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Broadcasting Delay Avoidance with Advance Network Code by constrained traffic over unreliable Wireless Link

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Abstract

The demand for using wireless networks for applications that generate packets with strict per-packet delay con- strains is increasing now-a-days. In addition to delay constraints, such applications also have various traffic patterns and require guarantees on throughputs of packets that are delivered within their delay constraints. Still, a mechanism for serving delay con- strained traffic needs to specifically consider the unreliable nature of wireless links, which may vary from a LINK to LINK. Also, as it is usually infeasible to gather response in- formation from all clients after each trans- mission, broadcasting delay-constrained traffic requires addressing defy of the lack of response information. We study a model that jointly con- siders the application requirements on

(i) Traffic patterns
(ii) Delay constraints
(iii) Throughput requirements
(iv) Wireless limitations also in- clouds

- Unreliable wireless links
- Lack of feedback information

Based on this model, we develop a general framework for designing feasibility-optimal broadcasting policies that applies to systems with various network coding mechanisms. We demonstrate the usage of this framework by designing policies for three different kinds of systems:

- One that does not use network coding,
- One that employs XOR coding

- Network that allows the usage of linear coding.

Keywords: Scheduling, Broadcast, Deadlines, Delays, Network Coding.

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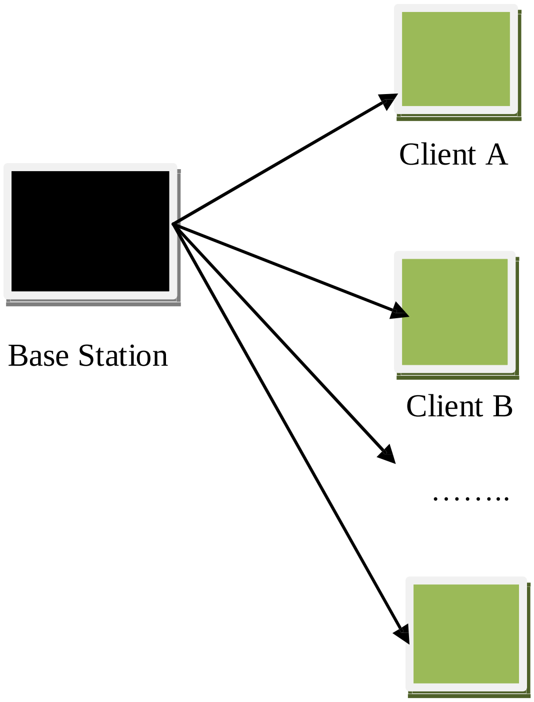
1. Introduction

There will be a growing need for using wireless networks for serving delay con- strained flows, such as VoIP and multimedia streaming due to huge demand on the wire- less network usage. In this paper we study system where a base station is broadcasting or distributing a message to a number of wireless clients.



One most significant challenge for broadcast traffic in wireless networks is that wireless links are usually unreliable, and their qualities differ from client to client. To avoid those challenges over unreliable link is **Automatic Repeat reQuest (ARQ**), where clients provide feedback information to the base station after each transmission using either **acknowledgments (ACKs) or negative acknowledgments (NACKs).** On the other hand, as the overhead of gathering feedback information (i.e,) ACK or NACK will increases the size of the network. By means of ARQ for wireless broadcasting can incur significant delay and is not scalable. Thus, a solution for wireless broadcasting that does not require feedback information is needed.

Current effort has shown that that the capacity of wireless broadcasting over unreliable links. It can be increased by employing network coding **[1].**

[2] and **[4]** describes the comparison of performance of network traffic over unreliable network using coded and uncoded techniques.

In this paper we put forward a systematic model base on **[5]**. Two features distinguish this model from those in previous studies **[5][7]**

- Preceding studies focus on unicast, where the base station has feedback information on whether a transmission is successful after each transmission, and the base station can incorporate this information to make scheduling decisions. On the other hand, this work addresses broadcast, where the base station has no feedback information after each transmission, and needs to schedule packets without relying on such information.
- This work allows the option of using different network coding mechanisms.

