ISSN : 0974 - 7435 Volume 10 Issue 19

2014

BioTechnology

An Indian Journal

FULL PAPER

BTAIJ, 10(19), 2014 [11561-11570]

Coding opportunity routing protocol based on dynamic redundancy control in wireless network

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ABSTRACT

As opportunity routing protocol relies on the received encoded packet to estimates the number of forwarding packets, and it makes that the node does not know whether its sending packets cause data redundancy and other issues for the downstream node's updating information, thus this paper proposes wireless network coding opportunity routing protocol based on dynamic redundancy control. The agreement will from the perspective of linear space abstract opportunity routing based on network coding as a general opportunity routing, assign each forwarding node forwarding priority in accordance with the ETX distance between forwarding node and the destination node. Forwarding nodes near the destination node will preferentially broadcast the forwarding packets and zero space vector of received linear space. After hearing the broadcast information, nodes with low priority judge the amount of information contained in its linear space according to the zero space vector, then dynamically determines the number of node's forwarding packets. Since the reception of the downstream node has been considered when deciding the forward packets, thus reduces transmission of invalid information and reduces overhead. Finally conducts experiments and experimental results show that: compared to the classical MORE protocol, the proposed agreement improves network throughput reduces overhead.

KEYWORDS

Routing design; Wireless protocol; Dynamic redundancy; Null space.

INTRODUCTION

Wireless Mesh Networks has wide application value in cases such as building wireless MAN, offering access to high bandwidth wireless network because of its low-cost, flexible deployment and other characteristics. How to design efficient routing is a key problem that wireless Mesh network needs to solve. Radio channel has characteristics such as broadcast, time-varying and probabilistic packet loss and so on, while the traditional routing design uses a deterministic way to achieve end to end data transmission by storing and forwarding, in the case of frequent packet loss, this approach will spend a lot of network resources because of link retransmission. Opportunistic routing provides a new way for addressing these issues in Wireless Mesh Networks[1-3]. Opportunistic routing nodes does not determine in advance the next hop node before forwarding the data, the node sends packets through broadcast, all neighbor nodes closer to the destination node will participate in packet forwarding after hearing the broadcast packet. Opportunistic routing uses the multichannel diversity gain brought by the natural characteristics of wireless channel to improve network throughput, but it requires complicated priority scheduling mechanism to avoid the issue of multiple neighbors' repeated forwarding. Network coding can simplify the opportunistic routing design, through the use of network coding, a forwarding node can bring multiple forwarding neighbor useful information. In addition, different forwarding nodes can still send linearly independent coded packets with higher probability without the complex scheduling mechanism, avoiding repeated transmission of the same package[4-7]. But the introduction of network coding makes the control of each node' forwarding redundancy a challenge. Chachulski S etc., presented the first opportunity routing protocol based on network coding[8-10]. The protocol designed a heuristic algorithm, controlled each forwarding node's redundancy after calculating the expected forwarding expectation of each forwarding node received from the upstream node's encoding packets, and conducted a physical test, the results show MORE can significantly improve network throughput. But MORE protocol uses a single batch and end-to-end acknowledgment mechanism and it increases the delay and additional network overhead. Most of the current opportunistic routing which based on network coding have adopted MORE heuristic algorithms and have improved these two shortcomings. Yujin Lin and others used simultaneous transmission of multiple batches to improve the transmission efficiency[11-13]; Yunfeng Lin etc., set a sliding window on sender to solve the feedback delay problem to a certain extent through real-time control of the window position and size[14-15]; Tian Xianzhong, etc,. remised congestion problem of non-real-time data transmission by adopting rate control[16-18]; Wu Haisheng and others remised the retransmission redundancy problem of end-to-end confirmation delay by multi-batch rotation[19-21]. Koutsonikolas D, etc., put forward CCACK (Cumulative Coded Acknowledgments) protocol, using the cumulative encoding recognition technology to achieve cached data confirmation of multiple downstream nodes on the same upstream node, and evaluate the flow congestion degree based on confirmation, whereby regulate the transmission rate of various streams and improve the fairness between flows[22].

