

AAaS: Area Approaching and Spray-and-Wait Routing Scheme for DTN in Android

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Abstract—Most of the existing DTN routing algorithms have been studied in the simulation environment. They are not sufficiently used to the historical location and historical neighbor's information. So AAaS(Area Approaching and Spray-and-Wait) routing algorithm is proposed, which considers the practicability of the algorithm and the rules of the node's movement and the law of the meeting. AAaS divides the map into areas by the administrative area, public places and areas the DTN nodes clustered with historical GPS position. Each area maintenance the frequency vectors of different time scales and the frequency vectors of the historical encountered neighbor. AAaS forwards the bundles by these frequency vectors in the bundle lifetime, select the appropriate next hop, more efficient use of the limited bandwidth of encountered nodes in DTN network. Finally, the prototype of AAaS routing algorithm is implemented in Android based on Bytewalla. The experimental results prove that, even in the case of the buffer is not limited, the AAaS is more efficient than Epidemic in the use of the limited bandwidth between encountered nodes.

Index Terms—Delay tolerant networks, Routing, GPS Position.

I. INTRODUCTION

Delay-, Disruption-, and Disconnection Tolerant Networks (DTN) [1] is a kind of network which is with changeful topology, lack of connectivity from source to destination, using save-carry-forward strategy to transform information. The bandwidth between encountered nodes is limited. So the key problem is that when to transform data to a neighbor node and to save or not to save the copies of data. The existing solutions are often implemented on the simulator. Such as the solution which chooses to use a lot of copies, and the solution which will make the decision based on the node's historical experience such as the probability to meet another node, the geographical positions, the speed of the node and the social behaviors, as well as the mixed solution which will use both the advantages of the two above. The paper puts forward the AAaS solution to improve the routing in DTN according to the existing solutions and the bundle's life changes. The AAaS solution's most important contribution is the two points below. First, node will choose different next-hops for different lifetime's bundles using the mixed routing solution in order to improve the usage of encountered bandwidth. Second, this paper implement it in Android based on Bytewalla.

In the DTN network, nodes transform data when they meet. The utilization of bandwidth when the nodes meet affects

the efficiency of the total network. The movement of the node has some regular patters often. Then transform bundles according to these regular patters which are analyzed via nodes's movement and meet in different time slices using the node's GPS information, historical neighbors information and the region information, and avoid transforming data to these nodes who can't reach the destination for example to transform the bundle who's lifetime is several minutes to the neighbor who will need several hours to reach the destination. In the first stage, AAaS solution make the data close to the destination node. The node determines whether the bundle can be transmitted to the neighbor node and whether to save the bundle's copies by comparing its own and the neighbor's probabilities to reach the destination. In the second stage, use the Spray-and-Wait method to delivery data to the destination node as soon as possible. In addition, the transmission of data packets between nodes must be transmitted in accordance with the priority order.

Another problem is the lack of algorithm in the actual system. Most of the existing routing algorithms only be realized on the simulation environment without the experience of running on the real system. To realize and run a routing algorithm will meets problems such as how to obtain and analyze the useful information, cache management and the effects of devices's performance. At present, some of the DTN program's examples such as DTN2 [2] and Bytewalla [3] are followed by the DTN [4] implementation and integrated with the epidemic routing algorithm. DTN2 is based on the Linux system and using C language to achieve the program. Bytewalla is an Android application using Java. At present, Android devices are already very popular so that we can get the GPS information, the region information conveniently and store rich resources. So, the AAaS was implemented based on Bytewalla.

The content of this paper is organized as follows. The second part compares the existing routing algorithms with the AAaS algorithm. The third part introduces the AAaS routing algorithm in detail. The fourth part describes the experiment's process. The fifth part is the conclusion of this paper.

II. RELATED WORK

Since the DTN network has been proposed, the existing routing algorithms usually take the following methods to

improve the delivery rate of data packets, reduce the delay and control expenses.

