

# Delay-Sensitive Transmission Scheme for VM based Networks in Cloud Computing Data Center

Ji Lu<sup>1,2</sup>, Zhiyi Zhang<sup>2</sup>, Junfang Wang<sup>2</sup>, Ning Li<sup>2</sup>

<sup>1</sup>School of Computer Science and Technology, Huazhong University of Science and Technology, Wuhan, China;

<sup>2</sup>Key Laboratory of Science and Technology on Information Transmission and Dissemination in Comm.Net.,  
54<sup>th</sup> Research Institute of CETC, Shijiazhuang, China

**Abstract**—A delay-sensitive transmission scheme based on network coding (NC) is proposed for VM based Networks in Cloud Computing Data Center to improve packet transmission performance. By employing NC mechanism with an efficient combination strategy of lost packets, the proposed transmission scheme is designed to improve packet transfer delay, as well as network throughput for multicast broadcast services in VM based networks. Simulation results show the effectiveness of the proposed scheme under typical channel conditions.

**Keywords**—Cloud Computing; Network coding; opportunistic network coding; VM based networks; multicast broadcast services

## I. INTRODUCTION

Cloud Computing Data Centers have become the most powerful techniques for information delivering and sharing, and are widely used in many kinds of Clouds<sup>[1]</sup>. In order to improve the resource utilization in Cloud Computing Data Centers, the computer virtualization technique<sup>[2]</sup> is used to create many Virtual Machines (VM) in a physical one, thus introducing new problem of information delivering and sharing among VMs. The 802.1 qbg and 802.1 qbh are proposed to deal with this problem<sup>[3]</sup>. However, these standards don't consider of the packet transmission performance caused by the random and burst packet losses when executing multicast or broadcast for several or many VMs. So providing high throughput and low delay multicast and broadcast for VMs is a challenging technique problem to be addressed.

Network coding<sup>[4]</sup> (NC) based transmission scheme maintains high throughput for networks and existing works on this scheme optimize the throughput by using opportunistic NC<sup>[5]</sup>, where the retransmission packet is generated by properly mixing of lost packets. Opportunistic NC based scheme is more appreciated with its explicit and usefulness<sup>[6]</sup>, so it is of great significance for designing Opportunistic NC based scheme that is expected to achieve higher throughput performance.

On the other hand, packet transfer delay of NC based retransmission schemes is increased because a lost packet has to wait until it has selected as a candidate packet and encoded into a retransmission packet so as to achieve more NC opportunities. It can cause traffic flow at VM and a bad impact on the upper-layer applications<sup>[7]</sup>. Thus, the packet transfer delay is one of the most important issues to be

addressed for multicast and broadcast over VM based Networks.

This paper proposes an Opportunistic NC based transmission scheme for multicast broadcast services (MBS) in VM based networks. It is realized by establishing a combination strategy to select lost packets in a sorted order that optimizes not only for packet transfer delay but also, and more important, for network throughput.

## II. ONC BASED TRANSMISSION SCHEME

### A. Opportunistic NC based Retransmission

We consider MBS over VM based networks where the Switch is able to transmit a packet to  $M$  VMs in a time slot, and VMs send their ACKs respectively if they received a packet. The retransmission packet generated at  $S$  by proper mixing of lost packets from different VMs is transmitted, as a result, multiple VMs can recover their own lost packets with a single retransmission from  $S$ , thus increasing throughput. Let  $\{P_1, P_2, \dots, P_N\}$  and  $P_r$  denote the set of original packets and a retransmission packet respectively, where  $N$  is the number of original packets.  $P_i (1 \leq i \leq N)$  and  $P_r$  can be represented as a  $L$ -length binary sequence  $\{p_{i1}, p_{i2}, \dots, p_{iL}\}$  and  $\{p_{r1}, p_{r2}, \dots, p_{rL}\}$ . Then the XOR operation of this scheme for  $p_{rj} (1 \leq j \leq L)$  can be described as

$$p_{rj} = \sum_{i=1}^N \alpha_i p_{ij} \bmod 2, \quad j = 1, 2, \dots, L, \quad \alpha_i \in \{0, 1\} \quad (1)$$

where  $\alpha_i = 1$  if  $P_i$  has the opportunity to combine into  $P_r$  and  $\alpha_i = 0$ , otherwise.

