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Preamble Random Access & Downlink Scheduling-Based QoS Assurance in LTE – A Applications

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Abstract

Nowadays, the technology which connects and manages the city assets through the numerous low cost sensing devices refers to smart city which changes the human life as the smarter one. The key process for the efficient smart city applications is the interconnection among the Machine Type Communication (MTC) devices. The impact of changes in these connections violates the performance of MTC in following parameters throughput, delay and power consumption. Hence, the assurance of above-mentioned Quality of Service (QoS) parameters is the important and challenging task in dynamic environment. Long Term Evolution (LTE) and its Advanced version (LTE-A) offers the solutions to the issues in QoS achievement. The issues such as contention, congestion, limitation of 4Gservices across Random Access (RA) scheme and the switching of Discontinuous Reception (DRX) operational modes limit the performance of LTE-A. To alleviate these issues, this paper proposes the Preamble Random Access-based Downlink Scheduling Scheme (PRADSS) scheme with the two operational stages. Initially, the proposed work utilizes the collision-based RA approach on the basis of the binary splitting tree technique. The effective handling of massive data traffic and the cooperation of LTE with the Medium Access Control (MAC) resolves the collisions among the preambles. Then, it utilizes the downlink scheduling to overcome the issues due to simultaneous switching of DRX operating modes. The priority estimation for the User Equipment (UE) and the allocation of resources based on the priority values reduce the delay effectively. The extensive simulations of proposed work regarding the throughput, delay, and power consumption against the existing scheduling approaches under normal and power saving mode confirms the effectiveness of real-time traffic in smart city applications.

Keywords: Collision Reduction, Long Term Evolution-Advanced, Machine Type Communication, Preamble, Random Access, Scheduling.

INTRODUCTION

Recently, the mechanical automated applications such as Internet of Things (IoT) and smart grid changes the living styles of human beings with an interaction among the machines. For the successful mechanical automation, the efficient Machine-to-Machine (M2M) communication is necessary and it is a difficult task. Each device in communication plays the three types of roles such as sensor, decision maker and the action executer. The layering architecture which describes connections among the Machine Type Communication (MTC) devices participated in 3GPP and IEEE 802.16p structure. Advanced or IEEE WiMAX2.0). An establishment air interface connection is the preliminary stage in 3GPP for Random Access (RA) in the communication channel. Due to the requirement of resources by 3GPP, RA is necessary for the delivery of requests to the Base Station (BS). The congestion during the RA through Channel (RACH) is the most critical and open challenge due to the huge number of MTC devices in M2M communication [1]. But, the scheduling-based data transmission and the contention-based data delivery make the previous schemes as infeasible for cellular networks. Hence, the new stabilization scheme such as Long Term Evolution (LTE) and its extension namely LTE-Advanced are evolved in the research studies which adopts network coordinated random access stabilization scheme called Access Class Bearing (ACB). In this scheme, each device is responsible for the transmission of access requests to the BSs and each BS determine the stabilization parameter p corresponding to cell. The occurrence of several congestions creates the low value of p which results in high-delay among the MTC devices.

To reduce the delay, the new scheme called congestion-aware admission control (CAAC) scheme[2] is introduced which groups the MTC devices on the basis of low and high priority classes. In ACB, the particular class is blocked during the congestion with the probability value. Compared to ACB, the prior definition of probability values is absent in CAAC scheme. The effects of Evolved Packet System (EPS) nodes such as mobility management entity (MME), serving gateway (SGW), and Packet data network gateway (P-GW) compute the rejection probability during the congestion. According to this probability value, the node in Radio Access Network (RAN) namely eNodeB either accepts or rejects data traffic in MTC. The delay of incoming packets from the application layer directly induces the congestion in MME which leads to high and variable buffer latencies. But, the congestion at S-GW and P-GW largely affects the outgoing buffer length. Due to these effects, the rejection probability p is derived. The adjustments in the probability values control the congestion levels at MME in CAAC scheme. The variations of probability values (high and low) according to the congestion level decide the admission control operation. The factors such as overload and the underutilization affect the performance of CAAC scheme. To address these factors, the MME utilizes the Proportional Integral Derivative (PID) with the available local information. The proper maintenance of MME queue in the optimal value using PID-based framework efficiently avoids the system overload and underutilization. The effective handling of queue variations is an indicating parameter of severity level in congestion.

Due to the dynamicity in the elements, the resource allocation is made as the dynamic process which is not proficient in above-mentioned schemes due to the huge number of RA-sub-frames and preamble. The introduction of Code Expanded RA scheme [3, 4] makes the resource allocation as dynamic which is helpful in LTE-A. The preservation of physical layer and the minimum changes in the medium access control layer enable the bursty RA loads. The illustration of code expanded RA scheme comprises following processes:

1) Occurrence of RA in LTE-specific sub-frame
2) Introduction of shortcoming while reducing the collisions
3) Ambiguities introduction at the BS with respect to the code words transmitted.

