Mobile Broadband Services: Classification, Characterization, and Deployment Scenarios

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ABSTRACT

A classification for mobile broadband services and applications is proposed that distinguishes between interactive and distribution services, and identifies the types of information supporting each one. A taxonomy is also proposed for applications' characterization parameters, divided into five different types: service characteristics, traffic and communications parameters, service components, and operation environments. Because the multiservice traffic analysis of a mobile broadband system, with a given mixture of applications, requires the definition of their main operation environments, the respective deployment scenarios are defined. By incorporating these classifications and available forecast information, predictions of broadband application usage in deployment scenarios such as residential, business, and industrial markets are presented.

INTRODUCTION

Around 10 years from now, mobile broadband systems (MBSs) [1] will play an important role in the mobile communications market, mostly in urban areas to cover hotspots in the center of large cities, where very high demand is foreseen. However, today there is still some difficulty in the identification of the main services and potential applications of such systems, primarily due to the emerging nature of future applications and today's lack of customer interest in those contents or applications, which is delaying the deployment of broadband access wired networks. One of the main obstacles to its introduction consisted of the insistence on developing these services only from the technical point of view of telecommunications and computer engineers, hence not considering proper marketing input about what people really need.

Moreover, even the set of applications for Universal Mobile Telecommunications System (UMTS) is not yet completely defined. The problem partly arises from the lack of accurate marketing input on the development of applications (i.e., answers to questions like: What do clients need? What price would they pay for them? What will the market growth be?), and also from ergonomic design aspects of portable terminals supporting multimedia information, which can ultimately determine customer acceptance and the level of subscriber base for those systems. Customers would like to use these new services just as they use the phone: hang on, dial, and talk.

MBSs are expected to support simultaneous provision of several services to single or multiple users. Due to the diversity of characteristics of the services to be supported, different requirements arise for resource usage and service component access by various applications; each application supported by these services has access to various service components. The amount of resources that must be available in each cell depends on the mixture of supported applications, and also the total number of users.

The deployment scenario of each anticipated application, in terms of usage, is one of the important aspects to be determined. Although there are currently only few forecast results available for mobile communications, the Research and Development on Advanced Communications Technologies in Europe — Tool for Introduction Scenarios and Techno-Economic Evaluation of the Access Network (RACE-TITAN) project has already done some estimations for narrow-, wide-, and broadband applications in the residential market of fixed networks [2, 3], and European Telecommunications Standard Institute — Radio Equipment and Systems (ETSI-RES) [4], the UMTS Forum, [5] and the RACE-MBS project [6] have also presented some forecasts for future wireless and mobile broadband systems.

In this article the available data about mobile broadband services/applications classification is put together and their characterization parameters are identified, which enables some insight into new approaches to performance analysis in MBS. Because of the sensitivity of system load to application usage and other parameters (e.g., average duration, service component characteristics, and terminal mobility), an accurate identification of the deployment scenarios for such systems is need-

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ed, and of crucial importance for cellular planning purposes. Such identifiable deployment scenarios will be essential for multiservice traffic analysis and engineering purposes, thus becoming the main motivation for the realization of this work.

Based on recent UMTS forecast data [7], Global System for Mobile Communications (GSM) evolution [8], and other visions [9], in order to clarify the MBS concept we present the identification of the new UMTS/MBS boundary in terms of data rates and user mobility from the European perspective. Two different important aspects are then considered. On one hand, a classification for services and applications is proposed based on International Telecommunication Union — Telecommunication Standardization Sector (ITU-T) Recommendation I.211 [10]. It distinguishes between interactive and distribution services. On the other hand, a taxonomy is proposed for applications characterization parameters, which are divided into different types: service characteristics, traffic and communications parameters, service components and operation environments as well. Asynchronous transfer mode (ATM) terminology is used, although it is not necessary for future MBS to be based on it. The keystone perspectives for the definition of the deployment scenarios are described, and some references to previous work on applications usage for MBS, HIPERLAN (which also uses ATM as enabling technology), and UMTS are given. Because the notation used in each of those references is diverse, compatibility of notation is also worked out. A proposal for eight MBS deployment scenarios is described based on forecasts for narrow-, wide-, and broadband applications. The range of variation of the characterization parameters is first given. Finally, values for application usage and the density factor in each scenario are proposed, by combining the results available in previous work. Conclusions are drawn.

UMTS/MBS Boundary

The MBS concept is not yet completely defined, and the boundaries on data rates, operation scenarios, and mobility can be a bit dispersed. Hence, in order to differentiate MBS from other systems and present the framework of its services and applications, it is important to clarify the concepts and their evolution.