Fig.1 shows the overview of ONC based retransmission.  $S$  transmits  $P_1, P_2$  and  $P_3$  and  $R_1, R_2$  and  $R_3$  lost  $P_1, P_2$  and  $P_3$  respectively. Then the retransmission packet  $P_r$  is generated by XOR operation of  $P_1, P_2$  and  $P_3$  and is transmitted. Then  $R_1$  can recover  $P_1$  by XOR operation of  $P_r, P_2$  and  $P_3$ , and  $R_2$  and  $R_3$  can recover their lost packet in a similar way.

The throughput efficiency<sup>[4-5]</sup> is used as the evaluating metric for various transmission schemes, and is defined as the rate of the number of original packets to the number of transmitted packets. Packet transfer delay is defined as the number of transmission slots when a packet is successfully received at a VM.

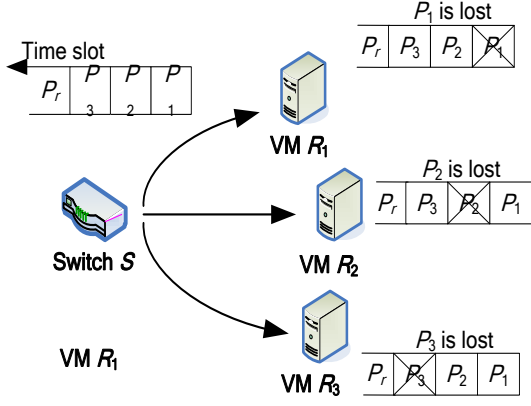


Fig.1 VMs based networks.

### B. Proposed Transmission Scheme

For achieving higher throughput, the packets encoded in a retransmission packet should be selected to make more VMs retrieve their lost packets. On the other hand, the lost packet can be selected and retrieved in a sorted order so as to decrease packet transfer delay. The lost packet which has the most important time level in each VM is selected to be encoded in a retransmission packet so that each VM can retrieve its lost packet from the retransmission packet, thus improving throughput and packet transfer delay.

Three stages are as follows.

Stage 1: The switch  $S$  broadcasts  $N$  packets for all VMs then a VM  $R$  who receives the packet of the current transmission slot response ACK signals to  $S$ . So  $S$  is able to know which packets from which VMs are lost. Note that the stage is the same as in the traditional ARQ mechanism and the transmission of ACKs assumes to be instant for simplicity.

Let an  $M$  row and  $N$  column matrix  $\Omega$  denote the packet loss information, and the  $i^{\text{th}}$  ( $1 \leq i \leq M$ ) row of  $\Omega$  represents the lost packets for  $R_i$ , and the  $j^{\text{th}}$  ( $1 \leq j \leq N$ ) column of  $\Omega$  represents whether  $P_j$  is lost or not for  $M$  VMs. Let  $\omega_{ij}$  denote an element in  $\Omega$ , then  $\omega_{ij}=1$  if  $R_i$  loses  $P_j$  and  $\omega_{ij}=0$ , otherwise. An example of  $\Omega$  is shown in Fig.2. The lost packets in a VM can be reordered according to their time importance levels. Without loss of generality, we assume the lost packet  $P_\alpha$  has a more important time level than  $P_\beta$  if  $\alpha < \beta$ .

Packet Receiver	$P_1$	$P_2$	$P_3$	$P_4$	$P_5$
$R_1$	0	0	0	1	0
$R_2$	0	0	1	1	0
$R_3$	0	1	0	0	1
$R_4$	1	0	1	0	0

Fig. 2 The packet loss information.

Stage 2: Transmits the retransmission packets, then  $R$  sends an ACK signal to  $S$  if it receives the retransmission packet. The lost packet owning more important time level in a VM has a priority to be efficiently selected and encoded into a retransmission packet. Therefore,  $R$  is able to recover the most important lost packet as a priority from the

retransmission packets, thus improving the packet transmission delay.

As shown in Fig.2, two retransmission packets are generated as  $P_{r1}=P_4 \dot{\Delta} P_3 \dot{\Delta} P_2 \dot{\Delta} P_1$  and  $P_{r2}=P_4 \dot{\Delta} P_5 \dot{\Delta} P_3$ , as a result,  $R_1$  can recover  $P_4$  from  $P_{r1}$  by XOR operations  $P_{r1} \dot{\Delta} P_3 \dot{\Delta} P_2 \dot{\Delta} P_1$ ,  $R_3$  can recover  $P_2$  and  $P_5$ .  $R_4$  can recover  $P_3$  from  $P_{r2}$ , then  $P_1$  from  $P_{r1}$  in a similar way.

