Fairness and Satisfaction Model for DTN Applications Using Various Transportation Means

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Abstract. Delay Tolerant Network suffers from lack of resources and disconnected contact nature. In DTN, all possible methods are used to transmit data including the physical transportations means. Aircrafts in commercial routes have been proposed to carry data from ground users along their flying routes. Delivery probability is compared when using aircrafts, buses and ferries. Results show that aircrafts provide higher delivery probability which is up to 62% better compared with buses and ferries. Furthermore, when there is lack of resources, it is difficult to satisfy all users' demands for traffic. We propose a Fairness and Satisfaction (FS) model to enhance the users' satisfaction during DTN limited and scarce resources. Various scenarios are tested for the FS model through intense simulations. FS model, when implemented, will improve user's satisfaction up to 18 % and DTN fairness up to 20 % compared with the same scenario lacking the model.

Keywords: Delay Tolerant Network (DTN), Quality of service (QoS), Aircraft and User's Satisfaction.

1 Introduction

Delay tolerant networks work in the environment of limited communication infrastructures where links are disconnected and might not be available for a long time. In addition to using the standard transmission medium in these challenged conditions, transportation means have been used in DTN literature to carry data for DTN applications. Buses, ferries, bicycles, motorbikes and trains have been proposed for DTN[1][2][3][4], sometime by physically transporting the saved data on a storage medium such as USP memory or by wirelessly exchanging data, whenever a transportation vehicle comes in range with the users. We have proposed using aircrafts in commercial routes [5] because they have larger coverage area and fly over remote areas where communication infrastructure is limited. In this paper, we will set a scenario and compare between using buses, ferries and aircrafts. The results show that using aircrafts will provide better delivery probabilities and more user satisfaction. This is mainly because all requesting users are in range with the flying aircraft at most of the time due to the flying high altitude whereas this is not the case with buses and ferries.

Furthermore, these transportation means are considered as contacts and represent the main resources in DTN. The more number of vehicles will mean more opportunities to send data and therefore more resources. However, these resources are normally scarce and limited in DTN which might degrade its ability to satisfy all users' requests of traffic. The users will compete with each other to get access to the passing contact and this will lead to congestion. Whenever a contact exists, all users will try to get access to it in order to transmit their data but unfortunately not all of them will be able to send theirs due to the contact limited capacity and numbers. However, after another wait, another contact might arrive, where the same competition will be repeated among users and again not all of them will be able to send their data. Therefore, there is a need for a system that should try to improve each and every user chances of getting access to the contact resources especially during severe shortage of resources. The system should be fair to allocate the resources equally among the users and give a chance to as many users as possible to send their data.

Throughout this paper, we will show the improvement in the level of user satisfaction when applying the FS model compared with the same scenario lacking our model. FS model will be applied to aircrafts, buses and ferries which act as intermediate node/gateway to help it decide fairly which user to select. This decision will be used by other vehicles to ensure that they satisfy as many users as possible.

2 Related Work

DTN has increasingly become a hot research topic and the IRTF DTNRG [6] is leading the effort to expand the research of DTN in various topics. In DTN literature, many transportations means are used to carry data for DTN applications. We proposed using an aircraft as a DTN carrier at remote locations [5]. At UMass Amherst [2], they used public buses travelling on scheduled routes to exchange data using Wi-Fi nodes in a project called Diesel Net. Ref [3] proposed using ferries and suggested that the users could schedule their movement to match the ferries movements in order to send their data. We will compare between these three types of transportations in DTN environment in the coming sections.

However, there are limited references that discuss the user satisfaction in DTN. Ref [7] proposed a data delivery method for DTN for various users based on the relative importance of their data requests, which is something like the users class of service CoS classification in DTN. They proposed a carry-and-forward technique to enhance the overall user satisfactions and achieved better users satisfactions compared with the conventional first in first out FIFO method. Our FS model will also consider the class of service CoS of the user, but furthermore, it will consider other metrics such as the history of users previous admissions as we shall see later in the model discussion.

Furthermore, many references in the literature discuss the resources management in DTN but each one is targeting a certain resource. Some of them discuss how to save the buffer resources which is important for some DTN applications like the sensors network. The concept of message ferrying is proposed in [8] where they proposed allocating the buffer resources between users at different connections sessions. In our aircraft application, we assume unlimited buffer space and we consider the aircraft communication bandwidth as the only resource. The bandwidth will increase with the longer time the aircraft stay in line of sight contact with the ground users. Also, more aircrafts will mean more contacts and therefore more resources. Ref [9] also discusses the resource management using adaptive optimal buffer management scheme for various message sizes. It implements a dropping policy to enhance the delivery rate and reduce the delivery delay. Our FS model will decide which users to accept by managing the bandwidth resource of the aircraft.

