Design and Development of Medium Access Control Scheduler for Uplink in LTE eNodeB

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Abstract—Long Term Evolution (LTE) is a major step in mobile radio communications, and is beyond 3G systems and is the next generation cellular system of 3GPP. 3GPP’s Long Term Evolution is defined by the standardization body’s Release 8. LTE uses OFDMA and SC-FDMA as its radio access technology with advanced antenna technologies such as Multi-Input Multi-Output (MIMO), for both downlink and uplink. LTE is a system with complex hardware and software. In case of Long Term Evolution (LTE), the scheduler in the Medium Access Layer (MAC) layer of the eNodeB allocates the available radio resources among different UEs in a cell through proper handling. LTE schedulers are part of layer 2 protocol stack and are one such module which can dramatically increase or decrease the performance of the system. In this paper, we are presenting various types of scheduling schemes of LTE and their advantages. The output conditions such as memory usage and execution time for varying number of users are investigated for three of the scheduling methods: Proportional Fair (PF), Modified-Largest Weighted Delay First (MLWDF) and EXP-Proportional Fair (EXP-PF) scheduling algorithm. Developed algorithms are tested for single-cell/multi-cell with multiple-user scenarios in both TDD/FDD frame structure.

Index Terms—Long Term Evolution (LTE), Architecture, eNodeB and Medium Access Layer (MAC) layer Scheduling algorithms.

I. INTRODUCTION

LTE of UMTS is just one of the latest steps in an advancing series of mobile telecommunications systems and introduced in 3rd Generation Partnership Project (3GPP) Release8. LTE uses orthogonal Frequency Division Multiplexing (OFDM) and Single-Carrier Orthogonal Frequency Division Multiple Access (SC-FDMA) as its radio access technology with advanced antenna technologies such as Multi-Input Multi-Output (MIMO). Duplexing is a method for two-way transmission in either frequency domain or time domain. Downlink carries information from eNodeB to UE while uplink carries information from UE to eNodeB. Frequency Division Duplexing (FDD) and Time Division Duplexing (TDD) are two duplexing schemes used in LTE. TDD uses single channel for both downlink and uplink transmission. Separate time slots are allocated for downlink and uplink. FDD and TDD both require guard band or guard interval for effective operation and to avoid channel interference. LTE scheduler algorithm’s needs to be designed at layer 2 (called as MAC layer) stack of LTE for both uplink and downlink. Uplink supports the SC-FDMA technology whereas downlink supports OFDMA technology as an access method [1].

OFDMA facilitates distribution of subcarriers to different users at the same time. In practice group of contiguous subcarriers are allocated to single user. OFDM is a popular multicarrier scheme in which closely spaced subcarriers are used to carry data in LTE downlink. LTE uses novel SC-FDMA scheme in uplink which has lower PAPR (Peak to Average Power Ratio) compared to OFDM and thus facilitating low-complexity and frequency-domain equalization at the receiver. One of the major drawbacks of using OFDM is high PAPR [2]. PAPR is the measure of high dynamic range of input amplitude.

II. LTE ACCESS NETWORK ARCHITECTURE

Figure1 provides a general overview of LTE access network architecture, which is alternatively referred to as Evolved-Universal Terrestrial Radio Access Network (E-UTRAN). E-UTRAN is composed of a single type of access level component, the eNodeB [4]. An eNodeB acts as the terminal point of all radio communications carried out by the UE, and relays data flows between the radio connection and the Evolved Packet Core (EPC) network. EPC is an IP-based, multi-access core network that makes it possible for operators to deploy one packet core network for multiple 3GPP radio access technologies (GSM, HSPA, and LTE) [8]. The functionality of EPC revolves mainly around mobility management, policy management, security, and acting as the Internet gateway for access level nodes. An eNodeB is connected to two units in EPC: Mobility Management Entity (MME) and Serving Gateway (S-GW).

Image: Figure 1: LTE access network (E-UTRAN) architecture

The eNodeB manages usage of radio resources by means of distributing radio resources among UEs with active transmissions, admitting or rejecting new connections arriving at the eNodeB’s coverage, and prioritizing traffic flows according to their associated QOS attributes. The eNodeB is responsible for mobility related tasks such as handover mechanisms for UEs moving from one eNodeB to another, and also UE tracking when in idle in cooperation with MME in EPC. The coordination among neighboring eNodeBs occurs through a logical interface that connects eNodeBs together that is known as the X2 interface.
III. SCHEDULING IN LTE

Scheduling is defined as allocating pre-determined number of sub-carriers for a fixed time to each requesting UEs. There are various methods of scheduling, such as channel dependent or channel aware scheduling methods and channel unaware scheduling. LTE scheduler algorithm need to be designed at layer2 (called as MAC layer) stack of LTE for both uplink and downlink.Schedulers are one such module which can dramatically increase or decrease the performance of the system. Uplink supports the SC-FDMA technology whereas downlink supports the OFDMA technology as an access method. LTE supports for advanced antenna techniques such as MIMO. Since Uplink supports the SC-FDMA technique as its access technology, each users need to be allocated a contiguous Resource Blocks (RBs) which leads to the complexity of the system. 

