Analysis of the Factors which Influence on QoS in LTE Networks

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Abstract – **LTE is widely used 4G technology, which provides simultaneously voice, data and video (with different priority) on networks. The major concept of the LTE network uses the QoS bearers technique that provides high performance in packet delivery based on prioritization of the traffic. In this paper is proposed multifactor analysis of the applicability to prioritize users in order to fit the bandwidth requirement, while satisfying the application needs.**

Keywords –**LTE, QoS, optimization of QoS in LTE.**

I. Introduction

According to published in February 2015 prognosis of Cisco System for the period 2014-2019 [7], the Global mobile data traffic will grow three times faster than global fixed IP traffic from 2014 to 2019. The Mobile data traffic will grow 10-fold from 2014 to 2019, a compound annual growth rate of 57%, and it will reach an annual run rate of 291.8 Exabytes by 2019, up from 30.3 Exabytes in 2014. The prognosis of Ericsson [12], in turn, suggests that by 2018 it is expected a growth of smart phones up to 4.5 milliard and growth of mobile video traffic by 60% annually. These estimates require the search of optimal 4G solutions in terms of QoS offered by telecom providers.

Requirements of IMT-Advanced [6] for 1 Gbit/s speeds for fixed and 100 Mbit/s for mobile users present two challenges for providers of wireless services:

1.Optimization of the dynamic selection of the best interfaces of multi-interface devices according to user requirements and limitations in the models of devices such as power consumption, user fees, and application specific requirements for QoS (delay, latency and throughput);

2.Scalability of the work of billions of devices on the wireless network.

Under these requirements, providers of 4G services choose between two advanced wireless technologies - LTE [9] or WiMAX [10], as the success of one or the other technology is determined by a number of factors such as:

- the effectiveness of the business model that the telecommunications companies follows,
- the economic indicators related to the implementation,
- provided by the technology options,
- user expectations for QoS of the offered services,
- the support of the QoS by the service providers.

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Equipment manufacturers have an impact too. The fact is that the manufacturers switch to hybrid networks WiMAX / LTE to provide several 4G technologies with the prospect of merging them in future LTE-Advanced. Initially the telecom operators deploy WiMAX as an extension of the already offered DSL-services to provide customers with greater coverage with high speeds. LTE is viewed as an option for higher bandwidth than the existing networks. Companies such as Vodafone, Verizon, China Mobile, AT & T, Nokia and Ericsson stake in their equipment of LTE, while Huawei rely on both the two technologies, predicting that in the countries of Africa and Latin America will long dominate WiMAX technology and equipment, maintenance of WiMAX / LTE will dominate in those markets. The beginning of hybrid schemes supporting WiMAX / LTE is placed in 2010 from companies such as Huawei, Vodafone, KDDI, UQ Communication and others.

Solutions are needed to improve QoS in terms of delays in larger loads and any packet loss. For communications to be successful, it is also essential to focus on network traffic prioritizes for different types of communication streams.

II. Essence of Management of Traffic by Priority in LTE Networks

Even with the developing of LTE technology the QoS for uplink is discussed by many authors [3,4,5,8,11]. After the first implementations of LTE the focus in the allocation of resources is shifting towards to the profit maximization and user satisfaction [12].

In 3GPP, the QoS Class Indicator (QCI) consist of basic classes, which are defined as ‘default’, ‘expedited forwarding’, and ‘assured forwarding’. It means: expedited forwarding is used for ‘strict’ priority (video and voice), and ‘assured forwarding’ is used for business differentiation (e.g., weighted-fair priority).

In LTE network traffic management achieving QoS is considerably more complicated than in WiMAX. LTE is for users who are willing to pay a higher price, but get more bandwidth for communications or advantage in providing access to the network at peak load hours if introduced the prioritization. But the prioritization applies not only for the consumers but also for the services themselves.

