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# Implementation of Max-SNR Opportunistic Scheduling in Cross Layer Design

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***ABSTRACT: The spectrum efficiency in wireless networks is becoming increasingly important to satisfy the expanding need for remote services, particularly reasonable remote Internet services. Various wireless users will encounter distinct circumstances on the channel, which are time-varying and location dependent at a given time. To exploit the wireless time-varying nature, a cross-layer design method called Opportunistic scheduling is used. Opportunistic scheduling increases the overall system performance and user fairness requirements under certain Quality of Service (QoS). The main idea behind this opportunistic scheduling algorithm is to make use of the time-varying channel and a user with the highest channel condition should be scheduled at a specified moment. The progressions in Wireless innovation made opportunistic scheduling a famous research point as of late. The demand for QoS provisioning is increasing and using a scheme which allows only users with best channel conditions to transmit at high transmission power cannot be satisfied.***

***The objective of this paper is to implement opportunistic scheduling while adhering to fairness and QoS constraints, using Max-Min fair algorithm. In brief, a wireless network has been simulated using Qualnet simulator. An opportunistic scheduler that uses Max-Min fairness scheduling has been implemented, at the Media Access Control (MAC) layer. Here, the base station gathers the Signal to Noise Ratio (SNR) of all the nodes and then schedules the users using Max-Min algorithm, based on these SNR values. The same scenario is then implemented using Strict Priority, which is a Non-opportunistic scheduling algorithm. The resulting throughput, fairness, delay and jitter of both the algorithms are then compared.***

***Keywords: Cross-layer design, Opportunistic Scheduling, Strict-Priority, Max-Min, QoS, SNR, and QualNet.***

## I. INTRODUCTION

Cross Layer design is a multi-layer co-operation, which combines the resources and creates a network that is highly adaptive. To meet the challenging data rates, to gain higher performance and quality of service for various real and non-real time applications, this is required. In order to achieve information sharing and to obtain highest adaptivity possible for any network, cross layer design is required. To schedule the users dependent on good channel conditions, opportunistic scheduling is used; opportunistic denotes the ability to schedule the users. However, the transmission at higher data rates opportunistically presents a significant trade-off between efficient resources and dimension of fulfillment among various remote users. For example, allowing users close to the base station to transmit at high transmission energy can lead to elevated performance, yet forfeits the transmissions of different users. Such a method cannot fulfill the expanding interest for QoS provisioning in the developing high-rate information remote systems. The objective is to improve the efficiency of remote resources by using time-varying channel conditions while controlling the QoS dimension among users in the meantime. The constraint that is considered here is the fairness quotient. In order to implement opportunistic scheduling in real time system, fairness and users' service requirements are the two issues which need to be addressed. The channel measurements of various users are not symmetric in all actuality and thus, a scheme is structured distinctly to amplify the general throughput which could be extremely one-sided, particularly when there are users with broadly divergent separations from the base station. For instance, the users near the base station are just permitted to transmit, which results in high throughput, yet transmission of different users is yielded. Then, a scheduling technique ought to not exclusively be worried about maximizing the long-term normal throughputs, on the grounds that various applications may have various utilities and administration limitations by and by. For ongoing applications, latency is the significant concern: a user need to recess quite a while till it find the opportunity to transmit, if the channel variations are excessively moderate. When structuring a scheduling procedure, the test is to address these issues while in the meantime utilizing the multiuser gain intrinsic in a framework. Spectrum utilization is important in improving the efficiency, particularly to give high-rate-data service. Yet, the ability to use higher information throughputs in an opportunistic manner, presents the trade-off issue between remote resource efficiency and dimensions of fulfillment among users. So as to separate the multi-user diverseness benefits, the cellular system itself has to satisfy certain requirements. [1] Access to the base station is required to quantify the channel quality: in the downlink, every receiver needs to follow its own channel signal-to-noise proportion (SNR) and give the feedback data to the base station. Transmissions from the base station should be scheduled on a short timescale among the users and furthermore to adjust users' information rates to the quick channel quality. This is the motivation behind why the opportunistic scheduling has gotten loads of consideration as of now. Traditionally, fairness is ascribed to resource allocation and distributing in Wireless systems administration area. The outcome of an uneven distribution among various users may prompt asset starvation, asset wastage or excess designation.

