The Universal Mobile Telecommunications System represents the emerging European standard for next-generation cellular systems that transmit data as well as voice on a global basis.

UMTS: The Fusion of Fixed and Mobile Networking

Donal O'Mahony
Trinity College, Dublin

Cellular telecommunications technology is evolving from analog and digital mobile telephony systems into flexible voice-and-data systems that offer users complete global mobility. Systems based on analog transmission were termed first-generation systems and had limited capabilities. Second-generation systems are based on digital transmission and offer some advanced user services (see the sidebar on the next page, "Evolution of Cellular Systems"). The industry is now looking to the next generation of systems, which is expected to provide full personal and terminal mobility between dense metropolitan environments and sparsely populated regions around the globe.

In Europe, the name given to the future third-generation system is the Universal Mobile Telecommunications System. This article introduces UMTS technology and looks at the choices facing system designers now and in the years ahead. To help negotiate the landscape of technical and regulatory acronyms that accompany this story, see the sidebar, "Mobile Telecommunications Glossary."

WHAT IS UMTS?

UMTS does not at present refer to any concrete specification for a mobile communications service. Rather, it represents the consensus of ideas among the major interest groups in the European mobile communications sector. The Research in Advanced Communications for

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EVOLUTION OF CELLULAR SYSTEMS

Mobile cellular telephony has been available to users around the world for many years. In the United States, the Advanced Mobile Phone Service (AMPS) was pioneered by Bell Laboratories in the 1970s, while the same general services were provided in Europe by systems such as Nordic Mobile Telephony (NMT) and Total Access Communications Systems (TACS). These systems were based on analog transmission; they are designated *first-generation systems*.

In 1982, the Conference for European Post and Telecommunications (CEPT) established a group to design a Pan-European telephony system. This work was taken up by the European Telecommunications Standards Institute (ETSI), a body whose members are drawn from European manufacturers, network operators, users, and others. The work resulted in the Global System for Mobile (GSM) Communications standard, which proved exceptionally popular and the basis for European *second-generation systems*. The original technology has been extended in capability and applied to many different operating frequency bands. By 1997, GSM or its derivatives was established in over 100 countries worldwide. It is predicted that by 2001, GSM will have a combined subscriber base of 300 million involving more than 300 operators in 130 countries.

In the United States, the popular analog AMPS system evolved to become a second-generation mobile telephony service through the introduction of two new services that can operate side-by-side within the same frequency spectrum.[1] The first is the IS-54 North American Digital Cellular (NADC) system, adopted in 1992; it uses AMPS signaling to reserve resources, but transfers speech in digital form once they are reserved. The second is a more advanced system called IS-95; it uses spread-spectrum modulation techniques, but also operates side-by-side with the older AMPS traffic.

In Japan, a completely new digital system called Personal Digital Cellular (PDC) was adopted,[1] rather than evolving something from the multiplicity of existing analog systems. PDC shares some properties with NADC in terms of modulation schemes, but it is more akin to Europe's GSM in terms of capabilities. For cordless applications, the Japanese also developed a digital Personal Handyphone System (PHS), which has gained widespread acceptance.

While each of these three global regions was migrating from first-generation analog systems to successor digital systems with different characteristics, the International Telecommunications Union was attempting to build consensus on a global third-generation digital system. In 1985, an interim working party was set up to devise a Future Public Land Mobile Telecommunications System (FPLMTS). This name was subsequently replaced with the more manageable title of International Mobile Telecommunications 2000 (IMT-2000).[2]

While few would disagree with the goal of working toward a single mobile communications service that would operate globally, the reality is that each region—Europe, the US, and Japan—comes from a different starting point and wants to make the transition from second- to third-generation as painless as possible for themselves. To effectively represent its positions at a global level, the European mobile communications industry has come together to develop the Universal Mobile Telecommunications System—its vision of third-generation mobile systems—and the steps required to evolve toward it.

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Europe (RACE) program—a major research initiative sponsored by the European Union from 1987 to 1994—contributed substantially to the UMTS concept[1] through a suite of individual projects that investigated air interfaces, high-speed operation, network structure, network planning, and other important issues. The follow-on program, Advanced Communications Technologies and Services (ACTS), is developing these issues further,[2] and includes a number of projects that will demonstrate UMTS capabilities.

