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# Survey on Various Algorithms for Packet Scheduling in LTE Downlink Transmission

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**Abstract:** After the evolution of LTE and the advent of 4G technologies, there is a high need to optimize the performance and achieve high Quos and QoE. Scheduling is the process of allocation of physical resources to the User Equipments (UEs) dynamically by the scheduling algorithms implemented in the encode. This paper investigates theoretically the performance and other details of the algorithms defined so far for scheduling in LTE downlink. This paper also lists the popular measurements/Quos characteristics to be analyzed in an LTE downlink scheduling algorithm.

**Key words:** Downlink · LTE · Packet Scheduling · Qos

## INTRODUCTION

The main objective of 3GPP was to create a generalized standard for global telecommunication [1, 2, 3]. It defined the feasibility of enhancing the UMTS and UTRA beyond HSPA. This project called Long Term Evolution (LTE) is the next step for cellular services. This is the evolution of RAN (Radio Access Network). This project provides a smooth migration towards 4G wireless systems. WiMAX is also a similar standard for 4G wireless technology [4, 5, 6].

The core aims of 4G technologies include high data rate, low latency, optimized radio access technology, supporting flexible bandwidth, reduce the complexities of Ues (User Equipments) and systems, high efficiencies, increased signal range, better response time and mainly interoperability with circuit switched legacy systems [7, 8, 9]. The applications of WebTV, online gaming, video calling, push-to-talk, push-to-view, FTP (File Transfer Protocol), video streaming and other data intensive tasks of the users are one of main reasons for the need and success of the 4G technologies [10, 11, 12].

The architecture of LTE is flat (System Architecture Evolution), unlike its predecessors (wherein the architecture was hierarchical) which makes it an ideal technology for cellular services [13, 14, 15]. Also it allows for support for packet-switched traffic, offers great Quos and provides services on top of IP (Internet Protocol) [16].

**Architecture of Let:** The high level architecture of LTE consists of three main components:

- The User Equipment (UE)
- The Evolved UMTS Terrestrial Radio Access Network (E-UTRAN)
- The Evolved Packet Core (EPC)

**The User Equipment:** It is actually a mobile termination point. It holds the UICC (Universal Integrated Circuit Card) which runs the USIM (Universal Subscriber Identity Module) application.

**The E-Outran:** This is the access network of LTE.

It handles all the radio communication between UE and the EPC. It consists of evolved Base Stations called eNodeBs (eNBs) that control the UEs. It controls the handover and the scheduling of physical resources of LTE Ues.

**The EPC:** The core network of LTE is the Evolved Packet Core. It consists of the below most important components:

- MME (Mobile Management Entity) that acts as a controller of UE operations by signaling HSS.
- HSS (Home Subscriber Server) that is the central database of all subscribers' details.

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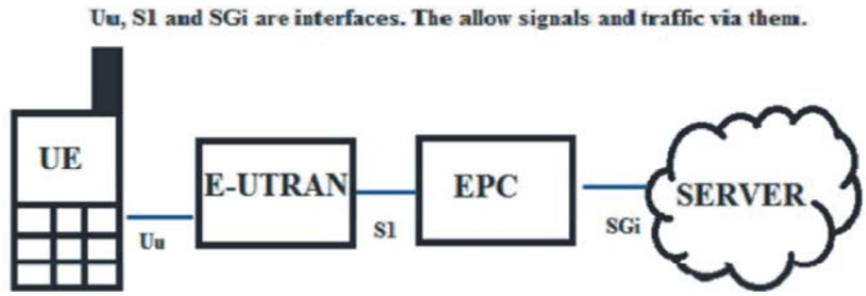


