The 8th International Scientific Conference
eLearning and software for Education
Bucharest, April 26-27, 2012
10.5682/2066-026X-12-128

QOE-ORIENTED MULTIMEDIA DELIVERY ALGORITHM FOR E-LEARNING IN NEXT GENERATION WIRELESS NETWORKS

Vasile Horia MUNTEAN, Marius OTESTEANU
"Politehnica" University Timisoara, Timisoara, Romania
E-mail: horia.muntean@etc.upt.ro, marius.otesteanu@etc.upt.ro

***Abstract**: During the last years, many research efforts in e-learning were focused on developing new content delivery algorithms able to improve the quality of the learning process from content distribution point of view. Considering the increase in terms of users that request access to learning content from their mobile devices, efficient delivery is an important aspect for the mobile learning process. The paper will describe in detail a novel solution for adaptive multimedia content delivery over wireless networks, the Dynamic Quality-Oriented Adaptation Scheme (DQOAS) which focuses on mobile e-learning. The proposed algorithm concentrates on performing multimedia content management in accordance with end-user learning profile and preferences, also considering the network conditions. By using DQOAS the end-user quality of experience (QoE) during learning process is improved, as shown in previous papers that investigate the benefits of the algorithm when IEEE802.11 networks are used. The paper presents also the behavior of DQOAS for multimedia content delivery in next generation networks and in particular over Long Term Evolution (LTE) networks.*

***Keywords:** QoS, content adaptation, E-learning, LTE, multimedia*

I. INTRODUCTION

LTE is an all-IP network technology standardised by the 3rd Generation Partnership Project (3GPP) in Release 8 which uses new multiple access schemes on the air interface. Orthogonal Frequency Division Multiple Access (OFDMA) is used in the downlink and Single Carrier Frequency Division Multiple Access (SC-FDMA) is employed in the uplink to fulfil all the ambitious requirements for data rate, spectrum efficiency, latency, and capacity. Another important technique used is Multiple Input Multiple Output (MIMO) that involves using multiple transmitters and receivers to achieve higher bit rates and improved coverage [1]. An important aspect in LTE is Quality of Service (QoS) support, based on data flow prioritization and traffic differentiation, using simple QoS profiles based on QoS Class Identifiers (QCI). This paper proposes a new adaptive multimedia streaming solution over 4G LTE Wireless networks, designed for mobile e-learning. The algorithm concentrates on performing an optimal multimedia content management in accordance with end-user learning profile, his preferences and knowledge level, and network conditions. The algorithm can accommodate a larger number of users while also supporting higher end-user QoE during the learning process by considering important factors that influence user perceived quality.

The paper is structured as follows. Section II will present the technical aspects and the studies performed by researchers regarding the quality of service in LTE in case of traffic mix connections for uplink and downlink. Section III will describe in detail the DQOAS algorithm while section IV will present the test results. Conclusions will be drawn in section V.

II. RELATED WORK

As LTE evolves and important operators in the telecommunication world such as AT&T, Verizone or Telefonica started the LTE deployment, researchers start to develop algorithms capable of further improving LTE content delivery. However of very high interest is research on proposing various improved scheduling algorithms for both uplink and downlink, in different traffic conditions, involving multiclass flows. The scheduling solutions are looking at reducing the resource utilization while increasing the system capacity to support a larger number of users with an acceptable QoS.

The work performed in this area can be classified [3] based on the design of the scheduler, related to traffic: scheduling for non-real-time flows [4] and scheduling for non-elastic (real-time) flows [5]. The awareness parameter of the LTE scheduler can also be a good classifier. Considering this, we have queue-aware, channel-aware [6] and queue&channel-aware schedulers [3].

In what concerns the uplink (UL) schedulers, it was proven in [7] that by using semi-persistent (SP) scheduling for Voice over IP (VoIP) in LTE, one can obtain better performances than group scheduling when no group interactions occurs. An opportunistic scheduling algorithm is presented in [8], based on HELGA (Heuristic Localized Gradient Algorithm) gradient algorithm. Using this solution, the resource blocks are allocated to users while considering retransmissions requests and maintaining the allocation constraints. Three channel-aware scheduling algorithms for UL are detailed in [6]. Two of the presented algorithms (First Maximum Expansion and Recursive Maximum Expansion) are offering a simple solution for resource blocks localized allocation, while the third (Minimum Area-Difference th the Envelope) is able to perform closer to the optimal combinatorial solution.