Many references of DTN resource management are in the form of new routing algorithms while our model is a complementary mechanism applied to the routing algorithms. The Probabilistic Routing Protocol using History of Encounters and Transitivity (PRoPHET) [10] eliminates the production of replications based on history encounters in order to enhance the resource utilizations. Flooding is used in Epidemic routing [11] where the nodes replicate and transmit the bundles to all other nodes which do not have a copy of those bundles and this replication consumes many of the network resources. Spray & Wait routing algorithm [12] sprays a number of copies into the network and waits for at least one of these messages to arrive at destination. The prioritizations concept is implemented in MaxProp [13] and is based on scheduled transmitted and dropped packets where the historical data of past meetings is used to decide the possibility of future meetings. MaxProb routing will be used in our scenario because it the best routing algorithms among the other three to provides better performance.

FS model can be applied to any DTN routing algorithm and we argue that it can provide extra improvements in the performance as we shall see in the coming sections.

3 Fairness and Satisfaction Model Concept

Routing can be considered as a data push operation where each node tries to forward its data bundles to other nodes through various routes, which ensures faster and optimum performance of data delivery from a source to a destination. In the case of DTN, the process will be a store and forward one because the next nodes might not be available for some time. On the other hand, FS model can be considered as a data pull operation where the node decides which one to admit first and which to reject, from a group of interested transmitting nodes.

As shown in Fig.1, which shows pull/push concept, there are 5 users (1 to 5 at area X) who want to send/receive data from/to 5 other users (6-10 at area Y). There are 2 aircrafts (AA and CC) in direct contact with the users while 2 other aircrafts (BB and DD) acting as intermediate nodes. The aircrafts are considered mobile intermediate routers/gateways for the users. FS model is applied at those aircrafts that while receiving the data, they can apply the model to select which to accept among the interested users. This is considered as a pull operation. Now the aircraft wants to forward the data using the routing algorithm to the next contact. This is considered a push operation. For example, aircraft AA applies the pull concept (FS model) from users 1,2,3,4 and 5, while it applies the push concept (Routing) to forward it to intermediate aircrafts BB and DD.

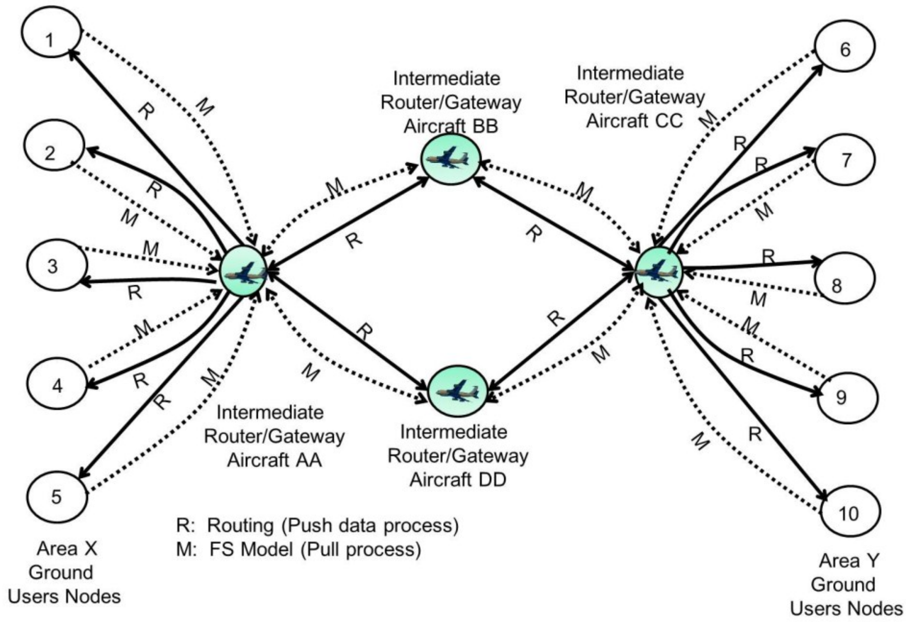

Fig. 1. Push/Pull concept of the FS model

FS model will apply fairness during the selection process and for that we will use Jains fairness index [14] to evaluate the model performance. Jains index will evaluate the fairness of distributed resources for a group of users competing for a common bottleneck channel at a particular time.

