E-UMTS Services and Applications Characterisation

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ABSTRACT

Different points of view are compared for the classification of Enhanced UMTS (E-UMTS) mixture of applications, namely ITU-T I.211, UMTS Forum and 3GPP ones. A set of characterisation parameters (e.g., data rate, tolerance to delay and error, and session duration) is described, and a first assignment of parameter values for these services is proposed. An overview of E-UMTS deployment scenarios and supported services is then presented, based on the views of nowadays-relevant players. The influence of mobility in E-UMTS is discussed, and mobility models and scenarios are given. Deployment and mobility scenarios include expected population density, mobility characteristics, and usage of service mix, for each environment. A number of nearly thirty applications are considered. However, a reduced set of applications is needed for simulations purposes, and scenarios were defined with a selection of the most relevant applications. Finally, E-UMTS traffic generation and activity models, based on population and service penetration values, were described and characterised. ON/OFF states were characterised by appropriate statistical distributions and parameters.

I. INTRODUCTION

Enhanced UMTS (E-UMTS) is a UMTS evolution step, which provides bit rates higher than 2 Mbit/s in the uplink and downlink directions over a 5 MHz frequency carrier, Fig.1.

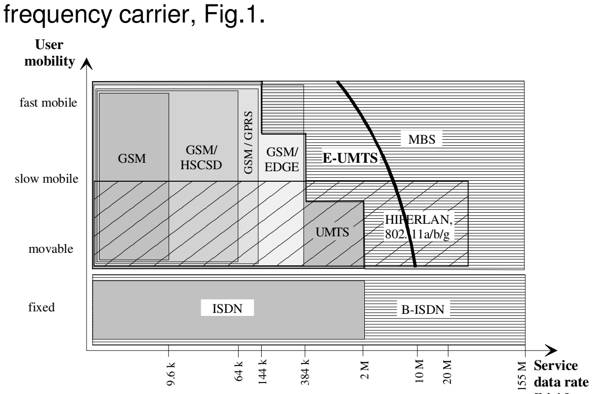

Figure 1: Enhanced UMTS concept.

It enables the provision of new wideband services and a significant reduction of the price per bit, running over flexible QoS enabled IP based access and core networks, and making possible an effective end-to-end packet based transmission. European projects (e.g., IST-SEACORN [1]) will propose a set of enhancements to UMTS, which include, among others, advanced modulation and radio transmission techniques, improved strategies for IP routing and QoS assurance.

Unlike HSDPA, which will mostly extend UMTS maximum achieved data rates for the downlink, E-UMTS will allow for expansion in both down- and uplink directions. Hence, it will support wideband real-time/time-based mobile applications with a very high system capacity, and will set the ground for an initial introduction of actual broadband mobile applications, an important step towards 4G. E-UMTS will be a first step to achieve the goal of ubiquitous and seamless communications [2], scaling system capacity for mass-market services, which implies a capacity of the order of Gbps/km^2 will be available, and starting the emergence of adaptive services and new network modes, e.g., multicast, multihop and peer-to-peer. While, in the WLAN domain, it is becoming possible with IEEE 802.11b, a, g, etc., in the mobile communications domain, E-UMTS will be a first step to achieve this goal. Furthermore, with the use of multiple devices with various radio interfaces, E-UMTS will be the first 3.5G system to support values of capacity comparable to the ones needed, and will allow for the introduction of the ABC (Always Best Connected) concept [3], even before the introduction of OFDM/WCDMA and UWB systems for 4G. In this context, instead of being a competing technology, E-UMTS will be complementary to the various types of WLANs (and other radio interfaces and access technologies).

In this paper, the available data about mobile applications characterisation parameters is put together, enabling some insight into new approaches of performance analysis in E-UMTS. In this context, parameters are divided into six different types: service, traffic, communications, session and activity, service components, and operation environments.

The effect of the proposed enhancements will be evaluated by means of simulation. For that purpose a set of services need to be used, in order to create a complete and realistic simulation framework, impacting directly on traffic generation models. These services will be accessed from a variety of operation environments each with its distinctive set of service preferences, usage patterns, and associated mobility profiles. As an answer to these services and environmental conditions a matching set of deployment strategies need to be studied, adapted, and simulated.

Terminal mobility has a great influence in most UMTS communication aspects involving either performance or traffic generation as a result of handover. Issues such as radio resource management, location management and QoS, as well as traffic handling capacity, are directly affected by mobility. The purpose of mobility models is to describe typical terminal movement so that performance analysis may be made. On the one hand, many link level simulations will require the knowledge of detailed terminal position so that the effectiveness of studied techniques such link adaptation (adaptive coding and modulation) transmission diversity and beam forming may be evaluated. On the other, some E-UMTS techniques, such as IP transport resource management, may not always require a detailed knowledge of individual terminal movement and positioning. In these cases, a mobility model that describes the average rate of handovers and cell cross-over velocity may be more convenient for traffic simulation purposes.

The **usage** of each application, i.e., the duration of connections of a given application relatively to the total duration of all application connections, is one of the most important aspects to be determined. These data will be essential for multi-service traffic analysis and engineering purposes, and it is the main motivation for the realisation of this study. Although there are nowadays few forecast results available for mobile communications, the RACE-TITAN project has already done some estimations for narrow-, wide- and broadband applications in the residential market of fixed networks [4], [5], as well as ETSI-RES [6], the UMTS Forum [7] and the RACE-MBS project [8].

To collect applications data for SEACORN simulation purposes, a pragmatic approach is followed with the intention of extracting a service framework that is possible to implement, with low complexity, and maintaining a realistic and coherent model. At the same time, a further step is taken in traffic modelling by introducing Long Range Dependence models, better adapted to wireless IP communications. These are based on recent research on field data that has concluded that traditional traffic models produce too optimistic results when used to model some data traffic. This may result in networks that are under dimensioned and therefore under-performing with respect to theoretical expectations.

The number of services and environments that has been considered initially has been integrated and condensed into a smaller set of services and service environments to meet the technical demands of the simulation tools. Without this summarisation effort the framework proposed would pose considerable difficulties to implement due to the amount of computing resources it would require from simulators. A subset of services and environments are therefore selected. Three operation environments, and four or five services result, depending on environment.

Different types of classification are presented in Section II. Section III describes characterisation parameters, while Section IV covers the range of variation of the parameters. Section V presents an overview of the UMTS Forum, ETSI HIPERLAN, RACE-MBS and RACE-TITAN projects views on service mixtures and deployment scenarios. They complement each other in supplying a background basis for the environment options to be selected for E-UMTS trials. The influence of mobility is discussed in Section VI, and a set of mobility models is given. Three models correspond to particular operation environments, and describe the behaviour of individual terminals, while the fourth looks at average tele-traffic behaviour. Section VII presents a set of scenarios that put together all components of E-UMTS deployment situations. These include expected population density, mobility characteristics and expected usage of service mix for each environment. Section VIII describes the selected set of services, environments and source traffic models to be used in E-UMTS simulations. They cover voice, interactive data (Multimedia web browsing, Instant Messaging for Multimedia) and streaming based services (Video-telephony, HD Video-telephony). Conclusions are drawn in Section IX.

II. CLASSIFICATIONS

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, being characterized by the service attributes, and also by traffic and communications characteristics. A service is defined as a generic set of applications with similar characteristics, or a single application that is significant on itself. According to ITU-T I.211, applications and services can be divided into the following different groups: interactive (conversational, messaging, and retrieval) and distribution (broadcast, and cyclical) [9], Table 1.

