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Impact of Mobility on Aggregate Traffic in Mobile Multimedia System

D. R. Basgeet¹, J. Irvine², A. Munro¹, P. Dugenie³, D. Kaleshi¹, O. Lazaro²

¹Networks & Protocol Group, EEE,
University of Bristol, UK
email D.R.Basgeet@bristol.ac.uk,

²EEE, University of Strathclyde
Glasgow, Scotland
email j.m.irvine@strath.ac.uk

NexWave Solutions SA, 34967
Montpellier Cedex 2, France

Abstract

In the wireless context, the underlying user behaviour together with the unpredictability of the air interface will have a high impact on traffic (both in space and time) shaping the traffic over the mobile network. In this paper, we investigate the impact of mobility on the aggregate traffic for a wireless packet data networks in the City Area of Bristol, UK, in order to show if the mixture of voice and data applications exhibit self-similarity. We also compare the queuing performance of these new data models with the traditional Poisson model to investigate how these new models affects the provisioning and dimensioning of future wireless data networks.

Keywords

Wireless data networks, mobility model, teletraffic models, self-similarity, multimedia.

1 INTRODUCTION

The rapid proliferation of the Internet and growth of mobile users, coupled with emergence of new data services for 3G systems, means that in the future, mobile networks will have to operate with mixes of voice and data traffic. Recently in multimedia communications, much attention has been paid to long range dependent traffic and measured results have shown that teletraffic characteristics of local area networks (LANs) and wide area networks (WANs) exhibit self-similar behaviour [2].

As mobile networks develop, the core mobile network is increasing packet based. The GPRS adds an IP-based packet network to the circuit switched GSM core network. The UMTS Release 99 network uses the same approach, but with Release 4 and Release 5 the traffic currently carried on circuit switched bearers will move over to IP transport.

Using an IP based core mobile network raises the question of dimensioning. Traffic which has a self similar behaviour requires larger buffers for a given load as the traffic is more bursty [3]. It may be expected that multimedia traffic over mobile networks will exhibit self-similarity in the same manner as on fixed networks, but most traffic characterizations were performed on wired networks, and there are no results indicating how the traffic generated by both voice and multimedia services will behave in the mobile environment. The aggregate traffic will be affected by a number of factors. The user's location will directly affect the routing of the traffic. It will also alter the loading on the air interface and the interference generated. The radio channel quality, in terms of shadowing and interference, will affect the rate of transmission. It may also cause retransmissions

or dropped connections, depending on the service type. The radio link quality will also be affected by location, and therefore by user mobility.

Mobility and teletraffic models have been used to capture the movement and calling behaviour of mobile users as a means for planning and dimensioning of cellular networks. The fluid, gravity and Markovian models [1] have been used as basic tools for the characterisation of user mobility in wireless networks while the traditional Poisson process has proved to be an accurate tool to describe voice users' activity for both fixed and cellular networks. More sophisticated mobility [5] and teletraffic [6-9] models have now become available, which allow consideration of the problem of aggregate traffic on mobile networks.

In this paper, we address this issue by investigating the impact of mobility on the aggregate traffic in order to study if the self-similar behaviour also prevails in future wireless data networks, and if it does, what effects will this have on the dimensioning and provisioning of those networks. This paper is organised as follows. Section 2 presents our modelling framework and we describe the integration of our mobility and service models. Section 3 highlights our simulation platform for our investigation. Section 4 presents the analysis of the aggregate traffic trace. We investigate the effect that the new traffic models have on the network and present the simulation results in Section 5 and Section 6 concludes the paper.

2 MODELLING FRAMEWORK

The objective of teletraffic engineering is to provide cost-effective dimensioning of network resources in order to satisfy the demand of mobile users at a predefined quality of service (QoS). As such, the accuracy of mobility and traffic models becomes essential for providing optimum network configuration. While the modelling of traffic models have been mainly tackled using the Poisson distribution, future data applications can no longer be characterised by using this simple approach [3]. In this context, there has been a lack of study which combines both data applications while taking into account the effect of user mobility.

To tackle this issue, we have developed an object modelling platform which includes a set of tools to model user movement and their calling behaviour and a cellular communications system superimposed on the topological area under consideration. Our modelling approach is depicted in Figure 1 and has been divided into the following components: *Mobility Model, Service Model, and Investigation.*

2.1 Mobility Model

Our mobility model is based on a mathematical framework centred on a scalable algorithm for the prediction and tracking of mobile users that can be applied to a large number of possible environments, ranging from wide area networks (WANs) to local areas networks (LANs) [4, 5] and has the following characterising features:

- mobile users having the same mobility behaviour are grouped into specific classes of mobility (CM). For our model, three CM have been considered: *Business* (BC), *Residential* (RC) and *Others* (OC).
- **Area Zones** – The geographical area under consideration is divided into regions having specific mobility related characteristics. Four environments have been considered: *Working*, *Domestic*, *Shopping* and *Streets*.
- **Attractivity Points** (APs) – These represent locations that attract users with a specific CM and at which mobiles spend a certain amount of time.
- **Time Periods** – In the context of a wireless network, the *rush hour* (RH) and the *busy hour* (BH) can be identified. Both of these times periods are taken into account in our mobility model.