Guo Xian proposed multi-hop wireless network coding-aware routing protocol security, analyzed the safety issues which existed in the process of discover "coding + routing" in the network coding system DCAR, proposed for coding-aware secure routing protocol security goals, designed the secure routing protocol DCASR based on the coding perception DCAR which used cryptographic mechanisms to ensure credible route establishment and the opportunity to discover the correct coding[23]. Modeling multi-hop wireless networks is characterized and analyzed routing protocol security, the introduction of the thread and the thread location adjacent to where the concept of extended security system logic LS2, presents analysis of routing protocol security logic LS2-RP. Fu Bin, etc. who made the congestion-aware routing mechanism and network coding data transmission method is proposed by combining an approach based on the degree of regional neighbors congestion detection method. Basis on this, it proposed a congestion-aware network coding based on reliable routing protocol. To the negative coding problem of the existing COPE agreement, Yang proposed the opportunity to routing protocol NCAOR with a sense of having network coding. The agreement and the opportunity take advantage of routing and network coding to achieve efficient message delivery. In each hop, the nodes are neighbors to select multiple redundant set of nodes constituting the opportunity to assist data transmission. In each hop, the nodes are neighbors to select multiple redundant set of nodes constituting the opportunity to assist data transmission. After receiving the packet, chance nodes using local knowledge and listening neighbors topology packet forwarding packets received information to determine network coding opportunities, and through integrated path distance and coding gain assess the utility function of packet forwarding performance, smart set forwarding response time. YANG Zhang and put forward a new network coding-based wireless sensor network directed diffusion routing protocol. In directed diffusion process of establishing the use of random linear network coding, the relay node for the received packet before forwarding network coding to reduce the number of transmitted packets in the network to optimize network bandwidth utilization. Tan lump and put forward a unicast communication network coding based Wireless Mesh network routing protocol, which introduces condition link consumption, using Markov chain model to design routing metric, next hop is more than consumption conditions of the data nodes in the network code combinations, select the path with the lowest consumption values condition the encoded packet transmission.

Most of the above algorithms design routing from the perspective of a single packet, assign the same priority for the forwarding nodes, relying on received coded packet estimate the number of node's forwarding packages, nodes do not know whether its sending package exists updated information in the downstream nodes, so there is a large number of invalid transmission. This paper proposes the opportunity routing protocol DRNCOR based on dynamic redundant network coding, abstracts opportunity routing based on network coding as a general opportunistic routing from the perspective of the linear space, assign each forwarding node forwarding priority according to the ETX distance from the forwarding node to the destination node, forwarding nodes near the destination node will preferentially broadcast the forwards packets and space zero vector of received linear space, after hearing the broadcast information, nodes with low priority judge the amount of information contained in its linear space according to the space zero vector, then dynamically determines the number of node's forwarding packets. Since the reception of the downstream node has been considered when deciding the forward packets, thus reduce transmission of invalid information and reduce overhead.

SYSTEM MODEL

The Wireless Mesh Network can be represented as a directed graph $G(V,E)$, where, V is the vertex set which represents the set of nodes in the network, E is the code set which represents the link set in the network diagram. Link of nodes v_i and v_j is represented as edge e_{ij}, the link loss rate between v_i and v_j is defined as the weight ε_{ij} of edge e_{ij}.

Null space confirmation

From the updated space's construction method, we can get the following null space vectors's construction method and test methods:

(1) Construction of the zero space vector group

Each node takes its ID as the seed to randomly generate M hash matrix in $a=\left[a_{ij}\right]$ is the batch size. Multiply encoding vector of the P_c with H_i in turn, then get the matrix Δ_i, solving a random zero space vector.

$n_j=\left(N_1,N_2,N_k\right)$ satisfy the following formula:

$$m_{ij}=\min\left\{\sum_{pq}w_{pq}\right\},v_p,v_q\in r_{ij}\in \quad \textbf{(1)}$$
$$Rtn_j=\left(N_1,N_2,N_k\right)$$

Randomly generate O zero space vector in the same method, put this O zero space vector into the header at the same time.

(2) Decision Method

Upstream node P takes the ID of the downstream node as a seed to generate a corresponding hash matrix, and use N_j and corresponding H_j to conduct O times null space test for each u vector in P_c,P_a,P_b.

$$E=\frac{1}{n(n-1)}\sum_{i\neq j}\frac{1}{d_{ij}}=\frac{1}{n}\sum_{k=1}^{n}\left(\frac{1}{n-1}\sum_{j=1,j\neq k}^{n}\frac{1}{d_{kj}}\right) \quad \textbf{(2)}$$

For vectors u, it was sentenced to recognized state, if and only if O determination meet formula (2).

