical layers are (Lukmani, 2002):

- User interface;
- Memory management;
- System management; and
- Communication layer.

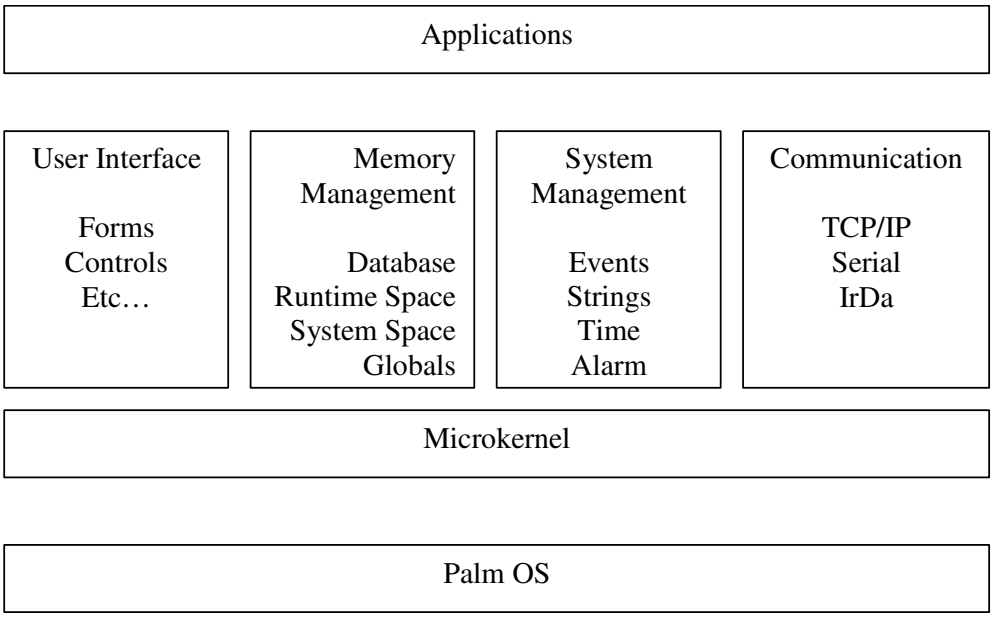


Figure 11: Palm OS structure (adapted from Lukmani, 2002)

2.4.2 Symbian OS

Psion originally developed the Symbian operating system when it was known as the EPOC OS. Symbian was originally an alliance between Ericsson, Nokia, Matsushita, Motorola, Psion, Siemens. In January 2003 Samsung bought in and have since released the i300 and i700 (Figure 9) pdaPhones. The Symbian OS has been specifically developed to meet the requirements of the mobile/SmartPhone market. Hence, the constraints for mobility, code size, memory and power requirements. Due to it being targeted at phone integrated devices, power management is an issue, where the device needs to be responsive in all situations and provide extended hours of operation on a single charge. To help overcome this issue the Symbian OS implements most of its multitasking through event-driven ($1x10^1$ bytes) messaging rather than with multi-threading ($1x10^3$ bytes) providing more efficient power usage. Code reuse is achieved by an object-oriented design, developing the system at the same time as the primary applications, and by using C++ for a system code, from kernel upwards.

Different to the Palm OS, the Symbian realies on multitasking where the base layer provides the fundamental APIs, and the middleware layer provides the graphics, data and other components to support the Graphical User Interface (GUI) and other applications. The EIKON is the System GUI framework, and finally there are the applications (Lukmani, 2002).

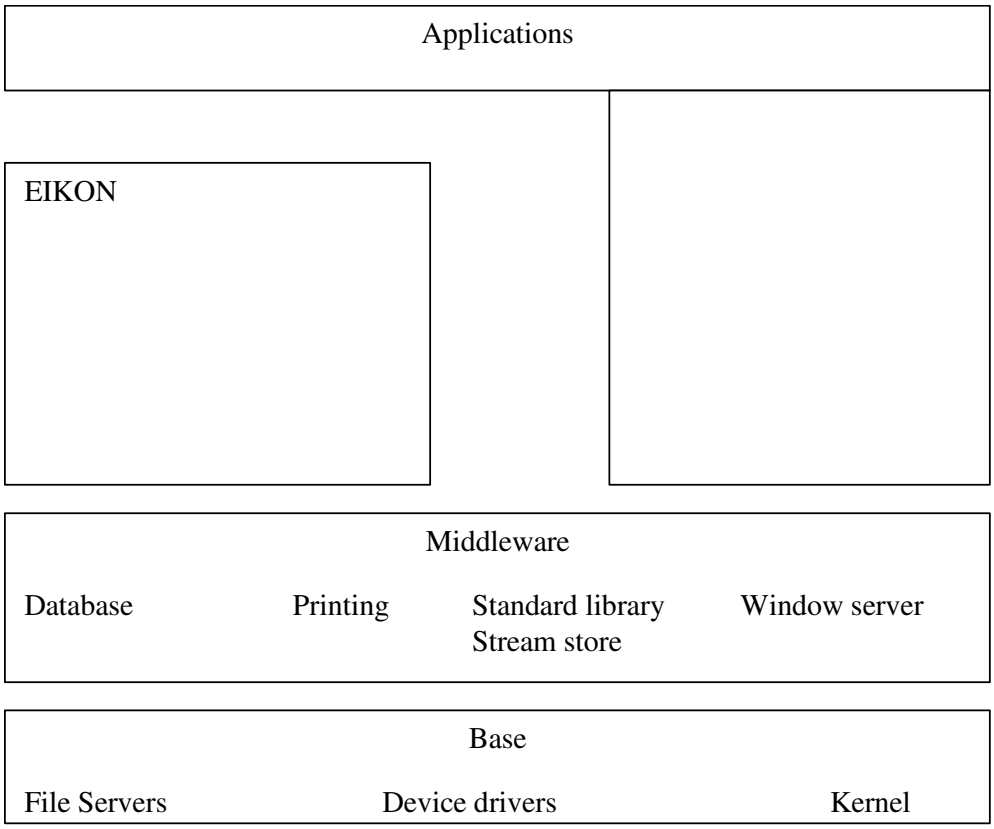


Figure 12: Symbian OS system architecture. (adapted from Lukmani, 2002)

2.4.3 Windows CE OS

Developed by Microsoft, Windows CE is a scaled down version of the Windows OS used on PCs targeted at the hand held device market. The earlier versions were difficult to navigate with the user being bombarded with a multitude of pop-up screens before reaching the intended target. However, the newer version/s of CE in PocketPC have been made more user friendly.

CE is a modular operating system allowing it to be reconfigured by the manufacturer on the fly if necessary. The advantage is that small mobile devices with small power and memory storage may utilise only the required components of the operating system, saving precious space and energy. The Kernel provides memory management, task scheduling and interrupt handling. The graphics/window/event manager (GWE) integrates the user interface functions of graphical output and user input. The object store is the persistent memory of Windows CE and includes files, the registry, and a database. Finally, the communications interface includes infrared via IrDA TCP/IP, and serial drivers (Lukmani, 2002).

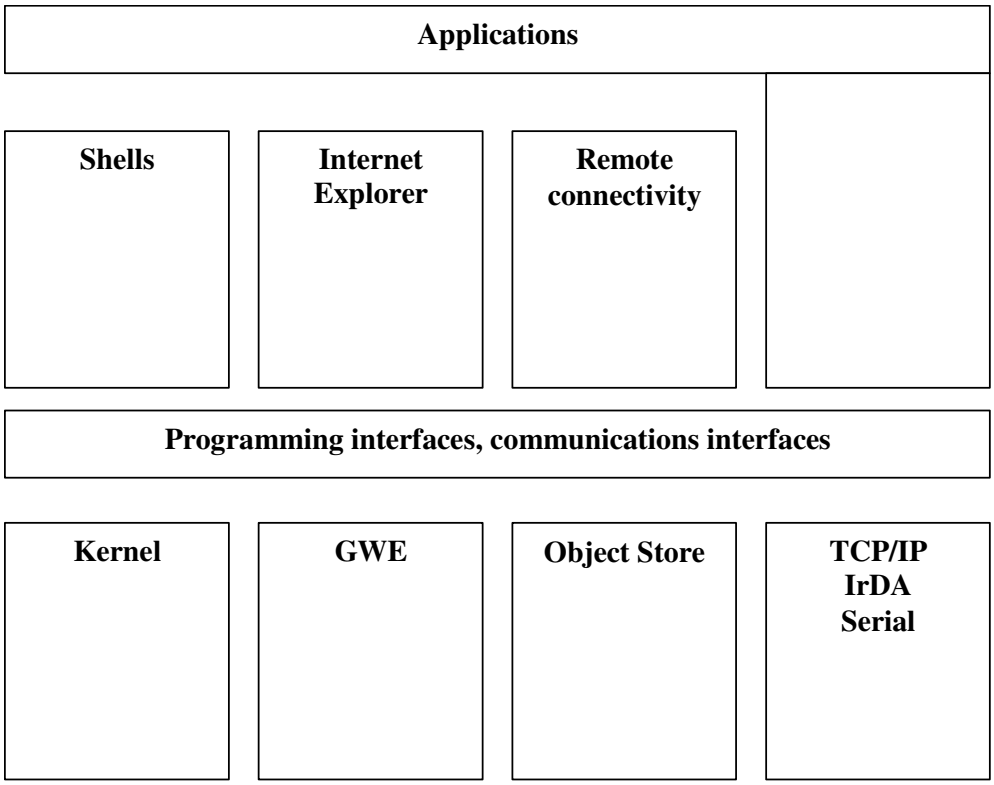


Figure 13: Windows CE OS system architecture (adapted from Lukmani, 2002)

Table 3 provides a summary of the features of the three main operating systems on hand held devices.

Table 3 Comparisons of Main OS System Features (Lukmani, 2002).

Feature	**Palm**	**Symbian**	**Windows CE**
User Management	Traditionally, single user system. Can be multiuser as well.	Typically a single user operating system	Typically a single user operating system
Task Management	It provides for only a single application to be running at a time, but other applications can be called from another, so switching between applications is facilitated. Internally, multi tasking is done in Palm.	Real-time microkernel with low-interupt and task switching latency provides multitasking with pre-emptive, priority driven scheduler.	Supports 32 simultaneous processes and unlimited number of threads, limited only by physical memory
Power Management	Palm OS has different power operation modes to save power: sleep, doze and running.	None	None
User Interface	Easy to access applications and user friendly in operation, recognizes only Palm handwriting alphabet.	The EIKON handle all interface related elements including buttons, dialogs and menus. The Symbian OS supports display, keyboard and sound.	Windows CE provides menu controls, dialogs and supports sound. The similarity of the interface with the windows desktop is distinct market advantage.
Memory Management	Divided as follows: Dynamic heap: for storing	Symbian has a memory management unit (MMU) concept to provide separate address spaces for each	A protected virtual memory system that supports up to 32MB memory per process protects applications against

Feature	Palm	Symbian	Windows CE
	global variables for program execution, stack and dynamically allocated memory, inline with a RAM of a desktop OS. Storage: this holds permanent data, such as databases, files and application codes, and is therefore not cleared on reset.	application.	each other.
Security	none	Low	High. Windows CE has support for cryptography with a cryptography library (Cryptographic Application Programming Interface CAPI) to securely store information in memory. Additional data security can be achieved by using the smart card interface of Windows CE.
Memory Protection	None	Yes	Yes
Supported Processors	Motorola Dragon Ball	NEC ARM	X86, ARM, MIPS SH3/4, PowerPC
Hand Held Usage (typical)	PDA	SmartPhone	PDA

2.4.4 Java

While on the topic of operating systems it is worth mentioning Java applications. Although there are Java OSs that are used on Hand held devices e.g. SavaJe by SavaJe Technologies for SmartPhones, the beauty of the Java language is that it is platform (OS) independent without the need to be rewritten or recompiled by the programmer for each separate platform. However, a device requires a Java Virtual Machine (JVM) for it to operate. A JVM, an implementation of the Java Virtual Machine Specification, interprets compiled Java binary code (called bytecode) for a computer's processor (or "hardware platform") so that it can perform a Java program's instructions. A Java virtual machine can either interpret the bytecode one instruction at a time (mapping it to a real processor instruction) or the bytecode can be compiled further for the real processor using what is called a just-in-time compiler.

Table 4 lists the majority of the operating systems in use on today's hand held devices.

Table 4 Operating System on current Handheld devices.

Manufacturer	Operating System
3Com	Palm
Microsoft	Windows Pocket PC; Windows CE; Windows CE.Net; Windows Smartphone, Windows XP
Symbian	Symbian (formerly EPOC)
Various	Linux
Research In Motion	Blackberry
Vtech	VT

Manufacturer	Operating System
Franklin	eBookMan
Apple	Newton (now defunct)
Casio	PV
IBM	DOS
SavaJe Technologies	SavaJe (Java Based)

2.4.5 On-Device Software

Table 5 is a list of the types of software applications currently available for installation on hand held devices. An extensive list of software products accessible through all mediums by Handheld devices is provided in APPENDIX B: AVAILABLE SOFTWARE USED BY HANDELD DEVICES IN THE CONSTRUCTION INDUSTRY.

Table 5 Types of On-Device Software Available for Handheld Devices.

Description	Example Software Developers
Mapping Software for GPS	Pharos; Delorme
GPS data logging Software	GEOAPS
CAD	123-D Software
Word Processing Software	DATAVIZ; Blue Nomad; Iambic
General Data Logging	GEOAPS
Tools for co-ordinate generation and calculation, interaction with AutoCad	GEOAPS
Wireless Printing	DDH Software
Data exchange software Access and ODBC databases	DDH Software
Language Translation Software	DDH Software
Text to Speech conversion	IBM
Multimedia Presentation Software	Synergy Solutions
Synchronisation Software	PumaTech
Application Development Tool	PumaTech, Paragon Software
Phone Management	Hands High Software
Font Management and Development	Hands High Software
Security Software	Palmation Software
On-screen keyboard software	Stevens Creek Software
Duplicate data entry identification and removal	Stevens Creek Software
Biometric User Authentication software	CIC

Description	Example Software Developers
Inventory software for bar code scanners on hand helds.	Fundamental Objects
Virtual Private Network software	Fundamental Objects
Java enabling software	esmertec
Vehicle Logging software	Little Wing Software Development
Language extension software	Paragon Software
Military Operations software	Warrior Solutions
Cross Platform Communication	SoDoeg Technologies
Java Virtual Machines	WabaSoft Technologies
Encryption Software	Chapura
Custom data collection software	Pen Computer Solutions
Voice Recognition software	Voice Signal Technologies
Hand Writing Recognition	Design-Universe
Time Tracking Software	Zoskware

2.5 Connectivity: The wireless evolution

One of the main advances in technology which is making Handheld devices more attractive to mobile site based industries is the advent of wireless capabilities. In this case connectivity refers to a mobile worker having access to the back office or site office system through various wireless enabling technologies and services including: Infrared, BlueTooth, Wireless-Fidelity (Wi-Fi or 802.11), General Packet Radio Service (GPRS), Code Division Multiple Access (CDMA), Global System for Mobile communications (GSM) and Third Generation (3G) broad band technologies. The following provides a brief introduction to the various wireless technologies used on Handheld devices today.

2.5.1 Infrared

Infrared Radiation (IR) or Infrared refers to energy in the region of the electromagnetic radiation spectrum at wavelengths longer than those of visible light, but shorter than those of radio waves. Correspondingly, the frequencies of IR are higher than those of microwaves, but lower than those of visible light. This technology has been used for many years for remote control of home entertainment systems such as television and stereo. IrDA is an international organization that creates and promotes inter-operable, low-cost infrared data interconnection standards. IrDA is a point-to-point, narrow angle (30° cone), ad-hoc data transmission standard designed to operate over a distance of 0 to 1 meter and at speeds of 9600 bps to 16 Mbps. Adapters now include the traditional upgrades to serial and parallel ports.

Features of IrDA (Gupta, 2003):

- Range: From contact to at least 1 meter. Can be extended to 2 meters. A low power version relaxes the range objective for operation from contact through at least 20 cm between low power devices and 30 cm between low power and standard power devices. This implementation affords 10 times less power consumption;

- Bi-directional communication is the basis of all specifications;
- Data transmission from 9600 b/s with primary speed/cost steps of 115 kb/s and maximum speed up to 4 Mb/s; and
- Data packets are protected using a CRC (CRC-16 for speeds up to 1.152Mb/s and CRC-32 at 4 Mb/s).

This technology is a standard wireless built-inn connectivity option widely available on Handheld devices today.

2.5.2 BlueTooth

Bluetooth is a high-speed, low-power microwave wireless link technology, designed to connect phones, laptops, PDAs and other portable equipment together with little or no work by the user. Unlike infra-red, Bluetooth does not require line-of-sight positioning of connected units. The technology uses modifications of existing wireless LAN techniques but is most notable for its small size and low cost. To avoid interference and to ensure security, the frequency hops in a sequence, which only the connected devices know and recognise.

Whenever any Bluetooth-enabled devices come within range of each other, they instantly transfer address information and establish small networks between each other, without the user being involved.

Features of BlueTooth (Gupta, 2003):

- Operates in the 2.56 GHZ ISM band which is globally available (no license required);
- Uses FHSS (Frequency hop spread spectrum);
- Can support up to 8 devices in a piconet;
- Omni-directional, non line of sight transmission through walls;
- 10m to 100m range;
- 1mW power; and
- Extended range with external power ampilifier (100 meters).

BlueTooth technology is now available as a standard built-in connectivity inclusion on various Handheld devices e.g. Palm Tungsten T and CDL Paron (Figure 14). In the majority of cases BlueTooth connectivity is provided, at this point in time, through add-ons such as USB adaptors and slot in Cards (Figure 15).

Palm Tungsten T CDL Paron

Figure 14 Built-in BlueTooth enabled device examples Palm (www.palm.com) & CDL (www.cdlusa.com/).

TDK USB BlueTooth Adpator Palm BlueTooth Card

Figure 15 BlueTooth enabling add-on examples TDK (http://l8shop.net/Products/TDK-USB-Bluetooth-Adaptor-2904.asp) and Palm (http://www.palmone.com/)

2.5.3 Wireless Fidelity

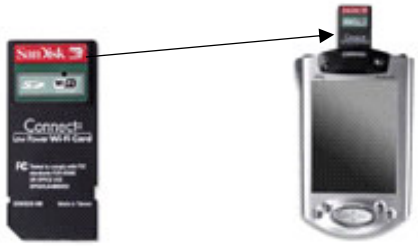
Wireless Fidelity (Wi-Fi), or 802.11b as it is commonly known, is used to wirelessly link devices up to a few hundred metres apart. Wi-Fi is specified in the 802.11b specification from the Institute of Electrical and Electronics Engineers (IEEE) and is part of a series of wireless specifications. The 802.11b technology operates in the 2.4 GHz range offering data speeds up to 11 Mbps. The modulation used in 802.11 has historically been phase-shift keying (PSK). The modulation method selected for 802.11b is known as complementary code keying (CCK), which allows higher data speeds and is less susceptible to multipath-propagation interference.

The main drawback with Wi-Fi is its susceptibility to external access by unauthorised users, sometimes allowing free internet connection. It comes with a security tool called Wired Equivalent Privacy (WEP), which has proven poor security. Wi-Fi hot spots are now available at public places such as transport interchanges, business parks and coffee shops. These hot spots allow the user to wirelessly access the Internet and send e-mail.

Wi-Fi connectivity is now available as a standard built-in e.g. Palm Tungsten C and Tohsiba e750 (Figure 16). In the majority of cases Wi-Fi connectivity is provided, at this point in time, through add-ons e.g. SD cards (Figure 17).

Palm Tungsten C Toshiba e750

Figure 16 Built-in Wi-Fi enabled device examples Palm (http://www.palmone.com/) and Toshiba (http://uk.computers.toshiba-europe.com/)



Sandisk SD Wi-Fi card

Figure 17 Wi-Fi enabling SD Card Sandisk (http://www.sandisk.com/consumer/sdwifi.asp)

2.5.4 Global System for Mobile Communications

Global System for Mobile communications (GSM) are a family (GSM, GPRS, EDGE, UMTS) of second generation (2G) and third generation (3G) digital wireless mobile phone systems that allow Handheld devices to access the Internet and make phone calls. It uses a variation of Time Division Multiple Access (TDMA). TDMA is a technology used in digital cellular telephone communication that divides each cellular channel into three time slots in order to increase the amount of data that can be carried. The GSM version of TDMA digitises and compresses data, then sends it down a channel with two other streams of data, each in its own time slot. It operates at either the 900 MHz or 1800 MHz frequency band. It is currently the most widely used of the wireless telephone technologies having at the end of 2002 over 787 million subscribers available in over 190 countries (GSM World, 2003). General Packet Radio Service (GPRS) is part of the family of GSM wireless voice and data enabling services and is commonly referred to as 2.5G for its evolutionary steps toward 3G. It enables 'always-on', higher capacity, Internet-based content and packet-based data services. This provides services such as colour Internet browsing, e-mail on the move, powerful visual communications, multimedia messages and location-based services. It promises data rates from 56 up to over 150 kbps. Due to this faster data rate middleware originally needed to adapt applications to the slower speed of wireless systems are not required. With packet service, users only pay for actual data transferred to the mobile device. As mentioned previously a current trend in Handheld devices is to enable wide area network (WAN)

capabilities to traditional PDA based devices. GSM/GPRS is now available on several devices e.g. Carrier Devices Qtek 1010 and Orange SPV E100 (Figure 18). GSM capability is available as an add-on for older versions of Handheld devices e.g. REALVision Carpe Diem V clipon for Palm V or Vx models (Figure 19).

Carrier Devices Qtek 1010

Orange SPV E100

Figure 18 Built-in GSM/GPRS built-in device examples Carrier Devices (http://www.nfc.co.nz/fascination.asp?NewsID=65&Page=2) and Orange (http://www.sonicsound.co.uk/spv.htm).

REALVison Carpe Diem V

Figure 19 GSM enabling add-on example by REALVision (http://www.palminfocenter.com/).

2.5.5 Code Division Multiple Access

Code Division Multiple Access (CDMA) also uses a variation of TDMA technology. It refers to a family of 2G and 3G wireless communications. CDMA is a form of multiplexing, which allows numerous signals to occupy a single transmission channel, optimising the use of available bandwidth. The technology operates on ultra-high frequency (UHF) systems in the 800 MHz and 1900 MHz bands. CDMA uses analog-to-digital conversion in combination with spread spectrum technology. The frequency of the transmitted signal is then made to vary according to a defined pattern (code), which is then intercepted by a receiver with the same programmed response code, so it follows exactly along with the transmitter frequency. This makes cloning difficult due to the large amount of possible frequency-sequencing codes

and hence enhanced security. CDMA uses a technology called soft handoff, which minimises signal breakup and is compatible with other cellular technologies. CDMA offers data download rates up to 115 kbps in it's eight-channel form.

CDMA phone capabilities are available as a builit-in feature on several Handheld devices e.g. Samsung Nexio S160 and Toshiba/Audiovox 2032 (Figure 20).

Samsung Nexio S160

Toshiba/Audiovox 2032

Figure 20 Built-in CDMA enabled device examples Samsung (http://www.bargainpda.com/?newsID=993&showComments=true) and Tohsiba/Audiovox (http://www.pdastreet.com/)

2.5.6 Third Generation

Third Generation (3G) Wireless Technology generally refers to mobile communication services that enable Handheld devices (e.g. pdaPhones) to use higher bandwidth data services than that commonly found today. First (1G analogue) and Second (2G digital) generation mobile systems used a fixed amount of bandwidth for each user. 3G allows the user to have access to the entire potential capacity of the base station. With this is a potential to have download speeds of 2 Mbps. TechnologyWatch (2003) reports that this service may not be widely available before 2005. Even though 3G services are not widely available at this point in time, there is already talk of 3.5G-High-Speed Downlink Packet Access (HSDPA) technology by UbiNetics, the global 3G-technology company. This technology promises data download rates of up to 14.2 Mbps. The following section discusses the main 3G technologies available today.

Enhanced Data GSM Environment

Enhanced Data GSM Environment (EDGE) is a 3G member of the GSM (3GSM) family of wireless communication services. It is designed to deliver data download rates up to 384 kbps and enable the delivery of multimedia and other broadband applications. EDGE is built on existing GSM standards, using the same TDMA frame structure and existing cell arrangements. Nokia (e.g. 6200) and Motorola (e.g. T725) currently have EDGE enabled devices on the market, albeit dedicated mobile phones (Figure 21).