In terms of terminal mobility and supported data rates, MBS operation will begin where UMTS ends. Under RACE European R&D initiatives in mobile systems, a first definition of MBS and related systems was presented, where it was assumed that UMTS supports data rates up to 2 Mb/s in every mobility scenario [1, 9]. However, with the standardization of UMTS this concept evolved, and the current MBS/UMTS boundary is presented in Fig. 1 [7, 8]. The associated staircase shape shows that 2 Mb/s is only being achieved by movable terminals in UMTS, whereas slow and fast mobile terminals are accessing communications up to 384 and 144 kb/s, respectively.

Besides, the concept of GSM evolved, and new modes are beginning to operate: High Speed Circuit Switched Data (HSCSD), General Packet Radio System (GPRS), and Enhanced Data Rates for GSM Evolution (EDGE). Although a staircase shape is also likely to appear at the upper

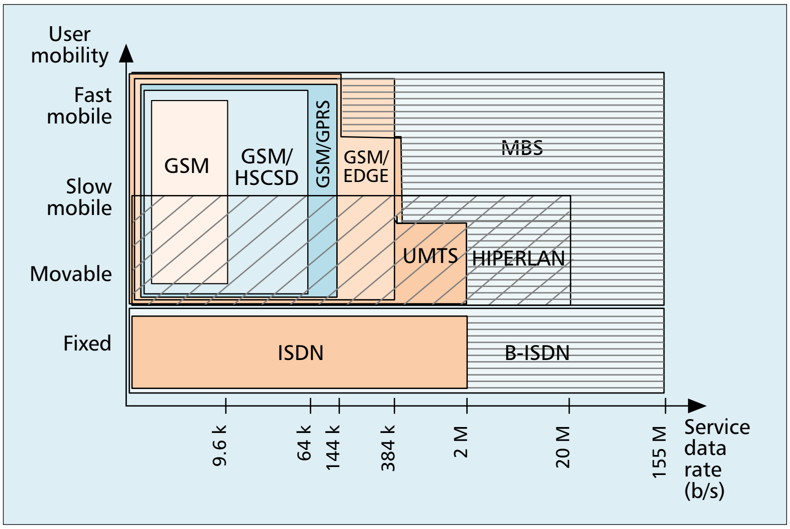

Figure 1. *UMTS/MBS boundary.*

data rates in MBS, corresponding to limitations in achievable data rates for higher-mobility scenarios as well, 155 Mb/s is still considered achievable.

Finally, it is worth noting that because MBS is a microcellular system, where propagation is mainly in line of sight (LoS), a drawback is identified in its operation scenarios: its deployment in rural areas seems to be impracticable.

Broadband Services Classification

The classification of broadband services and applications is done according to ITU-T Recommendation I.211 [10], which is for fixed broadband integrated services digital network (B-ISDN); it includes applications with data rates in the range of MBS ones (e.g., high definition video and high multimedia applications). An application is defined as a task that requires communication of one or more information streams between two or more parties that are geographically separated, and is characterized by service characteristics, and also traffic and communications characteristics [11]. A set of applications with similar characteristics, or even a single application, can be classified as a service if they have a common set of characteristics, the service characteristics mentioned above, widely speaking. This is a general way to classify applications and group them into classes (of services), as is done in ITU-T I.211; one generalizes it for the mobile communications market.

In this context, services are first classified according to their service characteristics:

- Intrinsic time dependency (time or non-time-based , TB or NTB)
- Delivery requirements (real-time or non-real-time, RT or NRT)
- Directionality (unidirectional or bidirectional, Und or Bid)
- Symmetry of communications (symmetric or asymmetric, Sym or Asy)
- Interactivity
- Number of parties

Communications can be either Und or Bid, and the latter can be either Sym or Asy. It is also

In terms of delivery requirements, a real-time application is one that requires information delivery for immediate consumption; in contrast, non-real-time information may be stored (perhaps temporarily) at the receiving points for later consumption.

important to immediately distinguish the concepts of intrinsic time dependency and of delivery requirements. TB information must be presented at specific instants to convey its meaning, that is, time is an integral part of the information to be communicated or the information has a time component; typical TB types of information are video, audio, and animation, while NTB information includes images, graphics, and text. An application can include both TB and NTB information.

In terms of delivery requirements, an RT application [11] is one that requires information delivery for immediate consumption; in contrast, NRT information may be stored (perhaps temporarily) at the receiving points for later consumption. The former requires enough bandwidth, while the latter requires sufficient storage (and potentially bandwidth as well, if delivered at high speed). Examples are given in [11] that illustrate the difference.

According to ITU-T I.211, services can be classified as interactive or distributed [10]. Interactive services have a two-way exchange of information (other than control signaling) between two subscribers or between a subscriber and a service provider, and include the following three different categories: conversational, messaging, and retrieval services [12]. Distributed services are those whose information transfer is primarily one-way, from service provider to subscriber, and include broadcast services, where the user has no control over the presentation of the information, and cyclical services, which allow the user some measure of presentation control.

