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Optimizing Scheduling Policies and Analyzing Delay in Multi-Hop Wireless Networks

P.Pavan kumar Reddy[1], Manohar Gosul[2]

[1]M.Tech in CSE Dept ,[2]Associate Professor

CSE Dept, S.R ENGINEERING COLLEGE
Warangal, ANDHRA PRADESH, India

Abstract: **In this paper a multi-hop wireless network is considered to analyze the delay performance. We assume that there is a fixed route between a given source and destination pair. The multi-hop nature of network may cause complex correlations of the service process. In order to handle them, we propose a queue grouping technique. An interference model is assumed which is set based. With the help of interference constraints the lower bound of delay performance is obtained. To achieve this systematic methodology is used. The simple-path delay-optimal policy we designed is used for wireless networks. Empirical studies revealed that our approach is good to optimize scheduling policies and analyzing delay in multi-hop wireless networks.**

Key Words:-**Multi-hop wireless network, delay, flow control, wireless mesh network, optimization, queuing analysis, scheduling**

I. INTRODUCTION

Wireless Sensor Networks (WSNs) are widely used in many real world applications for the purpose of location monitoring in various domains. The popularity of these networks is due to the innovations in the field of sensor technology. The sensor technology is being developed rapidly and that has really contributed to the increase in the usage of Wireless Sensor Networks in various applications. For the purpose of performance improvement in all such applications throughput is important. Throughput and utility of a multi-hop wireless network are important aspects of much of the research conducted on such networks. In such systems and its applications like embedded network control, system design, voice and video over IP performance metrics like delay plays a crucial role and the delay is the open problem in such systems. As there are complex interactions over wireless networks, this problem is so complex and needs lot of research. Furthermore, the interference in the wireless networks makes it worst. In this paper, we use a systematic methodology for delay analysis and also a scheduling policy in order to achieve delay performance with respect to lower bound.

We analyze a multi-hop wireless network with many source and destination pairs provided traffic and routing information. The packet flow is as described here. A source node sends packets into network. In turn the packets move through network and finally reach the destination. Fig. 1 shows three flows pertaining to wireless multi-hop network.

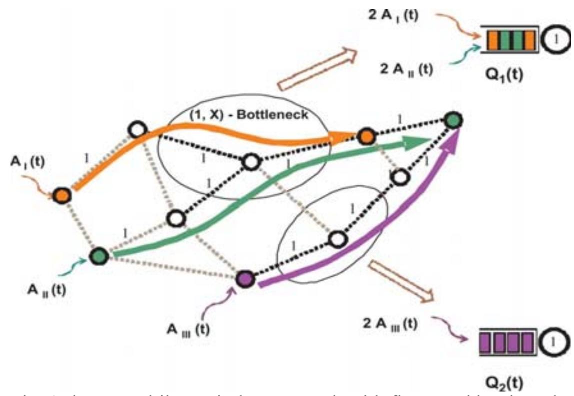

Fig. 1 shows multihop wireless network with flows and bottlenecks

As the transmission medium is shared, at each node a packet is queued in its path and waits for an opportunity for it to be transmitted. Scheduling can be done on two links that do not cause interference with each other. Such links are known as activation vectors. The unit capacity of each link is one packet in a slot. Delay performance of any scheduling policy is influenced by interference. In [20] the use of exclusive set of links is used to demonstrate the single hop traffic. In this paper we define bottleneck as a set of links such that no more than one of them can simultaneously transmit. In [20] sharper upper bounds could be used. However, in this paper our focus is to derive fundamental bound on performance of any policy. As per our consideration the lower bound analysis is an important step. In this regard [3] is similar to this paper. We also reengineer a back – pressure scheduling policy whose delay performance is close to the lower bound. Our contributions in this paper are a new queue grouping technique; new technique to reduce the analysis of queuing upstream of a bottleneck; derivation of a fundamental lower bound on the system wide average queuing delay of packet in multi-hop wireless network; extensive discussion and numeral studies.

II. PROPOSED SYSTEM MODEL

This section describes system model. We consider a wireless network which is represented as G = (V, L) where set of nodes in the network is represented by V and L denotes the set of links. Unit capacity is associated with each link. We consider N number of flows. Each flow contains source and destination pairs (si, di). We assume a fixed route between source and destination nodes. Exogenous arrival stream of each flow is computed as.

