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Tracking Strategy Based on Multi-Detector Collaborating in Delay Tolerant Networks

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Abstract. Target tracking problem in DTN (delay tolerant network) networks has been widely concerned. The current strategy is mainly related to the single detector tracking the single destination. This paper presents a distributed target tracking strategy based on multi-detector collaborating, by remote detection mechanisms DTRs (distant tracker records) and close cooperative data exchange mechanism TRs (tracker records) for multi-detector collaborative track. That avoids conflict and redundancy detection to improve track efficiency. Theoretical analysis and experiments verify that the strategy can effectively reduce the tracking steps to improve the success rate as compared to the traditional method.

Keywords: delayed communication synergy, direct communication synergy, multi-detector, target tracking

1 Introduction

DTNs (Delay Tolerant Networks) are a special type of wireless network [1]. It has random mobile nodes. It lacks of sustained end to end path and has limited load of transmission that result in low success rate of data transmission with the larger transmission delay [2-6]. In recent years, target tracking has drawn more and more attention in DTNs. Target tracking and routing forwarding belong to the common basic problems in DTN, with a high similarity between the two, so we usually adopt routing forwarding methods for target tracking. For target tracking, detector tracks according to direct or indirect information left by the target node. Routing forwarding utilizes the chance of nodes encountering to send messages from the source node to the destination node. Routing forwarding methods include Epidemic routing, opportunistic routing, Spray, Wait, and so on. Opportunistic routing forwarding method is the most common one. It avoids a large number of copy in the single copy and multiple copy method, but it brings a large delay because of nodal mobility.

In view of this problem, Chen K and Shen H presented a novel uniformly distributed destination track strategy (DSearching)-combination of objective preference and random mobility--making detectors quickly and effectively find the target node according to the preference areas MPT (Mobility Pattern Table) and Mobile trajectory set VRs (Transient Visiting Record) carried by near nodes [7-8]. The strategy does not depend on the base station and global information. It tracks target adaptatively, to some extent improves the universality of target tracking. However, this distributed strategy abandons reliance on global information [9]. MPT and VRs are carried by ordinary nodes. That has certain instability and may lose MPT and VRs simultaneously. It reduces the reliability and success rate of target search.

To cope with these problems, we present a distributed tracking strategy based on multi-detectors collaboration—TBMC (tracking by multiple concord). It can exchange information, directly or indirectly, between the detectors. This strategy firstly divides the entire DTNs network into several sub-areas according to node's social preferences and there is no overlap between the sub-areas. The area nodes record MPT of all the nodes according to strategy in the literature [8-12]. At the same time, reliable nodes re-

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cord trajectory (VRs) of the target node. The multi-detectors according to the search priority order start searching from target's preference areas in the first round of the MPT respectively. Each detector searches according to MPT and VRs. Between the detectors, there are DTRs (Distant Tracker Records) and TRs (Tracker Records). The detectors avoid conflict detection to ensure that there is no overlapping area of each detector's search. Eventually, the TBMC strategy reduces search time, increases reliability, and improves the success rate.

The main contributions of this paper are as follow:

1) We got designed a collaborative strategy of multi-detectors for DTNs to ensure more efficient tracking.

2) We combined multi-detectors tracking with distributed information exchange strategy to make track process localized, and to reduce dependency on global information.

The remainder of the paper is organized as follows: The section 2 describes related work of the current DTNs target tracking. The principle and specific design of TBMC is detailed in section 3. The section 4 analyses the track effectiveness. The section 5 discovers the optimal number of detectors; the simulation results are presented in section 6, and the conclusion of our research is there in section 7.

2 Related Work

Dynamic target tracking is a common type of target tracking [11-14]. The target nodes in these scenarios have one thing in common that they are on the move [15-16]. This phenomenon carries complication. Since the target position changes all the time, detectors need to know the target position at each moment where the difficulty is.

As to the target tracking mode, there are generally two categories: the use of information of meet node [17-19] and use of geographic information [16, 20-22]. Using information of meet node to track the target, detector will encounter many nodes in the process of tracking. These nodes have met the target node somewhere before. Some nodes have a high similarity with the destination node. The both belong to the same community [22, 24-25]. By utilizing the information provided by the meet node, detectors will find the target node as soon as possible. There are many situations to make use of geographic information. For example, to predict the future movement using the node position history information, the geographic information can used in the network consisting of vehicles, employing the navigation system to determine the location and then forwards the data to node that may has the highest probability of reaching the destination [26-27]. The above two methods are feasible, but they get the target position information in an indirect way and result in too long and low accurate search [28-30]. To deal with these problems, Chen K and Shen H propose DSearching: leaving the next position of target node in the original area. That leaves the detector a direct, continuous movement locus set (VRs). This method, Cenwits, Random, PROPHET and other track strategies have greatly improved success rate, average latency, and average path length and so on. While nodes need more memory to store two types of information set, MPT and VRs of other nodes. It may bring some adverse effects in demanding network environment.