Factors such as resource allocation policies, channel conditions, delay sensitive/insensitive traffic, available resources etc, can influence the QoS for LTE downlink. To overcome these problems, some new methods were needed to enhance the default QoS offered by regular IP service providers. One step towards solving these problems is detailed in [3], where the performances of the new proposed scheduler are analysed in an environment with different traffic classes. The results are suggesting that a channel&queue aware scheduler is well suited for LTE downlink. The packet scheduling in case of LTE downlink mixed traffic is analysed in [9] and [10]. The results in both studies show the necessity of service prioritization and differentiation for delay-critical services (e.g. VoIP) when they are delivered together with delay-insensitive traffic like web surfing.

III. DQOAS ALGORITHM

DQOAS extends the Quality Oriented Adaptation Scheme (QOAS) [2] by adding a new parameter in the adaptation process: user QoE expectation levels. This way, the delivery of multimedia content is done considering the user quality expectations, not only the network conditions. DQOAS is designed to perform dynamic content adaptation for the multimedia stream in a wireless environment, considering the end-users' preferences and network conditions. The aim is to obtain a higher QoE for the learning process and to increase the number of simultaneous connected/satisfied users.

In Figure 1, the Feedback module from the client side has the role of monitoring all changes in network conditions. It registers all parameters that can influence the multimedia delivery (delay, loss rate and jitter) and sends them to the N-level Builder in form of short reports. N-level Builder has a second input from the Rules&Param block, represented by a list that summarise the user and session information.

The adaptation process together with dynamic level building process, are performed during three steps, presented below.

1. Initialisation of the Level

When a new user is connected and requests a multimedia stream, the algorithm needs some delivery levels in order to be able to perform content adaptation. Since the new user has no QoE expectation levels determined by the Estimation Module, the QOAS module is requested to statically assign these initial levels, based just on the network conditions. The expectation level for this new user is set to 0 in the list of rules and parameters. When the list is sent to the N-Level Builder Module, the new user with the QoE level set to 0 is detected, and a level request will be forwarded to QOAS Module for building the static levels. QOAS algorithm builds on request, for every new user, M potential quality levels: L1 L2 … Lj … LM, where L1 is the lowest bitrate and LM is the maximum bitrate (the video bitrate).

After this step, the system can estimate the minimum expectation level for the new user and the statically built levels will be dynamically updated. On the client side, the QoE estimation will determine the quality level that represents the acceptable stream quality and this indicator will be associated to the new user in the Rules&Params list so that on the next retransmission of the list, the N-Level Builder will not consider this user as being new.

Taking into account the acceptable quality level, DQOAS algorithm will build a new set of levels, bounded by the user QoE expected level and the maximum video level LM, and will dynamically update them in order to perform a user-oriented dynamic adaptation.

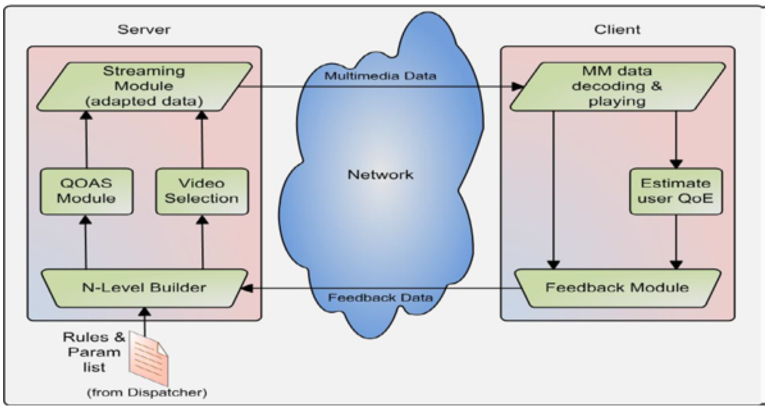

Figure 1. DQOAS architecture

2. Dynamic Update of the Quality Levels

Dynamic update of the quality levels for users involved in streaming sessions is be triggered by different variables: new users attaching or detaching to the network, changes in the delivery conditions, etc. N-Level Builder is the entity responsible of triggering the update decision based on the inputs received from the Feedback module and from the Dispatched (Rules&Param list).

