Application of Fountain Codes to Cognitive Radio Networks and MBMS – A Review

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ABSTRACT
The inefficient usage of limited radio spectrum resources with its increased demand has opened the doors for an innovative communication technology. The recently proposed concept of cognitive radio network can use the licensed bands of primary users for its data transmission without causing interference to them. The LT (Luby Transform) code and Raptor code, types of Fountain codes (class of erasure correcting codes) seems a promising approach to enhance the performance of wireless multimedia services. Since, the bandwidth usage is minimized with the use of Fountain code; it seems to be optimal to use it for cognitive networks. The paper discusses the work which has applied LT and Raptor coding for MBMS (Multimedia Broadcast/ Multimedia Services) and cognitive networks and proposes a solution to further enhance the performance of cognitive radio networks.

Keywords
Cognitive radio, Fountain codes, LT (Luby Transform**)** code, Raptor code.

1. INTRODUCTION
Radio spectrum is a scarce resource. The regulatory body Federal Communication Commission (FCC) is responsible for radio spectrum resources and regulation of radio emissions. The FCC assigns spectrum to licensed holders, *primary users* (PU) on a long term basis for large geographical regions. However, FCC found that most radio frequency spectrum was underutilized or inefficiently utilized. Therefore, now they have proposed the notion of secondary utilization where the users who have no spectrum licenses, the *secondary users* (SU) are allowed to use temporarily unused licensed spectrum.

Cognitive radio technology has brought a revolutionary change in communication paradigm and is receiving a growing attention in recent years [1]. This technology can provide faster and more reliable wireless services by utilizing the existing spectrum band more efficiently and without interference to primary users. The cognitive radio network users need to be aware of dynamic environment and adaptively adjust their transmission or reception parameters based on interactions with the environment and other users in the network to execute its task efficiently without interfering with licensed users or other cognitive radios. Since, cognitive radio is a secondary user; it has to vacate the band immediately as soon as there is arrival of primary user. Therefore, it is indeed very important for cognitive radio that transmission should be achieved with less bandwidth requirement and that correct data decoding should be possible at receiver side without the need of ACK (acknowledge) signal and Automatic Repeat Request (ARQ).

To overcome this problem, a new class of erasure correcting codes known as fountain codes (also known as rate less erasure codes) is introduced and is under consideration to be used for transmission over cognitive radio network. The fountain code acts as a channel code to combat the effects of loss against PU interference and other channel conditions and helps receiver to decode complete data accurately. The fountain code produce limitless number of encoded symbols from given set of source symbols such that original source symbols can be recovered from any subset of encoded symbols of size equal to or slightly larger than number of source symbols. There are two classes of fountain codes: Luby Transform (LT) codes and Raptor codes. Although Raptor codes are the most efficient codes, a new class of fountain codes, RaptorQ codes has been introduced recently which seems to be more promising than its previous version Raptor code with increased coding efficiency and improved reception overhead and with performance almost like ideal performance of fountain code.

The paper mainly concerns with the use of fountain codes for different applications. Section 2 describes the concept presented in various papers using different types of fountain codes for MBMS or cognitive radio networks. Section 3 provides conclusion, comparative analysis of explained work with the associated future work.

2. LITERATURE REVIEW
2.1 Raptor Code for MBMS
M. Luby, T. Gasiba etc all in [2] discusses file distribution over wireless mobile broadcast networks. The paper first introduces the multimedia delivery sessions in wireless broadcast networks consisting of three phases:

1. Announcement of service and setting up network and identification of that service by user.

2. Data transmission phase where original data along with some redundant data is broadcasted and

3. A post delivery file repair phase where individual users served to recover original file.

The work is mainly focused on phase 2 i.e. data transmission phase. Firstly, LT codes which are the first practical implementation of fountain codes is introduced in which large number of random and encoded symbols can be generated as required. But the code is inefficient in terms of additional symbols required for successful decoding at receiver side. Almost, about 10% of extra symbols are needed for full recovery. Also, the decoding complexity is greatly increased for larger size data blocks.

So, a new class of fountain code, Raptor codes has been used for file delivery over mobile broadcast network which are supported by Third Generation Partnership Project (3GPP) for terminals participating in MBMS services. Although Raptor code is an extension on LT code, it is the systematic code in contrast to LT code which is non-systematic code. Hence, all the source symbols appear in encoding symbols of Raptor codes. The results shows that Raptor code is useful for larger file transmission with relatively low encoding and decoding complexity as specified in 3GPP. The future work proposed in this paper is the use of Raptor code for video broadcasting over internet, peer to peer distribution etc.

2.2 LT code and Raptor code for Cognitive network

In paper [3] A. Asareh, T. Fujii discusses various cognitive radio network paradigms. The authors suggests that the underlay paradigm is the most desirable scheme as in this the cognitive users (SU) can access the channel whether the PU has occupied the channel or not. For this, the cognitive user transmits its signal below tolerable interference threshold of primary user and hence secondary user's packets get easily erased and cannot make their way to receiver. Therefore there arises the need to use erasure recovery methods. The authors have also described the usage of Fountain codes for this purpose. Both the types of fountain codes i.e. LT code and Raptor code are applied to cognitive radio network considering PU as wireless LAN network. The simulation results provided shows that both these methods give better results in terms of higher throughput as compared to conventional error recovery method such as ARQ (Automatic Repeat Request). Among both the methods, Raptor Code outperforms the performance of LT code. So, using Fountain code for cognitive radio environment seems to be optimal as compared to any conventional methods.