In a large-scale network, the larger coverage area and moving area of nodes making an excessive storage, could lead to a memory overflow before detector finds the target node. In addition, the target information is preserved by the ordinary nodes that have their own moving trajectory. Nodes carrying information may move to the other unknown subarea before detector arrives. That obtains error MPT and VRs and results in trace path redundancy, waste of tracking resources, and even failing track. Especially in some emergency situations we need to find the target node with the shortest possible time. In the case you can make use of the scalability features of distributed network to achieve the fastest rescue goal. We may sacrifice other indicators such as the cost of energy to track regarding time as the main measure. As DSearching does not apply to these situations, in order to resolve these problems, we propose an improved distributed multi-detectors target tracking strategy based on collaboration.

3 Tracking Strategy Based on Multi-Detector Collaborating

In this section, we introduce the design of the tracking strategy based on multi-detector collaborating. This chapter is divided into three sections. The first section is the network model, and it describes the principle and procedures of dividing the whole network area into some sub-areas. The second section is information collection, and it mainly introduces the expression form and specific content of the VRs and MPT and the experimental sample chart. VRs and MPT are the mediation of information transmission for TBMC. The third section is tracking strategy based on multi-detector collaborating. It is the core content of this chapter. It specifically describes the search process of TBMC and two kinds of communication mechanisms in the process of searching–DTRs and TR. Fig. 2 and Fig. 3 describe the above two communication mechanisms.

Tracking strategy based on multi-detector collaborating firstly divides the entire network into some sub-areas. After the initialization of detectors, all detectors enter into each area according to the priority and the order in the MPT. Then, detectors search the target nodes one by one on the basis of VRs and MPT. To avoid duplication of search between detectors that results in redundant waste, the detectors exchange information in the way of areas collaboration. When the detectors stay within communication range of each other, they inform their companion of track area set NC by a simple message delivery. Outside the search range, the detectors leave their track information in behind areas having already searched to inform other detectors their trajectory and direction. At the end, detector launch long-distance transmission to notify all other detectors to stop searching until one finds the target node.

3.1 Network Model

This paper discusses the DTNs that possess social properties, in which nodes move in a particular mode and have their own preferred places called popular places-- apartment, cafeteria, and library etc. [5-7]. The whole network is divided into several independent sub-regions according to these preferences.

We divided the entire DTN area into sub-areas under following rules (see Fig. 1):

1) Each sub-area contains only one popular place.

2) The area between two popular places is evenly split into the two sub-areas containing the two places.

3) There is no overlap among sub-areas.

For example, in Fig. 1, the red circle represents the popular place. We can see from Fig. 1 that there is only one popular place in each sub-area, and the area between two popular places is evenly split into the two sub-areas containing the two places (a=b and c=d).

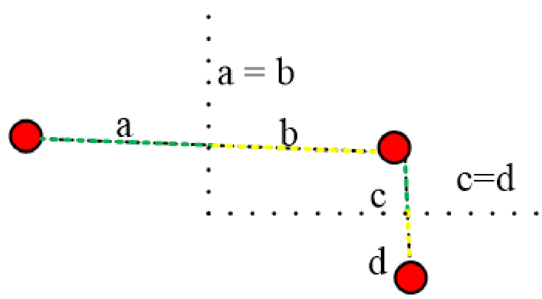

Fig. 1. Division of sub-areas in DTNs

3.2 Information Collection (Representation of Node Mobility)

Our track strategy is a completely independent distributed search. Before starting to track, we need to gather some local information. We assume that information has been collected already before initialization.

VRs (Transient Visiting Records). When a node N_i transfers to area A_{new} from the old area A_{prev}, a transient visiting record will be produced and be preserved by nodes in the previous area. Detector can obtain the information when it arrives. VR contains information as follows:

VR: <N_i, A_{new}, A_{prev}, Time, T_s, Seq>

N_i represents node ID. A_{prev} represents out sub-area. A_{new} represents next sub-area entering. Time represents the time when the node finds that it enters Anew. T_s is the TTL of the VR, and Seq is the sequence number. Seq increases by 1 when a new VR is created.

VR carried by nodes will be deleted when the node leaves the current area or VR’s survival time becomes zero. So node can save storage space.

