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Article *in* International Journal of Applied Engineering Research · December 2015

1 author:

Satheesh Monikandan Balakrishnan
Periyar Maniammai University

International Journal of Applied Engineering Research, ISSN 0973-4562 Vol. 10 No.87 (2015)

A Study on LTE Networks and Performance Analysis of Downlink Scheduling Algorithms

SatheeshMonikandan B,
Research Scholar,
PeriyarManiammai
University, Thanjavur.
Head - Department of ECE
Indian Naval Academy,
Ezhimala, Kerala.
sathy24@yahoo.com

C.Arunachalaperumal,
Associate Professor,
Department of ECE, S.A.
Engineering College,
Chennai-77.
arunachalaperumal@saec.ac.in

Dr.A.Sivasubramanian
Principal,
Mount Zion College of
Engineering,
Kadammanitta,
Kerala.

Abstract

The future wireless networks rely on the new technological advance named Long Term Evolution (LTE) to face the basic challenges like, high data rate real time traffic, need of high QoS, reliable and robust communication link end ever increasing demand for network services. Now-a-days multimedia services are getting more popular among the mobile or cellular users. Seamless multimedia services are possible with the enhancement in data rate. Long Term Evolution is the technology which offers higher capacity and inherent IP support and becomes the effective candidate for the 4G and beyond services. In addition to the faster data rate, LTE provide lower latency for real-time services through Differentiated Services support. Resource allocation plays a vital role in LTE networks. The performance of the LTE networks mainly depends on how effectively the frequency channels are adapted and assigned to the users in each Transmission Time Interval (TTI). The scheduling algorithms should have low complexity and able to distribute time slots and frequency carriers to the users. The major challenge in LTE is to balance QoS and fairness. Hence, it is very essential to design a down link scheduling scheme in order to guarantee the users service quality. This paper discusses some scheduling algorithms designed for the purpose.

Key words: LTE, Scheduling, Radio Access Network, OFDMA, Round Robin.

I.Introduction

The ever growing demand for network services, especially the multimedia services have raised new challenges to the design of future cellular networks. With the bandwidth constraint, the real-time multimedia services have to be considered differently in order to satisfy the QoS. The LTE system introduced by the 3GPP project group brings the cellular communication system to the 4G scenario with it's high capacities and IP based services. The goal of LTE was to increase the capacity and speed of wireless data networks using new DSP (digital signal processing) techniques and modulations that were developed around the turn of the millennium. LTE supports scalable carrier bandwidths, from 1.4 MHz to 20 MHz and supports both frequency division duplexingand time-division duplexing .The IP-based network architecture, called the Evolved Packet Core (EPC) designed to replace the GPRS Core Network, supports seamless handovers for both voice and data to cell towers with older network technology such as GSM, UMTS and CDMA2000. As LTE radio access network is based on Orthogonal Frequency Division Multiple Access (OFDMA), it can support a wide range of multimedia and internet services in high mobility environment. Scheduling plays important role in distribution of radio resources to the various users of LTE network. In order to achieve more QoS, the efficient use of radio resources is very essential.

II.LTE Network Architecture

The LTE architecture mainly consists of two entities, the evolved Node-B (eNodeB) and the Mobility Management Entity/Gateway(MME/GW). Figure 1 shows the simplified architecture of LTE network. The eNode-B is the node between the users and the core network. The eNodeB takes responsibility of allocation of available RBs among all users within the cell and is fixed at the center of the cell[1]. Every eNodeB is interconnected by means of interfaces that are standardized in order to allow multi-vendor interoperability.The Mobility management entity (MME) is the control node that processes the signaling between the User Equipment (UE) and the Core Network (CN). The main functions of MME are session management and mobility management. The radio access network of LTE is Evolved Universal Terrestrial Radio Access Network(E-UTRAN) which consists of a network of eNodeBs.TheeNodeBs are interconnected via X2 interface and are also connected to MME/GW entity via S1 interface.The E-UTRAN is responsible for all radio-related functions, which can be summarizedbrieflyas:

• Radio resource management (RRM) – This covers all functions related to the radio bearers suchas radio bearer control, radio admission control, radio mobility control, schedulinganddynamicallocation of resources to UEs in both uplink and downlink.

