A Multi-hop Wireless Multicast Broadcast Services Using ANCR

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ABSTRACT: *Network coding was the major improvement for packet retransmission schemes in wireless multicast broadcast services (MBS). In the existing system the researchers use three main schemes: ONCR (Opportunistic network coding retransmission), FNCR (Full network coding retransmission) and ANCR (Adaptive network coding retransmission). First two schemes are not efficient because, in ONCR it will transmit the packets which are not intent to send to the receiver. In FNCR, it decreases the bandwidth efficiency because of re-transmitting all the packets in addition with the required packets. In order to overcome the above drawbacks, Adaptive network coded schemes are used to improve the bandwidth efficiency in MBS using a combination of opportunistic and full network coded re-transmission. It can be applied for the single-hop wireless broadcast services. In the proposed system, this transmission scheme is applied for the multi-hop wireless broadcast service. It has the advantage of more effective bandwidth usage and in reducing the re-transmission.*

Keywords: Multicast Broadcast Services (MBS), FNCR, ONCR, ANCR, Packet Retransmission

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1. Introduction

Multicast Broadcast Services (MBS) have emerged as the essential applications and are considered in the design of all wireless networks due to the increasing demand of an application that are requested by all receivers located in the coverage area of a wireless access node. In multicast, the receivers are interested in receiving only a subset of the packets transmitted by the access node. In broadcast, the receivers are interested in receiving all the packets transmitted by the access node. Due to the high demand on MBS applications and their high bandwidth requirements, it is very important to develop new techniques that can improve the system bandwidth efficiency in order to satisfy these demands with the quality of service.

To achieve a reliable multicast/broadcast, all the receivers must correctly detect all the information packets they requested from the access node. Since wireless communication channels are lossy in general, the guarantee of packet delivery is achieved through packet retransmission using Automatic Repeat Request (ARQ) or Forward Error Correction (FEC). However, both schemes retransmit lost packets separately, which considerably reduces the number of receivers benefiting from each retransmission. This process results in more retransmissions and thus leads to slow system bandwidth efficiency.

Since these are not efficient, bandwidth efficiency is achieved by network coding [1]. Several works aimed to exploit it for packet retransmission, as a substitute to ARQ/HARQ in wireless networks. So in the existing system, they introduced two schemes which focus on improving bandwidth and reducing loss of retransmission. Opportunistic Network Coded Retransmission (ONCR) combine lost packets of different receivers such that some of them recover one of their missing packets upon correct delivery of this combined packet. The second one, the Full Network Coded Retransmission (FNCR) was proposed to improve wireless multimedia broadcast.

It has been shown that both ONCR and FNCR schemes achieve a considerable gain in bandwidth efficiency compared to ARQ. Each of these two schemes usually outperforms the other in different receiver and demand and feedback settings [8]. The continuous and rapid change of these settings in wireless networks limits the bandwidth efficiency gains if only one scheme is always employed. To select the scheme for the higher bandwidth efficiency, it uses the proposing scheme.

So a new scheme Adaptive Network Coded Retransmission (ANCR) which is a combination of Opportunistic and Full Network Coded Retransmissions is used. The proposed scheme adaptively selects, between these two schemes, the one that is expected to achieve the better bandwidth efficiency performance. The core contribution in this Adaptive Selection scheme is focusing on the derivation of an ONCR performance metric that achieves efficient selection when compared to an appropriate full network coding. This metric is derived by modeling the ONCR graph representation as a random graph and computing its chromatic number using a famous result from random graph theory [2].

2. Related Work

2.1 Network Coding

Since its first introduction [1], network coding has been a great attraction to several studies as a routing and scheduling scheme that attains maximum information flow in a network. The core idea of the network coding is packet mixing using several techniques such as the packet XOR and linear coding. Both trends have been proposed for a wide range of applications.

2.2 Index Coding

The index coding includes a sender, a set of receivers, a set of packets and lossless channels between the sender and these receivers. The objective of the index coding problem is to define the packet coding schedule that delivers the requested subsets of packets by each of the receivers with the minimum number of transmissions.