MPT (Long-Term Mobility Pattern Table). In addition to the transient visiting record, the node also needs to record the long-term mobility information that mainly consists of the staying probability and next sub-area's probability. The probability is obtained after large amounts of data test and records it in the form of MPT. MPT will update at set intervals. Table 1 shows the MPT of this article's simulation. For example, the first line of Table 1 says the staying probability of the node in the sub-area A_5 is 0.35; if not stopping, the probability of going to the next sub-area A_8 is 0.80, and the probability of going to the next sub-area A_2 is 0.20. The value of Seq is 1, indicating the first update. The value in the first column of Table 1 declines from top to bottom, which means the staying probability of the node reduces in some areas.

Table 1. Mobility pattern table on a node

Rank	Sub-area	Staying Prob.	Next sub-area and probabilities	Seq
1	A_5	0.35	$A_8(0.80)$ $A_2(0.20)$	1
2	A_2	0.20	$A_1(0.70)$ $A_3(0.30)$	1
3	A_6	0.11	$A_5(1.00)$ $A_0(0.00)$	1
4	A_8	0.09	$A_7(0.60)$ $A_9(0.40)$	1
5	A_4	0.08	$A_1(0.50)$ $A_7(0.50)$	1
6	A_1	0.06	$A_2(0.65)$ $A_4(0.35)$	1
7	A_3	0.05	$A_2(0.90)$ $A_6(0.10)$	1
8	A_7	0.04	$A_4(0.50)$ $A_8(0.50)$	1
9	A_9	0.02	$A_6(0.85)$ $A_8(0.15)$	1

The meanings of the parameters in the Table 1 are listed below:

Table 2. The meaning of the parameters in the Table 1

Parameters	Meaning of the parameter
Rank	staying probability of node in descending order
Sub-area	sub-area to stay in next step
Staying Prob.	corresponding staying probability at a certain sub-area
Next sub-area and probabilities	if not staying, the sub-area node will go ahead and the corresponding probabilities
Seq	batch of updating

3.3 Tracking Strategy Based on Multi-Detector Collaborating

When obtaining the necessary information, DSearching tracks target according the hint in the VRs and MPT. To improve the tracking efficiency, we propose a mixed and collaborative distributed track strategy based on multi-detector-TBMC. In TBMC, detectors can communicate with each other and inform each other of the trajectory of target node and other detectors. Once one of all the detectors finds the target node, it notifies all other detectors to stop searching.

We assume that the number of detectors is X. After initialization, all detectors enter x sub-areas where the target node most likely to stay, i.e. the top x on the MPT, respectively based on the priority.

Compared to a single detector tracking, the multiple detectors tracking may bring the following issues:

i. Detector continue to search sub-areas have been searched,

ii. Entering into the area in process of searching,

iii. More than one detector leave for the same sub-region.

To resolve these problems, we have designed the TBMC (Tracking by Multiple Concord). For the TBMC, we take it into two circumstances. When the detector stays within the communication range, we adopt direct communication synergies TRs (direct transmission record). Otherwise; we launch the remote delayed communication synergies DTRs (delayed transmission record).

Direct Collaboration TR. When the detector stays within communication range, it can directly transmit information through packet switching. When a detector is about to enter a sub-area X_i, another detector b will transfer the data set TR to detector a if detector b is searching in sub-area X_i. TR contains the number of detector and target node. The sub-areas those have been explored before A_{pre1}-A_{preX}, will be searched in next step, skipped for remaining lifetime T_s. After obtaining these information, detector a will quit sub-area X_i and continue to exclude from the sub-area has been searched and to be searched. Then detector a will leave for the bigger probability staying sub-area after comparing the surrounding probability for the sake of averting tracking redundancy. The specific interaction information of TR is shown below and the process of interaction is shown in Fig. 2.

TR: <b, N_i, A_{new}, A_{pre1} ... A_{preX}, X_i, X, T_s, Seq>

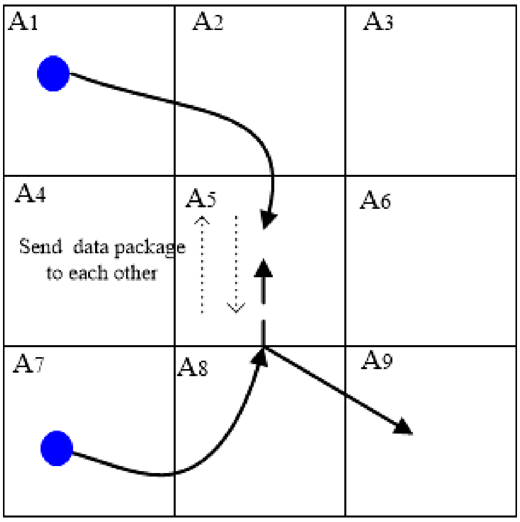

Fig. 2. Communication synergies of TR

Before lifetime of the detector reach to 0, detector launch long-distance transmission to notify all other detectors to stop searching if one finds the target node. Although the transmission distance is far, it will only be adopted once and the energy consumption is negligible.

