

# Internet of Planets (IoP): a new era of the Internet

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## Abstract

Internet of Planets (IoP) is a concept that enables solar planets to communicate with each other using the Internet. While there is a plethora of researches on IoP, Delay-Tolerant Network (DTN) has emerged as the most advanced technology in recent years. DTN is an asynchronous networking technology that has been deployed for the networking environment in which steady communication paths are not available, and therefore it stores receiving data in a data storage and forward them only when the communication links are established. DTN can be applied to sensor networks and mobile ad-hoc network (MANET), as well as space communication that supports data transmissions among satellites. In DTN networking environments, it is crucial to secure a scheme that has relatively low routing overhead and high reliability to achieve efficiency. Thus, this paper proposes a time (delay) information based DTN routing scheme which is able to predict routing paths for achieving efficient data transmissions among the nodes that have comparatively periodic moving patterns. The results of the proposed DTN routing algorithm using NS-3 simulation tools indicate satisfied levels of routing performance in comparison with existing DTN algorithm.

*Index Terms*—IoP, Internet of Planet, DTN, Delay-Tolerant Network.

## 1. INTRODUCTION

From the past to the present, space communication has used radio waves [1] as it is the fastest communication system that uses a radio for data transportation. The principle of radio communication is the same as that of optical communication using an optical cable. However, since there is no optical cable in outer space, information is precisely controlled by transmitting a radio signal. There are many advantages, but it also has a fatal weakness; which is the distance. If you are located close to Earth, such as a space station or the moon, that is fine, but when you move farther away, you will experience a weaker signal that drastically reduces your speed. In order to solve this problem, many research institutes and universities are actively researching for a suitable communication method in space. Among them, DTN is a very suitable communication protocol for interplanetary communication.

Delay Tolerant Network (DTN) is a network structure designed to enable communication in end-to-end unstable networks [2]. The early DTN was a concept proposed to connect the Internet with very long transmission delays such as probes and space communications in space. With the advent of technologies such as battery-powered sensor networks and inter-vehicle networks with various mobility, today the concept has been extended to the Delay and Disruption Tolerant Network, which includes the Opportunistic concept. Conventional wireless networks (WLANs) use heterogeneous networks to establish routing paths in advance and transmit messages using them. However, in the environment where network infrastructure is lost, communication breakdown occurs frequently and it is difficult to apply the existing TCP/IP protocol. To solve this problem, DTN uses store-carry-forward-based message delivery to enable communication by preserving messages through relay nodes even when end-to-end

connections are unstable. In the absence of direct routing paths between source and destination nodes, messages are delivered using neighboring nodes as relay nodes.

In this paper, we add delay and authorization information to the existing routing table reflecting the characteristics of DTN. The authorization field checks the IDs of neighboring nodes and increases routing reliability. The delay field reduces the overhead and speeds up routing based on the delay information of each node. We propose a routing method that can improve the efficiency of the existing DTN routing protocol using two additional information. Chapter 2 describes the ongoing research on the current DTN routing method. In Chapter 3, we propose an algorithm and compare the efficiency of the algorithm proposed in this paper with the existing DTN routing method. Finally, Chapter 4 describes the conclusion and future research direction.

## 2. RELATED WORKS

### A. Delay Tolerant Network

The DTN routing protocol is used in various ways depending on the purpose. Protocols such as an Ad Hoc On-Demand Distance Vector (AODV) and Optimized Link State Routing (OLSR), which are used in Mobile ad-hoc network (MANET), discard packets if no destination exists in the node's own routing table. Therefore, it cannot operate under DTN environment where intermittent disconnection occurs due to topology changes. There can be no nodes, no neighbor nodes willing to send on a network which is disconnected and isolated. However, if there is a good condition of network with a delay, the nodes can store the data and pass it to the destination. On the other hand, the type of civil carrier communication in the delay is an unsuitable protocol in situations where the delay is sensitive, such as vehicle communication and autonomous driving. In the case of DTN, data transfer does not have to be made immediately, and the purpose is different from the above situation.