Nokia 6200

Motorola T725

Figure 21 3G EDGE enabled available mobile phone examples Nokia (http://store.yahoo.com/1800mobiles/nokia6200activ.html) and Motorola (http://commerce.motorola.com/consumer/QWhtml/m_t725.html).

Universal Mobile Telecommunications Service

Universal Mobile Telecommunications Service (UMTS) is a 3G wireless communication service. It is also based on the GSM standard and has the capability of providing data download rates of 2Mbps no matter where the user is located globally. Access is provided through a combination of terrestrial wireless and satellite transmissions. Until UMTS is fully implemented users have the option of using multi-mode devices that are capable of switching between currently available GSM 900 MHz and 1800 MHz services. UMTS has been identified as operating in a frequency range of 1885-2025 MHz for the IMT-2000 systems and 1980-2010 MHz and 2170-2200 MHz for the satellite portion of UMTS systems. The technology is already available on various dedicated mobile phone devices e.g. Samsung (SGH-Z100) (Figure 22).

Samsung SGH-Z100

Figure 22 3G UMTS enabled mobile phone example Samsung (http://www.infosyncworld.com/news/n/3678.html).

Wideband Code-Division Multiple Access (WCDMA)

Wideband Code-Division Multiple Access (WCDMA), or IMT-2000 direct spread as it is officially known, is based on its predecessor narrow band CDMA standard. As with all 3G technologies it offers higher data download rates i.e. 2Mbps in WLAN environment or 384 Kbps in a WAN environment. The input signals are digitised and transmitted in coded, spread-spectrum mode over a broad range of frequencies. A 5 MHz-wide carrier is used, compared with 200 kHz-wide carrier for narrowband CDMA. The technology is also available on dedicated mobile phone devices e.g. Sanyo (V-SA701) and Nokia (6650) (Figure 23).

Sanyo V-SA701

Nokia 6650

Figure 23 3G WCDMA enabled moblile phone examples Sanyo (http://www.3g.co.uk/PR/Jan2003/4658.htm) and Nokia (http://www.nokia.com/nokia/0,,73,00.html)

Table 6 provides a summary of the electromagnetic radiation spectrum, range and data download rate for comparison of the different wireless connectivity options.

Table 6 Wireless Technology Comparisons of Main Features

Wireless Technology	**Electromagnetic Radiation Spectrum**	**Range (m)**	**Data Download Rate**
Infrared	2.4 GHz	Up to 1	Up to 16 Mbps
BlueTooth	2.56 GHz	Up to 10 Up to 100 with amplifier	Up to 721 Kbps
Wi-Fi	2.4 GHz	Up to 200	Up to 11 Mbps
GSM	900 and 1800 GHz	Limited by Service	Up to 14.4 Kbps
GPRS	900, 1800, 1900 GHz	Limited by Service	Up to 150 Kbps
CDMA	800 and 1900 GHz	Limited by Service	Up to 115 Kbps
EDGE	-	Limited by Service	Up to 384 Kbps
UMTS	1885-2025 MHz (IMT-2000) 1980-2010 MHz & 2170-2200 MHz (Satellite Portion)	Limited by Service	Up to 2 Mbps
WCDMA	5 MHz	Limited by Service	Up to 2 Mbps

2.6 Device to Device Communication

One direction that is appearing is technologies or applications which allow different devices to communicate with each other. One of these is BlueTooth mentioned previously. Another is Java also mentioned previously. Other device-to-device enabling technologies include Jini (Sun), ChaiServer (Hewlett-Packard), Inferno (Lucent Technologies) and Universal Plug and Play (Microsoft). The following provides a brief introduction to these other technologies.

2.6.1 Jini

Jini allows all types of devices to be connected into so-called impromptu networks. Jini allows access to new network services and creates a network consisting of all types of digital devices without extensive planning, installation, or human intervention. Each device broadcasts the services it offers to all other devices in the community allowing the services to be used by all members of the network (Amor, 2002).

By using objects that move around the network, the Jini architecture makes each service, as well as the entire network of services, adaptable to changes in the network. The Jini architecture specifies a way for clients and services to find each other on the network and to work together to get a task accomplished. Service providers supply clients with portable Java technology-based objects that give the client access to the service. This network interaction can use any type of networking technology such as RMI, CORBA, or SOAP, because the client only sees the Java technology-based object provided by the service and, subsequently, all network communication is confined to that Java object and the service from whence it came. When a service joins a network of Jini technology-enabled services and/or devices, it advertises itself by publishing a Java technology-based object that implements the service API. This object's implementation can work in any way the service chooses. The client finds services by looking for an object that supports the API. When it gets the service's published object, it will download any code it needs in order to talk to the service, thereby learning how to talk to the particular service implementation via the API. The programmer who implements the service chooses how to translate an API request into bits on the wire using RMI, CORBA, XML, or a private protocol (Sun Mircosystems, 2003).

2.6.2 ChaiServer

ChaiServer adds functionality to the ChaiVM by allowing web-based connections to other devices on a network. ChaiServer has a scalable architecture that allows appliance designers to install only those portions that are required by the appliance. It provides a scalable, compact, robust web server with a very small read-only memory footprint, ranging from 200-400K, making ChaiServer suitable for Handheld devices.

ChaiServer is a small application server for embedded applications. It's written in Java, and will run on any virtual machine. It allows devices to provide information about themselves (such as status and device characteristics) and be controlled through a Web page. It also includes an application framework. This framework is the basis of the so-called ChaiServices, that enable programs running on a device to make use of networking and the web server (Eurescom, 2000).

2.6.3 Inferno

Inferno consists of a small footprint operating system that can connect to networks or run programs within a virtual machine. It supports programs written in two languages: Limbo, which translates Java applications on the fly, and PersonalJava, the stripped down version of Java. Inferno can run directly on hardware platforms or can be hosted on standard operating systems. It is a distributed architecture-independent network operating system that models

all available resources as files. The virtual machine hides the differences in hardware, and the name spaces are personalisable and it has built-in security mechanisms (Amor, 2002).

2.6.4 Universal Plug and Play

Universal Plug and Play (UPnP) is an extension of the plug and play hardware recognition system, which was introduced with Windows 95. UPnP technology is a distributed, open networking architecture that employs TCP/IP and other Internet technologies to enable seamless proximity networking, in addition to control and data transfer among networked devices in the home, office, and public spaces.

UPnP only works with Microsoft operating systems. It allows the tying of devices together without needing a computer. UPnP is an evolution of an existing technology, taking on the burden of the underlying technology. Amor (2002) comments that this makes UPnP more complex, less innovative, and less elegant. However, he does comment that it works well as a complementary technology for Jini.

2.7 Automatic Data Collection

Due to the current limitations of hand held devices that rely solely on traditional Graphical User Interfaces (GUIs) with cumbersome manual data entry and interaction, the move towards the use of automated technologies in mobile devices seems an obvious choice. The need for hands-free/eyes-free data entry in the mobile workforce environment has many advantages including the potential increase in productivity, accuracy, ergonomics, and safety. The four main areas of current use of automated data collection for Handheld devices are Speech Technologies, Bar Code Scanning, Radio Frequency Identification and Biometric User Authentication.

2.7.1 Speech Technology Software

Speech technology in this case refers to the use of speech for automated processes through a computing environment. This technology includes Speech Recognition, Text-to-Speech (TTS) processing, Interactive Voice Response (IVR) and Speaker Verification. The major developers in speech technology software include IBM, Dragon, ScanSoft (formerly SpeechWorks), Nuance, InterVoice and Inflection Technologies.

Speech Recognition Software

Speech, or Voice Recognition as it is sometimes referred, is one area of speech software research and development that is receiving much attention currently, and all indications, the future. Speech Recognition includes automated dictation, command and verification applications.

2.7.1.1.1 Dictation

Dictation was one of the first forms of speech recognition software commercially available. It involves a person speaking at the computer via a microphone and the computer turning the spoken words into text and displaying them onscreen. There are two types of dictation software: discrete and continuous. Discrete systems require that the speaker speak slowly and distinctly and separate each word with a short pause. Continuous speech systems allow the speaker to speak in a more natural manner and in some cases allow the context of the speech to be determined due to group processing. Most dictation systems require extensive voice training during which the computer system becomes accustomed to a particular voice and accent. Current companies that offer solutions for the PC are Dragon Naturally Speaking, IBM Via Voice, Philips FreeSpeech, Lernout&Hauspie Voice Xpress, and MacSpeech.

2.7.1.1.2 Voice Recording

A number of the newer handhelds (eg. Palm Tungsten, Sony Clie, HP iPAQ, Toshiba Pocket PC, etc.) now come standard with a voice recorder – with the amount of recording time dependant on the amount of free RAM available. On a Palm Tungsten T, for example, a 128 Mb SD card will hold approximately 520 minutes of voice recorded data, using its built-in "Voice Memo" program. Unfortunately, due to power limitations of the battery, continuous recording of this type of duration would not be possible unless attached to a secondary power source. Once the voice data has been recorded, it is just a simple step to download the digital recording to a computer "as is", for storage and retrieval, or allow voice recognition software to import the digital recording file and translate it into text.

2.7.1.1.3 Speech Command

Speech command software enables the control of computers through giving voice commands to the computer or device and it completing the action automatically. The most recognisable use of this software is in high-end mobile phones where a number is dialled through voice commands (e.g. Voicedial-Fonix). This is known as pattern recognition. Voice commands are also available via some operating systems e.g. Macintosh OS X10.1. Typical software applications currently available for the automated speech control of Handheld devices include Calender, Contacts and Inbox applications e.g. IBM Via Voice.

2.7.1.1.4 Natural Language Speech Recognition

Natural Language Speech Recognition (NLSR) software has the ability to understand a much wider vocabulary and whole phrases which may contain more than one piece of information and not necessarily in the correct order. The NLSR is capable of two-way interaction between computer and user. An example is its ability to respond in a logical and smart way. For example it can question input and rephrase questions. A typical application is online banking where the user can ask for an account balance on a particular account and the balance is read out by the computer.

2.7.1.1.5 Speaker Verification

Speaker Verification systems are a form of biometric technology known as Auditory Biometrics that uses speech recognition engines to simultaneously authenticate a speaker, essentially for security purposes. This enables increased efficiencies over traditional manual authentication systems.

Text-to-Speech

Text-to-Speech (TTS) is the ability for a computer or system to take a normal written sentence and turn it into spoken words. This is not new technology, as the Macintosh OS has had this capability for a number of years and Microsoft have included these types of applications since the introduction of the Windows 2000 OS.

Interactive Voice Response

Interactive Voice Response (IVR) systems involve a menu of options with the ability to select the appropriate option by using a telephone keypad. They are the recorded voice you encounter when paying a bill or contacting a large organisation such as a bank. Some IVRs include a speech recognition system.

Table 7 is a list of currently available speech technology software applicable to Handheld devices.

Table 7: Currently available Speech Technology software for Handheld devices.

Manufacturer	Name	Description
IBM	Via Voice Mobility Suite	Provides appointment, contact, email and task entries.
	Via Voice Translator	Translates words and phrases and can account for context and differences in grammar between languages and allows text translation to and from English and French, Italian, German and Spanish.
Dragon	PDsay	Developed to speech-enable Pocket PC devices. Provides voice interaction with the Personal Information Management (PIM) tools, it also uses Text-To-Speech (TTS) technology to read appointments, contacts, tasks, and e-mail messages.
ScanSoft	ASR-1600	The ASR-1600 Mobile SDK for Microsoft® Windows® CE and Linux® operating systems comprises a flexible, noise robust, medium-sized vocabulary, speaker independent speech recognition engine.
	VoCon SF	Developers tool to add highly accurate voice command and control capabilities to a wide range of embedded hardware and software applications. Supports over 16 languages, has ability to scale from DSP to RISC platforms.
	VoCon 3200	Speaker-independent and continuous speech capable, its noise management and acoustical capabilities allow speech recognition in noisy environments.
	ASR-300	Word-based speech recognition engine, which provides accurate recognition in very noisy environments and operating conditions. Suited for command and control, hands-free operation, digit input or name search in products such as hands-free mobile phones, navigation systems, telematic products and multi-media systems.
	X/mode Multimodal	Allows true multimodal applications, combining voice, visual and audio interfaces on a single mobile device and a single session.
	RealSpeak	Speech-enables a wide range of applications, including unified messaging systems, interactive voice response (IVR) applications, and information portals, and to provide synthesised speech capabilities to mobile, automotive, game and PC/multi-media applications.
	SpeechSecure SF	SF utilizes biometric technology to verify an identity based on the unique characteristics of his or her vocal patterns and has capability to isolate the passphrase from surrounding noise.
Conversay	Mobile Conversay	Is a speaker-independent, continuous speech recognition engine. Users don't have to "train" the system and may speak in a natural voice. Clear, robust, text-to-speech capabilities allow the end-user to reliably access information.
Nuance Communications Inc.	Nuance 8.0	Allows individuals to use text, graphics and speech to interact with WAP applications or any other application running on wireless phones or PDAs.
	Verifier 3.0	Uses voiceprints of an individual's name, phone number, social security number, account number, or PIN to authenticate that person using the company's "It's Me" technology. The technology has been tightly integrated with the Nuance's speech recognition software, and supports a number of languages.
InterVoice	Omvia Speech	Omvia™ Speech is the industry's most complete and powerful suite of voice-driven solutions.

2.7.2 Bar Code Reading

Bar code reading is another automatic data collection method worthy of mention. Most people would be aware of this technology through personal experience when shopping for their groceries at the supermarket, where products are charged through bar code scanning machines at the counter. It has also been used for many years for mobile/field industrial applications such as product and material inventory in the retail sector and identity verification (ID Swipe Cards) in general.

There are two types of bar code scanning technologies used in today's hand held devices: pen type barcode readers and laser bar code scanning.

Pen type barcode readers have a light source and a photo diode placed next to each other in the tip of a pen or wand. To read a bar code, you drag the tip of the pen across all the bars, in a steady even motion. The photo diode measures the intensity of the light reflected back from the light source and generates a waveform corresponding to the widths of the bars and spaces in the bar code. The barcode reader sends the waveform to the decoder, which decodes the waveform and sends it to the computer in a traditional data format.

Laser barcode scanners work the same way as pen type barcode readers. The main difference is that Laser barcode scanners use a laser beam as their light source, and typically employ either a reciprocating mirror or a rotating prism to scan the laser beam back and forth across the bar code. As with the pen type bar code reader, a photo diode is used to measure the intensity of the light reflected back from the bar code.

As mentioned previously the PDT devices were originally designed for industrial Handheld scanning applications having built-in scanning capabilities. Once again the convergence of devices is evident for PDTs where now there are numerous devices that are PDA like in configuration and appearance. The major PDT manufacturers with a leaning towards hybrid PDT/PDA devices, also known as Portable Palm Terminals (PPTs), are Symbol Technologies, Intermec and PSC. There are also several add-ons currently available allowing PDA based devices bar code scanning capabilities including plug-in peripherals, CompactFlash cards with Wand and slip-on plug-in attachments. Bar coding technologies have potential uses within the AEC industry, the most obvious being on-site materials and equipment inventory. This process has the potential to improve both the efficiency and quality of on-site inventory data collection, as well as indentifying various components within a facility, which need to be identified as part of an asset/facilities management process.

2.7.3 Radio Frequency Identification

Radio Frequency Identification (RFID) also known as dedicated short-range communication (DSRC) is an automatic data collection system similar in theory to bar code reading. The transmission of signals is achieved through the electromagnetic or electrostatic coupling in the radio frequency portion of the electromagnetic spectrum. The RFID system consists of an antenna and a transceiver, which read the radio frequency and transfer the information to a processing device, and a transponder, or tag, which is an integrated circuit containing the radio frequency circuitry and information to be transmitted. The main differences between RFID and bar code scanning is RFID does not require line-of-sight reading and can be read at greater distances (up to 90 feet) from the source object. The Psion 7535 (Figure 3) has add-on RFID capabilities.

The source object is typically referred to as a tag. The tag has a microprocessor and memory, as well as an antenna. There are two types of tag, Active and Passive, although there are some variations within each type (see Table 8). Active tags run on battery power and passive tags receive their power through the radio frequency electro-magnetic field generated by the reader. Applications are similar to that of bar code readers, however, the

RFID technology allows read/write capabilities, giving field personnel the ability to update/edit data pertaining to a particular item (see Table 9). Due to this ability it has been used extensively for asset management functions. This technology has been used for some time in the nuclear, haulage, automotive, agricultural and retail industries.

Table 8 RFID Tagging Type Specifications (BRE, 2002)

Tag Type	**Frequency Range**	**Typical Read Range**	**Typical Capacity**	**Mounting Options**
Glass- Passive Tag	Low	<1m	<8k bit	Set in epoxy resin Custom designed holders Glue to item
Plastic Disc- Passive Tag	Low	<1m	<8k bit	Custom designed holders Glue to item Fasteners
Card- Passive Tag	Low/Medium	<1m	<8k bit	Designed to be carried as a smart key or as an identity badge Glue to item
Label- Passive Tag	Medium	<1m	<8k bit	Self Adhesive Paper Self Adhesive Plastic Lamination build on
Active Tags	Medium/High	<2m	Unlimited	Custom built enclosure

Table 9 RFID Tagging Type Uses and Benefits or Otherwise (BRE, 2002)

Tag Type	**Typical Uses**	**Advantages**	**Disadvantages**
Glass- Passive Tag	Animal ID Product ID Car Security	Cheap Resistant to water/chemicals dirt Can be used in animal tissue	Limited read range and capacity Need special holder for many applications
Plastic Disc- Passive Tag	Animal ID Asset ID Security Access	Cheap Resistant to water/chemicals dirt Easy to attach to wood	Limited read range and capacity
Card- Passive Tag	Security Access Smart Card Ski Pass	Greater capacity than magnetic swipe cards Cards can double as a visual identity card	More expensive than magnetic swipe cards
Label- Passive Tag	Parcel Tracking Luggage Tracking Laminated with Signs, Doors, etc.	Cheapest tag format (Paper Label) Can be combined with a visual label such as barcode Label can be easily fixed during manufacture	Must be mounted on a clean flat surface Limited durability Will not work on metal without a spacer

Tag Type	Typical Uses	Advantages	Disadvantages
Active Tags	Vehicle ID Production Line control	Good read range Can be used as part of Local Positioning Systems High data capacity Can form part of a larger system, e.g. automatic data capture	Expensive Limited battery life

2.7.4 Biometric Security

As mentioned previously Speech Verification is an Auditory Biometric technology currently used on mobile phones.

Another form of Biometric technology used on Handheld devices is fingerprint sensing. To date there has been no two fingerprints found that are identical. That is why this form of identification has been used successfully for many years in criminology applications. Fingerprint sensing offers to replace or complement passwords enabling a higher level of convenience and network security. The two main types of fingerprint verification sensor systems used today are optical and solid-state. The solid-state units (also called silicon or chip sensors) are more suited to Handheld devices due to their relatively small size. There are currently several types of solid-state technologies used in Handheld devices capacitive and temperature. The capacitive type determines the distance to the fingerprint ridges and fingerprint valleys by measuring the electric field strength, which drops off as the inverse of distance (Xia & O'Gorman, 2001). The temperature or thermal type has been designed to image the temperature difference of a finger related to touching ridges versus non-touching valleys. Of these types of processing technologies there are also two main designs regarding the way the fingerprint is processed: area and swipe type. Manufacturers of fingerprint sensor technologies for handheld devices include Atmel, AuthenTec and Fujitsu.

Hewlett Packard currently uses the Atmel AT-77C101B FingerChip thermal swipe design sensor for its iPAQ H5550 Handheld device (Figure 24). AuthenTec produces the EntrePad AES 3500 capacitive sensor, which it claims is the smallest area fingerprint sensor, specifically for wireless devices including PDAs. Fujitsu Microelectronics produces the MBF300 capacitive swipe design sensor, which is also aimed at the mobile and PDA market. The CDL Paron device mentioned previously has built-in biometric fingerprint security (Figure 14).

HP iPaq H5550

Figure 24 HP Handheld with built-in Atmel thermal fingerprint sensor security (http://welcome.hp.com/country/us/eng/prodserv.html).

2.8 Digital Cameras

A number of newer handhelds now have the ability to capture digital photographic images either through a built-in digital camera (eg. Sony Clie, Palm Zire 71, etc) or via an “add-on” digital camera (eg. Veo Traveller), however there is a large range in their overall quality, functionality and level of resolution.

Sony Clie PEGNZ90G with built-in 2mp digital camera

Palm Zire 71 with built-in 0.3mp digital camera

Figure 25 Sony and Palm PDAs with built-in digital cameras

There is a growing number of devices (mainly Phone-PDAs and PDA-Phones) with built-in cameras, and while some of the newer ones are boasting capabilities only seen in quality dedicated cameras only a couple of years ago, others are still only providing basic digital camera functionality (see Table 10 below).

Table 10 Comparison of Handhelds with built-in digital cameras

Manufacturer	Product Name	Specifications/Features
Alphacell	M6	Integrated Color Camera CMOS based Video & Image capture at 640 x 480 resolution (VGA)
Ericsson/Sony	P800	Camera image size up to 640 x 480 pixels Color depth 16 million colors (24 bit)
HNT	Exilion 201	Video camera 1/7inch CMOS image sensor CIF (352x288) resolution
HNT	IMT-2000	Camera module 1/7" CMOS image sensor 352x288 resolution
MiTAC	mio 8380	Built-in 110K pixel camera with zoom function
Motorola	A760	Build-in digital photo/video camera
Palm	Zire 71	Integrated Camera • Available Resolutions: 640x480, 320x240, 160x120 (VGA)
Pogo	nVOY e100 Communicator	Built-in Colour Camera 320x240 pixels
SAMSUNG	SPH i700	640x480 pixel integrated camera
SK Telecom	IMT2000 WebPhone	Built-in Camera
Sony	CLIÉ PEGNX70VG	Built-in 310,000 pixel CMOS image sensor camera, 260 degree rotating angle
Sony	CLIÉ PEGNZ90G	Built-in 2 mega pixel, 1/2.7 CCD image sensor, 2X digital zoom, Auto focus, Red-eye reduction, 260 degree rotating angle

Rather than providing a built-in digital camera and thereby adding to the complexity and cost of the handheld, a large number of hand held devices are able to include digital camera capabilities through the use of "add-on" digital camera modules that utilise either the device's expansion slot (usually SD or CF) or its main connection bus. Some of the earlier style "add-on" cameras were the Kodak PalmPix cameras for the Palm M100 and M500 handhelds (see Figure 26 below).

Kodak PalmPix for Palm M100

Kodak PalmPix for Palm M500

Figure 26 Discontinued Kodak PalmPix cameras

Maximum resolution for the M100 PalmPix was 640x480 pixels with 800x600 pixels for the M500 model – however both these cameras have since been discontinued and support for existing cameras is limited.

Veo however, have taken up where Kodak left off and are continuing to develop add on cameras for a range of handheld devices utilising different operating systems. Entry level cameras – with a maximum resolution of 640x480 pixels – use either the SD (Palm) or CF (Pocket PC) card slot and come with necessary image capture software (see Figure 27 below).

Veo Traveller SD Card

Veo Traveller CF Card

Figure 27 Veo Traveller "plug-in" digital cameras for both Palm and Windows Handhelds

Veo have also developed a higher end camera – with a maximum resolution of 1280x1024 pixels – for not only themselves but also for Palm and HP to be marketed under their own brand names (see Figure 28 below).

Palm SD 1.3 megapixel Camera

HP “photosmart” 1.3 megapixel Camera

Figure 28 Palm and HP 1.3 megapixel SD “plug-in” digital cameras

Overall, the majority of these devices (ie: anything with a resolution under 1 megapixel) should only be considered as novelties rather than proper digital image capturing devices. The main limitations with these cameras are:

- Lack of image resolution;
- Lack of zoom capabilities;
- Poor focusing capabilities;
- Poor lens quality – which affects image quality; and
- Limited internal image development software capabilities.

Even the high resolution cameras (ie: Sony Clie PEGNZ90G and Veo/Palm/HP 1.3 mp) have significant limitations relating to:

- Image storage limitations within the handheld;
- Lack of optical zoom capabilities;
- Poor focusing capabilities on the Veo/Palm/HP camera;
- Lens quality – which affects image quality; and
- Limited internal image development software capabilities.

Although the higher end devices are now able to capture digital images at a reasonable resolution, if digital image quality really is an important issue, then one should possibly consider a dedicated digital camera instead, where good image quality is not compromised by the limitations imposed on a device that is really a non-core function of the handheld device. Selecting a dedicated camera does not however have to limit connectivity, because by selecting a camera that utilises the same expansion card format for storing the digital images, it is possible for the images to be downloaded to the handheld for incorporation into documents and databases or transmitted wirelessly.

