RTT TECHNOLOGY TOPIC
September 2006

Memory spots, motes and Mu chips

Introducing this month's Hot Topic

In last month's Hot Topic, we discussed the evolving role that micro electrical mechanical systems (MEMS) are playing in cellular handset design.

The combination of silicon geometry scaling and micro miniaturisation techniques together are transforming phone form factor and functionality.

There are however other devices that are acquiring new capabilities and shrinking in size. We use technologies at the scale of nanometres (one billionth of a metre) to build structures at atomic or molecular level which are combined in to devices that are either measured in micrometres (one millionth of a metre), or millimetres (one thousandth of a metre).

For the purposes of this Hot Topic we will define these devices as **'Micro Devices'.**

We review three classes of 'micro device', **'Memory Spots'** (a device announced recently by HP Labs in Bristol) **'Motes'** (being developed in the US as a result of various 'smart dust' projects), and the **Hitachi Mu chip** (an ultra miniaturised RF ID device).

These devices store information and/or collect information and/or provide identification. All of them are communication devices.

Our particular interest is to consider **how we communicate with these devices** and **whether the cellular phone has a valid role in this communication process.**

We compare these micro device applications with a present larger form factor application (contact less smart cards)and suggest some technical and commercial commonalities.

We discuss the present status of 'phone to device' communication systems, particularly RF systems and protocols and question whether there are plausible cellular phone business models to justify development investment in this intriguing but challenging application sector.

We highlight certain factors that suggest adoption time scales may be longer than commonly supposed.

Micro Devices - how small is small?
MEMS and micro miniaturisation techniques in combination with silicon geometry scaling are allowing us to deliver storage functionality, information gathering

functionality, identification and communication capability in increasingly small devices.

The table below lists three form factors ranging from a grain of rice (small) to a grain of sand (very small) to a grain of dust (very very small).

A grain of dust typically has a diameter of a few tens up to 200 or 300 micrometers, hence the term 'micro device'.

Products are available in all three form factors or becoming available within the next two to three years. All three product sectors present distinct communication challenges and (hence) potential communication value opportunities.

Table 1 Micro Device Form Factors and Functionality - three examples

Small	**Very small**	**Very very small**
Grain of Rice < 4 millimetres	Grain of Sand <2 millimetres	Grain of Dust <500 micrometres
Example Product		
Memory Spot (HP Labs)	Motes (Intel web site)	Mu Chip (Hitachi)
Information delivery device	**Information collection device**	**Identification device (RFID)**
2mm by 4mm including integrated antenna 256 kilobit to 4 megabit storage	1mm by 1mm (mote sized) Typically with sensing capabilities- temperature, light, vibration, acceleration, air pressure	0.4mm by 0.4mm by 60 micron 0.15mm by0.15mm by 7.5 micron
Data transfer rate up to 10 M/bits/s	Data transfer rate Device and application dependent	Data transfer rate 12.5k/bits/s
Distance -close coupled	Distance - 20 to 30 metres	Up to 400mm

Both the Memory Spot (HP Labs) and Mu Chip (Hitachi) products are passive, generating power inductively from the interrogating device.

The Memory Spot is a CMOS device with an intended storage capacity of between 256 kilobits and 4 megabits and a claimed transfer rate of 10 megabits per second. The device has a built in antenna and can be embedded on a sheet of paper or any suitably friendly surface. Suggested consumer applications include adding a Memory Chip to photographs or postcards or books to provide an audio (voice or music) or imaging (still and video imaging) or extended text download capability (microdot applications). As such, it can be described as an 'information storage and delivery device'. The public announcement of this device in June this year created substantial interest.

Hitachi's Mu chip is a miniaturised RF tag and fits into the' very very small' category starting with a 0.4 by 0.4 millimetre (400 micrometre) device and going down to a

0.15 by 0.15 millimetre device with a height profile of 7.5 microns . It is an identification device with a 128 bit address capability. It can function as an RF Bar code or IP address identifier. The devices work at 2.45 GHz and are ASK modulated with a bit rate of 12.5 kbps but need an external antenna (54mm by 1.5mm by 0.22mm) to maximise read distance.

In the middle 'grain of sand' category we have the various 'mote devices' also sometimes described as 'smart dust devices' with their genesis in US projects aimed at realising an autonomous sensing computing and communication system within a cubic millimetre (a 'mote'), though present devices are significantly larger.

The idea of these devices is that they can be scattered across an area and form a self organising network of interconnected interactive objects which are either battery powered, solar powered or vibration powered. Their purpose is primarily to capture information on the physical world, for example temperature, ambient light, vibration, acceleration and air pressure - they are information collection devices.