DTN routing has the following two characteristics. 1) Store-carry-forward: if the next hop node to deliver is closer to or more likely than the destination, send the information it has. 2) Store-carry-replicate: if the data is difficult to transmit, store the data and forward the replicate to the other party. If a node knows in advance about the next node, it can send information comfortably. Fig.1, illustrates the basic operation of the DTN. In the figure,  $t$  stands for time,  $S$  for sender (source planet), and  $D$  for receiver (destination planet). As depicted in Fig.1, by using DTN - the data is temporarily stored and transferred to the next planet despite the long distances. This way of transmitting data is called "Transitive Networking". Thus, the DTN automatically stores and transmits a part of data to nodes or satellites, to construct a much faster and more reliable network.

### B. Routing Protocols in DTN

The DTN routing protocols in the DTN environment are largely divided into deterministic and stochastic routing protocols [3]. The deterministic routing protocol assumes a situation whereby the node knows in advance the movement or location information. Accordingly, a method of transmitting a message using information of each node such as mobility information can be applied. In [4], Oracle-based technique is discussed which performs transmission using oracle information, and in [5], routing technique using space-time graph is discussed which predicts the path that a node moves in advance. Hence, in this paper, we assume that the network situation is flexible and the information needs to be estimated.

Since stochastic routing protocols assume an environment where network changes are unknown, it is necessary to consider when and to which node to deliver a data. In [6], they introduce Epidemic Routing, where random pair-wise exchanges of messages amongst mobile hosts ensure eventual message delivery. The multifarious goals of their work are maximization of message delivery rate by minimization of message latency and the total resources consumed in the delivery process. In [7], they introduce a routing scheme, called Spray and Wait. As the name suggests, this "sprays" a number of copies into the network, and then "waits" till one

of these nodes reaches the destination. They demonstrated that ‘Spray and Wait’ scheme outperforms existing schemes with respect to both average delay of message delivery and number of transmissions per message delivered. Table 1 illustrates the key characteristics of Epidemic routing [6] versus Spray and Wait [7]).

The algorithm proposed in [8] consider the problem of routing in intermittently connected networks. In such networks, there is no guarantee that a fully connected path between source and destination exist at any time, rendering traditional routing protocols unable to deliver messages between hosts. They propose a probabilistic routing protocol for such networks. In [9], they exploit two social and structural metrics, namely centrality and community, using real human mobility traces. The contributions of their paper are two-fold. First, they design and evaluate BUBBLE, a novel social-based forwarding algorithm that utilizes the aforementioned metrics to enhance delivery performance. Second, they empirically show that BUBBLE can substantially improve forwarding performance compared to a number of previously proposed algorithms.

Many stochastic routing techniques, including epidemic routing, exchange node information when another node is adjacent to the source node’s transmission range. This method, such as spreading a message, is known to be most effective for delivering messages in unpredictable network environment. However, since each node in the DTN has a limited buffer, the copying of the message becomes static. This overloads the network, resulting in lower message rates and higher overhead. These routing techniques copy the message to all nodes that come into contact without determining the efficient spread of the message. As a result, unnecessary messages are distributed throughout the network, and the load of the node buffer increases, thus reducing the number of relay nodes that can carry messages, which causes problems in message delivery. In addition, when the node density of the network is high, the number of copied messages increases rapidly, which causes problems in the resource utilization of the network.