• Header Compression – This helps to ensure efficient use of the radio interface by compressingthe IP packet headers that could otherwise represent a significant overhead, especially for small packets such as VoIP.

• Security – All data sent over the radio interface is encrypted.

• Connectivity to the EPC – This consists of the signaling toward MME and the bearer pathtoward the S-GW.

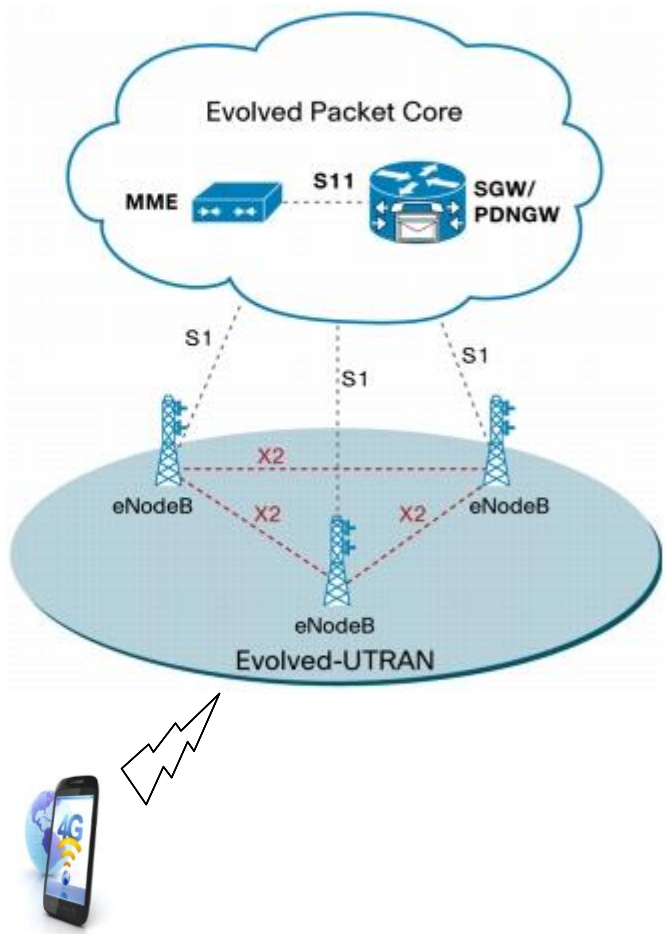

Figure 1 LTE Network

The eNodeBs are interconnected via X2 interface and are also connected to MME/GW entity via S1 interface. The X2 interface protocol consists of two planes namely, X2-User Plane (X2-UP) and X2-Control Plane (X2-CP). The X2 Protocol stack is shown in Figure2. The LTE X2-UP protocol tunnels end-user packets between the LTE eNodeBs. The tunneling function supports the identification of packets with the tunnels and packet loss management. LTE X2-CP has SCTP as the transport layer protocol. The load management function allows traffic load information and exchange of overload information between LTE eNodeBs to handle traffic load effectively. The handover function enables one eNodeB to handover the UE to another eNodeB. The LTE X2 control plane external interface (X2-CP) is defined between two-neighbor eNodeBs. The transport network layer is built on SCTP on top of IP. The application layer signaling protocol is referred to as X2-AP (X2 Application Protocol).

