International Journal of Research (IJR)
e-ISSN: 2348-6848, p- ISSN: 2348-795X Volume 2, Issue 10, October 2015
Available at http://internationaljournalofresearch.org

A survey enabling data integrity protection in regenerating coding based cloud storage

S.Manikanth #1& N.Venkatadri #2

#1 PG Student, Dept. Of CSE, SKR College Of Engineering And Technology, Kondurusatram, Manubolu,Nellore,AP

#2 Assoc. Professor, Dept. Of CSE, SKR College Of Engineering And Technology, Kondurusatram, Manubolu,Nellore,AP

Abstract-

Cloud computing refers to the various remote systems inter connected through the internet. We can outsource data, software, and infrastructure from the cloud environments. Once we outsource storage there is a possibility for the data for the data to get corrupted or be hacked. The general solution is to stripe the data across multiple servers. In the setting the repair traffic will be high and the fault tolerance will be low. In order to improve the storage efficiency and the repair traffic regenerating codes have been use. In this paper we will discuss about the various regenerating codes that have evolved from time to time.

Index Terms- Erasure coding; regenerating codes; cloud storage; I/O overhead.

I.INTRODUCTION

Due to the decreased storage pricing and the decreasing bandwidth, leading it firms implement software as a service(saas), infrastructure as a service(iaas) inside their data centers. This new paradigm of providing services and infrastructure is called cloud-computing. The volume of data generated and stored by the cloud users is rapidly increasing exponentially every day. In order to maintain the massive volume of data being stored, cloud storage systems must be scalable. In this case, it becomes a major challenge for cloud storage systems to maintain data integrity due to large volume of data and the large number of disks used. Even though the number of disk failures is small within a data center, it may increase due to the addition of the large volumes of disks. Moreover other systems in the data center may cause outages of data, making data unavailable or even get lost.

To guarantee the integrity of data stored in the cloud, it is natural to store replicas in multiple cases, such that data loses can be managed when there is at least one replica running. However, replicas can significantly reduce the storage efficiency. For example, if data are stored with 3-way replication, the effective storage space can be no better than 1/3 of the total consumed storage space. If the design objective is to maximize the storage efficiency without sacrificing the ability to tolerate disk failures, the storage system should store data encoded by erasure coding. Before the emergence of cloud computing, erasure coding has long been proposed to detect or correct errors in storage or communication systems. For example, RAID 6 can compensate for at most 2 disk failures by parity coding, whose storage efficiency is at most 1 – (2/n) where n is the total number of disks. Reed-Solomon codes can provide even more flexibility such that any number of disk failures under a certain threshold can be tolerated. Wual[1], an online secure storage service, uses Reed-Solomon codes to ensure data integrity, by encoding data with Reed-Solomon codes after encryption. However, two main drawbacks conventionally prevent erasure coding from being practical and popular in cloud storage. First, to read or write data, the system needs to encode or decode data, leading to high access latency and a low access throughput due to the CPU limit. Second, though erasure coding stores data as multiple coded blocks, when one coded block gets lost, the system must access multiple coded blocks that are sufficient to recover all the data. This overhead makes the repair with erasure

International Journal of Research (IJR)
e-ISSN: 2348-6848, p- ISSN: 2348-795X Volume 2, Issue 10, October 2015
Available at http://internationaljournalofresearch.org

coding very expensive in terms of both bandwidth and disk I/O overhead. Unfortunately, applications hosted in the cloud are sensitive to the disk I/O performance, and bandwidth is always a limited resource inside the data center since most data centers introduce link oversubscription[2].

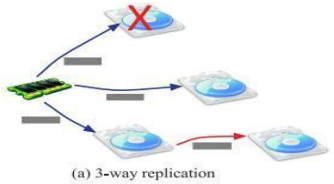
In this paper, we examine recent advances of these coding techniques. Specifically, we introduce coding techniques that optimize the overhead of data repair in the objective of minimizing the bandwidth consumption and increasing the storage efficiency. Due to the high frequency of data repairs and the high repair overhead of convention alerasurecoding, optimizations in both of these two axes fall into the considerations of data repair.