UMTS attempts to fulfil the Quality of Service, QoS, request from the application or the user, in order to reach this UMTS Forum and 3GPP use the following traffic classes [10]: (i) conversational, CONV, (ii) streaming, STR, (iii) interactive, INTR, and (iv) background, BACK.

Table 1: Correspondence between services and applications.

Service Hierarchies	**Type of Information**	**Examples of Broadband Services**	**Examples of Applications**	**3G framework**	
				Market	QoS
Interactive, Conversational	Sound	Sound	Voice	RV	CONV
			Voice over IP	RV	CONV
	Moving Pictures And Sound	Video-telephony	Various purposes	RV	CONV
		HD Video-telephony	Tele-education	RV	CONV
		HIMM Videoconference	Various purposes	RV	CONV
		Video-conference	Tele-advertising	CI	CONV
		Video Surveillance	Mobile Video Surveillance	MMS	CONV
	Data	High Volume File Transfer Servic.	Data File Transfer (FTP)	MIA	INTR
	Document (multimedia)	Mixed Document Communications Service	Multimedia (MM) Web Browsing	MIA	INTR
			Collaborative working	MIEA	CONV
			Mobile Tele-working	MIEA	CONV/INTR
		High-resolution Image Service	Interactive Remote Games	CI	CONV
			Still Images Communication	CI/MMS	INTR
Interactive, Messaging	Mixed Document	Multimedia Mail	Instant Messaging for MM	MMS	BACK/ INTR
Interactive, Retrieval	Text, Data, Graphics, Sound, Still Images, Moving Pictures	Broadband Videotext	Audio Streaming	RV	STR
			E-commerce	MIA	STR
			Tourist Information	LBS	INTR
		Data Retrieval Service	Remote Procedure Call	MIEA	INTR
		Multimedia Retrieval Service	Urban Guidance	CI	INTR
			Mobile Portal (Content / commerce)	CI	INTR
			Assistance in Travel	LBS	INTR
Distribution, Broadcast	Moving Pictures and Sound	Video Distribution Service	Micro movies (including video clips)	CI	STR
Distribution, Cyclical	Text, Graphics, Sound & Still Images	Full Channel Broadcast Videography	E-newspaper	CI	INTR

MIA - Mobile Internet Access; MIEA - Mobile Intranet/Extranet Access; CI - Customised Infotainment; MMS - Multimedia Messaging Service; LBS - Location-Based Services; RV - Rich Voice.

The distinguishing factor of these classes is how delay-sensitive traffic is. While the conversational class is the most delay-sensitive, the background class is the less one.

The following relation can be established between 3GPP and ITU.T I.211 classes:

- Conversational class is the same in both classifications. There is a bi-directional dialogue between live end-users.
- Multimedia streaming has to be with retrieval and broadcast classes. Information is given in a continuous flow or stream.
- Interactive class can be connected with almost every I.211 class, except broadcast. User requests data from remote equipment.
- Background class treats communications like mail interchange, and is related with I.211 messaging class.

From the market perspective [11], services are the portfolio of choices offered by services providers to users, and can be charged separately. The study presented in [11] identifies six service categories that represent the majority of the demand for 3G services over the next five years. Besides voice, applications are classified into content connectivity (Internet) and mobile ones. While the content connectivity applications can be either mobile Internet access or mobile intranet/extranet access, mobile applications are divided into three categories: customised infotainment, multimedia messaging services (MMS) and location based. A classification according to Market and QoS points of view is shown in Table 1.

III. CHARACTERIZATION PARAMETERS

Service parameters are necessary to characterize end-to-end services and their requirements. They may easily become quite numerous, perhaps too numerous for many simulations. Therefore it could be useful to distinguish parameters into service, traffic, communication, service components, activity model, and operation environments as well. From the operation environments, in the mobile domain, terminal mobility is of key relevance.

The classification of services in terms of ITU-T I.211 Recommendation categories and types of information was done in [12], for a set of 16 applications operating in an 'E-UMTS alone' environment [12], [13].

Besides these applications, E-UMTS can support some UMTS specific ones, like voice, audio streaming, voice over IP, video clip transfer, or even others, with high foreseen demand, e.g., still image transfer, mobile portals or interactive games [14].

A. Service Characteristics

The service characteristics are the following [12]:

- Intrinsic time dependency: time-based, TB, or non-TB, NTB;
- Delivery requirements: real-time, RT or non-RT, NRT;
- Directionality: unidirectional, Und, or bi-directional, Bid;
- Symmetry of the connection: Symmetric, Sym, or Asymmetric, Asy, and the respective asymmetry factor;
- Interactivity: existence or not;
- Number of parties: one-to-one, 1-1, one-to-many, 1-m, or multi-party (multi);

B. Traffic Characteristics

On the one hand, it is important to characterise the generation process for applications:

Generation process - It describes the statistical distribution of session inter-arrivals (e.g., Poisson).

Distribution of the duration - If a negative exponential distribution is used to model call duration the parameter corresponds to the mean value $1/\mu$. Other distributions such as the lognormal are also used for this purpose [15].

Average duration of connections - It refers to the connection holding time.

On the other hand, it is important to describe accurately assumptions on latency/delay and channel hierarchy/ bandwidth, i.e., data rates.

Latency/end-to-end delay - Absolute delay is one of the key QoS performance parameters that must be satisfied by the broadband network [16]. In the context of service characterization, it is the maximum transfer time (in one way) that is tolerated by the service. To provide interactive response to viewers the response time between a user action and its effect should be less than 100 ms.

Data rate - It is important to define the average data rate associated with services. Specifying the average bandwidth requirement for a 'bursty' application is a challenge, because it varies according to the duration for which the average is taken. Furthermore, the values obtained vary widely across different users (such as the ones from image browsing), even for the same applications, because everyone has a unique usage pattern.

C. Communication Characteristics

The communications characteristics consist on burstiness, service classes, BER, and protocol.

Burstiness - it is defined as the ratio between the peak and the average bit rates [17], several types of communication being highly 'bursty' in nature.

Service Classes - To support broadband applications, and based on QoS parameters, three classes of services must be supported [18]: best-effort delivery (ATM Forum ABR class of service), real-time (RT) delivery of time-based information (CBR or VBR), real-time delivery of non-time based information. ISO and NISO stand for isochronous & non-isochronous traffic, respectively [9].

Bit error rate (BER) - It is a non-dimensional variable that expresses service tolerance to uncorrected errors in the bearer service, including non-delivered information. It is calculated as the ratio between bits received with error or omitted, and the overall received bits.

Communication Protocol - The most common communication protocols [19] are User Datagram Protocol (UDP) and Transmission Control Protocol (TCP). While TCP coordinates the confirmation and retransmission of packets that are lost during a communication session, UDP does not provide any guarantees to data delivery.

D. Session and activity Model

Detailed parameters describe service behaviour in terms of traffic generation. Two levels of behaviour may be distinguished: call/session, representing traffic generation process (birth and death), and activity models. Call and session parameters follow:

- BHCA and inter-arrival time,
- Arrival distribution.

Activity models describe the relationship between active and silent periods in either direction. They are different depending on type of service, and the purpose of the model, and are the following:

- Duration and its distribution,
- Average active/inactive time,
- Active/inactive time distributions (e.g., expon.).

In E-UMTS both data and conversational communications are similarly supported as PDP context establishment. In general, up- and downlink parameter have different values.

