On the Simulation of Communication Protocols with Multiple Mobile Nodes

Yuping Li[1], Sa Meng[2*], Yilin Zhang[1], Ke Li[1], Zhanjie Guo[3]

[1] School of Information Technology, Shangqiu Normal University, China
[2] School of Computing and Artificial Intelligence, Southwest Jiaotong University, China
[3] Department of Electrical and Electronic Engineering, Zhengzhou technical college, China
ping032200@163.com, summerincuit@gmail.com, zm19890409@126.com, like108@163.com, 309691840@qq.com

Abstract

In this paper, a high-performance routing protocol with multiple mobile nodes based on reliable active nodes is put forward since network nodes are not involved in the reliability work when the existing OSPF routing protocol forwards the packet, which results in several problems such as a low rate of packet forwarding, the long average delay of end-to-end, high energy consumption of network nodes and short service lifetime of nodes. The hierarchical model of active networks with multiple-mobile nodes was built, in which, reliable active nodes were divided into forwarding nodes and reliable nodes based on the functional requirements of this model, and consideration was given both to the efficiency and reliability of packet transmission. Besides, the energy consumption of network communication was calculated on the basis of this model and the packet transmission power was controlled. A high-performance routing protocol with multiple mobile nodes was designed to estimate the packet transmission delay time, calculate the forwarding moderate index of nodes, and select neighbor nodes in the active network. The simulation results show that this routing communication protocol effectively improves the packet forwarding rate, lowers the total energy consumption, shortens the average delay of end-to-end, and extends the service life of network nodes.

Keywords: Routers, High performance, Reliable active node

1 Introduction

Owing to the continuous expansion of the application scope of the internet, many new apps have emerged, such as information release, remote teaching, process control, e-commerce, etc. These new apps share a common characteristic, namely reliable data communication transmission, which requires the sender to transfer valuable data efficiently to the receiver [1-2]. To realize efficient data transmission, multicast communication technology has emerged [3]. Multicast communication allows one or several hosts to send a single packet to several hosts, but it has some disadvantages, such as feedbacks explosion, serious data loss, difficult recovery of lost data, and so on [4-5], which requires us to find a routing protocol for the reliable transmission of multicast communication data. The hierarchical routing protocol based on the Grover quantum search algorithm was put forward in the reference [6]. The protocol applied the Grover quantum search algorithm to search the maximum routing within the limited number of hops of the quantum wireless communication network as the target path of hierarchical communication, which avoided channel conflicts in the transmission process and implemented the stable transmission. However, it had a problem of a low packet forwarding rate. The partitioning-based hierarchical routing protocol is proposed in the reference [7], which divided network nodes into clusters through partitioning. It selected the cluster head node of data transmission using a three-level selection strategy, took the remaining energy of network nodes into full account, and guaranteed balanced energy consumption of nodes in the cluster. However, it was characterized by a long average delay of end-to-end, the high energy consumption of nodes, and so on. A routing protocol based on the weighted threshold was put forward in reference [8], which built several non-intersecting communication transmission paths through hierarchical network security routing. Then it selected several communication paths based on the security requirements of the network base station, partitioned the communication data with the weighted threshold, and forwarded the processed communication data in multiple paths. This routing protocol would shorten the service life of nodes. Aiming at the disadvantages and defects of the above-stated routing protocol, a high-performance routing protocol with multiple mobile nodes based on reliable active nodes is proposed and designed in this paper.

2 Preliminary

2.1 Active Network

The basic idea of the active network is that the program and data can be transmitted on the network together with the packet. Use the computing power of the intermediate node to process the data in the data packet to a certain extent. Active network changes the processing mode of “store-forward” in the traditional network to “store-compute-forward” processing mode [9-11]. The active network changes the architecture of the traditional network. Executable active code data packets replace traditional data packets and programmable active nodes replace intermediate nodes in the active network.

The active network has the following characteristics:

*Corresponding Author: Sa Meng; E-mail: summerincuit@gmail.com
DOI: 10.53106/160792642022072304012

(1) Programmability: the packet of an active network can be described in one or several languages, thus becoming a “tailor” resource for network services. In an active network, the development of protocol can be accelerated by standardizing the programming of network nodes as well as the description and allocation of node resources. Besides, the protocol can be deployed dynamically without requiring a standardized arbitration institution.

