MODIFIED Q-AWARE SCHEDULING ALGORITHM FOR IMPROVED FAIRNESS IN 802.16J NETWORKS

Rama Reddy T [1], Prasad Reddy PVGD [2], Satya Prasad R [3] and Suresh Batha [4]

[1] G.B.R College(PG Courses), Anaparthi(AP), India
[2] Andhra University, Visakhapatnam, India
[3] Nagarjuna University, Guntur, India
[4] S.T.P.I., Kakinada, India

ABSTRACT

Deployment of Multi-hop Relays in WiMax based Cellular Networks is considered as a cost effective solution to increase the Coverage area of Base Station and also to improve the Network Capacity with high quality short links. Scheduling became a challenging task in these Multi-hop Relay Wireless Cellular Networks of IEEE 802.16j standard. H. Chen, X. Xie and H. Wu proposed a Q-aware Scheduling Algorithm in which back-pressure flow control mechanism is used to reflect current Q size of the Relays and considered high back-pressure links to include in Concurrent Transmission Scenarios, to maximize the throughput. This focus on high back-pressure links, leads to starvation of Mobile Stations having low back-pressure links, resulting unfairness in some cases. To remedy this situation, a Fair Link Inclusion (FLI) mechanism is applied in Greedy Algorithm of Q-aware Scheduling Algorithm. Simulation results show that Modified Q-aware Scheduling Algorithm with FLI mechanism has reasonable improvement in fairness and maintaining steady throughput when compared with existing algorithms.

KEYWORDS

WiMax, Multi-hop Relay Stations, Mobile Stations, Fairness and Throughput, Scheduling

1. INTRODUCTION

The requirement of High Speed Data Services to mobile users became a necessity and receiving a great deal of attention from the Research and Academia as well as the Service Providers. Hence more and more work is under progress to gain very high speed data transfers especially thru Broadband Wireless Cellular Networks. One of the cost effective solution to this requirement is Multi-hop Relay Wimax(Wireless interoperability for Microwave Access) Networks, also known as Wireless Metropolitan Area Networks(Wireless MANs), based on IEEE 802.16j[2] standard. Various developments have undergone in Wireless Cellular Networking from the first generation Mobile Services[3],[4], to the second generation technologies GSM[5],CDMA[6] and to the third generation(3G) technologies UMTS[7]and IMT[8]. WiMax with its competitive technologies LTE and 3GPP[9],UMB[10] joined into this group . The goal of these technologies is to provide anytime, anywhere high-speed broadband connectivity at an affordable cost[11] to support various applications like voice, data and video streaming[25-28].

The traditional cellular networks, with a base station(BS) as the only serving station in a cell, the coverage area should be kept small to provide better service to the Mobile Stations(MS) near the cell boundary because the capacity of the link varies with range[12]. A simple solution to provide better service is to deploy more BSs within a given area, which incurs high installation costs. In search of a reasonable, cost effective solution, the concept of Multi-hop Relay (MR) Stations stood as a promising technology. In MR Cellular Networks, one or more Relay Stations (RS) can

DOI : 10.5121/ijcnc.2014.6308

be placed to relay information from a BS to an RS/MS. Thus, a multi-hop relay wireless network [2] can be deployed with one BS and probably multiple RSs and MSs to achieve high throughput, more coverage, enhanced capacity and improved quality. An RS can be deployed in a cell to relay information from a BS to mobile stations(MSs) and vise versa. The RS has no direct backhaul connection to the network and hence it is much simpler and easier to deploy than the BS. It has been shown that using RSs can improve cell coverage, user throughput and system capacity. A Multi-hop Relay(MR) network is being specified as an amendment to the IEEE 802.16e standard with the purpose of cell coverage extension, user throughput improvement and/or system capacity enhancement. In this Relay based Cellular Networks, along with the benefits mentioned, there are some disadvantages(with more no. of hops), like increase in transmission time, resulting delayed acknowledgments, forces unnecessary retransmissions, and hence can potentially decrease the throughput.

As 802.16j standard specifies only the framework for Relay based Wireless Cellular Networks and Physical Layer details like OFDMA [13], but left the concept of scheduling of resources for open discussion. Hence various Scheduling algorithms were developed to achieve more throughput and better fairness, but these algorithms didn't address the buffering (Queues) at RS. Buffering at RS may be common for Distributed Scheduling algorithms but is not considered in many existing Centralized Scheduling algorithms except in [1]. The Queue aware Scheduling Algorithm [1] was proposed based on Concurrent Transmission Scenarios (CTS) to maximize the overall network throughput by considering the varying Q sizes of the RSs and the advantage of simultaneous packet transmission by considering CTS.

In [1], the authors proposed a Greedy Algorithm to find the CTSs and formulated the scheduling problem as a Linear Programming problem to achieve high throughput. For that they considered only high back pressure links to add them to CTSs. But the drawback of this algorithm is, it always considers those links with high back pressure(the Queues of high traffic MSs) for the purpose of adding them to CTSs, resulting starvation to low traffic MSs whose Queue lengths are small at relay stations, ultimate result is unfairness in certain cases, which are addressed in this paper. To overcome this situation, Fair Link Inclusion(FLI) mechanism has been proposed in Greedy Algorithm while selecting the links to include them into CTSs. Simulation results show that FLI based Modified Q-aware Scheduling Algorithm has reasonable improvement in fairness and similar performance in throughput when compared with existing algorithms.

The rest of the paper is organized as follows. Section II discusses related work. Section III explains the drawbacks of Q-aware Scheduling algorithm and the proposed FLI based Modified Q-aware Scheduling algorithm. Section IV presents Simulation results and Section V summarizes the paper.

2. RELATED WORK

In Wireless Cellular Networking, Relay Stations can be of two types, Ad hoc Relay Stations and Well Controlled Relay Stations. Ad hoc Relay Stations have several advantages and different distributed routing and scheduling schemes [16]–[20]. Special Ad hoc Relay Stations can be placed at strategic locations to reduce congestion and for load balancing in a cell by redirecting the traffic via the specified RS to a neighboring cell's BS which is having less traffic. While such ad hoc solution enjoys great flexibility in RS deployment, it faces significant signaling overhead and high complexity and low reliability in routing (especially when quality-of-service is required). The complexity is also more in ad hoc RS design as well as the algorithm design. In contrast to the *ad hoc* implementation of relay network, to reduce the complexity, well-controlled RS are introduced, which can be incorporated into the current network with insignificant architecture modification and small implementation overhead. One such attempt is the development of a WiMAX draft standard, IEEE 802.16j [2], which is a revision of WiMAX standard IEEE 802.16e for incorporating relay concept into WiMAX networks. In 802.16j, BS runs the scheduling algorithm and maintains full control over RS, while RS is for traffic relay only and uses the same spectrum as BS and MS. Hence these well controlled RS are simple to design and deploy.