E. Service Components

A given application can be supported by different services, having as a consequence different characteristics in terms of type of information, which are the following: sound, moving pictures or video, document (multimedia), data, text, graphics and still images. If applications have access to more than one type of information simultaneously, a simple activity/inactivity model is not enough, and a model for service components (that maps into the types of information) has to be defined for multi-service purposes. Details related to the service components (sound, data and video), and their correspondence with applications [20], were left for further work.

IV. RANGE OF VARIATION

In Table 2, the range of variation of the parameters is identified. Table 3 covers communications and traffic parameters. All applications are interactive.

Table 2: Enhanced UMTS service characteristics.

Applications	Intrinsic time dependency	Delivery requirements	Directionality	Symmetry / Assymmetry	Asymmetry factor	Nb. of parties
Voice	TB	RT	Bid	Sym	S	1-1, 1-m
Voice over IP					S	1-m
Video-telephony (Various purposes)				Sym/Asy	S	1-1
HD Video-telephony (Tele-education)					S / low	1-1
HIMM Videoconference					S	multi
Videoconference, tele-advertising					low	multi
Mobile Video Surveillance				Asy	5UL-0.001DL	1-1
Data File Transfer (FTP)	NTB				4UL-1DL	1-1
Multimedia (MM) Web Browsing	TB				1UL-5DL	1-1
Collaborative working				Sym	S	1-1, 1-m
Mobile Tele-working					S	1-1
Interactive Remote Games	TB/NTB			Asy	26UL-1000DL	1-1, 1-m
Still Images Communication	NTB				26UL-1000DL	1-1
Instant Messaging MM	TB	NRT			4UL-100DL	1-1
Audio Streaming		RT			4UL-100DL	1-1, 1-m
E-commerce					4UL-100DL	1-m
Tourist Information	NTB				4UL-100DL	1-m
Remote Procedure Call		NRT/RT			4UL-100DL	1-m
Urban Guidance	TB				5UL-1e3DL	1-m
Mobile Portal (Content/commerce)	TB/NTB	RT			1UL-5DL	1-m
Assistance in Travel	TB	NRT/RT			5UL-1e3DL	1-1
Micro movies (including video clips)	TB/NTB	RT	Und (with commands in the reverse link)		26UL-1000DL	1-m
E-newspaper	NTB	NRT	Bid		1UL-5DL	1-m

Table 3: Communication and traffic parameters.

Applications	Traffic characteristics			Communication characteristics			
	Rb [kb/s]	Avg. duration	Latency/ delay [ms]	Burstiness	Serv.Class	BER	Protocol
Voice	4-25	3	150	1	ISO&CBR/ RT-VBR	10^{-4}	UDP
Voice over IP	4-25	3	150	1	ISO&CBR/ RT-VBR	10^{-4}	UDP
Video-telephony (Various purposes)	32-384	5	200	1-5	ISO&CBR/ RT-VBR	10^{-4}	UDP
HD Video-telephony (Tele-education)	2000	30	200	1-5	ISO&CBR/ RT-VBR	10^{-4}	UDP
HIMM Videoconference	32-384	30	200	1-5	ISO&CBR/ RT-VBR	10^{-4}	UDP
Videoconference, tele-advertising	384-2000	30	200	1-5	ISO&CBR/ RT-VBR	10^{-4}	UDP
Mobile Video Surveillance	32-384	10-120	200	1-5	NISO&CBR	10^{-4}	UDP, TCP
Data File Transfer (FTP)	64-2000	1-5 s	10 s	1-50	NISO&CBR	10^{-6}	TCP
MM Web Browsing	384-2000	1-15	few sec.	1-20	ISO&RT-VBR	10^{-6}	TCP
Collaborative working	64-2000	15-50	500	1-20	ISO&CBR(VBR)	10^{-6}	TCP
Mobile Tele-working	384-2000	15-50	200	1-20	ISO&CBR(VBR)	10^{-6}	TCP
Interactive Remote Games	64-1000	10-30	50	1-30	ISO&CBR(VBR)	10^{-7}-10^{-6}	UDP, TCP
Still Images Communication	64-1000	1-10	1000	1-20	ISO&CBR(VBR)	10^{-7}-10^{-6}	TCP
Instant Messaging for MM	1000-4000	0.1-3	15 s	1-20	NISO&UBR	10^{-6}	TCP
Audio Streaming	12-128	3-60	10 s	1-5	ISO&CBR/ RT-VBR	10^{-6}	UDP, TCP
E-commerce	64-1000	5	500	1-20	ISO&RT-VBR	10^{-6}	TCP
Tourist Information	64-1000	10-15	500	1-20	ISO&RT-VBR	10^{-6}	UDP
Remote Procedure Call	64-1000	5	250	1-50	NISO&ABR	10^{-6}-10^{-4}	TCP
Urban Guidance	128-4000	5-10	1-5 s	1-5	NISO&CBR	10^{-6}	TCP
Mobile Portal (Content/commerce)	64-2000	5-15	1-5 s	1-50	ISO&RT-VBR	10^{-6}	TCP
Assistance in Travel	128-4000	20-360	500	1-5	ISO&CBT & RT-VBR	10^{-6}	TCP
Micro movies (including video clips)	64-384	3-5	10 s	1	NISO&CBR	10^{-6}	UDP
E-newspaper	1000-2000	20	500	1	ISO&RT-VBR	10^{-6}	TCP

V. HYPOTHESIS FOR 3G AND BEYOND

A. UMTS Forum Perspective

The UMTS Forum has identified six operational environments [7]: i) CBD – City business district (in building), ii) Suburban (in building or on street), iii) Home (in building), iv) Urban (pedestrian), v) Urban (vehicular) and vi) Rural in- & outdoor. The density of potential users per km^2 and the foreseen cell types have also been identified in low (pedestrian), medium and full (high) mobility scenarios.

UMTS penetration figures for years 2005 and 2010 in each operating environment can be extracted from these reports for each service class, Table 3.3 of [7]. 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 given in Table 3.1 of [7]. In order

to achieve the number of active users it is necessary to know the busy hour connection attempt, BHCA, defined as the ratio between the total number of connections and the total number of subscribers in the considered area during the busy hour [7].
New forecasts are available in [21] for the categories of voice, location based services, business MM messaging service, mobile Internet access, consumer MM messaging service, mobile Intranet/Extranet access, and customised infotainment.

B. HIPERLAN Perspective

ETSI has identified the following three deployment scenarios for HIPERLAN [6]: Office, Industry and Studio (TV, radio or recording). The usage of applications deployed in those scenarios is presented in Tables 9-11 of [6], as well as their average data rate; different sets of applications exist in each of the scenarios. In this work, these values are the basis for the cases of E-UMTS deployment scenarios with movable or low mobility terminals.

C. MBS Perspective

In the perspective of the MBS project, mobile applications can be divided into movable, slow (< 36 km/h) and fast mobile, each of them having different associated data rates, Table 4.1 of [8]. The fast mobile ones are: City Guidance, Freight and Fleet Management, Emergency, Pictorial Data for Travel, Public Transport Information, Electronic Newspaper, Traffic Advice, HDTV (High Definition Television) Contribution, Audio-visual Library and Surveillance of Property. The ones associated with slow mobility are: Access to Banking Services, Special Needs (health), Repair Assistance, CAD (Computer Added Design) Interconnection and HD Videophone; the movable ones are Tele-consultation and Wireless LAN Inter-connection. User groups have been identified, and related with the following five geographical areas: Primary roads, City centres, Residential areas, Industrial areas and Hotspots. Estimations have been made for mature MBS on the busy hour rate, i.e., the percentage of total potential users that is active during the busiest hour [8]: these values are used here as a basis for the definition of various scenarios in a geographical area. Different notations are adopted in [6], [7], [8] for the usage. In order to have a common notation some definitions are presented in [9].

