A Mathematical Model for Urgency Weight Calculation with Scheduling and Congestion Control for Mobile Ad hoc Grid Layer

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ABSTRACT
The Modified Max weight algorithm (MM) manages traffic and schedules the prioritized jobs in mobile Ad hoc Grid Layer (m-AHGL) based on joint scheduling and congestion control along with the calculation of urgency weight and the proposed algorithm achieves network utility maximization with effective maintenance of Per Destination Queue (PDQ). The priority for the jobs to be scheduled are based upon the type of application, transmission rate and packet size. Amongst the above parameters, the nature of application is given importance in the calculation of priority. The proposed MM calculation of urgency weight for prioritized jobs controls congestion and also provides a solution for the arrival of two jobs with equal urgency weights.

General Terms
Mobile ad hoc grid, scheduling jobs

Keywords
Congestion control, MM urgency weight, PDQ, urgency weight, scheduling

1. INTRODUCTION
W L.Bui (2010) had stated the convergence of joint scheduling and congestion has paved the way to achieve network utility maximization and to reduce contention among the nodes. The shared nature of wireless medium makes resource allocation complex [1]. Kelly(1998) aims to solve the problem of Network Utility Maximization [NUM]. The isolation of scheduling and congestion control algorithms resulting in poor interaction could not achieve optimization in NUM. Network Utility Maximization can be used to model various resource allocation problems and network protocols. NUM formulation can be generalized to be included with contention resolution, transmit power etc., [2]. YungYi and Mung Chiang (2009) had mentioned the constraint level dynamics dealing with topology and battery power. They also provide a measure for the raised issues by having a set of constraints for the participating nodes [3]. Matthew Andrews (2009) had discussed the benefits of combining congestion control and scheduling in communication networks. [4].A.Stolyar (2005) developed GPD and a study is made on the problem of congestion control of networks where both traffic sources and network processing nodes may be randomly time varying [5].

Umot Akoyl et.al (2008), addressed one of the limitation in GPD is contention resolution among nodes. They discussed that the wireless Greedy Primal Dual algorithm (w-GPD) had overcome the limitations of GPD. A solution has been provided for the nodes for channel access and contention resolution is provided as such, the node having the maximum urgency weight is likely to transmit without considering the battery power, memory and processor of the nodes, the limitation of their work in wGPD. These are the parameters to be considered for the nodes in ad hoc network. But in ad hoc networks all the nodes are almost in motion, as most of devices are wireless devices which contest in ad hoc networks. This work provides the solution for the limitation of wGPD by considering only the nodes which satisfy a set of policy dealing with battery power, memory and cpu power forms the network and thus reducing the contention among the nodes. The nodes satisfying the conditions are associated to form adhoc network, the resourceful nodes in the formed network could handle jobs faster and reduce the waiting time of job, and thus congestion can be avoided. Scheduling dynamics are not been thought in previous work for the account of scheduling data. With the exponential growing applications in the communication world, importance should be given to the application of the job [6].

Gupta and kumar (2000), to achieve power control they had a limit over multi user interference and maximized the number of simultaneous single hop transmissions [7]. Taussilas and Ephremedes (2000) had chosen the scheduler, that maximizes the sum of queue length to be scheduled links, and referred to as weight. This max-weight method requires centralized computation and exponential computation complexity [8].

Ravin Ahuja et al(2009) developed a dynamic priority scheduler for advance reservation in grid computing, without considering the parameters for computing priority [9]. Mohamed Salah and shawky (2010) stated that the purpose of congestion control is to avail the best utilization of the network nodes with available resources. The hop-by-hop congestion control approach followed in this method takes the capacities of the internal link, but it is not feasible with end-to-end approach. Due to packet scheduling and different location of the users the wireless networks usually follow per queue flowing [10]. Yi and shakkotai (2007) argued that hop-by-hop scheme were possible over wireless networks and had developed a hop-by-hop control scheme converges in the absence of delay and proportional allocation of bandwidth to various users. [11]. According C.Lochert et.al (2007), congestion control is a key problem in mobile ad-hoc networks and due to shared medium, and congestion not only affects overloaded nodes but also affects the whole area [12].

In order to achieve better utilization of the network, single hop transmission with joint scheduling and congestion control mechanism are used. This paper discusses various issues of joint scheduling and congestion control mechanisms and a mathematical model is developed using the MM scheduling algorithm for ad hoc grid wireless networks. The existing primal dual algorithms solves optimization problem and motivated us to develop this proposed Modified Max-weight scheduling algorithm by enhancing the existing max-weight scheduling algorithm by the introduction of the concept of priority. In addition to this, a solution is provided, for the situation where two urgency weights are equal. Section 2 discusses the proposed architecture followed by PDQ maintenance in Section 3 and conclusion in section 4.