No Distributed Routing, as in ad hoc relays, is needed in 802.16j since centralized scheduling is implemented in BS. [21] studies the scheduling algorithm in 802.16j, where directional antennas are used to exploit the space reuse of frequency resources under a Manhattan-like environment. Although scheduling algorithm is provided to enhance network throughput, the process to determine concurrent transmission scenarios in re-lay network is not addressed therein. In [22] a multi-hop wireless mesh backhaul network with in-band relay is considered. Each RS aggregates traffic for nearby MS. A linear programming model is then developed to calculate the minimum time to transmit a fixed data load from BS to every RS over possibly multiple hops. Since the transmission time is minimized for the fixed data load, throughput is maximized. However, this approach does not address the varying traffic load (or queue size) of each RS, neither does it consider the frame-based feature of WiMAX network or other wireless networks.[1] considers the varying traffic load(Q size) of each RS and also considers the frame-based feature of WiMax networks. In this paper, the authors focused on maximizing the overall network throughput by identifying Concurrent Transmission Scenarios efficiently but have not focused the fairness in a specific way, that leads to severe starvation in certain real time scenarios.

3. MODIFIED Q-AWARE SCHEDULING ALGORITHM FOR 802.16J NETWORKS WITH IMPROVED FAIRNESS

In [1], the authors discussed wireless relay network architecture, challenges and presented a Linear Programming (LP) model for scheduling algorithm in multi-hop relay networks, and also discussed a Greedy Algorithm to find Concurrent Transmission Scenarios(CTS) in relay networks which are part of the input to LP problem.

3.1 Architecture and Challenges

Figure. 1 illustrates the architecture of wireless cellular relay network such as IEEE 802.16j [2] with frame-based transmissions. BS connects to RS and/or MS, and each RS can connect further to other RS and/or MS. RS only forwards traffic to/from MS and generate no traffic of its own. RS is transparent to MS, and MS does not involve in routing packets for other MS. BS, RS, and MS all share the same spectrum, thus no additional hardware such as a second physical interface is needed. BS needs to gather the downlink real time queue size of its associated RS and this queue information is sent to BS using uplink bandwidth. The resulting signaling change due to uplink queue status report is insignificant, and the corresponding uplink bandwidth consumption is negligible. After gathering RS queue information, BS runs the scheduling algorithm to obtain the downlink scheduling results and broadcasts the results to RS and MS.

In contrast to the *ad hoc* architecture discussed in Sec. II, this centralized approach of building a cellular relay network, let BS have full control of its associated RS and MS. The signaling and architecture change due to the introduction of RS is limited. No software or hardware upgrade is needed in MS, and the signaling change of reporting RS queue size is restricted between RS and BS. Hence this centralized approach is deemed a feasible solution and will not be considered as a burden by cellular network operator.

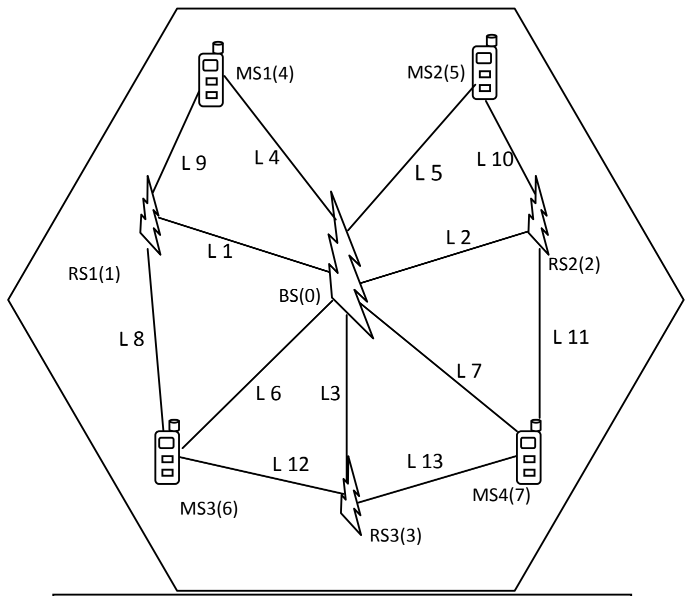

Fig 1: Architecture of Relay Based Cellular Networks

Concurrent transmission scenario can be defined as a set of all links that can transmit at the same time, i.e., no two links in a concurrent transmission scenario can share the same transmitter or receiver. For example, in Fig. 1, l_4, $l_{8,}$ l_{10} and l_{13} forms a concurrent transmission scenario and these four links can happen simultaneously, while l_4 and l_9 cannot form a transmission scenario. Let K denote the total number of concurrent transmission scenarios, and S_k represents the k^{th} transmission scenario with $1 \leq k \leq K$. In each frame t, all transmission scenarios share the frame duration T in Time Division Multiplexing (TDM) manner, and the time portion occupied by scenario S_k at frame t is denoted by $T_k(t)$.

Scheduling in cellular relay networks is challenging. First, as the input for the scheduling algorithm, concurrent transmission scenarios need to be determined in an efficient way. When adding a link candidate into a concurrent transmission scenario, it must be guaranteed that adding this link will not decrease the total throughput of this scenario. However, it is not practical to traverse all possible links searching for concurrent scenarios due to the non-linear growth of links with respect to number of MS and RS. The second challenge is due to fact that wireless cellular networks are frame-based, and the corresponding scheduling algorithm must take this factor into consideration. In each frame, different concurrent scenarios must share this frame duration. Thus arises the issue of fair allocation of time resources among various MS who share one frame, while still achieving the goal of maximum network throughput. The third challenge is to let the scheduling algorithm adjust to the real-time queue size change in RS. The fourth challenge is to provide uniform service to all the users in the Network, which requires the consideration of proportional fairness in the system.

