

Source Traffic Modelling for Enhanced UMTS Simulation

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Abstract — Enhanced UMTS traffic generation and activity models are described and characterised, based on population and service penetration values. As a reduced set of scenarios is needed for simulation purposes, scenarios were defined with a selection of the most relevant applications. ON/OFF states have been characterised by appropriate statistical distributions for long-range dependence, and parameters for source traffic modelling have been presented.

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. 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. 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.

IST-SEACORN [1] proposed scenarios that include expected population density, deployment and mobility characteristics, and usage of service mix for each environment [2]. A number of near 30 applications were considered distributed among different service classes (Sound, High Interactive Multimedia, Narrow-, Wide-, or Broadband, depending on data rates [3]). However, to meet the technical demands of the simulation tools a reduced set of services and environments were 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 (offices, business city centre, and vehicular), with four or five services each depending on the environment. 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 (e.g., reflecting long-range dependence), the activity within a call can be modelled. The 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.

Section II presents deployment scenarios and hypothesis for traffic generation. Section III starts by presenting activity parameters, with a description of average active versus inactive durations, and of average file sizes as well. Then, details on traffic source models and parameters are presented for Speech, Multimedia Web Browsing, Instant Messaging for MM (Multimedia), Assistance in Travel, WLAN Interconnection, and MPEG-4 video, often corresponding to long-range dependence. Conclusions are drawn in Section IV.

II. DEPLOYMENT SCENARIOS

A. Scenarios for Simulation

In IST-SEACORN, scenarios definition includes expected population density, deployment and mobility characteristics, and usage of service mix for each environment [2]. To meet the technical demands of the simulation tools, from scenarios with tens of applications, a reduced set of services and environments were 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 (offices, OFF, business city centre, BCC, and vehicular, VEH) with four or five services each depending on the environment. Proposed applications and their relative usage are shown in Table I.

Table I
Proposal for Applications Usage in each of the SEACORN Simulation Deployment Scenarios

Applications Usage [%]	R_b [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 MM (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 / m²)		0.150	0.031	0.012

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This table is obtained from [2] by assuming, as a simplification, that the most significant application accounts for 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. Here, the ROA scenario is called vehicular (VEH). The population density factors for each of the scenarios are the ones from [2]. Data rates are aligned to existing standard values in UMTS and HSDPA.

For a more complete description of the operation environments, the definition of scenarios from mobility is needed. Details are given in [3].

B. Call Generation and Traffic Parameters

From the values of usage for OFF, BCC, and VEH scenarios, it is important to obtain, for each considered service, the values of the busy hour call attempts, BHCA, to be used in simulations. BHCA 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,

$$BHCA_j = \frac{Usage_j}{\tau_j} \cdot M_T \cdot \bar{f}, \quad (1)$$

where M_T is the number of users in the cell, the average call duration, and \bar{f} is the average traffic per user (or, the average fraction of active users), which can vary from 0 to 1.

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 asymmetry 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 II. 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.

Table II
Call generation and traffic parameters

Applica- tions	Data rate [kb/s]	Session arrival rate[min^{-1}]			τ [min]	Sym. UL/DL
		OFF	BCC	VEH		
VOI	12	0.50	0.54	0.84	3	1
VTE	128	0.45	0.48	0.48	3	1
MWB	384	0.16	0.21	0.19	15	0.25
IMM	1024	0.15	-	-	15	0.05
ATR	1536	-	-	0.11	20	0.07
HDT	2048	-	0.09	-	30	1
WLI	12780	0.03	-	-	60	0.25

Values for session arrival rate are derived from service penetration and session duration values, considering $\bar{f} = 0.03$. 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, during the busy hour.

$$U_j = \frac{SessArrRate_j \cdot M_T \cdot P_j \cdot \tau_j}{\sum_i SessArrRate_i \cdot M_T \cdot P_i \cdot \tau_i} \quad (2)$$

The conversion to BHCA can be done by using (1).