In [7], it has been shown that finding the optimal solution of the index coding problem is NP-hard. Most of these heuristics are different simplifications of suboptimal graph-coloring solution of the index coding problem.

2.3 Network Coded Retransmission

In [5] and [9], the diversity of received and lost packets at different receivers is broken by using the ONCR scheme as a substitute of ARQ/HARQ, respectively. In [6], a hybrid ARQ-FNCR scheme was proposed for wireless multimedia broadcast. The concept of network coded retransmissions is to minimize the average packet detection delay and the average sender queue size, respectively, in wireless broadcast [4].

3. System Model And Parameters

The model consists of a wireless access node, such as a base station which is responsible for delivering multicast or broadcast packets $R = \{R_1, \ldots R_M\}$ of M receivers. The access node initially transmits a MBS frame consisting $p = \{p_1, \ldots p_N\}$ of N packets. During this phase, each receiver listens to the packets it requested and all the correctly received packets are stored in its memory. For each lost packet, each receiver sends a NAK packet to the access node. The access node keeps a table of received and lost packets by all receivers that will refer to as the feedback table. At the end of the initial transmission phase, three sets of packets can be associated with each receiver R_i.

• The Has set (denoted by $\mathbf{H}_i$) is defined as the set of packets correctly received by R_i. This set includes both desired and undesired packets by this receiver.

• The Complementary set (denoted by $\mathbf{C}_i$) is defined as the set of packets that were not correctly received by R_i whether requested or not.

• The Wants set (denoted by $\mathbf{W}_i$) is defined as the set of packets that are both requested and lost by R_i in the initial transmission phase of the current MBS frame.

At the end of the initial transmission phase, a packet retransmission scheme is employed to deliver the lost packets to the receivers that requested them. After this processs, the whole procedure is re-executed for a new MBS frame.

4 .ONCR and FNCR Schemes

4.1 ONCR Scheme

The ONCR scheme combines the lost packets of different receivers such that some of them recover one of their missing packets upon correct delivery of this combined packet. Each packet combination is performed so as to maximize the number of receivers that directly recover one of the requested and lost packets upon correct reception of this coded packet.

The process of 'opportunistic packet coding sequence to minimize the number of re-transmissions' is equivalent to solving the corresponding index coding problem. Since solving of the index coding problems is NP-hard, the graph-coloring approximation, proposed in [3], can be used to efficiently implement the ONCR scheme in case of lossless re-transmissions.

The graph-coloring implementation of the ONCR scheme starts by generating a graph **G(V, E),** in which each packet $\in W_i$ for every I induces a vertex $V_{i,\ j}$ in the graph. Two vertices $V_{i,\ j}$ and $V_{k,\,l}$ in G are connected if one of the following is true:

- J = l (i.e., vertices represent the same lost pocket from two receivers i and k);
- $J \in H_k$ and $l \in H_i$ (i.e.,the requested packet of each vertex is in the has set of the receiver that induced the other vertex).

After the construction of the graph, clique partitioning is performed on it. For each clique, a coded packet 'XORing the packets' are generated and transmitted. Since clique partitioning of a graph is equivalent to the coloring of its complementary graph, the minimum achievable number of re-transmission (T_q) using this technique is equal to

$$T_q = X(G^c)$$

where X (G^c) is the chromatic number of graph G^c (V, E^c).

After the initial transmission phase, the access node constructs a graph 'G' as described, finds a maximal clique in it, and broadcasts an XOR of all the packets represented in its vertices.

Each receiver sends a NAK packet to the access node if it lost this re-transmission packet. If there is any loss of packets, it will result NAK packets which get used by the access node to update the feedback table. Then it is further used to construct a new graph, and the above mentioned process is re-executed. This process continues until each receiver correctly receives the requested packets.

4.2 FNCR Scheme

The FNCR scheme has been proposed for packet retransmission to improve wireless multimedia broadcast.

In general, the FNCR scheme combines all the MBS frame packets in each retransmission using linear network coding. Coding coefficients can be either deterministic or selected from a large field such that a large number of coded packets are guaranteed to be linearly independent almost surely. There transmission procedure continues until all receivers get enough packets to decode all packets of the MBS frame.