In LTE network QoS is between end-user devices and PDN Gateway applying the ‘bearers’. ‘Bearers’ is a set of network configurations to provide a special handling of traffic to its set prioritization. Their hierarchy is presented in Table I. Default bearer is established when the user equipment (UE) connects to the LTE network, while Dedicated bearer is established whenever must be set QoS for a specific traffic type (service) as VoIP, video and etc.

GBR (Guaranteed Bit Rate) provides guaranteed bandwidth and monitors two parameters in directions uplink and downlink:

- GBR- minimum GBR for EPS bearer,
- MBR- maximum GBR for EPS bearer,
- Non-GBR bearer does not provide guaranteed bandwidth and also monitors two parameters in directions uplink and downlink: A-AMBR-general maximum speed permitted for the entire non-GBR throughput for specific APN (Access Point Name) and UE -AMBR- overall maximum speed permitted for the entire non-GBR throughput for all of APN particularly UE.

TABLE I
HYERARHICAL OF LTE QOS

LTE QoS		
Dedicated Bearer		Default Bearer
Non-GBR	GBR	Non GBR
QCI 5-9 APN-AMBR UE-AMBR TFT ARP L-EBI	QCI 1-4 GBR MBR TFT ARP L-EBI	QCI 5-9 APN-AMBR UE-AMBR APN IP Address ARP

ARP (Allocation and Retention Priority) is used to decide whether the distribution of resources is to be modified according to the new bearer or to maintain the current distribution of the resource.

TFT (Traffic Flow Template) is associated with Dedicated bearer, while Default bearer may or may not have TFT. TFT defines rules based on the source or destination address or protocol used, so that the UE and the network know which IP packets to send over the individual Dedicated bearer.

L-EBI (Linked EPS bearer ID). Each dedicated bearer is always connected to one of the default bearers and L-EBI notifies the Dedicated bearer to which default bearer is connected.

In LTE networks for differentiation of QoS same as in WiMAX are applicable classes which here are called QoS Class of Identifier (QCI). They define the basic characteristics of the IP packet level, as presented in Table II.

TABLE II
QCI CLASSES IN LTE

QCI	Bearer Type	Priority	Delay of the Packet	Packets Loss	Example of Traffic Type
1	GBR	2	100ms	10^{-2}	VoIP
2		4	150ms	10^{-3}	Video call
3		3	50ms	10^{-3}	Real time games
4		5	300ms	10^{-6}	Video stream
5	Non-GBR	1	100ms	10^{-6}	IMS Signaling
6, 8, 9		6, 8, 9	300ms	10^{-6}	TCP based services – chat, ftp...
7		7	100ms	10^{-3}	Voice, video, interactive games

Then in the cell is applied a preemption algorithm, which allows high priority requesting bearers to displace low priority connected bearers in order to reduce the cell load. This algorithm coupled with a priority-based admission control can achieve low dropping and blocking probabilities.

III. EXPERIMENTS

The Functions for management of QoS in access networks are responsible for the efficient allocation of resources in a wireless interface. They are generally defined as the control algorithms of radio resources (Radio Resource Management) and incorporate power management (Power Control), control of the transfer connection (Handover Control), access control (Admission Control), managing load (Load Control) and the management packet (PS), but directly related to QoS level cell are the last three. They are used to ensure a maximum throughput for individual services. The aim is to achieve keeping the network throughput as high as possible at a small price of only a bit more handovers.

LTE uses multiple access technology (OFDMA) and the total bandwidth is divided into Resource Blocks (RBs) in the frequency domain. The Data is transmitted in the Transport Blocks (TB) in one transmission time interval (TTI) for 1ms. Each RB consists from 12 subcarriers (each of them is 15kHz). The frame is 10ms and divides into ten equal subframes. Each subframe contains 2 slots*0.5ms. Each RB is related to one slot in time. One TB is related to 1 subframe and it is the minimum unit to schedule. The serve rule is to find first space that can fit the TB. If there are not enough RBs in the current TTI, the scheduler tries to find resources in the next TTI. This strategy minimizes the response latency, which is the best practice for delay sensitive traffic.