2. CONSTRAINTS FOR THE CAPABLE NODES TO FORM ADHOC NETWORKS

A A The conditions for the nodes to form a schedulable region is given by

$S \subseteq L$

The schedulable region is a function of the nodes with following criteria. They are

$\left(i, j, CPU_j, MEM_j, BAT_j, r_{ij}\right)$

where is the *S*- Schedulable region, *N* - Number of nodes, i is the sender node, j is the receiver node, CPU_j is the computation capacity of N_j, MEM_j is the memory capacity of N_j, BAT_j is the battery availability of N_j and r_{ij} - flow rate from node to i to j.

These dynamic availabilities should satisfy the following conditions

$$\underset{N_i \in N}{\forall} CPU_i \leq \underset{N_j \in N}{\forall} CPU_j ,$$

$$\underset{N_i \in N}{\forall} MEM_i \leq \underset{N_j \in N}{\forall} MEM_j ,$$

$$\underset{N_i \in N}{\forall} BAT_i \leq \underset{N_j \in N}{\forall} BAT_j$$

where, N is the total number of nodes available in mobile ad hoc grid environment, CPU_i, MEM_i and BAT_i are the dynamic requirements of master node N_i. CPU_j, MEM_j and BAT_j are the dynamic availabilities of slave node N_j. The nodes which satisfy the above constraints form the schedulable region.

II.1 MECHANISM OF hop –hop BY approach

The formation of queue to each destination, called as Per Destination Queue (PDQ) for jobs with the next hop of destination is shown in Figure 1. This model follows a hop-by-hop approach, Node based approach followed in this model, do not require any assumption on arrival rate. This characteristic is an added advantage when used in the ad hoc networks as it is hard to predict the arrival rate due to random movement of nodes. Each job is supposed to form a queue to its destination, and follows hop-by-hop approach to its destination, where, $d_1, d_{2,} \ldots d_n$ are the destinations followed by Node N – Current Node, Node n(i,d_1) – Node for next hop of destination.

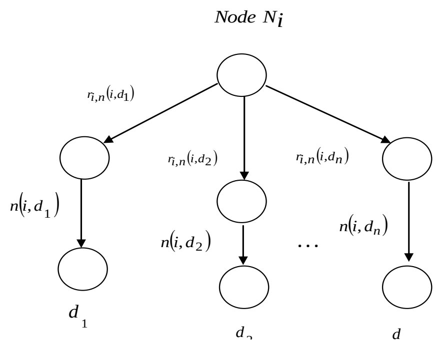

Figure 1 Node – Next Hop- Destination

II.2 PDQ MAINTENANCE

This section deals with the maintenance of Per Destination Queue. The Jobs arriving at node N , are sent to each $d_1$and d_2. Based on the calculated priority, the jobs are transferred to the next hop and the corresponding urgency weight is calculated, based on which the transfer of job occurs.

MODIFIED MAX-WEIGHT URGENCY WEIGHT CALCULATION

Each link corresponds to a destination that serves the job origin node. A Job may enter the network at any node with its destination as a subset of network nodes. Each job reaches its destination by appropriate routing through the network. The priority of each job computed is sorted into low, medium and high priority jobs. The model proposed calculates the urgency weight of the prioritized jobs. The nodes are synchronized to start service at the beginning of the time slot.

The existing method urgency weight is calculated as follows,

$$W_d^i = \left[q_d^i - q_d^{n(i,d)}\right] \times r_{ij} \quad [6] \quad (1)$$

Here, q_d^i is the PDQ size at the current node, $q_d^{n(i,d)}$ is the PDQ size at next hop for the destination and r_{ij} is the rate of flow from the source to the destination. In the existing method only urgency weight is considered, neither priority of jobs and neither solution provided for the arrival two jobs with equal urgency weights. This work, based on the calculation categorizes the jobs into high, medium and low priority jobs. The urgency weight calculation for high priority job is given by,

The calculation of urgency weight for each priority is shown here.

