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Routing Algorithm for DTN Based on Congestion Control

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Abstract

Different from Internet networks, DTN has its own unique characteristics, like intermittent connectivity, low data transfer rate, high latency and limited storage and node resources. Routing technology is always the key to DTN research. In this paper, a routing protocol that is PNCMOP was proposed. It makes some improvement of Epidemic routing protocol, and also to decrease the end-to-end average delay and improve delivery ratio, especially with congestion control. Simulation results show that PNCMOP achieved a good performance.

Keywords: *DTN, congestion control, routing protocol*

1. Introduction

Delay tolerant Network (DTN) is a new Network [1] [2], these networks tend to have intermittent connectivity, low data transfer rate, high latency, limited storage and node resources, and the frequent change of network topology structure etc. Common DTN networks have:

A. Remote Areas of Network Transmission

Network infrastructure in developing countries or remote areas are usually not perfect and cannot access the Internet, use the opportunity network technology to provide non-real-time, but the price is cheap, relatively available network services [3] [4]. DakNet [5] developed at MIT, deployed in the remote areas of India to provide Internet services to the opportunity to network. DakNet include: and Kiosk devices deployed in the village, MAP (mobile access points) equipment and Internet deployment in the town AP devices on public transport vehicles, interface communication between these devices using Wi-Fi. The villagers through PDA and Kiosk devices to exchange data; between the rural and urban bus after the Kiosk near the equipment, MAP and Kiosk device to exchange data bus to town, MAP connected to the Internet to upload or download data via the AP. A similar system also provide information services to the nomads of northern Finland, the Saami Network Connectivity [6] and Berkeley and Intel Research Institute are jointly developed Tier project [7].

B. Military Ad-Hoc Networks [2]

Such networks may be deployed in a hostile environment, due to node mobility, unpredictable environmental factors or deliberate human interference may cause network fragmentation. In addition, when a high-priority business, low-priority business needs to compete for bandwidth and the high-priority business, which will make the message is forwarded to experience larger queuing delay. Meanwhile, for the reliable and safety considerations, such systems require stringent protection measures underlying infrastructure.

C. Vehicle Network

Equipped with short-range wireless interface, the increase in the vehicle, a vehicle traveling on the road due to the speed, the density unevenness is formed a vehicle opportunity networks. Such networks have a huge potential for security applications in Traffic Accident,

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traffic detection, traffic congestion forecast addition, the opportunities for communication vehicles and roadside access points to provide Internet access and commercial applications.

D. Wildlife Tracking

In a wide range of wildlife tracking applications, DTN more advantages than traditional static sensor network mesh structure. Zebra Net [8] is a design by Princeton University, used to track the African savannah zebra network system. SWIM (Shared Wireless Infostation Model) [9] is a monitoring ocean whale underwater opportunity to network. The special Tag embedded in the whale's periodic collection of monitoring data.

E. Terrestrial Mobile Networks [2]

In many cases, due to the conflict in the mobility of the node or a radio frequency (RF), these networks may become unthinkable separated. Difficult to form an end-to-end (E2E) path and the fragmentation of the network can predict. For example, a commuter bus can be used as a tool for message store and forward, because it has only a limited number of RF communication ability is limited communication range. Kind of bus travel from one place to another place, it can be in the vicinity of the client (clients) and it will be destined for the location of the remote machine (remote clients) message exchange service.

2. Architecture OF DTN

Figure 1, Internet architecture including the application layer, network layer, transport layer, data link layer and physical layer. DTN architecture, in order to solve the DTN in the presence of high delay, intermittent connection, low data transmission rate, the storage and the node resource constrained, on the basis of the Internet architecture and between the application layer and the transport layer the new protocol layer insert an end-to-end data-oriented messages-bundled layer, also known a the bundle layer of (Bundle layer) [10]. The Bundle layer to form a network covering the use of store-and-forward mechanism to overcome network the interrupt problems [11]. The Bundle layer protocol with a specific area of the underlying agreement with each other with different protocol stack, providing a similar service to the gateway connected to different LAN boundary so that you can communicate between different types of networks. The Bundle layer [12] Key features include: data transmission, in accordance with the "storage-carry-Forward" intermittent connection between processing nodes, can take advantage of predictable or random connections.