3.1 FS Model Design

FS model is working based on collecting feedback administration metrics data from all users of their class of service CoS, Time of their request, number of past acceptances and number of past rejections. FS model will assign a weight value for each metric and decide which user to admit first based on the highest metrics weight. Each contact will use the latest feedback administration data for his decision and these data will be updated after each contact session. The model will allocate the whole bandwidth to users one after another and will not distribute it among users. During scarce resources, if the contact carries a fragment from all users, it might end up - in the worst cases- that none of them is able to process his data because they all haven't received all their fragments. Therefore, FS model is providing fair and better resources allocation using this concept which is more useful at scarce resources only.

3.2 QoS Contact-to-Contact /End-to-End

There are requirements to provide end-to-end QoS and hop-to-hop QoS in traditional networks. However, in DTN the links are not guaranteed and the next hop arrival might not be known and there might be other local hops for the node within its area. Therefore, providing this concept might be difficult and impractical in DTN environments. Instead, we think the QoS in DTN disconnected environment should be provided per contacts because it is the main resource. Whenever a contact becomes available, it will implement the QoS requirements through collaborations with other contacts by referring to the past data recovered from the nodes. This way, providing the QoS contact-to-contact in DTN is more visible and this can be illustrated in Fig. 1 as users 1 to 5 and aircraft AA or users 6-10 and aircraft CC. Furthermore, end-to-end QoS can be provided based on the performance of the routing algorithms and the availability of contacts and this can be illustrated in Fig. 1 as users 1 to 5 and users 6-10 exchanging data using intermediate aircrafts AA, BB, CC and DD.

We will have two sets of results. The first is contact-to-contact which considers the average results of all contacts applying the model within a group of users' nodes and a particular contact. This set will evaluate the FS model performance results with respect to the satisfied users and fairness. The second set of results will be based on the end-to-end satisfied users and fairness from source to destination. It might consider multiple contacts and the routing algorithms among nodes and contacts.

4 Simulation Results

We will evaluate the performance of using aircrafts compared with using buses and ferries. Furthermore, we will evaluate the performance of FS model.

4.1 Simulation Scenario

The scenario assumes three remote locations, A, B and C where each area has a group of users. These locations have limited communication infrastructure and they use all types of available links including the transportation means of buses, ferries and aircrafts. As shown in Fig. 2, the areas are at the shore of a big lake where buses, aircrafts and ferries operate between the three locations. Whenever any of the vehicles (bus or aircraft or ferry) approaches the area, the ground user will try to send their data to the passing vehicle which in turn will deliver it to the next area and take other data to another area and so on.