$\{A_i(t)\}^{\infty}_{t=1}$

The service time of a packet is considered a single unit. Another assumption is that the exogenous arrival stream of each flow is independent. Set of links where mutual interference is not caused and thus can be scheduled simultaneously are known as activations. Two hop interference model is used in the simulation studies as it can model the behavior of large class of MAC protocols. It is because it supports virtual carrier sensing which makes use of CTS/RTS message.

A. FINDING AVERAGE DELAY LOWER BOUNDS

For a given multihop wireless network, the methodology used to derive lower bounds on the system wide average packet delay. The network flows are partitioned into many groups and each group passes through a bottleneck. In the process the queuing of each is individually analyzed. The intention behind grouping is to maximize the delay system wide. When a flow is passing a bottleneck, the sum of queues is lower bound both upstream and downstream. By using statistics of the exogenous arrival processes, the computation of lower bound on the system-wide average delay is performed. The reduction of a bottleneck to a single – queue system is justified by our analysis. A greedy algorithm has been implemented that takes a system with flows and bottlenecks as input and generate a lower bound on the system-wide average packet delay.

Greedy Partitioning Algorithm:

This algorithm is meant for dividing the whole wireless network into many single – queue systems and get bound on expected delay.

Algorithm 1: Greedy Partitioning Algorithm

1: Z ← {1,2,….N}
2. BOUND ← 0
3. repeat
4. Find the (K,X)-bottleneck which maximizes $E[D_X]$
5. BOUND ← BOUND + $A_X E[D_X]$
6. Z ← Z\ i: i ε X
7: until Z = Φ
8. return BOUND

$$\frac{}{\sum_{i=1}^{N} \lambda_i}$$

Fig. 1shows greedy partitioning algorithm

A dynamic program can be used for optimal partition. However, this approach is computationally expensive. For this reason in this paper the greedy algorithm presented in table1 was developed in order to find average delay of a wireless network which contains bottlenecks.

III. Design Of Delay-Efficient Policies

Delay efficient scheduler designing is an important question in multi-hop wireless networks. Delay efficient policies can improve performance of multi hop wireless networks. It is extremely complex to derive delay optimal policies for general purpose although it is easy for specific networks such as tandem and clique. The delay efficient scheduler that works for all networks must satisfy the criteria given below.

- It has to ensure high throughput. This is important for any scheduling policy to maintain delay under control. If not the delay may become infinite when loading is heavy.
- When there are multiple flows running in the network, these flows must be allocated resources equally. Therefore no flow is starved from sufficient resources. The non interference links are to be managed in such a way that no links are starved from resources and service as starvation leads to an increase in the average delay of the system.

As the network is dynamic and has complex interactions, it is not easy to achieve the criteria or properties mentioned above. This is due to lack of prior knowledge about flows and complex interactions in a multi hop wireless network. As learned from the work of [2], and [11], we opted to use back-pressure policy with fixed routing. In the context of wireless networks, the back-pressure policy has been widely used to solve problems of multi hop wireless networks [10], [11]. The research community has realized the significance of studying such policy in terms of delay, network stability and complexity of interactions for different flows. The proposed policy is meant for managing queues pertaining to flows in the decreasing order of size. This is considered from the source node to destination node. By using a value known as differential backlog this has been achieved. The differential backlog is used as the weight for the link and scheduling. The scheduling that is matching highest weight is considered. This is the reason this policy is referred to as back-pressure policy. This policy has been studied and applied to various networks of multi hop nature such as tandem, clique and so on.

A. Back-Pressure Policy

The policy known as back-pressure can lead to large delays. This is because from the destination the backlogs are gradually larger. The flow of packets is from larger queue to a shorter queue. Moreover it is possible that some of the links may remain idle. The result of this is that there will be larger delays at bottlenecks. Experiments with this policy were done with various network topologies such as tandem queue, dumbbell, tree and cycle. As per the results it likely that upstream queues of a bottleneck grow long resulting in larger delays. Observation for clique and tandem network is that increase in priority of packets close to destination results in reduction of the delay. The same thing is known as LBFS rule in wired networks [1]. This policy is similar to the policy in [3].

IV. Implementation In Ns2

The simulation of the practical work has been implemented in network simulation tool that is NS2 running in Linux OS. The simulation results are shown in this section. The simulation of delay analysis with 9 nodes is presented in fig. 2.

