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A Survey on Peer-to-Peer File Sharing using Network Coding in Delay Tolerant Networks

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Abstract: Peer-to-peer file sharing using network coding for Delay Tolerant Network (DTN) is becoming increasingly popular. However, the transmission of file is very challenging because of the time-varying and unreliable wireless channels, no end-to-end connectivity, and system performance in terms of throughput, reliability, link stress and frequent peer join and leave so higher churn. Because of such open issues present in any DTN, It is very difficult to meet the requirement to improve system performance for higher throughput, good reliability and frequent peer joining or leaving. It is easy to apply network coding in peer-to-peer networks are for two reasons: 1. In peer-to-peer network, the topology is not fixed. So, it is very much easier to create the topology which suits the network coding; 2. Peer-to-peer network every nodes are end hosts, so it is easier to perform the complex operation related to network coding like decoding and encoding rather than storing and forwarding the message. This paper has considered number of theoretical and practical scenarios where network coding or its variant is applied on peer-to-peer file sharing based on Network coding with the aim to improve performance parameters like throughput and reliability. This paper has mainly focused on the comparative analysis of peer-to-peer file sharing using Random Linear Network Coding.
Keywords: Network Coding, Random Linear Network Coding, Overlay Network, peer-to-peer Network, Delay Tolerant Network.

I. INTRODUCTION

Application layer multicast can be incorporated in peer-to-peer technology. Scalability problem of web-based applications can be easily eliminated with the help of peer-to-peer networking. Throughput and reliability of a system can be improved by using network coding technology. By using network coding for multicast we can fully utilize the network capacity.

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In [4] random network coding was applied to content distribution, in which nodes encode their received messages with random coefficients. Compared to deterministic network coding, random network coding is inherently distributed. In random network coding, nodes can determine the edge functions of its outgoing edges independently by generating random coefficients for the edge functions. The advantage of random network coding is that there is no control overhead to construct and maintain a linear coding scheme among nodes. However, the edge vectors of a receiver’s incoming edges may not be linearly independent. In other words, a receiver may not recover the original messages even it receives k or more messages (here k is the multicast capacity of the multicast network). It is required to encode a message in a very large field, so it reduces the probability of failing to decode messages. Another drawback of random network coding is the increased data traffic. As there is no deterministic path for data delivery, all the nodes take part in relaying the data to the receivers even if it is not necessary. As a result, the same message may be transmitted through the same link multiple times.

Though their capabilities and popularity, existing end-system cooperative scheme like BitTorrent has much inefficiency and because of that its overall performance also decreases. Such inefficiencies are more pronounced for large and heterogeneous populations, during flash crowds, in environments with high churn, or when cooperative incentive mechanisms are in place [4].

In Network Coding technique, Every time a client needs to send a packet to another client, the source client generates and sends a linear combination of all the information available to it (similarly to XORing multiple packets). The reconstruction of original information would be done after client receive enough linearly independent combinations of packets. In this paper, a variant of Network Coding that is Random Linear Network Coding (RLNC) is examined for peer-to-peer file transfer for reliability and robustness.

II. NETWORK CODING

Network Coding (NC) was first introduced in 1999 by R. W. Yeung and Z. Zhang as an alternative to routing. Serious works on using network coding began from 2003. Files can be divided into many small packets, each of them may route from different path to the destination. By using network coding we can significantly improve the probability of delivery in a spontaneous network. In Network coding (NC), instead of forwarding packets as it is, nodes may recombine two or more input packets into one or more output packets.

In figure 1, the source node s wants to send 2 bits b1 and b2 to t1 and t2, so it sends bit b1 to node 1 and b2 to node 2,

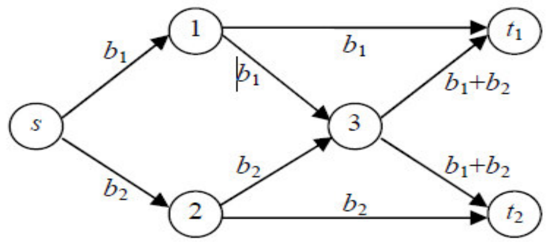

Fig. 1 Example of one source and two receivers coded network [6]

now node 1 and node 2 sends their bits to node 3 which performs XOR operation and send result as one bit This not only reduces the number of transmission, but also lets nodes t1 and t2 extract required bits b2 and b1 by applying XoR operation on (b1, b1+b2) and (b2, b1+b2), respectively.

Figure 2 shows the successful reception of information does not depend on receiving specific packets but on receiving sufficient number of independent packet hence improved fault tolerance.