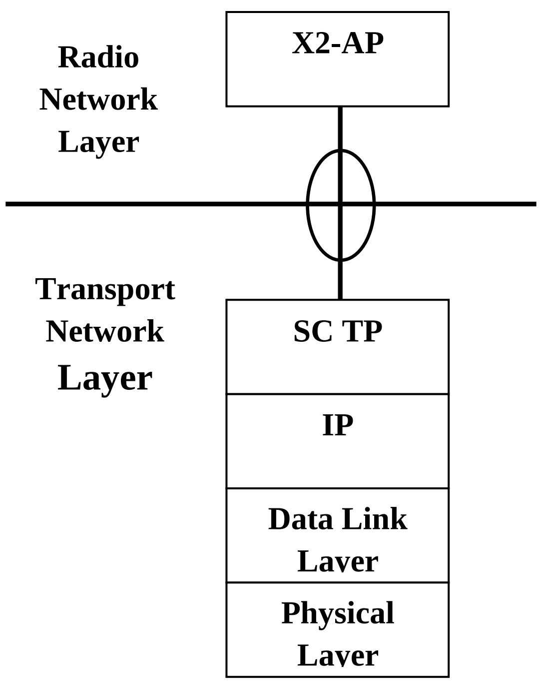

Figure 2: X2-Protocol Stack

The S1 interface is the interface between the LTE RAN and evolved packet core. S1 interface protocol stack is described in Figure 3. In S1 interface also there are two functions, S1-UP (User Plane) and S1-CP/S1-MME (Control Plane). The S1 user plane external interface (S1-U) is defined between the LTE eNodeB and the LTE S-GW. The S1-U interface provides non guaranteed data delivery of LTE user plane Protocol Data Units (PDUs) between the eNodeB and the S-GW.Transport network layer is built on IP transport and GTP-U.

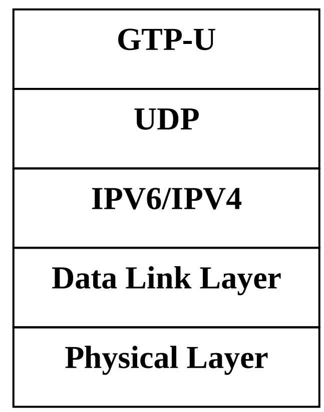

Figure 3: S1-Protocol Stack

UDP/IP carries the user plane PDUs between the eNodeB and the S-GW. A GTP tunnel per radio bearer carries user traffic. The S1-UP interface is responsible for delivering user data between the eNodeB and the S-GW. The IP Differentiated Service Code Point (DSCP) marking is supported for QoS per radio bearer. The LTE S1-MME interface is responsible for delivering signaling protocols between the eNodeB and the MME. S1-MME interface consists of a Stream Control Transmission Protocol (SCTP) over IP and supports multiple UEs through a single SCTP association. It also provides guaranteed data delivery.

III. Radio Resource Management

Radio Resource Management (RRM) is an eNodeB application function that ensures the efficient use of available radio resources. RRM manages the assignment, re-assignment and release of radio resources with consideration of single and multi-cell aspects. The main objective of RRM is to control the use of radio resources in the system. This must be accomplished while the Quality of Service (QoS) requirements of the individual radio bearers are met and the overall used radio resources on the system level are minimized. RRM includes a different algorithms that provide services such as power control, allocation of resources, mobility control and QoS management to ensure the best use of the available radio resources.The Radio Resource Control (RRC) layer in the eNB makes handover decisions based on neighbor cell measurements reported by the UE.The RRC performs paging of the users over the air interface, broadcasts system information, controls UE measurement and reporting functions such as the periodicity of channel quality indicator (CQI) reports and then allocates cell-level temporary identifiers to active users. It also executes transfer of UE context from serving eNB to the target eNB during handover and also performs integrity protection of RRC messages. The RRC layer is responsible for maintenance and setting upof radio bearers.

IV. Scheduling

LTE employs OFDMA, users allocated a specific number of subcarriers for a predetermined amount of time. These are referred to as physical resource blocks (PRBs) in the LTE specifications. PRBs have both time and frequency dimension. Allocation of PRBs is handled by a scheduling function at the eNodeB. Scheduling is the method through which eNB decides which UEs should be given resources to send or receive data.LongTerm Evolution scheduling is done per sub-frame level. It is important to understand key terms Channel quality indicator (CQI), Buffer Status Report (BSR) and Quality of Service (QoS). CQI (Channel quality indicator) is a 4 digit value sent to eNB by UE as a feedback for downlink channel.CQI informs eNB about the channel quality in downlink.