(2) Computability: different from the traditional network nodes, the function of the active nodes is not simply to store and forward various data, but also has strong computing power. The calculation is distributed on each active node of the network, and can perform semantic analysis, understanding, calculation and other processing on the data flowing through it.

(3) Mobility: the active network can transmit active packets encapsulated with executable codes. The active packets can move in the active nodes. The flowing active nodes can obtain and execute the codes in the active packets so as to purposefully collect and process the data of managed resources.

(4) Dynamic configurability: new services developed by users can be dynamically installed to managed devices through active messages, thus reducing the development and loading time of network services and reducing the overhead of network maintenance.

2.2 Active Router Architecture

A router is a hardware device that connects two or more networks. It acts as a gateway between the networks. It is an intelligent network device that reads the address in each data packet and then decides how to transmit. Data is transmitted from one subnet to another and can be processed by the routing function of the router. In network communication, routers have the function of judging network addresses and selecting IP paths and can build flexible link systems in multiple network environments.

With the function of the programmable switch, active routers add active packets to the functions of traditional routers, and its architecture is shown in Figure 1, where the packet classifier can classify the active packets in the header of the active encapsulation protocol and send them to different execution environments for processing. The active program manager decides the execution environment where the active program is loaded and exchanges information with the corresponding execution environment.

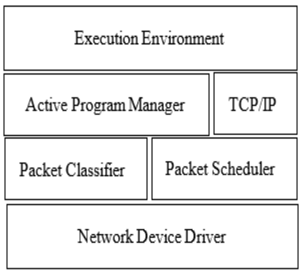


Figure 1. Architecture of an active router

2.3 Active Nodes

The key to the architecture of an active network lies in its active nodes, which can execute active codes and compute and process the communication packet. The corresponding network structure is responsible for standardizing addressing and end-to-end resource allocation. Active nodes can compute and modify the contents of passing-by data packets. The composition of active nodes is shown in Figure 2.

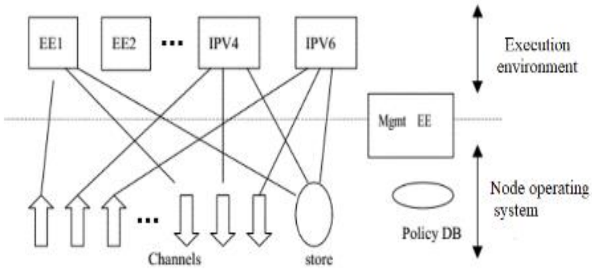


Figure 2. Composition of active nodes

The node operating system provides basic functions for the execution environment, manages and schedules the resources of the nodes, including link bandwidth, CPU cycle and memory. The node operating system separates the execution environment from specific resource management operations, and isolates multiple execution environments to avoid mutual influence. The interaction between the node operating system and the end-point users is separated by the execution environment.

Node structure is composed of the active packets, active expansion, and active secure routing facility, which are interconnected and have the following functions:

(1) Active packet: it contains executable active codes, and the execution of active codes can finish some specific tasks, thus realizing certain functions. An active packet can be moved in the network.

(2) Active expansion: it can be dynamically loaded and reside on active nodes but without mobility. It is responsible for explaining active packets and executing active codes.

(3) Active secure routing facility: responsible for completing node transmission and management of the node operating system.

Active nodes run in two modes: first, separation mode, where the active program is separately inserted into each programmable active node, isolating from the actual data packet. Users send the program to the active nodes and store them and execute the program to process data upon arrival. The second, is integration mode, where the program and data are integrated into one data packet and then sent to the network. Each data packet shall contain an active program. When it reaches the active nodes, the program will be explained by the active nodes [12-13]. Later, the processed data would be sent again. Among the active nodes, there is a unified execution environment and explaining method to execute these active programs. The nodes provide the basic functions for the execution environment, such as managing the resources of active nodes, coordinating in the process of resource transmission, computing and storage. The processing of data packet by active nodes is shown in Figure 3.