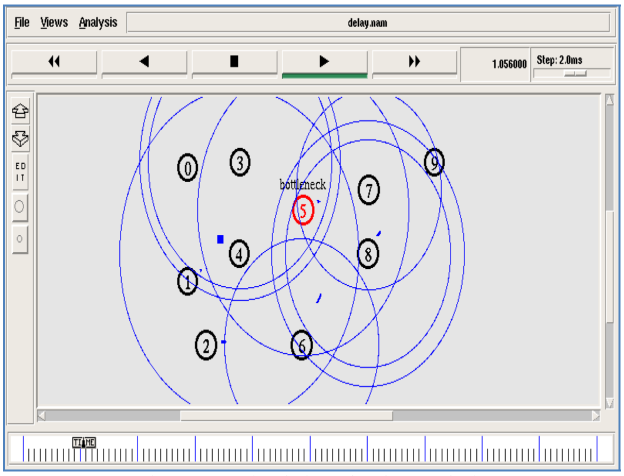

Fig. 2: NS2 Simulation of Delay Analysis

As can be seen in fig. 2, the nodes like 0, 1 and 2 are taken as source nodes that can send packets to destination nodes through multiple paths. The rest of the nodes like 3, 4, 5, 6, 7, 8, and 9 are destination nodes. The source nodes can send packets to destination nodes though multiple paths. The blue circles in the picture represent channel propagation. The proposed system analyses delay and identifies bottlenecks. The bottleneck is identified at node 5. The bottleneck causes delay in packets. The delay in packets may lead to packet loss. The blue spots here and there represent packet flow among the nodes.

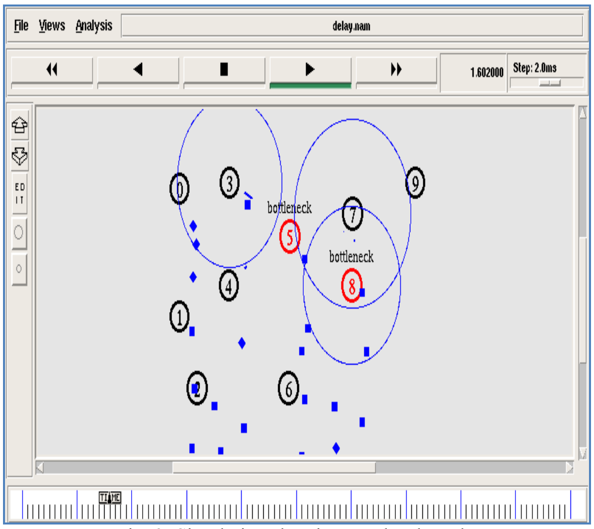

Fig. 3: Simulation showing two bottlenecks

As can be seen in fig. 2, the nodes like 0, 1 and 2 are taken as source nodes that can send packets to destination nodes through multiple paths. The rest of the nodes like 3, 4, 5, 6, 7, 8, and 9 are destination nodes. The source nodes can send packets to destination nodes through multiple paths. The blue circles in the picture represent channel propagation. As simulation shows the nodes 5 and 8 are identified as bottlenecks that cause problems in packet transmission. They actually cause delay in transferring packets that eventually lead to packet loss.

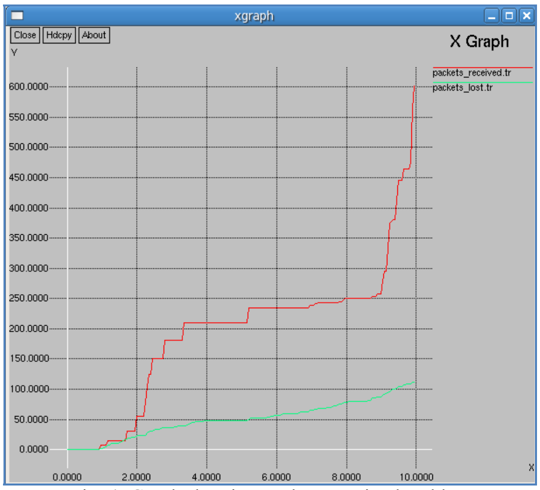

Fig. 4: Graph showing packets received and lost

As can be seen in fig. 4, X axis shows time in milliseconds while the Y axis shows packet rates in bits. The red curve shows the rate of packets received while the other color curve shows packet loss while the communication is made between source and destination. Due to the delay analysis and optimizing the scheduling policies, the packet loss is greatly minimized.

V. Illustrative Example

The methodology we proposed and tested on various topologies mentioned in the previous section is described here. We analyze the back-pressure policy and the lower bounds. The lower bounds can also help to understand back-pressure policy well. Maximal policy [9], [5] and back pressure policies are compared. For a given interference model, we computed set of graphs exclusively. We also implemented greedy algorithm. The arrival stream at each source is a collection of active and idle periods. The lower bounds are obtained using algorithm 1. For expected single queue system we use analysis proposed in [4].