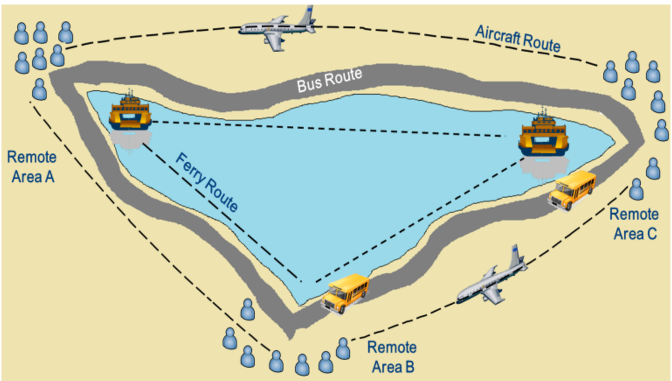

Fig.2. FS Model Senario

4.2 Simulation Configuration

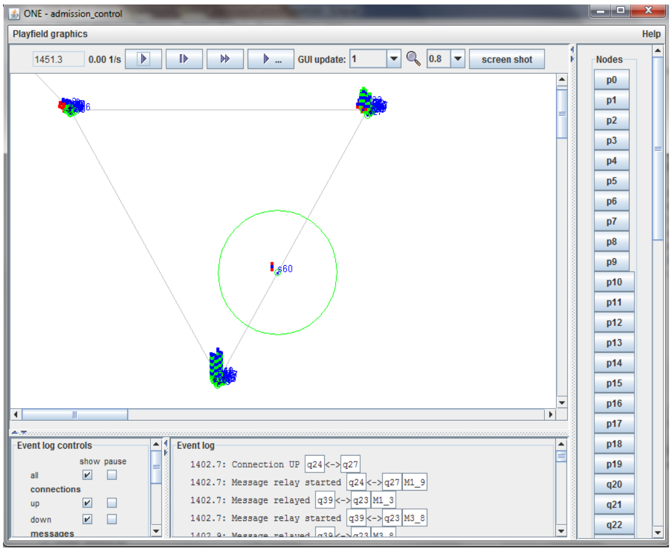

Fig. 3. Scenarios configurations in ONE simulator

We have used Opportunistic Networking Environment (ONE) simulator [15] which is a DTN simulator platform for testing the routing and applications protocols. FS model is configured in ONE simulator and the cluster movement model is used for the model scenario as shown in Fig. 3 which illustrates the simulator GUI. The scenario assumed three locations, i.e. A, B and C, which appears in Fig.3 as the group of dotes. The transportation vehicle, which appears in Fig.3 as the circle in route between the clusters locations, is moving between them and collecting data from ground user nodes to send them to other nodes in another area. Every time the vehicle passes by cluster nodes, the decisions of which nodes are selected or rejected will be updated and used by the next vehicle to enable it to take acceptance decision and so on until all vehicles pass throughout the set simulation time.

Simulation time is in seconds and it is assumed that a full day of 24 hrs is equivalent to 5000 seconds simulation time. 24 hrs is chosen because the transportation means normally have daily schedules of their journeys routes which will be repeated every day. All users and vehicles have equal data rate and ground users create and try to send messages only when the vehicle contact is their LOS range. It is also assumed that all transportation means are in continuous movements in their routes for the whole day and they only stop at the end of the day.

Table 1. Simulator ONE settings

Transportation Mean	Bus	Aircraft	Ferry
Max Real Speed (Km/hr)	120	900	60 (32.4 knot)
Equivalent Simulation speed (m/s)	33.3	250	16.6
Real Wait Time (min)	5	30	10
Equivalent Simulation Wait Time (s)	17.35	104.1	34.7
Range Km	5	100	5

All scenarios are run for 5000 seconds which represent 24 hrs in the scenario time. The scenarios are set for 20 users distributed randomly per location and 2 vehicles for each transportation type. Table 1 shows the setting of the various transportations means. Different vehicle speeds are used where the aircraft is the highest of 900 km/hr and the ferry is the lowest with 60 km/hr. Transportations vehicles are set to stop and wait at each cluster, i.e. the duration time they are in LOS with the ground users. Aircrafts have longer wait time because they fly at high altitude of around 11000 m; therefore, they will have longer contact time and larger coverage range. Each real value will have an equivalent simulator value based on the assumption that 24 hr is equal to 5000 seconds. The performance metric is the delivery probability, user's satisfactions, average processing delay and the fairness. It will be used to evaluate the performance of FS model for various scenarios.

4.3 Simulation Results

The simulator is run for various simulation times. From 1000 to 5000 seconds and the results are obtained as follows:

4.3.1 Transportation Means Comparison

Fig. 4 shows the obtained delivery probability results for a scenario of 2 vehicles and 20 users per location when FS model is enabled. The delivery probability is the overall delivered messages out of the generated one regardless of the users. It shows that aircrafts have higher delivery probability between 85-95 % compared with buses and ferries whose values range between 20 to 30%. Overall, aircrafts are having up to 62 % improvements over buses and ferries. This is due to that all users are within the aircraft range; therefore, all have better opportunities to send their data. On the other hand, buses and ferries have smaller range because they are at ground level; therefore, not all the users are in their range. Furthermore, the wait time i.e. contact LOS, is larger with the aircrafts because they are at high altitude and therefore can stay longer time over the ground users to enable them to send more data, while the buses and ferries are staying shorter time and they become out of range. This shows the potential of using aircrafts in this special situation and its usefulness at remote locations.

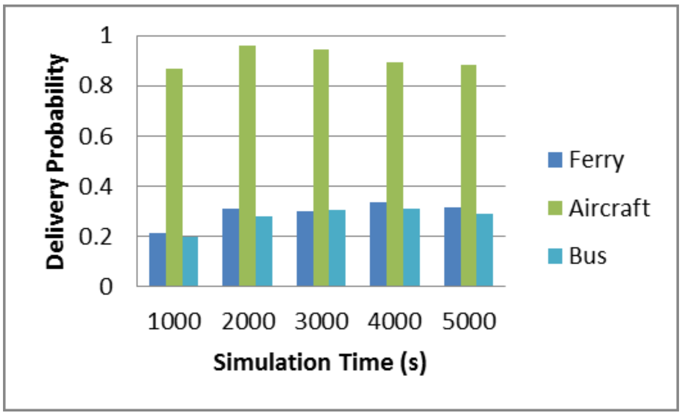

Fig. 4. Delivery probabilty of various transportation means

4.3.2 FS Model Comparison

The previous section compared the results of aircrafts with ferries and buses when FS model is implemented. However, in this section we will compare the results between the three transportation means with and without FS model.