One drawback of the FNCR scheme for wireless multicast is that it necessitates the delivery of all packets of the MBS frame to all receivers regardless of their needs.

Assuming the lossless re-transmissions, the number of retransmission packets needed for receiver R_i to correctly decode all

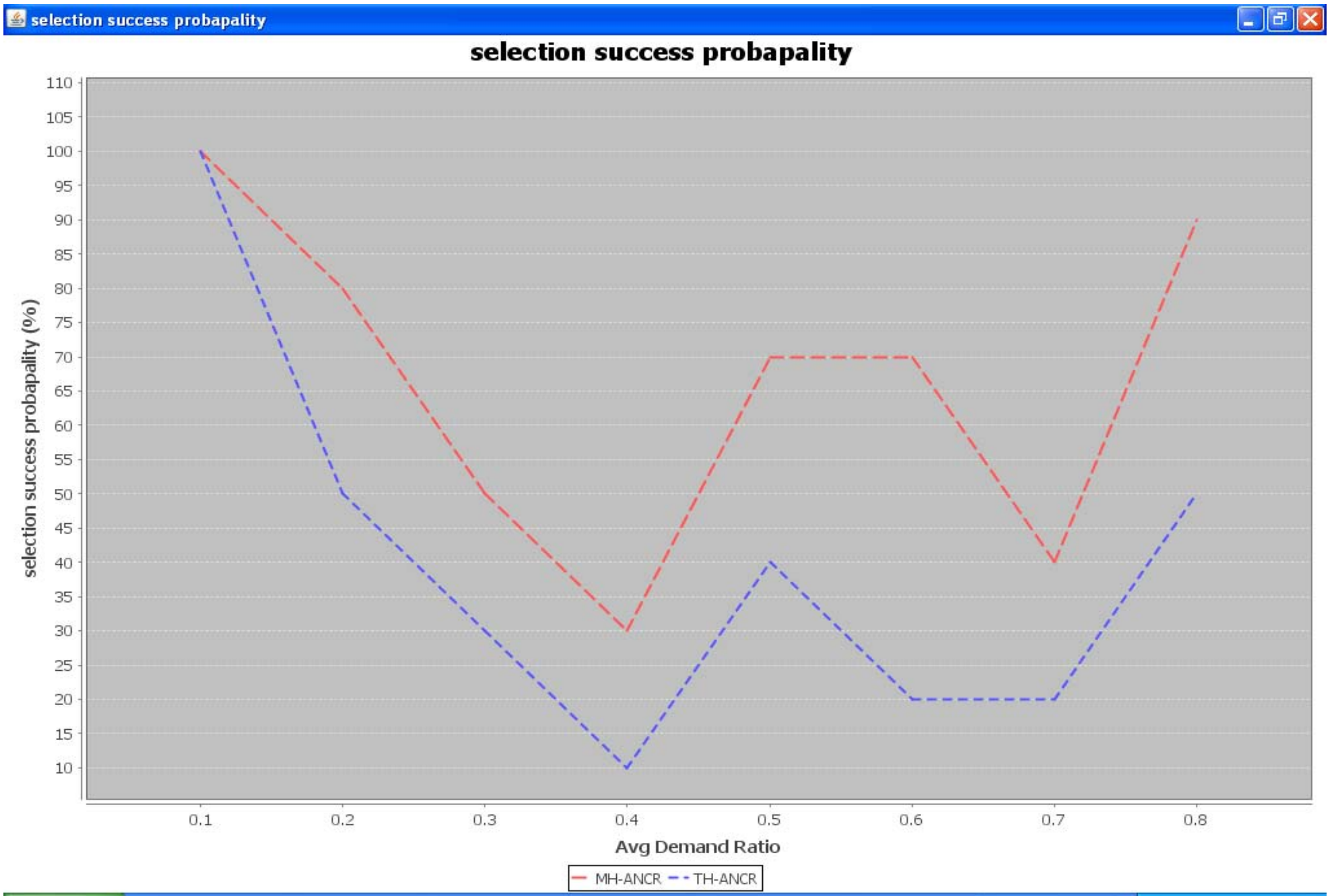

Figure 1. Selection success probablity Multi-hop vs Single hop ANCR

the packets is equal to the cardinality of is complimentary set C_i. Consequently, the number of lossless re-transmission (T_f) is equal to

