Much has been spoken in recent years about the “convergence” of the telecommunications and broadcasting industries. Today, both industries have made the analogue-to-digital transition – with GSM/3G and DAB/DVB respectively. Many companies from both industries now accept that there is potential for new revenue streams – that could be created through collaboration, but not through convergence.

The Virtual Centre of Excellence in Mobile and Personal Communications (Mobile VCE) was conceived to undertake leading-edge, industry-led, academic research for the mobile communications industry. This article discusses the motivations and constraints of their latest research initiative – which explores broadcast-mobile interworking – and describes the origins of the programme, its structure and key research themes.

Introduction

The history, capabilities, assets, culture and fears of the broadcast and telecom industries are quite different. Such factors influence what is commercially possible. Mobile network operators have paid vast sums of money for 3G spectrum, which contrasts with what they perceive as the “free spectrum” that has been allocated to broadcasters. Consequently, they do not wish to see broadcasters providing telecom services to telecom customers. Similarly, broadcasters fear the loss of existing spectrum allocations as the analogue shutdown approaches, with the completion of the transition to DVB. Against such deep-rooted concerns, the prospect of some kind of convergence of new 3rd generation (3G) mobile networks and digital broadcast networks is remote.

However, on the ground, something further is happening. SMS voting in live TV shows is creating new revenues for both the mobile operators and the broadcasters. This is an indicator of the potential for real mutual benefits, without the need for “convergence”, if ways can be found for the two industries not to converge, but rather to interwork – each protecting and safeguarding its own independence and assets.

It is against such a background that the Virtual Centre of Excellence in Mobile and Personal Communications – Mobile VCE – was conceived and is now undertaking a programme of research based around such concepts of interworking, aimed at delivering benefits to both industries. This article explores the motivations and constraints of collaboration, describes the conceptual origins of the research programme, and presents its structure and key research themes. We describe the evolution of the industrially-driven requirement for interworking, a requirement identified in Mobile VCE’s “Vision 2010” which was developed in 1998 and published two years later [1]. Today, it has become widely adopted across the global mobile industry and now forms part of the ITU’s future vision document [2]. We then proceed to summarize some early scenarios and assumptions developed by our industrial and academic members over the past year, and the next steps to be taken in translating these requirements into deliverables that our industrial members can eventually exploit in the commercial world.
The strengths of broadcast & mobile systems

Interworking between broadcast and mobile systems brings the prospect of new services which, to be successful, must fulfil two important requirements – they must meet real user needs and must be easy to use.

Successful new services are difficult to predict. Much effort has been spent on the, largely fruitless, search for a “killer application” for 3G mobile systems; many today feel that the “killer application” will in fact comprise a multitude of niche applications, servicing the many market segments that will continue to emerge. Most successful new technologies allow us to do something we were already doing before, but in a more convenient or effective manner. Wireless is an enabling technology for the ubiquitous dissemination of information and for communication, and both these applications are quite mature. This means that what 3G is actually likely to represent is an increase in convenience and depth over a number of applications, and that revenue opportunities will come from increased use of these services as their costs fall and their usefulness rises, rather than from a small number of “killer applications”. It also means that it should be possible to see the precursors of these services already in operation today.

Another lesson learnt from history is that services must be tailored to their application. When TV was in its infancy, many predicted that it would cause the demise of the cinema. While the immediacy of broadcast news did kill off newsreels, people still like the cinema experience for feature films, and cinemas continue to prosper. A similar situation applies between newspapers and broadcast news, where newspapers can give more in-depth coverage. This suggests a potential for services that are much more than just the sending of existing broadcast content to mobile handsets. Looking beyond 3G, the question therefore is: “Which services would the broadcast and mobile networks be able to deliver more effectively, or even uniquely, if interworking together?”

Traditional services within the broadcast industry are relatively mature, having developed over decades, which contrasts with the relatively short history of mobile telecommunications. So one approach is to consider what mobile networks can offer the broadcast networks. This breaks down into several key attributes including interactivity, mobility and personalized subscriber information, and real-time billing systems.

**Interactivity** has begun to be implemented over the recent past, within the context of digital television through the use of standard, wired, telephone lines – often with the user’s connection being a condition of subsidy for the set-top box. More recently, mobile (and fixed) phones have been very effectively, and profitably, used as a back channel for televoting in live TV and other programmes.