A. Using multi copies of data packets

Using multi copies of data packets get the highest rate of delivery in ideal circumstances such Epidemic [5] algorithm which transmits data packets with flooding method. Using multi copies of data packets can obtain the highest delivery rate and the lowest delay when the bandwidth, buffer, and computing resources are not limited. In the practical system, the resources are very limited, so the AAaS algorithm uses the Spray-and-Wait [6] algorithm to control the number of copies. Spray-and-Wait [6] algorithm sets the upper limit of the amount of copies. And its routing process is divided into two stages: Spray and Wait. Execute the Spray phase when the bundle's amount is more than one: copy half amount of the bundles to the neighbor and set the amount of its own's bundles to half amount. In the Wait phase, the bundle is carried to the destination node at last. The AAaS uses Spray-and-Wait as a routing method in the later stage, which can significantly improve the delivery ratio of bundle to the target node.

B. Using historical encountered information

The use of historical meet information with neighbor nodes is also an effective information to estimate the future probability of encounter. The PROPHET [7] algorithm uses the historical neighbor information to calculate and maintain the probability data of meet with neighbor, and the probability data can be transmitted through the neighbors. Sending packets to the next hop with higher probability of encountering. This method is feasible in real system, and the simulation results are also good. Because of the bundle's lifetimes are different, so evaluating the probability of meet with neighbor should consider the time factor. The AAaS maintains the probability of encounter information in different time periods and using different time scales to avoid the data packets been sent to the neighbor which can't send the data in the effective time.

C. Using GPS position and related information

Using node's location information and speed information to predict the next movement and the location of nodes, such as GeoDTN [8], MOVE [9], MAPD [10]. Position information and speed information can accurately predict the future of a node in a short period of time. If the network nodes are stationary, the current position can be predicted in the future. If the node is moving at a constant speed, the velocity can be predicted in the future as well. But in the DTN scene, the node's movement is complex, and short time prediction is often the local optimal solution rather than the global optimal solution. In order to solve the problem of bundle's differences in survival periods, AAaS divides the map into regions, and analyze the moving regular patterns of nodes in different time scales according to the historical GPS position information. Then Use these regulars to choose the right carrier as the next hop.

D. Using hybrid information

Many routing methods combined several algorithms, such as GeoSpray [11], AaR [12]. GeoSpray [11] combined the Spray-and-Wait method with analyzing the geographical location information, so that the Spray process is more effective. AaR [12] algorithm is divided into two parts: Approaching and Roam. In the Approaching stage, search the suitable node according to the location information and velocity information. In the Roam stage, use multi copy method to improve the delivery ratio. AaR has a great inspiration to the AAaS algorithm of this paper, AAaS is also divided into two stages: Approaching Area and Spray-and-Wait. The improvement of AAaS lies in the following points: a) According to the administrative area, public places, node clustering data and hierarchical, forming a tree of regional division structure. Each region reflects the social attributes of the carriers, and the regional level reflects the node's ability of movement. The moving law is expressed by the frequency of the various regions. This can reflect the movement of the nodes in different regions at a low price. b) The source node only needs to know the location of the destination node and need not to know the accurate GPS information. c) Analyzing the data of the motion law and the data of the historical neighbors makes the algorithm compatible for the bundles with different survival periods.

III. DESIGN

A. architecture

AAaS algorithm (in Figure 1) is mainly composed of three parts: routing algorithm module, area management module and neighbor management module. The routing algorithm module decides whether to transmit the bundle and delete the local copy if it encounters a neighbor node. The region management module detects the information of the current region and analyze the regular patterns of the nodes's motion between different regions. The neighbor management module analyzes the regular pattern when encountering with historical neighbors and analyzes the regular pattern of neighbors.

B. routing

AAaS routing process is divided into two phases: the Area Approaching phase and the Spray-and-Wait phase. When the node is not in the area where the destination node is in (called the destination area), choose the node which can arrive in the destination area as the next hop in the bundle's lifetime and decide whether to keep the copies considering the regular pattern of the history of the neighbors. When a node is in the destination area, the Spray-and-Wait policy is used to deliver the data to the destination.

