Mobile Multimedia:
A Communication Engineering Perspective

Gabriele Kotsis[1], Alois Ferscha[2], Wolfgang Schreiner[3], Ismail Khalil Ibrahim[1]
Johannes Kepler University Linz - Austria
1) Dept. of Telecooperation
Email: {gk; ismail}@tk.uni-linz.ac.at
2) Institut für Praktische Informatik
Email: ferscha@soft.uni-linz.ac.at
3) Research Institute for Symbolic Computation (RISC-Linz)
Email: wolfgang.schreiner@risc.uni-linz.ac.at

1. Introduction

Advances in wireless communication technology specifically the development of the IEEE 802.11 protocol family and the rapid deployment and growth of GSM (and GPRS) networks have enabled a broad spectrum of novel and out breaking solutions for new applications and services. Voice services are no longer sufficient to satisfy customers' business and personal requirements. More and more people and companies are demanding for mobile access to multimedia services. Mobile multimedia seems to be the next killer application in mobile communications after the success of GSM and SMS. It enables the industry to create products and services to better meet the consumer needs. However, an innovation in itself does not guarantee success, it is necessary to be able to predict the new technology adaptation behaviour and to try to fulfil customer needs rather than wait for a demand pattern to surface.

It is beyond all expectations that mobile multimedia will create significant added value for costumers by providing mobile access to Internet-based, multimedia services, video conferencing and streaming. Mobile multimedia is one of the mainstream systems for the next generation mobile communications, featuring large voice capacity, multimedia applications and high-speed mobile data services. As for the technology, the trend in the radio frequency area is to move from narrowband to wideband with a family of standards tailored to a variety of application needs. Many enabling technologies including WCDMA, software-defined radio, intelligent antennas, and digital processing devices are greatly improving the spectral efficiency of third generation systems. In the mobile network area, the trend is to move from traditional circuit-switched systems to packet-switched programmable networks that integrate both voice and packet services, and eventually evolve towards an all-IP network [6].

While for the information explosion, the addition of mobility to data communications systems has enabled new generation of services not meaningful in a fixed network e.g., positioning-based services. However, the development of mobile multimedia services has only started and in the future we will see new application areas opening up [6][10].

Research in mobile multimedia is typically focused on bridging the gap between the high resource demands of multimedia applications and the limited bandwidth and capabilities offered by state-of-the art networking technologies and mobile devices.

Communication Engineering approaches this problem by considering not only characteristics of the networks and devices used, but also on the tasks and objectives the user is pursuing when applying / demanding mobile multimedia services and exploit this information to better adapt those services to the needs of the user.

1.1 What is mobile multimedia

Mobile multimedia is defined as a set of protocols and standards for multimedia information exchange over wireless networks. It enables information systems to process and transmit multimedia data to provide the end user with services from various areas, such as the mobile working place, mobile entertainment, mobile information retrieval and context based services.

Multimedia information as combined information presented by more than one media type (text [+pictures] [+graphics] [+sounds] [+animations] [+videos]) enriches the quality of the information and is a way to represent reality as adequate as possible. Multimedia allows the user to enhance his/her understanding of the provided information and increases the potential of person to person and person to system communication.

Mobility as one of the key drivers of mobile multimedia can be decomposed into:

User mobility: The user is forced to move from one location to location during fulfilling his activities. For him the access to information and computing resources is necessary regardless his actual position. (e.g. terminal services, VPNs to company-intern information systems)

Device mobility: User activities require a device to

fulfill his needs regardless of the location in a mobile environment (e.g. PDAs, notebooks, Cell-phones,…)
Service mobility: The service itself is mobile and can be used in different systems and move seamlessly among those systems (e.g. mobile agents).
The special requirements coming along with the mobility of users, devices, and services and specifically the requirements of multimedia as traffic type bring the need of new paradigms in software-engineering and system-development but also in non-technical issues such as the emergence of new business models and concerns about privacy, security or digital inclusion to name a few.

1.2 Why Mobile Multimedia

The key feature of mobile multimedia is around the idea of reaching customers and partners regardless of their location and delivering multimedia content to the right place at the right time. Key drivers of this technology are on the one hand technical and on the other hand business drivers.

