International Journal of Modern Electronics and Communication Engineering (IJMECE) ISSN: 2321-2152
Volume No.-7, Issue No.-1, January, 2019

RAL-PLFEC: RAPTORQ Based Application Layer and Physical Layer Forward Error Correction for Cloud Environment

Benjamin Franklin I[1]
Research Scholar, Manonmaniam Sundaranar University, Tirunelveli
Department of Computer Applications
St. Joseph's College of Arts and Science (Autonomous)
Cuddalore, Tamilnadu
E-mail: franklinbenj@gmail.com

Ravi T N[2]
Department of Computer Science
Periyar EVR College (Autonomous)
Trichy, Tamilnadu
E-mail: proftnravi@gmail.com

Abstract: Data sharing in the cloud computing system permits multiple users to spontaneously share their data, which improves the efficiency of work in co-operative environments. Though, how to ensure the integrity of data sharing within a group and how to effectively share the outsourced data without packet loss are terrible challenges. So, it is important to handle the packet loss detection efficiently and logically when accessing the cloud computing environment. Forward error correction (FEC) is a technique of attaining packet loss control, in which redundancy data is added to the packets to detect and correct the bit errors. This paper suggests a RAL-PLFEC method which is based on application layer and physical layer FEC to allow protection against the data corruption and data loss in the cloud environment. RaptorQ is a FEC technology executed with Low-Density Parity-Check (LDPC) that offers application-layer and physical layer defense against the packet loss in the cloud. This proposed method facilitates to reconstruct the data completely, lost in during transmission by allowing packet flow and delivery services. The proposed method achieved a significant reduction on the transmission overhead and packet loss rate when compared with the traditional FEC scheme.

Keywords: Application Layer FEC, Forward Error Correction, Physical Layer FEC, RaptorQ

I. INTRODUCTION

Cloud computing and cloud storage management have become hot topics in recent decades. Both are changing the lifestyle and greatly improving production efficiency in some areas. At present, due to limited storage resources and the requirement for convenient access, one may prefer to store all types of data in cloud servers, which is also a good option for companies and organizations to avoid the overhead of deploying and maintaining equipment when data are stored locally. The cloud server provides an open and convenient storage platform for individuals and organizations, but it also introduces security problems [1].

Cloud computing trusts on the computing and storage infrastructure provided by the cloud data centers and are becoming a highly accepted computing paradigm [2]. It extends a range of applications offered to mobile users beyond the conventional office applications by supporting applications requiring graphical hardware, such as 3D virtual environments, or large storage capacity to store the 3D medical images [3-5]. As multiple users are sharing the cloud infrastructure, this technology provides these resources in a cost-effective manner.

Because of the rapid growth in the applications that are accepted on the movable wireless devices, it becomes essential to protect data distributed through these devices from vulnerabilities. According to A.D Wyner [6], the presence of error detection codes, error correction codes and information security systems are still observed as two dissimilar procedures in modern communication systems. Error correction is carried out at the physical layer through this the security is achieved at the upper layers. Nowadays, a security procedure is planned and applied with the expectations of how to deliver error-free data. Due to the development of resource restricted wireless devices and ad hoc networks, encryption at higher level had become problematic to implement. Consequently, the existing methods are focusing broadly how to employ the process of encryption at the physical layer.

Forward Error Correction (FEC) is a scheme of finding packet error in data transmission in which the cloud user (Client) sends redundant packet data and the cloud storage (Cloud service provider) identifies only the few packets of the data that comprises no obvious errors. Since FEC does not need handshaking between the user and the cloud, it shall be used for distribution of packet to many cloud location concurrently from a single user. The FEC schemes are classified into two categories; one for protecting data from data corruption and other for protecting against the data loss. In FEC scheme, the protection against the data corruption is carried out at the physical layer (PHY-FEC), whereas the detection of data loss is done at the application layer (AL-FEC). A hybridized Interleaved Automatic Repeat Request (IARQ) and Enhanced Adaptive Sub-Packet Forward Error Correction mechanism (EASP-FEC) (IARQ -EASP-FEC) is applied to improve the video quality for effective video streaming in the cloud environment [7]. Instead of employing different encryption schemes [8, 9] at the physical layer with different modules to correct the errors, a joint scheme for error detection and correction is introduced in this work. This paper proposes a RAPTORQ-based application layer and physical layer FEC to enable protection against the data corruption and packet loss in the cloud environment. By combining the error detection and error correction techniques, this proposed work achieves improved security, efficiency, speed and optimum utilization of the hardware and software usage.

The rest of this paper is structured as follows. Existing error correction schemes are described in Section II. In Section III, the cross layer FEC approach including AL-FE: RAPTOR Q and PHY-FEC is illustrated as the proposed methodology. Section IV presents the results obtained from the simulation study on this methodology. The concluding note on the proposed work is presented in Section VI.

