Report No. 15 from the UMTS Forum

Key Components for 3G Devices

UMTS Forum, January 2002

This Report has been produced by the UMTS Forum, an association of telecommunications operators, manufacturers and regulators. The UMTS Forum comprises of IT and media industries interested in broadband mobile multimedia that are active both in Europe and other parts of the world and who share the vision of UMTS (Universal Mobile Telecommunications System). These are key industry members of the Forum and have contributed significantly to this Report. In terms of a technology platform UMTS will move mobile communications forward from today's environment to the Information Society incorporating third generation mobile services that will deliver speech, data, pictures, graphics, video communication and other wideband information direct to people on the move. UMTS UTRA (Universal Terrestrial Radio Access) is a member of the IMT-2000 family of standards.

This Report has been generated by one of the UMTS Forum Working Groups, the Information and Communication Technologies Group (ICTG), and addresses issues on Devices and IC Components of 3G Devices.

Report 15 is one of the family members of UMTS Forum Reports on different aspects of deploying UMTS networks.

The views, conclusions and detailed recommendations expressed in this Report are purely those found and expressed during the work of creating this document and exempts National Administrations who are UMTS Forum members from being bound to them.

Revision 1.9

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1 Executive Summary

The next generation of wireless devices holds great promise for consumers - everything from high-speed data communications to multimode phones that can be used practically anywhere in the world. But manufacturers will have to solve a variety of perplexing issues, ranging from current limitations in multimode transceiver operation, large displays, through manufacturing-yield problems and overheated handsets to insufficient battery life and performance before they can realise the promise of 3G. The traditional mouse and alphanumeric keyboard have been replaced with a scaled down keyboard or numeric keypad. Perhaps most noticeable is that the computational capacity of these devices is often limited by the low-power CPUs needed to conserve battery life.

Furthermore, communications applications are expanding their service features to meet the rapid growth in usage of the Internet and related technologies. One new function that needs to be integrated on the keypad is the "@" key.

It is also important for content providers or application developers to know what types of devices and capabilities will be available in both the short and long term for 2.5G and 3G services. Different applications will have different requirements on device hardware. Many applications will require a larger screen with higher resolution than today's cellular handsets. Other applications will require better CPU performance and therefore better battery performance and memory storage. It is also important that component manufacturers understand the wishes of the network operators and design components to meet fast-growing market needs. But hardware constraints will have to be considered thoroughly when developing applications and content.

1.1 Barriers

Many of today's wireless devices use programmable microcontroller and digital-signal-processor cores combined with embedded memories and numerous peripheral modules all on a single chip. Microcontrollers are a specific type of microprocessor that have more I/O ports and interrupts than a general CPU as well as on-chip random-access memory (RAM) and read-only memory (ROM). External Flash and Burst Flash memories are also used. But the complexity extends beyond mere technology and process challenges.

Future gadgets will be made to 0.1 µm designs, have more than 200 million transistors, operate at 500 MHz and work within 1V constraints. Processor cores will be configurable, and re-configurable processors will handle image, speech, data, web connectivity, mobile and in-home needs. As devices and services become more complex the demands on memory will

increase enormously. Within just the last 24 months, myriad audio, video, PDA and cellular products have equipped people not only to carry around data, images and audio but also to swap devices between various types of hardware. New technologies include flash memory cards and small disk drives. Flash devices, a relatively young technology, contain one or more non-volatile solid-state memory chips. They have no moving parts and retain data in the absence of power. Like these, but an industry unto itself, is the PC card; now almost 10 years old, the business-card-sized memory and application device is widely used to add functions to mobile computers.

1.2 Memory

Memory is key to retaining complex data on a device. It enables storage of programs, audio and video files and provides users with more efficient data compression methods. Sufficient memory also allows devices to run Java applications that require large amounts of memory to implement.

In order to run the GPRS protocol stack and service-associated applications, a minimum code size is necessary to perform the communication and application parts of the software. The code size for GPRS and UMTS requires up to eight times the memory requirements of classical GSM.

1.3 CPU

The physical implementation of the UMTS receiver coupled with the applications that will be provided on mobile networks requires fast DSPs that will exceed the requirements for GSM by one or two orders of magnitude.

New applications on mobile devices will require a greater MIPS performance, for example MPEG-4 needs 130-160 MIPS processing power.

1.4 Batteries and Power Consumption

The overall power consumption of a device is very important and should be kept to a minimum. The development cycle for batteries is quite slow and has not yet reached maturity for full-scale deployment. It takes battery manufactures between 5 and 12 years to develop batteries with increased power that maintain the size required for a UMTS device. Current battery technologies (Ni-Cd, Ni-MH, Li-Po) are not always able to support the increased power requirements.

Hardware developers, application developers and content providers should take great care when laying out the structure and design of feature capabilities in mobile devices.

1.5 DISPLAYS

Display manufacturers have recognised the potential that 3G communications will bring. In Japan, i-mode phones are currently equipped with colour screens. Cellular phones, with a few exceptions, do not come equipped with colour screens, which are considered to be an extra cost factor. Users will however wish to have colour displays at no extra cost. Cost is a major issue; large screens are the predominant cost element of a handset.

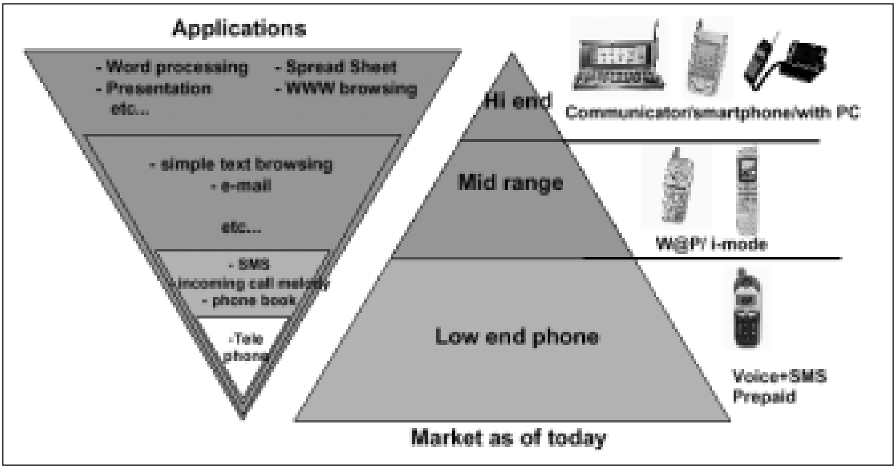
This Report addresses a number of these issues and provides a fundamental guideline for components required in 3G devices. It also serves as a reference document.

2 DEVICE CAPABILITIES AND THEIR FUTURE EVOLUTION

2.1 BASIC REQUIREMENTS OF UMTS DEVICES

Today, 2G and 2.5G cellular terminals are classified in the market as low-end, mid-range or high-end according to their features and functionality (Figure 2.1). For UMTS devices, such device classifications are no longer applicable. Because of the many different types of applications, there will be several different types of UMTS devices in terms of form, features, functionality and capability depending on the requirements of content, applications and usage models.

Figure 2.1: Today's 2G/2.5G Mobile Phone Market Segments



Source: UMTS Forum

Based on today's market segmentation for mobile phones, the following classification can be expected for UMTS devices in the initial phase of UMTS services:

- Voice-centric data device;
- Data-centric with voice-capable device.

The first candidate UMTS device is a voice-centric data-capable device that is a natural migration path from 2G/2.5G to UMTS/3G for simple voice with enhanced capabilities and functionality. Devices in this category may be addressed to users who are using low-end or mid-range 2G terminals and are familiar with current information services such as WAP or i-mode.

The second candidate is a data-centric device such as a PDA with voice or data communication capability. These devices are already available as "smartphones" or "communicators" based on 2G or 2.5G technologies and are mainly addressed to business users. Because the requirements on capability and functionality of these devices are much more complex than voice-centric data devices today, "smartphone" or "communicator" type devices would be good candidates to realise the full capability of UMTS in the initial service phase.

A key factor to ensure the success of UMTS services will be the introduction of UMTS services and devices into the existing mobile phone market segments.

As many UMTS service scenarios are possible, associated with different types of content and applications, there will also be many different requirements on UMTS devices. But multi-application platforms require longer lead times and more development resources for UMTS devices.

In order to ensure the availability of UMTS devices, the service scenarios, content type and corresponding applications should be clarified at a much earlier stage in the development cycle.

All devices intended to interact with "rich" content will need to offer digital rights management (DRM) functions.[1] Without DRM, rights owners of content will be unwilling to offer their assets for delivery via UMTS networks.

2.2 User Expectations and Requirements

Besides the above-mentioned attributes, users will have basic expectations on UMTS devices:

- The user interface for available services and applications should ensure ease of use;
- Low-cost devices with attractive (trendy), ergonomic designs and high battery life;
- High data rates up to 384 kbit/s enabling top-class mobile multimedia services that include new value added services;
- Consistent user experience and nationwide availability of services, leading to the need for multimode devices;
- UMTS, as an IMT-2000 family member, will deliver usable services and devices worldwide;
- "Always available services"[2] will allow "always on" or "always on-line" type operation.

[1] This also applies to "multifunctional devices" and "complementary devices".

[2] Volume-based charging for received or sent data on a packet data service will bring "always available services".

These requirements will vary according to the circumstances of each region and country. In some countries where mobile information services (e.g. i-mode or WAP services) are already well established, the first focus of users may be enhancement of terminal features and capability compared with existing 2G or 2.5G services.

In addition to service migration from 2G/2.5G to UMTS/3G, deployment of UMTS/3G in small cells would require UMTS/3G devices to include both 2G/2.5G and UMTS/3G transceivers in a dual-mode device. Of course, either single-mode or dual-mode UMTS/3G transceivers will have a serious impact on device concepts as long as most existing 2G or 2.5G standards are unable to inter-operate. On the other hand, network operators have a significant opportunity to provide users with migrated services, enabling users to enjoy some scaled-down UMTS/3G services over 2G/2.5G networks and terminals.

The need for 2G/2.5G and UMTS/3G dual-mode devices should be clarified in the early development stages of UMTS/3G devices to ensure the availability of appropriate devices at the right time in the market.

In the mid to long term, new multimedia and mixed data capabilities in UMTS/3G services will create several additional requirements on UMTS/3G devices:

- Some user groups may create particular market segments according to their usage and may require dedicated UMTS devices. (Application implementation based on specific usage or user group.)
- Service convergence (UMTS and DxB[3]) will require a specific UMTS device.

2.3 Categories of Devices

2.3.1 Multifunctional Devices

As can be observed in the market, 2G and 2.5G terminals are already integrating additional functionality based on services or usage (Table 2.1).

[3] Digital Audio Broadcasting and Digital Video Broadcasting.

Table 2.1: Added Functionality Implemented in Recent 2G and 2.5G Terminals

Service/Usage	Function	Corresponding components	Remarks
Music download/listen	MP3 Player	MP3 player (software and hardware) Memory (internal and external)	
Still picture	Digital Camera	CMOS or CCD sensor and associated circuits Corresponding I/O components	Corresponding display will be required according to picture quality
Gaming	Game	Java or similar software platform for on-line gaming Memory (internal and external)	
Watch	Watch	Corresponding software Corresponding I/O components	
Calculator	Calculator	Corresponding software Corresponding I/O components	
Voice recorder	Voice Recorder	Corresponding software Corresponding I/O components Memory	
Navigation/Location-based services	Positioning Download map Route planning etc.	Corresponding software for positioning Corresponding hardware (GPS receiver, Faint Magnetic sensor, etc.)	See location-based services section in UMTS Forum Report 14
Ad hoc connectivity	Bluetooth™ Other RLANs[4]	Corresponding hardware (RF, Baseband and µPC) and software	
Incoming call melody	Incoming call melody	Melody LSI Corresponding software	
PDA	PDA	Higher quality display Touch screen and /or pen input Applications corresponding to PDA features	

Source: UMTS Forum

Some of the above functionality would also be required on UMTS/3G devices with enhanced or upgraded functionality based upon market requirements and sometimes on UMTS/3G service scenarios.

[4] RLANs in this regard include DECT, HiperLANs, IEEE 802.1x etc. that can realise *ad hoc* wireless connectivity for UMTS/3G devices.

But additional functionality requires higher power consumption as well as having a negative impact on cost. The question of additional functionality should be considered carefully in the light of market requirements and implemented in such a way as to minimise these issues.

2.3.2 Complementary Devices

The above-mentioned multifunctional devices are based on a mobile phone centric approach. New multimedia and mixed data services would create further opportunities for UMTS devices to be complementary to other electronic devices.

Considering the high level of complexity entailed in integrated multifunctional devices, a feasible approach is to enable traditional portable (consumer or business user) devices to interwork with UMTS terminals implementing core access functionality. Examples would include a digital camera interworking with a UMTS terminal, which would enable a user to transfer a digital image to the terminal for incorporation in a multimedia message. The possible combinations are very wide ranging.

As has already been seen in the market as one of the terminal solutions for 2G/2.5G, a device like a PC card that only contains the UMTS core would be one candidate for a complementary UMTS device. This kind of implementation for UMTS functionality could bring several benefits:

- All necessary user interfaces are already on the host device according to the associated application.
- Some host devices such as PCs provide well-specified APIs for application implementation. This has a positive impact for device manufacturers, enabling them to minimise development lead times and easily create “plug and play” platforms.
- As all components apart from the UMTS core are re-used on the host device, the total cost could potentially be minimised.

As a further enhancement, such a UMTS core function could be fully integrated into other electronic devices as a core module. In Japan, some notebook PCs already contain a full PHS core module (Figure 2.2).

Figure 2.2: Integrated PHS Function in Notebook PC

Source: Fujitsu

2.4 MINIATURISATION

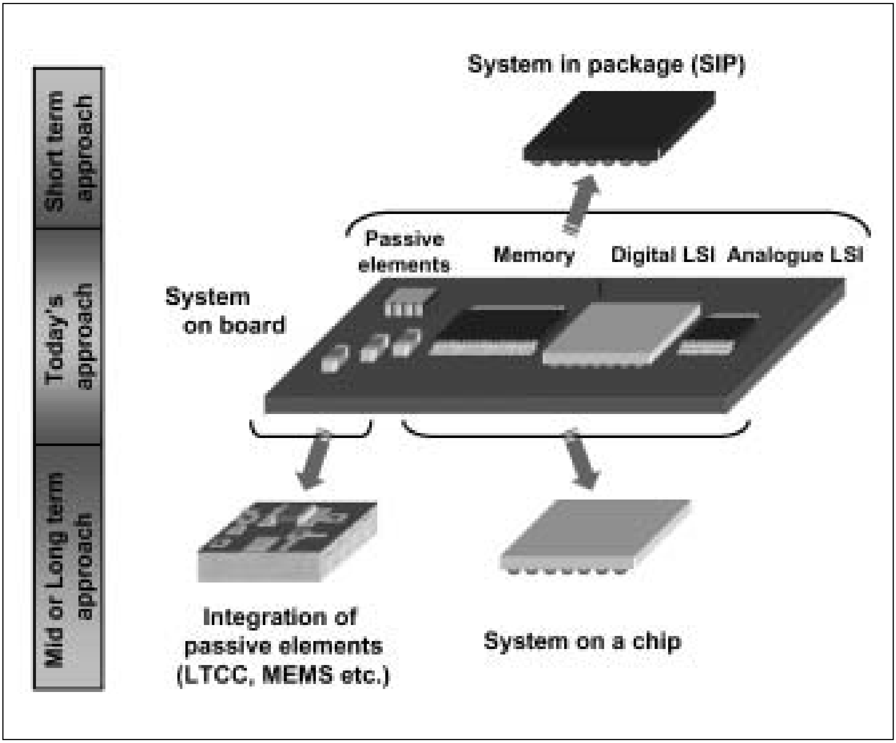
Many different applications are expected to be implemented in UMTS devices. For each application, corresponding additional components or elements need to be employed. This will have some impact on the terminal design from a form factor perspective. On the other hand, most users want to carry as small and as light a device as possible even though new functionality or features are added.

In order to meet such market requirements, further miniaturisation is one of the key issues and this requires further miniaturisation or integration of all related components on UMTS devices.

