Modern blockchain-based routing protocol to increase reliability in delay-tolerant networks

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Abstract

Delay-tolerant networks (DTNs) allow data transmission in secluded areas, where long delays and disconnections are tolerant. In delay-tolerant networks, the end-to-end route may not be available at the time the packet is sent, therefore, packets may be stored in intermediate nodes and routed to the destination at an appropriate opportunity. This network provides secure and reliable connections on joint discontinuous and alternating devices. This article introduces a new routing, which uses blockchain technology. The proposed method increases the packet delivery rate and reduces the packet drop rate. The results showed that the blockchain-based method has better results compared with the existing methods.

Keywords: Blockchain, Node, Routing, Delay Tolerant Networks

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1. INTRODUCTION

The concept of delay-tolerant network was originally proposed as a method for interplanetary Internet access [1]–[2]. Deep space communication may suffer from very large delays, low data rates, possibly discrete reception and transmission time periods, and scheduled intermittent connections.

The Internet protocol set is not suitable for DTN scenarios. The TCP protocol delivers data in the order of transmission, so any data loss causes a minimal RTT delay and reduced throughput. Establishing a TCP connection requires at least one RTT. If the delay is longer than the communication opportunity, no data will flow at all. If the RTT is large, the slow start mechanism of TCP takes a long time to increase the communication efficiency, which reduces the communication proficiency. Because TCP retransmission is end-to-end, it may not be efficient for high loss rates. In addition, a maximum data rate RTT requires a buffer that may be too large in delay-tolerant scenarios. The UDP protocol leaves the responsibility of acknowledging data receipt and retransmission to the application layer or some standard middleware (e.g. Remote Function Invocation, RMI), and as a result the same problems will still exist. Routing protocols are also affected because they require on-time updates, which may lead to misinterpretations of the current state of the network. In addition, many routing protocols assume that the network is not segmented, which is the normal situation in delay-tolerant networks. The BGP protocol, which performs routing between IP autonomous systems, is built on top of TCP and has the problems of TCP.

Although many optimizations have been done in order to increase the efficiency of TCP in satellite networks [3]–[4], space communication has challenges that require special protocols. The Advisory Committee of Spatial Data Systems [5] has addressed this problem by standardizing protocols.

The widespread release of mesh networks, ad hoc networks and sensor networks that rapidly change network connectivity, presents new opportunities for delay-tolerant networks. In these cases, several solutions are presented, which are not general for a wide range of applications. The main goal of the DTN research group is to provide a generic network architecture that can be used in cases where end-to-end delay is high, destruction is intermittent, or failure rates are likely to be high.

Common routing algorithms in wireless networks are divided into two categories: non-passive and passive. In the non-passive method, the routing tables were formed and maintained using the control messages of these tables. Whenever a packet had to be sent in the network, routing was done using existing tables (such as AODV [6]). In the passive method, these tables did not exist before, and when needed, these tables were formed and used for routing, and later they were destroyed (such as OLSR) [7].

In both of the above methods, it was implicitly assumed that the network is connected and simultaneously there is an end-to-end path between each source-destination pair of network nodes.

Unfortunately, in delay-tolerant networks, none of the above assumptions are true. In delay-tolerant networks, often network information such as connecting nodes toghether and network joint is not available for nodes. Common routing algorithms such as AODV and OLSR will not work properly in delay-tolerant networks, because in these protocols, when a packet reaches an intermediate node and that intermediate node does not have an end-to-end path to the destination of the received packet, the packet will be dropped.

The routing algorithms of delay -tolerant networks can be classified based on different criteria. A common classification is to classify the algorithms based on the movement model of the network nodes. Based on this, we will have two types of routing algorithms: definite and stochastic [8]. If the movement behavior of the nodes is definite and certain, or at least predictable, the sending of messages can be scheduled from the beginning and according to the type of timing of sending messages, some optimal goals can be achieved. On the other hand, in the stochastic case, it is assumed that the next connection of the network is completely stochastic and unpredictable. So the nodes carry the data with them and send them to other nodes at the right time. In the discussion of delay tolerant networks, the terms routing and guidance are used interchangeably.