Stage 3: It has a probability of having two or more irrecoverable packets in  $R$  (e.g.  $P_3$  and  $P_4$  in  $R_2$ ) and  $R$  can't recover its lost packets from the minimum number of retransmission packets generated in stage 2<sup>[4]</sup>. So  $S$  has to transmit these packets to accomplish the retransmission. An explicit algorithm is proposed to find out the irrecoverable packets at  $S$ .

Let an  $N$ -dimension vector  $\gamma_i$  denote which packets among  $N$  packets are included in the  $i^{\text{th}}$  retransmission packet  $P_{r_i}$  and  $\gamma_i(j)=1$  represents  $P_j$  is in  $P_{r_i}$ . Let  $\Psi = [\varphi_1, \dots, \varphi_j, \dots, \varphi_N]$  and  $\varphi_j$  denote the information that which combination packet embodies  $P_i$ . If  $\varphi_\varepsilon = \varphi_\zeta$  ( $\varepsilon \neq \zeta, 1 \leq \varepsilon, \zeta \leq N$ ),  $P_\varepsilon$  and  $P_\zeta$  are irrecoverable packets. The  $\varphi_j$  for a VM  $R_n$  is given by

$$\left. \begin{aligned} \beta_0 &= \omega_{nj} \\ \beta_i &= 2^i \cdot \gamma_i(j) \cdot \beta_{i-1} + \beta_{i-1}, \quad i=1, 2, \dots, \eta \\ \varphi_j &= \beta_\eta \end{aligned} \right\} (2)$$

where  $\beta_i$  is an intermediate variable and  $\eta$  denotes the number of retransmission packets.

### III. PERFORMANCE ANALYSIS

#### A. Throughput Efficiency

When  $N$  is sufficiently large, the optimized throughput efficiency  $T^*$  of ONC based retransmission scheme is given by [4-5]

$$T^* = 1 - \max_{i \in \{1, 2, \dots, M\}} \{q_i\} \quad (3)$$

Where  $q_i$  is the packet loss probability of  $R_i$ .

Let  $T$  denote the throughput efficiency of the proposed scheme. The number of original packets transmitted in stage 1 is  $N$ . When  $N$  is sufficiently large, the expected number of retransmissions  $E(r)$  is dominated by the number of lost packets of the VM who has maximum packet loss probability. So we obtain

$$\begin{aligned} E(r) &= N \cdot q_{\max} + N \cdot q_{\max}^2 + N \cdot q_{\max}^3 + \dots \\ &= N \cdot \sum_{i=1}^{\infty} q_{\max}^i = \frac{N \cdot q_{\max}}{1 - q_{\max}} \quad (4) \end{aligned}$$

where  $q_{\max} = \max\{q_1, q_2, \dots, q_M\}$  and  $N \cdot q_{\max}^i$  is the expected number of retransmissions for the lost packets which happen in the processing of transmitting  $N \cdot q_{\max}^{i-1}$  packets. The number of retransmissions in stage 3 is a high-order infinitesimal of  $q_{\max}$  under certain conditions, as shown in Fig.3. The rate of the number of irrecoverable packets in respect to the number of source packets is very small when using  $M=10$  and a small  $q_{\max}$  (on the order of  $10^{-2}$ ). Thus the number of

retransmissions in stage 3 can be neglected.

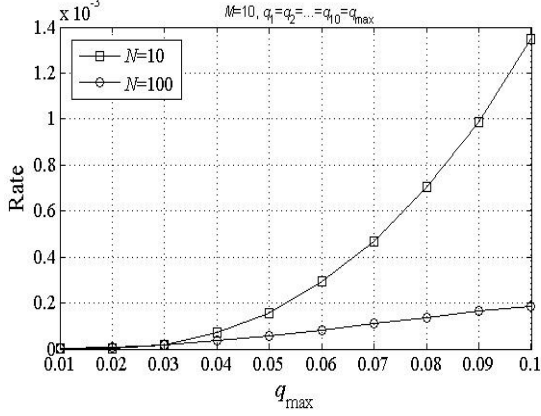


Fig.3 study of  $o(q_{\max})$  term for stage 3.

Then  $T$  can be obtained as

$$T = \frac{N}{N + E(r) + N \cdot o(q_{\max})} \approx 1 - q_{\max} \quad (5)$$

Thus the throughput efficiency of proposed scheme is in accordance with the optimal throughput efficiency of ONC based retransmission scheme.

