CHAPTER 2
LITERATURE REVIEW

There have been several proposals to implement network coding in P2P network for a large scale content distribution in the recent years. The research articles and various mechanisms related to a large scale content distribution and use of network coding for a large scale P2P multimedia content distribution are surveyed and a detailed discussion is presented in this chapter.

2.1 CONTENT DISTRIBUTION APPROACHES

CDN is called either Content Delivery Network or Content Distribution Network. It helps to distribute the large scale multimedia contents across the web. In a typical web host, all the files are located centrally within a web server and delivered from there on demand. Therefore the site load time depends upon the capability of the server. CDN system keeps the copies of the large scale content at different servers which are located across a global network. These networks are made up of a number of dedicated servers which work as disseminated hosts of the contents particularly the static contents such as images, videos, audio, CSS files etc. Users are offered with contents from the servers located at the nearest point of occurrence. The host selection is done based on IP address of the users (Kim & Ryoo 2010).
2.1.1 Advantages of CDN

Some of the advantages of Content Delivery Network are listed as follows:

1. It reduces the resources usage of the user’s parent host, since the bandwidth consumption media and theme contents are offered through CDN.
2. It decreases connectivity latency due to the nearby located distributed servers.
3. Bandwidth can be saved. As the media and theme contents are provided from the CDN servers, it will save the bandwidth of the central server.
4. It decreases bounce rate. Bounce rate is proportionate to the user’s satisfaction. Usually people stay away from a sluggish loading site.
5. It increases the life of web hosting plan.

2.1.2 Types of CDN

Content Delivery Network is centrally classified into three different classes namely: P2P CDN, Push CDN and Pull CDN.

2.1.2.1 P2P CDN

This type of approach uses the P2P protocol. Big companies like AT&T and some nonprofit organizations utilize P2P system for content distribution. In this system no caching is involved. Here users are also the part of the CDN. The users not only access the content, but also share the parts of the contents with others. While downloading the contents, they do upload also without disturbing the normal browsing experience. Because of less hardware and resources usage, several CDN providers offer their P2P service at free of cost. PPS tv, PeerCast, Freecast etc are a few examples of P2P CDNs.
2.1.2.2 Push CDN

In these kinds of CDNs, the contents are physically pushed to the CDN servers. Those servers operate as secondary servers to the central server. Here, contents are physically located at the CDN servers. Central server obtains the contents and pushes it into the CDN servers. Amazon Cloudfront is an example of this kind of technique. If you have a relatively static site with large files to download, Push CDN is the best choice. Push CDN system is also called Hosted CDN system.

2.1.2.3 Origin pull CDN

Origin Pull CDN mechanism is totally different from the Push CDN technique. Here, the large scale contents are located in their respective web servers only. There is no physical uploading of contents to the CDN servers in this technique. Here, the CDN draws files from the central servers and stores it. As per the user requests, instead of distributing files from the central server, the contents will be distributed from the cached copies of the nearby CDN server. The CDN will maintain the contents until it expires. Pull CDN is also called a Relayed CDN. This technique is the most suggested one for WordPress blogs. But if you don’t want to maintain your contents in your central server to save the disc space, then you have to go for Push CDN. An average or poor performance to the first requesting user is the main disadvantage of Pull CDN. For the first user who attempts to access the content, the CDN needs to query the original server, pull the content and serve the user. This process takes a little bit time, but once the content is cached, it will be served from the CDN servers. But it can be controlled by setting the content expiration time. Origin Pull CDN can further be classified into two different categories. They are: Full Site Content Delivery and Partial Site Content Delivery.
2.2 MAJOR CLASSES OF P2P SYSTEMS

Traditionally, there are two different classes of P2P network which have been used in practice, such as structured and unstructured P2P networks. Structured P2P networks arrange their link structures around metric-spaces like DHTs, whereas in unstructured networks, the nodes are often organized around graph-theoretic properties that provide opportunity to devise algorithms with probabilistic behavior (Ranjan et al. 2006). One more P2P model is combination of both structured and unstructured network, called hybrid model.

