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Research Opportunism Delay Tolerant Network Routing Algorithm based on Energy

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Abstract

Delay Tolerant Network (referred to as DTN), tend to have a high latency , low transmission rate , intermittent connections, nodes frequently move , delay tolerance, fault tolerance , limited storage and communication features harsh environment , the traditional TCP-based / IP Internet technology to-end communications cannot provide good service . This article aims to delay proposed opportunistic routing algorithm performance based on energy (EROD) tolerant network environment , solve network in extremely harsh environments , end to end path does not exist , the message routing and forwarding problems. Under the premise to ensure reliable transmission of messages , minimize transmission delay and reduce the messaging process of resource consumption.

Keywords*: DTN; energy ; EROD; routing algorithm ;*

1. Introduction

With the rapid development of modern science and technology , network communication technology is constantly improved and perfected , the demand for network increasingly high. Thus some of the new network have emerged, including interplanetary networking, wireless car self-organizing networks, ecological environment monitoring networks, disaster recovery networks, access remote villages and wireless sensing network. Delay tolerant network came into being , K. Fall and other researchers propose binding properties of such networks delay tolerant network models. Since 2003 the concept of delay tolerant network proposed , delay tolerant network will get the recognition and support of many network communication researchers , research in this direction quickly become one of the hotspot network[1].

Delay tolerant network , also known as the "Challenge of the network ," comes from the interstellar communications network. Now refers to at any point in time , there is almost no source address to the wireless mobile network end of the path to the destination address . DTN networks tend to have high latency , low transmission rate , intermittent connections, nodes frequently move , delay tolerance, fault tolerance , limited storage and communications harsh environment and other characteristics , the traditional end communication based on TCP / IP Internet technology unable to provide good service .Traditional Internet network during message routing when there is a basic assumption that can always find a path from the source node to the destination node -end path ; even in nodes with mobile ad hoc network , while taking into account the dynamic topology resistance, but a data delivery process , the network topology is the same. But in reality , the mobile network is limited wireless communication range , often there will be a long period of network partition (partition), so that the source node sends a message , you may not find a route to the destination node -end path. Thus the performance of traditional routing algorithms will significantly decline, or even unusable[2].

Given the unique nature , and it is widely used DTN network in real life , the importance of research of its increasingly prominent. Since DTN concept was put forward in 2003 , and various scholars attention . The study was divided on DTN architecture , DTN routing and

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transmission of information security three parts[3]. The DTN routing delay tolerant network as heavy in, and has become the primary object of study the majority of researchers.

2. Related Works

Delay tolerant network early major research institutions , there are three : interplanetary Internet (IPN), the Internet Research Task Force (Internet Research Task Force) established DTNRG (DTN Research Group) and the Defense Advanced Research Agency (DARPA). Now with the increasing refinement of the concept of delay tolerant network is a major university researchers worldwide favor and attention of domestic and foreign universities network researchers have also invested a study delay tolerant network.

As one of the core routing delay tolerant network research , becoming DTN research scholars' research priorities and focus. Research DTN routing can also be roughly divided into mobile model , unicast routing , multicast routing and routing anycast four directions . Scholars on the basis of the traditional model of random movement have proposed the establishment of model -based vehicle mobile map -driven disaster mobility model based on role assignments , etc. , but also provides some scenes CRAWDAD project tracking and recording real life, these are for the better Research routing mobile model and lay a solid foundation.In recent years , under the joint efforts of researchers , DTN unicast routing continuous improvement and perfection , has been part of the route to the limit , such as the route of infection (epidemic routing). Heuristic opportunistic routing and routing social route has recently become a hot spot in the DTN routing industry caused a new round of upsurge [4].

This paper studies unicast routing , delay tolerant network due to the characteristics of each are not the same, the route to the destination , and mechanisms will be different , different DTN unicast routing mechanism has a different key ideas . The following describes the different routing mechanism classification current research status and trends , and the subsequent merger will be detailed summary of recent DTN routing algorithms and thinking at home and abroad .

