M-Commerce Perceptual Quality of Service

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Abstract. Motivated by previously identified user perceptual tolerance to varying multimedia Quality of Service (QoS), this paper shows that the Business to Customer (B2C) user experience with mobile commerce (m-commerce) can be enhanced if the underlying mobile communication is subject to certain thresholds of perceptual QoS (PQoS).

1 Introduction

A central issue to the acceptance of B2C applications is the one of quality [1][5][8][18] which has two main facets in an m-commerce environment: *of perception* and *of service*. The latter characterises the technical side of computer networking and represents the performance properties that the underlying network is able to provide. The former is a novel term that we use and gives a more complete characterisation of the human side of the m-commerce experience. That QoS impacts upon the success of m-commerce applications is without doubt, as it plays a pivotal role in attracting and retaining customers. Frustrated customers will leave a site if they perceive it as being slow (for instance), causing lost revenue. To compound the topic, mcommerce sites are likely to be compared to the users actual shopping experiences in the physical world and their normal purchasing and browsing interactions in that environment. Whilst the advent of multimedia enhanced m-commerce applications offering, for instance, video footage of merchandise to be bought, will go someway towards alleviating this factor, in a mobile communication environment such applications will have severe constraints put upon them by limited bandwidth, further highlighting the importance of QoS provision mechanisms.

The structure of the paper is as follows. Section 2 looks at how QoS issues in m-commerce from the prism of e-commerce whilst section 3 reviews research in the area of perceptual QoS and shows its applicability to wireless communications and m-commerce. Section 4 integrates QoS and PQoS into an m-commerce communications architecture. Conclusions are drawn in section 5.

2 The QoS Perspective: Lessons Learned from e-Commerce

The majority of e-commerce QoS requirements stem from the fact that the e-commerce server has been identified as the main resource upon which rests the success of such

applications. In a B2C session scenario, the user is, irrespective of the client device, interested in getting good quality search results and in the speed of the transactions, both of which are server dependent [7]. The longer the response delay, and the poorer the search results, the less inclined will the user be to shop from that specific e-commerce site, resulting in lost revenue.

Server response times have thus been identified as a key metric in e-commerce scenarios. It is therefore logical for QoS considerations to concentrate on ways on how to manage such response times [4][7][9], and a primary focus has been on the identification of the specific characteristics of e-commerce servers workloads. Such workloads have been found to be significantly different from traditional Web server workloads, and to be characterised by short and frequent requests, an abundance of dynamic data being generated, variable think times, and undefined session lengths [4][7]. Whilst there have been attempts to model e-commerce server traffic and requests using clustering techniques based on factors such as session-length, requestclass mix, and navigational behaviour [4][13], the frequency of such requests implies that QoS cannot be negotiated on a per-request basis, as is the case with distributed multimedia.

Even though e-commerce server workloads have been found to display time -of-day patterns (i.e. busiest during the day and least busy in early mornings), there are nonetheless substantial fluctuations to be found. Although the existence of flash surges in server workload at times when promotions are running on the respective ecommerce site or during traditionally shoppingintensive periods, such as those preceding Valentines Day or Christmas Day, is to be expected, even when these factors are missing, observation of e-commerce server workload has found request rates to vary by a factor of nine [4]. However, it is precisely this relative unpredictability of server workload which make the application of traditional QoS management techniques especially opportune.

Admission control algorithms have thus been proposed in order to provide predictable ecommerce response times [9] Such algorithms would ensure user satisfaction with a B2C context from two points of view: not only would server delay latency be bounded, but denial of service attacks would also be prevented. The latter is especially an issue of concern in e-commerce systems, as server workload analysis has identified that a non-negligible percentage of requests are issued by robots, automatically collecting, for instance, price-information by “crawling” through a site. Such robot-originated requests have a significant impact on server processing capacity, degrading the service provided to customers. Whilst work has been done on identifying particular characteristics of robot-sessions, the issue is further complicated by robots intentionally behaving like users [4] [14].