For bandwidth consumption, Dimakisetal[3] proposed a family of regenerating codes. Based on a model inspired by network coding, the repairs of coded data can be modeled into an information flow graph, with a constraint that maintains the ability to tolerate disk failures. Based on this model, an optimal tradeoff between storage and bandwidth can be derived, such that given the amount of data stored on the disk; we can obtain an optimal lower bound of the amount of data that should be transferred during the repair. In the tradeoff curve, two extreme points attract much more attention than interior points, corresponding to the minimum storage cost and the minimum bandwidth cost, respectively. To achieve these two extreme points, many papers proposed instances of regenerating codes that either constructs randomized codes that maintain the tolerance against disk failures with a high probability, or construct deterministic codes using interference alignment. With the help of deterministic coding, lost data can be repaired exactly, suggesting that we can construct systematic codes to achieve an access latency as low as replicas. Moreover, cooperative regenerating codes make it possible to repair from multiple disk failures with an even lower bound of bandwidth consumption, with the help of cooperation among participating servers. In this paper, we examine the various

II. ERASURE CODING AND ITS PERFORMANCE METRICS

A. Erasure codes in Storage Systems

In a storage system where data are stored on a large number of commodity disks, it is clear that disk failures cannot be considered as just exceptions, but as a rule. Therefore, the storage system has to store redundancy such that when a certain number of disks lose data, data can still be accessible from other disks. For example, the N - way replication, which stores N replicas in N different disks, is able to tolerate at most N - 1 disk failures. Figure 1a illustrates an example of 3-way replication, where the original data are disseminated into 3 different disks and any one disk is able to repair or access the original data. However, N -way replication can only achieve a storage efficiency of 1\N at best. Erasure coding, on the other hand, is able to tolerate the same number of disk failures, yet with a much better storage efficiency. Among erasure coding, Maximum Distance Separable (MDS) codes (e.g., Reed-Solomon codes[4]) achieve the optimal storage efficiency. Suppose that in the storage system, data are organized in the unit of data object, which may correspond to a file or a fix-sized block in different storage systems. Assume that a data object can be stored onto n disks. Given an arbitrary number of k, where k < n, (n, k) MDS codes can guarantee totolerate at most n - k disk failures, i.e., k disks are sufficient to access any bit of the original data. Specifically, the data object is encoded into n coded blocks and are uniformly disseminated into the n disks.



(a) 3-way replication

International Journal of Research (IJR)
e-ISSN: 2348-6848, p- ISSN: 2348-795X Volume 2, Issue 10, October 2015
Available at http://internationaljournalofresearch.org

Suppose the size of the data object is M bits, the size of each coded block should be M\k bits, if we do not consider the metadata of the data object. In this sense, the storage efficiency of MDS codes is at best k\n. Compared to the 3-way replication as shown in Fig. 1b, (5; 3)MDS codes can still tolerate at most 2 disk failures, while improving the storage efficiency by 80%. To access the data object, the system needs to access k different coded blocks (from k different disks) and recover the original data object by the decoding algorithm of the corresponding MDS codes. Apparently, the decoding algorithm incurs additionalaccess latency. To improve the access latency, the storage system can use a cache to store one replica of the original data object as well [5]. Recovering the whole data object for data access may sound reasonable in most cases. However, from the point of view of the storage system, it is totally unnecessary to recover the whole data object if we only need to repair one lost coded block, as what we need is just a very small portion of the data object. Unfortunately, before the appearance of regenerating codes, all MDS codes, to our best knowledge, require to access at least k disks to repair even only one disk, while in the case of replication, to repair one replica we only need to transfer one replica. This requirement can dramatically increase bandwidth overhead in a data center, and significantly affect the performance of the storage system and other applications hosted in the cloud.