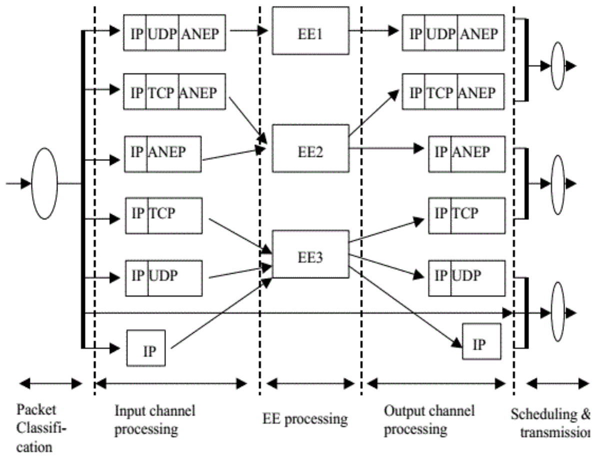


Figure 3. Processing of data packet by active nodes

3 High-performance Routing Protocol with Multiple Mobile Nodes

3.1 Communication Protocol Model with Multiple Mobile Nodes in An Active Network

In traditional Internet, network nodes are usually not involved in reliability work. Active network is programmable, which can not only enable active network nodes to be involved in reliability work, but also improve the data transmission efficiency and implement the prior configuration of network services by customizing the specific services of active nodes. Network nodes would load and execute the program while processing the data packet to modify or extend the basic configuration of the network, thus implementing fastly and dynamic deployment of the new protocol, providing new services and making the network more flexible and extensible. The hierarchical model of routing protocol with multiple mobile nodes is shown in Figure 4.

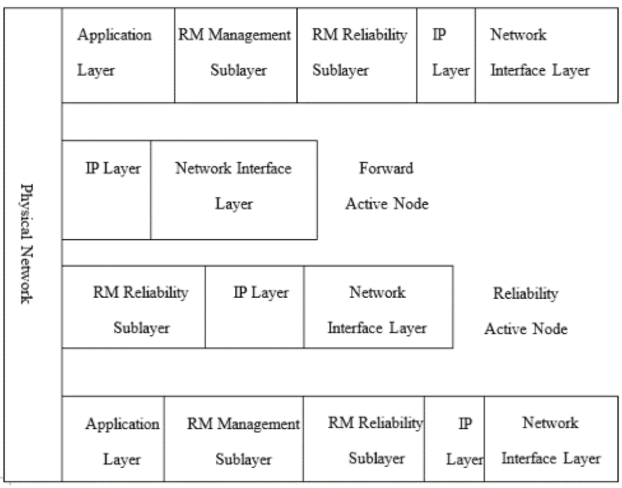


Figure 4. Hierarchical model of routing communication protocol with multiple mobile nodes

The hierarchical model of routing protocol with multiple mobile nodes in an active network makes use of the traditional Internet IP layer, but the IP layer cannot ensure the reliability of data transmission.

Multicast communication layer mainly provides connection-oriented reliable data flow service to the network application layer. It consists of RM management sub-layer and RM reliability sub-layer, of which the former is responsible for building and releasing session connection, and the latter is responsible for reliable communication data transmission. Active nodes only implement the reliable transmission of data in the multi-cast communication layer but take no charge of network connection management. The multi-cast communication layer puts a series of programs that can process the reliability of communication data in the package with the active network technology. Data sender, receiver and reliable active nodes may complete reliability processing tasks through executing the reliable programs in the package. The application layer of the model mainly implements the dynamic configuration of services by selecting reliable active nodes.

Reliable active nodes are usually divided into forwarding nodes and reliable nodes based on the functional requirements of this model. Forwarding active nodes share similar functions as traditional network nodes, which mainly implement specific functions using active network technology. To handle reliability work, reliable active nodes shall have the following functions:

(1) Reliable active nodes detect whether the package is correct or not and deal with the data packet loss retransmission application of lower nodes in time.

(2) Implement communication data cache and restore original data in time in case of data loss.

(3) Reliable active nodes respond to the packet loss retransmission application by sub-nodes of the active network in local multicast method and finish establishing a hierarchical model of routing protocol with multiple-mobile nodes in the active network, thus improving the transmission efficiency of the communication data packet.