In wireless radio networks, the base station should allow access of as many users as possible to increase revenue. On the other hand, the quality of service should be guaranteed in order to provide satisfactory service. The maximum number of users a base station can support is bound by the system bandwidth. Under the restriction of QoS, if the maximum bandwidth is achieved, new connection requests should be rejected.

Let capacity of cell is C. Then the load L of cell at time slot t is

$$L = \sum_{i=1}^{n} L_i(t) \quad (1)$$

where $L_i(t) = \frac{b_i^u}{b_i(t)}$ (2)

and $L \leq C$ (3)

If bearer j want to use the same cell in the same time slot t, this will be possible if

$$L + L_j(t) \leq \quad (4)$$

If this condition is not executed, this means that the resources in the current TTI are not enough and scheduler must reorder resources in the whole TTI window and must allocate resources in reserved bandwidth. In this case a task is to find spaces big enough for the new request. If there are not enough resources in the current TTI, the scheduler tries to find resources in the next TTI. This strategy minimizes the response latency, and thus is useful for delay sensitive traffic.

But this procedure is not applicable for beacon transmissions (it is sent among devices each 100ms), because of emergency information it conveys, therefore the reserved resource blocks exist to accommodate the temporary overload.

This means, that important factors for QoS are: the Modulation and Coding Scheme (MCS) which be used, the MAC Transport Block (TB) size, the allocation bitmap which identifies which RBs will contain the data transmitted by the eNB to each user, number of users and prioritization of users.

IV. Results

In this approach it is used the Rapid Miner 6.0 to create a model of influence of multi-factors on QoS parameters in LTE network such as real throughput and drop ratio. The drop ratio is defined as the number of the rejected beacons to the number of the accepted beacons. For non-prioritization scheme, the beacons are rejected due to the cell overload. New arrival beacons can only be accepted after some users move out the service region, resulting in load reduction. For prioritization scheme, the rejected beacons are the ones that are removed by the congestion control algorithm.

The test data is obtained according to the values of TB size reported in [1], considering an equal distribution of the physical resource blocked among the users using Resource Allocation Type 0 as defined in Section 7.1.6.1 of [1].

Let TTI duration is 1ms. To calculate the throughput allocated to each user formulae (2) is used. The acceptable relative tolerance (standard deviation) is

$$\sigma = 0. \qquad (5)$$

This tolerance is needed to take an account for the transient behavior at the beginning of the simulation.

The main part of DataSet is presented in the Table III.

TABLE III
CALCULATED DATA FOR MODEL OF QOS IN LTE NETWORK

Number of users	Through put [Mbps] with MCS=22	Through put [Mbps] with MCS=16	Through put [Mbps] with MCS=12	Drop ratio with prioritization by distance	Drop ratio without prioritization
1	10.000	9.400	9.350	0.000	0.000
2	8.978	8.378	8.328	0.020	0.100
3	7.956	7.356	7.306	0.020	0.100
4	6.933	6.333	6.283	0.013	0.100
5	5.911	5.311	5.261	0.013	0.040
6	4.889	4.289	4.239	0.010	0.040
7	3.867	3.267	3.217	0.010	0.040
8	2.844	2.244	2.194	0.004	0.024
9	1.822	1.222	1.172	0.004	0.024
10	0.800	0.200	0.150	0.003	0.023

The input DataSet is partitioned into 10 subsets of equal size. Of the 10 subsets, a single subset is retained as the testing DataSet, and the remaining 9 subsets are used as training data set. The cross-validation process is then repeated 10 times, with each of the 10 subsets used exactly once as the testing data. Then results can be averaged to produce a single estimation. The learning processes usually optimize the model to make it fit the training data as well as possible.