Figure 1: Generic Modelling Approach

2.2 Service Model

Research related to first and second generation mobile communications systems focused primarily on increasing the capacity for voice service. However, with the recent popularisation of Internet services such as Web browsing, WAP and the increasing demand of portable computer, it is apparent that future generation of wireless systems must be capable of supporting both voice and multimedia applications.

To incorporate both voice and data services, we have constructed a service model which links the type of service (voice or data) allocated for each individual mobile user to its *class of mobility* and the *time of the day* period. As such the service model has been divided into two sub-models: *Service Traffic Model* and *Service Distribution Model*.

2.2.1 Service Traffic Model

The service traffic model characterises the different types of services that a mobile user is allocated when engaged in a call and users may choose from one of the number of different services: voice, web browsing (WWW), File Transfer Protocol (FTP), Wireless Application Protocol (WAP) or Email.

Voice traffic has been modelled in terms of talk spurts through an exponential ON/OFF process consisting of alternating active and silent period of times. The ON state represents the talk spurts during which packets are generated at a constant rate while the OFF state represents the silence period. The ON and OFF periods are assumed to be negative exponentially distributed, each having a mean of 1.0 and 1.4 seconds respectively.

Web browsing is characterised during a browsing session and we have adopted the same approach based on the studies [6, 7] to model WWW sessions which makes use of a structure comprising of page, object and packet. Parameterisation of the WAP model, has been done using the results from the study presented in [9]. The overall file sizes within a site are uniformly distributed with mean value ranging from approximately 600 to 1000 bytes. Finally, email sessions have been characterised using the FUNET model presented in [8] which approximates the Email connection sizes by a truncated Cauchy distribution with a maximum message size of 10 Kbytes. The average size of the Cauchy Email connection is 830 bytes. The parameters for the packet data services, WWW and WAP are summarised in Table 1. The service traffic model also includes a FTP model which has been modelled in a similar manner to WWW, only with a single request [12].

Table 1: Parameters for Traffic Models

WWW Model		
	Distribution	Value
Page Size	Pareto	Mean: 5.55, Shape 2.43
Object Size	Pareto	Mean: 2.43, Shape 1.318
TCP Size	Constant	536 bytes
WAP Model		
Page Size	Constant	1
Object Size	Uniform	Between 1 to 15 TCP packets
TCP Size	Constant	100 bytes

2.2.2 Service Distribution Model

The Service Distribution model characterises how often a mobile user in a particular CM uses a particular service. The service arrival rate is assumed to be a Poisson process. Table 2 presents the service arrival rate for each CM during the peak period considered and Table 3 shows the heuristic distribution to characterise the usage of *voice* and *data* services.

Table 2: Service Arrival Rate for all mobile users vs. Time

Class of Mobility (CM)	Service Arrival Rate (calls/user/hr)		
	7-8 am	8-9 am	9-10 am
Business Class (BC)	3.5	4.5	5.5
Residence Class (RC)	5.5	4.0	3.0
Others Class (OC)	3.0	4.0	5.0

Table 3: Service Penetration Rate per Service and CM

CM	Service Penetration Rate (P_s)				
BC	P_s	WWW	FTP	Email	WAP
Data	50%	50%	10%	30%	10%
Voice	50%				
RC	P_s	WWW	FTP	Email	WAP
Data	10%	40%	10%	20%	30%
Voice	90%				
OC	P_s	WWW	FTP	Email	WAP
Data	30%	20%	10%	20%	50%
Voice	70%				

2.3 Radio Model

To investigate the impact of mobility on the aggregate traffic, we have implemented a discrete-time event-driven, object-oriented simulator which models an Enhanced Data Rates for GSM (EGPRS) system.

2.4 Simulation Environment

The cellular network is deployed over the City Area of Bristol having an 8 km $\times$ 8 km area extension as shown in Figure 2. The geographical area is divided into four environments: *Working*, *Domestic*, *Shopping* and *Streets* and is overlaid with a Manhattan grid configuration of 41 Base Stations (BTS) with each BTS is having a coverage area of

Figure 2: Deployment of EGPRS Cellular Network

1 km, a cluster size of four and a sample of 1700 mobile users has been assumed during the simulation.

2.5 Air Interface

The simulator uses 3G EGPRS system air interface, with 200 KHz channels and utilises a frame structure similar to GSM. A fixed channel allocation scheme is considered with three carriers per cell giving 24 channels per cell based on Time Division Multiple Access (TDMA) concept with each carrier divided into eight slots.

When a mobile user contends for a channel and if resource is available, it is allocated to the requesting mobile and the unit object resources are marked "occupied". When the a specific data service is allocated to a mobile, the size of the application is determined based on the distribution detailed in Table 1. The bits to be transmitted are packetised into Radio Link Control (RLC) blocks which are formatted into TDMA bursts for transmission over the air interface according to the relevant EGPRS modulation coding scheme [10]. If no resources are available, the mobile user backs off and tries again after on the next frame. The availability and use of resources can also be tracked to produce performance statistics at each BTS in terms of packets dropped.