$$T_f = \max |C_i| \text{ where } i \in R$$

5. Adaptive Network CODED Retransmission (ANCR) Scheme

The aim is to design an efficient and adaptive scheme that can adaptively select the network coded re-transmission scheme for each wireless MBS frame. This scheme is referred as the ANCR scheme. The ANCR scheme should select the re-transmission scheme which is expected to achieve the smaller number of retransmissions according to the system, demand, and feedback parameters. For the broadcast case, it has been proved that the FNCR scheme is optimal.

Therefore, it will be focusing on the multicast case. For each MBS frame, the ANCR scheme selects one of the two schemes by comparing metrics representing the number of retransmissions for each of them. The scheme having the lower metric is selected to be executed for this MBS frame.

In order to determine the better scheme for packet retransmission in each frame, it should compute a prior estimate of the number of re-transmissions of each scheme. Since it is very difficult to find analytical expressions for the exact number of retransmission of both ONCR and FNCR schemes in case of lossy retransmission, two methods have been introduced to estimate the performance.

The methods are given under the sub-headings, 5.1 and 5.2.

5.1 Method

Estimate their performance through their number of lossless re-transmission.

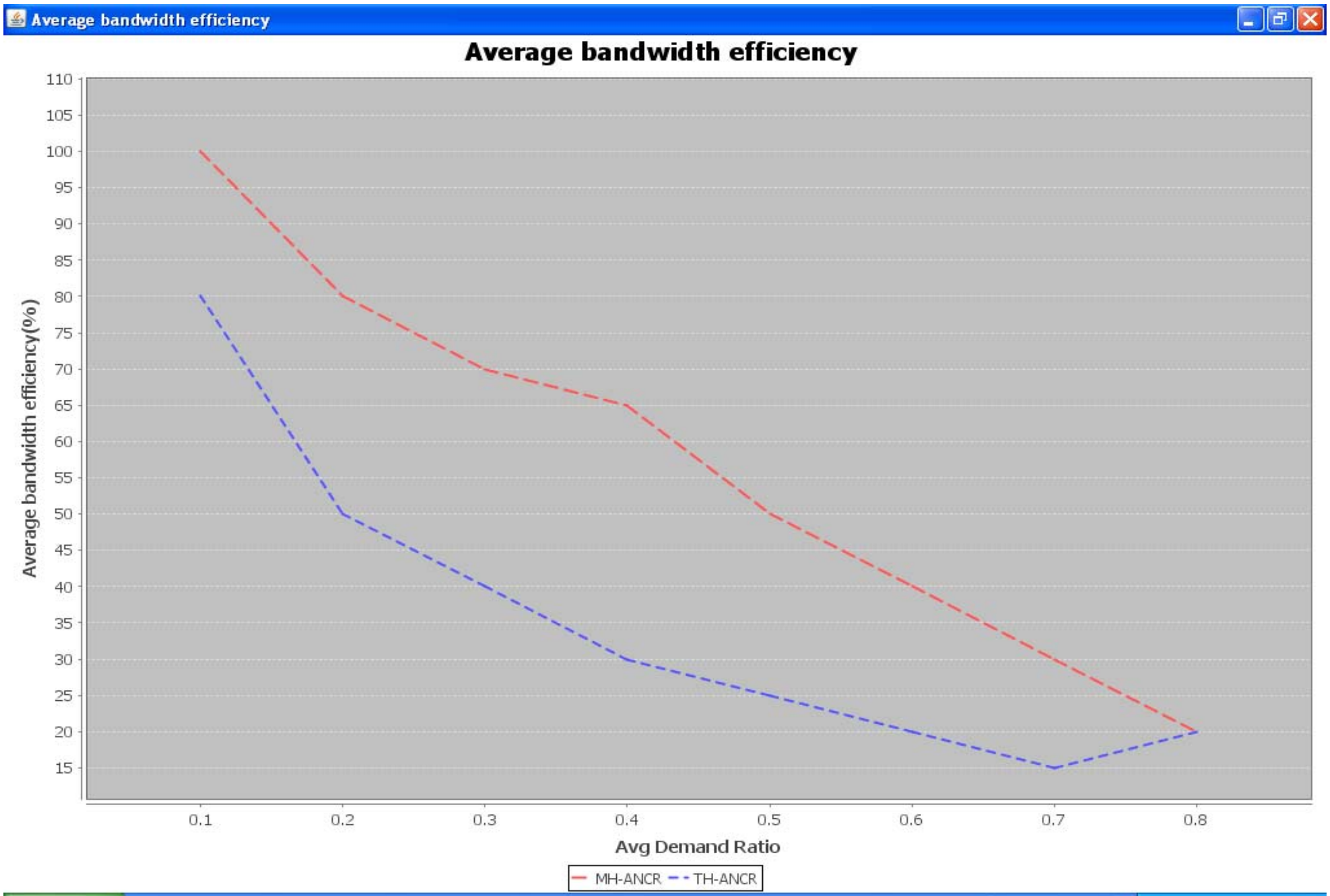

Figure 2. Average bandwidth efficiency Multi-hop vs Single hop ANCR