Theorem 1 Suppose $N_1^T...N_M^T$ is a set of zero space vector that the upstream node P receives from the downstream node o, assuming that u is an encoding vector of P_b and P_c of P, if $P's$ O times null space test all meet formula (2), then the probability that P is linearly independent to all encoding vectors of D is $2_{-s}\times O$.

Proof: Let Ω_d as the linear space generated from encoding vectors of D in P_c, if $P_c\in\Omega_D$, then $p=\sum_i a_i d_i$ (d_i is the encoding vector in P_c), the construction of the zero space vector shows that

$$B=\alpha\times\max(LD_k,k-1,\cdots,n) \quad \textbf{(3)}$$

As $H_1,...H_M$ is built randomly, so $H_jN_j^T$ is randomly distributed in the null space Ω_D. Known from lemma 1 that if p meet $pH_jN_j^T=0$ u, the probability that $p\in\Omega_D$ is 2_{-s}, after P conducts O times independent null space detection, the probability that $p\in\Omega_D$ is $2_{-s}\times O$, then the probability that u is linearly independent to encoding vectors of D is $2_{-s}\times O$, prove up.

In simulation, s takes 8, O takes three, which get a good transmission. Although DRNCOR header added several zero space vectors, DRNCOR does not need to carry sending credit value of each node, header overhead is still less than that of the MORE protocol.

Basic model of opportunity routing protocol based on network coding

In a Mesh network, set S as the source node, R as the destination node, select forwarding node set $B_\infty = \beta \times C$, FN_e, according to the ETX standard. If $i \prec j$, then we say that the ETX distance from FN_i to the destination node is greater than FN_j, or FN_i is the upstream node of FN_j. Let $s\_w_x \succ 0$ be the h raw data packets within the same batch, and $s\_w_x \succ 0$ as a set of linear independent encoding packets sent from a forwarding node. Known from the random network coding principle: $u_j = \sum_i c_{ij} u_i$, c_{ij} is the coding coefficient, u_j's corresponding code vector is $\left(c_{j1}, c_{j2}, ..., c_{jh}\right)$, c_{ij} is a random number comes from Galois field GF2s, all operation follows finite field arithmetic rules. Assuming that all encoding vectors within the same batch form a space vector Ω, any forwarding node FN_i's received subspace is Ω_i, then $\Omega_i \subset \Omega$. it is not difficult to understand when $c_h \notin \Omega_i + 1 \cup \Omega_i + 2 \cup \Omega u$, u_k has updated information on downstream node. Since there is a one-to-one correspondence between encoding packets and encoding vectors received from the same batch by any node, so the linear space generated respectively by the two has isomorphism and update status on downstream node is the same. In order to facilitate the discussion of these two space we uniformly call these two spaces as node FN_i's space or node FN_i's cache space.

Definition 1 updated space: ψ_{ij} is called the updated space of FN_i to FN_j, if and only if $\psi_{ij} \in \Omega_i$ and $\psi_{ij} \cap \Omega_j$ is an empty set. Then all the updated space of FN_i to its downstream nodes ψ_i is $A = \left(a_{ij}\right) n \times n, \partial, \beta$.

PROTOCOL DESIGN BASED ON DYNAMIC REDUNDANCY CONTROL

Solution of updated space

Lemma 1: Assume that the linear space generated by the matrix A is ΩA, Z_A is an arbitrary zero space vector of ΩA, if all elements of the vector are selected from the GF2s, when $v \in \Omega A$, v meets Z_A, the probability that $V'T = 0$ is 2-s. Arbitrarily select a zero space vector of FN_j to multiply vectors of FN_i, and determine whether there is quadrature. By Lemma 1, we know that if product of FN_i's zero space vector multiplying a vector C_x is 0, then the probability that $C_x \not\subset \Omega_j$ is $2 - s$. Wherein, s is the size of a finite field, if select n independent null space vector and the test is 0, then the probability that $C_x \not\subset \Omega$ is $2 - ns$, when n is large enough, this value is negligible. Take a maximum linearly independent vectors group c_1, c_2, ... c_l of all nodes that are perpendicular to the zero space vector and then to solve a set of base of FN_i, if the group satisfies $\left(E_1, E_2, ...E_F, C_1, C_2, ...C_L\right)$,then the resulting linear space from (E1, E2, ... EF) is ψ_{ij}. Proof is omitted.

