Yevgeni Koucheryavy · Giovanni Giambene ·
Dirk Staehle · Francisco Barcelo-Arroyo ·
Torsten Braun · Vasilios Siris
Editors

Traffic and QoS Management in Wireless Multimedia Networks

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Contributors

List of Editors

Mari Carmen Aguayo Torres Universidad de Malaga, Spain, aguayo@ic.uma.es

Khalid Al-Begain University of Glamorgan, United Kingdom, kbegain@glam.ac.uk

Francisco Barcelo-Arroyo Universitat Politecnica de Catalunya, Spain, barcelo@entel.upc.es

Hans van den Berg TNO, The Netherlands, j.l.vandenberg@telecom.tno.nl

Thomas M. Bohnert SAP Research, Switzerland, tmb@nginet.de

Torsten Braun University of Bern, Switzerland, braun@iam.unibe.ch

Orlando Cabral University of Beira Interior, Portugal, orlando-cabral@iol.pt

Ivan Ganchev Telecommunications Research Centre, University of Limerick, Ireland, ivan.ganchev@ul.ie

Giovanni Giambene University of Siena, Italy, giambene@unisi.it

Geert Heijenk University of Twente, The Netherlands, geert.heijenk@utwente.nl

Andreas Kassler Karlstad University, Sweden, andreas.kassler@kau.se

Maria Kihl Lund University, Sweden, maria@telecom.lth.se

Yevgeni Koucheryavy Tampere University of Technology, Finland, yk@cs.tut.fi

Israel Martín-Escalona Universitat Politecnica de Catalunya, Spain, imartin@entel.upc.edu

Dmitri Moltchanov Technical University of Tampere, Finland, moltchan@cs.tut.fi

Edmundo Monteiro University of Coimbra, Portugal, edmundo@dei.uc.pt

Máirtín O'Droma Telecommunications Research Centre, University of Limerick, Ireland, mairtin.odroma@ul.ie

Veselin Rakocevic City University London, United Kingdom, v.rakocevic@city.ac.uk

Michal Ries University of Technology Vienna, Austria, michal.ries@nt.tuwien.ac.at

Vasilios Siris Institute of Computer Science, FORTH, Greece, vsiris@ics.forth.gr

Dirk Staehle University of Würzburg, Germany, staehle@informatik.uni-wuerzburg.de

Burkhard Stiller University of Zurich, Switzerland, stiller@ifi.uzh.ch

Vasos Vassiliou University of Cyprus, Cyprus, vassiliou.v@ucy.ac.cy

Fernando Velez University of Beira Interior, Portugal, fjv@ubi.pt

List of Contributors

Chapter 2

Khalid Al-Begain, Ivano Alocci, Luis Orozco Barbosa, Boris Bellalta, Tudor Blaga, Chris Blondia, Fernando Boavida, Gennaro Boggia, Pietro Camarda, Cristina Cano, Maxweel Carmo, Chrysostomos Chrysostomou, Luca De Cicco, Marius Cinteza, Pedro Cuenca, Marília Curado, Francisco M. Delicado, Jesús Delicado, Virgil Dobrota, Alexander N. Dudin, José Tomás Entrambasaguas, Samuele Giannetti, Gerardo Gómez, Luigi A. Grieco, Yevgeni Koucheryavy, Gabriel Lazar, Marios Lestas, Paulo Loureiro, Carlos Macián, Lefteris Mamatas, Ion Marghescu, Saverio Mascolo, Michela Meo, Dmitri Moltchanov, Vilena V. Mushko, Marc C. Necker, Miquel Oliver, Zigmund Orlov, Panagiotis Papadimitriou, Jose F. Paris, Cristina Parraga Niebla, Andreas Pitsillides, Javier Poncela González, Tatiana Radulescu, Sylwia Romaszko, Aduwati Sali, Jorge Sá Silva, Michael Scharf, Anna Sfairopoulou, Paulo Simões, Vassilis Tsaoussidis, José Miguel Villalón, Suleiman Y. Yerima

Chapter 3

Manuel Alvarez-Campana, Aurimas Anskaitis, Fredrik Berggren, Virgil Dobrota, Darius Guršnys, Tomaz Javornik, Algimantas Kajackas, Gorazd Kandus, Pasi Lassila, Remco Litjens, Andreas Mäder, Seferin Mirtchev, Mihael Mohorcic, Marc Necker, Christian Nyberg, Aleksi Penttinen, Eduard Popovici, Tatiana Radulescu, Michal Ries, Miha Smolnikar, Vasos Vassiliou, Jorma Virtamo