1) *area approaching phase*: In this stage, transmit the data to the node who can arrive in the destination area in bundle's survival period. Consider from the following two aspects: whether to transmit bundles to neighbor, whether to store the copies. Nodes exchange the regular motion pattern information of its own with each other when they meet. According to the bundle's survival period and the moving

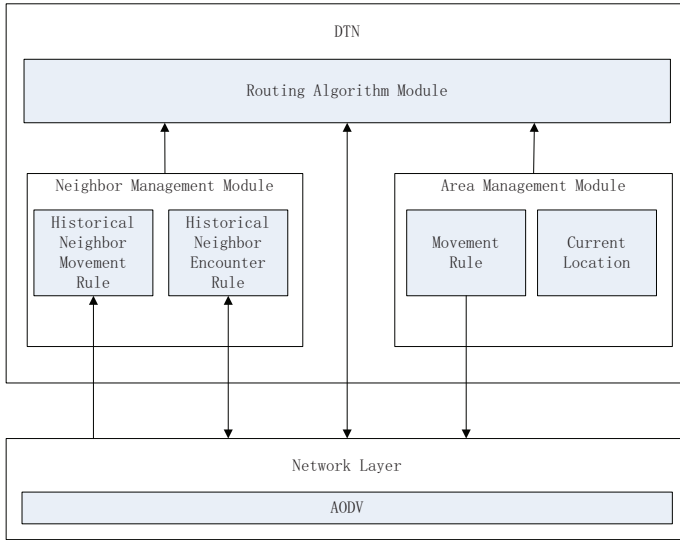


Fig. 1: the architecture.

law of both sides to calculate the opportunity value of the two sides to reach the destination area (the paper will explain the calculation and compare process later). If the opportunity value is greater than the threshold, regard as reachable. All regions forms a tree structure, compare the current node and the neighbor which is closer to the destination node (called the destination area). When a neighbor is closer to the destination, the packet is forwarded. If there is a historical neighbor node whose opportunity to the region is higher than the present node, keep the copies. When nodes meet, save or update the neighbor node's motion pattern data. According to the size of the cache space, delete the motion pattern data of the nodes rarely meet. After forwarding the bundle to the neighbor, calculate the chance to reach the target area of the nodes those can meet in the future via the relative information of historical meeting neighbors.

2) *spray-and-wait phase*: When a node is in the target area, use the Spray-and-Wait [6] way to improve the probability of data been delivered to the destination. Once the node is out of the target area, it does not send data until entered the target area again or the packet's time is out. The Spray-and-Wait is a kind of flooding forwards method with limited number of copies. Suppose the number of copies of the bundle is L . When L is more than 1, the amount of copies's $L/2$ will be transmitted to the neighbor, and the local bundle copies's amount is set to $L/2$; when $L=1$, the node carries the data packets until encounter with the destination node.

C. area management module

The nodes's motion patterns are important data to calculate the opportunity of the neighbor to reach the target area in the effective time. Analyzing the motion pattern needs to consider the different levels of bundle, the accuracy, the accuracy of the cache, and the computational cost. According to the administrative area, public places, the degree of aggregation of nodes, cut the map into different regions, then classify the regions into serval levels as a tree structure, such as: China,

Time Range	[0:00, 1:00)	[1:00, 2:00)	...	[22:00, 23:00)	[23:00, 24:00)
Frequency	f0	f1	...	f22	f23

Time Range	Sunday	Monday	...	Friday	Saturday
Frequency	f0	f1	...	f5	f6

Time Range	January	February	...	November	December
Frequency	f0	f1	...	f10	f11

Fig. 2: the time scale frequency vectors.

Beijing, Haidian District, Beijing Institute of Technology. Cut the time into different areas by different time interval: by the hour, by week, by month. The nodes maintain the frequency data in each region in different time periods.

The frequency vector of the three time scales is maintained in the AAaS: the hour, the week, the month (as shown in Figure 2). If a defined action occurs at a time period, the frequency vector of the time adds 1. And at the same time, the corresponding time period's frequency vector can add 1 at most. Time frequency vector will decay with time.

The frequency vector of nodes on different regions in different time scales can reflect the node's motion pattern. According to the characteristics of the administrative area, public places and node aggregation, divide the map into different sub regions, then aggregate the regions to form a region tree. The root node of the tree is the whole map.