II. RELATED WORKS

In recent years, FEC scheme is used to improve the service quality in mobile broadcast stream. FEC mechanisms are characterized into those employed at the physical layer or at any upper level layers overhead it or application layers [10]. Existing method of LDPC [11] or Turbo codes [12] are used in physical layer of data broadcasting. Nowadays, an efficient FEC scheme of Raptor code [13] or RaptorQ [14] have been used in the upper layer. All these FEC procedures are improved for communicating single layer video. This traditional FEC method to accomplish a more effective distribution for various multi-layer media by applying an Unequal Error Protection (UEP) to the distribution stream, in which more important layers get full FEC protection. It was executed using the existing upper layer FEC systems within DVB (DVB-H [15] or DVB-SH [16]) or 3GPP (MBMS [17]) by deploying dissimilar code rates to the diverse video layers. UEP can be implemented by applying different hierarchical modulation [18] or coding for various video layers [19] in the physical layer. But, when UEP is completed in such a way that both streams are independent, the referencing video layer (enhancement layer) is impracticable if the referenced base layer of video is inappropriate.

In the traditional method, UEP is used to create FEC parity data for a separate layer. Numerous defense systems have been proposed, in which the layer characteristics are improved by considering the UEP performances within FEC algorithm [19-27]. This method is further enhanced by the Layer-Aware FEC (LA-FEC) [28-31]. However, instead of altering the basic FEC algorithm, it prolongs existing FEC algorithms towards enhanced decoding abilities in case of dependent video layers. The simple FEC algorithm is not changed, thus maintaining the improved correction performance and simple backwards compatible introduction into existing systems. The LA-FEC method can be deployed to the physical layer or upper layer FEC. In this research work, we concentrate on the upper layer FECs.

Bouras and Kanakis [32] proposed the integration of AL-FEC error protection application at the edge layer. This scheme provides a significant reduction on the overall network load and efficient protection than the existing error control methods such as Automatic Repeat Request (ARQ). However, the AL-FEC suffers from the transmission overhead and high packet loss rate due to the transmission of minimum repair symbols.

Drawbacks

From the survey, the following handicaps were identified and are listed below as a research gap

- No assurance on the FEC rate executed at the sender's end which exactly reflects the current network condition.
- The loss of data packets during the transmission from user to cloud are not considered in normal traditional method.
- When same packets are shared between users to cloud during packet loss detection, which leads to redundancy problem.

To eradicate/overcome the abovementioned problems, this research work aims to implement the cross layer FEC (Application Layer + Physical Layer) mechanism for improving the quality of data transmissions on the cloud and to calculate the packet rate of the data transmitted over the cloud.

III. RAL-PLFEC

In this section, the cross layer approach can be used for packet loss detection and retrieval of the lost packet to achieve the best overall quality. Furthermore, to achieve better quality of cloud service, the application layer's FEC need to be combined with physical layers'. The block diagram of such packet communication over cloud computing is illustrated in Fig.1.

From Fig.1, user uploads their video data into cloud. In first stage the video packets are encoding the uncompressed video sequence into a compressed bit stream, where I frame contents are internally embedded with RAPTOR Q FEC codes. This compressed bit stream is then passed to lower layers of OSI network stack. On sender MAC layer video frames are fragmented to mitigate the erroneous channel effects and passed to Physical layer of WLAN where the video bit stream undergoes the convolutional encoding as a part of WLAN standard and modulation to get passed through WLAN channel to cloud. On the physical layer of receiving end, modulated bit stream is demodulated and FEC codes assist in eliminating bit errors up to maximum probability, passed to higher layers and finally decoded by application decoder to retrieve the video clip

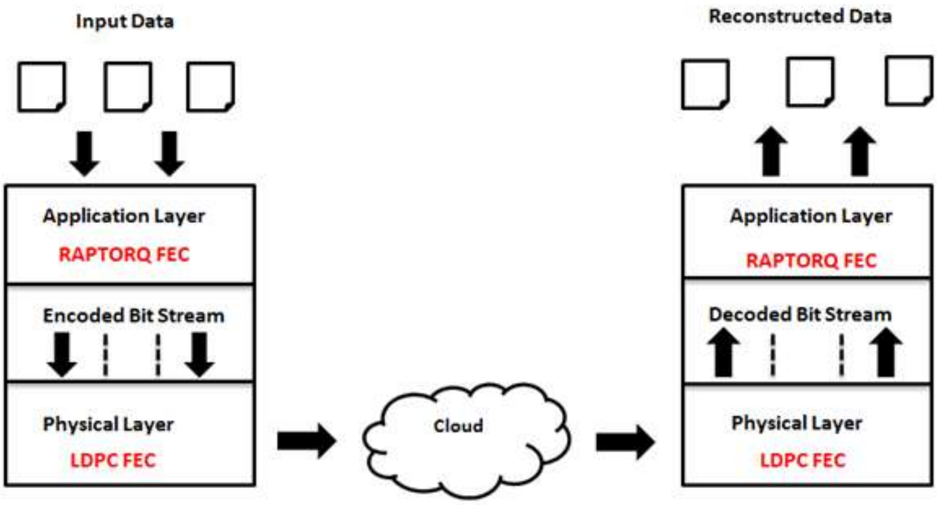

Figure 1 Overall Diagram of Proposed work

stored earlier. In this way, erroneous packets are passed unchecked to next cloud user.