Die size packages are already available commercially using the latest semiconductor packaging technology. In order to realise further integration and miniaturisation several different approaches are on-going (Figure 2.3). As a mid or long-term approach, further integration on LSI chips as well as integration of passive elements is being investigated heavily.[5] As a short-term approach, several manufacturers are introducing System in Package (SIP) solutions. Under such circumstances handset manufacturers should choose an appropriate solution according to their product design concept, cost and availability in order to meet market requirements.

[5] Such as LTCC (Low Temperature Co-fired Ceramics), MEMS (MicroElectroMechanical Systems) or System on a Chip (SOC).

Figure 2.3: Several Approaches for Further Integration and Miniaturisation



Source: Nikkei Electronics No. 782

2.5 Evolution of the Semiconductor Process

The digital IC process could achieve 0.09 µm technology as of today (year 2001) with a concerted effort by the semiconductor industry even though the technology limitation has been previously announced as 0.13 µm.

The RF IC process could achieve the same process rule basically, but RF performance requirements limit the finest process to the 0.18 µm level today.

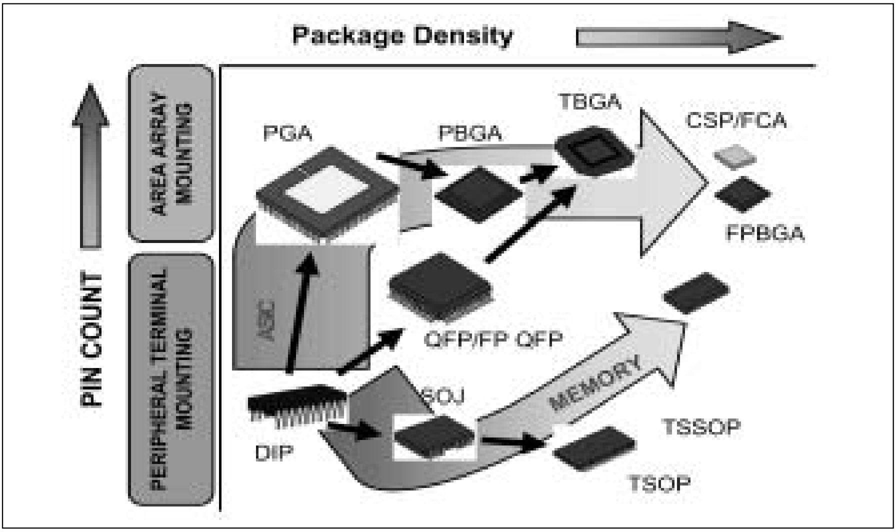
Such efforts on deploying further advanced processes will enable a continuous evolution for downsizing the IC die itself. That will result in the smallest form factor and highest integration level on ICs in conjunction with corresponding packaging technology.

2.6 Evolution of Packaging Technology

In the late 1970s, most ICs were still DIP (Dual In-line Package). During the 1980s, manufacturers made the transition to SMT (Surface Mounting Technology) and this technology brought dramatic changes to all electronic devices, making them smaller and bringing a fully automated assembly process to the production line.

Initially, SOP (Small Outline Package) or QFP (Quad Flat Package) were used for semiconductor packages. Then further developments took place where the tendency was either to remove the package completely or to make it slightly larger than the die. More recently, FPBGA (Fine Pitch Ball Grid Array) and CSP[6] are emerging as new packaging technologies enabling further miniaturisation of end products (Figure 2.4).

Figure 2.4: Package Trends for Memory-ICs and ASIC / Logic-ICs[7]



Source: NEC

[6] There are two different CSPs. One is the so-called Chip Scale Package (package size is 1.2 x die size) and the other is the Chip Size Package or Wafer Level CSP (package size = die size). There are three major types of CSP designs: 1) Moulded custom lead frame with leads remaining within the perimeter of the body; 2) Using a rigid interposer such as a laminate or ceramic; and 3) Using a flexible interposer.

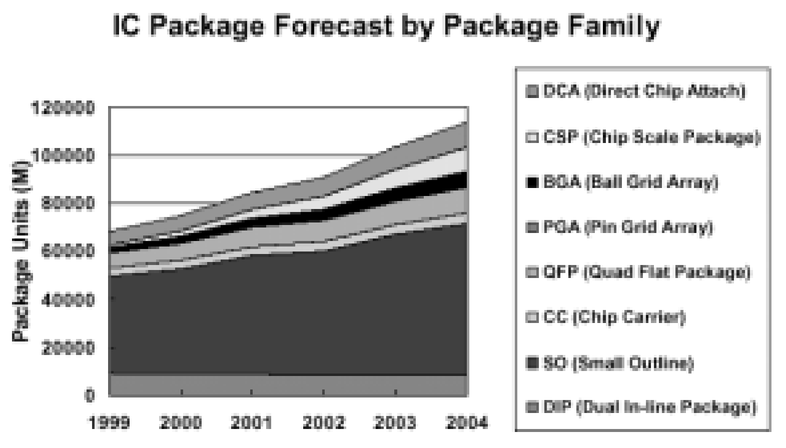
[7] The figure also shows the pitch of the different packages. PBGA measures 1.27mm, TBGA 1.0mm, FP QFP 0.8mm, CSP 0.5mm and FCA 0.24mm. (Source: NEC.)

With the trend towards higher frequency ranges and faster processing speeds in electronic devices, achieving the shortest interconnections in ICs becomes an important factor in meeting electrical performance requirements. This trend continuously accelerates further integration and miniaturisation.

FCA (Flip Chip Array) has been around for more than 30 years and offers the highest integration densities because it is the same size as the die itself. FCA enables the shortest signal paths that bring good electrical performance at higher frequencies.

However, FCA requires more complicated assembly and handling processes at the end product manufacturers as well as fine pitch patterning and formation of fine solder bumps for the PC motherboard. As long as such issues are not resolved, other packages such as BGA, QFP and CSP will mainly be used (Figure 2.5).

Figure 2.5: IC Package Forecast by Package Family

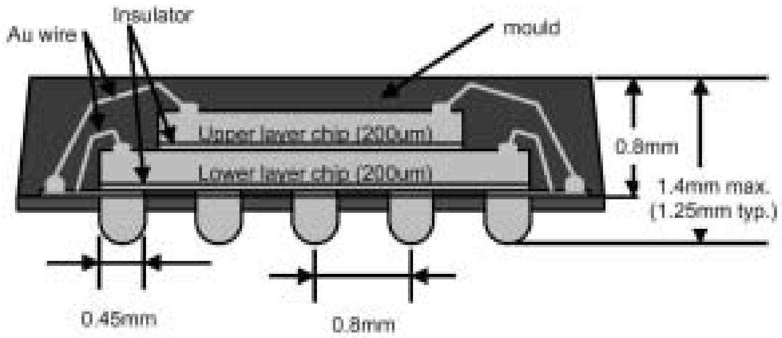


Source: World IC Packaging Market, April 2000

2.7 Multi-Dimensional Integration

S-CSP (stacked-CSP) was developed to realise higher integration whilst keeping the advantages of CSP or BGA packages. In an S-CSP, two or three layers of die are stacked between insulators and interconnected to a tape substrate by bonded gold wires (Figure 2.6).

Figure 2.6: An Example of S-CSP



Source: Nikkei Electronics No. 739

Stacked-chip package integration has turned out to be one of the enabling key technologies for integrating more memory without increasing PC board area or end product size, weight and cost. Today, S-CSP has already been heavily used in wireless or handheld applications, mainly for the memory section.

In the case of a 16-Mbit flash device and a 2-Mbit SRAM, integrating both elements into an S-CSP saves 60mm^2 compared with using separate FBGAs. Stacking flash and SRAM in an S-CSP requires only about one third the area and weight of separate TSOPs for a factor of three increase in packaging density.

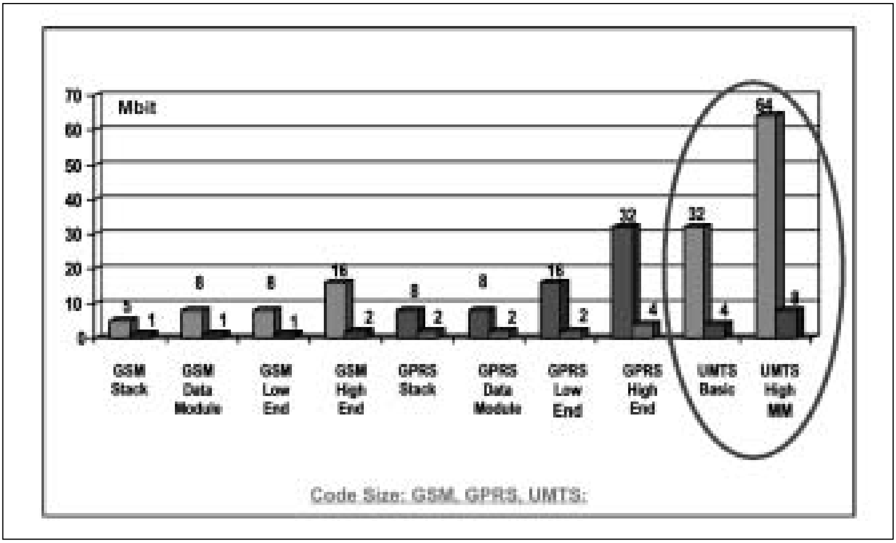
Japanese mobile phone makers are pursuing triple-chip S-CSP, stacking the flash-plus-SRAM combination on top of the DSP ASIC, to cost-effectively crack the 60cc and 60g benchmark when delivering mobile phones such as “i-mode” in small form factors. Current S-CSP solutions for handsets employ wire-bond interconnection technologies. However, the future stacked-packaging road maps anticipate combinations of wire-bond and flip-chip-in-package interconnection for a range of die size and performance requirements. These interconnect advancements and the established S-CSP infrastructure to support flash-plus-SRAM for mobile phones could be applied also to a wider range of device combinations, package platforms and end-market applications.

Stacked-chip interconnection, ball grid array and CSP technology are merging and such technology elements will support further integration and miniaturisation for future portable electronic devices and terminals.

2.8 MEMORY CAPACITY

In order to run the W-CDMA or GPRS protocol stacks and the service-associated applications, a minimum code size is needed to perform the communication and application parts of the software. Figure 2.7 shows typical values of Flash and SRAM sizes for GSM, GPRS and UMTS handsets.

Figure 2.7: Code Size: GSM, GPRS and UMTS[8]



Source: Infineon

The memory requirements would normally be decreased by manufacturers through further optimisation of the implementation of the UMTS core signalling and protocol stack.

However, the actual implementation is not clearly specified in today's specifications.

In order to minimise memory requirements and processing power requests, every opportunity to use the most efficient standardised protocol for signalling, etc. will help to reduce the final cost of the product.

[8] The left hand columns indicate the required Flash size, the right ones the SRAM size. The exact values depend on the mobile phone's display size and may change depending on applications.

2.9 Processing Power

The physical implementation of the UMTS receiver coupled with the application-rich environment of service-driven UMTS demands intensive layer 1 DSP-related operations. This exceeds the values for GSM by one to two orders of magnitude. Table 2.2 illustrates the approximate processing requirements for UMTS calculated for a data transmission rate of 384 kbit/s.

Table 2.2: An Example of Approximate Values of Processing Requirements for UMTS

Processing requirement	MIPS
Digital filtering (RRC, channelisation)	3600
Searcher (frame, slot, delay path estimation)	1500
Rake (TVI, correlators)	650
MRC	24
Channel estimation	12
AGC and AFC	10
De-interleaving, rate matching and decimator	15
Speech codec	10
Turbo coding	52
Total DSP MIPS	5871 MIPS[9]

Source: Infineon

However, in order to maintain the overall power consumption of a UMTS mobile station at acceptable levels and to keep the silicon die size economically viable, an optimised split of DSP hardware and firmware is necessary. An intelligent split of the DSP tasks performed in the hardware or firmware allows the DSP bus loading to be reduced and releases the DSP for higher level and added value UMTS applications. Chip-rate operations should generally be performed in hardware and symbol-rate operations in firmware. Such a design approach off-loads the DSP firmware to a theoretical level of about 50 MIPS. This allows the DSP hardware to be allocated for supporting the added value 3G applications.

Several functional blocks can be implemented in the DSP firmware:

- Channel estimation
- SIR computation
- Frequency correction

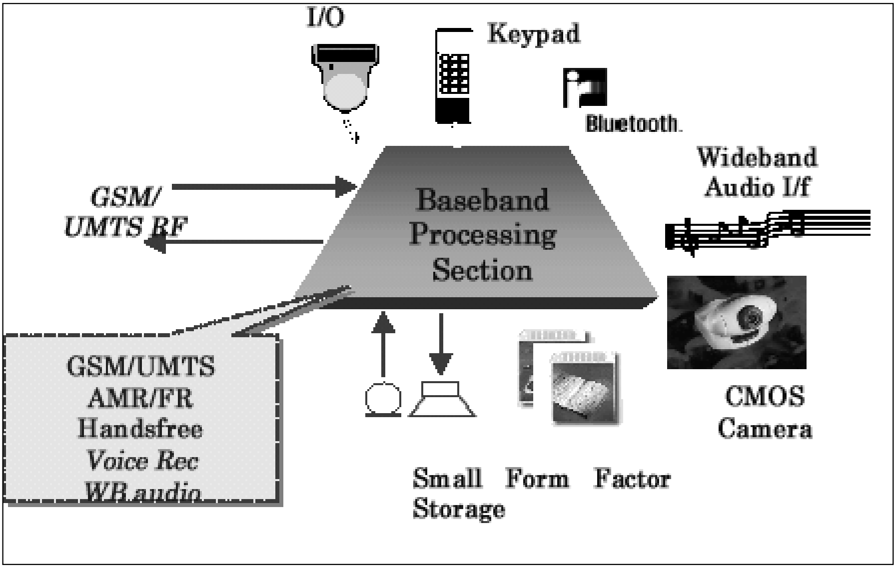
[9] The quoted values should be understood in relation to the comments in the text concerning the split between hardware and firmware. It is important not to misinterpret the number of MIPS presented in the calculation above.

- AGC
- Turbo coding
- Rake correlators and TVI (partly)
- UMTS scheduler
- AMR speech codec
- Video and wideband audio codec
- Voice recognition
- GSM specific blocks (i.e. equaliser, FCB, eFR)
- Functions related to digital rights management (e.g. authentication, key management, encryption and decryption).

The multimedia platform requires a controller architecture open to standard operating systems (e.g. EPOC, RTOS, WinCE) and third party applications and has to offer a standard toolkit, including compilers and debuggers.

Figure 2.8 shows an example of the interface environment of a dedicated UMTS multimedia platform.

Figure 2.8: Interface Environment of a UMTS Multimedia Platform



Source: Infineon, Note: WB audio[10]

[10] WB audio means high quality audio, realising MP3 player functionality with corresponding external components.

Meeting the challenging requirements for saving PCB space, overall system power consumption and bill of materials, a single-chip baseband processing solution seems best-placed to exploit the current possibilities of semiconductor technology. Dual-mode UMTS FDD[11] / GPRS mobile class B, multi-slot class 12 should be addressed with a monolithic IC to embed dual-core (DSP and MCU) along with the following functional blocks (only the most important are listed):

- High performance DSP core
- 32-bit architecture RISC MCU
- On-chip all A/D and D/A converters
- Baseband / RF filtering stages
- RF serial interfaces
- W-CDMA and GSM modem
- All W-CDMA and GSM specific blocks
- Video, wideband audio and analogue voice interfaces
- Video capture unit and interface to a CMOS camera
- USIM, small form factor flash cards and keypad interfaces
- IrDA and Bluetooth interfaces
- 32-bit data bus to the external Flash / RAM.

Emerging UMTS applications and services will require greater MIPS performance. Table 2.3 presents some examples.

Table 2.3: Estimated Processing Power for UMTS Applications

Emerging applications for UMTS	Estimated processing power requirement (MIPS)
Speech recognition	50- 70
Text-to-speech	40- 50
Handwriting recognition	60- 80
VoIP	140-200
Wideband audio	40-100
JPEG	50- 60
MPEG-4	130-160
Java interpretation	200-300
V.90 modem	50- 80

Source: Infineon

[11] TDD should also be considered in the mid to long term.