2. Recent works

There has been increasing research in providing services for delay-constrained flows using wireless networks. Hou*et al.* **[5]** has analytically studied the problem of scheduling several delay-constrained unicast flows in unreliable wireless environments. This work has been extended to allow variable-bit-rate flows **[6]** and various models for wireless links **[7].**In this paper, we extend the model in **[5]** to model broadcast flows. Zhang and Du **[8]** have proposed a cross-layer design for multimedia broadcast. Raghu Nathan et *al.* **[9]** have proposed scheduling policies for broadcasting delay-constrained flows. This work only focuses on minimizing the total number of expired packets and does not consider the different throughput requirements on different flows for each client. Gopala and El Gamal**[10]** have studied the trade-off between throughput and delay of broadcasting. They have only studied the scaling laws of average delay, and thus their results are not applicable to scenarios where strict per-packet delay bounds are required. Zhou and Ying **[11]** have studied the asymptotic capacity of delay-constrained broadcast in mobile ad hoc networks.

Won *et al.***[12]** have proposed multicast scheduling policies to achieve proportional fairness. They have assumed that wireless transmissions are reliable when a proper data rate is selected, and all clients provide information of their channels to the base station in every time- slot.

Deb *et al***.** **[13]** have studied multicasting real-time video streams using WiMAX. Network coding has emerged as a powerful technique to improve the capacity of wireless networks. Chaporkar and Proutiere**[14]** have proposed an adaptive network coding policy to improve throughputs of multihop unicast flows. Ghaderi*et al*. **[1]** has quantified the reliability gain of network coding for broadcasting in unreliable wireless environments. Nguyen *et al*. **[15]** have compared the throughputs of broadcast flows in systems employing network coding and those without network coding. Lucani*et al*. **[16]** have analysed the computational overhead of using different network coding schemes.

Kozat**[17]**has studied the throughput capacity when erasure codes are employed. These works focus on throughputs and do not consider delays. Both Pu*et al.* **[4]** and Gangammanavar and Eryilmaz**[2]** have studied optimal coding strategies for broadcasting delay-constrained flows. Their works require the base station to obtain feedback information from clients frequently, and thus may not be scalable.

3. Framework for Designing Feasibility- Optimal Policies

We now bring in a framework for designing feasibility-optimal policies under any schedule space. Since the base station does not have feedback information from clients, it cannot know the actual timely- throughput received by each client for each flow. However, with the facts of channel reliabilities, the base station can estimate the timely-throughputs by calculating the probability that a client obtains the packet of Theorem 2, we have that limsup

$$K \to \infty 1 K K-1 X t=0$$

$$E\{X i \in I, n \in N d i, n(tM)+\} \le 2BM^2 q*.$$

4. Scheduling Without Network Coding

Now we consider the three different kind of coding mechanisms. We first consider a system where networking coding is not in a job. In each time-slot, the base station or a sender can only transmit the raw packet from a flow that has generated one packet in the interval.

We demonstrate that there exists a polynomial-time algorithm that solves the integer programming problem. Suppose that, at some time in an interval, the packet of flow has been broadcast times. The probability that client *n* has not received the packet from flow *i* during the first transmissions, and receives this packet when the base station broadcasts the packet from flow *i* for *th* the time is. Thus, we can define the ***weighted marginal delivery probability*** of the *t th* transmission of flow as

$$mi(ti) := X n \in N d i, n(k) + pn(1 - pn) ti - 1.$$

Algorithm 1 Greedy Algorithm

1: Number flows as 1, 2,..., |I|

2: **for i**=1to|I|**do**

3:$ti \leftarrow 1$

4:$mi \leftarrow P n \in N di, n(k) + pn$

5: **end**

for

6: **for**τ=1to$T$

do

7:$i \leftarrow \text{argmax} j \in S k m j$

8:$ti \leftarrow ti + 1$

9:$mi \leftarrow P n \in N di, n(k) + pn(1 - pn) ti - 1$

10: **end**

for

11: **for i**=1to|I|**do**

12: **for** τ=1to*ti***do**

13: broadcast the packet from flow *i*

14: **end for**

15:$n\in$N**do**

16:$di,n(k + 1) \leftarrow di,n(k) + qi,n - [1 - (1 - pbi,n)ti]$

17: **end for**

18: **end for**

5. Broadcasting with pair wise XOR coding

Now we deal with the use of pair wise XOR coding for broadcasting. We assume that the base station can either broadcast a raw packet from a flow, or it can choose to broadcast an encoded packet from flow packet from flow, the XOR of a packet from flow with a packet from flow, which we shall henceforth denote by. A client can recover the packet from flow either upon directly receiving a raw packet from flow, or upon receiving a raw packet from flow and an encoded packet, for some. We exhibit a simple example where a system with pair wise XOR coding can achieve strictly better performance than one without network coding.