In December 1996, more than 60 organizations representing operators, equipment manufacturers, information industry companies, and regulators came together to form the **UMTS Forum**, which acts as a focal point for industry views on UMTS.

On the standardization front, the European Telecommunications Standards Institute (ETSI) established a special group to work on UMTS. The group has defined objectives[3] and a number of scenarios[4] detailing how the current European mobile systems could migrate to UMTS. In May 1997, the European Commission also entered the process, soliciting the views of industry and the public as to what, if any, regulation is required to assist with timely development of UMTS. In October, the EC released its policy position on further development of this technology.[5]

Many mobile and fixed network services are already in widespread use. It is therefore envisioned that UMTS will integrate with existing services, and permit user and terminal mobility among them. Thus, a user in a building that has a mix of fixed and mobile terminals should be able to access network services by registering on any terminal. In the case of a mobile terminal, users could move from a pic-

MOBILE TELECOMMUNICATIONS GLOSSARY

ACTS	Advanced Communications Technologies and Services—Research program sponsored by the European Union.
B-ISDN	Broadband Integrated Services Digital Network—Standard for signaling in broadband networks.
CDPD	Cellular Digital Packet Data—North American standard for transferring packet data over cellular phone channels.
COBUCO	Cordless Business Communications—European collaborative project funded under the ACTS program to develop a UMTS demonstrator employing DECT technology as the radio access network.
DECT	Digital European Cordless Telecommunications—Standard for cordless phones.
EXODUS	Experiments On the Deployment of UmtS—European collaborative project funded under the ACTS program to identify transition paths from second- to third-generation systems.
GPRS	General Packet Radio Service—Standard for transferring packet data to and from GSM phones.
GSM	Global System for Mobile Communications—European standard for second-generation digital communications.
HCSD	High-Speed Circuit Switched Data—Standard for transferring high-speed data over aggregated GSM channels.
IMT-2000	International Mobile Telecommunications 2000—Evolving global standard for third-generation mobile communications.
IMUN	International Mobile User Number—Number used to dial a subscriber in third-generation mobile networks.
IN	Intelligent Network—Architecture for providing advanced services in telecommunications networks.
ISDN	Integrated Services Digital Network—Circuit-switched digital network service.
LANE	LAN Emulation—ATM Forum standard for emulating a local area network across an ATM network.
MBS	Mobile Broadband Services—Name given to the provision of very high bit-rate services over wireless channels.
MPOA	Multi-Protocol Over ATM—ATM Forum standard to link a number of local networks across an ATM backbone catering to many different network protocols.
PHS	Personal Handyphone System—Japanese standard for cordless phones.
PSTN	Public Switched Telephone Network—Conventional phone network.
RACE	Research in Advanced Communications for Europe—Research program sponsored by the European Union.
RAINBOW	Radio Independent Broadband on Wireless—European collaborative project funded under the ACTS program to develop a generic UMTS access infrastructure.
S-PCS	Satellite Personal Communications System—Use of satellites to provide ubiquitous mobile communications.
TACS	Total Access Communications System—Standard for analog telephony deployed widely in Europe.
UMTS	Universal Mobile Telecommunications System—European evolving standard for third-generation mobile communications.
UPT	Universal Personal Telephony—Evolving standard for the provision of personal mobility across many different kinds of fixed and mobile networks.
WARC	World Administrative Radio Conference—Regular meeting of global authorities to decide on allocation of spectrum.

ocell inside the building to a neighborhood microcell or macro-cell when they exit the building (see Figure 1). In areas of sparse population or where users are moving at high speed, they should be able to switch to wireless services provided by satellite. The movement between these different services should be as seamless as possible with a consistent service environment maintained at all times.

In keeping with the overall trend in networking, UMTS is expected to make higher bandwidths available both for telephony services (in the form of high-quality speech) and for data users (in the form of flexible bandwidth on demand up to whatever ceiling is reasonable in terms of radio spectrum availability). In Phase 1 of ETSI's migration plan,[4] this extends to a ceiling of 2 Mbps per user, with higher bandwidths coming later.

TECHNOLOGY CHOICES

As UMTS research and standardization activities progress, the vision for it becomes more detailed. This process has surfaced several issues that must be addressed. This section describes the technology choices facing system designers in relation to UMTS.

