Survey Paper on Peer-to-Peer Information Exchange in Wireless Network using Network Coding

PriyankaThota

Abstract - In this paper, we study how network coding is useful for information exchange to be scheduled among peers to achieve high network throughput and lower transmission delay in wireless network, which helps in the throughput improvement, energy efficiency and delay minimization of the network.

Keywords: wireless network, network coding, scheduling.

1. INTRODUCTION

Network coding is a technique where, instead of simply relaying the packets of information they receive, the nodes of a network will take several packets and combine them together for transmission. This can be used to attain the maximum possible information flow in a network. Network coding is a field of information theory and coding theory. Network coding has emerged as a promising information theoretic approach to improve the performance of both peer-to-peer (P2P) and wireless networks. It has been widely accepted and acknowledged that network coding can theoretically improve network throughput of multicast sessions in directed acyclic graphs, achieving their cut-set capacity bounds. Recent studies have also supported the claim that network coding is beneficial for large-scale P2P content distribution, as it solves the problem of locating the last missing blocks to complete the download

One of the motivating uses of sensor net technology is the monitoring of emergency or disaster scenarios, such as floods, fires, earthquakes, and landslides. Sensing networks are ideal for such scenarios since conventional sensing methods that involve human participation within the sensing region are often too dangerous. These scenarios offer a challenging design environment because the nodes used to collect and transmit data can fail suddenly and unpredictably as they may melt, corrode or get smashed. This sudden, unpredictable failure is especially troubling because of the potential loss of data collected by the sensor nodes. Often, the rate of data generated within a sensor network greatly exceeds the capacity available to deliver the data to the data sinks. With so many nodes trying to channel data to the sink node, there is congestion and delay in the neighborhood of the sink. This phenomenon can be described as a funneling effect, where much of the data trying to reach the sink is stalled. It is during this time that data is especially vulnerable to loss if the nodes storing the data are destroyed or disconnected from the rest of the network. Even if state-of-the-art compression techniques such as distributed source coding or routing with re-coding are applied, there can be a significant delay between the time a unit of data is generated and the time at which it reaches the sink. We define the persistence of a sensor network to be the fraction of data generated within the network that eventually reaches the sink. Our solutions are based on the observation that even though there is limited bandwidth to forward data towards the sink, there still remains sufficient bandwidth for neighboring nodes to exchange and replicate one another’s information. While such replication does not increase the rate at which data moves toward the sink, it does increase the likelihood that data will survive as some of the storage points fail

Network coding has been widely recognized as a promising information dissemination approach to improving network performance by allowing and encouraging coding operations at intermediate network forwarders. Network coding, in contrast, allows each node in a network to perform some computation. Therefore, in network coding, each message sent on a node’s output link can be some function or “mixture” of messages that arrived earlier on the node’s input links. Thus, network coding is generally the transmission, mixing (or encoding), and re-mixing (or re-encoding) of messages arriving at nodes inside the network, such that the transmitted messages can be unmixed (or decoded) at their final destinations. Primary applications of network coding include file distribution and multimedia streaming in peer-to-peer P2P) overlay networks, data persistence in sensor networks, and information delivery in wireless networks. Incorporation of network coding into these applications brings many benefits such as throughput improvement, energy efficiency, and delay minimization.

With network coding, it may be possible to increase throughput by pushing both streams through the bottleneck link at the same time. The method is simple. Using network coding, the node can mix the two streams together by taking their exclusive-OR (XOR) bit-by-bit and sending the mixed stream through the link. In this case, XOR is the function computed at the node. This increases the throughput of the network if the two streams can be disentangled before they reach their final destinations. This can be done using side information if it is available downstream. Network coding can minimize the amount of energy required per packet (or other unit) of information multicast in a wireless network and can also minimize the delay, as measured, by the maximum number of hops for a packet to reach a receiver. Network coding can be employed to solve the Cooperative Peer-to-peer Repair (CPR) problem, where centralized and distributed CPR algorithms are proposed based on observed heuristics. Cooperative Peer-to-Peer Repair (CPR) has been proposed to recover from packet losses incurred during 3G broadcast. In Cooperative Peer-to-Peer Repair (CPR), nodes simultaneously receiving identical MBMS (Multimedia Broadcast/Multicast Service) content can collaboratively repair lost packets over IEEE 802.11 links. The heuristics reflect some intuitive superficies instead of the essences of network coding based information exchange. In addition, the undetermined parameters in CPR algorithms constitute another open issue: how to tune them to adapt the scheduling algorithms. Such deficiencies motivate us to explore a more insightful scheme to maximize wireless coding gain, i.e., the benefit of combining network coding and wireless broadcast. The scheduling issue in the CPR problem can be reduced to a peer scheduling issue by making nodes (peers) send coded packets which are combinations of all packets in a node. Specifically, the peer scheduling issue is about how to intelligently schedule the transmission opportunities among peers to maximize the wireless coding gain. Due to the shared wireless channel and the de facto half-duplex transmission feature, peer scheduling policies have a direct impact on the overall network throughput. In many cases, the gap between the optimal and the average is huge.