$$T_q = X(G^c) \text{ and } T_f = \max |C_i| \text{ where } i \in R$$

Since finding the chromatic number of a graph is NP-hard, it is required to find an approximation for X (G^c).

5.2 Method 2

Extend the lossless ONCR graph representation by including loss pattern information in it, which would generate a lossy ONCR graph model negotiation of G^c. This process can estimate the chromatic number of this new graph and would compare it to a lossy approximation of the FNCR scheme performance. In both the methods, the chromatic number of a graph is estimated.

To compare the two methods and decide the complexity level needed to obtain an efficient algorithm, the two approaches are applied to derive π in G^c and propose a design for negotiation of G^c and compute its π accordingly.

5.3 Approach 1

In this approach, both the vertices identities and the content of the *'Has'*, *'Complementary'* and *'Wants* 'sets of all receivers is ignored. This approach considers only the graph vertex set size (V), the system parameters (M, N) and the cardinalities of the different sets that can be extracted from the feedback table. In this approach, the number of re-transmissions mostly depends on the cardinalities of the sets and not their contents.

5.4 Approach 2

One drawback of the previous approach is the need to compute π for each MBS frame, since it depends on the cardinalities of the feedback table sets.

In this approach, it ignores these cardinalities in addition to the vertices identities. Consequently, this approach considers only