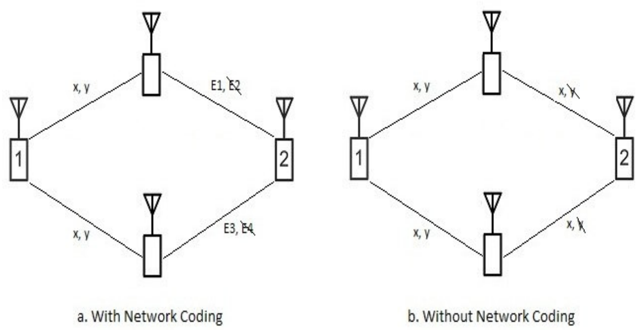

Figure 2: Example showing benefit of network coding in lossy networks.

Network coding approaches have their own pros and cons. XoR-based, as illustrated in Fig. 1, is the simplest approach which applies XoR operation on the received blocks. Due to the diversity of coded blocks, a network coding based solution is much more robust in case the servers leaves early (before all peers have finished their download) or in the case of high churn rates (where nodes join only for short period of time or leave immediately after finishing their download [11]. Random Network Coding (RNC) node can apply this approach on different blocks of a segment.

RANDOM LINEAR NETWORK CODING (RLNC)

There are two types of network coding Linear Network Coding (LNC) and Random Linear Network Coding (RLNC). In traditional network, relay node or router simply forward the information packets destined to other node. In LNC [2], source node or intermediate node or router allows to combine number of packets it has received or generated into one or several outgoing packets, where addition and multiplication are performed over the field G. Linear combination is not concatenation; if we linearly combine packets of length L the resulting encoded packet also has size L.

In LNC, meaningful coefficients should be used for encoding and decoding of packets. LNC requires central authority to control generation of this meaningful coefficient. Algorithms employed for this should be centralized. But in wireless networks due to node's mobility and heterogeneity of network distributed approaches are suitable.

So RLNC [11] suggests the random generation of the encoding coefficient. In wireless networks, channels have a bigger error rate, higher interference between channels, unknown network topology. So protocols used in wireless networks should be optimized for above conditions. In RLNC, each node generates its own coding coefficient for each encoded packet. Also coefficients are sent to the destination in the packet header. So, the destination can decode the packet without knowing network topology or encoding rules, even if the topology is not fixed. Number of successful transmission was measured for two cases in [6] with and without random linear network coding. Simulation results show that there is an increase in number of successful in the case of random linear network coding.

In RLNC, random generation of the encoding coefficients assures with high probability a linear independence of the output packets from a node for a sufficiently large size $q = 2^m$ of the finite field GF[5]. For multicast scenario, probability that RLNC is valid is at least $(1-d/q)^n$, where d is group size i.e. number of destination nodes, q refers to the field size and n refers to the number of links[7].

III. PEER-TO-PEER NETWORKING

In peer-to-peer network every computer in the network can act as a client or a server for the other nodes in the network. It allows shared access to various resources such as files, peripherals, and sensors without the need for a central server. Use of P2P technology can yield significant benefits, such as enhancing efficiency by allowing faster file transfers, conserving bandwidth, and reducing storage needs.

IV. PEER-TO-PEER FILE SHARING

1. BitTorrent: BitTorrent is the best example of an end system cooperative architecture. BitTorrent splits large files into small blocks, which allows users to download multiple blocks in parallel from different nodes. Once a user has downloaded a given block, that person's computer can immediately behave as a server for that particular block and serve anyone else looking for the file. Inefficiencies in BitTorrents are more pronounced for large and heterogeneous populations, during flash crowds, in environments with high churn, or when cooperative incentive mechanisms are in place [4]. In BitTorrent, finding the proper scheduling of information across the overlay topology so that nodes do not have to wait unnecessarily for new content to arrive is very difficult [4]. The BitTorrent system uses a combination of the Random and Local Rarest schemes. In the beginning each node uses Random and after a few blocks have been downloaded it switches to Local Rarest.

2. Paircoding: It improves file sharing by using sparse network codes. Paircoding distributes only a linear combination of two parts which alleviates the coupon collector problem of BitTorrent without the computational overhead of Practical Network Coding [13].

In their paper [13] they present some analytical method to compare the effectiveness of file sharing system and they also compare BitTorrent, Network Coding and Paircoding. By providing this analysis in [13] they conclude that

i) Paircoding shares files at least as good as BitTorrent
ii) For four different rounds, paircoding performs as good as Network Coding and better than BitTorrent.

From the tests in [13], they found by doing simulation for 100000 simulation runs in which one seed distributes a file of n = 30 blocks to a leech under the uniformly distributed random selection policy. For BitTorrent the seed randomly selects one block for upload, while for Paircoding the seed randomly chooses two blocks and then uploads a linear combination (code block) of them. While in Network Coding each code block is a linear combination of all n blocks. According to [13], paircoding overtakes and has clearly more success in providing new data after 22^{nd} round. They also found that paircoding requires a near optimal number of disk read/write operations.

