Research Article

Survey on Various Downlink Resources Allocation Scheduling Schemes Proposed in Long Term Evolution

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Abstract: LTE is a 4G technology in cellular network which provides high quality of services and also supports a large variety of applications. One of the major problems in LTE is allocation of resources among multiple users on the downlink of a LTE cellular network, this problem is discussed in detail. Scheduling is a process of dynamically scheduling the Radio resources to UE's, scheduling procedure is carried out by scheduler or packet scheduler. The scheduling algorithms in LTE are not standardized by the 3GPP, hence various proposed scheduling scheme are available in LTE literature that are classified based on certain criteria and discussed. The scheduler should take all considerations such as fairness, throughput, and efficiency into account while performing the process of scheduling the scarce radio resources to the users. The main objective of any Resource allocation scheduling scheme is to utilize efficiently the available channel bandwidth and achieve the desired QoS requirements, maximize the network performance.

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INTRODUCTION

Innovation of smart devices, Internet of Things (IOT) that led to Machine to Machine communication have a huge demand for high bandwidth, Existing technology such as 3G are incapable of fulfilling the demands. Long term evolution was developed to satisfy the huge demand for bandwidth. Third Generation Partnership Project (3GPP) [1] Developed LTE as a 4G wireless broadband technology, it is the successor of 3G net-work. Applications such as video downloading, online gaming, mobile web-browsing and social networking are increasing which gave rise to the cellular network technology 3GPP LTE (4G). The rapid growth in the cellular communication services are expected to continue in next decade also. In this evolution of cellular network technology, LTE is an important factor and in December 2009 LTE network services started its functionality. LTE subscriber users are expected to be 2.6 billion by 2019, while still there is a growth in mobile date traffic. The major design goals or aim behind LTE network are increased spectrum efficiency, reduced cost, low simplicity and higher user bit rate, minimum latency and robustness. LTE achieves the above mentioned goals by using various Radio Resource Management (RRM) procedures.

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ARCHITECTURE OF LTE

LTE is an IP based flat network architecture, containing Evolved Packet System (EPS), which includes core network named Evolved Packet Core (EPC) and Radio access network named Evolved UMTS Terrestrial Radio Access Network (E-UTRAN). E-UTRAN has evolved NodeB (eNodeB), which is the evolved base station and User Equipment (UE) as its components, it handles the Radio communications between the UE and the EPC [2]. eNodeB controls UE in one or more cells, serving eNodeB is the base station that is currently communicating with the UE. The two main functions supported by eNodeB are: i) It controls the low-level operations of all its UE. ii) It uses the Analogue and Digital signal processing functions of the LTE air interface to send and receive Radio transmissions to all its UE. eNodeB connects with EPC using s1 interface and it connects with nearby base stations using x2 interface. The basic architecture of LTE is shown in the Figure 1.

The eNodeB performs RRM functions which includes dynamic resource allocation, eNodeB measurement configuration and provision, radio admission control, connection mobility control, Radio Bearer control and Inter-cell Interference Co-ordination (ICIC). In LTE internal architecture the UE is a Mobile Equipment (ME), the parts of ME are: i) Mobile Termination:- which is responsible for communication. ii) Terminal Equipment: - which is responsible for terminating the data streams. iii) Universal Integrated Circuit Card (UICC):-also known as Subscriber Identity Module (SIM) card, runs as an application. UE is

connected to eNodeB over the Uu interface. Downlink (Dl) is a air interface to receive or download data to the UE from eNodeB and Uplink (Ul) is a air interface to send data from UE back to the enodeB. EPC (the core network) - the main functionality of EPC is to communicate with packet data network in outside world such as internet, private corporate network or IP multimedia subsystem. It is also responsible for connecting with other 3GPP and non-3GPP networks. The set of control elements in EPC are Mobile Management Entity (MME), Home Subscriber Server (HSS), Serving Gateway (SGW), packet-data S-GW and P-GW.