D. RACE-TITAN Forecasts

From the RACE-TITAN project [4], [5] one extracted forecasts for 2010, defined as a percentage of the total residential market. Table 4 presents the adaptation of these forecasts to E-UMTS.

Table 4: E-UMTS possible scenario (high mobility).

Demand as a percentage of the market		Residential	E-UMTS
Voice	-	55 %	57%
High Interactive MM	< 144 kb/s	15 %	16 %
Narrowband	[144,384] kb/s	10 %	11 %
Wideband	]384, 2 048] kb/s	15 %	16 %
Broadband	> 2 Mb/s	5 %	-

Here, the 144 kb/s limit of TITAN-ISDN applications was extended to 384 kb/s. Applications with data rates in the range [144, 384] kb/s were designated by narrowband ones, whereas the ones with data rate lower than 144 kb/s are high interactive multimedia ones. Although E-UMTS supports data rates up to 8-10 Mb/s, in scenarios with considerable mobility (like urban, main roads, trains or even business city centre scenarios), in some cases, one is considering an upper value of 2 Mb/s.

VI. MOBILITY MODELS

The purpose of mobility models is to describe typical terminal movement so that performance analysis may be made. Two basic types of models are covered: individual terminal and tele-traffic mobility models. Individual terminal models cover indoor (office), city centre and road mobility types, while the tele-traffic mobility model deals with average values, and may be parameterised from pedestrian to highway velocities, thus covering all types of environments.

A. Office Environments

From the mobility perspective, indoor environments are characterised by slow speeds (pedestrian or slow vehicular) and relatively well defined mobility paths, determined by architectural topology and activity patterns. Each particular environment may however exhibit its own distinctive features. Among others, the following may be enumerated: home, office environments, airport and train stations, commercial zones, theatres/public diversion, and parking zones.
The particular case of office environments is characterised by a "boxy" topology, where office rooms are interconnected by passage areas, or corridors. Users will spend considerable time stationary at a desk and when in motion will move towards a particular destination using a given path. Destinations may be chosen randomly, using a uniform distribution. Two cases may be considered, concerning nature of movements. In the first one, both source and destination are an office room, while, in the other, either source or destination is a corridor position.
The important parameters are the mean ratio of room- to-corridor situated mobile terminals, r = 85%, the average time in office room, T_r, = 10min and the mobile speed, v_m = 3Km/h. Their values can be adjusted to particular environment conditions, especially the average office time and ratio ones.

B. Outdoor-to-Indoor Pedestrian - Business City Centres

As the name implies this mobility model is associated with a business city centre environment where base stations are placed outdoors but also cover internal building areas [22]. To represent city centres, the Manhattan Model, i.e., a rectangular grid of intersecting streets, is normally used. Homogeneous squared buildings, with 200 m side and 30 m wide streets could characterise the environment. This sort of environment is characterised by small areas with high buildings, high user density and pedestrian mobility.

The urban mobility model is highly related to the Manhattan-like structure defined above. In such structure, mobiles move along streets and may turn across streets with a given probability. Mobile's position is updated every 5 metres, and speed can be changed at each position update according to a given probability. The mobility model is described by the following parameters:

- Mean speed: 3 km/h.
- Minimum speed: 0 km/h.
- Standard deviation for speed (normal distribution): 0.3 km/h.
- Probability to change speed at position update: 0.2.
- Probability to turn at cross street: 0.5.

Mobiles are uniformly distributed in the street and their direction is randomly chosen at initialisation.

C. Vehicular Environment

Vehicular environment applies to scenarios in urban and suburban areas outside the rise core, where the buildings have nearly uniform height, and are characterised by larger cells and higher transmit power.

The vehicular reference mobility model uses a pseudo-random process with semi-direct trajectories. The mobile position gets updated according to the de-correlation length and direction can change at each position update following a given probability within a sector. For reference example, it can be assumed that mobile's speed is constant, and that the mobility model is defined by the following parameters [22]:

- Speed: 36-81 km/h.
- Probability to change direction at update: 0.2.
- Maximum angle for direction update: 45º.
- De-correlation length: 20 metres.

Mobiles are uniformly distributed on the map, and their direction is randomly chosen. The cell radius is 2000 m for services up to 144 kb/s, and 500 m for data rates above 144 kb/s. The base station antenna height must be 15 meters above the average roof top height. The deployment scheme is a hexagonal cell layout with distances between base stations equal to 6 km. Tri-sectored cells should be used.

D. Flow Equilibrium Model for Traffic

The high mobility associated with E-UMTS calls for a tele-traffic analysis, where both new connections and handover connections traffic must be considered simultaneously. In a first approach, linear coverage geometries, where mobiles travel randomly through cells located end-to-end, can be considered. In a linear coverage geometry, cells are placed end-to-end, and mobiles can handover only from a cell to one of the two adjacent ones; a connection comprises successive sessions τ_1, τ_2, τ_3, ... in cells traversed by a mobile terminal, and its duration τ follows an exponential distribution whose mean is $\bar{\tau} = 1/\mu$ [23], where μ is the service rate. The channel occupancy time τ_c is the time spent by a user in communication prior to handover (or subsequent to handover) or connection completion, and also follows an exponential distribution with reasonable accuracy [24].

The cell dwell time τ_h is the residing time of a mobile within a cell. Further assuming that the dwell time is exponentially distributed with mean $\bar{\tau}_h = 1/\eta$, then the channel occupancy time is $\tau_c = \min\{\tau, \tau_h\}$, i.e., it is either the time spent in a cell before crossing the cell boundary if the connection continues, or the time until the channel is relinquished [23]. As the minimum of two exponential random variables is also exponentially distributed with parameter $\mu_c = \mu+\eta$, the mean channel occupancy time is given by

$$\bar{\tau}_c = \frac{1}{\mu_c} = \frac{1}{\mu+\eta} \qquad (1)$$

The cross-over rate, η, can be derived by knowing the average speed of terminals. As a service parameter it may be relevant if there is a typical mobility pattern associated with the service. E-UMTS scenarios of mobility are the characterised by a triangular distribution for the velocity with average velocity, V_{av} =1, 10, 15 and 22.5 m·s^{-1}, for the pedestrian (PD), urban (UB), main roads (MR) and highways (HW) scenarios, respectively, Table 5.

For these scenarios, a triangular distribution is considered for the velocity [25], with average $V_{av} = (V_{max}+V_{min})/2$, and deviation $\Delta = (V_{max}-V_{min})/2$. This leads, to the following cross-over rate

$$\eta = \left\{ \frac{2R}{\Delta^2} \left[(V_{av}+\Delta) \cdot ln\left(\frac{V_{av}+\Delta}{V_{av}}\right) - (V_{av}-\Delta) \cdot ln\left(\frac{V_{av}}{V_{av}-\Delta}\right) \right] \right\}^{-1} \qquad (2)$$

when V_{min}, Δ>0, and, when V_{min}=0, to the limit

$$\eta = \frac{V_{av}}{2 \cdot ln(2)} \cdot \frac{1}{(2R)}. \qquad (3)$$

Table 5: Characteristics of the Scenarios of Mobility.