Let $\mathrm{W}_\mathrm{d}^\mathrm{i}$ be the urgency weight of job at each node. Let H_d^i, M_d^i, and L_d^i be the high, medium and low priority jobs at queue by the end to timeslot t. Let $r_{i,n(i,d)}$ be the channel rate between node i and node (i,d). Different priority jobs are defined as follows

In our analysis, for a high priority job q_d^i becomes

$$q_d^i = q_d^{i(NDMA/MA, LR, Hi)} \qquad (2)$$

where, NDMA/MA is application id, LR is packet size and Hi transmission rate.

The PDQ size at current node is written as

$$q_d^{i(NDMA/MA, LR, Hi)} = H_d^i \qquad (3)$$

where, H_d^i represents the high priority of a job at Per Destination Queue

The PDQ size of the node at next hop is written as

$$q_d^{n(i,d)} = H_d^{n(i)} \qquad (4)$$

The destination of the job at the next hop is given by

$$H_d^i - H_d^{n(i)} \qquad (5)$$

Urgency weight is the difference between PDQ size of high priority job at the current node and the PDQ size high priority job of next hop multiplied by priority and the rate of flow

Substituting eqn (5) in (1)

$$\left(W_d^i\right)_{Hi} = \left(H_d^i - H_d^{n(i)}\right) \times P_h \times r_{ij} \qquad (6)$$

For a medium priority job from equation (2) q_d^i becomes

$$q_d^i = q_d^{i(RD, LR, med)} \qquad (7)$$

where, RD is the application id, LR is the packet size and med is the transmission rate.

The PDQ size at current node

$$M_d^i = q_d^{i(RD, LR, Med)} \qquad (8)$$

where, M_d^i represents the medium priority of a job at Per Destination Queue

The pdq size of the node at next hop is written as

$$q_d^{n(i,d)} = M_d^{n(i)} \qquad (9)$$

The destination of the job at the next hop

$$M_d^i - M_d^{n(i)} \qquad (10)$$

For the medium priority, the urgency weight is the difference between PDQ size of medium priority job at the current node and the PDQ size medium priority job of next hop multiplied by priority and the rate of flow

Substituting equation (10) in (1)

$$\left(W_d^i\right)_{med} = \left(M_d^i - M_d^{n(i)}\right) \times P_m \times r_{ij} \qquad (11)$$

For a low priority job from equation (2) q_d^i becomes

$$q_d^i = q_d^{i(GA, LR, lo)} \qquad (12)$$

where, GA is the application id, LR is the packet size and lo is the transmission rate.

The pdq size at current node is given by

$$L_d^i = q_d^{i(GA, LR, lo)} \qquad (13)$$

where, L_d^i represents the low priority of a job

The PDQ size of the node at next hop is

$$q_d^{n(i,d)} = L_d^{n(i)} \qquad (14)$$

The destination of the job at the next hop is

$$L_d^i - L_d^{n(i)} \qquad (15)$$

The urgency weight of low priority job is given by the difference between PDQ size of low priority job at the current node and the PDQ size low priority job of next

hop multiplied by priority and the rate of flow.

Substituting equation (15) in (1)

$$\left(W_d^i\right)_{low} = \left(L_d^i - L_d^{n(i)}\right) \times P_{lo} \times r_{ij} \qquad (16)$$

Total urgency weight is the sum of urgency weight for high priority, medium and low priority jobs multiplied by the rate of flow from the current node to next hop

Let r_{ij} be the rate of flow from i^{th} node to the next hop j^{th} node (i,j). Therefore, $W_d^{(i)}$ be the urgency weight of i^{th} node, total urgency weight is the sum of the equations $(15)+(16)+(17)$ and can be written as

$$W_d^{(i)} = \left(W_d^i\right)_{Hi} + \left(W_d^i\right)_{med} + \left(W_d^i\right)_{lo} \qquad (17)$$

$$W_d^{(i)} = \left\{\left(H_d^i - H_d^{n(i)}\right) \times P_h + \left(M_d^i - M_d^{n(i)}\right) \times P_m + \left(L_d^i - L_d^{n(i)}\right) \times P_l\right\} \times r_{ij} \qquad (18)$$

The following scenario is considered for scheduling of jobs to the scheduler. They are as follows