With the above processes, the code expanded scheme provides the conclusion such that the codewords exist in the virtual frame are higher than the codewords actually sent. The multiple combinations of transmitted codewords yield the observation regarding the introduction of phantom codewords which are unavailable in mobile equipment. But, the generation of phantom codewords largely affects the performance and it is significant only for low load conditions. Even though the small drawbacks are available, the efficiency of this approach is substantially high for high loads.

The enormous amount of IoT traffic handling with the diverse quality of service (QoS) requirements depends on the provision of reliable and high-data rate communication in LTE-A system. According to the diverse service communications, the LTE-A utilizes the heterogeneous networks (HetNets) [5] technology in which two cells are grouped together such as macrocells (Mcells) and femto cells (Fcells) to provide the mobility support and boost up the data transmissions. The extensible deployment of Fcells causes the co-channel interference between Mcells and Fcells which degrade the system performance. Besides, the unplanned random behaviors of IoT-oriented Fcells introduce the difficulties in performance evaluation and QoS assurance. Due to the existence of connections among the various types of devices in the IoT framework, the generated data traffic is more. With an assumption like each user participated in the communication has the some portion of the bandwidth, the existing frameworks utilized the SGW scheme to assure the QoS requirement. Besides, the Partial Spectrum Usage (PSU) and the Collision Avoidance (CA) capabilities are not considered. The incorporation of Fcell randomness into the HetNets performance provides the convergence of the service-differentiated IoT applications. When the Mcell frequency reuse factor is equal to one, the violation in previous assumptions creates the interference which is not neglected. Hence, the new interaction strategy is evolved which considers the inter-macro interference to perform an effective communication. But, the existence of diverse complexities in the circuitry among the devices initiates the congestion in RA mechanism in LTE-A networks. LTE-A includes the Discontinuous Reception (DRX) with the light and deep sleep modes to alleviate the issues raised from the previous works. The changes of receiver into sleep mode and the UE into deep sleep mode have the direct impact on the QoS constraints which increase the packet loss or delays. To overcome the issues, this paper proposes a “Preamble Random Access-based Downlink Scheduling Scheme” for enhancement in LTE-A applications. The novel contributions of proposed work are listed as follows:

1) A collision resolution-based RA approach with the m-array contention tree splitting technique makes the high-density access as regular which leads to effective handling of congestion in RA mechanism in LTE networks.

2) Handling of massive data traffic and coexistence with the LTE-MAC protocol without any modifications support the 4G utilization in LTE networks

3) Priority-based resource assignment and the opportunistic scheduling schemes reduce the packet delay or loss rate due to the DRX sleep modes..

The rest of the paper organized as follows: Section II describes the various related works regarding the access scheme and scheduling in LTE-A. Section III illustrates the implementation process of proposed Preamble Random Access-based Downlink Scheduling Scheme (PRADSS) in detail. Section IV provides the performance analysis of the proposed work in detail. Finally, this paper concludes in Section V.

RELATED WORK

In this section, the review of traditional works regarding the resource allocation, random access protocols and power spectrum usage in LTE-A with the merits and demerits. Initially, the review of research studies related to the improvement of RA of channel is necessary. The comprehensive discussion reported in [6] highlighted the techniques with their strength and weakness. The future trends were derived with the complex efforts regarding the improvements in energy efficiency with less delay. This energy-efficient LTE mechanism played an important key role under the deployment of M2M works. The lack of own resource allocation mechanism and bandwidth in above techniques offered the less support for the effective communication among the Mobile Terminals (MTs). But, the multi-home capabilities with the constant and variable bit rates caused the radio resource allocation problem in the heterogeneous networks. A novel resource allocation algorithm [7] was proposed in which the BS and the Access Point (AP) performed their own resource allocation for the intercommunication among the MTs. Through the enabling of wireless access connections among the wireless access of BS, the multiple radio interfaces provide the sufficient bandwidth for each MT. The lack of prior probability declarations induced the interferences among the MTCs. To alleviate the interferences, a contention-based random-access protocol[8] was designed for wireless networks in which the number of users participated in the communication are known in prior. The division of the operational rounds into several equal numbers of slots with the similar durations predicts the users and their resolution in the data transmission. With the prior probability declaration, the independent access of wireless link by the users under slot allotment achieves the successive cancellation. By utilizing the optimum access probabilities, the throughput values were better than the previous protocols. The incorporation of large number of instruments in the particular cell requires the measure of intersystem dependencies. An assessment of three operational stages in GSM radio access like random access, granted and the data transmission stages was provided in [9] provided the required support for large number of smart meters in the cell. The elaborate discussions provided in this paper directed towards the enhancements in access granted and data transmission channels. The consideration of interstate dependencies and the independent treatment of access stages in 3GPP-GSM radio links provided the unreliable results. The convergence of the efficient resource reuse pattern was the necessary requirement. The introduction of self-organization rule [10] on the basis of the transmit power provided the required convergence. The two variations such as autonomous and coordinated resource allocation according to self-organization rule with the specific constraints minimized the power level. The system level simulations on the self-organization rule showed the controversies in the power efficiency and system capacity.

