Improving JPEG 2000 Images Delivery over GPRS Mobile Networks

Charles M Sarraf, Rihab M Wakim
Department of Computer Sciences
Université Saint-Esprit de Kaslik
Kaslik
LEBANON

Abstract: - The General Packet Radio Service (GPRS) is a bearer service for GSM Mobile Networks, which is supposed to greatly improve the access of mobile users, to packet data networks, such as the Internet or enterprise network. On the other hand, today's digital imagery is extremely demanding, not only from the quality point of view, but also from the image size aspect. Current image size covers orders of magnitude, ranging from web logos of size to high quality scanned images. The JPEG2000 international standard represents advances in image compression technology where the image coding system is optimized not only for efficiency, but also for scalability and interoperability in network and mobile environments. Digital imaging has become an integral part of the Internet, and JPEG2000 is a powerful new tool that provides power capabilities for designers and users of networked image applications. We present, in this paper, a solution, based on existing transport protocol (TCP), for improving JPEG2000 images delivery over GPRS mobile networks, based on performance evaluation in a live network.

Key-Words: - **GSM, TDMA, GPRS, 3G, QoS – Quality of Service, JPEG, JPEG2000.**

1 Introduction

Over the last decades, Internet and Mobile Systems have been largely developed and deployed.

The GSM cellular system provides digital switched circuits that are multiplexed both in frequency (FDMA) and time (TDMA). It also provides data transmission at various data rate (9.6 and 14.4 kbps).

In order to address, in GSM networks, data services based on IP protocol, GPRS [1] was developed. With GPRS, user's packets will be directly routed from the mobile network to packet switched network. Networks based on the Internet Protocol (IP) and X.25 are supported by the current version of GPRS [2]. Users of GPRS are supposed to benefit from shorter access time, higher speed rate and lower cost than traditional GSM data access.

A brief description of the GSM system can be found in [7] and detailed description of GPRS system can be found in [8].

Since GPRS is the foundation that third generation mobile systems will be based on, performance evaluations and tests of GPRS networks is an active area of research [9]. TCP performance [3][6], buffering [4], scheduling [5] and mobility procedures have been studied through analytical analysis and simulation as well as experimental testing over deployed networks [10].

Images are wieldy used in the Internet today, the common images formats such as GIF and JPEG are dominating the web, other formats such as PNG is also used but at smaller scale. The current standards, such as JPEG, have been in use for more than a decade now. They have proved to be a valuable tool during all these years, but they cannot fulfill the advanced requirements of today. Today's digital imagery is extremely demanding, not only from the quality point of view, but also from the image size aspect. Current image size covers orders of magnitude, ranging from web logos of size of less than 100 Kbits to high quality scanned images of approximate size of 40 Gbits. The JPEG2000 international standard represents advances in image compression technology where the image coding system is optimized not only for efficiency, but also for scalability and interoperability in network and mobile environments. Digital imaging has become an integral part of the Internet, and JPEG2000 is a powerful new tool that provides power capabilities for designers and users of networked image applications [13].

We present, in this paper, an evaluation for delivering JPEG2000 images over GPRS networks and we propose a solution to improve such delivery.

The evaluation is based on measurements done in a live GPRS network deployed in Lebanon. Some details and results presented in this paper are affected by implementation and configuration issues, the version, the standardization and the supplier of the GPRS networks and the terminal equipments. Therefore, we cannot claim that the presented results apply to all GPRS networks and users.

The structure of this paper is as follows. Section 2 will present an overview of GPRS. An overview of JPEG2000 is presented in Section 3 while Section 4 will address the TCP issues over GPRS mobile networks. We present our method for improving JPEG2000 images delivery in section 5. Results will be presented in section 6. And section 7 will conclude by summing up.

2 Overview of GPRS mobile networks

General Packet Radio Service GPRS[2] is, as extension to the GSM System, provides GSM users with Internet access through a Packet switched technology instead of the circuit switched access that was originally provided with the earlier releases of the GSM. A brief description of GSM system can be found in [7] and a detailed description of GPRS system could be found in [1].

With GPRS, Packet data traffic runs over a new IP backbone, which is separate from the existing GSM core network that is mainly used for speech. This improves the accessibility for the mobile users and optimizes the usage of the radio and backbone resources.