A brief description of these categories follows [12]:

- Conversational services provide the means for Bid dialog communication with Bid RT (not store-and-forward), end-to-end information transfer between two users, or between a user and a service provider host.
- Messaging services offer user-to-user NRT communication between individual users via storage units with store and forward, mailbox, and/or message handling (e.g., information editing, processing, and conversion) functions.
- Retrieval services provide the user the capability to retrieve information stored in information centers (i.e., in general, available for public use). This information is sent to the user on demand only, with the possibility of being retrieved on an individual basis.
- Broadcast services provide a continuous flow of information, which is distributed from a central source to an unlimited number of authorized receivers connected to the network. Each user can access this flow of information, but has no control over it (e.g., the starting time or order of the presentation of the broadcast information).
- Cyclical services allow distributing information from a central source to a large number of users. However, the information is provided as a sequence of information entities (e.g., frames) with cyclical repetition. So the user has the ability of individual access to the cyclical distributed information, and can control start and order of presentation.

The basic service components are audio, video and data. Moreover, audio can be subdivided into voice (VOI) and high-fidelity audio (HIF), video can be supported by interactive video (IVI), and high definition video (HDV), whereas data can support low (LOD), medium (MED), and high data rates (HID). An alternative hypothesis for data would be to divide it into RT and NRT [8].

Besides the audio component, which will not be relevant for MBS traffic analysis purposes, the following types of information are identified in the Recommendation: moving pictures or video, document (multimedia), data, text, graphics, and still images. From these, several combinations can be distinguished [10]. The classification of mobile communications services in terms of I. 211 categories and types of information is done in Table 1, where some wireless and mobile specific ones were added to those referred to by the Recommendation. It is worthwhile to note that since service components are directly related with the types of information supporting each application, these hierarchies organize the applications according to the service components that will support them.

For this set of 21 applications, the related service characteristics are presented in Table 1, except for interactivity (because every application is interactive, even TV programs distribution, considered here already with a return channel) and number of parties: conversational and messaging interactive services are one-to-one communications (except videoconference, which is one-to-many); retrieval interactive services are one-to-one communications, whereas distribution services are one-to-many communications.

Characterization Parameters

Besides the service characteristics, already presented, one can identify the following characterization parameters for mobile broadband applications: traffic, communications, service components (and their statistical behavior) and the operation environment (where terminal mobility is an important aspect). The scenarios of mobility are characterized by a triangular distribution for the velocity, with average velocity V_{av} = 0, 1, 10, 15 and 22.5 ms^{-1}, for the static (ST), pedestrian (PD), urban (UB), main road (MR), and highway (HW) scenarios, respectively. The remaining characterization parameters are the following [11, 13]:

Traffic characteristics
- Traffic generation process (e.g., Poisson or Bernoulli)
- Distribution of duration
- Average duration
- Transmission rate
- Latency/delay

Communication requirements
- Burstiness
- Class of service
- Error guarantees

Service components
- Distribution of the generation process (e.g., Poisson or Bernoulli)
- Distribution of duration
- Average duration
- The number of times each is accessed

Operation environments
- Framework
- Nature of applications:a business (BUS) or familiar (FAM)
- Environment: indoors (Ind) or outdoors (Outd)

Service hierarchies	Type of information	Examples of broadband services	Examples of applications	Service characteristics			
				Intrinsic time dep.	Delivery reqs.	Direc-tionaity	Symm./asymm.
Interactive, conversational	Moving pictures and sound	HD videotelephony	1. Tele-education				Sym/Asy
		ISDN videoconference	2. Tele-advertising				
		Video surveillance	3. Mobile video surveillance	TB	RT		
		Video/audio information transmission service	4. HDTV outside broadcast				
	Data	High-speed unrestricted information Tx. service	5. Wireless LAN interconnection		NRT/RT		Asy
		High volume file transfer service – FTP	6. Data file transfer (FTP)	NTB	RT	Bid	
	Document (multimedia)	High resolution image communications service	7. Professional images	TB/NTB	RT		
		Mixed document communications service	8. Desktop multimedia				
			9. Mobile emergency services				
			10. Mobile repair assistance	TB	RT		Sym
			11. Mobile teleworking				
			12. Freight and fleet management				
Interactive, messaging	Mixed documents	Multimedia mail	13. Electronic mailbox service for multimedia	TB	NRT	Bid	Asy
Interactive retrieval	Text, data, graphics, sound, still images, moving pictures	Broadband videotex	14. E-commerce	TB			
			15. Multimedia library		RT		
			16. Tourist information	NTB		Bid	
		Data retrieval service	17. Remote procedure call				Asy
		Multimedia retrieval service	18. Urban guidance	TB	NRT/RT		
			19. Assistance in travel				
Distributed broadcast	Video	MPEG2–4	20. TV programs distribution	TB	RT	Bid	Asy
Distributed cyclical	Text, graphics, sound, and still images	Full channel broadcast videography	21. E-newspaper	TB	NRT	Bid	Asy