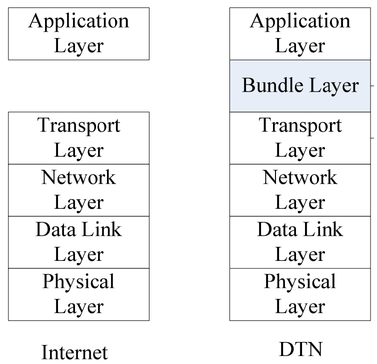

Figure 1. Internet and DTN architecture comparison

3. Routing IN DTN

Routing is a process that packets are transmitted from the source node to the destination node. Routing protocols generally include: the establishment of the network topology, the maintenance of these three parts of the network topology and routing algorithm.

A. Routing Features in DTN

In the DTN, due to the limited radio frequency coverage and distribution of a wide range of mobile nodes, limited energy resources, high interference or channel impairments lacks the necessary connectivity between nodes, network intermittent, DTN routing design need to be considered the following problems:

(1) routing policy, DTN covers a variety of network link connectivity is relatively poor, so it is necessary according to the different scenarios, using different routing strategies;
(2) the capacity of the connection, the capacity size close relationship to the amount of data can be exchanged between the two nodes;
(3) the node cache space and its management problems, in order to deal with the longer network interruption nodes need to buffer packets, intermediate nodes need enough buffer space to store messages waiting to be sent;
(4) the processing capability, DTN intended to be connected not through the traditional network protocol communication device, these devices are not only small in size and usually limited processing capability;
(5) the energy problem, DTN nodes may sometimes be due to the small size, limited carry energy, is the lack of infrastructure and an unfriendly environment, resulting nodes cannot be timely charge supplementary energy node of data packet transmission and storage, a series of operations and everywhere requires energy, thus the complexity of the algorithm is small, the fewer number of bytes sent routing strategy can be effective in reducing energy consumption.

B. Routing Goal in DTN

DTN has its unique characteristics, and routing goal is different from the traditional networks. The traditional routing is the shortest path or the minimum number of hops. DTN routing is more concerned about the successful delivery ratio of packets. That is the routing goal in DTN is to maximize the packet successfully passed to the destination node.

C. Epidemic Routing Algorithm

Epidemic routing algorithm, which is essentially a flooding routing protocol, it is the easiest routing algorithm based on replication strategy.

This routing mechanism, whenever two nodes to reach each other can be the area of communication, the two nodes will swap each other messages, copy the data packets to each other. When a new node becomes reachable due to mobility or other reasons, and then copies the extra backup. Each network node carrying their messages forwarded to all nodes encounter.

If sufficient network cache and network resources such as bandwidth, the spread of the routing protocols to guarantee minimum packet delivery delay, and to find the shortest path to reach the destination node.

4. PNCMOP

Priority based Node Cache Management Optimal Path algorithm (PNCMOP) is designed based on the Epidemic routing algorithm. The Epidemic algorithm has no packet arrival notification, therefore, when a packet arrives at the destination node, the packet remaining copies will continue to "contact - infection" exist and diffuse between the nodes, it will cause congestion for storing restricted nodes.

Three Stages of PNCMOP:

(1) copy forwarding stage; based on copy Bundle distributed strategy;
(2) congestion control stage; priority-based node cache management;
(3) optimal path computation stage, based on the measure of the weighted average of the routing mechanism. Next, this three stage workflow will be introduced:

A. Copy Forwarding Stage

In this paper, the easiest source node sends replica way made improved. In order to establish route, source node broadcast few copies of a route message in the network until any copy message reach destination node. Traditional blooding algorithms cause high overhead for the network, so the copy forwarding stage must be improved.

Definition 1: AV_Delay_i is the average connection delay for node

$$AV\_Delay_i = t / con_i \tag{1}$$

Where: t is unit time; con_i is the total number of neighbors who connect with node i in t.

Definition 2: $delay_0$ is a constant connection delay, system can change its value according to overhead of the network.