2.10 Consumption

The increase of processing power required in UMTS together with a more complex RF section to handle both modes will lead to an increase in overall handset power consumption.
Assume the entire RF section includes:

- RF front-end
- GPRS transceiver (or receiver and transmitter)
- W-CDMA transceiver (or receiver and transmitter).

Assume further that the RF section is built upon a direct conversion receiver and direct modulation transmitter and uses chips based on GaAs, HBT, SiGe and BiCMOS technologies. Table 2.4 then gives the estimated RF section power consumption achievable in both the high and low output power states of a dual mode UMTS/GPRS terminal.

Table 2.4: Expected Consumption for UMTS RF Section

	RF FE	RF RX	RF TX
High P_{out}	300mA	50mA	50mA
Low P_{out}	50mA	0	100mA

Source: UMTS Forum

Assume the baseband processing section includes:

- DSP core
- MCU core
- ADCs
- DACs
- GPRS/W-CDMA modem
- GPRS/W-CDMA specific blocks
- SRAM
- Interfaces (as described above).

Assume also that power supply levels will continue to decrease and will reach values of 1.3V down to 0.75V. Table 2.5 then gives the estimated power consumption for the baseband section.

Table 2.5: Estimated Power Consumption for UMTS Baseband Section

MIPS (Dhrystone 2.1)	mW/MIPS
800	0.6
500	0.4
200	0.2

Source: Infineon

2.11 Multimode and Multiband Transceivers

2.11.1 System Partitioning

As there will be many different applications in place for UMTS/3G services, the implementation of associated applications will be handled in early UMTS devices by individual processors as separate functions from the UMTS/3G core functionality. In some regions, UMTS/2G (or 2.5G) implementation will be required as UMTS will have limited coverage at the beginning of service. This requires UMTS and 2G and/or 2.5G multimode architecture on the device platform.

Even when a multimode architecture is integrated, the platform needs to be small in size and cost effective.

Later generations will integrate the RF modem and applications engine to reduce costs further.

2.11.2 UMTS Modem Component Trends

Direct conversion is a method of converting RF signals into baseband signals. The direct conversion architecture requires no IF stage. IF mixers and IF channel selection filters, normally realised using SAW (Surface Acoustic Wave) filters, are no longer needed. So this architecture has significant potential for reducing the total parts count and has been one of the main obstacles in the way of single chip RF architectures.

But there are some issues with the direct conversion technique (Table 2.6). The DC offset voltage caused by leakage current in the local oscillator, as well as other factors, could enter the mixer and be amplified with other signals to degrade both the noise figure and the sensitivity. To resolve the DC offset, a compensation circuit in the RF transceiver with feedback control from the baseband section is required. Such a compensation process would require further processing in the baseband section and would have some impact on processing power.

Nevertheless, direct conversion would be an ideal method for multiband mobile phone design. As has already been seen with the GSM dual-mode phone architecture example, direct conversion could reduce the number of RF components from the usual 150 to around 90, reducing RF circuit cost by about 30% and size by 30% to 50%.

Table 2.6: Comparison between Direct Conversion, Low IF and Super-Heterodyne Methods

Method		Direct Conversion (Zero)	Low IF (and Near Zero IF)	Super-heterodyne
Part count		Low	Good	High
Stability		Slightly inferior	Good	Very good
IF processing	IF frequency	0 (no IF stage)	100 - 150 kHz	100 - 200 MHz (= 1/10th of RF)
	IF mixer	Not needed	Not needed	Needed
	SAW filter	Not needed	Not needed (handling with onchip filter)	Needed
	Channel selection	Lowpass filter	Bandpass filter	Bandpass filter
Issues to be improved		Improving noise characteristics (DC offset removal, LO leakage prevention)	Improving stability (removing image frequency component)	Reducing parts count (increasing integration level)

Source: Nikkei Electronics Asia

2.11.3 Improved Baseband Processors

In 1G and 2G system handsets, DSPs (Digital Signal Processors) are needed only to support a single application, such as the processing of real-time dedicated-channel voice data (an application that is deterministic). There are two primary semiconductor technologies for implementing baseband signal processing

- ASIC (high performance, low initial cost but not changeable once committed to fabrication).
- DSP (software programmable).

However, 3G systems will perform real-time communications and have a number of other uses, including support for non-real-time applications, such as Internet access.

DSPs must support the requirements of both the 3G wireless communications infrastructure (base stations) and terminals (handheld devices). Traditional DSP designs cannot address all the requirements of base-station processing in 3G. Furthermore, future DSPs need to provide support for software-programmable logical and relational operations for any additional non-deterministic functionality. Handsets are expected to be software-upgradable through the network in order to take advantage of service improvements and additional applications that will occur over time. 3G DSP devices must become more than just DSPs. DSPs today are well-suited for processing voice or video traffic. But, when it comes to data, the processing features are weak or non-existent. Efficient data handling means adding 3G wireless applications that need DSPs that will balance the demand for greater processing capability, more features, and lower power consumption.

The need for processing power to handle the rigorous demands of 3G specifications is certainly important. But, that need for processing must be balanced with other requirements as well. For example, an optimal DSP solution for 3G wireless base stations cannot simply offer many billions of operations per second. It should also eliminate many of the costly and power-hungry ASICs and field-programmable gate arrays (FPGAs) required in today's systems. It should allow designers to more easily add next-generation features that make efficient use of available frequencies and higher bit rates in 3G systems.

UMTS requires the use of advanced radio and processing techniques to meet the needs of higher radio frequencies and the higher data rates specified. In order to achieve this high microprocessor speeds will be required of the order of ten times that used currently for GSM.

- UMTS only (GSM 80 MIPS, UMTS *10 [800 MIPS])
- Dual Mode (Hybrid GSM/UMTS at different frequencies)
- Internet / data server requirements.

2.11.4 Higher Levels of Integration

Manufacturers are now moving all of these components onto the boards themselves to achieve major gains in downsizing.

Dual-band mobile telephones have twice as many components in the RF stage than single-band mobile phones. This is because one set is required for each waveband, plus a branching filter to direct the signal from the antenna to the correct circuit. This calls for multi-layer board manufacturing technology and high-frequency circuit design technology. Some suppliers offer multi-layer boards today that are based on their own multi-layer ceramic capacitor manufacturing technology.

They are looking further to integrate passive components, hoping to productise single-module versions of the mobile phone RF stage and Bluetooth interface RF stage.

Equipment manufacturers are now facing the need for an increase in components due to the shift to IMT-2000 systems. There is also a need to halve the RF stage to handle new functional demands such as music distribution. As a result, they have no choice but to accept these RF modules.

This RF transceiver integrated circuit will be built into various portable systems, leaving baseband processing in mobile phones and data communications for the microprocessor or digital signal processor. With a single-chip RF transceiver every piece of portable equipment could contain a "software mobile phone."

Component manufacturers are facing demands for cost reduction of the order of 25% to 30% a year. Many firms in the business agree that cost reduction on this level cannot be achieved through mere fine-tuning; a major change, backed up by major capital investment, is needed.

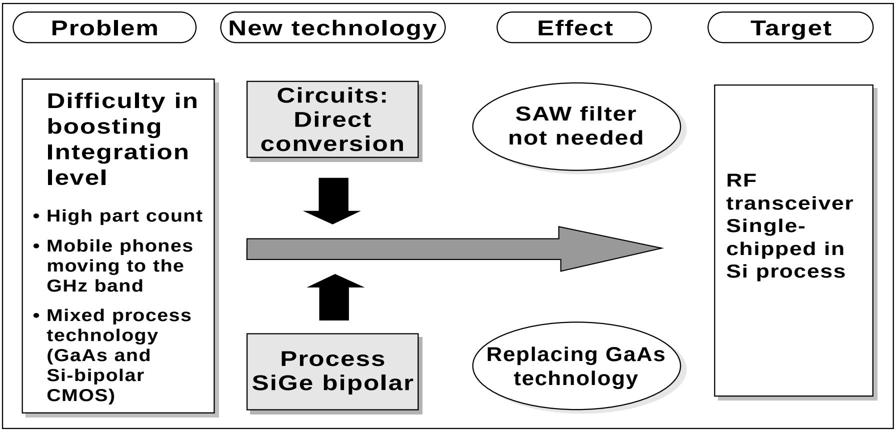
There seems to be two different ideas about what this "major change" will be.

- The first involves SiGe bipolar complementary metal oxide semiconductor (CMOS) technology, a manufacturing process suited to semiconductor devices with high-frequency analogue circuits.
- The second involves the adoption of the Zero IF or direct conversion architectures for enabling major reductions in component counts.

Both approaches are directed at resolving immediate mobile phone problems, but will come into full-scale use in IMT-2000 networks that use the 2.4 GHz band, Bluetooth short-haul wireless data communications technology and 5 GHz high-speed wireless local area networks.

RF circuits in mobile phones have until now, had many parts and this has been a major obstacle to achieving smaller phones. Now, circuits and process technologies have combined to significantly boost the level of integration (Figure 2.9). The circuit technology implements direct conversion, which converts the signal directly from RF to baseband, skipping the IF stage. This means that the SAW filters used in the IF stage can be eliminated, significantly reducing the parts count. In process technology, SiGe bipolar manufacturing is accelerating the single chipping of the low-noise amplifiers and mixers formerly implemented in GaAs. If Si bipolar technology is used for the high-frequency RF components for IMT-2000 in the 2.4 GHz band, they will be unable to meet dissipation or noise specifications.

Figure 2.9: Two Technologies for Single-Chip RF Circuits



Source: UMTS Forum

3 TRENDS IN COMPONENT TECHNOLOGY

3.1 DISPLAY TECHNOLOGY

The display represents perhaps the single most important component of a UMTS device: future mobile communications will be concerned more with viewing a screen than with listening to an ear piece. Users will interact through the display in many different environmental conditions for almost all device applications. They will need to view high information content multimedia as well as the high bandwidth video promised by the UMTS infrastructure.

Display image quality will be top of the agenda for UMTS device design.

The display is also likely to function as an input device through the use of "soft keys". For effective interaction between users and displays, a direct-view display must be as large as possible within the constraints of a portable device.[12] The display's physical characteristics will increasingly dominate handset design. The vast improvements in display performance and functionality compared with current GSM handsets must come with little or no power consumption penalty. This is a key challenge for display manufacturers. Underpinning all of this, component cost will play a significant role.

Table 3.1 summarises the key characteristics of displays for UMTS devices. The data in the right-hand column represent expected specification targets for 2"-3" class displays. These figures should be scaled for larger display sizes.

Table 3.1: UMTS Display Criteria and some Targets for 2"-3" Class Displays

Resolution:	QCIF (e.g. 176 x 3 x 220), moving to portrait QVGA (240 x 3 x 320)
Contrast / Brightness:	Sufficient for indoor and outdoor use (c.f. colour reflective: >20:1 / >30%)[13]
Illumination:	For non-emissive technologies: power target <20mW
Colour:	4-bit RGB for multimedia, moving to 6-bit RGB
Frame rate:	Static image to 15 Hz (MPEG-4), moving to 60 Hz video
Power:	<1mW static image (standby), <20mW video
Interface:	Digital parallel or serial link, becoming standardised
Bezel:	2-6mm, moving to absolute minimum (non-display) area
Thickness:	1.5mm, moving to <1mm
Weight:	~15g moving to <10g

Source: UMTS Forum

[12] Micro-displays have the potential to present a large image to the viewer, but the immersive nature of their use, and the fact that navigation and input cannot easily be combined, limit their applications in UMTS devices. They are not discussed further in this chapter.

[13] Benchmarks for brightness vary considerably; this figure is based on the percentage of collimated white light (incident at 30º to the normal) reflected in the normal direction, compared with that reflected by a Lambertian reflector.

No single display technology can currently satisfy all of the specifications above, though some come close. For this reason, and the fact that display manufacturers sense a huge market potential for mobile devices, research and development of display technology is intense with many companies offering competing technologies. The following subsections review the key contenders for direct-view displays for UMTS devices, and indicate how display R&D will improve this important component in the future.

3.1.1 Passive Matrix Displays

The simplest displays for mobile applications are passive matrix displays. A passive matrix display is an array of pixels, each of which contains an optical element that is sandwiched between column and row electrodes. Passive addressing via the column and row electrodes puts limitations on the achievable display resolution and levels of grey-scale that can be programmed at each pixel.

The most common example of this type of display is the monochrome STN LCD, which happens to be the dominant display for GSM mobile phones and low cost personal digital assistants. In STN Liquid Crystal Displays, the optical element is a Super Twisted Nematic liquid crystal that modulates the transmission of light through polarisers positioned at each side of the liquid crystal cell. STN materials have a sharp transmission-voltage response and a slow switching speed (e.g. >100ms), and as such are well suited to binary (black or white state) passive addressing, although 3-4 bit grey-scale can be achieved. Displays of this type are particularly suitable for text and simple graphics display, and this is sufficient for many of today's low-bandwidth applications. These reflective displays are very low power and are commonly illuminated by a (near white) LED. Given that monochrome STN LCDs have low power consumption and are very cheap to manufacture, it is not difficult to understand their current prevalence.

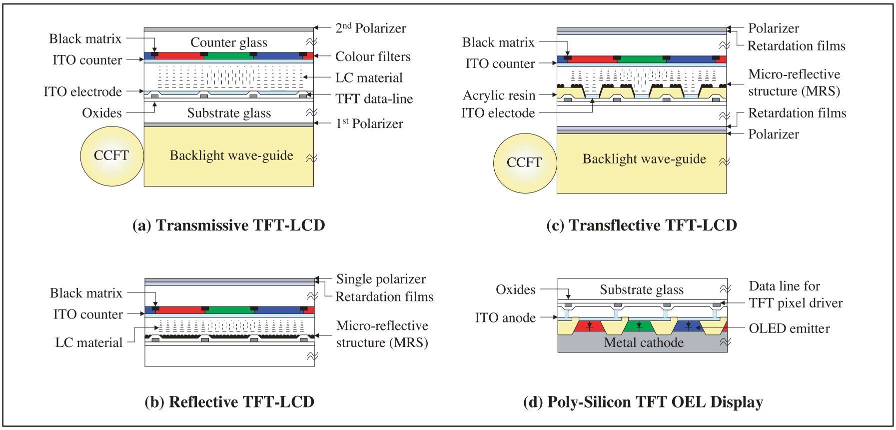
Higher performance colour STN LCDs offer desirable benefits for multimedia applications, though the introduction of colour filters can reduce total display brightness and certainly increases the unit cost. Transflective technology helps ensure that pixels make the most of both ambient light and back-light sources. Although not capable of matching the performance of TFT LCDs, the best CSTNs of today can achieve 65,000 colours for still images and 15 frames per second video at intermediate resolutions. Most European mobile handset manufacturers are expected to launch products with CSTN LCDs towards the end of 2001 or the beginning of 2002. UMTS applications may well require a higher performance display, especially if higher resolution is needed or the terminal combines camera-type functionality. One of the more interesting technological developments is the move to plastic substrates. Plastic STN LCDs offer lighter weight, greater impact resistance and the option to have custom (e.g. non-rectangular) display shapes.

The successful development of organic electroluminescent (OEL) materials has brought the display industry another richly-behaving optical element. These materials emit light in proportion to the current flowing through them, and have the advantages of high brightness and of being very thin: they are already being widely used as monochrome watch backlights. R&D of OEL materials is aimed at achieving a high colour gamut (efficient red, green and blue emitters), longer device lifetimes, and improving mass production techniques. Passive OEL displays suffer the same limitations as STNs in terms of achievable resolution, and a secondary issue is that the matrix power consumption can be high due to the currents flowing in the addressing electrodes. As in liquid crystal technology, many of these problems are solved by active addressing.

3.1.2 Active Matrix Displays

Higher performance displays are composed of active matrix pixels. Each pixel typically includes an optical element and switch. The switch is an active component such as a TFT (thin-film transistor) or, less commonly, a TFD (thin-film diode), and is addressed by column (data) and row (scan) lines. TFTs are normally fabricated from a thin-film of amorphous Silicon (a:Si), though complete construction of the TFT requires the deposition of several additional layers, including the addressing lines. Today, this can be achieved with a minimum of five photolithographic masks, which keeps the cost of active matrix displays competitive. Although more expensive to manufacture than passive displays, the active matrix pixel switch permits a larger total number of pixels in the display, higher resolution, higher contrast and accurate grey-scale pixel programming.

