PERFORMANCE IMPROVEMENT OF VEHICULAR DELAY TOLERANT NETWORKS USING PUBLIC TRANSPORTATION SYSTEMS

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ABSTRACT

In some networks, communications are sometimes interrupted and packet sending encounters many delays due to lack of permanent connection between the nodes. Inter-vehicular and inter-satellite networks, which are the so-called delay-tolerant networks, are an example to this type. This paper proposed a new routing algorithm, which could increase efficiency of this kind of networks using predictability feature of bus movement in a vehicular network. In this paper, bus routes were considered the backbone for vehicular network and, knowing route of bus and destination of packets, the proposed algorithm, which was able to use this information, was introduced. In addition, the proposed algorithm was simulated to prove its efficiency and then it was compared with other algorithms in different conditions. The obtained results indicated acceptable efficiency of the proposed algorithm.

KEY WORDS

Public transportation system, vehicular networks, delay-tolerant networks, roadside units

1. INTRODUCTION

Using delay-tolerant networks is greatly efficient and effective in most of commercial applications and road safety systems. As an example, vehicular networks can be used for the awareness of other vehicles from upcoming traffic lights, regulation of roads' traffic load and reduction of travel time. Moreover, the facilities provided by vehicular networks can be used to inform other vehicles about an event and prevent occurrence of chain accidents.

In many studies and also according to many industrial experts, using vehicular networks for traffic safety and other commercial applications can reduce costs. Although current configuration and installation of vehicular network is slightly costly, in near future, many applications will be available based on data delivery as delay-tolerant by vehicular networks.

Below in this paper, first, delay-tolerant networks are introduced with a focus on routing challenges and some examples of the algorithms proposed in this field are presented. Then, the proposed algorithm is introduced and compared with the algorithms presented in the previous section.

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1.1. Delay-Tolerant Networks

The research workgroup of delay-tolerant networks has been established as a part of the Internet research workgroup, the purpose of which is to specify protocol design rules and architecture needed for delay-tolerant networks that can easily work in the environments in which permanent connections are not available.

Members of research workgroup of delay-tolerant networks have defined a basic architecture for this type of networks. Kevin Fall was the first who determined challenges and problems existing in IP address based networks and introduced delay-tolerant communication architecture. This architecture is based on a message-oriented layer and implemented on a transport layer, which was called Bundle. The devices in which this layer is implemented are called delay-tolerant nodes. Packets are stored and kept in this layer until a proper connection becomes available.
This layer is responsible for reliable delivery of packets to the destination and assurance from their successful delivery. Due to the implementation of Bundle layer in different types of transport layers, it is possible to support heterogeneous networks using delay-tolerant gateways; for instance, the Internet can support several networks. However, these networks may have different data connection layers.

In order to optimize network efficiency, routing algorithm must select the appropriate contact based on the next step and determined transport time. When no connection is available, the message received from higher layers is kept in Bundle layer to set a proper contact or, finally, the message is discarded. Considering the main nature of delay-tolerant networks and unavailability of permanent connections, increasing packet delivery rate and reducing final delay are among the main goals of routing algorithms.

When routing algorithm has better information about the current state of network topology and its future variations, it can adopt more effective decisions in terms of sending messages. Routings in which current status of topology and its future changes are predictable are called deterministic delay-tolerant routing. Sending packets can be done in a scheduled way by deterministic routing; as a result, network efficiency is improved and resource application is reduced. On the other hand, nodes may randomly move and have little or no information about future variations of network topology. In this way, delay-tolerant routing randomly sends packets step by step. In such a case, packet delivery is probabilistic and without any guarantees. Meanwhile, there are some mechanisms which predict contacts based on the information about previous state of the network or determine nodes' movement path for packet carriers. Random routing technique has more focus on repeating packets and controlling network drowning by messages in order to make an appropriate balance between using network resources and enhancing its efficiency in the absence of information related to the network's future variations.

2. RELATED WORKS

So far, numerous algorithms have been introduced for routing in delay-tolerant networks. In this section, some examples of these algorithms are introduced.

