International Journal of Future Generation Communication and Networking
Vol. 8, No. 6 (2015), pp. 257-270
http://dx.doi.org/10.14257/ijfgcn.2015.8.6.25

Column Generation Algorithm-Based DTN Routing Strategy in Complex Data Transmission Scenario

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Abstract

An ideal routing strategy shall be able to help the delay tolerant network (DTN) achieve an optimal transmission performance under the premise of lower energy consumption. However, due to the diverse of the application scenarios, it is hard to use one or more types of routing strategies as a universal optimum solution. There is a need to establish a routing strategy model of the corresponding DTN network for different application scenarios, analyze and evaluate the strategy model in combination of the knowledge of the operational research and statistics. For a complex data transmission DTN network scenario, with the introducing of a line programming method, the big-data and multi-node network transmission problem can be abstracted to a large-scale line programming problem. In this paper, the feasibility of solving the large-scale line programming problem by the column generation algorithm has been analyzed, and a column generation algorithm-based DTN routing strategy under the complex data transmission scenario has been designed. This routing strategy can realize the quantization of the routing strategy performance by the column generation algorithm. Also, by the simulation experiments, the performance of complex data transmission DTN routing strategy under different factors has been analyzed, and the performance of the column generation algorithm-based DTN routing strategy has been compared with the performance of the traditional jet waiting routing strategy.

Keywords: *DTN routing strategy; line programming; column generation*

1. Introduction

Delay Tolerant Network (DTN) is special network architecture abstracted from the real scenario. It is a constrained network [1-6] that fulfils the communication if the wireless network nodes have been damaged, the network has been segmented, the nodes cannot communicate physically, and an active or random contact between the mobile nodes shall be relied on. The main difference between the DTN network and the traditional networks such as the Internet is, in most application scenarios, DTN network has no reliable end-to-end path. So the network delay is longer, and the energy and storage are limited. In order to maintain the link connectivity, the wireless communication nodes often use a "store-carry-forward" mechanism to ensure a higher delivery success rate under long time delay. Basing upon this data transmission method, in the literature [7-8], researchers have proposed various application scenarios, such as the intermittent connective wireless sensor networks, periodic connected satellite network. Due to the DTN network has higher achievability, it has become an important research direction of wireless communication in academic in recent years. Among them, the core problem of research and application of DTN network is to design a high efficiency and low consumption DTN routing strategy that is suitable for specific application scenarios.

DTN has two types of typical use scenarios [9]: the first type is complex data transmission scenario, which is characterized in the variety data nodes, instable links and complicated network environment; the second is military/science DTN networks under limited communication resource environment; under this scenario, the communication resources are extremely scarce, almost no information infrastructure support such as base; the mobile nodes are divided into several groups, and scattered in different regions within the radius of task execution; this scenario is mainly used for important actions such as the scientific research, military missions and disaster relief.

The complex data transmission type DTN network mainly includes: the city bus network, the security monitoring network, the mobile agent node network, and the dense car connection network [3]. The data nodes are varieties, links are not stable, and the network environment is complicated. The complex data transmission DTN network mainly uses directional routing strategies, such as the data mules strategy, the prophet strategy. Due to the lack of treatment on the real-time information of the global nodes, it cannot get a global optimal solution in essence. Therefore, there is a need to perform a linear extraction on the real-time information of the global nodes and abstract the seek for a global optimal routing strategy to the sake for a line programming problem. In general DTN network protocol family [11-12], the prophet routing (Prophet) is similar to it [13], but due to the prophet routing cannot use different cognition levels for the different network environments, this is a waste of network resources to a certain extent. To solve the optimal problem of complex data transmission DTN routing strategy, there is a need to extract and classify all kinds of information in the network and establish a corresponding cognition model. In existing directional routing strategies, only by adopting a line programming method can the parameter family of complex network environment be globally operated. Therefore, this paper abstracts the complex network conditions to a large-scale line programming problem, and utilizes a column generation algorithm to obtain the optimal DTN routing strategy.

2. Column Generation Algorithm-Based DTN Routing Strategy in Complex Data Transmission Scenario

The core idea of this paper is to modeling for a complex network with multiple transmission targets based on the abstract class of the messages, and perform an optimal solution by the column generation algorithm. Since the transmission nodes and the transmission channels in the complex network are being produced continuously and the expired nodes and the expired channels are being updated in phases, the constraint conditions, the edge set records and the point set records of the original line programming model are expanding rapidly, eventually led to the overloading of the system [14]. To avoid this, an equivalent construction method is adopted in modeling. In this method, the number of constraints will be significantly reduced, but the number of decision variables will increase. Due to a decision variable corresponds to an edge, so the increase in space is a linear expansion, which can reduce the system loads effectively. On the basis of the column generation algorithm and the Danztig-Wolfe decomposition, a main problem can be decomposed into several restricted master problems (RMPs), and then the RMP results can iterative until a global optimal solution can be obtained at last. The routing strategy proposed in this paper solves a global optimal transmission path by the column generation algorithm and measures the performance of the obtained optimal transmission path on the basis of the Dijkstra shortest path algorithm.