A node will maintain its frequency vectors data in different regions those can be arrived, and maintain the frequency vectors data of different time scales according to the size and the level of the regions and the node's activity. For example, the top regions maintain all time scales's frequency vectors, including the month scale, the week scale, and the hour scale; the most bottom region is only required to maintain the frequency vectors of the hour time scale. The configuration file specifies that which time scale's frequency vector should be maintained considering the level of the regions.

In the use of the motion pattern data, generate the effective time vectors at different time scales based on the bundle's survival period. When a bundle is in the survival period, the time vector is 1, otherwise it is 0. Effective time vector multiplied by the frequency vector can obtain the motion pattern data in the survival period of the bundle.

D. neighbor management module

The node maintains the frequency vectors in all the different time scales for each historical neighbor. The related frequency vectors add 1 when the node meets a neighbor. Every time after a period of time, the frequency vector attenuates according to a factor number. When the nodes meet each other, exchange each other's motion pattern data and keep it. If there is already the data, update it.

To store the rule data of encountering with the historical neighbor and the rules of the neighbor's movement data has cache limit. Assuming that the amount of neighbor's motion pattern data is M, and the upper limit amount of it is N, usually N is 3 to 2 times of M. Both the data of encountering with the historical neighbor and neighbor's motion pattern are sorted by the values of the frequency vectors. When the amount of data in cache reaches the maximum, replace the old data with the latest.

E. Chance value compute

The chance value as follows is divided into two types.

1) *current neighbor's chance value*: The current neighbor's chance value evaluate the probability of that neighbor reach the destination area. The lifetime of bundle is split into vectors in different level by the above mentioned method. These vectors are valid time vectors which is composed by 0 or 1. A component of time vector mean this time segment is valid if it's value is 1. We denote i as a time level, x as the weight of current time level, a as valid time vector, b as the terminal area's frequency vector. Then the chance value of current neighbor reaching a area chance value C is calculated as Equation1.

$$C = \sum (a_i \times b_i) \quad (1)$$

2) *History neighbor's chance value*: The probability of encountering history neighbor and history neighbor area moving regular pattern will be all considered during AAaS compute the history neighbor's chance value. We denote i as the current time level, S as the threshold, l as the encounter frequency vector, a as the valid time vector, b as the frequency vector of the historical neighbor's terminal area. So the history neighbor's chance value of a area C is calculated as Equation2.

$$C = \sum \left(\frac{\text{MIN}(S_i, a_i \times l_i)}{S_i} \times a_i \times b_i \right) \quad (2)$$

IV. EXPERIMENT

In order to evaluate the effect of the route algorithm in the actual system, this paper chooses the contrast experiment with epidemic. Epidemic is a traditional DTN routing algorithm with Bytewalla. The design of experiment is as follows:

A. Experimental environment

Experimental equipment is the Intel mobile phone with Android system. In order to facilitate the experiment in real system, we add a simulator to control the connectivity of nodes by distance in network layer. As shown in Figure 3, the simulator capture the network packet and get the distance from each other through the neighbor distance table. If the distance is greater than the threshold in the configuration file, then the packet is discarded. If neighbor where the packet come from is not in the neighbor distance table, compute the distance and update neighbor distance table with neighbor's GPS location from the GPS interface. The neighbor distance table maintains the distance between this node and historical