3. Microsoft Avalanche: Raymond W. Yeung in [13] mentioned that, Avalanche can improve the expected file download time over BitTorrent by 20 to 30%. Avalanche uses collaborative content distribution network. Raymond W. Yeung in [13] mentioned that, in a collaborative content distribution network, new users can join the network as a node at any time as long as the distribution process is active. Upon arrival, the new user will contact a tracker (a centralized server) that provides a subset of other users already in the system, forming the set of neighboring nodes of the new user. Subsequent information flow in the network is possible only between neighboring nodes.

According to Raymond W. Yeung in [13], Avalanche divides the file into k data blocks, B_1, B_2, …., B_k, and uploads possibly coded versions of these blocks to different users at random. Avalanche uses RLNC for file distribution. The main idea is, node will download a block from a neighboring node if that node has at least one block not in a linear span of all the blocks possessed by that block. If a node has received enough linearly independent blocks it can decode the whole file. The application of network coding in the Avalanche considerably reduces the file download time. The reason behind it is that a coded block uploaded by a node contains information about every block possessed by that node. From [13], the other benefit of Network Coding in the Avalanche is, if a node leaves the network before the end of the distribution process, it is more likely that the remaining nodes have all the information necessary for recovering the whole file.

4. PPFEED (Peer-to-peer File Sharing Based on Network Coding): The basic idea of PPFEED is to construct an overlay network over the source and the receivers such that it can be decomposed into multiple combination networks. A combination network is a multicast network with a regular topology. The topology of a combination network is a regular graph which contains three types of nodes: source node, relay node and receiver node. A combination network contains a source node which generates messages, n relay nodes which receive messages from the source node and relay them to the receiver nodes, and C_n^k receiver nodes which receive messages from the relay nodes. There are k links connecting the source node to the n relay nodes respectively. For every k nodes out of the n relay nodes, there are k links connecting them to a receiver node. Since there are a total of C_n^k different combinations, the number of receiver nodes is C_n^k. The capacity of each link is 1 [12].
In [12] they have mentioned how PPFEED works when Peers joining and Peer leaving. They also discuss the data dissemination with the help of three rules which are based on how messages are forwarded in intra-neighbor and inter-neighbors. They also compare their approach with Narada which is a representative overlay multicast scheme without network coding. In this they claim that the average finish time of PPFEED is 15 – 20% shorter than that of Narada. They also found that Narada needs more retransmission. The average number of retransmissions of PPFEED is about 5 when p=0.9 while that of Narads is 30. Here they assume the link failure probability of an overlay link is 1-p to simplify the analysis. When there is dynamic peer join/leave configuration, the average finish time of Narada increases by about 25%, while PPFEED increases by about 18%, which indicates that PPFEED is more robust under dynamic peer join or leave.

5. Network Coding for Large Scale Content Distribution: In their paper [4] they apply network coding for large unstructured overlay networks for large scale content distribution because the randomization introduced by the coding process eases the scheduling of block propagation and because of that make the distribution more efficient. In [4] they demonstrate through simulations that the expected file download time improves by more than 20-30% with network coding. In [4] their model can be used to either distribute block of the original file, or blocks of encoded information, where encoding can happen either only at source, or both at the source and at the network. In their paper [4] they assume the symmetric links, where the download capacity is equal to the upload capacity of a node and both capacities are independent.

In this technique they have use two mechanisms to discourage free riding. In first they gave priority to exchanges over free uploading to other nodes. In second they have use the incentive mechanism, which is inspired by the tit-for-tat approach used in the BitTorrent network [14]. For performance measure they calculate the time it takes for each user to download the file, they also considered the average download time, maximum download time and the standard deviation of the waiting times among all clients. Other metric for performance measure is the overall utilization of network means how fast the network can push the information to the users. The network throughput is measured as the total number of block transferred in a unit of time. For dynamic arrivals and dynamic departures they simulated the scenario where every 40 nodes arrive after every 20 rounds and the file size is 100 blocks. In [4] they also assumes that node stay in the system 10 more rounds after they finish the download and the server is always available. For the flash crowd environment Network Coding provides an improvement of 40% compared to source coding and 200% compared to no coding. When they allow the nodes to leave the system immediately after they finish the download they found in [4] that only 40% of the nodes finished their downloading when source coding was used and only 10% of the nodes finished downloading when no coding was used.

V.DELAY TOLERANT NETWORK (DTN)

Delay Tolerant Networks (DTNs) are occasionally connected networks that suffer from frequent network partition. In [17] they have mentioned that, intermittent connectivity in Internet causes loss of data, so DTN support communication between intermittently-connected nodes using the store-carry-forward routing mechanism. DTN overcome the problems associated with intermittent connectivity, asymmetric data rates, and high error rates by using store-and-forward message switching [9].