3 HANDHELD TECHNOLOGY IN THE CONSTRUCTION INDUSTRY

This section discusses in general the impact that Handheld technology is having and may in the future have on the Construction Industry. The range of uses has been determined through a survey of available software applications. The uptake in Queensland Australia is discussed including several case studies of the use of Handheld technology in Queensland's Construction Industry. Case studies on the benefits or otherwise of Handheld technologies has been reviewed as well as a brief explanation of some of the technologies looking to address some of the drawbacks of the current crop of Handheld devices. A brief discussion on MCommerce in construction is provided including the technologies which are driving this technological advance.

3.1 Range of Uses in the Construction Industry

In order to determine the applications of Handheld devices in the construction industry a survey of the available software over the internet was used. The following list provides a comprehensive summary of the functions that are being addressed for construction management that is available on a Handheld device either through ASP, Client/Server or On-Device Software.

2D & 3D CAD; Accounting; After Sales Service; Bidding; Business Development; Certification Tracking; Change Order Management; Client Management; Code Checking; Commissioning Management; Communication Management; Contact Management; Contract Management; Contractor Management; Cost Control; Design Management; Diary Document Management; Drawing Register; Earned Value Management; Equipment Management; Estimating; Feasibility Analysis; Financial Analysis & Management; HR & Training Management; Knowledge Management; Land Acquisition; Marketing; Materials Management; Milestone Tracking; Option Management (Project Home Builders); Payroll; Performance Management; Procurement Management; Productivity Analysis; Project Collaboration; Project Scheduling; Project Variance Analysis; Purchase Management; Quality Control; Resource Management; Risk Management; Safety Management; Sales Management; Stores Management (Stock Control); Tender Management; Time-Attendance Management; Tool/Plant Management; Virtual Design Centre.

3.2 Queensland Construction Industry

3.2.1 Uptake of Handheld Computing Devices in Queensland, Australia

A recent (July, 2003) survey was conducted into ICT in the Queensland Construction Industry. The survey was sent to members of a prequalification database supplied by the Queensland Department of Main Roads and the Queensland Department of Public Works. One of the questions asked "how often did the respondents require the use of a Handheld computing device for their work". Of the 67 respondents 44.8% responded that they never and 22.4% at least occasionally require the use of a Handheld computer. This indicates that at the present point in time Handheld computing has not made a great impact in to the construction industry in Queensland.

3.2.2 Field Inspectors Diary Organiser (FIDO)

Engineering consultancy Gutteridge Haskins Davey (GHD) has developed a software package which aids Field Inspectors, Supervisors and Engineers in carrying out typical field data collection and construction management tasks. This system has been used on various

road construction projects throughout Queensland including the Pacific Motorway linking the Gold Coast to Brisbane, and Eumundi bypass on the Sunshine Coast.

The system consists of three parts (GHD, 2002):

- The Device Hardware

Handspring Visor Deluxe. Docking station using either a USB or serial connection is used for transferring data to a network PC for final processing.

- The Palm database

Uses a relational database called thinkDB 2 from thinkingBytes Technology. This uses a proprietary database structure called tinyByte which has the ability to interface to standard databases.

- The Access database

    - The Palm database is synchronised with the PC and network files and the data is transferred to a Microsoft Access Inspector's database.
    - A second process occurs later where final engineer verification is performed before storing the data as a permanent record in the Microsoft Access Project database.
    - The network database is also maintained in respect to information that needs to be updated to the palm unit. This covers program activity codes, contract notices, plant, labour and material classifications as well as client standard schedule items.

The system is used to enter diary data for people other than inspectors. While the Inspector level is the most detailed, the option exists for entries as either a Supervisor or an Engineer. These higher levels are useful for the other people to record observations and events in which they played a part, for example the sign-offs on the printed daily diary are adjusted for the level of diarist involved. Figure 29 shows the system's database structure.

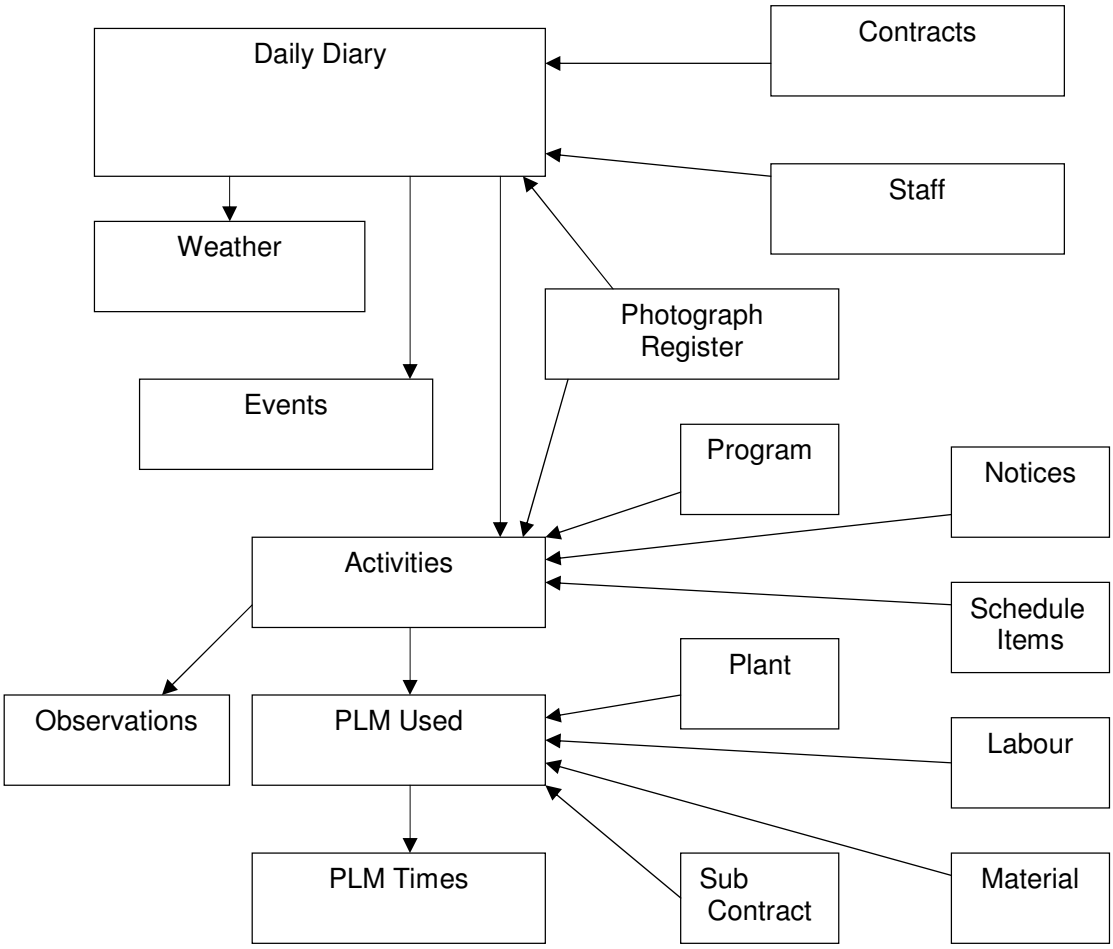


Figure 29 FIDO system database structure (GHD, 2002).

3.2.3 E-Site

A number of years ago, major contracting company Thiess undertook an investigation into computerised contract and construction management systems that would also allow the use of handheld computing devices for data capture and retrieval on construction sites. Although their investigation looked at both local and international systems available at that time, none were deemed to meet the requirements of Thiess. Unable to find a suitable existing system, Thiess decided to develop their own system, called E-Site.

Developed using the Fox Pro database language, E-Site (having recently been upgraded to Version 2, providing greater functionality) allows forepersons, supervisors and site engineers the ability to interact with the central project database via the use of handheld computing devices utilising the Palm operating system.
The type of information collected by the handheld devices includes:

- Field record capture;
- Daily Diary entries;
- Cost control/cost centre information; and
- And more.

Benefits include single point data entry responsibility and accurate real time data collection. The only issue identified as a potential problem of using handheld devices was cultural and

related to the initial reluctance of some of the older staff to use the devices. However, it was also noted that with suitable training and familiarity with the system, these problems were quickly overcome.

Although no formal study into the benefits of the use of handheld devices has been undertaken within Thiess, anecdotal evidence suggests that the system saves time (estimated at approximately 1 hr/day/person) and that data accuracy was improved.

Although the new version is only a couple of months old, Thiess are constantly looking at ways to improve the system and improve functionality. Some of these developments will be instigated by the advances in handheld technology itself.

3.3 Benefits or Otherwise of Current Handheld Computers in Construction

This section looks at several case studies that have attempted to measure the benefits or otherwise of using Handheld computers on construction projects. The first (Saidi et al, 2002) was evaluated through a combination of theoretical modelling and field observations. The second (Rebolj, 2000) assessed a road construction project, where the main focus was on the effect on communication through using Handheld computing devices. The third (Bowden et al, 2002) trialled four different Handheld devices on a construction project with the main focus being a comparison of the various devices. They also surveyed the thoughts of the trial participants on Handheld devices in general. The fourth (TechnologyWatch, 2003b) specifically investigated the use of RFID technology in construction and identified potential benefits.

The Home Building industry's uptake of Application Service Provider technology in the United States is discussed including the benefits as identified by industry.

3.3.1 Case Studies

Saidi et al (2002) tested the hypothesis that "Hand Held computers can indirectly increase direct work by directly decreasing the amount of support work and idle time within an activity". They applied their evaluation technique to six hypothetical construction field activities punchlisting, materials tracking, Materials Safety Data Sheets (MSDS) access, drawing access, Requests For Information (RFIs) and quantity surveying. Table 11 summarises the results of the evaluation process for the six activities.

Table 11 Results of Tests for Hypothetical Construction field activities (Saidi et al, 2002).

Activity	Elementary Tasks Eliminated	Activity Cycle Time reduction (%)	Overall Potential Delay reduction (%)
Punchlisting	14	40	50-70
Materials Tracking	9	26-51	88-95
Materials Safety Data Sheets	5	59-71	65-75
Drawing Access	3	70	64-72
Requests For Information	1	16-23	83-91
Quantity Surveying	6	60	N/A

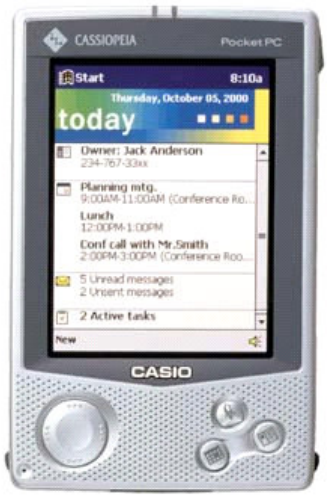
Saidi et al (2002) found, through field trialling of a Handheld device, that limitations exist on their functionality due technological boundaries. These limitations involve features such as

screen size, screen visibility, processing capability and input method. From this trialling process they formulated a list of construction related tasks that are suited or otherwise to Handheld devices, as presented in Table 12. Overall they also concluded that the most significant benefit that Handheld devices provided was their ability to provide real-time access to relevant information on the job-site, and to send real-time information back from the jobsite to the appropriate decision makers.

Table 12 Examples of Tasks Suited and Not-suited for Handheld Devices in Construction (Saidi et al, 2002).

No.	**Tasks that are Suited**	**Example**
1	Tasks that require access to large amounts of text information	Reading MSDS sheets, building codes, knowledge base, etc.
2	Tasks that require viewing a small detail of a document	Viewing close-up of a steel beam connection diagram
3	Tasks that require the entry of binary data	Answering yes/no questions, checking-off items on punch lists
4	Tasks that require the entry of data into a form	Filling-in a safety or equipment usage report, recording material receiving information, etc.
5	Tasks that require instant transfer of small amounts of information to and from a network.	Sending and receiving e-mails, looking up the latest material procurement information.
No.	**Tasks that are not Suited**	**Example**
1	Tasks that require computer processing power comparable to that found in desktop computers	Editing a 3-D construction drawing
2	Tasks that require a “big-picture’ view of a document	Viewing a drawing or a network schedule
3	Tasks that require a constant (i.e., always on) connection to a computer network	Working with data stored on a mainframe
4	Tasks that require a considerable amount of manual data entry (or writing).	Writing a progress report
5	Tasks that are likely to be performed mostly in direct day light, or under very bright artificial lighting	Working with no roof overhead during the day
6	Tasks that actually put work in place	Nailing, cutting, digging and etc.

Rebolj et al (2000) conducted a Case Study on a civil engineering road construction project. One of the main focal points of the study was the investigation of information exchange between project participants using available GSM technologies. They concluded that their results indicated efficiency of communication was significantly improved by using current mobile computing components: unmodified currently available PDAs (i.e. Casio Cassiopeia E-125, Figure 30), attached mobile phones and web services. They too found that the PDA had its limitations, the main issues being the small screen size, unsuitability for site conditions e.g. dust, strong light, rain, rough handling, and the difficulty in performing data input.



Casio Cassiopeia E-125

Figure 30 Unmodified Casio Cassiopeia E-125 used for Rebolj et al (2000) case study.

Bowden et al (2002) conducted a field trial of four devices in conjunction with the contractor consortium of Carillion, Alfred McAlpine, Balfour Beatty and Amec (CAMBBA). The participants included Senior Managers, Functional Managers, Site/Section Managers, Surveyors, Health and Safety Engineers as well as construction staff and sub-contractors. Although the main focus of this trial was to compare the various devices, users were also asked to evaluate the usefulness of having access to different information through using the Handheld devices for various site tasks. The rating system was on a scale of 1-5 with 5 representing 'very useful'. Table 13 summarises the responses.

Table 13 Responses to Usefulness Survey (Bowden et al, 2002)

Task	**Rating**
Method Statements	3.8
Drawings	3.6
Inspection test sheets and similar documents	3.5
Diary	2.9

The participants were also asked whether they would be happy overall to use a Handheld device for their work, with 88% confirming a positive response.

Bovis Lend Lease (UK) has used an RFID tagging system for deliveries during construction and maintenance. As mentioned previously this technology is currently available on Handheld devices. They identified the following benefits (TechnologyWatch, 2003b):

- A reduction in the number of lost delivery notes and payment delays: resulting disputes can cost 15000 Pounds or more to resolve on a typical project;
- Improved material management: trials indicate a 2 to 5% saving in material costs;
- Greater maintenance productivity by giving engineers, as well as clients, instant access to maintenance history, settings and other essential information; and
- Reduction in defects: defective items are identified, tracked and replaced.

3.3.2 Home Building Industry

Due to the ability of Handheld devices to have access to the internet and hence, back office applications through Client/Server or ASP, real time access is providing increased efficiencies for onsite construction operations. It appears the home building industry is at the forefront in uptaking this technology, particularly in the United States. Michael Holigan, the CEO MH2 Technologies claims that homebuilders using their ASP service are saving 14 to 40 days per house (McGarvey, 2003). Goldman Sachs Research estimates that in the United States US$16000 to US$28000 per home can be saved through greater efficiencies provided by mobile wireless technologies (McGarvey, 2003). Felix Vasquez, CIO of home builder D.R.Horton estimates a possible 5% saving on the cost of every home they build (McGarvey, 2003). Anumba & Ruikar (2002) commented that Internet based tools provide the following benefits regarding project management/online collaboration:

- Easier management of construction projects;
- Easier access to project information from anywhere anytime;
- Faster transaction time;
- Better transparency in the exchange of project information;
- Better collaboration between construction project partners;
- Savings on project cost;
- Streamlined construction business processes;
- Reduction in paperwork;
- Reduction in rekeying of information; and
- Reduction in errors.

3.3.3 Technologies Addressing Current Problems

As discussed in the previous section there are several technological limitations placed on Handheld computers in their current form. One recurring problem identified is the limitation due to the small screen size on most Handheld devices today. This makes viewing typical construction documents such as drawings and schedules a slow and cumbersome task. The following topics discuss some technologies which are helping address the screen size limitations of the current Handheld devices.

Orientation driven navigation

A technological advance in screen navigation has been developed by Innoventions Inc. called the RotoView. RotoView technology has a unique Navigation mode. During Navigation mode, the hand-held small display navigates the large stored virtual display in response to changes in orientation at which the device is held. In particular, it allows web browser to navigate a large display in all directions.

The features of the technology include (Innoventions, 2003):

- Allows users to view relatively large virtual documents (e.g. web pages) in mobile units with small-sized displays, and provides seamless switching between navigation and fixed modes, using a single hand;
- Dynamically changing correlation between orientation changes and display navigation to accommodate the user's natural and intuitive hand control movements;
- Combines efficient image navigation with image magnification;
- Can be implemented within the device's Operating System and enhance all other applications running on the device;
- By using solid-state sensor technology that does not need to be precise (RotoView software algorithm "improves" upon sensor measurements), RotoView can be integrated with mobile systems at a relatively low cost;

- Can be utilised as an add-on to existing mobile devices having an expansion slot; and
- RotoView is suitable for navigating rapidly changing displays (e.g. streaming video).

Near Eye Displays

One of the current solutions addressing the screen size problem is Near-eye Displays. Near-eye Displays are tiny screens positioned close to the eye that offer the appearance of being full-sized displays. Typically these are included as part of a pair of eyeglasses, where one eye can focus on the display while the other is free to let you see where you are going (Figure 31). MicroOptical Corporation and Interactive Imaging Systems (IIS) in partnership have developed the Second Sight M1100. This is the first head mounted display expansion for Handheld devices which does not require an external power source. It connects using an IIS card to any CompactFlash or PCMCIA slot on a Windows OS based Handheld device. The software provides full VGA screen resolution mimicking a 15" screen at 2 feet from the user's eye.

Figure 31 Eyewear mounted near eye display (Hardy, 2003)

3.3.4 M-Commerce in Construction

Due to the connectivity options mentioned previously access to the Internet for mobile workers is available and improving exponentially. This means that web enabled mobile workers are able to access back office systems without the need for device loaded software. In general there are two ways that a hand held user can access the back office system, either in a Client/Server type arrangement or through an Application Service Provider (ASP). The main difference between these two systems is that the ASP is a third party foreign to the organisation and or project.

Client/Server

The Client/Server arrangement appears, from the literature surveyed, to be prevalent for the larger construction organisations specialising in large commercial projects. These are typically organisations with sophisticated corporate databases and systems that occupy substantial office space. Typically they would have dedicated IT professionals to maintain such a system, and sufficient capital resources to outlay for the required IT infrastructure and software applications. In this case the client purchases the software from the vendor, hosts the database and software, and serves the mobile workers using Handheld devices, as well as other external project collaborators.

Application Service Providers

From the literature surveyed it appears one of the major trends in the construction industry is towards using Application Service Providers (ASPs) to host project data and relevant software as opposed to the client organisation. This enables the client to be thin. Thin refers to the user not requiring large amounts of sophisticated hardware, as well as the required

software, to run the application, only an Internet browser. This trend is most obvious for SMEs, where the major uptake of the service appears to be software aimed at the home building industry. It is suitable for companies that can't or don't want to outlay large amounts of capital to run the latest software packages on their own systems. The potential savings are not only on capital outlay but also on the maintenance of the systems, where for smaller companies the cost/benefit ratio of employing a dedicated IT professional may not be advantageous. To access and use the service a lease agreement is used. For example in the United States leasing rates vary from $75/house (Buildtopiea's service) to $150/house (MH2 Technologies' service) to a flat (not per-house) rate of $2499 (BuilderCentral's service).
In many cases the software is available in either an ASP or back office application. Life Cycle Asset Management

Due to the emergence of Life Cycle Asset Management and Public Private Partnerships (PPP), both the traditional Public sector and many of the large private sector construction organisations are reviewing their approach to the lifecycle of their assets. The three basic stages in this lifecycle are (Brown, 2002):

1. Surveying, land contamination etc.- register the information on the Information Channel and the pass to the next phase.
2. Construction- design, build and delivery of the asset and collation of all electronic as-built data, then pass baton on.
3. Facilities management- maintain manage the asset, continually updating electronic data as the asset develops and changes.

One of the areas that Handheld devices has had a large impact is Operations & Maintenance. This has been traditionally in the manufacturing sector, where automatic data collection and wireless connectivity and synchronisation technologies have provided increased efficiencies. These technologies also have the potential to improve the AEC industry through improved data collection systems, hence improving efficiency of the operations & maintenance of the life cycle i.e. Facilities Management.

4 THE FUTURE FOR HANDHELD TECHNOLOGY

The speed at which technology improves at the present time is staggering. One thing that is agreed by many is that Moore's Law will continue i.e. processor power doubles every 18 months. Being able to separate long-term future technology advancements that specifically target hand held devices is almost impossible. This is evident through the fact that some of the current Hand held devices have bigger storage capacity, faster CPUs and better screen resolution than desktop PCs several years previous. Moreover, there are currently available handheld devices running full PC operating systems e.g. Tiqit-eightythree (Figure 3) is using an MS XP OS. The wireless evolution and the Internet are changing the way organisations across the board are doing business. The following discussion looks at technologies that are likely to be commercially available in the next 5-10 years on Handheld devices. A brief discussion on a possible replacing/competing technology for Handheld devices, i.e. wearable computers, is also provided giving insight into the possible face of mobile computing, hence construction computing, beyond the 10 year horizon.

4.1 RFID Technologies

A study led by the Building Research Establishment in the UK on RFID technologies identified future prospects for this technology in the construction industry. Some examples of the possibilities include (BRE, 2002):

- Tracking reinforcement throughout the installation process. This will include confirmation of handover status and updating of the CAD model from the handheld. They will also be able to identify the correct building component for installation using the RFID tags and download CAD drawings showing where and how to install the component and how to observe the health and safety requirements; and
- Linking RFID tags to CAD based asset management tracking systems. With an Internet enabled Handheld scanner information such as health and safety requirements, maintenance notes can be accessed and edited.

This possibility is very real in the near future with the technology already available, the take-up in construction industry being the real barrier to its implementation.

4.2 Two-Way Human-Computer Interaction

As with many technological advances of recent times, science fiction and peoples imaginations provide an embryonic view of what the future reality may be. This is definitely the case for Two-Way Human-Computer interaction. This type of technology can be seen in the Stanely Kubrick film "2001: A Space Odyssey" where the computer named "Hal" interacts with humans on a personal level. Sprint Advanced Technology Laboratory has been developing what is known as "Intelligent Agents" for several years. These intelligent agents are able to carry out verbal requests. The long-term goal for Sprint is to enable the user and the intelligent agent to communicate seamlessly, whether using a desktop or Handheld device (Louie, 2001). This is possible because the intelligent agent resides on a network server.

4.3 Future Generations of Mobile Communications: 3G, 4G, 5G….

Future mobile communication technological advance is one of the core drivers for more enabled mobile Handheld devices. Until these services are global and provided at a reasonable cost to the user, most of the other future technologies identified will not be feasible for mobile Handheld devices. The transitional generation service from 2G to 3G, 2.5G or GPRS, is widely available at current. The 3G services such as UMTS, WCDMA, and EDGE are currently available at limited locations around the world and on limited devices.

The following section looks at some of the technologies which will enable future generation mobile communications.

Ohmori et al (2000) identified the following enabling technologies to provide for future generation mobile communication systems:

- Modulation and Signal Transmission- refers to robust modulation demodulation schemes to withstand frequency-selective fading;
- Propogation- refers to improvements in mobile propagation characteristics of microwaves;
- Software Radio- refers to coexistence of several mobile telecommunication services;
- Smart Antennas- refers to intelligent functions such as suppressions of interference signals, auto tracking of desired signals, and digital beamforming with adaptive space-time processing technologies for future mobile communications;
- Radio on Fibre- refers to transmitting radio signals through optical fibres;
- Network Architecture and Protocol- refers to air interface protocol suitable for IP packet transmission, location registration, and base station network configuration, wireless QoS control, network configuration that facilitates the introduction of the microcells, and integrated seamless service control with 3G cellular and wireless LANs; and
- Devices- refers to important components in high-frequency systems such as high-efficiency power amplifiers, ultra-low-temperature compact receiver amplifiers, and antennas.

Ohmori et al (2000) also discussed the various candidates for future generation communication systems. These include:

- 4G-Cellular Systems- This is involves three layers-
    - the physical network providing access and routing functions in an integrated format for both radio and core networks;
    - the middleware environment acts as a bridge between the application and physical network and provides functions such as QoS mapping, address conversion, plug and play, security management, and an active network; and
    - The application environment is an open interface enabling third parties to develop and provide new applications and services easily.