DTN routing roughly divided into replication -based routing , routing and forwarding hybrid combination of the two routing mechanism based routing.

Achievements routing infrastructure: Infrastructure routing routing mechanism introduced Agent, Throwboxes and ferry nodes and other participants. These special nodes in a particular communication environment DTN , introduced either these nodes dynamic motion or static communication hotspot deployment , designed to create more contact opportunities for DTN communication , thereby reducing the network delay, in order to optimize the network DTN performance. The early prediction based routing are: space-time diagram routing and PLSR (predictable link-state routing). Routing model is now the main research directions for social networking route[5]. With the advent of facebook, schools and other social communication sites, DTN routing algorithm gives researchers a new inspiration.The researchers also found that contact with the social network model many DTN network model has a certain similarity, therefore, put forward a model social network routing routing on the basis of the model : Paolo , who tolerate network distribution model study / subscribe for the delay , proposed SocialCast routing algorithm ;SimBet routing using social network analysis techniques proposed new social routing algorithm, using social network node moves small world phenomenon, some sports sexually active central node as a secondary node to compensate for the route ; Pan et al mention BUBBLE routing in the literature algorithm by using a social network nodes collectively , each node belongs to a different set of the same frequency in the set of communication nodes , the routing message forwarded As the first group belong to the same destination node (Group) node and the destination node belongs to through movement of the same collective node

concentration, fast-forwarding the message to the destination node.

Copy -based routing , especially opportunistic routing is now become a major hotspot DTN routing , many scholars at home and abroad to get some results in opportunistic routing . Typical copy routing based routing for infection routing (Epidemic Routing). Vahdat and Becker raised from the initial applied intermittently connected network of infection route (Epidemic Routing) algorithm proposed so far, after many improvements. Infection route of representatives : MaxProp, message forwarding settings according to their priority status information , routing to forward packets in order of priority of messages ; RAPID, messages to sort through the utility value of the function , using a purpose -specific routing metric ; PREP, based Communication overhead messages and gives priority to the message . However, these improvements are flooding routing algorithm has a high computational complexity[6] , making deployment difficult. Thrasyvoulos et al Spray and Wait, created during the initial message , define the maximum number of copies of the message , the message is divided into two cases -Spray case node spread news copy , in the case of a single copy of the message Wait Wait a direct and the opportunity to meet the destination node , and then realize spread the message ; then the scholars put forward to improve the routing Spray and Focus , Focus under different circumstances that a single copy of the message can be forwarded a copy of the message to help enhance the transmission rate and reduce delays.These two routing algorithms on spending far beyond the flood routing restrictions , but the transmission rate is low in contrast . Samuel C. Nelson , et al proposed the idea of routing based spray Encounter-Based Routing , a particular advantage of the flow characteristics of the network , the probability of future encounter node to infer from past data , thus to improve the routing of the transmission rate limit ; recently proposed based limits Cost-Effective Multi-period Spraying routing, According to the message transmission time is divided into multiple stages , a number of additional copies of the message will be spread at every stage of the network , and then wait for some time the news spread.

The current study has been DTN routing initial results , but most reliable transport routes to reach yet are unable to ensure a reasonable rate of resource consumption and latency tolerance, or there is a node routing algorithm is too complex , the performance in the actual route performance is low and difficult to deploy , there are still not enough to complete the routing considerations , cannot be fully applicable to the corresponding DTN network. Therefore , DTN routing network for real DTN still has a large challenge for DTN routing performance improvements , there are still larger space for innovation.

3. Proposed Scheme

Based on the research of DTN routing algorithms, for some defects existing routing algorithm, the improved new DTN routing algorithms. Currently, most delay tolerant network routing algorithm failed to better consider the node energy factors, and energy node plays the role cannot be ignored in delay tolerant network reality scene.Especially in the energy -constrained nodes (eg smart phone used in people's daily life / walkie-talkie) network, the energy consumption when the node is completed, regardless of the node and the destination node how many times the message encounters (incoming communication within range of each other) , will always be because there is no adequate energy nodes cannot successfully communicate with the purpose of forwarding the message packet. Therefore , this article focuses on the route to consider the impact of node energy and improve existing routing algorithms defective part , proposed new energy-based DTN routing algorithms.