MAC SCHEDULERS IN LTE NETWORKS

Scheduling is a process of dynamically schedule Radio resources for UE's under good radio channel conditions, It also leads to fast communication. In LTE, scheduling procedure is carried out by scheduler or packet scheduler, which is present at eNodeB MAC layer. Scheduler is a important component for the efficient utilization of radio resources and in LTE the Transmission Time Interval (TTI) is only 1ms. In every TTI the scheduler in eNodeB performs the radio resource scheduling and the UE's give information about the perceived radio quality to the scheduler as an input so that the scheduler decides, which Modulation and Coding Scheme (MCS) to use. To optimize the capacity of the system and end user performance, the radio resource Management algorithms (scheduling algorithms) are very critical. The scheduling algorithms in LTE are not standardized by the 3GPP, hence the network vendors and operators can design and can also tune the algorithm based on their specific needs.

Scheduling Algorithms

A scheduling algorithm has to determine the process of allocation of resources among the various different users and the way in which it is done. The main objective of any scheduling scheme is to utilize efficiently the available bandwidth and achieve the QoS requirements of its users. MAC schedulers are very crucial element of the LTE and are in charge for allocating very efficiently the radio resources to all its users having different QoS requirements. The scheduler should take all considerations such as fairness, throughput, and efficiency into account while taking the decision of scheduling the scarce radio resources to the users. The various Downlink Resource Scheduling schemes are classified and are shown in the Figure 2.

DOWNLINK RESOURCE ALLOCATION SCHEDULING SCHEMES IN LTE NETWORK

There are different downlink resource allocation scheduling schemes present in literature, these can be studied for the purpose of understanding the various concepts connected to scheduling design. These scheduling schemes differ in terms of various aspects such as input parameters, service targets, objectives and QoS requirements. We classify these schemes in four groups of strategies: (i) channel Independent Qos-Unaware; (ii) channel Independent QoS-aware; (iii) channel Dependent Qos-unaware; (iv) channel Dependent Qos-aware.

Independent QoS-Unaware Scheduling Schemes

Channel unaware scheduling strategies were first introduced in wired networks, mostly developed to work in Operating Systems and cabled communications to face the problems such as fairness, flow priorities and deadline expiration. In these algorithms, it is assumed that the channel conditions such as channel is error free in transmission and channel is time variant. In LTE these algorithms are not realistic in applications, hence jointly used with channel unaware schemes to improve the overall system performance. The following are the algorithms in this class of classification :- 1) First In First Out (FIFO): is one of the simplest resource allocation scheduling algorithms. The resources are scheduled in the order of resources requested, same as FIFO queue. This technique of scheduling the resources is very simple. The disadvantage of this scheme is that it is unfair in terms of fairness and inefficient. 2) Round Robin (RR): It provides good fairness performance of the resources among its users. It makes sure that the active user receives equal transmission of resources during its turn. This algorithm does not depend on any channel conditions, hence regardless of its channel quality. It assigns equal radio resources to each user. Disadvantage is that the system throughput is not optimized and not efficient. 3) Blind Equal Throughput (BET): BET stores the previous average throughput achieved by user, hence provides through-put fairness by ensuring a fair allocation of resources among its users. 4) Resource Preemption: Several different type of priority schemes are defined in history, where fairness is not always considered or at least not required for all users. One of the simplest approach is resource preemption [3] with high priority for classes of users, this technique can be exploited to handle and differentiate the different QoS and non QoS flows as well, provided some techniques are used by the scheduler to avoid the starvation of low priority application.

Channel Independent QoS-aware Scheduling Schemes

The following are the algorithms in this class of classification :- 1) Weighted Fair Queuing (WFQ): Is a very simple approach used to avoid the possibility of starvation which is an alternative to the introduction of priorities. The specific weight (wi) is associated with i-th user which is used to correct the user specific metric. Higher the weight, higher the resources are allocated and no starvation is possible because of this metric utilized. 2) Guaranteed Delay: This method is used to

