

## Improving Throughput In Multi-Hop Wireless Networks Using Greedy Partitioning

### Alogrithm

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### ABSTRACT

In multicast networks we can distribute the data packet of information to several systems instead of having to send that packet once for every destination. By this 5, 10, or 100 machines can receive the same packet, bandwidth is conserved. Also, when you use multicasting to send a packet, you don't need to know the address of everyone who wants to receive the multicast; instead, you simply "broadcast" it for anyone who is interested.

We mainly focuses on delay performance of a multi-hop wireless network in which the routes between source-destination pairs are fixed. We develop a new queue grouping technique to handle the complex correlations of the service process resulting from the multi-hop nature of the flows and their mutual sharing of the wireless medium. We present the system called clique is a special wireless system. The lower bound analysis provides useful insights into the design and analysis of optimal or nearly optimal scheduling policies.

### Related work

- **MIMO (multiple input, multiple output)**

**MIMO** (multiple input, multiple output) is an antenna technology for wireless communications in which multiple antennas.

### 802.11n

802.11n is an addition to the 802.11 family of standards. The goal of 802.11n is to increase wireless local area network (WLAN) speed A smart antenna is a digital wireless communications antenna system that takes advantage of diversity effect at the source

- **Long Term Evolution (LTE)**

Long Term Evolution (LTE) is a 4G wireless broadband technology developed by the Third Generation Partnership Project (3GPP)

- **SISO (single input, single output)**

SISO (single input, single output) refers to a wireless communications system in which one antenna is used at the source

- **MISO (multiple input, single output)**

MISO (multiple input, single output) is an antenna technology for wireless communications in which multiple antennas are used

- **SIMO (single input, multiple output)**

SIMO (single input, multiple output) is an antenna technology for wireless communications in which multiple antennas are used

Multicast is communication between a single sender and multiple receivers on a network. Typical uses include the updating of mobile personnel from a home office and the periodic issuance of online newsletters. Together with anycast and unicast, multicast is one of the packet types in the Internet Protocol Version 6 (IPv6).

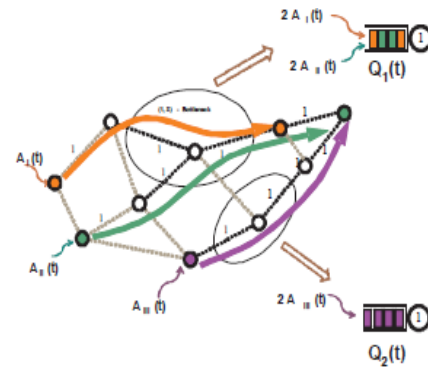


Fig. 1. A typical multi-hop wireless network with multiple flows, each having exogenous arrivals at the source. Some of the important bottlenecks have been highlighted.

Multicast is supported through wireless data networks as part of the Cellular Digital Packet Data (CDPD) technology.

Multicast is also used for programming on the MBone, a system that allows users at high-bandwidth points on the Internet to receive live video and sound programming. In addition to using a specific high-bandwidth subset of the Internet, Mbone multicast also uses a protocol that allows signals to be encapsulated as TCP/IP packet when passing through parts of the Internet that cannot handle the multicast protocol directly.

### EXISTING APPROACHES:

A large number of studies on multi-hop wireless networks have been devoted to system stability while maximizing metrics like throughput or utility. These metrics measure the performance of a system over a long time-scale. For a large class of applications such as video or voice over IP, embedded network control and for system design; metrics like delay are of prime importance. The delay performance of wireless networks, however, has largely

been an open problem. This problem is notoriously difficult even in the context of wireline networks, primarily because of the complex interactions in the network (e.g., superposition, routing, departure, etc.) that make its analysis amenable only in very special cases like the product form networks.

The problem is further exacerbated by the mutual interference inherent in wireless networks which, complicates both the scheduling mechanisms and their analysis. Some novel analytical techniques to compute useful lower bound and delay estimates for wireless networks with singlehop traffic were developed in. However, the analysis is not directly applicable to multi-hop wireless network with multihop flows, due to the difficulty in characterizing the departure process at intermediate links.

The metric of interest in this paper is the system-wide average delay of a packet from the source to its corresponding destination. We present a new, systematic methodology to obtain a fundamental lower bound on the average packet delay in the system under any scheduling policy. Furthermore, we re-engineer well known scheduling policies to achieve good delay performance viz-a-viz the lower bound.