A. AL-FEC: RAPTORQ

RaptorQ codes [14] are a linear block code used in error detection/correction process at the application layer of a network system and described by its generator matrices. A block diagram of Systematic RaptorQ Encoder/Decoder is shown in Fig. 2.

Let ‘t’ be a vector of K source symbols (Video Packets) that are to be encoded ($1 \leq K \leq 56{,}403$). The size of each source symbol T varies from 1 to 1024 bytes for the usual practical cases. An arbitrary vector t of size K is padded with zeros to a vector t' of size K'. This operation is performed by the "Padding" block in Fig. 2. The size of K' can be any value from a subset of source block size values, distributed in the range from 1 to 56,403, for which RaptorQ code is defined. The mapping of K to K' minimizes the amount of table information that needs to be stored and enables faster encoding and decoding. Additionally, the padding zero symbols are not transmitted but they are a-priori known at the decoder and act as an additionally available parity information. Vector d, at the input of the pre-code, consists of L symbols: the K' padded source symbols in vector t' plus L+K' zero symbols in the vector ‘z’.

The pre-code matrix A encapsulates several sub matrices. G_{LDPC1} and G_{LDPC2} are the generator matrices of two regular low density parity check codes (LDPC), defined over Galois Finite (GF) field with two elements. Second important matrix is High Density Parity Check Code (HDPC) that is defined over the GF. So, this matrix can be defined as GHDFC.

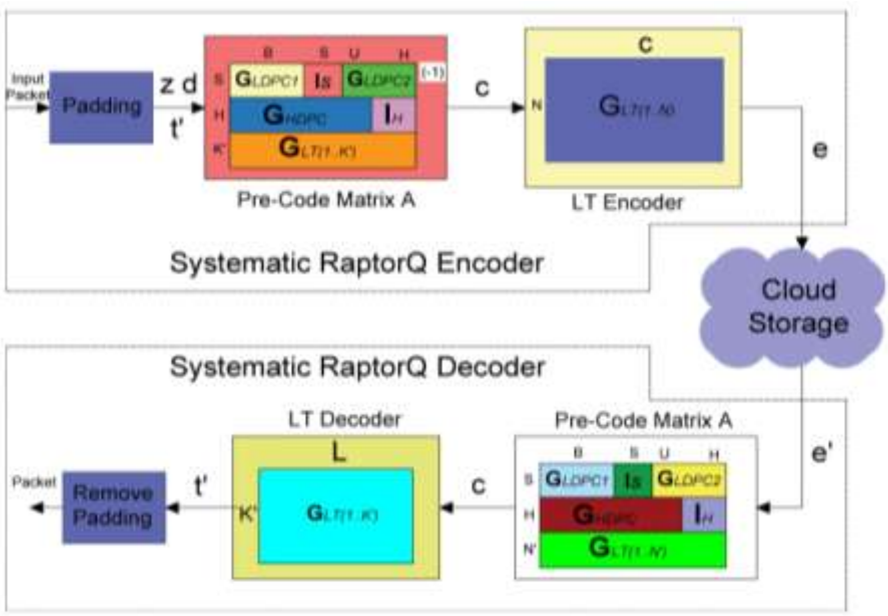

Figure 2 Block Diagram of RAPTORQ for Encoding and Decoding process

RaptorQ code is having the alteration of HDPC code matrix rather than traditional Raptor and to enhance its performance any other linear block code is also used in recent researches. In order to reduce the whole RaptorQ code, the first K' rows of the Luby Transform matrix $G_{LT(l..K')}$ [33] is merged with pre-code matrix 'A'. I_s and I_H are identity matrices. The number of rows N (N ≥ K) in the LT encoder matrix $G_{LT(l..N)}$ are set according to the desired rate and the expected channel erasure probability. The RaptorQ encoding process is performed according to (1), where the most time consuming operation is the inversion of matrix A.

$$e_{N\times1} = G_{LT(1..N)} \cdot A^{-1}_{L\times L} \cdot d'_{L\times1} = G_{LT(1..N)} \cdot C_{L\times1} \quad (1)$$

The decoding procedure of RaptorQ code interchange the positions of the pre-code matrix A and the G_{LT} Encoder (to be used as G_{LT} Decoder) matrix, as illustrated in Fig. 2 with G_{LT} LT generator matrices properly sized. This permits for successful decoding when only the first K encoded packets have been received and no errors are identified in the channel. The input vector e' is padded with encoded symbol of N' (K≤N'≤N) along with S+H zeros. So final size is M= N' +S+H. At initial stage N'=K, then its regularly incremented to make the matrix 'A' as invertible. Furthermore, the difference between N' and K, i.e., (N'-K) is equal to or greater than the number of lost packet during transmission. Decoding process of RaptorQ is calculated by Equation (2).

$$t'_{K'\times1} = G_{LT(1..K^1)} \cdot A^{-1(T)}_{M\times L} \cdot e'_{M\times1} = G_{LT(1..K^1)} \cdot C_{L\times1} \quad (2)$$

The pre-code matrix A in the RaptorQ encoder has to be inverted only once, for a fixed source block size K. On the other hand, the pre-code matrix A in the RaptorQ decoder has to be inverted with every decoded block of data. For the purpose of comparison, the Raptor code structure and operation for application layer FEC can be consulted in [34-36].