Scenario	V_{av}[m·s^{-1}]	Δ [m·s^{-1}]
Static	0	0
Pedestrian	1	1
Urban	10	10
Main roads	15	15
Highways	22.5	12.5

Different types of mobility are assumed for each application in each of the scenarios.

VII. E-UMTS SCENARIOS DEFINITION

It is still difficult the have a clear view for the deployment scenarios in E-UMTS. However, it is already possible [12] to clearly distinguish the following eight deployment scenarios: i) business city centre, BCC (vehicular or pedestrian), ii) urban residential, URB (vehicular or pedestrian), iii) primary roads, ROA, iv) trains, TRA, v) commercial zones – COM (e.g., airports, railway stations, hospitals, commercial centres, universities), vi) offices, OFF (buildings), vii) industry, IND (large factories plant), and viii) home, HOM.

From the data available for UMTS (data rate from 144 kb/s up to 2 Mb/s), MBS and HIPERLAN (> 2 Mb/s), it is possible to perform an updated extrapolation for E-UMTS communications. Broadband applications (> 2 Mb/s) will only be supported in scenarios without relevant mobility; hence, the offices and industry scenarios will be defined separately. Because the data from the RACE-TITAN project is for the residential market, some changes have to be done for business and mixed (half-business / half-residential) ones, Table 6. One considers an increase of 15 % on the demand of narrow- plus wideband applications from the residential market to the mixed one, and also from the mixed to the business market, corresponding to a decrease in traditional markets, i.e., sound and voice.

Values for offices and industrial markets have slight differences compared with the business market [22], Table 7. In the context of these scenarios, new applications, like Control data, Monitoring [6], TV Programme Distribution (MPEG2-4), Wireless LAN Inter-connection and Professional Images, are considered. One further assumes that there is a correspondence between deployment scenarios and envisaged markets:

- Residential: URB, and HOM.
- Mixed: ROA, TRA, and COM.
- Business: BCC, OFF, and IND.

Table 6: Assumptions for Usage in various Markets.

Services	Data rates [kb/s]	Demand, % of the market					
		Residential		Mixed		Business	
Sound	-	57		42		27	
High Interact MM	≤ 144	16		16		16	
Narrowband	]144,384]	11	27	18.5	42	26	57
Wideband	]384,2 048]	16		23.5		31	

Table 7: Assumptions for Offices and Industry.

Services	Data rates [kb/s]	Demand [%]	
		Offices	Industry
Sound	-	25	15
High Interact. MM	≤ 144	15	10
Narrowband	]144,384]	20	20
Wideband	]384, 2 048]	25	40
Broadband	> 2048	15	15

Values are proposed for the usage of applications at the eight scenarios, Table 8.

The set of applications considered are the ones from [12] plus Broadband, Sound and High Interactive Multimedia ones [14]. In Table 8, besides values for usage, the envisaged approximated maximum data rates, R_b, are introduced for all applications, in order to establish the service class (Sound, High Interactive Multimedia, Narrow-, Wide-or Broadband). These data rates refer to the link with higher bit rate (either the up- or the downlink). Asymmetric applications (e.g., FTP) will only need such high bit rates in one of the ways. The density factors for each of the scenarios are presented as well [8]. In the business market there is a fundamental difference between the BCC scenario, and the OFF and IND ones: applications are movable (not mobile) in the latter, hence, broadband applications, with data rates up to 8 Mb/s, can be supported.

As an example, the following assumptions have been done for the business market (including BCC, OFF and IND scenarios):

- For Sound applications, while the usage is 27 % in BCC it is 25 % in OFF, and 15 % in IND, i.e., slight differences exist among them. As an example, the values for application usage in BCC are the following: Voice, 14 %, Voice over IP, 10 %, and Audio streaming, 3 %.
- High Interactive Multimedia applications have an overall usage of 16 % in BCC, 15 % in OFF, and 10 % in IND. In the case of BCC, the usage is distributed in the following way: Interactive remote games, 1.5 %, Still images communication, 3 %, Mobile portal, 3 %, Micro-movies, 1.5 %, Video-telephony, 3 %, Video-conference, 2% and Collaborative working (& tele-presence), 2%. The slight difference between OFF and IND comes from the lower usage of entertainment applications (Interactive remote games and Micro-movies).
- Narrowband applications have an usage of 26 % in BCC and 20 % both in OFF and IND. As an example, in the BCC scenarios the values for the usage are distributed in the following way: Video-conference for tele-advertising, 3.2 %, Data file transfer (ftp), 5.5 %, Multimedia Web browsing, 11.8 %, and Broadband Videotex for E-commerce, 5.5. %. While the differences to the OFF scenario are slight, there are important differences to the IND scenario [4]: one only considers 6 % of FTP usage and 14 % of Web browsing usage, while the other applications are not used.
- For Wideband applications the usage is 31 % in BCC, 25 % in OFF, and 40 % in IND.. The data from the MBS project, Table 4.1 of [8], and from HIPERLAN, Table 9 and 10 of [6], were used, except for Instant Messaging for Multimedia, E-newspaper and Remote procedure call, since data was not available. An example follows on the way that parameters have been obtained for this class of

service in the BCC scenario: one considers an usage of 2.2 % of Instant Messaging for Multimedia, 3.7 % for E-newspaper and 2.2 % of Remote procedure call; next, the sum of these values was subtracted from the 31 % of usage of Wideband applications, a value of 22.9 % being obtained; finally, this usage was distributed by the remaining applications in the Wideband service class proportionally to the values for the usage extracted from Table 4.1 of [8], which are used as weights.

- The usage of broadband applications is 15 % in OFF and IND. In OFF, one considers the following values for the usage: TV programme distribution (MPEG2-4), 4.5 %, Wireless LAN Interconnection, 6.5 %, and Professional images, 4 %. In IND one do not consider TV programme distribution because entertainment is less likely to occur. Instead one introduces an important application: Control data, with a usage of 10 %.

In other types of market, residential (URB and HOM) and mixed (ROA, TRA and COM) the procedure followed to determine the values of the usage was similar, and data for wide- and broadband applications was extracted from data for HIPERLAN [6], and MBS [8], and from Section V as well. The names of the deployment scenarios are approximately the same from [8], and the data from hotspots has been considered for the Train and Commercial Zones deployment scenarios; the Home scenario was considered as being similar to the Urban one, with slight changes in the usage, except for the one of Tele-working (higher usage at home), Assistance in Travel and Urban Guidance (lower usage at home).

Again, it is worthwhile to note that, in the industrial deployment scenario, from the applications used in other scenarios fewer applications are used (the use of entertainment applications is less likely), while some specific new ones were considered. Thus, the values for the usage of applications common to other scenarios were adapted from the office scenario, according to what one expects on what their relative importance will be in the industrial scenario.

Table 8: Proposal for Applications Usage in each Deployment Scenario.