#### B. Packet Transfer Delay

Let  $E(d_i)$  denote the expected packet transfer delay of source packet  $P_n$  ( $1 \leq n \leq N$ ) for VM  $R_i$ . If  $R_i$  recovers  $P_n$  without retransmission, then the transmission delay is  $n \cdot t$  since  $n$  packets is transmitted, where  $t$  denotes the time of a transmission slot, otherwise the transmission delay is about

$$(N + \frac{n \cdot q_i}{1 - q_i}) \cdot t \quad (6)$$

Thus  $E(d_i)$  for  $R_i$  is given by

$$E(d_i) = n \cdot t \cdot (1 - q_i) + \left( N + \frac{n \cdot q_i}{1 - q_i} \right) \cdot t \cdot q_i$$

$$= \frac{n}{1 - q_i} \cdot t \cdot q_i \quad (7)$$

According to Eq. (7), the packet transfer delay for a VM is determined by its own packet loss probability so that the VM can recover the source packets from the retransmission packets with the least delay, thus improving the packet transfer delay.

#### IV. SIMULATION RESULTS

To evaluate the performance of the proposed retransmission scheme, by using MATLAB, we set up the experiment for MBS over VM based networks as shown in Fig.1.  $S$  transmits a packet to VMs in a time slot and all the transmitted packets have the same size. We have compared our scheme with traditional ARQ scheme and a typical scheme<sup>[8]</sup>, referred as FAN, under random packet losses and burst packet losses channel conditions. For random scenario, the packet loss probabilities of VMs are set to be equal. For the burst one, a two-state Markov model is used to classify the channel into *good* state and *bad* state and the packet loss probability is 0.001 and 0.5

for *good* state and *bad* state. Let  $P_{gb}$  and  $P_{bg}$  denote state transition probability at each transmission slot for  $P_{good \rightarrow bad}$  and  $P_{bad \rightarrow good}$ . The state transition probability  $P_{gb}$  varies and  $P_{bg}$  is set at 0.4.

##### A. Throughput Efficiency

Fig.4 describes the results of average throughput efficiency for random and burst scenario respectively, where  $M$  is set at 10. As the increasing of packet loss probability, the ONC based schemes are much better than the ARQ approach. The proposed scheme outperforms ARQ and FAN scheme, in addition, it has better performance than FAN under burst scenario due to FAN's combination strategy cannot dynamically change the selected packets based on what the VMs have received.

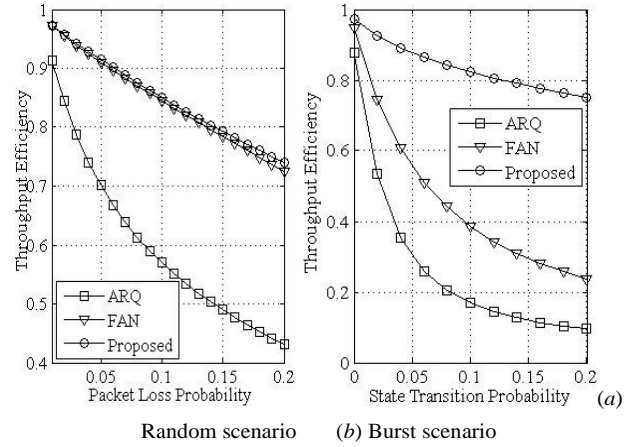


Fig.4 Throughput efficiency

Fig.5 shows average throughput efficiency in respect to the number of VMs for random and burst scenario respectively. Packet loss probability and state transition probability are equal to 0.1,  $N$  is set to 100. The throughput efficiency of proposed scheme always outperforms ARQ scheme by employing ONC technique. As the number of VMs increases, the results of the proposed scheme are better than that of FAN because of the efficient packet selection strategy.

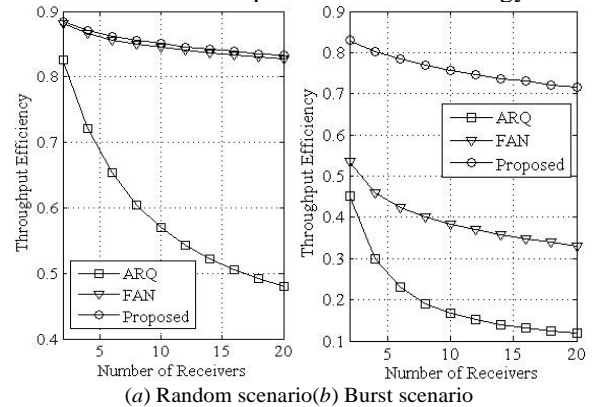


Fig.5 Throughput efficiency versus the number of VMs

Fig.6 shows average throughput efficiency in respect to the number of packets for random and burst scenario. The packet loss probability and state transition probability are 10%, and  $M$  is 10. With the number of packets increases, the proposed scheme outperforms

ARQ and FAN scheme, and the results are significantly better than that of FAN scheme for burst packet losses due to the adaptive selection of lost packets caused in retransmissions.