Figure 1 the data forwarding condition a time between forwarding nodes in the network in a certain moment, the solid line represents the transmission data that downstream nodes received successfully from the upstream nodes, the dotted line indicates the feedback that the upstream nodes monitored form the downstream nodes. By definition 1 we can know, the updated space of FN_i to D is $c \middle| c = b \times (1,1,) b \neq 0$, if FN_j broadcast its zero space vector, then FN_j can successfully notifies FN_i with a certain probability that it has received the space $c \middle| c = b \times (1,1,) b \neq 0$, then FN_i cancels the contract and selects only FN_j as the forwarding node, which can reduce network overhead.

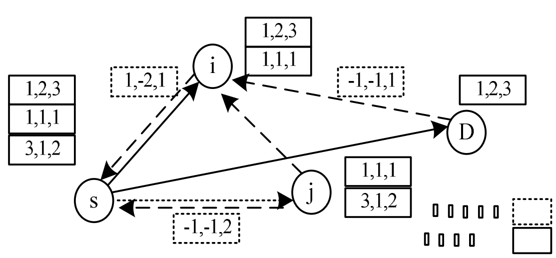

Figure 1 : Transmission process of opportunity routing based on network coding

From the above discussion we know that information transmission process of opportunity routing protocol based on network coding can be abstracted as the information transmission process of a common opportunity routing protocol which take linear space as data elements. Priority scheduling mechanism of general opportunity routing is still valid to opportunity routing protocol based on network coding in reducing information's repeated sending. To design low-overhead opportunity routing protocol based network coding should start from designing dynamic redundancy control and forwarding priority's scheduling mechanism.

Server operating

1) Sorted storing. When a code receives a coded packet, it will firstly extract the batch number of header and forwarding set list, if the node is not in forwarding set, or the batch number of coded packet is less than of the current forwarding node, then discard it. If receive the current batch encoding package, then firstly extract encoding vectors, then use the Gaussian elimination method to determine whether it is linearly related to the encoding vector of p_C, if they are linearly independent,then put the entire coding package into the p_C. Furthermore, all current batch encoding packets from the upstream node should be extracted into the p_A, all encoding packets from downstream nodes should extract null space vector sets and the ID number of the sending node into p_N. If the p_N already contains the zero vector space of current batch from the same downstream node, then only save the new zero space vector.

2) Zero Space confirm. Each time a node receives a coded packet it should conduct a null space inspection. Inspection method: Let C as the coding vectors of received packet, if the received packet is from the upstream node, then in turn conduct a zero space test for C and all zero space vectors from p_N (test method C). If the test is true, that the code pack has no updated effect on the downstream node, labeled as 1, otherwise labeled as 0; If the received packet is from the downstream node, extract null space vector sets, sequentially conducts zero space test on encoding vector of p_C, p_A and p_B (encoding vector that the storage node has already broadcast coded packet). Suppose the encoding vector's rank in the p_C is R_C, the rank of encoding vector set which is labeled as 1 of p_A and p_B is RACK, when $R_C = RACK$, at this point the node has no updated information on downstream node, then the transmission flag is set to 0. The node calculates the expected sending value T_X_credit according to confirmed status.

3) Set the transmit timer. Each node receives a new batch of data, it will clear the transmit timer, set the new batch as the current batch, and open a new for the new batch, the node begins forwarding encoded packets when the timer expires. In order to let the downstream node feedback in advance, the initial period of timer is set to $\alpha_t \times$ (N -node _ index), wherein T is the mean transmission delay of each packet, α is the weighting coefficient which used to adjust transmission rate according to the network congestion, the paper takes α as a fixed value 2, N is the number of forwarding node set, node _index refers to the order number of collection of nodes(source node's transmission cycle is set as data's input cycle).

4) ACK packet's processing. When the destination node p_C full rank, the use encoding packets of p_C to complete the decoding through solving linear equations and send an ACK packet to the source node, ACK packet will be forwarded in accordance with the shortest path to the source node. When a forwarding node receives an ACK packet sent from the destination node, immediately cancels the timer of corresponding batch, stop broadcasting coded packets. Source node begins sending the next batch of packets since it receives the ACK packet.

