Optimal Energy Routing Protocol Algorithm in Wireless Network

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Abstract—As some nodes in the wireless network are supplied by the battery, energy is critical to data transmission, to optimize the energy consumption of the wireless network and prolong the network lifetime, the optimal energy routing protocol algorithm is proposed. The algorithm of this text uses threshold energy and average residuary energy to balance the energy consumption, uses network coding to reduce the energy consumption, unify them to optimize the network energy effectively. Finally the comparative simulation experiment between this algorithm and COPE, DSR algorithm is conducted in the variance of energy consumption in unit time, energy consumption in unit bit and residuary energy, the result shows the energy optimization routing protocol algorithm this text puts forward can reduce the transmission energy consumption and balance the network energy allocation.

Index Terms—Route Selection; Network Nodes; Energy Consumption; Coding Protocol

I. INTRODUCTION

In the wireless communication network, the network nodes exchanges information by using its wireless transceiver, when they are out of the other’s communication range, they can achieve the multi-hop communication with the help of other intermediate nodes [1]. Suppose that the network nodes are supplied by the battery, some nodes cannot work once the battery runs out, and this can lead to the division of the whole network since the lack of relay-operated intermediate nodes, more seriously, most survival nodes can not communicate. Thus the energy optimization is one of the most important researches of wireless network routing protocol [2].

To prolong the network lifetime, the selection of the route should consider two aspects: one is the balanced energy consumption of every node; two is the reduction of the overall energy consumption. While traditional wireless network routing protocols, such as DSR proposed by Johnson D, AODV proposed by Perkins C, select the route according to ETX and ETT, but ignore the energy [3-4]. The existing energy aware routing protocol selects the route according to the energy, such as the MTPR protocol proposed by Toh C K and others, it takes the minimum overall transmission power among all links as the measurement, the selected route may have more hops which causes too much delay, and if the route selected by many streams has cross, the crossed node energy can run out early, this measurement does not take the lifetime of single node into consideration [5]. The MBCR protocol proposed by Toh C K and others selects the route according to the residual energy of the node, but because of the limitation of the measurement, most nodes of the selected route have more residual energy, several nodes have less residual energy [6]. The MMBCR protocol proposed by Toh C K and others can guarantee the fairness of the nodes consumption as compared to the above two protocols, but the route selected by this protocol can consume more energy [7]. The CMMBCR protocol proposed by Niu Nan and others not only takes the fairness of node energy consumption into account, but also the selected route has less overall energy consumption. There are many theoretical researches on the extension of network lifetime, but they can not use the existing resources to save energy in real meaning [8-9].

The LEACH protocol is developed particularly for the wireless sensor network. This self-adaptive routing protocol prolongs 15% network lift cycle than the traditional routing protocol. Based on the LEACH, LINDSEY S and others get the PEFASIS protocol which communicates with the closest neighbor node with the minimum power [10]; the periodic cluster rotation can distribute the load with high energy consumption to different nodes equally, thus it balances the energy consumption of nodes. The energy-saving routing protocol CHFPC proposed by Ding Yiming adds the power control mechanism and predicts the cluster according to energy and distance [11]; it saves the energy consumption of the network by adjusting the power during the transmission of clustering routing and data. Zhao Yonghui proposes a energy balancing routing algorithm EBRRLP which is based on reinforcing learning prediction; this algorithm transmits the behavior of nodes by reinforcing learning prediction and selects the node with the optimal predicted value to send data by using the ε greedy strategy, then the principal-agent incentive system is adopted to restrain the selfishness of the forwarding nodes and keep the maximum utility of nodes; it has better predictive effect and higher
throughput, and it can reduce the energy consumption effectively and balance the energy load [12].