3 The PQoS Perspective: Lessons Learned from User Studies

As the pressure to add value to customers shopping experience increases, so will the usage of multimedia in m-commerce environments. Moreover, increased data sizes associated with even low presentation quality multimedia (compared to that of voice and text traffic) as well as the relatively low bandwidth available to mcommerce applications will make the underlying communication system struggle to provide an optimum QoS, resulting in unwanted features such as congestion, as well as data loss and errors.

However, this does not necessarily imply that there is an incompatibility between m-commerce applications and their usage of multimedia. Thus, although a user might be slightly annoyed at, say, the lack of synchronisation between audio and video streams in an advertising clip, it is highly unlikely that (s)he will notice, for instance, the loss of a video frame out of the 25 in a second of footage, especially if inter-frame differences are small. In fact there has been a rich body of work which has studied the perceptual impact of varying multimedia QoS, which shall now be presented, highlighting their relevance to mobile communications.

3.1 Media Synchronisation Perception

Media synchronisation refers to the temporal relationship between two or more kinds of media or separate data streams. In a multimedia context this definition can be extended such that synchronisation in multimedia systems comprises content, spatial and temporal relations between media objects. The most comprehensive results on the perceptual impact of synchronisation skews between media were reported in [6].

In the lip synchronisation experiment, the test subjects viewed 30-second clips of a speaker in a TV news environment featured in head, shoulder and body shots. Such shots enabled the viewers not to be disturbed by background information and to concentrate their attention on the gesture, eyes and lip movement of the speaker. Moreover, the fact that the test scenes had high temporal redundancy make them ideal for transmission at low frame rates, with consequently relatively low bandwidth requirements, characteristic of wireless transmissions. In an m-commerce environment, such shots could be used, for example, in the cases of a tennis pro explaining the features and qualities of a tennis racquet that the customer is considering buying.

Skews were artificially introduced between the video and audio streams of the clip. The main result obtained was that the dependency between perceived quality and lip synchronisation skew displayed a U-shaped characteristic, whereby between -80ms and +80ms lip synchronisation was deemed acceptable by most of the test subjects, with very few saying that if there was an error it affected the quality of presentation. A comparison using languages other than English (the language of the news-cast) revealed no difference in the results. Similarly, there were no variations between people with different habits regarding the amount of TV and films watched. Lastly, no difference was detected between the same person speaking in a fast, normal, or slow manner.

Synchronisation between *audio* and *animation* is also of potential importance to m-commerce applications, as can be exemplified by audio commentary of an animated representation of a product of interest to the user. Here, the perceptual tolerance limits identified were similar to the case of lip synchronisation, with a skew of $\pm$80ms being tolerable. In synchronisation between *video and text* or *video and images* two cases can be distinguished. In the *overlay* mode, the image or text offers additional information to the displayed video sequence, as is the practice of having subtitles placed close to the topic of discussion in a multimedia video. Irrespective of video content, a skew of around 240ms has been shown to be sufficient in this case. When no overlay occurs, skew is less serious. In this case one could imagine a drawing detailing assembly instructions of a product being displayed together with a low frame rate video detailing

the products appearance when assembled. Here, a synchronisation of around 500ms between the video and image or the video and text is deemed sufficient, half the value of the roughly 1s required for human perception of simple images.

3.2 Frame Rate Perception

Apeteker et al.[2] have investigated the impact on human perception of different frame rates. They coined the term human receptivity to mean not only just how the human user perceives multimedia video shown at diverse frame rates, but also more distinct aspects of a users acceptance of a video message. These include clarity and acceptability of audio signals, continuity of visual messages, lip synchronisation during speech, and the general relationship between visual and auditory message components.

Video clips were shown to users in a windowed multitasking environment. Each multimedia video clip in turn was presented at three different frame rates (15, 10, and 5 frames per second - fps), in a randomised order. Users rated the quality of the multimedia videos on a 7-point scale. A total of 60 people were tested for the 24 types of clips. The most relevant result to come out of their work was that the dependency between human receptivity and the required bandwidth of multimedia clips is non-linear. Consequently, for certain ranges of human receptivity, a small variation of it leads to a much larger relative variation of the required bandwidth. Bearing in mind the low frame rate videos used in their experiments (5fps, with a bit rate well within the reach of 2.5 and 3G mobile technology), this perceptual property can be exploited in a bandwidth-constrained mobile communication environment by sacrificing a small amount of receptivity in return of a much larger relative amount of bandwidth, which could be used by future m-commerce sessions.

