Research Article

Comparative Analysis of MAC Scheduling Algorithms in Long Term Evolution Networks using NS3

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Abstract: Best effort data network does not guarantee real-time transmission of data. Such network is not suitable for real-time applications. Long Term Evolution (LTE) networks guarantee the high data rates that require MAC scheduler at base station called as anode to which User Equipments (UEs) are connected. The scheduler allocates the available radio resources for high data rate application among the connected UEs. Improper allocation largely impacts the throughput. Comparison of different scheduling algorithms would help in understanding their performance that helps in designing the improved scheduler at the eNodeB. In this paper, the performance of three most popular LTE MAC schedulers is studied. The Round Robin, Priority Set Scheduler and Proportional Fair schedulers are simulated in NS3.24 using LTE scenario transmitting real-time voice packets with various channel conditions of the UE for observing the performance of each scheduler through various QoS parameters such as throughput, delay and jitter. It is observed that the performance of the round robin scheduler is better compared to the other two in terms of throughput, delay and jitter at uplink as well as downlink.

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INTRODUCTION

LTE is the fastest growing technology in mobile broadband and Machine to Machine communication where high bandwidth is required as 3G and other existing technologies are incapable of fulfilling the demands. Third Generation Partnership Project (3GPP) [1] developed LTE as a 4G wireless broadband technology in 2004. The major design goals of LTE network include increased spectrum efficiency, reduced cost, low simplicity with higher user bit rate, minimum latency and robustness. LTE is an IP based flat network architecture where circuit switched core is replaced by packet switched core to achieve high data rate. It consists of an Evolved Packet System (EPS), 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) works as evolved base station and User Equipment (UE) as its components. It handles the Radio communications between the UE and the EPC [2]. The eNodeB performs radio resource management layer functions such as dynamic resource allocation, eNodeB measurement configuration and provision, radio admission control, connection mobility control, radio bearer control and inter-cell interference co-ordination. Downlink (Dl) is an air interface to receive/download data to the UE from eNodeB at 100 Mbps whereas Uplink (Ul) is an air interface to send data from UE back to the eNodeB at 50 Mbps [2].

Scheduling of radio resources for UEs dynamically is carried out by the packet scheduler at MAC layer of eNodeB at every transmission time interval which is equal to 1ms in LTE. The scheduler helps fast communication and efficient utilization of radio resources. Several packet scheduling algorithms in LTE are proposed to improve the performance in terms of Quality of Service (QoS) metric such as throughput, jitter and delay. QoS defines how a particular user data should be treated in the network. It ensures high-quality performance in real-time multimedia applications. QoS requirement of LTE scheduler includes throughput, delay and jitter. Throughput is the rate of production in general terms, whereas it is the rate of successful message delivery over a communication channel in the context of communication networks. Delay in packet transmission specifies the time taken to travel from one point to another across the communication network. The variation in the latency during the transmission of data packets over time across the communication network is jitter. The constant latency measurement indicates the non-existence of jitter across the network. Jitter results from network congestion, timing drift and route changes. LTE packet scheduling is affected by many factors including traffic generated by UEs,

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QoS level required for current transmission of data and radio conditions. As part this work, we studied the capability of LTE schedulers in various traffic environments. Various simulation environments such as NS3 [3] exist in the literature with the packet schedulers. As NS3 is recent and widely used simulation environment, we have chosen it as our simulation environment. The design aspects of the implemented LTE schedulers in NS3 are studied in this paper through the performance analysis in terms of throughput, delay, and jitter at uplink and downlink.

RELATED WORKS

The growth of LTE technology usage needs to address the limitations of the existing LTE schedulers in terms of QoS provisioning. This indicates that there is scope for researchers to design/tune the LTE schedulers based on the specific needs. Various LTE schedulers are implemented in the standard simulation environment such as NS3. Proportional Fair (PF) scheduling algorithm allocates resources in order to satisfy the requirements on spectral efficiency and achieve fairness among users. The PF scheduler is evaluated as given in [4][5]. It does not consider other LTE schedulers. The MAC layer throughput of some scheduler available in NS3 is compared as performance analysis of LTE scheduler in [6] that is extended in [7]. It considered only throughput. Various other QoS parameters are not analyzed in this work.

Many works exist on the performance comparison of the LTE scheduler. They either analyze the performance only at downlink or not using NS3. In this paper, we compare the performance of three schedulers in terms of throughput, delay and jitter. The paper comprises of total five sections. The following sections include Section III where the various MAC scheduler implemented in ns3 is described; Section IV where the simulation model, simulation procedure, performance parameters, and simulation results are discussed; Section V to conclude the paper.

WORKING OF THE MAC SCHEDULERS IN LTE NETWORKS

This section describes the functionality and working principal of the MAC protocols used in LTE networks.

