Improving Path-Coverage for Moving Targets in Wireless Multimedia Sensor Networks

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Abstract —Aimed at the path coverage problem for wireless multimedia sensor networks, MTPCA (Moving Target based Path Coverage-enhancing Algorithm) algorithm is proposed. This algorithm introduces the improved probabilistic model into the virtual potential field based directional sensor network coverage. In order to correct the centroid position of sector area covered by sensor node in traditional probabilistic model, this algorithm puts forward the concept of coverage impact factor to obtain better coverage effect. Furthermore, in MTPCA, multimedia sensor nodes acquire the real-time position information of target point through the discretization of the path curve. In this way, we further adjust the moving directions of each sensor to completely cover all the points along with the path curve. And meanwhile, for the sensing overlapping regions, according to the master active node selection criteria, MTPCA makes no-master nodes asleep for the purpose of energy-saving. The simulation results show that the algorithm can optimize the resource allocation, achieve the satisfactory coverage ratio, and extend the network lifetime.

Index Terms—Wireless multimedia sensor networks (WMSN), path coverage, moving target, energy efficiency, virtual potential force, probabilistic model

I. Introduction

With the technology development of wireless networks and sensing devices, data types of sensor nodes are also diversified rapidly, from the original scalar data to audio, video, and image et al. multimedia data, and therefore compose the wireless multimedia sensor networks (ab. WMSN). Compared with the scalar sensor nodes, multimedia sensor nodes usually have more complex structure, have the data processing and transform module and require the higher network bandwidth. Furthermore, multimedia sensor needs to transmit a large amount of data when communicating with other sensors. Therefore, the traditional techniques of data processing are really not suitable for WMSN [1]. In addition to that, multimedia sensors are more costly in comparison with the common ones such as temperature sensor nodes, which determines they cannot be deployed within the coverage area unlimitedly. So, how to reduce the number of active multimedia nodes, prolong the network lifetime and improve the whole network applicability has become an issue of widespread concern [2], [3]. And in this paper, this problem is closely related to the path coverage of network.

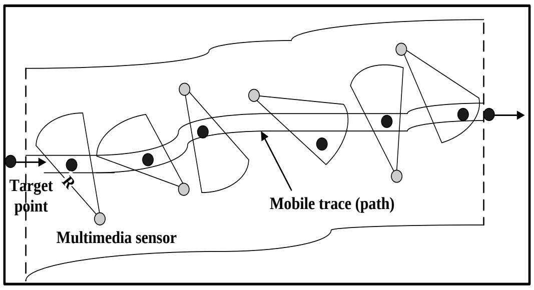

Fig. 1. Problem description of path coverage.

At present, most of the domestic and foreign monitoring systems based on WMSN are static systems. That is to say, we deploy the multimedia sensor nodes in advance and these nodes cover all the areas of concern. In the research of the path coverage [4]-[7], as shown in Fig. 1, it mainly uses the directional perception model, which is more meaningful in dealing with video or images sensing data (where R represents the longitudinal radius of viewing area, usually equaling to the sensing radius of multimedia sensor node). Based on this model, the traditional path coverage technique transfers the path into a set of discrete points. Through deploying the sensor nodes, it makes use of the interaction [4] between nodes or adds the force [5] from target points to make nodes moving, and finally achieves the full path coverage. However, this method tends to ignore the mobility of target and the connectivity of neighboring nodes. Apart from it, the traditional path coverage is lack of flexibility. The presence of a large number of active nodes also increases the network energy consumption and shortens the network lifetime.

This paper proposes a novel wireless multimedia sensor network path coverage algorithm aimed at the mobility of targets. In addition, based on the improved probability model, it uses collaborative communication and interactive force between sensor nodes, making nodes to adjust the moving directions, in order to achieve that fewer multimedia nodes monitor the path of moving targets and meanwhile maximize the coverage. For the overlapped coverage areas, it will set the "master active nodes" and select only one from lots of node candidates

Manuscript received August 4, 2014; revised November 25, 2014.
This work was supported by the Foundation Name under Grant No. 61202355 etc.
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doi:10.12720/jcm.9.11.843-850

according to certain rules, and then makes the other nodes asleep. The certain rules would be executed at the end of the whole algorithm which can effectively reduce energy consumption.