B. PHY-FEC

Wireless physical layer is defined as a layer is used to protect data from unauthorized access in noisy channel. Hence, the role of wireless physical layer is to incorporate features that facilitate data to be retrieved from the corrupted received packet/frame.

To improve the data security, punctured binary low-density parity check code is used in FEC mechanism. Some definitions and notation were introduced in this section that will be used in the remaining sections.

LDPC codes have been presented to achieve or reach near to FEC over many channels [37]. The bipartite graph is used to specify the LDPC code in which the graph is combination of check nodes and variable nodes. This variable node is used to denote the code word and constraints are imposed with code word, it can be denoted by check nodes. The degree distribution is the important parameter which is used to describe the bipartite graph and it is specified in the form of two polynomials $\lambda(x) = \sum_{i=2}^{d_v} \lambda_i x^{i-1}$ and $\rho(x) = \sum_{i=2}^{d_c} \rho_i x^{i-1}$. Let consider, maximum variable are represented by the values d_v and d_c, 'i' be the check nodes of degree and the fractions of edges connected to variable are represented by ρ_i and λ_i respectively. From the node perception, the portion of variable nodes of degree i is represented by λ_i and $\lambda_i = (\lambda_i/i)/(\sum_{i=2}^{d_v} \lambda_i/i)$.

In LDPC code, the 'punctured' effectively refers that some of its variable nodes are not transferred. A way of describing how an LDPC is punctured is by a puncturing distribution $\pi(x) = \sum_{i=2}^{d_v} \pi_i x^{i-1}$ where π_i represents the portion of variable nodes of degree i which are punctured [38]. This form of puncturing distribution is very useful for an asymptotic analysis of LDPC codes which are punctured. Let us consider the portion of all punctured bits are denoted as p, so that $p = \sum_{i=2}^{d_v} \pi_i \hat{\lambda}_i$. In this coding scheme, messages are transmitted over the punctured bits. We have to form the puncturing pattern like no subset of punctured bits forms the stopping set, if not some message (punctured) bits would be unrecoverable in the decoder.

Let us consider, 's' be the No. of message bits, 'n' be the No of transmitted code word bits and 'd' be the LDPC code dimension.

The design rate is denoted as

$$R_d = \frac{d}{n} \quad (3)$$

and the secrecy rate is represented as

$$R_s = \frac{s}{n} \quad (4)$$

For certain packet transmission, the number of punctured (message) bits is smaller than 'd'. In such cases, some arbitrarily selected dummy bits are combined with the punctured message bits to cover the bit locations that are independent in a code word. Usually in such cases $R_s < R_d$. On the other hand if a code is left un-punctured and assuming that all independent bit locations carry messages then $R_s = R_d$.

There are some powerful techniques for the analyses of LDPC decoders are present. Most notably, the method of density evolution, developed in [39], tracks the evolution of the probability density function (PDF) of messages as they are passed between check and variable nodes in the decoding process. Density evolution is computationally challenging, but Chung et al. [40] presented that it can be simplified efficiently if the messages are considered to have Gaussian PDFs. Namely, in that case the density evolution can be reduced to tracking only one parameter: the mean $m_u^{(k)}$. For the analysis of $m_u^{(k)}$ it is convenient to define the following function

$$\phi(x) = \begin{cases} 1 - \frac{1}{\sqrt{4\pi x}} \int_R^1 \tanh\frac{u}{2} \; e^{-(u-x)^2/4x} du, & if\ x > 0 \\ 1, & if\ x \le 0 \end{cases} \quad (5)$$

IV. PERFORMANCE ANALYSIS

This section presents the performance results, the efficiency of the proposed work and to indicate the amount of improvement in providing protection using AL-FEC and PHY-FEC on the cloud in a combined manner. A theoretical performance evaluation of the proposed RAL-PLFEC protection scheme applied on the cloud, presents results on the impacts of the proposed RAL-PLFEC scheme on the average transmission overhead and on the average cloud traffic with respect to both packets transmitted towards the cloud server or packets transmitted on the backwards for control operations such as requesting the retransmission of lost packets from the cloud server to the cloud user.