Figure 3.1: Four of the most common Active Matrix Display Cross-Sections



Source: UMTS Forum

The most common active matrix display is the TFT LCD (Figure 3.1a) which, without question, is the colour display of choice for high performance display products such as digital cameras and notebook PCs. In transmissive TFT LCDs, the optical element is usually a Twisted Nematic liquid crystal that modulates the transmission of light supplied by a back-light through orthogonal polarisers positioned at each side of the liquid crystal cell. Twisted Nematic materials have a shallow transmission-voltage response and a fast switching speed (e.g. 25ms), and can therefore achieve 8-bit or higher RGB grey-levels (16 million colours) at 60 Hz updates (i.e. “true colour“ video).

Over the past 10 years, the primary market for TFT LCDs has been notebook PCs and development activities have focused on two main characteristics. Firstly, display size has been extended - a challenge intimately linked with the TFT process yield and large-substrate manufacturing techniques. Secondly, display resolution has consistently improved, such that TFT LCDs can now top 200 ppi. This has involved improvements to the TFTs themselves. Today, the highest performance TFTs involve recrystallisation of deposited a:Si to create Poly-Silicon TFTs. Because the process must take place below the melting point of the glass substrate, the technology is sometimes referred to as low-temperature poly-silicon and the displays as LPS displays. Poly-silicon transistors have over 100 times the performance of standard a:Si TFTs. This impacts heavily on the overall display performance and characteristics, and is discussed further in the display electronics section.

The key technological issue of TFT LCDs that has to be addressed for application to mobile communications products is power consumption. The more common transmissive display requires a high power back-light based on a cold cathode fluorescent lamp (CCFL). In parallel with this, most TFT LCDs are tuned to operate at 60 frames per second in order that no blurring of moving objects (such as mouse pointers) is observed. A TFT LCD display in a notebook PC is the most power-hungry component of the whole device yet UMTS users will demand battery charging requirements similar to their mobile phone handsets.

Several display manufacturers have developed colour Reflective TFT LCDs which do not require a back-light (Figure 3.1b). To maximise the use of ambient light, a single polariser is used, and micro-reflective structures give some optical gain (higher brightness) at the expense of viewing angle. Similarly, careful choice of colour filters can give higher brightness at the expense of contrast ratio. Although these displays appear bright outdoors they can appear dim in indoor environments. A manually controlled front-light may therefore be supplied and activated when used in dark conditions. The power consumption of this type of display is very low, yet a high total number of colours and high refresh rate can be achieved for displaying colour graphics and video, making them very suitable for electronic games, etc.

A closely related type of display is the Transflective TFT LCD (Figure 3.1c). Each display pixel is divided into a transmissive and a reflective portion thereby achieving the best of both worlds

under bright and dark ambient conditions. The back-light power is less than that required for purely transmissive displays and, in contrast to such displays, the image does not get washed out by bright sunlight, etc. This type of display has recently appeared in a popular mobile phone in the Japanese market.

OEL benefits significantly from active matrix addressing, and it has been predicted that Active OEL displays based on poly-silicon TFTs will play an increasingly important role (Figure 3.1d). As previously discussed, OEL brings the advantages of excellent emissive image quality.[14] Given the potentially simpler display assembly and manufacturing steps as compared to liquid crystal technology, high performance poly-silicon TFTs are being considered since more than one of them can be implemented at each pixel to implement a small current-mode driver circuit. This "pixel circuit" is very power efficient and can minimise luminance non-uniformity across the display.

3.1.3 Display Electronics

Some of the key advances in displays for mobile applications are being made within the display drivers. This circuitry takes display image data that is transmitted to the display module and supplies it in the appropriate format to the row and column address lines of the (passive or active) display matrix. Progress is being made on two fronts. Firstly, the ways in which the driver circuits are fabricated and connected to the display matrix are being diversified. This affects display bezel size and module assembly costs. Secondly, improved circuit architectures are being implemented in the drivers in order to achieve higher functionality and lower power consumption.

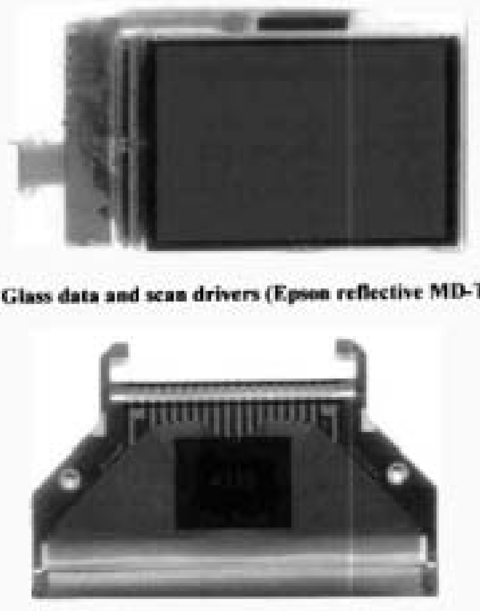
Currently, the majority of row and column driver circuits are fabricated as Silicon ICs. These are attached to the display matrix such that there is one electrical connection between each driver IC output and each row or column signal line. One of the most popular attachment techniques is referred to as Chip On Glass (COG), in which the silicon IC dies are flip-chip bonded directly onto the glass substrate of the display (Figure 3.2a). A disadvantage of this technique is that a 3-5mm substrate overhang (bezel) is required at two edges of the display on which to mount the ICs. This is particularly undesirable for displays mounted in physically narrow mobile phone handsets. A technique that improves upon this is Tape Carrier Package (TCP); here the ICs are mounted on a flexible (plastic) printed connector (FPC) that can be attached to a substrate overhang of about 2.5mm (Figure 3.2b). The FPC is folded behind the display, ensuring that the footprint of the driver IC does not add to the display

[14] Note that, although OEL displays have a higher efficiency than transmissive LCDs, they cannot achieve the low power consumption of a purely reflective LCD.

bezel size. With both COG and TCP, the fine connection pitch (<100µm) of high resolution displays can lead to associated yield and assembly problems which can affect cost.

New circuit techniques that are being introduced in driver ICs involve inclusion of RAM to minimise the need for power-consuming data transmission to the display when the images are static, direct digital interfaces to a standard bus and the introduction of special partial-display update modes.

Figure 3.2: Common Driver Interconnect Strategies



(a) Chip On Glass data and scan drivers (Epson reflective MD-TFD panel)

(a) 250um Tape Carrier Package data driver (From Sharp a:Si TFT-LCD display)

Source: UMTS Forum

One of the main driving forces for developing CMOS Poly-Silicon TFTs has been the fact that both the active matrix and the driver circuits can be fabricated simultaneously. Such “integrated drivers“ can achieve very high resolution as there are no fine-pitch interconnect problems. Far fewer signals are needed to connect to the panel, and the display bezel sizes can be made very small, giving a compact and robust display. In addition, the driver power consumption can be optimised for the display matrix, or include functions fashioned specially to a customer’s specification. Several LCD manufacturers are now mass-producing LPS displays

with integrated drivers, though in many cases the drivers are analogue and require off-panel custom IC support. These displays tend to be small (1.5” - 6”) because this is where the cost benefit of integrated drivers is at its highest (compared with the more conventional a:Si + COG solution).

Process developments are advancing TFT performance still further. This includes the longer-term research effort of developing TFTs on flexible plastic substrates, though performance must improve considerably if anything more than pixel switches are to be integrated. In standard LPS TFTs, excimer laser recrystallisation or rapid thermal annealing of a:Si generates poly-silicon grains with random crystal orientation. State-of-the-art TFT processes now employ catalytic crystallisation in order to achieve poly-silicon with automatically aligned crystal grains (exemplified by Sharp Corporation’s Continuous Grain Silicon, Figure 3.3), which gives much higher TFT mobilities. These strategies, coupled with feature sizes that will move from 4µm to 2µm over the next few years, will allow complex signal processing circuits to be fabricated at the same time as the active matrix. For small displays, these will include standard digital interfacing (digital liquid crystal gamma correction supported within the integrated drivers), and multimode, text, graphics and video capabilities for optimum (application dependent) display power consumption. It is anticipated that these displays, “System LCDs“, will be key for UMTS devices where the infrastructure for many user applications, ranging from low to very high information bandwidth, will be realised.

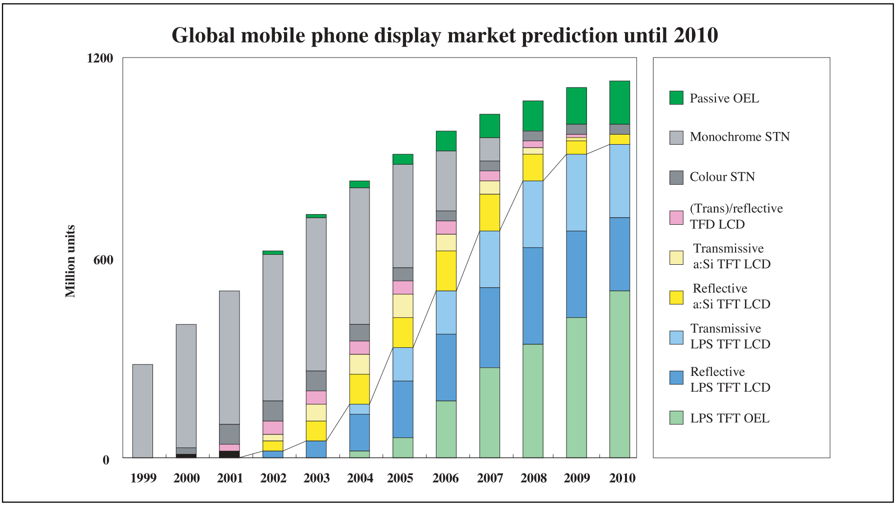
Figure 3.3: QVGA Display with Integrated Digital Drivers
(Sharp reflective CG-Silicon TFT panel)

Source: UMTS Forum

3.1.4 Market Trends and Predictions

Figure 3.4 shows some market predictions for display units for mobile phones over the next ten years. Global UMTS and W-CDMA developments are clearly anticipated in this prediction.

Figure 3.4: Global Mobile Phone Display Market Predictions



Source: Advanced Data Research, Japan (11/09/00)

During 2001, world supply is expected to be approximately 500 million units, with colour STN displays taking a large proportion of total sales since their unit price is significantly higher than monochrome STN displays. Also entering the market are reflective and transflective TFT LCDs. This is mainly accounted for by the Japanese mobile phone industry, currently one of the most advanced in the world with the early introduction of NTT DoCoMo's i-mode and the J-Phone information service. For the year 2001, a staggering 95% of newly manufactured mobile phones will be colour models: CSTN for lower specification handsets, TFT for higher performance handsets. In terms of display performance, European mobile phones are some way behind their Japanese counterparts, but most handset manufacturers are expecting to launch colour models (CSTN) for late 2002 or late 2003. TFT displays are anticipated to follow soon after.

Towards 2005, the dominance of LPS and advanced poly-silicon TFTs is emerging (indicted by the black line in Figure 3.4). This is not surprising given the announcements by several large LCD suppliers of their intention to invest in new LPS mass-production facilities. These include Toshiba, Sanyo, ST-LCD (Sony-Toyoda), and newcomers starting immediately with second

generation technologies such as Sharp, Seiko-Epson and Samsung (amongst others). Certainly for small displays, the advantages of drivers fabricated at the same time are clear to the end user, and from the viewpoint of the display manufacturer, it removes problems of sourcing the driver ICs and obviously speeds up product assembly. The importance of OEL is also illustrated, with a potential 50% of units for mobile communications production being based on OEL by 2010.

In summary, display manufacturers have not been slow to spot the potential that 3G mobile communications will bring, with many gearing up for high volume production of smaller higher performance displays. A range of diverse and competing display technologies will be available for future UMTS products.

3.2 Input Devices

Usability of UMTS devices is a key issue affecting both the implementation of applications and device design. As different applications may require different functionality and features, unification of input methods is an important factor in realising "easy to use" user interfaces. On the other hand, unification of new features could bring complexity to users to understand which input device is doing which function and/or feature.

Such MMI requirements will also change on each UMTS device according to implemented functionality and features. Some UMTS devices will have similar shapes and form factors with input methods and components (keypad and pointing device) similar to current mobile phones. Other smartphone-type UMTS devices may employ touch screens with associated input methods such as pen input and voice recognition.

Devices should not only support the display of character encodings and character sets in supporting internationalised content in local languages, they must also allow for the input of text in those local languages. The support of character encodings that work across multiple languages, such as Unicode and UTF-8, as well as the most popular encoding types in use on the Internet today is vital to the widespread availability of localised and internationalised content and services. Indeed, without that character input capability, the ongoing work on internationalised DNS (iDNS) could essentially make large sections of the Internet inaccessible in various parts of the world due to the imminent inclusion of internationalised domain names into the existing Internet infrastructure.

Internationalisation is required to support the following areas of functionality:

- Generation of text messages and broader text content in messaging;
- Internet Uniform Resource Locators;
- Form-based information entry via web and web-like services;
- Interactive text systems, such as Internet relay chat, web-based discussion services, customer support services, interactive television and instant messaging systems;

- Alphanumeric addressing and dialling;
- Text-to-speech, teletype, and other accessibility features required by those with disabilities.

3.2.1 Keyboards and Keypads

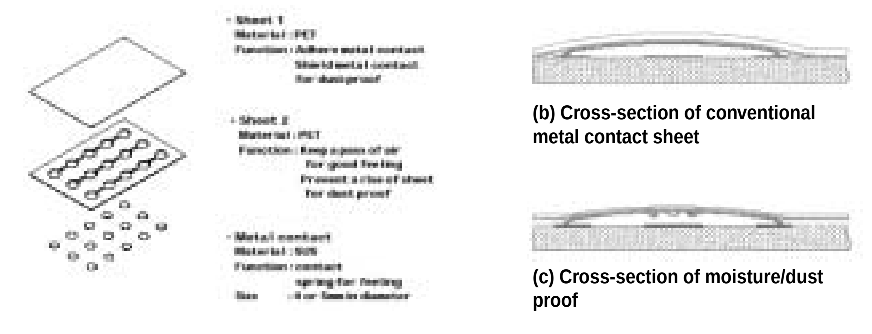
A basic requirement for a mobile phone input device is to employ at least ten keys for activating the phone and the line and for inputting telephone numbers. For this basic feature, most current mobile phones employ between 14 and 17 keys, normally realised using carbon printed or gold flashed substrate combined with a carbon printed rubber sheet, poly-dome sheet or metal contact sheet.

Important factors for such devices on the market today are:

- Cost;
- Feeling (click, or tactile feeling);
- Reliability (contact life cycle, dust and moisture proof).

Reliability is becoming an increasingly important factor as mobile phones change from voice-oriented to games-oriented usage. For i-mode phones in Japan, the minimum life cycle for the key panel has to guarantee at least one million contact cycles. Small form factors as well as the use of hands free kit result in phones being carried in users' pockets for much of the time; sensitivity to moisture from the human body becomes an issue. Figure 3.5 shows an example of a metal contact sheet that addresses such factors.

Figure 3.5: An Example of Moisture and Dust Proof Metal Contact Sheet



(b) Cross-section of conventional metal contact sheet

(c) Cross-section of moisture/dust proof

(a) Configuration of moisture/dust proof metal contact sheet

Source: ALPS Electric Co., Ltd

Even though it is possible to use ten keys for writing emails or inputting characters, this would not be acceptable to users. Other solutions have to be considered. Today, several sub-systems and technologies are already available to support these requirements. Some have already been used in market products. Separate small keyboards are available for current mobile phones and PDAs (Figure 3.6). Pen-input technology (touch screen, track pad and click) or voice recognition technology could also improve usability as alternatives to keypad-based input methods.

Figure 3.6: Examples of Add-On Keyboards for Mobile Phones and PDAs

Source: Ericsson, KDDI, Targus

For UMTS devices, specific services and applications will demand particular components, sub-systems or technologies to realise optimum usability.