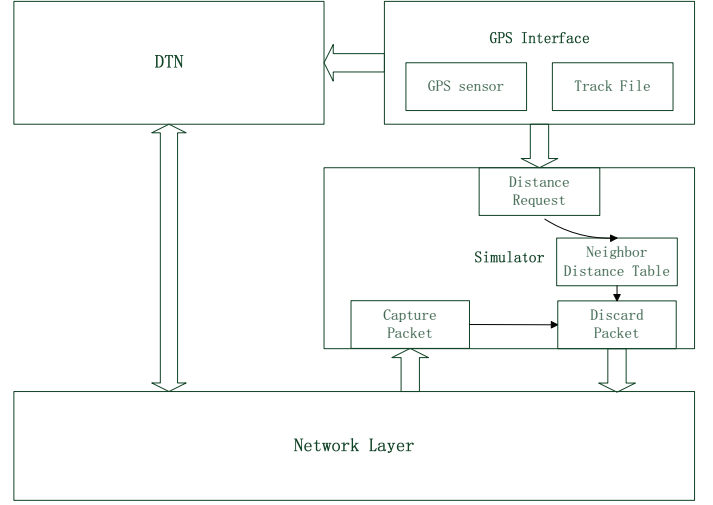


Fig. 3: the network layer simulator.

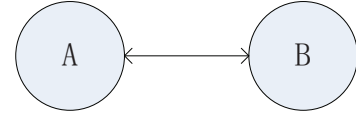


Fig. 4: the environment of experiment 1.

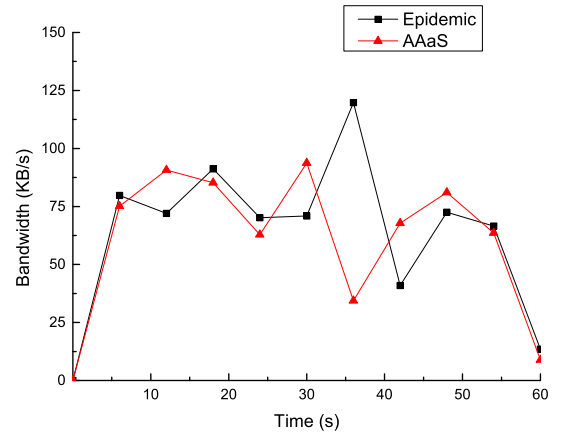


Fig. 5: the Data flow between two nodes.

neighbor, and recompute the distance regularly. The data source in the GPS interface contains the GPS sensor and the track file. When network simulator is running, GPS position is provided from the track file, so that the GPS information of all the nodes in the network can be obtained.

B. Experiment scheme

1) *Transmission speed test*: when the two DTN nodes meet, test the speed of epidemic and AAaS routing algorithm by sending bundles. This is the basic performance test of the protocol. Topological structure as shown in Figure 4.

This experiment tests the speed of the AAaS and epidemic routing algorithm to transmit data packets in a limited time between nodes. Through the Figure 5 and Figure 6, the

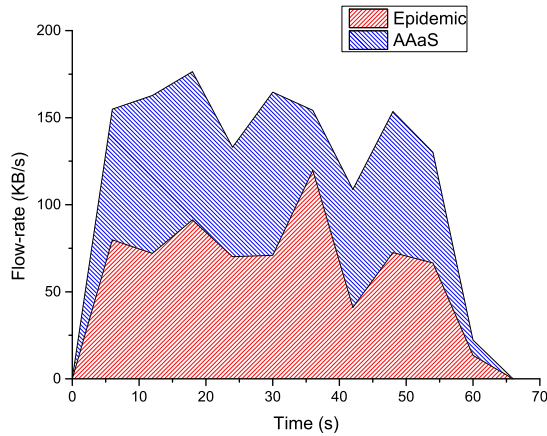


Fig. 6: the Bandwidth between two nodes.

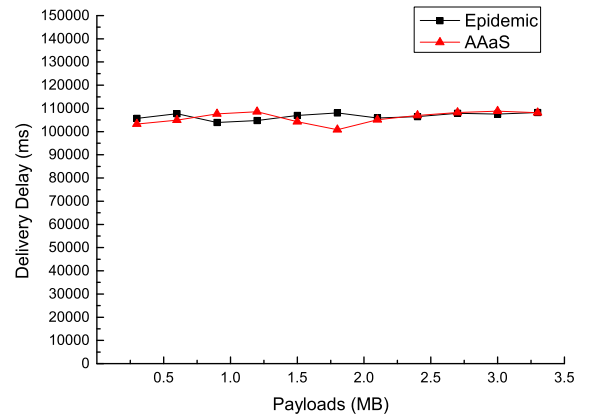


Fig. 8: the delivery delay of experiment 2.