2.2.1 Unstructured P2P Networks

Unstructured P2P networks don’t require any particular structure on the overlay network by design, but rather are created by nodes that arbitrarily form connections with each other (Jin & Gary 2010). Gnutella, Gossip (Deb et al. 2006), and Kazaa are examples of unstructured P2P protocols. Since there is no structure globally imposed upon the network, the unstructured networks are simple to construct and they allow for localized optimizations to diverse regions of the overlay network. The function of all peers in the network is similar and the unstructured networks are extremely robust in the presence of high rates of peer churn in network. However, the main restrictions of unstructured networks also happen from this lack of structure. In particular, when a peer wants to locate a desired piece of data in the network, the search query should be flooded throughout the network to identify as many peers as possible that share the data. Flooding causes a high amount of signaling traffic in the network and it also uses more CPU/memory. It also makes sure that search queries are always determined. Furthermore, as there is no connection between a peer and the content managed by it, there is no assurance that flooding will identify a peer that has the desired data. In Figure 2.1, unstructured P2P network is depicted where the nodes are not maintaining any structure.
2.2.2 Structured P2P Networks Model

In structured P2P network model, the overlay is arranged into a particular topology, and the protocol assures that any node can efficiently search the network for content or any kind of resource. Distributed hash table (DHT) is the most common implementation of structured P2P network. The ownership of content to a specific peer is assigned by using a variant of consistent hashing. This makes peers to find resources on the network by using a hash table implementation. Any node in the network can efficiently retrieve the value related with a given key. In order to route traffic through the network efficiently, nodes need to maintain lists of neighbours that are suitable for a particular criteria. This makes P2P networks less robust in the presence of high rate of churn. BitTorrent’s distributed tracker, the Kad network and the Coral Content Distribution Network are the some of the distributed P2P networks that use DHT implementation. In Figure 2.2, DHT implementation of P2P network is represented. Each node retrieves the content related to a given key like file 1 which is associated with key value 1234 in Figure 2.2.
2.2.3 Hybrid P2P Networks Model

Both peer-to-peer and client-server models are combined in hybrid models. In hybrid model, there is a central server which helps peers to find each other in the network. Spotify is an example for a hybrid model. There are different kinds of hybrid models, all of which make trade-offs between the centralized functionality offered by a structured server/client model and the node equality afforded by the pure P2P unstructured networks model. Since hybrid P2P model combines the features of both pure structured and unstructured P2P network model, it offers better performance than either traditional client-server model or P2P network model. The different types of P2P network model are depicted in Figure 2.3.
2.3 IMPACT OF REDUNDANT DATA TRANSMISSION IN P2P NETWORK

Peers in pure P2P network select blocks to be downloaded in a random and distributed manner based on their own view that these blocks are rare in their neighbourhood (Fan et al. 2009). Without having a global knowledge about the network, when there are many downstream links to a particular peer, some blocks are downloaded several times by upstream peers on different paths. It results in lack of new information flow coming to the downstream peer (Guo et al. 2005).

The downstream peer cannot use its full downloading capacity due to downloading of same copies of content multiple times on multiple paths. This duplication phenomenon has been described in many articles (Mundinger et al. 2008, Chen et al. 2012). In this section, explanation is given about how much duplication a given node generates, which is the basis for the proposed node selection problem in chapter 4. A loop free link from peer j to peer k is a sequence of nodes starting from j and ending at k in which two adjacent peers are connected by a link. A flow on a path from peer j to k is a mapping L→ M+.
which matches to capacity constraint of each link and flow preservation at each node on the link.

The total number of blocks available at peer j by time $t$ is represented as $T(B_j)$. Each peer on one path does not know which blocks have been chosen by peers on the other path. Therefore, it is assumed that the blocks are selected randomly. $b_{1t}$ blocks are chosen from $T(B_j)$ to transmit on link 1, and likewise, $b_{2t}$ random blocks are transmitted on link 2 by time $t$. The number of redundant block distribution on those two paths is $\frac{b_{1t}.b_{2t}}{T(B_j)}$

The number of useful or innovative blocks from peer j which are sent to peer k at time $t$ is defined as

$$I(t) = b_{1t} + b_{2t} - \frac{b_{1t}.b_{2t}}{T(B_j)}$$  \hspace{1cm} (2.1)