2.3 LT code for Cognitive network

The work in paper [4] presents an approach for transmission of multimedia data over cognitive radio networks. Here, the authors consider the PU arrival as Poisson's distribution. In this paper, proper number of sub-channels required to transmit data without loss is calculated and a metric is defined to measure quality of sub-channel. This work uses LT code to transmit multimedia data (by scaling) over cognitive radio network. It shows that there is an optimal number of sub-channels and optimal overhead that is induced in LT code that maximizes spectral efficiency of SUs. This is true in the sense that as overhead is induced, it helps receiver to decode packets correctly and sequentially and also transmission of ACK signal or retransmission of data again is eliminated because of usage of Fountain code. Thus, using LT code over cognitive radio network maximizes the throughput of system. The authors have proposed that the future work can include multiple secondary users and resulting interference minimization or different coding scheme can be used to increase system throughput.

2.4 Raptor code and RaptorQ code for MBMS

The work in [5] by C. Bouras, N. Kanakis etc all compares the two advanced techniques of Forward Error Correction (FEC) codes that belongs to the class of fountain codes- Raptor codes and recently introduced its superior version RaptorQ code. 3GPP has standardized Raptor code for MBMS services and it works quite effectively as well. But introduction of RaptorQ by Internet Engineering Task Force (IETF) motivates to address the performance drawbacks of standardized Raptor code. The work in the paper shows that the performance of RaptorQ code is extremely close to the ideal performance of fountain code as the amount of transmission overhead is greatly reduced in RaptorQ code as compared to Raptor code. Also one more advantage of RaptorQ code that is outlined in this paper is that it can operate on very large data lengths with increased coding efficiency and decreased redundancy. The simulation has been obtained by using ns-3 simulator. The simulation results verify the superiority of RaptorQ code over Raptor code. Hence, the author strongly suggests that RaptorQ coding technique is more beneficial for mobile systems or MBMS systems.

3. CONCLUSION & RESULTS

Cognitive radio is the key enabling technology used to increase usage of spectrum by allowing dynamic allocation of unused spectrum in changing environment. This process is also known as dynamic spectrum management.

Fountain codes are a new class of erasure correcting codes and its types LT code and Raptor code shows higher efficiency as compared to conventional codes. The result from [3] is shown in fig. 1 where the overhead of both LT and Raptor code is shown for 2 and 200 broadcast receivers. From Fig. 1, it can be concluded that there is no increase in overhead if number of receivers are increased.

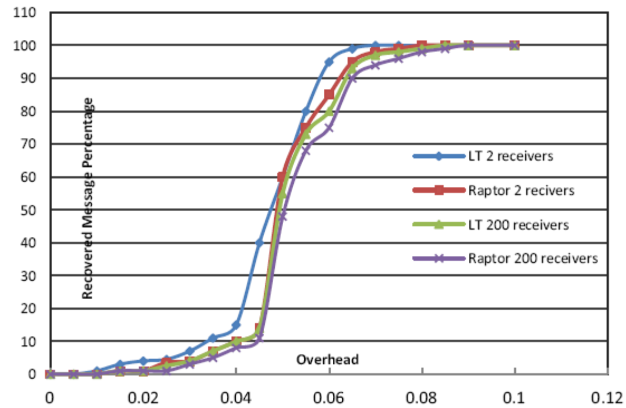

Fig 1: Overhead Simulation considering Various Secondary Receivers

Also these codes are rate-less in nature and do not have fixed code rate that must be chosen before encoding begins as is the case with conventional coding techniques and hence bandwidth wastage (in both cases of packet loss rate overestimated and underestimated) is minimized. Hence, these codes are replacing conventional coding techniques. Comparing LT code with Raptor code shows that later has low encoding and decoding complexity and can be used for larger data lengths. Therefore, 3GPP has standardized Raptor code for MBMS services. Table 1 shows the tabular comparison of above discussed literatures.

From the discussion, it is clear that applying LT code and Raptor code to cognitive radio network enhances its performance. Therefore, if the improved version of Raptor code i.e. RaptorQ code is applied to cognitive network, then it will further improve its performance or it can become close to ideal performance which is very much desirable. Also, RaptorQ performs almost like ideal fountain code for MBMS services so it can be same for cognitive radio network as well. The authors of this paper will try to optimize the performance of cognitive radio networks. More precisely, the bandwidth requirement will be minimized with increased coding efficiency.

Table 1. Comparative Study of Literatures

Literature No.	Authors	Coding Used	Network Used	Conclusion
[2]	M.Luby, M. Watson, T. Gasiba, T. Stockhammer, W. Xu.	Raptor Code	MBMS	Encoding & Decoding complexity is reduced which makes Raptor code more useful for wireless networks.
[3]	A. Asareh, T. Fujii	LT Code & Raptor Code	Cognitive Network	Both the coding techniques give higher throughput as compared to previous conventional techniques. Among the two, Raptor code gives better results.
[4]	H. Kushwaha, Y. Xing, R. Chandramouli, H. Heffes	LT Code	Cognitive Network	LT code maximizes spectral efficiency and system throughput.
[5]	C. Bouras, N. Kanakis, V. Kokkinos, A. Papazois	Raptor Code & RaptorQ Code	MBMS	RaptorQ code requires low transmission overhead than Raptor code. It operates efficiently in poor reception conditions. Hence, its performance is extremely close to ideal performance of Fountain code.

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