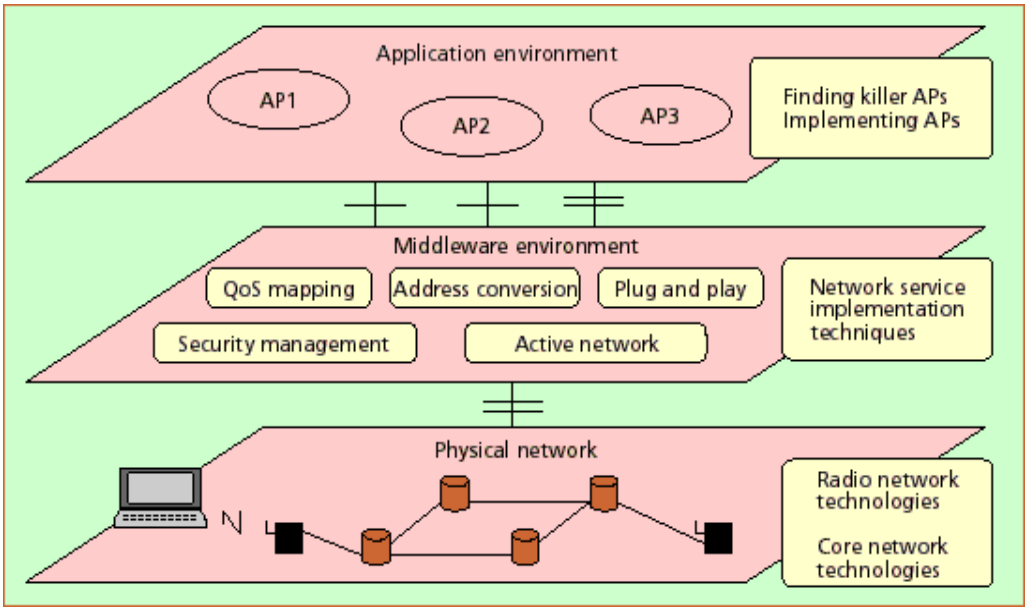


Figure 32 4G Cellular System Architecture (Ohmori et el, 2000)

- Broadband Wireless Access and Local Area Networks

The Japanese started working on a 4G system of this type in 1996. They called it the Multimedia Mobile Access Communication (MMAC) System. It is slated to be available after the 3G IMT-2000 network. The MMAC promises to provide two categories of high speed wireless access communications. The first will transmit up to 30 Mbps using 5.2 GHz and service both indoors and outdoors. The second will provide ultra-high speed WLANs indoors, which can transmit high-speed signals up to 600 Mbps using the millimetre-wave radio band (e.g. 60 GHz). Prototype millimetre-wave wireless LANs have been developed to demonstrate feasibility of 60 GHz WLAN systems with asynchrononous transfer mode (ATM) or 100-base Ethernet interfaces operating at data rates up to 155 Mbps.

- High Altitude Stratospheric Platform Station Systems

The High Altitude Stratospheric Platform Station System (HAPS) involves a platform at approximately 20 km high in the stratosphere creating a mesh like network through optical intercommunication links. A broadband access link is the link between the platform station and the user station. The anticipated frequency band of the access link is expected to be millimetre-wave band. The expected bit rate of the access link is 25 Mbps for most fixed and portable terminals to 200 Mbps for limited fixed terminals with antennas larger than standard.

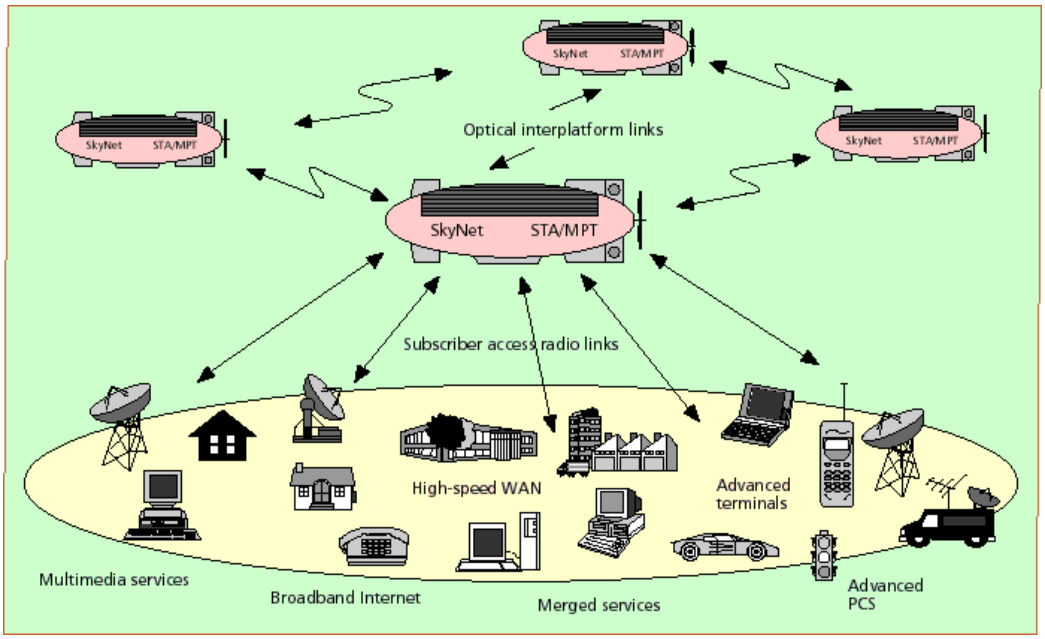


Figure 33 The concept of a HAPS wireless access network (Ohmori et el, 2000)

Gazis et al (2002) investigated 4G mobile communication systems with a view to proposing a set of priorities for a research agenda. They commented that the widely accepted vision for 4G includes “a heterogeneous communication landscape comprising different wireless access systems in a complementary manner where the user, supported by his/her personal intelligent agent (s), enjoys untethered connectivity and ubiquitous access to applications over the most efficient combination of wireless systems available”. Furthermore, they predicted that future mobile communication systems will be “heterogeneous in nature, forming an integrated network environment that comprises various wireless technologies and

access systems in a complementary manner". They expect that wireless access networks, regardless of their internal technical details, to have the following in common (Gazis et al, 2002):

- A dynamic address assignment mechanism (e.g., DHCP, SLP, GPRS/UMTS) that is capable of associating a short-lived or long-lived IP address to the respective wireless interface at the mobile terminal.
- A transparent IP forwarding service that is accessible over the logical termination of the IP layer at the mobile terminal and one or more gateways (e.g., GGSN, Mobile IP-aware router) at the wireless access network infrastructure. The IP forwarding service is established by employing signalling procedures (e.g., PDP context signalling in the UMTS case) specific to the technical architecture of each wireless access network.

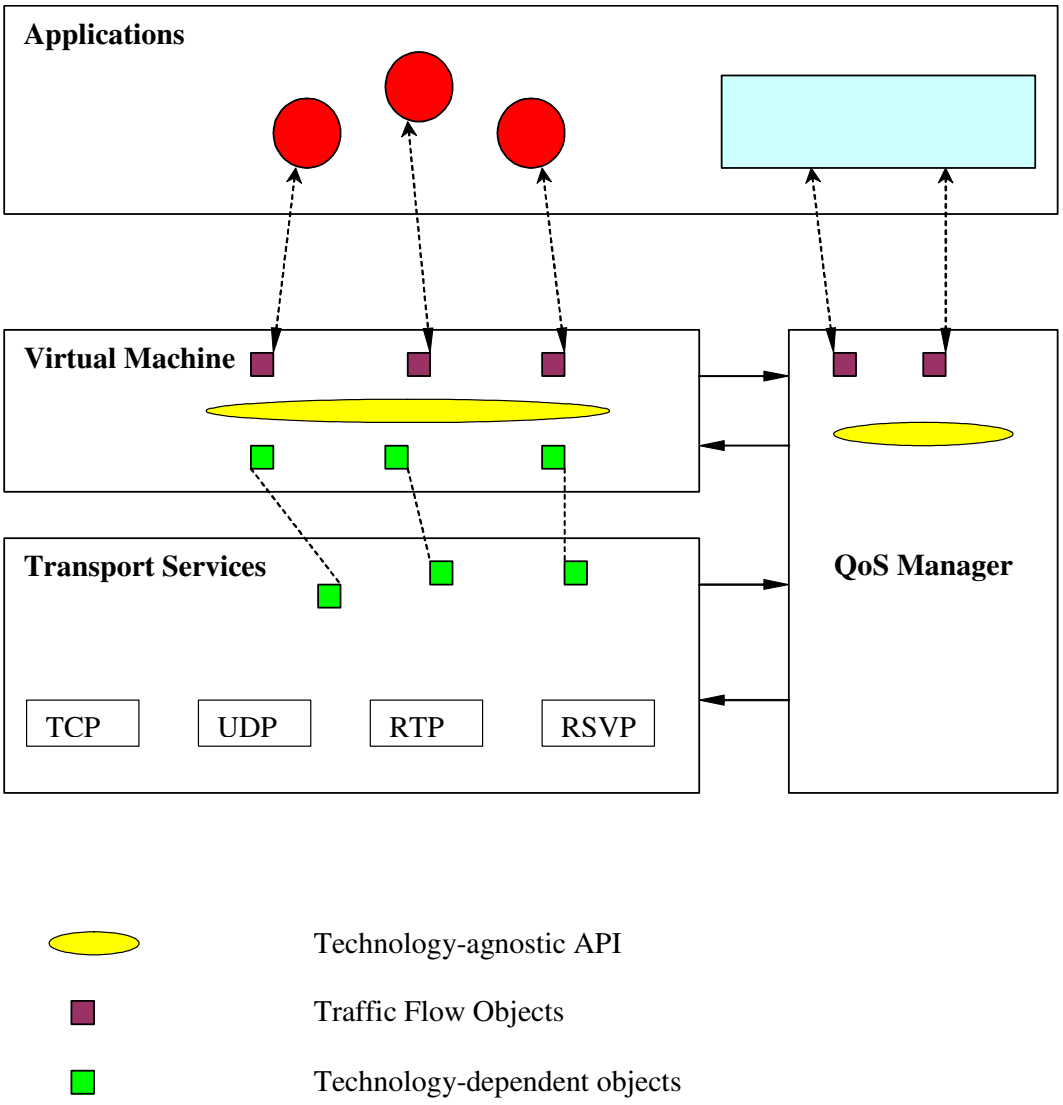


Figure 34 Architectural components of 4G mobile execution environments (Gazis et al, 2002)

The future generation of mobile communication technologies will enable greater functionality for Internet applications. Experts are already talking about the new Internet or Xnet. The X Internet will allow the user's computer to receive mini-programs that manipulate the information sent along with it so it can be customised for the device it's being sent to. This

will allow other users to get access to what has been done and have the benefit of whatever modifications or improvements made (Axelrod, 2001).

4.4 Future Power Options for HandHeld Devices

One of the main drawbacks to Handheld devices at current is the more functional they become the larger the drain on the power system. This means that Handheld devices with ever more colourful screens and faster processors require recharging at least on a daily basis. With this in mind alternative sources of energy to power devices would make them more applicable to a mobile workforce, which may use the devices away from the office environment for days on end. Several of the current research areas dealing with this issue are Fuel Cell technologies, Silver Polymer Batteries, Photovoltaic technologies and Mirco-engines. The following section gives a brief overview of these technologies.

4.4.1 Fuel Cells

Fuel cells create power by converting methanol into water. Fuel cells produce significantly more power than an equivalent size battery. Currently portable Direct Methanol Fuel Cells provide five times higher energy density than rechargeable lithium-ion batteries currently used in Handheld devices. However, there are several problems to overcome before this technology is fully functional on Handheld devices. One problem is how to deal with the wasted water. The latest prototypes put the water back into the same container as the methanol and have ways to deal with the gradually decreasing concentration of methanol in the mix (Hardy, 2003). Other problems include the high production costs comparable to rechargeable batteries and their size needs to be reduced.

4.4.2 Silver Polymer Batteries

The Military has used Silver Zinc batteries for over 50 years. Zinc Matrix Power Inc. has recently developed commercially viable prototype Silver Polymer batteries. These batteries have an energy-to-weight ratio comparable to lithium batteries widely used at current for Handheld devices. However, the silver and zinc reactants are much more dense than lithium and graphite, the Silver Polymer Battery has much more energy and power into a given size, making them suitable for Handheld devices. Silver Polymer prototypes have achieved well over 2 kilowatts per liter, which is several times the power level of the current lithium batteries used for Handheld devices (Hardy, 2003b).

4.4.3 PhotoVoltaic & Hydrogen Fuel Cells

Scientists at the Fraunhofer Institute in Germany are working on replacing existing rechargeable batteries used for Handheld devices with a miniature version of the hydrogen fuel cell used to power electric cars. A prototype has been developed which is integrated in the lid of a Casio Handheld device. This enables the device to be fully autonomous of external electricity supply. The overlapping design of the cells provides an output of 35 milliamps per square centimetre in direct sunlight. The researchers have overcome a problem which had previously made the cells unviable for this type of use. This relates to the need for the solar cells to be cleaned of an electrically passivating layer of silicon oxide or nitride. To overcome this problem a special laser is used to remove the coating off the required contact points making these solar cells a viable alternative to other sources of energy.

4.4.4 Micro-engines

Scientists at the Birmingham University are developing motors or micro-engines that are smaller than typical batteries that run on lighter fluid. They are only a couple of millimetres in size but are able to generate up to 300 times as much energy as an ordinary battery. The head of the team Dr. Kyle Jiang, predicts that all portable devices that currently use batteries will get their power from micro-engines before 2010 (The University of Birmingham, 2003).

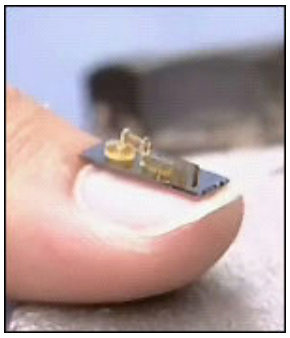


Figure 35 Micro-engine technology (Hardy, 2003).

4.5 Keyboard Technologies

As mentioned previously one of the drawbacks for Handheld computers is the difficulty in entering data. Although there are add-ons that provide full keyboard functionality, having to carry around this type of equipment is not suitable for the mobile worker. One solution is to create a keyboard which is in a sense not there i.e. virtual and physically unburdening. There are currently two developments trying to address this problem using laser and infrared technology.

VKB Ltd is developing a virtual keyboard by projecting a laser image onto a flat surface. They are allowing for the situation where a flat surface is not available by the inclusion of an alternative text entering system (Hardy, 2003).

Figure 36 Virtual keyboard through laser imaging. (Hardy, 2003)

HoloTouch, Inc has developed a holographic keyboard incorporating infrared technology. In this case a 3D image of a keyboard floats in the air in front of the user. An infrared detector scans the plane of the holographic image to detect which character is being keyed. This technology is already commercially available in the form of touch-less information kiosks.

The challenge is being able to reduce its current size to fit into a Handheld device (Hardy, 2003b).

4.6 Random Movement Printing Technology

Although not identified previously as a drawback to the use of Handheld devices the ability to print decent sized documents away from the office printer is still one limitation. In order to address this problem PrintDreams has developed a new technology called Random Movement Printing Technology (RMPT). The PrintBrush printer is a concept design using RMPT. Text and pictures are loaded onto the PrintBrush from a Handheld computing device using BlueTooth. The PrintBrush device is swept by hand across any type of paper, irrespective of dimensions, simalteneously printing the scanned images/text. The approximate dimensions of the printer are the length of a pen and thickness of a mobile phone, allowing it to fit into the pocket. PrintDreams expects these will be commercially available sometime in 2005 (Hardy, 2003).

Figure 37 Prototype random movement printing device (Hardy, 2003)

4.7 Flexibile Handhelds

Sony is developing prototype flexible Handheld devices. The latest version is called the Gummi, which is controlled by bending the device. Piezoelectric pressure sensors and a touch panel are built into the device. At this point in time it is essentially a data collection device only, without the ability to enter text and the like (Hardy, 2003).

Figure 38 Flexible Handheld prototype Gummi by Sony (http://zdnet.com.com/2100-1103_2-1022554.html)

4.8 Wearable Computers

One of the emerging trends in pervasive computing is towards wearable computing. A discussion on this topic has been included due to the possibility of these types of devices replacing or at least competing with current Handheld devices in the near future. Wearable computing refers to devices which are always-on and have sensors that measure their environment constantly. The main objective of wearable computers is for the computer to carry out the users required tasks without any direct user interaction. Some of the technologies which are making wearable computers a reality are Augmented Memory, Augemented Reality and Intellectual Collectives. The following briefly discusses these enabling technologies.

Figure 39 Wearable computers the future for the Construction Industry (http://www.microopticalcorp.com/Applications/wearable.html).

4.8.1 Augmented Memory

Augmented Memory or Remembrance Agent (RA) allows the wearable device to store additional information about the wearers, their lives, and business-related topics. A simple example of the use of augmented memory would be a traditional scheduling program that alerted the wearer just before a meeting by flashing an alert to a heads-up display or whisper the information in their ear (Amor, 2002). Another example is in a networking situation the RA could remind the wearer who a certain person was, provide important information about the person and display notes taken at the last meeting with this person (Amor, 2002).

4.8.2 Augmented Reality

Augmented Reality refers to the combination of real and virtual services to assist users in their environments (Amor, 2002). One example of the possible use in construction is a completed virtual 3D model can be used to check the progress of a real project at anytime. The most prominent ideas for new augmented reality applications are Body Tracking, Face Recognition, Language Translators, Visual Filter, Navigation and Repair Instruction (Amor, 2002).

4.8.3 Intelligent Collectives

Intelligent Collectives refers to the technologies which allow clothing to react to certain environments. For example Starlab have developed a coat that changes its behaviour depending on weather conditions i.e. when it's cold it warms up and when it's hot it cools down. Starlab are working on several ideas for clothing including implanting a mobile phone into a shirt and clothes that produce energy when worn in the sun. Amor (2002) commented that the first would possibly be caps with built-in mobile phones or shirts with an Internet connection.

4.9 Market Forecasts for Handheld Devices

As an indication of the future uptake of Handheld computers/Smartphones across industries the following predicted market volumes, as viewed by leading ICT market research organisations, is provided in the following tables.

Table 14 Forecasted Handheld Shipments Worldwide Excluding Smartphones (EMARKETER, 2002)

Market Forecaster	**2004 ($x10^6$)**	**2005 ($x10^6$)**	**2006 ($x10^6$)**
DATAMONITOR	169.8	227.7	300.9
ABN AMRO	29.2	-	-
CSFB Technology Group	31.8	-	-
eTForecasts	35.6	-	-
Gartner Dataquest	31.6	39.2	
International Data Corporation (IDC)	-	70.9	-
UBS Warburg	53.7	-	-
Aberdeen Group	30.7	39.3	-

Table 15 Forecasted Handheld Shipments Worldwide Including Smartphones (EMARKETER, 2002)

Market Forecaster	**2004 ($x10^6$)**	**2005 ($x10^6$)**	**2006 ($x10^6$)**
DATAMONITOR	169.8	227.7	300.9
Morgan Stanley	364.0	-	-

The traditional PDA form of organisers that connect to PCs are expected to lose their dominance to account for only one-half of the market in 2005. The other half is expected to be dominated by convergent pdaPhones (EMARKETER, 2002). This is also the opinion of eTForecasts, which predicts that convergent devices i.e. pdaPhones will represent a substantial portion of the overall PDA market over the next five years. They comment that this will be stimulated by the rollout of 2.5G and 3G cellular networks (EMARKETER, 2002).

Jeff Hawkins, a co-founder of both Palm and Handspring, also believes that the traditional PDA type Handheld will be replaced by convergent pdaPhone devices. That is why Handspring is moving away from traditional Handhelds toward the pdaPhone devices such as the Treo (Figure 9) range (Shim, 2003).

5 CONCLUSION

In the calendar year 2002 the Palm OS devices by 3COM (Approx. 4.5M) and Handspring (Approx. 700 K) dominated the market with approximately 5.1 Million units sold worldwide. The Microsoft OS devices by Hewlett-Packard, Sony and Casio had a combined market share of approximately 3.4 Million units sold for the calendar year 2002.

The main trend currently for Handheld devices is the convergence of traditionally separate devices such as the mobile phone, PDA/Handheld computer, PDT (Bar Code Scanners, RFID) and GPS terminals into one fully integrated device. The main convergence currently is the mobile phone with Handheld computer. This has sparked a flourish of industry Alliancing between traditional Handheld computer manufacturers and mobile phone manufacturers. The main ones being, Microsoft with various mobile phone manufacturers such as Orange, O2, Audiovox, Hitachi and Siemens; Symbian consortium with e.g. Sony, Nokia; and 3COM/Palm with e.g. Kyocera and Samsung. Included in the integration trend are other wireless connectivity options such as Infrared, Bluetooth, and Wi-Fi. In the interim manufacturers of current Handheld devices are providing for these capabilities through add-on peripheral devices and various slot types i.e. Secure Digital (SD)/ Multimedia Card (MMC) slots, CompactFlash (CF)/Microdrive slots, PC slots, Springboard slots (Handspring) and Memory Stick slots.

With the broadening of communication networks through future communication technologies, i.e. 3G and beyond, the usefulness of Handheld devices for construction activities should improve. This enables the mobile worker faster and more reliable real time access to site and back office systems providing improved efficiencies on current systems. It also enables the mobile worker to access Application Service Providers (ASPs) that host various sophisticated software programs through their Handheld device.

Case studies reviewed (Saidi et al, 2002; Robolj et al, 2000; Bowden et al, 2002) have shown that the current Handheld devices can improve productivity on construction sites, however, current devices have their drawbacks for construction use. The main ones being the limitations of small screen size, the unsuitability for site conditions (dust, strong light, rain, rough handling) and the difficulty in performing data input. There are several technologies currently being developed which address the drawbacks identified.

The developments of most significance to the construction industry are automatic data collection technologies such as Speech, Bar Code Reading and Radio Frequency Identification (RFID), which will improve data input. Available digital camera capabilities provide the field worker with improved data collection abilities, however this is limited on the current crop of Handheld devices. To overcome the limitations due to screen size emerging technologies such as Orientation Driven Navigation, Near Eye displays have and are being developed. There are currently available add-ons that give the required ruggedness (resistance to dust, water and rough handling) to the required level for current standard Handheld devices.

Other emerging technologies that are looking to improve current Handheld technologies include power sources (Fuel Cells, Photovoltaics, Micro-engines, Silver Polymer batteries) keyboards (Virtual Laser image, Holographic), printing (Random Movement technology), navigation (Flexible Handhelds).

Looking to the future it appears the traditional Handheld computing devices will be competing with Wearable Computers. Wearable computers offer much greater potential benefit to the mobile worker through greater use of automated processes. In a sense, the Handheld devices at current and in the near future are a testing ground for some of the technologies slated for wearable computers in the more distant future.

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7 GLOSSARY

API- An application program interface (API - and sometimes spelled application programming interface) is the specific method prescribed by a computer operating system or by an application program by which a programmer writing an application program can make requests of the operating system or another application. An API can be contrasted with a graphical user interface or a command interface (both of which are direct user interfaces) as interfaces to an operating system or a program.
ASP- Application Service Provider. Application Service Providers are third-party entities that manage and distribute software-based services and solutions to customers across a wide area network from a central data center. Refers to companies which provide a hosting facility over the internet for software applications. You don't need to have the software on your hard drive to run the software, you access it over the internet.
CDMA- Code Division Multiple Access refers to any of several protocols used in so-called second-generation (2G) and third-generation (3G) wireless communications. As the term implies, CDMA is a form of multiplexing, which allows numerous signals to occupy a single transmission channel, optimizing the use of available bandwidth. The technology is used in ultra-high-frequency (UHF) cellular telephone systems in the 800-MHz and 1.9-GHz bands.
CORBA- Common Object Request Broker Architecture (CORBA) is an architecture and specification for creating, distributing, and managing distributed program objects in a network. It allows programs at different locations and developed by different vendors to communicate in a network through an "interface broker." CORBA was developed by a consortium of vendors through the Object Management Group (OMG), which currently includes over 500 member companies.
CRC- Cyclic redundancy checking (CRC) is a method of checking for errors in data that has been transmitted on a communications link. A sending device applies a 16- or 32-bit polynomial to a block of data that is to be transmitted and appends the resulting cyclic redundancy code to the block. The receiving end applies the same polynomial to the data and compares its result with the result appended by the sender. If they agree, the data has been received successfully. If not, the sender can be notified to resend the block of data.
DHCP- Dynamic Host Configuration Protocol (DHCP) is a communications protocol that lets network administrators manage centrally and automate the assignment of Internet Protocol (IP) addresses in an organization's network. Using the Internet Protocol, each machine that can connect to the Internet needs a unique IP address.
DSP- Digital signal processing (DSP) refers to various techniques for improving the accuracy and reliability of digital communications. The theory behind DSP is quite complex. DSP works by clarifying, or standardizing, the levels or states of a digital signal. A DSP circuit is able to differentiate between human-made signals, which are orderly, and noise, which is inherently chaotic.
Encryption- Encryption is the conversion of data into a form, called a ciphertext, that cannot be easily understood by unauthorized people. Decryption is the process of converting encrypted data back into its original form, so it can be understood.
Extranet- An extranet is a private network that uses the Internet protocol and the public telecommunication system to securely share part of a business's information or operations with suppliers, vendors, partners, customers, or other businesses. An extranet can be viewed as part of a company's intranet that is extended to users outside the company. It has also been described as a "state of mind" in which the Internet is perceived as a way to do business with other companies as well as to sell products to customers.
GPRS- General Packet Radio Service (GPRS) is the next generation of mobile phone and data transmission technology. It offers the potential for "always on" mobile connectivity, with users charged for the amount of data transmitted and received rather than for connection time. This and CDMA are referred to as Wide Area Networks.
GSM- Global System for Mobile communication is a digital mobile telephone system that is widely used in Europe and other parts of the world. GSM uses a variation of time division

multiple access (TDMA) and is the most widely used of the three digital wireless telephone technologies (TDMA, GSM, and CDMA). GSM digitizes and compresses data, then sends it down a channel with two other streams of user data, each in its own time slot. It operates at either the 900 MHz or 1800 MHz frequency band.