$R_j$ is the rate at which blocks flow in to node j, the number of blocks available at node j at time $t$. $T(B_j) = R_j.t$. The effective throughput from peer j to peer k is defined as

$$\text{Eff}_T = \frac{I(t)}{t} = b_{1} + b_{2} - \frac{b_{1}b_{2}}{R_j}$$  \hspace{1cm} (2.2)

The effective bandwidth can be obtained by generalizing the equation 2.2 where there are $n$ links connecting peer j and peer k.

$$\text{Eff}_T = b_{1} + b_{2} + \ldots + b_{n} - \frac{b_{1}.b_{2} + b_{1}.b_{3} + \ldots + b_{n-1}.b_{n} + b_{1}.b_{2}.b_{3} + \ldots + b_{n-2}.b_{n-1}.b_{n} \ldots \ldots \ldots \ldots \ldots \ldots (-1)^{n} b_{1}.b_{2} \ldots \ldots b_{n}}{R_j^{n-1}}$$  \hspace{1cm} (2.3)

Due to useless blocks on the links, the effective throughput $\text{Eff}_T$ is smaller than the flows on all the links from peer j to peer k.

$$\text{Eff}_T = b_{1} + b_{2} + \ldots + b_{m} - d$$  \hspace{1cm} (2.4)
Here $d$ is the rate at which redundant data transmission takes place. It is always lesser than zero.

Now the value of $d$ can be found by using the equation 2.3 and 2.4.

$$d = \frac{b_1b_2 + b_1b_3 + \ldots + b_nb_n}{R_j} - \frac{b_1b_2b_3 + \ldots + b_nb_{n+1}b_{n+2} + \ldots + (-1)^n b_nb_{n+1}b_{n+2} \ldots b_n}{R_{j-l}} \quad (2.5)$$

The association between redundant rate $d$ and consisting flows has been observed and they contribute to the development of the coding node selection mechanisms. First, duplication rate is higher with more number of consisting flows. If a certain flow $b_i$ is considered separately and all other flows are fixed, equation (2.5) can be written as

$$d = U_i b_i + V_i \quad (2.6)$$

where $U_i$ and $V_i$ are independent from $b_i$. Equation (2.6) represents the relationship between redundant flow rate and each separate flow from peer $j$ to peer $k$. It is observed that when a given flow rate $b_j$ increases, the redundant flow rate $d$ also increases.

Second, redundant flow rate is higher when there are more amount of flows from peer $j$ to peer $k$. The redundant flow rate and effective throughput with $n$ flows from peer $j$ to peer $k$ are represented as $d(n)$ and $\text{Eff}_j, b_1, b_2, b_3, \ldots b_n$ and $d(n+1)$ are the redundant flow rate when a new flow $b_{n+1}$ is included in the network. It is possible to calculate whether received flow is redundant or not by using the following

$$d(n+1) = d(n) + \frac{\text{Eff}_j(n), b_{n+1}}{R_j} \quad (2.7)$$

which means $d(n+1)$ is greater than $d(n)$.

Hence, it is concluded that

$$d(l) > d(n) \forall l > n \quad (2.8)$$
Here, the relationship between n and d in Figure 2.4 (a) are shown when there are 3 flows b1, b2, and b3 from peer j to peer k. Here it is set in such way that \( R_i = 8 \), \( b_1 = b_2 = 2 \) and \( b_3 \) varies from 1 to 4. In Figure 2.4 (b), \( R_i = 6 \), \( b_1 = b_2 = 1 \) are set and more flows are injected into the network with bandwidth equal to 1 and the number of flows \( n \) from 2 to 6 are changed. By avoiding the
transmission of redundant data flow in the network, higher throughput and shorten download time are achieved. The redundant data transmission happens on multiple delivery links. Hence, it is necessary to optimize the whole system. The system reported in chapter 4 indentifies a set of nodes from which redundant flows slowdown mostly the throughput to other nodes.