3.2 Communication Energy Consumption Control of An Active Network

Priority is given to the communication energy consumption in the design and selection of routing protocol in the hierarchical model with multiple-mobile nodes in an active network. Suppose $E_{Tx-elec}(l)$ is the energy consumed by the transmitting circuit when the active network transmits lbit data; $E_{Tx-amp}\ (l,d)$ is the energy consumed by power amplifier when the active network transmits lbit data and the communication transmission distance is d, so the calculation formula of the energy consumption of transmitter can be obtained as follows:

$$E_{Tx}(l,d) = E_{Tx-elec}(l) + E_{Tx-amp}\ (l,d) \qquad \textbf{(1)}$$

Suppose E_{elec} is the energy consumption of each bit of communication data in the transmitting circuit or receiving circuit of an active network; ε_{fs} and ε_{mp} are the free space transmission and multi-path attenuation transmission of communication data in an active network respectively, and its value is related to the selected network communication channel model; d0 is a distance constant between the transmitter and the receiver. Rewrite the above formula (1) into the following form:

$$E_{Tx}(l,d)=\begin{cases} lE_{elec}+\varepsilon_{fs}d^2, d<d_0 \\ lE_{elec}+\varepsilon_{mp}d^4, d\geq d_0 \end{cases} \quad \textbf{(2)}$$

$$d_0=\sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}} \quad \textbf{(3)}$$

According to the above-stated calculation, it is clear that when the communication transmission distance d is more than d0, the active network path consumption is relatively great. Therefore, the communication transmission distance is generally required not to exceed d0, and the calculation formula of energy consumption when the receiver receives lbit data is as follows:

$$E_{Rx}\,(l)=\,E_{Rx-elec}\,(l)=lE_{elec} \quad \textbf{(4)}$$

In which, $E_{Rx-elec}\,(l)$ is the energy consumed by the receiving circuit of an active network to receive 1bit data. The analysis of communication energy consumption may avoid the energy consumption problems occurring in the process of transmitting the data packet. Next, the power of the hierarchical model of the routing protocol is controlled to ensure the service life of the hierarchical communication model and reduce network delay.

3.3 Power Control for the Hierarchical Model with Multiple Mobile Modes in An Active Network

The power control for the hierarchical model with multiple mobile nodes in an active network (namely selecting a proper communication data transmission power) is of great significance for improving network throughput, prolonging network service life and reducing network response delay [10]. Suppose $v_{rep}(S,D)$ is pre-set transmission rate of the communication data packet from the source node S to the target node D; $v_{S\to i}(P_s)$ and $Delay_{S\to i}(P_s)$ are the actual transmission rate and transmission delay of the communication data packet sent from the source node S to candidate node i at the power ps respectively; F (i) and N (i) are the next hop candidate forwarding node-set and neighbor node-set stored by the network source node S respectively; *d (S, D)* and *d (i, D)* are the Euclidean distance between node S and D as well as i and D in the active network; t_{rep} is the remaining transmission time of communication data packet, in which $v_{rep}(S,D)$ and $v_{S\to i}(P_s)$ are calculated in the following formulas:

$$v_{rep}(S,D)=\frac{d(S,D)}{t_{rep}} \quad \textbf{(5)}$$

$$v_{S\to i}(P_s)=\frac{d(S,D)-d(i,D)}{Delay_{S\to i}(P_s)} \quad \textbf{(6)}$$

According to the above calculation formula of active network communication energy consumption, the energy consumption of communication data packets sent from source node S to destination node *D* is:

$$E(S,D)\approx E_{Tx}(l,d)+E_{Rx}(l)\cdot E^{S\to i}(P_s)\times C^{S\to i}(p_s)\times\frac{d(S,D)}{d(S,D)-d(i,D)},\ i\in F(i) \quad \textbf{(7)}$$

In which, $E^{S\to i}(P_s)$ and $C^{S\to i}(p_s)$ are the actual energy consumption of unit data packet sent from the source node S to the candidate node i at the power ps in the active network. According to the above calculation, in order to ensure that the communication data packet reaches the target node within the pre-set transmission time limit, realize the power control of the multiple mobile node routing protocol hierarchical model in an active network, and reduce the routing overhead as much as possible, the following two conditions need to be met:

$$v_{rep}(S,D)\leq v_{S\to i}(P_s) \quad \textbf{(8)}$$

$$E(S,D)=min \quad \textbf{(9)}$$

In which, min is the minimum value of *E (S, D)*.