Spectrum Usage

As part of its effort to foster a single third-generation standard worldwide, the ITUs first act under its IMT-2000 initiative was to reserve an amount of radio spectrum for the new global mobile standard. At the 1992 World Administrative Radio Conference (WARC-92), the bands of 1,885 to 2,025 MHz and 2,110 to 2,200 MHz were specified globally for IMT-2000. In addition, the bands of 1,980 to 2,010 MHz and 2,170 to 2,200 MHz were reserved for the satellite component of the proposed global service.

Although the intention was to reserve this bank of spectrum on a worldwide basis for IMT-2000, the Federal Communications Commission (FCC) in the United States preempted the availability of IMT-2000 standards and engaged in a spectrum auction in late 1994,[6] which resulted in the allocation (within North America) of large portions of the bandwidth to operators providing Personal Communications Services (PCS). Diverse technologies are currently used to let users share access to these services, including a GSM derivative called PCS-1900, as well as other TDMA and CDMA schemes.

The European DECT service and the Japanese PHS service also have spectrum overlaps with the ITU/WARC-92 allocation. As a result, it is unlikely that IMT-2000—whatever form it eventually takes—will be based on a common wireless interface deployed on a worldwide basis. The best one can hope for is that existing systems operating in this part of the spectrum can evolve toward a point where some degree of integration is possible.

If existing cellular telephony systems can evolve to become an integral part of UMTS, existing spectrum in the 900- and 1,800-MHz bands may satisfy much of the demand for telephony services, with the designated UMTS spectrum being used primarily for new wideband services.

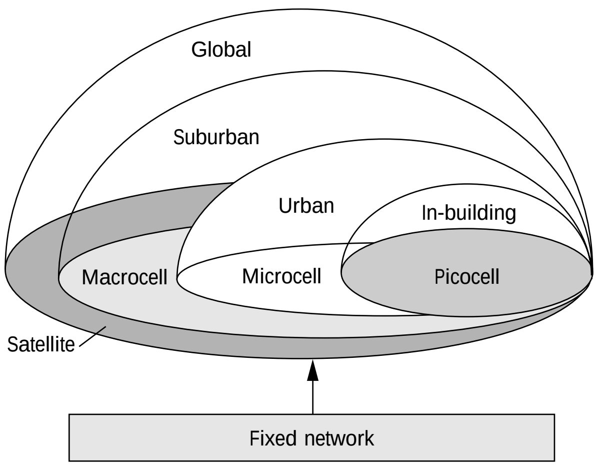

Figure 1. Use of different cell sizes in UMTS and their integration with the fixed network.

Radio Access Techniques

The ETSI standardization groups have debated the radio access method to use in sharing the new UMTS spectrum. Following a lengthy process to define requirements and develop a formal set of selection procedures, the choice was narrowed by the end of 1997 to two: Wideband Code Division Multiple Access (W-CDMA) and a hybrid technique involving time division multiplexing and CDMA. A final selection of the access method for terrestrial UMTS is scheduled for early 1998.

Deployment Schedule

Table 1 shows the regional variations in deployment schedules for third-generation mobile services. Japan's schedule is the most ambitious, aiming to deploy IMT-2000 systems by