2.1. Analyzing the Column Generation Algorithm

For a large-scale line programming (LP) of the block angular structure, first of all, the mathematical representation is established:

$$
\begin{array}{l}
\max C_1X_1 + C_2X_2 + C_3X_3 + \cdots + C_pX_p \\
s.t. \\
A_1X_1 + A_2X_2 + \cdots A_pX_p = b_0 \\
B_1X_1 \qquad\qquad\qquad\qquad = b_1 \\
\qquad B_2X_2 \qquad\qquad\quad = b_2 \\
\qquad\qquad\qquad\qquad\quad \vdots \\
\qquad\qquad\qquad B_pX_p = b_p \\
X_i \geq 0, i = 1, \cdots, p
\end{array}
$$

Wherein, C_i, A_i, B_i, b_i, X_i, and b_i are the matrixes with specific dimensions. As shown in Figure 1, according to the Danztig-Wolfe decomposition method, the large-scale LP problem can be divided into many standalone sub-problems. So, solving the original large-scale LP problem is equivalent to a numbered iteration between solving the MP (master problem) and its sub-problems. In each iteration, MP controls the constrains for connecting with the sub-problems by the $[f_i, \mathbf{u}_i]$ information (wherein, f_i is the value of the target function, $\mathbf{u}_i$ indicates the solution of the i sub-problem) provided by the sub-problems. MP sends its own solution $[\pi, \gamma_i]$ as the price multiplier to each sub-problem. The sub-problems update the target functions according to their respective price multipliers. MP calculates the updated sub-problem constraints based on the updated target functions. The algorithm iterates in this way till a solution of the large-scale LP problem can be obtained.

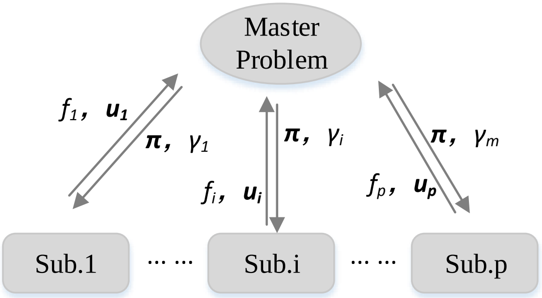


Figure 1. Danztig-Wolfe Decomposition Mechanism

By the Danztig-Wolfe decomposition, the MP problem corresponding to the original LP problem is:

$$
\begin{array}{l}
\min z = \sum_{i=1}^{p} \sum_{j=1}^{N(i)} (C_i X_i^{\,j}) \lambda_{ij} \\
s.t. \\
\quad \sum_{i=1}^{p} \sum_{j=1}^{N(i)} (A_i X_i^{\,j}) \lambda_{ij} = \boldsymbol{b}_0 \\
\quad \sum_{j=1}^{N(i)} \lambda_{ij} = 1, i = 1, \ldots, p \\
\quad \lambda_{ij} \geq 0, i = 1, \ldots, p; j = 1, \ldots, N(i)
\end{array}
$$

Wherein, $N(i)$ indicates the number of extreme points in the feasible region of the i th LP sub-problem.

For the large-scale LP problems, it is unavoidably to get all the extreme points and express the complete MP problem by a formula. Here, there is no need to know all the extreme values of extreme sub-problems explicitly as long as the equivalent RMP can be solved. The RMP problem can be constructed through the column generation algorithm dynamically. The main steps executed by the algorithm are:

(1) by using a two-phase algorithm, get two initial extreme points X_i^1, X_i^2 for each $i = 1,\dots,\mathrm{p}$ to obtain the initial RMP; get the $\lambda_{11}, \lambda_{12}, \dots, \lambda_{p1}, \lambda_{p2}$ and the simplex multiplier π_s ; decompose the π_s to $\pi_s = [\pi \mid \pi_0]$; wherein, π corresponds to the coupling constraint, π_0 corresponds to p convex combination constraints, $k = k_0 + +$; here, $k_0 = 2$ is the number of initial extreme points;

(2) price solving

$$u_i = \min(C_i - \pi A_i) X_i - \pi_{oi}$$
$$s.t. \quad B_i X_i = \boldsymbol{b}_i ,\ X_i \ge 0,\ \ i = 1,\dots,\mathrm{p}$$

By this, the extreme point $X_i^k, i = 1,\dots,p$ can be obtained; wherein, π_{oi} is the ith component of π_o ; if $u_i \ge 0$ for all the $i = 1,\dots,\mathrm{p}$, then the optimal solution obtained by RMP is the optimal solution of the original LP problem and the algorithm terminates; otherwise, $u_s = \min\{u_i : u_i < 0\}$ and turn to Step (3);

(3) add a column P_s

$$P_s = \begin{pmatrix} A_s X_s^k \\ e_s \end{pmatrix}$$

Wherein, e_s is a unit vector of Dimension p, and its component s is 1;

(4) solve the new RMP to get $\lambda_{11}, \lambda_{12}, \dots, \lambda_{p,1}, \dots, \lambda_{1,N(\mathrm{p})}$.

