Enhanced UMTS Deployment and Mobility Scenarios

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ABSTRACT

An overview of Enhanced UMTS (E-UMTS) deployment scenarios and supported services is presented, based on the views of nowadays-relevant players. The influence of mobility in E-UMTS is discussed and a set of mobility models is given. Then, a set of scenarios is described, that put together the most important components of E-UMTS deployment situations. These include expected population density, mobility characteristics, and expected usage of service mix, for each environment. A number of nearly thirty applications, divided into in five groups (Sound, High Interactive Multimedia, Narrowband, Wideband, Broadband), is considered.

I. INTRODUCTION

IST-SEACORN (Simulation of Enhanced UMTS access and Core Networks) addresses the next step in UMTS evolution. The project will propose a set of enhancements to UMTS, which encompass radio interface, access network, and core network. They will allow supporting data rates up to 8-10 Mb/s in both directions (up- and downlink), and include, among others, advanced modulation and radio transmission techniques, improved strategies for IP routing and QoS assurance at the radio access and core networks. It will allow going beyond HSDPA (high-speed downlink packet access), supporting new applications with higher data rate, and giving the users more capacity. The effect of these enhancements will be evaluated by means of simulations.

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 may be more convenient for traffic simulation purposes.

The usage of each application, i.e., the percentage of connections of a given application relatively to the total number of applications, 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 [1], [2], as well as ETSI-RES [3], the UMTS Forum [4] and the RACE-MBS project [5].

Section II presents an overview of the views of the UMTS Forum, ETSI HIPERLAN, RACE-MBS and RACE-TITAN projects. 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 III, 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 IV 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. Five groups of applications are considered: Sound, High Interactive Multimedia, Narrowband, Wideband, and Broadband. Conclusions are drawn in Section V.

II. HYPOTHESIS FOR 3G AND BEYOND

A. UMTS Forum perspective

The UMTS Forum has identified six operational environments [4]: 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, given in Table 3.3 of [4]. 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 [4]. 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 [4]. New forecasts are available in [6] for the categories of simple and rich voice, location based services, business multimedia messaging service, mobile Internet access, consumer multimedia messaging service, mobile Intranet/Extranet access and customised infotainment.

B. HIPERLAN perspective

ETSI has identified the following three deployment scenarios for HIPERLAN [3]: Office, Industry and Studio (TV, radio or recording). The usage of applications deployed in those scenarios is presented in Tables 9-11 of [3], 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 [5]. 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 Aided 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 [5]: these values are used here as a basis for the definition of various scenarios in a geographical area. Different notations are adopted in the various sources for applications usage [3], [4], [5]. However, in order to have a common notation, some definitions were already presented in [7].

D. RACE-TITAN Forecasts

From the RACE-TITAN project [1], [2], one extracted forecasts for 2010, defined as a percentage of the total residential market. Table 1 presents the adaptation of these forecasts to E-UMTS, where the 144 kb/s limit of TITAN-ISDN applications was extended to 384 kb/s.

Table 1. 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	]384,2 000]kb/s	15 %	16 %
Broadband	> 2 Mb/s	5 %	-

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), one is considering an upper value of 2 Mb/s. Higher data rates are supported in offices and industries.

III. MOBILITY MODELS

The purpose of mobility models is to describe typical terminal movement, enabling system performance analysis. Two basic types of models are covered: individual terminal and tele-traffic mobility ones. 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, 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
- Parking zones

The particular case of office environments is characterised by a "boxy" topology, where office rooms are inter-connected by 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 the 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,* the average time in office room, T_r, and the mobile speed, v_m. Their values are presented in [8], and can be adjusted to particular environment conditions, especially the average office time and ratio values.

B. Outdoor to Indoor Pedestrian - Business 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 [8]. To represent city centres, the Manhattan Model is normally used, which is a rectangular grid of intersecting streets. 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 low mobility (pedestrians).

The urban mobility model is highly related to the Manhattan-like structure. 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 [8]:

- 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 m 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 are 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 $\bar{\tau} = 1/\mu$ [9], 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, which can also be modelled by an exponential distribution with reasonable accuracy [10].