3.2 Linear Programming Model for the Scheduling Algorithm

A linear programming model is used to implement the scheduling algorithm for wireless cellular multi-hop relay network. An example of the cellular relay network is shown in Fig. 1, which has M mobile stations and R relay stations under the control of one BS. The downlink frame duration is T seconds, and the frames are indexed by t in the time domain. One-to-M downlink data transmission is considered, with BS serving as the single source, and the 'm' MS serving as destinations. The transmission can be accomplished by a direct link from BS to MS, or by relay links via the RS. In each RS, a designated queue is maintained for each MS. The dynamic queue information of each RS is sent to BS in the uplink frame that precedes each downlink frame, and based on these queue information, BS makes the scheduling decision for the downlink frame. For the convenience of discussion, each node including BS, RS and MS is assigned a unique node ID and each link is given a unique link ID, as indicated in Fig. 1.

With the goal of maximizing total network throughput, the scheduling algorithm need to determine $T_k(t)$ and $x^m_{ij}(k, t)$ for each S_k, given the input of each RS's queue size, each link's transmission power, distance between two end nodes of each link, and the set of S_k. The proposed scheduling algorithm is summarized by the linear programming (LP) model in Table I.

Table I

Lp Model For Scheduling In Cellular Relay Networks [From Ref: 1]

Object Function : maximize $\sum_m a_m(t)$;

INPUT VARIABLES
1 : MS index m;
2: Frame index t ;
3: Frame duration T ;
4: RS node i's queue status $Q^m_i(t)$;
5: A set of concurrent transmission scenarios S_k, $1 \le k \le K$;
6: Power used from node i to j, P_{ij} ;
7: Distance between node i to j, d_{ij};

OUTPUT VARIABLES :

1. $x^m_{ij}(k, t)$, scheduled packets transmitted from node i to node j over link l_{ij} in S_k at frame t, destined for MS node m;
2. $T_k(t)$, scheduled time duration for scenario S_k;

CONSTRAINTS:
1. $a_m(t) = \sum^K_{k=1} \sum_n x_{nm}(k,t)$, where n is m's upstream node;
2. $Q^m_i(t) + \sum_{k=1} \sum_s x^m_{si}(k,t) = \sum^K_{k=1} \sum_r x^m_{ir}(k,t) + Q^m_i(t+1)$, where s and r are RS node, i's upstream and downstream nodes, respectively;
3. $\sum_m x^m_{ij}(k,t) \le R_{ij}(k,t) \times T_k(t)$, for link l_{ij};
4. $R_{ij}(k,t) = w\log_2\left(1 + \dfrac{P_{ij}/d^{\alpha}_{ij}}{N_0 + \sum_{(x,y)\in sk,(x,y)\neq(i,j)} P_{xy}/d^{\alpha}_{ij}}\right)$

   Where α is the path loss exponent, N_0 is noise power;
5. $\sum^K_{k=1} T_k(t) = T$;

Let $x^m_{ij}(k, t)$ denote the number of bits transferred from node i to node j destined for MS node m in scenario S_k at frame t, given that there is a direct link l_{ij} from node i to node j. Node i the upstream node of node j, and node j the downstream node of node i. Let Rij (k, t) denote the data rate of link l_{ij} , and the upper bound of Rij (k, t) can be calculated according to Shannon's theorem. The actual data sent over l_{ij} in S_k at frame t, $\sum_m x^m_{ij}(k, t)$, should be less than R_{ij} (k, t) × $T_k(t)$, which is the maximum possible bits. This capacity constraint indicates that a link's data load in a scenario is subject to the data rate and the scheduled time for this scenario.

Since each RS node *i* has a queue for every MS node *m*, and $Q^m_i(t)$ denote the size of this queue at the beginning of downlink frame *t*. Since MS consumes only the packets destined for itself and MS does not relay packet, there is no need for MS to maintain any queue. The flow constraint for each RS requires that the sum of $Q^m_i(t)$ and the packets arrived from node *i*'s upstream nodes destined for MS node *m* in frame *t*, be equal to the packets destined for MS node *m* that are forwarded to node *i*'s downstream nodes, plus the remaining packets in this queue of RS, which become the outstanding packets $Q^m_i(t+1)$ at frame $t+1$. This flow constraint reflects dynamic queue change in each RS. Let $a_m(t)$ denote the packets arrived in MS node *m* at frame *t*.

Apparently, $a_m(t) = \sum^{K}_{k=1} \sum_n x_{nm}(k, t)$, where node *n* and *m* has a link l_{nm} between them. Packets arriving in MS node *m* at frame *t* is the sum of packets sent by its neighboring nodes over all scheduled transmission scenarios at frame *t*.

The characteristics of the proposed scheduling algorithm are highlighted by constraints in in Table I. Constraint 1 derives the throughput for MS node *m* in frame *t*, revealing the concurrent transmission nature of the multi-hop cellular networks. Constraint 2 indicates the queue awareness of the proposed scheduling algorithm by monitoring the dynamic RS queue status, and this queue awareness is not addressed by the related work discussed in Section II. Constraint 3 illustrates the capacity constraint of a link in scenario S_k. Constraint 4 applies Shannon's Theorem to calculate the upper bound of link data rate with consideration of the interference caused by concurrent transmissions. Constraint 5 states the time constraint of all concurrent scenarios in a frame, signifying the frame-based feature of this approach.

3.3 Finding Concurrent Transmission Scenarios with Fairness Consideration

In Table I, the input variable 5, is a set of concurrent transmission scenarios S_k, $1 \leq k \leq K$, and each S_k is derived based on current network topology. Since the number of links grows non-linearly with the number of nodes in the network, it is unpractical to use an exhaustive algorithm to search for all possible scenarios. Thus, a greedy algorithm is used to derive a subset of all scenarios, as illustrated in Algorithm 1.

The greedy algorithm for finding concurrent scenarios has been studied extensively, and the proposed greedy algorithm is similar to those in [12] and [17]. During the process of finding S_k, a candidate link is added into S_k when the object function can be maximally increased by adding this candidate link. This process is repeated until no more candidate link can be added into S_k. In Algo. 1, L_{min} is a chosen threshold, which stands for the minimum number of candidate links on which the current searching process for S_k can still continue. If the number of candidate links is less than L_{min}, all links will be added into the candidate links pool.