With network coding, each node of the distribution network is able to generate and transmit encoded blocks of information. The randomization introduced by the coding process eases the scheduling of block propagation, and, thus**,** makes the distribution more efficient. This is particularly important in large unstructured overlay networks, where the nodes need to make block forwarding decisions based on local information only. The main advantage of using network coding for distributing large files is that the schedule of the content propagation in the overlay network is much easier. With network coding, each generated block is a combination of all the blocks available to the transmitter and thus if any of them is useful downstream then the generated block will also be useful.

Wireless networks are indispensable; they provide the means for mobility, city-wide Internet connectivity, distributed sensing, and outdoor computing. Current wireless implementations, however, suffer from a severe throughput limitation and do not scale to dense large networks, so in this paper we use COPE, a new architecture for wireless mesh networks. COPE substantially improves the throughput of wireless networks. COPE inserts a coding shim between the IP and MAC layers, which identifies coding opportunities and benefits from them by forwarding multiple packets in a single transmission. In addition to forwarding packets, routers mix (i.e., code) packets from different sources to increase the information content of each transmission. We show that intelligently mixing packets increases network throughput. Our design is rooted in the theory of network coding. Prior work on network coding is mainly theoretical and focuses on multicast traffic. It addresses the common case of unicast traffic, dynamic and potentially bursty flows, and practical issues facing the integration of network coding in the current network stack. We evaluate our design on a 20-node wireless network, and discuss the results of the first test-bed deployment of wireless network coding. The results show that COPE largely increases network throughput. The gains vary from a few percent to several folds depending on the traffic pattern, congestion level, and transport protocol. Most current research focuses on block scheduling problems. Besides opportunistic snooping neighbor states, COPE successfully handles the block scheduling problem by intelligently XOR-ing packets. A multi-partner scheduling scheme employs the Deadline-aware Network Coding technique to adjust the coding window for meeting the time sensitive requirement of media streaming service. An energy efficient NBgossip scheme utilizes network coding for neighborhood gossip in sensor ad hoc networks. The Rarest First algorithm is advocated through real experiments from being replaced with source or network coding in the Internet. The rarest first idea can be employed in wireless network coding. However, directly applying this idea to peer scheduling is not necessarily optimal. Sensor networks are especially useful in catastrophic or emergency scenarios such as floods, fires, terrorist attacks or earthquakes where human participation may be too dangerous. However, such disaster scenarios pose an interesting design challenge since the sensor nodes used to collect and communicate data may themselves fail suddenly and unpredictably, resulting in the loss of valuable data. Furthermore, because these networks are often expected to be deployed in response to a disaster, or because of sudden configuration changes due to failure, these networks are often expected to operate in a "zero-configuration" paradigm, where data collection and transmission must be initiated immediately, before the nodes have a chance to assess the current network topology. One of the motivating uses of sensor net technology is the monitoring of emergency or disaster scenarios, such as floods, fires, earthquakes, and landslides. Sensing networks are ideal for such scenarios since conventional sensing methods that involve human participation within the sensing region are often too dangerous. These scenarios offer a challenging design environment because the nodes used to collect and transmit data can fail suddenly and unpredictably as they may melt, corrode or get smashed. We propose Growth Codes, a new class of network codes particularly suited to sensor networks where data collection is distributed. Growth Codes employ a dynamically changing codeword degree distribution that delivers data at a much faster rate to network data sinks. Furthermore, the code words are designed such that the sink is able to decode a substantial number of the received code words at any stage. This is particularly useful in sensor networks deployed in disaster scenarios such as floods, fires etc. where parts of the network may get destroyed at any time.