Chapter 4

Firas Albalas, Chitra Balakrishna, Dinko Begusic, Tudor Blaga, Frank Brouwer, Irene de Bruin, Yewen Cao, Eduardo Cerqueira, Marília Curado, Virgil Dobrota, Tomás Entrambasaguas, Yusun Fu, Bernd Gloss, Gerardo Gómez, Algimantas Kajackas, Gorazd Kandus, Gabriel Lazar, Paulo Mendes, Edmundo Monteiro, David Morales, Augusto Neto, Roman Novak, Nikola Rozic, Juan J. Sánchez, Antonietta Spedalieri, Luis Veloso, Andrej Vilhar, Neill Whillans, Youqian Xiao

Chapter 5

Stefano Avallone, Hans van den Berg, Marcel Castro, Peter Dely, Patrick Goering, Carles Gomez, Robbert Haarman, Philipp Hurni, Jonas Karlsson, Fei Liu, Ruy de Oliveira, Josep Paradells, Frank Roijers, Barbara Staehle, Dirk Staehle, Thomas Staub

Chapter 6

Torsten Braun, Orlando Cabral, Hasan, David Hausheer, Jorge Infante, Gorazd Kandus, Mihael Mohorcic, Cristian Morariu, Miquel Oliver, Peter Racz, Fernando Velez, Martin Waldburger, Ning Wang

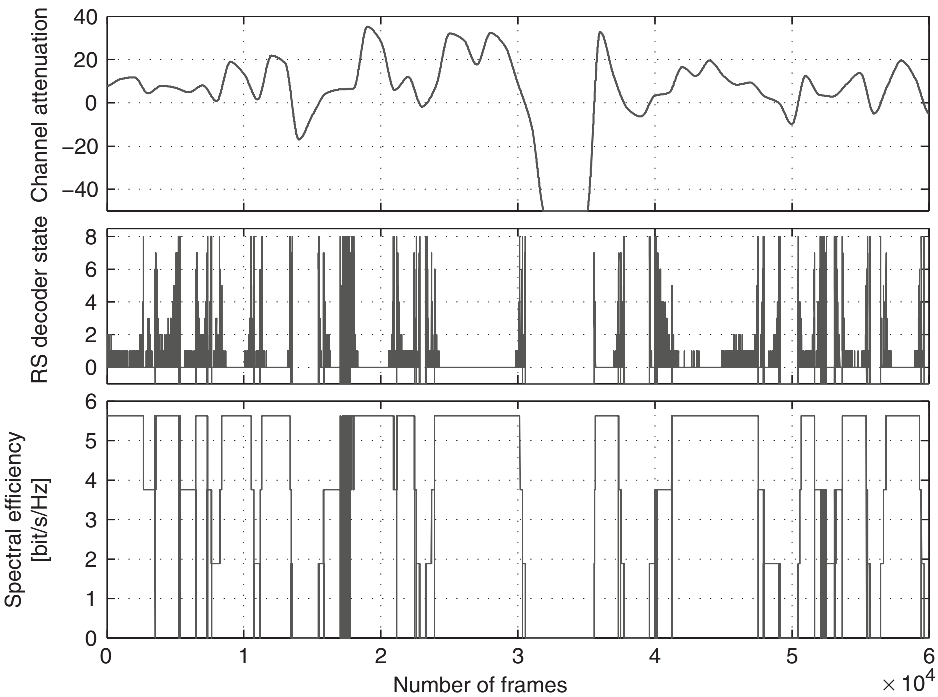

Fig. 3.14 FEC performance and spectral efficiency in HAP channel (copyright © 2007 IEEE [Smo07])

channel attenuation over 60,000 frames, the middle graph shows the RS decoder state in a given frame in terms of the number of corrected bytes (with the value –1 denoting that RS was no longer able to restore the original data), and the bottom graph gives the current spectral efficiency. Comparing the average spectral efficiencies of all three scenarios on the same section of railway track leads to the conclusion that switching based only on the RS decoder state information (for "down" switching), that is, the *only RS* scenario, provides similar performance to the *without RS* scenario, where only the value of estimated E_s/N_0 is observed when deciding for a switch. Moreover, the *with RS* scenario combining information on RS decoder state and estimated E_s/N_0 further improves the performance in terms of average spectral efficiency.