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Generally, fairness is ascribed to resource allocation and sharing in Wireless networking domain. The outcome of an out of line resource assignment among various users may prompt starvation of the resource, wastage of resource or redundant allotment. To decide, regardless of whether the users or applications are accepting a decent amount of framework resource, fairness measures or metrics are utilized in system designing. Opportunistic schedulers are greedy in their behavior, thus fairness performance is always a concern. During the poor channel quality, opportunistically scheduling the users can result in under serving a few users, while during better channel quality, the other users are over-served. Hence, the scheduler needs to be monitored, while allocating the resources to maintain a strategic fairness from injustice among users in the long haul. Jain's index, temporal fairness, and utilitarian fairness are the various measurements characterized for fairness. The most popular fairness metrics is the Jain’s index, which is used for studying fairness performance of the schedulers.[8].

## II. RELATED WORK

Accessible literature on opportunistic scheduling addresses the scheduling problem from different perspectives. Various strategies are suggested to carry out opportunistic scheduling, ranging from simple heuristic calculations to complicated numerical models. Most of these proposals are subclasses of four notable categories: distributed scheduling, fairness, capacity, and QoS. Additionally, a few recommendations work with full channel state data while others with non-full channel state data.

In [1], they have referred numerous research papers and have given an analysis of various algorithms based on their QoS, capacity, and fairness performances. The different approaches used to improve capacity, QoS, and fairness performance is explained. Their issues and limitations have been specified. It is mentioned that, in contrast to Round Robin, the proposal with focus on restriction can yield up to 37 percent rise in ability and 70 percent delay reduce. The QoS recommendations provided up to 30 percent improvement in performance and up to 80 percent improvement in delay. It has been said that proportional fair schedulers achieve a base Jain index of 0.6 while maintaining the QoS necessities. Figure 1.1 represents the QoS and fairness constraints of opportunistic scheduling.

In [2] - [6] schedulers try to maximize capacity and have base stations with full CSI. The desirable and instant understanding of the CSI of users in actual deployments is hardly practical, because CSI of versatile users is procured by means of feedback in cellular systems. To manage this issue, numerous proposals influence the learning of users' channel measurable statistics, and CSI tests, instead of the information of the definite and immediate CSI.

In [7], three opportunistic scheduling algorithms- Iterative Pure Hungarian, Max Min Fair Hungarian and Backlog-Based opportunistic algorithms have been implemented, in both homogenous and heterogeneous channel conditions. The aggregate throughput and fairness have been compared for all the 3 algorithms. Max-Min Fair Hungarian is shown to have performed better in varying traffic, heterogeneous conditions. In [8], Proportional Fair (PF) and Maximum throughput (MT) scheduling have been implemented and analyzed. Results show that PF outperforms MT in terms of fairness, but in Rayleigh fading channels there is about 10 percent system capability loss.

In [9], the authors present optimal planning agreements in OFDM frameworks with three unique fairness requirements, particularly utilitarian, temporal and minimum performance fairness.

In [10], the authors mainly focus on the various issues regarding opportunistic scheduling. They cornerstone on the real time issues of implementing various proposed algorithms like PF, ORR, etc. Issues associated with wireless networks in [14]: After some time and space, the remote channel changes and has current memory (or small scale) owing to multipath. These channel differences are caused by either distant device motion or changes in the overall physical situation, leading to detector errors. This results in burst errors during which packets cannot be transferred efficiently on the connection. Due to fading, small-scale channel differences are such that circumstances of different channels can change asynchronously from "excellent" to "awful" within a few milliseconds and the other way around. Furthermore, solid forward error correction codes (i.e. low rates) cannot be used to dispense with mistakes as this method leads to reduced spectral productivity.

Despite small-scale differences in channels, there are also spatio-temporal variations that form a much more prominent time scale. A large-scale variation of the channel means that the ordinary state of the channel depends on user fields and concentrations of interference. On these lines, due to small-scale modifications in the channel and large-scale changes, some consumers may intrinsically demand more channel access time than others depending on their region or mobile velocity, regardless of whether their data rate necessity is equivalent to or not equivalent to other users.

In the literature survey of papers, there are certain issues with the proposed techniques.

1) Optimality under sensible presumptions: There are several opportunistic scheduling techniques, which are optimal under certain assumptions. The most common assumptions are listed below:

- Full CSI accessibility at the base station for mobile users.
- Queues that are completely or immensely backlogged.
- Constant mobile user numbers (no one leaves or connects to the channel).
- Offline scheduling, scheduling of single user in a single channel network per frame and scheduling.