Table 1 Decoding Failure Probability with Symbol Overhead

Symbol overhead (O)	Raptor	RaptorQ
2	10^{-1}	$10^{-1.5}$
4	$10^{-1.5}$	10^{-2}
6	10^{-2}	$10^{-2.5}$
8	$10^{-2.5}$	10^{-3}
10	10^{-3}	$10^{-3.5}$
12	$10^{-3.5}$	10^{-4}
14	10^{-4}	$10^{-4.5}$
16	10^{-5}	10^{-5}

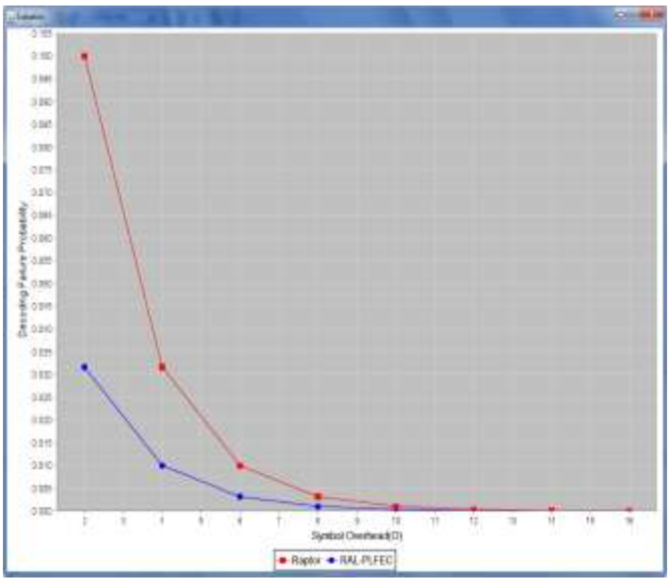

Figure 3 Performance Comparison of Decoding Failure Probability Vs Symbol Overhead (O)

The coding performance of block codes, such as Raptor and RaptorQ codes, over an arbitrary GF(q) fled has a theoretical limit. At the receiver side, the approximate probability of successful decoding with 0=1,2,3,... extra symbols (in addition to any K correctly received encoded symbols) is given by (6) [12]. Fig. 3 shows the possible failure probability of a block code over GF(q). From Table 1, it is witnessed that the large size finite fields gains a tremendous improvement in their performance. The coding performance of RaptorQ code benefits from that fact.

$$P_{success} \approx 1 - \frac{1}{q^{O+1}} \quad (6)$$

The simulation results of RaptorQ with LDPC provides a 99% probability of successful decoding with no extra symbols, while Raptor code requires 8 extra symbols for the same performance. For probability of successful decoding of 99.9%, RaptorQ with LDPC code requires one extra symbol, while Raptor code needs 16. Table 1 shows the variation of the decoding failure rate with respect to the symbol overhead. It shows that the proposed mechanism is having lower failure rate than the traditional Raptor method.

Table 2 Decoding Time with Data Block Size

Data Block Size(KB)	Decoding Time (Sec)			
	RaptorQ(s)	AL-FEC	PL-FEC	RAL-PLFEC(s)
16	24	28	29	20
64	35	42	43	32
32	49	56	59	46
128	55	62	71	52
256	67	76	80	60
512	82	90	92	77

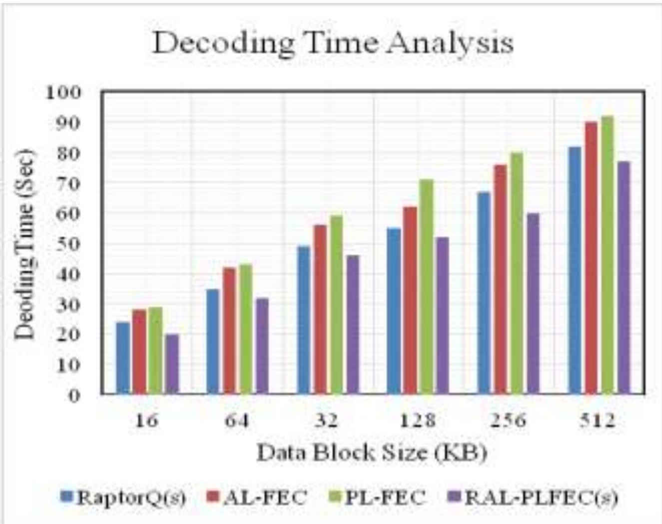

Figure 4 Performance Comparison of Decoding Time Vs Data Block Size

Fig. 4 shows the similar scenario, when RaptorQ code is employed with its LDPC algorithm. The values above the bars show the time remaining, before the decoding of the next received block of data must start, in order to keep real time multimedia broadcasting. The values in Fig. 4 show that RaptorQ with IDGE decoding algorithm is not able to perform the FEC on time with any of data block size K when compared with proposed RAL-PLFEC combination. Table 2 depicts the decoding time with respect to data block size. Its shows that, when increasing the data block size the corresponding decoding time is also be increased. The RAL-PLFEC of the proposed mechanism is lower than the hybrid RaptorQ with IDGE.

In Fig. 5 we evaluate the reduction on the average RAL-PLFEC transmission overhead of the delivery against different values of average packet loss rate in the range of 5% to 20% providing an indication on how the proposed scheme operates on different reception conditions of the cloud network with the number of user per cloud server. Table 3 presents the variation in the transmission overhead reduction with average packet loss rate. When increasing an average packet loss rate the corresponding transmission overhead reduction is also increased. But compared with existing Raptor, the proposed method is having lower loss rate.