3.4 Routing Protocol based on the Communication Transmission Power of An Active Network

The high-performance routing protocol with multiple mobile nodes based on reliable active nodes includes routing strategy and neighbor node management of the hierarchical model of an active network [14], which are respectively described below:

1. Routing selection mechanism of the hierarchical model

(1) Routing

When the source node S of the active network needs to send a data packet, it shall judge whether the network sink node is the next hop node of the data packet. If it is, the data packet will be sent to the sink node directly from the source S without requiring relay node. Or, the forwarding adaptation index $\theta_{S\to i}$ of all nodes will be calculated in the neighbor node set F (i), and the index is calculated according to formula 10. The node with the highest $\theta_{S\to i}$ shall be taken as the next hop forwarding node of the source node S according to formula 11.

$$sink\theta_{S\to i}=\alpha\times\frac{v_{S\to i}(P_s)}{\sum_{i\in F(i)}v_{S\to i}(P_s)}+\beta\frac{E^{S\to i}(P_s)}{E_i}+\gamma\times\ PRR \quad \textbf{(10)}$$

$$v_{rep}(S,D)\leq v_{S\to i}(P_s) \quad \textbf{(11)}$$

$$\alpha+\beta+\gamma=1 \quad \textbf{(12)}$$

In which, α, β and γ are weight coefficients respectively. Based on the calculation above, if all nodes of set F (i) do not meet formula 12, neighbour node management mechanism would be launched to search for the qualified next hop forwarding node.

(2) Routing delay

$$Delay_{S\to i}(\,P_s\,)=T_c+T_t+T_p+T_q+T_s=\frac{T_2-T_1}{2} \quad \textbf{(13)}$$

$$Delay_{S\to i}^{i+1}(P_s)=aE(S,D)Delay_{S\to i}^{i+1}(P_s)+\frac{1-\alpha}{T}\times\sum_{k=\max(t,t-T)}^{i-1}Delay_{S\to i}^{i+1}(P_s) \quad \textbf{(14)}$$

In formula 11, T_c is the time spent in competing for active network channels; T_t is data packet transmission time and T_p is data packet processing time respectively; T_q is the delay time of data packet queue to be sent and T_s is the sleeping time of node; T_1 is the moment when the communication packet enters the multicast communication layer recorded by the source node S; T_2 is the moment when the sub-node receives the data packet; *(T2-T1)/2* is the time of single-hop transmission delay of the communication data packet. Upon thorough consideration of energy consumption and transmission power, the weighted average is introduced in formula 11. In formula 12, T is the time of channel competition in the active network; $Delay_{S\to i}^{t}(P_s)$ and $Delay_{S\to i}^{k}(P_s)$ are the data packet transmission delay time between adjacent nodes at t moment and k moment respectively; Where α must meet the condition of $0 \leq \alpha \leq 1$, if the transmission delay of the packet in the active network changes greatly, then a higher α is adopted; otherwise a lower α is adopted.

(3) Quality of transmission link

The quality of data packet transmission link of an active network directly decides whether data packet can be reliably transmitted to the target node within the time limit. Therefore, the routing mechanism in the hierarchical protocol of reliable nodes should take the quality of transmission link into account when selecting the next-hop forwarding node for the data packet, to guarantee reliable and real time transmission of the data packet. Quality of link of an active network is judged by the arrival success rate of communication data packet, and the specific measurement formula follows:

$$PPRR = \left[1 - (\tfrac{8}{15})(\tfrac{1}{16})\sum_{j=2}^{16}(-1)^{j} exp\ (20\gamma(d)(\tfrac{1}{j} - 1))\right]^{176} \quad \textbf{(15)}$$

Where $\gamma(d)$ is the signal-to-noise ratio and j is the energy consumption value, where $j \in F(i)$.

In which, $\gamma(d)$means the communication signal-to-signal ratio of an active network. j means the energy consumption of the communication link, where $j\in F(i)$.

2. Neighbour node management mechanism

(1) Adjustment of transmission power of neighbour nodes

Node i selects some nodes that meet the requirements on data packet transmission from set F (i) to reduce node transmission power linearly in an active network.

(2) Discovery of neighbour nodes

Calculation results are judged according to formula 4 and formula 6, whether nodes meet the requirements on transmission energy consumption and transmission power. If yes, $\theta_{S\to i}$ is calculated, and the node with the biggest $\theta_{S\to i}$ is selected as the next-hop forwarding node for data packet transmission. Otherwise, the data packet transmission power of node i is increased and the communicating table is updated until it finds the node that satisfies the transmission requirement.