II. Problem Description and Related Definitions

A. Problem Description

In path coverage, multimedia nodes deployment generally obeys a certain probabilistic distribution. Therefore, it can easily lead to uneven coverage in some parts of path. Therefore two problems should be solved: 1) How to use the mobility of nodes to cover all positions of path; 2) How to choose a master active node with responsibility of monitoring the areas covered by several nodes at the same time. Thus we can reduce the energy consumption of the whole network and prolong the network life cycle. This paper provides answers to the above two questions.

B. Network Coverage Model

Based on the directed sensor model in two-dimensional space, the issue of path coverage can be formalized to a quintuple, i.e. $<A, R, \vec{V}, \alpha, \theta>$, as shown in Fig. 2, where A represents the position of one multimedia sensor node in coverage regions, R is the sensing radius that can be described as line AD in Fig. 2, $\vec{V}$ represents the perception direction, i.e. $\overrightarrow{AB}$, α represents the perception angle, and θ represents the angle between the perception direction and horizontal direction.

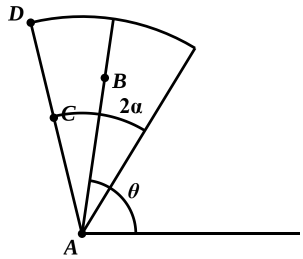

Fig. 2. Directional sensor perception model.

As shown in Fig. 1, path is a continuous curve. And the problem of path coverage can be transformed into how all the points are covered by sensor nodes deployed in this monitoring area. Therefore, we can make path curve discretization, which generates a set of discrete points that is marked with Ω .

C. Related Definition

Definition 1 Euclidean Distance: the Euclidean Distance from node $S_i(x_i, y_i)$ to point $S_p(x_p, y_p)$ is denoted as $d(S_i, S_p)$:

$$d(S_i, S_p) = \sqrt{(x_i - x_p)^2 + (y_i - y_p)^2} \tag{1}$$

Definition 2 Probability Perception Model: the Perceived probability of node S_i to the target t_j in the monitoring area is shown below:

$$P_{ij} = \begin{cases} 1, & 0 \le d(s_i, t_j) \le R_1 \\ e^{-\beta\left[d(s_i,t_j)-R_1\right]}, & R_1 \le d(s_i, t_j) \le R_2 \\ 0, & R_2 \le d(s_i, t_j) \end{cases} \tag{2}$$

where R_1 and R_2 are the values of different radius, and $R_1 < R_2$ (There is a compensatory explanation for their relationship in section 3.1). β is an adjustable parameter associated to the characteristics of hardware architecture of multimedia node.

Based on the probability model in Eq. (2), the set of nodes represented by S contains all multimedia sensors in the coverage region. The perception progress of path curve can be defined as follows: for each order $pair(S_i, w)$, where $S_i \in S \quad w(x_{w,} y_w) \in \Omega$, it can use a function, for example $f(S_i, w)$ to represent a certain capacity of the sensor node S_i covering the target point w . Therefore, the coverage of points in the curve can be defined as follows:

Definition 3 The target point w in the curve covered by the set of sensor nodes. Marked as $\varphi_s(w)$:

$$\varphi_s(w) = \begin{cases} 1, \text{ if } \eta\left(f(S_1, w), f(S_2, w), \cdots, f(S_N, w)\right) > 0 \\ 0, \text{ otherwise} \end{cases} \tag{3}$$

where η represents a synthesis function used to measure the effect of interaction between each two nodes. N represents the total number of sensor nodes. So the coverage of path curve L is defined as definition 4.

Definition 4 The coverage of path curve L covered by the set of sensor nodes S , marked as $C_s(\mathrm{L})$:

$$C_s(L) = \frac{\int_{w \in L} \varphi_s(w) dw}{|L|} \tag{4}$$

where $|L|$ represents the length of path curve, showing the continuous representation of the set of points in the curve.