Table 1. *Classification of services and applications in terms of categories and types of information.*

- Mobility scenario (ST, PD, UB, MR and HW)
- Service provision: public (PUB) or private (PRI)
- Deployment scenario

From the traffic characteristics, the data rate, R_b, determines the classification of applications in low-MBS ($R_b \leq 384$ kb/s), wideband (384 kb/s $< R_b \leq 2$ Mb/s), or broadband ($R_b > 2$ Mb/s), according to Fig. 1. It is also important to accurately describe the assumptions on latency/delay. Absolute delay, or latency, is one of the key quality of service (QoS) performance parameters that must be satisfied by the broadband network [14]. To provide interactive response to viewers the response time between a user action and its effect should be less than 100 ms. To support network-based video games, a response time of 50 ms or less is required to support twitch actions. This puts an upper bound on the transmission times in each direction, which imposes minimum up- and downstream bandwidth requirements. By definition, latency requirements only apply to RT applications [14]; thus, there is no latency requirement for NRT applications, although the associated delay is identified as a QoS issue.

From the communications characteristics, burstiness is defined as the ratio between the peak bit rate and average bit rate [12]; several types of communication are highly bursty in nature. If this feature were adequately reflected in network design, considerable economizing in network design should be achieved. Regarding classes of service, and according to ITU-T terminology, the service traffic may be classified into:

- Isochronous traffic (ISO), to be circuit-switched in order to avoid time delay variations (integrity should be guaranteed in case of congestion)
- Non-isochronous traffic (NISO), to be fragmented into independently delivered and switched packets (out of sequence also)

To support broadband applications and based on QoS parameters, the following five specific service classes must be supported: constant bit rate (CBR), RT variable bit-rate (RT-VBR), both isochronous; and NRT variable bit rate (NRT-VBR), available bit rate (ABR), and unspecified bit rate (UBR); the last three are nonisochronous.

Keystone Perspectives for Deployment Scenarios

The RACE-MBS Project

In the perspective of the MBS project, mobile applications can be divided into movable, slow (< 36 km/h), and fast mobile, each having differ-

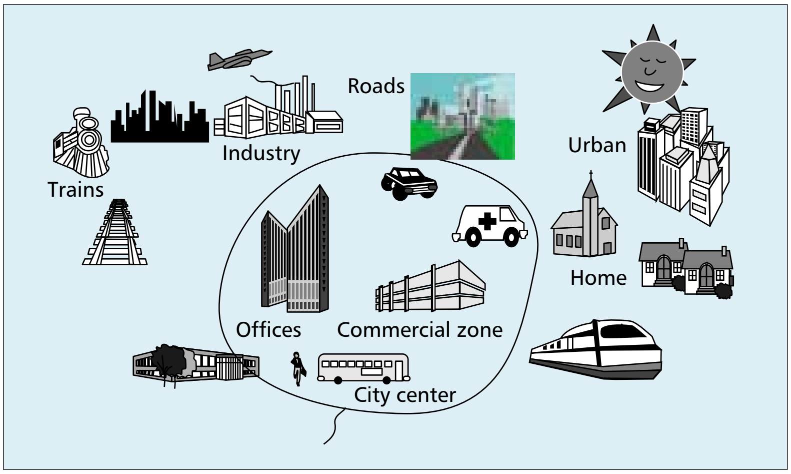

Figure 2. *MBS deployment scenarios.*

ent associated data rates [6, Table 4.1]. The fast mobile ones are city guidance, freight and fleet management, emergency, pictorial data for travel, public transport information, electronic newspaper, traffic advice, high definition TV (HDTV) contribution, audio-visual library, and surveillance of property. The ones associated with slow mobility are access to banking services, special needs (health), repair assistance, computer-aided design (CAD) interconnection, and HD videophone; the movable ones are teleconsultation and wireless LAN (WLAN).

The MBS project has also identified the following user groups and estimated their market penetration:

- Emergency professionals — 70 percent
- Commuters — 30 percent
- Mobile/on-call professionals — 50 percent
- Families/tourists — 20 percent
- Specialist group — not related to other applications — market penetration not determined

The following five geographical areas have also been identified: primary roads, city centers, residential areas, industrial areas, and hotspots. Estimations have been made for mature MBS at the busy hour rate, that is, the percentage of total potential users active during the busiest hour [6]: these values are used here as a basis for the definition of various scenarios in a geographical area.