Case 1: $W_d^1 = W_d^2$

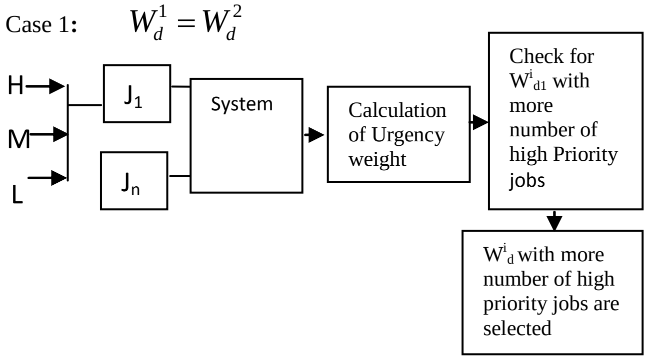

Figure 2 Schematic representations of scheduled jobs with same urgency weight

Step 1: Arrival of jobs based on Priority

Step 2: Calculation of urgency weight for the arrived jobs at the node

Step 3: If $W_d^1 = W_d^2$

i) check for W_d^n with more number high priority jobs

ii) arrived jobs having more number of

higher priority jobs will be selected for scheduling. If the urgency weights are equal, then transfer the job from the PDQ which consists of maximum number of higher priority jobs.

If $w_i^{d_k} = w_i^{d_l}$ then PDQ $\left[d_j\right] \Leftarrow \max\left[H_i^{d_k}, H_i^{d_l}\right]$

$J_T \Leftarrow PDQ\left[d_j, J_h\right]$

II.4 ALGORITHM FOR ARRIVAL, DEPARTURE AND URGENCY WEIGHT CALCULATION

1. [Initialize all simulation clocks]

Repeat for I=1,2,-- N-1

JOB-CLOCK [I] ← 9999 (a large number)

JOB-CLOCK [N] ← 0 (Clock N is arrival clock)

MAIN-CLOCK ← 0

2. [Main Loop]

Repeat While MAIN-CLOCK< SIMULATION-TIME

J ← MIN (JOB-CLOCK)

MAIN-CLOCK ← JOB-CLOCK [J]

If J=N

then call ARRIVAL else call DEPART (J)

… Procedure ARRIVAL

1. [Determine the PDQ corresponding to the job's destination address]
2. [Determine the position to be added by using the priority value of the job]

End

. . .

Procedure DEPART (J)

1. [Update the JOB-CLOCK and MAIN-CLOCK]
2. [Identify the job to be transferred to the scheduling process]
3. [Calculate the urgency weight for the PDQ]

…

Procedure URGENCY

1. [Read the size of PDQ in node N[i], total number of higher priority jobs, total number of medium priority jobs and total number of lower priority jobs]
2. [read the size of next hop to node N[i], total number of higher priority jobs, total number of medium priority jobs and total number of lower priority jobs in next hop NH[i]]
3. [Read the injection rate IR[i] from node N[i] to next hop NH[i]]

$$\left(W_d^i\right)_{Hi} = \left(H_d^i - H_d^{n(i)}\right) \times P_h$$

$$\left(W_d^i\right)_{med} = \left(M_d^i - M_d^{n(i)}\right) \times P_m$$

$$\left(W_d^i\right)_{low} = \left(L_d^i - L_d^{n(i)}\right) \times P_{lo}$$

$$W_d^{(i)} = \left\{\left(H_d^i - H_d^{n(i)}\right) \times P_h + \left(M_d^i - M_d^{n(i)}\right) \times P_m + \left(L_d^i - L_d^{n(i)}\right) \times P_l\right\} \times r_{ij}$$

4. Return

3. RESULTS AND DISCUSSION

The average waiting time in the system, probability of a job wait in PDQ and average time spent in PDQ are the parameters considered for the high, medium and low priority jobs. The simulation results show that the above parameters considerably reduce their time for the execution and this priority based queuing model is suitable for faster execution of jobs.