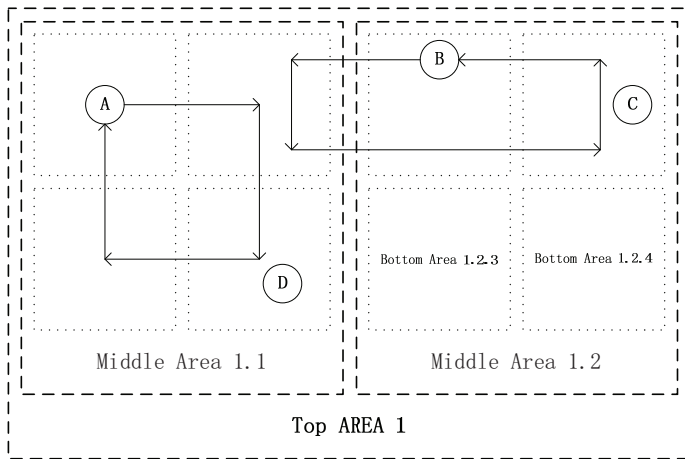


Fig. 7: the environment of experiment 2 and 3.

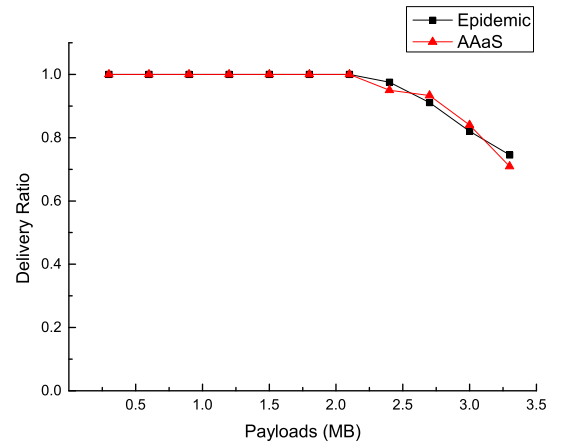


Fig. 9: the delivery rate of experiment 2.

transmission speed of AAaS and epidemic in the limited time of encountered node is close to each other. The total amount of transmission data is close too. Therefore, it is concluded that the bandwidth between encountered nodes of epidemic is almost the same as AAaS's. How to utilize the limited bandwidth resources in the time of the meeting will have a direct impact on the effectiveness of the routing algorithm.

2) *The source node sends bundles to one destination node:* In the scene as shown in Figure 7, the node A is moving around in the four sub area of area 1.1, while node B is moving around in area 1.1.2, area 1.2.1 and area 1.2.2. Node C is static in the area 1.2.2. The period of Node A is T_a , and period of node B is T_b . We assume that A has know the node C's current area information, bundle's lifetime range from $\text{MAX}(T_a, T_b)$ to $2\text{MAX}(T_a, T_b)$. The delivery rate and delivery delay will be test when node A is required to transmit bundles to node C using routing algorithm of epidemic and AAaS, respectively.

In this experiment, the node A only sends bundles to C. Transmission data union is bundle in DTN. We set a bundle payload size of 300K. When node A sends a different number of bundle to C, the delivery rate and delay of these bundle are

recorded. Each number of experiment repeat 5 times, taking the average as the final data.

In the Figure 8 and Figure 9, the average delay of the bundle payload that can be successfully delivered of epidemic is the same as that of AAaS. The delivery rate of the two is very similar, almost in the 2.4M of the data (8 bundle) began to appear the decline in delivery rate. This also shows that during the encountered time routing algorithm can only guarantee the transmission of the 7 bundle, once the total data volume reached 2.4M of the payloads to be forwarded to the neighbor, it can not guarantee full delivery, no matter it is epidemic and AAaS. With the increase of the bundle payloads need to transmitted, the delivery rate continues to fall. When the source node is sent to one destination node only, the AAaS and epidemic performance effects are the same.