Hot Spot- For users of portable computers equipped for wireless, a hot spot (or hotspot) is a company providing Internet connection and virtual private network (VPN) access from a given location. For example, a business traveller with a laptop equipped for Wi-Fi can look up a local hot spot (access point), contact it, and get connected through its network to reach the Internet and their own company remotely with a secure connection.

IP- The Internet Protocol (IP) is the method or protocol by which data is sent from one computer to another on the Internet. Each computer (known as a host) on the Internet has at least one IP address that uniquely identifies it from all other computers on the Internet. When you send or receive data (for example, an e-mail note or a Web page), the message gets divided into little chunks called packets. Each of these packets contains both the sender's Internet address and the receiver's address. Any packet is sent first to a gateway computer that understands a small part of the Internet. The gateway computer reads the destination address and forwards the packet to an adjacent gateway that in turn reads the destination address and so forth across the Internet until one gateway recognizes the packet as belonging to a computer within its immediate neighborhood or domain. That gateway then forwards the packet directly to the computer whose address is specified.

Java Client- Java is conceptually a platform independent technology. Java clients, such as Web Vision, can run inside a browser and are portable across browser versions and hardware platforms (in theory). This technology utilizes the resources at the local machine, although programs are distributed centrally.

LAN- A local area network (LAN) is a group of computers and associated devices that share a common communications line or wireless link and typically share the resources of a single processor or server within a small geographic area (for example, within an office building). Usually, the server has applications and data storage that are shared in common by multiple computer users. A local area network may serve as few as two or three users (for example, in a home network) or many as thousands of users (for example, in an FDDI network).

ODM- Original Design Manufacturer. An ODM both designs and manufactures its own products. To make use of the distribution and sales channels of companies with established brand names, an ODM often sells its products to another company who puts on its logo and sell the products as its own products.

OEM- Original Equipment Manufacturer is used to refer to the company that acquires a product or component and reuses or incorporates it into a new product with its own brand name.

PAN- A personal area network (PAN) is the interconnection of information technology devices within the range of an individual person, typically within a range of 10 meters. For example, a person traveling with a laptop, a personal digital assistant (PDA), and a portable printer could interconnect them without having to plug anything in, using some form of wireless technology. Typically, this kind of personal area network could also be interconnected without wires to the Internet or other networks.

PDN- A network established and operated by a telecommunications administration, or a recognized private operating agency, for the specific purpose of providing data transmission services for the public.

PDP- A PDP (Packet Data Protocol) Context is a logical association between a MS (Mobile Station) and PDN (Public Data Network) running across a GPRS network. The context defines aspects such as Routing, QoS (Quality of Service), Security, Billing etc.

Piconet- A network of devices connected in an ad hoc fashion using Bluetooth technology. A piconet is formed when at least two devices, such as a portable PC and a cellular phone, connect. A piconet can support up to eight devices. When a piconet is formed, one device acts as the master while the others act as slaves for the duration of the piconet connection. A piconet is sometimes called a PAN.

QoS- Quality of Service. A measure of how reliable a carrier’s service is. Usually expressed in

RFID- Radio Frequency Identification is a technology that incorporates the use of electromagnetic or electrostatic coupling in the radio frequency (RF) portion of the electromagnetic spectrum to uniquely identify an object, animal, or person. RFID is coming into increasing use in industry as an alternative to the bar code. The advantage of RFID is that it does not require direct contact or line-of-sight scanning. An RFID system consists of three components: an antenna and transceiver (often combined into one reader) and a transponder (the tag).
RISC- Reduced Instruction Set Computer (RISC) is a microprocessor that is designed to perform a smaller number of types of computer instructions so that it can operate at a higher speed (perform more millions of instructions per second, or MIPS). Since each instruction type that a computer must perform requires additional transistors and circuitry, a larger list or set of computer instructions tends to make the microprocessor more complicated and slower in operation.
RMI- Remote Method Invocation (RMI) is a way that a programmer, using the Java programming language and development environment, can write object-oriented programming in which objects on different computers can interact in a distributed network.
SLP- The Service Location Protocol (SLP) is a protocol or method of organizing and locating the resources (such as printers, disk drives, databases, e-mail directories, and schedulers) in a network. SLP is intended to give users an easy-to-use interface to a network's resource information. The protocol defines and oversees communications and operations that take place among entities called user agents (subscribers or workstations), service agents (peripherals and resources), and directory agents (peripherals and resources within service agents). Rearrangement or maintenance of services, or installing new devices, is possible without the need for reconfiguring individual workstations.
SOAP- Simple Object Access Protocol (SOAP) is a way for a program running in one kind of operating system (such as Windows 2000) to communicate with a progam in the same or another kind of an operating system (such as Linux) by using the World Wide Web's Hypertext Transfer Protocol (HTTP)and its Extensible Markup Language (XML) as the mechanisms for information exchange.
TCP- Transmission Control Protocol (TCP) is a set of rules (protocol) used along with the Internet Protocol (IP) to send data in the form of message units between computers over the Internet. While IP takes care of handling the actual delivery of the data, TCP takes care of keeping track of the individual units of data (called packets) that a message is divided into for efficient routing through the Internet.
terms of availability and measured, as how often available, by .99999 or five nines, which is the top level of reliability.
Thick Client- where a client carries out much of the processing at it's site or within it's hardware.
Thin Client- refers to server based computing (on the client side). Also thought of as the Architecture that allows a client device to exchange data with a host with minimal processing at the client level. On the server side, there can be a simple WebServer (for static pages), or Active Server Pages (ASP) or Java Server Pages (JSP) often running inside an Application Server to provide dynamic content from a database. This technology's primary benefit is centralized data (for updates, security, etc), and browser only client.
URL- A URL (Uniform Resource Locator, previously Universal Resource Locator) - pronounced YU-AHR-EHL or, in some quarters, UHRL - is the address of a file (resource) accessible on the Internet. The type of file or resource depends on the Internet application protocol. Using the World Wide Web's protocol, the Hypertext Transfer Protocol (HTTP) , the resource can be an HTML page (like the one you're reading), an image file, a program such as a common gateway interface application or Java applet, or any other file supported by HTTP. The URL contains the name of the protocol required to access the resource, a domain name that identifies a specific computer on the Internet, and a pathname (hierarchical description of a file location) on the computer.
VPN- Virtual Private Network is a way to use a public telecommunication infrastructure, such as the Internet, to provide remote offices or individual users with secure access to their organization's network. A virtual private network can be contrasted with an expensive system

of owned or leased lines that can only be used by one organization. The goal of a VPN is to provide the organization with the same capabilities, but at a much lower cost.

WAN- A wide area network (WAN) is a geographically dispersed telecommunications network. The term distinguishes a broader telecommunication structure from a local area network. A wide area network may be privately owned or rented, but the term usually connotes the inclusion of public (shared user) networks. An intermediate form of network in terms of geography is a metropolitan area network (MAN).

WAP- Wireless Application Protocol is a specification for a set of communication protocols to standardize the way that wireless devices, such as cellular telephones and radio transceivers, can be used for Internet access, including e-mail, the World Wide Web, newsgroups, and Internet Relay Chat (IRC). While Internet access has been possible in the past, different manufacturers have used different technologies. In the future, devices and service systems that use WAP will be able to interoperate.

Wi-Fi- Wireless Fidelity is the popular term for a high-frequency wireless local area network (WLAN). The Wi-Fi technology is rapidly gaining acceptance in many companies as an alternative to a wired LAN. It can also be installed for a home network. Wi-Fi is specified in the 802.11b specification from the Institute of Electrical and Electronics Engineers (IEEE) and is part of a series of wireless specifications together with 802.11, 802.11a, and 802.11g. All four standards use the Ethernet protocol and CSMA/CA (carrier sense multiple access with collision avoidance) for path sharing.

WLAN- A wireless LAN is one in which a mobile user can connect to a local area network (LAN) through a wireless (radio) connection. A standard, IEEE 802.11, specifies the technologies for wireless LANs. The standard includes an encryption method, the Wired Equivalent Privacy algorithm.

WML- Wireless Markup Language, formerly called HDML (Handheld Devices Markup Languages), is a language that allows the text portions of Web pages to be presented on cellular telephones and personal digital assistants (PDAs) via wireless access. WML is part of the Wireless Application Protocol (WAP) that is being proposed by several vendors to standards bodies. The Wireless Application Protocol works on top of standard data link protocols, such as Global System for Mobile communication, code-division multiple access, and time division multiple access, and provides a complete set of network communication programs comparable to and supportive of the Internet set of protocols

WPAN- A wireless personal area network (WPAN) is a personal area network - a network for interconnecting devices centered around an individual person - in which the connections are wireless. Because most personal area networks are wireless, these terms are virtually synonyms. Typically, a wireless personal area network uses some technology that permits communication within about 10 meters - in other words, a very short range. One such technology is Bluetooth, which was used as the basis for a new standard, IEEE 802.15.

XML- Extensible Markup Language (XML) is a flexible way to create common information formats and share both the format and the data on the World Wide Web, intranets, and elsewhere. XML, a formal recommendation from the World Wide Web Consortium (W3C), is similar to the language of today's Web pages, the Hypertext Markup Language (HTML). Both XML and HTML contain markup symbols to describe the contents of a page or file.

8 APPENDIX A: HANDHELD HARDWARE COMPARISONS

Manufacturer	Product Name	OS	ROM/HARD
ACER	N-25	Pocket PC 2002	32MB Flash
ACER	N-25W	Pocket PC 2002	32MB Flash
ACER	S-55	Palm OS® 4.1	4 MB Flash ROM
ACER	S-65	Palm OS® 4.1	4 MB Flash ROM
Alphacell	M5	CE.NET 4.1	8 MB Flash ROM
Alphacell	M6	CE.NET 4.1	16 MB Flash ROM
ASUS	MyPal A600	Pocket PC 2002	32MB Flash
Audiovox	Maestro PDA1032C	Pocket PC CE	32MB Flash
Audiovox	Thera (2032SP)	Pocket PC 2002	32MB Flash
bsquare	Power Handheld (maui)	CE.NET 4.1	32MB Flash
Carrier Devices	Qtek 1010	Pocket PC 2002	32MB Flash
Casio	IT-500	CE.NET 4.1	64 MB Flash ROM
Casio	Casio Cassiopeia IT-700RFSTD	CE	32 MB Flash ROM
Casio	Casio Cassiopeia BE-300	CE 3.0	16 MB Flash ROM
Casio	Casio Cassiopeia E-100	CE	16 MB Flash ROM
Casio	Casio Cassiopeia E-125	Pocket PC	32 MB Flash ROM
Casio	Casio Cassiopeia E-200	Pocket PC 2002	64 MB Flash ROM
Casio	Casio Cassiopeia EM-500	Microsoft Pocket PC	16 MB Flash ROM
Casio	Casio Cassiopeia PV-S400Plus	Casio PV	4 MB Flash ROM
Casio	Casio Cassiopeia PV-S600Plus	Casio PV	4 MB Flash ROM
CIIT	Multimedia PDA	Mizi Linuette Linux	32 MB Flash ROM
Compal Electronics	PD-131	Pocket PC	16 MB Flash ROM
Compal Electronics	PD-600C	Pocket PC	32 MB Flash ROM
Consumer Direct Link/IBM	Paron	Linux 2.4x kernel	32 MB Flash ROM
Dell	Dell AXIM X5	Pocket PC 2002	32 MB Flash ROM
Dell	Dell AXIM X5-ADV	Pocket PC 2002	48 MB Flash ROM
Empower Technologies	PowerPlay III	Linux DA	2 MB Flash ROM
Empower Technologies	PowerPlay V	Linux DA	2 MB Flash ROM
Ericsson/Sony	P800	Symbian OS 7.0	32 MB Flash ROM
FIC	Cavalry 500	Pocket PC 2002; CE.NET	32 MB Flash ROM
FIC	Cavalry 600	Pocket PC 2002; CE.NET	32 MB Flash ROM
FIC	KJ001	Pocket PC 2002	32 MB Flash ROM
FIC	KJ003	Pocket PC 2002	32 MB Flash ROM
Fossil	Wrist PDA	Palm OS® 4.1	2 MB Flash ROM
Franklin	eBookMan EBM-900	eBookMan OS 2.0	NA
Franklin	eBookMan EBM-901	eBookMan OS 2.0	NA
Franklin	eBookMan EBM-911	eBookMan OS 2.0	NA
Fujitsu/Siemens	Pocket LOOX 600	Pocket PC 2002	32 MB Flash ROM
G.MATE	Yopy-YP3700	Linux ARM, X window System	32 MB Flash ROM
G.MATE	Yopy-YP3500	Linux ARM, X window System	32 MB Flash ROM

G.MATE	Yopy-YP3000	Linux ARM, X window System	16 MB Flash ROM
Garmin	iQue 3600 Personal Organizer	Palm OS® 5.2.1	32 MB Flash ROM
Garmin	NavTalk GSM	NA	16 MB Flash ROM
Gradiente	Gradiente Partner	Pocket PC Phone Edition	32 MB Flash ROM
Group Sense PDA (GSPDA)	V-2002	Linux kernel 2.4.18	32 MB Flash ROM
HandEra	HandEra 330	Palm OS® 3.5.3	2 MB Flash ROM
HandEra	HandEra TRGPro	Palm OS® 3.5.3	2 MB Flash ROM
Handspring	Treo 300	Palm OS 3.5.2H	16 MB Flash ROM
Handspring	Treo 270	Palm OS 3.5.2H	16 MB Flash ROM
Handspring	Treo 180	Palm OS 3.5.2H	16 MB Flash ROM
Handspring	Visor Pro	Palm OS 3.5.2H3	16 MB Flash ROM
Handspring	Visor Platinum	Palm OS 3.5.2H3	8 MB Flash ROM
Handspring	Treo 90	Palm OS 4.1H	16 MB Flash ROM
Hewlett Packard	iPAC H2210	Pocket PC 2003	64 MB Flash ROM
Hewlett Packard	hp iPAQ™ H1910 Pocket PC	Pocket PC 2002	16 MB Flash ROM
Hewlett Packard	hp iPAQ™ H3950 Pocket PC	Pocket PC 2002	32 MB Flash ROM
Hewlett Packard	hp iPAQ™ H3970 Pocket PC	Pocket PC 2002	48 MB Flash ROM
Hewlett Packard	hp iPAQ™ H5450 Pocket PC	Pocket PC 2002	48 MB Flash ROM
Hewlett Packard	Jornada 728 Handheld PC	Pocket PC 2000	64 MB Flash ROM
Hewlett Packard	Compaq C-Series 2010c	CE 2.0	32 MB Flash ROM
Hewlett Packard	HP iPAQ 5455 Pocket PC	Pocket PC 2002	48 MB Flash ROM
HHP	Dolphin 7200 RF	GS DOS	8 MB Flash ROM
HHP	Dolphin 7300 RF	CE 3.0	32 MB Flash ROM
HHP	Dolphin 7400 RF	CE 3.0	32 MB Flash ROM
HHP	Dolphin 7450 RF	CE 3.0	32 MB Flash ROM
Hitachi	Multimedia Communicator NC1	Pocket PC Phone Edition	NA
HNT	Exilien 101	Linux Linuette kernel 2.4 or CE	32 MB Flash ROM
HNT	Exilien 102	Linux Linuette kernel 2.4 or CE	16 MB Flash ROM
HNT	Exilion 201	Linux Linuette kernel 2.4 or CE	32 MB Flash ROM
HNT	IMT-2000	Linux and Java	32 MB Flash ROM
HNT/Hangil	Exilien 104 (C 3224)	Linux OS	16 MB Flash ROM
IBM	Workpad 8602-20X Personal Organizer	Palm OS	2 MB Flash ROM
IBM	Workpad 8602-10U Personal Organizer	Palm OS	2 MB Flash ROM
IBM	e-LAP	Palm OS	32 MB Flash ROM
IBM/Consumer Direct Link	Paron	Linux OS 2.4xkernel	32 MB Flash ROM
Infomart	Kaii	Lineo Embedix Plus OS	32 MB Flash ROM
Intel/Xircom	REX 6000 MicroPDA	Proprietary OS	2 MB Flash ROM
Intermec	700 Series	Pocket PC 2002	64 MB Flash ROM
Invair Technologies	Filewalker Messenger	Linux kernel 2.4.18	32 MB Flash ROM

Invair Technologies	Filewalker Business	Linux kernel 2.4.18	16 MB Flash ROM
Kyocera	7135	Palm OS 4.1	16 MB Flash ROM
LXE	MX4	CE 3.0	32 MB Flash ROM
Master Integrated Appliances	Beagle PDA	Linux kernel 2.4	32 MB Flash ROM
Master Integrated Appliances	PA-200B	Linux kernel 2.4	32 MB Flash ROM
Matsucom	onHand	W-PS-DOS version 1.16	2 MB Flash ROM
MiTAC	CAT PDA	Linux OS	4 MB Flash ROM
MiTAC	mio 8380	Smartphone 2002	32 MB Flash ROM
MiTAC	Mio 338 Ez Pack	Pocket PC 2002	32 MB Flash ROM
MiTAC	Mio 338 Plus	Pocket PC 2002	64 MB Flash ROM
MiTAC	Mio 339	Pocket PC 2003	32 MB Flash ROM
MiTAC	Mio 588	Pocket PC 2003	64 MB Flash ROM
Mizi	GSL	Linux Mizi	32 MB Flash ROM
Mizi	EnDA C3224- Phone edition	Linux Mizi	32 MB Flash ROM
Mizi	Taiwan I	Linux Mizi	32 MB Flash ROM
Mizi	HNT 101	Linux Mizi	32 MB Flash ROM
Mizi	HNT 102 G	Linux Mizi	32 MB Flash ROM
mm02	XDA	Pocket PC 2002	32 MB Flash ROM
Motorola	Motorola HandEra 330	Palm OS 3.5	2 MB Flash ROM
Motorola	A760	Linux Monte Vista	NA
NEC	Mobilepro P300 Personal Organizer	CE	32 MB Flash ROM
NEC	MobilePro 200E	Pocket PC 2002	32 MB Flash ROM
NEC	Mobilepro 790 Personal Organizer	CE	32 MB Flash ROM
NOKIA	9210	Symbian OS 7.0	NA
Orange	Orange SPV	Smartphone 2002	16 MB Flash ROM
Oregon Scientific	ECHO PDA	Proprietary OS	512 KB Flash ROM
Packard Bell	Pocket Gear 2060	Pocket PC 2002	32 MB Flash ROM
Packard Bell	Pocket Gear 2030	Pocket PC 2002	64 MB Flash ROM
Palm	Tungsten-C	Palm OS 5.2.1	64 MB Flash ROM
Palm	Tungsten-W	Palm OS 4.1.1	8 MB Flash ROM
Palm	Tungsten-T	Palm OS 5.0	4 MB Flash ROM
Palm	Zire 71	Palm OS 5.2.1	16 MB Flash ROM
Palm	i705	Palm OS 4.1	4 MB Flash ROM
Palm	m515	Palm OS 4.1	16 MB Flash ROM
Palm	m130	Palm OS 4.1	8 MB Flash ROM
Panasonic	Toughbook CF-P1	CE 3.1	32 MB Flash ROM
Philips	Nino 320 Personal Organizer	CE 2.0	8 MB Flash ROM
Philips	Velo 500 16MB Personal Organizer	CE	8 MB Flash ROM
Philips	Nino 312 Personal Organizer	CE 2.0	8 MB Flash ROM
Pogo	nVOY e100 Communicator	NA	NA
PSC	Falcon 4210	CE 3.0	32 MB Flash ROM
Psion	Psion Revo	Symbian OS 5.0	8 MB Flash ROM

Psion	Psion Series 5mx	Symbian OS 5.0	16 MB Flash ROM
Psion	Psion Series 7	Symbian OS 5.0	16 MB Flash ROM
Psion	Psion 7035 Hand Held Computer	IBM DOS 7.0	4 MB Flash ROM
Psion	Psion netpad 1000 series	Symbian or CE.NET	32 MB Flash ROM
Psion	Psion netpad 3000 series	Symbian or CE.NET	32 MB Flash ROM
Psion	7535	CE.NET 4.1	32 MB Flash ROM
Psion	Psion netpad 5000 series	Symbian or CE.NET	32 MB Flash ROM
Psion	Sonic Blue Mako Personal Organizer	Symbian OS 5.0	8 MB Flash ROM
RIM	Blackberry 6750 Wireless Hand Held	Blackberry OS	10 MB Flash ROM
RIM	Blackberry 6710 Wireless Hand Held	Blackberry OS	16 MB Flash ROM
RIM	Blackberry 6510 Wireless Hand Held	Blackberry OS	8 MB Flash ROM
RIM	Blackberry 6210 Wireless Hand Held	Blackberry OS	16 MB Flash ROM
RIM	Blackberry 5810 Wireless Hand Held	Blackberry OS	8 MB Flash ROM
RIM	RIM 957 Wirless Handheld	Blackberry OS	8 MB Flash ROM
RIM	RIM 950 Wirless Handheld	Blackberry OS	4 MB Flash ROM
RIM	RIM 857 Wirless Handheld	Blackberry OS	8 MB Flash ROM
RIM	RIM 850 Wirless Handheld	Blackberry OS	4 MB Flash ROM
Royal	Linea 16 Personal Organiser	Linea OS	16 MB Flash ROM
Royal	Lin@x	Linux OS	16 MB Flash ROM
SAMSUNG	i330	Pocket PC Phone Edition	32 MB Flash ROM
SAMSUNG	SPH i700	Pocket PC Phone Edition	64 MB Flash ROM
SAMSUNG	Nexio S150	CE 3.0	32 MB Flash ROM
Sharp	Zaurus SL5500	Linux OS, Qtopia, Personal Java	16 MB Flash ROM
Sharp	Zaurus SL5600	Linux OS, Qtopia, Personal Java	64 MB Flash ROM
Siemens/AT&T	Wireless SX56 Pocket PC Phone	Pocket PC 2002	32 MB Flash ROM
Siemens/Fujitsu	Pocket Loox 600	NA	32 MB Flash ROM
SK Telecom	IMT2000 WebPhone	Tynux Linux OS Kernel 2.4	32 MB Flash ROM
Softfield Technology	ST VR3	Linux VR OS	16 MB Flash ROM
Sony	CLIE PEGSJ20G	Palm OS 4.1	4 MB Flash ROM
Sony	CLIÉ PEGSJ22G	Palm OS 4.1	4 MB Flash ROM
Sony	CLIE PEGSJ30G	Palm OS 4.1	4 MB Flash ROM
Sony	CLIÉ PEGSJ33G	Palm OS 4.1	4 MB Flash ROM
Sony	CLIE PEGT665CGD	Palm OS 4.1	4 MB Flash ROM
Sony	CLIÉ PEGT665CG	Palm OS 4.1	4 MB Flash ROM
Sony	CLIÉ PEGTG50G	Palm OS 5.0	16 MB Flash ROM
Sony	CLIÉ PEGNX70VG	Palm OS 5.0	16 MB Flash ROM
Sony	CLIÉ PEGNZ90G	Palm OS 5.0	16 MB Flash ROM
Sony/Ericsson	P800	Symbian OS 7.0	16 MB Flash ROM
Symbol Technologies	PDT 8000	Pocket PC 2002	64 MB Flash ROM
Symbol Technologies	PDT 8100	Pocket PC 2002	32 MB Flash ROM
Symbol Technologies	PPT 2800	Pocket PC 2002	32 MB Flash ROM
Symbol Technologies	SPT 1800	Palm OS 4	4 MB Flash ROM