Example1:

Consider a system with two flows that generate one packet in each interval, and only one client whose channel reliability is. Assume that there are six time-slots in an interval. Suppose that the base station transmits each packet three times in an interval. Then, we have. Thus, a system with timely-throughput requirements is not feasible when network coding is not employed. On the other hand, a system that employs pair wise XOR coding can transmit each of the three different types of packets, the raw packet from each flow and the encoded packet, twice in each interval, which achieves.

6. Broadcasting with linear coding

In this section, we address the use of linear coding to improve the performance of broadcasting delay constrained flows. We assume that, in addition to raw packets, the base station can also broadcast packets that contain linear combinations of packets from any subset of flows. A client can decode all packets from the subset of flows if it receives at least packets that contain linear combinations of packets from these flows.

If a client receives less than packets containing such linear combinations, none of the packets from these flows can be decoded. We first exhibit a simple example where a system that uses linear coding provides better performance than one that does not use network coding.

Example 2:

Consider a system with one client, whose channel reliability is, three flows that generate one packet in each interval, and nine time-slots in an interval. A similar argument as that in Example 1 shows that is not feasible when network coding is not employed. On the other hand, if the base station employs linear coding and broadcasts a linear combination of the three flows in each time-slot, the client can decode all packets from the three flows if it receives at least three packets out of the nine transmissions in an interval, which has probability0.91015625.

As in Section VI, we address the problem of finding a tractable scheduling policy under some mild restrictions, and then compare its performance against a feasibility-optimal policy without these restrictions. Suppose that the Greedy Algorithm schedules transmissions for the packet from flow in some interval. We sort all flows so that, and enforce the following restrictions.

1. Flows are grouped into subsets as L1, L2…LN. In each Time-slot, the base station broadcasts a linear combination of packets from flows in one of the subsets. The intuition behind this restriction is that we only combine packets that have been scheduled similar numbers of times.

The base station broadcasts linear combinations of packets from the subset a total number of times, where we set. The intuition behind this restriction is that we aim to enhance the performance of flows within without hurting other flows. The two restrictions above are called the **adjacent combination restriction and the transmission conservation restriction for linear coding.**

7. Broadcasting with linear coding

We have implemented the three scheduling algorithms proposed in this paper, namely, the Greedy Algorithm, the Pair wise XOR algorithm, and the Optimal Grouping algorithm, in ns-2. We compare their performances against a round-robin scheduling policy. We use the Shadowing module in ns-2 to simulate the unreliable wireless links between the base station and clients. In the Shadowing module, the link reliability decreases as the distance between two wireless devices increases. The relation between link reliability and distance is shown in fig. We implement our algorithms based on the IEEE 802.11 standard. Under 802.11, broadcasting a packetwithsize160bytes, which is the size of VoIP packets using the G.711 c o d e c , takes about 2 *Mr*s. we assume the length of an interval is 40 *ms*, and hence it consists of 20timeslots.

We consider the scenario where a base station is broadcasting 10 delay- constrained flows to 20 clients that are evenly distributed in a 780 × 1040 area. We consider two different topologies and timely throughput requirements of clients. The first one is called the ***symmetric topology***. In the symmetric topology, the base station is located at the centre of the domain, i.e., at position (390, 520).

The timely throughput requirements of each client are α *for* flows 1–5, and β *for* flows 6–10. That is, we set

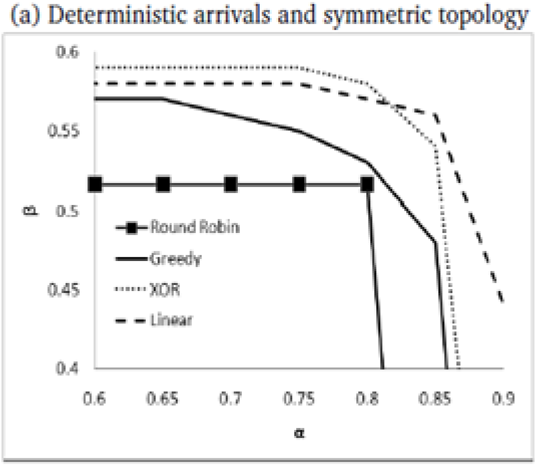
$q_{i,n} = \alpha$ if $i \leq 5$, and $q_{i,n}=\beta$ if $i > 5$, where α and β are tuneable variable store flect that clients may have different timely throughput requirements for different flows. The other topology that we consider is called the *asymmetric topology*, where the base station is located at position (520, 650). Further, clients in different regions may subscribe to different flows. The timely throughput requirements of flows subscribed to by clients in each region are summarized in Table 1. We set $q_{i,n}= 0$ if $q_{i, n}$ does not appear in TABLE . We study two different types of traffic patterns for packet arrivals, namely, ***deterministic arrivals*** **and** ***probabilistic arrivals***.