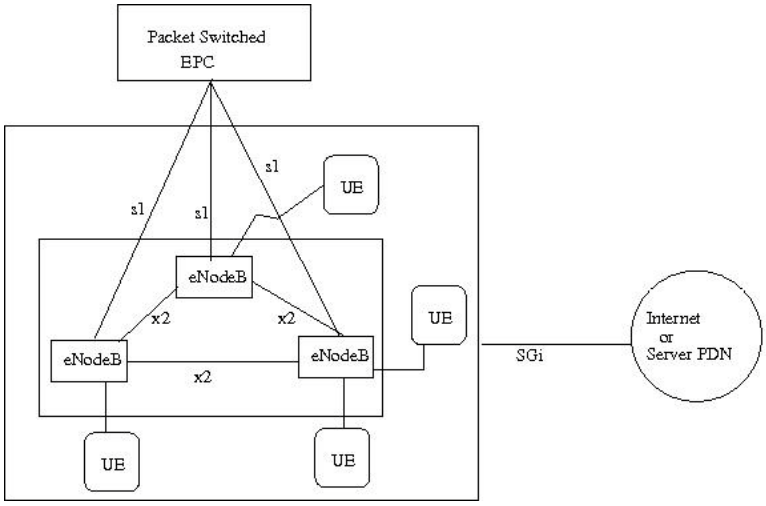

Figure 1: LTE Architecture

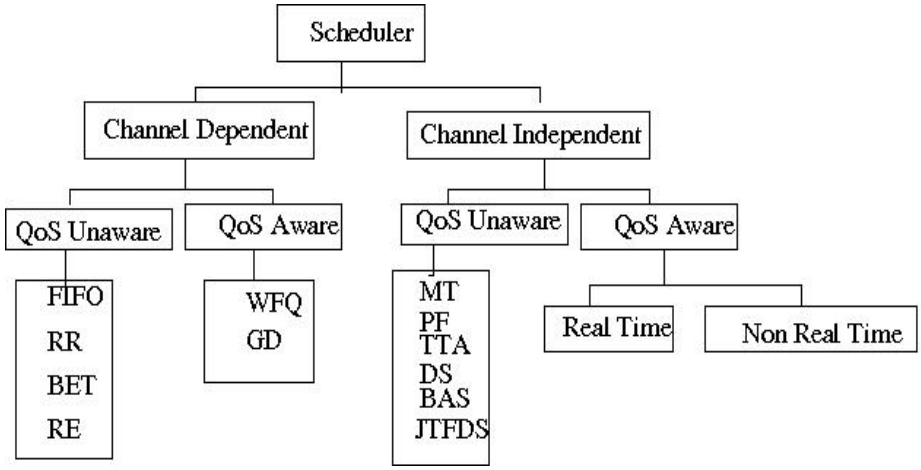

Figure 2: Classification Downlink LTE Scheduler

avoid packet drops, so that each packet has to be received well within a pre-defined deadline. This can be done by defining metric information about specific packet timing which includes both time instant when packet was created and packets deadline. For real time operating system and wired networks, Early Deadline First (EDF) one of the variation of this method is used, that schedules the packet with closet deadline expiration first, it is dependent on the system parameter, which is the probability for i-th user and this parameter gives the probability that a packet is to be dropped due to the expiration of the deadline metric. The aim of these policies is to avoid the problem of deadline expiration.

Channel Dependent QoS-unaware Scheduling Schemes

This scheme uses the Channel Quality Indicator (CQI), which is periodically sent from UEs to eNB, using which the scheduler can find out the channel quality. Hence the maximum achievable throughput of the system can be predicted. If di(t), dik(t) are the throughput for i-th user at (t) TTI over the bandwidth and over kth RB respectively.

These values can be calculated or can be estimated. Channel awareness in wireless network can be explained from the above values defined. The following are the algorithms in this class of classification:-1) Maximum Throughput: Maximizes the throughput of the system by selecting a user having the best channel quality. Disadvantage: Does not guarantee a fair resource sharing among the users that experiences poor channel conditions. The equation of this algorithm is M i(t) = Ri(t) where Mi(t) is priority of user i at scheduling interval t, Ri(t) is the instantaneous data rate or bandwidth of user i at scheduling interval t. 2) Proportional fair scheduler: Proportional fair algorithm was developed [4] to provide an alternative that satisfies the requirements on spectral efficiency as well as fairness guarantee. The aim of the algorithm is to