### 2.4 MAX FLOW MIN-CUT THEOREM

In optimization theory, the max-flow min-cut theorem states that in a flow network, the maximum amount of flow send from the source to the sink is equal in capacity to the minimum cut. The minimum cut is defined ‘when removed minimum number of edges from the network causes the situation that no flow can pass from the source to the sink’.

Let NW = (P, L) be a network with SN and DN being the source and the destination of the NW respectively. Here P represents nodes and L represents link between nodes. It is directed graph. SN and DN belong to N. The capacity of a link is a mapping C: L \to M, denoted by C_{uv}. It denotes the maximum amount of flow that can pass through link.

A Flow is mapping FL: E \to M, denoted by FL_{u,v}, subject to the following constraints

1. \( FL_{uv} \leq C_{uv} \) for each \( (u,v) \in L \) (Capacity Limit)
2. \( \sum_{u: (u,v) \in N} FL_{uv} = \sum_{u: (u,v) \in N} FL_{uv} \) for each \( v \in V \setminus \{SN,DN\} \)
   (conservation of flows)

The value of flow is described by \([FL] = \sum_{v \in L} FL_{SN,DN}\). It represents the amount of information flow which passes from the source to the receiver. By using network coding scheme, it is possible to achieve the max-flow bound with min-cut throughput. It means the value of [FL] can be maximized with minimum cut.
2.5 NETWORK CODING IN P2P CONTENT DISTRIBUTION

Network coding techniques appeared as promising techniques for application level overlay multicasting and distribution of large scale content. Theoretical results proved that network coding techniques can asymptotically achieve the maximum capacity of a network (Li SYR et al. 2003; Chou & Wu 2007; Wu & Curran 2012). A large body of research has focused on the analysis of the potential benefits of coding techniques for P2P content distribution. Some attempts have been made to extent the P2P content distribution applications with network coding techniques to maximize bandwidth utilization and error resilience. Gkantsidis (Gkantsidis & Rodriguez 2005) used network coding techniques for a large scale content distribution. The randomization introduced by the coding process makes the data scheduling easier. They proved that the expected file average download time and robustness is improved with the help of network coding techniques. They made a comparison between traditional random and source coding techniques and network coding techniques and showed that the NC approach requires lesser amount of time for each peer to download the entire content. An Avalanche proposal by Microsoft is the relevant result to make use of network coding for content distribution (Yeung 2007). It divides the content into multiple chunks and generates the coded block by using RLNC. Then the coded block will be sent to its neighbours along with randomly generated coding coefficients. These coding coefficients are used by receiving peer to decode the original content. Several researchers concentrate on reducing the coding complexity of network coding techniques. Generation based network coding has been proposed to reduce coding complexity (Shojania & Li 2007). According to this approach, the sender may select a segment or generation in a sequential order, and then transmit a new encoded block in the corresponding segment to the receiver. The unlucky combination problem occurs when RLNC is used.
Downloader- Initiated Random Linear Network Coding (DRLNC) is used to solve the above said problem in P2P File sharing system (Nan Wang & Nirwan Ansari 2011). Upload complete is the performance metric. It has been taken into consideration to analyze the proposed system. Upload complete means “how many rounds does the network take for all the peers to obtain the whole information”. In this scheme, all the peers need to share their buffer map to their neighbours frequently. The chunked network coding system called Swifter (Xu et al. 2008) was introduced in 2008. It is a pull-based P2P content distribution system. It consists of mainly five different components. They are neighbour manager, segment scheduler, an encoding and decoding module, a dependence checker, and a buffer-map manager. Improved version of this system was introduced in 2011 and it is referred to as I-swifter. Along with the basic components of Swifter, I-swifter (Jinbiao Xu et al. 2011) introduced additionally two more components called requests reducer – restrict the unnecessary request transmission from any peer to the serving peer, and an encoding vectors reducer - eliminates the transmission of encoding vectors. The following graph in Figure 2.5, shows the performance comparison made in (Gkantsidis & Rodriguez 2005). They made a comparison among the source coding, random selection and network coding approaches for large scale content distribution and the result shows that network coding approach outperforms both source coding and random in terms of download time. This graph also shows that network coding reduces the failure rate.
It is noted that conventional network optimization aims to maximize information flow by utilizing as much link capacity as possible. At the same time, network coding begins with the assumption that full link capacity utilization has already been achieved wherever possible and then attempts are made to further increase the network throughput at the receiver by performing coding at intermediate nodes (Joon & Won 2010). Although network coding may be performed at all the nodes in some relevant literature, an interesting observation is that a maximum download rate can be achieved by performing the coding operation at a relatively small portion of the network (Xing H et al. 2010). Though random network coding emerges as a promising alternative to the traditional methods till date in theoretical perspective, its benefit in real-world content distribution systems have not been examined fully with respect to a number of significant performance metrics such as average download completion times and peer dynamics (Fragouli & Parker 2006). Hence, a question is raised: which nodes in the network have to carry out coding operations or how does one use most of network capacity at a nominal cost with respect to network coding resources. In response to this question, a minimal set
of nodes need to be selected to carry out coding operation and this has been proved to be a NP-hard problem.