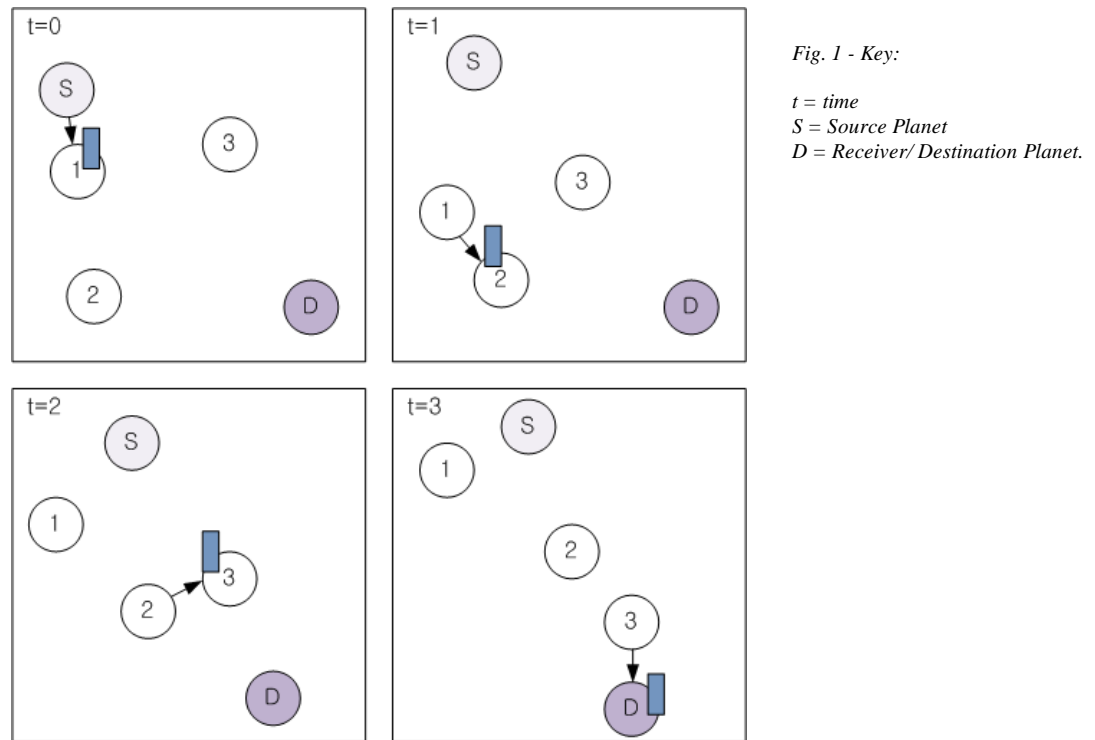


Fig.1. Basic operation of DTN.

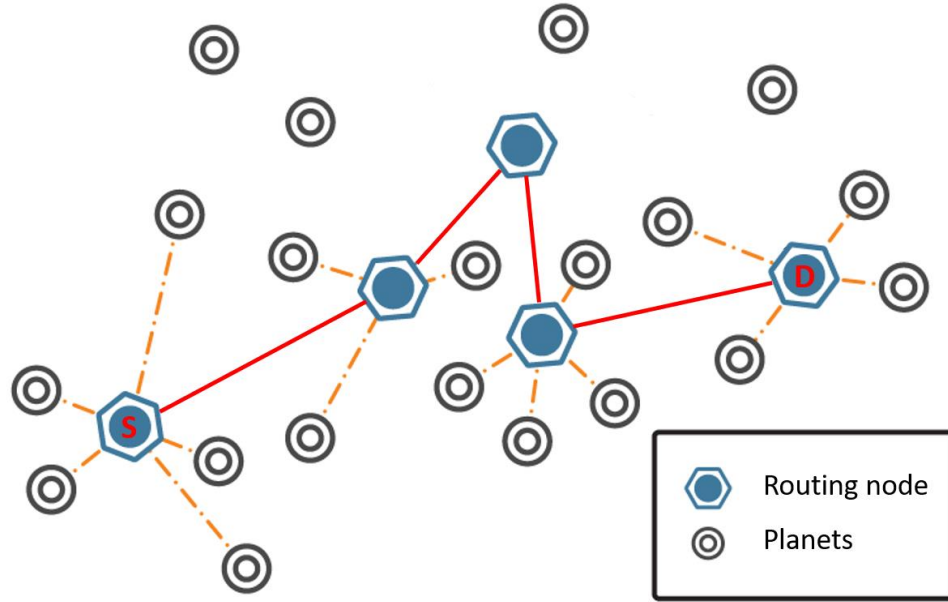


Fig.2. DTN topology and its corresponding node.