Broadcasting is the most frequently used operation in mobile ad hoc networks (MANETs) for the dissemination of data and control messages in many applications. Usually, a network backbone is constructed for efficient broadcasting to avoid the broadcast storm problem caused by simple blind flooding, where only selected nodes, called forwarding nodes that form the virtual backbone, forward data to the entire network. In MANETs, the forwarding node set for broadcast is usually selected in a localized manner, where each node determines its own status of forwarding or non-forwarding based on local information, or the status of a node is designated by its neighbors. Network coding-based broadcasting focuses on reducing the number of transmissions each forwarding node performs in the multiple source/multiple message broadcast application, where each forwarding node combines some of the received messages for transmission. With the help of network coding, the total number of transmissions can be reduced compared to broadcasting using the same forwarding nodes without coding. We exploit the usage of directional antennas to network coding-based broadcasting to further reduce energy consumption. A node equipped with directional antennas can divide the omnidirectional transmission range into several sectors and turns some of them on for transmission

Broadcast is a mechanism for disseminating identical information from one source to many receivers. It is widely used in many applications ranging from satellite communications to wireless mobile ad hoc networks. Reliable broadcast requires that every receiver must receive the correct information sent by the source. When the communication channels between a source and receivers are lossy, the appropriate schemes must be used to provide reliable transmissions. Depending on the applications, these schemes can be classified into two main approaches: retransmission and Forward Error Correction (FEC). Using retransmission approach, the source simply rebroadcasts the lost data if there is at least one receiver not receiving the correct data. This approach assumes that the receivers can somehow communicate to the source whether or not it receives the correct data. On the other hand, using the FEC approach, the source encodes additional information together with the data before broadcasting them to the receivers. If the amount of lost data is sufficiently small, a receiver can recover the lost data using some decoding schemes. Multi-partner scheduling is another challenging task. Traditional cooperative scheduling schemes, such as smallest-delay algorithm and pull-based gossip algorithm, assign requests to partners based on the local neighborhood information, for example, content in the local buffer and the available bandwidth among partners. These schemes suffer from inefficient use of network resources in large and heterogeneous populations. Some recently proposed schemes leverage network coding to improve the throughput utilization and facilitate the design of an optimal solution for static file download applications. With network coding, each peer (including the server) performs a linear combination on available segments and relays the combined segments to the neighbors. When a node receives enough linearly independent combinations, the original media can be reconstructed. However, it is difficult to apply network coding to the MoD system. First, since media play starts before all segments are downloaded, some segments may miss the playback deadline before being decoded, which causes severe performance degradation. Second, the peers have limited buffer capacity and maintain different parts of segments, so it is difficult for collaboration among partners due to the different ranges of encoded segments they own.

The recent advances in peer-to-peer, mobile ad hoc and wireless sensor networks have triggered the design of robust, simple, scalable and energy efficient information exchange algorithms. The use of gossip algorithms to solve this problem was first proposed by Demers et al. They used the idea for lazy update of data objects in replicated databases across many sites. In particular, they decomposed the update procedure into two steps. At first, every site chooses another site at random and the two sites exchange with each other their complete database contents. After this, once a site receives new updates, it becomes a “hot rumor” and periodically updates other sites randomly. Since then, gossip algorithm has been an interesting topic for many researchers. Using this algorithm reduces the time and energy consumption required to disseminate all information in the energy constrained networks. In NB gossip nodes do not simply forward messages received, instead the linear combinations are sent out.