1.2.1 Technical Drivers

Evolutions in technology pushed the penetration of the mobile multimedia market and made services in this field feasible. The miniaturization of devices and the coverage of radio networks are the key technical drivers in the field of mobile multimedia.
Miniaturization: The first mobile phones had brick-like dimensions. Their limited battery capacity and transmission range restricted the use of them in mobile environments. Actual mobile devices with multiple features fit into cases with minimal dimensions and can be (and are) carried with the user in every situation.
Radio Networks: Today's technology allows radio networks of every size for every application scenario. Nowadays public wireless wide area networks cover the bulk of areas especially in congested areas. They enable (most of the time) adequate quality of service. They allow location-independent service provision and virtual private network access.

1.2.2 Business Drivers

Market evolution: The market for mobile devices changed in the last years. Ten years ago the devices have not been really mobile (short-time battery operation, heavy and large devices) but therefore they have been expensive and affordable just for high class business-people. Shrinking devices and falling operation- (network-) costs made mobile devices to a mass-consumer-good available and affordable for everyone. The result is a dramatically subscriber growth and therefore a new increasing market for mobile multimedia services.
Service Evolution: The permanent increasing market brought more and more sophisticated services, starting in the field of telecommunication from poor quality speech-communication to real-time video conferencing. Meanwhile mobile multimedia services provide rich media content and intelligent context based services.

1.2.3 Players

The value chain of mobile multimedia services describes the players involved in the business with mobile multimedia. Every service in the field of mobile multimedia requires that their output and service fees must be divided to them considering interdependencies in the complete service life-cycle.
Network operators: They provide the end-user with the infrastructure to access services mobile via wireless networks (e.g. via GSM/GPRS/UMTS).
Content Provider: Content provider and –aggregators license content and prepare it for end-users. They collect information and services to provide customers with convenient service collection adapted for mobile use.
Fixed Internet Company: Those companies create the multimedia content. Usually they provide it already via the fixed Internet but are not specialized on mobile service provisioning. They handle the computing infrastructure and content creation.
App Developers and device manufacturers: Thy deliver hard- and software for mobile multimedia services and are not involved with any type of content creation and delivering.

2. Enabling Technologies

2.1 Wireless Wide Area Networks

After the first-generation analog mobile systems, the second-generation (2G) mobile digital systems were introduced around 1991 offering higher capacity and lower costs for network operators, while for the users, they offered short messages and low-rate data services added to speech services. Presently, the 2G systems are GSM, TDMA, PDC and cdmaOne [Figure 1]. GSM is used in most parts of the world except in Japan, were PDC is the second-generation system used [18].
An important evolution of the 2G systems, sometimes known as 2.5G, is the ability to use packet-switched solution in GPRS (General Packet Radio System). The main investment for the operators lies in the new packet-switched core network, while the extensions in the radio access network mainly is software upgrades. For the users GPRS offers the possibility to always be online and only pay for the data actually transferred. Data rates of up to 20 kbps per used time slot will be offered, and with multiple time-slots per user in the downlink, attractive services can be offered [13].

The shift to third-generation in the radio access networks is presently ongoing. The ITU efforts through IMT-2000 have led to a number of recommendations. These recommendations address areas such as user bandwidth, richness of service