A overload problem was considered as the important challenge in the RA scheme. The overview of the impact of massive terminals on the LTE and LTE-A provided in [11] handled the overload problem effectively. The major solution to the overload problem was the congestion elimination on RA without affecting the communication process. But, the existence of high packet delay and losses increased the power consumption and degraded the QoS constraints. To overcome this issue, Mushtak et al [12]proposed a downlink scheduling technique called Discontinuous Reception (DRX) concept in LTE which improved the QoS constraint. Even though the power consumption was minimum level, the consideration of QoS parameters with the fair resource allocation scheme provided the difficulties in scheduling process. Hence, the trade-off between the delay and power consumption was the major deficiency in traditional approaches. Fowler et al [13] presented the brief review of the fixed DRX cycles and their comparison with the adjustable one under heavy burst data traffic. A semi-Markov process was employed to model the data traffic model in order to achieve the trade-off between the wake-up delay and power consumption. The existence of the complex inter-dependencies among the devices leads to the degradation of QoS performance. Hence, the maximization of Cell Selection Biasing (CSB) with respect to the QoS constraints was necessary. Sivaraj et al[14] developed the analytical model which captured the interdependencies between the enhanced Inter Channel Interference Coordination (eICIC) techniques and carrier aggregation. The joint optimization of eICIC and the CA through the dependency measurement increased the spectrum utilization rate against the Mcells. With the enormous data transmissions and receptions in the heterogeneous environment, the researchers turned their attention into the development of new mobile networks called Rel-10. Khan and Sheik [15] proposed the solution for the future developments of mobile wireless networks on the basis of Rel-10 LTE-A. Initially, the the high-level overview was presented with the inclusion of carrier aggregation and spectrum utilization capabilities in order to reduce the power consumption level in the frequency division multiplexing-based heterogeneous networks.

The modifications in the protocol operations without changes in the physical layer were the major deficiency in the LTE-A networks. Madueno et al [17] proposed a LTE RACH scheme on the basis of delay oriented M2M services and the synchronous traffic arrivals. They applied the collision reduction resolution algorithm with respect to the splitting trees which achieved the minor modifications without any changes in physical layer. The promising and wide margin results were achieved with this scheme. But, the insufficient resource allocation mechanism caused the major problem in the scheduling process. The same authors extended the collision reduction mechanism with the proactive approach[19] for the standard cellular operation. The proactive approach consists of two operating phases namely estimation and serving. In the first case, the number of packet arrivals was estimated. Based the arrival information, the resources are allocated in the second case (serving phase). In this process, the central manager was employed to allocate the resources corresponding to the operations. The violation in the performance of resource manager caused the serious problem such that resource unavailability which leads to disturbances in the communication process. Ismail et al [20] the radio resource allocation scheme for the heterogeneous wireless networks equipped with the Mobile Terminals (MTs). The prediction-based resource allocation algorithm was used to allocate the resources for the communication process. This approach did not require any centralized resource manager which provided better communication than the traditional works. On the basis of the available resources, the computation of bandwidth played the major role in resource allocation process. Due to the absence of centralized resource manager, the proposed approach was well suitable for dynamic environment (call arrivals and departures at random time). But, the time required for accessing the data transmission medium was more due to the unavailability of channels in the allotted time period. Shirvanimoghaddam et al [21] proposed a novel multiple access scheme for M2M communication on the basis of the capacity. The provision of permissions M2M devices to transmit the information in the same channel simultaneous achieved the satisfactory delay performance. The near optimal performance was achieved and the guarantee to QoS parameters was also provided in this scheme. The minimum number of preambles was insufficient to achieve the reliable M2M communication. Jang et al [22] proposed a novel RA scheme to increase the number of preambles by partitioning the cell coverage into the multiple group regions spatially. With the increase in number of preambles, the huge size machine nodes were accommodated. The reduction in collision probability reduced the access delay compared to the traditional schemes. The literature review of traditional techniques highlighted the following issues:

1) The initial step to transfer the data in LTE network is Random Access (RA) which was suffered by the contention issues due to three cases such as initial access, recovery from the radio connection and the non-synchronization of uplink with the radio connection status. The irregular and high-density access features leads to congestion in RA mechanism in LTE networks.
2) Due to the extensive complexities in the circuitry between the devices and receiver, the power across the User Equipment (UE) is drained and the utilization of 4G services across the RA is limited.
3) LTE additionally includes the concept of Discontinuous Reception (DRX) with the light and deep sleep modes. But, the switching between the active and deep sleep mode causes the receiver to go into sleep mode and UE into deep sleep mode state. Due to the direct impact of DRX sleep modes on QoS constraints, more packet loss or delays occurred.