4.3.2.1 Contact-to-Contact Results

The first set of results is between the ground users and the approaching contacts. The results are obtained for users' satisfaction within contacts. It does not consider the end-to-end routing of data or delivering the data to its final destination. All it considers is the transfer of the user's messages to the passing contact. Users satisfactions is a measure of how many users successfully delivered all their generated messages out of the overall available users. Fig. 5 shows user satisfaction improvements in applying FS model compared with the lack of it for the three transportation means which varies between 2- 18%. Transportation type has no major impact on the model results because the outcome will mainly depend on how long the contact is available for the ground users. As mentioned earlier, messages are generated during contact time only. Therefore, buses have the best user satisfaction because they have the shortest wait time and therefore have less number of generated messages per user, which increases the user's chances of acceptance. Aircrafts have the second best user satisfaction level because they have the highest speed which means more wait time occasions for the ground users.

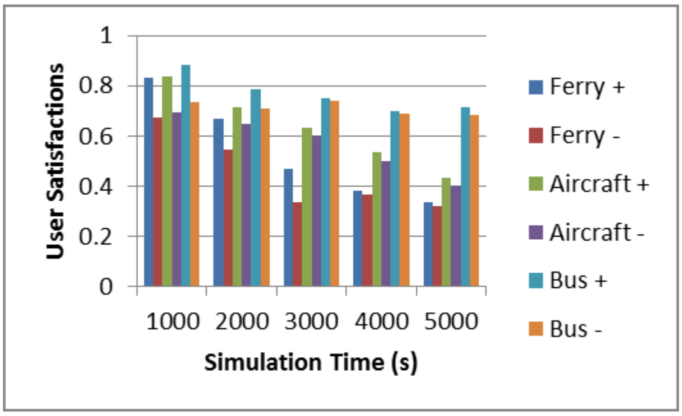

Fig. 5. Contact-to-contact users satisfactions

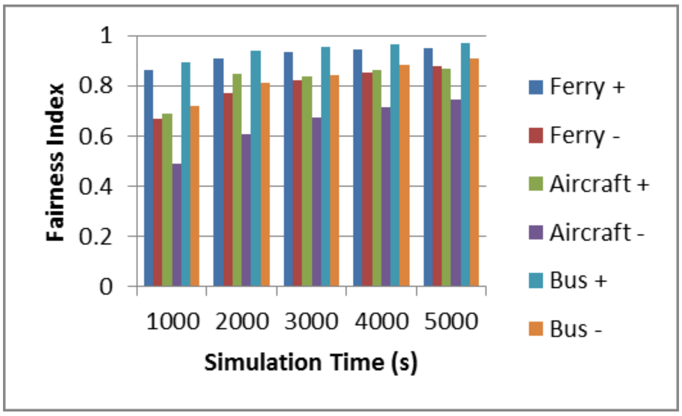

Fig. 6. Contact-to-contact fairness index

Fig. 6 shows Jains fairness index results for allocation of the available resources. The results show improvements in the fairness between 5-20 % compared with the lacking of FS model. Buses and ferries have better fairness results because their users generated fewer messages during the same simulation time compared with aircrafts. However, FS model provides fairness improvements regardless of the transportation means used.