Applications Usage [%]	R_b **[kb/s]**	**BCC**	**URB**	**ROA**	**TRA**	**COM**	**OFF**	**IND**	**HOM**
Sound									
Voice	12	14.0	29.0	21.5	21.5	21.5	13.0	7.5	29.0
Voice over IP	12	10.0	21.0	15.5	15.5	15.5	9.0	6.0	21.0
Audio Streaming	64	3.0	7.0	5.0	5.0	5.0	3.0	1.5	7.0
Total		**27.0**	**57.0**	**42.0**	**42.0**	**42.0**	**25.0**	**15.0**	**57.0**
High Interactive Multimedia (HIMM)									
Interactive remote games	128	1.5	1.5	1.5	1.5	1.5	1.0	0.0	1.5
Still images communication	128	3.0	3.0	3.0	3.0	3.0	3.0	2.5	3.0
Mobile portal	128	3.0	3.0	3.0	3.0	3.0	3.0	2.5	3.0
Micro-movies	128	1.5	1.5	1.5	1.5	1.5	1.0	0.0	1.5
Video-telephony	128	3.0	3.0	3.0	3.0	3.0	3.0	2.0	3.0
HIMM Videoconference, various purposes	128	2.0	2.0	2.0	2.0	2.0	2.0	1.5	2.0
Collaborative working (& tele-presence)	128	2.0	2.0	2.0	2.0	2.0	2.0	1.5	2.0
Total		**16.0**	**16.0**	**16.0**	**16.0**	**16.0**	**15.0**	**10.0**	**16.0**
Narrowband									
Videoconference (Tele-advertising)	384	3.2	1.5	2.2	2.2	2.2	3.0	0.0	1.5
Data File Transfer (ftp)	384	5.5	2.3	3.9	3.9	3.9	4.0	6.0	2.3
Multimedia Web Browsing	384	11.8	4.9	8.4	8.4	8.4	9.0	14.0	4.9
Broadband Videotex (E-commerce)	384	5.5	2.3	4.0	4.0	4.0	4.0	0.0	2.3
Total		**26.0**	**11.0**	**18.5**	**18.5**	**18.5**	**20.0**	**20.0**	**11.0**
Wideband									
Monitoring	480	-	-	-	-	-	-	5.0	-
Instant Messaging for Multimedia	1024	2.2	1.0	1.2	1.5	1.9	8.0	4.0	1.7
Remote Procedure Call	1024	2.2	2.5	1.8	2.0	4.0	2.0	8.0	2.5
Mobile Tele-working	1536	5.4	0.7	2.0	1.5	2.0	2.5	2.5	3.1
Assistance in Travel	1536	2.7	3.5	6.0	2.0	3.0	1.5	1.5	1.0
Urban Guidance	1536	0.8	1.1	2.0	1.5	1.9	0.5	0.5	0.5
Mobile Video Surveillance	1536	0.3	0.2	0.1	-	0.2	0.3	10.0	0.2
Tourist information	1536	2.7	0.3	1.4	2.5	3.5	0.5	0.5	0.3
E-newspaper	1536	3.7	3.2	3.0	8.0	4.0	4.7	5.0	3.2
HD Videotelephony (Tele-education)	2048	11.0	3.5	6.0	4.5	5.0	5.0	3.0	3.5
Total		**31.0**	**16.0**	**23.5**	**23.5**	**23.5**	**25.0**	**40.0**	**16.0**
Broadband									
Control data	3840	-	-	-	-	-		10.0	-
TV program. distribution (MPEG2-4)	12780	-	-	-	-	-	4.5	0.0	-
Wireless LAN Interconnection	12780	-	-	-	-	-	6.5	1.5	-
Professional Images	12780	-	-	-	-	-	4.0	3.5	-
Total							15.0	15.0	
Density Factor (Number of users / m^2)		0.031	0.012	0.012	0.111	0.150	0.150	0.004	0.015

Finally, it is worthwhile to note that the values presented for the maximum data rates are approximate, and refer to the link with higher bit rate (either the up- or the downlink). Asymmetric applications (e.g., FTP) will only need such high bit rates in one of the ways whereas, for bursty VBR applications (e.g., Desktop MM), the average bit rate can be much lower, leading to an improvement of the resource usage, and a statistical multiplexing gain occurs.
For a more complete description of the operation environments, the definition of scenarios from mobility is needed. Details are given in [26].

VIII. SOURCE TRAFFIC AND SIMULATIONS

To meet the technical demands of the simulation tools a reduced set of services and environments are therefore selected. Without this summarisation effort the framework proposed would pose considerable difficulties to implement due to the amount of computing resources it would require from simulators. As a result we have three operation environments and four or five services each depending on the environment.
Proposed applications and their relative usage are shown in Table 9. This table is obtained from Table 8 by assuming that the most significant application accounts or all the traffic usage in that service group. The envisaged approximate data rates are introduced for all applications, in accordance with the service class associated with the application (Sound, High Interactive Multimedia, narrowband, wideband or broadband). The population density factors for each of the scenarios are presented as well [9]. Data rates are aligned to existing standard values in UMTS and HSDPA.

Table 9: Proposal for Applications Usage in each of the SEACORN Simulation Deployment Scenarios.

Applications Usage [%]	Data Rate [kb/s]	OFF	BCC	VEH
Sound				
Voice (VOI)	12.2	**25.0**	**27.0**	**42.0**
High Interactive Multimedia				
Video-telephony (VTE)	128	**15.0**	**16.0**	**16.0**
Narrowband				
Multimedia Web Browsing (MWB)	384	**20.0**	**26.0**	**18.5**
Wideband				
Instant Messaging for Multimedia (IMM)	1024	**25.0**		
Assistance in Travel (ATR)	1660			**23.5**
HD Video telephony (HDT)	2048		**31.0**	
Broadband				
Wireless LAN Interconnection (WLI)	12780	**15.0**	-	-
Density Factor (users / m^2)		0.150	0.031	0.012

A. Application Traffic

The amount of generated calls is dependent on the number of potential users and the session arrival rate per user that characterises each service and environment. Call duration, and activity pattern determines traffic behaviour, Figure 2.

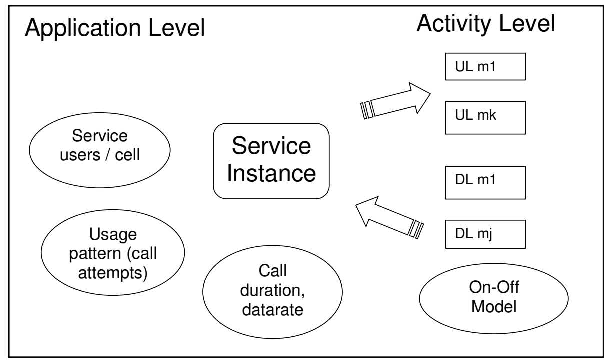

Figure 2: Application traffic

User density per environment is defined in Table 9. Penetration rates of E-UMTS services are used to account for different adoption rates between services in each year and evolution of service take-up along the years. Service penetration rates for the year 2010 are estimated extrapolating and adapting those made for UMTS [7]. They are stated in Table 10.

Table 10: E-UMTS Penetration Rates (2010).

Applications	OFF	BCC	VEH
Voice	0.3	0.3	0.3
Video-telephony	0.2	0.2	0.2
Multimedia web browsing	0.15	0.15	0.12
Instant Messaging for Multimedia	0.2	-	-
Assistance in Travel	-	-	0.2
HD Video-telephony	-	0.2	-
Wireless LAN Interconnection	0.15	-	-

The total number of application j subscribers M_j, is given as a function of the penetration, P_j, by

$$M_j = P_j \cdot M_T \qquad (4)$$

where M_T is the total population of potential users.

B. Busy Hour Call Attempt

From the values of usage one is considering in SEACORN for OFF, BCC, and VEH scenarios it is important to obtain, for each considered service, the values of the busy hour call attempts to be used in simulations. Busy hour call attempt represents in this case the total number of call attempts by all users considered in one simulation. They will correspond the users covered by a radio cell or part of a cell.

$$BHCA_j = \frac{Usage_j}{\overline{\tau}_j} \cdot M_T \cdot \overline{f} \qquad (5)$$

where M_T is the number of users in the cell, $\overline{\tau}_j$ is the average call duration and $\overline{f}$ is the average traffic per user, which can vary from 0 to 1. From the values for usage of Table 9, considering a user population of M_T = 100, one can obtain the results for the office environment, as an example, Figure 3.