3.2.2 Other Keypad Factors

In terms of keypad features, lessons should be drawn from past industry oversights concerning different digits and alphanumeric layouts on device keypads (which eventually led to the ITU E.161 keypad digit and format recommendation). The broader functionality of UMTS devices will, unless studied, create similar and new sets of consistency issues. Related issues include:

- The imminent arrival of instant messaging unification into the mobile market through application gateways (such as the SMS-to-ICQ gateway currently in operation) as well as UMTS-specific services.
- The internationalisation of DNS, requiring that devices have the ability to locate hosts with domain names written in foreign character sets and languages.
- Recent moves towards a text-based telephony addressing system and service.

- M-commerce systems, directory services and portals targeted towards users requiring integration of privacy policy handling and control and management of metadata transferred to and from handsets.

These issues have to be considered in a broader context - the UMTS device market place will be diverse and multi-language where different language glyphs, punctuation, symbols and directions may apply.

ETSI and the ITU have produced various narrow guidelines for conventional basic user requirements.[15] However, convergence and technology advances within UMTS dictate a more thorough study and understanding of inputting requirements.

A basic UMTS keypad and keyboard requirements guideline is desirable to avoid errors and the unwelcome scenario of devices within the UMTS family having differing keypad or keyboard characters and layouts.

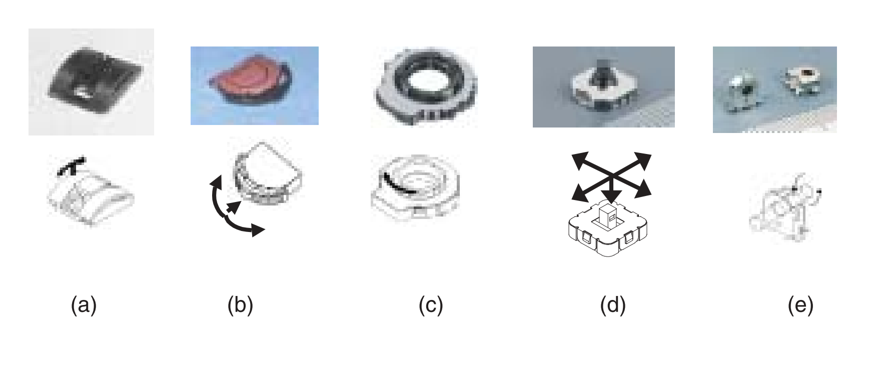
With the trend towards even more innovative device features and designs that go beyond conventional keypads - often incorporating icons, pictograms, and symbols for interaction and inputting instead of keys - there are new sets of usability challenges to be met by the UMTS device sector. Awareness and planning of these matters is vital, at least until work is done to expand the scope of existing recommendations, or more probable, new human factor recommendations from organisations such as ETSI establish clear recommendations that extend to new UMTS devices.

3.2.3 Pointing Devices

Beside keypads, some recent mobile phones employ so-called “pointing devices” that allow the user to scroll the menu or to select a subject on the display. Many different kinds of pointing devices have been implemented onto mobile phones for such usage (Figure 3.7).

[15] These include ETR 345 and ed.2 (Text Telephony), and ITU-T E.161 (Arrangement of Digits).

Figure 3.7: Examples of Pointing Devices[16]



Source : ALPS Electric Co., Ltd

Pointing devices can improve usability for specific applications and functionality. Applications such as mobile gaming will require dedicated pointing devices to satisfy the “easy to play” principle for users.

Development trends for pointing devices focus on further miniaturisation and the ability to deploy re-flow soldering techniques on current devices already employed in consumer electronic products. As UMTS devices will take their product style as a combination of mobile phones and portable electronic devices, suitable candidates for pointing devices might already be available in larger form factors in appropriate portable electronic devices.

3.3 Cameras

According to early UMTS device concepts several devices are going to integrate digital camera capability.

This is already happening in Japan for 2G terminals where a number of manufacturers have developed digital cameras in mobile phones. Some Japanese network operators are expecting still images to be an important component of 3G services. In such circumstances the development of UMTS/3G devices equipped with digital cameras can be expected.

[16] Currently available SMD input devices for mobile phones: (a) top-faced slide switch with centre push; (b) side-faced slide switch with centre push; (c) small rotary encoder (Jog); (d) 4-directional switch with centre push; (e) very small rotary encoder.

Complementary Metal-Oxide Semiconductor (CMOS) image sensors have been highlighted recently as a candidate technology for integrating digital camera capability into mobile phones. CMOS image sensors offer lower power consumption and a much smaller physical integration area than the Charge-Coupled Device (CCD) image sensors which are conventionally used for digital still cameras and camcorders that require high picture quality. For a long time CMOS image sensors have been "a modest product" lagging CCD image sensors as most image sensors were designed for high picture quality products. CMOS image sensors have been accepted only for certain products that focus on low power consumption rather than picture quality.

The mobile phone market requires image sensors with a smaller size and reduced weight. The latest CMOS sensor technology could bring around 110,000-pixel[17] with 1/7" optics, a form factor of <10mm x 10mm x 10mm and low consumption of <100mW. On the other hand, CCD could bring 350,000 ~ 380,000-pixel with 1/6" optics. However, the physical integration area is rather bigger than that for CMOS sensors as CCD requires 3-4 different supply voltages. And power consumption for CCD is still over 200mW.

Following penetration into the mobile phone market, the next opportunity for image sensors would be to satisfy the requirements of the PDA and notebook PC markets. For these market segments, an image sensor that could achieve 640 x 480 dots, or Video Graphics Array (VGA) compliant, picture quality is mostly required. CMOS and CCD image sensors will be competing technologies in this sensor market that needs products with a resolution of VGA-compliant quality. At present, both technologies are neck-to-neck as far as mobile or portable devices equipped with camera modules are concerned and both have shortcomings in their characteristics. CMOS image sensors used in dark environments suffer deterioration in colour production quality and increase of output noise. CCD image sensors offer better quality but rather high power consumption as well as a larger integration area. CMOS image sensors are facing the challenge of improving picture quality along with downsizing whilst CCD image sensors are facing the challenge of reducing their size and power consumption.

For UMTS devices, both technologies have the potential to be employed as key components of digital camera capability. The key issues when implementing such components into UMTS devices will depend heavily on the product concept. Requirements on form factors, power consumption and picture quality for UMTS services and applications would serve as a guide to select the right components for appropriate devices.

3.4 Battery Technology

There are several different types of batteries available in the market. The advantages and disadvantages of the most common types of batteries currently used for mobile phones are summarised in this section.

[17] Most CMOS image sensors developed for mobile phones are based on 352 x 288 pixels, i.e. based on CIF-compliant quality levels.

3.4.1 Primary Batteries (Non-Rechargeable Batteries)

Some mobile phones use this type of battery. The advantage is that the user does not need to charge the mobile phone. However, primary batteries are not environmentally friendly and are an expensive option for long term use. Secondary batteries (rechargeable batteries) are the most sensible solution delivering the best size, weight, talk time and cost ratio today.

3.4.2 Secondary Batteries

Some characteristics of the four main types of secondary batteries considered for mobile phones are summarised in Table 3.2.

Table 3.2: Comparison between Existing Secondary Batteries for Mobile Phones

Ni-Cd	Ni-Cd	Ni-MH	Li-ion	Li-Po
Advantages	Charges very fast Can be cycled 750-1000 times Easiest to recharge after lengthy storage Safest of all battery types to ship or store 30% more effective of all battery types in extreme temperatures	Less affected by memory Over 35% greater power capacity than Ni-Cd No hazardous materials used in manufacture Can be cycled 350-500 times	High energy density Lightweight, almost 50% less than Ni-Cd Self discharge rate extremely low No memory effect	High energy density Lightweight, almost 75% less than Ni-Cd Self discharge rate extremely low No memory effect Possible to make in different shapes (very thin form factor possible)
Disadvantages	Loses around 10% of capacity within the first 24 hours Self discharge rate after the first day is almost 10% per month Memory effect Hazardous material used	Takes twice as long to charge than NiCd Charger may need a temperature sensor for safest recharge Loses about 20% of capacity within the first 24 hours Self discharge rate after the first day is almost 10% per month Memory effect	Takes 8-15 hours to charge Can be charged about 250 times (newer technology getting better results) Very costly (>3times Ni-Mh) Made from hazardous materials Danger of explosion during corrosion when exposed to moisture	Takes 8-15 hours to charge Can be charged about 250 times (newer technology getting better results) Very costly (>3times Ni-Mh)

Source: UMTS Forum

3.4.2.1 Nickel Cadmium (Ni-Cd)

Ni-Cd rechargeable batteries were used in the first generation of mobile phones. Although a robust and cost-effective option, they are no longer used in most current mobile phones. This is due to the major drawback of regularly having to discharge the battery fully before recharging. Failure to do so compromises the ability of the cell to store energy to the battery's specified capacity. This is known as the memory effect.

3.4.2.2 Nickel metal hydride (Ni-MH)

Ni-MH batteries share the same advantages as Ni-Cd in terms of robustness and low cost. However, they can be charged at anytime and have better capacity for a given volume and weight.

3.4.2.3 Lithium-ion (Li-ion)

Although more costly, Li-ion batteries offer excellent value due to their high energy density characteristics. They weigh 50% less, with 20% less volume, whilst giving the same energy density output as Ni-MH batteries. Li-ion batteries can also be charged quickly, taking only 1-2 hours to reach near-optimum charge. Li-ion batteries have a very low self discharge rate.

3.4.2.4 Lithium polymer (Li-Po)

Li-Po batteries are actually Li-ion cells. The difference is that the electrolyte in Li-ion cells is in liquid form whereas Li-Po cells use a polymer plastic (or jelly). This allows greater flexibility in designing Li-Po battery packs to required shapes. Li-Po batteries share nearly the same behaviour and characteristics as Li-ion batteries. However, since it is more difficult for ions to move in polymer than in liquid electrolyte, some Li-Po batteries are known to under-perform, especially in low temperature conditions.

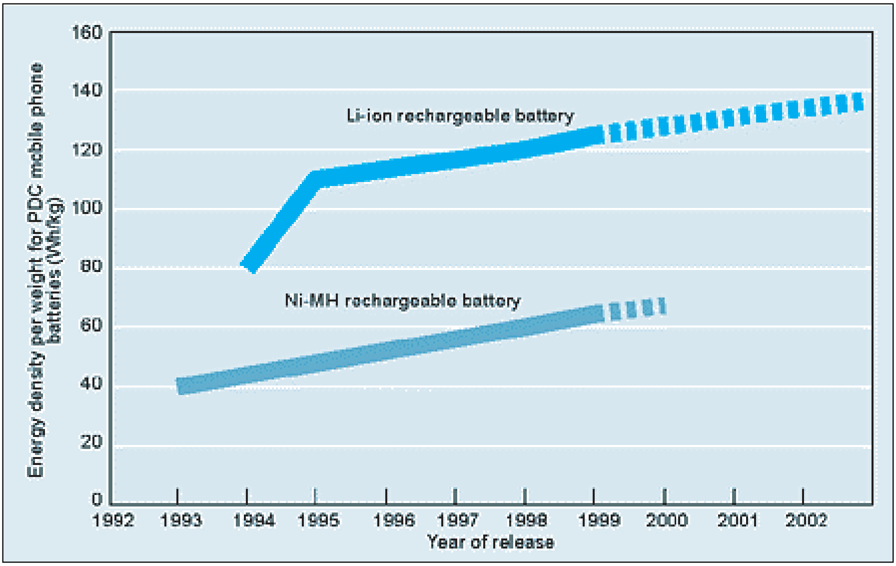
3.4.3 Evolution of Energy Density

Hardware manufacturers and service providers are eager to pile power-sucking features and capabilities into handheld terminals, but battery technology is still limping along. It takes semiconductor manufacturers about 18 months to double the number of transistors on a

piece on silicon and thus give a huge performance boost to the device they run. However, it takes battery manufacturers 5 to 10 years to achieve a comparable increase in power.

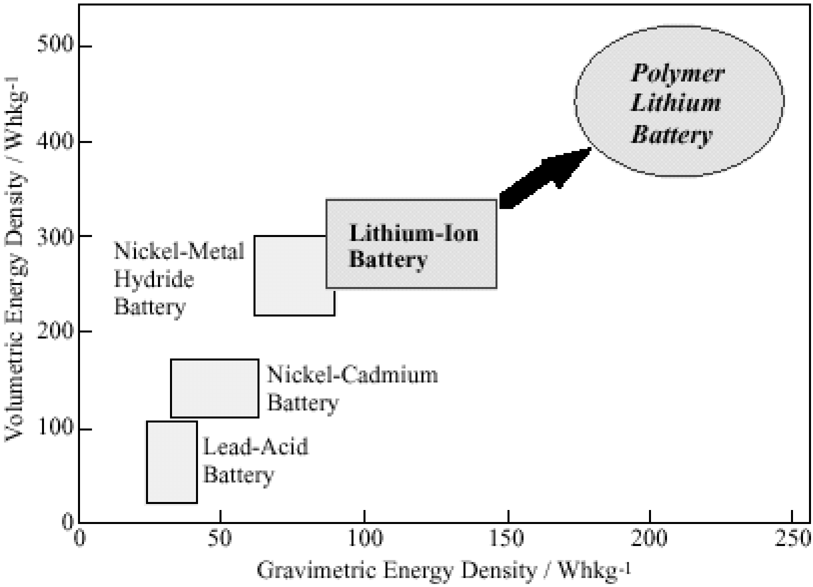
The evolution of energy density to date shows an increase of around 10% to 15% per year if there are no changes in core technology or key battery materials (Figures 3.8 and 3.9).

Figure 3.8: Evolution of Energy Density of Ni-MH and Li-ion Batteries



As of 1999; Source: Nikkei BP

Figure 3.9: Evolution of Energy Density based on Different Battery Technologies



Source: Sanyo

3.4.4 Future Battery Technologies

The high expectation of deploying numerous applications and features on future UMTS/3G devices means that considerably higher energy densities in batteries will be required. But the evolution of energy density is not fast enough to increase battery capacities sufficiently within short time scales. This may limit the number of applications and features on UMTS/3G devices.

Some alternative energy sources such as solar cells or mechanical energy systems could help maintain battery life. But they could not do more than that. Several new battery technologies are under development.

3.4.4.1 Zinc-Oxygen battery

Zinc-Oxygen cells have been developed achieving a volumetric energy density of 860 Wh/l - two to three times more energy density than other batteries currently available on the market.

A Zinc-Oxygen cell is a primary battery and takes oxygen from the air to produce electricity. It is lighter and delivers higher capacity than other batteries. According to one company that has developed a prototype Zinc-Oxygen cell, talk times up to 20 hours could be achievable for mobile phones.

3.4.4.2 Fuel cells

Fuel-cell technology has been investigated intensively by the automotive industry for many years as a future environmentally friendly energy source for cars. Some companies have also investigated the use of fuel cell technology in portable electronic devices including mobile phones. The advantages of fuel cells include an energy density 10 times higher than current Li-ion batteries and the ability to recharge the battery (re-fuel) in just a few seconds.

Some companies have already made prototypes of fuel cell-based batteries for mobile phones using methanol (Figure 3.10).

Figure 3.10: Prototypes of Fuel Cells for Mobile Phones

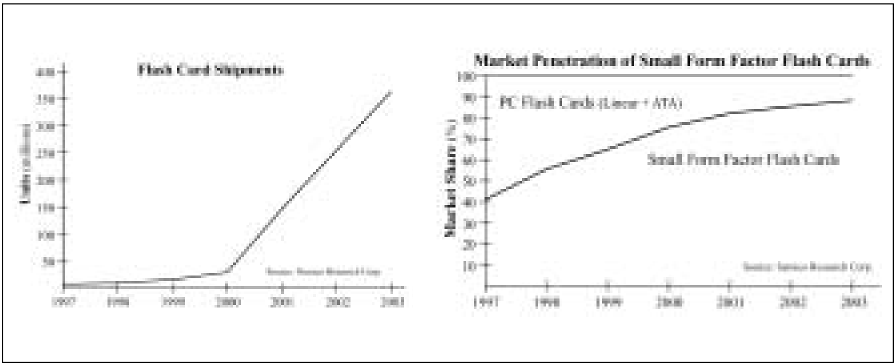
Source: Manhattan Scientifics, Motorola

3.5 Memory Storage Devices

3.5.1 Flash Memory Devices

The trend for electronic devices to migrate from analogue to digital technology has resulted in significant changes in storage devices. The digital camera boom combined with the popularity of silicon-based portable audio players has resulted in the introduction of several different types of small form factor flash cards over the past couple of years. This market is increasing rapidly (Figure 3.11).