B. Performance Metrics

It has been made clear that it is not enough to consider only the storage efficiency and the tolerance against disk failures in cloud storage systems. The performance metrics that should be considered when designing erasure coding for cloud storage should also include:

- *Repair Bandwidth:* To repair failed disk, data stored onthat disk should be repaired in a replacement disk. The server with the replacement disk, called a newcomer, needs to retrieve data from some existing disks. If the servers that host these existing disks, called providers, send out the raw data of their coded blocks, the bandwidth used to transmit the existing coded blocks equals the size of these coded blocks and then the newcomer encodes the received data by itself to generate the lost data. However, if encoding operations

  can be performed both on the newcomer and providers rather than on the newcomer only, a much smaller amount of data can be transferred.

In the pioneering paper of Dimakis et al[3], a surprising and promising result was shown that the bandwidth used in the repair can be approximately as low as the size of the repaired block by encoding operations of providers and the family of erasure codes that achieves the optimal bandwidth consumption during the repair was called regenerating codes.

- *Repair I/O*. Besides bandwidth, another performancemetric in the repair for erasure coding is disk I/O at the participating servers. Specifically, the writing operations are performed only at the newcomer, and the amount of data written should equal the size of the coded block. As the writing operations are unavoidable, what we really care is actually the amount of data read from disks of providers. Similar to the bandwidth consumption, conventional erasure codes will ask for providers to read k blocks in total just to repair one block.

- *Access latency*. Due to the decoding operations, theaccess latency of data

International Journal of Research (IJR)
e-ISSN: 2348-6848, p- ISSN: 2348-795X Volume 2, Issue 10, October 2015
Available at http://internationaljournalofresearch.org

encoded by erasure coding has to be much larger than replicas. However, systematic codes, in which the original data can be embedded into code blocks, are able to maintain a higher storage efficiency than replicas while achieving a low access latency, since we now only need to access the systematic part with no decoding operations. This attractive property of systematic codes comes with a high price that makes the repair much more complex than non-systematic codes, because the repaired data should be exactly the same as the lost data, at least for the embedded original data. Therefore, the deterministic construction of codes must be considered when designing systematic erasure codes for cloud storage.

- *Storage efficiency*. The storage efficiency denotes theratio of the amount of the original data to the actual amount of data stored on disks. In other words, given the same amount of data, with a higher storage efficiency we can use a smaller amount of storage space to tolerate the same number of disk failures. MDS codes achieve the optimal storage efficiency, i.e., given n and k, MDS codes can be constructed such that any k among all n coded blocks are sufficient to recover the original data.)

III.VARIETIES OF REGENERATING CODES

A. Information Flow Graph

To investigate the bandwidth consumption in repairs with erasure coding, Dimakis et al.[3] proposed to use the information flow graph, which is a tool used in the analysis of network coding, as a model to characterize the tradeoff between storage and bandwidth.

As shown in Fig. 2, in the information flow graph, all servers can be categorized as the source, storage nodes, and the data collector. The source denotes the server where the data object is originated. Suppose that the size of the data object is M bits.

After encoding, coded blocks of α bits are disseminated into n storage nodes. Particularly, the source is represented by a vertex and a storage node is represented by two vertices in the information flow graph. The weight of the edge corresponds to the amount of data stored in the storage node. Thus, after thedissemination, all n storage nodes store α bits and any k of them suffice to recover the original data object, suggesting that k$\alpha \leq$ M A virtual vertex called data collector is able to connect to any k storage nodes to recover the original data object. When a storage node fails, a newcomer does not just connect to k available storage nodes, but d storage nodes as providers (d $\leq$ k). Different from

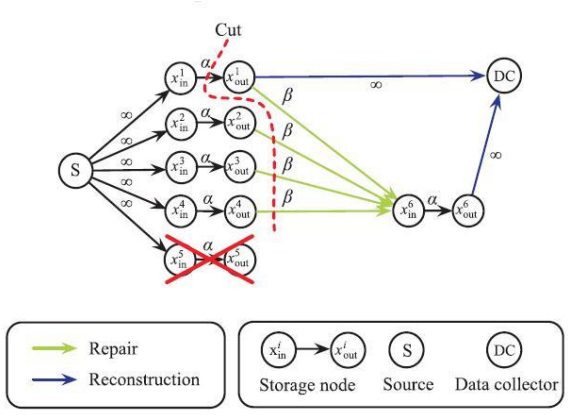


Fig 2: An illustration of the information flow graph that corresponds to (4,2) MDS codes. This figure was firstly shown in Ref. [9].