In Epidemic method, every node has a list of all the packets that are in standby mode and exchange their packets with each other as soon as contacting other nodes. This method guarantees packet delivery because the packet will be delivered to the destination at least via one route; however, this algorithm has problems such as large overhead, high transport cost and high memory usage. This algorithm can have the best efficiency if nodes have unlimited bandwidth and buffer; however, according to the current conditions and limitations, it is not possible to provide unlimited bandwidth and buffer. So, algorithms should be introduced which smartly use current bandwidth, memory and other resources [6].

Another algorithm of this group is Spray and Wait. Instead of sending copies to all the nodes with which it is in contact, this algorithm sends copies to only a limited number; i.e. N copies of packets are provided and sent to the first N nodes with which it is in contact. Then, in case no destination is found, no other copy is made in the first phase and message carriers will have direct transmission of packet sending [8].

Another algorithm in this method is an algorithm that tries to prevent blind sending of copies. This algorithm is called PRoPHET and its logic is based on history of nodes' movement. Since nodes usually move in a certain manner, their next location can be predicted by gathering time and space information of the nodes. This information is calculated according to history of the nodes that have been already encountered by this node [4].

Considering the above points, this algorithm determines the criterion for probability of successful delivery of packets to the destination from current node. The nodes that have more contact with each other have higher probability of packet delivery. Then, they send copies to those nodes.

3. THE PROPOSED ALGORITHM

By studying the nature of nodes' mobility in vehicular networks, it was concluded that nodes were buses in the network which had a fixed route and continuously passed it. Therefore, predictability feature of movement of these nodes was applied.

In the proposed algorithm, vehicles studied bus routes when getting in contact with them; if a bus was moving to the destination, they would deliver packets to that bus. Considering feature of storing, transporting and sending packets, the bus would carry the packet to deliver it in the final destination. In this algorithm, if a vehicle wanted to deliver the packets but there was no bus for delivery, it would only deliver the packets to N encountered vehicles which could control the network traffic.

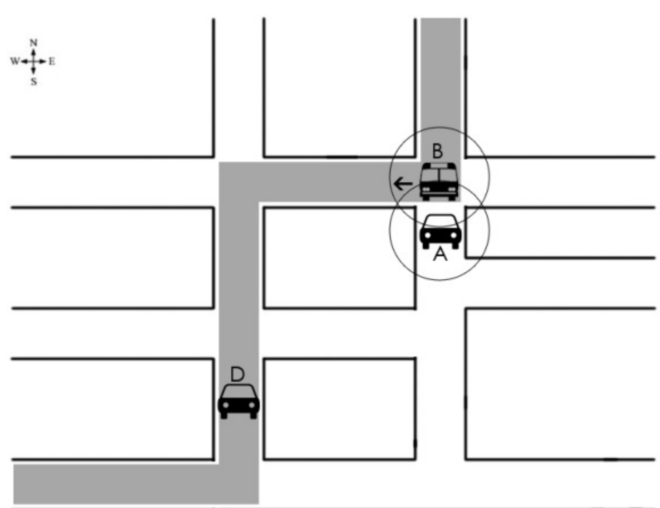

Figure 1: Packet sending to destination by Bus B

For example in Figure 1, Vehicle A has a packet that should be sent to Vehicle D. Route of Bus B is marked gray. Considering that Bus B is moving toward the destination, Vehicle A delivers the packet to Bus B. In the proposed algorithm, in addition to using bus routes, roadside equipment was also applied. However, due to high cost of the equipment, attempts were made to minimize their application. To this end, the equipment was placed only on the crossroads on which two buses crossed each other. When nodes were in contact with roadside equipment, they sent them a copy of their packets. Then, the roadside unit delivered them to the suitable bus. Thus, indirect bus routes were also used which increased rate of packet delivery.