ETSI HIPERLAN

ETSI has identified the following three deployment scenarios for HIPERLAN [4]: office, ,ndustry, and studio (TV, radio, or recording). The usage of applications deployed in those scenarios is presented in [4, Tables 9–11], as well as their average data rate; different sets of applications exist in each scenario. In this work these values are the basis for the cases of MBS deployment scenarios with movable or low-mobility terminals.

UMTS Forum

The UMTS Forum has identified six operational environments [5]:

- CBD — City business district (CBD) (in building)
- Suburban (in building or on street)
- Home (in building)
- Urban (pedestrian)
- Urban (vehicular)
- Rural indoor and outdoor

The density of potential users per square kilometer and the foreseen cell types have also been identified in low (pedestrian), medium, and full (high) mobility scenarios.

It was assumed, at least initially, that services are deployed on a platform based on the existing Digital Enhanced Cordless Telecommunications (DECT) and GSM. However, UMTS capability will be higher than that of GSM, also depending on service bit rates/classes and the use of low-/high-mobility terminals. It is foreseen that by 2010 the cell radii will be at the limit (e.g., 75 m for CBD, 2 km for suburban cells, and 600 m for urban cells), and further reduction may not be economically feasible [5]. UMTS penetration figures for 2005 and 2010 in each operating environment can be extracted from these reports for each service class [5, Table 3.3]. These figures are based on extensive market research within Europe and represent the fraction of the density of potential users for each of the operation environments in [5, Table 3.1].

In order to achieve the number of active users, it is necessary to know the busy hour connection attempt, *BHCA*, which is defined as the ratio between the total number of connections and the total number of subscribers in the considered area measured during the busy hour [15] (values are presented in [5, Table 3.4]).

Notation and Definitions

Different notations are adopted in various sources [4–6]; therefore, in order to have a common notation some definitions follow. Since one is dealing with applications beyond simple voice service, the term *connection* is used in this article instead of *call*. The total number of application j subscribers during the busy hour, M_j, is given as a function of the penetration, P_j, by $M_j = P_j \cdot M$, where M is the total number of potential users.

The *BHCA* of application j is given by the ratio between the total number of active connections of application j, N_{connsj}, and the total number of subscribers using it in the considered area measured during the busy hour, or

$$BHCA_j = \frac{N_{conns\,j}}{M_j}, \quad (1)$$

the total number of application j active connections being

$$N_{conns\,j} = BHCA_j \cdot P_j \cdot M. \quad (2)$$

The usage of application j, U_j, is defined by the percentage of application connections relative to the total number of active applications, and can be obtained as a function of $BHCA_j$ in a given deployment scenario by

$$U_j = \frac{N_{conns\,j}}{\sum_i N_{conns\,j}} = \frac{BHCA_j \cdot P_j}{\sum_i BHCA_j \cdot P_i}, \quad (3)$$

where the sum is done for all applications operating in the considered scenario.

Another measure for application j "usage" is the busy hour rate, BHR_j, given by the ratio between the total number of active application connections j and the total number of potential users, that is,

$$BHR_j = \frac{N_{conns\,j}}{M} = \frac{N_{conns\,j} \cdot P_j}{M_j}. \quad (4)$$

From this, the following relation exists:

$$BHR_j = BHCA_j \cdot P_j. \quad (5)$$

It leads to the following equation for the usage of application j as a function of the busy hour rate

$$U_j = \frac{BHR_j}{\sum_i BHR_i} \quad (6)$$

These definitions allow using data from each of the references in a uniform manner.

Deployment Scenarios

Types of Environments

It is still difficult to have a clear view of all operation environments in MBS. However, it is already possible to clearly distinguish the following ones (Fig. 2):

- Business city center (BCC), vehicular or pedestrian
- Urban residential areas (URB), vehicular or pedestrian
- Primary roads (ROA), including highways
- Trains (TRA)
- Commercial xones (COM), large public places
- Offices (OFF), buildings, not residential
- Industry (IND), large factories plant
- Home (HOM), rooms in residences

Besides the residential market we also consider business, mixed (half business, half residential), and Industrial, with different assumptions for demand.

RACE-TITAN Forecasts

Forecasts for demand (defined as a percentage of the total market) have been extracted from the RACE-TITAN project for the residential market. From 2005 to 2010 it is foreseen that the increase in demand for such multimedia applications will be:

- ISDN applications (< 144 kb/s): 20–25 percent
- Wideband applications ([144, 2000] kb/s): 10–15 percent
- Broadband applications ([2, 8] Mb/s): 2–5 percent

One can assume that applications with data rates in the range [144, 384] kb/s will be supported by MBS (designated low MBS). Consequently, one has considered as an approximation that in 2010, from ISDN applications (25 percent), 2/5 of the total demand (i.e., 10 percent) can be included as low MBS applications and the remaining 3/5 (i.e., 15 percent) ISDN data applications.