In order to integrate GPRS into the existing GSM network, two new nodes, as illustrated in Fig. 1, called GPRS support nodes (GSN) and a unit called Packet Control Unit (PCU) have been introduced [2]. These additional elements are mainly responsible for routing the data packets between the mobile stations and the external data networks without going through the GSM backbone.

The Serving GPRS Support Node (SGSN) handles packet data traffic of users in a geographical area, called service area while the Gateway GPRS Support Node (GGSN) connect the GPRS network to the external data network. GPRS users use the existing GSM radio interface to transmit their data packets from their mobile stations to a SGSN that serving the service area where they are located. In general, SGSN provides packet routing to and from an SGSN service area. It serves all GPRS subscribers that are physically located within the SGSN service area [2].

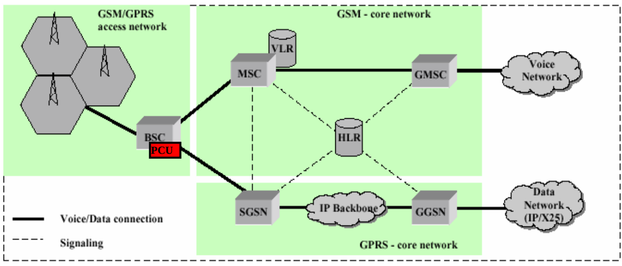

Fig. 1 – GPRS system architecture

The GGSN provides the interface towards other GPRS networks and towards the external IP networks.

GPRS, with a similar coding scheme technique to the one deployed in conventional GSM, extends the two previously defined coding schemes to four, to provide a data transfer rate of 9.05, 13.4, 15.6 and 21.4 kbps respectively.

By combing multiple time slots on the same carrier, GPRS achieves a maximum data transfer rate of 171.2 kbps. Like packet data network, many users share the same time slots.

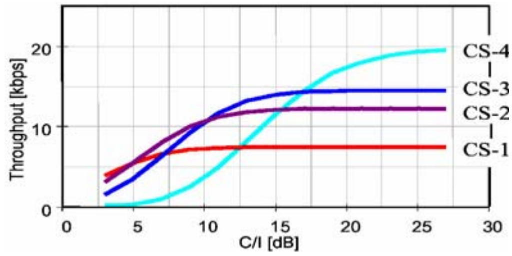

Fig. 2 – Coding schemes for GPRS

Coding schemes, as illustrated in Fig. 2, are selected based on C/I ratio, a strong signal provides a better data rate, while a low C/I will result in a low data rate. Under very good conditions a data rate of 21.4 kbps could be achieved.

3 Overview of JPEG2000

3.1 Introduction

With the continual expansion of multimedia and Internet applications, the needs and requirements of the technologies used grew and evolved. In March 1997, a call was launched for contributions to develop new standard for the compression of still images, the JPEG2000 standard [12][13]. This project, JTC 1.29.14 (ISO/IEC 15444-1 or ITU-T

Rec.T.800), was intended to create a new image coding system for different types of still images, with different characteristics (natural images, scientific, medical, remote sensing, text, rendered graphics, etc.). This coding system provides low bit-rate operation with rate distortion and subjective image quality performance superior to existing standards.

JPEG2000 is a standard for image compression method and file format. This is the successor of the well-known traditional JPEG format written by the ISO group Joint Photographic Experts Group. JPEG2000 is an image coding system that uses state-of-the-art compression techniques based on wavelet technology. Its architecture lends itself to a wide range of uses from portable digital cameras to advanced pre-press, medical imaging and other key sectors. Compared to JPEG, JPEG2000 offers higher compression without compromising quality, progressive image reconstruction, lossy and lossless compression.

While JPEG compression is based on the DCT, a form of sinusoidal transform. There is another class of transforms, based on functions known as "wavelets" that instead of sinusoidal functions use sets of functions that resemble jagged pulses. They can in principle represent a time domain waveform with fewer coefficients than sinusoidal functions. JPEG2000 has replaced the DCT with a wavelet transform. The ISO JPEG2000 committee officially released the specification in 2001 under the designation of "ISO 15444"[12]. Software supporting the new image format is now gradually becoming available but not yet by the most common web browsers.