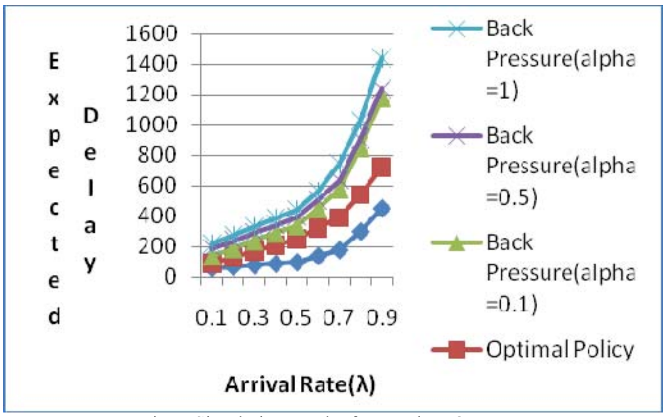

Fig.5. Simulation results for Tandem Queue

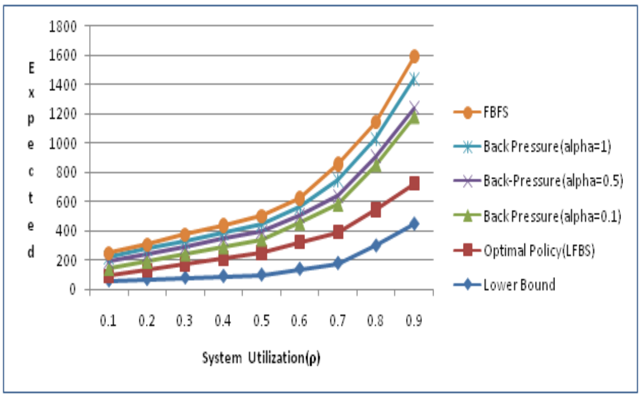

Fig. 6 Shows simulation results for clique

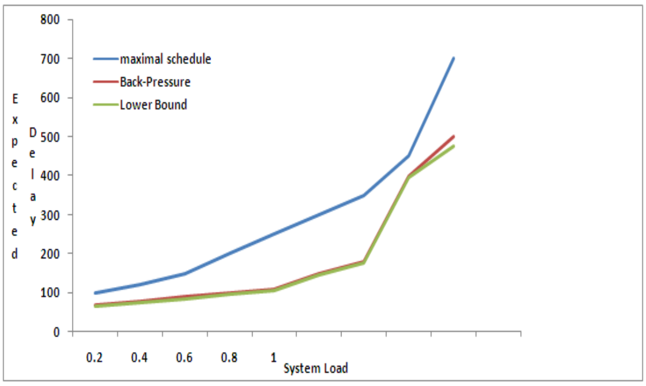

Fig. 7 shows simulation results for dumbbell topology

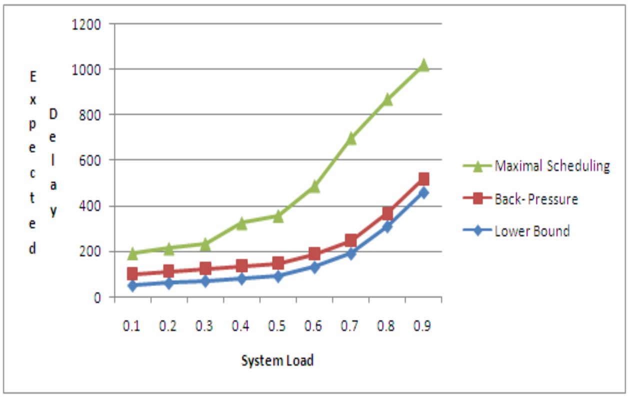

Fig. 8 shows simulation results for tree topology

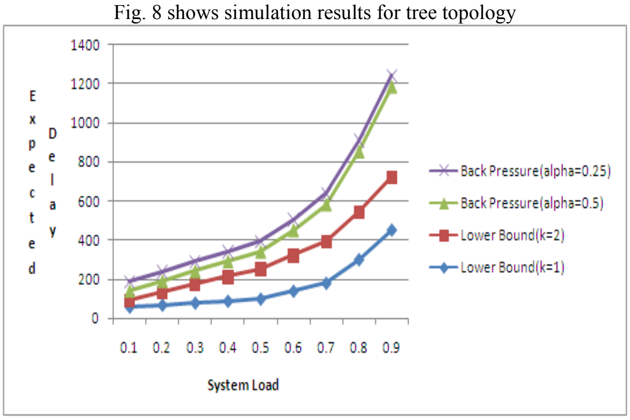

Fig. 9 shows simulation results for cycle topology

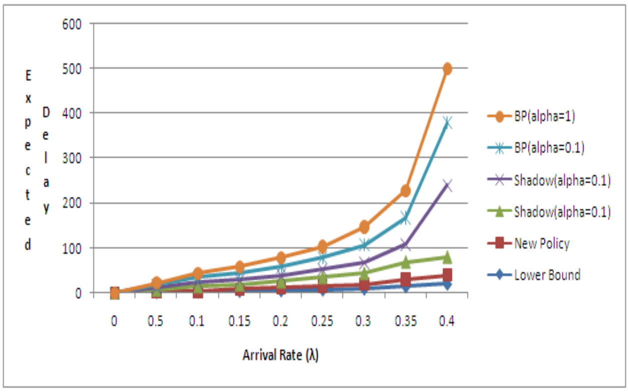

Fig. 10 Simulation results for linear network

VI. Discussion And Related Work

Research that has been done so far on wireless networks [9], [10], and [11] focused on stability of the system. The schemes developed for stability the back – pressure policy has been used. It is also known as throughput-optimal policy. Expected delay analysis of these systems is focused in this paper.

In order to test the stability of increase it or study workload, fluid models are used. It is described in [15] that maximum pressure policy can reduce workload process for heavy traffic networks. In [10], [7], [12], and [18] stochastic bounds using Lyapunoy drifts method is used to derive upper bounds. This has not been extended to multihop traffic. In order to calculate large deviation results for cellular systems large deviation results are used in [16] and [14]. This kind of analysis for multihop wireless network is not easy as there are complex interactions. For this reason our approach is different and used to reduce the wireless network into singe queuing systems and then analyzed for obtaining lower bound. This technique along with back pressure policy captures essential features of wireless networks. Very important advantage of lower bound is that it supports analysis of large class of arrival processes as described in [4]. In addition to this our approach also depends on the ability to compute the bottlenecks in the system. The characterization of bottlenecks in wireless networks is very difficult to achieve. Instead of those characterizing exclusive sets [8] is good for delay analysis. Even though it is good approach, it is not sufficient to obtain tight lower bounds. Developing a delay optimal policy that can achieve least average delay is very challenging. Such schemes were described in [13].