This helps eNB to allocate proper Modulation and coding scheme and Resource block for UE.Buffer Status Report is a UE way of informing network that it has certain data in its buffer and it requires grants to send this data. QoS (Quality of Service) explains how a particular user data should be treated in the network. QoS is implemented between UE and PDN Gateway and is applied to a set of bearers.For example VoIP packets are prioritized by network compared to web browser traffic. UE computes the CQI value from downlink channel and sends value to the eNBand sends BSR reports to eNodeB. Based on BSR, CQI and UE-QoS, eNodeB computes MCS value and PRB mapping information and send it to the UE in downlink.

Round Robin Scheduling

Round Robin is the simplest scheduling method which distributes the resources equally to all the users. It works by allocating the resource blocks to the non-empty Radio link control (RLC) queues in cyclic order. These non-empty RLC queues are also referred as active flows. If all the flows are allocated to some RBGs (Resource block Group) then they all are transmitted in the same sub frame. Otherwise, some of the flows are left unassigned then the allocation in the next frame will start from the last flow that was not allocated. The modulation and coding scheme for different transmission channels are allocated according to the received Channel Quality Indicator (CQI).

Downlink scheduling methods:

The classical downlink scheduling methodologies can be divided into two categories: Fairness-based schemes and capacity-based schemes. Capacity-based user scheduling algorithms first selectone user with the highest capacity and then successively select the next user providing the highest sum capacity. Fairness-based schemes try to ensure throughput fairnessamong all users.

Proportional Fair Scheduling

The Proportional Fair (PF) scheduling supports high resource utilization while maintaining good fairness among network flows.A user is likely to be scheduled when its instantaneous channel quality is high relative to its own average channel condition over time.

Maximum throughput scheduling

The Maximum throughput scheduler maximizes the throughput of the base station. The maximum throughput is achieved by allocating resources on the basis of channel condition only. The user with the highest value of wideband CQI index is scheduled first. The scheduling and calculation of the throughput is very similar to that of Proportional Fair scheduling algorithm.

QoS-Aware Round Robin Scheduling:

The QoS-aware RR (QRR) scheduler[2] is designed to give priority to real-time flows without considering any channel quality information into account. The QRR scheduler is similar to the standard RR case, but the difference is that the parameter τ is introduced in QRR to prioritize real-time flows. τ corresponds to a weight parameter in the well-known Weighted RR scheduler [3] and used as a configurable weight parameter to determine the degree of priority level. When τ is set to 1, both schedulers are the same. The algorithm of the QRR scheduler is explained in Algorithm 1. If the k-th user has a real-time traffic it gets $n*\tau$ RBs, otherwise n RBs, where n is the number of RBs allocated to this user in one round. Here, K is the number of UEs and RB_maxis the total number of RBs.

QoS-Aware Best CQI Scheduling

The QoS-aware Best CQI (QBC) scheduler is designed to give priority to real-time flows by considering the channel qualities of UEs. The configurable parameter δ is used as a priority threshold to treat real-time flows as its having the channel conditions. When δvalue is 1, the QBC scheduler work as Best CQI, while δvalue is 0 QBC treats all real-time flows as it's having the best channel quality. The value of δcan be managed and QOS is enabled. K and RB_maxrepresent the number of UEs and the maximum number of RBs, respectively.CQI feedbacks of all UEs for each RB are received and maxCqiValis calculated using cqiList. After this calculation, candidatesList, which consist of UEs with maxCqiValchannel conditions, is generated. Up to this point all operations are the same as the standard Best CQI. In QBC, real-time flows with lower CQI values are also added to candidatesListif their CQI values are greater than $maxCqiVal*\delta$. Finally, each RB is allocated to UE which is randomly selected from candidatesList.