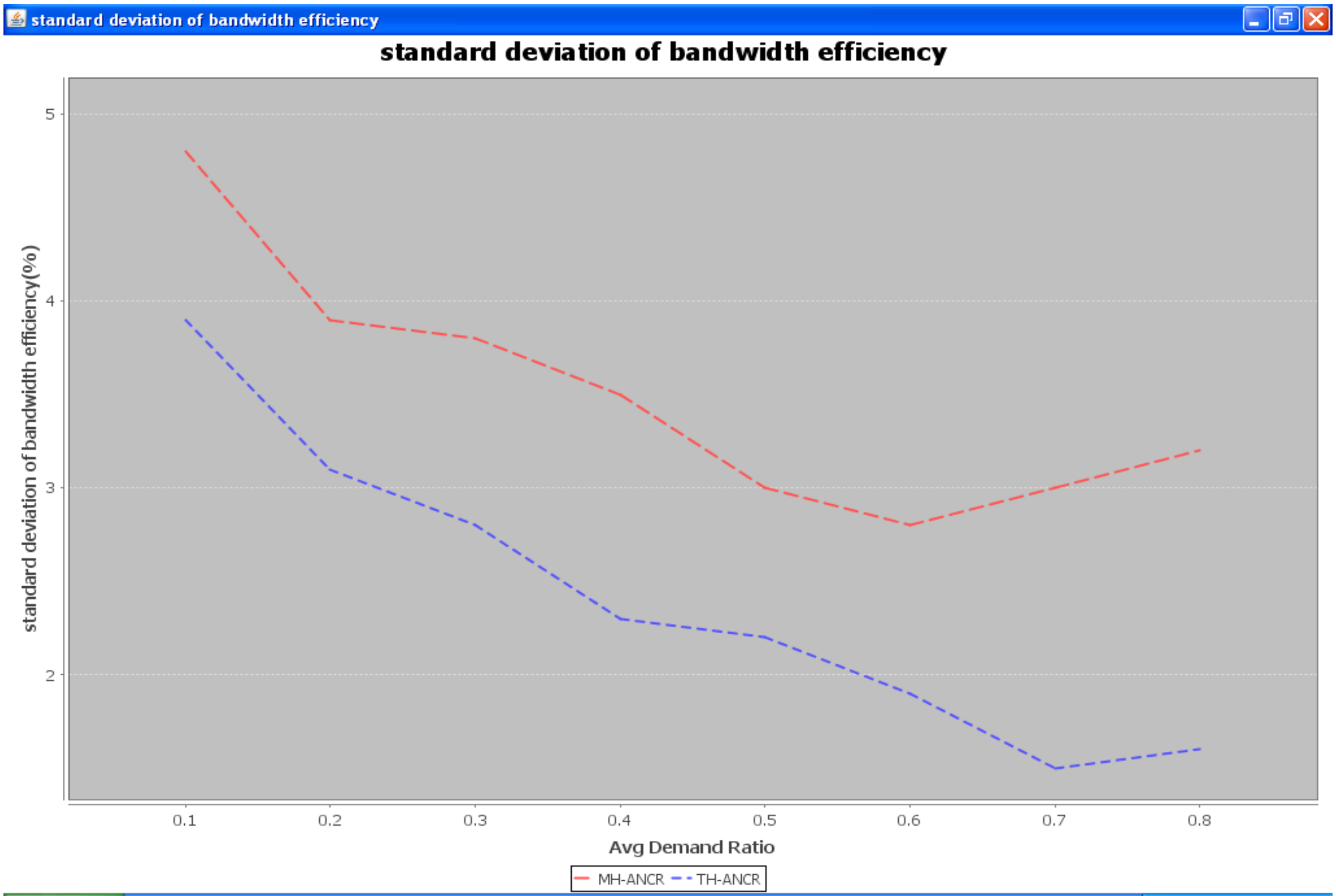

Figure 3. Standard deviation of bandwidth efficiency Multi-hop vs Single hop ANCR

the vertex set size V, the system parameters (M, N) and the parameters of the packet request-loss random process. In this approach, the packet loss probability is approximately fixed with the help of the receiver's packet loss probability averages. Despite of the 'accuracy affect in selection' caused by this approach, the algorithm is satisfactory.

5.5 Approach 3

In the previous two approaches, it ignores re-transmission packet losses that might occur at different receivers when estimating the ONCR and FNCR performances. In this approach, it aims to consider these loss possibilities in the estimation model to test whether this achieves a better performance than the previous two approaches. Since we don't know the loss realization that will occur during the re-transmission phase at the selection time, we will assume that an average number of loss events will occur at each of the receivers.

5.6 Performance Result

For Approaches 1-3, the average and standard deviation of bandwidth efficiency achieved by the ONCR, FNCR, optimal selection, and ANCR schemes against the number of receivers M for N = 30 and μ = 0.4. The Metric employed to evaluate different value of this term is the 'Selection Success Probability'. ANCR Scheme succeeds in selecting with lower number of re-transmission, divided by the total number of trials.

6. Conclusion

In this paper, an adaptive scheme for packet retransmissions to improve the bandwidth efficiency in wireless MBS using a combination of opportunistic and full network coding is designed. The proposed 'scheme selects' from these two schemes, is expected to achieve the better bandwidth efficiency performance. To compare the different complexities levels, we presented three selection approaches. For the three considered approaches, simulation results showed that our proposed scheme almost achieves the bandwidth efficiency performance that could be obtained by the optimal selection between the ONCR and FNCR schemes.

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