The network coding is proposed by Ahlswede R and others, its intermediate nodes encode data packages from different flows and them out on the radio [13]. It takes advantage of the broadcast property of the wireless network and reduces network traffic and energy consumption. The COPE protocol proposed by Katti S and others is based on opportunistic coding and opportunistic interception, it is the first one to apply network coding in real wireless network, but it is passive to waiting for coding opportunities other than find them [14]. The PNC-COOP proposed by Poocharoen P also uses the opportunistic coding to reduce transmission energy, but opportunistic coding can gain limited opportunities on the network, it can not use the coding opportunities to reduce the energy consumption to the maximum extent [15]. To find more coding opportunities, a new type coding-aware routing emerges as the times require, it searches the coding opportunities actively and improves the property of network coding largely. The existing ECX, CRM pay much attention to find coding opportunities and improve the throughput while always ignore the energy consumption of nodes in the network.

It can thus be seen, this text proposes COER to reduce the network energy consumption by using the network coding and prolong the network lifetime by balancing the energy consumption of the nodes.

This paper mainly made a work in the following areas expansively and innovatively:

(a) Some nodes of the wireless network are supplied by the battery and energy is very important for the data transmission, the following experiment is conducted to optimize the energy consumption of the wireless network and prolong the network lifetime. Thus the optimal energy routing protocol algorithm is proposed. It analyzes the routing process, it is a combination of route with less energy consumption and route with balanced energy consumption of nodes, and it uses network coding to reduce the energy consumption. The introduction of ARE makes the node which transmits the packet to choose a node whose ARE is more than other nodes but less than the threshold in its neighbor nodes, thus it can balance the network energy consumption. The process of building a route can not only choose a route according to the metric the text mentioned, but also avoid route flooding by the routing cache strategy.

(b) In order to further verify the correctness and validity of the optimal energy routing protocol algorithm this text proposes, the comparative simulation experiment between this algorithm and COPE, DSR algorithm is conducted in the variance of energy consumption in unit time, energy consumption in unit bit and residuary energy. The experiment uses a 50m×50m range network with 25 nodes distributed randomly; the communication range between nodes is 20m and the initial energy of every node is 50j. The result shows it is better than COPE and DSR algorithm in the above three aspects, the optimal energy routing algorithm can reduce the transmission energy consumption and balance the energy allocation of the network, thus it prolongs the network lifetime authentically.

II. BASIC IDEA

As is shown in figure 1, there are 8 nodes in this network and one stream f1(8→6→4→2), now there is a new stream f2(1→3→5→7), assume that their traffic is 200kb/s, the initialized energy of every node is 10J, the speed of consuming energy of every node is 50nJ/bit (because the received energy is much less than the transmitting energy, it is ignored ). Route chosen by f2 consumes different energy from the route chosen by f1, thus the speed of consuming energy of every node is different. Figure 1 (a) (b) (c) show the routes chosen by f2 when aims to the traditional shortest routing, the coding-aware routing and the coding-aware optimal energy routing this text puts forward respectively. Table 1 expresses the overall energy consumption of the above three routes, and the residual energy of nodes in the whole network after 500s. This text uses network coding to reduce the energy consumption and searches the coding opportunities actively by coding-aware to reduce the transmission of data package. Stream f2 will choose the route which has more crosses with f1 to transmit data in order to find more coding opportunities actively, then the route f2 chooses is 1→3→6→7 , just as is shown in figure (b). From table 1, the overall energy consumption of route chosen by coding-aware routing is more than that of route chosen by the traditional shortest routing, and node 6 runs out after 500s, this unbalanced energy consumption of nodes may lead to the interruption of network communication, which does not achieve the goal of reducing energy consumption by coding-aware.

![Figure 1. Comparison diagram of different paths](image_url)

| TABLE I. | THE ANALYSIS OF NETWORK ENERGY OF STREAM F1 AND F2 UNDER DIFFERENT ROUTINGS AFTER 500s |
|-------------------------------|-------------------------------|-------------------------------|-------------------------------|
| The name of routing protocol | The path of stream f1 | The overall energy consumption /J of the path of stream f1 | The residual energy/J of nodes 1-8 after 300s |
| The shortest path routing | 2→4→6 | 200×10² × 500×50×10⁻⁶×4 = 25 | 6,10,5,5,10,5 |
| Coding-aware routing | 1→3→6→7 | 200×10² × 500×50×10⁻⁶×3 = 15 | 5,5,10,10,0,10,5 |
| Coding-aware optimal energy routing | 2→4→5 | 200×10² × 500×50×10⁻⁶×2 = 10 | 5,10,10,5,5,10,5 |

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From table 1, the algorithm this text puts forward can balance the energy consumption of nodes and requires less overall energy consumption of the selected path, this is the main idea of COER.