The JPEG 2000 international standard represents advances in image compression technology where the image coding system is optimized not only for efficiency, but also for scalability and interoperability in network and mobile environments. Digital imaging has become an integral part of the Internet, and JPEG2000 is a powerful new tool that provides power capabilities for designers and users of networked image applications.

3.2 JPEG2000 image format

The JPEG2000 file format, JP2 format, provides a foundation for storing application specific data (metadata) in association with a JPEG2000 codestream, such as information which is required to display the image [12].

Conceptually, the JP2 format encapsulates the JPEG2000 codestream along with other core pieces of information about that codestream. The building-block of the JP2 format is called a box. All data is encapsulated in boxes. The Recommendation defines several types of boxes; the definition of each specific box type defines the kinds of data that may be found within a box of that type. Some boxes were defined to contain other boxes.

The image may be divided into tiles. These tiles are rectangular arrays that include the same relative portion of all the components that make up the image. Thus, tiling of the image actually creates tile-components that can be decoded independently of each other. These tile-components can also be extracted and reconstructed independently. This tile independence provides one of the methods for extracting a region of the image.

Fig.3 provides a reference grid of JPEG2000 image. The reference grid is a rectangular grid of data points with the indices from (0,0) to (Xsiz-1, Ysiz-1). An “image area” is defined on the reference grid by the dimensional parameters, (Xsiz, Ysiz) and (XOsiz, YOsiz). Specifically, the image area on the reference grid is defined by its upper left hand grid point at location (XOsiz, YOsiz), and its lower right hand grid point at location (Xsiz-1, Ysiz-1).

As seen in Fig.3, the reference grid is partitioned into a regular sized rectangular array of tiles. The tile size and tiling offset are defined, on the reference grid, by dimensional pairs (XTsiz, YTsiz) and (XTOsiz, YTOsiz), respectively.

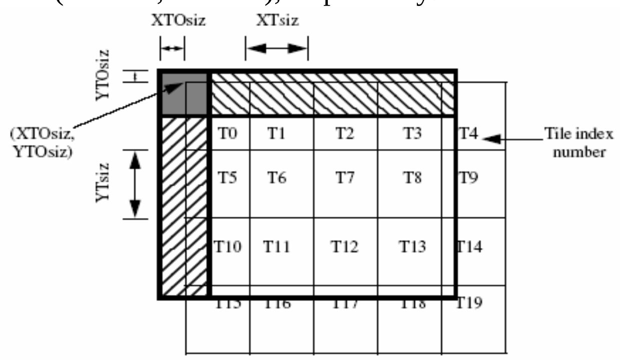

Fig. 3 – JPEG2000 image reference grid

Every tile is XTsiz reference grid points wide and YTsiz reference grid points high. The top left corner on the first tile (tile 0) is offset from the top left corner of the reference grid by (XTOsiz, YTOsiz). The tiles are numbered in raster order.

4 Delivery issues – TCP performance over wireless networks

Unfortunately, low bandwidths, high bit-error rates (BER), and frequent disconnections characterize wireless links. These characteristics are highly divergent from those observed on wired networks. The problem is further compounded by packet losses and long delays in communication introduced into wireless networks due to the mobility of users and the resultant need for hand-offs. Hence, it is essential that protocols that cater to the specific characteristics of wireless communication be developed. There are two approaches to solving the problem, either develop a protocol from scratch that takes care of the above issues or modify existing protocols so that they provide a scalable solution to the problem.

The existing transport protocol, for image delivery, is TCP [17], [18], which is well tuned to the traditional networks made up of wired links and fixed hosts. TCP provides reliable end-to-end delivery of packets between hosts in packet-switched computer communication networks [17]. It provides reliability by maintaining a running average of estimated round trip delay and mean deviation, and re-transmitting packets that are either not delivered within a certain timeout interval, computed as the sum of smoothed round trip delay and four times the mean deviation, or upon arrival of duplicate acknowledgements. Because of the relatively low error rates on wired network, TCP correctly attributes these losses to congestion in the network. TCP reacts to packet losses by dropping the transmission (congestion) window at the sender and initiating congestion control mechanisms like slow start that reduce the load on the network.