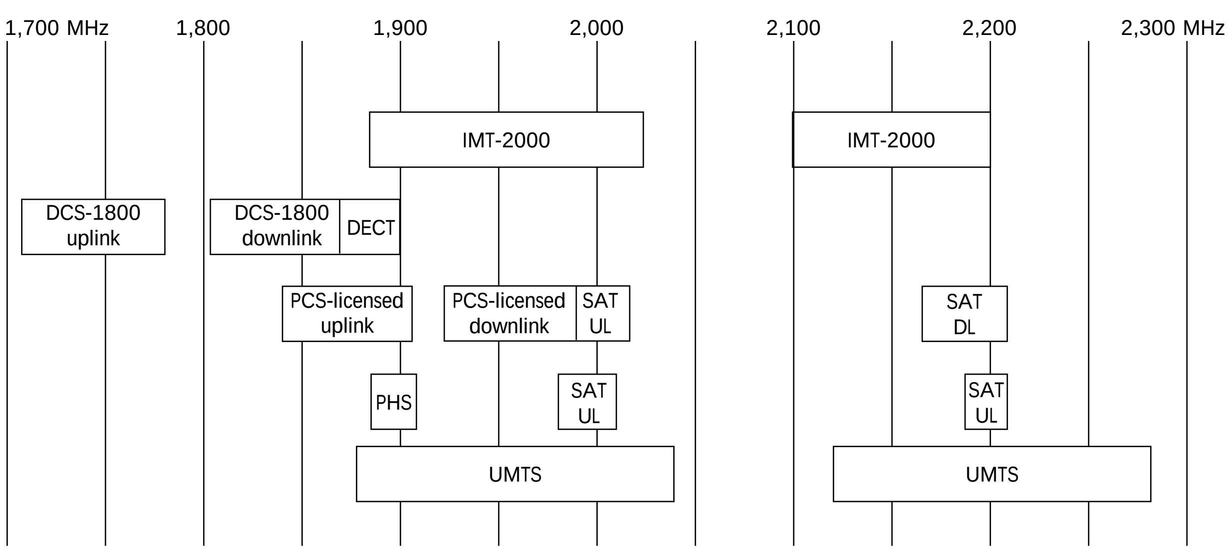

Figure 2. Spectrum allocation in different regions relative to UMTS and IMT-2000.

the year 2000. Europe aims to have final recommendations for UMTS in place by the end of 1999, with deployment of basic UMTS services by 2002 and full deployment following in 2005. The United States has a much more laissez-faire attitude, opting to let the marketplace dictate the pace of standardization. Accordingly, its deployment schedule for IMT-2000 is set loosely between 2003 and 2005.

Table 1. Regional schedules for third-generation deployment.

Region	Planned third-generation deployment
Japan	Initial deployment by the year 2000
Europe	Final recommendations by the end of 1999
	Deployment of basic services by 2002
	Full deployment in 2005
US	Sometime between 2003 and 2005

Integration with Fixed Network

In a UMTS network, personal mobility services allow a user to register on any terminal for access to network services. This capability extends to the fixed network and should go a long way toward removing any distinctions between mobile and fixed networking.

A crucial question in this context is what form the fixed network will take. Continuing the theme of evolutionary growth, UMTS has been based on the idea that current PSTN and ISDN networks are developing toward a broadband ISDN network, where end-to-end connectivity is established using ATM cells as the basic carrying mechanism. There are ongoing investigations about whether ATM should exist only in the fixed network or alternatively wireless ATM should be used across the radio path to deliver the same services to mobile terminals as would be available to a B-ISDN user.

Internet users have a contrary vision of what form the fixed network will take.[7] The Internet backbone uses ATM technology, but only to allow low-level multiplexing of multiple streams on high-speed links. The Internet is fundamentally connectionless, and its protocol structure and addressing scheme bear little similarity to their counterparts in B-ISDN. The proliferation of the Internet protocol has made the vast majority of networked data applications dependent on the availability of IP services. Recent work in resource reservation[8] and the development of Internet telephony and streaming media technology have enhanced the viability of the Internet for real-time applications.

The ATM Forum has invested a lot of work in the development of LAN Emulation (**LANE**) and Multi-Protocol Over ATM (**MPOA**) standards as mechanisms to provide an Internet service over an ATM network. Some parts of the networking community nevertheless reject these mechanisms.[9] Several alternative technologies such as IP switching and tag switching have emerged, which employ ATM technology while preserving the overall Internet architecture.

As things stand, the UMTS standards community sees the Internet as just another end-to-end data application for UMTS, and many benefits of UMTS either will not be available to users or will need to be replicated at the IP level. As an example, mobile Internet users will have to either use UMTS to contact their home point of Internet access or invoke Mobile IP services at an access point in the visited network.

Today, advanced telephony services such as freephone, televoting, and call redirect, as well as some core mobility functions, are delivered by Intelligent Network (IN) entities residing at nodes within the network and communicating with each other using sophisticated signaling protocols. The UMTS network architecture—as envisaged by major research projects in the ACTS program such as **COBUCO**, **EXODUS**, and **RAINBOW**—involves the development of additional IN functional entities and the enhancement of existing ones that deliver telephony related services.