III. SOURCE TRAFFIC MODELLING

A. Session and 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). The activity within a call is modelled by defining an average duration of each period, together with an adequate statistical distribution. 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 sequences (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 or inactivity time.

Table III describes average active versus inactive durations, the corresponding file sizes of activity packet call periods and statistical distributions of the active and inactive durations.

Table III
Application activity parameters

Applica- tions	Active state (ON)			Inactive state (OFF)	
	Avg.[s]	Filesize[KB]	Distrib.	Avg.[s]	Distrib.
VOI	1.4s	2.14	Expon.	1.7 s	Expon.
VTE	τ			0	
MWB	5	240	Pareto	13	Pareto
IMM	5	640	Weibull	90	Pareto
ATR	60	11520	Weibull	14	Pareto
HDT	τ			0	
WLI	5	7988	Weibull	1	Pareto

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.

B. Speech Source Model

For simulation, speech sources are based on Adaptive Multi-rate (AMR) codecs with only the 12.2 kbps mode. Each AMR 12.2 kbps source is modelled with an ON/OFF

model for discontinuous transmission (DTX) as follows:

- Voice Call Duration Distribution: exp., mean: 180 sec,
- Duration of On-state Distribution: exp., mean: 1.4 sec,
- Duration of Off-state Distribution: exp., 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 [4] [5]. Mapping of AMR data into MAC PDUs is done according to the description in [5]. 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 if IPv6 is used [6].

C. Multimedia Web Browsing (MWB)

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 IV. 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 file size parameter stated in Table III. Inactive time (or reading time) is modelled by a Pareto distribution with a minimum of 3 s, and average of 13 s, Figure 1.

Table IV
Multimedia Web Browsing traffic model parameters

Entity	Distribution	Parameters
Session arrival [h ⁻¹]	Exponential	Mean = 0.16~0.21
Session duration [min]	Exponential	Mean = 15
Packet Calls Size [kB]	Pareto	$\alpha=1.1$, $k=22\text{KB}$ (Mean=240KB)
Inactive Time distribution [s]	Pareto	$\alpha=1.5$, $k=3\text{s}$ (Mean = 13 s)

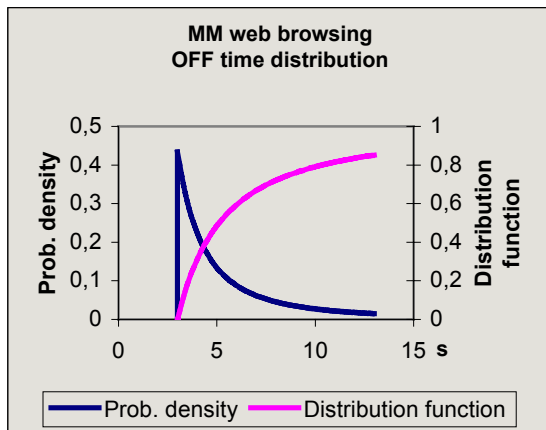


Fig. 1. MWB inactive time distribution.

D. 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. Messages will not have a minimum size, and therefore the Weibull distribution is used to model packet call size, Table V. A graphical representation of the distribution is shown in Figure 2.

Table V
Instant Messaging for Multimedia traffic model parameters

Entity	Distribution	Parameters
Session arrival [h ⁻¹]	Exponential	Mean = 0.15
Session duration [min]	Exponential	Mean = 15
Packet Calls Size [kB]	Weibull	$\alpha=1$, $\beta=640$ (Mean = 640KB)
Inactive Time distribution [s]	Pareto	$\alpha=1.5$, $k=30\text{s}$ (Mean = 90s)