Most of the works that have been done in the field of routing in delay-tolerant networks can be divided into two general categories: flooding protocols and routing protocols [9]. Flooding protocols represent one of the types of stochastic methods according to the information available from the movement of nodes. If a network node has no information about the state of the network, the only thing it can do is stochastically send packets to its neighbors. But if a node can estimate the probability of sending some of its neighbors, it can make a better decision at the stage of sending packets. Protocols in this category are known as history-based or estimation-based protocols.

Another approach in describing these algorithms is to divide them into source routing and routing at each step [7]. In origin routing, the full path of the packet is determined at the origin and is placed in the packet. The path of the packet is determined once and it does not change while the packet travels the network. On the contrary, in routing at each step, the next step of the packet is determined at each step of the routing path. Routing in each step allows the packet to use local information about existing calls and buffer status at each step, which was not available at the originating node.

Delay Tolerant Networks (DTNs) are wireless networks with transient communication features built by mobile nodes. Therefore, the network is divided into several islands, and the reason for this is the unpredictability of node movements, the small number of nodes in a certain geographical area, or the communication spectrum of nodes. To overcome this problem, the concept of delay tolerant networks (DTN), which is sometimes known as ((local area network)), has been used. A node in DTN basically stores the message and forwards it to the next node when the connection is established. This process continues until there are too many routing protocol messages proposed for the DTN. The most important of them are Epidemic, PROPHET, Spray and Forward. However, these routing protocols are designed for nodes without energy constraints. Like a vehicle. Therefore, due to the increase of mobile devices such as smartphones and personal tablets that are limited in energy supply, many energy efficient DTN protocols have been introduced. As far as we know, energy efficient DTN routing protocols that have been presented before have assumed a fixed node movement model, such as Random walk model, Random waypoint model, or map based shortest path model etc .In wireless communication tools, most of the energy is spent on transmission. Different movement models will have different number of encounters with other nodes. As a result, the number of data transmissions will be different and finally the energy consumption level of mobile nodes will be different. In these networks, there is no permanent path between the source and destination nodes most of the time. For this reason, conventional routing methods in ad hoc networks are not effective in DTN. In these networks, the storage and sending mechanism is used to exchange messages. This will waste network resources. The proposed method tries to increase the reliability of the network by checking and controlling the number of packets distributed in the network. This method reduces the number of scattered packets in the network and increases the percentage of message delivery to the destination node. In this research, it is hoped that the comparison of the proposed method with other similar methods and other routing algorithms will show the effectiveness of the proposed method. Various events in the failure of networks and the disconnection of some sensitive points of this type of networks for various reasons and as a result of the loss of the efficiency of the networks have caused many researchers in this field to conduct extensive studies in discovering errors and problems which so far thay were succeed to solve this problem in this field relatively well. Efforts have also been made to solve the discovered problems, which have been able to solve the problem of routing networks to some extent. Each of the existing proposed methods has various weaknesses, among which we can point out high energy wastage and delay. In this research, it has been tried to provide a solution with the least information and cost, in addition to increasing the reliability factor of network stability in case of an error at any point, the speed of network reconstruction and discovery of optimal routes for routing accident-affected points has also been increased. Also, this solution is not limited to fixed nodes and can be implemented by networks with mobile nodes as well. This article aimed to investigate the reasons and how to reduce the delay in the DTN network by presenting a new algorithm and to investigate the causes of energy loss and how to save energy in the DIN network and to provide a method to reduce it and to investigate the reliability of the DTN network and how Improving its performance and investigating how to improve the efficiency of the DTN network.

2. RELATED WORKS

Routing strategies in the delay tolerant network are divided into two categories: Repetition and Knowledge. In the repetition method, there are multiple copies of the message in the network. Repetition-based algorithms can be divided into two categories: flood-based algorithms and quota-based algorithms. Knowledge-based strategies indicate how a strategy uses information about the state of the network to make routing decisions and how it obtains this information [10].