Long-Distance Collaboration DTRs. Because of the limited communication range of the detector, detectors cannot communicate with each other if their distance exceeds communication range. We adopt a distributed manner leaving the track of detectors to the subsequent detectors. This method effectively avoids repetition. In this case, the nature of the detector is also similar to a node. When the detector b moves from one sub-area to another sub-area, it will leave their track record DTR in leaving sub-area. In addition to relevant information in the TR, DTR contains its own time of departure T_{left}. When other detectors come to this sub-area searched, they will find nodes carrying DTR.DTR records direction of the previous detector. At this point, the circumstance is similar to TR. The later detector a will judge the departure time T_{left} of detector b. When the time from departure to now is less than threshold T_{limt} and survival time doesn't return to zero, the detector a will avoid these areas and select not searched sub-area as the next search according to the information in the DTR, select not searched detector sub-area to the next search. Otherwise, it indicates that the DTR has failed and detector a will continue to explore this sub-area. Threshold T_{limt} should be designated based on the application's needs and it is equal to the survival time of DTR in this article. The specific structure of DTR is shown below and the process of long-distance interaction is shown in Fig. 3.

DTR: <b, N_i, A_{new}, A_{pre1} ... A_{preX}, X_i, X, T_{left}, T_s, Seq>

4 Track Effectiveness Analysis

The reason why we present the TBMC is the higher requirement in tracking time and success rate. So, in this section, we compare the single-detector tracking with the TBMC in the tracking effectiveness to analyze the improving extent in TBMC. This chapter is mainly divided into two sections. The first section is success rate analysis, it analyses tracking method for multi-detectors not collaborating and for TBMC. The second section is analysis of repeating step, it analyses tracking method for multi-detectors not collaborating and for TBMC. This chapter theoretically proves the effectiveness and efficiency of TBMC.

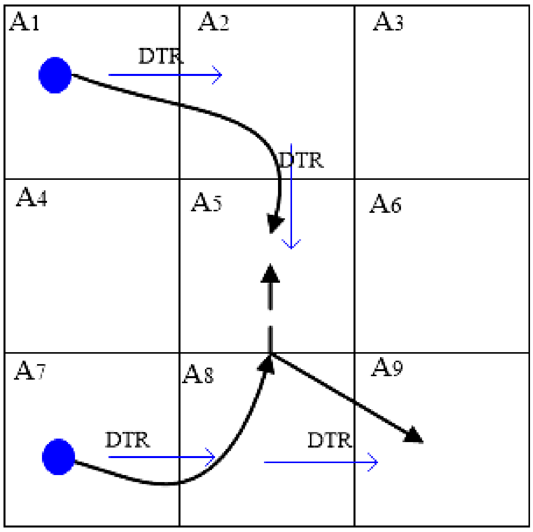

Fig. 3. Communication synergies of DTR

4.1 Success Rate Analysis

Analysis of Success Rate for Multi-Detectors not Collaborating. We set the probability of finding the VRs and MPT of each sub-region as p_v and p_m, respectively. We assume that the average probability of finding the target node successfully based on MPT is $\tilde{p}$. Then, the successful probability of finding the target node after MPT having been found can be expressed as:

$$p' = 1 - (1 - \tilde{p})^m \quad \textbf{(1)}$$

So the success rate can be expressed by the following equation (2):

$$p_{ss} = 1 - \{1 - (p_v + (1 - p_v) \times p_m \times p')\}^m \quad \textbf{(2)}$$

Analysis of Success Rate for TBMC. p_{ss} and $p_{ss}{}'$ represent the probability of finding the target node successful for two detectors, respectively. The success rate p_{sm} of the entire network can be expressed by the following equation (3):

$$p_{sm} = 1 - (1 - p_{ss})(1 - p_{ss}{}') \quad \textbf{(3)}$$

The degree of improvement for TBMC can be expressed by the following equation:

$$\theta = p_{sm} \div p_{ss} \quad \textbf{(4)}$$

The value θ will be greater than 1, and the specific value will be verified in the coming experimental section.

4.2 Analysis of Repeating Step

Analysis of Repeating Step for Multi-Detectors not Collaborating. Assume the number of sub-regions is X. As there is no communication mechanism between the detectors, each detector's searching path will be exactly the same when all the VRs are not missing. That means the repetitive rate is 100% and the detectors are redundant. In the case of losing VRs, detector will continue to search based on MPT.