3) *The source node transmits bundles to two destination nodes:* A static node D is added in the region 1.1.4 in the above scenario. Assumption that node A knows the current region information of C. We test the delivery rate and delivery delay of epidemic and AAaS respectively, when A sends bundles to C and carries the bundles sent by other node to

V. CONCLUSION

In this paper, we propose and implement a new routing algorithm: AAaS. AAaS analysis of the node's motion pattern and the rules of encountering with neighbors, combining with the map information to analyze and maintenance the regular patterns data in different time scales. Make the routing decision considering these rules and the data packet's lifetime, so as to use the bandwidth resources efficiently in DTN network. In addition, the AAaS is implemented on the basis of Bytewalla in real system. And the AAaS algorithm is better than the traditional Bytewalla algorithm in the case of the resource of nodes is limited. At the same time, the Epidemic routing algorithm's delivery rate is the highest and time delay is the least in the simulation experiment when the cache's storage space is not limited. But in real system during to the time and bandwidth limits, Epidemic routing algorithm can't achieve the optimal effect. Fortunately, the AAaS algorithm can be more efficiently when using the node's motion pattern data and the bandwidth resource of the network in actual scenes.

In the future work, a set of algorithms for dividing the most underlying regions in the actual is needed. Because the node's frequent gathering places at the most bottom area need to be identified. This not only should combine with the facilities and location information in the map, but also need to analyze the information by a machine learning method. In addition, optimizing the management of the motion pattern data stored in the node will be good as well. And the AAaS routing algorithm can be also implemented in the simulator environment, and compares with other routing algorithms.

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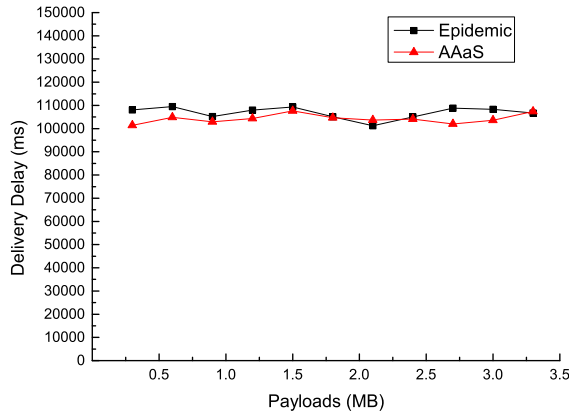


Fig. 10: the delivery delay of experiment 3.

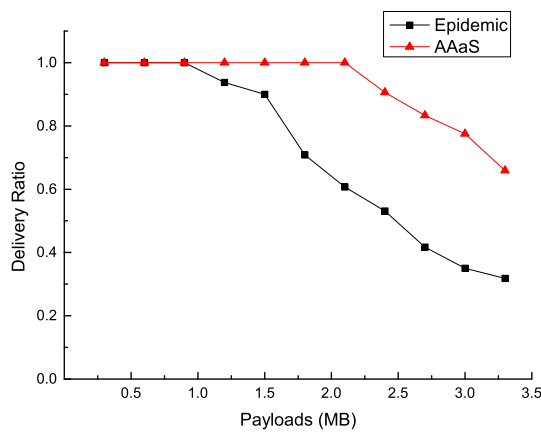


Fig. 11: the delivery rate of experiment 3.

D.

The source node A sends a certain number of bundles to the C and carries the same number of bundles which were sent to the D, and we record the delivery rate and the delivery delay of bundles which were sent to C. Experiment with different bundle numbers were repeated for 5 times, and the mean value was taken. As shown in the Figure 10 and Figure 11, in the limited time period, epidemic begin to loss bundles when the total bundle payload volume reached 1.2M. The AAaS has not loss any bundle until the total bundle payloads reached 2.4 M. The AAaS performance is close to the Experiment2: Source node sends data to a destination node. This shows that AAaS is more reasonable than epidemic in choosing which bundle to send during encountered time. In the limited time of encounter, Epidemic algorithm sending all bundles to the neighbors without filtering wastes a lot of bandwidth and decreases the delivery rate. Additional, the delay of the bundle which is successfully sent out in the limited meet time is similar. So it's obvious that the efficiency of the AAaS routing algorithm based on Bytewalla is much the same as epidemic.

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