**Mobility** comes into play when people are on the move, when they want specific, time-sensitive and often location-sensitive information. Mobile networks can provide location information to broadcast networks, or can allow location-specific information – normally broadcast in a local area – to be provided outside that area (for example, allowing viewers to watch their own local news programmes whilst away from home).

**Personalisation** is a more complex issue in a broadcasting context. If data must be sent individually to a subscriber, then that part of the radio spectrum is serving only one user, which is expensive and imposes severe capacity and cost restraints. However, in many cases, whilst some of the information is personalised, much may be common to a number of users, making broadcast a more efficient delivery mechanism for such services. In combination with the time-shifting possibilities of caching (either in the handset or at local access

### Abbreviations

<table>
<thead>
<tr>
<th>3G</th>
<th>3rd Generation</th>
</tr>
</thead>
<tbody>
<tr>
<td>DAB</td>
<td>Digital Audio Broadcasting (Eureka-147)</td>
</tr>
<tr>
<td>DVB</td>
<td>Digital Video Broadcasting</td>
</tr>
<tr>
<td>GSM</td>
<td>Global System for Mobile communications</td>
</tr>
<tr>
<td>IoN</td>
<td>Interworking of Networks</td>
</tr>
<tr>
<td>IP</td>
<td>Internet Protocol</td>
</tr>
<tr>
<td>IPR</td>
<td>Intellectual Property Rights</td>
</tr>
<tr>
<td>ITU</td>
<td>International Telecommunication Union</td>
</tr>
<tr>
<td>LAN</td>
<td>Local Area Network</td>
</tr>
<tr>
<td>MMS</td>
<td>Multimedia Messaging Service</td>
</tr>
<tr>
<td>MoU</td>
<td>Memorandum of Understanding</td>
</tr>
<tr>
<td>MVNO</td>
<td>Mobile Virtual Network Operator</td>
</tr>
<tr>
<td>PAN</td>
<td>Personal Area Network</td>
</tr>
<tr>
<td>PDA</td>
<td>Personal Digital Assistant</td>
</tr>
<tr>
<td>PDE</td>
<td>Personal Distributed Environment</td>
</tr>
<tr>
<td>QoS</td>
<td>Quality of Service</td>
</tr>
<tr>
<td>SMS</td>
<td>Short Message Service</td>
</tr>
<tr>
<td>WE</td>
<td>Wireless Enabler</td>
</tr>
<tr>
<td>WLAN</td>
<td>Wireless Local Area Network</td>
</tr>
</tbody>
</table>
points for transmission over low-cost wireless LAN links to a mobile device), combined services from broadcast and cellular networks may become highly effective.

An example of a service that can make use of interworking is a weather forecast. “On-demand” access to a weather forecast has been possible through telephones or newspapers, but to receive a high-quality visual version with commentary, a user has had to wait for a TV broadcast. A 24-hour TV weather channel solves the problem of users not having to wait, but is not a particularly efficient use of bandwidth and, not being tailored to the user, it lacks revenue opportunities.

For some time, it has been possible to download compressed video of a weather forecast from broadcasters’ websites but, over a dial-up modem, this has been slow and the quality has been poor. With an ADSL link, the quality and immediacy improves to the point where it become a practicable service. 3G mobile will allow the user to press a button on their handset and see the forecast for their chosen area almost immediately, wherever they are. It is likely that many users in an area would be interested in a weather forecast at some point during the day and, in an interworking environment, it would be possible to broadcast the forecast at regular intervals and cache it on the handset – with access information and billing transmitted over the 3G network. In ten years time, such basic services will have become low-cost commodities and, as 3G networks begin to saturate, mobile operators will wish to free up their spectrum for higher value-added services, whilst still retaining some revenue from the provision of such multicast services.

**Practical constraints**

When considering the interworking of broadcast and mobile systems, there are a number of limiting factors which constrain the designer’s freedom. Some of these are technical issues; many, however, belong in the business or regulatory domains, and technical solutions will need to take these into account.

**Industry investment**

A very significant business constraint on future systems, particularly in the current financial climate, is that both the broadcast and cellular industries have made very substantial investments in their existing infrastructure. They will not wish to make major alterations to these networks, or add new infrastructure, without a good financial return being possible.