Here are some of the assumptions that can have a major impact on a proposal's results. Since, CSI is obtained through user feedback from the base station. Assuming each user sends feedback on each slot and on each sub-channel, and then a large amount of bandwidth is wasted for feedback only.

2) Implementation: The gain obtained from opportunism is not at all explored. Henceforth, we think investigating such executions would give experiences into unanticipated issues and outcomes of opportunistic scheduling.

3) All the opportunistic scheduling schemes has signaling costs involved in it, since scheduling choices inherently rely upon channel. The users must constantly estimate the channel circumstances and report them to the base station. The signaling cost to estimate the scheduling gain should therefore be taken into consideration.[10]

4) Since the channel conditions are estimated by the users, different estimation mistakes can happen in the scheduling methods. The various sources of estimation errors are: channel estimation error, errors in the parameters engaged in scheduling systems, and errors triggered by delays such as transmission delay, estimation delay, and time-slot limitation, etc. Estimation will generally be great if the channel condition variation is comparatively slow.

5) Fluctuation in the channel condition is exploited by Opportunistic scheduling and furthermore, consequently scheduling gain naturally relies upon the amplitude of the channel differences. The more prominent the variation of channel circumstances, the greater the number of customers, the greater the performance gain, when all is said in done. The fluctuation in the time scale is another problem in opportunistic scheduling. When all is said in done, the more prominent the variation of channel conditions, the bigger the quantity of users, the better the performance gain. Another concern in opportunistic scheduling is the fluctuation in the time scale. Channel variation should be mild enough to allow users to detect and attempt it. The variation of channels ought to be moderate enough for users to gauge and endeavor it. Then again, fluctuation ought to be quick enough, with the goal that users won't encounter outrageous long deferrals. In spite of the fact that numerous data users are delay-tolerant and scandalous delays can trigger upper-layer problems, such as timeout for TCP.[17]

6) Between scheduling benefit and temporary performance, there is a trade-off. As a rule, the more grounded the channel circumstances time relationship (i.e., the slower the channel variation), the more horrible the transient performance, and the more prominent the temporary performance improvement, the less the scheduling gain.

## III. SCHEDULING ALGORITHMS

### Strict Priority Scheduling:

Strict priority scheduling is utilized to encourage the support for latency-sensitive traffic. The priority such as high, medium or low is assigned by the scheduler to each flow, which guarantees that the high priority flow to be served first, then the flow with medium priority and lastly the flow with low priority. All the frames are drained by the strict priority scheduler lined in the highest priority queue before serving the lower priority classes. Helplessness with this sort of administration is that, a low-priority line will possibly starve.

In this algorithm, scheduler schedules the frames depending on the QoS class, distinct priority queues are then allocated. These queues are served from the highest to the lowest according to their priority as shown in Figure 3.1.

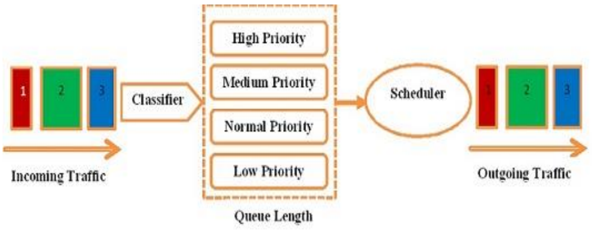

**Figure 3.1: Strict Priority Queuing**

The figure in 3.2 shows the order of the frames scheduled by the scheduler, servicing two queues.

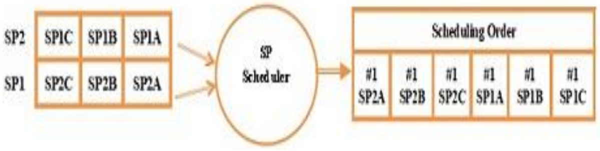

**Figure 3.2: Strict Priority Scheduling**

For every connection, a priority function (PRF) is defined in the system. Depending on the channel conditions such channel quality, QoS, and services status across the layers, the priority function is updated dynamically. The greatest priority connection is scheduled at every time. Each connection on the MAC layer belongs to a single class of service and is connected to a set of QoS parameters to quantify its characteristics.

The figure in 3.3 shows the flow of frames with different priorities.