3.1 DTN Typical Opportunistic Routing Algorithm Analysis

Prophet route is to improve routing decisions in the traditional TCP / IP routing mechanisms proposed. Prophet with a single copy of the forwarding mechanism , using a simple prediction mechanism to calculate the probability of a relay node successfully delivered the message packet , and forwards the message to the appropriate relay nodes in descending order of probability successfully submitted . Prophet route to some extent reduce network transmission delay, however, make a single copy of the forwarded message successfully reached the limit lower rate , routing mechanism needs to be improved[7].

Epidemic routing forwarding mechanism proposed multi- copy replication , the message buffer node forwards the packet to all nodes meet , and save a copy of the packet. Such a routing mechanism , due to excessive packet replication copies forwarded on the network independently , resulting in a large amount of network overhead, especially node buffer consumption. Although the network conditions idealized state can achieve a higher rate of successful submission message , but is limited in the network environment , especially the node buffer size is limited , the routing performance will become very inefficient routing mechanism undesirable.

Spray-and-Wait routing Epidemic routing based on the proposed limit the number of copies of copy - Forwarding routing mechanism . The route is divided into two phases Spray and Wait : eruption phase (Spray) , the package provides a copy of the data to the network, the number of eruptions is L, each communication node will forward a copy of the message or their own half of the number of messages copy to encounter node ; until their number for a copy of the message into the waiting transport (Wait) stage - relay node messages saved copy of the message until it reaches the destination node , to transmit messages .Spray-and-Wait a copy of the forwarding mechanism in the receipt of the control message , and thus to a certain extent control the network overhead . However, because of the random message routing , no decision affecting the route , while the average delay makes the transmission of the message cannot be effectively controlled.

3.2 Energy DTN -based Opportunistic Routing

In this paper, a typical routing algorithm -based defect analysis , combined with the node 's energy factor , proposed new and improved routing mechanism-based on energy DTN opportunistic routing (Energy-aware Routing in Opportunistic DTNs, EROD).

EROD routing using limited number of copies of copy - forwarding mechanism , while remaining energy circulation and select node node as the routing decisions impact factor , the optimal routing decisions to select the appropriate relay nodes. Thus, the use of copy - forwarded message routing technology to improve the success rate of submitting the same time, through the use of copy restrictions to control network resource overhead purposes , and can enhance the effective packet forwarding node under consideration of the energy situation , a comprehensive optimization other routing indicators (such as transmission delay , energy consumption, etc.) .

DTN opportunistic network on a plurality of sets , etc. can be viewed as an ordinary mobile wireless network nodes , the node movement pattern of random , unpredictable , most DTN routing algorithm proposed for this network scenario . EROD on the basis of the concept of opportunistic network model, the energy properties of nodes in the network model to supplement and perfect [8].

3.2.1 Energy Monitoring Model

EROD basic opportunistic routing network model based on building energy monitoring model to simulate the energy consumption of each node in the route . In the network model , nodes in addition to its basic properties (such as node ID, node buffer size , *etc*.) , it also

has a new attribute - energy value of the node.

In the beginning of the simulation of each node will receive an initial energy value of the routing during the simulation of the energy values will vary with the route is carried out continuously until the final energy consumption of less than 0 is turned off. Wherein the node energy consumption can be divided into two main parts: the scan and transmit consumption consumption. Scanning consumption refers to the node energy consumption in the process is not moving constantly scan update into the node within its radio communication range of the time ; forwarding node energy consumption refers to the routing decisions based on the message packet is forwarded to the appropriate relay node consumes needed .

In EROD routing algorithm , the energy cost of the node will be updated in real time and monitoring, and the residual energy factor as a route to optimize routing decisions. In addition, the energy monitoring simulation model can be easily applied to all other routing algorithms , thereby monitoring the various routing algorithm in routing process in the case of energy consumption.