Fig. 1: High level architecture of LTE

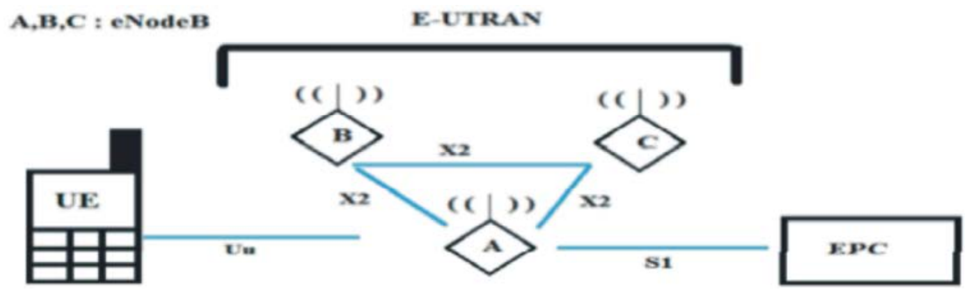


Fig. 2: The E-UTRAN architecture

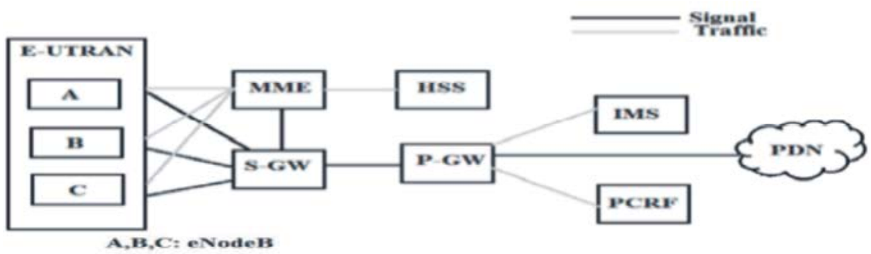


Fig. 3: The EPC Architecture

- PDN-GW (Packet Data Network Gateway) that connects with the outside Internet
- S-GW (Serving Gateways) that routes data between Base Station and the PDN-GW

**Lte Characteristics:** Some of the key characteristics of LTE are listed in Table 1.

In addition to all of the above characteristics, MIMO Antenna schemes are also incorporated to achieve maximum performance and efficiency. To name a few, the below parameters are to be considered:

- AAA (Authentication)
- Connections and Sessions (Firewalls)
- Web connect, IP pools, Quos, Traffic (the Gateways)
- Bearer establishment (MME)
- Uploading, RRM (end)
- Queue load (switches)
- CPU, memory (physical servers)
- Call setup
- Capacity
- Interfaces
- Spectral efficiency and bandwidth
- Packet loss and delay

**Key Performance Parameters for Lte:** Figure 3 depicts the overall architecture of LTE that helps in identifying the key performance parameters for LTE. The below sections discuss some of the most commonly used parameters for measuring performance.

**Quos:** Two main types of bearers based on their bit rates are:

- GBR (Guaranteed Bit Rate) bearers: provide the minimum bit rate for services (multimedia services).
- Non GBR bearers: do not provide the minimum bit rate (best effort services like FTP).

Table 1: Characteristics of LTE

| Sl No | Characteristics | Requirements |
|---|---|---|
| 1 | Bandwidth | 1.4, 3, 5, 10, 15, 20 MHz |
| 2 | Downlink | OFDMA (Orthogonal Frequency Division Multiple Access) |
| 3 | Uplink | SC-FDMA (Single Carrier Frequency Division Multiple Access) |
| 4 | Packet Data rates | Uplink: 100Mbps Downlink: 50Mbps (For 20MHz spectrum) |
| 5 | RAN Round Trip Time | <30ms |
| 6 | Cell Size (Coverage) | 5-100 km (minor degradation after 30 km) |
| 7 | Modulation | Uplink: QPSK, 16QAM, 64QAM Downlink: QPSK, 16QAM, 64QAM |
| 8 | Range of mobility | 500Km/h |
| 9 | End user latency | <10ms |
| 10 | Duplexing Schemes | Frequency Division Duplex (FDD), |