maximize the throughput. Disadvantages: Unlikely to support real time services because it does not consider each users buffer in-formation. 3) Throughput to Average (TTA): This algorithm acts as an intermediate between Maximum Throughput and Proportional fair. Disadvantages: Guarantees minimum level of service to every user. Does not exploit channel conditions. Advantages are that it provides a very good level of fairness to each user. 4) Joint time and frequency domain schedulers: Joint time and frequency domain schedulers are developed to provide a balance between scheduling efficiency and computational complexity. In [2] a two step technique is provided for distributing the radio resources. a) TD packet scheduler chooses a subset of active users from users connected to eNB in the TTI b) FDPS identifies the priority of active users and RB is allocated to the users. The TD scheduler limits the number of user which in turn reduces the scheduling complexity at FDPS. Advantage: Using two scheduling algorithm contributes to maximize the performance of the system. 5) Delay Sensitive schedulers: were developed to minimize the average delay, average data delivering delay can be considered as overall system performance while neglecting the problem of expiating packets. In [3], to optimize the minimum average delay a cross layer algorithm was proposed. Authors, in their proposed work demonstrate how the overall packet delivering delay is kept constant even while the cell load increases. In their work, each data packet has a delay function. QoS in these delay sensitive schemes can be only attained at the expense of system efficiency. Proposed algorithm also tries a tradeoff between the QoS and maximizes the throughput. Detailed description can be found in [4]. 6) Buffer-aware schedulers: It be used to avoid packet loss, the main concept of buffer aware schedulers is to use buffer management schemes to minimize the packet loss. In [6][41], Buffer-Aware Traffic Dependent (BATD) scheme is presented to minimize the probability of packet dropping. Packet may be dropped due to the overflow of the receiver buffer. The aim of this scheme is to provide fairness along with system throughput. This scheme makes use of the status information present in the buffer, which is reported by users to the eNB.

Channel Dependent QoS-aware Scheduling Schemes

A overview of QoS aware solutions that are available in the literature are described. In this classification, channel condition as well as QoS requirements is considered. For each flow, a set of QoS parameters are known to the scheduler, it use's those data to guarantee the required performance, either in terms of delay or data rates. The following are the algorithms in this class of classification :- 1) Schedulers for guaranteed data rate: One of the available scheduler that guarantee's data rate are priority set scheduler (PSS). PSS selects users having the highest priority from set of users that is users for whom urgent resources have to be allocated so that they meet the QoS requirements. The rest of users are assigned the lower priority set. In [5] Priority set are grouped based on the QCI of each user. Scheduler assigns Resource Block (RB) to the users present in the highest priority set then to the users present in the lowest priority set using PF metric. Resource block allocation is performed, when users with highest priority reach the guaranteed bit rate. For the left over resources that are free after this allocation, the above mentioned procedure can be repeated with user having second highest priority and lower priority set. This scheme provides high spectral efficiency as well as providers robust in terms of QoS provisioning. 2) Schedulers for guaranteed delay requirements: Schedulers for guarantee the bounded delay fall under this classification of QoS-aware scheme, as one of the primary reason is delivering the QoS constrained packet within a certain limit of deadline. It is also valid for video streaming and VoIP flows which are real time services.

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Real-Time Scheme

Semi-persistent for VOIP scheduling scheme: The main aim of this scheme is to increase the VoIP capacity of the network that

is supporting maximum number of VoIP calls. This scheme can be classified as channel-unaware scheduler schemes. In this approach the radio resources are grouped into several groups of RBs, each block is assigned to specific users. Resource allocation of the RB groups is done in dynamic fashion as well as persistent way. In [6], the author use a new way by coupling the same resources in persistently depending on channel conditions. In which the VoIP users with good channel condition are paired along with users having bad channel conditions, because of which users with bad channel condition are favored and balance is maintained.

Non Real-Time Scheme

Energy aware scheduling scheme: Increasing traffic in the cellular network increases the energy consumed and hence electricity cost will be doubled in the future, which will have an impact on the environment. Hence the aim of Energy Aware Strategies is to minimize the power consumption of any network. A easy approach to minimize energy consumption is to maximize the spectral efficiency of the given network. Power or energy consumption can be reduced by reducing the transmission power at eNB and user are designed with a scheme to minimize the rate of power consumption, which will in turn expand the spectrum occupation. Resource allocation can be done under a very low traffic load of the network, which will maximum the spectral efficiency and in turn reduces the energy consumed.

CONCLUSIONS

In this paper, a very simple approach is done for the survey on different available resource allocation algorithms in downlink LTE.A very good design of any allocation algorithm should be implemented easily with very less computational cost. There are very good theoretically available algorithms or scheme which is very difficult to implement in real devices also requires a very high computational cost, hence a good algorithm should be implemented in real devices very easily. In this paper, a comparison among the scheduler has been carried out so that each scheduler has its own advantages and disadvantages. We can conclude that, in this paper different approaches with their own specifications are studied and described in detail.

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