3.3.3 HSDPA Performance Based on Measurements

The performance of HSDPA has been largely investigated in the past years. Most of the studies, however, rely on analytical models or simulation techniques, in general following a more or less theoretical approach; see the discussion in Section 3.2.1.1. As the number of HSDPA networks in operation grows and users start using them, there is a lack of knowledge about the real performance provided by this technology. Some recent papers present results based on measurements in a laboratory [Hol06a], in scenarios that clearly differ from the real conditions found in a live HSDPA network. In this respect, it is worth mentioning a few studies based on measurements of commercial HSDPA networks [Der06, Jur07]. These studies, however, focus on measurements related to one HSDPA user, without taking into account the influence of other simultaneous HSDPA users sharing the capacity of the cell. Although this aspect can be neglected in early HSDPA network deployments, as the number of users increases it should definitely be taken into account.

Precisely one of the main contributions of this work is the realization of measurements in a scenario with multiple HSDPA users accessing the same cell. As the traffic load in many UMTS/HSDPA commercial networks is rather low, HSDPA traffic was generated by several students participating in the measurement experiments. The results motivated the investigation of the impact of TCP (Transport Control Protocol) configuration parameters on the observed performance, concluding the convenience of employing large TCP receive window sizes. Further details can be found in [TD(07)033].

The measurement scenario located in a teaching laboratory at the Universidad Politécnica de Madrid is within the range of an HSDPA/UMTS macro-cell covering the university campus. A total of 28 students, subdivided on two shifts, participated in the measurements campaign. The experiments were carried out from 1100 to 1400 on work days (i.e., during the network's busy hours). Each student had a desktop computer with a Category 6 (3.6 Mbit/s) HSDPA device. The students performed several basic experiments including Web navigation sessions, Web-based on-line speed tests, and file downloads.

During the first experiment, students conducted a 5-minute Web navigation session. Figure 3.15 shows the probability density function (PDF) and the complementary cumulative distribution function (CDF) for the downlink peak rate of the experiments. The average download peak rate was 870 kbit/s, with 85% of the users obtaining a peak rate above 550 kbit/s. These bit rates are at application level, which in part explains why the figures are below the physical bit-rate of the employed HSDPA devices (3.6 Mbit/s). In addition to protocol overheads, we should also consider the non-optimum indoor

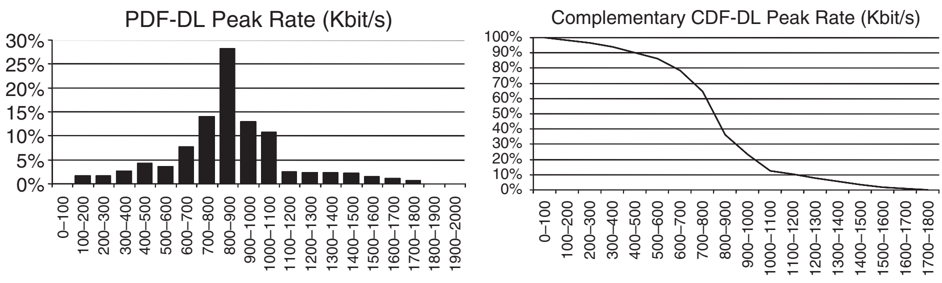

Fig. 3.15 Results for HSDPA Web navigation experiments

propagation conditions at the laboratory, the non-HSDPA traffic load in the cell (the experiments were run at the busy hour), and, of course, the relatively high number of HSDPA users in the cell (a dozen). Taking into account these considerations, we can conclude that the results are quite satisfactory.

In the next experiment setup, users downloaded a number of files from a FTP (File Transfer Protocol) server. Three different file sizes were considered: 100 Kbyte, 1 Mbyte, and 10 Mbytes. For each file size, the experiment was repeated four times. For comparison purposes, the same experiments were performed previously with a single HSDPA user in the cell. The results are summarized in Fig. 3.16. For the single-user case (left-hand graphic), the average download throughput was between 500 kbit/s and 950 kbit/s, while the maximum download throughputs ranged from 675 kbit/s to 1100 kbit/s. It is worth observing that the results are considerably better for large file sizes. In the multiuser scenario (right-hand graphic), the average download throughput was between 450 kbit/s and 640 kbit/s, while the maximum throughputs ranged from 850 kbit/s to 1100 kbit/s. When interpreting these results, one should observe that the experiments were not synchronized (i.e., the users decided freely on the time they started the file downloads without taking into account how many of them were simultaneously connected to the FTP server). While in principle this approach does not allow for accurately interpreting the effect of the HSDPA capacity sharing, it has the advantage of being more in line with the traffic observable in real networks, where the user behaviors are not scheduled.