2.2. Constructing a Large-scale Line Programming Model by the Abstract Classes of the Messages

To obtain the large-scale line programming model corresponding to reality, first of all, there is a need to obtain the input variables such as the dynamic topology changes and the traffic demand of the network. According to the study and theory of Jain [9], the routing strategy of optimal performance shall consider all the dynamic changes of the network during the construction of the original line programming model. And the performance of the routing strategy that only considers some dynamic changes of the network will be restricted to a certain degree. The upper-limit of the performance is determined by the cognitive degree of the dynamic changes of the network. In order to get the original line programming model, cognitive abstract classes shall be constructed to meet the cognitive demand of real-time network situation of the algorithm.

Jain has put forward 6 kinds of directional routing strategy [9] based on 6 cognition degrees of network. Wherein, the simplest abstract class is the "first contact" in which there is no any other useful information has been recorded except for the neighbor nodes of each node. As with the changes of cognition degree, the performance of these 6 cognition models will have a tendency to be promoted significantly under the same algorithm. A node using this cognitive abstract class will start to move after selecting a neighbor node randomly. In addition to record the basic information, other cognitive abstract class also records the activation time of a specific channel. The experiment found that algorithms taking other cognitive abstract classes are much better than the abstract class taking the "first contact" algorithm in performance. In the cognitive abstract classes, the cognitive degree of the network information depends on the completeness of the above 3 message databases, and the normal flooding routing strategy does not process these 3 cognitive message databases. In the complex data transmission network scenario, due to the lack of the cognition of the entire network, the performance of the flooding routing is worst. Some cognition models only use one or two databases of the above 3 cognitive message databases, such as the prophet routing. This type of routing cannot meet the performance requirements in the sub-network structure of the complex data transmission scenario.

In a complex data transmission scenario, to use the column generation algorithm, a complete cognition model that consists of all three message databases must also be used in synchronization. The message databases of the complete cognition model are the input of the column generation algorithm-based DTN routing strategy presented in this paper.

2.3. Solving the Line Programming Model by the Column Generation Method

In the original line programming model of the complex data transmission DTN network, the input data of the model include: the message set, edge set and the continuous transmission time interval in the transmission process.

2.3.1. Input Data of the Algorithm:

V : complex network point set;
E : complex network edge set;
P : continuous transmission time interval in the transmission process;
I_q : time slice; wherein, $I_q \in P$, and $I_q = [t_{q-1}, t_q)$;
$c_{e,t}$: information capacity on Time t, Edge e, $e \in E$;
$d_{e,t}$: information delay on Time t, Edge e, $e \in E$;
b_v : information capacity of node v;
K : message set;
I^v : set of the edges of which the target node is v in E ;
O^v : set of the edges of which the source node is v in E ;
$s(k)$: source node of k , wherein, $k \in K$;
$w(k)$: injection time of k , wherein, $k \in K$;
$d(k)$: destination node of k , wherein, $k \in K$;
$m(k)$: size of k , wherein, $k \in K$;
R : set of paths.

2.3.2. Decision Variables:

$N^k_{v,t}$: indicates the size of buffer occupied by message k on node v at Time t (t $\in$ P);

$X^k_{e,I}$: indicates the size of messages that have been transmitted when the message k arrives at Edge e at Time I (I $\in$ P);

$R^k_{e,I}$: indicates the size of messages that have been accepted when the message k leaves from Edge e at Time I (I $\in$ P).

2.3.3. Target Function:

The performance of algorithm is expressed by the target function. The aim is to reduce the average transmission time delay as much as possible. This equals to reduce the sum time delay of all the messages. The minimum sum network time delay can be expressed by:

$$\min\sum_{v\in V}\sum_{k\in K}\sum_{I_q\in P}\left(\sum_{e\in I^v} R^k_{e,I_q}-\sum_{e\in O^v} X^k_{e,I_q}\right)(t_{q-1}-w(k)) \tag{1}$$

Wherein, $\sum_{e\in I^v} R^k_{e,I_q}-\sum_{e\in O^v} X^k_{e,I_q}$ indicates the size of a message queue when the message lefts Edge e minuses the size of the message queue when the message arrives at Edge e within the period I_q; $t_{q-1}-w(k)$ is the stay time of the message at Edge e.