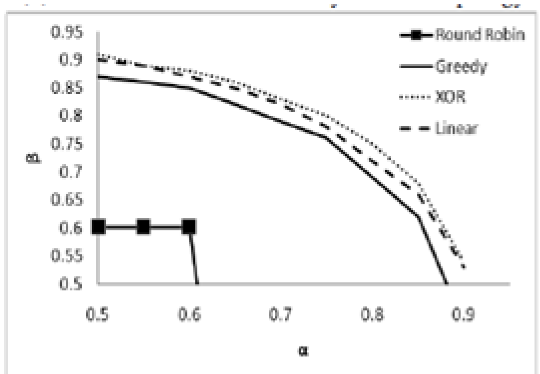
For deterministic arrivals, we assume that all the 10 flows generate one packet in each interval. This corresponds to flows carrying constant-bit- rate traffic, such as the G.711 codec for VoIP. For probabilistic arrivals, we assume that each flow generates one packet with some probability, independent of the packet generations of other flows, at the beginning of each interval. This scenario corresponds to flows carrying variable bit- rate traffic, such as MPEG video streaming., we assume each of flows 1–5 generates o n e packet with probability 0.9, and each of flows 6–10 generates one packet with probability 0.6, at the beginning of each interval.
We close this section by comparing the Pair wise XOR algorithm for XOR coding and the Optimal Grouping algorithm for linear coding.

In the scenario with deterministic arrivals and symmetric topology, the Optimal Grouping algorithm has much better performance than the Pair wise XOR algorithm. However, the advantage of the Optimal Grouping algorithm becomes less prominent in the other three scenarios, and sometimes it even performs worse than the Pair wise XOR algorithm. The Optimal Grouping algorithm allows combining more than two flows, and thus explores more coding possibilities, which is why it achieves better performance in the first scenario.

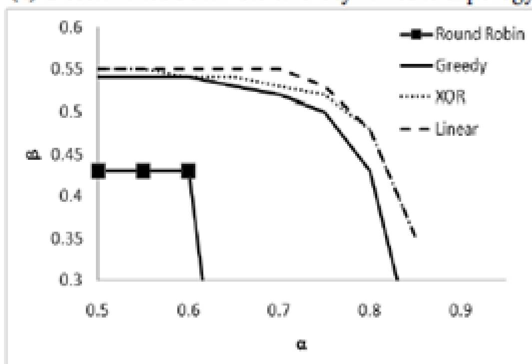
On the other hand, in systems where the number of generated packets in each interval is less, as in the scenario with probabilistic arrivals, or when the topologies are asymmetric, it becomes less beneficial to combine a large number of packets. In such systems, the Pair wise XOR algorithm may benefit from its simpler coding structure.

(a) Deterministic arrivals and symmetric topology





(c) Deterministic arrivals and asymmetric topology



(d) Probabilistic arrivals and asymmetric topology

Figure 2: Simulation results

8. Conclusions and future work

We have studied the problem of broadcasting delay -constrained flows in unreliable wireless environments. We have extended a previous model, which only models uncast flows, to address the additional challenges introduced by broadcasting. This model jointly considers the traffic patterns and delay constraints of flows, the timely throughput requirements of clients, the nature of unreliable wireless links, and the lack of feedback in broadcast. This model also allows the optional usage of various network coding mechanisms. We have proposed a general framework for designing feasibility-optimal scheduling policies. We have demonstrated the usage of this model by developing scheduling policies for three different types of systems, one without network coding, one that employs XOR coding, and the other using linear coding. Simulation results have shown that the three proposed policies achieve much better performance than a round-robin policy. They also show that policies incorporating network coding have better performance than the feasibility- optimal policy for systems without network coding. This result demonstrates that using network coding can increase the capacity of wireless networks for broadcasting delay- constrained flows. One important difference between our work and other existing work on broadcasting delay-constrained traffic is that our work does not require frequent feedback from clients.

Thus, in large networks, our work should offer much better performance as it avoids the large overhead of gathering feedback. On the other hand, when the size of the network is small, it might be beneficial to obtain feedback from clients and utilize such information. It is an open problem to determine when the price of gathering feedback outweighs the benefit of such information. Also, in the two network coding schemes discussed in this work, we have imposed some simplifying restrictions in order to obtain tractable policies. Whether these restrictions can be relaxed is another challenging problem that requires future research.

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