4 Simulation and Result Analysis

The routing communication protocol based on active network proposed in this paper is compared with the hierarchical communication routing protocol based on Grover quantum search algorithm and the hierarchical communication routing protocol based on partition. The number of surviving nodes, the overall energy consumption of nodes, the packet forwarding rate and the average end-to-end delay are compared.

The hierarchical communication routing protocol based on Grover quantum search algorithm is described in detail in reference [6]. Through the establishment of quantum channels at both ends of the relay point, the information sent by the source end is obtained to realize the transmission of multi-level quantum wireless network information. Combined with Grover quantum search algorithm, the path with the largest routing metric within a limited number of hops is searched as the target path.

A hierarchical communication routing protocol based on partition is described in detail in reference [7], which forms clusters based on partition. It adopts a three-level cluster head selection mechanism and next hop cluster head selection algorithm.

The simulation experiment environment was Linux operating system and ns-allinone-2.29, 100 nodes were selected in the active network, and all nodes are randomly distributed.

The accuracy of network node transmission can be effectively improved by the detection of the energy of wireless network information transmission nodes. Suppose the initial energy of each node is 0. 5J. Network base station is selected according to the above-established hierarchical model.

Using three different routing protocols, the change of the number of surviving nodes in the network with the time of the simulation test; the change trend of the overall energy consumption of the network nodes with the time of the simulation test, the change of the data packet forwarding rate with the number of data packets forwarded, and the average of end-to-end delay with the packet forwarding rate are shown in Figure 5 to Figure 8, respectively.

From the comparison test results in Figure 5, it is clear that with the passage of simulation time, the number of surviving nodes of three kinds of routing protocols is declining, but the reduced quantity is different. All forwarding nodes in the network disappear when the simulation experiment of the partitioning-based hierarchical routing protocol lasts for about 220s and the simulation experiment of hierarchical routing protocol based on Grover quantum search algorithm lasts for about 400s. The routing protocol proposed in this paper can increase the surviving duration of all network nodes remarkably, and there were still some nodes surviving till the end of the simulation experiment, since the routing protocol gives priority to the energy consumption of active network communication, which avoids the early disappearing of forwarding nodes of the data packet in the active network.

According to Figure 6, the routing protocol proposed in this paper features lower energy consumption of network nodes at any moment during the simulation than that of the other two routing protocols, displaying a greater energy-saving advantage, since it implements the power control of hierarchical communication model in the active network, greatly reduces the routing overhead and saves the energy consumption of data packet.

According to Figure 7, with the constant increase of data packets to be forwarded in the network, the packet forwarding rate of different routing protocols has decreased. The routing protocol based on reliable active nodes selects high-quality link as the forwarding node of the data packet, so the decrease of packet forwarding rate is the smallest, which effectively increases the forwarding rate.

According to Figure 8, when the forwarding rate of the data packet in an active network is relatively small, the network flow changes slightly, and at this moment, the average end-to-end delay performance of three routing protocols differs slightly. But when the forwarding rate continues to increase, it would lead to long packet queue delay and increase the average delay of end-to-end. But the routing protocol based on reliable active nodes updates the packet transmission delay between adjacent nodes with the weighted mean method, launches the neighbor node management mechanism, and selects better next-hop forwarding nodes, thus effectively reducing the average end-to-end delay of packet forwarding.