Genetic Algorithm based Scheduling

Genetic Algorithm (GA), which is inspired by the "survival-of-the-fittest" principle, is a population based meta-heuristic provides a way for exploring the search space in complex optimization problems. GA based LTE downlink scheduler [4] is proposed to allocate radio resources to the users according to the predefined objective function. Initially, a set of population is generated using the appropriate chromosomes. This solution set is periodically updated using the crossover and mutation operations on the current population to generate individuals for the next generation [5]. A set of individuals whose fitness values are higher are kept whereas others are eliminated in the selection phase. This process is repeated until the maximum number of iterations reached.

V. Performance Analysis

In Round Robin scheduling the users are assigned with resource blocks (RB) without bothering the channel conditions or CQI feedback. As every user is scheduled equally, this algorithm guarantees fairness but the throughput performance is poor. It is seen that the maximum cell throughput for round robin scheduling is lesser than the other scheduling algorithms. The Round Robin algorithm does not adapt the Adaptive Modulation and Coding (AMC) based on the CQI feed back.

The Fair scheduling tries to maximize the total cell throughput while having a better balance between throughput and fairness. The QoS aware Round robin scheduling algorithm offers almost same cell throughput values for both real-time and non real-time traffic scenarios.The real-time throughput value increases with the increase of priority weight and the non real-time throughput decreases for every 1000 TTIs. As the QoS Aware CQI scheduling is concerned, the average cell throughput is increased by 10% in real-time traffic.

The GA based scheduling, generates a set of initial solutions using the appropriate chromosomes and the set is updated periodically based on the cross over and mutation processes. From the simulation results, it is observed that the GA based scheduling algorithm quickly converges to a solution which satisfies the target cell throughput. Figure 4 shows the comparison of scheduling algorithms in terms of throughput and Figure 5 shows in terms of fairness. As the Genetic Algorithm based scheduler operates in Throughput mode and Fairness mode, it able to achieve the target throughput with better fairness.

