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Adhoc Network – Energy Efficient Networking in XOR and Random Linear Network Coding

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Abstract- RLNC-based broadcasting and introduce an analytical model that captures the performance of coding-based broadcast schemes. This paper proposes a new design a novel RLNC-based broadcast algorithm that for the first time applies RLNC over CDS-based broadcasting. The proposed algorithm provides a more systematic pruning of redundant transmissions without compromising RLNC's efficiency. We also investigate generation management that is a key issue in RLNC and introduce a new distributed scheme that is suitable for mobile environments. Finally, through extensive simulations, we show that the proposed algorithm outperforms XOR-based as well as RLNC-based schemes even when global knowledge is used for managing packet generations.

Keywords- [ADHOC, Random Linear Network Coding, Connected Dominating Set]

I. Introduction

Wireless networks have been thoroughly studied over the past four decades. Today more than ever before, we witness the results of the research in this field, since users are connected wirelessly around the clock using a diverse range of devices, e.g., laptops, tablets and smart phones. However, in conventional wireless networks, network connectivity is still limited in the sense that it depends in the existence of a fixed infrastructure, such as an access point or a base station. To provide wireless communication when fixed infrastructure is absent, the research community introduced the concept of wireless ad hoc networks. In this class of networks, user devices form a self-organizing network that requires minimum user intervention and it is deployed easily with minimal cost and planning. Communication is direct when nodes are within each other's range, otherwise nodes rely on other nodes to forward their packets. Despite their unique features, wireless ad hoc networks have yet to make the transition to the commercial world. Most real-world deployments are ephemeral and are built to provide short-term communication. Some of the application areas include battlefield communications in military operations, search and rescue operations during a disaster, data gathering of environmental conditions in hostile environments and communication for educational reasons in classrooms, campuses and conferences. Recently, the growing popularity of the concept of Internet of Things is paving the way for commercially viable wireless ad hoc networks. The main idea is to extend Internet connectivity beyond traditional devices like personal computers, smartphones and tablets to a diverse range of devices and everyday things that will communicate and interact with the external environment. Towards this direction, wireless ad hoc networks can play an important role in enabling the communication between things/devices and relaying data traffic to the Internet infrastructure. Another area of deploying wireless ad hoc networks is when censorship disrupts or filters conventional communication networks. In these cases, the distributed nature and adaptability of ad hoc networks render them perfect to promote free speech and allow public communication. Furthermore, wireless ad hoc networks can be combined with the existing infrastructure in order to extend the network coverage, capacity and scalability. Especially, there is an increasing research interest in extending the capacity of cellular infrastructure through wireless ad hoc networks. Such approaches will have a great impact on the current carrier networks which are overloaded by high traffic demands.

XOR-based approaches encode packets on a hop-by-hop basis using bitwise XOR and then forward them using a Connected Dominating Set (CDS) based broadcasting algorithm. Although this strategy has been proved successful, we bring to light several occasions where its performance severely degrades and the coding gain 3 becomes negligible. Motivated by this finding, we examine in depth the synergy of network coding and the underlying broadcast algorithm and reveal that the weak link is a component of the baseline algorithm known as "the termination criterion". We introduce a new XOR-based broadcasting algorithm which incorporates a novel termination criterion fully compatible with XOR coding. Moreover, we revisit the coding internals in order to enhance the overall performance in terms of energy efficiency, delivery delay and utilization of network resources. RLNC-based approaches operate on an end-to-end basis in the sense that intermediate nodes are not required fully decoding and re-encoding the encoded packets. Initially, generated packets are grouped in the so called “generations”. Encoded packets are produced as random linear combinations of the packets in a generation, based on the theory of finite fields, and then probabilistically forwarded. We introduce an analytical model that captures the performance of coding-based broadcast schemes that focus on energy efficiency.

II. Proposed Work

2.1 Random Linear Network Coding

Random Linear Network Coding (RLNC) has been successfully used for efficient broadcasting in wireless multi-hop networks. In this chapter, we focus on the problem of multi-source broadcasting using RLNC in mobile ad hoc networks. Initially, we develop an analytical model which reveals that the usual approach to combine RLNC with probabilistic forwarding may significantly impact RLNC’s performance. Motivated by this finding, we take the novel approach to combine the resilience offered by RLNC with the pruning efficiency of CDS-based broadcasting.

2.2 XOR coding principles

In XOR-based coding, each node collects information about the native packets received by its neighbors. The information is collected by overhearing the wireless medium and by exploiting local connectivity information. Let Bu denote the buffer containing the native packets received by node u and B v u denote v’s view of the same buffer. A node u may choose a set of native packets B ′⊆Bu and produce an encoded packet, by using bitwise XOR, in the presence of a coding opportunity. This means that a set B ′≠∅ can be found such that, according to u’s view, each node v ∈ N (u) has received at least |B′ |−1 of the native packets in B ′ , i.e., |Bu v ∩B′ | ≥ |B′ |−1, ∀v ∈ N (u). XOR-based coding works on a hop-by-hop basis, i.e., a receiver of an encoded packet should be able to decode it. Successful decoding depends on the consistency of B u v , i.e., whether B u v=Bv. Decoding failures occur when |Bv ∩ B′ |.