A policy was proposed in [17] that demonstrate the delay for given flows less than the constant factor. The experiments were conducted for quasi reversible networks. In [17] a scheme named “paissonation scheme” was proposed and this was causing the delay to be increasing. To overcome these drawbacks, the lower bound analysis is described and implemented in this paper which works under general interference constraints for general class of arrival processes. For switches the algorithm given in [6] has been studied. The simulations in that paper suggest a fact that the delay reduced with the alpha value. This is also used to analyze heavy traffic [19]. The drawback in these researches is that they did not focus on multihop wireless networks. The fact such as MWM-policy for switched networks can be observed with back-pressure policy of multihop wireless network is not known. The process that works for single hop may not work intuitively for multihop wireless networks.

VII. CONCLUSION

In wireless networks delay analysis is an open problem which is very challenging. This problem is further intensified with the interference in wireless network. For this reason, new approaches are essential to overcome this problem in multi-hop wireless network. We focused on lower bound analysis in order to reduce the bottlenecks in multi-hop wireless systems. For specific wireless network we could a sample-path delay-optimal scheduling policy could be obtained. The analysis we did is general and works for a large class of arrival processes. It also supports channel variations. Identifying bottlenecks in the system is the main problem and the lower bound helps in finding near-optimal policies.

REFERENCES

[1] S. H. Lu and P. R. Kumar, "Distributed scheduling based on due dates and buffer priorities," *IEEE Trans. Autom. Control*, vol. 36, no. 12, pp. 406–1416, 1991.

[2] T. Leandros and A. Ephremides, "Stability properties of constrained queuing systems and scheduling policies for maximum throughput in multihop radio networks," *IEEE Trans. Autom. Control*, vol. 37, no. 12, pp. 1936–1948, Dec. 1992.

[3] L. Tassiulas and A. Ephremides, "Dynamic scheduling for minimum delay in tandem and parallel constrained queuing models," *Ann. Oper.Res.*, vol. 48, pp. 333–355, 1993.