Direct call algorithm, after the source node generates a message, the source of the message carries the message until it contacts the destination directly and delivers the message to the destination at the time of contact with the destination [11].

In epidemic routing, it is proposed that each node sends the packet to all its neighbors at the time of receiving it, provided that they have not yet received the packet. Although in this method the joint area of the network is saturated, it also consumes a lot of resources in the network. This algorithm can be useful only for cases where there are no packets in the queue of nodes or the capacity of the lines is very high, otherwise due to the fullness of the buffers in some nodes, it is possible to delete the packets. Another of its weaknesses is that it consumes a lot of resources and causes a lot of overhead, but it is resistant to the failure of nodes and the network. This routing works by placing a message in a local buffer when it is sent and is tagged with a unique identifier. When two nodes communicate, they send each other a list of all message IDs in their buffers. This list is called state summary vector. Using the summary vector makes the nodes get the messages from exchanging with each other, the massages that they don't have [12].

In order to reduce the overhead caused by epidemic routing based on the summary vector, the Bloom filter was used in this routing [13]. A Bloom filter is a data structure used to query membership. For each node in the network, a Bloom filter is considered. Therefore, when a node wants to send a packet, it adds its Bloom filter to it, which represents the neighbors that exist in the buffer of that node. Therefore, when this packet is received in the neighboring node, the neighboring node finds out what packets the sending node has, so when the two nodes meet, the node sends the packets that the neighboring node does not have them. Therefore, in this way, they exchange the packets that in both neighbor nodes do not exist.

Jiagao et al. presented a vehicular delay tolerant network routing algorithm based on Bayesian network. Delay Tolerant Networks (DTN) are new wireless cellular networks that suffer from frequent interruptions, high latency, and lack of a complete source-to-destination path. In VDTN, most nodes have certain movement patterns, however, traditional routing algorithms in DTNs do not consider this feature well. In this paper, a new routing algorithm based on Bayesian network (BN) is proposed to build a prediction model that aims to predict the movement patterns of nodes in real VDTN scenarios. In the first step, a comprehensive BN model is created, where more features of the nodes are selected to improve the prediction accuracy of the model. Then, according to the complexity of the BN structure learning problem, a new structure learning algorithm, K2 algorithm based on genetic algorithm (K2-GA), is proposed to efficiently search for the optimal BN structure. The simulation results show that the proposed VDTN routing algorithm based on the BN model can improve the delivery ratio with a small transmission overhead [14].

Rosas et al. presented a context-aware self-adaptive router for delay-tolerant network in disaster scenarios. In general loss of communication as a result of widespread damage to communication infrastructure in disaster or emergency scenarios, mobile ad-hoc networks can play an important role in improving communication in affected areas and working on network disruptions. This paper proposes a self-adaptive context-aware routing protocol for delay-tolerant networks that is able to adapt to different scenarios and allows network participants to automatically select a DTN protocol according to the past performance of routing protocols under the current scenario. The proposed protocol shows a significant reduction in energy consumption with a good trade-off with delivery rate [15].

In 2019, Roberto et al. have presented an optimal solution to the routing problem in vehicular delay-tolerant networks with a deep learning approach. The purpose of vehicular networks is to provide a communication framework for the movement of vehicles, road infrastructure and pedestrians. Such networks are ushering in a new era of services that will make areas such as security and safety, information, transactions, entertainment and sustainability (green transportation) more efficient than today, especially in the future era of self-driving vehicles and self-driving cars. , the harsh nature of vehicular environments makes it very difficult to achieve efficient inter-vehicular communication. Vehicular delay-tolerant networks (VDTNs), as these networks are called, have highly dispersed and intermittent connections, and the lack of a fixed topology poses one of the main challenges: Packet routing. A wide range of routing algorithms have been proposed in recent years to optimize communication in vehicular networks, and significant progress has been made in this field, but the search for optimal performance is still ongoing.In this paper, we investigate a deep learning approach to the routing problem in VDTN, And we propose a routing architecture and algorithm based on deep neural networks that help routers make packet forwarding decisions based on the current conditions of their surroundings. In order to evaluate the performance of the proposed architecture, simulations were performed that show significant gains in terms of network overhead and hop count with respect to popular routers, while maintaining acceptable packet delivery rates and moderate delivery delays [16].

