Design of a Unified Multimedia-Aware Framework for Resource Allocation in LTE Femtocells

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ABSTRACT

In future 4G communication networks, it is expected that most of the bandwidth will be used to serve multimedia applications. Thus, there is a need for scheduling mechanisms, which can manage various types of multimedia communication (interactive, conversation, video streaming, etc.) and provide adequate Quality of Experience according to the application needs. The most promising candidate for 4G systems, i.e., Long Term Evolution, also integrates femtocells as a cost-effective solution for pervasive communication. In such a scenario, the implementation of effective scheduling mechanisms becomes even more important. Finally, before implementing scheduling policies on real devices, validation through simulation studies is often employed. For all these reasons, we investigated the implementation of an adaptive scheduling mechanism for an LTE scenario with femtocells within the well known ns3 simulator. This paper describes the preliminary steps of this activity.

Categories and Subject Descriptors

C.2.1 [**Network Architecture and Design**]: Network communications, wireless communication; I.6.8 [**Simulation and Modelling**]: Discrete event

General Terms

Design; Verification

Keywords

Simulation, LTE, multimedia, packet scheduling

1. INTRODUCTION

4G systems are often identified with the Long Term Evolution (LTE) of 3G cellular systems, such as the Universal Mobile Telecommunications System (UMTS). LTE offers multicarrier approach for multiple access. For the downlink, it uses Orthogonal Frequency-Division Multiple Access (OFDMA) and Single-Carrier Frequency-Division Multiple Access (SC-FDMA) in the uplink direction. LTE incorporates the evolution of radio access with the help of Evolved-UTRAN (E-UTRAN), therefore, LTE in conjunction with System Architecture Evolution, which includes Evolved Packet Core, is known as Evolved Packet System (EPS).

EPS uses the concept of bearer, which is basically the flow for traffic with defined Quality of Service (QoS) requirements for the User Equipment (UE). According to 3GPP standards, the QoS parameters for LTE systems are: QoS Class Identifier (QCI), Allocation/Retention Priority (ARP), Guaranteed Bit Rate (GBR), Maximum Bit Rate (MBR) and Available Maximum Bit Rate (AMBR). The QCI involves the following parameters for each bearer type: Resource type, Priority, Packet Error Loss Rate and Packet Delay Budget. Scheduling of radio bearers is done in eNodeB of E-UTRAN, so that resources can be allocated according to their QoS requirements and availability in eNodeB. The eNodeB is the intermediate point between all the users and core network; therefore, radio resource management takes place at the eNodeB.

It is expected that future communication networks will have more and more real time contents. As surveyed by Cisco in 2011 [1], this will amount to 65% of traffic by 2014. In such a context, it will become more common to translate