### **PROPOSED APPROACH:**

We analyze a multi-hop wireless network with multiple source-destination pairs, given routing and traffic information. Each source injects packets in the network, which traverses through the network until it reaches the destination. For example, a

multi-hop wireless network with three flows is shown in Fig. 1. The exogenous arrival processes  $A_I(t)$ ,  $A_{II}(t)$  and  $A_{III}(t)$  correspond to the number of packets injected in the system at time  $t$ . A packet is queued at each node in its path where it waits for an opportunity to be transmitted. Since the transmission medium is shared, concurrent transmissions can interfere with each others' transmissions. The set of links that do not cause interference with each other can be scheduled simultaneously, and we call them activation vectors (matchings). We do not impose any a priori restriction on the set of allowed activation vectors, i.e., they can characterize any combinatorial interference model. For example, in a  $K$ -hop interference model, the links scheduled simultaneously are separated by at least  $K$  hops. In the example show in Fig. 1, each link has unit capacity; i.e., at most one packet can be transmitted in a slot. For the above example, we assume a 1-hop interference model.

The delay performance of any scheduling policy is primarily limited by the interference, which causes many bottlenecks to be formed in the network. We demonstrated the use of exclusive sets for the purpose of deriving lower bounds on delay for a wireless network with single hop traffic. We further generalize the typical notion of a bottleneck. In our terminology, we define a  $(K, X)$ -bottleneck to be a set of links  $X$  such that no more than  $K$  of them can simultaneously transmit. Figure 1 shows  $(1, X)$  bottlenecks for a network under the 1-hop interference model. In this paper, we develop new analytical techniques that focus on the queuing due to the  $(K, X)$ -bottlenecks. One of the techniques, which

we call the “reduction technique”, simplifies the analysis of the queuing upstream of a (K, X)-bottleneck to the study of a single queue system with K servers as indicated in the figure. Furthermore, our analysis needs only the exogenous inputs to the system and thereby avoids the need to characterize departure processes on intermediate links in the network. For a large class of input traffic, the lower bound on the expected delay can be computed using only the statistics of the exogenous arrival processes and not their sample paths. To obtain a lower bound on the system wide average queuing delay, we analyze queuing in multiple bottlenecks by relaxing the interference constraints in the system. Our relaxation approach is novel and leads to nontrivial lower bounds.

### Theorem:

For a (K,X)-bottleneck in the system, at any time  $T \geq 0$ , the sum of the queue lengths  $SX$  in  $X$ , under any scheduling policy is no smaller than that of the reduced system, i.e.,  $QX(T) \leq SX(T)$ . Proof: We prove the above theorem using the principle of mathematical induction. Base Case: The theorem holds true for  $T = 0$ , since the system is initially empty. Induction hypothesis: Assume that the theorem holds at a

time  $T = t$ , i.e.,  $QX(t) \leq SX(t)$ .

Induction Step: The following two cases arise.

Case 1:  $QX(t) \geq K$

$$\begin{aligned} QX(t+1) &= QX(t) - K + AX(t) \\ &\leq SX(t) - K + AX(t) \end{aligned}$$

$$\begin{aligned} &\leq SX(t) - IX(t) + AX(t) \\ &= SX(t+1). \end{aligned}$$

Case 2:  $QX(t) < K$ .

Using Eq. (III.11), we have the following,

$$\begin{aligned} QX(t+1) &= AX(t) \\ &\leq SX(t) - IX(t) + AX(t) \\ &= SX(t+1). \end{aligned}$$

Hence, the theorem holds for  $T = t + 1$ .

Thus by the principle of mathematical induction, the theorem holds for all  $T$ .

### TECHNICS :

#### 1) MULTI-HOP WIRELESS NETWORK MODEL

Multi-hop wireless network with multiple source-destination pairs, given routing and traffic information. Each source injects packets in the network, which traverses through the network until it reaches the destination.

#### 2). DELAY PERFORMANCE OF WIRELESS NETWORKS

The delay performance of wireless networks, however, has largely been an open problem. This problem is notoriously difficult even in the context of wireline networks, primarily because of the complex interactions in the network (e.g., superposition, routing, departure, etc.) that make its analysis amenable only in very special cases like the product form networks. The problem is further exacerbated by the mutual interference inherent in wireless networks which,

complicates both the scheduling mechanisms and their analysis. Some novel analytical techniques to compute useful lower bound and delay estimates for wireless networks with singlehop traffic were developed. However, the analysis is not directly applicable to multi-hop wireless network with multihop flows, due to the difficulty in characterizing the departure process at intermediate links.