This paper proposes the new framework to alleviate such issues by integrating the DRX concept with the collision resolution-based RA.

PREAMBLE RANDOM ACCESS-BASED DOWNLINK SCHEDULING SCHEME

The trade-off between the minimum power consumption and the QoS assurance is the core idea behind the proposed work. In the traditional DRX model, the number of reattempts in RA scheme if the current frame is undergone a failure condition is insufficient during the switch between the operating modes. Besides, the improper RA causes the collisions if the multiple MTC devices are employed. To alleviate these issues, the proposed work integrates the preamble-based RA scheme with the scheduling scheme. Fig.1shows the architecture model for proposed Preamble Random Access-based Downlink Scheduling architecture

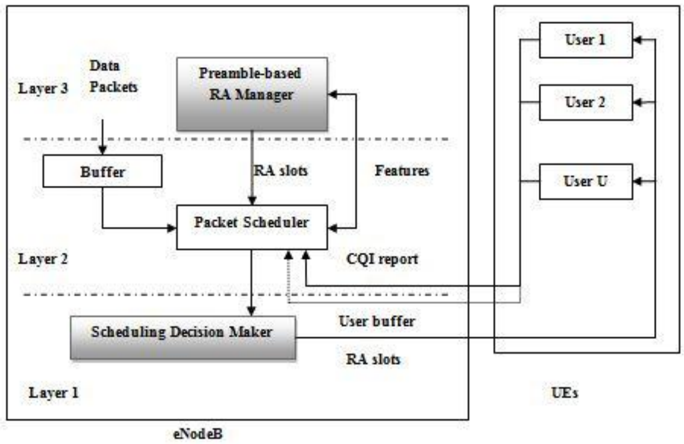

Figure 1: PRADSS architecture

The optimization in the number of preambles in the reserved set the basis of collision rate at each level provides the necessary slots for the communication. The architecture comprises the two major elements such as User Equipment (UE) and eNodeB(eNB). The major blocks of eNB are preamble-based RA manager, packet scheduler, and buffer. The manager collects the major dependencies of the RA slots from the packet scheduler. The buffers status, Channel Quality Indicator (CQI) and user buffer status are transmitted to the packet scheduler. Based on these features, the scheduling decision is made regarding the RA slots. The prior preamble-based RA on the basis of the contention tree reduces the collisions effectively.

Preamble-based RA

Due to the increase in collision rate beyond the threshold values, the eNB allocates the resources into the virtual frame. On the basis of QoS requirements, the duration of each virtual frame is adjusted. The UE transmits their identity and the randomly generated attempts to the eNB for the mapping of these attempts with the RACH subcarriers. But, the transmission of multiple UEs in the same preamble in the same RA slot leads to the difficulties in the decoding process. The colliding MTC devices initiate the retransmission of RA requests based on the preambles available in the reserved set. The repetition in the collision process in colliding MTC within the allotted preambles initiates the new set of preambles until the decoding process is finished. An optimistic tree algorithm illustrated in Fig. 2 facilitates the channel access for the high-priority MTC devices.

The basic splitting algorithm is modified with the binary tree concept to avoid the collision problem in RA scheme. The root in the tree specifies the number of contention-based preambles in which the collisions are occurred. The root is considered as the level 0 and the set of preambles are reserved at level 1 if the collisions are observed in level 0. If the collisions are created in level 1, then the set of preambles are created in level 2. This process is periodically continued to avoid the collision. On the basis of the collision rate, the number of preambles is adjusted dynamically. Besides, the adjustments in the counts of preambles resolve the contention tree state at the individual RA frame. For the high value of the collision rate, then the more number of preambles (P) are required which increase the levels of tree.

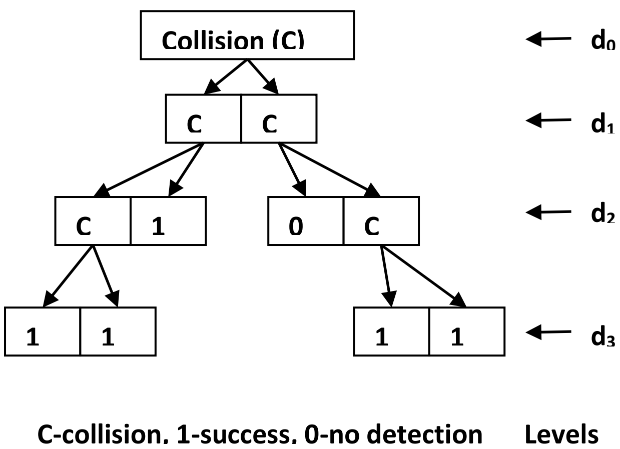

Figure 2: Contention tree-RA model

The impact of count of preambles on the delay performance lies in two cases as follows:

Case i) High value of preambles (Phigh)

For the high value of preambles, each level of tree consumes more time to resolve.