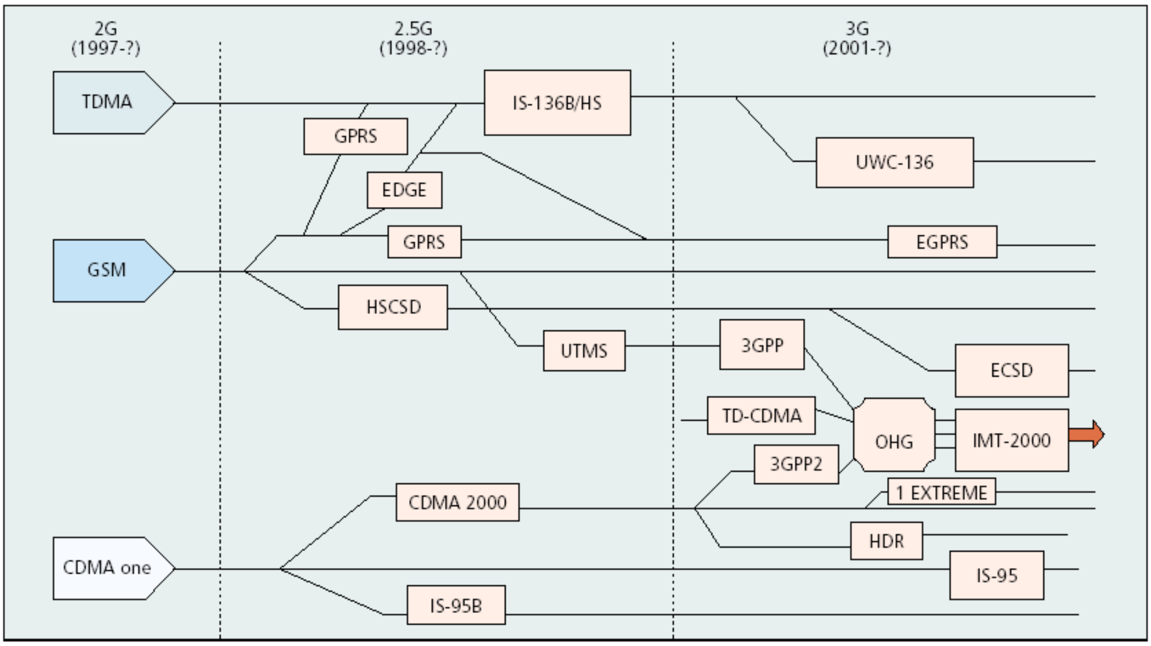

Figure 1: Evolution Scenarios towards 3G Networks [18]

offerings (multimedia services), and flexibility (networks that can support small or large numbers of subscribers). The recommendations also specify that IMT-2000 should operate in the 2-GHz band. In general, however, the ITU recommendations are mainly a set of requirements and do not specify the detailed technical solutions to meet the requirements [43][45][49].

To address the technical solutions, the ITU has solicited technical proposals from interested organizations, and then selected/approved some of those proposals. In 1998, numerous air interface technical proposals were submitted. These were reviewed by the ITU, which in 1999 selected five technologies for terrestrial service (non-satellite based). The five technologies are [15]:

- Wideband CDMA (WCDMA)
- CDMA 2000 (an evolution of IS-95 CDMA)
- TD-SCDMA (time division-synchronous CDMA)
- DECT
- UWC-136 (an evolution of IS-136)

Here is a brief description of each one of these selected technologies

Wideband CDMA (WCDMA)

The worldwide introduction of WCDMA took place in 2001 and 2002, starting in Japan and continuing to Europe. In the U.S, several 3G alternatives will be available. GSM and TDMA operators can evolve toward EDGE, with WCDMA as a possible step, while cdmaOne operators can evolve toward cdma2000 systems.

WCDMA, as specified by the third-generation partnership project (3GPP), is a 3G system operating in 5 MHz of bandwidth. Variable spreading and multicode operation is used to support a multitude of different radio access bearers. Different service classes are supported by an advanced quality-of-service (QoS) support. Data rates of up to 384 kbps for wide area coverage are provided [6][13][18].

EDGE is an evolution of GPRS with data rates of up to 60 kbps per time-slot together with improved spectrum efficiency. EDGE uses higher-order modulation together with link adaptation and incremental redundancy to optimize the radio bearer to the radio connection characteristics. Currently, additions in the form of a new set of radio access bearers to align EDGE toward WCDMA are being standardized within the R5 of the 3GPP standards. The same service classes as in the WCDMA and the same interface to the core network will be used [19][25].

CDMA 2000 (an evolution of IS-95 CDMA)

cdmaOne has evolved into cdma2000 and is available in two flavors, 1x and 3x. The former uses the same 1.25 Mhz bandwidth as cdmaOne and supports up to approximately 600 kbps, while the latter is a multi-carrier system using 3.75 Mhz and supporting approximately 2 Mbps at the moment, the focus on 3x is very limited. As a complement to 1x, the 3GPP2 has recently specified 1xEV-DO (1x Evolution-Data Only). 1xEV-DO uses a separate 1.25 Mhz carrier and supports best-effort data traffic only, using a new air interface compared to cdma2000 carrier. The peak rate in the 1x EV-DO downlink is almost 2.5 Mbps, excluding overhead. Phase two of the 1x evolution, known as 1xEV-DV (1x Evolution-Data and Voice), is currently being discussed within 3GPP2 and there are a number of proposals under consideration. The purpose is to specify an extension to cdma2000 1x in order to support high-rate data and voice on the same carrier [6][13][18].