Client operation

1) Determine the forwarding set. Source node put all the nodes which has connection with itself and the ETX to the destination node is smaller than that of itself into the forwarding set, and numbered sequentially from far to near according to the ETX.

2) Generate an encoded packet. The source node divides the packet into different batches, each contains K raw data packets, and put these K original packets into the p_C. Source node and the forwarding node, in a way randomly conducts network coding according to stream encoding, re-encode the encoding package of UC coded packet to generate new code package p_j, and calculate the zero space vector group UC(calculation method described in 3.3). Codec pack and zero space vector updates at any time according to the received content of server and zero space confirmed situation, reduce the wait time when transmit opportunities.

3) Update the forwarding cycle. Most of opportunity routing is set between the MAC layer and the network layer, and it can in any time, according to the received packets, update the cache package of current batch at the MAC layer, guarantee that the node sends packets in accordance with the latest update node status and forwarding redundancy bidding. DRNCOR although located in the application layer DRNCOR if easy for application, it can not immediately update cache of the MAC layer, therefore this paper in the case of a single cast stream, take whether the channel is idle for the transmission opportunity criteria, reducing the waiting time of transmitting and the probability of collision between the nodes. When the timer times out, the forwarding node periodically obtain a channel state from the physical layer, if the channel is idle, then transmit counter $T_x\_counter$ and forwards judgment after increasing T_x_credit, While double the period of sending timer, so that after the end of transmission gives out opportunities to forwarding neighbor; If the channel is busy, then the timer delay halved for the local node's quick access to forwarding opportunities.

4) Forward judgment. When forwarding timer expires, the node does not immediately send packets, nodes need to meet the following conditions: (a) forwarding flag is 1; (b) $T_x\_counter \succ 0$. When the above conditions are met, the node broadcasts a coded packet, and puts the encoding vector of broadcast packet into UB, while $T_x\_counter$ minus 1.

Calculation of credit values

Code pack (vector) which is confirmed as 0 is not surely in the updated space, but also can bring updated information to the downstream node. Suppose that E of p_c in FN_j is recognized to 0, the sending node of E is FN_j , then the probability that E is not received by the downstream node is $\prod_k \succ j^{\varepsilon} jk$. Also to ensure that at least one downstream node receives an updated package, then the corresponding forwarding expectation is:

$$f = \frac{\sum_{i=1}^{Num} f_i}{Num \times n} \tag{4}$$

So for P_c , forwarding credit value of all its unacknowledged encoded packet is

$$w_k = \begin{cases} 0, LD_k < C \\ \dfrac{LD_k - C}{C_\infty - C}, C < LD_k < C_\infty \\ 1, LD_k > C_\infty \end{cases} \tag{5}$$

Suppose that the number of confirmed vector of P_c is R_M , remove the amount of recognized information in the p_A and p_B , the forwarding credit value of all nodes updating information can be approximated as:

$$A = \left(a_{ij}\right) n \times n, \partial, \beta \tag{6}$$

$$R(p) = \frac{1}{2}\sum_{i=1}^{k}\left\|k_i - t_i\right\| \tag{7}$$

THE SIMULATION AND ANALYSIS

Setting of experimental environment

This paper uses QualNet network simulation platform to respectively conduct simulation comparison on DRNCOR protocol and MORE protocol. Using the following simulation environment: 40 nodes, randomly distributed within a 1500 × 1500m area, node's average RF distance is 200m, link bandwidth is 11Mbps, MAC layer is 802.11b, using a constant bit rate (CBR) business model, the packet type is UDP, sending number is 1000, the packet length is 512 bytes. To simulate the lossy channel, drop out the successfully received packets in the MAC layer by a certain probability, the link's average packet loss rate is set to 0.4. Batch size takes a constant value 12.

In order to evaluate the real-time services's performance such as transport voice of this protocol, changes the source input rate, compare the average end-to-end throughput in the case of a single stream and single cast, average end-to-end time delay of each batch, normalized overhead and delivery rates.

Analysis of experimental results

To evaluate the performance of the transmit voice of protocol and other real-time business, and to change the source input rate, it compared the both average end-throughput in the single unicast stream and the average end to end delay for each batch, and normalized overhead and delivery rates.