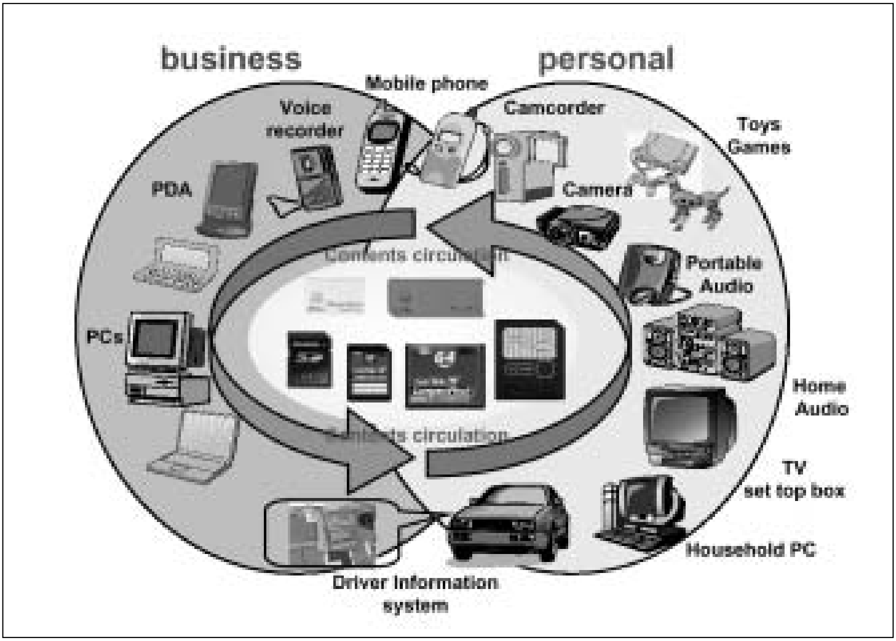
Figure 3.11: Flash Card Market Forecast



Source: Semico Research Corp.

The trend towards the use of flash cards has extended to other electronic devices recently. Users can carry stored data in the card and re-use it on another device whenever they want. Such convenience would further boost the circulation of cards amongst many devices and create new usage models for users (Figure 3.12).

Figure 3.12: Corresponding Devices for Small Form Factor Flash Cards



Source: UMTS Forum ICTG[18]

This trend is also apparent in telecommunications. Some mobile phones have implemented interfaces for small flash cards, mainly for data storage for MP3 players and digital camera features on the phone. UMTS devices will need to implement similar functionality or features associated with small form factor flash card devices, particularly as UMTS/3G terminals will have the capability to handle a higher level of multimedia content than current generation mobile phones.

But at present there are many different incompatible cards. This creates complexity for users attempting to access the same content on different electronic devices with different card interfaces. Standardised physical and electronic features would be beneficial both for users and for the related industries. Table 3.3 presents a comparative summary of current small form factor flash cards.

[18] The UMTS Forum ICTG Group summarised information from the Multimediacard Association (MMCA), SD Card Association (SDCA), CompactFlash Association (CFA), SSFDC (Solid State Floppy Disk Card) Forum and Sony.

Table 3.3: Comparison of Small Form Factor Flash Cards

	CompactFlash Card™	SmartMedia Card™	Multimedia Card™	Secure Multimedia Card	Secure Digital Card™	Memory Stick™	Memory Stick Duo™
Size (mm)	42.8 x 36.4 x 3.3 (x 5.0 type II)	45 x 37 x 0.76	32 x 24 x 1.4	32 x 24 x 1.4	32 x 24 x 1.4	21.5 x 50 x 2.8	20 x 31 x 1.6
Weight (g)	8~15	2	1.5		2	4	2 (4g w/catridge)
Memory capacity (Mbyte)	8, 16, 32, 48, 64, 96, 128, 160, 192	2, 4, 8, 16, 32, 64	4, 8, 16, 32, 64	32, 64	32, 64	4, 8, 16, 32, 64	4, 8
Supply voltage	3.3V / 5V	3.3V / 5V	2.7~3.6V 1.8V*	2.7~3.6V 1.8V*	2.7~3.6V	2.7~3.6V	2.7~3.6V
Current		40mA	27mA	40mA		35mA	
Connector	50 pins, plug and socket	22 pads	7 pads	7 pads	9 pads	10 pins plug and socket	10 pins plug and socket
Connector cost		>$1.0	<$0.50	<$0.50	<$.050	>$1.0	>$1.0
Mating cycles	10,000		10,000	10,000	10,000 (est.)	10,000 (est.)	10,000 (est.)
ESD tolerance	+/- 15kV, body +/- 1.5kV, GND and pins		+/- 4kV contact pads; +/- 8/15kV, non contact pads area	+/- 4kV contact pads; +/- 8/15kV, non contact pads area	+/- 10kV contacts; +/- 15kV, air discharge		
Interface	ATA, true IDE (parallel); controller is built in; read is 1~2 Mbit/s; write is 150k~2 Mbit/s	Smart Media (parallel); does not contain a controller; data transfers at up to 1.7 Mbit/s	MMC or SPI (serial); controller is built in; read speed is 14 Mbit/s; write speed is 3 Mbit/s	MMC or SPI (serial); controller is built in; read speed is 14 Mbit/s; write speed is 3 Mbit/s	SD (MMC compatible, serial); controller is built in; data transfers at up to 2 Mbit/s	MS (serial); controller is built in; read speed is 2.45 Mbit/s; write speed is 1.5 Mbit/s	MS (serial); controller is built in; read speed is 2.45 Mbit/s; write speed is 1.5 Mbit/s
Unique ID	Yes, compliant to SDMI 1.0	Yes, compliant to SDMI 1.0	RAM version: Yes, compliant to SDMI 1.0 ROM version: No	Yes, compliant to SDMI 1.0	Yes, compliant to SDMI 1.0	Yes, compliant to SDMI 1.0	Yes, compliant to SDMI 1.0
Roadmap (byte)	Type I: 192M Type II: 448M	2001: 128M	2001: 128M 256M	2001: 128M	2001: 128M 2001~2: 256M 2002: 512M 2003: 1G	2001: 128M 2002: 256M, 512M 2003: 1G	2001: 32M, 64M 2002: 128M 2003: 256M
Compatibility		Mixed	Forward/ Backward	Forward/ Backward		Forward/ Backward	Forward/ Backward
ROM version		No	Yes		No	No	No

Source: Hitachi, CFA, SSFDC, MMCA, Sony

Some of the memory devices shown in Table 3.3 can be uniquely identified. Such identification is required by most digital rights management systems. The Secure Digital Music Initiative (SDMI) also requires the existence of unique and tamperproof ID for compliance with its SDMI Specification 1.0 Part 1. Hence, all UMTS applications that are to deal with "rich" content will also require such a unique ID. This ID can, however, be embedded into the memory card, the device itself or the SIM Card.

Memory devices are also going to have other enhancements. Several manufacturers have already announced specific functional modules based on each card specification such as a GPS card module, TV tuner module, Bluetooth™ module, digital camera module and fingerprint recognition module.

These enhancements will create new uses and applications for the user and could also be implemented on UMTS devices as one of the product concepts. Potentially, some UMTS applications could be realised through such modules without integrating corresponding hardware onto the terminal. Figure 3.13 shows some examples of enhanced modules for the Memory Stick™.

Figure 3.13: Examples of Memory Stick™ Expansion Modules (prototypes)[19]

Source: Sony

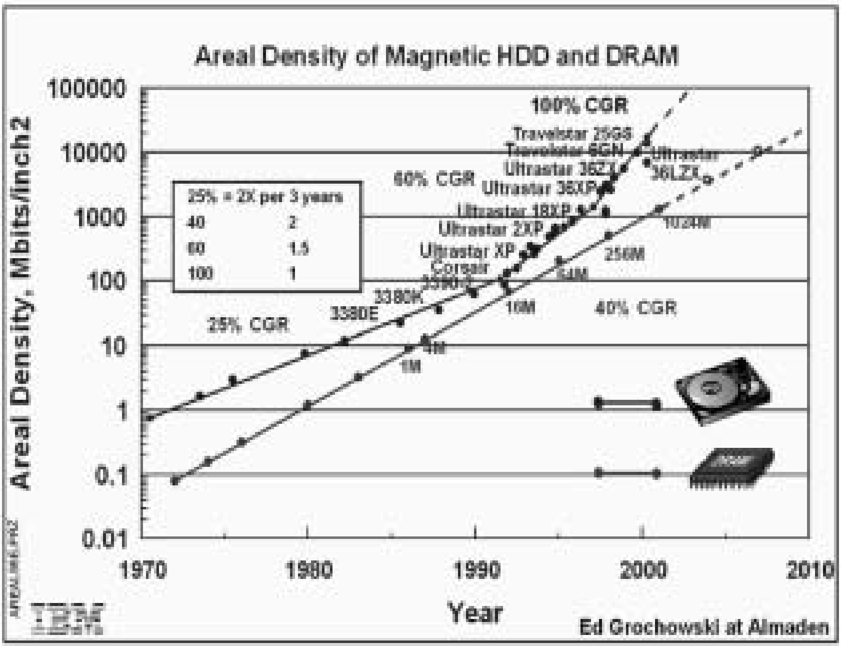
[19] From the left: GPS module, Camera module, Bluetooth™ module (upper), and Fingerprint Recognition module (lower).

3.5.2 Hard Disk Devices

Along with the introduction of small form factor flash cards, several manufacturers have developed similar data storage card products based on Hard Disk Drive (HDD) technology.

One of the big advantages of HDD cards is their extremely high data storage capacity compared with other card storage devices. The trend to increased capacity is boosted by the PC industry and supported by technology innovations for each associated HDD element. At the end of 2000, the recording density of HDD had achieved 20 Gbit/in^2 in commercial use and over 60 Gbit/in^2 in some advanced research programmes. Today, the areal recording density is increasing by 100% annually (Figure 3.14).

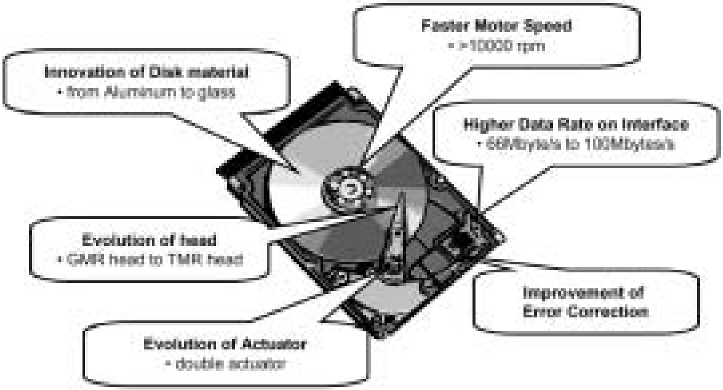
Figure 3.14: Evolution of HDD Areal Recording Density



Source: IBM

According to the latest information, 100 Gbit/in^2 could be realistic by 2002-2003 and 500 Gbit/in^2 is targeted for 2005 by some advanced research organisations in Japan.[20] Figure 3.15 shows the various elements that will contribute to the achievement of an HDD areal recording density of 100 Gbit/in^2.

Figure 3.15: Elements that support 100 Gbit/in^2 Areal Recording Density[21]



Source: Nikkei Sangyo Shinbun, February 2000

Following these trends, HDD will be implemented as a main data storage device in digital consumer electronic products such as set top boxes and VCR or TV systems for digital broadcasting.

The technology evolution of hard disk devices also raises the prospect of small size HDD cards for portable electronic devices. An HDD card product already exists today with 1 Gbyte data capacity and the same form factor as the CompactFlash™ card (Figure 3.16).

[20] ASET (Association of Super-Advanced Electronics Technologies, www.aset.or.jp) has set a new target for HDD areal recording density of 500 Gbit/square inch by 2005.

[21] GMR: Giant MagnetoResistive, TMR: Tunneling MagnetoResistive.

Figure 3.16: An Example of a Small Size HDD Card

Source: IBM[22]

Such small size HDD cards could be an alternative memory storage device for UMTS devices particularly for digital broadcasting services and applications.

However, as HDD cards have a higher power consumption than flash based memory card devices, the total operating time of the UMTS device would be decreased. The power consumption issue needs to be thoroughly investigated before implementing such technology in UMTS devices as the main data storage mechanism.[23]

3.5.3 Other Memory Storage Devices

Besides the storage devices already mentioned, magnetic tape and optical storage could be alternatives for data storage in UMTS devices. Based on current trends for electronic devices on the market, the use of magnetic tape as a conventional storage device is being replaced by other solutions such as flash based memory storage, magnetic disk or optical storage.

Many optical storage devices are used today for music and video content in the consumer electronics industry and for data storage in the PC industry. Table 3.4 shows currently available optical storage technologies.

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[22] IBM's microdrive™ provides 1 Gbyte memory capacity on a 1 inch disk.

[23] Power consumption of microdrive™ is about 300mA in operation and 40mA in standby.

Table 3.4: Comparison of Currently Available Optical Storage Technologies

		Read-Only		Write Once		ReWritable			
Media		CD-ROM	DVD-ROM	CD-R	DVD-R	CD-RW	DVD-RAM	DVD+RW	DVD-R/W
Capacity									
Size of media		650MB	4.7GB (~17GB)[24]	650MB (2GB)[25]	3.9GB (4.7GB)	535MB[26] 650MB (2GB)[25]	2.6GB & 5.2GB (4.7GB)	3GB & 6GB	3.95GB (4.7GB)
Main purpose		Read data, audio and multi-media content	Read data, audio and high-end multi-media content	Data and audio recording, pre-mastering, archiving, software distribution	Data, audio and video recording, pre-mastering, data archiving	Remov-able mass storage, file sharing, backups	High-volume removable mass storage and daily backups	High-volume removable mass storage and daily backups	Content creation for DVD-ROM and DVD-Video drivers
Compatibility									
Drive	CD-ROM	Read		Read		Read[27]			
Drive	CD-RW	Read		Read/ Write		Read/ Write			
Drive	DVD-ROM	Read	Read	Read[28]	Read	Read	Read[28]	Read[29]	Read
Drive	DVD-RAM	Read	Read	Read	Read	Read	Read/ Write		Read
Drive	DVD+RW	Read	Read	Read	Read	Read		Read/ Write	Read
Drive	DVD-R/W		Read		Read				Read/ Write

Source: UMTS Forum

These optical data storage technologies could be employed for extended data storage in UMTS devices if the following issues can be resolved:

- Most UMTS applications will require re-writable capability or write-once with high data capacity;
- The need to employ a read / write drive mechanism in the UMTS device. Impacts on space and power consumption must be considered;
- The need for small size media with reasonable data capacity.

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24 Capacity depends on DVD media format. Single Side Single Layer format allows 4.7GB capacity and Double Side Double Layer format allows 17GB capacity.

25 Based on ML (MultiLevel) recording technology.

26 535MB in UDF format and 650MB in ISO-9660 format.

27 Requires CD-ROM drive to be multiRead. UDF reader software is also required in order to read UDF-formatted media.

28 First generation DVD-ROM drives could not read CD-R and DVD-RAM discs.

29 Requires minor modifications.

Some optical data storage devices intended for use in portable or mobile devices are already available. Such devices have already realised 500 Mbytes data capacity based on a write-once format with almost the same form factor as existing small form factor flash cards.

With further technology evolution such as the deployment of ML (Multilevel) recording technology, the eventual recording capacity of such small size optical discs is expected to be more than five times higher than current DVD discs. Such technology evolution may support new uses and applications for portable devices, including UMTS devices.