The copy number NUM should be proper to the network because cache, bandwidth and other resource are limited in DTN network.

$$NUM = \sum n_i \tag{2}$$

Where: $n_i = \begin{cases} 0 & if\,(AV\_Delay_i < delay_0) \\ 1 & if\,(AV\_Delay_i > delay_0) \end{cases}$

The source node sends NUM copies to the neighbor nodes whose AV_Delay_i is bigger than $delay_0$.

Because of that it uses flooding mechanism to cause the high routing expenses, we increase a path field set in the root message packet to save the node ID that the packet ever arrived, for example: $set\{ID_j, ID_k ...\}$. First, When the packet arrives a node i, node i add its own ID to the set and forward NUM copies of this message to its neighbors except those neighbors whose node ID has already in the set. This algorithm can reduce the number of packets in the network during the root discovery procedure.

B. Congestion Control Stage

In this paper, we consider a Bundle priority order:

(1) packets whose all destination nodes are neighbor nodes are preferentially transmitted to;

(2) packets that are very far away in the network will not be transmitted, are assigned a higher priority.

Epidemic cache management use FIFO (First In First Out) strategy to ensure the fairness of the packet cache, but bad management node congestion. In this paper, use priority based discarding strategy to node cache management:

Without affecting the overall network delivery ratio, nodes can discard a message under the following conditions:

(1) a copy has been sent to the destination node;

(2) there is not enough bandwidth routing in the entire life cycle of between the node and the destination node of ;

(3) even if the node discard some copies of ,the others are still likely to be successfully delivered.

In order to estimate whether packets that satisfy Condition a., use the confirmation message that sent back from the destination and transmitted to all nodes in the network; for estimating whether the message satisfy the condition b., using the priority policy; Condition c. is the most difficult to estimate. This article uses the hop count as a weak predictor, giving priority to discarding the packet that has been transmitted farther, because these messages are most likely to have been successfully received.

In this paper, the cache management strategy immediately delete the message has been successfully received replicas (lowest priority), and then discard lower priority packets has reached the threshold number of hops, then drop packets under but bigger hops.

C. Optimal Path Computation Stage

This article is concerned in the figure $G=(V,E)$, the optimal path chosen for a given source node $s \in V$ to the destination node $d \in V$ .There are several metrics we must consider when chose a optimal path such as hops, minimum energy of link, waiting delay. In DTN, Waiting delay is inversely proportional to possibility of link connectivity that is easy to get, so we can calculate path connectivity degree instead of waiting delay.

(1) hops

The number of hops in the route discovery process, when you want to send the packet node sends a route request, the request message transmitted through multiple hops to the destination node; the destination node sends a response when the response message arrives at the source node, the source node extract section paths hops.

(2) the possibility of path connectivity

Definition 3: D_{path_i} is path connectivity degree of $path_i$

Definition 4: $P_{(i,j)}$ is encounter probability of node i ($i \in V$) and node j ($j \in V$).

The possibility of path connectivity consists of every link along the path, and link connectivity possibility is equal to $P_{(i,j)}$.

Definition 5: t_{new} is the time point when nodes meet at this time; t_{old} is the time point when nodes meet at last time; t_{older} is the time point when nodes meet at the time before last time.

$$P_{(i,j)} = P_{(i,j)} \bullet \frac{t_{new} - t_{old}}{t_{old} - t_{older}} \tag{3}$$

Definition 6: $t_{ij} = t / n_{ij}$ is used to measure the average time of node i and node j meet. Where: t is unit time, n_{ij} is the total number of node i connect with node j in t

Path connectivity degree D_{path_i} is affected by $P_{(i,j)}$ and t_{ij} :

$$D_{path_i} = \sum_{x=s}^{d-1} P_{(x,x+1)} \bullet \frac{1}{t_{ij}} \tag{4}$$

Therefore, the path of least wait for the overhead is connectivity to the most likely path.

(3) Node Minimum Remaining Energy RB_{e_i}

RB_{e_i} can be obtained in the routing discovery process. Only be possible when the value is higher than the energy threshold to select the path. This allows the nodes in the network energy consumption as evenly distributed as possible, to avoid the result of the excessive consumption of energy because some nodes overburdened.

