3G Performance Gains of Network Coding in Evolved 3G Mobile Network for MBMS
Abstract—3GPP has defined a Multimedia Broadcast and Multicast Service (MBMS), which is a major enhancement in the downlink of the 3G standard. The focus of MBMS is on the efficient management of radio and core network resources while reusing as much existing functionality as possible. On the other hand, Network Coding has been proved that can achieve the throughput capacity of an arbitrary multicast session by allowing intermediate nodes encode the incoming packets before forward. In this paper, we focus on the performance of random network coding for MBMS in evolved 3G mobile network. Basis on the architecture of multiple cell service of MBMS, we propose a multicast scheme using random network coding (RNCM). In this scheme, we integrate the capability of random network coding and the several service channel provided by the Base Stations (BS) in a MBMS cell. The simulation results show that RNCM scheme can increase the throughput of network significantly.

Keywords—3GPP, MBMS, evolved 3G mobile network, random network coding, network throughput

I. INTRODUCTION

In mobile network, the demand of multimedia services becomes much more than before. 3GPP has defined a Multimedia Broadcast and Multicast Service (MBMS) which provides a seamless combination of multicast and broadcast transport technologies into the 3G network.

Fig.1 illustrates the MBMS architecture. The architecture is extended from the original 3GPP packet switched domain. MBMS reuses much of the existing 3G functionalities [1], [2]. It adds a new entity called Broadcast/Multicast service center (BM-SC) which acts as an MBMS server. The BM-SC manages certain control tasks, such as membership, session and transmission, proxy and transport, service announcement, and security, etc.

MBMS is divided into single cell service and multiple cells service according the number of service cells. In multiple cell service, a MBMS cell includes several normal cells. All BSs in a MBMS cell can provide multimedia service for terminal (UE) registered in any cell at the same time.

This work is supported by Fudan University Graduate Innovation fund
In this paper, we focus on how to apply network coding technique into MBMS under multiple cell service in order to improve the throughput of mobile network. A multicast scheme using random network coding (RNCM) is proposed. In this scheme, UE can make use of the signals from any BSs in the MBMS cell. Based on the simulation results, we conclude that the spectral efficiency and throughput of network can be improved significantly.

The rest of the paper is organized as follows. Network model and multicast schemes are introduced concretely in section 2. In section 3, we compare the proposed scheme with traditional delivery scheme based on the results of simulations. In addition, the influence of the parameter of RNCM for the network throughput is analyzed. Finally, we conclude with a few remarks in section 4.

II. MBMS NETWORK MODEL AND MULTICAST SCHEMES

A. MBMS Network Model

The MBMS network model is shown in Fig. 2 under multiple cell service, which includes three Normal cells. The data are transmitted in packets. Each packet has \( n \) bits. UEs use positive and negative acknowledgments (ACK/NAK) to notice which packet is received correctly or not for file distribution service. And all ACKs/NAKs are assumed instantaneous and reliable. The Raptor forward error correcting (FEC) code is used to increase reliability for continuous receptions and playback application. We assume that all BSs in this MBMS cell provide the same service for all members in a multicast group i.e. UEs can not only utilize the packet from registered cell but also neighbor cells.

B. Current Multicast Scheme

With the limitation of paper length, the current multicast (CM) scheme for file distribution service is introduced in this subsection. The CM scheme can be depicted as follows:

1) The BM-SC takes the original packets \( p_1, p_2, \ldots, p_K \), which are applied by UEs in a MBMS cell, from content provider and distributes them to all BSs in this MBMS cell. Then all BSs multicast these packets to UEs.

2) The UE checks the correctness of arrival packet \( p_i \) with CRC and drops the wrong ones and uses ACK/NAK to notice BS which packet is received correctly or not.

3) The BSs retransmit the current packet once a NAK is received. When all ACKs are received the BSs for this packet, the BSs begin to multicast the next packet.

4) Repeat 1)-3), until all UEs receive all original packets.

In this scheme, UE maybe receive a packet several times. We assume that UE store the packet first correctly received and drop the follow ones.