In order to evaluate the impact of the TCP configuration on the HSDPA performance, the FTP experiments were repeated for the single-user case varying the TCP receive window size and turning on and off the SACK (selective acknowledgment) option. The results are summarized in Fig. 3.17. The results show that – except for the smallest file – the TCP receive window size has a significant impact on the download throughput. In general, increasing the

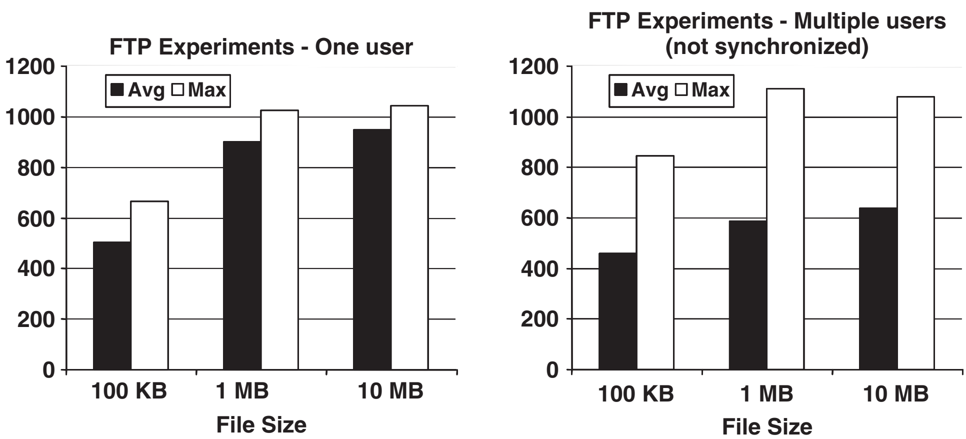

Fig. 3.16 Results for HSDPA file transfer experiments

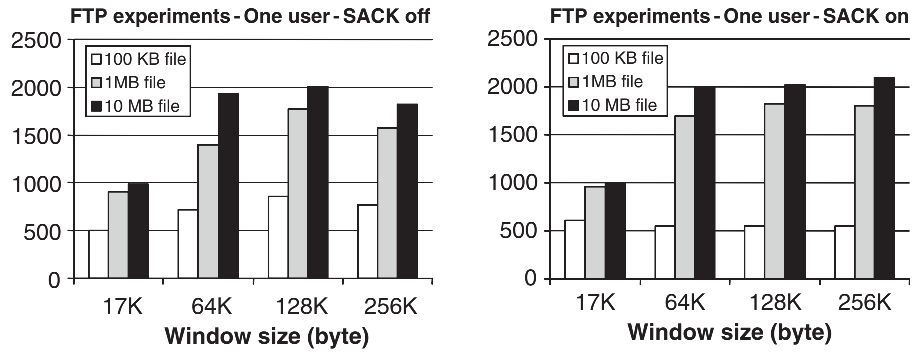

Fig. 3.17 Impact of TCP parameters in the results of FTP experiments

window size leads to higher bit rates. However, there is a maximum window size that, if exceeded, makes it necessary to turn the SACK option on in order to avoid throughput degradation. For small file sizes, using large TCP windows and SACK does not seem to provide any performance improvement. The explanation is that for short file sizes, the TCP connection setup hand-shake procedure and the slow start mechanism do not allow exploitation of the high capacity available in the HSDPA link. This conclusion is quite interesting as it leads us to reconsider the results of the Web navigation experiments. Recent studies report a typical Web page size of around 130 Kbytes [Lev06], which is close to the smallest file size considered in our experiments. Therefore, we can conclude that for conventional Web navigation, the moderate size of Web pages themselves does not permit full exploitation of the high bit rates provided by HSDPA. For further results and interpretation, please refer to [TD(07)033].

In this section, results on the performance of TCP applications over HSDPA based on measurements on a commercial network were presented. One of our main contributions is the realization of measurements in a scenario with multiple HSDPA users simultaneously accessing the same cell. Despite the high variability of the results, the experiments with Web traffic show that the user-perceived quality is very satisfactory and similar to the one achievable with an ADSL line of 1 Mbit/s.

Results for file transfer experiments, far from exhaustive, reveal the capacity sharing effect on the HSDPA downlink channel. In addition, we observe that small file sizes exhibit a download throughput lower than expected, as the transfer finishes before the maximum bit rate can be reached. Considering typical Web page sizes ($\sim$130 Kbytes), we conclude that conventional Web navigation cannot fully exploit the HSDPA capacity.

Our final set of experiments focused on evaluating the effect of TCP receive window size and SACK option. The results indicate that for traffic volumes above 1 Mbyte, large receive window sizes (128 Kbytes or more) and SACK lead to higher download throughputs (up to 100% increase in some experiments).