(4) Multi-metric weighted average routing

Think about hops, path connectivity degree and node minimum remaining energy, and with the weighted average method for calculation of link cost function F , the linear planning model is shown below.

$$\begin{cases} \min F = \lambda h + \mu E + \varphi \dfrac{1}{D} \\ 0 < h < h_0 \\ 0 < E < E_0 \\ D_0 < D \end{cases} \tag{5}$$

Where λ is the weight of adjusting hops; μ is the weight of adjusting remaining energy; φ is the weight of adjusting the path connectivity degree. We set h_0, E_0, D_0 according to situation of the network.

When considering the optimal path selection bias problem, set the three parameters λ, μ and φ .When λ is large, the optimal path selection results are biased in favor of the path of the smaller number of hops; When μ is large, the optimal path selection results are biased in favor of the remaining minimum energy path; When φ is large, the most excellent path selection results are more concerned about the path connectivity degree.

5. Simulations

The article uses NS2 to simulate PNCMOP. Analysis the following three routing performance indicators: packets successfully delivery ratio, end-to-end average delivery delay and node energy consumption.

A. packets successfully delivery ratio;

$$delivery\ ratio = \frac{number\ of\ successfully\ delivered\ packets}{total\ number\ of\ packets} \times 100\% \quad (6)$$

(1) the relationship between node rate of movement and the delivery ratio of the packets.

The number of the mobile nodes is 40, the maximum rate of movement of nodes respectively lm/s, 3m/s, 6m/s and 9m/s, the residence time is 0, the simulation time is 500s, the data stream is a CBR stream, 10 communication connections, send two packets per second. The simulation results are as follows Figure 2.

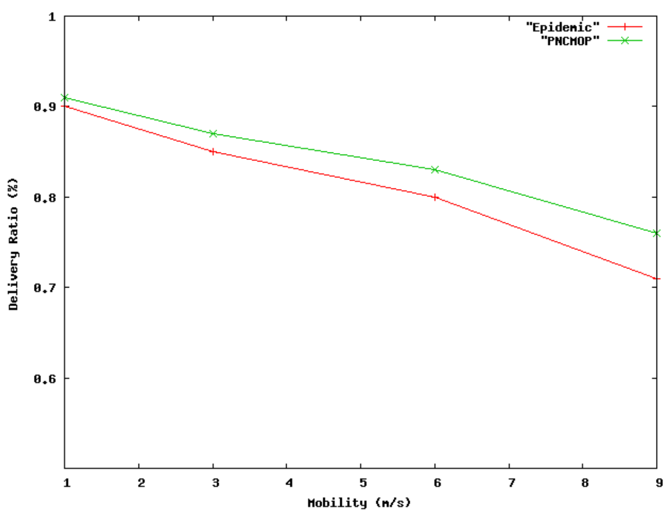

Figure 2. Node mobility rate and packets delivery ratio.

In Figure 2, Nodes increase in the rate of movement, message delivered successfully reduced. When the node mobility rate is low, the two protocol packets successfully pass rate is less, along with the node mobility rate of increase the Epidemic packet delivery rate faster than PNCMOP fast after both the decline rate is basically the same.

(2) The relationship between numbers of node and the delivery ratio of the packets.

The node mobility rate is 3m/s, the numbers of nodes respectively 20, 40, 60 and 80, the residence time is 0, the simulation time is 500s, and the data stream is a CBR stream, 10 communication connections, sends two packets per second. The simulation results are as follows Figure 3.

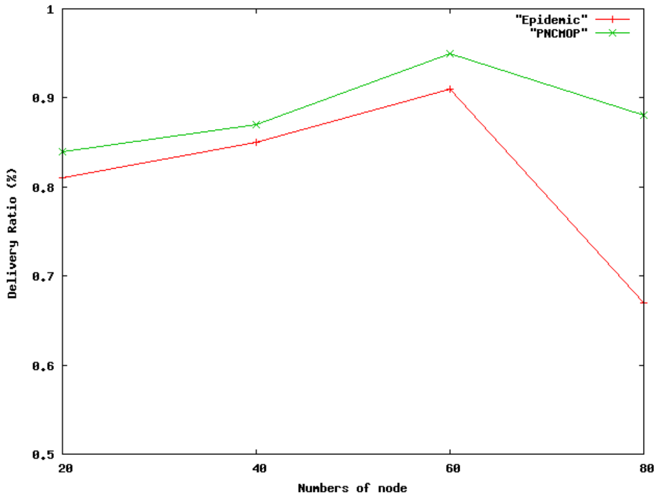

Figure 3. The numbers of node and packets delivery ratio.