Throughput and average end-to-end delay

The average throughput is defined as the ratio of the total number of decoded bits of destination node and data transmission time ; the average end-to-end time delay of each batch is defined as the average time interval the source node's sending to the destination node to complete a batch of decoded data.

The simulation results are shown in Figures 2 and 3, it can be seen from the figure in addition to outside input cycle 20ms, DRNCOR throughput and the average end-to-end delay of each batch are superior to MORE Agreement. In particular when source node's sending period exceeds 30ms, DRNCOR throughput exceeds MORE for about 45%~00%, and the average per batch end-to-end time delay of DRNCOR is approximately half of MORE. On one hand this is due to DRNCOR can dynamically adjust its transmission amount according to the feedback, effectively inhibits the upstream node's sending redundant packets, reducing the useless data's transmission; on the other hand, when replies the ACK packet on the destination node, the most forwarding nodes are recognized as null-space to stop contracting, reducing the competition for channel with ACK packet, reducing the time delay of end-to-end recognition; secondly, MORE protocol depends upon the received coded packet as its forwarding power, when the transmission cycle becomes longer, the node will be in a wait state, when the source rate is low the latency will increase, while DRNCOR'S forwarding is driven by the downstream node's freshness, even without receiving a new coded pack, as long as the downstream node exists updated information, it will automatically forward all the information, thus DRNCOR delay is less than that of MORE. Also it can be seen from Figure 3 DRNCOR'S advantage decreases in the case of high-speed service, because when the source node's sending speed is relative fast, the forwarding time delay scheduling mechanism will be affected, DRNCOR'S downstream node can not timely feedback the latest information to the upstream node, the upstream node can not get adequate feedback and timely adjust transmission redundancy, huge sending out of invalid packets' occupies the channel, affects the updated package's transmission efficiency.

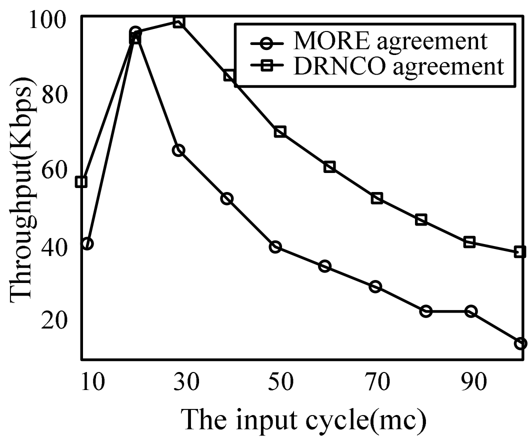

Figure 2 : Average end-to-end throughput

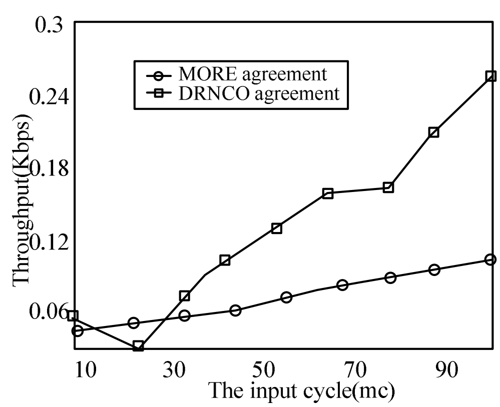

Figure 3 : Average end-to-end delay per batch

Normalized overhead and delivery rates

Normalized overhead is defined as the ratio of the forwarding packets number in the entire network and the number of destination node's successfully decoded packages; delivery rate is defined as the ratio of number of destination node's successfully decoded packages and number of the source node's sending packets.

The simulation results are shown in Figure 4, Figure 5. It an be seen from Figure 4, when the transmission cycle time is less than 20ms, both MORE and DRNCOR'S normalized overhead increases with the decrease of the transmission cycle; when sending period is greater than 20ms, MORE'S overhead will gradually increase, while DRNCOR'S overhead will continue to decrease. When the source node's transmission cycle reaches 100ms, DRNCOR overhead is about MORE'S 46% overhead. This proves that DRNCOR can dynamically regulates sending redundancy and can effectively reduce the transmission overhead of the network.

In addition, when DRNCOR is with high information source, since the conflict causes, that feedback information can not be timely and correctly received by the upstream node, affecting its feedback performance, increasing the invalid transmission.