TD-SCDMA (Time Division-Synchronous CDMA)

UTRA TDD was developed to harmonize with the FDD component. This was achieved by harmonization of important parameters of the physical layer and a common set of protocols in the higher layers are specified for both FDD and TDD [53]. TD-SCDMA has significant commonality with UTRA TDD. TD-SCDMA combines TDMA system with an adaptive CDMA component. TD-SCDMA eliminates the uplink/downlink interference, which affects other TDD methods by applying "terminal synchronization" techniques, so TD-SCDMA can support of all radio network scenarios (Wide Area - Macro, Local Area - Micro, Hot Spots - Pico and Corporate Networks) to provide full service coverage. In this way, TD-SCDMA stands alongside W-CDMA and CDMA2000 as a fully-fledged 3G standard [55].

DECT

DECT (Digital Enhanced Cordless Telecommunications) [21] is a common standard for cordless personal telephony established by ETSI. DECT is used for those cordless communication systems which supports only indoor and pedestrian environment, but it does not allow full network coverage so is not satisfied to all requirements of third generation system.

UWC-136 (an evolution of IS-136)

DECT is based on TDMA. Not same as UWC-136 (also based on TDMA), which uses two separate bandwidths (200 kHz provides medium bit rates up to 384 Kb/s and 1.6 MHz provides highest bit rates up to 2 Mb/s), DECT uses only one carrier with 1.728 MHz bandwidth. Variable bit rates are achieved by allocating different numbers of basic channels to a user. TDMA is flexible for TDD with asymmetric services and the training sequence is optimized for high bit rate services [53]

2.2 Wireless Local Area Networks

Wireless local area networks (WLANs) based on the different versions of IEEE 802.11 standard have been around for some years in the 2.4 GHz ISM band. Data rates up to 11 Mbps with reasonable indoor coverage have been offered. The next step in the WLAN evolution is the new systems developed for the 5 GHz band. Products based on two different standards, HIPERLAN 2 (H2) and IEEE 802.11a, will be available starting in early 2002. The physical layers of the two are more or less identical, with a carrier spacing of 20 MHz, OFDM modulation, and data rates up to 54 Mbps. The difference is the MAC protocol, where Hiperlan 2 has a more advanced protocol supporting QoS and mobility in a consistent way [6].

IEEE 802.11x

The IEEE 802.11 standard [28] offers several wireless LAN technologies for use in the unlicensed 2.4 and 5 GHz bands. Legacy 802.11 systems operate in 2.4 GHz band with three different PHY layers sharing the same MAC layer. These PHY layer specifications are the seldom-used infrared (IR) technology, and the more popular direct sequence spread spectrum (DSSS) and frequency-hopping spread spectrum (FHSS) systems, achieving 1 and 2 Mbps data rates. Operating under the same 802.11 MAC layer in the 2.4 GHz band, higher data rates are supported by the IEEE 802.11b PHY layer specification – 5.5. and 11 Mbps. The recent task group IEEE 802.11g has been formed to draft a standard that achieves data rates higher than 22 Mbps. Alternatively, in the 5 GHz band, the IEEE 802.11 standard offers the 802.11a specification that uses OFDM, achieving data rates up to 54 Mbps. The task group 802.11e has been created to accommodate additional QoS provisions and security requirements at the MAC layer while supporting all of the previously mentioned legacy 802.11 PHY layers.

Wi-Fi

The Wireless Ethernet Compatibility Alliance (WECA) is another trade association. WECA officially changed its name and now is known only as the Wi-Fi Alliance. Unlike the other bodies listed here WECA does not define standards. It certifies that equipment from different suppliers will interoperate successfully. To do this it has created a trademark - Wi-Fi - which equipment that they have tested as meeting a common interpretation of the 802.11b standard can use. It is important to note that while products which have been certified as Wi-Fi by WECA are interoperable with each other, product specific features may not be interoperate (and this may include some security features when interoperating with different manufacturers equipment). Without interoperability between manufacturers (or even different products from the same manufacturer) users would have to buy all their supplies from a single supplier.

HiperLAN/2

The European Telecommunications Standards Institute (ETSI) defines HiperLAN/ 2 as a flexible Radio LAN standard designed to provide high speed access up to 54 Mbps to a variety of networks including 3G mobile core networks, ATM networks and IP based networks, and also for private use as a wireless LAN system. Basic applications include data, voice and video, with specific Quality of Service (QoS) parameters taken into account. HiperLAN/2 systems can be deployed in offices, classrooms, homes, factories, hot spot areas like exhibition halls, and more generally where radio transmission is an efficient alternative or a complement to wired technology. It is worth noting that HiperLAN/ 2 has been developed in conjunction with the Japanese standards body, the Association of Radio Industries and Broadcasting.