In a network comprising wireless links characterized by high bit-error rates, intermittent connectivity and handoff related losses; TCP reacts to packet losses by dropping its window size, and initiating congestion control or avoidance mechanisms. This is because it has no means of distinguishing between transmission related losses and losses due to congestion. Such a TCP reaction results in an avoidable reduction in the link bandwidth utilization and consequently, a significant degradation in performance in the form of poor throughput and high interactive delays [19].

Many projects and research works, [14], [15] and [16], have tested and evaluated the performance of TCP over GRPS Mobile Networks. Various schemes have been proposed to improve the performance of TCP over wireless links as summarized in [11]. These protocols are believed that they lay the foundation for all subsequent research in this area.

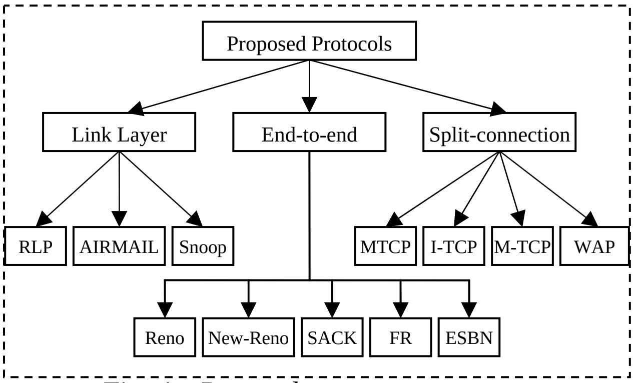

Fig. 4 – Protocols summary

The different proposed protocols were classified into three categories: link layer protocols, end-to-end protocols, and split connection protocols. Figure 4 shows these protocols.

5 Our Proposed Solution

Our solution consists in dividing a JEPQ2000 image into multiple tiles, based on the optimal tile size, and transmits the image tile by tile. In order to determine the optimal tile size, we evaluate the transmission, for download and upload, of different image sizes coded with different tile sizes over a live network deployed in Lebanon, as well as the encoding and decoding times used to convert the images from BMP to JPEG2000 format. Results of such evaluation are presented in Section 6.

Our solution, based on existing TCP protocol, consists of introducing a Gateway in the IP backbone within the GPRS network; as illustrated in Fig.5; such gateway will re-format the downloaded JPEG2000 images by using multiple tiles with the optimum tile size, and deliver the image, tile by tile to the client, tiles will displayed as they come. For the uploaded images, the GPRS client must re-format the image into multiple tiles and transmit them to the Gateway, which may re-group the image as in its original format or transmit as it is. In order to re-group the image into its original format, a protocol is needed to convey the necessary information prior to image transmission.

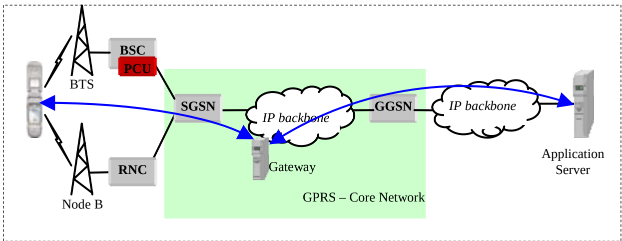

Fig. 5 – Architecture of proposed solution

Our solution will improve the delivery of the image, by providing optimal tile size, customized to a specific GPRS network for upload and download, and will provide on the fly display of the image as tiles arrive.

6 Results

Our testing consisted of taking different categories of images with different sizes and coding them using different tiles' sizes. The different tiles' sizes, that were used, are: (512,512), (256,256), (128,128), (100,100), (80,80), (64,64) and (32,32).

Our evaluation consisted of measuring the encoding and decoding times, using OpenJpeg library developed by the Communications and remote sensing Laboratory, Université catholique de Louvain, Belgium [20], as well as the transmission times over a live GPRS network deployed in Lebanon.