[4] H. Dupuis and B. Hajek, "A simple formula for mean multiplexing delay for independent regenerative sources," *Queue. System Theory Application.* vol. 16, pp. 195–239, 1994.

[5] T. Weller and B. Hajek, "Scheduling non uniform traffic in a packet switching system with small propagation delay," *IEEE/ACM Trans. Netw.*, vol. 5, no. 6, pp. 813–823, Dec. 1997.

[6] I. Keslassy and N. McKeown, "Analysis of scheduling algorithms that provide 100% throughput in input-queued switches," in *Proc. 39th Annu. Allerton Conf. Commun., Control, Comput.*, Monticello, IL, Oct. 2001

[7] E. Leonardi, M. Mellia, F. Neri, and M. A. Marsan, "On the stability of input-queued switches with speed-up," *IEEE/ACM Trans. Netw.*, vol.9, no. 1, pp. 104–118, Feb. 2001.

[8] K. Jain, J. Padhye, V. Padmanabhan, and L. Qiu, "Impact of interference on multi-hop wireless network performance," in *Proc. ACM MobiCom*, 2003, pp. 66–80.

[9] P. Chaporkar, K. Kar, and S. Sarkar, "Throughput guarantees through maximal scheduling in wireless networks," in *Proc. 43rd Annu. Allerton Conf. Commun., Control, Comput.*, 2005, pp. 1557–1567.

[10] L. Georgiadis, M. J. Neely, and L. Tassiulas, *Resource Allocation and Cross-Layer Control in Wireless Networks, Foundations and Trends in Networking*. Delft, The Netherlands: Now, 2006, vol. 1.

[11] X. Lin, N. B. Shroff, and R. Srikant, "A tutorial on cross-layer optimization in wireless networks," *IEEE J. Sel. Areas Commun.*, vol. 24, no. 8, pp. 1452–1463, Aug. 2006.

[12] M. J. Neely, "Order optimal delay for opportunistic scheduling in multi-user wireless uplinks and downlinks," in *Proc. 44th Annu. Allerton Conf. Commun., Control, Comput.*, Sep. 2006, pp. 67–76.

[13] Y. Xi and E. M. Yeh, "Optimal capacity allocation, routing, and congestion control in wireless networks," in *Proc. IEEE. ISIT*, Jul. 2006, pp. 2511–2515.

[14] L. Ying, R. Srikant, A. Eryilmaz, and G. E. Dullerud, "A large deviations analysis of scheduling in wireless networks," *IEEE Trans. Inf.Theory*, vol. 52, no. 11, pp. 5088–5098, Nov. 2006. [15] J. G. Dai and W. Lin, "Asymptotic optimality of maximum pressure policies in stochastic processing networks," 2007.

[16] V. J. Venkataramanan and X. Lin, "Structural properties of LDP for queue-length based wireless scheduling algorithms," in *Proc. 45th Annu. Allerton Conf. Common., Control, Compute.*, 2007, pp. 759–766.

[17] S. Jagabathula and D. Shah, "Optimal delay scheduling in networks with arbitrary constraints," in *Proc. ACM SIGMETRICS-Performance*, Jun. 2008, pp. 395–406.

[18] M. J. Neely, "Delay analysis for maximal scheduling in wireless networks with bursty traffic," in *Proc. IEEE INFOCOM*, 2008, pp. 6–10.

[19] D. Shah and D.Wischik, "Heavy traffic analysis of optimal scheduling algorithms for switched networks," 2008.

[20] G. R. Gupta and N. B. Shroff, "Delay analysis for wireless networks with single hop traffic and general interference constrains," *IEEE/ACM Trans. Netw.*, vol. 18, no. 2, pp. 393–405, Apr. 2010.

P.Pavan Kumar Reddy received the B.Tech Degree in Computer Science and Engineering from Ramappa Engineering College, Warangal, A.P, India. Currently pursuing M.tech in Computer Science and Engineering at SR Engineering College, Warangal, from JNTU Hyd, India.

Manohar Gosul received the B.Tech degree in Computer Science & Engineering from Poojya Doddappa Appa Engineering College, Gulbarga, India and M.Tech degree in Computer Science & Engineering from Poojya Doddappa Appa Engineering College, Gulbarga, India. Currently he is an Associate Professor in the department Computer Science & Engineering, SR Engineering College, Warangal, India. His research interests include Network security and Ad-hoc networks.