HiperLAN/2 offers a number of advantages over 802.11a in that it incorporates quality of service (QoS) features. However, there is a long tradition of Europe developing standards which are not adopted because the US does something different.

Most observers suggest that HiperLAN/2 will loose out to 802.11a, but that some of the features developed by ETSI will be incorporated in revised versions of the 802.11a standard.

2.3 Wireless Personal Area Networks

At the same time as 3G standards are being introduced, other air interfaces have been developed and standardized. First of all, Bluetooth is already available, enabling devices to communicate over short distances. The strength of Bluetooth is low power consumption and a design enabling low-cost implementations. Bluetooth will be integrated into mobile phones, laptop computers, PDAs, and so forth. The first version of Bluetooth offers up to 700 kbps, but higher data rates, up to approximately 10 Mbps, are currently being standardized for later releases. We give brief description of the relevant existing technologies [10].

IrDA

Infrared Data association (IrDA) [30] is an international organization that creates and promotes interoperable, low-cost infrared data interconnection standards. IrDA has a set of protocols covering all layers of data transfer and, in addition, has some network management and interoperability designs. IrDA protocols have IrDA DATA as the vehicle for data delivery and IrDA CONTROL for sending the control information. In general, IrDA is used to provide wireless connectivity technologies for devices that would normally use cables for connectivity.

IrDA is a point-to-point, narrow angle (30° cone), ad-hoc data transmission standard designed to operate over a distance of 0 to 1 meter and at speeds of 9600 bps to 16 Mbps. Adapters now include the traditional upgrades to serial and parallel ports.

HomeRF

HomeRF [27] is a subset of the International Telecommunication Union (ITU) and primarily works on the development of a standard for inexpensive RF voice and data communication. The HomeRF Working Group has also developed the Shared Wireless Access Protocol (SWAP). SWAP is an industry specification that permits PCs, peripherals, cordless telephones and other devices to communicate voice and data without the usage of cables. It uses a dual protocol stack: DECT for voice, and 802.11 packets for data. It is robust, reliable, and minimizes the impact of radio interference. Its target applications are home networking, as well as remote control and automation.

Bluetooth

Bluetooth [13][42] is a high-speed, low-power microwave wireless link technology, designed to connect phones, laptops, PDAs and other portable equipment together with little or no work by the user. Unlike infrared, Bluetooth does not require line-of-sight positioning of connected units. The technology uses modifications of existing wireless LAN techniques but is most notable for its small size and low cost. Whenever any Bluetooth-enabled devices come within range of each other, they instantly transfer address information and establish small networks between each other, without the user being involved. To a large extent, Bluetooth have motivated the present WPAN attempts and conceptualizations; moreover, it constitutes the substance of the IEEE 802.15.1. WPAN standard.

IEEE 802.15 WPAN

The 802.15 WPAN [23][32][33] effort focuses on the development of consensus standards for Personal Area Networks or short distance wireless networks. These WPANs address wireless networking of portable and mobile computing devices such as PCs, PDAs, peripherals, cell phones, pagers, and consumer electronics; allowing these devices to communicate and interoperate with one another. The goal is to publish standards, recommended practices, or guides that have broad market applicability and deal effectively with the issues of coexistence and interoperability with other wired and wireless networking solutions.

3. Mobile Multimedia Services

3.1 Overview

The concept of Mobile Multimedia Services was first introduced in 1992, when the ITU realized that mobile communications was playing an increasingly important role. It began work on a project called *FPLMTS* (Future Public Land Mobile Telecommunications System), aiming to unite the world under a single standard.

Given the fact, however, that this acronym is difficult to pronounce, it was subsequently renamed *International Mobile Telecomunications—2000* (IMT-2000).

IMT-2000 is a single family of compatible standards defined by a set of ITU-R Recommendations. The main objectives for IMT-2000 are [46][47]:

- High data rates, 144 Kbps/384 Kbps for high mobility users with full coverage and 2 Mbps for low mobility users with limited coverage.
- Capability for multimedia application and all mobile applications.
- high spectrum efficiency compared to existing systems
- high flexibility to introduce new services
- high degree of commonality of design worldwide
- Use of a small pocket terminal with seamless global roaming.

The main applications will not only on traditional voice communications, but also on services such as e-mail, short messages, multimedia, simultaneous voice and data and the broadband integrated service digital network (B-ISDN) access [47].