VI. PEER-TO-PEER FILE SHARING IN DTN

1. Cooperative File Sharing in Hybrid DTN: In [17] they have mentioned two important implementation issues in a DTN environment: cooperative file discovery and cooperative file download. In the proposed scheme in [17], each node runs a file discovery process and file download process. In this scheme large file is divided into pieces of 256KB. They also propose that each file is associated with metadata that contains information about the file including URI (Uniform Resource Identifier). For file discovery in their [17] scheme, metadata are distributed earlier and in larger amounts and it also stores in a node for longer period of time than files.

They in [17] proposed two methods for file discovery 1. Cooperative File Discovery and 2. TIT-FOR-TAT File Discovery. In cooperative file discovery nodes try their best to send metadata queried by other node. In tit-for-tat file discovery they have provided incentive mechanism. They weigh metadata by the sum of the credits of the nodes requesting metadata.

2. Bluetorrent : In [18] they have created pure peer-to-peer protocol which enables file transfer among mobile nodes using Bluetooth. BlueTorrent shares contents by using file swarming, mainly due to the limited bandwidth and the short contact duration.

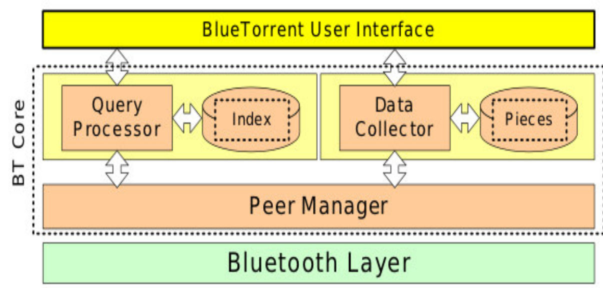

Figure 3: BlueTorrent Architecture [18]

Here in BlueTorrent, Peer manager module manages physical neighbors from among which it tries to choose the best peer. It uses node distance to evaluate the contact duration with a neighbor node. BlueTorrent is equipped with lightweight database so query processor module will be used when it tries to find out the required content BlueTorrent shares contents by using file swarming. Each node has a bitmap of the available pieces for efficient piece reconciliation. Whenever a connection is available, peers first exchange their bitmaps to locate missing pieces through simple bit operations. The size of a typical bitmap is very small and the related overhead is negligible. The size of a piece is selected based on the characteristics of the Bluetooth bandwidth and mobility patterns.

3. A Delay/Disruption Tolerant Solution for Mobile-to-Mobile File Sharing (M2MShare): M2MShare [20] uses Bluetooth to create a Peer-to-Peer overlay network and uses node mobility to reach data content on other local disconnected networks. M2MShare works on store-delegate-and-forward model. Here a peer delegates an unaccomplished task to other peers in the overlay network. M2MShare [20] dynamically establishes forward routes along the destination path by exploiting social relations existing between peers users. This is done by limiting delegations only to frequently encountered peers, which users can pass on by the same geographical location at the same time frequently enough. In [20] the history of previous encounters is then used as heuristic evaluation of whether a peer is a good candidate for delegations. This allows assigning tasks only to nodes that we should meet again in the future, so they can return the result of the task back to us. M2MShare [20] uses an asynchronous communication strategy in which a client peer, in search for a file, can delegate to another peer, a servant, the task of searching for the file and returning it to the requester. Delegation system is at the root of M2MShare [20]. These permits widely extending the area of where to look for the searched file, in a network composed of spread out and poorly connected nodes.

They in [19] and [20] implements protocol stack providing following modules. 1. Search Module 2. DTN Module 3. Transport Module 4. Routing Module and 5. MAC Module.

VII. CONCLUSIONS AND OPEN PROBLEMS

In this paper we have reviewed a peer-to-peer file sharing scheme without network coding, with sparse network code and with network coding. Comparatively the advantages of network coding can be summarized as follows. (a) Scalability. The total available bandwidth is also increases with increase in the network size. (b) Efficiency.

The receiver can always recover the original message. (c) Reliability and Resilience. The redundant links improves the reliability (d) Topology awareness. The PPFEED approach in [12] shows that the topology clustering schemes can greatly reduce link stress and improve throughput. Scheduling of content propagation in the overlay network is much easier by using network coding for distributing large files [4].

Peer-to-peer file sharing in Delay Tolerant Networks has its own challenges. Benefits of network coding in peer-to-peer file sharing in traditional networks are well understood. So, network coding based peer-to-peer file sharing for Delay Tolerant Networks is a promising approach that should be explored.

In Network coding based demand driven resource distribution in peer-to-peer networks, efficient mixing of content chunks based on demand pattern is likely to improve performance significantly [1].

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