The simple operation (XOR operation) to combine the packets in the network code based distribution has the advantage of encoding and decoding the packets faster (Fragouli et al. 2008). However, encoding packets with simple operation over GF(2^q) has two main restrictions. First, only the undelivered native packets with distinct intended peers can be encoded together. Hence, the potential coding opportunities cannot be fully utilized. Actually, the undelivered native packets with common intended peers also have the potential to be coded together by more common coding operations for improving transmission efficiency. Second, the search for the best possible set of undelivered packets to code is very complex. It is also NP-complete problem. In this thesis, the proposed systems are evaluated with traditional system by giving more importance to the download time and computational complexity. These two are very important performance indicators for network code based P2P content distribution.

2.5.1 Performance Indicator

Download time

The best possible performance indicator in P2P and Client-server content distribution system is that how long one can take to finish its download. In order to find the answer for this question, one has to measure the time between the start and finish of a download. With a client-server system, the lowest possible download time can be measured from the size of the downloading file and the available bandwidth to download. But in case of P2P network, the files are divided into fragments and spread through the network. There is a time delay between the broadcast of a fragment by the server and the reception of that fragment by all other peers in the network. This spread delay
calculation is very complex and it is further complicated when the dynamic network is considered.

The bandwidth used to download is closely related to the download time $T$ as

$$FS = \int_0^T B_u dt$$  \hspace{1cm} (2.9)

Here $F$ represents the size of the file and $B_u$ represents bandwidth used to download. It is possible to have the highest possible available bandwidth with $B_e$, that is effectively available bandwidth to any node in the network. The bandwidth efficiency can be defined as the ratio between bandwidth used and effective bandwidth. Such as

$$B_{ef} = \frac{B_u}{B_e} \times 100\%$$  \hspace{1cm} (2.10)

$V_l$ represents the number of innovative vectors and $V_T$ denotes total number of vectors, received in the download time $t$. To measure the performance of the nodes in the P2P network where network coding is used, the same performance is used as an indicator. The used bandwidth is compared with the effectively available bandwidth to send the coded packet. The used bandwidth is

$$B_u = \frac{V_l}{t}$$  \hspace{1cm} (2.11)

and effectively available bandwidth $B_e$ is

$$B_e = \frac{V_T}{t}$$  \hspace{1cm} (2.12)

Then bandwidth efficiency is calculated by using both $B_u$ and $B_e$ as follows

$$B_{ef} = \frac{B_u}{B_e} = \frac{V_l}{V_T}$$  \hspace{1cm} (2.13)
Computational complexity

To recover the original packets from the received global encoding vectors $E_j$, and information vector $I_j$, one should make the left part of the matrix into the reduced echelon form using row operations. One makes use of the Gaussian elimination algorithm for this process. This algorithm considers the rows $E_j$ in order of arrival. The non-innovative rows are reduced to zero. In this way, it is possible to identify whether received vector is innovative or not after its arrival. The complexity of a coding algorithm is measured as the number of required standard operations to perform the coding operation. The first received row is in echelon form so need not perform any standard operations. After receiving the second row, there is a need to perform subtract and multiplication operation with first row to bring it in echelon form. It requires $(L_n+1)$ standard operations, where $L_n$ represents length of the information vectors.