A. Energy Balance

COER sets a threshold for every node of the network, when the route finds the energy of one node is lower than its threshold, this node will discard the routing request information. But there are two problems: one is that when the problem is found, the energy of neighbor nodes is not enough which is lower than its threshold, the requesting information of the route can not get to the destination node, thus this requesting can not success; the other is when the problem is found, the energy of neighbor nodes is enough which is higher than its threshold, but their higher portions are different, we’d like choose nodes with more residual energy if they have the same energy consumption. The way to solve the first problem is to increase serial number to the source nodes and resend the same requesting information of the route, when the intermediate node receives the routing requesting information with added serial number, it will lower its threshold. The other problem can be solved by ARE which is brought later, it can select the nodes with more residual energy among nodes with enough energy.

B. The Minimum Energy

If some nodes of a new stream have coding opportunities with other streams, that means the data packages being transmitted by these nodes have been transmitted by the existing stream, it does not need extra energy. Therefore, beginning with the coding-aware, this text searches for the coding opportunities as many as possible to reduce the energy consumption. Because what we consider is the sum of energy consumption on this path, we need a metric to computing the overall energy consumption with the gain.

Only by combining them to form a unified metric, can we select a route which can achieve the balance between energy balance and minimum energy.

The above two points are the emphasis of this text, but the potential problems appearing during the searching of routing can not be ignored. The existing coding-aware routing are mostly based on DSR, but DSR has a fatal weakness—to search coding opportunities roundly, the source node and intermediate node will broadcast the routing request information RREQ, while much more RREQ broadcasting will jam the links, and every RREQ not received by the destination node will send a RREP to the source node by unicast, thus many RREPs are easily to collide at the source node, which will affect the quality of paths. Meanwhile the whole process of searching routes is prolonged.

This text adopts a new way to explore coding opportunities, it decides if a node has coding opportunities during the process of RREQ, and the intermediate node transmits the received RREQ selectively, the destination node is the final selector of the received RREQ. RREP can only be sent to the source node by unicast along the selected path. As for the long time-delay, this text uses the cache of the intermediate node to speed up the building of route setup.

III. PROPOSED SCHEME

From the above main idea of COER, the following questions need to be clarified in detail: a) how do these two ways balance the energy consumption; b) how to find the coding opportunities and coding links during the process of routing request; c) how to define a metric which combines the energy balance and the minimum consumption; d) how to reduce the flooding of RREP and take use of the routing cache during the process of route discovery; e) what is the specific process of route discovery.

A. Balance Energy Consumption

1) The Energy Threshold

The energy threshold is introduced to control the energy consumption of nodes, the process of route selection only takes nodes whose residual energy is larger than its threshold into account, for example, after receiving the routing request information the node \( i \) will judge its \( \text{RE}(i) \), if \( \text{RE}(i) > \text{threshold}(i) \), \( i \) may transmit this RREQ, otherwise it will be discarded. If the \( \text{RE} \) of the neighbor nodes of a network node are lower than their thresholds, then the source node adds serial number and resend the same RREQ. When the intermediate node receives this RREQ, it will lower its threshold. In order to avoid the cascade effect, the \text{DROP\_ROUTE\_REQ} information should be broadcast by the first node who’s \( \text{RE} \) is lower than its threshold, after receiving the \text{DROP\_ROUTE\_REQ} information, the successor nodes will know a RREQ has been discarded, when the second RREQ with added serial number is received, the successor node will lower its threshold to avoid the source node adding serial numbers over and over, and the second RREQ information is expected to get to the destination node.