According to formula (1), the optimization of the routing performance of the whole network equals to solve the minimum value of total transmission time delay of all the messages in the network.

2.3.4. Constraint Conditions:

Author names and affiliations are to be centered beneath the title and printed in Times New Roman 12-point, non-boldface type. Multiple authors may be shown in a two or three-column format, with their affiliations below their respective names. Affiliations are centered below each author name, italicized, not bold. Include e-mail addresses if possible. Follow the author information by two blank lines before main text.

To limit the redundant computing generated in line programming, only five constraint conditions are used in the study of this paper. Suppose the sum of message k transmitted on Edge e at period I_q is sum, then:

$$sum=\begin{cases} N^k_{v,t_q}-N^k_{v,t_{q-1}}+m(k) & \text{when } s(k)=v, w(k)=t_q \\ N^k_{v,t_q}-N^k_{v,t_{q-1}} & \text{otherwise} \end{cases} \tag{2}$$

$$R^k_{e-1,I_q,t_{q-1}}=X^k_{e,I_q,t_q} \tag{3}$$

Formula (3) indicates for the Edge e, the size $R^k_{e-1,I_q,t_{q-1}}$ of a message queue when the message lefts the previous Edge $e-1$ equals to the size X^k_{e,I_q,t_q} of the message queue when the message arrives at Edge e within the period I_q;

$$\sum_{k\in K} N^k_{v,t_{q-1}}\le b_v \tag{4}$$

Formula (4) indicates the size $N^k_{v,t_{q-1}}$ of the buffer occupied by the message k at node v would not exceed the information capacity of node v at any time.

$$N^k_{v,t_{q-1}}=\begin{cases} m(k) & \text{when } v=s(k) \text{ and } t_0=w(k) \\ 0 & \text{otherwise} \end{cases} \tag{5}$$

$$N^k_{v,t_0}=\begin{cases} m(k) & \text{when } v=d(k), \\ 0 & \text{otherwise} \end{cases} \tag{6}$$

According to the Danztig-Wolfe decomposition algorithm and in combination with the constraint conditions, Formula (2), (3), (4), (5) and (6), the RMP can be obtained:

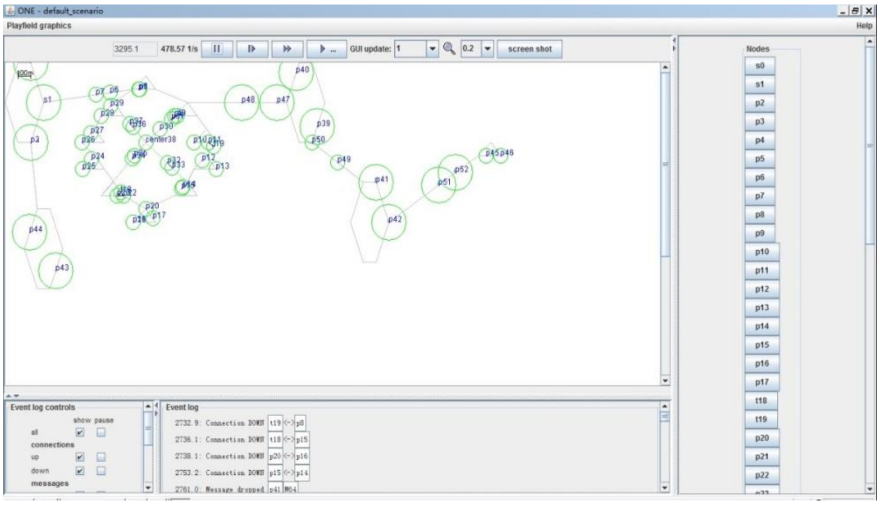
$$\begin{aligned} &\min\sum_{k\in K}\sum_{r\in R} d(r)f(r) \\ &s.t. \sum_{r\in R} f(r)=m(k) \qquad \forall k\in K \\ &\qquad f(r)\ge 0 \qquad \forall k\in K, r\in R \end{aligned} \tag{7}$$

Wherein, R is the set of the paths between the source node and the destination node of message k. Due to the line programming model has reduced the number of constraint conditions to prevent the generating of too many interactive operations, the number of decision variables has been increased greatly. The reason for this is that the association paths shall be prepared for each possible channel during the plan. However, in real application, only a small part of decision variables would participate into the computing of data stream in beat case. Here, a column generation algorithm must be used to identify and depart this part of decision variables from the variable set. According to the line programming theory, the column generation algorithm can process the amount of data at a exponential rate. For MP plus constraint conditions, formula (2-6), the column generation algorithm would generate RMP and compute the corresponding simplex table.

Substitute the result to solve the price, add the generated additional columns to the new restricted main problem, finally, perform recursion repeatedly, a global approximate optimal solution can be obtained.