Conventional MDS codes, the newcomer can receive β bits from each provider, $\beta \leq \alpha$ represented by the weight of the edge between the provider and the newcomer. After receiving a total of $r = d\beta$ bits from providers, the newcomer stores α bits and becomes a new storage node. It is required that after any rounds of repairs, the MDS property that any k coded blocks suffice to recover the original data object always holds. In other words, the data collector can connect to not only the storage nodes that receive data directly from the source, but the storage nodes repaired from newcomers in repairs as well. Besides, the weights of edges attached to the source or the data collector are all set to be infinity.

Therefore, the repair problem in the storage system can be interpreted as a multicast problem in the information flow graph, where the source is

International Journal of Research (IJR)
e-ISSN: 2348-6848, p- ISSN: 2348-795X Volume 2, Issue 10, October 2015
Available at http://internationaljournalofresearch.org

multicasting data to all possible data collectors. It is well known in the multicast problem that the maximum multicast rate equals the minimum cut separating the source from any receivers, and this rate can be achieved through network coding[6]. Thus, it can be proved that the MDS property holds after any rounds of repairs, if the min-cut in the information flow graph is no less that the size of the original data object. By calculating the minimum min-cut in the information flow graph, given d and β we can derive the minimum value ofα, and then we obtain the tradeoff curve between α and the total bandwidth consumption r.

B. Minimum-storage Regenerating codes and minimum-bandwidth regenerating codes

The codes that achieve that the min-cut in the information flow graph equals the amount of the data object is called regenerating codes. Given the tradeoff between storage α and bandwidth r , two special cases of regenerating codes interest us most, which correspond to the minimum storage space required at storage nodes and the minimum total bandwidth consumption in the repair, respectively.

The regenerating codes that achieve the minimum storage in storage nodes is called Minimum-Storage Regenerating (MSR) codes, where$(\alpha_{MSR}, r_{MSR})=(\frac{M}{k}, \frac{Md}{k(d-k+1)})$. Notice that now α equals to the size of coded blocks of conventional MDS codes, and thus MSR codes can be regarded as MDS codes. However, since $r=\frac{Md}{k(d-k+1)} \to \frac{M}{k}$ as $d \to \infty$, MSR codes consume bandwidth in the repair approximately the same as the amount of one coded block, while conventional MDS codes consume bandwidth that equals the size of k coded blocks. In this sense, MSR codes save a significant amount of bandwidth in the repair.

The other extreme points in the tradeoff between storage and bandwidth is called Minimum-Bandwidth Regenerating (MBR) codes, where $(\alpha_{MBR}, r_{MBR}) = (\frac{2Md}{k(2d-k+1)}, \frac{2Md}{k(2d-k+1)})$MSR codes achieve the minimum bandwidth consumption among regenerating codes. Though MBR codes require more storage than MSR codes, the newcomer only needs to receive exactly the amount of data it needs to repair, and the storage and bandwidth both converge to $\frac{M}{k}$ when d is large enough.

To implement regenerating codes, the simplest way is to use random linear coding[7] which is inspired by network coding. Dividing the original data object into k blocks, a coded block produced by random linear coding is a random linear combination of the k blocks. The encoding operations areperformed on a Galois field GF(2^q). As a Galois field size of 2^8 corresponds to a byte in the computer, q is usually set to be an integral times of 8 to make encoding operations convenient. Given any k coded blocks and their coding coefficients, the decoding operations are just solving the corresponding linear system with k unknowns (i.e., original blocks) and k equations. When q is large enough, such as 16 or 32, any k coded blocks can be decoded with a very high probability.