As mentioned previously, message repetition is used in delay-tolerant networks. Accordingly, in each contact of the packet with routing algorithm, some copies of the message are sent to the encountered nodes; therefore, the packet would probably reach its final destination while there are copies of the packet in the network. Since these messages are unused and only waste memory of nodes and transport of packets, the proposed method had an idea for disposing these unused packets. Considering the structure of streets in the urban environment and bus routes, it can be concluded that route of buses is a backbone for vehicular network in urban environments, which covers most of the streets.

In the proposed algorithm, the number of bus routes was assumed L; as mentioned earlier, bus routes act as the backbone of vehicular network; therefore, each message should arrive at the destination at most in L steps and the packets which have passed more than L steps are the unused ones that increase network traffic and waste memory of nodes. So, in the proposed algorithm, each packet was sent only to L steps. Figure 2 shows the routing decisions used in the proposed algorithm as a pseudo-code.

```
Set N to Number of copies for relay message
Set L to Number of bus routes
While (Messages Hop Count <= L)
   Do
Routing strategies in cars
If (encountered Node=BUS) and (encountered Node paths contains destination location)
            Do
            Forward message to encountered Node
            Else
            Do
            Forwarding message randomly to N node
Routing strategies in Buses
If (encountered Node=BUS) and (encountered Node paths contains destination location)
            Do
            Forward message to encountered Node
            Else if (encountered Node=RSU)
            Do
            Fetch RSU messages that can be delivered to the destination by this BUS
            Else
            Do
            Forwarding message randomly to N node
Routing strategies in RSU
If (encountered Node=BUS) and (encountered Node paths contains destination location)
            Do
            Forward message to encountered Node
Else if (encountered Node = Destination)
            Forward message to encountered Node and delete from RSU Buffer
```

Figure 2: Pseudo-code of the proposed algorithm

4. SIMULATION

In this section, efficiency of the proposed method is evaluated and investigated. Then, it is compared with Epidemic and Spray and Wait algorithms.

In this paper, ONE (opportunistic network environment) was used for evaluating efficiency of the proposed method. This simulator has been written in Java and is open source. ONE simulator is devoted to delay-tolerant networks; thus, this simulator was used for simulating the proposed algorithm.The simulation environment consisted of 16 bus routes, each of which had 5 buses that went back and forth on these routes. In addition, 15 roadside units were used at the intersection of bus routes. Simulation period was equal to 6 h in all the scenarios.

One of the most important criteria for evaluating routing algorithms is their rate of successful packet delivery. Therefore, in the first scenario, capability of packet delivery was evaluated. Figure 3 demonstrates rate of successful packet delivery in three different algorithms.

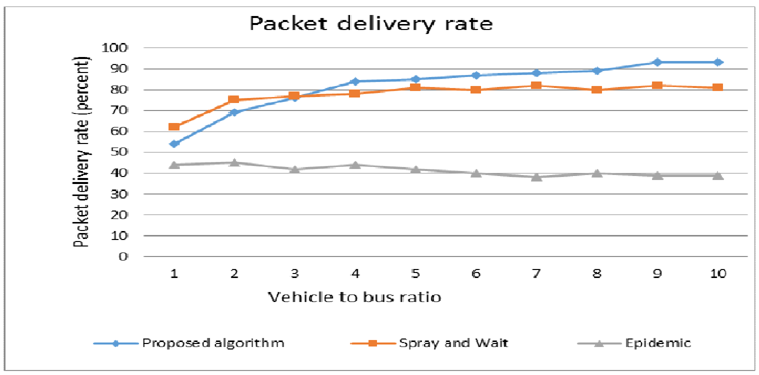

Figure 3: Percent of packet delivery in routing algorithms

As can be seen in the figure, the more the number of nodes, the better the performance of the proposed algorithm would be. Below, mean delay of packets is investigated in different algorithms. Latency of each packet indicates time interval between time of packet development and its delivery to the destination. Results of this comparison are given in Figure 4.