Uplink scheduling determines which UEs is allowed to transmit and with which resource blocks during a given time interval. However, unlike downlink scheduling, uplink scheduling cannot automatically know the transmission demand from a UE. Thus, before the UE can transmit data to the eNodeB, it first sends a Scheduling Request (SR) to request the transmission permit. When the scheduler in the eNodeB receives the SR, it replies with a scheduling grant for the request [6]. In addition, the scheduler determines the time/frequency resource which the UE should use as well as transport format. After the UE has received the information of assignment, it can transmit data with required parameters over a sub-frame when the grant is valid.

IV. PROBLEM DEFINITION
The eNodeB Medium Access Control (MAC) scheduler is a decision module of the Open System Integration (OSI) layer2 that chooses how to distribute the resources between UEs using scheduling algorithms. Uplink uses the SC-FDMA technology which makes resource block allocation to UEs challenging. SC-FDMA allocates contiguous RBs to each UE hence leading to the complexity of schedulers. To maintain the fairness, QOS and throughput various scheduling algorithms such as channel aware scheduling or channel dependent scheduling is proposed.

Air interface related processing is performed by the MAC and Physical layers in the LTE eNodeB and UE. The MAC sub layers in the eNodeB and UE are responsible for multiplexing the contents of broadcast channels onto the transport channels presented by the physical layers. The physical layers in the eNodeB and UE map the transport channels to the associated physical channels, which are combined to form the downlink and uplink channels of the air interface. The MAC scheduler in the eNodeB is responsible for dynamically scheduling the LTE air interface in both the downlink and uplink directions.

V. METHODOLOGIES
- Literature review for Mobile Communication Standards, LTE (Long Term Evolution), OFDMA, SC-FDMA, TDD, FDD, Multi-Core Multi-Processor Scheduler (MCMPS) and Scheduling Algorithms is carried out by referring 3GPP documents.
- To arrive at design specifications based on SRS (Software Requirement Specifications) and to identify algorithm for scheduling, on MCMPS based TDD/FDD Receiver using the literature review.
- To develop the identified scheduling algorithm for MCMPS based TDD/FDD Receiver using design specifications.
- The flowchart for identified MAC Scheduler algorithms are developed based on design specifications and reviewed literature.
- Developed flowcharts for MAC scheduler are simulated using tools.
- Test cases are developed for testing the simulated MAC scheduler algorithms.
- The simulated MAC scheduler algorithms for TDD/FDD receiver are validated using developed test cases.

VI. DESIGN AND DEVELOPMENT OF SCHEDULING ALGORITHMS
This section discuss about the system development phase of the uplink scheduling algorithms using open source framework of LTE simulator. It contains requirement gathering, requirement analysis and system structure design using block diagram. LTE-Sim has been written in C++.
A. Design of Proportional Fair Scheduling Algorithm

Proportional fair is a compromise-based scheduling algorithm. It is basically based upon maintaining a balance between two competing interests: Trying to maximize total wireless network throughput while at the same time allowing all users at least a minimal level of service which is done by assigning each data flow a data rate or a scheduling priority (depending on the implementation) that is inversely proportional to its anticipated resource consumption.

B. Design of M-LWDF Scheduling Algorithm

The Modified-Largest Weighted Delay First (MLWDF) algorithm belongs to the LWDF family. It tries to meet delay guarantees by prioritizing data according to the queuing delay the packets have experienced. A delay guarantee violation occurs when the packets of user i experience a steady-state delay Ti, which exceeds some delay threshold Di. The value of Di is one of the defining characteristics of the different data types and depends on the negotiation process initiated before any data is transmitted. QoS guarantees require that the probability of such violations must be smaller than some pre-fixed threshold δi. The M-LWDF is a very attractive scheduling protocol used for wireless networks, as it varies the transmission rates of packets, depending on the channel condition.

C. Design of EXP-PF Scheduling Algorithm

In a wireless system, the system capacity is constant, so that each user’s throughput is directly related to the number of allocated slots for transmission. Hence, it is easy to reserve system resource for real time service users in a wireless system. However, in an adaptive modulation and coding (AMC/TDM) system, the system capacity is time varying and depends on the service times of users, so that it is hard to find optimum priority rule for real and non-real time services. An AMC/TDM system cannot reserve service slots enough to satisfy QoS of real time service since the transmission rates per slot changes with respect to time. The EXP rule algorithm can support both real time and non-real time service users in an AMC/TDM system, but the throughput of a non-real time user is not maximized. The EXP-PF algorithm optimizes the throughput of non-real time service users and the EXP rule for real time service users.
VII. CONCLUSION

Memory used to simulate the process increases from 40 Mb to 70 Mb with the increase in number of UEs from 10 to 30 and it is independent on the scheduling algorithm used by the eNodeB.

The time required executing the simulation increases from 1 minute to 14 minutes with the increase in number of UEs from 10 to 30; it depends on the scheduling algorithm used by the eNodeB. In fact, the PF algorithm requires less time than other scheduling strategies due to its very simple implementation.

REFERENCES