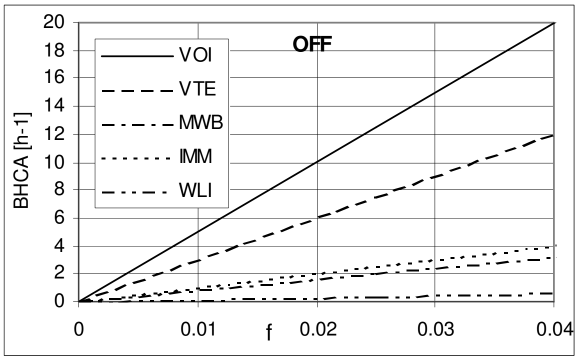

Figure 3: BHCA for the office environment (M_T = 100)

C. Call generation and traffic parameters

Call generation and traffic parameters describe service behaviour in terms of traffic generation. They include average data-rate, session arrival rate per user during the busy hour, average call duration, burstiness and symmetry factor. The term call usually refers to conversational services while session refers to data connections. Because in E-UMTS both entities are similarly supported on PDP context establishment the concept is basically the same.

It must be referred that, since uplink and downlink data-rates are not necessarily equal the data-rate parameter value refers to the higher value between the two, which in all exemplified cases is the downlink. The set of parameters that describe these services from the traffic modelling perspective are defined in Table 11. Call and session related parameters are used to model the birth and death of calls and sessions.

Session arrival rate represents the average number of calls generated per service subscriber during the busy hour. The Poisson process is used to model session arrivals. Values for session arrival rate are derived from service penetration and session duration values, considering $\overline{f}$ *=0.03*. These parameters are tightly associated for each application and deployment scenario as formulated below. Usage U_j, is expressed as a ratio between the traffic for service *j*, (derived from session arrival rate, duration and number of subscribers) and the total produced traffic, over the busy hour.

$$U_j = \frac{SessArrRate_j \cdot M_T \cdot P_j \cdot \tau_j}{\sum_i SessArrRate_i \cdot M_T \cdot P_i \cdot \tau_i} \qquad (6)$$

Table 11: Call generation & traffic parameters

Applications	Data rate [kb/s]	Session arrival rate $[h]^{-1}$			Avg.duration τ [min]	Symmetry UL/DL
		OFF	BCC	VEH		
Voice	12	0.50	0.54	0.84	3	1
Video-telephony	128	0.45	0.48	0.48	3	1
Multimedia web browsing	384	0.16	0.21	0.19	15	0,25
Instant Messaging for Multimedia	1024	0.15			15	0,05
Assistance in Travel	1536			0.11	20	0,07
HD Video-telephony	2048		0.09		30	1
Wireless LAN Interconnection	12780	0.03			60	0,25

Table 12: Application activity parameters

Applications	Active state (ON)			Inactive state (OFF)	
	Avg.[s]	Filesize[KB]	Distrib.	Avg.[s]	Distrib.
Voice	1,4s	2.14	EXP	1,7 s	Expon.
Video-telephony	τ			0	
Multimedia web browsing	5	240	Pareto	13	Pareto
Instant Messaging for Multimedia	5	640	Weibull	90	Pareto
Assistance in Travel	60	11520	Weibull	14	Pareto
HD Video-telephony	τ			0	
Wireless LAN Interconnection	5	7988	Weibull	1	Pareto

D. Session activity parameters

Session activity parameters describe the detailed aspects of traffic within a call. This is accomplished by means of an alternating active/inactive state model (ON/OFF). By defining an average duration of each period, together with an adequate statistical distribution, the activity within a call can be modelled. Video telephony applications are always active in both directions and so do not have OFF periods.

The basic model for application data normally uses a web session as a paradigm, although the model may be used for all types of data. A session is composed of a set of active periods made of packet seuences (packet calls) separated by inactivity periods. A packet call is a sequence or burst of packets, corresponding e.g. to a web page or other data item. Inactivity periods between packet call arrivals are often called reading time (or inactivity time). This model is described in [22].

Table 12 describes average active versus inactive durations, the corresponding file sizes of activity packet call periods and statistical distributions of the active and inactuve durations. It may be noted that streaming services do not exhibit inactive states therefore the ON state is equal to call duration and OFF state duration is zero.

E. Speech source model

For simulation, speech sources are based on AMR codecs with only the 12.2 kbps mode. Each AMR 12.2 kbps source is modelled with an ON/OFF model for DTX, having the following statistics:

- Voice Call Duration Distribution: Exponential, mean: 180 sec,
- Duration of On-state Distribution: Exponential, mean: 1.4 sec,
- Duration of Off-state Distribution: Exponential, mean: 1.7 sec.

During talk spurts the source generates 32-byte speech payload at 20 ms intervals, while due to DTX during silence periods a 7-byte payload carrying Silence Descriptor (SID) frame at 160 ms intervals is generated [27] [28]. Mapping of AMR data into MAC PDUs is done according to the description in [26]. If we assume the typical VoIP protocol stack employing Real-Time Transport Protocol (RTP) encapsulated in User Datagram Protocol (UDP), which is further carried by the IP the combination of these protocols introduces total of 40 bytes header data when using IP version 4 (IPv4), and 60 bytes header when using IP version 6 (IPv6) [29].

F. Multimedia web browsing

This data source model is based on source models for web browsing but considers higher average file sizes due to the multimedia nature of the service. Multimedia traffic exhibits potentially large file sizes with heavy tail distribution patterns. Each session is modelled as a WWW application, consisting of a sequence of packet calls corresponding to file downloads having the statistics shown in Table 13. It must be noted that the reading time (or time between packet calls) may be adjusted to produce different data-rates and simulate multiple users. The packet call size corresponds to the filesize parameter stated in Table 12. Inactive time (or reading time) is modelled by a Pareto distribution with a minimum of 3s and an average of 13s (Figure 4).

Table 13: Multimedia web browsing traffic model.

Entity	**Random Variable**	**Parameters**
Session arrival [h]-1	Exponential	Mean = 0.07~0.09
Session duration [min]	Exponential	Mean = 15
Packet Calls Size [KB]	Pareto	α=1.1, k=22KB (Mean=240KB)
Inactive Time distribution [s]	Pareto	α=1.5, k=3s (Mean = 13 s)

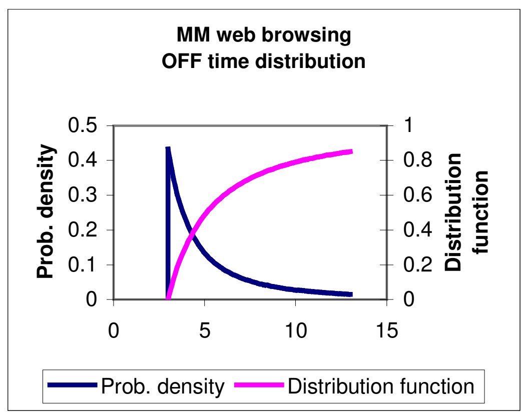

Figure 4: Multimedia Web browsing inactive time distribution

G. Instant Messaging for Multimedia (IMM)

Real-time Multimedia messages will be exchanged between users via a MM Instant Messaging server. There will be a pattern of exchange / read sequences as in MM Web browsing. It is considered that messages will not have a minimum size, and therefore the Weibull distribution is used to model packet call size Table 14.