Case ii)Low value of preambles (Plow)

For the low values of preambles, the number of levels in the tree is more which also increase the delay.

Based on above cases, the proper selection of preambles is the necessary stage to select the required slots in each level of the tree. The algorithm to compute the RA slots is listed as follows:

Preamble-based RA algorithm

1. *Initialize the threshold values for collision a,b (a<b)*
2. *Initialize the preambles for contention-free slot (P, P_a, P_b)// $P<P_a<P_b$*
3. *Set the additional slots Δa and Δb*
4. *Estimate the collision rate from features*
5. ***While*** $(C_{rate} \neq 0)$
6. ***If*** *(b>C_{rate} ≥a)*
7. *Assign P= P_a and $\Delta = \Delta a$*
8. ***ElseIf***(b≤ C_{rate} >a)
9. *Assign P= $P_b$and$\Delta = \Delta b$*
10. ***Else***
11. *P= Pand$\Delta = \Delta$*
12. *Reserve the preambles*
13. *Send the response to packet scheduler*
14. *Broadcast the slots to the scheduler*
15. *Call DSS()*

Initially, the values such as collision threshold, preambles are initialized. Then, the additional slots are assigned according to the preambles. The features or dependencies from the scheduler are transmitted to the manager. Based on the features, the collision rate is estimated. Until the zero collision rate, the slot assignment process is initiated. If the collision rate is in between the threshold values, then the preambles and the slots through step 6 to 11. Once the slots are assigned, then the corresponding preambles are reserved and transmit the response to the packet scheduler. The scheduler receives the status of buffer and slot availability to predict the relevant slots for the transmission.

Scheduling Scheme

The scheduling scheme comprises the set of UEs in left hand size and the layered eNB (Layer 1-Layer 3) in the right hand side. The packet scheduler receives the CQI reports from the UEs to predict the channel conditions. The simultaneous collection of buffer status information by the scheduler avoids the packet loss. The prioritization of UEs based on the following five features or dependencies efficiently minimizes the packet loss during the reattempts

Channel condition

The data rates and modulation scheme for the specific UE is estimated by the scheduler. This estimation depends on the CQI reports from UEs during the uplink frequency.

Average throughput

The data transmitted within the allotted time window specifies the system throughput. Based on the history of UE throughput, the number of resources is defined.

UE buffer status:

Each UE is assigned with the buffer with the fixed length for packet storage. The insufficient spaces in the buffer lead to packet loss in the traditional work. But, the prior preamble based RA process limits the buffer length. Besides, the computation of priority for the UEs avoids the packet loss.

DRX status:

The impact of DRX status directly affects the trade-off between the power conservation and QoS guarantee. The binding of delays and RA slots within the threshold must require the information regarding DRX status.

Delay:

To minimize the packet loss and increase the priority of UE, the time duration for the oldest packet is considered as the important feature and hence delay also measured for scheduling.

In addition to above dependencies, the scheduling process requires three measures such as Fair Factor (FF), Buffer Factor (BF) and the Priority Function (PF). Table I describes the list of symbols and descriptions in detail.

Table 1: Symbols and Description

Symbols	**Description**
Th_{avg}	Average throughput
Th_{ach}	Achievable throughput
t_c	Contention window
t	Time period
L_{Rxbuff}	Received buffer length
N_s	Used space
φ	Exponential factor
δ	DRX status indicator
b_{rate}	Bit rate
$delay_F$	Delay factor

On the basis of the channel conditions from the CQI reports, the algorithm initially computes the maximum achievable throughputs for each resource and slots availability. The provision of balance between the throughput and the resource availability described by the fair factor as follows:

$$FF = \frac{Th_{ach}}{Th_{avg}} \quad (1)$$

$$Th_{avg}(t) = \left(1 - \frac{1}{t_c}\right) * Th_{avg}(t-1) + \frac{1}{t_c} * Th_{ach}(t-1) \quad (2)$$

The solution to the packet loss due to the buffer flow is derived from the buffer status report. The transmission of UE buffer information in the uplink frequency facilitates the preservation of buffer in the downlink frequency. The buffer information comprises two namely, length of the received buffer and the space used by the UE. For each Transmission Time Interval (TTI), the buffer factor is expressed as

$$BF = \frac{L_{Rxbuff} - N_s}{L_{Rxbuff}} \quad (3)$$

Based on the traffic flow types such as Real Time (RT) traffic and Non-Real Time (NRT) traffic, the priority for the resources and slots are estimated as follows:

$$P_{NRT} = \delta(FF + BF) \quad (4)$$

$$P_{RT} = delay_F \delta(FF\left(\frac{b_{rate}}{th_{avg}}\right)^{\varphi} + BF) \quad (5)$$