3.2.2 EROD Routing Algorithm

EROD routing algorithm is designed to select the route of the relay node into consideration multi-target multiple routing nodes sports activity , the residual energy optimization problems such as impact factor . Calculated using linear optimization utility value of the node (Utility), and a copy of the forwarded message proportionally according to the size of the utility value , in order to achieve optimal routing decisions. The following will first introduce utility computing node values, specific work EROD routing algorithm is described in detail on this basis[9] .

1 utility value (Utility) is calculated

Utility value of compute nodes (Utility), is a combination of multiple routes factor linear multi-objective optimization problem solution. The utility value of a node indicates the appropriate level of the node as the message relay node. Taking into account the energy -constrained opportunistic DTN network scenario, the main factor affecting the route for the remaining energy movement activity nodes and nodes , EROD connected mainly with the degree of change in the node (Change of degree of connectivity) and the remaining nodes two main attributes influencing factors as the energy utility value calculation. Connection variation which also indicates the moving node level of activity (ie, mobility) node.

Suppose the neighbor nodes i in the node (the node is currently connected) the set $L=\{n_1, n_2..n_k\}$ of problems to select the best relay node will change to the mathematical model , as shown in Equation 1 :

$$\max \mathrm{U}(n_i)=\max\begin{bmatrix}F(n_i)\\E(n_i)\end{bmatrix}, \mathrm{s.t.E}[n_i]\geq Threshold_E \quad (1)$$

Which $F(n_i)$ indicates the degree of n_i connectivity changes , $E(n_i)$ indicating that the residual energy of neighbor nodes n_i , $Threshold_E$ said the remaining energy threshold.

3.2.3 EROD Routing Key Technologies

EROD thought replication -based routing algorithm , as well as a copy of the network routing restrictions. On this basis, according to the utility value of the node in proportion to forward a copy of the message to the appropriate relay node . EROD routing thought the four key technologies can better describe the routing algorithm work thinking : routing decisions , buffer management, energy management and the successful submission of a message after the ACK mechanism**.**

A. Routing Decisions

Limited copies of the message, the message is created by a message at the beginning attach flag L to achieve, and flag indicates L that the message is to allow the maximum number of copies in the network exists in the routing process in the network by supporting the message routing decisions total copy unchanged L .

EROD , the routing decision not to select only the appropriate relay node, and then copy the message packet forwarded directly to the relay node ; but node update utility value of its neighbors in its neighbor nodes , and according to the utility value copy of the message package size is calculated for each relay node is assigned to an appropriate amount of scale. Thus , the higher the value of the utility node has a better sport because of activity and plenty of energy , making it the message packet is forwarded to the opportunity to network more , so there are more number of copies of the message[10] .

EROD routing decision-making process is as follows:

The neighbors of the node A is the local node A is now assumed that the network topology shown in Figure B, C, D, and assuming the Connection node A connector according to the list in order, (B, C, D). At this node A message on the buffer routing decisions are as follows:

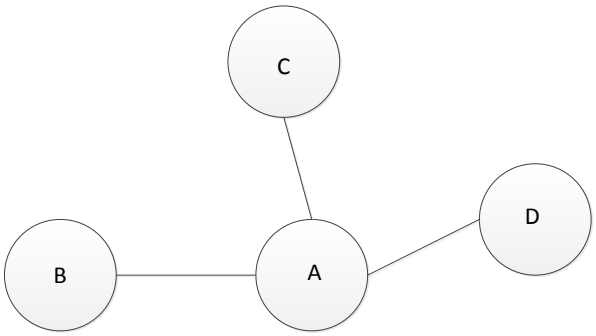


Figure 1. Local Network Topology Diagram a Node A

1) A first node in the list in the order in connection connected at their respective message buffer in order to find node B, C, D is the destination node for the message , if there is in turn transmitted to the respective destination node to complete the successfully submitted copies of the message and the message has been forwarded to delete.