As shown in the graphs below, 5 Categories of images were used. Categories varied according to BMP images' sizes. First category contained images with sizes less than 500 Kbytes. Second Category contained images with sizes between 500 Kbytes and 1MB. Images in the third category had sizes varying between 1 MB and 2 MB. Fourth Category had images with sizes between 2 MB and 3 MB. Finally, images' sizes in the fifth category were greater than 3 MB. Results presented in this paper are based on one image from each category. Images were selected based on average size and compression ratio.

Fig. 6 shows the JPEG2000 image size, Table 1 presents the number of tiles, while Fig. 7 presents the increased percentiles compared to 1 tile.

Results have shown that dividing a JPEG2000 image into multiple tiles with a tile size of 128 or 64 will increase its size by value between 3% and 16% depending on the category, such increase in size will have no impact or a minor impact on the total time consisting of the times for encoding, decoding and transmission as shown in Fig. 8.

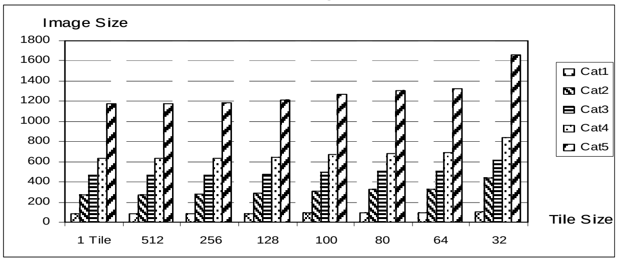

Fig.6 – Image size based on Tile's size

	512	256	128	100	80	64	32
Cat1	1	2	6	9	12	20	72
Cat2	4	16	49	81	121	169	676
Cat3	12	35	126	216	330	504	1980
Cat4	4	12	48	80	130	192	768
Cat5	9	25	100	169	256	400	1512

Table1. Number of Tiles based on Tile's size

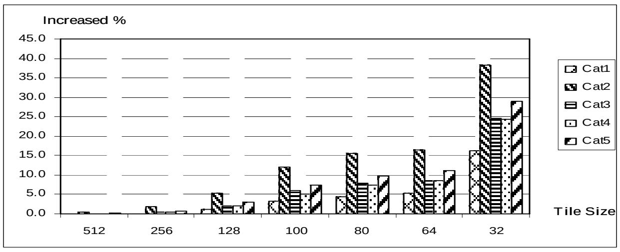

Fig.7 – Increased % compared to 1 Tile

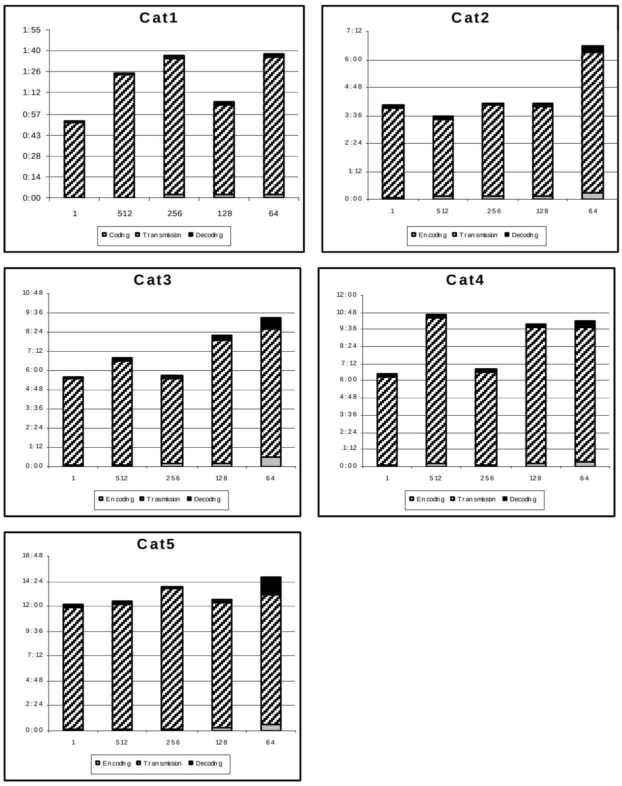

Fig.8 – Total times based on Tile's size

Results have also shown that the time for transmission consist the major part of the total times. Therefore introducing a Gateway in the GPRS network, in order re-format the image, will have minor impact on the total time while improving dramatically the delivery of the image.