This has a number of implications. Successful implementation of interworking in the short term will require modifications to the networks to be minimized. Mobile networks are moving towards a packet-switched core, based on the Internet Protocol, IP, and a number of approaches have suggested interworking, based on IP. However, the case for IP in a broadcast network – with constant bit-rate streams requiring guaranteed QoS – is still under evaluation. Despite work on the role of IP within the DVB project, implementation in broadcast networks is unlikely to be universal and is probably some years off. Thus, interacting with non-IP networks is a likely requirement as a first-stage evolutionary step.

Another implication is that any solutions should be standardized as much as possible, in order to maximize the market potential and reduce the costs.

**Business models**

Any successful interworking must give all parties an opportunity to increase their revenues. However, this does not simply mean “the broadcast operator” and “the mobile operator”. The business models for both broadcast and cellular systems have become more complex in recent years, with a loosening of existing vertical relationships. This is particularly true in the mobile case, where we are moving from a position where the network operator does everything (provides the terminal, connection and service) to a point where users would provide their own terminals, and network operation would be split from service provision. Mobile Virtual Network Operators (MVNOs) are entering the market as service providers, offering branded services over networks owned by others. The broadcast industry has always been more diverse, with some content provision always being outsourced, and users buying their own terminals. However, similar factors apply, with a divi-
sion appearing between companies specialising in network provision and those specialising in the service aspects.

The industrial partners within Mobile VCE decided that there should be no single business model – rather, the technology options should cater for a number of different situations, as different companies would have different revenue models relating to their place in the supply chain (see Fig. 1).

Any system must respect the needs of all the parties involved. This includes the fact that operators will want to remain fully in control of their own networks, and will probably be unwilling to release full information on its real-time performance, which could be highly valuable to competitors. Operators will also have security concerns about giving access to control and user information. A further factor is the regulator, who may well act to open up networks and require that certain information be made available [3].

**Security**

There are significant philosophical differences between broadcast and mobile networks, in their approach to security.

The nature of a broadcast network, with most information flowing from the network to the user terminal, means that security of the network has traditionally presented relatively few difficulties. When terminals are required to contact the network, the likelihood is that the terminals (for example, set-top boxes) will have been supplied by the network operator in advance, and will have been designed to work only with that operator’s system. However, security of the information being delivered is very important, making content protection a priority.

In contrast, the value of the data delivered by a mobile network has traditionally been fairly low. While 2G and 3G systems include quite comprehensive security of the content over the air, especially for 3G systems, some operators do not activate the optional encipherment. The unpredictability of channel use, and the lower bit-rates over the channel, make cryptanalysis more difficult in any case. The focus in the mobile network case has been security of the network, given that terminals are constructed to open standards and can roam from network to network. Strong terminal authentication is used to ensure that only authorised terminals can access the network and to ensure integrity of billing.

These differences affect the operation as well as the security. If content has low value, relaying it between terminals presents few problems. Therefore, a distributed terminal – with the user accessing content in the most convenient manner – is a common theme in emerging mobile scenarios. For example, a laptop might be used...
to send and receive SMS or MMS messages, if it is available. On the other hand, broadcasters are more wary of distributed terminals. For example, differing views are taken on whether a set-top box can be connected to a second television in another room. While this presents few difficulties if only one television can be used at a time, a wireless-distributed terminal removes infrastructure constraints and could potentially allow multiple households in a single block of flats to view content from a single set-top box.

Wireless-distributed terminals thus require authentication between the different entities making up the “terminal”, as well as trust between the gateway manufacturer and the content provider. More generally, there is an urgent need for a systematic approach to solving the security and content protection issues arising when content is distributed via both mobile and broadcast technologies, and when the content access devices may be spread across a distributed terminal.

Both broadcast and mobile systems often use secure hardware for their implementations, and secure hardware is likely to play a key role in securing content in this new environment. However, the user is unlikely to accept having to have large numbers of smart cards, for example, to access multiple services. On the other hand, any solutions which share secure hardware would involve a very high degree of trust on the part of the parties involved. Any architectural solution to the identified security issues will need to determine how trust arising from the use of a hardware security token can be distributed across a collection of devices in a personal environment.