2) The Average Residual Energy

To reduce the rate of the next-hop node running out quickly, the neighbor node with more residual energy of the intermediate node \( i \) is expected to send data, inspired by the article A Load-Balanced Route SELEC-TION for Network Coding in Wireless Mesh Networks, we use ARE to show the current average residual energy of a node, define the average residual energy of node \( j \) \( \{ j \in N(i) \} \cap j \notin d,j \notin d \) expresses \( j \) is not a coding node, for details see § III) in the neighbor nodes of \( i \) as:

\[
N(i) = \sum_{k \in N(i) \setminus \{i\}} \text{RE}(k)
\]

In it, \( N(i) \) is the set of the neighbor nodes of node \( i \), then \( |N(i)| \) is the number of the neighbor nodes of node \( i \). From (1) the ARE of a node is the relative value of the ARE of all neighbor nodes of the last hop node. The reason for adding \( \text{RE}(j) > \text{threshold}(j) \) in this formula is...
to show the insignificance when compares node j, which shows the relative state of the neighbor nodes with enough energy of node i, with node lower than its threshold. The next-hop node with more enough energy can be selected from many nodes with enough energy by using the ARE.

B. Coding

A new coding condition is proposed to judge if one node has coding opportunity and find coding opportunities during the process of the routing request. Meanwhile the coding links can be detected during the process of RREQ by using the coding strategy from A Load-Balanced Route SELECTION for Network Coding in Wireless Mesh Networks.

1) The Coding Condition

Define a node as r, the set of the neighbor nodes of node r is N(r), the source node of stream f is S, the destination node is D, the path S→D is P, if node r is on the path P, then r ∈ p. Define a tool to detect coding opportunity: coded form, its structure is cf = {(Upf(p, f), p, r, q, s)}. f flows through node r, p is the last hop node of node r, Ups(p, f) is the set of the upstream nodes of node p on the stream f, q is the next-hop node of r, s is used to judge if the package r receives is a data package, or if node p is a coding node, if so s = d, otherwise s = c. A coding set is used to judge if a node has coding opportunity, the form of this coding set is cs = {cf1, cf2, ..., cfk} = {Upf(p1, f1), p1, r, q1, s1, ..., Upf(pn, fn), pn, r, qn, sn}, n coding forms can be in a coding set, which means there are n packages of n streams encoding at a node, then the condition of two random cfj and cfj′ (i, j < n) encoding together:

\[
q_j = 1 \text{ or } q_j \in N(l)s_j = c \text{ amog } l
\]

\[
= Upf(p_j, f_j)u 
\]

\[
q'_j = 1 \text{ or } q'_j \in N(l)s'_j = c \text{ amog } l
\]

\[
= Upf(p'_j, f'_j)u 
\]

Stream fj and stream fj′ can encode at node r only if they meet the above two conditions, otherwise they can not. Meeting the above two conditions, COPE can find more coding opportunities.

2) The Coding Strategy

The source node s will broadcast a RREQ after stream f initiating a routing request; add extra head for RREQ to store the detected coding links, the specific coding strategy shows as the followings:

(a) The initialization of the source node coding links=Θ

(b) When the intermediate node r receives the route request,

Firstly, check if there is the path of the last hop node p → r. if so, it means there is coding opportunity at node p, then update s in the coding form p → r attached to RREQ, if not, s = c;

Secondly, build a coding form, for every neighbor node v, (1 ≤ i ≤ m, m is the number of neighbors of node r) of r, there is cf = {Ups(p, f), p, r, q, s}, if node r has the coding form cs(i k e the code number of node r), judge if every coding form of cf and cs meets the above coding conditions, if so, update coding links=coding links ∪ {r → v}.

C. The Routing Metric of the Energy

COPE can not only balance the energy consumption but also choose a path with the minimum overall energy consumption.