In Figure 3:

(1) When a little numbers of node, packets delivery ratio was slightly lower, because the little number of nodes, the less opportunity to contact between the nodes, packets cannot arrive at the destination node on time, while the node cache is limited, when the storage space is full, discards the packets in cache;

(2) When the numbers of node increase, packets delivery ratio increases, the appropriate nodes, packets delivery ratio is higher.

(3) Increasing the number of nodes, packets delivery ratio would decrease. The reason is that the numbers of node increases, the network may occur congestion, resulting in the packets delivery ratio decreased. But Copying and forwarding strategy was used in PNCMOP, saving the message copy in the network, and joined the node cache management congestion control scheme, packets delivery ratio of PNCMOP is higher than that of Epidemic.

Therefore, an appropriate increase in the number of packet replication, help to improve the packet successfully delivery ratio.

B. end-to-end average delivery delay

(1) The relationship between moving rate of node and end-to-end average delivery delay.

The number of the mobile nodes is 40, the maximum rate of movement of nodes respectively lm/s, 3m/s, 6m/s and 9m/s, the residence time is 0, the simulation time is 500s, the data stream is a CBR stream, 10 communication connections, send two packets per second. The simulation results are as follows Figure 4.

In Figure 4, when the certain nodes, with the rate of growth of the node move, the average delay increases. PNCMOP agreement, the average delay less than the Epidemic delay. When the rate of movement of the nodes is small, the delay of both the rate of change is slow. When node mobility rate gradually increased the lead to establish the connection is broken, the delay between the two have a more substantial growth. PNCMOP agreement of the growth rate is slower than the growth rate of the Epidemic protocol. PNCMOP agreement Bundle priority routing mechanism, it is possible to choose a better performance node as the next hop is relatively small, so the delay.

(2) The relationship between numbers of node and end-to-end average delivery delay.

The node mobility rate is 3m/s, the numbers of nodes respectively 20, 40, 60 and 80, the residence time is 0, the simulation time is 500s, and the data stream is a CBR stream, 10 communication connections, sends two packets per second. The simulation results are as follows Figure 5.