3.3 Quality of Perception

A different approach to evaluating the perceptual impact of varying QoS was adopted in [10]. Recognising multimedias *infotainment* duality, the authors proposed to enhance the traditional view of QoS with a user-level defined *Quality of Perception (QoP)*. This measure encompasses not only user satisfaction with multimedia clips, but also his ability to perceive, synthesise and analyse the informational content of such presentations. An investigation into the interaction between QoP and QoS was undertaken.

Users from diverse backgrounds and ages (12-58) were presented with a set of 12 short (30-45 seconds duration) multimedia clips. These were chosen to be as varied, ranging from relatively static news to the highly dynamic rugby football. Clips were shown with the same set of QoS parameters, unknown to the user. After each clip, the user was asked a series of questions (ranging from 10 to 12) based on what had just been seen and the experimenter duly noted the answers. Lastly, the user was asked to rate the quality of the clip that had just been seen on a scale of 1 - 6 (with scores of 1 and 6 representing the worst and, respectively, best perceived qualities).

QoS parameters that were varied in the experiments include spatial (colour depth) and temporal parameters (frame rate). Two different colour depths were considered (8 and 24-bit), together with 3 different frame rates (5, 15 and 25 fps). A total of 12 users were tested for each (*frame_rate*, *colour_depth*) pair. In summary, the results obtained

in the QoP experiments showed that a significant loss of frames or colour depth reduction does not proportionally reduce users understanding of and satisfaction with the presentation, which has important implications in bandwidth constrained environments such as m- B2C ones. Moreover, users also have difficulty in absorbing audio, visual and textual information concurrently, tending to focus on one of the visual media and audio at any one moment. Lastly, user satisfaction, although strongly related to content, depends on the aim of the presentation, as users are likely to ignore QoS degradations if also viewing for information.

3.4 Perceptual Impact of a Multimedia

Presentation in Low Bandwidth Environments Low bandwidth environments, such as the ones typical of mobile communications, need not necessarily imply their unsuitability for multimedia presentations, especially if perceptual considerations are taken into account. As was shown in the previous subsections, low video frame rates do not significantly impact upon the perceived quality of multimedia applications – this was true for both the human receptivity and QoP measures of perceptual multimedia quality. Moreover, media loss, as long as it infrequent and of short sizes, is well within the limits of perceptual tolerance.

The question arises, however, of what the cut-off rate is beyond which the quality of transmitted audio and video becomes unacceptable to human users. Whilst [6] did not explicitly consider the impact of low frame rates on lip synchronisation, [12] showed that audio and video are not perceived as being synchronised for frame rates of less than 5 fps. Moreover, the results presented in [12] corroborate [11] that the jitter associated with video frame presentation times (20ms) produces skew that is well within the limits of human perception. The impact of low frame rates on speech intelligibility was also investigated in [3] where it is shown that when speakers can see each other on a low-frame-rate video screen, they articulate more clearly than the case where they cannot see each other and are communicating only over an audio link. This contrasts with the case when speakers can see each other face to face, when their speech is less clear.

So, whilst a frame rate of 5fps would seem to be a perceptual cut-off point beyond which quality is no longer acceptable, in practice this might actually be lower. The reason for this is that the perceptual impact of multimedia quality as experienced by users is task-dependent, as identified in [11], where a loss of 99% of video frames was shown to be still regarded as acceptable quality if the users engage in tasksolving, a situation not unlike ones encountered in m-commerce applications. Thus, multimedia presentations, even when subjected to extremely high losses and presented at very low frame rates, need not necessarily impact negatively on the user multimedia- enhanced m-commerce experience.