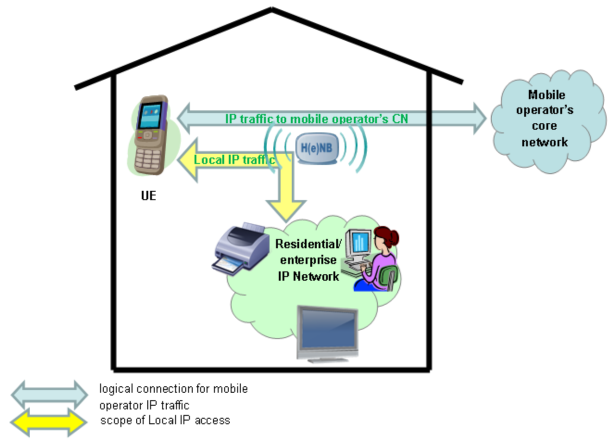

Figure 1: Generic Femto Network Architecture

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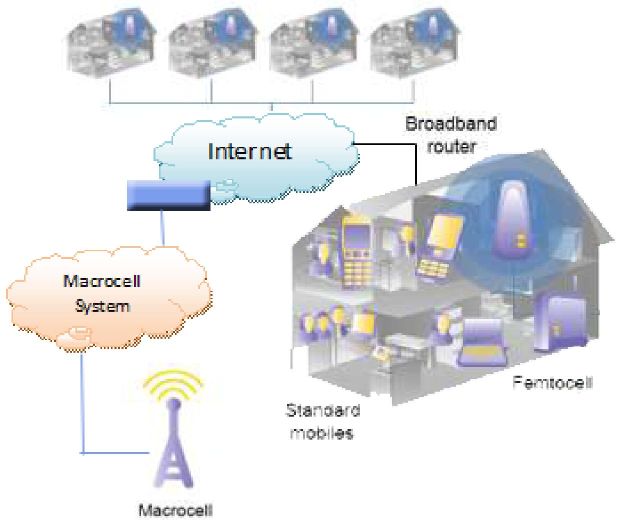

Figure 2: Femtocells Traffic Flow

from QoS to Quality of Experience (QoE), i.e., also involving subjective perception of delivered content. At the same time, increased demand of traffic and coverage is leading to low-cost solutions for network deployment. One promising solution in this sense is represented by femtocells. A femtocell employs coordinated access technology, which is low powered with reduced cost, and can be used to enhance the cell capacity/coverage as well as provide self-organization features. The generic femtocell scenario is illustrated in Fig. 1 [10].

The equipment that is in the customer-premises and provides connectivity with a 3GPP UE over E-UTRAN wireless air interface to the mobile operator network using a broadband IP backhaul is known as HeNB in [3]. Another interesting point to exploit LTE femtocells can be traffic offloading, because local contents will not pass through core network or the eNB. These can be scheduled and routed exclusively via the HeNB, as in Fig. 2.

Referring to our report [4], where we analyzed latest research trends for Multimedia QoE/QoS provisioning, by considering collected articles from top leading journals, conferences, magazines, and letters in the last 5 years, we found that Radio Resource Management (RRM) aimed at multimedia is still relatively unexplored in LTE networks. Even though researchers investigated Multimedia QoS for other OFDMA-based technologies, for example IEEE 802.16, very little attention has been paid to multimedia service provisioning in LTE networks, especially including femtocells. This is the major motivation behind this research.

RRM is an important research issue in high speed communication networks which are facing an increasing demand for high quality service, in particular for multimedia applications. Optimizing network resource allocation and efficiently assigning resources is a challenging task. For wireless systems, where communication channels are time-varying, the resource allocation can take advantage of variable conditions to enhance the system performance. An important issue for future communication systems is quality provisioning relatively to multimedia applications, which often have demanding requirements. Particularly, video packets have stringent deadlines and are prone to packet losses [5]. Moreover, the RRM needs also to address the cases where a mixture of multimedia and non-real time traffic is present.

Among the existing solutions where real time and non real time traffic are managed over an OFDMA network, we mention [12] that provides a resource allocation mechanism involving the following QoS metrics: number of supported users, throughput, transmission rate and packet drop rate. Also [8] considers different kinds of traffic, but the technology of reference is a Wireless Personal Area Network (WPAN). This paper presents an extensive performance evaluation, by means of both network simulation and theoretical analysis, to get results in terms of delay, blocking probability, offered load and system utilization.

In particular, we focus on the Downlink Scheduling in HeNB. The goal here is to provide better quality to the end users which are running GBR applications, while at the same time maintaining an acceptable quality for non-GBR users, in the following generically referred to as NGBR. To this end, we implemented a simple priority algorithm which will be referred to as Adaptive Fair Delay Prioritized Scheduling (AFDPS) and is described in detail in the following sections. We have implemented AFDPS within the Network Simulator 3 (ns3) [2], and verified the applicability of such a solution to provide adequate QoE level to both GBR and NGBR users.

2. PROPOSED MODEL

The main objective of the present paper is to provide a unified framework for downlink scheduling and radio resource management for LTE network. The proposed solution is developed for the base station of an LTE femtocell known as HeNB. The purpose of this algorithm is to provide efficiency to GBR contents while at the same time preserving fairness for NGBR contents as well.