From the UMTS forecasts for 2005 one can also conclude that in the mobile market, from ISDN applications, 18 percent are going to be ISDN data (< 144 kb/s), whereas only around 2 percent are going to be low MBS applications ([144, 384] kb/s). This means that in 2010 the usage of these low MBS applications (10 percent), relative to others in the mobile market, will be five times larger than in 2005. However, as the demand is normalized to the total usage of all applications, these quantities do not exactly reflect the increase in the total number of users, which will possibly lead to an additional increase of low MBS application usage.

<table>
<tr><th rowspan="2">Services</th><th rowspan="2">Data rates [kb/s]</th><th colspan="6">Demand [%]</th></tr>
<tr><th colspan="2">Residential</th><th colspan="2">Mixed</th><th colspan="2">Business</th></tr>
<tr><td>Voice</td><td>–</td><td colspan="2">55</td><td colspan="2">40</td><td colspan="2">25</td></tr>
<tr><td>ISDN data</td><td>< 144</td><td colspan="2">15</td><td colspan="2">15</td><td colspan="2">15</td></tr>
<tr><td>Low MBS</td><td>[144,384]</td><td>10</td><td rowspan="3">30</td><td>15</td><td rowspan="3">45</td><td>20</td><td rowspan="3">60</td></tr>
<tr><td>Wideband</td><td>]384, 2000]</td><td>15</td><td>20</td><td>25</td></tr>
<tr><td>Broadband</td><td>> 2000</td><td>5</td><td>10</td><td>15</td></tr>
</table>

Table 2. *Assumptions for the various markets.*

Proposal for Mobile Broadband Communications

From the data available for MBS and HIPERLAN (data rates higher than 2 Mb/s) and UMTS (applications with data rates from 144 up to 2 Mb/s) in the cases presented, it is possible to do an updated extrapolation for mobile broadband communications. Because the data from the RACE-TITAN project is for the residential market, some changes had to be made for the business and mixed markets (Table 2). One foresees the demand for wide- and broadband applications increasing 5 percent from the residential to the mixed market and also from the mixed to business ones, corresponding to a decrease in traditional markets, mainly voice. Although these estimations may look too aggressive for applications including TB RT video and high multimedia, perhaps they are not. Considering that these applications will only be introduced/available for wide public use in the context of UMTS and beyond, when the difficulties in ergonomic design of the handsets are solved, we strongly believes that a phenomenon comparable to mobile Internet in imode will occur (most Japanese people are experiencing their first contact with the Internet using i-mode terminals, and it is a huge commercial success). In view of these facts, the forecasts for MBS-only usage are those in Table 3. Different from RACE-TITAN, in this work it was assumed that data rates up to 32 Mb/s can be achieved in MBS. Even higher data rates, up to 155 Mb/s, will be achieved in the future (e.g., with the ABR service class, i.e., a VBR class with a minimum bandwidth guarantee).

Values are included for the industrial market, assuming that broadband applications have the same usage as in the business market, whereas low MBS applications have lower usage, resulting in higher usage of wideband ones. One further considers that the residential market corresponds to the URB and HOM deployment scenarios, mixed to the ROA, TRA, and COM

MBS usage (percentage of the market)		Residential	Mixed	Business	Industrial
Low MBS	[144,384] kb/s	33%	33%	33%	22%
Wideband	]384, 2000] kb/s	50%	45%	42%	53%
Broadband	> 2 Mb/s	17%	22%	25%	25%

Table 3. *MBS-alone usage for each of the markets.*

ones, and business to the BCC and OFF ones.

Applications

Parameters and Usage

Following the discussion from an earlier section, in Table 4 we present values for the traffic and communications parameters, and the operation environments as well.

Values for the usage of each application are proposed for the eight ddployment scenarios (Table 5). The envisaged maximum data rates are also presented in order to establish the type of applications (low -MBS, wide- or broadband). The density factors (number of users per net area, e.g., total area of the streets to be covered or actual coverage area in a commercial zone) are also proposed for every scenario [6].