The repeating step can be expressed by the following pseudocode:

Data: n, m, and k means numbers of nodes, areas and detectors. VRs, MPT as the calculated data

```
Begin
01: Initial detectors location list d[k]
02: Get the biggest mp[k] in MPT table based on the priority
03:for i←1 to k
04:{
      { d[i]←mp[i]}
05: for i←1 to k
     06:  { Try to communicate with other detectors according position d[i]
     and range Rd
07:  if found other detector in range then
08:       {launch the TRs
09:       exchange the searched areas mark in mark[n]}
10:  else
11:       Try to launch the DTRs
12:       if found available DTR then
13:             exchange the searched areas mark in mark[n]}    }
14:for i←1 to k
15: { {while VRs is found do
16: get target areas Anext according to VRs
17:       if Anext didn't mark as searched area in mark do
18:             d[i]←Anext
19:             end searching
20:       else
21:             drop this VRs nav info, try to find new VRs}
22:  {while MPT is found do
23:       get target areas Anext according to NPT
24:       if Anext didn't mark as searched area in mark do
25:             d[i]←Anext
26:             end searching
27:       else
28:             drop this MPT nav info.try to find new MPT}}
29:  announce the nav info mission, search failure
End
```

$T(i)$ represents the repeating step for Multi-Detectors not Collaborating, and it can be expressed by the equation (5):

$$T(i) = 1 + \left\{ p_v + \left({p_m}^2 + (1 - p_m)^2 \right)(1 - p_v) \right\}(i - 1) \tag{5}$$

Analysis of Repeating Step for TBMC. TBMC will repeat the search in the following two cases:

i. When the searching time m of the detector exceeds DTR's living life t, DTR in the sub-area is disabled.

ii. When the DTR is lost (the lost threshold of DTR is h in this article).

Then, the repeating step can be expressed by equation (6):

$$T'(i) = \left\{ \frac{(m - t)}{t} T(i) + hT(i) \right\}(i - 1) \tag{6}$$

5 Optimal Number of Detectors

As above mentioned, multiple detectors can search collaboratively, so the exact number is not fixed. We can adjust number of detectors according to the actual need.

In the larger network, we have the more strict requirements on time and accuracy. We can adopt the aforementioned multi-detector tracking strategy. Such a situation is very common in real life. For example, when an emergency situation requires to find the patient's location in the shortest possible time.

When the intelligence is required to be delivered to a specified person in the time-critical environment, we can calculate the optimal number x of detectors according to our algorithm when an ideal time or accuracy rate has been given based on the real situation.

As we regard time as the main measurement, we will discuss the optimal number of detectors in the case of constraint searching time in the article. If we stipulate a certain time, know searching cost and energy consumption. Then correlate it positively with the number of detectors. We will find the optimal number of detectors- the minimum number satisfying the known searching time.

6 Experiment

Multiple detectors simultaneously search the target node from different sub-areas and actively avoid competition through mutual collaboration between detectors. This mechanism reduces the average latency and increase the success rate. Next, we experimentally verify the improvement of searching efficiency for TBMC.

We mainly investigate the effects of the success rate, the average path length, average node memory usage and average delay caused by detector's number. Figs. 4-7 show the search results and specific data tracking effects for single, two and three detectors, respectively. We set the confidence interval to 95% in the paper.

6.1 Experiments with Different Locator Rates (TTL)

We vary the TTL of each locator to see how different methods scale to locator TTL.

Success Rate. As shown in Fig. 4, the three broken lines represent success rate of three searching methods respectively: the single detector' tracking (DSearching), two detectors' tracking and three detectors' tracking. We see the success rates of the following three methods: three detectors' tracking> two detectors' tracking> DSearching.