When designing the objective function of the greedy algorithm, the authors apply the back pressure flow control mechanism in [22]. This mechanism states that in order to maximize the end-to-end throughput in multi-hop wireless network, the selected concurrent transmissions must be able to maximize the object function, which is defined as:

$$F(S) = \sum_{(i,j)\in S} w_{ij} R_{ij},$$

where S is a set of multiple links that can form a concurrent transmission scenario; (i, j) is a data link in S with sender node i and receiver node j; R_{ij} is the data rate of link (i, j); w_{ij} is the weight of link (i, j). w_{ij} is also called the back pressure of link (i, j), since it is defined as

$$w_{ij} = \max_m(Q^m{}_i - Q^m{}_j),$$

where $Q^m{}_i$ and $Q^m{}_j$ are the queue length destined for node m in sender node i and receiver node j, respectively.

Algorithm 1: Modified Greedy Algorithm to Find Concurrent Scenarios with Fairness Consideration

Object Function: maximize $F(S_k) = \sum_{(i,j)\in S_k} w_{ij} R_{ij}, \quad 1 \le k \le K$
Set A = {m : Fm >= Fmin} /* set of MSs whose relative fairness value Fm >=Fmin */
Set B = {m : Fm < Fmin} /* set of MSs whose relative fairness value Fm < Fmin */
for $k = 1$ to K **do**
  if $(k = 1)$ or $(|\psi_k| < L_{min})$ **then**
    set $\psi_k = \{(i, j) : (i, j)$ is an allowed link$\}$;
  end if
  Set $S_k = \emptyset$;
  Set (p,q) = a single link chosen at random from ψ_k ;
  while $F(S_k \cup \{(p, q)\}) > F(S_k)$ **do**
    Set $S_k = S_k \cup \{(p, q)\}$;
    Set $\psi_k = \psi_k \setminus \cup_{(i,j)\in\psi_k} \{(i, j) : \{(i, j)\} \cap \{(p, q)\} \neq \emptyset\}$;
    if $(|\psi_k| = 0)$ **then** /*check whether any allowed links are available */
      Break; /* exit from while loop */
    end if
    if $(B \neq \emptyset)$
      Find out $(p, q) = \arg\max_{(i,j)\in\psi_k} F(S_k \cup \{(i, j)\})$; $\forall$ L(i,j) $\ni$ $w_{ij} = \max_m(Q_i^m - Q_j^m)$, m$\in$B
    else
      Find out $(p, q) = \arg\max_{(i,j)\in\psi_k} F(S_k \cup \{(i, j)\})$;
    end if
  end while
  Set $\psi_{k+1} = \psi_k$;
end for

In order to maximize objective function F(S), and hence to increase network throughput links with high back pressure are favored in Greedy Algorithm [1]. Intuitively, selecting links with higher back pressure for transmission might lead to severe starvation in certain cases.

Case 1: A set of Mobile Stations, say group A, are running applications with High Data requirement and other set of Mobile Stations, say group B, are running Low Data requirement applications. As per the Greedy Algorithm of Q-aware scheduling algorithm, in every frame it tries to select those links which are having high back pressure, that is the links related to the mobile stations of Group A are get selected**.** The Problem with this case is, as the stations of Group A are always having high back pressure in their corresponding Queues at every relay station (RS), all the Concurrent Transmission Scenarios contain the links which serve Group A Mobile Stations only. Hence Group B stations suffer from starvation resulting severe unfairness in the system.

Case 2 : Suppose all the Mobile Stations in the network are having full load. As the links in the Greedy Algorithm are selected randomly to add them to a Concurrent Transmission Scenario, $S_{k,}$ there may be a chance to skip the links of certain Mobile Stations which ultimately suffers from starvation resulting unfairness in the system.

Reason : From the above two scenarios, it is clear that the Algorithm performance is nearly equal to Max-Flow Scheduling algorithm[15] in which, to achieve high throughput in the system, only some stations get proper service, and some other stations suffers from starvation. The problem identified in the above scenarios is due to the non consideration of proportional fairness of the Mobile Stations at any stage, especially while adding the links to Concurrent Transmission Scenarios, only the links with High Back Pressure are considered.

Solution: In the modified Q-aware scheduling algorithm with Fair Link Inclusion (FLI) mechanism, the current Normalized throughput (Xm) values of MSs are considered as follows:

$$X_m = Th_m/Req_m$$

where Th_m is the actual Data Rate, $Req_m$is the Requested Data Rate of Mobile Station ‘m’.

In this FLI mechanism, relative fairness value, F_i, for every mobile station, $m_{i,}$ is calculated with respect to $X_{max,}$ the highest X value.

$$Fi = Xi / Xmax$$

Hence, the resultant Fi values ranges from 0 to 1. Then divide the Mobile Stations into two groups(A and B) with respect to minimum Required Fairness value(Fmin), such that

$$F_m >= F_{min} > F_n, \text{ where } m € A, n € B$$

while selecting the links to add to CTS, the algorithm first considers those links which serve the stations(of Group B) with low normalized throughput values. Before every execution of the Scheduling Algorithm, the Groups are re-organized based on the current value of Xm and Fm.

The modifications done in the Greedy Algorithm are specified with underline in Algorithm 1. Steps 2,3,13,17,18 and 20 are included to achieve required fairness. Step 17 is the Key wh ich improves Proportional Fairness in the system.

Step 2 : <u>Set A = {m : Fm >= Fmin} /* set of MSs whose relative fairness value Fm >=Fmin */</u>

and

Step 3 <u>: Set B = {m : Fm < Fmin} /* set of MSs whose relative fairness value Fm < Fmin */</u>

The above two steps are included to divide the mobile stations into two groups, Fair(A) and Unfair(B). Initially set A is empty and set B is full as all the stations ‘Xm’ values are equal to zero. When required fairness(F_{min}) is achieved in the system set B will become empty and the algorithm approximates to normal Q-aware scheduling algorithm.

Step 17: <u>Find out $(p, q) = \arg\max_{(i,j)\in\psi_k} F(S_k \cup \{(i, j)\}); \forall L(i,j) \ni w_{ij} = \max_m(Q_j^m - Q_i^m), m \in B$</u>

step 17 is the main step in the proposed FLI mechanism. When set B is non empty (step 16), that means, some stations are below the required fairness level and hence step 17 is to be executed. Here only those links related to the stations in set B are considered to add them to CTS. Hence while solving the LP problem, the sets S_k, (1<=k<=K) contains the links corresponding to the mobile stations of set B. Here also those links, with high back pressure are considered, among the unfair stations. Hence throughput maximization goal is also considered in this logic. Automatically, the stations from set B are get serviced and hence in the next iterations, their Xm values are get increased so as to include them into set A.