The proposed model is a priority based scheduling mechanism, where GBR traffic users are prioritized over NGBR ones. For both classes of users, a channel-aware scheduling rationale is applied. The flow diagram of the proposed model is shown in Fig. 3. This algorithm is basically adaptive and opportunistic, in a sense that it assigns the Resource Blocks (RBs) to the users based on their Channel Quality Indicator (CQI) value, which changes over time. Thus, the overall resource block assignment changes accordingly. In the downlink, the SINR is calculated for each RB assigned to data transmissions which is the ratio of the power of the intended signal from the considered eNB by the sum of the noise power plus all the transmissions on the same RB coming from other eNBs (the interference signals).

Thus, this algorithm acts at the MAC layer by taking advantage of information from the physical layer (PHY) and utilize it at the Radio Link Control (RLC) layer, particularly within the scheduler. This enhances the efficiency of resource management process to be dynamic and opportunistic.

First of all, the RLC layer calculates the Head Of Line (HOL) delay for the bearers, and then it passes this value to the MAC scheduler. The scheduler calculates the remaining HOL delay according to the current time and then it rearranges all the bearers in ascending order according to their remaining HOL delay values. This sorting is performed so that urgent bearers, which have minimum remaining HOL delay, get RBs assigned earlier and choose the initial best

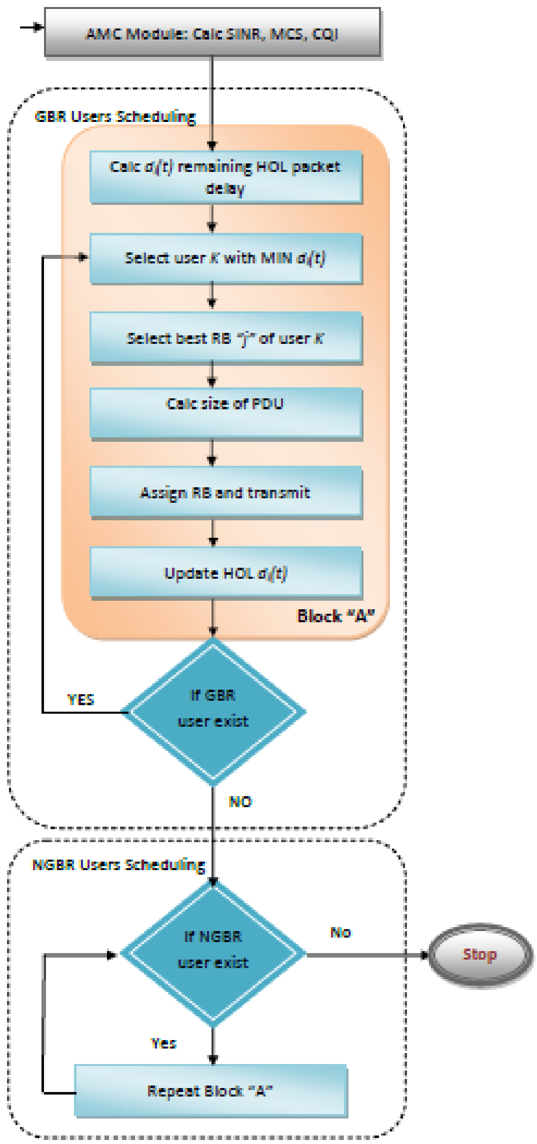

Figure 3: Algorithm workflow

ones. In this way, the GBR bearers get better QoS. The RBs allocation is done in Proportional Fair manner [13]. Before assigning RBs to the selected user, the size of the PDU is computed based upon already collected CQI and computed MCS value for those users. Therefore, the size of the PDU might be different from that of the upper layer SDU, because it depends on the channel condition for that user. In this sense, this algorithm is opportunistic/adaptive in the packet size as well. Therefore, the computations regarding the queue size, SDU arrival time, HOL delay are crucial and should be done carefully. Once the RBs are assigned to selected users in the scheduler, the RLC module is triggered to transmit the specified amount of data, i.e., the computed PDU size, from each bearer. After the PDU is transmitted, the HOL delay is updated, and the resulting value is sent from the RLC to the scheduler at each scheduling instance, i.e., every millisecond.