3. Simulation Experiment and Performance Analysis

The experiment uses ONES as the simulation platform. To get enough samples from the experiment, the simulation process would be repeated for 200 times randomly. A schematic diagram of the simulation networking of the complex data transmission DTN network is shown in Figure 2.



show pause
all ☑ ☐
connections
up ☑ ☐
down ☑ ☐
messages

```
2732.9: Connection DOWN t19 <-> p8
2736.1: Connection DOWN t18 <-> p15
2738.1: Connection DOWN p20 <-> p16
2753.2: Connection DOWN p15 <-> p14
2761.0: Message dropped p41 M64
```

Figure 2. Schematic Diagram of the Simulation Networking of the Complex Data Transmission DTN Network

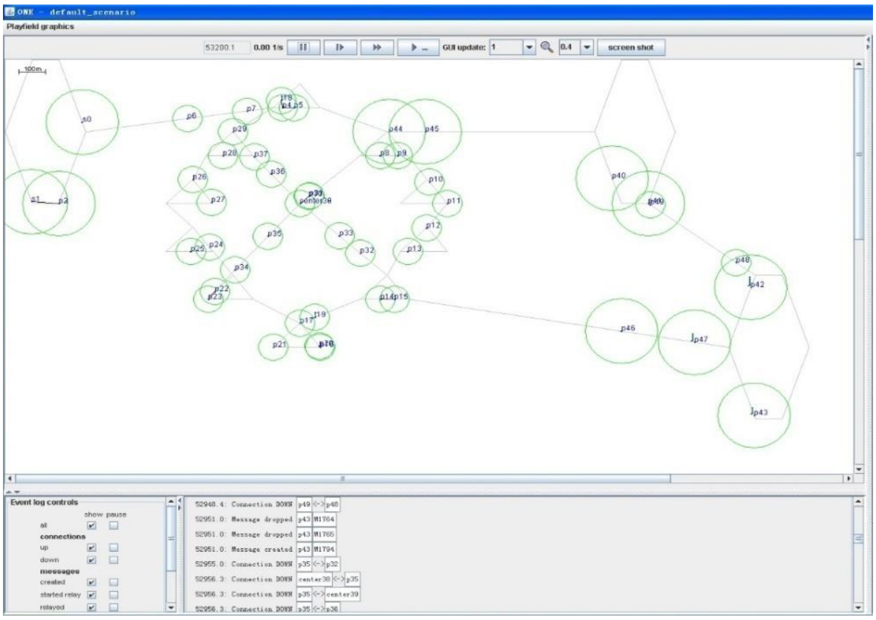
In all the following experiments, the parameter settings are: $p_1, p_2, p_3, \cdots, p_{39}$ are the low energy consumption nodes, p_{40} to p_{51}, and s_0, s_1, s_2 are the high energy consumption nodes (with higher communication range and movement speed), and the data source node s_0 is still in these experiments. The experiment duration is 24h (86400s in total) in reality, while the clock of ONES is set to 1ms in simulation of the 1s in reality. Therefore, the duration of an experiment is 86.4s. The movement speed of the high energy consumption node is 1.5 unit length/ms, and the movement speed of the low energy consumption node is 1 unit length/ms. The number of data source nodes s_0 is 1, the number of the high energy transmission nodes is 14, the number of the low energy consumption transmission nodes is 39, and the number of links is 72.

3.1. Performance Analysis of Complex Data Transmission DTN Routing Strategy under Different Factors

In complex data transmission scenario, the routing table of the transmission nodes in the directional DTN routing strategy will update with the condition of network continuously. The changes of the network conditions will lead to the changes of the decision variables and the constraint conditions, and thus affect the calculation results of the column generation algorithm, resulting in the changes of the experimental data. Factors influencing the network transmission performance there include: (1) link completeness. The network topology changes if one or more links in the network has/have been disconnected, which will lead to the number of decision variables and constraint conditions change, resulting in the change of the experimental data; (2) the length of the node message queue. The relationship between the length of the message queue and the network transmission performance is not linear. Suppose that the length s of the message queue takes a specific numerical value, the transmission performance of the entire network is the best; (3) the maximum survival time of the datagram. In a network environment with a huge amount of data transmission, if the maximum survival time of the datagram is short, the delivery rate may drop down; if the maximum survival time reported by the data is too long, the possibility of network congestion may increase, and the delivery rate may be affected. Therefore, there is no direct linear relationship between the maximum survival time of the datagram and the delivery rate. Here, the performance of the column generation algorithm-based DTN routing strategy under the complex data transmission scenarios are analyzed in combination with the following 3 influencing factors respectively.