The delay factor is regarded as the priority multiplier which is used to increase the priority values of UEs whose data close to delay thresholds. Correspondingly, the bit rate is adjusted by the exponential factor if the UE achieves the throughput lower than the average value. Hence, these are used as the basic measures for RT. But, these measures are irrelevant in NRT due to the insensitive to delay and independent of bit rate. The algorithm to compute the priority function for the resources is described as follows:

Downlink scheduling scheme

1. *Estimate the average and achievable throughput from features*
2. ***For each** TTI*
3. *Compute the fair factor from equation (1)*
4. *Update the average throughput from equation (2)*
5. ***EndFor***
6. *Collect the buffer status information*
7. ***If** (UE buffer==empty)*
8. *Set* $N_s = 0$
9. *Increment for new packet arrival*

10. ***Else***
11. *Set* $N_s = L_{Rxbuff}$
12. ***End***
13. *Compute the buffer factor from equation (3)*
14. ***If*** *(i=RT)*
15. *Compute the priority function using (5)*
16. ***ElseIf****(i=NRT)*
17. *Compute the priority function using (4)*
18. ***End***
19. *Broadcast the resource information based on priority values*

For each TTI, the computation of buffer factor prior to the scheduling mechanism decides the mode of operation of UEs. The full exploitation of high bandwidth for LTE-A networks is the major advantage alternate to the DRX concept. Additionally, the DRX status added in the priority estimation decides the participation level of UE in the operation. Here, the DRX status defines the state of UE indirectly. If the δ value is 1, then it denotes the active mode of UE and it is in out of scheduling process otherwise. Hence, the prior preamble-based RA and downlink scheduling considers the UEs whoever in active mode reduces the resource consumption effectively.

SIMULATION SETUP

The eNB is considered as the static node and the UE regarded as the pedestrians moving with the speed of 5km/H. The Voice Over Internet Protocol (VOIP) traffic model is the basic model for the evaluation of proposed work. A single hexagon cell with the only one sector operating in the bandwidth of 5 MHz. The utilization of fading models highly contributes to the simulation of realistic channel conditions. Table II describes the simulation parameters used in the evaluation of proposed work.

Table 2: Simulation Parameters

Parameters	Value
eNB radius	250 m
Number of sectors/eNB	3
Target area	Single sector
Number of UEs	15
eNB total transmitting power	20 W
Fading model	Fast
UE speed	5km/Hr
Operating frequency band	2 GHz
System channel bandwidth	5 MHz
No. of resources	25
Traffic model	VoIP
VoIP delay	100ms
DRX active duration	4 TTIs
DRX sleep duration	0, 7, 10, 20, 30, 40 and 50 ms

The parameters considered for the evaluation of performance of the system are discussed as follows:

System throughput

The measure of accumulated data rates of all the UEs in bits/secs is referred as throughput.

Throughput fairness index

The relationship between the throughput and the number of resources is defined by the metric called fairness. The equation to describe the throughput fairness index is described as follows:

$$J(x_1, x_2, x_3, \dots, x_n) = \frac{(\sum_{i=1}^{n} x_i)^2}{n \sum_{i=1}^{n} x_i^2} \quad (6)$$

Where, x_i-throughput for i^{th} UE. The best case provides the maximum value of 1 which means all the UEs achieves the same system throughput.

Packet delay

The difference between the time duration between the creation of packets and the generation of acknowledgement to represent the successful delivery of the packets from the destination node is called as packet delay.

Packet Loss Rate

The measure of how many packets lost from the total number of packets sent is expressed as Packet Loss Rate (PLR). The packet loss indicates the acknowledgement failure within the delay threshold value.

$$PLR = \frac{Number\ of\ packets\ lost}{Number\ of\ packets\ sent} \quad (7)$$

Performance Analysis

In this section, the variation of various performance parameters listed above against the delay, DRX sleep duration are investigated and they are compared with the previous schemes such as BestCQI, Round Robbin (RR), proportional Fair, and DSS[12]. The evaluation comprises three types of operating modes as follows:

Normal mode

All the schedulers are used in same simulation setup. The receivers allotted to the UE are switched on in the same time period which means less power is consumed. The consideration of active and sleep modes in proposed work provides optimal performance compared to traditional BestCQI.

Power saving mode

In this mode, the performance of proposed work is evaluated in the power saving environment with the UE active duration in 1 TTI and sleep duration 7 TTI.

Power saving mode with QoS

In this mode, the performance of schedulers is investigated under QoS-based power saving environment. Here, all the schedulers are operated in the different DRX cycles. The active duration is fixed as in normal mode and the sleep duration is changed to high value to save more power.