3 INVESTIGATION

Using the mobility, service and radio system dynamics mentioned in Section 2, we have monitored the aggregate traffic data generated on the downlink of the each BTS as shown by Monitor 1 in Figure 3. Traffic nearer the core of the network (Monitor 2) was also recorded.

Figure 3: Traffic Trace

The aggregated traffic trace generated by mobile users involved in the different services for the three hour period, was collected for our statistical analysis. Downlink traffic was measured, as it has a higher load. WWW and WAP traffic is asymmetric, and it was assumed that the mobile user was the client in each case.

3.1 Simulation Results

Figure 4, shows the aggregation of the trace into various time frames for the BTS located in the Working Environment. For each plot, we can observe different burst lengths on different time scales which indicates the existence of self-similarity in the trace. This property was confirmed using the Abry-Veitch [11] estimator based on wavelet

transform to estimate the H parameter as shown in Figure 5. The H parameter was observed to be 0.845.

The variation of the self-similar behaviour with time was studied by analysing the H parameter of the aggregated traffic trace for two BTS located in the *Working* and *Residence* environments respectively over the three different 1-hour time scale period. Simulation results presented in Figure 6 indicate that the aggregated traffic of voice and data is self-similar for both environments and this behaviour prevails over different time scales and for different traffic loads dictated by the service penetration rate assumed in Table 3.

Figure 4: Sample Aggregation of WWW, WAP, FTP, Email & Voice

Figure 5: Log-Scale Graph for Aggregation of Traffic Trace

Figure 6: Variation of H Parameter with Time

The Hurst parameter demonstrates that the traffic trace generated by different mix of both voice and data services generated at different points in the network based on user mobility, is self-similar in behaviour. In the case of the working environment, the Hurst parameter is above 0.8, which is close to the range of 0.8 to 0.85 found for pure web traffic [9]. The proportion of web traffic in this scenario is sufficient to ensure that its effect dominates. The residential environment has a lower value of Hurst parameter, although it is still significant and the traffic still self-similar.

4 EFFECT ON THE NETWORK

The immediate question that arises from the above results is what impact does these traffic patterns have on the dimensioning and provisioning of the wireless network.

To tackle the above issue, we have performed a comparative queuing analysis for the service model against the traditional Poissonian approach by implementing a discrete queue on the backbone of wireless core network having a finite buffer size and connected to the 41 BTS configuration shown in Figure 2 through a fixed channel (Monitor 2 in Figure 3). The departure process from this buffer is deterministic with a First In First Out (FIFO) discipline and no priority scheme has been considered for both the voice and the mix traffic sources generated by the service model. Using this configuration, we have investigated the effect of wireless multimedia services on the dimensioning of the wireless data network by investigating two key network metrics: Buffer overflow probability (Loss of packets) and the Average queuing delay of the packets.

4.1 Buffer Overflow Probability vs. Capacity

For this investigation, we have used a finite buffer size and have varied the channel capacity of the link connecting the core network to the SGSN. The comparison of mixed voice traffic was performed under the same traffic load so as to produce comparable traffic loads on the network during the simulation process.

Figure 7: Buffer Overflow Probability vs. Capacity

Figure 7 illustrates the behaviour of buffer overflow probability for different channel capacity configurations and from the simulation results, we can see that voice traffic trace exhibits an exponentially fast decaying behaviour as compared to the traffic trace generated by both voice and data services as channel capacity increases.

4.2 Average Queuing Delay vs. Capacity

Figure 8 shows the average queuing delay obtained by the traffic generated from the short-range dependent traffic source and the mix traffic of data and voice. From the graph, it can be clearly seen that as capacity of the channel is increased, the average queuing delay of the voice packets decreases sharply whereas there is no significant decrease in the average queuing delay of voice and data packets. This is due to the bursty nature of the traffic trace generated by data applications as illustrated in Figure 4.

Figure 8: Average Queuing Delay vs. Capacity

The results obtained for the two key network metrics match the observations that have already been seen on LAN and WAN [2, 3] and clearly indicate that the use of Poissonian models will greatly underestimate the provisioning and dimensioning requirements of the future wireless data networks.

5 CONCLUSION

Our simulation results show that the aggregated traffic generated by mobile users when using a traffic mix of voice and data services (WWW, WAP, Email & FTP) exhibit the self-similar behaviour. This behaviour has been observed over different time scales and for the different data and voice service irrespective of the service penetration rate defined in Table 3. However, different service mixes do change the Hurst parameter, with working environments having more bursty traffic and working ones. From a teletraffic point of view, these results allow us to predict that the implementation of multimedia services in the wireless domain will significantly change the traffic profile.

As a step forward to show the effect that this resulting change in traffic will have on the dimensioning of the core network, we have investigated the queuing performance of wireless data networks with traffic traces generated from voice and mixture of both voice and data traffic. Simulation results indicate that bursty traffic generated from the mix traffic trace causes higher packet loss and average queuing delay in the network as compared to the traditional Poissonian traffic model. As such we conclude that short-range-dependent traffic source models can no longer be used as a benchmark for the planning and dimensioning of future wireless data networks.

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