In Step 12, Set $\psi_k = \psi_k \setminus U_{(i,j)\in\psi_k} \{(i, j) : \{(i, j)\} \cap \{(p, q)\} \neq \emptyset\}$; some links are get removed from $\psi_{k,}$ which are connected to the selected link(p,q), then there may be a chance of having no links in $\psi_{k.}$. To check this condition , step 13 is included.

Step 13: **if (|ψ_k| = 0) then** /*check whether any allowed links are available */

and if there are no more links in the allowed set of links, then exit(step 14) from the while loop to continue with next CTS calculation.

Consider a simple example with a Base Station, 4 Relay Stations, 12 Mobile Stations and 16 Links as shown in Fig 2.

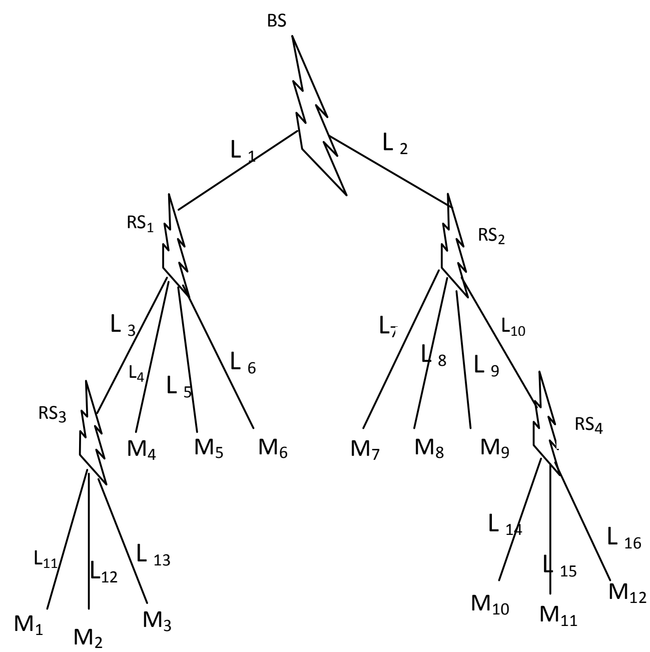

Fig 2: Architecture of a Network

	MS1	MS2	MS3	MS4	MS5	MS6	MS7	MS8	MS9	MS10	MS11	MS12
BS	900	80K	1200	75K	1900	79K	1050	85K	1345	95K	1850	68.5K
RS 1	650	66K	750	63K	1600	45K	0	0	0	0	0	0
RS 3	500	44K	425	0	0	0	0	0	0	0	0	0

Table 2 showing Queues Status at BS and RS

Table 2 shows the Queue sizes of Mobile Stations at BS and RSs. The even numbered mobiles' Queues contains, packets in thousands, to represent Group A, i.e., the Stations with high data traffic and hence heavy Queue loads with high back pressures. The Odd numbered mobiles' Queues contains packets in hundreds to represent Group B, i.e., the Stations with low data traffic and hence lesser Queue loads with low back pressures. Mobile Stations 1,2 and 3 are indirectly connected to RS1, hence RS1 maintains their Queues also. Zero values in the table represent that the MS is not connected to that RS directly or indirectly.

	MS1	MS2	MS3	MS4	MS5	MS6	MS7	MS8	MS9	MS10	MS11	MS12
Xi	0.207	0.72	0.225	0.72	0.27	0.72	0.225	0.72	0.225	0.765	0.27	0.9
Fi	0.23	0.8	0.25	0.8	0.3	0.8	0.25	0.8	0.25	0.85	0.3	1

Table 3 : Xi(Normalized Throughput) and Fi(Relative Fairness) Values

In table 3, the normalized throughput, Xi, values of Group A are taken above 0.5 and Group B are taken below 0.5 and the corresponding relative fairness values, Fi, are also shown.

The results of Greedy Algorithm:

Number of Concurrent Transmission Scenarios, K = 6
Scenarios generated:

$S_1 = \{L_{10}^{12}, L_4^4, L_{12}^2\}$; $S_2 = \{L_{16}^{12}, L_8^8, L_4^4, L_{12}^2\}$; $S_3 = \{L_7^7, L_4^4, L_{12}^2, L_{14}^{10}\}$;

$S_4 = \{L_9^9, L_4^4, L_{12}^2, L_{14}^{10}\}$; $S_5 = \{L_{11}^1, L_8^8, L_4^4, L_{14}^{10}\}$; $S_6 = \{L_4^4, L_8^8, L_{12}^2, L_{14}^{10}\}$;

The results of Modified Greedy Algorithm:

Required Fairness, $F_{min} = 0.5$, Number of Concurrent Transmission Scenarios, K = 6
Scenarios generated:

$S_1 = \{L_2^{10}, L_5^5, L_{11}^1, L_{15}^{11}\}$; $S_2 = \{L_5^5, L_7^7, L_{11}^1, L_{15}^{11}\}$; $S_3 = \{L_3^3, L_7^7, L_{15}^{11}\}$

$S_4 = \{L_{11}^1, L_5^5, L_7^7, L_{15}^{11}\}$; $S_5 = \{L_3^3, L_7^7, L_{15}^{11}\}$; $S_6 = \{L_7^7, L_5^5, L_{11}^1, L_{15}^{11}\}$

where S_k - k^{th} Concurrent Transmission Scenario,
L_i^m - i^{th} Link with respect to mobile m.

The First Link in CTSs is not considered for results comparison as it is selected at random in the algorithm. It is clear from the above results that the Links corresponding to Mobiles in set B(odd numbered) are not selected by Greedy Algorithm, where as the modified version gives priority to those mobiles which are in set B. As the Concurrent Transmission Scenarios contain the links corresponding to set B, they will get their share in Scheduling and hence will improve their Xi values so as to join in Group A in the next iterations.

The proposed Modified Q-aware Scheduling Algorithm with FLI mechanism has shown reasonable improvement in fairness and maintaining steady throughput when compared with existing algorithms.

4. SIMULATIONS AND DISCUSSIONS

To compare the performance of the proposed Modified Q-aware Scheduling algorithm with other scheduling algorithms with respect to Fairness and Throughput, the Simulations have been carried out using custom simulator implemented in Java. The results show that the fairness achieved with Modified Q-aware with FLI has reasonable improvement than Q-aware, Non Q-aware and Direct Transmission Algorithms. Throughput results of Modified Q-aware with FLI, show that the performance is nearer to Q-aware algorithm and far better than Non Q-aware and Direct Transmission Algorithms.

