GJCRT : Global Journal of Computer Science Research & Technology
ISSN (online): 2349- 0608

OVERVIEW OF LONG TERM EVOLUTION(LTE) SCHEDULERS

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ABSTARCT:

The increasing number of user's demanding service's have encouraged intensive research in wireless communications. Future generations of cellular communicat --ions requires higher data rates and a more reliable transmission link with the growth of multimedia services. Long Term Evolution (LTE) is one of the fastest growing technologies which supports variety of applications like video conferencing, video streaming, VoIP, file transfer, web browsing etc. In order to support multiple applications, Radio Resource Management (RRM) procedure is one of the key design roles for improving the system performance. In this paper we discussed a 4G technology known as LTE and its scheduling policies. We discussed about four scheduling algorithms and also discuss the requirements of designing a scheduler.

INTRODUCTION

LTE system effectively utilizes the resources by dynamically scheduling the users in both frequency and time domain. However, scheduling algorithms are not defined in the Third Generation Partnership Project (3GPP) specifications. Therefore, it becomes one of the special interests for service providers. The emerging applications with different throughput, delay, Packet Loss Rate (PLR) and bandwidth requirements emphasize the need of a network capable of supporting range of services. To fulfill this need Long Term Evolution (LTE) was introduced by Third Generation Partnership Project (3GPP) [1]. The main objective of the LTE network is to enhance the data rate so as to provide the radio resources for variety of highly demanded services, while taking into consideration a satisfied level of Quality-of-Service (QoS) to all active users. For this requirement, LTE system uses Orthogonal Frequency Division Multiple Access (OFDMA) technology in the Downlink (DL) and Single Carrier- Frequency Division Multiple Access (SC-FDMA) in the Uplink (UL). The OFDMA technology divides the available bandwidth into multiple sub-carriers and allocates a group of sub-carriers to a user based on its QoS requirements. Hence, the design of efficient resource allocation algorithm is important for effective use of radio resources to meet the system performance targets.

Scheduling for Orthogonal Frequency Division Multiple Access (OFDMA) based systems can be described as the problem of assigning users for a given sub-channel at a given time slot based on the users' channel conditions and resource requirements. To overcome this drawback, QOS improve the overall system performance in cellular networks. To be able to full fill this, QOS plays the key role. QOS defines priorities for certain customers / services during the time of high congestion in the network.

As of first quarter of 2014, LTE users have already reached the 200 million mark with mobile data traffic in Q1 2014 exceeding the total mobile data traffic in 2011 [4]. It is reported in [4] that there will be 2.6 billion LTE subscriptions by the end of 2019, while a 10x growth in mobile data traffic is predicted between 2013 and 2019. In order to address this challenge an efficient radio resource management module is needed of which the packet scheduler is an important component.

OVERVIEW OF LTE ARCHITECTURE

LTE network provides spectrum flexibility where the transmission bandwidth can be selected between 1.4 MHz and 20 MHz depending on the available spectrum. The peak data rate, which is the important parameter by which different technologies are usually compared, generally depends on the amount of spectrum used. The allowed peak data rate for the DL and UL is equal to 100 Mbps and 50 Mbps respectively. The network architecture of LTE consists of core network called Evolved Packet Core (EPC) and access network called Evolved-Universal Terrestrial Radio Access Network (E-UTRAN) as shown in Fig. 1.

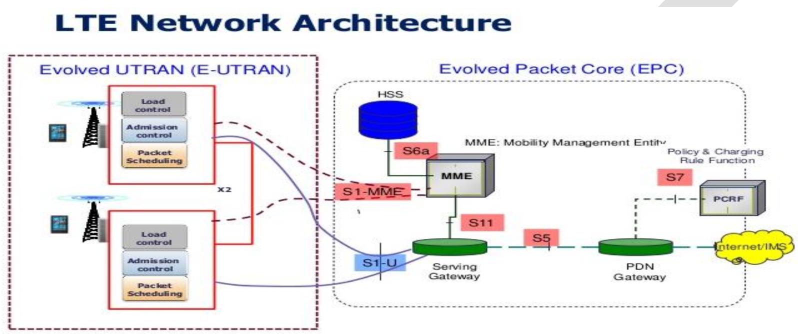

Fig 1 : LTE network architecture for scheduling data between E-UTRAN and EPC.