Table 14: IMM traffic model parameters.

Entity	**Random Variable**	**Parameters**
Session arrival [h]-1	Exponential	Mean =0.08
Session duration [min]	Exponential	Mean = 15
Packet Calls Size [KB]	Weibull	α=1, β=640 (Mean = 640KB)
Inactive Time distribution [s]	Pareto	α=1.5, k=30s (Mean = 90s)

A graphical representation of the distribution is shown in Figure 5.

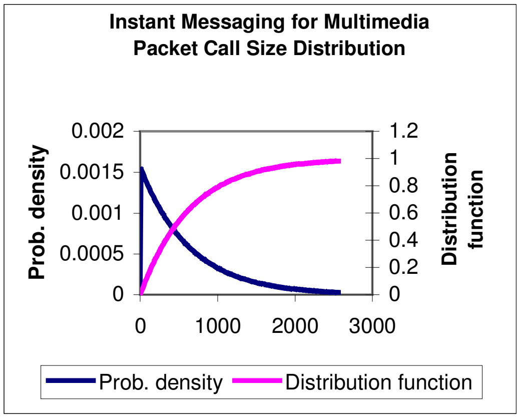

Figure 5: Instant Messaging for Multimedia Packet Call Size Distribution

H. Assistance in travel

This service consists on
a) City Guidance – a tourist can have assistance to meet a given location through this application, choosing the best path and informing him/her the average time it takes to get there. Additionally, virtual reality images may be shown offering a virtual tour or guidance through super-imposed imaging by means of an adequate visualisation device such as eyeglasses.
b) Traffic Advice and Road Conditions – this component of the application is intended to provide user-oriented information (data, video and audio comments) about how to get to a destination and the traffic conditions. A user can decide on the more convenient road to reach a specific destination, get information about parking, traffic flow and traffic forecast. Images of the path and critical spots may be shown (e.g. on a built-in car device such as the windscreen or ergonomic terminal).
The service combines location based services with personal assistance and may use interactive video streaming for virtual reality sessions. The following modelling approach may be followed, using the Weibull distribution with the parameters detailed in Table 15:

Table 15: Assistance in travel traffic model parameters.

Entity	**Random Variable**	**Parameters**
Session arrival [h^{-1}]	Exponential	Mean =0.07
Session duration [min]	Exponential	Mean = 20
Packet Calls Size [KB]	Weibull	α=1.2, β=12246 (Mean = 11520KB)
Time Between Packet Calls [s]	Pareto	α=1.5, k=3 s, (Mean = 13 s)

I. Wireless LAN interconnection

Wireless LAN interconnection is expected to follow a behaviour similar to LAN data traffic. Accounting for a slight leveling due to source traffic aggregation, a Weibull distribution with a shape parameter of α=1.5 is used, to produce a less pronounced distribution tail, as shown in Figure 6.

Table 16: Wireless LAN interconnection traffic model parameters.

Entity	**Random Variable**	**Parameters**
Session arrival [h]-1	Exponential	Mean = 0.015
Session duration [min]	Exponential	Mean = 60
Packet Calls Size [KB]	Weibull	α=1.5, β=8848 (Mean =7988KB)
Time Between Packet Calls [s]	Pareto	α= 2, k=0.5s (Mean = 1s)

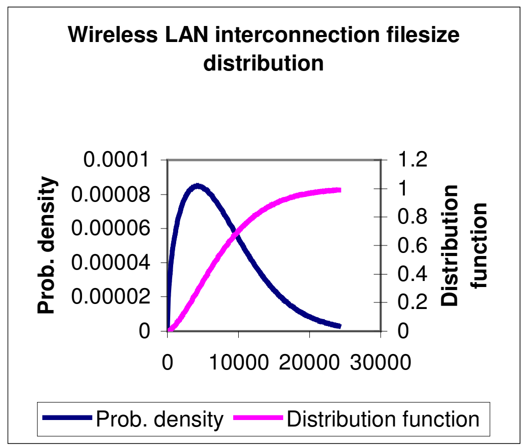

Figure 6: Wireless LAN interconnection filesize distribution

J. MPEG-4 Video Model

MPEG-4 was developed for Internet and mobile applications and will be extensively used in UMTS, together with H.263, which has similar characteristics. MPEG-4 encoders generate three types of frames: I frames, P frames and B frames.
Several methods to model and simulate MPEG video traffic have been presented [30], [31]. These models describe a MPEG video stream, and are suitable for streaming and real time videotelephony simulations: The method of simulation involves an initial determination of the statistic profile of the stream by means of an actual sampling of a recorded stream. Individual profiles for each type of frame are gathered into histograms and a statistical distribution is shaped to the sample for each frame, reproducing the strong autocorrelation between frames and especially between each type of frame. The Gamma, Weibull

and Lognormal distributions are almost equally suitable to this purpose. In [30] a set of statistical data that captures a set of MPEG samples is analysed. The results obtained are presented in Table 17 for reference, but for each particular application a previous sampling and statistical study needs to be conducted for optimal results.

Table 17: Statistic summary for the frame size sequence [30].

Statistic	All Frames	*I* Frames	*P* Frames	*B* Frames
Number	41 760	2 784	11 136	27 840
Sample Mean [kbit]	41.7	197.1	58.0	19.6
Sample Standard Deviation [kbit]	51.7	63.8	37.3	5.7
Maximum [kbit]	343.1	343.1	284.6	60.0
Minimum [kbit]	0.56	36.2	0.56	0.57

The lognormal distributions was found to be the more adequate to fit this data and the results for each type of frame are presented in Table 18.

Table 18: Lognormal distribution parameters for frame size in kbit [30].

Frame Type	Lognormal			
	μ	σ	E(x)	Stand. Dev. (x)
I	5.1968	0.2016	184.40	37.56
P	3.7380	0.5961	50.18	32.78
B	2.8687	0.2675	18.26	4.97

IX. CONCLUSIONS

Future 3.5 G systems have to be able to support nowadays applications and new ones, with different capacity and requirements, hence new classifications and characterisation of these applications are needed. This work presents a description of different classifications and characterisation parameters, and a first assignment of the range of variation of the parameters. Parameters include among others data rate, tolerance to delay and error, busy hour call attempt, session duration and activity/inactivity models. This is an important step in order to define realistic simulation traffic scenarios and models.

After presenting nowadays views on operation environments, mobility models were defined for specific E-UMTS environments. A set of scenarios was drawn by associating values of service usage with each of the eight deployment scenarios. Nearly thirty services were considered, grouped into Sound, High Interactive Multimedia, Narrow-, Wide- and Broadband. They are an example of a mixture of applications that may exist in E-UMTS. However, a reduced set of applications is needed for simulations purposes. A selection of the most relevant service environments and applications is then brought to the foreground and proposed as the key scenarios, thus responding to the necessity of diminishing the burden on simulation work.

Then, a traffic generation model was described in order to allow quantification and description of traffic offered to the E-UMTS network. This model is based on population and service penetration values in order to determine call generation rates for the constituent services within each of the selected scenarios. For each service an activity model was described, and the ON and OFF states were characterised by appropriate statistical distributions. Concerning streaming services, a model for streaming video was outlined, based on MPEG-4 trace statistics. This completes the basic output to the SEACORN simulation work, whose objective is to determine the aggregate traffic, packet error rates, detailed loss rates, and other parameters.

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