Symbol Technologies	SPT 1550	Palm OS 4	4 MB Flash ROM
Symbol Technologies	PPT 8800	Mobile 2003	32 MB Flash ROM
Symbol Technologies	PDT 8037	Pocket PC 2002	64 MB Flash ROM
Symbol Technologies	PDT 8056	Pocket PC 2002	64 MB Flash ROM
Tiqit Computers	Tiqit eightythree	XP OS	10 GB Hard
T-Mobile (Danger Inc.)	Pocket PC Phone Edition	Pocket PC Phone Edition	32 MB Flash ROM
T-Mobile (Danger Inc.)	Sidekick	Danger OS	4 MB Flash ROM
Toshiba	e550G	Pocket PC 2002	32 MB Flash ROM
Toshiba	Toshiba e570 Pocket PC	Pocket PC 2002	32 MB Flash ROM
Toshiba	Pocket PC e310	Pocket PC 2002	32 MB Flash ROM
Toshiba	Pocket PC e740 W/Bluetooth	Pocket PC 2002	32 MB Flash ROM
Toshiba	Pocket PC e740 WiFi	Pocket PC 2002	32 MB Flash ROM
Toshiba	Pocket PC e330	Pocket PC 2002	32 MB Flash ROM
Toshiba	2032SP (Thera)	Pocket PC 2002	32MB Flash
ViewSonic	Pocket PC V35	Pocket PC 2002	32MB Flash
Vtech	Helio	VT OS	2 MB Flash ROM
Xircom	Rex 5001	Truesync Desktop	512 KB Flash ROM
Xircom/Intel	REX 6000 MicroPDA	Proprietary OS	2 MB Flash ROM

Manufacturer	Product Name	RAM	Processor	Screen Size	Resolution
ACER	N-25	64 MB SDRAM	Intel XScale PXA-250 400 MHz	3.8"	240x320
ACER	N-25W	64 MB SDRAM	Motorola DragonBall VZ 33 MHz	3.8"	240x320
ACER	S-55	16 MB SDRAM	Motorola DragonBall VZ 33 MHz	3.0"	320x320
ACER	S-65	16 MB SDRAM	Motorola DragonBall VZ 33 MHz	3.0"	320x320
Alphacell	M5	20 MB SDRAM	ARM9 140 Mhz	34.8mmx43.6mm	176x220
Alphacell	M6	24 MB SDRAM	ARM9 140 Mhz	74mmx41.6mm	320x180
ASUS	MyPal A600	64 MB SDRAM	Intel XScale PXA-250 400 MHz	3.5"	240x320
Audiovox	Maestro PDA1032C	32 MB SDRAM	Intel StrongARM 206 MHz	NA	240x320
Audiovox	Thera (2032SP)	32 MB SDRAM	Intel StrongARM 206 MHz	NA	240x320
bsquare	Power Handheld (maui)	64 MB SDRAM	Intel XScale PXA-250 400 MHz	4.0"	640x480
Carrier Devices	Qtek 1010	64 MB SDRAM	Intel StrongARM 206 MHz	3.5"	240x320
Casio	IT-500	32 MB SDRAM	Intel XScale PXA-250 400 MHz	3.5"	240x320
Casio	Casio Cassiopeia IT-700RFSTD	32 MB RAM	NEC VR4122 (150MHz)	NA	240x320
Casio	Casio Cassiopeia BE-300	NA	NEC VR4131 166 MHz	NA	240x320
Casio	Casio Cassiopeia E-100	16 MB RAM	NEC VR4121 131 MHz	NA	240x320
Casio	Casio Cassiopeia E-125	32 MB RAM	NEC VR4122 150MHz	2.5"x3.25"	240x320

Casio	Casio Cassiopeia E-200	64 MB RAM	Intel StrongARM 206 MHz	3.5"	240x320
Casio	Casio Cassiopeia EM-500	16 MB RAM	NEC VR4122 150MHz	2.5"x3.25"	240x320
Casio	Casio Cassiopeia PV-S400Plus	4 MB RAM	NC3022 20 Mhz	2.4"x2.56"	160x160
Casio	Casio Cassiopeia PV-S600Plus	4 MB RAM	NC3022 20 Mhz	2.4"x2.56"	160x160
CIIT	Multimedia PDA	32 MB SDRAM	Intel StrongARM 206 MHz	3.5"	240x320
Compal Electronics	PD-131	32 MB RAM	NEC VR4121 131 MHz	79mmx59mm	240x320
Compal Electronics	PD-600C	64 MB RAM	Intel StrongARM 206 MHz	79mmx59mm	240x320
Consumer Direct Link/IBM	Paron	64 MB RAM	Intel StrongARM 206 MHz	NA	240x320
Dell	Dell AXIM X5	32 MB SDRAM	Intel XScale 300MHz	3.5"	240x320
Dell	Dell AXIM X5-ADV	64 MB SDRAM	Intel XScale 400MHz	3.5"	240x320
Empower Technologies	PowerPlay III	8 MB RAM	Motorola DragonBall 16 MHz	NA	240x320
Empower Technologies	PowerPlay V	8 MB RAM	Motorola DragonBall 16 MHz	NA	240x320
Ericsson/Sony	P800	12 MB RAM	NA	NA	208x320
FIC	Cavalry 500	64 MB SDRAM	Intel XScale PXA-250 400 MHz	3.5"	240x320
FIC	Cavalry 600	64 MB SDRAM	Intel XScale PXA-250 400 MHz	3.5"	240x320
FIC	KJ001	64 MB SDRAM	Intel StrongARM 206 MHz	3.8"	240x320
FIC	KJ003	64 MB SDRAM	Intel XScale PXA-250 400 MHz	3.5"	240x320
Fossil	Wrist PDA	2 MB RAM	Motorola DragonBall VZ 33 MHz	NA	160x160
Franklin	eBookMan EBM-900	8 MB SDRAM	NA	NA	240x200
Franklin	eBookMan EBM-901	8 MB SDRAM	NA	NA	240x200
Franklin	eBookMan EBM-911	16 MB SDRAM	NA	NA	240x200
Fujitsu/Siemens	Pocket LOOX 600	64 MB RAM	Intel XScale PXA-250 400 MHz	53.6mmx71.5mm	240x320
G.MATE	Yopy-YP3700	128 MB RAM	Intel StrongARM 206 MHz	3.5"	240x320
G.MATE	Yopy-YP3500	128 MB RAM	Intel StrongARM 206 MHz	3.5"	240x320
G.MATE	Yopy-YP3000	32 MB RAM	Intel StrongARM 206 MHz	3.5"	240x320
Garmin	iQue 3600 Personal Organizer	NA	Motorola DragonBall MXL ARM 9 200 MHz	3.8"	320x480
Garmin	NavTalk GSM	NA	NA	31.7mmx38.47mm	132x160
Gradiente	Gradiente Partner	32 MB RAM	Intel Strong ARM AS 1110 206 MHz	NA	240x320
Group Sense PDA (GSPDA)	V-2002	32 MB RAM	Intel StrongARM 206 MHz	NA	240x320
HandEra	HandEra 330	8 MB RAM	Motorola DragonBall VZ 33 MHz	2.2"x2.9"	240x320
HandEra	HandEra TRGPro	8 MB RAM	Motorola DragonBall-EZ™ 16MHz	2.2"x2.2"	160x160
Handspring	Treo 300	NA	Motorola DragonBall VZ	NA	NA

			33 MHz		
Handspring	Treo 270	NA	Motorola DragonBall VZ 33 MHz	NA	NA
Handspring	Treo 180	NA	Motorola DragonBall VZ 33 MHz	NA	NA
Handspring	Visor Pro	NA	Motorola DragonBall VZ 33 MHz	NA	NA
Handspring	Visor Platinum	NA	Motorola DragonBall VZ 33 MHz	NA	NA
Handspring	Treo 90	NA	Motorola DragonBall VZ 33 MHz	NA	NA
Hewlett Packard	iPAC H2210	64 MB SDRAM	Intel XScale PXA-250 400 MHz	NA	240x320
Hewlett Packard	hp iPAQ™ H1910 Pocket PC	64 MB RAM	Intel XScale PXA-250 200 MHz	57.6mmx76.8mm	240x320
Hewlett Packard	hp iPAQ™ H3950 Pocket PC	64 MB RAM	Intel XScale PXA-250 400 MHz	57.6mmx76.82mm	240x320
Hewlett Packard	hp iPAQ™ H3970 Pocket PC	64 MB RAM	Intel XScale PXA-250 400 MHz	57.6mmx76.82mm	240x320
Hewlett Packard	hp iPAQ™ H5450 Pocket PC	64 MB RAM	Intel XScale PXA-250 400 MHz	57.6mmx76.8mm	240x320
Hewlett Packard	Jornada 728 Handheld PC	32 MB RAM	Intel StrongARM 206 MHz	6.5"	240x640
Hewlett Packard	Compaq C-Series 2010c	20 MB RAM	NA	NA	240x640
Hewlett Packard	HP iPAQ 5455 Pocket PC	64 MB SDRAM	Intel XScale PXA-250 400 MHz	2.26"x3.02"	240x320
HHP	Dolphin 7200 RF	2 MB RAM	AMD ELAN SC310 386SX	NA	119x73
HHP	Dolphin 7300 RF	32 MB RAM	Intel StrongARM 206 MHz	NA	160x240
HHP	Dolphin 7400 RF	32 MB RAM	Intel StrongARM 206 MHz	3.8"	240x320
HHP	Dolphin 7450 RF	32 MB RAM	Intel StrongARM 206 MHz	3.8"	240x320
Hitachi	Multimedia Communicator NC1	NA	Intel XScale PXA-250 400 MHz	NA	NA
HNT	Exilien 101	32 MB RAM	Intel StrongARM 206 MHz	4.0"	640x480
HNT	Exilien 102	16 MB RAM	Intel StrongARM 206 MHz	3.8"	240x320
HNT	Exilion 201	32 MB RAM	Intel StrongARM 206 MHz	4.0"	640x480
HNT	IMT-2000	32 MB RAM	Intel StrongARM 206 MHz	4.0"	640x480
HNT/Hangil	Exilien 104 (C 3224)	16 MB RAM	Intel StrongARM 206 MHz	3.8"	240x320
IBM	Workpad 8602-20X Personal Organizer	NA	Motorola DragonBall EZ MC68EZ328 16 MHz	NA	160x160
IBM	Workpad 8602-10U Personal Organizer	NA	Motorola DragonBall EZ MC68EZ328 16 MHz	NA	160x160
IBM	e-LAP	30 MB RAM	PowerPC 405LP	4"	240x320
IBM/Consumer Direct Link	Paron	64 MB RAM	Intel StrongARM 206 MHz	NA	240x320
Infomart	Kaii	128 MB RAM	SH3 160MHz	NA	240x320
Intel/Xircom	REX 6000 MicroPDA	NA	NA	NA	240x120
Intermec	700 Series	NA	Intel StrongARM 206 MHz	3.8"	240x320

Invair Technologies	Filewalker Messenger	64 MB RAM	TI Omap 5910 Dual Core 150 MHz	42mmx63mm	160x240
Invair Technologies	Filewalker Business	32 MB RAM	Intel Strong ARM 133 MHz	42mmx63mm	160x240
Kyocera	7135	NA	Motorala Dragonball MZ 33 MHz	NA	NA
LXE	MX4	64 MB RAM	Intel StrongARM 206 MHz	3.8"	240x320
Master Integrated Appliances	Beagle PDA	32 MB RAM	Intel StrongARM 206 MHz	NA	240x320
Master Integrated Appliances	PA-200B	32 MB RAM	Intel StrongARM 206 MHz	NA	240x320
Matsucom	onHand	NA	16 Bit	NA	102x64
MiTAC	CAT PDA	8 MB SDRAM	NEC VR 66 MHz	4.1"	240x320
MiTAC	mio 8380	16 MB RAM	Intel XScale PXA-250 200 MHz	2.2"	176x220
MiTAC	Mio 338 Ez Pack	40 MB RAM	Intel XScale PXA-250 200 MHz	3.5"	240x320
MiTAC	Mio 338 Plus	40 MB RAM	Intel XScale PXA-250 400 MHz	3.5"	240x320
MiTAC	Mio 339	64 MB SDRAM	Intel XScale PXA-250 400 MHz	3.6"	240x320
MiTAC	Mio 588	64 MB RAM	Intel XScale PXA-263 400 MHz	3.5"	240x320
Mizi	GSL	32 MB RAM	Intel StrongARM 206 MHz	NA	240x320
Mizi	EnDA C3224- Phone edition	32 MB RAM	Intel StrongARM 206 MHz	NA	240x320
Mizi	Taiwan I	32 MB RAM	Intel StrongARM 206 MHz	NA	240x320
Mizi	HNT 101	32 MB RAM	Intel StrongARM 206 MHz	NA	640x480
Mizi	HNT 102 G	32 MB RAM	Intel StrongARM 206 MHz	NA	240x320
mm02	XDA	32 MB RAM	Intel StrongARM 206 MHz	NA	240x320
Motorola	Motorola HandEra 330	8 MB RAM	Motorala Dragonball MZ 33 MHz	NA	240x320
Motorola	A760	NA	NA	NA	NA
NEC	Mobilepro P300 Personal Organizer	32 MB RAM	Intel StrongARM 206 MHz	3.8"	240x320
NEC	MobilePro 200E	64 MB RAM	Intel XScale PXA-250 200 MHz	3.5"	240x320
NEC	Mobilepro 790 Personal Organizer	NA	NA	NA	640x240
NOKIA	9210	NA	ARM9-based RISC CPU	NA	NA
Orange	Orange SPV	NA	120 MHz TI OMAP ARM	2.2"	176x220
Oregon Scientific	ECHO PDA	NA	Proprietary	NA	NA
Packard Bell	Pocket Gear 2060	64 MB RAM	Intel StrongARM 206 MHz	3.5"	240x320
Packard Bell	Pocket Gear 2030	NA	Intel StrongARM 206 MHz	3.5"	240x320
Palm	Tungsten-C	NA	Intel XScale PXA-250 400 MHz	NA	320x320
Palm	Tungsten-W	16 MB SDRAM	Motorala Dragonball MZ 33 MHz	NA	320x320
Palm	Tungsten-T	16 MB RAM	Texas Instruments	NA	320x320

			OMAP™ 1510 (ARM)		
Palm	Zire 71	NA	Texas Instruments OMAP310(ARM); 144MHz	NA	320x320
Palm	i705	8 MB RAM	Motorala Dragonball MZ 33 MHz	NA	160x160
Palm	m515	NA	Motorala Dragonball MZ 33 MHz	NA	160x160
Palm	m130	NA	Motorala Dragonball MZ 33 MHz	NA	160x160
Panasonic	Toughbook CF-P1	32 MB RAM	Intel StrongARM 206 MHz	3.5"	240x320
Philips	Nino 320 Personal Organizer	8 MB RAM	75MHz 32-bit MIPS-based PR31700 RISC	NA	240x320
Philips	Velo 500 16MB Personal Organizer	8 MB RAM	MIPS R3910	NA	480x240
Philips	Nino 312 Personal Organizer	8 MB RAM	75MHz 32-bit MIPS-based PR31700 RISC	NA	240x320
Pogo	nVOY e100 Communicator	NA	NA	3.5"	240x320
PSC	Falcon 4210	32 MB RAM	MIPS core RISC CPU,32 bits,92 MHz	NA	240x320
Psion	Psion Revo	16 MB RAM	36MHz ARM 710T RISC CPU	NA	480x160
Psion	Psion Series 5mx	NA	36MHz ARM 710T RISC CPU	NA	640x240
Psion	Psion Series 7	NA	Intel Strong ARM 133 MHz	7.7"	640x480
Psion	Psion 7035 Hand Held Computer	8 MB RAM	AMD Elan SC400 486DX,33 MHz	2.44"x2.44"	160x160
Psion	Psion netpad 1000 series	64 MB SDRAM	Intel StrongARM 206 MHz	NA	640x240
Psion	Psion netpad 3000 series	64 MB SDRAM	Intel StrongARM 206 MHz	NA	640x240
Psion	7535	128 MB RAM	Intel XScale PXA-255 400 MHz	3.5"	240x320
Psion	Psion netpad 5000 series	64 MB SDRAM	Intel StrongARM 206 MHz	NA	640x240
Psion	Sonic Blue Mako Personal Organizer	16 MB RAM	36MHz ARM 710T RISC CPU	NA	480x160
RIM	Blackberry 6750 Wireless Hand Held	2 MB RAM	NA	NA	NA
RIM	Blackberry 6710 Wireless Hand Held	2 MB RAM	NA	NA	NA
RIM	Blackberry 6510 Wireless Hand Held	1 MB RAM	NA	NA	160x100
RIM	Blackberry 6210 Wireless Hand Held	2 MB RAM	NA	NA	NA
RIM	Blackberry 5810 Wireless Hand Held	1 MB RAM	NA	NA	NA
RIM	RIM 957 Wirless Handheld	1 MB RAM	NA	NA	NA
RIM	RIM 950 Wirless Handheld	512 KB RAM	NA	NA	NA
RIM	RIM 857 Wirless Handheld	1 MB RAM	NA	NA	NA
RIM	RIM 850 Wirless Handheld	1 MB RAM	NA	NA	NA
Royal	Linea 16 Personal Organiser	NA	400 MHz	NA	160x160
Royal	Lin@x	32 MB RAM	Intel StrongARM 206 MHz	NA	240x320
SAMSUNG	i330	NA	Motorala Dragonball MZ 33 MHz	NA	160x240
SAMSUNG	SPH i700	64 MB RAM	Intel XScale PXA-255 300 MHz	3.5"	240x320

SAMSUNG	Nexio S150	64 MB RAM	Intel StrongARM 206 MHz	5"	800x480
Sharp	Zaurus SL5500	64 MB SDRAM	Intel StrongARM 206 MHz	3.5"	240x320
Sharp	Zaurus SL5600	32 MB SDRAM	Intel XScale PXA-255 400 MHz	3.5"	240x320
Siemens/AT&T	Wireless SX56 Pocket PC Phone	32 MB RAM	Intel StrongARM 206 MHz	NA	240x320
Siemens/Fujitsu	Pocket Loox 600	64 MB RAM	Intel XScale PXA-250 400 MHz	NA	240x320
SK Telecom	IMT2000 WebPhone	32 MB RAM	Intel StrongARM 206 MHz	4"	NA
Softfield Technology	ST VR3	16 MB RAM	NEC VR4181 MIPS 66MHz	NA	160x240
Sony	CLIE PEGSJ20G	16 MB RAM	Motorala Dragonball VZ 33 MHz	NA	320x320
Sony	CLIÉ PEGSJ22G	16 MB RAM	Motorala Dragonball VZ 33 MHz	NA	320x320
Sony	CLIE PEGSJ30G	16 MB RAM	Motorala Dragonball VZ 33 MHz	NA	320x320
Sony	CLIÉ PEGSJ33G	16 MB RAM	Motorala Dragonball Super VZ 66 MHz	NA	320x320
Sony	CLIE PEGT665CGD	16 MB RAM	Motorala Dragonball Super VZ 66 MHz	NA	320x320
Sony	CLIÉ PEGT665CG	16 MB RAM	Motorala Dragonball Super VZ 66 MHz	NA	320x320
Sony	CLIÉ PEGTG50G	16 MB RAM	Intel XScale PXA-250 200 MHz	NA	320x320
Sony	CLIÉ PEGNX70VG	16 MB RAM	Intel XScale PXA-250 200 MHz	NA	320x480
Sony	CLIÉ PEGNZ90G	16 MB RAM	Intel XScale PXA-250 200 MHz	NA	320x480
Sony/Ericsson	P800	16 MB RAM	NA	NA	208x320
Symbol Technologies	PDT 8000	128 MB RAM	Intel XScale PXA-250 400 MHz	3.9"	240x320
Symbol Technologies	PDT 8100	32 MB RAM	Intel StrongARM 206 MHz	NA	240x320
Symbol Technologies	PPT 2800	32 MB RAM	Intel StrongARM 206 MHz	NA	240x320
Symbol Technologies	SPT 1800	8 MB RAM	Motorola DragonBall VZ 33 MHz	NA	240x320
Symbol Technologies	SPT 1550	8 MB RAM	Motorola DragonBall VZ 33 MHz	2.3"	160x160
Symbol Technologies	PPT 8800	32 MB RAM	Intel XScale PXA-250 400 MHz	NA	240x320
Symbol Technologies	PDT 8037	128 MB RAM	Intel XScale PXA-250 400 MHz	NA	NA
Symbol Technologies	PDT 8056	128 MB RAM	Intel XScale PXA-250 400 MHz	NA	NA
Tiqit Computers	Tiqit eightythree	256 MB SDRAM	Pentium Class 300 MHz	NA	640x480
T-Mobile (Danger Inc.)	Pocket PC Phone Edition	32 MB RAM	Intel StrongARM 206 MHz	NA	240x320

T-Mobile (Danger Inc.)	Sidekick	16 MB RAM	NA	NA	240x160
Toshiba	e550G	64 MB SDRAM	Intel XScale PXA-250 400 MHz	3.213"x 2.409"	240x320
Toshiba	Toshiba e570 Pocket PC	64 MB SDRAM	Intel StrongARM 206 MHz	3.5"	240x320
Toshiba	Pocket PC e310	32 MB RAM	Intel StrongARM 206 MHz	3.5"	240x320
Toshiba	Pocket PC e740 W/Bluetooth	64 MB RAM	Intel XScale PXA-250 400 MHz	3.5"	240x320
Toshiba	Pocket PC e740 WiFi	64 MB RAM	Intel XScale PXA-250 400 MHz	3.5"	240x320
Toshiba	Pocket PC e330	64 MB RAM	Intel XScale PXA-250 300 MHz	3.5"	240x320
Toshiba	2032SP (Thera)	32 MB SDRAM	Intel StrongARM 206 MHz	NA	240x320
ViewSonic	Pocket PC V35	64 MB SDRAM	Intel XScale PXA-250 300 MHz	3.5"	240x320
Vtech	Helio	8 MB SDRAM	32-bit RISC processor 75 MHz	NA	160x160
Xircom	Rex 5001	NA	NA	2.6"	160x90
Xircom/Intel	REX 6000 MicroPDA	NA	NA	NA	240x120

Manufacturer	**Product Name**	**Screen Image**	**WI-FI**	**CDMA**	**GSM/GPRS**	**Hotsynch**
ACER	N-25	Colour	no	no	no	yes
ACER	N-25W	Colour	yes	no	no	yes
ACER	S-55	Colour	no	no	no	yes
ACER	S-65	Colour	no	no	no	yes
Alphacell	M5	Colour	no	no	yes	yes
Alphacell	M6	Colour	no	no	yes	yes
ASUS	MyPal A600	Colour	no	no	no	yes
Audiovox	Maestro PDA1032C	Colour	no	no	no	yes
Audiovox	Thera (2032SP)	Colour	no	yes	no	yes
bsquare	Power Handheld (maui)	Colour	no	no	yes	yes
Carrier Devices	Qtek 1010	Colour	no	no	yes	yes
Casio	IT-500	Colour	yes	no	no	yes
Casio	Casio Cassiopeia IT-700RFSTD	MonoChrome	yes	no	no	yes
Casio	Casio Cassiopeia BE-300	Colour	no	no	no	yes
Casio	Casio Cassiopeia E-100	Colour	no	no	no	yes
Casio	Casio Cassiopeia E-125	Colour	no	no	no	yes
Casio	Casio Cassiopeia E-200	Colour	no	no	no	yes
Casio	Casio Cassiopeia EM-500	Colour	no	no	no	yes
Casio	Casio Cassiopeia PV-S400Plus	MonoChrome	no	no	no	yes
Casio	Casio Cassiopeia PV-S600Plus	MonoChrome	no	no	no	yes
CIIT	Multimedia PDA	Colour	no	no	no	yes
Compal Electronics	PD-131	Colour	no	no	no	yes
Compal Electronics	PD-600C	Colour	no	no	no	yes
Consumer Direct Link/IBM	Paron	Colour	no	no	yes	yes
Dell	Dell AXIM X5	Colour	no	no	no	yes
Dell	Dell AXIM X5-ADV	Colour	no	no	no	yes
Empower Technologies	PowerPlay III	MonoChrome	no	no	no	yes
Empower Technologies	PowerPlay V	MonoChrome	no	no	no	no
Ericsson/Sony	P800	Colour	no	no	yes	yes
FIC	Cavalry 500	Colour	no	no	no	yes