1) The Overall Energy Consumption of the Path

From the above coding strategy, the coding node and link can be found during the routing request process, assume that the overhead of sending a data package p on the link l (l ∈ p) is cost, if p can not code with other package, it needs to be sent on link l, that means the cost is 1, if the cost is 0, that means package p is attached to other package, sent as a coding package, it does not need extra transmission. So

\[
\text{cost}(l) = \begin{cases} 
0 & \text{if } l \text{ is a coding link} \\
1 & \text{if } l \text{ is a coding link} 
\end{cases}
\]

So the total energy consumed on link l is:

\[
TE(l) = E_{\text{send}} \times \text{cost}(l) + E_{\text{rec}}
\]

In it, Esend is the energy consumption of sending data package p on link l, Erec is the energy consumption of receiving data package p. Adopting the energy consumption model proposed by Heinzelman and others, the energy consumption of receiving a kbin data package for the original model is:

\[
E_{\text{rec}}(k) = k E_{\text{elec}}
\]

The energy consumption of sending a kbin data package is:

\[
E_{\text{send}}(k) = k \left( E_{\text{send}} + E_{\text{amp}}d^r \right)
\]

In it, k is the bit number of the data package, Eelec is the energy consumption of sending units of bits of data, Eamp is the energy consumption of amplifying signal, d is the distance of sending node and receiving node, (the loss coefficient of the path, the value range is [2,4])

2) The Unified Metric of Energy Balance and Minimum Consumption
During the route selection, we hope to select a next-hop node which has more residual energy and consumes less, thus a unified metric is proposed to combine the ARE and the total energy consumption of the path:

$$COER(l) = \frac{TE(l)}{ARE(j)}$$ \hspace{1cm} (8)

$TE(l)$ is the energy consumption produced during the process of choosing the next-hop node $j$ by node $i$, or the total energy consumption of sending data by node $i$ and receiving data by node $j$, its value is determined by formula (3); $ARE(j)$ is the residual energy of node $j$, its value is determined by formula (1). Therefore, the more residual energy the node $j$ has and the less energy consumption the link $l$ produces, the smaller the value of $COER(l)$ is.

For the whole path $PL$, there is:

$$COER(PL) = \sum_{i \in PL} COER(l)$$ \hspace{1cm} (9)

The destination node calculates the received routing request in a period of time, then choose the path $p$ which has the smallest value of $COER$, that is

$$COER(p) = \min_{pl \in PL} \left( COER(PL) \right)$$ \hspace{1cm} (10)

This metric can select the path with the minimum energy consumption; and it can balance the energy consumption of nodes instead of dying early because of residual energy shortage under the condition of limitation of threshold.

D. The Routing Control

The routing control process is used to solve the flooding of the RREQ, make the forwarding nodes to broadcast the received RREQ selectively, and speed up the routing construction by using routing cache. The routing control process includes two parts: the routing cache strategy, the control strategy. In particular, DROP_ROUTE_CACHE and CANCEL_ROUTE_CAHCE from LEAR is used to solve the invalidation of the routing cache because of low battery capacity. DROP_ROUTE_CACHE is similar to DROP_ROUTE_REQ, it is used to inform the successor node which has lower energy than the threshold to lower its threshold after receiving the RREQ with added serial number again, and send a CANCEL_ROUTE_CAHCE message to inform the node to delete the routing cache which is getting to the destination node. Thus during the routing selection process, the path of the destination node is found in the routing cache of the node earlier, when the energy of the node which caches the path is not enough, another route with enough energy is needed.

1) The Route Cache Strategy

After receiving this RREQ, the intermediate node $r$ finds a route which gets to the destination node in its route cache and stops broadcasting this message, it consists of two steps:

Step 1: copy the path information of the best path and all the coding information of this path to ROUTE_CACHE, which is used to detect the energy condition of the successor nodes in the cache, node $r$ uses $uni_{cache}$ to send ROUTE_CACHE to the destination node,

Step 2: if there is node whose residual energy is lower than its threshold in the successor path, then this node uses $uni_{cache}$ to send a DROP_ROUTE_CACHE to the destination node along the cache path, making the successor node to adjust its threshold when the next routing request message arrives, and send a CANCEL_ROUTE_CAHCE message to node, deleting the route cache in node $i$.