The following assumptions are considered:

Applications	Traffic characteristics			Communications characteristics			Operation environments			
	R_b (kb/s)	Avg. dur. [min]	Latency/ delay (ms)	Burstiness	Service class	BER	Nature	Environment	Mobility scenario	Service provision
Low-MBS										
ISDN videoconference	384	30–45	200	1–5	ISO&CBR/ RT-VBR				St/H	PUB
Data file transfer (FTP)	384	Few seconds	1000	1–50	NISO& CBR	10^{-6}	BUS/ FAM	Ind/ Outd	All	PUB/ PRI
Desktop multimedia (Web browsing)	384	1–10	NRT	1–20	ISO& RT-VBR					
Broadband videotex (e-commerce)	384	–	500	1–20	ISO& RT-VBR					
Wideband										
Emailbox for multimedia	1500	0.1–3	5 min	1–20	NISO& UBR	10^{-6}			All	PUB/ PRI
Remote procedure call	1500	–	–	1–50	NISO& ABR	10^{-6}–10^{-4}				
HD videotelephony	2000	3	200	1–5	ISO&CBR/ RT-VBR		BUS/ FAM	Ind/ Outd	MR/H	PUB
Mobile teleworking	2000	15–25	500	1–20	ISO/CBR (VBR)					
Assistance in travel	2000	20–180	500	1–5	ISO&CBR/ RT-VBR					
Urban guidance	2000	5–10	500	1–5	ISO&CBR/ RT-VBR	10^{-6}				
Mobile video surveillance	2000	120	200	1–5	ISO&CBR RT-VBR		BUS	Ind/ Outd	All	PUB/ PRI
Tourist information	2000	15	500	1–20	ISO& RT-VBR		BUS/ FAM	Ind/ Outd		
E-newspaper	2000	20	500	1–5	ISO&CBR					
Broadband										
Mobile repair assistance	2400	20–40	200	1–5	ISO&CBR (VBR)		BUS	Outd	St/PED/ URB	PUB/ PRI
Multimedia library	2400	–	500	1–20	ISO& RT-VBR	10^{-6}	BUS/ FAM	Ind/ Outd	All	
Mobile emergency services	2800	20–45	200	1–5	ISO& CBR (VBR)		BUS	Outd	St/URB/ M R/H	
TV programs (MPEG2-4)	8000	90	500	1	ISO&CBR		BUS/ FAM	Ind/ Outd		PUB/ PRI
Professional images	10,000	6–20	1000	1–20	ISO&CBR (VBR)	10^{-6}		Ind/ Outd	All	
HDTV outside broadcast	10,000	50	500	1–20	ISO&CBR	10^{-10}–10^{-9}	BUS			
Wireless LAN interconnection	32,000	15	1000	1–50	NISO&UBR	10^{-6}		Ind/ Outd	St/URB/ M R/H	

Table 4. *Traffic, communications, and operation environment parameters.*

¶For low MBS applications the usage is 33 percent, except in the industrial scenario where it is 22 percent. For the former, 15 percent are from desktop multimedia (because of the importance of Web browsing), 7 percent from data transfer, 7 percent from broadband videotex for e-commerce (because of the increasing importance of this kind of application), and the remaining 4 percent from ISDN videoconference (e.g., for tele-advertising, e-commerce, and tele-education). In the industrial deployment scenario it was assumed that 15 percent of usage is from desktop multimedia and 7 percent from data transfer.

¶For wideband applications usage varies between 42 and 53 percent. Data from the MBS project [6] and HIPERLAN [4] has been used, except for emailbox for multimedia, e-newspaper, and remote procedure call, since data was not available. The names of the deployment scenarios are approximately the same as in [6], and data from *hotspots* is considered for the train and commercial zone scenarios; the home scenario is considered similar to the urban one, with slight changes in usage. In the office and industrial deployment scenarios one used data from HIPERLAN [4, Tables 9 and 10]. An example follows of how parameters have been obtained for this type of application in the BCC scenario: we considered usage of 3 percent for emailbox for multimedia, 5 percent for e-newspaper, and 3 percent for remote procedure call; next, the sum of these values was subtracted from the 42 percent of usage of wideband applications, and a value of 31 percent was obtained; finally, the usage of the remaining applications was determined as being proportional to the values for usage extracted from [6, Table 4.1], which were used as weights.

¶For broadband applications the methodology is similar to the one presented for wideband ones. Data from [6] was used, except for professional images and TV programs. Whereas professional images have high demand in business scenarios such as the office one, TV programs have higher demand in residential and mixed markets, where entertainment is more likely to occur (e.g., in the urban, home, or commercial zone deployment scenarios).