FIC	Cavalry 600	Colour	yes	no	no	yes
FIC	KJ001	Colour	no	no	no	yes
FIC	KJ003	Colour	no	no	no	yes
Fossil	Wrist PDA	MonoChrome	no	no	no	no
Franklin	eBookMan EBM-900	MonoChrome	no	no	no	yes
Franklin	eBookMan EBM-901	MonoChrome	no	no	no	yes
Franklin	eBookMan EBM-911	MonoChrome	no	no	no	yes
Fujitsu/Siemens	Pocket LOOX 600	Colour	no	no	no	yes
G.MATE	Yopy-YP3700	Colour	no	no	no	yes
G.MATE	Yopy-YP3500	Colour	no	no	no	yes
G.MATE	Yopy-YP3000	Colour	no	no	no	yes
Garmin	iQue 3600 Personal Organizer	Colour	no	no	no	yes
Garmin	NavTalk GSM	MonoChrome	no	no	yes	NA
Gradiente	Gradiente Partner	Colour	no	no	yes	yes
Group Sense PDA (GSPDA)	V-2002	Colour	no	no	no	yes
HandEra	HandEra 330	MonoChrome	no	no	no	yes
HandEra	HandEra TRGPro	MonoChrome	no	no	no	yes
Handspring	Treo 300	Colour	no	yes	no	yes
Handspring	Treo 270	Colour	no	no	yes	yes
Handspring	Treo 180	MonoChrome	no	no	yes	yes
Handspring	Visor Pro	NA	no	no	no	yes
Handspring	Visor Platinum	NA	no	no	no	yes
Handspring	Treo 90	Colour	no	no	no	yes
Hewlett Packard	iPAC H2210	Colour	no	no	no	yes
Hewlett Packard	hp iPAQ™ H1910 Pocket PC	Colour	no	no	no	yes
Hewlett Packard	hp iPAQ™ H3950 Pocket PC	Colour	no	no	no	yes
Hewlett Packard	hp iPAQ™ H3970 Pocket PC	Colour	no	no	no	yes
Hewlett Packard	hp iPAQ™ H5450 Pocket PC	Colour	no	no	no	yes
Hewlett Packard	Jornada 728 Handheld PC	Colour	no	no	no	yes
Hewlett Packard	Compaq C-Series 2010c	Colour	no	no	no	yes
Hewlett Packard	HP iPAQ 5455 Pocket PC	Colour	yes	no	no	yes
HHP	Dolphin 7200 RF	NA	yes	no	no	no
HHP	Dolphin 7300 RF	NA	yes	no	no	yes
HHP	Dolphin 7400 RF	NA	no	no	no	yes
HHP	Dolphin 7450 RF	NA	yes	no	no	yes
Hitachi	Multimedia Communicator NC1	NA	NA	yes	NA	NA
HNT	Exilien 101	Colour	no	no	no	yes
HNT	Exilien 102	Colour	no	no	no	yes
HNT	Exilion 201	Colour	no	no	no	yes
HNT	IMT-2000	Colour	no	yes	no	yes
HNT/Hangil	Exilien 104 (C 3224)	Colour	no	no	no	yes
IBM	Workpad 8602-20X Personal Organizer	MonoChrome	no	no	no	yes
IBM	Workpad 8602-10U Personal Organizer	MonoChrome	no	no	no	yes
IBM	e-LAP	Colour	no	no	no	yes
IBM/Consumer Direct Link	Paron	Colour	no	no	yes	yes
Infomart	Kaii	Colour	no	no	no	yes
Intel/Xircom	REX 6000 MicroPDA	MonoChrome	no	no	no	yes
Intermec	700 Series	Colour	yes	no	yes	yes
Invair Technologies	Filewalker Messenger	MonoChrome	no	no	yes	yes
Invair Technologies	Filewalker Business	MonoChrome	no	no	no	yes
Kyocera	7135	Colour	no	yes	no	yes
LXE	MX4	MonoChrome	no	no	no	yes

Master Integrated Appliances	Beagle PDA	Colour	no	no	no	yes
Master Integrated Appliances	PA-200B	Colour	no	no	no	yes
Matsucom	onHand	NA	no	no	no	yes
MiTAC	CAT PDA	MonoChrome	no	no	no	yes
MiTAC	mio 8380	Colour	no	no	yes	yes
MiTAC	Mio 338 Ez Pack	Colour	no	no	no	yes
MiTAC	Mio 338 Plus	Colour	no	no	no	yes
MiTAC	Mio 339	Colour	no	no	no	yes
MiTAC	Mio 588	Colour	yes	no	no	yes
Mizi	GSL	Colour	NA	NA	NA	NA
Mizi	EnDA C3224- Phone edition	Colour	NA	NA	NA	NA
Mizi	Taiwan I	Colour	NA	NA	NA	NA
Mizi	HNT 101	Colour	NA	NA	NA	NA
Mizi	HNT 102 G	Colour	NA	NA	NA	NA
mm02	XDA	Colour	no	no	yes	yes
Motorola	Motorola HandEra 330	MonoChrome	no	no	no	yes
Motorola	A760	NA	NA	NA	yes	yes
NEC	Mobilepro P300 Personal Organizer	Colour	no	no	no	yes
NEC	MobilePro 200E	Colour	no	no	no	yes
NEC	Mobilepro 790 Personal Organizer	Colour	no	no	no	yes
NOKIA	9210	Colour	no	no	yes	yes
Orange	Orange SPV	Colour	no	no	yes	yes
Oregon Scientific	ECHO PDA	NA	no	no	no	yes
Packard Bell	Pocket Gear 2060	Colour	no	no	no	yes
Packard Bell	Pocket Gear 2030	Colour	no	no	no	yes
Palm	Tungsten-C	Colour	yes	no	no	yes
Palm	Tungsten-W	Colour	no	no	yes	yes
Palm	Tungsten-T	Colour	no	no	no	yes
Palm	Zire 71	Colour	no	no	no	yes
Palm	i705	MonoChrome	no	no	no	yes
Palm	m515	Colour	no	no	no	yes
Palm	m130	Colour	no	no	no	yes
Panasonic	Toughbook CF-P1	Colour	yes	yes	yes	yes
Philips	Nino 320 Personal Organizer	Colour	no	no	no	yes
Philips	Velo 500 16MB Personal Organizer	Colour	no	no	no	yes
Philips	Nino 312 Personal Organizer	Colour	no	no	no	yes
Pogo	nVOY e100 Communicator	Colour	no	yes	yes	yes
PSC	Falcon 4210	NA	no	no	no	yes
Psion	Psion Revo	NA	no	no	no	yes
Psion	Psion Series 5mx	NA	no	no	no	yes
Psion	Psion Series 7	Colour	no	no	no	yes
Psion	Psion 7035 Hand Held Computer	MonoChrome	yes	no	no	yes
Psion	Psion netpad 1000 series	Colour	no	no	no	yes
Psion	Psion netpad 3000 series	Colour	no	no	no	yes
Psion	7535	Colour	no	no	no	yes
Psion	Psion netpad 5000 series	Colour	yes	no	yes	yes
Psion	Sonic Blue Mako Personal Organizer	NA	no	no	no	yes
RIM	Blackberry 6750 Wireless Hand Held	NA	NA	yes	no	yes
RIM	Blackberry 6710 Wireless Hand Held	NA	NA	no	yes	yes
RIM	Blackberry 6510 Wireless Hand Held	NA	NA	NA	NA	yes
RIM	Blackberry 6210 Wireless Hand Held	NA	NA	no	yes	yes
RIM	Blackberry 5810 Wireless Hand Held	NA	NA	no	yes	yes
RIM	RIM 957 Wirless Handheld	NA	NA	NA	NA	yes
RIM	RIM 950 Wirless Handheld	NA	NA	NA	NA	yes
RIM	RIM 857 Wirless Handheld	NA	NA	NA	NA	yes
RIM	RIM 850 Wirless Handheld	NA	NA	NA	NA	yes
Royal	Linea 16 Personal Organiser	MonoChrome	no	no	no	yes

Royal	Lin@x	Colour	no	no	no	yes
SAMSUNG	i330	Colour	no	yes	no	yes
SAMSUNG	SPH i700	Colour	no	yes	no	yes
SAMSUNG	Nexio S150	Colour	no	yes	no	yes
Sharp	Zaurus SL5500	Colour	no	no	no	yes
Sharp	Zaurus SL5600	Colour	no	no	no	yes
Siemens/AT&T	Wireless SX56 Pocket PC Phone	Colour	no	no	yes	yes
Siemens/Fujitsu	Pocket Loox 600	Colour	no	no	no	yes
SK Telecom	IMT2000 WebPhone	NA	NA	yes	NA	NA
Softfield Technology	ST VR3	MonoChrome	no	no	no	yes
Sony	CLIE PEGSJ20G	MonoChrome	no	no	no	yes
Sony	CLIÉ PEGSJ22G	Colour	no	no	no	yes
Sony	CLIE PEGSJ30G	Colour	no	no	no	yes
Sony	CLIÉ PEGSJ33G	Colour	no	no	no	yes
Sony	CLIE PEGT665CGD	Colour	no	no	no	yes
Sony	CLIÉ PEGT665CG	Colour	no	no	no	yes
Sony	CLIÉ PEGTG50G	Colour	no	no	no	yes
Sony	CLIÉ PEGNX70VG	Colour	no	no	no	yes
Sony	CLIÉ PEGNZ90G	Colour	no	no	no	yes
Sony/Ericsson	P800	Colour	no	no	yes	yes
Symbol Technologies	PDT 8000	Colour	yes	no	yes	yes
Symbol Technologies	PDT 8100	Colour	yes	no	yes	yes
Symbol Technologies	PPT 2800	Colour	yes	no	yes	yes
Symbol Technologies	SPT 1800	Colour	yes	no	yes	yes
Symbol Technologies	SPT 1550	NA	no	no	no	yes
Symbol Technologies	PPT 8800	Colour	no	no	no	yes
Symbol Technologies	PDT 8037	Colour	no	no	yes	yes
Symbol Technologies	PDT 8056	Colour	yes	no	yes	yes
Tiqit Computers	Tiqit eightythree	Colour	no	no	no	yes
T-Mobile (Danger Inc.)	Pocket PC Phone Edition	Colour	no	no	yes	yes
T-Mobile (Danger Inc.)	Sidekick	NA	no	no	yes	yes
Toshiba	e550G	Colour	no	no	no	yes
Toshiba	Toshiba e570 Pocket PC	Colour	no	no	no	yes
Toshiba	Pocket PC e310	Colour	no	no	no	yes
Toshiba	Pocket PC e740 W/Bluetooth	Colour	no	no	no	yes
Toshiba	Pocket PC e740 WiFi	Colour	yes	no	no	yes
Toshiba	Pocket PC e330	Colour	no	no	no	yes
Toshiba	2032SP (Thera)	Colour	no	yes	no	yes
ViewSonic	Pocket PC V35	Colour	no	no	no	yes
Vtech	Helio	MonoChrome	no	no	no	yes
Xircom	Rex 5001	MonoChrome	no	no	no	yes
Xircom/Intel	REX 6000 MicroPDA	MonoChrome	no	no	no	yes

Manufacturer	**Product Name**	**BlueTooth**	**Infrared**	**Springboard Slot**	**PC Slot**
ACER	N-25	no	yes	no	no
ACER	N-25W	no	yes	no	no
ACER	S-55	no	no	no	no
ACER	S-65	no	no	no	no
Alphacell	M5	yes	yes	no	no
Alphacell	M6	yes	yes	no	no
ASUS	MyPal A600	no	yes	no	no

Audiovox	Maestro PDA1032C	no	yes	no	no
Audiovox	Thera (2032SP)	no	yes	no	no
bsquare	Power Handheld (maui)	no	yes	no	no
Carrier Devices	Qtek 1010	no	yes	no	no
Casio	IT-500	yes	yes	no	no
Casio	Casio Cassiopeia IT-700RFSTD	no	yes	no	no
Casio	Casio Cassiopeia BE-300	no	yes	no	no
Casio	Casio Cassiopeia E-100	no	yes	no	no
Casio	Casio Cassiopeia E-125	no	yes	no	no
Casio	Casio Cassiopeia E-200	no	yes	no	no
Casio	Casio Cassiopeia EM-500	no	yes	no	no
Casio	Casio Cassiopeia PV-S400Plus	no	no	no	no
Casio	Casio Cassiopeia PV-S600Plus	no	no	no	no
CIIT	Multimedia PDA	no	no	no	no
Compal Electronics	PD-131	no	yes	no	no
Compal Electronics	PD-600C	no	yes	no	no
Consumer Direct Link/IBM	Paron	yes	yes	no	no
Dell	Dell AXIM X5	no	yes	no	no
Dell	Dell AXIM X5-ADV	no	yes	no	no
Empower Technologies	PowerPlay III	no	no	no	no
Empower Technologies	PowerPlay V	no	yes	no	no
Ericsson/Sony	P800	yes	yes	no	no
FIC	Cavalry 500	yes	yes	no	no
FIC	Cavalry 600	no	yes	no	no
FIC	KJ001	yes	yes	no	no
FIC	KJ003	yes	yes	no	no
Fossil	Wrist PDA	no	yes	no	no
Franklin	eBookMan EBM-900	no	no	no	no
Franklin	eBookMan EBM-901	no	no	no	no
Franklin	eBookMan EBM-911	no	no	no	no
Fujitsu/Siemens	Pocket LOOX 600	no	yes	no	no
G.MATE	Yopy-YP3700	no	yes	no	no
G.MATE	Yopy-YP3500	no	yes	no	no
G.MATE	Yopy-YP3000	no	yes	no	no
Garmin	iQue 3600 Personal Organizer	no	yes	no	no
Garmin	NavTalk GSM	no	no	no	no
Gradiente	Gradiente Partner	no	yes	no	no
Group Sense PDA (GSPDA)	V-2002	yes	yes	no	no
HandEra	HandEra 330	no	yes	no	no
HandEra	HandEra TRGPro	no	yes	no	no
Handspring	Treo 300	no	yes	yes	no
Handspring	Treo 270	no	yes	yes	no
Handspring	Treo 180	no	yes	yes	no
Handspring	Visor Pro	no	yes	yes	no
Handspring	Visor Platinum	no	yes	yes	no
Handspring	Treo 90	no	yes	yes	no
Hewlett Packard	iPAC H2210	yes	yes	no	no
Hewlett Packard	hp iPAQ™ H1910 Pocket PC	yes	yes	no	no
Hewlett Packard	hp iPAQ™ H3950 Pocket PC	no	yes	no	no
Hewlett Packard	hp iPAQ™ H3970 Pocket PC	no	yes	no	no
Hewlett Packard	hp iPAQ™ H5450 Pocket PC	yes	yes	no	no
Hewlett	Jornada 728 Handheld PC	no	yes	no	yes

Packard					
Hewlett Packard	Compaq C-Series 2010c	no	yes	no	yes
Hewlett Packard	HP iPAQ 5455 Pocket PC	no	yes	no	no
HHP	Dolphin 7200 RF	no	yes	no	no
HHP	Dolphin 7300 RF	no	yes	no	no
HHP	Dolphin 7400 RF	no	yes	no	no
HHP	Dolphin 7450 RF	no	yes	no	no
Hitachi	Multimedia Communicator NC1	NA	NA	no	NA
HNT	Exilien 101	no	yes	no	no
HNT	Exilien 102	no	yes	no	no
HNT	Exilion 201	no	yes	no	yes
HNT	IMT-2000	yes	yes	no	no
HNT/Hangil	Exilien 104 (C 3224)	no	yes	no	no
IBM	Workpad 8602-20X Personal Organizer	no	yes	no	no
IBM	Workpad 8602-10U Personal Organizer	no	yes	no	no
IBM	e-LAP	no	yes	no	yes
IBM/Consumer Direct Link	Paron	yes	yes	no	no
Infomart	Kaii	no	yes	no	no
Intel/Xircom	REX 6000 MicroPDA	no	yes	no	yes
Intermec	700 Series	yes	yes	no	yes
Invair Technologies	Filewalker Messenger	yes	yes	no	no
Invair Technologies	Filewalker Business	no	yes	no	no
Kyocera	7135	no	yes	no	no
LXE	MX4	no	yes	no	yes
Master Integrated Appliances	Beagle PDA	no	yes	no	no
Master Integrated Appliances	PA-200B	no	yes	no	no
Matsucom	onHand	no	yes	no	no
MiTAC	CAT PDA	yes	yes	no	no
MiTAC	mio 8380	no	yes	no	no
MiTAC	Mio 338 Ez Pack	no	yes	no	no
MiTAC	Mio 338 Plus	no	yes	no	no
MiTAC	Mio 339	no	yes	no	no
MiTAC	Mio 588	yes	yes	no	no
Mizi	GSL	NA	NA	no	NA
Mizi	EnDA C3224- Phone edition	NA	NA	no	NA
Mizi	Taiwan I	NA	NA	no	NA
Mizi	HNT 101	NA	NA	no	yes
Mizi	HNT 102 G	NA	NA	no	NA
mm02	XDA	no	yes	no	no
Motorola	Motorola HandEra 330	no	yes	no	no
Motorola	A760	yes	yes	no	NA
NEC	Mobilepro P300 Personal Organizer	no	yes	no	no
NEC	MobilePro 200E	no	yes	no	no
NEC	Mobilepro 790 Personal Organizer	no	yes	no	yes
NOKIA	9210	no	yes	no	no
Orange	Orange SPV	no	yes	no	no
Oregon Scientific	ECHO PDA	no	yes	no	no
Packard Bell	Pocket Gear 2060	no	yes	no	no
Packard Bell	Pocket Gear 2030	no	yes	no	no
Palm	Tungsten-C	no	yes	no	no
Palm	Tungsten-W	no	yes	no	no
Palm	Tungsten-T	yes	yes	no	no

Palm	Zire 71	no	yes	no	no
Palm	i705	no	yes	no	no
Palm	m515	no	yes	no	no
Palm	m130	no	yes	no	no
Panasonic	Toughbook CF-P1	no	yes	no	no
Philips	Nino 320 Personal Organizer	no	yes	no	no
Philips	Velo 500 16MB Personal Organizer	no	yes	no	yes
Philips	Nino 312 Personal Organizer	no	yes	no	no
Pogo	nVOY e100 Communicator	yes	yes	no	no
PSC	Falcon 4210	no	yes	no	yes
Psion	Psion Revo	no	yes	no	no
Psion	Psion Series 5mx	no	yes	no	no
Psion	Psion Series 7	no	yes	no	yes
Psion	Psion 7035 Hand Held Computer	no	yes	no	no
Psion	Psion netpad 1000 series	no	yes	no	no
Psion	Psion netpad 3000 series	no	yes	no	no
Psion	7535	no	yes	no	no
Psion	Psion netpad 5000 series	no	yes	no	no
Psion	Sonic Blue Mako Personal Organizer	no	yes	no	no
RIM	Blackberry 6750 Wireless Hand Held	NA	NA	no	NA
RIM	Blackberry 6710 Wireless Hand Held	NA	NA	no	NA
RIM	Blackberry 6510 Wireless Hand Held	NA	NA	no	NA
RIM	Blackberry 6210 Wireless Hand Held	NA	NA	no	NA
RIM	Blackberry 5810 Wireless Hand Held	NA	NA	no	NA
RIM	RIM 957 Wirless Handheld	NA	NA	no	NA
RIM	RIM 950 Wirless Handheld	NA	NA	no	NA
RIM	RIM 857 Wirless Handheld	NA	NA	no	NA
RIM	RIM 850 Wirless Handheld	NA	NA	no	NA
Royal	Linea 16 Personal Organiser	no	no	no	no
Royal	Lin@x	no	yes	no	no
SAMSUNG	i330	no	yes	no	no
SAMSUNG	SPH i700	no	yes	no	no
SAMSUNG	Nexio S150	no	no	no	no
Sharp	Zaurus SL5500	no	yes	no	no
Sharp	Zaurus SL5600	no	yes	no	no
Siemens/AT&T	Wireless SX56 Pocket PC Phone	no	yes	no	no
Siemens/Fujitsu	Pocket Loox 600	yes	yes	no	no
SK Telecom	IMT2000 WebPhone	yes	NA	no	NA
Softfield Technology	ST VR3	no	yes	no	no
Sony	CLIE PEGSJ20G	no	yes	no	no
Sony	CLIÉ PEGSJ22G	no	yes	no	no
Sony	CLIE PEGSJ30G	no	yes	no	no
Sony	CLIÉ PEGSJ33G	no	yes	no	no
Sony	CLIE PEGT665CGD	no	yes	no	no
Sony	CLIÉ PEGT665CG	no	yes	no	no
Sony	CLIÉ PEGTG50G	yes	yes	no	no
Sony	CLIÉ PEGNX70VG	no	yes	no	no
Sony	CLIÉ PEGNZ90G	yes	yes	no	no
Sony/Ericsson	P800	no	yes	no	no
Symbol Technologies	PDT 8000	yes	yes	no	no
Symbol Technologies	PDT 8100	no	yes	no	no
Symbol Technologies	PPT 2800	no	yes	no	no
Symbol Technologies	SPT 1800	no	yes	no	no
Symbol Technologies	SPT 1550	no	yes	no	no
Symbol Technologies	PPT 8800	no	yes	no	no

Symbol Technologies	PDT 8037	no	yes	no	yes
Symbol Technologies	PDT 8056	no	yes	no	yes
Tiqit Computers	Tiqit eightythree	no	yes	no	yes
T-Mobile (Danger Inc.)	Pocket PC Phone Edition	no	yes	no	no
T-Mobile (Danger Inc.)	Sidekick	no	yes	no	no
Toshiba	e550G	no	yes	no	no
Toshiba	Toshiba e570 Pocket PC	no	yes	no	no
Toshiba	Pocket PC e310	no	yes	no	no
Toshiba	Pocket PC e740 W/Bluetooth	yes	yes	no	no
Toshiba	Pocket PC e740 WiFi	no	yes	no	no
Toshiba	Pocket PC e330	no	yes	no	no
Toshiba	2032SP (Thera)	no	yes	no	no
ViewSonic	Pocket PC V35	no	yes	no	no
Vtech	Helio	no	yes	no	no
Xircom	Rex 5001	no	no	no	no
Xircom/Intel	REX 6000 MicroPDA	no	no	no	yes

Manufacturer	**Product Name**	**CF/Microdrive Slot**	**SD/MMC Slot**	**Memory Stick Slot**	**GPS**	**Bar Code**
ACER	N-25	no	no	yes	no	no
ACER	N-25W	no	no	yes	no	no
ACER	S-55	no	no	yes	no	no
ACER	S-65	no	no	yes	no	no
Alphacell	M5	no	yes	no	no	no
Alphacell	M6	no	yes	no	no	no
ASUS	MyPal A600	no	yes	no	no	no
Audiovox	Maestro PDA1032C	yes	yes	no	no	no
Audiovox	Thera (2032SP)	no	yes	no	no	no
bsquare	Power Handheld (maui)	no	yes	no	no	no
Carrier Devices	Qtek 1010	no	yes	yes	no	no
Casio	IT-500	no	no	no	no	yes
Casio	Casio Cassiopeia IT-700RFSTD	yes	no	no	no	yes
Casio	Casio Cassiopeia BE-300	yes	no	no	no	no
Casio	Casio Cassiopeia E-100	yes	no	no	no	no
Casio	Casio Cassiopeia E-125	yes	no	no	no	no
Casio	Casio Cassiopeia E-200	yes	yes	no	no	no
Casio	Casio Cassiopeia EM-500	no	yes	no	no	no
Casio	Casio Cassiopeia PV-S400Plus	no	no	no	no	no
Casio	Casio Cassiopeia PV-S600Plus	no	no	no	no	no
CIIT	Multimedia PDA	yes	no	no	no	no
Compal Electronics	PD-131	yes	no	no	no	no
Compal Electronics	PD-600C	yes	no	no	no	no
Consumer Direct Link/IBM	Paron	no	no	no	no	no
Dell	Dell AXIM X5	yes	yes	no	no	no
Dell	Dell AXIM X5-ADV	yes	yes	no	no	no
Empower Technologies	PowerPlay III	no	no	no	no	NA
Empower Technologies	PowerPlay V	no	no	no	no	no
Ericsson/Sony	P800	no	no	yes	no	no
FIC	Cavalry 500	yes	yes	no	no	no
FIC	Cavalry 600	yes	yes	no	no	no
FIC	KJ001	yes	yes	no	no	no