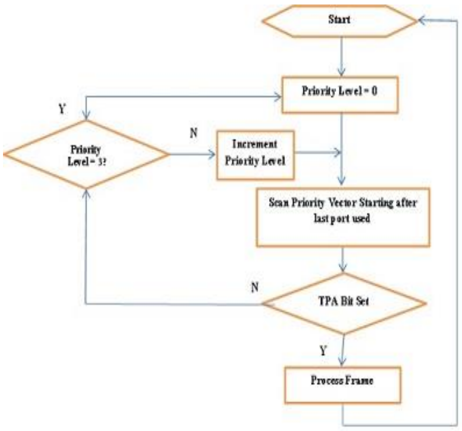

**Figure 3.3: Flow diagram of the Strict Priority scheduling**

### Max-Min Algorithm:

The target of the throughput max-min fairness is to amplify the base throughput everything being equal. Given N, the number of users in the framework, in which every user is ensured 1/N segment of the framework throughput. This goal is "completely" fair, since in any case, when there are users with exceptionally poor channel conditions, to accomplish max-min throughput fairness will cause noteworthy framework performance penalty. [2][3]

**Algorithm**

Steps involved:

- Consider x1, x2, x3,….., $x_n$ to be the demands of users 1, 2,...n respectively. Assume the capacity of the channel to be C.
- Depending upon the channel state information i.e. Signal to Noise Ratio (SNR) of the wireless channels allocates weights to each user.
- For Wireless Channels:

❖ If SNR =40dB, then the signal is Excellent.
❖ If SNR =25dB to 40dB, then the signal is Very good.
❖ If SNR =15dB to 25dB, then the signal is low.
❖ If SNR =10dB to 15dB, then the signal is Very low
❖ If SNR =5dB to 10dB then there is No signal.

- Normalize the weights with respect to the smaller weight.
- Initially share the resources equally between users i.e. C/n.
- Divide the excess share with the unsatisfied users.

### Design Constraints

The following are the design constraints of the algorithm:
1. The wireless networks contains maximum of 75 nodes.
2. The mobility speed of nodes is between 1mps to 40mps (meters per second).
3. The physical layer protocol is IEEE 802.11
4. The channel frequency is 2.4GHz.
5. The number of queues used for Max-Min scheduling is 4.
6. Maximum data rate is 2 Mbps.
7. Temperature is 290 Fahrenheit.
8. Input Queue size 150000 bytes.
9. Application which is enabled at each node is Traffic Generation.
10. Weather mobility interval is 10 seconds.
11. Simulation time is 100 seconds.

The constraints for the Max-Min algorithm are:
1. Resources are assigned arranged by expanding request, standardized by the weight.
2. No source gets a resource share bigger than its interest.
3. Sources that do not get satisfied with the demands, gets resource share in proportion to their weights.

### High Level Design for Opportunistic Scheduler

Our scheduler performs two major functions:
- Prioritizing the user
- Allocate resources

User provides CSI details to the first functionality which uses the SNR table and then updates the Weight table accordingly. This data is sent to Resource allocation module, which requires Resource allocation details from users, weight of each user from first module and it also requires Bandwidth table. On the basis of these input data, it allocates resources to each user based on their demands as shown in figure 3.4.

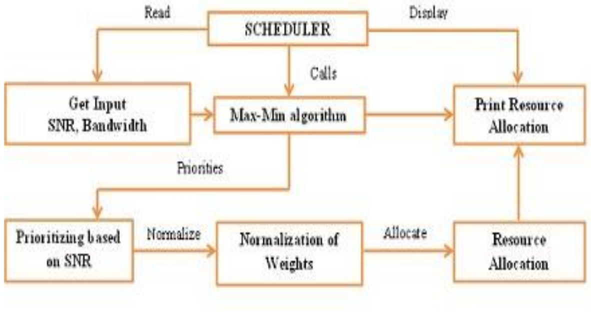

**Figure 3.4: Max-Min Scheduling**

Resource allocation is further divided into 2 modules. One is for initial sharing and other one for allocating resource for unsatisfied users so that they won't go to starvation. There are totally 3 phases which include:

**Normalizing the weights**: In measurements, standardization alludes to the development of adapted and scaled versions of statistics where the aim is that these standardized values make it possible to compare the respective standardized values for distinct datasets in a manner that eliminates the impacts of certain gross factors, as in the time series anomaly.[12].

**Initial Fair Sharing:** Initially all the users will be allocated resources which is proportional to their normalized weights.