Throughput

Figure: 3 show the system throughput in downlink environment against the different simulation periods respectively in normal mode.

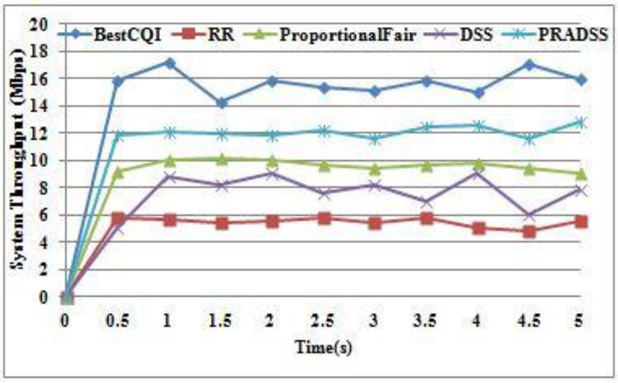

Figure 3: System throughput analysis for normal mode

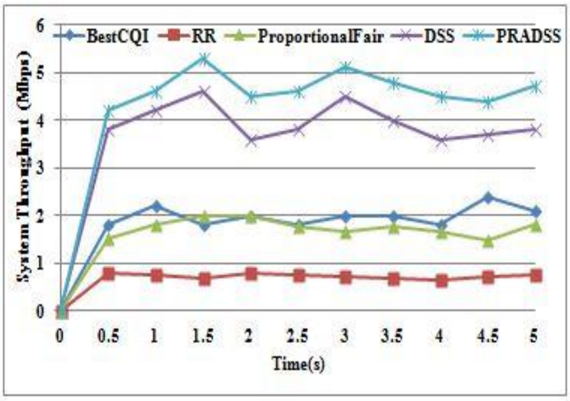

Figure 4: System throughput analysis for power saving mode

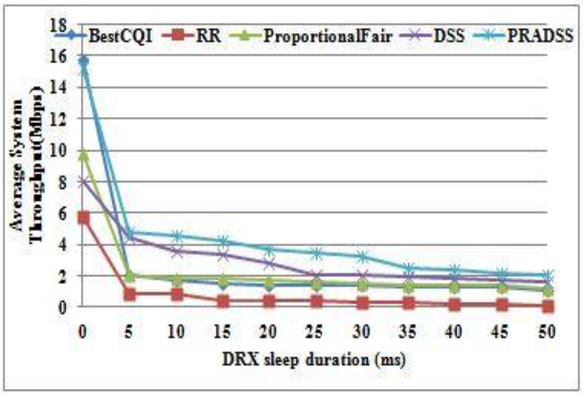

Figure 5: Average system throughput for QoS-based power saving

Figure: 4 and 5 shows the variations of the throughput values with respect to the time duration and DRX sleep duration under power saving and QoS-based power saving modes respectively. In the normal mode, the system throughput value for proportional Fair is high(9 Mbps) in the existing methods. The prior RA scheme to scheduling process increases the throughput values into 12.8 Mbps. The comparative analysis between the proposed PRADSS with the DSS scheme provides the 29.69 % improvement in throughput values. Similarly, the values of throughput are 19.15 and 21 % higher than the DSS scheme respectively in power saving and QoS-based power saving modes.

Throughput Fairness Index

Fig. 6 shows variations of throughput fairness index in downlink environment against the different simulation periods respectively in normal mode