On the other hand, the randomized construction of regenerating codes can suffer from a significant computational complexity, especially when parameters are not properly selected [8]. In additional, by no means the randomized regenerating codes can guarantee to repair data exactly as the lost data. Even worse, even a very large Galois field cannot ensure that any k code blocks are decodable, but only with a very high probability, due to the randomized coefficients. The number of repairs, however, cannot be easily limited, suggesting that after a large number of repairs data integrity cannot be maintained, as the randomness accumulates gradually in coded blocks.

Therefore, it is necessary to find explicit construction of regenerating codes, especially for MSR and MBR codes. Further, it is desirable that the lost block can be repaired exactly given the explicit construction.

C.Exact Regenerating codes

The most important tool used to construct exact regenerating codes is interference alignment, which is initially proposed for wireless communication. The basic idea of interference alignment is that the undesired vectors can be eliminated by aligning them onto the same linear subspace. Figure 3 illustrates how interference alignment helps to achieve exact regenerating

International Journal of Research (IJR)
e-ISSN: 2348-6848, p- ISSN: 2348-795X Volume 2, Issue 10, October 2015
Available at http://internationaljournalofresearch.org

codes.

We suppose that in Fig. 3 data are encoded by (n=4, k=2, d =3) MSR codes, i.e., any two of the four nodes can recover the original file. In each storage node, each coded block contains two coded segments, such as (A_1,A_2) in the failed storage node. To recover A_1 and A_2 , the newcomer contacts 3 storage nodes as providers and downloads half of a coded block, i.e., a coded segment from each provider to achieve the bandwidthconsumption of MSR codes. Notice that each provider owns coded segments containing components of B_1 and B_2 , which are undesirable to the newcomer. To eliminate B_1 and B_2 , each provider can send a segment in which B_1 and B_2 are aligned onto the same linear subspace of $B_1 + B_2$. Clearly,$B_1 + B_2$ can be eliminated as one unknown and A_1 and A_2 can be decoded by solving three equations with three unknowns.

As for exact MBR codes, Rashmi et al.[9] proposed a Product-Matrix construction which is able to explicitly construct (n,k,d) exact MBR codes on a finite field of size n or higher with anychoices of n, k, d if $k \leq d < n$. The Product-Matrix construction produces vector MBR codes such that a coded block contains multiplecoded segments, just like the example shown in Fig. 3.

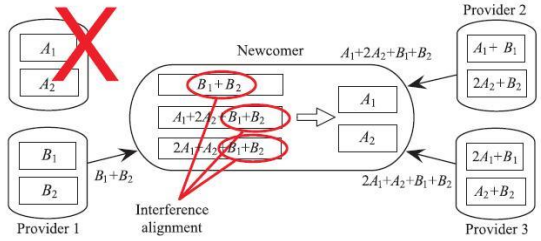


Fig 3: An example of (4,2,3) exact MSR codes. By interference alignment, the loss of (A1,A2) can be repaired exactly since B1 and B2 are eliminated by aligning them onto B1 + B2 in three providers.

As for exact MSR codes, the choices of parametersbecome more complicated. Suh and Ramchandran[10] proposed an explicit construction of scalar exact MSR codes where $d > 2k-1$, over a finite field of size atleast 2(n-k).Rashmi et al[9] improved the choices of parameters such that $d \geq 2k-2$, by constructing exact MSR codes using the Product-Matrix construction, with a larger finite field of size at least n.(d-k+1). In Ref [11], Shah et al. had proved that no scalar exact MSR codesexist when d <2k-3.

Cadambe et al[12]. andSuh and Ramchandran[13] showed that any choices of (n, k, d) could be achieved asymptotically when constructing vector exact MSR codes, as the field size goes to infinity. Constructing regenerating codes on a very large finite field is impractical due to its overwhelming encoding/decoding overhead. Papailiopoulos and Dimakis[14] showed that (n= k +2 , k, d = k+ 1) vector exact MSR codes can be constructed explicitly, combining interference alignment and Hadamard matrices.