In 2018, Li Yan et al presented a congestion-tolerant distributed route-based routing for vehicular delay-tolerant networks.Packet routing is important for Vehicular Delay Tolerant Networks (VDTN). Opportunistic routing algorithms based on historical records do not have sufficient accuracy in forwarder selection due to the randomness of vehicle movement. Route-based routing algorithms deal with the randomness of vehicle movement, but cannot be directly used in VDTNs due to their dependence on APs. In this paper, we develop a distributed path-based routing algorithm (called MobiT) for VDTNs. This non-trivial task faces three challenges. First, the vehicle tracks must be sufficiently collected. Second, routes cannot be updated frequently due to the limited resources of the repository nodes. Third, achieving high routing performance even with partially aggregated routes. Our real tracking technology is the foundation of the MobiT plan. Utilizing multiple vehicle roles, MobiT uses service vehicles that travel across large areas to collect vehicle routes and relies on service vehicles and roadside units (called schedulers) to plan routes. Using regular time congestion mode of road segments, MobiT schedules the packet to arrive at the roadside unit before the destination vehicle to improve the routing performance. In addition, MobiT uses long-term vehicle movement patterns to aid in routing. Our tracking simulation and real tests show the effectiveness and efficiency of MobiT [17].

In 2019, Lalit et al presented an energy-based incentive scheme for opportunistic secure routing in vehicular delay-tolerant networks. The opportunistic forwarding mechanism in delay tolerant networks (DTN) exposes the network to vulnerabilities. Existing routing protocols become very difficult to secure for delay-tolerant networks due to the unavailability of sufficient contacts. Designing a secure routing protocol is essential to overcome these problems. Energy is one of the critical parameters in data transmission and incentives should be provided to vehicle DTN nodes based on the energy spent on a particular message. This paper presents a secure routing mechanism based on the trust value of automotive DTN nodes. The incentive scheme is based on the energy spent by the DTN node as a vehicle for successful data transmission. Routing is based on the trust value of the vehicle's DTN nodes, and an incentive is provided upon successful message delivery. An origin node offers payment for successful delivery based on the time at which the message is delivered. The trust authority evaluates the credibility and trust value for the participating vehicle DTN nodes based on the energy and efforts spent in successfully delivering the message [18].

In 2020, Hinnerkiwe et al presented congestion-aware geocaching routing in vehicular delay-tolerant networks. Vehicular delay-tolerant networks (VDTNs) are networks of vehicles that communicate wirelessly, where there is no permanent end-to-end connection. VDTNs have a highly variable topology, with frequent partitions, and possibly low node density. Therefore, delay-tolerant routing adopts a save-forward message transfer model, where messages have a useful Time-To-Live (TTL) and are stored until a good call opportunity occurs. To improve the probability of delivery at the cost of increasing network congestion, multiple duplicates of the message can be generated. In this paper, we propose a V-GRADIENT geocast routing protocol that monitors node density, buffer occupancy, and interest in geocast groups to dynamically adapt dispatching techniques to broadcast messages in the geographic region of interest. The simulation results show that V-GRADIENT is able to control network congestion and deliver messages effectively, which results in better delivery ratio, lower delay, and a small increase in overhead compared to existing protocols [19].