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 [9]. As the minimum of two exponentially distributed 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, which, in turn, concerns terminal equipment speed. 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 [11] for the velocity with average velocity, V_{av}=1, 10, 15 and 22.5 ms^{-1}, for the pedestrian (PD), urban (UB), main roads (MR) and highways (HW) scenarios, respectively, Table 2.

Table 2. Scenarios of Mobility Characteristics.

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

This leads, to the following cross-over rate

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

when V_{min}, $\Delta>0$, while, when $V_{min}=0$, the limit is

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

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

IV. E-UMTS SCENARIOS DEFINITION

It is still difficult the have a clear view for the deployment scenarios in E-UMTS. However, as it is referred in [12], it is already possible to clearly distinguish the following eight deployment scenarios:

- Business City Centre, BCC (vehicular or pedestrian)
- Urban Residential, URB (vehicular or pedestrian)
- Primary Roads, ROA
- Trains, TRA
- Commercial Zones – COM (e.g., airports, railway stations, hospitals, commercial centres, universities)
- Offices, OFF (buildings)
- Industry, IND (large factories, plants)
- Home, HOM.

From the data available for UMTS (applications with data rates 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, by incorporating forecasts for broadband applications. Because the data from the RACE-TITAN project is for the residential market, some changes have to be done for the business and the mixed (half-business / half-residential) ones, Table 3. 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 [7], Table 4. In the context of these scenarios, new applications, like Control data, Monitoring [3], TV Programme Distribution (MPEG2-4), WLAN 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.

Values are proposed for the usage and the envisaged approximated maximum data rates, R_b, of applications at the eight scenarios, Table 5. The set of applications considered are the ones from [12] (High Interactive Multimedia, Narrow- and Wideband) plus Sound and Broadband ones. Data rates refer to the link with higher bit rate (either the up- or the downlink).

Table 3. Assumptions for usage in various markets.

Services	Data rates	Demand as a percentage of the market [%]							
	[kb/s]	Residential		Mixed		Business	
Sound	-	57		42		27	
High Interact. MM	≤ 144	16		16		16	
Narrowband	]144,384]	11	27	18	42	26	57
Wideband	]384, 2 000]	16		27.5		31	

Table 4. 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, 2 000]	25	40
Broadband	> 2000	15	15

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 [5]. In the business market there is a fundamental difference between the BCC, OFF and IND scenarios: applications are movable (not mobile) in the latter; hence, broadband applications, with data rates up to 8 Mb/s, can be supported. For a more complete description of the operation environments, the definition of scenarios from mobility is needed. Details are given in [13].

V. CONCLUSIONS

Deployment scenarios and mobility models are presented for the purpose of conducting simulation tests that will evaluate radio and network E-UMTS techniques within SEACORN. After presenting nowadays views on operation environments, mobility models were defined for specific environments (indoor/ office, business city centre, and vehicular), and a flow equilibrium tele-traffic mobility model was addressed. The latter class of models is suitable for network simulations where the knowledge of the exact position of the terminal equipment is not necessary.

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, and will be very useful for simulation and traffic engineering purposes.

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Table 5. Proposal for Applications Usage in each of the Deployment Scenarios.

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**	**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
Desktop 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	3.9	3.9	3.9	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	-
E-mailbox for Multimedia	1024	2.2	1.0	1.2	1.5	1.9	4.0	4.0	1.0
Remote Procedure Call	1024	2.2	2.5	1.8	4.0	4.0	8.0	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	10.0	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	1.3	4.5	5.5	0.5	0.5	0.3
E-newspaper	1536	3.7	3.2	3.0	8.0	4.0	5.0	5.0	3.2
HD Videotelephony (Tele-education)	1920	11.1	3.5	6.0	4.5	5.0	2.7	3.0	3.5
Total		**31.0**	**16.0**	**27.5**	**27.5**	**27.5**	**25.0**	**40.0**	**16.0**
Broadband									
Control data	3840	-	-	-	-	-		10.0	-
TV program. distribution (MPEG2-4)	7680	-	-	-	-	-	4.5	0.0	-
Wireless LAN Interconnection	7680	-	-	-	-	-	6.5	1.5	-
Professional Images	7680	-	-	-	-	-	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

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