2.3 Complexity of Coding Schemes

Both RLNC and XOR-based coding entail some communication, processing and storage space overhead. About the communication overhead, both schemes assume that an encoding vector is included in the header of each encoded packet. The processing overhead in RLNC is related to the implementation of the Gaussian elimination. Its complexity on a matrix with rank r is $O(r^3)$, however, implementing partial decoding can alleviate the decoding cost. On the other had, in XOR-based coding, the processing burden lies in finding coding opportunities. The optimal XOR-based algorithm is shown to be NP-hard, however, efficient suboptimal algorithms for finding coding opportunities have been proposed. Finally, while in RLNC each node is required to store all packets in a generation, in XOR-based coding, each node should store a list of recently received packets (in order to enable decoding) along with information about the packets received by each of its neighbors. To summarize, in our view, none of the above schemes is profoundly better than the other, in terms of the related overheads. Furthermore, the actual cost of each scheme depends on the implementation specifics, making it impossible for a more detailed comparison. Nonetheless, we will show, throughout the rest of the manuscript, that we take all necessary action to minimize the cost of the proposed scheme, e.g., we enable partial decoding, minimize the size of encoding vectors, keep the generation size small, etc.

2.4 Analysis of RLNC’s coding features

As mentioned previously, the driving force of this work has been the observation that RLNC is capable of providing robust coding features. To validate this view, we develop an analytical model that portrays the performance of RLNC in the context of broadcasting. Before continuing with the analysis, we briefly describe the system model. Table 4.1 summarizes the notation used in this chapter.

2.5 System model Network Model

We consider multihop wireless ad hoc networks. We model such a network as a random geometric graph (RGG). The nodes are deployed over an area A×A. We focus on the generic approach of uniform node deployment which captures static and some cases of mobile networks (e.g., when node movement follows the random direction model. Moreover, our study is valid for the node distribution resulting from the random waypoint movement model. A link between a node pair (u, v) exists when the Euclidean distance d(u, v) is smaller than a transmission range R. The neighborhood N (v) of a node v is the set of nodes connected to v with a link, i.e., N (v) = {u | d(u, v) ≤ R}. Loss Model: The network consists of unreliable links. The transmission of a packet over a link fails with probability ρ, which is independent of other links. This assumption is common in the literaturefor wireless links without correlated shadowing and severe interference. Broadcast sources: We assume that multiple sources exist in the network. Created packets are grouped in generations of size g. For each packet added to a generation, the source broadcasts an encoded packet that is a random linear combination of the generation contents. Forwarding process: When receiving an innovative packet, each node implements a simple probabilistic forwarding protocol, i.e., forwards a new encoded packet with probability ω.

III. Experimental Results

Regarding RLNC, we use two variants, namely RLNCD and RLNCG. The first, uses the distributed generation management described. In the second, we assume that each node has global coding information, i.e., perfect knowledge of the coding status of other nodes. This scheme achieves the optimal allocation of packets across generations. Although it is unrealistic, we use it to illustrate the performance bounds of RLNC.

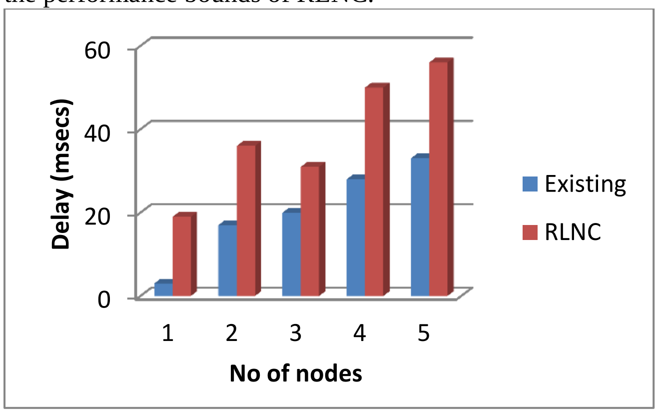

Figure 1: Delay

Figure 1 represented into delay values compare with existing and RLNC. The RLNC values are lower than existing values. So RLNC delay timing values are better result of energy efficient process.

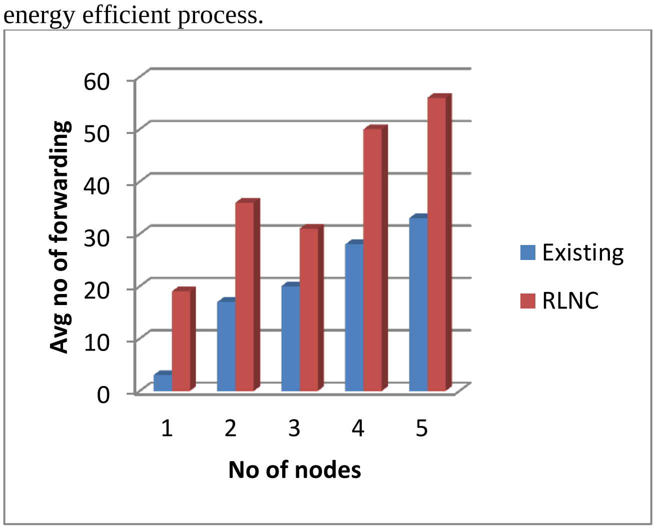

Figure 2: Average no of forwarding

Figure 2 represented into average no of forwarding values compare with existing and RLNC. The RLNC values are higher than existing values. So RLNC average no of forwarding timing values are better result of energy efficient process.

IV. Conclusion

Along with XOR-based coding approaches, we investigated energy efficient broadcast schemes that utilize random linear network coding (RLNC). Our key contribution in this field is that, for the first time, we combined the resilience of RLNC with the pruning efficiency of CDS-based broadcasting. The proposed novel RLNC-based broadcast algorithm that combines RLNC with a deterministic underlying scheme specially designed to prune transmissions provides a good result. In order to increase reliability in poorly connected nodes, we proposed an extension of the basic algorithm that enhances the topology-awareness. Moreover, we provided a practical distributed scheme for managing packet generations that is key issue in RLNC-based broadcasting when inter-source coding is used. Through extensive experiments, we demonstrated that our proposed algorithms significantly reduce the energy costs of broadcasting while at the same time achieve a better and faster delivery performance compared to state-of-the-art.

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