Application usage (%)	Data rate (kb/s)	BCC	URB	ROA	TRA	COM	OFF	IND	HOM
Low MBS									
ISDN videoconference	384	4	4	4	4	4	5.6		4
Data file transfer (ftp)	384	7	7	7	7	7	5.6	7	7
Desktop multimedia (Web browsing)	384	15	15	15	15	15	14.8	15	15
Broadband videotex (e-commerce)	384	7	7	7	7	7	7	7	
Total		33	33	33	33	33	33	22	33
Wideband									
Monitoring	500	–	–	–	–	–	–	11	–
Configuration data	600	–	–	–	–	–	–	1	–
Emailbox for multimedia	1500	3	3	2	3	4	7.5	7.5	4
Remote procedure call	1500	3	8	3	8	8	14	7.5	8
HD videotelephony	2000	15	11	9.8		9.2	0.9		15
Mobile teleworking	2000	7.3	2.2	3.	3.2	3.7	4.7	5	10
Assistance in travel	2000	3.6	11	16.3	4.8	5.5	3	–	1
Urban guidance	2000	1.1	3.3	3.3	3.2	3.7	1	–	0.5
Mobile video surveillance	2000	0.4	0.5	0.2	–	0.4	0.5	15	0.5
Tourist information	2000	3.6	1.0	2.1	4.8	5.5	1	–	1
E-newspaper	2000	5	10	5	10	5	9.4	–	10
Video multipoint monitoring	2000	–	–	–	–	–	–	5	–
Total		42	50	45	45	45	42	53	50
Broadband									
Freight and fleet management	2200	0.7	0.2	2.3	6	–	0.2	–	0.2
Mobile repair assistance	2400	0.2	0.1	0.3	–	1	–	3	0.1
Multimedia library	2400	7.4	4.4	5.6	–	6	6	3	3.5
Mobile emergency services	2800	1.8	0.1	1.6	–	–	–	–	0.1
TV programs (MPEG2–4)	8000	7.4	9	5	12	10.9	4.8	–	10
High-BW video multipoint monitoring	8000	–	–	–	–	–	–	0.5	–
Professional images	8000	2	1	1.5	2	2	4	2	1
HDTV outside broadcast	8000	0.1	0.	0.1	–	0.1	3	–	0.1
Control data	21,000	–	–	–	–	–	–	12.5	–
Wireless LAN interconnection	32,000	5.4	2.1	5.6	2	2	7	4	2
Total		25	17	22	22	22	25	25	17
Density factor (number of users/m^2)		0.031	0.012	0.012	0.111	0.150	0.150	0.004	0.015

Table 5. *Proposal for applications usage in each of the deployment scenarios.*

One foresees that the demand of wideband and broadband applications increases 5 percent from the Residential market to the Mixed one and also from the Mixed to the Business one, corresponding to a decrease in traditional markets, mainly voice.

In the industrial deployment scenario, from applications used in other scenarios fewer are used, while some specific new ones are considered. Thus, the values for the usage of applications common to other scenarios were adapted from the office scenario, according to what we expect their relative importance to be in the industrial scenario.

Finally, it is worth noting that the values presented for the maximum data rates are approximate, and refer to the link with higher bit rate (either the up- or downlink). Asymmetric applications (e.g., FTP) will only need such high bit rates in one direction, whereas for bursty VBR applications (e.g., desktop multimedia) the average bit rate can be much lower, leading to an improvement in resource usage and a statistical multiplexing gain.

CONCLUSIONS

The available data about mobile broadband services/applications is put together, and their characterization parameters are identified, enabling some insight on new approaches for multiservice traffic analysis in MBSs. According to ITU-T Recommendation I.211, services and applications can be distinguished as interactive and distributed ones, that is, bidirectional and unidirectional ones, broadly speaking. It also distinguishes services according to types of information, which map into service components that support them. A taxonomy is proposed for application characterization parameters, which are divided into service characteristics, traffic and communications parameters, and service components and operation environments as well, and results are provided for their range of variation.

The establishment of MBS deployment scenarios is of huge importance in the definition of the mixture of applications to be considered for multiservice traffic analysis purposes. Based on the available data from the UMTS Forum, ITU-T, and ETSI HIPERLAN, as well as some forecasts from RACE TITAN and MBS projects, we have identified the following eight environments: primary roads, business city centers, urban residential areas, trains, commercial zones, offices, industries, and homes. Moreover, they correspond to four types of market: residential, mixed, business, and industrial. By incorporating these classifications and available forecast information, predictions of broadband application usage in deployment scenarios such as residential, business, and industrial markets are presented. The predicted usage of broadband applications (> 2 Mb/s) increases from the residential market (17 percent) to the business one (25 percent), corresponding to a decrease in the usage of wideband ([384, 2000] kb/s) ones (from 50 down to 42 percent), and to a constant value for the usage of low MBS ([144, 384] kb/s) ones (33 percent); slight differences exist between the business and industrial markets. However, the actual number of users also depends on the density factor, which varies from 0.004 users/m^2 in industries to 0.150 users/m^2 in hotspots (e.g., offices). Although these estimations may look aggressive, perhaps they are not; for example, if a phenomenon like mobile Internet in Japanese imode occurs for these brand new mobile applications.

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