Table 3 Transmission Overhead Reduction with Average Packet Loss Rate

Average Packet Loss Rate (%)	RaptorQ(%)	RAL-PLFEC (%)
4	16	14
6	16.2	14.4
8	16.8	14.9
10	17.2	16.0
12	17.7	16.5
14	18.1	17.2
16	18.8	17.9
18	19.5	18.3
20	20	19

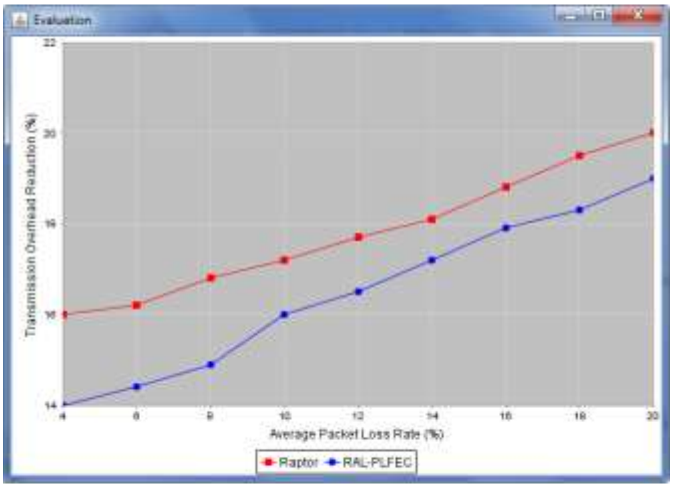

Figure 5 Performance Comparison of Transmission Overhead Reduction Vs Data Average Packet Loss Rate

In Fig.6 we provide simulation results evaluating the reduction on cloud traffic in terms of packets communicated against different values of average packet loss rate in the range of 5% to 20% and the user assigned on each cloud server fixed at 10. An immediate remark is that the cloud traffic reduction is increased with the average packet loss rate of the network increase. In more details, with 5% packet loss rate the scheme achieves more than 5% of cloud traffic reduction, with 12% packet loss rate the reduction reaches more than 7% and with 20% of packet loss rate the reduction is more than 9%. This behavior is a direct consequence of the increased reduction on the introduced transmission overhead while the average packet loss rate is increased since less repair symbols are transmitted compared to the case of the centralized computation of the transmission overhead. Table 4 depicts the variation in Transmission Cloud Traffic Reduction with average packet loss rate. When the *Average Packet Loss Rate* increases, the cloud Traffic Reduction is increases greatly. It shows that the proposed RAL-PLFEC is lower loss rate than the traditional Raptor.

Table 4 Transmission Cloud Traffic Reduction with Average Packet Loss Rate

Average Packet Loss Rate (%)	RaptorQ (%)	RAL-PLFEC (%)
4	5	4
6	5.4	4.4
8	6.2	5.2
10	6.9	5.8
12	7.5	6.2
14	8	6.9
16	8.6	7.3
18	9.1	7.8
20	9.5	8.6

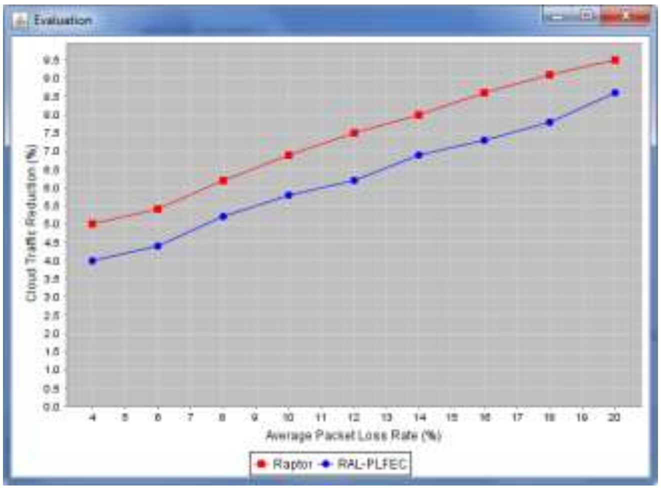

Figure 6 Performance Comparison of Transmission Cloud Traffic Reduction Vs Data Average Packet Loss Rate

V. CONCLUSION

This paper has presented an application and physical layer-based FEC (RAL-PLFEC) scheme for improving the quality of data transmissions over cloud environment. In compare to many traditional FEC systems, in which the FEC rate is identified at the user end on the basis of received information given by the cloud server, in the FEC mechanism proposed in this research paper, the FEC redundancy rate is calculated at the cloud server. Furthermore, the FEC redundancy rate is determined in accordance with both the cloud situation and the cloud traffic load. As an outcome, the FEC mechanism considerably enhances the packet deliver quality without overloading the cloud traffic with redundant packets. Our future work will contain further estimation of the proposed approach.