Since the exact repair makes much more sense for the systemmatic part than the parity part of exact regenerating codes, we can construct hybrid regenerating codes that only support the exact repair of the systematic part while the parity part is still repaired by the functional repair. Wu[15] constructed the (n,k,d = k+1) hybrid vector MSR codes when $2k \leq n$, where the field sizeis greater than $2^{\binom{2n-1}{2n-1}}$Tamo et al[16] and Cadambe et al[17] both proposed (n,k,d = n-1) hybrid MSR codes for arbitrary n and k.

D.Cooperative regenerating codes

In some storage systems, such as Total Recall[18] ,in order to prevent unnecessary repairs incurred by temporary node departures, the system repairs failed nodes in batch when the number of failed nodes reaches a certain threshold. Hu et al.[19] first found that if newcomers can cooperate, there exist cooperative regenerating codes that achieve a better tradeoffcurve between storage and bandwidth. Still analyzing the min-cut in the information flow graph, Hu et al.[19] showed that $(n, k, d = n-t, t)$ randomized Minimum Storage Cooperative Regenerating (MSCR) codes can achieve the bandwidth consumption of $\frac{M}{k} \cdot \frac{n-1}{n-k}$ with t providers (n-t $\geq$ k). Notice that the bandwidth consumption is independent of the number of providers.

A more general result of the bound of bandwidth consumption is $(n, k, d = k, t = n-k)$MBCR codes. Wang and

International Journal of Research (IJR)
e-ISSN: 2348-6848, p- ISSN: 2348-795X Volume 2, Issue 10, October 2015
Available at http://internationaljournalofresearch.org

Zhang[23] showed that as for all possible values of (n,k,d,t), there exist explicit constructions of exact MBCR on a field of size at least n.
On the other hand, when $d = k \neq n-t.(n,k,d,t)$ scalar MSCR codes can be constructed[20] . Le Scouarnec[24] discussed the construction of exact MSCR codes with some other choices ofparameters when $d \geq k = 2$ .The existence of exact MSCR codes with other values of parameters still remains an open problem.

E.Repair-by-transfer regenerating codes

The regenerating codes we have mentioned above require providers to encode their data to align vectors in a specific linear subspace and the newcomer to encode received data to eliminate undesired components. The arithmetic operations performed on a finite field can be expensive, if the field size is large. Thus, the cloud storage systems will favor the repair-by transfer property that in the repair no arithmetic operations are required at providers. With the repair-by-transfer property, the disk I/O overhead can be minimal since only data needed by the newcomer will be read from providers. Moreover, the storage node then can have no intelligence, such that its functionality can be implemented by hardware with a low cost. Some choices of parameters have been considered to construct the corresponding repair-by-transfer regenerating codes. Shum and Hu[25] and Hu et al.[26\ constructed $(n, k = 2, d = n-1)$ and $(n, k = n-2, d = n-1)$ functional repair-by transfer MSRcodes, respectively. On the other hand, $(n, k = n-2, d = n-1)$ exact MBR codes can be constructed over a finite field of size 2[27] . The existence of exact regenerating codes remains an open problem as for most other choices of parameters. The onlyknown result is that if $d \geq 2$ and $t \geq 2$, any (n,k,d,t) linearexact MBCR codes cannot achieve the repair-by-transfer property[23].

Nevertheless, Rashmi et al.[28] proposed an intuitive graph-based construction of repair-by-transfer exact MBR codes, where any missing block can only be repaired from its direct neighbors in the graph. Fractional repetition codes are employed in the construction such that direct neighbors share the same segmentand the newcomer only needs to receive replicas of the segments from its neighbors to repair itself, where no arithmetic operations are required not only at providers, but at the newcomer as well. It is shown that any $(n, k, d = n-1)$ MBR codes can be constructed uniquely with this method, n > k. Though repair-by-transfer regenerating codes are able to achieve the minimum disk I/O overhead, only some specific choices of parameters have instances of corresponding regenerating codes so far. Nevertheless, cloud storage systems can have a wide spectrum of parameter choices due to their own requirements. Therefore, it is desirable that erasure coding can achieve low disk I/O overhead with a wide range of parameter choices, even if some properties, such as the MDS property or the storage efficiency, will be sacrificed.