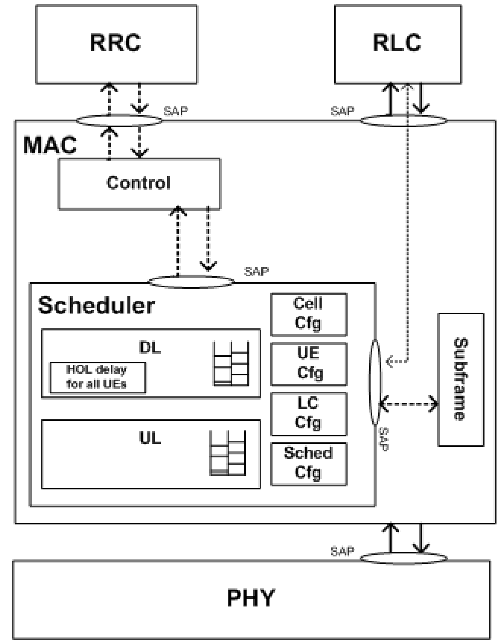

Figure 4: MAC Scheduler Interfaces

Similarly, after GBR bearers, the scheduler assigns resources to NGBR bearers, analogously to what done for GBR contents. In this way, it also provides efficiency for NGBR bearers, but comparatively GBR bearers resource allocation will get better QoE, as it takes place before NGBR resource allocation. This prioritization actually depends on the operator policy concerning the allocation of resources between GBR and NGBR bearers at each scheduling instance. Other implementation choices are possible according to policy of the network operator.

3. IMPLEMENTATION

The entire framework has been implemented and evaluated within ns3 [2], in particular using the LTE module developed by the LENA project [6] which supports the LTE MAC Scheduler API defined by the Femto Forum [10]. The ns-3 simulator is open source and can model different kinds of communication networks. It offers the advantage of being modular and describes the protocol stack in a comprehensive manner. In particular, the extension proposed in [6] models LTE networks in a detailed manner, especially for data link and physical layers. Our goal is to extend this representation so as to include cross-layer interactions with upper layers, especially the transport layer, where multimedia traffic may require special handling.

In particular, the structure of ns3 for LTE includes four modules which can be implemented with interchangeable solutions. The first one, called Radio Resource Control (RRC), acts a container of bearers with specified QoS requirements. The second one, modeling the RLC layer, associates the bearers with the physical devices. Two further modules, denoted as MAC and PHY, model the medium access and the physical channel, respectively. In particular, for the LTE implementation, the PHY layer provides a CQI measurement to all the associated UEs, which enables channel aware scheduling. Our solution deals with the MAC module and

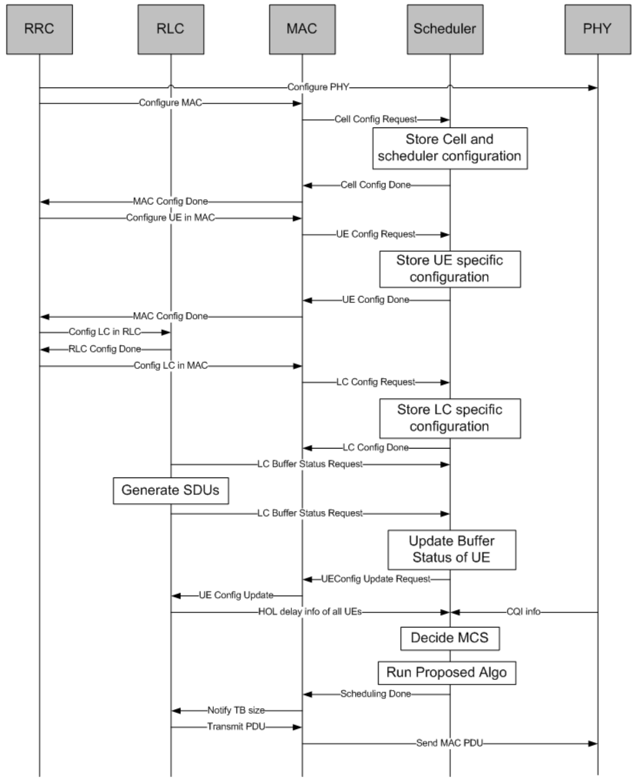

Figure 5: Sequence Diagram of System

was developed with reference to the MAC scheduler interface defined in the Femto Forum API [11] for what concerns the interactions with the other entities. Fig. 4 shows the flow of data and control between the MAC scheduler and PHY, RLC, and RRC. The primitives are also defined in the API, which are passed through various Service Access Points (SAPs). At every Transmit Time Interval (TTI) the subframe within the MAC triggers the scheduler. The TTI is set according to 3GPP standards as 1 millisecond.