2.6 ISSUES TO BE ADDRESSED

This section addresses the issues that are associated with the existing content distribution approaches. These issues are discussed in two perspectives: (i) Issues in P2P system for content distribution approach, and ii) Issues of network coding for P2P content distribution approach.

2.6.1 Issues in P2P System for Content Distribution

Movie file distribution is not the only application that requires a large volume of content distribution. Applications such as sharing of huge scientific data or bioinformatics databases among organizations require low cost and efficient solutions, and they face the same problems. P2P systems can offer low cost and scale free solution for content distribution. But, the focus of most P2P technologies, including Chord, CAN, Pastry, etc., had been put on lesser complex content mapping mechanism and efficient search mechanisms. Many of these applications are efficient while distributing small files such as MP3 or
images, which are a few Megabytes in size. This is because the searching time is necessary to the overall performance, and the time required to send the data is short when compared to the large files. For large scale contents like multimedia files or scientific data sets, the effectiveness of the searching process turns to be negligible issue to the overall performance, whereas the data transfer efficiency becomes the determinant of the distribution efficiency. Here, some of the issues related to P2P system for content distribution are discussed.

**Peer dynamics - Churn**

The independent arrival and departure of peers is called churn. It is an inherent property of P2P network. Any peer can join or leave the network when the user wants to begin or depart the application (Izhak et al. 2012). For a given cooperative characteristics of P2P system, the intermittent links between peers may lead to severe performance degradation with respect to file downloading time. Therefore, the user driven dynamic participation of peer should be considered when analyzing the performance of P2P system.

**Free rider**

A free rider is a peer who gets a resource such as block of content from other peers in the network without providing any to others in a selfish manner. This activity leads to a tangible level of unfairness to the rest of participant peers who contribute to the network (Amad et al. 2013). If more number of users is free riders in the network, the download performance will degrade for the peers who do contribute. A considerable performance degrade, may make some contributors to depart the network altogether, which worsens the situation further for the remaining peers. It is a major threat to the performance of P2P system (Zhao et al. 2012). Therefore, it is necessary to have a suitable mechanism to find and punish the free riders in the network (Manoharan & Ge 2013).
Bandwidth issue

The heterogeneity of peer bandwidth critically impacts the performance of the entire network and the individual peer. There are two reasons for the diversity of peer bandwidth. Firstly, there is a major heterogeneity of link access capacity. Measurement results taken from (Lo Piccolo & Neglia 2004) show that 8% of users are connected by using modem with speed of 64 Kbps or less, 60% having broadband connections like DSL, cable, T1, T3, 30% using very high bandwidth with 3 Mbps connections. Low bandwidth connections can directly degrade the peer’s downloading experience. There are several bandwidth allocation strategies proposed to enhance the performance of P2P network. For example, to enhance the incentive methods of BitTorrent P2P network, different bandwidth capacities should be allocated to peers based on their contributions. Peers who offer more services to others will be provided with a higher download priority and more bandwidth when compared to other peers who offer less service. The wide spread use of P2P file exchange makes congestion and performance degradation of today’s Internet. The traffic control strategies coping with extreme bandwidth utilization by P2P traffic are implemented on the ISP gateway, and they considerably affect the download performance of subnet users. An efficient incentive bandwidth allocation mechanism to prevent free rider activities can encourage seeds to continue in the network longer, and may also influence the peer churn.

Efficient overlay network construction under peer churn

Construction of efficient overlay network influences the performance of P2P network. The objective is to arrange the participating peers into a logical topology that should infer the underlying physical topology. The construction of non suitable overlay topology leads to an extra overhead and reduces the system performance drastically. The overlay construction should be scalable and reliable.
2.6.2 Issues in Using Network Coding for P2P Content Distribution

P2P networks represent one of the most promising platforms to use network coding, because end hosts on the Internet called peers, have the computational capability to carry out network coding. They are not restricted by existing Internet standards that manage most network switches at the core of the Internet. Hence, a network coding based P2P content distribution system has been introduced in recent years. It generates the coded packet at random to make the content sharing simple and more effective. Most of the traditional P2P content sharing systems implement a random or a rarest piece of transmission first strategy to avoid duplicate in transmission same packets and occurrence of rare piece in the network. Network coding technique can solve this problem in a simple manner. But, some research papers in the recent years demonstrate that network coding produces unnecessary overhead of encoding as well as decoding delay and transmission of additional extra message overhead. These make the performance of network coding to be not better than other systems that are not adapting to network coding mechanism (Chang et al. 2010). In this section, some of the challenging issues and open problems of network coding approach for P2P content distribution are described.