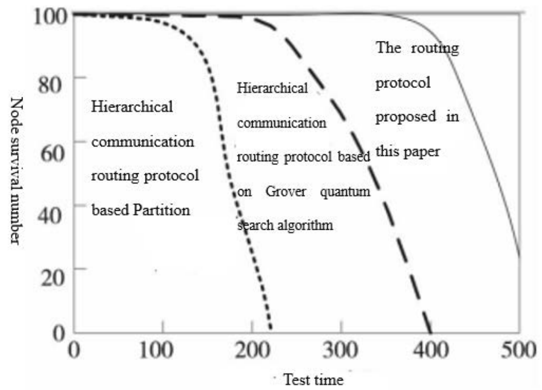


Figure 5. Comparison of the number of surviving nodes

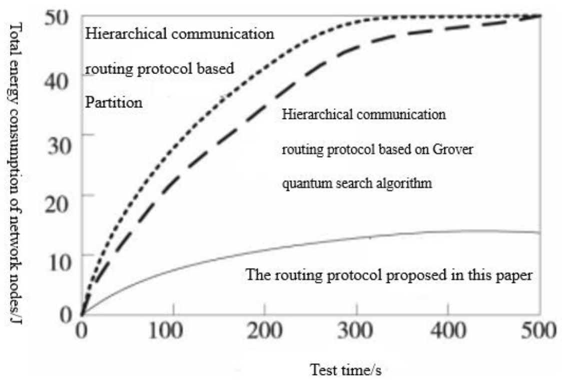


Figure 6. Comparison of total energy consumption

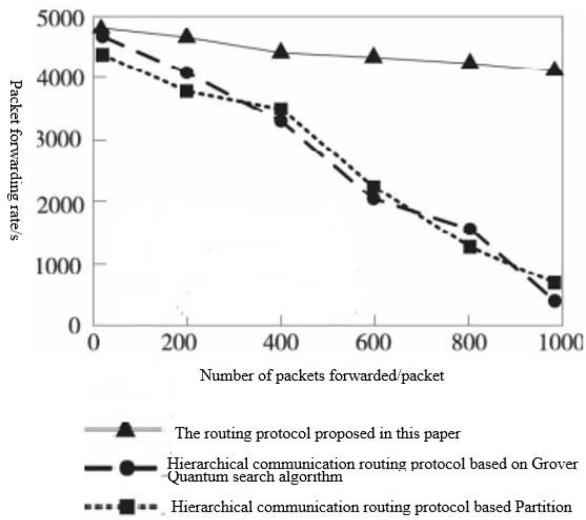


Figure 7. Comparison of data packet forwarding rate

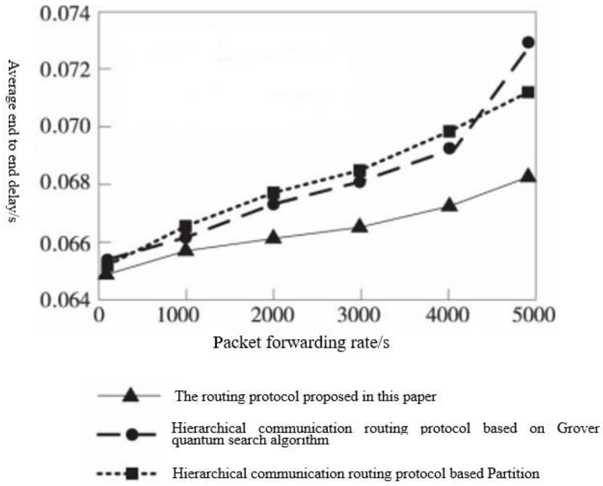


Figure 8. Comparison of average delay with end-to-end

5 Conclusion

A high-performance communication protocol with multiple mobile nodes based on reliable active nodes is proposed and designed in this paper, aimed at the disadvantages of multi-cast communication, such as high resource overhead at the network and server end, feedback explosion, severe data loss, and difficulty in recovering the lost data. The simulation experiment proves that the average delay of end-to-end can be effectively shortened by the routing protocol based on reliable active nodes, improve the packet forwarding rate, decrease the network resource overhead, and extend the service life of the network. The proposal of the routing protocol lays a foundation for the reliable multi-cast communication of the Internet.

Acknowledgments

The research is supported by key scientific research projects of colleges and universities in Henan Province (project number: 19B520023), in part by funding project for young backbone teachers of Shangqiu Normal University.

References

[1] Y. P. Li, Y. Li, Y. X. Wang, High Performance Multi-Mobile Node Routing Communication Protocol based on Reliable Active Node, *2020 6th International Symposium on System and Software Reliability (ISSSR)*, Chengdu, China, 2020, pp. 104-108.

[2] Chen, D. C. Li, J. C. Guo, Analysis and Implementation of a QoS-Aware Routing Protocol based on a Heterogeneous Network, *International Journal of Performability Engineering*, Vol. 16, No. 8, pp. 1235-1244, August, 2020.

[3] Y. K. Yao, J. B. Liu, Z. Ren, Efficient RPL routing protocol for Centralized Network Congestion Control, *Systems engineering and electronic technology*, Vol. 39, No. 12, pp. 2810-2816, 2017.