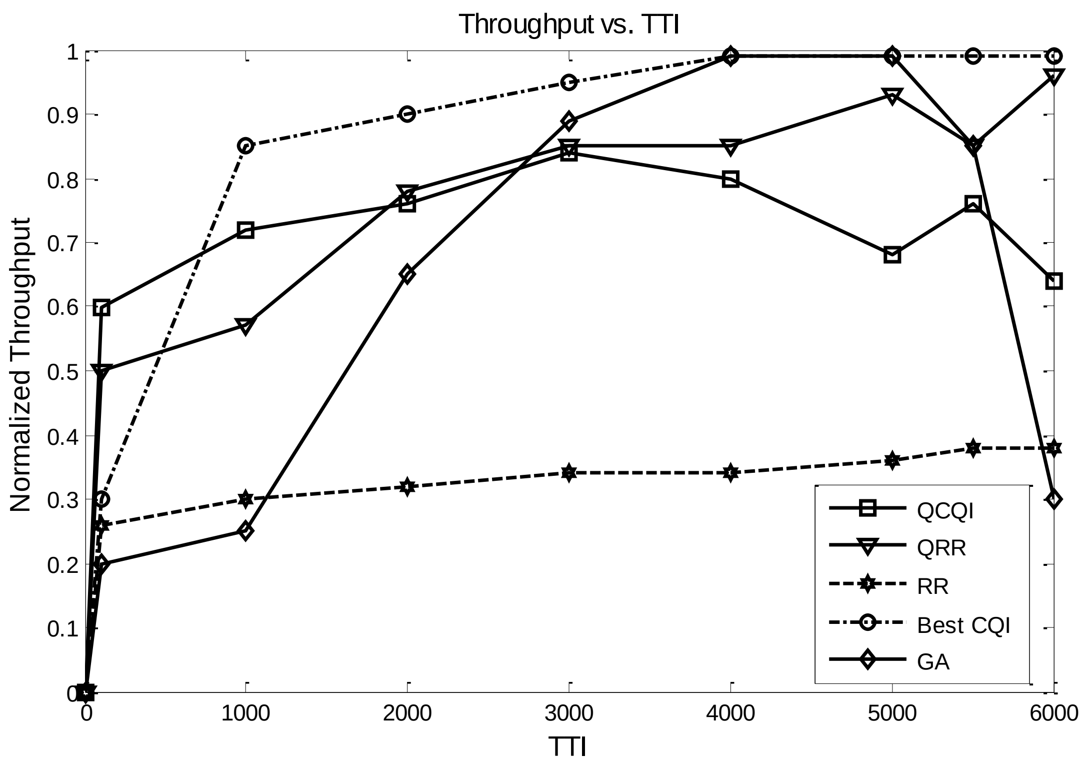

Figure4 Comparison of Normalized Throughput for different Algorithms

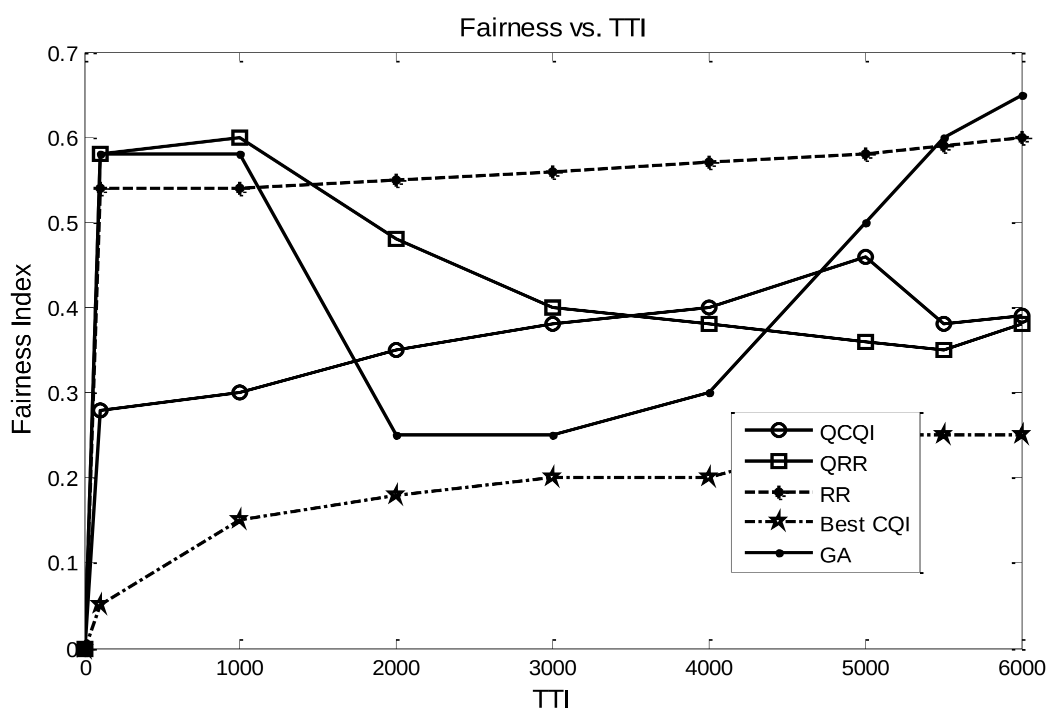

Figure 5 Comparison of Fairness for different Algorithms

VI. Conclusion

Nowadays several downlink scheduling algorithms have been proposed for the Long Term Evolution networks (LTE). In this paper the basic requirement of scheduling, the radio access network architecture and few scheduling algorithms are discussed. The basic scheduling algorithms like Round Robin scheduling, Proportional Fairness and CQI scheduling algorithms have failed to offer the QoS for the real-time traffic requirements. Hence, QoS aware scheduling and Genetic algorithm based Scheduling have been proposed. The simulation results ensure that the QoS aware scheduling and the GA based scheduling are performing better than the conventional algorithms. The GA based scheduling can be effectively used to have better throughput with the given fairness objectives. The performance can be further enhanced by increasing the number of eNodeB nodes.

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