3.6 Smart Card Technology

Smart cards play an increasing role as "active" security devices. Due to its microcomputer and programmable memory, a smart card can cater for the specific needs of the environment it is used in. Smart cards allow the secure handling and storage of sensitive data such as user privileges and cryptographic keys as well as the execution of cryptographic algorithms. They are secure tokens by means of which a user can be identified and authenticate a computer system or communication network and *vice versa*. The performance of a smart card depends to a large extent on the chip and the protocol run between the card and the interface device.

GSM is known to be the most successful application of smart card technology, using the SIM (Subscriber Identity Module) card as an intelligent authentication token for GSM networks. The use of a removable IC card designed as a true multi-application card and a corresponding USIM (Universal Subscriber Identity Module) application carrying the subscription was introduced in UMTS. This new type of card deserves a closer look.

Microprocessor chips used in smart cards consist of a CPU and three types of memory. The masked programmed ROM (Read Only Memory) usually contains the operating system of the card, the code for the USIM application, the various security algorithms and other general purpose code. The RAM (Random Access Memory) is used for the execution of the algorithms and as a buffer for the transmission of data. Subscription (or USIM) specific data (such as the authentication key K and IMSI), network and subscriber related information (such as abbreviated dialling numbers and short messages which are updated frequently or have to be changeable by the subscriber), and USIM Application Toolkit (USAT) applications are stored in non-volatile erasable memory.[30] Today's chips offer in excess of 100 kbyte of ROM, 64 kbyte (soon 128 kbyte) of programmable memory (EEPROM), up to 8 kbyte of RAM

[30] Usually EEPROM, Electrically Erasable Read Only Memory.

and extra hardware for the execution of public key algorithms. This makes the implementation of Public Key solutions for mobile commerce a reality.

Like the other components of UMTS networks the USIM is standardised by the Third Generation Partnership Project (3GPP). Table 3.5 provides an overview of the standards relevant for the USIM.

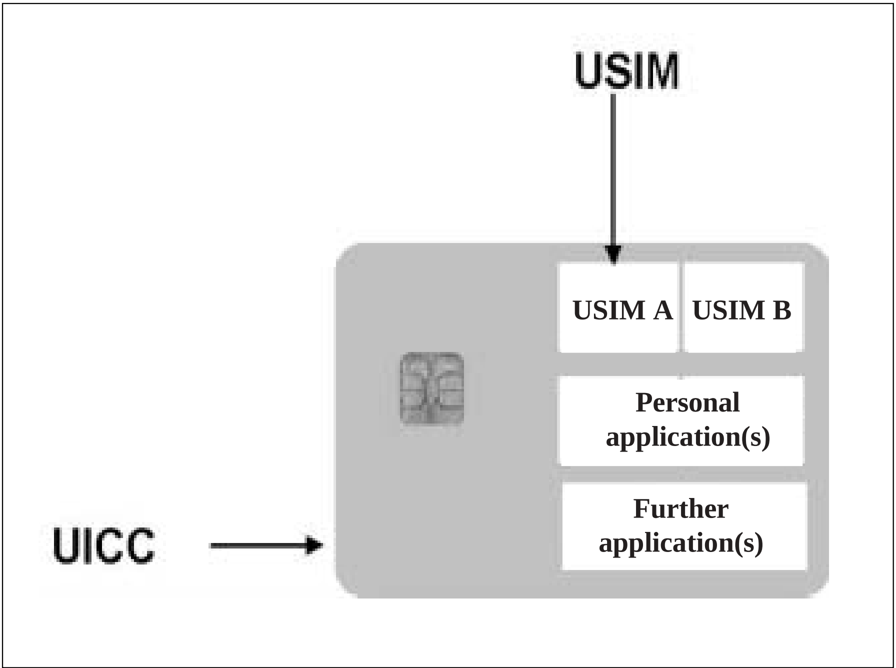
Table 3.5: Overview of Relevant USIM Standards

Specification	Description
TS 31.101/ ETSI TS 102 221	UICC-Terminal interface; Physical and logical characteristics
TS 31.102	Characteristics of the USIM Application
TS 31.111	USIM Application Toolkit (USAT) (the 3G version of the SIM Application Toolkit specified in GSM 11.14)
TS 33.102	3G Security; Security Architecture
TS 23.048 (formerly GSM 03.48)	(U)SIM toolkit secure messaging (stage 2)
TS 51.011 (formerly GSM 11.11)	Digital cellular telecommunications system (Phase 2+); Specification of the Subscriber Identity Module - Mobile Equipment (SIM - ME) Interface

Source: UMTS Forum

The really new and exciting feature of the USIM is that it breaks with the traditional notion that “SIM card equals GSM application”. The Universal SIM Card (UICC) forms the physical and logical platform on which the independent applications reside (Figure 3.17). The UICC is specified so that it can contain one or more USIM applications, as well as other applications (e.g. GSM application, payment applications). A combination card usually refers to a UICC comprising a USIM application and a GSM application.

Figure 3.17: Example of the UICC



Source: UMTS Forum

The core functionality of the USIM is the authentication of the subscriber to the 3G network and, an addition to the SIM's role in GSM, the authentication of the network to the subscriber. To achieve this task, the USIM carries the subscriber data as well as the operator specific keys and security functions. Depending on the respective situation, this is performed in a UMTS environment through the available 3G authentication parameters and in a GSM context through the available GSM security parameters. The USIM therefore enables a smooth migration to UMTS, supporting access to GSM as well as UMTS services. In order to establish the so-called Authentication and Key Agreement the network sends out the user authentication request RAND AUTN with AUTN containing the SQN, AMF and MAC. The USIM calls the security functions and uses the secret key K which is shared between the USIM and the AuC (Authentication Centre) in order to verify the AUTN and to compute the signed response RES and the CK and IK. Then the USIM sends back the user authentication response RES to the network, where it is verified against the XRES computed by the network. This mechanism achieves mutual authentication by the user and the network. In addition the USIM and the network keep track of the sequence numbers SQN to support mutual authentication.

Another interesting feature introduced by this new generation of cards is powerful phonebook functionality allowing a huge number of data entries and the storage of second names, email addresses, fax numbers, etc. The USIM also supports the development and deployment of USIM Application Toolkit (USAT) applications. USAT is the adapted “SIM Application Toolkit” (SAT), well-known from GSM, for operation in UMTS networks. USAT provides a set of commands and procedures that allow applications in the UICC to proactively interact and operate with any mobile phone that supports the specification. User specific applications can be developed, downloaded and stored on the USIM.

Being a multi-application card, the potential of the UICC goes far beyond network authentication. Capitalising on the USIM’s cryptographic power combined with encryption functionalities it can be used for authentication by an entire cocktail of m-commerce applications. USIM authentication establishes the billing relationship not only to the UMTS operator but also to a third party service provider. In this way the world of mobile multimedia is truly brought to the fingertips of the subscriber.

The UICC has been designed as a multi-application platform to support *independent* applications. Whereas in GSM a banking application, for instance, is always part of the GSM application – it uses the GSM mechanisms such as SMS – it may be completely independent in 3G. This application could also run when there is no link to a 3G network. For instance, an electronic purse could be used in a supermarket for payment purposes deploying directly the infrared or Bluetooth interface of the handset. It could even run *in parallel to and independent* of a USIM application. This is now possible by the use of logical channels that allow up to four independent applications to run in parallel on the UICC.

3.6.1 Operating System Independent Programming Language

USIM applications should be developed by an operating system programming or scripting independent language such as Java[31] or MULTOS Python. The key objective of such languages is interoperability: “write once – run everywhere”. An application has to be written only once and can, in theory, be executed on every platform that is compliant to the standards. For instance, the Java virtual machine (JVM) always looks the same to applications and is independent of the underlying chip platform, even if the cards are from different card manufacturers. Processes to achieve this objective are now in place in various committees and industry groups.

The improved post-issuance functionality extension is another benefit for a language like Java for smart cards as the software to be downloaded is, in the case of interoperability, the

[31] Java is a registered trademark of Sun Microsystems.

same for all smart cards in the field. Applets can be downloaded onto the cards over the air even if the cards are already in the field. Applets can also be updated and deleted over the air.

The integrated security concept allows multiple applets to exist on one card at the same time without affecting each other. A firewall protects the applications from each other. There is no possibility for an applet to inspect data from other applets or from the card that are not publicly available.

3.6.2 Java-Enabled Cards

The key feature of Java cards is their ability to manage the downloading of applications.
A typical example for a future Java card application would be a traveller who downloads a public transport ticket for Hong Kong while they are still in New York. By using the Java card the ticket downloaded (and, of course, paid for) through the Internet can then be read off-line by the access control gate in Hong Kong.

Some Java card platforms could offer a computing power of 30 to 40 MIPS, which is about the performance of a 486 processor incorporated on less than 16 square mm. In terms of design-ins Java offers the highest flexibility because it is able to handle more software, more applications and of course, multiple services. Maybe the biggest advantage of Java smart cards is the fact that every engineer with a Java system is able to develop applications for Java that can be used worldwide. Java controller will be a 32-bit version capable of implementation on smart cards that includes a memory-management unit for partitioning applications to enable separate processing of individual applications.

A fingerprint sensor, which makes the entering of a PIN code obsolete, or a small foil keypad can then be integrated into the card.

4 ABBREVIATIONS AND GLOSSARY

2G	Second Generation	Generic name for second generation networks, for example GSM.
2G+ or 2.5G	Second Generation Enhanced	Name given to 2G networks enhanced with GPRS or EDGE.
3G	Third Generation	Generic name for third generation networks, for example UMTS.
3GPP	Third Generation Partnership Project	A co-operation between regional standards bodies to ensure global interworking. www.3gpp.org
A/D or ADC	Analogue-Digital Converter	A functional block or circuit section to convert analogue signal to digital signal.
AFC	Automatic Frequency Control	Automatic Font Change + Automatic Frequency Control
AGC	Automatic Gain Control	A circuit designed to boost the amplitude of a signal to provide adequate levels.
AMF	Authentication Management Field	
AMR	Audio / Modem Riser	A specification developed by Intel for packaging the analogue I/O audio functions of modem circuitry together with a codec chip (which converts back and forth from analogue to digital) on a small board that plugs directly into a computer's motherboard.
API	Application Program Interface	An API (sometimes called 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.
Applet		An applet is a program that runs inside another application such as a web browser. The program starts when the page within which it is contained is downloaded. Applets are often used to create features including news bars (tickers) or more sophisticated interfaces than those supported by the HTML standard. Java is an example of a coding language in which applets can be created.
Areal density		The areal density of a disk drive is the number of bits that can be stored per square inch or centimetre. As areal density is increased, the number of tracks per inch and the number of bits per inch stored on each track also increase.
a:Si	Amorphous Silicon	A thin-film of Silicon used to produce TFT Displays.
ASIC	Application Specific Integrated Circuit	An ASIC is a chip designed for a special application, such as a particular kind of transmission protocol or a handheld computer.
ATA		This is the "official" name that American National Standards Institute group X3T10 uses for what the computer industry calls Integrated Drive Electronics.

AuC	Authentication Centre	
AUTN	Authentication Token	
BGA	Ball Grid Array	A type of semiconductor package.
BiCMOS	Bipolar Complementary Metal-Oxide Semiconductor	
Bluetooth™	Wireless standard	Short-range radio link standard. Uses unlicensed spectrum @ 2.45 GHz to provide 1 Mbit/s.
CCD	Charge-Coupled Device	A light-sensitive integrated circuit that stores and displays the data for an image in such a way that each pixel (picture element) in the image is converted into an electrical charge the intensity of which is related to a colour in the colour spectrum.
CCFL	Cold Cathode Fluorescent Lamp	
CD	Compact Disc	Initially used to store music, now used for data and increasingly movies.
CD-R	Compact Disc - Recordable	
CD-ROM	Compact Disc - Read Only Memory	
CD-RW	Compact Disc - Read/write Memory	
CFA	CompactFlash Association	CompactFlash is a silicon-based small form factor data storage.
CG-Silicon	Continuous Grain Silicon	
CIF	Common source Intermediate Format	Video resolution of 352 x 288.
CK	Ciphering Key	
CMOS	Complementary Metal-Oxide Semiconductor	
COG	Chip On Glass	
CPU	Central Processing Unit	The central part of a computer system that performs operations on data. In a personal computer the CPU is typically a single microprocessor integrated circuit.
CSP	Chip Sized Package or Chip Scale Package	A type of semiconductor package.
CSTN	Colour Super Twisted Nematic	See STN.
D/A or DAC	Digital-Analogue converter	A functional block or circuit section to convert digital signal to analogue signal.
DAB	Digital Audio Broadcasting	A digital radio technology used for radio broadcasting in a number of countries.
DC	Direct Current	
DCA	Direct Chip Attached	
DECT	Digital Enhanced Cordless Telecommunications	A wireless technology used for short range communications, for example cordless telephones.
Dhrystone 2.1		A benchmark to measure performance of computer or microprocessor in MIPS.
DIP	Dual In-line Package	A type of semiconductor package.
DNS	Domain Name System	
DRAM	Dynamic Random Access Memory	

DRM	Digital Rights Management	DRM is a type of server software developed to enable secure distribution - and perhaps more importantly, to disable illegal distribution - of paid content over the web. DRM technologies are being developed as a means of protection against the online piracy of commercially marketed material, which has proliferated through the widespread use of peer-to-peer file exchange programs.
DSP	Digital Signal Processing	DSP refers to various techniques for improving the accuracy and reliability of digital communications. Basically, DSP works by clarifying, or standardising, 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.
DVB	Digital Video Broadcasting	A digital radio technology used for television broadcasting in a number of countries.
DVD	Digital Video Disc	An acronym that officially stands for nothing, but is often expanded as Digital Video Disc or Digital Versatile Disc. The audio / video / data storage system based on 12- and 8-cm optical discs.
DVD-R	Digital Video Disc - Recordable	
DVD-RAM	Digital Video Disc - Random Access removable storage Media	A data storage device for which the order of access to different locations does not affect the speed of access. This is in contrast to, say, a magnetic disk, magnetic tape or a mercury delay line where it is very much quicker to access data sequentially because accessing a non-sequential location requires physical movement of the storage medium rather than just electronic switching.
DVD-ROM	Digital Video Disc - Read Only Memory	
DVD-R/W	Digital Video Disk - Read or Write Memory	
DVD+RW	Digital Video Disc - ReWritable	
DxB	Digital Audio Broadcasting and Digital Video Broadcasting	
E.161	ITU-T Recommendation E.161	The E.161 recommendation specifies the current arrangement of letters and symbols on the conventional telephone keypad. It defines the standard 10 and 12 button layout and the location of the 10 numbers and the * and #. It also specifies the association of letters to numbers, and defines a tactile identifier on button “5” to assist the blind.