The responsibility of eNB in the access network is to ensure that the necessary QoS for a bearer over the interface is met. Each bearer has an associated QoS Class Identifier (QCI) [2] and each QoS class is characterized by priority, tolerable packet loss, and tolerable delay as shown in Table 1.

QCI	Resource type	Priority	Packet delay budget	Packet error loss rate	Example services
1	GBR	2	100 ms	10^{-2}	Conversational voice
2		4	150 ms	10^{-3}	Conversational video (live streaming)
3		3	50 ms	10^{-3}	Real time gaming
4		5	300 ms	10^{-6}	Non-conversational video (buffered streaming)
5	Non-GBR	1	100 ms	10^{-3}	IMS signaling
6		6	300 ms	10^{-6}	Video (buffered streaming) TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)
7		7	100 ms	10^{-6}	Voice, Video (live streaming), Interactive gaming
8		8	300ms	10^{-3}	Video (buffered streaming) TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)
9		9		10^{-6}	

Table 1: List of GBR and NON GBR resource type.

Generally bearers can be classified into two categories based on the nature of the QoS they provide: Guaranteed Bit-Rate (GBR) bearers which are real time bearers and non-GBR bearers which are non real time bearers. At the physical layer, LTE supports both Time Division Duplex (TDD) and Frequency Division Duplex (FDD) modes. OFDMA is chosen as the DL access technology. The available bandwidth is divided into multiple Resource Blocks (RBs) based on time and frequency domains [3]. A RB is the smallest allocation unit in LTE which can be modulated independently. In the frequency domain the RB consists of 12 consecutive subcarriers and in the time domain it is made up of one time slot of 0.5 ms duration and adopts two slots as allocation period. The scheduling period is called as one Transmission Time Interval (TTI) and it lasts for 1 ms duration . The goal of a resource scheduling algorithm in the eNodeB is to allocate the time and frequency resources for each scheduling block (SB) in order to optimise a function of a set of performance metrics, e.g. a throughput, delay, or spectral efficiency

CHALLENGES IN DESIGNING SCHEDULER

1. Wireless channels are subject to time- and location-dependent signal attenuation, fading, interference, and noise that result in bursty errors and time-varying channel capacities.
2. In order to make scheduling decisions, certain information such as the number of sessions, their reserved rates and link states, and the statuses of session queues is needed by the scheduler. This information may easily be available for the downlink if the scheduler is located at the base station (BS). For the uplink, some means must be provided to collect queue status information and to inform MSs of their transmission times.
3. Another challenge arises from the need to maximize MS battery life. In order to conserve energy, it is preferable for an MS to transmit/receive in

contiguous time slots and then go into a sleep (very low energy consumption) mode for an extended period rather than to rapidly switch among transmit, receive, and sleep modes. However, this preference has to be balanced against the need to maintain QoS levels.

4. Handoffs are required in cellular networks when an MS, **S**, moves from its current cell **C**1 to a neighboring cell **C**2. Following a handoff, any packets for **S** that are queued at **C**1's BS will be forwarded to **C**2's BS. One problem that arises in time-stamp based scheduling is how the timestamp values for these packets ought to be changed. Another problem is that a handoff may result in the timestamps of packets of a new session being artificially low. This may cause the new session to receive extra service and hence introduce a fairness gap among sessions.
5. The total interference at an MS must be small enough to ensure an adequate signal-to interference ratio (SIR) for each session, thereby enabling its target bit error rate (BER) to be met. The scheduler should ensure that the number of simultaneous transmissions in the network is not so high as to result in excessive interference
6. A multi-hop network model is appropriate when little infrastructure exists, for example no BSs. The additional challenges posed by a rapidly changing topology and the fact that not all MSs are within communication range of each other need to be addressed

COMPONENTS OF SCHEDULER

1. An error-free service model that describes how the algorithm provides service to sessions with error-free channels.
2. A lead/lag counter for each session that indicates whether the session is leading, in sync with, or lagging its error-free service model and by how much.

3. A compensation model that is used to improve fairness among sessions. A lagging session is compensated at the expense of leading sessions when its link becomes error-free again.
4. A means for monitoring and predicting the channel state for every backlogged session (i.e., a session with packets available for transmission).

FEATURES OF SCHEDULING ALGORITHMS

Efficient link utilization: The algorithm must utilize the channel efficiently. This implies that the scheduler should not assign a transmission slot to a session with a currently bad link since the transmission will simply be wasted.