The sequence diagram of the initial setup starting from RRC until PHY is represented in Fig. 5. In particular, the original routines that our implementation develops are pictured in the "Scheduler" block interacting with the MAC entity of the ns3 simulator. Importantly, the developed software is entirely modular, and fully compatible with any design choice made in the other blocks, the only cross-layer requirements being the availability of a CQI value at the PHY module and the presence of a SDU-packetizer in the RLC module that enables the queue length updates in the scheduler, as visible from Fig. 5 under the "RLC" block.

4. CONCLUSIONS

We detailed the implementation of a multimedia-aware LTE scheduler for femtocell scenarios. The scheduler manages two priority classes, for GBR and NGBR traffic. This was successfully implemented in the well-known ns3 simulator. The resulting framework is entirely modular and therefore transparent to any specific choice in the simulation modules, as well as in the network entities it interacts with. Moreover, it can be adapted to different design needs for what concerns the management of multimedia flows.

Presently, the software has been evaluated to test its correctness and practicality. We expect to run more detailed simulation campaigns to quantitatively evaluate the performance of multimedia flows in LTE femtocell contexts. Finally, submission of the software for possible official release is also planned.

5. REFERENCES

[1] Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, white paper, 2010Ű2015. Available online at: *http://www.cisco.com/en/US/solutions/collateral/ ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.pdf*. Accessed July 2011.

[2] Network Simulator. Available online at: *http://www.nsnam.org*. Accessed July, 2011.

[3] 3GPP TS 22.220. Service requirements for Home Node B (HNB) and Home eNode B (HeNB), 2011.

[4] I. Ahmed, L. Badia. A quantitative review of the state of the art in quality provisioning for multimedia services over Next Generation Networks. Available online at: *http://www.imtlucca.it/iffat.ahmed*. Accessed July, 2011.

[5] L. Badia, N. Baldo, M. Levorato, and M. Zorzi. A Markov framework for error control techniques based on selective retransmission in video transmission over wireless channels. IEEE J. Sel. Areas in Comm., 28(3): 488-500, 2010.

[6] N. Baldo, M. Miozzo, M. Requena-Esteso, J. Nin-Guerrero. An open source product-oriented LTE network simulator based on ns-3. Proc. ACM MSWiM, 2011.

[7] K.W. Choi, W.S. Jeon, and D.G. Jeong. Resource allocation in OFDMA wireless communications systems supporting multimedia services. IEEE/ACM Trans. on Networking, 17(3): 926–935, 2009.

[8] M. Daneshi, J. Pan, and S. Ganti. Towards an efficient reservation algorithm for distributed reservation protocols. Proc. IEEE Infocom, 2010.

[9] H. Du, L. Fan, U. Mudugamuwa, and B.G. Evans. A cross-layer packet scheduling scheme for multimedia broadcasting via satellite digital multimedia broadcasting system. Proc. IEEE Globecom: 94-101, 2007.

[10] FemtoForums Ltd. The impact of femtocells on Next Generation Mobile Networks, 2011.

[11] FemtoForums Ltd. LTE MAC Scheduler Interface Specification, v1.11, 2011.

[12] X. Guo, W. Ma, Z. Guo, X. Shen, and Z. Hou. Adaptive resource reuse scheduling for multihop relay wireless network based on multicoloring. IEEE Communication Letters, 12(3): 176-178, 2008.

[13] S. Sesia, I. Toufik, and M. Baker. *LTE - The UMTS Long Term Evolution - from theory to practice*. Wiley, 2009.