Conclusion

Our work has evaluated various categories, based on their original sizes, of JPEG2000 images coded using different tiles' sizes and proposed a solution, based on exiting transport layer, TCP, to improve the performance of delivering JPEG2000 images over GPRS mobile networks.

We have described our solution and results of our measurements, in order to prove that introducing a gateway, in the GPRS IP backbone, will not have major impacts on the delay of delivering JPEG2000 images, but improving it taking in consideration that with one tile, if the TCP could not deliver the whole image, nothing will be received and displayed by the client, while by dividing the images into multiple tiles, which was one of the idea behind JPEG2000 standard, the client can receive and display parts of the image as they are received even though the connection is broken due to network problems.

References:

[1] G. Brasche and B. Walke. Concepts, services and protocols of the new GSM phase 2+ general packet radio service. IEEE Communications Magazine, pages 94-104, August 1997.

[2] GSM 03.60, General Radio Packet Service (GPRS); Service Description; Stage 2

[3] M. Meyer. TCP performance over GPRS. IEEE WCNC, September 1999.

[4] J. Ho, Y. Zhu, S. Madhavapeddy. Throughput and buffer analysis for GSM General Packet Radio Service (GPRS). IEEE WCNC, vol.3, 1999.

[5] J. Sau, C. Scholefied. Scheduling and quality of service in the General Packet Radio Service. IEEE ICUPC, 1998.

[6] H. Wiemann, A. Schieder, H. Ekstrom. Enhanced TBF features in GERAN. WPMC'01, Aalborg, Denmark, September 2001.

[7] M. Rahnema. Overview of the GSM System and Protocol Architecture. IEEE Communications, vol. 31, no. 4 pages 92-100, April 1993

[8] C. Bettstetter, H. J. Vogel, J. Eberspacher. General Packet Radio Service GPRS: Architecture, Protocols, and Air Interface. IEEE Communications Survey, vol. 2, no. 3, Third quarter 1999.

[9] J. Korhonen, O. Aalto, A. Gurtov, H. Laamanen. Measured Performance of GSM HSCSD and GPRS. IEEE ICC, June 2001.

[10] C. M. Sarraf. End-to-End Performance Test of Internet Services over GPRS Mobile Network. IST2003, August 16-18, 2003.

[11] Hala Elaarag, Improving TCP Performance over Mobile Networks, ACM Computing Surveys (CSUR) Volume 34 , Issue 3, September 2002, Pages: 357 - 374 Year of Publication: 2002, ISSN:0360-0300

[12] Martin Boliek, Coeditors Charilaos Christopoulos, and Eric Majani, Coding of Still Pictures, PROJECT: 1.29.15444 (JPEG 2000) ISO/IEC JTC1/SC29 WG1, JPEG 2000 Editor.

[13] Liu, Z. Karam, L., Mutual Information-Based Analysis of JPEG2000 Contexts, Image Processing, IEEE Transactions on, vol. 14, no. 4, April 2005 pages 411-422.

[14] C. M. Sarraf, L. EL-KHAZAN, T. ZOGHBY, J. MAKSOUD, S. EL-ASMAR, J. NASSIF, Measuring QoS for GPRS Mobile Networks, WSEAS Conferences, Prague, Czech Republic, March 13-15, 2005.

[15] R. Chakravorty, I. Camvright, Practical Experience with TCP over GPRS, in Proceedings of the IEEE Global Communications Conference (IEEE GLOBECOM 2002). Nov. 2002. Taipei, Taiwan.

[16] Meyer M, TCP Performance over GPRS Wireless Communications and Networking conference, 1999 WCNC. 1999 IEEE 21-24 Sept. 1999 Page(s):1248 - 1252 vol.3

[17] J. Postel, Transmission Control Protocol, RFC 793, September 1981.

[18] M. Allman, V. Paxson, and W. Stevens, TCP Congestion Control, RFC 2581, April 1999.

[19] R. Caceres, and L. Iftode, Improving the performance of reliable transport protocols in mobile computing environments, IEEE Journal on Selected Areas in Communications, vol. 13, June 1995.

[20] Communications and remote sensing Laboratory, Université catholique de Louvain, Belgium.