2) connected to the node A according to the order of the list , followed by the node B, C, D communication , the communication node A and B in an example (the node A process sequence fully consistent with the other nodes of the communication) :

First, the node A checks the energy of the node B flag S:

(1) S = 1, B node does not have enough energy to forward the message, the communications between the node A and the node B at this time , and will enter into a communication with the next connection ;

(2) S = 0, B nodes have sufficient energy for forwarding the message , node A will get the utility value of the Node B (the utility value for each node by the node itself to maintain updated) in proportion to the forwarded copy of the message B:

a) a copy of the message in the message is greater than the number (L> 1), the node A sends

$$\left\lfloor m_i \frac{U_B}{U_A + U_B} \right\rfloor$$

A copy of the message to the Node B, where A represents the total amount of copies of messages M_i in the node . Note that here "A copy of the message forwarded to the n-th B" does not mean that the n-th A copy of the message in turn forwards the message to B, A is actually stored in the message M_i buffer is only one copy of the

message , while its number of copies is reflected in the additional flag L of the message M_i . Therefore , A n a copy of the message forwarded to B, in fact, only a copy of the message transmission , but the L value when forwarding a copy of the message to be modified is set to n, and forwarded a copy of the message itself in the buffer after successful L value also made the following changes , the new L values are:

$$m_i - \left\lfloor m_i \frac{U_B}{U_A + U_B} \right\rfloor$$

Thus , the total amount of message forwarding process throughout the network copy of the message will remain unchanged.

b) a copy of the message number of the message (L = 1) M_k , the node A will stop the flooding of the message , and the message M_k is forwarded to the node with higher utility value . That Node A Node B utility value comparison :
i Node B is greater than the utility node A ($U_A < U_B$), node A forwards the message to Node-B, and deletes the message after a successful forwards a copy in a buffer ;
ii. Utility Node B if the value is less than or equal to the node A (), the node A does nothing for this message .

C) completed polls all messages in the message buffer , the node A and node B end of the communication , the next transferred to a connected communications.

B. Buffer Management

In the precious network resources DTN network, each node management message buffers for routing in terms of performance but also has important significance. Effective utilization of the nodes of the message buffer , the higher network routing performance, especially effective utilization of network resources will be boosted . In EROD routing node for buffer management is divided into the following three points :

1) Whether a copy of the message) each node every certain period of time (update Interval) sequentially iterate buffer messages and determine whether each message buffer timeout (TTL message has to 0) , remove the TTL timeout .
2) When the node receives a packet ACK reply message , check to determine whether there is a buffer own message packet , if there is deleted from the message queue the packet to free up more space for effective data buffer packet forwarding.
3) When a node is about to overflow the message buffer is full , the message buffer FIFO queue mechanism will follow the tail queue messages are discarded .

C Energy Management

In EROD , the energy management energy monitoring model is actually implemented . The energy management is divided into three parts:

1) First, before routing simulation begins , as the network initial energy value of each node (Initial Energy) assignment , and define the energy scan update cycle τ_1 , energy consumption per scan number and energy consumption forwarding number .

2) Secondly, in the route , every other time period τ_1 , the node will update the energy value (the energy consumption minus the scanning beam) :

$$Energy_{new} = Energy_{old} - ScanEnergy$$

Each successfully forwarded a message packet , the node will update the energy value :

$$Energy_{new} = Energy_{old} - TransferEnergy$$

4) Finally , when the node updates its energy value found $Energy_{new} \le Threshold_E$, then the node flag bit S is set to 1 (S = 1), said node is no longer have enough energy to become a relay node. When found $Energy_{new} \le 0$, the node shutdown (to change their radio communication range : $TransRange = 0$) , indicating that the node is no longer alive.

D. ACK mechanism successfully submitted message

When the destination address of the message is successfully received the message M_i , ACK will be routed across the network in a similar manner Epidemic , simply flooding packets transmitted reply message M_i . Despite the flood of messages ACK will bring some network resource consumption, however, due to a relatively common message ACK packet in terms of much smaller share of bandwidth consumption , and the node receives the ACK packet is not stored ACK packet to the buffer queue , not occupy message buffer node. Therefore, using a simple transmission of the message packet can be stopped global flooding unnecessary quickly , the release message in the message buffer is invalid data packet , to a greater extent, to improve the effective use of network resources.