In 2018, Maggia et al. presented a privacy-preserving opportunistic routing protocol for vehicular delay-tolerant networks. This paper proposes a Privacy Preserving Opportunistic Routing Protocol (ePRIVO) for Vehicular Delay Tolerant Networks (VDTN). ePRIVO models a VDTN as a time-varying neighbor graph where edges correspond to the neighbor relationship between pairs of vehicles. This solves the problem of routing decisions by vehicles while keeping their information private, i.e., vehicles calculate their similarity and/or routing criteria in a private way using the scheme Paillier homomorphic encodings are compared. The effectiveness of ePRIVO is supported through extensive simulations with synthetic mobility models and real mobility tracking. Simulation results show that ePRIVO provides very low encryption costs on average in most scenarios. In addition, ePRIVO shows average gains of approximately 29% and 238% in terms of delivery ratio for real and artificial scenarios compared to other privacy-preserving routing protocols [20].

Savita and Kumar in 2021 have presented routing protocols in delay tolerant networks with comparative and experimental analysis. A Delay Tolerant Network (DTN) is a network that can handle long delays and data loss effectively in challenging scenarios and environments. Considering the mentioned challenges, it is necessary to study how to design routing protocols to adapt to such networks. Currently, research in this area is focused on improving the data delivery ratio and minimizing the delay in routing protocols. This paper reviews advanced routing protocols for delay tolerant networks (DTN) and also performs their comparative analysis. DTN routing protocols are divided into four categories: collision-based, time-based, infrastructure-based, and hybrid, etc. This classification depends on the information used to route the relay selection. We have also discussed some inherent drawbacks such as energy consumption, delivery rate and buffer limitations of existing routing algorithms. We have also performed an empirical analysis and observed the performance of the most popular existing collision and timing algorithms. This article presents an extensive study of routing protocols with their advantages and disadvantages [21].

In 2020, Pandey et al presented a hybrid routing approach for vehicular delay tolerant networks. In vehicular delay tolerant networks, the connection (VDTN) between source and destination cannot always be achieved in every required period. As a result, the bearer node stores the message in its intrinsic buffer until an opportunity arises to send. Fixed nodes facilitate message storage and message forwarding. It also helps to improve VDTN performance. Due to the mobility of the nodes, the bit error rate is high, while the bit error rate in fixed nodes is relatively low. In VDTN, the bit error rate is not considered in most routing schemes. In this paper, a hybrid routing approach is introduced to overcome the above issues. Some features of vehicular ad hoc networks (VANET) are related to PROPHET routing protocol for VDTN. VANET propagation models are implemented for mobile node communication and without it for VDTN. Environmental deterrence effect is also considered and this can be positive or negative. This makes the two-dimensional composite routing approach very worthy. Simulation and performance analysis of the hybrid approach is performed through the Opportunistic Network Environment (ONE) simulator. The results show that the proposed routing approach performs better with the parameters of delivery ratio and average delivery delay [22].

In 2022, Argino et al. presented a comparison of statistical and analytical routing approaches for delay tolerant networks. In delay-tolerant networks (DTNs) with uncertain call schedules, the communication parts and their reliability are specified in advance. To maximize the probability of end-to-end delivery, a limited number of message copies are allowed across the network. The multi-copy routing optimization problem is naturally modeled as a Markov decision process with distributed information. Two advanced solution approaches are statistical model checking with timing sampling, and RUCoP analytical algorithm based on probabilistic model checking. In this paper, we provide an in-depth comparison of these two approaches. We use an extensive benchmark suite that includes stochastic networks, scalable binomial topologies, and realistic loop-road satellite networks in low Earth orbit. We evaluate the resulting message delivery probabilities as well as the computational effort. Our results show that both methods are suitable tools for obtaining reliable routes in DTN and show a trade-off between scalability and solution quality [23].

In 2019, Yuan et al. presented a Q-Learning dual routing in delay tolerant networks. Delay-tolerant networks (DTNs) are wireless cellular networks where nodes are scattered and end-to-end connectivity is rare. Intermittent connectivity in DTNs makes efficient delivery of messages challenging. Research results have shown that the reinforcement learning-based routing protocol can achieve a reasonable balance between routing performance and cost. However, how to more accurately predict the next hop of messages is still open. In this paper, the Double Q-Learning Routing (DQLR) protocol is proposed, which investigates the next hop routing selection in a distributed manner and solves the overestimation problem with the Double Q-Learning algorithm. In addition, average value and dynamic reward mechanisms are proposed to accommodate node mobility and network topology change, which improves network performance. The simulation results show that the DQLR protocol can increase the delivery ratio with low overhead [24].