References

[1] J. Shen, T. Zhou, D. He, Y. Zhang, X. Sun, and Y. Xiang, "Block design-based key agreement for group data sharing in cloud computing," *IEEE Transactions on Dependable and Secure Computing*, pp. 1-1, 2017.

[2] H. Yuan, C.-C. J. Kuo, and I. Ahmad, "Energy efficiency in data centers and cloud-based multimedia services: An overview and future directions," in *Green Computing Conference, 2010 International*, 2010, pp. 375-382.

[3] M. Choi, J. Park, and Y.-S. Jeong, "Mobile cloud computing framework for a pervasive and ubiquitous environment," *The Journal of Supercomputing*, vol. 64, pp. 331-356, 2013.

[4] P. Simoens, F. De Turck, B. Dhoedt, and P. Demeester, "Remote display solutions for mobile cloud computing," *Computer*, vol. 44, pp. 46-53, 2011.

[5] M. Shiraz, A. Gani, R. H. Khokhar, and R. Buyya, "A review on distributed application processing frameworks in smart mobile devices for mobile cloud computing," *IEEE Communications Surveys & Tutorials*, vol. 15, pp. 1294-1313, 2013.

[6] A. D. Wyner, "The wire-tap channel," *Bell system technical journal*, vol. 54, pp. 1355-1387, 1975.

[7] Benjamin Franklin I and T. N. Ravi, "Hybridized Interleaved Automatic Repeat Request and Enhanced Adaptive Sub-Packet Forward Error Correction mechanism for Cloud " *International Journal Of Research In Electronics And Computer Engineering* vol. 6, pp. 81-88, Oct-Dec 2018.

[8] A. Zuquete and J. Barros, "Physical-layer encryption with stream ciphers," in *Information Theory, 2008. ISIT 2008. IEEE International Symposium on*, 2008, pp. 106-110.

[9] A. Ahmad, A. Biri, and H. Afifi, "Study of a new physical layer encryption concept," in *Mobile Ad Hoc and Sensor Systems, 2008. MASS 2008. 5th IEEE International Conference on*, 2008, pp. 860-865.

[10] E. T. V1.1.1, "Digital Video Broadcasting (DVB); Upper Layer FEC for DVB Systems," Feb 2011.

[11] D. J. MacKay and R. M. Neal, "Near Shannon limit performance of low density parity check codes," *Electronics letters*, vol. 32, pp. 1645-1646, 1996.

[12] C. Berrou, "The ten-year-old turbo codes are entering into service," *IEEE communications magazine*, vol. 41, pp. 110-116, 2003.

[13] A. Shokrollahi, "Raptor codes," *IEEE/ACM Transactions on Networking (TON)*, vol. 14, pp. 2551-2567, 2006.

[14] M. Luby, A. Shokrollahi, M. Watson, T. Stockhammer, and L. Minder, "RaptorQ forward error correction scheme for object delivery," 2070-1721, 2011.

[15] T. ETSI, "102 472 V1. 3.1, titled Digital Video Broadcasting (DVB); IP Datacast over DVB-H: Content Delivery Protocols (TS102-472 hereinafter) was published as Reference," *RTS/JTC-DVB-251, European Telecommunications Standards Institute*, pp. 01-64, 2009.

[16] T. ETSI, "102 584 V1. 2.1 (2011-01)," *Digital Video Broadcasting (DVB), DVB-SH Implementation Guidelines*.

[17] G. T. V9.4.0, "3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Multimedia Broadcast/Multicast Service (MBMS); Protocols and codecs," 2009-2010.

[18] C. Hellge, S. Mirta, T. Schierl, and T. Wiegand, "Mobile TV with SVC and hierarchical modulation for DVB-H broadcast services," in *Broadband Multimedia Systems and Broadcasting, 2009. BMSB'09. IEEE International Symposium on*, 2009, pp. 1-5.

[19] S. Mirta, T. Schierl, T. Wiegand, P. Inigo, C. LeGuern, C. Moreau, *et al.*, "HD video broadcasting using scalable video coding combined with DVB-S2 variable coding and modulation," in *Advanced satellite multimedia systems conference (asma) and the 11th signal processing for space communications workshop (spsc), 2010 5th*, 2010, pp. 114-121.

[20] R. Morelos-Zaragoza and S. Lin, "Some results on linear unequal-error-protection codes specified by their generator matrix," in *International Symposium on Applied Algebra, Algebraic Algorithms, and Error-Correcting Codes*, 1991, pp. 259-268.

[21] C. Kilgus and W. Gore, "A class of cyclic unequal error protection codes (Corresp.)," *IEEE Transactions on Information Theory*, vol. 18, pp. 687-690, 1972.

[22] I. Boyarinov and G. Katsman, "Linear unequal error protection codes," *IEEE Transactions on Information Theory*, vol. 27, pp. 168-175, 1981.

[23] N. Rahnavard and F. Fekri, "New results on unequal error protection using LDPC codes," *IEEE Communications Letters*, vol. 10, pp. 43-45, 2006.