### 3). BACK-PRESSURE POLICY

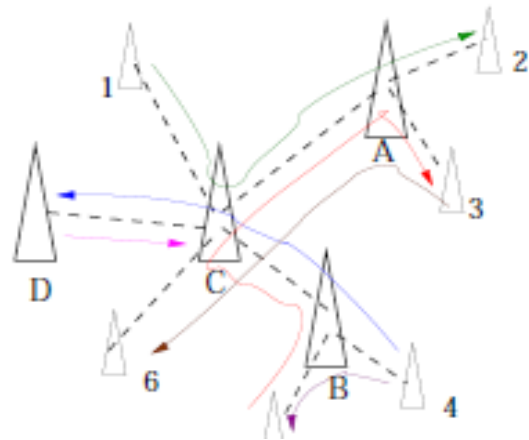
The back-pressure policy may lead to large delays since the backlogs are progressively larger from the destination to the source. The packets are routed only from a longer queue to a shorter queue and certain links may have to remain idle until this condition is met. Hence, it is likely that all the queues upstream of a bottleneck will grow long leading to larger delays. A common observation of the optimal policies for the clique and the tandem network is that increasing the priority of packets which are close to the destination reduces the delay.

### 4). GREY TECHNIQUE MODULE

1. Start with a vector of link prices.
2. Obtain the tra\_c injected into the network by each source (congestion control and routing problem).
3. Obtain the schedule with maximum aggregate price (scheduling problem).
4. Update prices (price updation) and go to Step 2.

It is well-known that when the step-sizes in the price updation algorithm are chosen

appropriately, the algorithm given above converges to the optimal solution of the primal problem within certain range [2].



Clique network with interference constraints such that only one pair of nodes can communicate at given time.

The general research on the delay analysis of scheduling policies has progressed in the following main directions:

- Heavy traffic regime using fluid models:

Fluid models have typically been used to either establish the stability of the system or to study the workload process in the heavy traffic régime. The maximum-pressure policy (similar to the back-pressure policy) minimizes the workload process for a stochastic processing network in the heavy traffic regime when processor splitting is allowed.

- Stochastic Bounds using Lyapunov drifts:

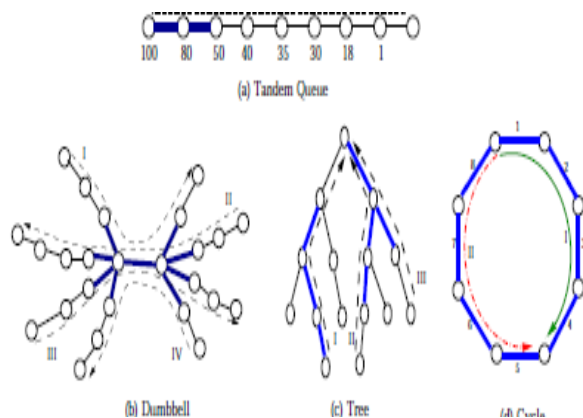
This method is developed and is used to derive upper bounds on the average queue length for these systems. However, these results are order results and provide only a

limited characterization of the delay of the system. For example, the maximal matching policies achieve  $O(1)$  delay for networks with single-hop traffic when the input load is in the reduced capacity region. This analysis however, has not been extended to the multi-hop traffic case, because of the lack of an analogous Lyapunov function for the back-pressure policy.

- Large Deviations: Large deviation results for cellular and multi-hop systems with single hop traffic have been to estimate the decay rate of the queue-overflow probability. Similar analysis is much more difficult for the multi-hop wireless network considered here, due to the complex interactions between the arrival, service, and backlog process.

## 5. DESIGN OF DELAY EFFICIENT POLICIES

A scheduler must satisfy the following properties.



- Ensure high throughput: This is important because if the scheduling policy does not guarantee high throughput then the delay may become infinite under heavy loading.

- Allocate resources equitably: The network resources must be shared among the flows so as not to starve some of the flows. Also, non-interfering links in the network have to be scheduled such that certain links are not starved for service. Starvation leads to an increase in the average delay in the system.

## CONCLUSION

The above properties are difficult to achieve; given the dynamics of the network and the lack of a priori information of the packet arrival process. In the light of the previous work we choose to investigate the back-pressure policy with fixed routing. The back-pressure policy has been widely used to develop solutions for a variety of problems in the context of wireless networks and the importance of studying the trade-offs in stability, delay, and complexity of these solutions is now being realized by the research community. This policy tries to maintain the queues corresponding to each flow in decreasing order of size from the source to the destination. This is achieved by using the value of differential backlog (difference of backlogs at the two ends of a link) as the weight for the link and scheduling the matching with the highest weight. As a result, the policy is throughput optimal. Henceforth, we shall refer to this policy as only the back-pressure policy. We first study the delay optimal policy for a clique network.

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