In 2020, Chorasia et al. presented a packet priority based routing approach for vehicular delay tolerant network. "Vehicle Delay Tolerant Network (VDTN)" appears as a challenging network. VDTN is characterized by the unavailability of the previous terminal path between the source and destination nodes. Therefore, routing is one of the central issues in such networks. Packets are stored in a node's buffer and are only scheduled from that buffer. Hence, node output buffer management is important. This paper develops a routing mechanism that limits the number of copies to be distributed in the network along with scheduling packets based on their priority. The distribution of copies is limited using the remaining message lifetime and the predicted time to delivery. Also, packet priority is based on its type, i.e. emergency packets, traffic related packets and general purpose packets. The proposed routing algorithm is estimated on the "Opportunistic Network Environment (ONE)" simulator. The evaluation results show that the proposed routing algorithm outperforms the existing VDTN routing approaches [25].

3. SUGGESTED METHOD

Security, trust and privacy in the opportunistic network are always complicated and difficult. The choice of intermediate node in Oppnet depends on various factors, among which trust is the main parameter. When designing routing protocols in Oppnet, dynamic network topology, limited buffer size of nodes, energy, frequent links between nodes, limited resources, etc. are many factors through which routing becomes a critical task. Many researchers introduced different security approaches with new features. Each existing protocol has its own unique features as well as some limitations. Some factors such as; the inconsistent behavior of nodes, active and passive attack in the network, privacy issues, message integrity, trust between nodes, etc. motivate the author to introduce the blockchain-based routing protocol in the opportunistic network.

A sequence of techniques used in diverse applications with decentralized, irrefutable and immutable features is known as blockchain technology. Smart contracts, record keeping, securities, fraud reduction, digital currency, etc. are among the applications of BT. Blockchain is the main method used for Bitcoin. This currency is digital, a new concept introduced by Satoshi Nakamoto in 2008.

In this method, each node in the opportunistic network uses the block ID.

This model works in two phases.

1. Authentication phase
2. Trust phase

in the authentication phase; Whenever an oppnet node wants to communicate in the network, the node creates a request for the same function. A block is created with the user ID and now this block is broadcast to the network for authentication. Each oppnet node in the opportunist network receives the block with the user ID, the elected node in the authentication network verifies the requested block. If this block is confirmed by the selected node, this block can become part of the network. This confirmed block is now added to the current blockchain with a unique block ID. In the trust phase; According to the blockchain header, the node receives/sends the message to the relay node.

Authentication phase

Authentication step; at this stage, all nodes are created with a verified public key provided by blockchain technology.

It prevents the hash composability attack, computational attack, and solves the problem of parallel search, memory storage, and pseudo-random array.

Phase of trust

A set of authenticated blocks "B" is used as an input parameter. Communication in the network depends on the trust value of the majority of nodes (B). The trust value given by each node is 0 or 1. 0 indicates complete trust and 1 indicates complete lack of trust. Whenever the trust of a node is calculated as 0, that node will not be part of the network and will not be removed from the network automatically. The concept of blockchain with trust between nodes in the opportunistic network, provides the possibility of achieving many advantages such as: availability, compatibility, decentralized network and message integrity.

4. RESULTS AND EVALUATION

Different parameters have been used for evaluation, which are described below.

Packet delivery ratio: This parameter should be as high as possible when releasing packets in the network. The ratio of the successful transmission of packets to the total number of packets generated in the network is known as the packet delivery ratio.

Packet loss ratio: It is defined as the ratio of the number of lost packets to the number of created packets. Whenever the node's buffer occupancy is sufficient, the opportunistic node drops packets. This parameter should always be lower.