Progress has also been made in the development of other signal processing techniques and concepts for use in tomorrow's wireless systems. These include smart antennas and diversity techniques, better receivers, and hand over and power control algorithms with higher performance [6].

3.2 Classification of Services

Mobile multimedia services aims to combine the Internet, telephones, and broadcast media into a single device [47][48].
To achieve this, IMT-2000 systems have been designed with six broad classes of service in mind. None of them are yet set in hardware but they are useful for regulators planning coverage and capacity, and perhaps for people buying terminals when they finally become available.
It's likely that 3G devices will be rated according to the types of service they can access, from a simple phone to a powerful computer.
Three of the service classes are already present to some extent on 2G networks, while three more are new and involve mobile multimedia. In order of increasing data rate,

- **Voice.** Even in the age of high-speed data, this is still regarded as the "killer app" for the mobile market. 3G will offer call quality at least as good as the fixed telephone network, possibly with higher quality available at extra cost. Voicemail will also be standard and eventually integrated fully with email through computerized voice recognition and synthesis.
- **Messaging.** This is an extension of paging, combined with Internet email. Unlike the text-only messaging services built into some 2G systems, 3G will allow email attachments. It can also be used for payment and electronic ticketing.
- **Switched Data.** This includes faxing and dial-up access to corporate networks or the Internet. With always-on connections available, dial-up access ought to be obsolete, so this is mainly included to support legacy equipment. In 3G terms, *legacy* means any product that doesn't support a fully packet-switched network.
- **Medium Multimedia.** This is likely to be the most popular 3G service. Its downstream data rate is ideal for Web surfing. Other applications include collaborative working, games, and location-based maps.
- **High Multimedia.** This can be used for very high-speed Internet access, as well as for high-definition video and CD-quality audio on demand. Another possible application is online shopping for "intangible" products that can be delivered over the air; for example, music or a program for a mobile computer.
- **Interactive High Multimedia.** This can be used for fairly high-quality videoconferencing or videophones, and for telepresence, a combination of videoconference and collaborative working.

The data rates of these services are shown in Table 1, together with their level of asymmetry and switching mode.

These services refer to three basic levels [whyless.com] by which these services are structured according to the dependencies among these services

1. **Basic Level Services**: Those services form the building blocks of other more complex applications and services e.g., voice, messaging, data retrieval, video, etc., and can

Table 1: Service Characteristics Characteristics [49]

Services	*User nominal bit rate [kbit/s]*	*Effective call Duration [s]*	*User net bit rate [kbit/s]*	*Coding factor*	*Asymmetry factor*	*Service bandwidth [kbit/s]*
High interactive MM	128	144	128	2	1/1	256/256
High MM	2000	53	1509	2	0.005/1	15/3200
Medium MM	384	14	286	2	0.026/1	15/572
Switched data	14	156	14.4	3	1/1	43/43
Simple messaging	14	30	10.67	2	1/1	22/22
Speech	16	60	16	1,75	1/1	28/28

be used as stand alone services or form the ingredients of higher level services and applications

2. **Value Added Services**: Those services form the intermediate level services formed by one or more basic level services. VAS offer optimised functionality to suit the needs of diverse professional groups. Examples of such services are wireless home networking, high data rate PAN, high density networks, P2P communication collaboration, Internet/Intranet access, video conferencing, telemetry, location based services, payments, and UMS

3. **High Level Applications**: Those address the specific requirements and interests of professional or consumer user groups. These are functionally stand-alone and serve the full range of user needs. They are formed by supporting services. Examples can be business applications, transaction management, information applications, entertainment applications, telematics, construction, electronic healthcare, provision, e-government, e-learning, wireless home networking, etc,

The above taxonomy refers to the functionality of the service and the group of users it targets. In the context of mobile multimedia, the basic level services refer to the collection, sharing and exchange of multimedia data, while the value added level refers to the provision and distribution of the multimedia information, and the high level applications is concerned about the usage and consumption of the data.

4. About this special issue

Within this special issue on advances in mobile multimedia, we will bring more insights on the key issues that have already been presented above. We have selected four papers from the best papers presented at MoMM2003: The International Conference on Advances in Mobile Multimedia, with one invited paper and one tech note to cover the whole range of mobile multimedia from data retrieval to data indexing and from context awareness to reachability of services, and from energy efficiency to security.

The first paper by Maria Indrawan et al. From Monash University, Australia presents a novel mobile agents architecture, which allows minimum redundancy of data transmission in a client server database connection in a frequent disconnections environment. The system supports disconnections events caused by network failure or client's power failure.