Questions we want to try and answer
Do we want or need cellular phones to be able to talk to these micro devices?
If so, what are the technology, engineering and business challenges and opportunities?

Contact Less Smart Cards at 13.56 MHz- a technology, engineering and business model?
A starting point is to look at a (larger) device that we already talk to, the contact less smart card, and see what lessons we might learn.

Contact less smart cards are similar to the Memory Spot in that they are typically close coupled applications in which the two devices (the reader and the smart card) are either touching or within a few millimetres of each other. This is 'Near Field Communication'.

There is an international standard ISO14443 for contact less smart cards also known as RF tags, operating at 13.56 MHz, close to the GSM clock reference at 13 MHz. (an advantage and/or disadvantage). The devices are ASK or BPSK modulated, either passive (load modulation) or active with a range from 0 to 200 millimetres.

A vendor forum exists to promote the standard with support from Master Card, Visa International, Microsoft, Nokia, NEC, Panasonic, Renesas, Philips, Samsung, Sony, TI and (more recently) HP.

There are 4 types of Contact Less Smart Card (tag) categories determined by memory footprint and transfer speed detailed in the table below

Table 2 Contact less Smart Cards

Tag type	1	2	3	4
Memory	1KB	2KB	1MB	64 KB
Data rate	106 kbps	106kbps	212 kbps	106 to 424 kbps

In the UK, every time you use a London Underground Oyster Card, the 13.56 MHz transmitter in the oyster terminal device at the turnstile is irradiating your 'smart' oyster card with RF energy, your oyster card then uses this energy to transmit your ID back to the device.

There are no compelling technical reasons why this function cannot be included as a mobile phone function. It could be passive or active and unidirectional or bi directional. If bi directional, the phone could read information stored at the turnstile (timetables, delays, special travel offers).

The point to make is that the purpose of the technology and engineering used in the oyster card is to facilitate a commercial transaction. The technology and engineering issues are relatively straightforward to address, the commercial issues are arguably more complex.

In practice we still use dedicated smart cards not cellular phones to access these systems. This is because we do not have NFC transponders as a standard item in phones. The reason we do not have NFC transponders as standard items in phones is that it adds cost and the associated value model depends on having commercial agreements in place which require cross industry consensus and therefore take time to negotiate. Nokia's promotion of 'service discovery' in addition to ticketing and electronic purse applications (Master Card and Visa's involvement in the vendor group) may help market adoption.

Contact less Smart Cards and Memory Spots - uni-directional and bi directional value

The Memory Spot in some ways represents a development of the Contact Less Smart card business model but with the focus on information transfer rather than transaction facilitation. This implies a need for higher data rates (at 2.4 GHz) than those available using NFC (at 13 MHz).

Although the Memory Spot is a contact less smart memory information dispensing device, the provision of information and transactional value are closely related. Reading about things prompts us to buy things.

This comes down to the simple principle that a unidirectional exchange has a certain value. Uploading our ID to a turnstile has convenience value, reading a Memory Spot has interest and information value. If the exchange can be made bi directional then the value increases.

Contact less Smart Cards, RF ID and Memory Spots

Our second micro device example, the Hitachi Mu chip, is intended to function as an RF bar code and or RF ID device. RF bar codes offer some advantages over conventional bar codes, for example non line of sight and multiple read capability and additional address bandwidth to support electronic product codes rather than standard (universal) product codes. They are also beginning to be used in passport systems. The downside for consumer and retail applications has been their expense though the cost in volume is now less than 20 cents.

Traditional printed label bar codes however are effectively zero cost and have benefited from years of intensive investment in optical scanning techniques.

RF ID tags also have competition from other offerings such as long wave magnetic systems operating at wavelengths below 450 KHz. These system options have their own standard (IEEE P1902 Standard for Long Wavelength Wireless Network Protocol) and some application advantages, for example the ability to work underwater and/or underground.

As with RF tags, magnetic tags can be active or passive. The active devices have a claimed life of 10 years or more from a (coin sized) lithium battery. Read rates are typically between 300 and 9600 bits/s.

RF ID tags and long wave magnetic tags both have sufficient address bandwidth to support IPV4 or IPV6 addresses.This suggests a shift in functionality beyond present 'visibility network' or 'visible asset' applications to a broader application base in which wireless interrogation of an RFID prompts the interrogating device to access a web page.

To place this in the context of our Oyster card and Memory Spot examples, we do not necessarily need to download information from an embedded device other than an IP address which is then used to access information from a supporting web site.

Contact less Smart Cards, RF ID, Memory Spot and Mote (Smart Dust) applications

Our third micro device example, mote sized Smart Dust devices, seem very different. These devices are intended to be deployed as self configuring ad hoc networks that interact with each other. These devices can potentially all have IP addresses and can be a part of a sensing and surveillance network. They combine local storage capability, intelligence and communications capability.