3.3 EROD Routing Target

EROD routing algorithm uses these key technologies , intended to improve the message submitted on the basis of the success rate of the integrated optimization routing number of indicators . Theoretically , EROD routed through copying - forwarding technology and scientific routing policy to route messages to further improve the success rate of submission ; while the use of copy control technology, while using a simple and quick ACK response mechanism that can effectively forwards the message overhead control within reasonable limits ; node energy as one factor routing strategies that can circumvent activist but less than the residual energy of the node is mistakenly selected as a relay node , increase the effective forwarding route from the side , and further enhance the message submission rate of success .

4. The Experimental Results and Analysis

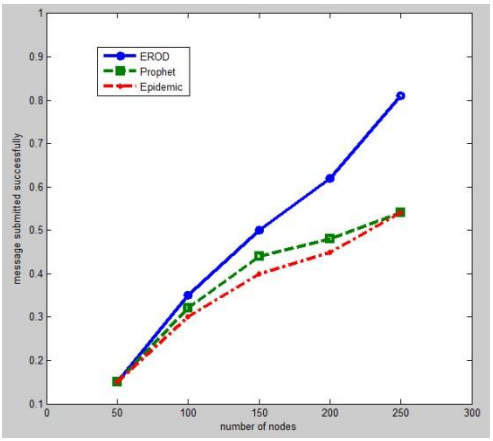
According to the design of the test program, this article will Epidemic routing , Prophet Routing and Spray-and-Wait routes were achieved in the framework of the energy model . And to be fair , the use of the optimal algorithm Spray-and-Wait a two -point routing , and Spray-and-Wait and EROD maximum message routing using the same number of copies 10 .

Initialization energy node simulation scenarios for the three routes , in the latter part of the simulation are finite state . In such an environment , the paper records of the three routing performance indicators: message transmission arrival rate , average latency and network overhead than message.

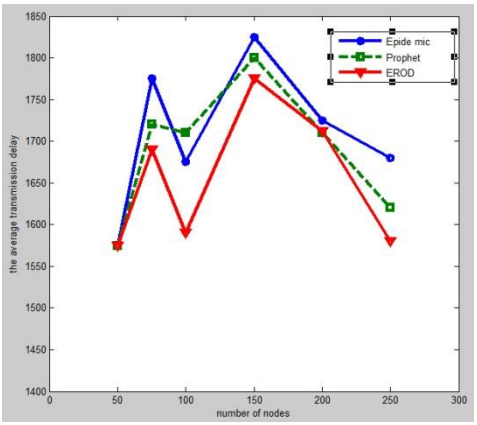
4.1 EROD Routing Algorithm Routing Performance Compared with the Other

Figures 2 and 3 are given in the routing algorithm of the three moving scenes RWP message transmission rate , the average delay , the comparison of the residual energy. Among them, the icon SNW routing refers Spray-and-Wait routing .

Message transmission arrival rate is not difficult to see that the message reaches all routing algorithm increases with node density and constantly improved. And EROD in RWP scene can achieve with Spray-and-Wait routing algorithm is very similar to the message transmission rate, and Spray-and-Wait message transmission rate is slightly higher and EROD. But there is much higher than EROD message transmission arrival rate Epidemic Routing and Prophet route.