The disparity between the UMTS and Internet visions has emerged from the rapid progress of Internet technology and deployment. When UMTS ideas were first formulated, supporting Internet technology was not a major objective. This aspect of the UMTS vision must be reworked to take a more realistic view of fixed network evolution and how UMTS can be integrated with it.

Integration of Ground and Satellite Components

Satellites are particularly useful in mobile communications.[10] Where coverage is required in areas of sparse population or from moving ships or trains, they provide an ideal solution. They are also useful for providing seamless continuity of service within a primarily terrestrial network.

By their nature, satellite systems typically achieve coverage of very large areas of the planet's surface. To provide service at an acceptable cost, they must draw in users from as much of their catchment area as possible. In this situation, a globally unique standard formulated by IMT-2000 is preferable to adopting regional solutions.

In the US, many Satellite Personal Communications Systems (S-PCS) have been proposed consisting of constellations of orbiting satellites offering service to users across the North American continent and in some cases worldwide. No comparable European proposals exist to date. The experience of operating some of these networks over the next few years will provide valuable input to the standardization of satellite components for both IMT-2000 and UMTS.

Depending on the lessons learned from these experiences, three levels of integration are possible between the satellite and terrestrial components of UMTS/IMT-2000.[10] The first level is network integration and occurs at a call level. The second level, equipment integration, requires common service standards and dual-mode terminals. The final level is system integration, where the satellite is an integral component of the terrestrial network and handover can be supported between terrestrial and satellite megacells.

Handling Personal Mobility

Personal mobility is a major UMTS objective. In practice, this means that UMTS users could approach any fixed or mobile UMTS terminal, register their presence, and then elect to access services (telephone, fax, data, and so on) on this terminal. Any calls made to an International Mobile User Number (IMUN) will use UMTS mobility management features to find the user at the terminal of registration.

A somewhat complementary service that has been standardized in ITU is the so-called Universal Personal Telecommunications. UPT aims to give users personal mobility across many different networks including PSTN, ISDN, and mobile. Users are issued unique individual UPT numbers, which can be used to contact them regardless of location. Associated with each UPT user is a *profile* that can be interrogated and modified only by the user. By manipulating this profile, the user can designate specific terminals for call delivery and call origination, and will also be able to access advanced services such as call screening and call forwarding.

Both UMTS and IMT-2000 intend to support UPT services. A minimal integration scenario is to treat the UMTS network in the same way as PSTN or ISDN, with parallel registration procedures and no UMTS access to the user's UPT profile. In a world where UMTS networks were widely deployed, the existence of UPT's personal mobility features would be somewhat superfluous, yet the advanced services that can be achieved in association with the user profile would still be desirable. An alternative approach is to support a UPT-like profile for each UMTS user and to either dispense with UPT, or somehow integrate the UPT and UMTS user profiles. Work is ongoing within the ACTS program to determine which of these approaches is the more useful.

Handling Data

Historically, mobile communications have focused on handling simple telephony services and incorporating advanced speech-related services available to users of the fixed (PSTN) network. As data becomes increasingly important, users expect to be able to employ many different applications from mobile terminals that demand efficient support of bursty data traffic.

The GSM Phase 2+ standardization takes two different approaches to this problem. The first is referred to as High Speed Circuit Switched Data.[11] HCSD works by aggregating a number of low-rate (speech) channels into a single channel offering bandwidths up to 64 Kbps and beyond. This service is quite suitable for constant-bit-rate applications such as video-telephony, but it suffers from the need to reserve bandwidth for sustained periods of time and so may not be most suited to a highly bursty data application. To address this need, GSM Phase 2+ has standardized a second service called the General Packet Radio Service.[12] GPRS offers a packet transfer and routing service for both Internet and X.25 networks. Bit rates of 14 Kbps to 115 Kbps are achievable.

In the US, the most widely deployed data scheme supported in cellular networks is the Cellular Digital Packet Data (CDPD) standard. It offers bit rates of up to 19.2 Kbps and operates as an overlay to the analog cellular network. All of the different PCS systems currently being deployed offer some form of digital data service along similar lines to the GPRS.

The DECT standard has one of the more advanced data facilities available in wireless systems.[13] Packet radio was designed into this standard from the beginning, and an error-corrected data service is available that can deliver up to 552 Kbps throughput—significantly higher than any competitive system.