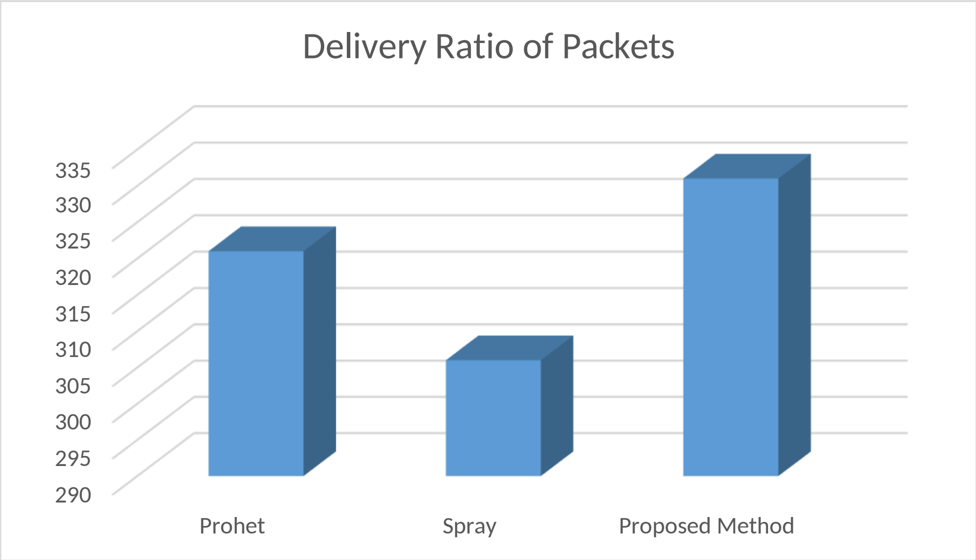

Figure 1. Packet delivery ratio

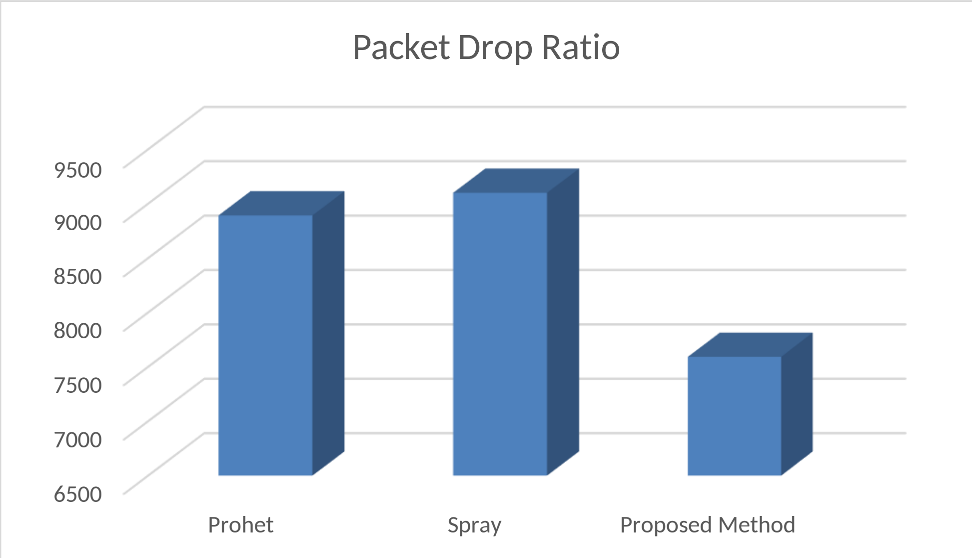

Figure 2. Packet loss ratio

As shown in Figures 1 and 2, the proposed method based on blockchain has a higher efficiency than other methods.

5. CONCLUSION

The main goal of delay tolerant network is to provide secure and reliable communication in discontinuously connected devices. Considering the main challenges of this network, here the secure routing protocol based on blockchain is proposed. The blockchain idea can be used to provide a reliable source-to-destination link for packet propagation in the network. With the adoption of blockchain technology, a reliable framework for a delay-tolerant network has been provided. The results have shown that the proposed method works better than the previous methods based on the two parameters of packet delivery ratio and packet loss ratio.

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