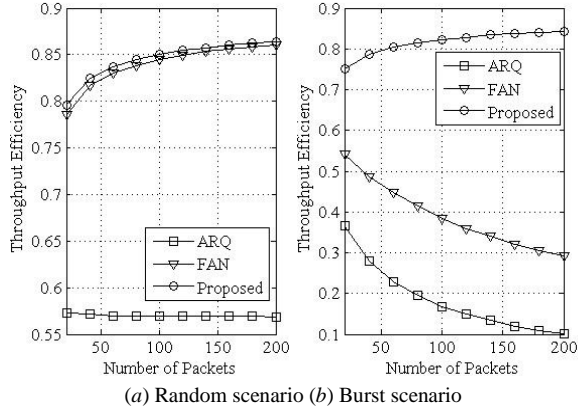


Fig.6 Throughput efficiency versus the number of packets

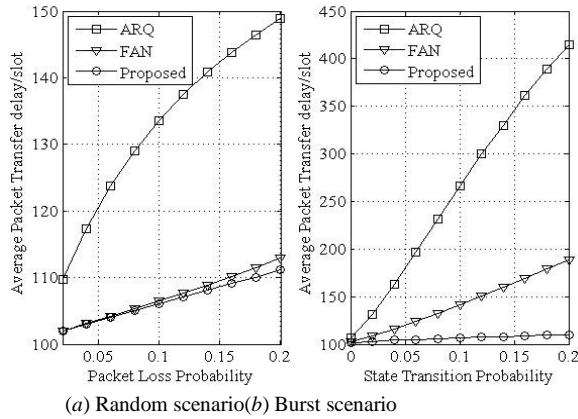


Fig.7 Average packet transfer delay

### B. Packet Transfer Delay

The proposed scheme improves the expected packet transfer delay of a packet, as described in Eq. (8). Further, Fig.7 shows average packet transfer delay for random and burst scenario respectively.  $M$  is set at 10 and  $N$  is set at 100. The proposed scheme outperforms ARQ and FAN scheme with the packet loss probability and state transition probability increases, because the lost packets are selected in a sorted order of the proposed scheme.

### V. CONCLUSION

An ONC based delay-sensitive retransmission scheme is proposed for multicast broadcast services (MBS) in VM based networks. The lost packet owning a higher time level in each VM is selected to be encoded so that the packet has a priority to be recovered, thus improving packet transfer delay and throughput. Simulations results show that the proposed

scheme maintains high network throughput and low packet transfer delay under typical channel conditions.

### REFERENCES

- [1] P. Wydrych, A. Przelaskowski, "Reviews of 'Cloud computing: automating the virtualized data center'," IEEE Comm. Magazine, vol.51, no.4, pp.14-15, 2013.
- [2] M. M. Hasan, H. Amarasinghe, A. Karmouch, "Network virtualization: Dealing with multiple infrastructure providers," IEEE International Conference on Communication (ICC), 2012:5890-5895.
- [3] W. Anjing, I. Mohan, D. Rudra, et al, "Network Virtualization: Technologies, Perspectives, and Frontiers," Journal of Lightware Technology, vol.33, no.4, pp.523-527, 2013.
- [4] D. Nguyen, T. Tran, T. Nguyen, et al, "Wireless broadcast using network coding," IEEE Trans. on Vehicular Tech., vol.58, no.2, pp.914-925, 2009.
- [5] L. Ji, W. Chengke, X. Song, et al, "Efficient broadcast transmission algorithms based on opportunistic network coding," Journal on Communications, vol.33, no.1, pp.64-70, 2012.
- [6] S. Yun, H. Kim, and K. Tan, "Towards zero retransmission overhead: a symbol level network coding approach to retransmission," IEEE Trans. on Mobile Computing, vol.10, no.8, pp.1083-1095, 2011.
- [7] T. Tran, T. Nguyen, B. Bose, et al, "A hybrid network coding technique for single-hop wireless networks," IEEE Journal on Selected Areas in Commu., vol.27, no.5, pp. 685-698, 2009.
- [8] F. Pingyi, C. Zhi, C. Wei, et al, "Reliable relay assisted wireless multicast using network coding," IEEE Journal on Selected Areas in Commu., vol.27, no.5, pp. 749-762, 2009.