Time Division Duplex (TDD) and Half-duplex FDD

Table 2: LTE downlink PS algorithms

| Sl No | Algorithm | Explanation | Parameter on which algorithm was developed | Merits | Demerits |
|---|---|---|---|---|---|
| 1 | Best CQI (B-CQI) | Choose the users with the highest SINR and allocate the resources among those users effectively | SINR CQI | Throughput is higher | Starvation for the users who have bad channel onditions. No fairness |
| 2 | Round Robin (RR) | Allocate equal packet transmission time to each user | Transmission time | Fairness is ensured | Low throughput (since channel conditions are not considered) |
| 3 | Proportional Fair (PF) | Choose a user with highest priority $k_i$ $k_i = argmax \frac{r_i(t)}{R_i(t)}$ Where Ri(t) is the average throughput of the user i in a window of time. | Priority based on throughput of the user | Trade off between throughput and fairness | Only for non-real time traffic; do not consider packet delay and packet loss (B-CQI, RR and PF) |
| 4 | Maximum Largest Weighted Delay First (M-LWDF) | Combine PF property with Head of Line packet delay | PF HOL packet delay | Good throughput, fairness and low loss rate | No power saving mechanism for real time traffic |
| 5 | Time and frequency domain scheduling | Implementation in two layers: 1. Scheduling in time domain (Fair) 2. Scheduling in frequency domain (Opportunistic) | Time domain: PF Frequency domain: frequency diversity gain | Good throughput and fairness | Delay in multimedia traffic Does not consider GBR |
| 6 | Admission control and resource allocation | Combine time and frequency domain scheduling and ensure that user delay never crosses a threshold (and that he gets a minimum throughput to satisfy Quos) | Time and frequency domain scheduling and threshold delay and throughput | Satisfy the real time and non-real time Quos requirements | Channel conditions not considered |
| 7 | Channel-adapted and buffer aware (CABA) | Decide based on: 1. CQI 2. Assumption that all UEs have limited bandwidth and buffer status is shared to encode 3. Treat non-real time and real time traffic separately | CQI and buffer status | Good throughput and fairness | Does not consider packet loss ratio and power saving mechanism |

In particular the factors to be considered are QCI (QoS Class Identifier), ARP (Allocation and Retention Priority), GBR and AMBR (Aggregate Maximum Bit Rate) to name a few.

**Cqi:** Channel Quality Indicator is generated based on the report of SINR given by the UE to the eNodeB. The reporting can be periodic or aperiodic. It is a 4-bit value that can indicate the channel quality of transmission. The main attributes of CQI are modulation, effective coding techniques and spectral efficiency.

**Buffer Status:** Depending on the amount of data present at the eNodeB (to be pushed) or the UE, the packet loss and drop rate can be lowered.

**Power Saving:** Power saving in UEs is done with the help of discontinuous reception (DRX) and with two modes:

- Light sleep DRX: puts UE to sleep for shorter durations; UE is not shut down and consumes less power than active mode.
- Deep sleep DRC: UE sleeps when packets are not received for longer periods of time; requires no power and sleep duration is long.

**Various Scheduling Algorithms for Downlink Packet Scheduling:** The algorithms used in uplink and downlink channels are different and the methodology used to allocate resources for individual users affects the performance of the entire system. Basically the algorithms are designed to optimize and maximize throughput and fairness. Table 2 lists the mostly commonly used PS algorithms and details about them

## CONCLUSION

This paper was to provide an insight on LTE downlink packet scheduling algorithms and to insist on the key parameters to be concentrated when choosing an algorithm for LTE downlink data transmission. There are different kinds of traffic that are possible in LTE like multimedia, video conferencing, VoIP, FTP, HTTP, gaming etc. One algorithm will not satisfy the different requirements and performance metrics for different traffic. This paper entirely focused on single cell PS algorithms. Future work is to analyze the performance of the different algorithms for different types of traffic.

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