**Resource allocation for unsatisfied users:** The allocated resources are subtracted from demand. Then resources for starved users are allocated using Max-Min algorithm.

## IV. SIMULATION MODEL

Figure 4.1 demonstrates a block diagram of a viable scheduling technique that fuses on-line parameters estimation. In our scheduling strategy, the base station needs to get data of every user's presentation esteem at a given availability to settle on the scheduling choice.

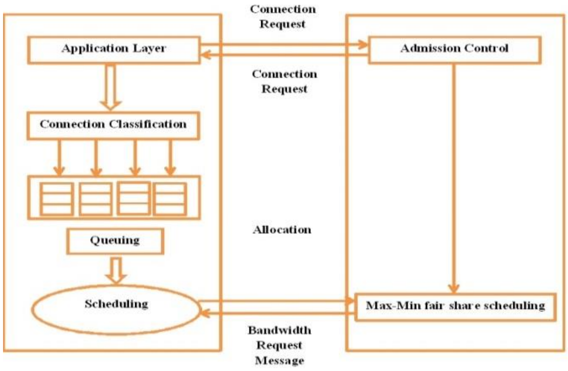

**Figure 4.1: Block diagram of the Scheduling Procedure**

At a schedule vacancy, a user could quantify the got signal power level (from the users' base station) and the interference power level. In light of the assessed SINR, the user would then be able to acquire its performance rate. The data is sent back to the base station, which can be practiced in a few different ways. For instance, every user could keep up a little signaling channel with the base station. On the other hand, the required data could be piggybacked as an acknowledgement packet. At that point the base station settles on the scheduling choice dependent on the scheduling strategy and transmits to the chose user. Last, parameters utilized in the scheduling approach are refreshed, which is examined straightaway.

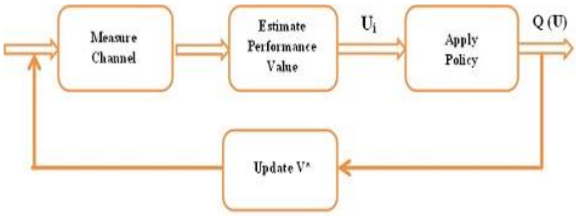

**Figure 4.2: Procedure of the scheduling approach with on-line parameter estimation.**

## V.COMPARATIVE ANALYSIS OF Max-Min AND Strict Priority Queuing

Using Qualnet Simulator 7.1, a wireless network is simulated. Qualnet simulator for modeling wired and wireless networks is an extensive instrument. Qualnet Architect is a graphical instrument that allows you to set up and execute an intuitive model. Channel propagation impacts such as fading, loss of route and shadowing models are given to enable network simulation to emulate real-world signal propagation. Using C++, programmers can create a new protocol or enhance current algorithms. Below are the simulation assumptions:

• Wireless network on a frame-by-frame basis is introduced. The quality of the channel is presumed to stay continuous per frame for each connection. It may differ from frame to frame, however.

- It is presumed that perfect CSI is accessible on both the receiver and the transmitter.
- Fixed number of mobile stations. Stations cannot be added or removed during the simulation.

### Test Cases

Wireless networks are simulated for 10, 25, 50 and 75 nodes. For each of these, simulation is done for without any mobility, with mobility (speed 1mps to 40mps) and also for with mobility (speed 1mps to 40mps) and weather. Random Waypoint mobility model with speed varying between 1mps and 40mps is used.

### Case 1: Network without mobility and weather conditions

Figure 5.1 depicts the network with different nodes setup for network without mobility and weather conditions. Each node is a mobile device. Cloud represents the wireless network. Application is Traffic Generation.

### Case 2: Network with mobility and weather conditions

Figure 5.2 depicts the network with different nodes setup for mobility and weather conditions. Each node is a mobile device. Cloud represents the wireless network. Application is Traffic Generation. The block represents the place which is subject to weather conditions. The mobility speed varies between 1mps to 40mps.