The relevance of these networks to cellular phones may seem tenuous. However the protocols for ad hoc networking are well established and already deployed in a number of two way radio system solutions so the concept of cellular phones interacting with these devices is at least plausible.

The cellular phone as a bridge between multiple devices and other network based information

The logic of using a cellular phone in any or all of the above applications is that the cellular phone provides a bridge to the outside world. Advantageously of course this is a toll bridge with an efficient and robust revenue capture (billing) capability including pre and post payment collection.

The technical challenge of using a cellular phone is that we need to support additional wireless systems and protocols which add cost and complexity to an already over loaded product platform.

Multiple RF options

Frequencies used presently include long wave (below 500 KHz), 1.95, 3.25, 4.75 and 8.2MHz (typically used for anti shop lifting tags in retail stores), Near Field

Communication in the 13 MHz ISM (Industrial Scientific Medical) band, the 27 MHz ISM band, the 430 to 460 MHz ISM band available in Region 1(Europe and Africa), the 902-916 MHz band available in Region 2(North and South America), the 918 to 926 MHz band used for RF ID in Australia, the 2.35 to 2.45 GHz ISM band, a possible band at 5.4 to 6.8 GHz and/or the use of Ultra Wide Band systems between 3 and 10 GHz.

UWB is potentially appealing in that there is a very scalable relationship between bit range and range (low bit rate/long range, high bit rate/short range). The frequency band (up to 10 GHz) is also useful for micro device form factors. However the multi band OFDM now proposed for UWB would be hard (potentially over complex) to implement in a micro transceiver.

There is some regulatory consensus that there should be three internationally agreed universal allocations for device to device communication, a low frequency allocation at 125 kHz, the NFC allocation at 13.56 MHz and the 2.45 GHz allocation. Early agreement on this would be useful.

These devices need to co exist with the other radio systems within the phone including wide area cellular and local area (Bluetooth and WiFi) and receive only functions such as GPS or DVB/DAB.

Multiple Protocol Stacks
Standardized radio protocol stacks include Bluetooth (optimized for throughput) and ZigBee (optimized for low power consumption), both of which have well developed vendor support. There are additionally operating systems optimized for low power consumption such as Tiny O/S and a range of specialized proprietary offerings.

Adoption time scales - bar codes as an example
Contact less smart cards and each of the micro device options referenced in this article (HP Memory Spot, Smart Dust Motes and micro RFID) all offer intriguing and potentially compelling cellular phone device and system level integration opportunities.

They are technically feasible and supported by radio standards and protocol stacks which are becoming relatively mature. The devices do not necessarily need to reduce in size but will increase in functionality and reduce in cost thus broadening their application profile. However business models may take longer to evolve than might be expected. Traditional bar codes provide an example.

The beginning of bar codes as we know them today can be traced back to a patent for 'a Classifying Apparatus and Method' filed in 1949 by Bernard Silver and Norman Woodland. Silver and Woodland were graduates at the Drexel Institute of Technology and were responding to a local food store's request for an automated method of reading product information.

It took twenty five years for the idea to evolve and for standards to be agreed, mostly getting agreement on the Universal Grocery Products Identification Code which evolved into the Universal Product Code. The first UPC scanner was installed in a supermarket in Ohio in 1974. The first product to have a bar code was a packet of

Wrigley's gum.

Bar codes are now ubiquitous but it has taken another 25 years for this to happen. Bar codes have taken over 50 years to become universally adopted.

Summary

Optical bar codes provide an example of a product that is now an integral part of every day life. The enabling idea was simple but required an enabling technology (optical laser scanning) to be available together with universal application standards in order to support ubiquitous deployment.

Today we have a new generation of MEMS based enabling technologies that are allowing us to build super small devices that can collect and store information and/or perform identification or labeling tasks that help us to interact more efficiently with the physical world around us.

It is tempting to position the cellular phone as the 'device of choice' for communicating with this new generation of micro devices.

The technical logic is that it is relatively easy to extend the present communications systems within the phone to include phone to device and device to phone communication applications.

However commercial logic suggests the business models to support these mass market application sectors will take some years to emerge.

About RTT Technology Topics

RTT Technology Topics reflect areas of research that we are presently working on.

We aim to introduce new terminology and new ideas to clarify present and future technology and business issues.

Do pass these Technology Topics on to your colleagues, encourage them to join our Push List and respond with comments.

Contact RTT

RTT, the Shosteck Group and The Mobile World are presently working on a number of research and forecasting projects in the cellular, two way radio, satellite and broadcasting industry.

If you would like more information on this work then please contact

geoff@rttonline.com

00 44 208 744 3163