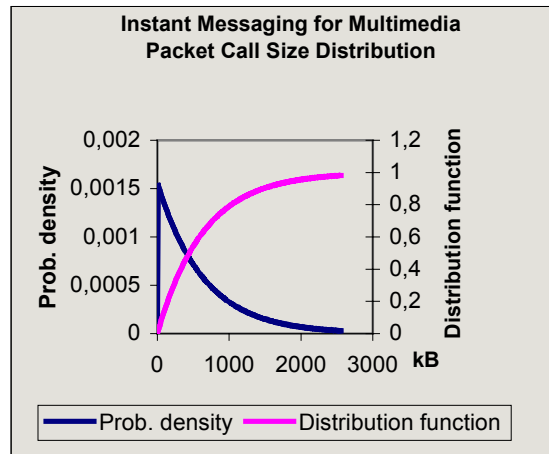


Fig. 2. IMM packet call size distribution.

E. Assistance in Travel (ATR)

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 Weibull distribution is used, Table VI.

Table VI
Assistance in Travel traffic model parameters

Entity	Distribution	Parameters
Session arrival [h^{-1}]	Exponential	Mean = 0.11
Session duration [min]	Exponential	Mean = 20
Packet Calls Size [KB]	Weibull	$\alpha=1.2, \beta=12246$ (Mean = 11520KB)
Time Between Packet Calls [s]	Pareto	$\alpha=1.5, k=3$ s, (Mean = 13 s)

F. Wireless LAN Interconnection

Wireless LAN Interconnection is expected to follow a behaviour similar to LAN traffic, Table VII. Accounting for a slight levelling due to source traffic aggregation, a Weibull distribution with a shape parameter $\alpha=1.5$ is used, to produce a less pronounced distribution tail, as shown in Figure 3.

Table VII
Wireless LAN Interconnection traffic model parameters

Entity	Distribution	Parameters
Session arrival [h^{-1}]	Exponential	Mean = 0.03
Session duration [min]	Exponential	Mean = 60
Packet Calls Size [KB]	Weibull	$\alpha=1.5, \beta=8848$ (Mean = 7988KB)
Time Between Packet Calls [s]	Pareto	$\alpha=2, k=0.5$ s (Mean = 1s)

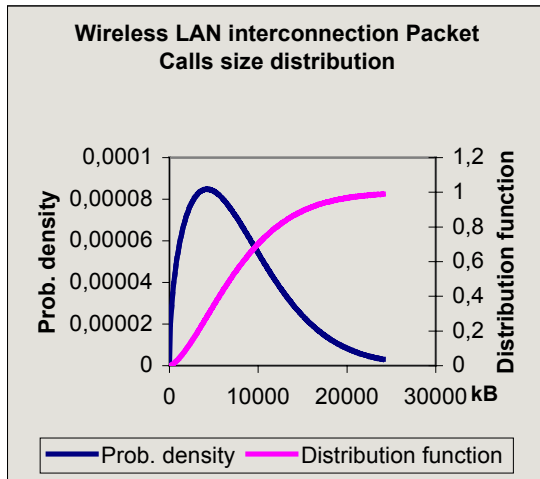


Fig. 3. WLI Packet Calls size distribution.

G. 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, P and B ones. Several methods to model and simulate MPEG video traffic have been presented [7], [8]. These models describe a MPEG video stream, and are suitable for streaming and real time videotelephony simulations. The Gamma, Weibull and Lognormal distributions are almost equally suitable to this

purpose. In [7] a set of statistical data that captures a set of MPEG samples is analysed, and details on the parameters are given. However, the main result from the ongoing research on MPEG-4 traffic simulation is that statistics can vary widely even in the case of similar material (e.g. coded movies). The only way of reaching an optimal fit involves the study of the particular source in question.

IV. CONCLUSIONS

In IST-SEACORN, as a reduced set of applications was needed for E-UMTS simulations purposes, a selection of the most relevant service environments and applications was chosen responding to the necessity of diminishing the burden on simulation work. A traffic generation model was described in order to allow quantification and description of traffic offered to the Enhanced 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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