The basic simulation setup consists of 1 Base Station, 3 Relay Stations, and 40 Mobile Stations. The MS are deployed randomly in a cell with radius 1km, and random way point model is used for MS's mobility with moving speed randomly chosen from 0 to 5m/s. The 3 RS are placed in fixed positions, with distance from BS to each RS set to 600m, and the angle between two neighboring RS set to degree 120^o. Traffic is generated in BS in a biased manner discussed in the scenario 1, that is more number of packets are generated(in thousands) for 20 stations and less number of data packets(in hundreds) are generated for the other 20 stations at uniform time intervals, and also on a per frame basis with Poisson distribution. Notice that the relay path from BS to MS may consist of one or more RS. Path loss models [23] are used to consider the propagation of the signal. Specifically, type D path loss model is used for BS and RS, since type D requires the antennas of both sender and receiver above the roof, while type E path loss model applies between BS/RS and MS, since type E requires only sender's antenna above the roof. Let $P\ L_D$ and $P\ L_E$ denote the path loss for type D and type E models, respectively.

4.1 Fairness Comparison

In this work, the focus is on the improvement of Fairness of the Q-aware scheduling algorithm, and the required modification is proposed in the Greedy Algorithm. The Modified Q-aware scheduling algorithm is compared with Q-aware, Non Q-aware and direct transmission. For direct transmission, to run the linear programming model in Table I, the corresponding concurrent transmission scenarios include direct links only. The scheduling algorithm in [12] does not assume buffering in intermediate RS nodes, therefore, the proposed approach is compared with no buffering in RS.

4.1.1. Jain's Fairness Index

Jain's Fairness Index [14] is used as one measure to compare fairness, and was defined as

$$f(x1,x2,....xn) = \frac{(\sum_{i=1}^{n} x_i)2}{n\sum_{i=1}^{n} x_i^2}$$

where $X_i = Th_i / Req_i$, which is the normalized throughput of MS_i, and 'n' is the total number of MSs.

Where Th_i and Req_i stand for the actual data rate(throughput) and the request date rate of MS $_i$, respectively. Jain's Fairness Index ranges from 0 to 1, and the more close to 1, the better the fairness. If $Th_i = Req_i$ for all i, or in other words, every MS obtains its requested data rate, then $X_i = 1$ for all i, resulting in Jain's Fairness Index equals to 1. The fairness comparison result is shown in Fig.3, and the Modified Q-aware approach has reasonable improvement in fairness performance. One reason is that FLI mechanism is applied along with back pressure mechanism while finding concurrent scenarios and it helps to include less fair links into CTS and remove traffic bottleneck in the network, hence achieving required fairness. The other reason is that relay links can improve the data rate of MS whose direct link has low data rate, and improve fairness. Direct transmission has the worst fairness performance among the four scheduling algorithms since links with higher data rates are always favored by the scheduler. Also shown in Fig. 3 is that all four scheduling algorithms have fairness performances degraded, if request data rate exceeds a certain threshold, that is, 1.5Mbps for Modified Q-aware, 1.4Mbps for Q-aware, 0.8Mbps for Non Q-aware and 0.5 Mbps for Direct Transmission.

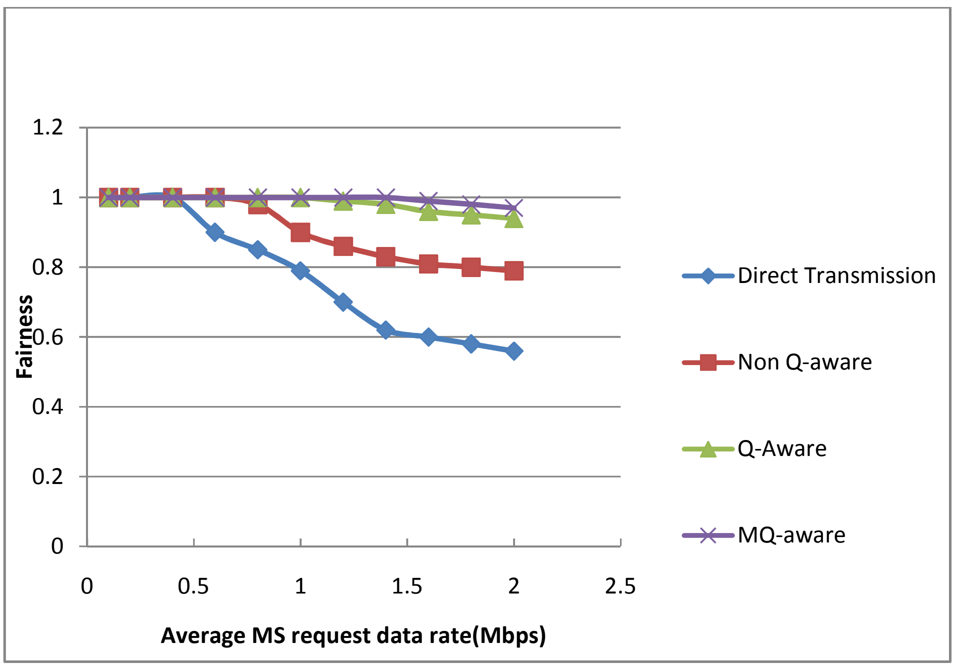

Fig 3: Fairness Comparison using Jain's Fairness Index

4.1.2. Proportional Fair Metric

Proportional Fair Metric[24] is also considered to study the Fairness performance.

Proportional Fair Metric(F) $=\sum_i \log R_i$, where R_i is the long term average service rate to user *i at* time *t.* Three scenarios are considered to compare the fairness among the 4 algorithms. In Scenario 1, Data packets are generated based on Poisson distribution. In Scenario 2, Data packets are generated in a Biased manner, that is , 20 MS are supplied with high data traffic and 20 MS are supplied with low data traffic. In Scenario 3, Data packets are generated in Random manner to simulate the real time environment. It is observed from Fig 4, the performance of the Modified Q-aware algorithm shows highest value of Proportional Fair Metric, which means this gives more uniform service to the users.