The Cross-Validation operator predicts the fit of a model to a testing data. This can be especially useful when separate testing data is not present.

The model is presented on the Fig.1 and Fig.2. The Meta Data is presented on the Fig.3.

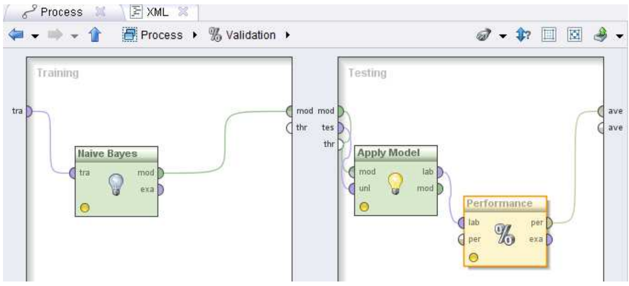

Fig. 1. X-Validation

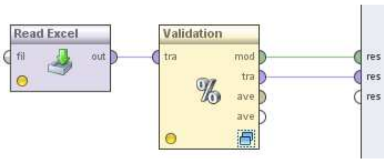

Fig. 2. Validation of the Model of QoS in the LTE Network

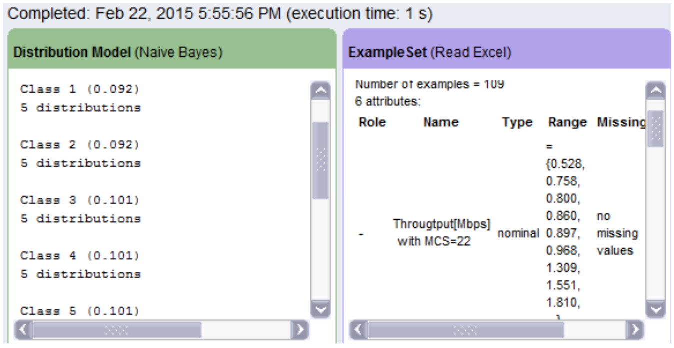

Fig. 3. Meta Data of Model

The Fig.4, Fig. 5 and Fig.6 presented throughput in Mbps with different MCS – 22, 16 and 12 respectively. In each case when number of users grows up, the throughput decreases. When comparing values among these figures, it is possible to see that for the equal number of users when MCS is more, throughput is more too. When the MCS decreases, the scatter of measured data for throughput increases.