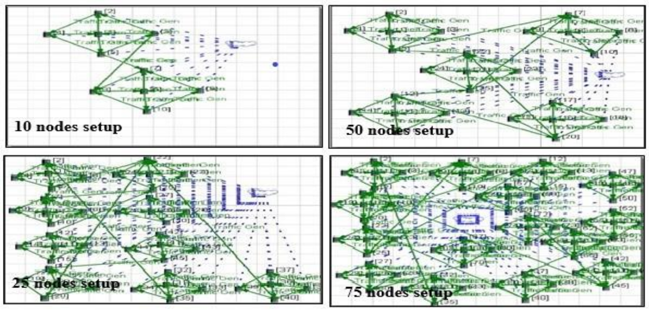

Figure 5.1: Nodes setup without mobility and weather conditions

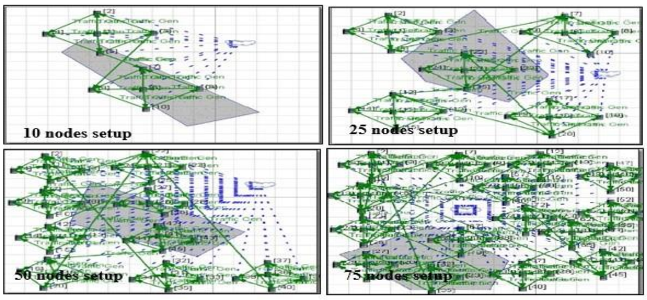

Figure 5.2: Nodes setup with mobility and weather conditions

## VI. RESULTS AND ANALYSIS

This section contains the tables and simulation results of fairness, throughput, delay and jitter for strict priority and Max-Min scheduling algorithm. This experiment is carried out for wireless networks which contain 10,25,50,75 nodes respectively.

Table 6.1 through 6.3 depicts:

- Jain's index which is a measure of fairness.
- Throughput which is a measure of QoS- Bits per second
- Delay which is a measure of QoS- seconds
- Jitter which is a measure of QoS- seconds

Table 6.1: Simulation without mobility and without weather

| Measure | Fairness | | Throughput (bps) | | Delay (seconds) | | Jitter (seconds) | |
|---|---|---|---|---|---|---|---|---|
| No. of nodes | Strict Priority | Max-Min | Strict Priority | Max-Min | Strict Priority | Max-Min | Strict Priority | Max-Min |
| 10 | 0.62 | 0.9184 | 84.0557 | 126.108 | 0.081 | 0.057 | 0.0379 | 0.027 |
| 25 | 0.764 | 0.894402 | 110 | 122.743 | 0.07 | 0.053 | 0.05 | 0.0438 |
| 50 | 0.785 | 0.88709 | 125.2 | 136.401 | 0.088 | 0.065 | 0.056 | 0.0507 |
| 75 | 0.768 | 0.893016 | 123 | 144.636 | 0.08 | 0.088 | 0.044 | 0.0617 |
| Average | **0.734** | **0.899486** | **110.5** | **132** | **0.079** | **0.065** | **0.346** | **0.0267** |

Table 6.2: Mobility simulation and no weather

| Measure | Fairness | | Throughput (bps) | | Delay (seconds) | | Jitter (seconds) | |
|---|---|---|---|---|---|---|---|---|
| No. of nodes | Strict Priority + Mobility | Max-Min + Mobility | Strict Priority + Mobility | Max-Min + Mobility | Strict Priority + Mobility | Max-Min + Mobility | Strict Priority + | Max-Min + Mobility |
| 10 | 0.734 | 0.85 | 109.269 | 117.7 | 0.077 | 0.062 | 0.044 | 0.034 |
| 25 | 0.58 | 0.875 | 106 | 131.194 | 0.06 | 0.124 | 0.085 | 0.079 |
| 50 | 0.764 | 0.86 | 123 | 142.931 | 0.0819 | 0.072 | 0.064 | 0.0487 |
| 75 | 0.775 | 0.892 | 120 | 140.164 | 0.079 | 0.094 | 0.0809 | 0.0614 |
| Average | **0.7132** | **0.86925** | **114.56** | **132.995** | **0.0744** | **0.088** | **0.0684** | **0.0557** |

Table 6.3: Simulation with mobility and weather

| Measure | Fairness | | Throughput (bps) | | Delay (seconds) | | Jitter (seconds) | |
|---|---|---|---|---|---|---|---|---|
| No. of nodes | Strict Priority + Weather | Max-Min + Weather | Strict Priority + Weather | Max-Min + Weather | Strict Priority + Weather | Max-Min + Weather | Strict Priority + | Max-Min + Weather |
| 10 | 0.65 | 0.75 | 96.65 | 109 | 0.02 | 0.01 | 0.12 | 0.05 |
| 25 | 0.5 | 0.739 | 85.78 | 112.7 | 0.08 | 0.142 | 0.135 | 0.08 |
| 50 | 0.74 | 0.895 | 115 | 146.3 | 0.082 | 0.078 | 0.056 | 0.0507 |
| 75 | 0.75 | 0.88 | 123 | 144.636 | 0.08 | 0.088 | 0.0442 | 0.0617 |
| Average | **0.66** | **0.816** | **105.10** | **128.159** | **0.0655** | **0.0795** | **0.0888** | **0.0606** |