FIC	KJ003	yes	yes	no	no	no
Fossil	Wrist PDA	no	no	no	no	no
Franklin	eBookMan EBM-900	no	yes	no	no	no
Franklin	eBookMan EBM-901	no	yes	no	no	no
Franklin	eBookMan EBM-911	no	yes	no	no	no
Fujitsu/Siemens	Pocket LOOX 600	yes	yes	no	no	no
G.MATE	Yopy-YP3700	yes	yes	no	no	no
G.MATE	Yopy-YP3500	no	yes	no	no	no
G.MATE	Yopy-YP3000	no	yes	no	no	no
Garmin	iQue 3600 Personal Organizer	no	yes	no	yes	no
Garmin	NavTalk GSM	no	no	no	yes	no
Gradiente	Gradiente Partner	no	yes	no	no	no
Group Sense PDA (GSPDA)	V-2002	no	yes	no	no	no
HandEra	HandEra 330	yes	yes	no	no	no
HandEra	HandEra TRGPro	yes	no	no	no	no
Handspring	Treo 300	no	no	no	no	no
Handspring	Treo 270	no	no	no	no	no
Handspring	Treo 180	no	no	no	no	no
Handspring	Visor Pro	no	no	no	no	no
Handspring	Visor Platinum	no	no	no	no	no
Handspring	Treo 90	no	yes	no	no	no
Hewlett Packard	iPAC H2210	yes	yes	no	no	no
Hewlett Packard	hp iPAQ™ H1910 Pocket PC	no	yes	no	no	no
Hewlett Packard	hp iPAQ™ H3950 Pocket PC	no	yes	no	no	no
Hewlett Packard	hp iPAQ™ H3970 Pocket PC	no	yes	no	no	no
Hewlett Packard	hp iPAQ™ H5450 Pocket PC	no	yes	no	no	no
Hewlett Packard	Jornada 728 Handheld PC	yes	no	no	no	no
Hewlett Packard	Compaq C-Series 2010c	no	no	no	no	no
Hewlett Packard	HP iPAQ 5455 Pocket PC	yes	yes	no	no	no
HHP	Dolphin 7200 RF	no	no	no	no	yes
HHP	Dolphin 7300 RF	yes	no	no	no	yes
HHP	Dolphin 7400 RF	no	no	no	no	yes
HHP	Dolphin 7450 RF	yes	no	no	no	yes
Hitachi	Multimedia Communicator NC1	yes	yes	NA	NA	NA
HNT	Exilien 101	yes	yes	no	no	no
HNT	Exilien 102	yes	no	no	no	no
HNT	Exilion 201	yes	no	no	no	no
HNT	IMT-2000	no	no	no	no	no
HNT/Hangil	Exilien 104 (C 3224)	yes	no	no	no	no
IBM	Workpad 8602-20X Personal Organizer	no	no	no	no	no
IBM	Workpad 8602-10U Personal Organizer	no	no	no	no	no
IBM	e-LAP	no	yes	no	no	no
IBM/Consumer Direct Link	Paron	no	no	no	no	no
Infomart	Kaii	yes	yes	no	no	no
Intel/Xircom	REX 6000 MicroPDA	no	no	no	no	no
Intermec	700 Series	yes	no	no	no	yes
Invair Technologies	Filewalker Messenger	no	yes	no	yes	no
Invair Technologies	Filewalker Business	no	yes	no	no	no
Kyocera	7135	no	yes	no	yes	no
LXE	MX4	yes	no	no	no	yes

Master Integrated Appliances	Beagle PDA	yes	yes	no	no	no
Master Integrated Appliances	PA-200B	yes	yes	no	no	no
Matsucom	onHand	no	no	no	no	no
MiTAC	CAT PDA	yes	no	no	no	no
MiTAC	mio 8380	no	yes	no	no	no
MiTAC	Mio 338 Ez Pack	no	yes	no	no	no
MiTAC	Mio 338 Plus	no	yes	no	no	no
MiTAC	Mio 339	no	yes	no	no	no
MiTAC	Mio 588	yes	yes	no	no	no
Mizi	GSL	yes	NA	NA	NA	NA
Mizi	EnDA C3224- Phone edition	yes	NA	NA	NA	NA
Mizi	Taiwan I	yes	NA	NA	NA	NA
Mizi	HNT 101	yes	NA	NA	NA	NA
Mizi	HNT 102 G	yes	NA	NA	NA	NA
mm02	XDA	no	yes	no	no	no
Motorola	Motorola HandEra 330	yes	yes	no	no	no
Motorola	A760	NA	NA	NA	NA	NA
NEC	Mobilepro P300 Personal Organizer	yes	yes	no	no	no
NEC	MobilePro 200E	no	yes	no	no	no
NEC	Mobilepro 790 Personal Organizer	yes	no	no	no	no
NOKIA	9210	no	yes	no	no	no
Orange	Orange SPV	no	yes	no	no	no
Oregon Scientific	ECHO PDA	no	no	no	no	no
Packard Bell	Pocket Gear 2060	no	yes	no	no	no
Packard Bell	Pocket Gear 2030	no	yes	no	no	no
Palm	Tungsten-C	NA	yes	no	no	no
Palm	Tungsten-W	NA	yes	no	no	no
Palm	Tungsten-T	NA	yes	no	no	no
Palm	Zire 71	no	yes	no	no	no
Palm	i705	no	yes	no	no	no
Palm	m515	no	yes	no	no	no
Palm	m130	no	yes	no	no	no
Panasonic	Toughbook CF-P1	no	yes	no	yes	yes
Philips	Nino 320 Personal Organizer	yes	no	no	no	no
Philips	Velo 500 16MB Personal Organizer	no	no	no	no	no
Philips	Nino 312 Personal Organizer	yes	no	no	no	no
Pogo	nVOY e100 Communicator	no	yes	no	no	no
PSC	Falcon 4210	no	no	no	no	yes
Psion	Psion Revo	no	no	no	no	no
Psion	Psion Series 5mx	yes	no	no	no	no
Psion	Psion Series 7	yes	no	no	no	no
Psion	Psion 7035 Hand Held Computer	no	no	no	no	yes
Psion	Psion netpad 1000 series	no	yes	no	no	no
Psion	Psion netpad 3000 series	no	yes	no	no	yes
Psion	7535	yes	no	no	no	yes
Psion	Psion netpad 5000 series	no	yes	no	no	yes
Psion	Sonic Blue Mako Personal Organizer	no	no	no	no	no
RIM	Blackberry 6750 Wireless Hand Held	NA	NA	NA	NA	NA
RIM	Blackberry 6710 Wireless Hand Held	NA	NA	NA	NA	NA
RIM	Blackberry 6510 Wireless Hand Held	NA	NA	NA	NA	NA
RIM	Blackberry 6210 Wireless Hand Held	NA	NA	NA	NA	NA
RIM	Blackberry 5810 Wireless Hand Held	NA	NA	NA	NA	NA
RIM	RIM 957 Wirless Handheld	NA	NA	NA	NA	NA
RIM	RIM 950 Wirless Handheld	NA	NA	NA	NA	NA
RIM	RIM 857 Wirless Handheld	NA	NA	NA	NA	NA
RIM	RIM 850 Wirless Handheld	NA	NA	NA	NA	NA
Royal	Linea 16 Personal Organiser	no	no	no	no	no

Royal	Lin@x	yes	no	no	no	no
SAMSUNG	i330	no	yes	no	no	no
SAMSUNG	SPH i700	no	yes	no	no	no
SAMSUNG	Nexio S150	no	no	no	no	no
Sharp	Zaurus SL5500	yes	yes	no	no	no
Sharp	Zaurus SL5600	yes	yes	no	no	no
Siemens/AT&T	Wireless SX56 Pocket PC Phone	no	yes	no	no	no
Siemens/Fujitsu	Pocket Loox 600	yes	yes	no	no	no
SK Telecom	IMT2000 WebPhone	NA	NA	NA	NA	NA
Softfield Technology	ST VR3	no	no	no	no	no
Sony	CLIE PEGSJ20G	no	no	yes	no	no
Sony	CLIÉ PEGSJ22G	no	no	yes	no	no
Sony	CLIE PEGSJ30G	no	no	yes	no	no
Sony	CLIÉ PEGSJ33G	no	no	yes	no	no
Sony	CLIE PEGT665CGD	no	no	yes	no	no
Sony	CLIÉ PEGT665CG	no	no	yes	no	no
Sony	CLIÉ PEGTG50G	no	no	yes	no	no
Sony	CLIÉ PEGNX70VG	yes	no	yes	no	no
Sony	CLIÉ PEGNZ90G	yes	no	yes	no	no
Sony/Ericsson	P800	no	no	yes	no	no
Symbol Technologies	PDT 8000	yes	no	no	no	yes
Symbol Technologies	PDT 8100	yes	no	no	no	yes
Symbol Technologies	PPT 2800	yes	no	no	no	yes
Symbol Technologies	SPT 1800	yes	no	no	no	yes
Symbol Technologies	SPT 1550	no	no	no	no	yes
Symbol Technologies	PPT 8800	yes	no	no	no	yes
Symbol Technologies	PDT 8037	yes	no	no	no	yes
Symbol Technologies	PDT 8056	yes	no	no	no	yes
Tiqit Computers	Tiqit eightythree	no	yes	no	no	no
T-Mobile (Danger Inc.)	Pocket PC Phone Edition	no	yes	no	no	no
T-Mobile (Danger Inc.)	Sidekick	no	no	no	no	no
Toshiba	e550G	yes	yes	no	no	no
Toshiba	Toshiba e570 Pocket PC	yes	yes	no	no	no
Toshiba	Pocket PC e310	no	yes	no	no	no
Toshiba	Pocket PC e740 W/Bluetooth	yes	yes	no	no	no
Toshiba	Pocket PC e740 WiFi	yes	yes	no	no	no
Toshiba	Pocket PC e330	no	yes	no	no	no
Toshiba	2032SP (Thera)	no	yes	no	no	NA
ViewSonic	Pocket PC V35	no	yes	no	no	no
Vtech	Helio	no	no	no	no	no
Xircom	Rex 5001	no	no	no	no	no
Xircom/Intel	REX 6000 MicroPDA	no	no	no	no	no

9 APPENDIX B: AVAILABLE SOFTWARE USED BY HANDELD DEVICES IN THE CONSTRUCTION INDUSTRY

Manufacturer	Product Name	Construction Usage
AEC Software	Fast Track Schedule for Palm OS	Project Sheduling
Austin Detek	FTMS CAD	Computer Aided Drafting (CAD)
Austin Detek	FTMS Remote	Task Results Management
Austin Detek	FTMS Project	Project Management/Tasks
Dexter+Chaney	Forefront	Cost Control/Payroll
Qquest Software Systems	Pocket E.T.C.	Time-Attendance Tracking
Ezijobz Software	Ezijobz SME	Quoting/Estimating/Project Scheduling
Accu-Tech Systems	mJobTime7	Cost Control/Payroll/Resource Management
BlueVolt	BlueVOLT	Cost Control/Payroll/Resource Management
Strata Systems	PunchList	Task Management/Scheduling
AirToolz Software	AirWavz	Task Management/Scheduling (Home Building)
Maxwell Systems	MaxCentral	Task Management/Scheduling/Resource Management/Document Management
UDA Technologies	Construction Office Mobile	Not Released yet. See office version
VirtualBoss Development Company	Pocket VirtualBoss	Task Management/Scheduling
MoriahCom	JobSite	Cost Control/Payroll/Resource Management
Home Construction Consulting	EZHomeBuild	Finance Management/Estimating/Quoting/Cost Control/Scheduling/Code Checking/Purchase Management (Home Building)
Timbre Software	Solstice for Pocket PC	Cost Control/Payroll/Resource Management/Purchase Management
LaserDispatch.com	Clear View Calender	Project Scheduling (Long Term)
Meridian Project Systems	ProjectTalk	Scheduling/Resource Management/Project Collaboration/Document Management/Cost Control/Purchase Management
Meridian Project Systems	Prolog Pocket	Resourse Management/Safety Management/Task Management
EK Solutions	PunchLister	Task Management/Warranty Management/Quality Control
CallTech America Inc.	ViewProject	Project Collaboration/Document Management
WaterWheel Software	Tracker 7	Tool-Plant Management
TDOC	TDOC	Project Collaboration/Document Management
Complan Network AS	WinPCS	Commissioning/Certification Tracking/Data Management/Quality Control (Oil&Gas Industry)
Evoco	AECit	Project Collaboration/Document Management/Scheduling/Web cam
AssetPM	AssetPM	Project Collaboration/Resource Management/Scheduling
PragmaticSoftwareCo.	Atrium	Document Management/Project Collaboration/Contact Management
PragmaticSoftwareCo.	Web Information Center	Project Collaboration/Bid Management/Contact Management
ATVIEW Inc.	Atview	Project Collaboration/Document Management
BidTek Construction Software Professionals	ViewPoint	Estimating/Accounting/Financial Management/Change Order Management/HR Management/Purchase & Materials Management/Cost Control/Equipement Management/Job Billing/Document Management
WebChili Corporation	BuilderWorkspace	Project Collaboration/Document Management
AutoDesk	BuzzSaw	Project Collaboration/Document Management
Construction Data Control Inc.	WIPnet	Project Collaboration/Document Management
Construction Data Control Inc.	cPM	Task Management/Scheduling
Citadon Inc.	ProjectNet	Project Collaboration/Document Management
Citadon Inc.	CW	Project Collaboration/Document Management
EPCCommands	Commands	Contract Management/Accounting/Financial Management/Change Order Management/Purchase & Materials Management/Cost Control/Equipement Management/Job Billing/Document Management

DSR Solutions Ltd.	Construct Optimus	Cost Control/Quality Control/Tender Management/Contractor Management/Earned Value Management/Stores Management/Performance Management/Procurement Management/Client Management/Resource Management/Project Variance Analysis/Risk Management/Communication Management/Change Order Management
ConstructionTrak.net	ConstructionTrak.net	Project Collaboration/Document Management
Emerging Solutions Inc.	Constructware	Document Management/Project Collaboration/Bid Management/Design Management/Financial Management/Risk Management/HR Management
Emerging Solutions Inc.	Constructware-subcontractor	Document Management/Bid Management/Tool-Plant Management/Contact Management
MP Interactive	eBuilder Enterprise	Project Collaboration/Document Management/Cost Control/Milestone Tracking
I-Construct	i-construct	Project Collaboration/Document Management/Task Management/Cost Control
IronSpire	JobSite	Project Collaboration/Document Management/Contact Management/Data Management/Bid Management
IronSpire	PrimSite	Project Collaboration/Document Management/Contact Management/Data Management/Bid Management
PL E Communications	Jobtrakker	Project Collaboration/Document Management/Bid Management/Change Order Management/Contact Management
myConstruction.com Inc	myConstruction.com	Project Collaboration/Document Management/Scheduling
CoCreate	onespace.net	Project Collaboration/Document Management/3D CAD
ICEAS	ICEAS	Project Collaboration/Document Management/Scheduling/Cost Control
Primavera Systems Inc	Primaver-Suite	Project Collaboration/Document Management/Contract Management/Scheduling/Risk Management/Time-Attendance Tracking
Primavera Systems Inc	Mobile Manager	Document Management/Scheduling
Procentive.com	Procentive	Project Collaboration/Document Management/Estimating
Profuse 2000	Profuse2000	Project Collaboration/Document Management/Contact Management
ECBridge	Coordinateonline	Project Collaboration/Document Management/Scheduling
Systemmates Inc	Projectmates	Project Collaboraiton/Document Management/Change Order Management/Task Management
ProjectGrid.com Inc.	ProjectGrid.com	Project Collaboration/Document Management/Financial Management/Scheduling/Change Order Management/Bid Management
4Projects	4Projects	Project Collaboration/Document Management/Safety Management
Rani Networks	?	Project Collaboration/Document Management/Scheduling/Cost Control/Resource Management
SiteStream Software	SiteStream	Land Acquisition/Sales Management/Client Management/Marketing/Cost Control/Purchase Management/Project Variance Analysis/Take-off/Financial Management/Project Collaboration/Document Management/Contact Management/
ERP Technologies	Construction Manager	Project Collaboration/Document Management/Scheduling/Estimating/Accounting/Client Management/Payroll/Purchase Order Management/Resource Management/Bid Management
Management Software Incorporated	JobOrder	Project Collaboration/Document Management/Cost Control/Scheduling/Purchase Order Management/Accounting
iManage	WorkSite	Project Collaboration/Document Management/Knowledge Management/Scheduling
Bricsnet FM	ProjectCenter	Project Collaboration/Document Management/Cost Control/Contact Management/Task Management
Corecon Technologies	Corecon Suite	Project Collaboration/Document Management/Cost Control/Estimating/Contract Management/Contact Management
BuildTopia.com	Complete	Sales Management/Bidding Management/Purchase Order Management/Design Management/Document Management/Scheduling/Cost Control/Project Collaboration.
Timberline	Mobile Estimating	Estimating

Timberline	Office	Project Collaboration/Document Management/Bidding Management/Contract Management/Cost Control/Variance Analysis/Estimating
MYCT Pty Ltd	MYCT	Project Collaboration/Document Management/Scheduling/Estimating/Accounting/Financial Management/Bid Management/Variation Analysis
True Systems	BuildTrak	Project Collaboration/Document Management/Sales Management/Client Management/Purchase Order Management/Estimating/Scheduling/Resource Management/Cost Control/After Sales Service
True Systems	WorkTrak	Accounting/Task Management/Purchase Order Management/Project Collaboration/Scheduling
Aktera	PocketPunch	Project Collaboration/Document Management/Task Management
i4Synergy	i4Builder	Project Collaboration/Document Management/Client Management/Marketing Management/Purchase Order Management/Cost Control/Scheduling/Sales Management/Task Management/Design Management/Bidding Management
Ballantine & Company	QuickGantt	Estimating/Task Management/Scheduling/Cost Control
HomeSphere	BuildSoft2Go	Scheduling/Task Management/Accounting/Purchase Order Management/Estimating
BuildLinks.com	BuildLinks	Project Collaboration/Document Management/Sales Management/Purchase Order Management/Scheduling/Client Management
BuildView	Communicator	Client Management/Progress Reporting/Interaction Manager/
BuildView	Enterprise Suite	Client Management/Progress Reporting/Interaction Manager/Virtual Design Centre
Computer Presentation Systems Inc.	WalkWrite	Task Management/Scheduling/Contact Management
Computer Presentation Systems Inc.	ScheduleBrowserLite	Project Collaboration/Scheduling/Task Management
Data-Basics	SAM Pro Enterprise	Project Collaboration/Document Management/Scheduling/Task Management
Data-Basics	CMAS Enterprise	Project Collaboration/Document Management/Accounting/Sales Management/Client Management/Cost Control/Purchase Order Management
Data-Basics	AEMAS	Project Collaboration/Document Management/Accounting/Sales Management/Client Management/Cost Control/Purchase Order Management/Safety Management
Intuit	MasterBuilder Enterprise 2003	Project Collaboration/Document Management/Change Order Management/Task Management/Client Management/Equipment Management/Financial Management/Financial Analysis/Estimating/Payroll
Sales Effectiveness Partners	SalesCloser for the internet	Sales Management/Change Order Management/Warranty Management/Contract Management/
MH2 Technologies	MH2Build	Project Collaboration/Document Management/Scheduling/Purchase Order Management/Sales Management/Warranty Management
MH2 Technologies	MH2Supply	Project Collaboration/Document Management/Scheduling/Purchase Order Management/Sales Management/Warranty Management
MH2 Technologies	MH2Inspect	Project Collaboration/Document Management/Scheduling/Purchase Order Management/Sales Management/Warranty Management
MH2 Technologies	MH2Sales	Project Collaboration/Document Management/Scheduling/Purchase Order Management/Sales Management/Warranty Management
MH2 Technologies	MH2Warranty	Project Collaboration/Document Management/Scheduling/Purchase Order Management/Sales Management/Warranty Management
PC Advisors	The Advisor Suite	Project Collaboration/Document Management/Scheduling/Options Management/Warranty Management/Contract Management/Feasibility Analysis/Financial Management/Sales Management/Bidding Management/Client Management
Phoraoh Information Services	Sales Manager Plus	Project Collaboration/Sales Management
Solutions On Site	Select On Site	Sales Management/Client Management/Marketing

Turtle Creek Software	Goldenseal	Project Collaboration/Document Management/Accounting/Prospect Tracking/Sales Management/Scheduling/Contract Management/Client Management
Versyss	Construction Manager	Project Collaboration/Document Management/Productivity Analysis/Cost Control/Change Order Management/Safety Management/Equipement Management/Payroll/Purchase Order Management
Heavy Construction Systems Specialists, Inc	HeavyJob Pocket	Productivity Analysis/Resource Management/Time-Attendance Tracking/Diary
Aconex	AconexAEC	Project Collaboration/Document Management/Bidding Management
E-Bid Systems Inc.	eBid Contract Sourcing Portal (CSP)	Project Collaboration/Document Management/Bidding Management
Bentley	MicroStation V8	3D Cad/Design Management/Document Management
InterSpec	e-SPECS On-Line	Project Collaboration/Document Management/Specification Development/Specification Management
Nemein	Nemein.net Projects	Project Collaboration/Document Management/Resource Management/Client Management/Scheduling/Task Management

10 APPENDIX D: SOME RELEVANT INTERNET HOT LINKS

The following is a list of useful websites related to hand held technologies:

http://pdaphonehome.com/
http://pocketpc.pdablast.com/
http://www.brighthand.com/
http://www.handspring.com/
http://www.hp.com/
http://www.linuxdevices.com/
http://www.palm.com/home.html
http://www.pdabuzz.com/
http://www.pdagold.com/
http://www.pdalive.com/
http://www.pdastreet.com/
http://www.pdatoday.com
http://www.pdatopsoft.com/
http://www.pdatreasures.com/
http://www.pdawerks.com/
http://www.planetpdamag.com/
http://www.rim.net/
http://www.symbian.com/

11 AUTHOR BIOGRAPHIES

Mr. TODD REMMERS

Present Position
Research Assistant, CSIRO Manufacturing and Infrastructure Technology.

Qualifications
Carpentry and Joinery Apprenticeship, Gold Coast Institute of TAFE, 1984.
Advanced Certificate in House Building Registration, Gold Coast Institute of TAFE, 1987.
BEng (Civil, Honours First Class), Griffith University, 2000.

Research and Industrial Experience
Mr. Todd Remmers has been involved in the building and construction industry since 1980. In 1981 he started a Carpentry and Joinery apprenticeship, which was completed in 1984. Following the completion of his apprenticeship, he worked mainly in the Home Building Industry in South East Queensland as sub-contract carpenter as well as commercial resort projects around Australia during a two year working holiday in 1988-89. Since completing his Engineering degree, he has worked in Local Government as a Development Engineer.

In 2002, Mr. Remmers joined the CSIRO's Building, Construction and Engineering (now Manufacturing and Infrastructure Technology) Division as a Research Assistant, to investigate issues relating to construction process efficiency, facilities/asset management and sustainable built environments. Relevant topics of research relating to this report Mr. Remmers has been involved with include and investigation in to design and documentation quality in the construction industry.

Mr. PAUL TILLEY

Present Position
Construction Systems Researcher, CSIRO Manufacturing and Infrastructure Technology.

Qualifications
BAppScBldg, Queensland Institute of Technology, 1982
M ProjMngt, Queensland University of Technology, 1998

Research and Industrial Experience
Mr. Paul Tilley has been involved in the building and construction industry for over 25 years, starting as a building cadet with the Queensland State Works Department in 1975. After 10 years with the State Works Department, Mr. Tilley decided to enter the world of private industry, working for a number of builders and project management consultants. Over the years, Mr. Tilley gained extensive construction industry experience – in both the public and private sectors – in such diverse areas as:

- Estimating
- Contract Administration
- Construction/Project Management
- Construction Planning and Programming
- Contract Claims Assessment
- Assessment of IT Applications for Construction

In 1995, Mr. Tilley joined the CSIRO's Building, Construction and Engineering Division as a Construction Systems Researcher, to investigate issues relating to construction process efficiency. Areas of research currently being investigated include, Construction Process Re-engineering (CPR), Lean Construction (LC) methods, the efficiency of information and communication flows in construction, the simulation of construction processes and the causes and effects of design and documentation deficiency in construction. Mr. Tilley is also interested in industry benchmarking and in developing indicators for measuring both project and industry performance. He is also a member of the Equitable Project Delivery issue group of the Construction Queensland initiative.

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