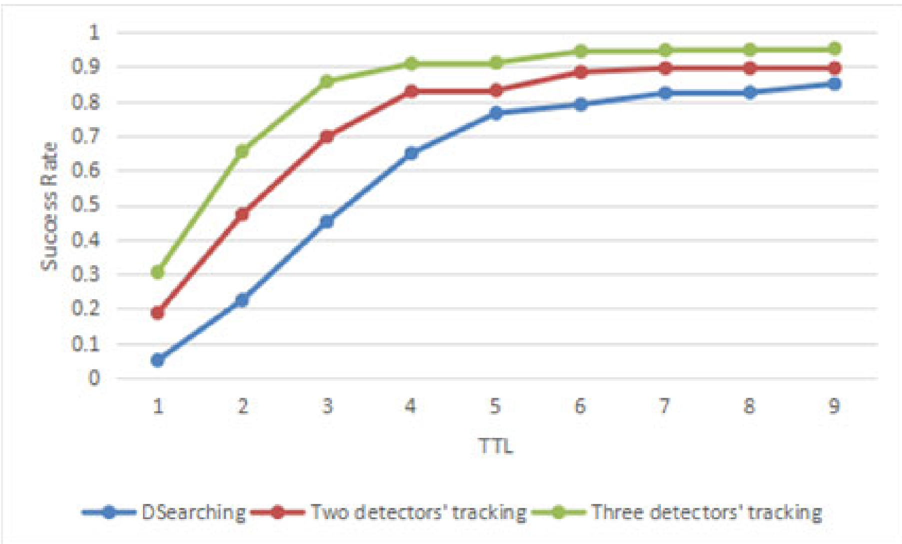

Fig. 4. Success rate

We find that the success rate increases with increasing TTL. On the one hand, when the TTL increases, detector's movement speed is much faster than that of the nodes. So detectors can find the target node after searching just a few sub-areas. On the other hand, when the detector is faster, the target node can be found before energy depletion of detectors and nodes. The above two reasons show that the success rate is positively correlated with TTL. We further observe that three methods have closer and closer success rate with each other. It is because when TTL is particularly large, locators in the three methods all can eventually find most target nodes, leading to a high success rate. However, this comes at the cost of high average delay, as shown in next section.

Average Path Length. As shown in Fig. 5, the three broken lines represent average path length of three searching methods respectively: the single detector' tracking (DSearching), two detectors' tracking and three detectors' tracking. We observe the average path length of the three methods as follows: DSearching> two detectors' tracking> three detectors' tracking.

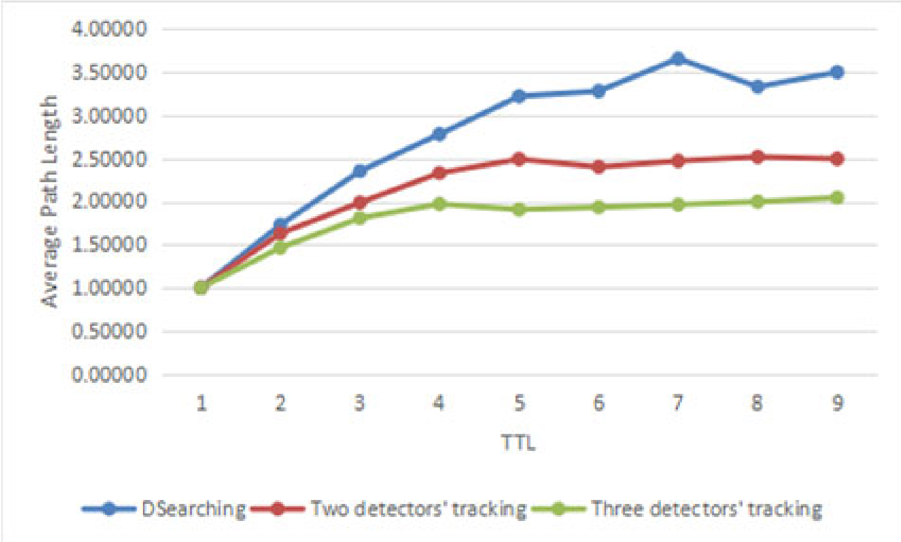

Fig. 5. Average path length

We also observe that the average path length increases with increasing TTL. This is caused by the same reason as we describe before. In two detectors' tracking and three detectors' tracking, there are more detectors than DSearching. And when the TTL increases, detector's movement speed is much faster than that of the nodes. So detectors can find the target node after searching just a few sub-areas.

It means two detectors' tracking and three detectors' tracking consume less searching time and produce shorter searching path length. In addition, when the detector is faster, the target node can be found before energy depletion of detectors and nodes. It also shortens average path length. The above two reasons show that the average path length is positively correlated with TTL. We further find that when TTL increases, three methods have closer and closer average path length with each other. It is because when TTL is particularly large, locators in the three methods all can eventually find most target nodes after searching many sub-areas, leading to a high success rate. However, it comes at the cost of long average search path length.

Average Node Memory Usage. As we can see in Fig. 6, the three broken lines represent average node memory usage of three searching methods respectively: the single detector' tracking (DSearching), two detectors' tracking and three detectors' tracking. We observe the average node memory usage of the three methods as follows: three detectors' tracking> two detectors' tracking> DSearching.