(a)



(b)

Figure 2. Each Route of Transmission Arrival Rate and Average Delay under the RWP Scene

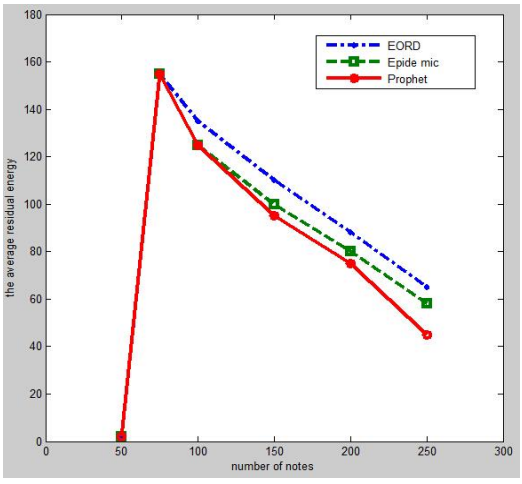


Figure 3. Under the Residual Energy of each Route RWP Scene

Although only a message transmission rate and EROD Spray-and-Wait similar , but the average delay performance EROD route showed a clear advantage . As can be seen from

Fig 2 (b), when the node is less than 150 , the average delay of the routing algorithm with the increase of the number of nodes increases , but reaches the top of the node 150 , the average delay of the routing algorithm as the increasing the number of nodes decreased . EROD and has the smallest average delay , it can be proved effective to reduce the average latency EROD energy-constrained network system messages.

Figure 3 , each node in the routing algorithm in the average residual energy after the end of the simulation , the remaining energy EROD far more than the other three routing algorithms, including Spray-and-Wait routing . EROD on the performance of the index clearly superior to the other three routing algorithms , which means the remaining energy of nodes EROD to factor in saving battery power node has been worked as a routing decisions.

5. Conclusion

In this paper, the key issues involved in designing the route departure , given the delay tolerant network routing design ideas. This paper describes the EROD routing algorithm designed to describe the calculation methods and EROD routing node utility value of the four key technology design - ACK mechanism for routing decisions , buffer management , energy management and success of submission of the news . EROD routing algorithm is suitable for energy -constrained opportunistic DTN network , designed to monitor the routes of energy consumption , and scientific strategies to effectively control message routing to forward a copy of the fully integrated to optimize routing performance.

References

[1] J. Ott and D. Kutscher, “A disconnection-tolerant transport for drive-thru internet environments//INFOCOM 2005”, 24th Annual Joint Conference of the IEEE Computer and Communications Societies. Proceedings IEEE. IEEE, **(2005)**.
[2] S. C. Nelson, A. F. Harris III and R. Kravets, “Event-driven, role-based mobility in disaster recovery networks”, Proceedings of the second ACM workshop on Challenged networks. ACM, **(2007)**.
[3] A. Keränen, J. Ott and T. Kärkkäinen, “The ONE simulator for DTN protocol evaluation”, Proceedings of the 2nd international conference on simulation tools and techniques. ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering), **(2009)**.
[4] P. Juang, H. Oki, Y. Wang, M. Martonosi, L. S. Peh and D. Rubenstein, “Energy-efficient computing for wildlife tracking: Design tradeoffs and early experiences with zebranet”, in Proc. ACM ASPLOS, **(2002)**, pp.96–107.
[5] A. Keranen, J. Ott and T. Karkkainen, “The ONE Simulator for DTN protocol Evaluation. In Simutools '09: Proceedings of the 2nd International Conference on Simulation Tools and Techniques, **(2009)**.
[6] B. Burns, O. Brock, B. N. Levine, “MV routing and capacity building in disruption tolerant networks. In: Proc. of the INFOCOM, **(2005)**.
[7] E. Daly and M. Haahr, “Social network analysis for routing in disconnected delay-tolerant MANETs”, In: Proc. of the MobiHoc 2007. Montreal: ACM Press, **(2007)**.
[8] W. Zhao, M. Ammar and E. Zegura, “A message ferrying approach for data delivery in sparse mobile ad hoc networks”, In: Proc. of the ACM Mobihoc 2004. Roppongi: ACM Press, **(2004)**.
[9] D. Fischer, D. Basin and T. Engel, “Topology dynamics and routing for predictable mobile networks”, In: Proc. of the ICNP, **(2008)**; Orlando.
[10] H. Pan, J. Crowcroft, “BUBBLE rap: Social-Based forwarding in delay tolerant networks”, In: Proc. of the MobiHoc, ACM Press, **(2008)**; Hong Kong.

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