Table 1. Comparison of routing protocol characteristics - Epidemic vs Spray and Wait

Routing Protocol	Message copies	Selection Method (Next Hop)	Drawbacks	Delivery Delay	Buffer size
Epidemic [6]	Unlimited	Indiscriminant flooding	High resource utilization (Buffer, bandwidth)	Low	Limited
Spray and Wait [7]	Limited	Randomness	Random decision making	Medium	Sufficient

### 3. ALGORITHM AND EXPERIMENTS

In order to apply to the IoP environment, we have modified and experimented with the existing routing algorithm developed in [10, 11]. The proposed technique in this paper adopts flooding-based message delivery such as Epidemic routing or Spray and Wait routing. In addition, routing method proposed in this paper minimizes the routing time from S (source) to D (destination) by using periodic delay information of node S when transmitting message from node S to node D in DTN environment topology where regular movement patterns exist. It predicts possible routes and transmits them. In the proposed routing method, a timer starts whenever each node encounters an adjacent node. The measured timer records the delays encountered by neighboring nodes in the routing table. It then adds a table that can record delay to the existing routing table to record the timer time and calculate the minimum delay. By adding the authorization field, each node knows the neighbor node ID and checks the ID when possible for reliable routing. Each node can predict the time to meet the adjacent node by using the delay information in the routing table. By setting the error range, it limits the node's search and communication except the time of meeting with the neighbor node within the error range, thereby saving the energy resources of the node. By using the table, it can identify whether the node is new or existing until network convergence, thereby increasing the reliability in message transmission.

Fig. 2 shows a wireless network topology. We used NS-3 [12] as the simulation tool to verify the performance of time routing. As shown in Fig. 2, the DTN environment is constructed, and the moving model has a random moving pattern and then a pattern in which nodes move in a circular shape based on a certain input size and speed. The simulation size was specified as 50 nodes

(planets) at 100,000 km horizontally and vertically to create a moving environment like satellites in space communication. The simulation period is 5000 seconds, which is the time to show the network convergence time; and the constant result of each routing algorithm because the node movement is set to the movement speed similar to the satellite. The transmission range, transmission energy, channel frequency, and signal noise of each node were kept at DTN default settings.

To evaluate the efficiency of delay information routing, a performance comparison experiment with existing DTN routing algorithm was carried out when there are nodes with constant moving patterns. Fig. 3 shows the experiment in DTN topology where the speed or movement pattern of nodes is irregular in the same environment as the previous topology. This figure shows response time while changing packet index at the DTN controller. To investigate the response time of the proposed algorithm, we experimented while changing the network packet index. We migrated the network data through the switch for the actual test-bed experiment. By using data migration software, we solved the problems of existing network data migration. It also improved: performance and productivity, interim results check/retry, job scheduling, efficient operation of large-scale data, cost reduction and test-bed development time savings. The response time was irregular before the packet index was 50, but the response time was stable from 50 when the packet index was 50. This means that the performance of the proposed algorithm is stable after certain number of packets index (around 50 packet index).

Finally, we experimented with the overall status of the network. Fig. 4. shows throughput, packet loss rate, and latency. The red solid line is the QoS measurement in a typical DTN network. Notable in this result is a significant amount of packet loss over time. In addition, we can see that the network latency occurs steadily after a certain period. The blue solid line is the result of applying our algorithm to the DTN network. Throughput is stable and network latency is considerably low. The network latency does not occur constantly, but it is insignificant and short. Considering various conditions, it shows that the proposed algorithm works well in IoP environment that processes enormous data.

In summary, DTN is an internet protocol that is created assuming connection in space where there is a lot of communication delay. Information is transmitted in a manner different from TCP/IP, which assumes that the connection will not be disconnected. For example, if a ship enters the shadow of a planet, the connection may be dropped, in which case the DTN is designed to keep the network node intact and to prevent loss of information without destroying data packets. However, existing communication protocols such as mobile ad hoc networks and sensor networks do not properly reflect DTN-specific characteristics. In addition, the routing protocols designed for DTN are also based on non-realistic assumptions such as random mobility, which leads to poor efficiency in actual IoP environment.