Round Robin

Round Robin (RR) [6] scheduler allocates the resource blocks between the flows generated from the UEs cyclically regardless of its channel quality with equal timeslot for transmission of packets. It does not consider its channel quality while allocating the resource blocks. It provides fair access of the resources during the transmission of packets. It does not allocate resources to all flows when the traffic flow is larger compared to the available resource block. The throughput degrades due to non-consideration of signal to noise ratio during the calculation of number of transmitting bits. Hence it is not efficient for QoS provisioning traffic. It is free from starvation situation as fair resource allocation gives the chance for all flow to transmit their packets. The excess packets in the flow will be allocated in a circular fashion in other sub-frames, since it cannot be allocated in the same sub-frame.

Proportional Fair

Proportional Fair (PF) scheduling algorithm allocates resources in order to satisfy the requirements on spectral efficiency and achieve fairness among users. It maintains balance between throughput and minimal level of service provisioning for all users either through assignment of data rate to each data flow or through the scheduling priority. This scheduling priority is inversely proportional to its anticipated resource consumption. It tries to maximize the total throughput. When the UE has high channel quality compared to the average channel condition with respect to the time, the resources are allocated to the UE with respect to the time. UE are allocated to different groups of resource block. The metrics are computed based on channel conditions and throughput of previous transmissions. Even though the aim of PF was to maximize the throughput, it can neither provide the best throughput nor provide the best fairness as it does not consider each user buffer content. Hence, PF is not suitable for real-time transmission of data.

Priority Set Scheduler

As PF and RR are not able to handle the priority for the type of traffics, a QoS aware scheduler algorithm called as Priority Set Scheduler (PSS) is designed. It comprises of frequency domain (FD) and time domain (TD) packet scheduler. The aim of PSS is provisioning of a defined target bit rate for all users [7]. Observable Matrix for guaranteed bit rate (GBR) is used to achieve part of a QoS requirement in PSS. The FD scheduler in PSS controls the fairness among UEs through the specified target bite rate (TBR). TD scheduler selects the UE with non empty radio link control RLC buffer. It decides priority to the group of UE based on the division of the UEs according to their TBR However, it does not consider delay requirements, making it perform less efficiently. The group of UEs with the highest priority is forwarded to the FD scheduler, which allocates resource block to each UE using PF scheduler.

SIMULATION

The comparison of MAC scheduler is simulated using NS3.24 to assess their performance. This section explains the simulation model used to compare the existing LTE schedulers.

Simulation Model

A simulation model for the LTE scenario consists of network model, propagation model, mobility model, and traffic model. The number of

UEs attached to each eNB in the designed LTE network scenario varies from five to fifty with the interval of five. The command-line arguments passed to the scenario include number of eNB and UE, distance between eNBs and inter packet interval. Each eNB and UE is configured with LTE stack protocol. The RRC connection is established between the attached eNB. SRS Periodicity is configured at least greater than the number of UEs per eNB to enable the simulation to run with more number of users without error. The PointToPointHelper used to create the Internet with the attribute of data rate of 100GB/s. The position of UE is setup through the constant position mobility model in different areas at a uniform distance from the eNB. The various MAC schedulers are setup, one at a time to gather the result for analysis. The Friis Spectrum Propagation Loss Model attribute is set for pass loss model. LTE device is installed to the eNBs and UEs for the collecting all traces. The duration of the simulation is configured for 50ms. Traffic generators such as for voice and FTP for best effort are set of remote hosts that act as the host for generating traffic scenario. Multiple remote hosts for each type of traffic are set for traffic generated from the Internet to the eNB and UEs. Each remote host routes to the default gateway for eNB. The voice traffic as VoIP traffic flow uses OnOffhelper by characterizing ON and OFF time of voice traffic. The constant packets are transmitted at regular intervals during ON time when the users spend on talking. The packets are not transmitted during the OFF time and the user stops from talking. For the best voice quality, G.711 codec is used with 0.45 ON time duration and 0.75 OFF time duration. The UDP echo server and echo helper is setup in a UDP echo module for simulation of best effort application. The UDP module is designed with three attributes that includes maximum packets transmitted, packet intervals and size of the packet. The python based framework, waf, is used for configuring, compiling, installing and running the developed LTE scenario. The trace file is analyzed to get the number of packets sent and number of packets received that gives the throughput, delay, and jitter. The analyzed values are used to plot the graphs using the GNU-Plot utility.

Simulation Procedure

The variable number of eNB and UE is the command line arguments passed through the scenario execution to the simulator. Following steps are used to perform simulation for each number of eNB and UE with each eNB combination. (1) The scenario is generated for the given number of eNB and UE with the specified position. The simulation scenario has eNB, UE with interval of five and specified remote host for voice traffic flow per UE using OnOffhelper, and UDP flow per UE Using onOffhelper. (2) The python based framework, waf, is used for configuring, compiling, installing and running the generated LTE scenario through NS-3.24 to get the result. (3) The trace file is analyzed to get the number of packets sent and number of packets received that gives the packet loss ratio and throughput for voice and background traffic. (4) The obtained throughput, delay, and jitter for voice and background traffic are maintained for observing the performance of the various schedulers. (5) The performance of the proposed scheduler is observed by computing the through throughput, which is defined as the number of bytes transmitted per unit of time. The throughput of voice and background traffic is computed for various schedulers to analyze the performance through the various throughput graphs using the gnu-plot utility.