Here it specifies the function η with the results of OR operations by probability function $f(s_i, w)$ in Eq. (5):

$$\begin{aligned} &\eta\left(f(S_1, w), f(S_2, w), \cdots, f(S_n, w)\right) \\ &= f(S_1, w) \parallel f(S_2, w) \parallel \cdots \parallel f(S_n, w) \end{aligned} \tag{5}$$

The probability function $f(s_i, w)$ is formalized as Eq. (6)

$$f(S_i, w) = \begin{cases} 1 \text{ if } \left| \dfrac{\overrightarrow{S_i w} \bullet \vec{V_i}}{|\overrightarrow{S_i w}| \bullet |\vec{V_i}|} \right| \ge |\cos\alpha| \\ 0 \text{ otherwise} \end{cases} \tag{6}$$

where $\vec{V_i}$ is the perception vector of multimedia sensor node S_i , α represents the perception angle and $\bullet$ is the operator of dot product.

III. Probability Model

A. Multiple Coverage

For any point in the target monitoring area, if it is covered by several multimedia sensor nodes simultaneously, the traditional judging principle is selecting one node with the maximum coverage probability from these nodes. However it ignores the simultaneous influence of every node on this target point. For example, the energy of the selected sensor node in monitoring area is almost exhausted and it cannot continue the subsequent monitoring, which would cause the requirement to re-selecting. There is no doubt that it wastes not only time but also energy. Thus, for WMSN with limited energy, how to take the multiple coverage of monitored points into consideration is very important [8], [9].

Based on Eq. (2), when the distance between the target point and one sensor node is smaller than the threshold value R_1 , the probability that target point is covered by this node is 1; When the distance value is between R_1 and R_2 , the probability depends on the distance value; When the distance value is larger than R_2 , the probability of target point being covered is 0. When the target point is covered by several nodes, i.e. the density of nodes in the monitoring area is high. If there are N nodes distributed in the target monitoring area (N is much larger than the number of nodes achieving full regional coverage), and then the current probability of target area being covered is marked as P_j :

$$P_j = 1 - \prod_{i=1}^{N}(1 - P_{ij}) \tag{7}$$

It's obvious that $P_j \geq P_{ij}$, i.e. the probability of area covered by several sensor nodes is larger than that of area covered by a single sensor node. And $P_j = P_{ij}$ is correct if the area is covered by only one sensor node.

B. Master Active Node Selection Criteria

When the moving target travels through the path curve, it is no necessary that all multimedia sensor nodes monitor it. For example, in the overlapped area, only one active node may be selected as the master node to complete monitoring according to a certain criteria. And the other sensor nodes in this coverage region would sleep to save energy [10]. Eq. (7) solves the calculation problem of probability that a target point is covered by several sensor nodes at the same time [11]. However, it doesn't solve the problem of which node should be chosen as the master when several nodes cover the same target point at the same time.

The measure function of node S_i covering target point w in the monitoring area is described as $Ef\left(S_i, w\right)$:

$$Ef\left(S_i, w\right) = C_s\left(L\right) - C_{s-\{S_i\}}\left(L\right) \text{ if } f\left(S_i, w\right) > 0 \tag{8}$$

In Eq. (8), if the point w is covered by the sensor node S_i and we delete the node S_i, the more awful the coverage of path curve is, the more important the node S_i is. So, the greater contribution the chosen node makes to the whole coverage, the fewer times we ensure to replace this currently chosen node. Therefore, when several nodes cover the target point at the same time, the sensor node whose value of $Ef\left(S_i, w\right)$ is maximum would be selected as the monitoring master node. And the other nodes would enter sleep.

IV. Path Coverage and Node Scheduling Algorithm

Only when the points on the moving target path are covered by multiple multimedia sensor nodes, there exist the problem of choosing the master monitoring node and the node scheduling algorithm would be executed.