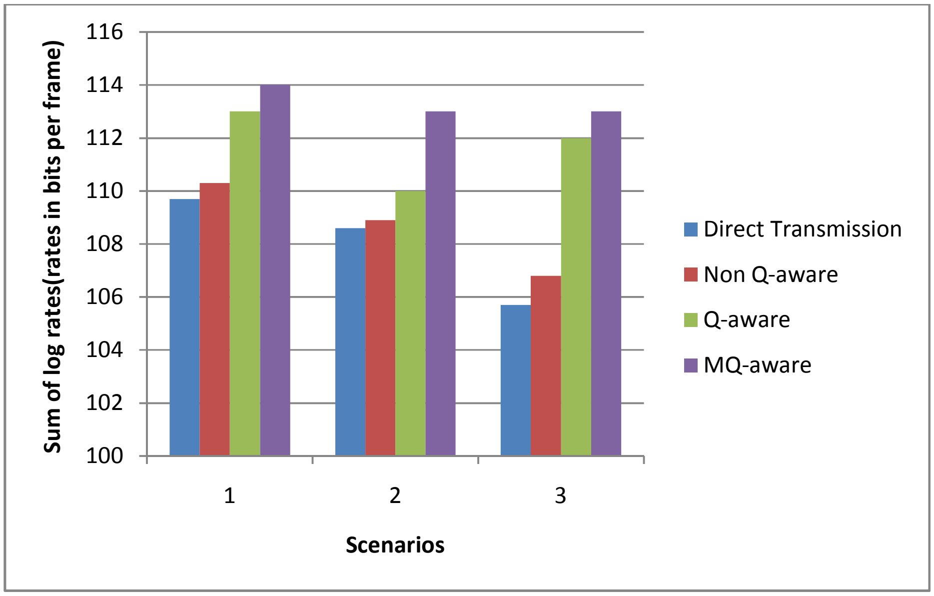

Fig 4: Fairness Comparison using Proportional Fair Metric

4.2 Throughput Comparison:

When the downlink traffic request for each MS is below 0.4*M bps*, all four scheduling algorithms can satisfy the request. When each MS's request increases from 0.4*M bps* to 1.4*M bps*, only Q-aware scheduling algorithm and Modified Q-aware scheduling algorithm can satisfy the request as shown in Fig. 5. In Modified Q-aware scheduling algorithm, the high back pressure links are considered when serving the starving stations in step 14 of Greedy Algorithm. Hence, the results show that the performance of Modified Q-aware scheduling algorithm is in line with Q-aware scheduling algorithm. This shows that relay links help improve network throughput compared to direct links. Also proven is the benefit of having buffers in RS, which allow RS to store remaining packets of the current frame, and have them ready for delivery for the next frame.

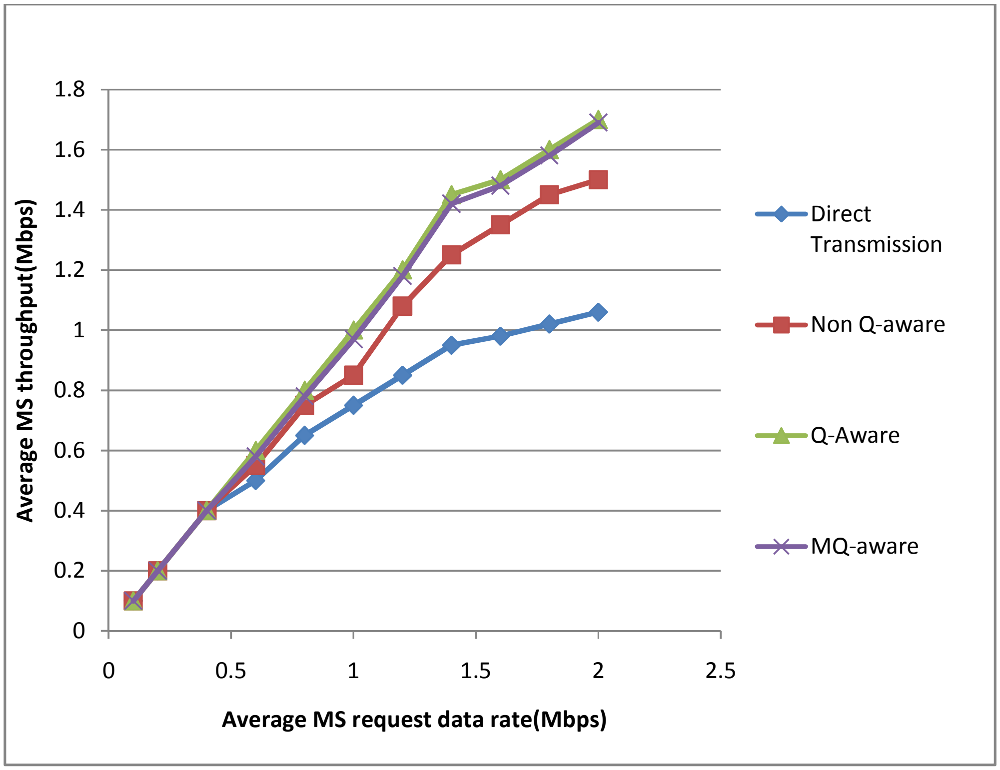

Fig 5: Throughput comparison

5. CONCLUSION & FUTURE WORK

With the modified Q-aware scheduling algorithm for multi-hop relay wireless cellular networks as IEEE 802.16j, a reasonable improvement in the fairness is achieved. A set of concurrent transmission scenarios is derived based on Fair Link Inclusion and back-pressure flow control mechanism, which are used as input for a linear programming model that determines the transmission schedules for multi-hop relay networks with improved fairness. The linear programming model maximizes the overall throughput, while taking into consideration the frame-based nature of cellular networks and the queue dynamics at the relay stations. Simulations based on IEEE 802.16 OFDMA mode have measured performance metrics such as fairness and throughput of the proposed modified scheduling algorithm, showing the effectiveness of our approach compared to other scheduling algorithms. This work can be extended further by considering the priorities of the packets while including the varying Q sizes at Relay Stations.

REFERENCES

[1] H. Chen, X. Xie and H. Wu, “A Queue-aware Scheduling Algorithm for Multihop Relay Wireless Cellular Networks”, IEEE Mobile WIMAX Symposium, 2009

[2] IEEE Standard for Local and Metropolitan Area Networks—Part 16: Air Interface for Fixed Broadband Wireless Access Systems—Amendment: Multihop Relay Specification, 2007, IEEE802.16j. [Online]. Available: http://www.ieee802.org/16/

[3] F. H. Blecher, “Advanced Mobile Phone Service,” IEEE Trans. Veh. Tech., vol. 29, no. 2, pp. 238–244, Jul. 1980.