. With the widespread deployment of broadband access, Media-on-Demand (MoD) streaming on the Internet is recently receiving increasing attention. In a MoD streaming service, music and movies can be delivered to asynchronous users with low delay and VCR-like operation support (e.g., pause, fast-forward, and fast-rewind). However, it is a big challenge to provide streaming to a large population of clients due to the limited server capacity and little deployment of IP multicast. Peer-to-peer (P2P) technology is one of the more promising solutions for providing streaming service over large-scale Internet users. Fig.1 depicts the general framework of a typical P2Pbased MoD system. In such a system, cooperative peers1 are organized into an overlay network via unicast tunnels. The streaming content is split into a sequence of segments, each of which is a smallest playable unit, and the server distributes these segments among clients of asynchronous demands. Each client caches a limited number of segments around its current play offset, which is the in-sequence index of the playing segment. The client exchanges its available segments with partners, who have close play offset and thus can provide the expected data with high probability. The users in the MoD system need to search for such partners, when joining or taking VCR operations. Since the users request the service asynchronously, and the contents buffered in one peer are continuously changing, an additional index structure is needed for the partner search upon peer joins or VCR operations. Without losing generality, we assume all peers have identical playing speed, so their partner relationship will not change unless they leave, fail, or take VCR-jump. After locating the partners, the user collaborates with them to schedule the data transmission and exchange the content. Therefore, partner search and multi-partner scheduling are the two main components in the P2P-based MoD system. It is noticed that the users form two types of overlay networks in the MoD system: the index overlay for partner search and the data overlay for media transmission. To avoid confusion, the term "index neighbor" denotes the neighbors in the index overlay, while "data neighbor" or "partner" represents the neighbors in the data overlay.

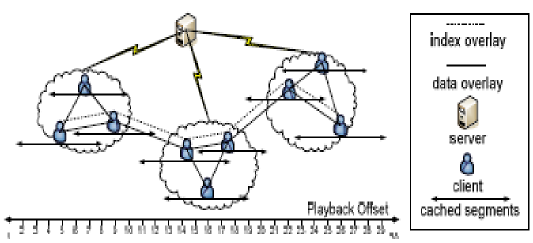

Figure 1 Typical P@P based MoD system

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II. NETWORK MODEL

We consider a network model; A remote Base Station (BS) broadcasts a batch of packets (blocks) 1 to nodes. Due to the fading and dynamics of cellular channels, each peer receives some (maybe all or none) of these blocks. To mitigate the congestion of downlinks from the BS to those nodes and release the bottleneck of the BS as network gateway, the nodes can share their received blocks with each other through local wireless networks. A local wireless network is comprised of several nodes which are also called peers in one-hop wireless scenario. These peers can communicate with each other directly through a commonly shared wireless channel in a half-duplex mode. In other words, if two peers are transmitting at the same time, their signals will interfere with each other, and no peer can correctly receive the signal. On the other hand, due to the broadcast nature of wireless channels, every other peer can receive the signal and recover the frames correctly when one and only one is transmitting. Without loss of generality, we assume randomly combined packets sent by a peer are linearly independent to each other since the probability of linear dependence is very low. Similarly, coded packets sent out from different peers are also assumed linearly independent to each other. Table I gives the notations used in this paper.

Network coding has been widely recognized as a promising information dissemination approach to improve the network performance. Compared with conventional packet forwarding technologies, network coding offers several significant advantages such as the potential throughput improvement, transmission energy minimization and delay minimization, by allowing and encouraging coding/mixing operations on intermediate forwarders, In addition, two key techniques, random coding and linear coding, further promote the development of network coding technologies. The random coding makes network coding more practical, while the linear coding is proved to be sufficient and computationally efficient for network coding. Primary applications of network coding include the file distribution and multimedia streaming on P2P networks, data transmission in sensor networks, and tactical communications in military networks and so on, where the application environment may be hostile or security/privacy-sensitive.

However, network coding is susceptible to possible malicious attacks, which pose great threats to the security and privacy of a network system.

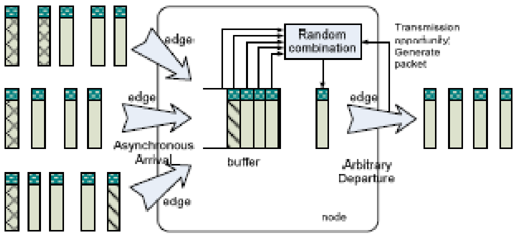

Figure 2 Random Coding at Intermediate nodes

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III. CONCLUSION

In this paper, we discuss about the issues of peer scheduling problems, Cooperative Peer-to-peer Repair (CPR) problem, Forward Error Correction (FEC), how to distribute, how network coding can be used for large scale content distribution and how can these issues be solved by using network coding in wireless networks

IV. REFERENCES

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