F. FMSR (Functionally minimum storage

which a file is striped over n servers using an (n,k)-FMSR code. Each server can be a storage site or even a cloud storage provider, and is assumed to be independent of other servers. An (n,k)-FMSRcode splits a file of size $|F|$ evenly into k(n-k) native chunks, and encodes them into n(n-k) code chunks,

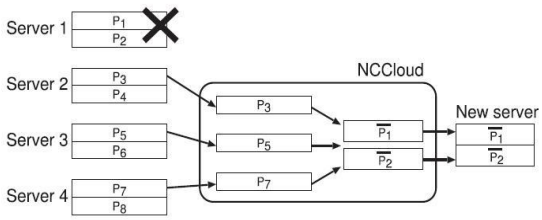


Fig 4:Example of how a file is repaired in (4,2)- FMSR codes.

IV. CONCLUSION

Throughout this paper, we give an overview of the various advances in regenerating codes for cloud storage systems. The design objective

generally transfers from data integrity to resource overhead such as bandwidth consumption and storage efficiency. The exact regenerating codes help to maintain systematic erasure codes in the storage system such that no decoding operations are required to recover the original file. The repair-by-transfer regenerating codes help to achieve a repair process without arithmetic operations on both the newcomer and the providers. The FMSR codes are used to regenerate the data across a multi-server setting and performs a two-phase checking on the new code chunks generated in the repair operation. Flat XOR-codes—erasure codes in which parity disks are calculated as the XOR of some subset of data disks. These advances reduce the bandwidth consumption of the repair operations.

REFERENCES

[1] Wuala,http://www.wuala.com/en/learn/technology, 2012.

[2] M. Al-Fares, A. Loukissas, and A. Vahdat, A scalable, commodity data center network architecture, in Proc. ACM SIGCOMM Conference on Data Communication (SIGCOMM), 2008.

[3] A. G. Dimakis, P. B. Godfrey, M. J. W. Y. Wu, and K. Ramchandran, Network coding for distributed storage system, IEEE Trans. Inform. Theory, vol. 56, no. 9, pp. 4539-4551, 2010.

[4] I. Reed and G. Solomon, Polynomial codes over certain finite fields, Journal of the Society for Industrial and Applied Mathematics, vol. 8, no. 2, pp. 300-304, 1960.

[5] C. Huang, H. Simitci, Y. Xu, A. Ogus, B. Calder, P. Gopalan, J. Li, and S. Yekhanin, Erasure coding in windows azure storage, in Proc. USENIX Annual Technical Conference (USENIX ATC), 2012.

[6] S.-Y. R. Li, R. W. Yeung, and N. Cai, Linear network coding, IEEE Trans. on Inform. Theory, vol. 49, no. 2, pp. 371-381, 2003.

[7] T. Ho, R. Koetter, M. Medard, D. Karger, and M. Effros, The benefits of coding over routing in a randomized setting, in Proc. IEEE International Symp. Inform. Theory, 2003, pp. 442-442.

[8] A. Duminuco and E. Biersack, A practical study of regenerating codes for peer-to-peer backup systems, in Proc. IEEE International Conference on Distributed Computing Systems (ICDCS), 2009, pp. 376-384.

[9] K. Rashmi, N. Shah, and P. Kumar, Optimal exactregenerating codes for distributed storage at the MSR and MBR points via a product-matrix construction, IEEE Trans. on Inform. Theory, vol. 57, no. 8, pp. 5227-5239, 2011.

[10] C. Suh and K. Ramchandran, Exact-repair MDS code construction using interference alignment, IEEE Trans. on Inform. Theory, vol. 57, no. 3, pp. 1425-1442, 2011.

[11] N. B. Shah, K. V. Rashmi, P. V. Kumar, and K. Ramchandran, Interference alignment in regenerating codes for distributed storage: Necessity and code constructions, IEEE Trans. on Inform. Theory, vol. 58, no. 4, pp. 2134-2158, 2012.

[12] V. R. Cadambe, S. A. Jafar, and H. Maleki, Distributed data storage with minimum storage regenerating codes – Exact and functional repair are asymptotically equally efficient, http://arxiv.org/abs/1004.4299, 2010.