Standardization of data services in UMTS has not yet begun in earnest, but different technologies will likely be used for different radio access networks with interworking being performed within the fixed network. Given the wide deployment of GSM and the need for interworking with second-generation systems, it would seem logical to base the UMTS data service on GSM's GPRS service.

Incorporating Higher Speed Services

The UMTS vision addresses bandwidths up to 2 Mbps, but the first implementations will likely operate at considerably lower speeds. There are, however, many emerging wireless technologies that can provide considerably higher speeds with small cell sizes.

The RACE and ACTS programs have developed Mobile Broadband Systems (MBS) that use spectrum in the 40- or 60-GHz bands to provide quasi-mobile access at speeds up to 155 Mbps in office and industrial environments.[14] It is hoped that when this technology matures, it can be easily integrated as an additional wireless access network for UMTS.

Migration Strategies

The design of a new system such as UMTS can be either evolutionary or revolutionary. When UMTS was originally conceived, it was futuristic relative to the cellular services available at the time. But these services, in particular GSM, have been evolving to include more and more capabilities and services. The facilities available in the core network have also been evolving to the point where Intelligent Network entities can play a much more important role in mobility management, while offering a whole new range of services to the mobile user.

In a revolutionary approach, existing cellular systems such as GSM would gradually be phased out and replaced with completely new systems, designed from scratch and offering a much greater variety of UMTS services with higher performance. While this may be appealing from a technical point of view, it ceases to be viable when the investment in second-generation mobile systems infrastructure is considered. It is also unlikely that mobile services customers would favor such an approach.

It is slightly less revolutionary to adopt a new radio access system that would deliver new UMTS services and operate with dual-mode terminals to preserve some level of compatibility with the old. In this scenario, the interworking between the two systems would take place within the fixed network.

One major consideration in UMTS design is to build on European strengths in cellular systems. Because Europe already has a huge installed base of GSM and its derivatives, and because these systems have continuously evolved from GSM Phase 1, Phase 2, and Phase 2+, it would be unwise to disrupt this progress. Thus, the ETSI strategy[15] is to evolve the core UMTS network from current GSM technology. This strategy has been amplified by industry representatives (for example, see the press release on this topic from Ericsson and others at http://www.ericsson.se/Eripress/3D_GEN.html).

In keeping with this strategy, a fully evolved GSM Phase 2+ network could act as a pre-UMTS system. More advanced capabilities could be delivered later in microcell and picocell environments by DECT or MBS, with the UMTS satellite component offering megacell coverage. New wideband full-UMTS services would be developed to work in the new spectrum allocations, with the point of interwork being the GSM core network.

As this system evolves and becomes more integrated with the B-ISDN and IN, it will gradually change to become the UMTS core network. The use of dual or multi-mode handsets should allow users to move from pre-UMTS systems to full UMTS capability and also to move between different radio access systems with full UMTS capability.

CONCLUSIONS

The UMTS goals involve the integration of evolved versions of today's second-generation digital cellular systems together with new terrestrial and satellite components. They also address a fusion of the mobile and fixed networks with a much greater role for intelligent network services. The integration scenarios take little account of the proliferation of IP-based networks, and some system redesign is necessary to correct for this.

To build on the strengths of GSM, the core UMTS network will evolve from the existing GSM service. UMTS support for data will probably be based on GPRS developed for GSM. Speeds available will vary from approximately 100 Kbps for a pre-UMTS, GSM-based system up to 2 Mbps for new UMTS radio access networks. Future mobile broadband systems may extend this up to 155 Mbps in restricted environments. The ETSI timetable for introducing these new systems shows the first equipment going into service in 2002, with full availability of third-generation UMTS services by 2005. ■

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Donal O'Mahony is a lecturer in computer science at Trinity College, where he also coordinates a research group working in the areas of networks and telecommunications. The research group addresses ongoing projects in high-speed network technologies, multimedia collaborative applications, network security, and electronic payment; it is a partner in the ACTS COBUCO European collaboration to develop a demonstrator system for third-generation mobile communications. O'Mahony received BA, BAI, and PhD degrees from Trinity College, after which he worked briefly in industry for SORD Computer Systems in Tokyo and IBM in Dublin.

Readers may contact O'Mahony at Computer Science Dept., Trinity College, Dublin 2, Ireland; e-mail Donal.OMahony@cs.tcd.ie.

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