C. Random Network Coding Multicast Scheme

In this subsection we introduce RNCM scheme, a new multicast scheme using random network coding for MBMS. The procedure of RNCT is introduced as below:

1) The BM-SC divides the original packets into several generations. Each generation has \( K \) packets \( p_1, p_2, \ldots, p_K \). The number of the last generation maybe small \( K \). The random network coding is just done in each generation. The encoding coefficient should be selected randomly from a sufficiently large finite field, in order to guarantees the UEs can decode the original packets \( p_1, p_2, \ldots, p_K \). The encoded packets are \( p_1', p_2', \ldots \).

2) The BM-SC continuously distributes the encoded packets \( p_1', p_2', \ldots \) in currently generation to all BSs in this MBMS cell. And these BSs multicast \( p_1', p_2', \ldots \) to UEs.

3) The UEs check the correctness of every arrival packet \( p_i' \) with CRC and drops the wrong ones. Then, the relativity of the correct packets is also be checked. When the number of correct and independent packets received by a UE is equal or larger than \( K \), this UE can decode the original packets \( p_1, p_2, \ldots, p_K \) in currently generation. Then UE notices BM-SC using ACK for current generation.

4) The BM-SC begins to deliver the next generation.

5) Repeat 1)-4), until all UEs receive all original packets.

In RNCM scheme, based on random network coding (RNC) the ACK is transmitted for successfully received a generation not for a packet. Consequently the radio resource used for transmitting ACK/NAK can be saved effectively. In addition, in order to control the complexity of encoding and decoding operation, the parameter of generation is necessary. The value of generation size \( K \) should fit multimedia service, i.e. \( K \) can not be set too large. Otherwise, the latency will be long. End user can not tolerate too long loading time for video service.
III. SIMULATIONS AND RESULTS

Through a lot of simulations, the performance gains of CM and RNCM scheme for MBMS are investigated under MBMS network model in this section. The normalized network throughput is used to describe the performance of above schemes. The value of multicast network throughput is normalized by the \( NetThr(N_0) \), which is the value of network throughput at the reference value \( N_0 \). The normalization equation is written as follow:

\[
\text{Norm}_\text{-NetThr}(N) = \frac{NetThr(N)}{NetThr(N_0)}
\]

(1)

Where \( N \) is an arbitrary plus real number.

Fig.3 shows the normalized network throughput of RNCM and CM scheme proceeded respectively for different number of UEs. In this case, \( N_0=50 \). Signal to Noise Ratio (SNR) is fixed. The RNCM scheme is implemented with generation size equal to 10, 100, and 1000 respectively.

Fig.4 shows the normalized network throughput of above two multicast schemes for different UE position. Radius of cell is 500 Meter. In this case, \( N_0=100 \). When UE is located at the edge of normal cell, i.e. the distance between BSs and UEs is equal to 500, the power spectrum density (PSD) of BSs in this MBMS cell is equal between each other. So Signal to Noise Ratio (SNR) is strongest. Consequently, the network throughput reaches maximum value.

Fig.5 shows the normalized latency for different generation size \( K \). In this case \( N_0=100 \), which is the value of generation size. The latency becomes longer while the generation size increases.

The normalized network throughput of RNCM scheme is four times as that of CM scheme in average, which reaches maximum value with \( K=1000 \). In addition, the change of UE numbers influences the network throughput little.
IV. CONCLUSION

In this paper, we propose a multicast scheme using random network coding (RNCM) for MBMS in evolved 3G mobile network. In this scheme, based on network coding technique the ACK is transmitted for generation not for packet. Consequently the radio resource used for transmitting ACK/NAK can be saved effectively. Through simulations, the network throughput increases four times by this scheme than the current multicast (CM) scheme. We also consider influence of generation size $K$, UE position and number for the performance of RNCM scheme. Especially, for file download service the large $K$ is suitable. In future work, we will investigate the performance gains of RNCM scheme for other kind service in evolved 3G mobile network.

REFERENCES