4 PQoS in m-Commerce

There are two competing factors in m-commerce. Firstly, the increasing pressure to add multimedia content to the shopping experience in order to attract and retain customers. Secondly, the bandwidth on offer, even at 3G and 4G level, might not be sufficient for

such applications, bearing in mind the potential increase in the number of users and the number and diversity of devices accessing m-commerce applications.

4.1 A User-oriented m-Commerce Architecture

A multimedia enabled B2C m-commerce architecture integrating user requirements is presented in Figure 1. Here, user profiles are created offline and store not only user shopping preferences but also multimedia quality preferences (such as “dont mind a black and white versions of images”, “start transmitting video at 5 fps, and do not transmit video if the available bandwidth is not enough for a 3fps display”). Such profiles are stored together with device profiles in an intelligent client interface, which may also, depending on the client capabilities devices include agents to enhance the shopping experience.

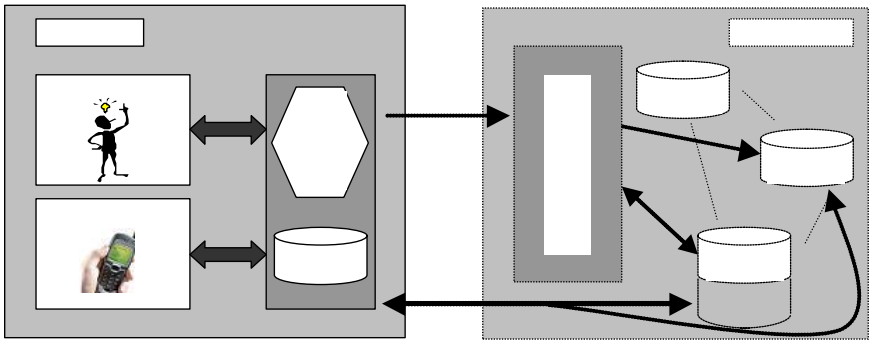

Fig. 1. Integrating User Considerations in an m-Commerce Architecture

The user and device profiles get sent, together with the initial client request to initiate the mcommerce session to a QoS broker, a virtual server which performs the call admission functions based on knowledge of workloads of servers comprising the server pool. If a session is admitted, the QoS broker passes on the client details both to an application server, in charge of commercial transaction management, as well as to a designated multimedia server. The latter accesses multimedia databases which store different quality versions of the same material, and dynamically retrieve into their caches the version corresponding to the requested quality.

Mobile devices are unlikely to possess significant computational capabilities, as any multimedia material is decompressed on the server side and sent uncompressed to the requesting device. Whilst dedicated multimedia (and application) servers ensure that the processing burden does not fall on one server, the fact that full-sized multimedia data would have to be transmitted to the client implies that, in the initial stages at least, transmission might have to start off with a lower quality and then, depending on resource availability, build on to the requested quality. Moreover, a scheme of quality adaptation has been shown to be perceptually preferable [11].

Lastly, a QoS monitor on the multimedia server periodically updates the QoS broker with QoS information relating to the transmitted multimedia content. Moreover, each such server adapts the WebGraph framework [17] to provide scaleable, dynamic presentations of multimedia, with each weblet potentially representing a different quality version of a multimedia clip (a 5 fps clip would have a weblet with a refresh rate of 0.2s, whilst one transmitted at 2 fps would have an associated weblet with a refresh rate of 0.5s).

5 Conclusions

Although multimedia applications have enhanced the user computing experience, little work has been done exploring how multimedia can improve and contribute to the take-up of m-commerce. Whilst this might stem from concerns rising from the narrow bandwidth available and the limited processing capabilities of m-commerce client devices, our paper has shown that, if user perceptual considerations are taken into account, previously identified human tolerance levels do not exclude incorporation of multimedia applications in m-commerce. On the contrary, multimedia applications can be transmitted with perceptually tolerable parameters, augmenting the user m-commerce experience. Also, if one bears in mind that technological improvements will lead to the increase of mobile devices processing power, incorporating multimedia in m-commerce applications becomes less of a challenge and more of a necessity.

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