Encoding and decoding complexity

Each peer needs to perform arithmetic operations over finite fields in order to generate the coded packets. After receiving coded packets, the peer needs to check whether a packet is innovative one or not and also to further code and forward the data or decode it. The peer which performs the coding operation has to do the following:

- \( O(n^2) \) operation in \( F(2^q) \) for linear combining of packets within each generation of size \( n \).
- \( O(i^2) \) binary operations for inversions and multiplications over \( F(2^q) \).
• $O(n^2)$ operation over $F(2^q)$ for matrix inversions by using Gaussian elimination method.

Security

While performing the coding operation, several packets need to be combined. It makes the overall system more vulnerable to attack from malicious peer in the network. Since multiple packets are combined with the coded packet, a single undetected corrupted packet can spread infection very fast. Hence, it is necessary to have techniques for checking whether the received packets are not corrupted. In the recent P2P system model, integrity of the packets is ensured by using cryptographic techniques. One approach is to use special homomorphic hash function to generate hash code for each coded packet with low computation complexity (Krohn et al. 2004). Gkantsidis and Rodriguez (Gkantsidis & Rodriguez 2006) also introduced mechanism to compute checksum to secure each coded block, called secure random checksums (SRC). They claimed that SRC is very efficient and highly secure.

Peer heterogeneity

The nodes in the most of distribution systems have different capabilities with different service components. They differ in terms of link capacity, computational power and required content quality. Since most of the peers access the network through low Internet connections, they are slow. Some users are connected to network through Broadband connection. They have higher capacity and are faster in the network. In a P2P network, fast node can have more neighbours to make use of their extra capacity. They may leave the system quickly after downloading the entire file within a short amount of time span. Network coding mechanism is expected to perform well in this environment.
Some of the other problems

Several open problems exist when a network coding is used in P2P network. Several researchers have given solution for the problems but still they need optimal solutions for implementing the network coding in real network. Some of the problems are listed here

- Efficient mixing of packets based on demand is likely to improve the performance of network code based content distribution in P2P network.
- Generation size, finite filed size and type of code are influencing parameter for network code based content distribution. The impact of these parameters needs to be analyzed and the optimal result for those improve performance of network coding has to be found (Angelin et al. 2014).
- Removal of packets from the network once they are delivered is a challenging issue in a network code based flooding since a delivered packet may be a part of many coded packets in the network.

2.7 RANDOM LINEAR NETWORK CODING (RLNC)

If the network topology is known, then the local coefficients leading to optimal performance gain in polynomial time (Jaggi et al. 2005). In a P2P environment, it is not likely to happen. The topology is not known at all times, and recalculating them each times makes the topology change. It would require a lot of time to gather. To solve this, Random network coding has been proposed by Chou et al (Chou et al. 2003). According to this approach, the coefficients of the local encoding vectors are randomly chosen to calculate the corresponding global coefficients and send those together with the information vector. Then the probability that a non-innovative vector is generated depends on the field size $|F|$ as (Deb et al. 2006).

$$ P \text{ (non innovative vector)} \leq \frac{1}{|F|} $$
If an appropriate field size $F$ is selected, then this probability is negligible. A small field size such as $2^8$ is suffices. It has been proved in simulation results (Wu et al. 2004). As random network coding offers good flexibility with respect to topology changes at the cost of some overhead, this is the coding type of choice for most of the network coding content distribution systems.