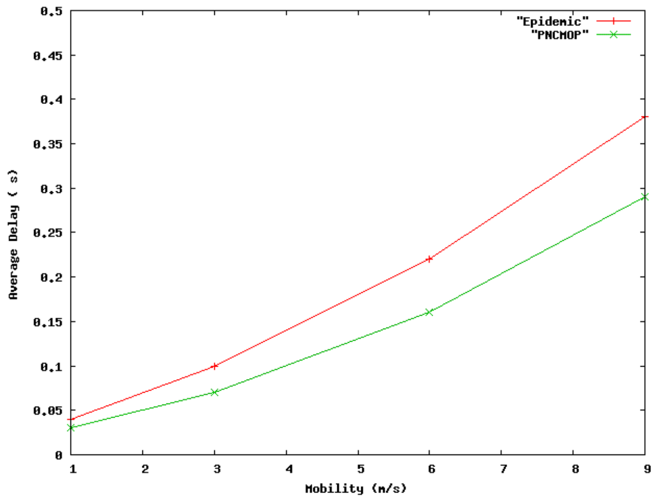

Figure 4. Node mobility rate and average delivery delay

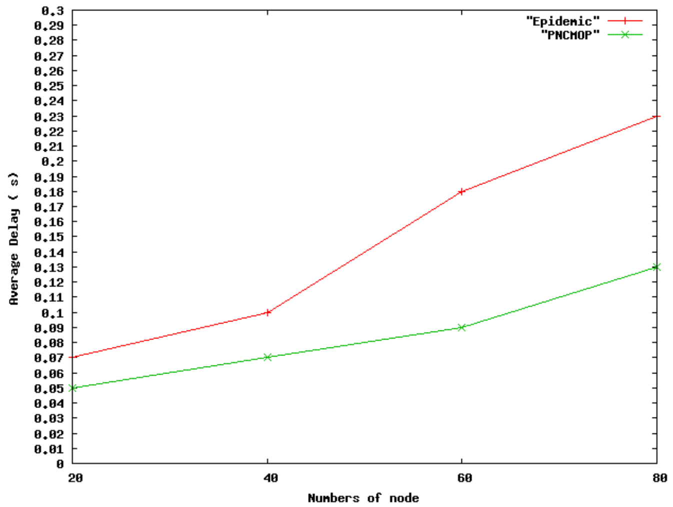

Figure 5. The numbers of node and average delivery delay

In Figure 5, messages For Epidemic agreement, when a small number of nodes, the number of copies the appropriate and conducive to the transmission of the message, so the delay is smaller; When an increase in the number of nodes, the increase in the number of information brought a copy of the message exchange between nodes certain extent, affected the delivery of messages, leading to an increase in transmission delay. For PNCMOP protocol, when fewer nodes, by increasing the number of copies of the packets to make up for network sparse insufficient, to ensure that the smaller the transmission delay; when the number of nodes increases, the control packets and the number of copies, to avoid the delay caused due to the large number of redundant.

C. Node average remaining energy

The PNCMOP agreement to increase the number of packet replication algorithms are relatively complex, so energy consumption than Epidemic. But PNCMOP protocol to ensure the case of a higher transmission rate of the packets and a smaller transmission delay than Epidemic significantly reduce the consumption energy of the network node, the message delivery, transmission delay and equalization of energy consumption.

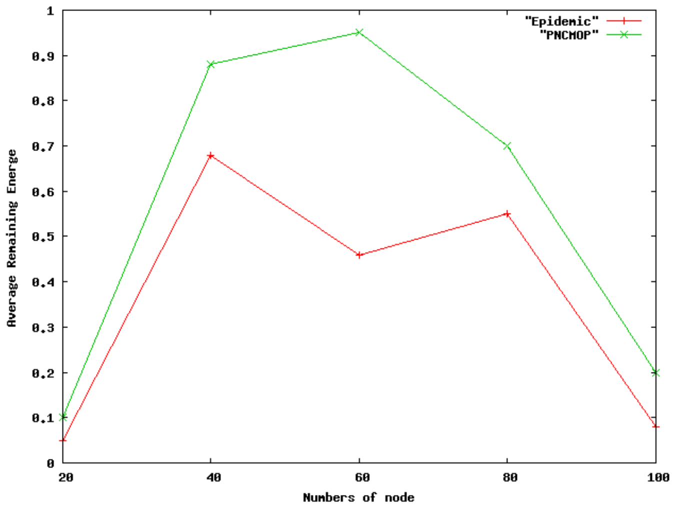

Figure 6. Node remaining energy comparison between two protocols

6. Conclusion

In this paper, On the basis of the Epidemic, design based congestion control DTN routing the agreement PNCMOP and the simulation analysis. PNCMOP algorithm workflow is divided into three phases, the selection phase based on copy Bundle distributed stage, based on the priority Bundle node cache management congestion control phase and the optimal path based on multi-the metric weighted average routing mechanism. Node in the network storage and rational use of energy is considered in the whole process, to try to prolong the survival time of the transfer nodes. The simulation PNCMOP routing protocol packets successfully pass rate, the average end-to-end delay and node residual energy "three performance indicators angle of PNCMOP and Epidemic routing protocols do analysis and comparison.

However, due to time constraints, this study is still not deep enough, summarized the shortcomings and areas for further improvement of the following aspects:

1) Due to the limitations of the simulation conditions, not enough to reflect all the characteristics of the DTN network, how to design an approximation model of network simulation scenarios of real DTN pending further study;
2) Algorithm packet distribution quantity and distribution way, determining multi-metric weighted average routing mechanism λ, μ and φ and other parameters of weighted
3) Routing security issues need to be further in-depth study formula, the calculation of probability in path metric, the determination of energy threshold and other issues are yet to be further research.

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