3.1.1. Link Completeness

Now, a quantitative test is performed according to the link completeness. The parameter for measuring the performance of experiment is the message delivery rate of the system. When a link is disconnected, the simulation experiment environment is shown in Figure 3.



```
52948.4: Connection DOWN p49 <-> p48
52951.0: Message dropped p43 M1764
52951.0: Message dropped p43 M1765
52951.0: Message created p43 M1794
52955.0: Connection DOWN p35 <-> p32
52956.3: Connection DOWN center38 <-> p35
52956.3: Connection DOWN p35 <-> center39
52956.3: Connection DOWN p35 <-> p36
```

Figure 3. Big Data Transmission Simulation Scenario Diagram if the Links are not Completed

Set a new simulation experiment environment. By comparing with the original experiment environment, we can find that the new simulation environment is lack of two key links. Now, perform 100 experiments under the two simulation environments respectively. In order to reflect the experimental results objectively, process and do statistics on the results of 200 times of experiments, and display the statistical results of the delivery rates changing with the time under these two experimental scenarios. Wherein, Figure 4 is the delivery rate distribution under a complete link condition; Figure 5 is the delivery rate distribution under an incomplete link condition; Figure 6 is the curve of the delivery rates changing with the time under a complete link condition; Figure 7 is the curve of the delivery rates changing with the time under a incomplete link condition.

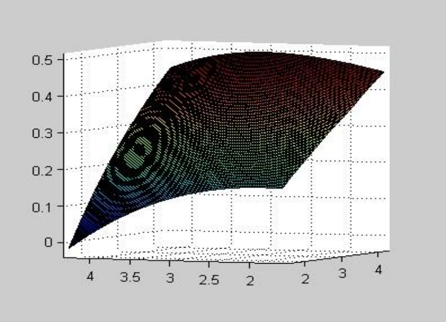


Figure 4. Delivery Rate Distribution under a Complete Link Condition

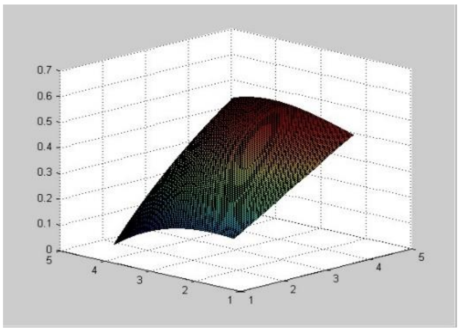


Figure 5. Delivery Rate Distribution under a Incomplete Link Condition

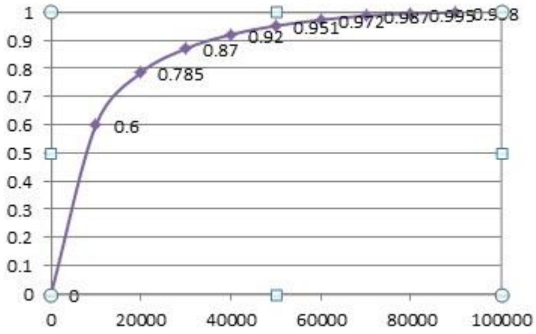


Figure 6. Delivery Rate Changing Curve under a Complete Link Condition

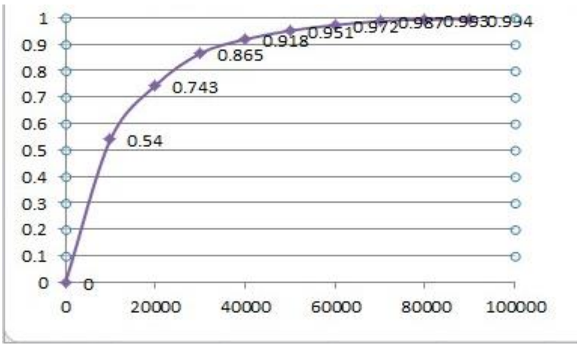


Figure 7. Delivery Rate Changing Curve under a Incomplete Link Condition

Figure 6 and Figure 7 show the delivery rate changing curves obtained within the same experiment time under two simulation scenarios by the column generation algorithm-based DTN routing strategy over the simulation time, the two simulation scenarios, the DTN routing strategy based on column generation algorithm in the same experiment time delivery rate curve. The experimental results show that: when the simulation time is less than 20000 ms, the delivery rate of the system that is lack of two main links is lower than the delivery rate of the system with a complete link; but as with the increase of time, the delivery rate of the system that is lack of two main links is close to the delivery rate of the system with a complete link, finally they are consistent. It indicates that the column generation algorithm-based DTN routing strategy can generate new constraints and decision variables with the change of the network situation after the link has been disconnected, so as to generate a new routing path in the nodes, and have repair effect on the transmission system.