RLNC is a simple yet powerful coding method. It achieves close to best possible throughput by using a decentralized algorithm in broadcast transmission schemes (Shrader & Ephremides 2012). Nodes can send random linear combinations of the packets they receive, with coefficients selected from a Galois field (GF). If the field size is large, there is a probability that the recipient(s) will get linearly independent combinations of coded packets. It should be noted that, even though random linear network code has excellent throughput performance, if a recipient gets an inadequate number of coded packets, it is particularly unlikely that they can decode any of the original packets from the coded packets. This can be solved by sending additional random linear combinations of coded packets until the receiver gets enough number of coded packets.

RLNC provides three unique benefits to improve the performance of P2P content distribution:

1. It significantly increases the information contained in each block, as it sends a random linear equation which may have information about each block of the file. This makes a high probability of linearly independent to already receive blocks in the receiving ends. It leads to a more efficient content distribution process.

2. Coding also significantly simplifies the issue of selecting the most appropriate block to download, by blindly distributing linear combinations of all existing blocks to downstream peers.
3. It has been theoretically proved that network coding improves the resilience to dynamic situations of peer arrivals and departures in P2P network. Because network coding eliminates the necessity of finding rare blocks, the problem of losing these rare blocks when peers leave the network is no longer an issue.

Based on the literature, there are three significant problems identified in RLNC (https://en.wikipedia.org/wiki/Linear_network_coding):

1. High decoding computational complexity because of using the Gauss-Jordan elimination method
2. High transmission overhead because of adding large coefficient vectors to coded packets
3. Linear dependency among coefficients vectors which can increase the number of non innovative coded packets

2.8 NETWORK CODING IN OTHER NETWORKS

Network Coding in Wireless network

COPE and MORE, two wireless networks which utilize network coding. Each of these insert a layer between the IP and MAC layers which contain important information used for encoding and decoding packets. Their performance gains are mentioned, and each has the potential to outperform traditional wireless routing networks. Analog NC, which is network coding at a physical level, which encourages packet transmission collisions.

Network Coding in Mobile and Wireless Sensor Networks

Mobile networks present an overt but rewarding difficulty for network coding implementations to overcome. In comparison to a desktop machine or laptop, cell phones have significantly smaller battery life and little computational power, which are two main resources network coding needs in order to better the performance of a system. But, broadcasting data to several
mobile devices could show to be a compelling reason to choose network coding with the propagation of data. Mobile networks in developing countries can also benefit from network coding Reliable Data Transfer Scheme (RDTS), a wireless sensor network created to reduce energy consumption during the transmission of data from the sensors to the central servers the network.

**Network Coding in Cloud and Distributed Storage**

Network coding mechanism can also be used for Cloud storage systems. Traditional storage networks implement RAID-5 or RAID-6, which both disperse incoming data, and encoded partitions created, onto several repositories. RAID-6 will be the foundation in contrast to Simple Regenerating Codes, also abbreviated to SRC. In addition to NC-Cloud, another form of network-coding storage which performs similarly to a linear network coding scheme is introduced. Several articles discuss concepts or include implementations which could improve the performance of network coding in Cloud and distributed storage networks. For added security during storage, a key could be provided during transmission of data from a user to the repository. NC-Audit, a network coding repository system emphasizes secure data access.

**NC-Flooding: distributed systems Using Network Coding**

The flooding algorithm, commonly used in distributed systems, is modified to incorporate network coding principles. The routing packet information and protocols are mentioned. A node count network operation is applied to the NC-enhanced flooding protocol, and theoretical analysis is also done. Flooding in distributed systems broadcasts a message across all nodes in a network. The distributed system must be strongly connected, meaning there must be at least one path from and to all other nodes in the system. In most distributed systems, a singular message or message type floods the network for a finite number of rounds.
2.9 SUMMARY

From the extensive literature review, (i) it is identified that most of the existing methods are not concerned about controlling the redundant traffic flow and it will unnecessarily increase the network load and reduce the network throughput in P2P network. (ii) It is clear that the traditional method of network coding is an unstable process if it is not used carefully in P2P network. Therefore, various modifications are needed in the traditional method of network coding to exhibit stable behavior and (iii) To date, though random network coding emerges as a promising alternative to the traditional methods in theoretical perspective, it’s benefit in real-world content distribution systems have not been examined fully with respect to a number of significant performance metrics such as average download completion time and peer dynamics.