Mobile VCE’s vision and research

Mobile VCE, formed in 1996, is a not-for-profit company, with a mission of industry-led, long-term, high-quality innovation, aimed at facilitating the growth of the mobile communications business (see the panel below). The main body of Mobile VCE research is organized in core programmes, in which all members are involved. The second such programme is ongoing while the third – Core 3 – began in Spring 2002.

Vision 2010

The Mobile VCE Vision Group, comprising senior industrialists and respected academics, has responsibility to form a coherent vision of long-term industry development. The Mobile VCE vision is that, by 2010, users will be served by a hierarchy of networks [1], including cellular, broadcast, local WLAN hotspot coverage, and...
Personal Area Networks (PANs) interconnecting multiple user devices (see Fig. 2). Wireless devices will have reduced in cost to the point where users will have many small specialised devices, most of them operating entirely autonomously; e.g., adjusting the lighting and temperature in a room to the user’s preferences as they enter it. Unlike today’s mobile communications where most usage is still person-to-person, machine-to-machine communication will become very much more important in the future.

Future systems will have five key elements:

- **Fully converged services**
  The distinction between personal communication and broadcast entertainment will slowly blur, with users accessing a seamless pool of content.

- **Ubiquitous mobile access**
  Mobile access to services will become the most convenient means of accessing communications and information services, and will also take a more significant role in broadcast and entertainment services.

- **Diverse user devices**
  Wireless devices will proliferate, with the user having a large number of small devices tailored to specific tasks.

- **Autonomous networks**
  Highly adaptive, efficient and self-managing networks will be required to support these devices.

- **Software dependency**
  Systems and users will increasingly become software dependant, as the complexity and flexibility requirements of systems increase. Users will make use of software agents to simplify complex tasks such as searching for information.

**Core 3 research programme**

To facilitate such possibilities identified by this vision, the Core 3 programme is pursuing three particular themes, structured as distinct research areas (see Fig. 3):

- **The user’s information environment**
  The vision foresees users being able to access content from a number of difference sources, seamlessly. A simple solution would be to provide a common terminal – a “super PDA” – which has the ability to access any network. However, this has many practical disadvantages and contradicts the market reality of users having many different specialised devices; in a consumer mass market, segmentation rules. The issues of management of user access to multiple networks and services, and their content, is addressed in the Personal Distributed Environment work area.

- **Provision of services across heterogeneous networks**
  Given the hierarchical nature of future networks (see Fig. 2), close co-operation between different network types for the provision of services is required. However, as noted in the discussion on constraints above, commercial and security concerns will limit the information flow between the networks. Having a common core network would solve these problems, but contradicts the assumption of autonomous networks – necessary to keep management tractable – and would also certainly be commercially
unacceptable. The issues of interconnecting networks under these constraints, particularly broadcast and cellular networks, is addressed by the Interworking of Networks work area.

**Transport support for interworking**

Interworking will require that terminals support simultaneous connections to multiple networks, possibly with different air interfaces. Future services will also require higher data rates to be supported in local areas over the short range, perhaps on an opportunistic basis. These issues are addressed in the Wireless Enablers work area.

Each of the three work areas is led by a Steering Group of industrial members. The Steering Groups are chaired by an industrialist, who is supported by an academic co-ordinator. In this way, a strong industrial drive is given to the work.

In addition to the three Steering Groups, a Systems Group exists to provide co-ordination within the programme, and technical liaison with the external activities. Membership of the Systems Group consists of industrial members chosen from different parts of the value chain, and a lead researcher from each of the three technical work areas. The industrialists were specifically chosen to provide a wide range of experience and to reflect the membership of Mobile VCE, coming from both the mobile and broadcast industries – including content providers, network operators, service providers and mobile infrastructure and handset manufacturers.

### Scenarios and assumptions

One of the early tasks of the Systems Group was to draw up representative scenarios used by the three technical work areas, in order to focus their work and align their interactions.

In the light of experience from previous core research, it was agreed to focus each scenario on a different topic within the overall research framework. In this way, there is broad coverage of all the important issues, and the most significant points are covered from a number of different perspectives. This was assisted by the wealth of experience from the different industrialists involved, and the researchers who identified prominent issues in their respective work areas. Five scenarios have been defined, each concentrating on different key aspects: (i) content presentation with varying devices and air interfaces, (ii) network topology, (iii) the content itself and service personalisation, (iv) interactive services and games and (v) mobility, including interaction with foreign devices.