3.1.2. Length of the Node Message Queue:

Now, perform grouping experiments according to the lengths of different node message queues. The parameter for measuring the performance of experiment is the message delivery rate of the system. Specifically speaking, do experiments on 10 groups of different node message queue lengths; 20 times for each group. In order to reflect the experimental results objectively, process and do statistics on the results of 200 times of experiments, display the statistical delivery rate results of the 10 groups in Figure 8, and display the delivery rate changing curve of the 10 groups in Figure 9; in which, the horizontal axis indicates the length of the node message queue and the vertical axis indicates the delivery rate. Except for the lengths of the node message queues, all the other general conditions of the experiments are the same.

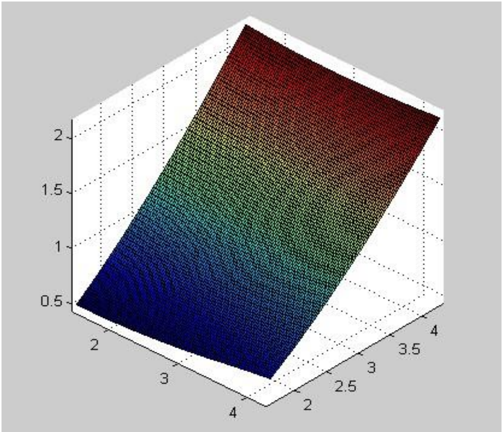


Figure 8. Schematic Diagram of Delivery Rate Statistics

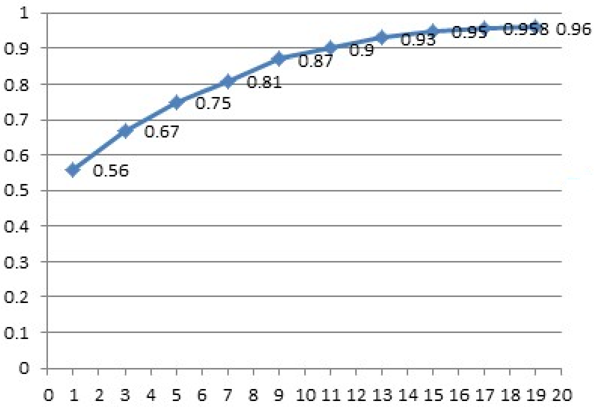


Figure 9. Schematic Curve Diagram of Delivery Rate Changes

Figure 9 indicates a curve showing the delivery rates of the 10 groups change with the lengths of the node message queues. The length of the message queue increased by 2 within a range of, [1-19]. Viewing from Figure 9, we can see that if the length of the node message queue is less than 9, the delivery rate can be improved significantly; and the delivery rate keeps flat in a range of 9 to 17. The experiment shows that the delivery rate can be increased with the increase of the length of the message queue within a certain range, and keep stable when a peak value has been reached. This is because that the column generation algorithm has been set with a termination threshold to prevent the infinite iterations generated in the optimal solution of RMP. Therefore, the delivery rate would not be increased obviously after the length of the message queue reached a certain value.

3.1.3. Maximum TTL of the Message:

Now, perform grouping experiments according to the maximum time to live (TTL) of different node message queues. The parameter for measuring the performance of experiment is the message delivery rate of the system. Specifically speaking, do experiments on 20 groups of different message maximum TTLs; 10 times of simulation experiments for each group. In order to reflect the experimental results objectively, process and do statistics on the results of 200 times of experiments, display the statistical delivery rate results of the 20 groups in Figure 10, and display the delivery rate changing curve of the 20 groups in Figure 10; in which, the horizontal axis indicates the maximum TTL of the message and the vertical axis indicates the delivery rate. Except for the TTLs of the messages, all the other general conditions of the experiments are the same.