2) The Routing Control Strategy

When the source node $S$ broadcasts the routing request message to the destination node $D$, the minimum residual energy on the current path is initialized as $MinRE = \infty$.

After receiving the routing request message, node $r$ compares $RE(r)$ with its threshold.

(A) If $RE(r) > threshold(r)$, judge if the residual energy of the current node is less than $MinRE$ at first, if so, update $MinRE = RE(r)$, meanwhile $r$ examines if the link $p \rightarrow r$ the routing request passes is recorded in the head of the routing request message, if so, there is coding opportunity at $p$, if not, there is no coding opportunity, then $r$ updates the coding opportunity message in the routing request information. Then operate according to the type of the received routing request information;

(a) If this routing request information is RREQ, then there are two conditions:

a) If this routing request information is RREQ, and this RREQ is the first one which $r$ receives from source node $S$ to destination node $D$, $r$ stores all the paths RREQ passes and makes the path RREQ passes as the best path $pc$ passing $r$, then check if there is a route getting to the destination node in node $r$, if so, conduct the route cache strategy step 1; if $r$ does not have route cache, it will transmit RREQ;

b) If this routing request information is RREQ, and this RREQ is not the first one which $r$ receives from source node $S$ to destination node $D$, when the value of $COER$ of the path $p$ passed by RREQ is less than that of the best path $pc$, if $COER(p) < COER(pc)$, the best path $pc$ will be updated by $p$, and then the message will be updated by $p$ when $CO-ER(p) = COER(pc)$, if $MinRE(p) > MinRE(pc)$, $pc$ will be updated.

If there is cache of the destination node in $r$, proceed the following route cache strategy step 1, if there is no cache, transmit RREQ; if $COER(p) > COER(pc)$, $pc$ will not be updated, if there is no cache in $r$, then discard this RREQ, if there is cache in $r$, proceed the route cache strategy step 1.

c) If the routing request information the intermediate node receives is ROUTE_CACHE, calculate the $COER$ value of the path passed by this route request information, and when $r$ builds the coding form, there is only one
stationary neighbor node, or the next-hop in the route cache.

(B) If $\text{RE}(r) < \text{threshold}(r)$, and the first routing request information $r$ receives is $\text{RREQ}$, then $r$ broadcasts $\text{DROP\_ROUTE\_REQ}$, if this is not the first time receiving the routing request information $\text{RREQ}$, then $r$ lowers its threshold($r$) by $d$; if $r$ receives $\text{ROUTE\_CACHE}$ at the first time, proceed the route cache strategy step 2, if this is not the first time receiving the routing request information $\text{ROUTE\_CACHE}$, then $r$ lowers its threshold($r$) by $d$.

E. The Route Discovery

COER chooses the nodes with relatively enough energy by energy threshold, the selected path has less energy consumption and can balance the energy consumption among these nodes by balancing the above two aspects, which prolongs the network lifetime. The process of the route discovery:

Step 1: The source node S starts the route discovery, and broadcast a $\text{RREQ}$ information ($\text{RREQ}$ includes the basic route information, paths it passes, the existing coding opportunities, and the extra coding opportunities detected during the transmission of $\text{RREQ}$ the header stores and the minimum residual energy on the path it passes)

Step 2: After receiving the routing request information, the intermediate node checks if it passes the loop, if there is loop, then discard this routing request information, otherwise, conduct the routing control process.

Step 3: The destination node of T times for every $\text{RREQ}$ and $\text{ROUTE\_CACHE}$ received, the first D update the information in the presence of coding opportunities. After a period of T,D will choose the best path P (the path with the minimum COER value). Then D will send $\text{RREP}$ to S along the opposite path of P.

Step 4: After receiving the $\text{RREP}$, the intermediate node will update its route table first, then reconstruct the code element cfb to describe the state of the new stream at r according to the code information recorded by $\text{RREP}$. According to the information recorded by $\text{RREP}$, we can know whether r is a coding node or not, if it is, r adds the code element cfb to the coding set corresponding to cfb; if it is not, r builds a new coding set{ cfb } and transmits the $\text{RREP}$.