From these basic scenarios, a number of important issues have been extracted. These include:

- **Dynamic topology** – including the need to identify characteristics of devices, device selection (for example, which of the many identical new devices to use), and trust relationships and their assignment;
- **Caching mechanisms** – including the location of such caches (in the terminal or set-top box, or in a local access point), and the management and updating of the caches;
- **Discontinuous coverage** – which can be combined with caching, to provide opportunistic low-cost high-bit-rate download to support other services in local areas;
Service negotiation – allowing the user to select from a much more varied selection of services, devices and possibly networks, and having the freedom to select their desired QoS level;

Billing – given that the user will want a simple, but nonetheless flexible, charging point for the wide range of services being offered.

Other issues include the provision of location-based and customisable services through a combination of mobile and broadcast delivery channels, and whether such channels will work in parallel with the mobile, within their own return channels, or whether a broadcast network will use a mobile return channel (see Fig. 4).

To support these scenarios, a number of assumptions have been explicitly documented – dealing with usage, network and transport – and which are contained within a “Book of Assumptions”, a living document which contains proposed reference frameworks for the technical work areas and which is updated over the life of the programme. The Book of Assumptions ensures consistency, as far as possible, across the technical work, ensuring that contradictory assumptions are minimized. It also allows the capture of results from one area to inform and support the work of another.

Research areas

As described earlier, the Mobile VCE Core 3 programme is structured into three technical fields, each overseen by an Industrial Steering Group. In this section we provide an overview of these areas.

Interworking of networks

The interworking of networks takes into consideration solutions which use functionality in one network to assist another network in delivering services to users, perhaps services which could not be supported by a single network on its own. A key point is that the networks do not converge – they remain autonomous independently-managed entities.

Four major issues are the focus of this research area:

- **Mobility Management** – looking at the issues of handing over information and data flows between broadcast and cellular networks, both IP- and non-IP-based.

- **Resource Management** – looking at what information could or must be made available between networks in order to allow effective resource management and, given that such information is unlikely to be freely available, what trade-offs exists between the operational efficiency and the information flow and level of trust.

- **End-to-End Security** – looking at the interworking of network level security between systems, again taking into account the issues discussed earlier.

- **Interworked Network Architecture** – providing an overall framework and architecture to test and verify solutions, including the construction of a tested, demonstrated, handover of flows, based on IP.
The Personal Distributed Environment

The Personal Distributed Environment considers the user’s perspective of the system, and his/her opportunities for new services and revenues. The user will have a multiplicity of different services available to him/her, over different mobile and fixed devices and networks, and this selection will change with time and location (Fig. 5). Management of this system will be complex, especially given that, as consumer products, the services must be very easy for the user to control if they are to find market success.

Three specific research areas are being focussed upon:

- **Personal access management** – The interaction of multiple devices within the user’s environment, which may be both local and remote to the user and may be dynamically changing. Issues such as the discovery of available devices and connections, and maintaining up-to-date status on them must be provided transparently to the user.

- **Personal service management** – The user may access multiple services, from multiple providers, over multiple networks. These may be changing dynamically, requiring resource trading mechanisms and negotiations between services, and essentially user-friendly access.

- **Security** – The issues of Authentication, Authorisation, Accounting and overall Security of a multi-device, multi-service personal distributed environment, both in terms of the security and authorisation of its elements, and the security and authorisation of content. This will build upon recent work by the IST SHAMAN project 1, which has provided an architecture for secure access to heterogeneous mobile networks (see also [4] for general background on security issues in the mobile environment).

Wireless Enablers

The work of the Wireless Enablers focuses on two main areas – multistandard terminals which can handle simultaneous connections to the networks of both industries, and high-speed personal networks to enable rapid transfer of data or content during brief periods when in the proximity of a suitable source.

The research on multi-standard terminals seeks to identify architectures that will enable a single silicon implementation to demodulate multiple standards in a cost- and power-efficient way. Many of the interworking

---

1. See [http://www.ist-shaman.org](http://www.ist-shaman.org) for all SHAMAN deliverables – all the SHAMAN output is public domain.
solutions require communication with two networks at the same time, so methods and enablers of achieving simultaneous support of multiple-bearers technologies are also considered.