[4] L. C. Godara, Handbook of Antennas in Wireless Communications. Boca Raton, FL: CRC, 2002.

[5] M. Mouly and M. B. Pautet, The GSM System for Mobile Communica-tions. Paris, France: Telecom, 1992.

[6] L. Harte, M. Hoenig, D. McLaughlin, and R. Kikta, CDMA IS-95 for Cellular and PCS: Technology, Applications, and Resource Guide. Chicago, IL: McGraw-Hill Professional, 1999.

[7] H. Holma and A. Toskala, WCDMA for UMTS. Hoboken, NJ: John Wiley and Sons, 2002.

[8] Y. S. Rao and A. Kripalani, "cdma2000 mobile radio access for IMT 2000," in Proc. IEEE Int. Conf. PWC, 1999, pp. 6–15.

[9] UTRA-UTRAN Long Term Evolution (LTE) and 3GPP System Architecture Evolution (SAE), 2006, 3GPP. [Online]. Available: http://www.3gpp.org.

[10] Ultra Mobile Broadband (UMB) Air Interface Specification, C.S0084, 2007, 3GPP2. [Online]. Available: http://www.3gpp2.org.

[11] Recommendation ITU-R, "Framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000,"International Telecommunication Union, June 2003.

[12] H. Viswanathan and S. Mukherjee, "Throughput-Range Tradeoff of Wireless Mesh Backhaul Networks," IEEE J. Sel. Areas Commun., vol. 24, no. 3, pp. 593–602, Mar. 2006.

[13] IEEE. (2005) IEEE 802.16e-2005 - IEEE Standard for Local and Metropolitan Area Networks Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems Amendment for Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands. [Online]. Available: http://standards.ieee.org/getieee802/download/802.16e-2005.pdf

[14] R. Jain, D. M. Chiu, and W. Hawe, "A Quantitative Measure of Fairness and Discrimination for Resource Allocation in Shared Systems," 1984, DEC Research Report, TR-301

[15] Yongchul Kim and Mihail L. Sichitiu, "Fairness Schemes in 802.16j Mobile Multi-hop Relay Networks", IEEE Globecom, 2010

[16] H. Luo, X. Meng, R. Ramjee, P. Sinha, and L. Li, "The Design and Evaluation of Unified Cellular and Ad Hoc Networks," IEEE Trans. Mobile Comp., vol. 6, no. 9, pp. 1060–1074, Jun. 2007.

[17] B. Radunovic and A. Proutiere, "On Downlink Capacity of Cellular Data Networks with WLAN/WPAN Relays," in Proc. 3rd IEEE RAWNET, 2007, pp. 1–7.

[18] M. F. Hossain, A. Mammel, and H. Chowdhury, "Impact of Mobile Relays on Throughput and Delays in Multihop Cellular Network," in Proc. IEEE ICWMC, 2008, pp. 304–308.

[19] J. Cho and Z. J. Hass, "On the Throughput Enhancement of the Downstream Channel in Cellular Radio Networks Through Multihop Relaying," IEEE J. Sel. Areas Commun., vol. 22, no. 7, pp. 1206–1219, Sept. 2004.

[20] Y.-N. Lee, J.-C. Chen, Y.-C. Wang, and J.-T. Chen, "A Novel Distributed Scheduling Alorithm for Downlink Relay Networks," IEEE Trans. Wireless Commun., vol. 6, no. 6, pp. 1985–1991, Jun. 2007.

[21] S.J. Lin, W. H. Sheen, I.K. Fu, and C.C. Huang, "Resource Schduling with Directional Antennas for Multihop Relay Networks in Manhattan-linke Environment," in Proc. IEEE Mobile WiMAX Symp., 2007, pp. 108–113.

[22] L. Tassiulas and A. Ephremides, "Stability properties of constrained queueing systems and scheduling policies for maximum throughput in multihop radio networks," IEEE Trans. Auto. Ctrl., vol. 37, no. 12, pp. 1936–1948, Dec. 1992.

[23] Multi-hop Relay System Evaluation Methodology, September 2006. [Online]. Available: http://ieee802.org/16/relay/docs/80216j-06-013.pdf.

[24] S. C. Liew and Y. J. Zhang, "Proportional fairness in multi-channel multi-rate wireless networks," in GLOBECOM. IEEE, Dec 2006, pp. 1–6.

[25] Bassam F.Gumaidah, Hasan H.Soliman and M.Obayya , "Study the Effect of Base Frequency on the Performance of WiMAX Network Carrying Voice", IJCNC, Vol.4, No.4, July 2012

[26] FarrukhEhtisham, Emmanouil A. Panaousis and Christos Politis, "Performance Evaluation Of Secure Video Transmission Over WiMAX", IJCNC, Vol.3, No.6, November 2011

[27] Iftekhar Ahmad and Daryoush Habibi, "A WiMAX Solution For Real-Time Video Surveillance In Public Transport", IJCNC, Vol.3, No.2, March 2011

[28] Jamil M. Hamodi and Ravindra C. Thool, "Investigate The Performance Evaluation Of IPTV Over WiMAX Networks", IJCNC, Vol.5, No.1, January 2013

Authors

Rama Reddy T has 15 years experience in teaching and is working an Asst. Professor in GBR College(PG Courses), Anaparthi, India. His research areas include Wireless Communications & Networking, Scheduling Algorithms and Network Security. He is also interested in Mobile Computing and Android Programming

Prof. Prasad Reddy PVGD has been in teaching for over 25 years in the Department of CS&SE, Andhra University. He served as Rector during 2011-12 and as Registrar during 2008-11 to Andhra University, Visakhapatnam, Inda. His Research areas include Soft Computing, Software Architectures, Knowledge Discovery from Databases, Image Processing, Number Theory & Cryptosystems

Dr. R. Satya Prasad has been in teaching for over 20 years. He is currently working as Associate Professor in the Department of Computer Science & Engineering, Acharya Nagarjuna University. His current research is focused on Software Engineering, Image Processing and Computer Networking

Dr. Suresh Batha has 8 years experience in teaching and 7 years experience in the present organization. He is serving as Joint Director in STPI, Kakinada, India. He is having hands-on experience in wireless point-to-point Internet communications. His Research areas include routing protocols, Scheduling and Security in Wimax both for PMP and Multihop Networks