If the expectation level determined by the QoE estimator for user Uk is Mk, this level must be inside the interval defined by L1 and LM, that represent the min and max static levels used by QOAS module. When Mk is determined, N-Level Builder module received a report and starts rebuilding the adaptation levels for user Uk. Each time there is a change detected by the QoE Estimator regarding the QoE expectation level for user Uk, N-Level Builder triggers the dynamic update of the quality levels.

The QOAS module allocates to every new user a fixed number of levels, M. But during the adaptation process, a user can have a variable number of levels, N that depends on the available bandwidth, network conditions, users' QoE minimum expectation level and on the total number of users. Using these quality levels that are specific to each user, DQOAS can perform a better video quality adjustment in accordance with user preferences.

3. Adaptation Mechanism

For every user involved in the e-learning session – U1 U2 … Uk … Up-1 Up – there is a dedicated entry in the Rules&Params list, that specifies the minimum expected quality: M1 M2 … Mk … Mp-1 Mp. For user Uk, DQOAS builds the dynamic levels in the interval between Mk and LM, by dividing the available bandwidth in intervals. The results obtained are closely related to the network QoS parameters, that are computed in real-time. Having these intervals gives the algorithm the possibility to tune and use the QOAS Module on these new levels computed for user Uk.

Streaming one file according to the user preferences (levels) is the responsibility of the Streaming Module while video selection is done by the Video Selection Module, based on the information presented in the Rules&Params list.

Figure 2 presents using pseudo-code the proposed algorithm, deployed on the architectural structure described above.

```
SERVER: Adaptation Module implementation (pseudo-code)

Begin

Is_Feedback (received package)
{         if (received package) is fbk then
                    Analyze_Report (received package)
          else
                    exit;
}

Analyze_Report
{
          Extract_Interest_Factors
          Estimate_User_Quality
          Network_Conditions
          Network_Infrastructure
          Decide_Rate
}

End
```

```
CLIENT: Feedback Module implementation (pseudo-code)

Begin

Is_Multimedia (received package)
{         if (received package) is Mm then
                    Report (received package)
          else
                    exit;
}

Report (received package)
{
          Calculate_Interest_Factors
          Build_Report
          Deliver_Report
}

End
```

Figure 2. DQOAS algorithm – pseudo-code representation

IV. TESTING AND RESULTS

The proposed algorithm was tested using the LTE System Level Simulator [11], capable of simulating LTE SISO (Single Input Single Output) and MIMO networks using TxD (Transmission Diversity) or OLSM (Open Loop Spatial Multiplexing) transmit modes. DQOAS functioning principle was implemented as an option for multimedia delivery, in order to test the utility and the results when the proposed adaptation algorithm is deployed over LTE networks. The simulation results obtained with DQOAS algorithm are compared with the results obtained when the original adaptation algorithm is employed, leaving just the LTE QoS architecture to manage the multimedia flows.

Figure 3 presents the simulation setup used. It consists of 7 eNodeBs with 10 User Equipments (UEs) attached to each. For testing purposes, we considered that each user receives two data streams, from which one has rich media content. The second stream simulates a web browsing connection that is being used simultaneously with rich media content streaming. One user from the 70 available was chosen in order to analyze the throughput and BLER. This is User 4, attached to eNodeB 1. Also, for every test scenario, the downlink scheduler used was Proportional Fair scheduler. The minimum required level for fulfilling the user's QoE for the multimedia stream (first stream) was set to 0.500 Mbps for all users. The second stream, which is a TCP download, the minimum accepted level is set to 0.250 Mbps. All users are moving randomly through the network map with a speed of 5 km/h. The throughput and BLER average values are calculated over the last 40 second of each simulation.

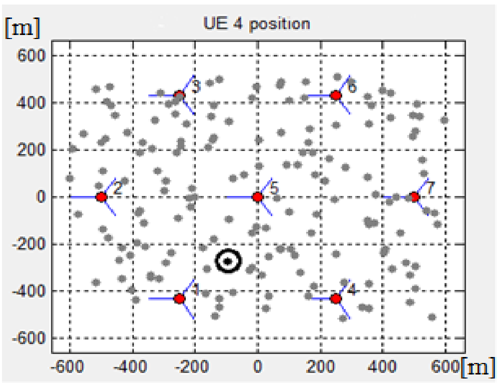

Figure 3. LTE network map - 7 eNodeBs with 10 UEs attached to each

In the first experiment, the original LTE prioritization scheme for service flows is used, along with the LTE delivery mechanism.