Delay bound: The algorithm must be able to provide delay bound guarantees for individual sessions in order to support delay-sensitive applications.

Fairness: The algorithm should redistribute available resources fairly across sessions. It should provide fairness among error-free sessions (short-term fairness) and error-prone sessions (long-term fairness).

Throughput: The algorithm should provide guaranteed short-term throughputs for error free sessions and guaranteed long-term throughputs for all sessions.

Implementation complexity: A low-complexity algorithm is a necessity in high-speed networks in which scheduling decisions have to be made very rapidly.

Graceful service degradation: A session that has received excess service at the expense of sessions whose links were bad should experience a smooth service degradation when relinquishing the excess service to lagging sessions whose links are now good.

Isolation: The algorithm should isolate a session from the ill effects of misbehaving sessions. The QoS guarantees for a session should be maintained even in the presence of sessions whose demands are in excess of their reserved values.

Energy consumption: The algorithm should take into account the need to prolong the MS battery life.

Delay/bandwidth decoupling: For most schedulers, the delay is tightly coupled with the reserved rate; that is, a higher reserved rate provides a lower delay. However, some high-bandwidth applications, such as Web browsing, can tolerate relatively large delays.

Scalability: The algorithm should operate efficiently as the number of sessions sharing the channel increases.

LIST ALREADY EXISTING SCHEDULING ALGORITHMS

1. Frame Level Scheduler:

The FLS [21] is a two-level scheduling scheme with one upper level and lower level. Two different algorithms are implemented in these two levels. A low complexity resource allocation algorithm based on discrete time linear control theory is implemented in the upper level. It computes the amount of data that each real-time source should transmit within a single frame, to satisfy its delay constraint. The proportional fair (PF) scheduler, originally proposed in [22], is implemented in the lower level to assign radio resources to the user, to ensure a good level of fairness among multimedia flows. The following equation calculates the amount of data to be transmitted.

$$u_i(k) = h_i(k) * q_i(k)$$

where *ui(k)* corresponds to the amount of data that is transmitted during the kth frame; '*' operator is the discrete time convolution. The above equation tells that the amount of data to be transmitted by the *ith* flow during the *kth* LTE frame is obtained by filtering the signal *qi(k)* (i.e., the queue level) through a time-invariant linear filter with pulse response *hi(k)*. Moreover, according to the results presented in [21], the FLS is a good candidate for guaranteeing bounded delays to multimedia flows, and also provides the lowest PLR. Thus, it ensures the highest video quality to mobile users.

***2*. Proportional Fair (PF)**

The PF scheduling algorithm provides a good tradeoff between system throughput and fairness by selecting the user with highest instantaneous data rate relative to its average data rate. For this algorithm, the metric east defines as the ratio between the instantaneous flow available for ith flow and the medium flow calculated at the moment

$$W_{i,j} = \frac{r_{i,j}}{\bar{R}_i}$$

where ri, j is calculated by the AMC module considering the value of the CQI on the j-th sub-channel is sent by the UE who is intended for i-th flow. A typical way to find a trade-off between requirements of fairness and spectral efficiency is the Proportional Fair (PF) scheme. The idea behind this is that the past average throughput can act as a weighting factor of the expected data rate, so that users in bad conditions will be served within a certain amount of time.

3. Modified Largest Weighted Delay First

The Modified LWDF (M-LWDF) is a channel-aware extension of LWDF and bounded packet delivering delay is provided. For, shaping the behavior of PF, MLWDF it uses information about the accumulated delay, assuring a good balance among spectral efficiency, fairness and QoS

provisioning. It was developed to support multiple real time data users

4. Maximum Throughput Scheduler (MTS):

The strategy known as Maximum Throughput (MT) aims at maximizing the overall throughput which assigns each Resource block to the user that can achieve the maximum throughput in the current TTI**.** As discussed earlier, opportunistic schedulers exploit instantaneous channel variations to maximize the cell throughput. One such algorithm is MTS that schedules the users with more favorable channel conditions. The associated scheduling metric is then

$$i_{MTS}(k) = \arg\max_{1 \leq i \leq N} r_i(k),$$

where ri(k) is the instantaneous rate of user i in time slot k, and it depends on the wideband CQI. It is worth remarking that MTS can achieve the maximum cell throughput but, if the average SINR distributions of different users are extremely unbalanced, it could result in the starvation of UEs experiencing bad channel conditions.

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