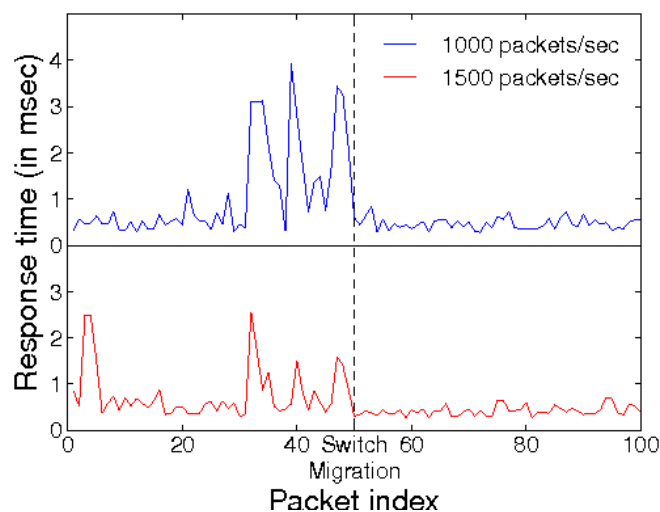


Fig. 3. Response time while changing packet index.

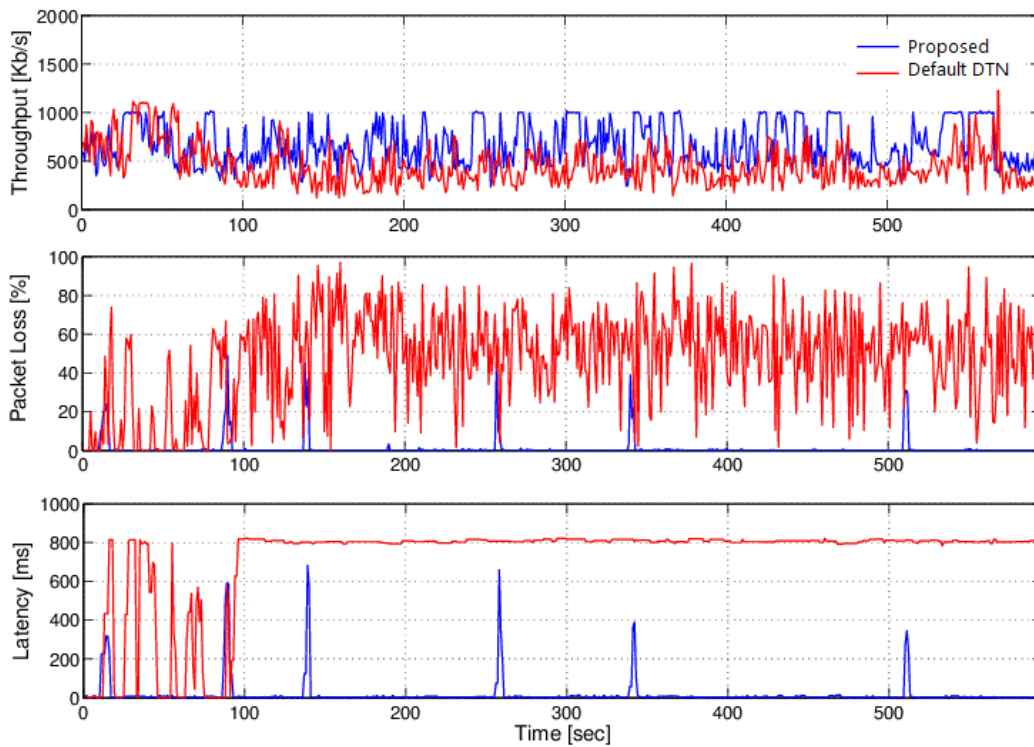


Fig. 4. Throughput, packet loss rate, and latency of QoS traffic flow for proposed scheme.

#### 4. CONCLUSION

The DTN proposal to solve the unstable network connection problem has been attracting attention because it can solve the network problem in the region where normal communication situation such as space or deep sea. However, the existing DTN routing was difficult to apply to the actual network because they only consider the transmission rate of the data. This paper proposes to find an efficient relay node in DTN to solve this problem. The proposed algorithm analyses the network status by using delay and authorization history in order to select an efficient relay node from DTN. In addition, since the actual movement of nodes differs from the model used in the simulation, there are certain rules. If further research is carried out and considering relay node selection according to buffer and energy of node, more stable DTN routing will be possible. If we overcome this, we will actually be able to connect the planets with the Internet – hence IoP.

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