[24] A. Bouabdallah and J. Lacan, "Dependency-aware unequal erasure protection codes," *Journal of Zhejiang University-Science A*, vol. 7, pp. 27-33, 2006.

[25] M. C. Bogino, P. Cataldi, M. Grangetto, E. Magli, and G. Olmo, "Sliding-window digital fountain codes for streaming of multimedia contents," in *Circuits and Systems, 2007. ISCAS 2007. IEEE International Symposium on*, 2007, pp. 3467-3470.

[26] D. Sejdinovic, D. Vukobratovic, A. Doufexi, V. Senk, and R. J. Piechocki, "Expanding window fountain codes for unequal error protection," *IEEE Transactions on Communications*, vol. 57, 2009.

[27] D. Vukobratovic, V. Stankovic, D. Sejdinovic, L. Stankovic, and Z. Xiong, "Scalable video multicast using expanding window fountain codes," *IEEE Transactions on Multimedia*, vol. 11, pp. 1094-1104, 2009.

[28] C. Hellge, T. Schierl, and T. Wiegand, "Mobile TV using scalable video coding and layer-aware forward error correction," in *Multimedia and Expo, 2008 IEEE International Conference on*, 2008, pp. 1177-1180.

[29] C. Hellge, T. Schierl, and T. Wiegand, "Multidimensional layered forward error correction using rateless codes," in *Communications, 2008. ICC'08. IEEE International Conference on*, 2008, pp. 480-484.

[30] C. Hellge, T. Schierl, and T. Wiegand, "Receiver driven layered multicast with layer-aware forward error correction," in *Image Processing, 2008. ICIP 2008. 15th IEEE International Conference on*, 2008, pp. 2304-2307.

[31] C. Hellge, D. Gómez-Barquero, T. Schierl, and T. Wiegand, "Intra-burst layer aware FEC for scalable video coding delivery in DVB-H," in *2010 IEEE International Conference on Multimedia and Expo*, 2010, pp. 498-503.

[32] C. Bouras and N. Kanakis, "AL-FEC Application on NGMN-Edge Computing Integrated Systems," in *2018 Tenth International Conference on Ubiquitous and Future Networks (ICUFN)*, 2018, pp. 364-369.

[33] M. Luby, M. Watson, T. Gasiba, T. Stockhammer, and W. Xu, "Raptor codes for reliable download delivery in wireless broadcast systems," in *CCNC 2006. 2006 3rd IEEE Consumer Communications and Networking Conference, 2006.*, 2006, pp. 192-197.

[34] T. Mladenov, S. Nooshabadi, and K. Kim, "Implementation and evaluation of Raptor codes on embedded systems," *IEEE Transactions on Computers*, vol. 60, pp. 1678-1691, 2011.

[35] M. Luby, T. Gasiba, T. Stockhammer, and M. Watson, "Reliable multimedia download delivery in cellular broadcast networks," *IEEE Transactions on Broadcasting*, vol. 53, pp. 235-246, 2007.

[36] T. Gasiba, T. Stockhammer, and W. Xu, "Reliable and efficient download delivery with Raptor codes," in *Turbo Codes&Related Topics; 6th International ITG-Conference on Source and Channel Coding (TURBOCODING), 2006 4th International Symposium on*, 2006, pp. 1-6.

[37] T. Richardson and R. Urbanke, *Modern coding theory*: Cambridge university press, 2008.

[38] J. Ha, J. Kim, and S. W. McLaughlin, "Rate-compatible puncturing of low-density parity-check codes," *IEEE Transactions on information Theory*, vol. 50, pp. 2824-2836, 2004.

[39] T. J. Richardson and R. L. Urbanke, "The capacity of low-density parity-check codes under message-passing decoding," *IEEE Transactions on information theory*, vol. 47, pp. 599-618, 2001.

[40] S.-Y. Chung, T. J. Richardson, and R. L. Urbanke, "Analysis of sum-product decoding of low-density parity-check codes using a Gaussian approximation," *IEEE Transactions on Information theory*, vol. 47, pp. 657-670, 2001.

AUTHOR'S BIOGRAPHIES

I. Benjamin Franklin is Assistant Professor in Department of Computer Applications, St. Joseph's College of Arts & Science (Autonomous), Cuddalore, Tamil Nadu, India. He has 13 years of teaching experience. He is currently pursuing Ph.D. in Manonmaniam Sundaranar University, Tirunelveli. He has published and presented 10 papers in various national/international journals and conferences. His area of interest includes Networking, Cloud Computing and Grid Computing.

T. N. Ravi is Assistant Professor and Research Co-ordinator of PG and Research Department of Computer Science, Periyar E.V.R. College (Autonomous), Tiruchirappalli, Tamil Nadu, India. He has 27 years of teaching experience and 15 years of research experience. His area of interest includes Parallel Computing, Data Mining, Networking and Image Processing. He has guided 30 scholars for M.Phil. and Ph.D. He has published more than 40 research papers in reputed international/national journals.