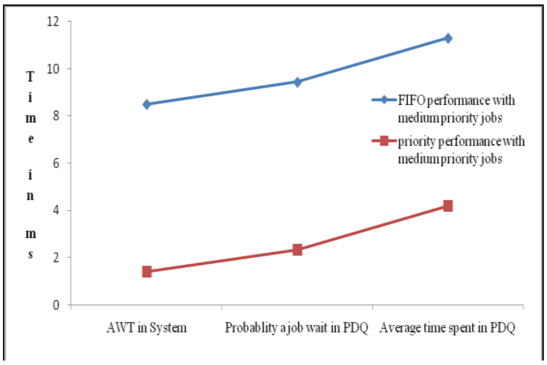

Figure 3 Comparison of high priority jobs

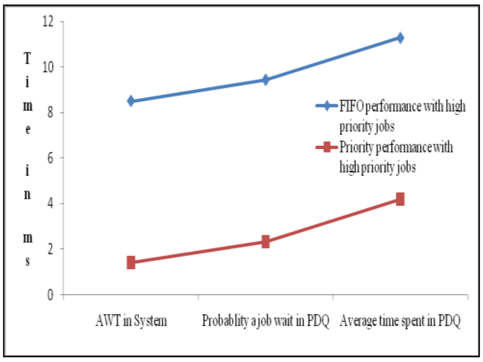

Figure 4 Comparison of medium priority jobs

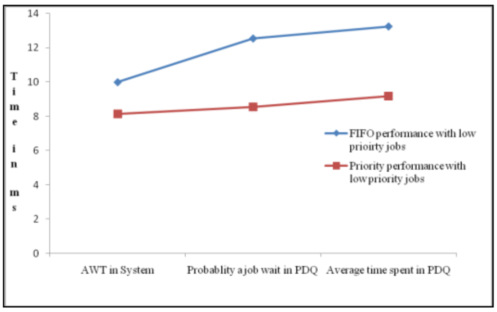

Figure 5 Comparison of low priority jobs

The comparison of execution of high, medium and low priority jobs in FIFO and priority discipline are shown in Figure 3, 4, and 5 respectively. The priority discipline model schedules the job based on priority, in which high priority jobs are given the precedence, followed by medium and low priority jobs. The low priority jobs with least preference shows a rise in the performance parameters, on association with other prioritized jobs is shown in Figure 5.

The graph reveals that though the prioritized jobs follow FIFO discipline, they consume more time on comparison with priority based queuing. As there is a considerable cut down in the overall time, this proposed model follows the priority queuing model together with the calculation of urgency weight, besides giving importance to nature of the job.

MM URGENCY WEIGHT CALCULATION

Total urgency weight is the sum of the urgency weights of high priority, medium and low priority jobs multiplied by the rate of flow from the current node to next hop.

$$w_d^{(i)}$$
$$= \left\{ \left(H_d^i - H_d^{n(i)}\right) \times P_h + \left(M_d^i - M_d^{n(i)}\right) \times P_m + \left(L_d^i - L_d^{n(i)}\right) \times P_l \right\} \times r_{ij}$$

MM urgency weight calculation method is implemented to categorize the jobs based on the urgency weight. The queue model considered here is M/M/1/∞/∞ with jobs on Poisson arrival pattern. The inter arrival time (I_{AT}) distributed by Markov distribution which denotes the time gap between $(k-1)^{th}$ job and the $k^{\ th}$ job enter into PDQ. Similarly the Transfer Time (TT) for N jobs is also specified by Markov distribution time. The arrival time of job k is denoted by the cumulative arrival time of the k^{th} job. Here, two PDQs viz. d_1 *and* d_2 are considered.

Table 3 and 4 describes the job queue maintenance and PDQ maintenance for the next hop of destination. This system in order to save power for wireless devices follows hop by hop approach. Node N_i consists of two PDQs for destination d_1 and d_2 . The jobs from these PDQs are transferred to the job scheduling process depends on their urgency weight which are tabulated in Table 5.

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TABLE I. JOB QUEUE MAINTENANCE FOR NEXT HOP

Main Clock	Events type					No. of Jobs based on priority		
	Arrival			Departure				
	AT	JOB ID	Priority	JOB ID	TT	$H_{d_1}{}^{n(i,d_1)}$	$M_{d_1}{}^{n(i,d_1)}$	$L_{d_1}{}^{n(i,d_1)}$
10	10	J_5	3	-	-	2	1	1
11	-	-	-	-	-	3	1	1
12	-	-	-	-	-	3	1	1
13	-	-	-	J_3	12	2	1	1
14	14	J_6	1	J_1	13	1	1	2
15	15	J_1	2	-	-	1	2	2
16	16	J_8	2	J_5	15	0	3	1
17	17	J_9	1	J_2	16	0	3	2
18	-	-	-	-	-	0	3	2
19	-	-	-	J_4	18	0	2	2
20	-	-	-	-	-	0	2	2
21	21	J_{10}	1	-	-	0	2	3
22	-	-	-	J_7	21	0	1	3