The paper by Agustinus Borgy Waluyo et al. from Monash University too introduces a Global Index for a multi channel indexing scheme. They developed a simulation model to analyze the performance of this scheme. The simulation model incorporates requests that return a single index and two indexes. They also study the effect of skew request distribution in the query performance. They concluded that Global Index provides a considerably better access time.

Rene Mayrhofer et al. from Johannes Kepler University Linz, Austria present an architecture that allows mobile devices to continuously recognize current and anticipate future user context. The major challenges are (1) that context recognition and prediction should be embedded in mobile devices with limited resources, (2) that learning and adaptation should happen on-line without explicit training phases and (3) that user intervention should be kept to a minimum with non-obtrusive user interaction. To accomplish this, the presented architecture consists of four major parts: feature extraction, classification, labelling and prediction. The available sensors provide a multi-dimensional, highly heterogeneous input vector as input to the classification step, realized by data clustering. Labelling associates recognized context classes with meaningful names specified by the user, and prediction allows forecasting future user context for proactive behaviour.

Reinhard Kronsteiner from Johannes Kepler University Linz, Austria introduces in his tech note a notion to classify services based on their reachability and provide a vision for service filtering in mobile multimedia.

While Lodewijk T. Smit et al. from the University of Twente, Netherlands present a control system that adapts a WCDMA receiver at run-time to minimize the energy consumption while providing an adequate Quality of Service (QoS). The adaptation is done at run-time, because of the dynamic environment of a mobile receiver. Simulations show that run-time adaptation to the environment decreases the energy consumption of a receiver and also improves other QoS parameters, such as a higher throughput and a lower frame error rate.

The last paper was an invited paper from Edgar R. Weippl from the Technical University of Vienna. This paper firstly addresses security aspects of mobile communication networks (WLAN, Bluetooth, Infrared, GSM/GPRS) and mobile devices. Secondly it elaborates on the security requirements (integrity, secrecy and availability) and solutions to protect multimedia content. Based on these findings specific requirements and implementation concepts for security of mobile multimedia are finally presented. The major contribution is the discussion of restrictions that hardware and software of mobile devices impose on established security solutions for multimedia content

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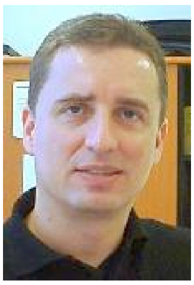
Univ. Prof. Mag. Dr. Gabriele Kotsis - Gabriele Kotsis received her master degree in 1991 (honoured with the Award of the Austrian Computer Society), her PhD in 1995 (honoured with the Heinz-Zemanek Preis) and the venia docendi in 2000 (computer science, from the University of Vienna). She was working as a researcher and teacher at the University of Vienna (1991-2001), at the Vienna University for Economics and Business Administration (2001) and at the Copenhagen Business School (2002). Since December 2002 she is holding a full professor position at the Telecooperation Department at the Johannes Kepler University of Linz. Her research interests include performance management of computer systems and networks, workgroup computing, mobile and internet computing, telemedia and telecooperation. She has experience in national and international research project in those areas, including for example the EU-funded international BISANTE project on network traffic modelling and simulation, where she was technical leader, or the EMMUS project on Multimedia Usability, where she was project coordinator. Gabriele Kotsis is author of numerous publications in international conferences and journals and is co-editor of several books. She is member of the Austrian computer Society, of IEEE and ACM. She is actively participating in the organization of international conferences and workshops.