Simulation Results

The results obtained from the designed LTE scenario in ns3 are throughput, delay and jitter. Delay in uplink for PSS scheduler is high compared to RR and PF schedulers with the varying number of UE whereas the delay in the downlink for PSS is slightly higher as shown in Figure 1 and Figure 2 respectively.

Jitter for PSS in uplink is high as delay is high as shown in Figure 3. The jitter in all three schedulers is close to each other in downlink with the varying number of UE as shown in Figure 4. The throughput of PSS is low compared to RR and PF with the varying number of UE as shown in Figure 5.

CONCLUSIONS

In this paper, we present a comparative performance evaluation of three MAC schedulers for LTE networks on the basis of throughput, delay and jitter with respect to number of UE nodes per eNodeB. It is observed that PSS and PF have similar results. RR is more efficient than other two. So, RR is more suitable for applications where QoS provisions are required. We plan to design QoS-aware LTE scheduler for improving the throughput in the future.

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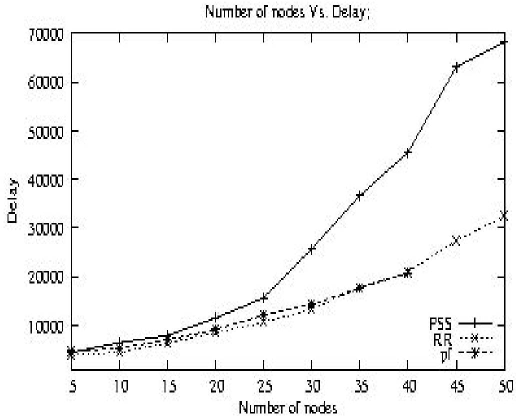

Figure 1: Delay for uplink

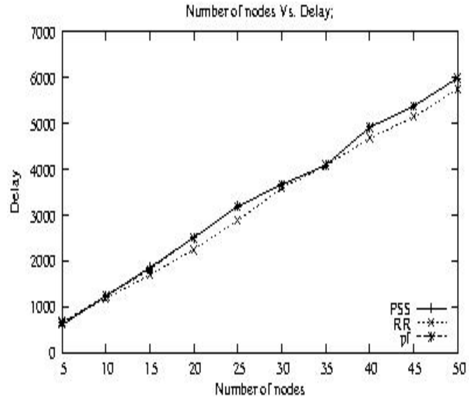

Figure 2: Delay for downlink

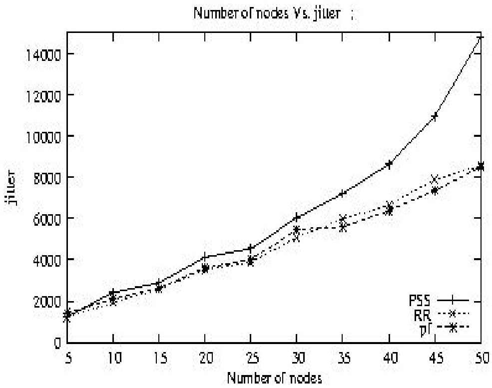

Figure 3: Jitter for downlink

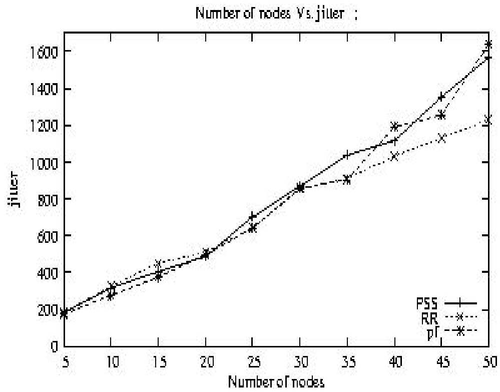

Figure 4: Jitter for uplink

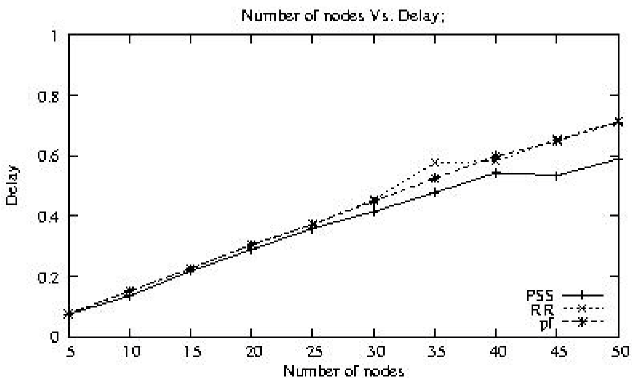

Figure 5: Throughput

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