[13] C. Suh and K. Ramchandran, On the existence of optimal exact-repair MDS codes for distributed storage, http://arxiv.org/abs/1004.4663, 2010.

[14] D. S. Papailiopoulos and A. G. Dimakis,

Distributed storage codes throughhadamard designs, in Proc. IEEE International Symposium on Information Theory (ISIT), 2011, pp. 1230-1234.

[15] Y. Wu, A construction of systematic MDS codes with minimum repair bandwidth, IEEE Trans. on Inform. Theory, vol. 57, no. 6, pp. 3738-3741, 2011.

[16] I. Tamo, Z. Wang, and J. Bruck, MDS array codes with optimal rebuilding, in Proc. IEEE International Symposium on Information Theory (ISIT), 2011, pp. 1240-1244

[17] V. R. Cadambe, C. Huang, S. A. Jafar, and J. Li, Optimal repair of MDS codes in distributed storage via subspace interference alignment, http://arxiv.org/abs/1106.1250,2011

[18] R. Bhagwan, K. Tati, Y.-C. Cheng, S. Savage, and G. M. Voelker, Total recall: System support for automated availability management, in Proc. USENIX Symposium on Networked Systems Design and Implementation (NSDI), 2004.

[19] Y. Hu, Y. Xu, X. Wang, C. Zhan, and P. Li, Cooperative recovery of distributed storage systems from multiple losses with network coding, IEEE Journal on Selected Areas in Communications, vol. 28, no. 2, pp. 268-276, 2010.

[20] K. Shum, Cooperative regenerating codes for distributed storage systems, in IEEE International Conference onCommunications (ICC), 2011.

[21] A. Kermarrec and N. Le, Repairing multiple failures with coordinated and adaptive regenerating codes, in IEEE International Symposium on Network Coding (NetCod), 2011.

[22] K. Shum and Y. Hu, Exact minimum-repair-bandwidth cooperative regenerating codes for distributed storage systems, in Proc. IEEE International Symposium on Information Theory (ISIT), 2011.

[23] A. Wang and Z. Zhang, Exact cooperative regenerating codes with minimum-repair-bandwidth for distributed storage, http://arxiv.org/abs/1207.0879, 2012.

[24] N. Le Scouarnec, Exact scalar minimum storage coordinated regenerating codes, in Proc. IEEE International Symposium on Information Theory (ISIT), 2012.

[25] K. Shum and Y. Hu, Functional-repair-by-transfer regenerating codes, in Proc. IEEE International Symposium on Information Theory (ISIT), 2012.

[26] Y. Hu, P. P. C. Lee, and K. W. Shum, Analysis and construction of functional regenerating codes with uncoded repair for distributed storage systems, http://arxiv.org/abs/1208.2787v1, 2012.

[27] N. B. Shah, K. V. Rashmi, P. V. Kumar, and K. Ramchandran, Distributed storage codes with repair-by-transfer and nonachievability of interior points on the storage-bandwidth tradeoff, IEEE Trans. on Inform. Theory, vol. 58, no. 3, pp. 1837-1852, 2012

[28] K. Rashmi, N. Shah, and P. Kumar, Explicit construction of optimal exact

regenerating codes for distributed storage, in Forty-Seventh Annual Allerton Conference on Communication, Control, and Computing, 2009.

[29] M.O. Rabin, ―Efficient Dispersal of Information for Security, Load Balancing, and Fault Tolerance,‖J. ACM, vol. 36, no. 2, pp. 335-348, Apr. 1989.

Guide Profile:

Mr.N.Venkatadri Was Born In Andhra Pradesh, India. He is Working as Asso.Prof.,M.Tech Department of CSE, SKR College Of Engineering and Technology,KonduruSatram, manubolu,Nellore(DT).

Student Profile:

Mr. S.Manikanth Was Born In Andhra Pradesh,India. He ReceivedB.TechDegree From JNTU Ananthapur.And he is pursuing PG in CSE from JNTU Ananthapur.