4.3.2.2 End-to-End Results

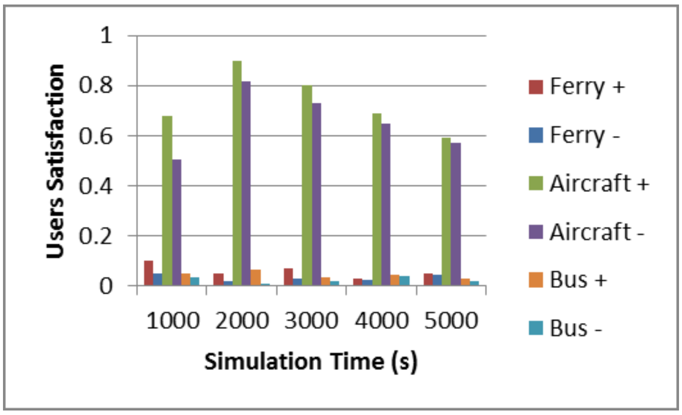

Fig. 7. End-to-end users satisfactions

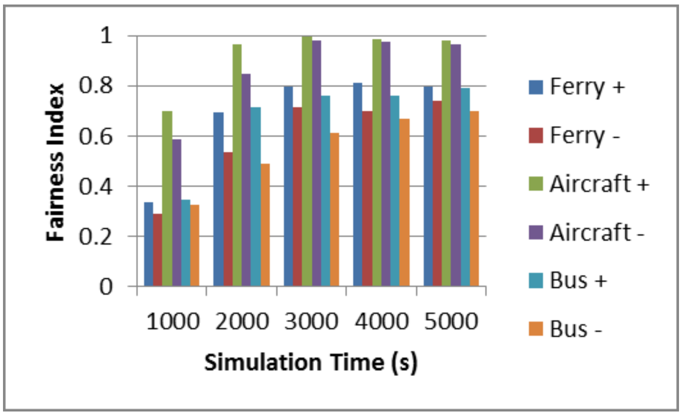

Fig. 8. End-to-end fairness index

The second set of results applies for the end-to-end concept which utilizes the routing to deliver messages to their final destinations. MaxProp [13] DTN routing is used to route the messages for the three transportation means. The obtained results in contact-to-contact section are relatively close to each other between the three transportation means. However, it is not the case with the end-to-end results which indicates a very high priority for using aircrafts compared with buses and ferries.

Fig. 7 shows the user's satisfaction of aircrafts reaching up to 90 % and improvement varies between 5-18 % compared with the lack of FS model. The improvements are higher at the early runs of simulation. On the other hand, buses and ferries have very limited user satisfaction, less than 10 %. These results come to an agreement with the results of the overall delivery probability shown in Fig. 4, but the difference is that Fig. 7 results are per users who delivered all their messages, while

Fig. 4 is per overall generated messages regardless of who generated them. Aircrafts have provided higher users satisfactions due to their large coverage which can reach all users, while this is not always the case with buses and ferries. Furthermore, applying FS model has improved this satisfaction by providing better allocations of resources for more users.

Fig. 8 shows the improvments in end-to-end fairness index for the various transportation means and FS model has improved the fairness for the end-to-end also by 5-18 % compared with the lack of it.

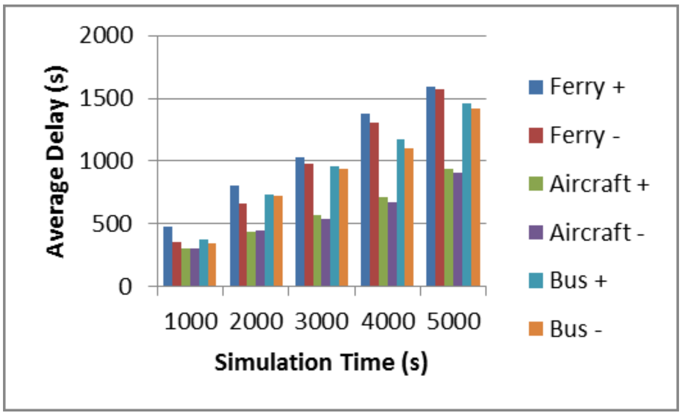

Fig. 9. End-to-end average processing delay

On the other hand, there is a small drawback for the model represented in the slight increase in the processing average delay which is the average time in seconds between message creation and delivery. Applying FS model will sometimes cause the delay to increase between 0 second in the best cases to 100 second in the worst case. Aircrafts have the smallest amount of delay due to their high speed and therefore will mean quicker delivery time and hence less processing time. It is not a very critical increase, and DTN is delay tolerant and hence the extra delay is considered insignificant.

5 Conclusions and Future Work

Various transportation means have been proposed for carrying DTN data due to the scarce and limited resources of its environments. Aircrafts in commercial routes are compared with buses and ferries. The simulation results showed higher delivery probability for using aircrafts due to their large coverage range. Furthermore, FS model is proposed to allocate the resources among users in DTN conditions. The model showed improvements in user's satisfactions and better fairness compared with the same scenario lacking the model. However, FS model will sometimes cause a slight increase in the average processing delay which is not very significant in DTN situation.

As part of our future work, we will implement the aircraft concept together with the FS model in various and more complicated scenarios for a larger number of vehicles and users to analyze its performance.

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