E.161		Adoption of this standard is now almost universal. However, until recently, confusion over differing device keypad layouts resulted in problems such as inaccurate alphanumeric dialling by users. With the advance of new UMTS devices that have different types of keypads and keyboards, positive lessons can be drawn from the reasoning and success of E.161. These lessons could possibly be used in any study of recommendations of keyboard arrangement of digits, letters, symbols, and other elements on UMTS devices to ensure that there is keypad / keyboard consistency and uniformity to assist developers, as well as end users.
EDGE	Enhanced Data rates for Global Evolution	A further enhancement to TDMA systems that allows for data speeds to 384 kbit/s.
EEPROM	Electrically Erasable Programmable Read-Only Memory	EEPROM is programmable read-only memory that can be erased and re-used.
eFR	enhanced Full Rate	
EPOC		An operating system designed for small, portable computer-telephones with wireless access to phone and other information services.
ESD	Electronic Software Distribution + Electrostatic Discharge	
ETR 345	ETSI Technical Report 345	To maximise device usability, and meet regulatory demands, consideration of an increasing range of device design factors is becoming necessary. This is particularly so in relation to the elderly and the disabled. The current benchmark device recommendation is ETR 345. This covers a series of human factor recommendations focused specifically towards the disabled and elderly. ETR 345 design recommendations include: * Keypad characteristics and components: such as size, spacing, shape, and separation of key groups. * Visual aspects: such as the visual contrast between characters and keys. * Textural and tactile considerations: how the blind or visually impaired can identify and use characters. * Keypad layouts: primarily in alignment with current ITU-E.161 recommendations.
ETSI	European Telecommunications Standards Institute	The standards body for Europe. www.etsi.org
FCA	Flip Chip Array	A type of semiconductor package.
FCB	Frequency Correction Burst	
FDD	Frequency Division Duplex	One technique used for wireless communication where the up link and down link are of different frequencies.
FE	Front-End	

Flash	Flash Memory	A type of constantly-powered non-volatile memory that can be erased and reprogrammed in units of memory called blocks.
FPBGA or FBGA	Fine Pitch Ball Grid Array	A type of semiconductor package.
FPC	Flexible (Plastic) Printed Connector	
FW	Firmware	Firmware is programming that is inserted into programmable read-only memory.
GaAs	Gallium Arsenide	
GMR	Giant MagnetoResistive	A technology for HDD magnetic head.
GND	Ground	An electrically neutral circuit having the same potential as the surrounding earth. Normally, a non-current carrying circuit intended for safety purposes. A reference point for an electrical system.
GPRS	General Packet Radio Service	Technique used to upgrade current TDMA networks. Allows a subscriber to gain up to eight 14.4 kbit/s channels. Also introduces packet switching.
GPS	Global Positioning System	A satellite-based positioning system.
GSM	Global System for Mobile communications	The most popular standard for 2G mobile networks.
HBT	Heterojunction Bipolar Transistor	
HDD	Hard Disk Drive	A mechanism that controls the positioning, reading, and writing of the hard disk.
HiperLAN		An ETSI standard that operates at up to 54 Mbit/s in the 5 GHz RF band. HiperLAN2 is compatible with 3G WLAN systems for sending and receiving data, images, and voice communications.
HTTP	http (Hypertext Transfer Protocol)	As in http://www.yoursite.co.nz. This is the system by which a webpage is downloaded by your browser. Related terms: html.
HW	Hardware	Hardware is the physical aspect of computers, telecommunications, and other information technology devices.
IC	Input Circuit + Integrated Circuit + Interrupt Controller	
ICQ Gateway		ICQ is currently the most popular Instant Messaging (IM) protocol in use today. An ICQ Gateway is an application that translates events in the gated protocol or system into or out of the ICQ system.
ICTG	Information and Communication Technologies Group	A working group of the UMTS Forum.
ID	Identity	
IDE	Integrated Drive Electronics	IDE is a standard electronic interface used between a computer motherboard's data paths or bus and the computer's disk storage devices.

iDNS	internationalised DNS (Domain Name System) server	A domain name system server resolves a domain name i.e. www.motive.co.nz to an internet protocol (IP) address - 216.71.203.42. You can access a site by typing either into your browser address bar.
IEC	International Electrotechnical Commission	
IEEE 802.11x		The Institute of Electrical and Electronics Engineers (IEEE) standard for wireless local area network (WLAN) interoperability.
IF	Intermediate Frequency	
IK	Integrity Key	
i-mode		Mobile information service offered by NTT DoCoMo in Japan.
IMSI	International Mobile Subscriber Identity	
IMT-2000	International Mobile Telecommunications	ITU initiative for a global standard 3G wireless data network.
IP	Internet Protocol	The dominant network layer protocol used with the TCP/IP protocol suite.
IrDA	Infrared Data Association	An industry-sponsored organisation set up in 1993 to create international standards for the hardware and software used in infrared communication links.
ISO	International Standards Organisation	A voluntary, non-treaty organisation founded in 1946, responsible for creating international standards in many areas, including computers and communications. Its members are the national standards organisations of 89 countries, including the American National Standards Institute. ISO produced the OSI seven layer model for network architecture. The term “ISO” is not actually an acronym for anything even though it is an anagram of the initials of the organisation’s name. It is a pun on the Greek prefix “iso-”, meaning “same”.
ISO-9960		The international standard for the file system used by CD-ROM. Allows filenames of only 8 characters plus a 3-character extension.
IT	Information Technology	
ITO	Indium Tin Oxide	The material used to fabricate the transparent electrodes (substrate + counter) in a TFT (Thin Film Transistor) display.
ITU	International Telecommunication Union	An international organisation within the United Nations System where governments and the private sector coordinate global telecom networks and services.
Java		Java is a programming language expressly designed for use in the distributed environment of the Internet.

JPEG	Joint Photographic Expert Group	Joint Photographic Experts Group; a graphics format used on Web pages. Standard for the compression of still pictures.
JVM	Java Virtual Machine	
K	Kilo	In referring to computers, a “kilo” is 1024 or 2 to the 10th power. (Note that it is actually slightly more than an even 1000.)
K-Java	Kilo-Java	Kilobyte (size) Java
LC	Liquid Crystal	A material of LCD.
LCD	Liquid Crystal Display	LCD is the technology used for displays in notebooks and other electronics devices. LCDs allow displays to be much thinner than cathode ray tube technology. LCDs consume much less power than LED and gas-display displays because they work on the principle of blocking light rather than emitting it.
LED	Light Emitting Diode	An LED is a special type of diode that emits light when electricity is applied to its anode and cathode.
Li-ion	Lithium-ion	A type of battery.
Li-Po	Lithium polymer	A type of battery.
LM recording	Multilevel recording	A technology to increase data capacity of optical disks.
LO	Local Oscillator	
LPS	Low-temperature poly-Silicon	A technology for active matrix displays.
LSI	Large Scale Integration	
LTCC	Low Temperature Co-fired Ceramics	A technology being used for ceramic substrate to integrate high frequency passive components into one ceramic substrate.
MAC	Media Access Control	Part of the physical layer of a network that identifies the actual physical links between nodes.
Mb	Mega bits	Mbit/s = Mega bits per second.
MB	Mega bytes	
MC	Music Cassette	A popular method of distributing music for portable players, being replaced by compact disks and mini disks.
MCU	Microprocessor Control Unit	
MD-TFD	Mobile Digital-Thin Film Diode	A type of active matrix display that provides lower consumption than ordinary active matrix displays.
ME	Mobile Equipment	
MEMS	MicroElectroMechanical Systems	An advanced technology that makes possible to integrate passive elements into semiconductor. MEMS is also known as micromachine technology.
MIPS	Million Instructions Per Second	A general measure of computing performance and, by implication, the amount of work a larger computer can do.
ML	MultiLevel	
MMC	Multimediacard	A silicon-based small form factor data storage.
MMCA	Multimediacard Association	

MP3	Music Player	The term has become synonymous with the MP3 player that delivers CD quality music. It is the MPEG-2 audio layer 3.
MPEG	Moving Picture Expert Group	A format used on Web pages to show motion; video. Standard for compression of moving pictures and sound. MPEG-4 and MPEG-2 are both in use.
MRC	Memory Resource Control	
MS	Memory Stick	A silicon-based small form factor data storage.
MULTOS	Multi-application Operating System	MULTOS is the first open, high security, multi-application operating system for smart cards (hence “MULT-OS“). Until the emergence of multi-application smart cards, each software application representing a product or service on a card was written for a specific operating system, which in turn was particular to a hardware (chip) or silicon platform supplier.
µPC	Micro Processing Controller	
Ni-Cd	Nickel Cadmium	A type of battery.
Ni-MH	Nickel Metal Hydride	A type of battery.
OEL	Organic Electroluminescent	A display technology.
OSI	Open Systems Interconnect	A model of network architecture and a suite of protocols (a protocol stack) to implement it, developed by ISO in 1978 as a framework for international standards in heterogeneous computer network architecture. The OSI architecture is split between seven layers, from lowest to highest: 1 physical layer, 2 data link layer, 3 network layer, 4 transport layer, 5 session layer, 6 presentation layer, 7 application layer. Each layer uses the layer immediately below it and provides a service to the layer above. In some implementations a layer may itself be composed of sub-layers. OSI is the umbrella name for a series of non-proprietary protocols and specifications, comprising, among others, the OSI Reference Model, ASN.1 (Abstract Syntax Notation 1), BER (Basic Encoding Rules), CMIP and CMIS (Common Management Information Protocol and Services), X.400 (Message Handling System, or MHS), X.500 (Directory Service), Z39.50 (search and retrieval protocol used by WAIS), and many others.
PBGA	Pitch Ball Grid Array	
PC	Personal Computer	Common term to describe the personal computer, usually based on a common architecture.
PC board or PCB	Printed Circuit board	A technology or substrate widely used for electronics devices.
PDA	Personal Digital Assistant	A portable computing device, typically hand-sized, and sometimes capable of transmitting data.
PET	Polyethylene-terephthalate	A material for metal contact sheet.
PGA	Pin Grid Array	

PHS	Personal Handyphone System	Japanese digital cordless phone standard being used like cellular phone today in Japan.
PIN	Personal Identification Number	
PKI	Public Key Infrastructure	A PKI enables users of a basically insecure public network such as the Internet to securely and privately exchange data and money through the use of a public and a private cryptographic key pair that is obtained and shared through a trusted authority.
P_{out}	Output Power	
QCIF	Quarter Common Intermediate Format	A video format for videoconferencing / desktop videophone. It is based on 30 frames per second, of size 144 lines by 180 pixels each, progressively scanned. QCIF frame size is obtained from CIF (Common Intermediate Format for video sequences) dividing by 2 the number of lines and of pixels per line, so that the total number of pixels is one Quarter that of CIF frames.
QFP	Quad Flat Package	A type of semiconductor package.
QVGA	Quarter-Video Graphics Array	See VGA.
Rake correlator		Typical indoor application problems like frequency-selective fading effects and multipath propagation are handled by a Rake-receiver that permits the simultaneous reception of multiple propagation paths by correlation with different synchronized versions of the spreading code.
RAM	Random Access Memory	Semiconductor read/write volatile memory. Data stored is lost if power is removed.
RAND	Random	
R&D	Research & Development	
RES	Response	e.g. Authentication Response
RF	Radio Frequency	
RGB	Red, Green, and Blue	RGB refers to a system for representing the colours to be used on a display.
RISC	Reduced Instruction Set Computer	A microprocessor that is designed to perform a smaller number of types of computer instruction so that it can operate at a higher speed.
RLAN	Radio Local Area Network	
ROM	Read Only Memory	
RRC	Radio Resource Control	
RTOS	Real-Time Operating System	A RTOS is an operating system that guarantees a certain capability within a specified time constraint.
RX	Receiver	
SAW	Surface Acoustic Wave	A technology commonly used for filter devices.
S-CSP	Stacked-CSP	A technology to provide higher integration of semiconductor chips in a single CSP.
SD card	Secure Digital card	A silicon-based small form factor data storage.

SDCA	SD Card Association	
SDMI	Secure Digital Music Initiative	Efforts and specifications for protecting digital music contents.
SiGe	Silicon Germanium	
SIM	Subscriber Identity Module	A computer chip set in a handset that contains information needed to identify the subscriber when connecting to the network, especially for billing purposes.
SIP	System In Package	A technology to provide higher integration of semi-conductor chips in a single package.
SIR	Serial Infrared	
SMD	Surface Mounting Device	A technology for reflow solderable components.
SMS	Short Message System	The system that enables the sending and receiving of short text messages, 160 characters. This system has proved phenomenally successful.
SMT	Surface Mounting Technology	A technology for reflow solderable components, systems and facilities.
SO	Small Outline	
SOC	System On a Chip	A semiconductor architecture to provide system level integration on a single chip.
SOJ	Small Outline J-lead	The electrical pins coming out of the chip are folded inwards with a 'J' shape. SOJ-packaged components are mounted directly on the circuit board's surface.
SOP	Small Outline Package	A type of semiconductor package.
SPI	Serial Peripheral Interface	A synchronous serial data protocol. It provides support for a high bandwidth (1 Megabaud) network connection amongst CPUs and other devices supporting the SPI.
SQN	Sequence Number	
SRAM	Static Random Access Memory	A type of random access memory that retains data bits in its memory as long as power is being supplied.
SSFDC Forum	Solid State Floppy Disk Card Forum	
STN	Super Twisted Nematic	Twisted Nematic (TN) displays twist polarised light to 90 degrees and have a limited viewing angle. STN displays were developed to twist polarised light between 180 to 260 degrees resulting in better contrast and a wider viewing angle.
SUS	Steel Use Stainless	
TBGA	Tape Ball Grid Array	
TCP	Transmission Control Protocol	A transport layer protocol that offers connection-oriented, reliable stream services between two hosts. This is the primary transport protocol used by TCP/IP applications.
TCP	Tape Carrier Package	
TDD	Time Division Duplex	One technique used for wireless communication where the up link and down link use the same frequencies.

TDMA	Time Division Multiple Access	
TFD	Thin Film Diode	A technology for active matrix displays.
TFT	Thin Film Transistor	A technology for active matrix displays.
TMR	Tunneling MagnetoResistive	A technology for HDD magnetic head.
TSOP	Thin Small Outline Package	A type of semiconductor package.
TSSOP	Thin Shrink Small Outline Package	A thin package - much thinner than SOJ. TSOPs are surface mount components, too.
TV	Television	General term used to describe broadcast and reception of video and audio.
TVI	Time Variant Interpolator	
TX	Transmitter	
UDF	Universal Disc Format	A standard developed by the Optical Storage Technology Association designed to create a practical and usable subset of the ISO/IEC 13346 recordable, random-access file system and volume structure format.
UDP	User Datagram Protocol	
UICC	Universal IC Card	A removable IC card containing a USIM. UICC provides storage capability for the following: * UICC related information: * IC card identification: a number uniquely identifying the UICC and the card issuer; * Preferred language(s); * Directory of applications.
UIM	User Identity Module	An expansion of the SIM that stores user ID and other information to improve security functions.
UMTS	Universal Mobile Telecommunications System	ETSI specified standard for 3G.
UMTS Forum	Cross industry body	Non-profit, independent forum that gives guidance to standards and other bodies in terms of market requirements and issues to be solved to allow for a smooth deployment of UMTS. www.umts-forum.org
Unicode		A 16-bit character set standard, designed and maintained by the non-profit consortium Unicode Inc. Originally Unicode was designed to be universal, unique, and uniform, i.e., the code was to cover all major modern written languages (universal), each character was to have exactly one encoding (unique), and each character was to be represented by a fixed width in bits (uniform).
USAT	USIM Application Toolkit	
USIM	Universal Subscriber Identity Module	The module that identifies, and is unique to, the mobile subscriber.

UTF-8	Universal Transformation Format-8	A Universal Character Set (UCS) Transformation Format in which each 16-bit or 32-bit character encoding of ISO 10646 is transformed into a 1, 2, 3, 4 or 5-byte encoding. UTF-8 has the property that the UTF-8 encodings of the first 128 characters are the same as their ASCII encodings and that, except for the null character itself (which has encoding 0), no character encoding contains a null byte.
V.90 modem		A type of analogue modem widely used in the world.
VCR	Video Cassette Recorder	
VGA	Video Graphics Array	A standard analogue monitor interface for computers. Also a video graphics resolution of 640 x 480 pixels.
VM	Virtual Memory	A method of making disk storage appear like RAM memory to the CPU, thus allowing programs that need more RAM memory than is installed to run in the system. This technique is slow compared to “real” memory.
VoIP	Voice over IP	The generic term used to describe the techniques used to carry voice traffic over IP.
WAP	Wireless Application Protocol	Used to allow the transmission of simple web pages in 2G networks. Consists of a protocol stack that covers layers 4 to 7 of the OSI model. Uses IP but replaces TCP and HTTP with UDP. Web pages are written in WML.
WB	Wideband Audio	WB audio means high quality audio, realising MP3 player functionality with corresponding external components.
W-CDMA	Wideband Code Division Multiple Access	The air interface being used for the IMT2000/UMTS terrestrial radio access network
WinCE	Windows CE	Windows CE is based on the Microsoft Windows operating system but is designed for including or embedding in mobile and other space-constrained devices.
WLAN	Wireless Local Area Network	Technology to provide high speed wireless service complementary to UMTS. A standard that operates at 2.4 GHz at speeds up to about 1.5 Mbit/s over a radius of about 300 metres. It provides a high quality signal by transmitting only when it seizes a clear channel in the already-overcrowded 2.4 GHz band.
WML	Wireless Markup Language	Wireless markup language provides the syntax which allows information to be displayed on WAP devices.
XRES	Expected Transfer Response	Expected authentication value delivered by the 3G HLR/AuC.

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