We find that all three broken lines are parallel linears. It indicates mutative TTL has no impacts on average node memory usage. Average node memory usage of three detectors' tracking is more than that of two detectors' tracking and that of DSearching. The reason is that three detectors' tracking and two detectors' tracking request more information left by the target node and collaborative detectors, such as VRs and DTRs. However, DSearching only needs the target's information. Three detectors' tracking co consumers the most node memory usage than others, but it is still a considered small memory consumption. Sensors can easily meet this requirement today. So the big node memory usage does not affect the overall tracking performance. At the same time, we further find that average node memory usage of two detectors' tracking is not twice of DSearching, and average node memory usage of three detectors' tracking is also not twice of DSearching. Because two detectors' tracking and three detectors' tracking greatly reduce the average search time and average search path length due to cooperation between detectors. Thus the frequency of indirect communication between detectors and update of target node's leaving information is low. So it just increases a bit of node memory.

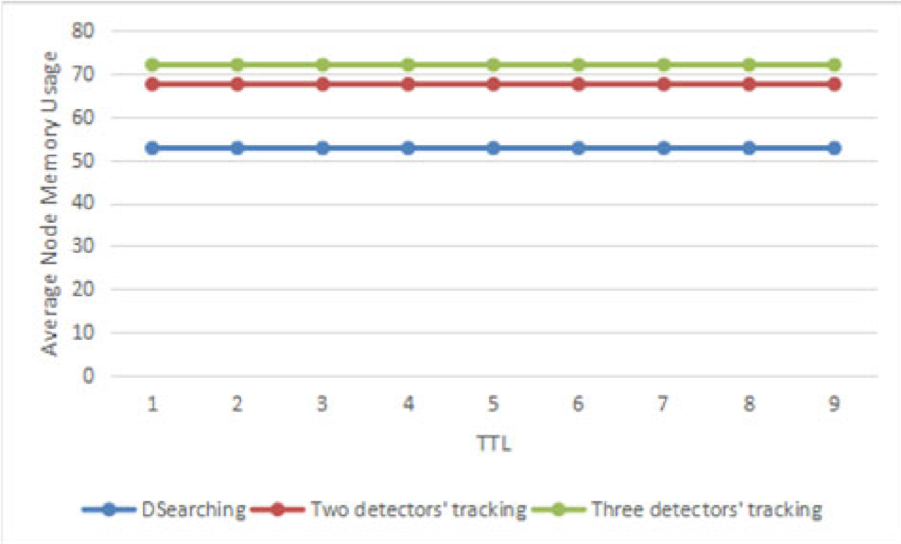

Fig. 6. Average node memory usage

Average Delay. As shown in Fig. 7, the three broken lines represent average delay of three searching methods respectively: the single detector' tracking (DSearching), two detectors' tracking and three detectors' tracking. We observe the average path length of the three methods as follows: DSearching> two detectors' tracking> three detectors' tracking.

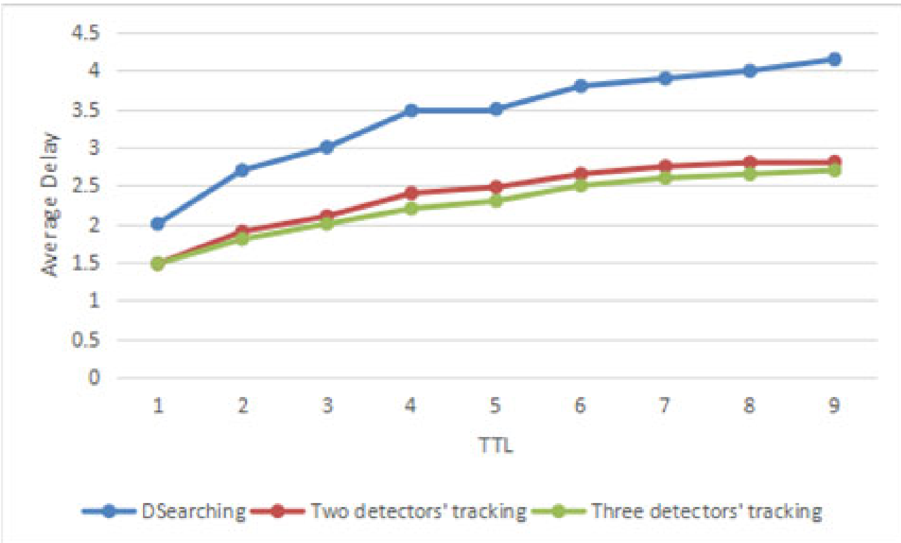

Fig. 7. Average delay

In Fig. 7, firstly we can see that the numerical average delay of these three methods is very small compared to traditional tracking method, such as method based on the meeting possibilities or geographical location. In traditional tracking methods, detectors almost follow node's rhythm, and they go when node goes and they stay when node stays. However, these three methods search target according to the information provided by MPT and VRs. Some nodes stay at their popular sub-areas for a very long time and cause a big average delay. The phenomenon can be resolved effectively in these three methods. At the same time, we find that the average delay increases with increasing TTL. As previously described above, locators in the three methods all can eventually find most target nodes, leading to a high success rate. However, this comes at the cost of high average delay. When the TTL increases to a certain value, the effect on the average delay caused by it becomes smaller and smaller. We further find that DSearching has the highest average delay. The reason lies in that two detectors' tracking and three detectors' tracking have two advantages: they have solved the problem of following nodes and have adopted DTR and direct communication synergy TR. It advances searching effectiveness and reduces delay. When the number of detector continues to increase, the average delay does not last significantly reduced because detector redundancy appears in the search.