Prof. Dr. Alois Ferscha received the Mag. degree in 1984, and a PhD in business informatics in 1990, both from the University of Vienna, Austria. From 1986 through 2000 he was with the Department of Applied Computer Science at the University of Vienna at the levels of assistant and associate professor. In 2000 he joined the University of Linz as full professor where he is now head of the department for Practical Computer Science. Prof. Ferscha has published more than 60 technical papers on topics related to parallel and distributed computing, like e.g. Computer Aided Parallel Software Engineering, Performance Oriented Distributed/Parallel Program Development, Parallel and Distributed Discrete Event Simulation, Performance Modeling/Analysis of Parallel Systems and Parallel Visual Programming. Currently he is focussed on Pervasive Computing, Embedded Software Systems, Wireless Communication, Multiuser Cooperation, Distributed Interaction and Distributed Interactive Simulation. He has been the project leader of several national and international research projects like e.g.: Network Computing, Performance Analysis of Parallel Systems and their Workload, Parallel Simulation of Very Large Office Workflow Models, Distributed Simulation on High Performance Parallel Computer Architectures, Modelling and Analysis of Time Constrained and Hierarchical Systems (MATCH, HCM), Broadband Integrated Satellite Network Traffic Evaluation (BISANTE, ESPRIT IV) and Distributed Cooperative Environments (COOPERATE) and Virtual Enterprises. Currently he is pursuing project work related to context based application frameworks in a "Wireless Campus" network, public community displays with wireless remote controls, geo-enhanced mobile navigation systems, RFID based realtime notification systems, wearable computing and embedded internet application frameworks.
He has been a visiting researcher at the Dipartimento di Informatica, Universita di Torino, Italy, at the Dipartimento di Informatica, Universita di Genoa, Italy, at the Computer Science Department, University of Maryland at College Park, College Park, Maryland, U.S.A., and at the Department of Computer and Information Sciences, University of Oregon, Eugene, Oregon, U.S.A. He has served on the committees of several conferences like Pervasive Computing, UMBICOMP, WWW, PADS, DIS-RT, SIGMETRICS, MASCOTS, TOOLS, PNPM, ICS, etc. Prof. Ferscha is member of the OCG, GI, ACM, IEEE and holds the Heinz-Zemanek Award for distinguished contributions in computer science.



Dr. Wolfgang Schreiner was born 1967 in Linz, Austria. Since 2002 he is Associate Professor for Practical Computer Science at the Johannes Kepler University Linz, Austria. Since 2001 he holds the Director of the Degree Programme "Engineering for Computer-based Learning" at the University of Applied Sciences in Hagenberg, Austria. Various research projects are guided by him as a director, currently the project "A Framework for Brokering Distributed Mathematical Services" sponsored by the Austrian Science Foundation. Further he is a regular program Committee member of EuroPVM/MPI, DAPSYS, and various other conferences. Dr. Schreiner is a regular referee of Concurrency and Computation: Practice and Experience, Journal of Symbolic Computation, EuroPar, and various other journals, conferences, EU programmes. Dr. Schreiner has experience as a developer / codeveloper of various parallel/distributed software systems (Distributed Maple, DAJ, PACLIB, and others). He has 33 refereed publications in journals, conference proceedings, academic publications. His research interests are in parallel and distributed computing, formal methods in computer science and elearning.

Dr. Ismail Khalil Ibrahim (ismail@tk.uni-linz.ac.at) is an Assistant Professor at the department of Telecooperation, Johannes Kepler University Linz since October 2002. Dr. Ibrahim holds a B.Sc. in Electrical Engineering, from the University of Technology, Baghdad, Iraq (1985), M.Sc., and Ph.D. (cum laude) in Computer Engineering and Information Systems from Gadjah Mada University - Indonesia (1998, 2001 respectively). Before joining Johannes Kepler University Linz, he was a research fellow at the Intelligent System Group at Utrecht University, Netherlands from 2001-2002 and the project manager of AgenCom project Software Competence Center Hagenberg - Austria from 2000-2001. He worked in the University of Technology - Baghdad Iraq from 1985-1990, in the Human Resources Training and Development Institute - Iraq from 1990-1996, in Gadjah Mada University -Indonesia from 1996-2000. His main research interests lay in the fields of E-commerce and Multimedia Applications, Mobile Multimedia Applications and Services, Database Applications and Techniques for the Web, Practical Experiences and Applications in Information Integration Systems, Agents for Information Retrieval and Knowledge Discovery, XML and Semi-structured Data Management, Information Systems Management and Development, Information Technology: Impact, Economic Analysis. Ismail is a member of ACM, SIGMOD, SIGKDD, SIGecom, member of the Iraqi Engineers Association (IEA), overseas Collaborator in the E-Commerce Lab at the National University of Singapore, editorial Board of the Columbian Journal of Computing (Revista Colombiana de ComputaciÛn). He is the organizing committee chair of the international workshop (later conference) on Information Integration and Web-based Applications & Services; IIWAS'99 (15-17 November 1999, Yogyakarta, Indonesia), IIWAS'00 (26-28 September 2000, Yogyakarta, Indonesia), iiWAS2001 (10-12 September 2001, Linz, Austria), and the General Conference Chairman of IIWAS2002 (10-12 September 2002, Bandung, Indonesia). His work has been published and presented at various conferences. He is also a reviewer for several conferences and journals.