The results obtained when PF scheduler is used are illustrated in Figures 4 that presents both the throughput and the BLER for each stream received by User 4.

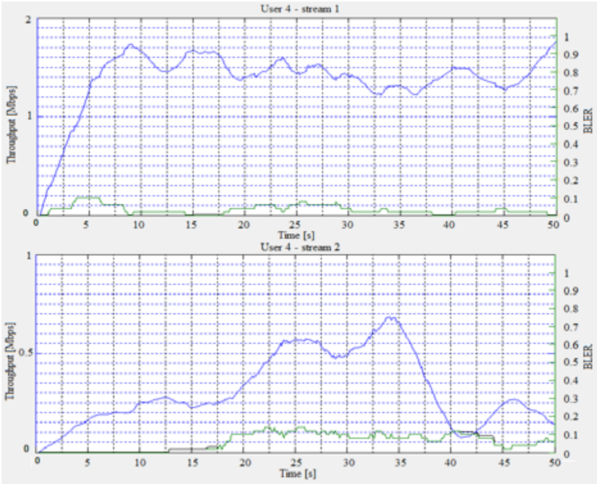

Figure 4. Exp.1 - Throughput and BLER for User 4 when PF scheduler is used

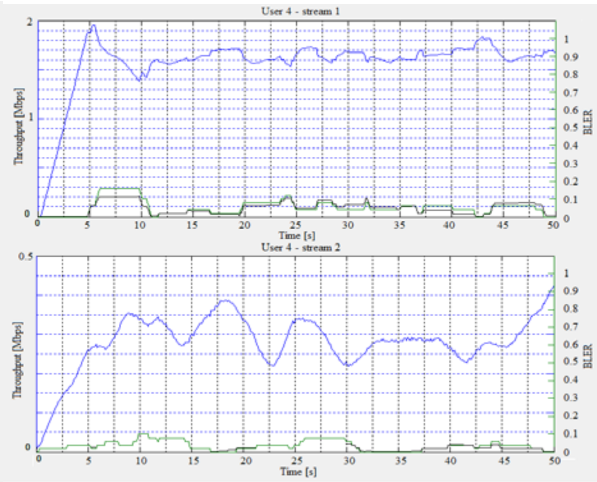

Figure 5. Exp.2 - Throughput and BLER for User 4 when PF scheduler is used

The average throughput of stream 1 when PF scheduler is used is 1.447 Mbps, satisfying the minimum requirements for User 4, 0.500 Mbps. For the second stream, the average throughput calculated shows a value of 0.418 Mbps. Even if the average throughput is above the required satisfaction rate (0.250 Mbps), there is a period of 6 seconds, between second 39 and second 45, when the experienced throughput is below the requested quality. In terms of user perceived quality, this 6 seconds interval can determine the user to terminate the session.

The second experiment performed using the 3GPP LTE technology is using the original flow prioritization mechanism in conjunction with the delivery algorithm proposed in this paper, DQOAS. User 4 throughput variation in time for the two streams when PF scheduler is used is presented in Figure 5. The average throughput value for the first stream is 1.671 Mbps, which is greater than the one obtained in similar conditions in the context of the first experiment. The second stream average throughput value, 0.292 Mbps, is smaller than the one obtained when LTE QoS mechanism is used, but it never drops for more than 2 seconds under the minimum required level, which is 0.250 Mbps. This is an important aspect, because the chances User 4 will terminate the session due to a long period of unsatisfactory quality are reduced. The primary goal of DQOAS is to keep the transmission rate over the required level, and only after that, if the network conditions are allowing it, to increase the delivery rate. Considering also the BLER values presented in Table 1, we can conclude that using the DQOAS mechanism for multimedia delivery over LTE networks generally improves the transmission quality, compared to the LTE QoS-based delivery mechanism. In terms of user satisfaction, for the first experiment the result was 48% and for the second it was 51%. Even if 51% satisfied users does not seems to be a good ratio, it is important to mention that this value was calculated considering all 70 users are using the same application simultaneously while moving randomly inside the network map.