Search Time. As shown in Fig. 8, the three broken lines represent search time of three searching methods respectively: Cenwits, DSearching and TBMC. We observe the search time of the three methods as follows: Cenwits> DSearching> TBMC.

In Fig. 8, we further observe that Cenwits has a relatively longer search time, and the reason lies in that Cenwits tracks the target node solely based on the instantaneous information left in the sub-areas. However, DSearching can simultaneously utilize the information left by the target node and the MPT collected before searching. Therefore, DSearching has a shorter search time than Cenwits. In addition, we can see that search time of TBMC is almost but not exact a half of that of DSearching. This is because we adopt two detectors to track cooperatively, and there are inevitable duplicate searches for the same sub-areas. Analyzing the above four main factors, we conclude that TBMC presents superior performance compared to other methods with different TTLs. The result also verifies our design goal: efficient node searching with acceptable cost.

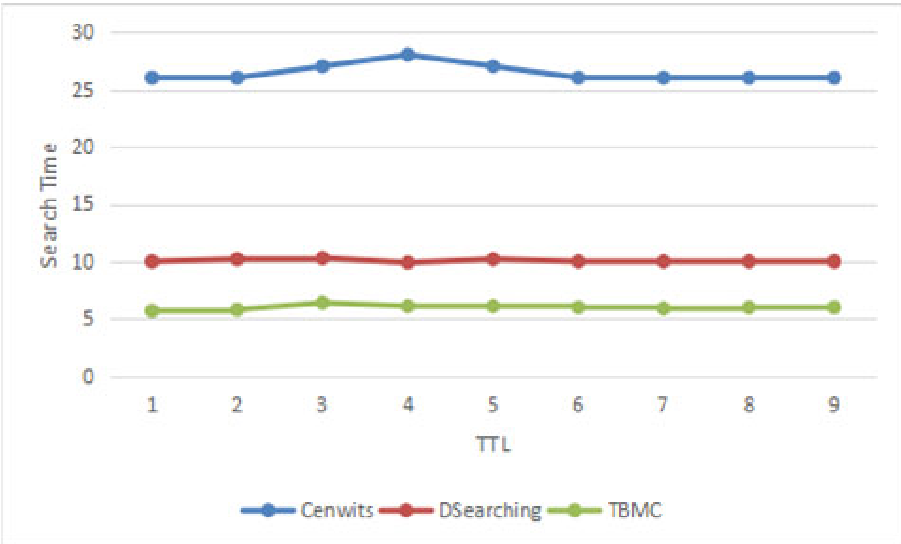

Fig. 8. Search time

7 Conclusion and Prospect

In order to further improve the search efficiency and expand the scope of applications based on the traditional method. This paper presents a multi-detectors collaborative distributed search method. It is a distributed target search method for DTNs mobile node. It is the basis of the conventional method to further improve the search efficiency. Collaborative distributed multi-detectors search method takes advantage of both dispersed in the network VRs and MPT. It traces the trajectory of the target node and also uses TR and DTRs. It extends the detector collaboration and mutual assistance. Under the method search path is not repeated, so that the search efficiency improved. Further it expands the scope of the actual scene of the applications that can adapt to a wide range of network, emergency search and the search time-critical environments. We performed theoretical analysis and simulation experiments. The result of theoretical analysis proves that TBMC can really improve search effect. The experiments verify that the multi-detector collaborative distributed search method is effective and efficient. It can improves success rate and reduce average delay and average path length at the cost of consuming some average node memory usage.

In future studies, we will continue to improve the target tracking method in the following areas: firstly, we should look for a more suitable node information transfer mode, reducing the failure searching case caused by the loss of VRs and MPT. It will greatly improve the success rate of the target track. There is an essential problem: mobile nodes in the DTNs lead to information loss. So the new method of transferring information should aim at this problem. Secondly, we can improve the detector's hardware, such as using the farther-communication-range detectors to search. In the search process, more direct communication mechanism is completed to cooperation rather than adopt so many DTRs. It will reduce the duplication of steps and node memory consumption will also reduce with the reduced DTRs. So that life expectancy of the entire network increases.

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