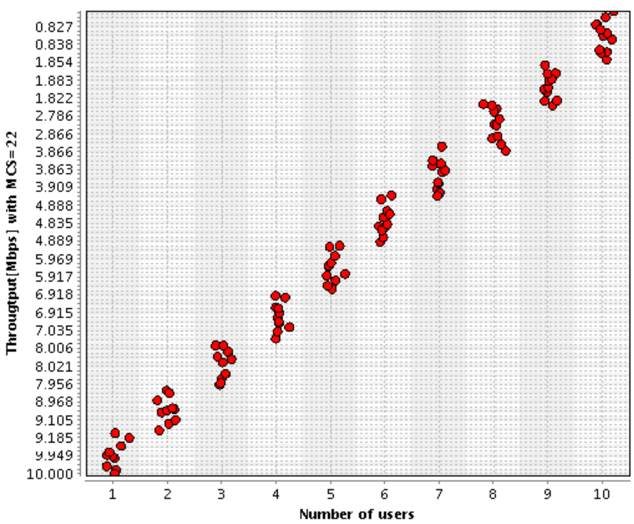

Fig. 4. Throughput with MCS=22

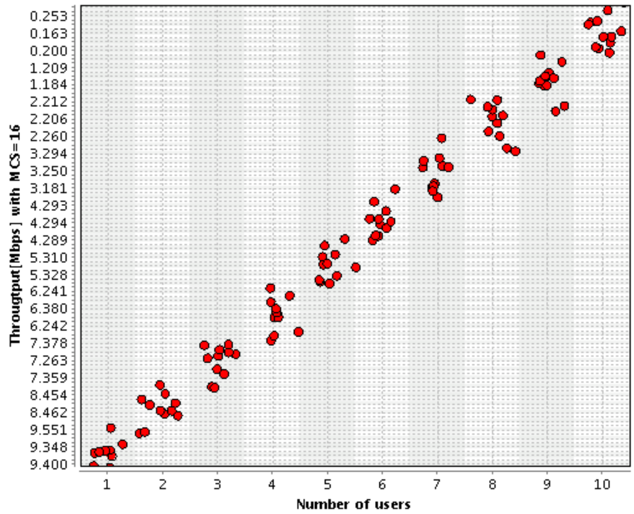

Fig. 5. Throughput with MCS=16

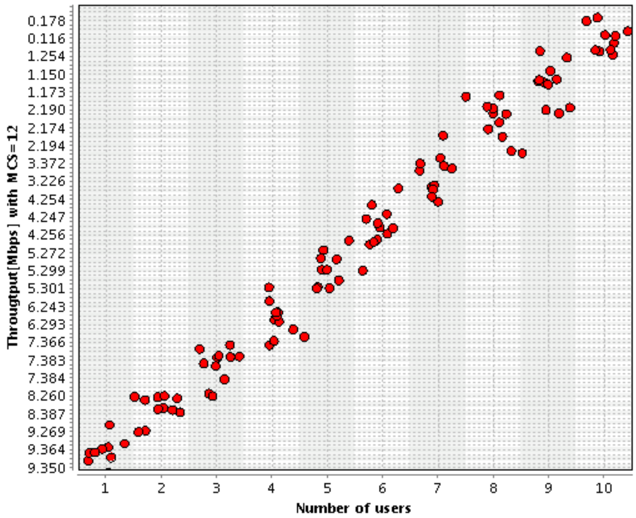

Fig. 6. Throughput with MCS=12

On Fig. 7 is presented the Drop ratio. It is possible to compare a/the number of drops when it is applied a/the prioritization, based on distance between the user and Base station and drops without prioritization.

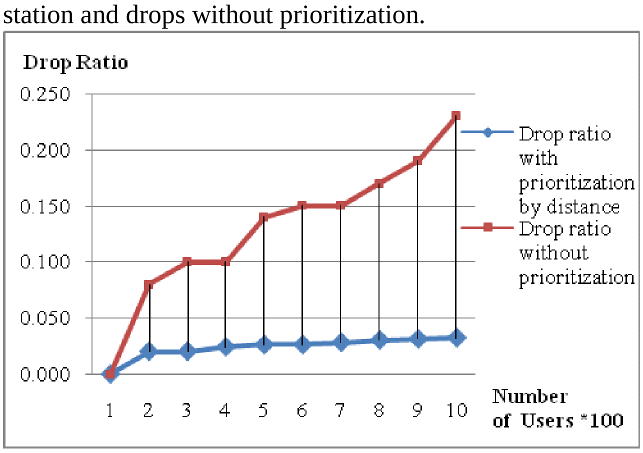

Fig. 7. Drop Ratio

When the number of users grows up, the numbers of rejected beacons grow up too. This is the reason to increase the drop ratio when the number of the users is increased.

The observed parameters degradation when connecting more users is related to the priority implemented scheduler, in which case the less priority queues may not be served in the case of network overload or congestion.

V. Conclusion

The main goal of researchers is creating a smart network which is flexible, robust and cost effective. Due to this reason QoS stays in focus in each network- wired, wireless or hybrid. In this paper is proposed an analysis of the applicability to prioritize users in order to fit the bandwidth requirement, while satisfying the application needs, based on analytical data for many factors as MCS which be used, the TB size, the number of users and the prioritization of users. There are presented two QoS parameters – throughput and drop ratio with/without prioritization. It was always assured a minimum transmission for all the service classes, although with different performances due to prioritization.

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