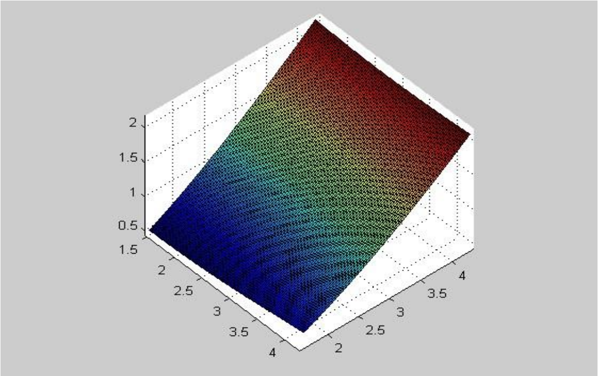


Figure 10. Delivery Rate Statistical Curve Diagram in TTL Experiment

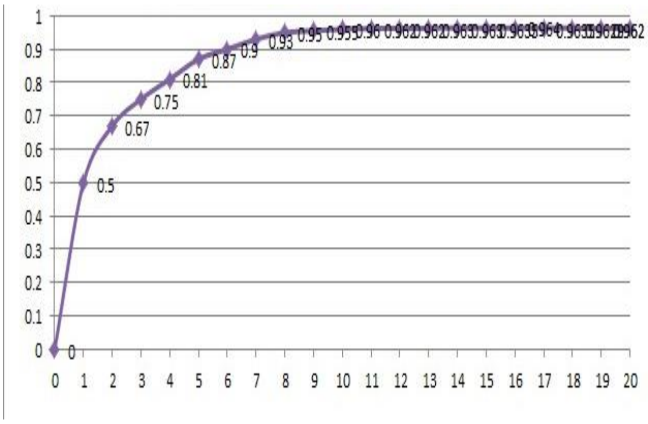


Figure 11. Delivery Rate Changing Statistical Curve Diagram in TTL Experiment

Figure 11 indicates a curve showing the delivery rates of the 20 groups change with the maximum TTLs of the messages. The experiment indicate that: if TTL＜10ms, the delivery rate can be improved with the increase of TTL significantly; the rate keeps flat in a range of 10ms to 16ms; and the rate drops down slightly after 16ms. It experiment shows that the delivery rate can be improved with the increase of TTL within a certain range, and can reach its peak value in a certain range; but it may be dropped down slightly if the peak value range has been exceeded. The reason for this is: in initial state, TTL is short, the data package loss is frequent, and the routing table information changes continuously, the iterations in solving the RMP by the column generation algorithm decreases, the final solution is not the optimal solution. This condition can be improved with the increase of TTL till the message TTL is too long for the bearing capacity of the network, so that too many unnecessary repeated constraint variables have been added for the column generation algorithm and the delivery rate of the system have been dropped down.

3.2. Comparison of the Performance of the Column Generation Algorithm-based DTN Routing Strategy and the Performance of the Jet Waiting Routing Strategy

In previous studies, the complex data transmission DTN network mainly uses a jet waiting routing strategy [15]. To compare the performance of the column generation algorithm-based DTN routing strategy with the performance of the jet waiting routing strategy, perform 100 times of experiments by above two methods under the same simulation environments respectively, sort and analyze the experimental results. The index for measuring the routing performance is the delivery rate of the message.

Figure 12 indicates the curves showing the delivery rates obtained by the column generation algorithm-based DTN routing strategy and the jet waiting routing strategy within the same experiment period in the case that the values of the TTLs of the messages are different. The horizontal axis indicates the maximum TTL of the message.

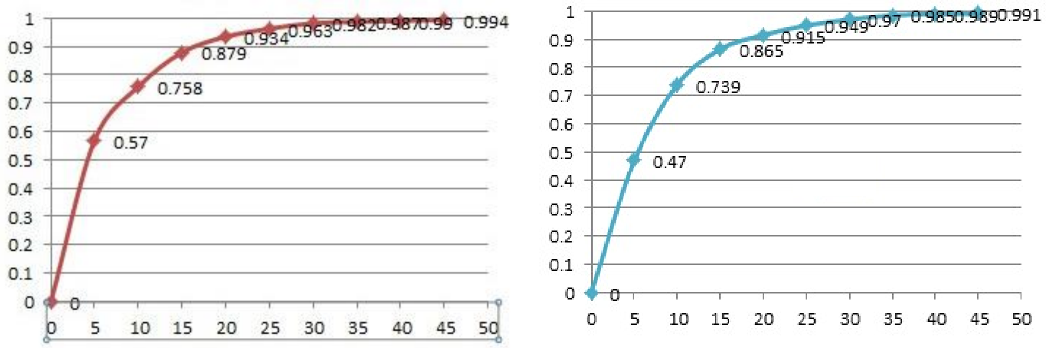


Figure 12. Curve of the Delivery Rates of the Column Generation Algorithm-based DTN Routing Strategy and the Jet Waiting Routing Strategy

Viewing from the Figure 12, we can see that if TTL＜5ms, the performance of the column generation algorithm-based DTN routing strategy is much more better than the performance of the jet waiting routing strategy. It shows that in a complex data transmission scenario with the congest communication status and shorter maximum TTL, the column generation algorithm-based DTN routing strategy can get a better a transmission result. Even if the maximum TTL of the message increases, the column generation algorithm-based DTN routing strategy still has a higher delivery rate. The simulation result shows that the performance of the column generation algorithm-based DTN routing strategy is much more stable than the performance of the jet waiting routing strategy.

4. Conclusion

In a complex data transmission scenario, comparing with the commonly used directional routing strategy, the column generation algorithm-based DTN routing strategy has obtained the better delivery rate.

Three nonlinear factors that affects the column generation algorithm-based DTN routing strategy are: (1) link completeness; (2) the length of the node message queue; (3) TTL of the datagram.

The column generation algorithm-based DTN routing strategy is able to be self-fixed and restored to some extend when the link is damaged and achieves the optimal performance when the length of the node message queue and the TTL of the datagram are in a certain range.

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