For high speed PANs, additional bandwidth-efficient transmission methods must be identified, as well as the appropriate spectrum, while considering improved methods of transmission to accommodate both bursty and isochronous data types. A further issue is the identification of suitable metrics for (overall network) spectrum efficiency in dense personal environments, in order to evaluate new access methods.

**Conclusions**

In the recent past, broadcasters have begun to cooperate with telecommunication operators to support interactivity. However, there is increasing recognition that mobile operators can provide more than simply a back channel – the mobile operators’ location and personalization information and billing systems, when combined with the broadcasters’ existing assets, represent opportunities for value-added services and new revenue streams.

Mobile operators fully recognize the value of their assets – both their knowledge of the end user and their highly developed, and evolving, transaction-based billing mechanisms. Mobile operators need broadcasters. The voice and messaging market is maturing in Europe, and operators need new revenue streams. The obvious answer is entertainment applications where content is provided to the customer, and it is the broadcast industry which has this experience – but mobile operators will not supplant the traditional role of the broadcaster.

On the other hand, broadcasters need mobile operators. The world is becoming increasingly personalised, and the mobile network’s abilities to communicate with, and bill, individual customers are very valuable assets. The broadcaster will not replace the mobile operator.

As Chief Executive of the Virtual Centre of Excellence in Mobile & Personal Communications – Mobile VCE – Walter Tuttlebee heads up a unique not-for-profit company established by the mobile phone industry and academia to undertake long-term, industry-steered, collaborative research (http://www.mobilevce.com). His role entails strong interaction with both academic researchers and Mobile VCE’s industrial member companies.

Prior to joining Mobile VCE, Dr Tuttlebee led industry R&D teams in 2nd and 3rd generation mobile communications, and operated in a Business Development role in both personal communications and digital broadcasting. He is series editor for the new Wiley Series on Software Radio, and editor of two books in the series. He holds an MBA from Cranfield and a PhD from Southampton, both in the UK, and is a Senior Member of the IEEE, a Fellow of the IEE and a Fellow of the RSA.

Derek Babb is the Technology Manager, Advanced Technology Group at Samsung Electronics Research Institute, a division of Samsung Electronics (UK) Ltd. He has over 20 years engineering and technology experience in telecommunications systems, mainly in mobile technology. In the past he has worked for the BBC, Multitone Electronics, Plessey Military Communications and Ericsson Mobile Platforms.

James Irvine is a lecturer in the Communications Division at Strathclyde University, Glasgow. He has worked on a number of European collaborative projects and is currently an Academic Coordinator within the Virtual Centre of Excellence in Mobile & Personal Communications – Mobile VCE.

Dr Irvine is co-author of *Digital Mobile Communications and the TETRA System* and *Data Communications and Networks: An Engineering Approach*, published by Wiley. His third book, *Introduction to Mobile Communication Systems and Networks* is due to be published in 2003. He is a Senior Member of the Institution of Electronic and Electrical Engineers, a member of the Board of Governors of the IEEE Vehicular Technology Society, and Editor of *VTS News*.

Georges Martinez works for Motorola Labs, France and Kevin Worrall for Crown Castle, UK.
Both industries must be mindful of each other’s needs. Attempts at solutions which involve convergence are unlikely to succeed, as commercial pressures will require companies to maintain tight control of their systems, whereas an approach based on co-operation and the interworking of autonomous systems will be able to deliver significant benefits. The combination of high-quality technical research and the collaborative and open culture within Mobile VCE holds good prospects for its industrial members to work alongside each other, building trust and identifying pragmatic and practical routes to new services and revenue streams, to the benefit of both industries, over the coming years.

**Acknowledgement**

The work reported in this article has formed part of the Core 3 Research Programme of the Virtual Centre of Excellence in Mobile & Personal Communications, Mobile VCE, http://www.mobilevce.com, whose funding support, including that of EPSRC, is gratefully acknowledged. Fully-detailed technical reports on this research are available to Industrial Members of Mobile VCE.

**Bibliography**


[4] Special issue on Security for Mobility