Step 5: after receiving $\text{RREP}$, S begins to send data along the path P.

IV. EXPERIMENTAL RESULTS

This text conducts simulation experiment for COER by using MATLAB language, observing the influence of COER protocol on the unit time, the energy consumption per bit and the residual energy allocation of the network nodes. We imitate a 50m×50m network distributing 25 nodes randomly, the communication range between nodes is 20m, the primary energy of every node is 50J. The mentioned loss coefficient of path $\gamma = 2$, $E_{\text{elec}} = 50n_{\text{j}} / \text{bit}, E_{\text{amp}} = 10p_{\text{j}} / \text{(bit.mj)}$. Assume that this network does not consider the problem of package loss, that means the probability of success of single hop transmission is 1. The flow velocity ranges from 0.2Mbit/s to 2Mbit/s, our experiment comparatively analyzes the COER, COPE and DSR in the variance of energy consumption in unit time, energy consumption in unit bit and residual energy.

Assume that the initial number of streams is 0, a data stream is produced every 1s, the flow velocity of every new data stream is 1Mbit/s, when the number of streams increases from 1 to 10, the average energy consumption of every stream per time is decreasing under the COER protocol, the simulation result in figure 2 also proves it. While the DSR has no coding opportunities, the data can not be transmitted, so the average energy consumption per time is changeless. COPE is passive to wait for the coding opportunities, so its property is less than that of the COER, during the process of producing these 10 streams, these three protocols have different energy consumption per bit because of different coding opportunities.

![Figure 2. The energy consumption per time of the changing number of streams](image)

![Figure 3. The energy consumption per bit of the changing number of streams](image)

![Figure 4. The energy variance of the changing number of streams](image)

We use the residual energy variance to describe the problem of energy load balancing. In this network, the initial number of streams is 0, a data stream with its 1Mbit / s velocity is produced every 1s, the value of the number of streams is the time premium of sending...
streams, different time means different number of streams in the network, from figure 4, the residual energy allocation of nodes becomes unbalanced with the increase of number of streams, but the protocol COER is better than the others.

When the network sends 5 streams fixedly, the velocity of every stream ranges from $0.2 \text{ Mbit/s}$ to $2 \text{ Mbit/s}$, with the increase of the velocity, the data sent in unit time increases, under the protocol of COER, DSR and COPE, the energy consumption of every stream in unit time increases, while the COER can find more coding opportunities because of the coding-aware protocol, it also takes the total energy consumption of the path into account, so it consumes less in unit time than DSR and COPE, COPE also consumes less in unit time than DSR, the trend of figure 5 shows the above results.

![Figure 5. The energy consumption of the changing velocity](image)

While with the increases of the velocity, the energy consumption per bit of the average stream of the fixedly sending 5 streams does not have obvious changes, COER consumes less than DSR and COPE in unit bit, COPE consumes less than DSR. But with the increase of the velocity, some coding packages can not be coded entirely, so the energy consumptions of COER and COPE shown in figure 6 begin to increase.

![Figure 6. The energy consumption per bit of the changing velocity](image)

Figure 7 shows the influence of the changing velocity on the uniformity of the residual energy, with the increase of the velocity, 5 streams are sent in different velocities, the residual energy variance of COER, COPE, DSR is increasing gradually, the residual energy of nodes becomes unbalanced, but the property COER is better than that of COPE and DSR.

![Figure 7. The energy variance of the changing velocity](image)

V. CONCLUSION

This text proposes an optimal energy routing algorithm, analyzing that we need a path which has less total energy consumption and can balance the energy consumption of nodes, it can also reduce the energy consumption by using the network coding. The introduction of the ARE makes the node which transmits the packet to choose a node which has more residual energy and is higher than its threshold among its neighbor nodes, thus balancing the energy consumption. From the simulation results: the optimal energy routing algorithm can reduce the transmission energy consumption, balance the energy allocation in the network, and thus prolong the network lifetime truly.

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