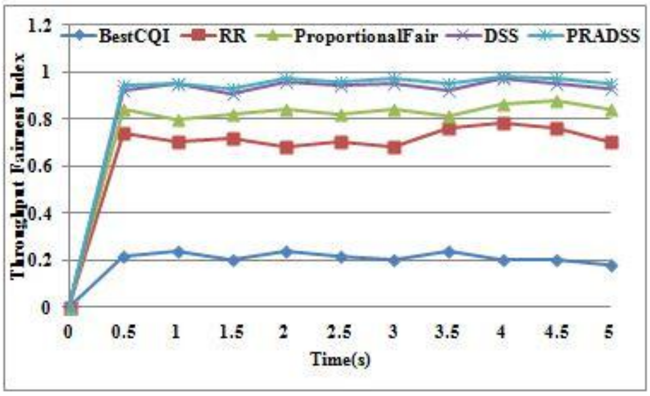

Figure 6: Throughput fairness index analysis for normal mode

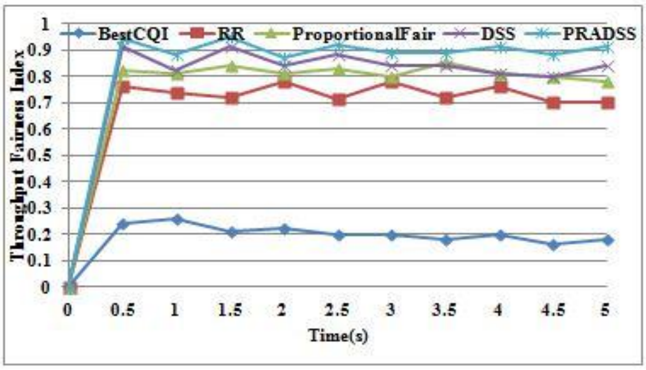

Figure 7: Throughput fairness index analysis for power saving mode

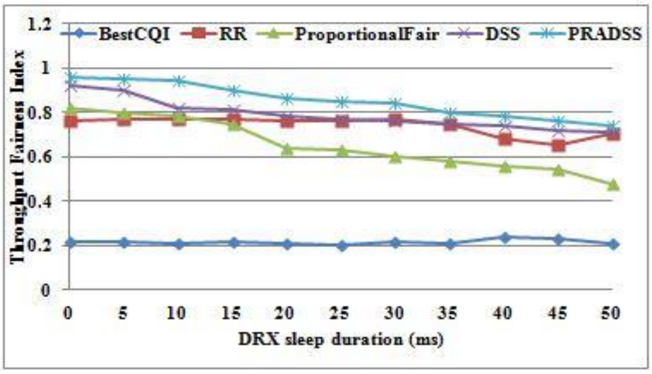

Figure 8: Throughput fairness index analysis for QoS-based power saving mode.

Figure: 7 and 8 shows the variations of the throughput fairness index values with respect to the time duration and DRX sleep duration under power saving and QoS-based power saving modes respectively. In the normal mode, the throughput fairness index of DSS is high(0.93) in the existing methods. The prior RA scheme to scheduling process increases the index into 0.95. The comparative analysis between the proposed PRADSS with the DSS scheme provides the 2.1 % improvement in throughput values. Similarly, the value of throughput are7.69 and 4.05 % higher than the DSS scheme respectively in power saving and QoS-based power saving modes.

Average Packet Delay

Figure: 9 shows variations of average packet delay variations in downlink environment against the different DRX sleep duration values.

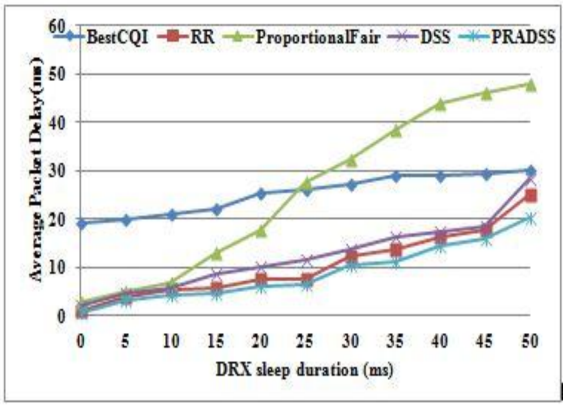

Figure 9: Average packet delay analysis for power saving mode

In existing methods, the delay consumed for the packet transmission is low in RR technique (1 ms and 25 ms) for minimum DRX sleep period (0 ms) and maximum (50 ms) periods respectively. The integration of RA mechanism with the downlink scheduling in proposed work reduces the delay values into 0.84 and 20.12 ms respectively. The comparative analysis states that the proposed work offers 58 and 28.65 % reduction in the delay compared to RR technique respectively.

Packet Loss Ratio Analysis

Table 3 describes the PLR analysis for the existing and proposed scheduling scheme under normal and power saving mode in detail.

Table 3: Packet Loss Ratio Analysis

Scheduling Mechanisms	Packet Loss Rate	
	Normal Mode	DRX Sleep Mode
BestCQI	0.1427	0.3268
Round Robin (RR)	0	0
ProportionalFair	0	0
DSS	0	0
PRADSS	0	0

In both normal and DRX sleep modes, the value of PLR is 0.1427 and 0.3268 respectively for the BestCQI scheduling algorithm. But, the proper resource allocation and the simultaneous switching between the active and sleep operating modes in further scheduling process reduces the loss into 0.

CONCLUSION

In this paper, the issues due to the congestions and the simultaneous switching of operational modes of DRX concept and their effects of QoS requirements are investigated. To alleviate such issues, this paper proposed the PRADSS scheme which contains two operational stages such as preamble-based RA and the downlink scheduling scheme. Initially, the proposed work utilized the collision-based RA approach on the basis of the m-array splitting tree technique. The effective handling of massive data traffic and the cooperation of LTE with the MAC resolved the collisions among the preambles. Then, it utilized the downlink scheduling to overcome the issues due to simultaneous switching of DRX operating modes. The priority estimation for the UE and the allocation of resources based on the priority values reduce the delay effectively. The extensive simulations of proposed work regarding the throughput, delay, and power consumption against the existing scheduling approaches under normal and power saving mode confirmed the effectiveness of real-time traffic in smart city applications.

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