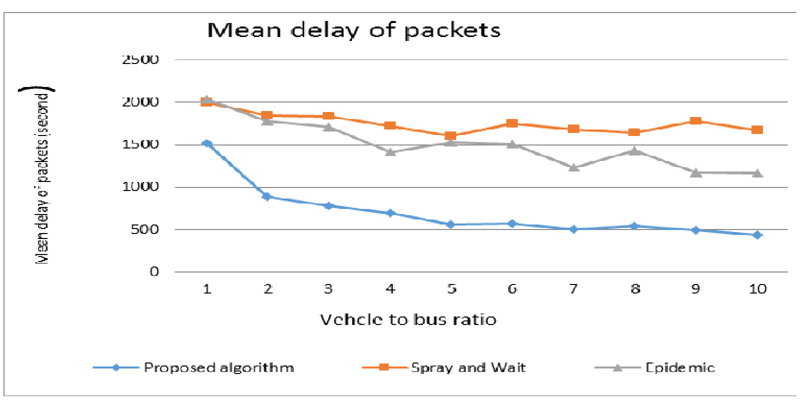

Figure 4: Mean delay of packet in routing algorithms

The more the number of nodes in the network, the more the possibility of contact would be; as a result, delivery of the packet to the considered destination would be faster. Increased number of nodes in all three algorithms can reduce delay time; however, this reduction was much more in the proposed algorithm than the other two.

Finally, overhead of these three algorithms was compared. For this comparison, effect of increasing the number of nodes was investigated. Figure 5 indicates overhead of the compared algorithms. In this figure, numbers in the general column show overhead of the algorithms. The simulator used in this algorithm considered ratio of all copied packets to the delivered packets as network overhead.

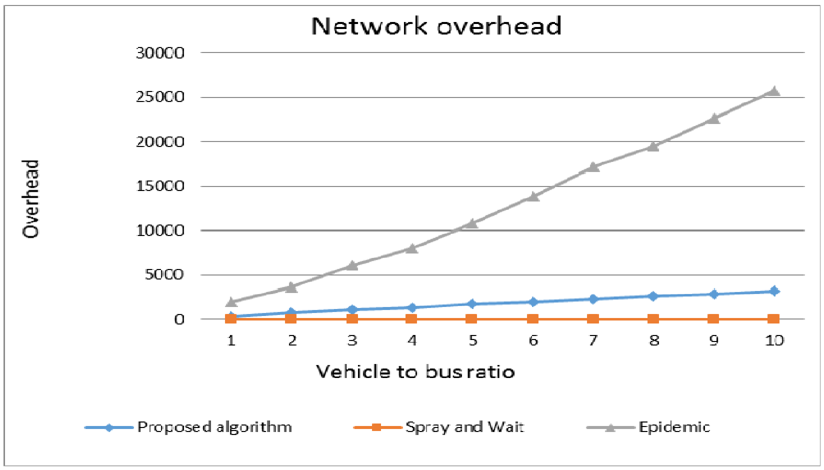

Figure 5: Mean network overhead of routing algorithms

As can be seen, increased network severely raised overhead of Epidemic algorithm, which can be due to blind sending mechanism in this algorithm. Overhead of Spray and Wait algorithm did not change with increasing the number of network nodes. As mentioned previously, packets are constantly repeated in Spray and Wait algorithm; therefore, change in the number of nodes does not affect overhead of this algorithm. Overhead of the proposed algorithm also increased with constant slope, which was much less compared with Epidemic algorithm.

By observing the results of the performed simulations, acceptable efficiency of the proposed algorithm and importance of using public transportation systems are found. Furthermore, importance of using an appropriate mechanism for network drowning using packets can be well understood.

5. CONCLUSIONS

Considering the current limitations, it is necessary to used delay-tolerant networks. Thus, in this paper, first, delay-tolerant networks were introduced and architecture of this kind of networks along with other examples of available algorithms was investigated. Then, predictability advantage of nodes' movement in public transportation systems was used to introduce the proposed algorithm. Later, simulation and comparison results demonstrated acceptable efficiency of the proposed algorithm and importance of using public transportation systems.

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