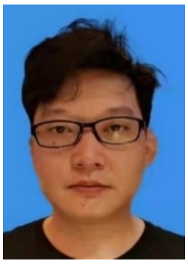
[4] L. Feng, Y. Lu, Z. C. Wei, Z. X. Zhu, X. Ding, Cross-Layer Power-Control-based Real-Time Routing Protocol for Wireless Sensor Networks, *International*

Journal of Distributed Sensor Networks, Vol. 9, No. 11, pp. 1-7, November, 2013.
[5] C.-Y. Chang, C.-Y. Lin, C.-T. Chang, W.-C. Chu, An Energy-Balanced Swept-Coverage Mechanism for Mobile WSNs, *Wireless Networks*, Vol. 19, No. 5, pp. 871-889, 2013.
[6] X. F. Zhao, X. F. Feng, Research on Target Coverage based on Mobile Node in Wireless Sensor Network, *Computer Development and Applications*, Vol. 23, No. 6, pp. 63-65, 2010.
[7] Y. Huang, C. D. Wu, Y. Z. Zhang, P.-J. Si, Coverage Optimization of Wireless Sensor Networks based on Mobile Nodes, *Journal of Northeastern University*, Vol. 33, No. 2, pp. 165-168, February, 2012.
[8] C. Wang, J. Luo, D. F. Zhang, W. Li, A Mobility-based Cluster Routing Protocol for Mobile Wireless Sensor Networks, *Computer Engineering and Science*, Vol. 34, No. 3, pp. 6-12, March, 2012.
[9] C. J. Zhai, J, M. Xu, Y. G. Liu, Energy Balanced Routing Protocol based on partition, *Journal of sensing technology*, Vol. 29, No. 1, pp. 80-87, 2016.
[10] Y. L. Chen, J. S. Lin, Y. F. Huang, F. K. Cheung, J. Y. Lin, Energy Efficiency of a Chain-based Scheme with Intra-Grid in Wireless Sensor Networks, *2010 International Symposium on Computer, Communication, Control and Automation (3CA)*, Tainan, China, 2010, pp. 484-487.
[11] J. C. Guo, D. C. Li, Z. Chen, Performance Analysis of Heterogeneous Traffic Networks based on sFlow and NetStream, *International Journal of Performability Engineering*, Vol. 16, No. 10, pp. 1598-1607, October, 2020.
[12] H. Z. Zhang, P. P. Chen, S. L. Gong, Weighted Spanning Tree Clustering Routing Algorithm based on LEACH, *2010 2nd International Conference on Future Computer and Communication*, Wuhan, China, 2010. pp. V2-223-V2-227.
[13] C. P. Chen, L. Zhang, J. Wang, J. Zhang, Application of Fault Diagnosis Expert System for Unmanned Vehicle Safety, *IOP Conference Series: Materials Science and Engineering*, Vol. 608, Article No. 012015, 2019.
[14] C. L. Chang, T. L. Lin, Delay-Based RREQ Routing Scheme for Wireless Mesh Network, *Journal of Internet Technology*, Vol. 10, No. 2, pp. 103-109, April, 2009.

Biographies

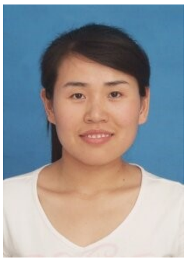
Yuping Li, female, Master's Degree, graduated from Henan Normal University, China, and currently works at Shangqiu Normal University. Research Area: network communication, system reliability, big data, and high-performance computing.

Sa Meng, female, doctor's degree, graduated from University of Electronic Science and Technology of China and is a postdoc scholar in the School of Computing and Artificial Intelligence at Southwest Jiaotong University now, China. Research Area: cloud computing, system reliability, system optimization.



Yilin Zhang, male, Master's Degree, Experimenter, graduated from Chongqing Normal University, China, and currently works at Shangqiu Normal University. Research Area: Network communication and high-performance computing.

Ke Li, male, Master's Degree, graduated from China University of Mining and Technology, China, and currently works at Shangqiu Normal University. Research Area: Network communication, big data, network technique.



Zhanjie Guo, female, Master's Degree, associate professor, graduated from Henan Normal University, China and currently works at Zhengzhou Technical College, Research Area: artificial intelligence, network technique.