TABLE II PDQ MAINTENANCE FOR DESTINATION

Main Clock	Events type					No. of Jobs based on priority		
	Arrival			Departure				
	AT	JOB ID	Priority	JOB ID	TT	H_{d_1}	M_{d_1}	L_{d_1}
10	10	J_5	3	-	-	2	1	1
11	-	-	-	-	-	3	1	1
12	-	-	-	-	-	3	1	1
13	-	-	-	J_3	12	2	1	1
14	14	J_6	1	J_1	13	1	1	2
15	15	J_1	2	-	-	1	2	2
16	16	J_8	2	J_5	15	0	3	1
17	17	J_9	1	J_2	16	0	3	2
18	-	-	-	-	-	0	3	2
19	-	-	-	J_4	18	0	2	2
20	-	-	-	-	-	0	2	2
21	21	J_{10}	1	-	-	0	2	3
22	-	-	-	J_7	21	0	1	3

TABLE III. JOB QUEUE MAINTENANCE FOR NEXT HOP d_2 , $n(i, d_2)$

Main Clock	Events type					No. of Jobs based on priority		
	Arrival			Departure				
	AT	JOB ID	Priority	JOB ID	TT	$H_{d2}{}^{n(i,d2)}$	$M_{d2}{}^{n(i,d_2)}$	$L_{d2}{}^{n(i,d2)}$
10	-	-	3	-	-	3	1	1
11	-	-	-	J_3	10	2	1	1
12	12	J_6	1	J_4	11	1	1	2
13	-	-	-	-	-	1	1	2
14	-	-	-	-	-	1	1	2
15	15	J_7	1	J_1	14	0	1	3
16	-	-	-	J_2	15	0	1	3
17	17	J_8	2	-	-	0	2	3
18	-	-	-	J_8	17	0	1	3
19	-	-	-	-	-	0	1	3
20	20	J_{10}	1	J_5	19	0	0	4
21	-	-	-	J_6	20	0	0	3
22	-	-	-	-	-	0	0	3

TABLE IV. PDQ MAINTENANCE OF DESTINATON d_2

Main Clock	Events type					No. of Jobs based on priority		
	Arrival			Departure				
	AT	JOB ID	Priority	JOB ID	TT	H_{d2}	M_{d2}	L_{d2}
10	-	-	-	-	-	2	1	0
11	11	J_4	1	-	-	2	1	1
12	-	-	-	J_2	12	1	1	1
13	13	J_5	2	-	-	1	2	1
14	-	-	-	J_1	14	0	2	1
15	-	-	-	-	-	0	2	1
16	-	-	-	J_3	16	0	1	1
17	17	J_6	2	-	-	0	2	1
18	-	-	-	J_5	18	0	1	1
19	-	-	-	J_6	19	0	0	1
20	-	-	-	-	-	0	0	1
21	21	J_7	3	-	-	1	0	1
22	-	-	-	J_7	22	0	0	1

TABLE.V JOB TO BE SUBMITTED TO SCHEDULING

Main Clock	Urgency Weight of PDQ [1]	Urgency Weight of PDQ [2]	Job to be Scheduled	
			PDQ [ID]	JOB [ID]
10	-12.5	8	PDQ[2]	J_3
11	-5.0	0	PDQ[2]	J_4
12	2.5	2.0	PDQ[1]	J_3
13	2.5	2.0	PDQ[1]	J_1
14	-2.5	6.0	PDQ[2]	J_1
15	0	0	PDQ[1]	J_5
16	5.0	4.0	PDQ[1]	J_2
17	0	4.0	PDQ[2]	J_2
18	7.5	4.0	PDQ[1]	J_4
19	7.5	8.0	PDQ[2]	J_5
20	5.0	6.0	PDQ[2]	J_6
21	10.0	-2.0	PDQ[1]	J_7
22	10.0	4.0	PDQ[1]	J_8

From the Table 5 for a clock time of 15, the urgency weight for the both the PDQs are zero. Since the PDQ with the maximum number of higher priority jobs viz. PDQ [1] ($H^i{d_2}$ = 1) has been selected to transfer the job. From the selected PDQ [1], the job with higher priority (J_5) is transferred to the scheduling process as defined in case 1.

4. CONCLUSION

In this paper, a mathematical model for the MM urgency weight calculation has been developed. The issues involved in scheduling a job in the constituted ad hoc network with resourceful nodes are discussed. Hop by hop approach was used here to save power for the wireless devices in ad hoc network and a model is developed to solve the problems when the jobs have equal urgency weight during the scheduling process. Here, PDQ with more number of high priority jobs have the priority to access the network. This model had reduced the congestion by considerable amount with respect to the existing model, as the nodes satisfying the constraints are united together to process the dispatched job. The NUM can be achieved with the speed up in execution, moreover the network formed by resourceful nodes which are capable of processing more number of jobs.

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