The delivery of media-rich content utilizes a large part of the available network resources and usually lasts for a moderate/long period, during which network conditions can vary. Considering that random losses are producing a greater negative impact on the users' QoE than a controlled reduction in quality, we can say that DQOAS offers an alternative for multimedia delivery over wireless networks, reducing the losses while improving the number of satisfied users.

Table 1. BLER values for the two experiments

Experiment	BLER – Stream 1 [%]	BLER – Stream 2 [%]
1	5.3	7
2	4.3	3.1

V. CONCLUSIONS

This paper presented an algorithm able to perform an optimal adaptation of the multimedia content streamed over a 4G LTE wireless network in accordance with end user's preferences, improving the e-learning quality. The simulation results are showing that using a dynamic stream granularity with a minimum threshold for the transmission rate, improves the overall quality of the multimedia delivery process, increasing the total number of satisfied users and the link utilization, by controlling the radio resources allocation. The algorithms' decision to terminate a session when this is considered to be unsatisfying proves to be good, because it allows it to reallocate those resources to other users, maintaining their delivery rate over the minimum accepted level. Compared with the default delivery scheme used in LTE, there is an important increase in the quality of e-learning process and the possible benefits are a lower loss rate for video streams delivered using this algorithm and an increase in the total number of simultaneous clients served, maintaining end-user perceived quality over the medium level of multimedia experience.

Acknowledgements

This work was partially supported by the strategic grant POSDRU 2009 project ID 50783 of the Ministry of Labour, Family and Social Protection, Romania.

References

[1] B. Furht, S. Ahson, Long Term Evolution – 3GPP LTE Radio and Cellular Technology. CRC Press, 2009.

[2] G.-M. Muntean, "Efficient Delivery of Multimedia Streams Over Broadband Networks using QOAS" in IEEE Trans. on Broadcasting, vol.52, No.2, pp. 230-235, June 2006.

[3] B. Sadiq, R. Madan and A. Sampath, "Downlink Scheduling for Multiclass Traffic in LTE" in EURASIP Journal on Wireless Communications and Networking, vol. 2009, Article ID 510617, 18 pages, July 2009.

[4] K. Seong, M. Mohseni and J. M. Cioffi, "Optimal resource allocation for OFDMA downlink systems" in Proceedings of the IEEE International Symposium on Information Theory (ISIT '06), Seattle, USA, July 2006.

[5] N. Chen, S. Jordan, "Downlink scheduling with probabilistic guarantees on short-term average throughputs" in Proc. of the IEEE Wireless Communications and Networking Conference, Las Vegas, USA, April 2008.

[6] L. A. de Temino et co., "Channel-Aware Scheduling algorithms for SC-FDMA in LTE Uplink" in IEEE 19th International Symposium on Personal, Indoor and Mobile Radio Communications, Cannes, France, Sept. 2008.

[7] H. Wang and D. Jiang, "Performance Comparison of Control-less Scheduling Policies for VoIP in LTE UL" in IEEE Wireless Communications and Networking Conference (WCNC 2008), Las Vegas, USA, April 2008.

[8] M. Al-Rawi et co. "On the Performance of Heuristic Opportunistic Scheduling in the Uplink of 3G LTE Networks" in IEEE 19th Int. Symposium on Personal, Indoor and Mobile Radio Communications, Cannes, Sept 2008.

[9] J. Puttonen et co., "Mixed Traffic Packet Scheduling in UTRAN Long Term Evolution Downlink" in IEEE 19th International Symposium on Personal, Indoor and Mobile Radio Communications, Cannes, France, Sept 2008.

[10] I. Siomina, S. Wanstedt, "The Impact of QoS Support on the End User Satisfaction in LTE Networks with Mixed Traffic" in IEEE 19th Int Symposium on Personal, Indoor and Mobile Radio Communications, Cannes, Sept 2008.

[11] J. C. Ikuno, M. Wrulich and M. Rupp, "System level simulator of LTE networks" in Proceedings of IEEE 71st Vehicular Technology Conference, Taipei, Taiwan, May 2010.