Figure 6.1 through 6.3 represents the graph plotted for the values in the tables mentioned above. From the graph it is clear that the Max-Min algorithm is more efficient than strict priority.

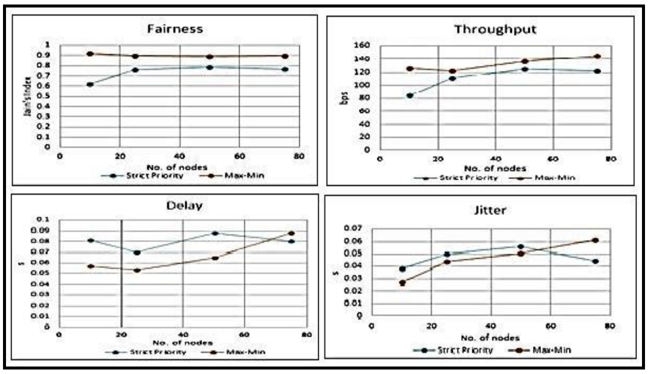

Figure 6.1 Simulations with no mobility and no Weather

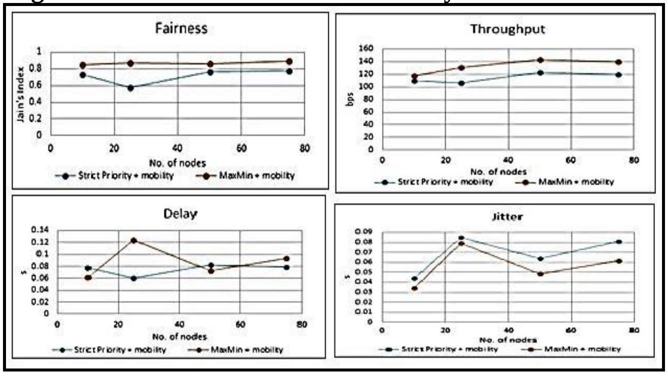

Figure 6.2 Simulation with mobility and no weather

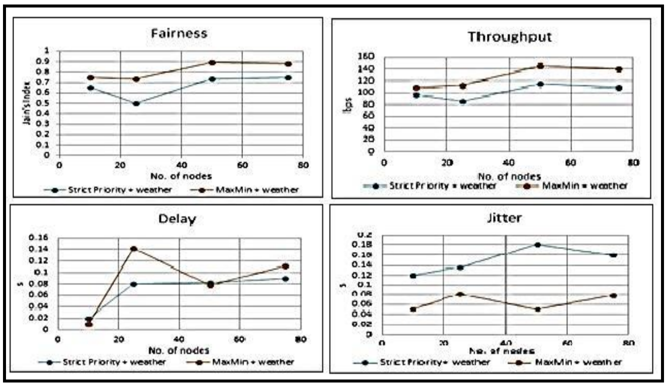

Figure 6.3 Simulation with mobility and weather

## VII. CONCLUSION

From the simulation outcomes, it can be inferred that, when compared to strict priorities, Opportunistic Max-Min fair algorithm provides better efficiency in terms of throughput, fairness and delay. Max-Min scheduling results in a greater level of fairness and throughput compared to Strict Priority. Max-Min has an index of fairness (Jain's Index) ranging from 0.8 to 0.9 whereas strict priority resulted in an index of fairness ranging from 0.58 to 0.75. The simulation findings also indicate that in situations with no mobility and variable weather conditions, Opportunistic Max-Min fair scheduling has less delay compared to Strict Priority. The delay for Opportunistic Max-Min ranges from 53ms to 88ms, while it varies from 70ms to 85ms for Strict Priority. In short, opportunistic scheduling introduces a fresh strategy to design, particularly for information traffic tolerant to delay. It has its own constraints and benefits. It is therefore essential for the system developer to take a holistic perspective of the cross-layer design to prevent potential system-wide adverse effects.

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