As can be seen from Figure 5, DRNCOR'S delivery rates is better than MORE'S, this is because when DRNCOR finds local information has updated information on the downstream node it will initiatively send packets to the downstream node, while MORE takes encoded packet received from upstream node as the forwarding power, which requires the source node keeps sending the same batch encoding package to promote the transmission of network information. Obviously, compared to MORE protocol, DRNCOR is more suitable to real-time services such as voice transmission.

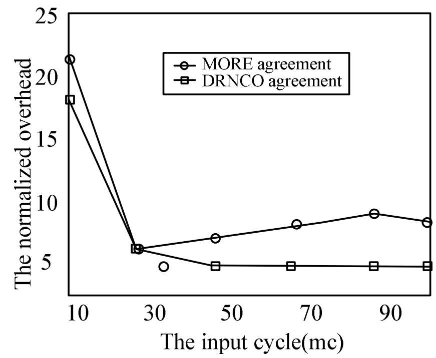

Figure 4 : Normalized overhead

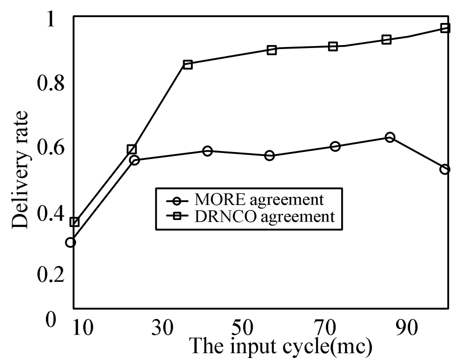

Figure 5 :Delivery Rate

Random network topology

In order to make the evaluation of protocol performance DRNCOR more universal, general and statistical significance, the simulation of this section makes randomly business model analysis to the protocol. The main method is using a random network topology to do several experiments, and discuss the changes of the number of opportunities for network coding with the increasing of the number of data streams in general. In the experiment, it uses the topology generation tool setdest which comes from NS2 to generate network topology (200 nodes are randomly distributed in the 1 000m × 1 000m scenario, nodes maximum moving speed 2m / s) simulate the quasi-static wireless mesh network topology. Simulation sequentially selected the number of data streams of 19 values from 10 to 100, the value of each number under the experimental results take the average of 50 times. Statistical results after the simulation shown in Figure 6.

As can be seen from Figure 6, with the increase in the number of data streams, the number of coding opportunities in network uptrend, but DRNCOR protocol network protocol coding opportunity was more than MORE protocol. It can be obtained from statistical simulation results that in the above simulation environment, the average number of coding opportunities is about 1.66 times of MORE Agreement. This result indicates that, in general, the network topology of the path DRNCOR protocol can effectively discovery process to find out the node as the routing code, which can be further improved network throughput.

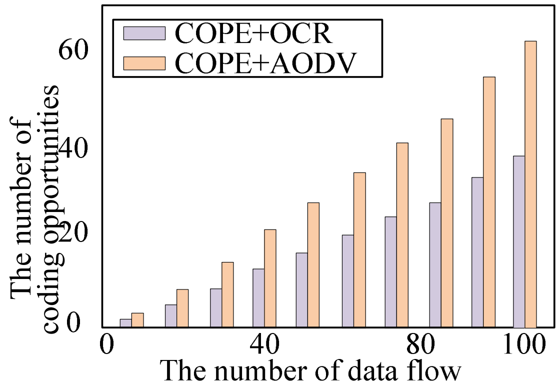

Figure 6 : The number statistics of coding opportunities in random network

CONCLUSION

This paper proposes a wireless network coding protocol DRNCOR which with low overhead for Wireless Mesh Networks. Experimental results show that the proposed protocol uses advantages of network coding to improve transmission of single data packet, but also can more accurately avoid information's retransmission after using network coding, and it has a certain reference value for the efficient design of wireless Mesh network protocol. The next step is to realize simultaneous sending of multiple batches in a single stream, to further improve network throughput, as well as design a rational control mechanism for congestion, and to improve fairness between flows.

ACKNOWLEDGMENT

The paper is supported by key discipline for computer application and technology of Hunan University of Science and Engineering. This work was supported in part by a grant from the Research Foundation of Education Bureau of Hunan Province, China (Grant No.12C0681), and supported in part by a grant from the Science Foundation of Education Department of Hunan Province, China (Grant No. 13C336).

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