A. Analysis of the Virtual force Based on the Probability Model

The problem of the path curve coverage can be simplified to an optimization problem: for the coverage area of N sensor nodes, at each moment k , the coverage of these nodes is transformed to a set of states, i.e.

$$\begin{aligned}\omega_k = \{ &< P_{1k}, R_{1k}, V_{1k}, \alpha_{1k}, \theta_{1k} >, \\ &< P_{2k}, R_{2k}, V_{2k}, \alpha_{2k}, \theta_{2k} > \cdots \\ &< P_{Nk}, R_{Nk}, V_{Nk}, \alpha_{Nk}, \theta_{Nk} > \}\end{aligned}$$

The final achievement of path coverage is the solution of a set of states:

$$\begin{aligned}\omega_{k'} = \{ &< P_{1k'}, R_{1k'}, V_{1k'}, \alpha_{1k'}, \theta_{1k'} >, \\ &< P_{2k'}, R_{2k'}, V_{2k'}, \alpha_{2k'}, \theta_{2k'} > \cdots \\ &< P_{Nk'}, R_{Nk'}, V_{Nk'}, \alpha_{Nk'}, \theta_{Nk'} > \}\end{aligned}$$

to make $C_{k'}(L) \geq C_k(L)$.

Unlike the area coverage, path coverage pays more attention to each point of the path curve, not just the sensor nodes. Therefore, when calculating the virtual force based on the virtual potential field, the interactions between sensor nodes and the path curve points need to be considered. Virtual potential force is mainly divided into two categories: the repulsion makes the multimedia sensor nodes' centroids away from each other, to eliminate overlapped coverage area; another is the gravity between the point on the path curve and the sensor node's centroid, to eliminate the blind coverage area. The effect from repulsion and gravity will finally lead to the following state: all the sensor nodes which cover the path curve will adjust their perception directions to achieve coverage as high as possible, at the same time make the blind spot and overlapping area as little as possible.

We will analyze the two kinds of forces respectively.

1) Repulsion between the centroids of nodes

When the distance between two sensor nodes is less than 2 times of the sensing radius R , it is possible that the two nodes' sensing areas have some overlaps, and there may exist repulsion. If several multimedia sensor nodes' perception areas exist overlaps, the coverage probability should be the maximum value among these nodes. In addition, according to the probability perception model, we can find that the impact caused by one node can be ignored when its probability is less than a certain threshold, and the threshold value can be determined by some related parameters such as R_2 , β and so on. It is supposed that the probability threshold is $e^{-\beta[R_2-R_1]}$ in this paper, and meanwhile $R=R_2$.

Under the force of repulsion, multimedia nodes will repel each other to maximize the coverage. But the condition that the distance between nodes is less than 2 times of R is only the necessary condition for the existence of overlapping regions but not the sufficient one, therefore, it is unreasonable to determine whether repulsion exists only depends on the distance between two nodes. Ref. [12] proposed that the situations which the perception area of sensor model has overlap are totally 11, besides, when the distance $R=R_2$ between two nodes is more than 2R, the repulsion cannot exist because there will no overlapping areas exist between the nodes.

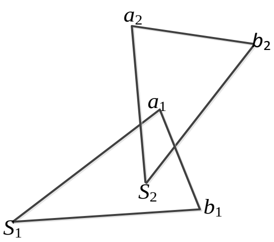

Fig. 3. The model of regional intersection.

Ref. [13] gives another condition to find the perception overlapped area: after the perception model is simplified as a triangle, we can determine whether there is overlapped area through judging whether two triangles have intersecting edges according to straddle test. The two triangles with overlapped area must have an edge intersection, such as the intersection between S_1a_1 and S_2a_2 in Fig. 3, and they should satisfy Eq. (9) at the same time, where * is the operator of cross-product:

$$\begin{array}{l}\left[(a_2-S_1)\times(a_1-S_1)\right]*\left[(a_1-S_1)\times(S_2-S_1)\right]\ge 0\\ \left[(S_1-a_2)\times(S_2-a_2)\right]*\left[(S_2-a_2)\times(a_1-a_2)\right]\ge 0\end{array} \quad (9)$$

When the relationship between two nodes S_i and S_j satisfies Eq. (9), there exists repulsion force S_j between them, we can define as:

$$\mathbf{F}_{rep}(i,j)=\begin{cases}\dfrac{k_{rep}}{d(x_i,x_j)^2}(\dfrac{x_i-x_j}{d(x_i,x_j)}), & SD_i\cap SD_j\ne\varnothing\\ 0 & , SD_i\cap SD_j=\varnothing\end{cases} \quad (10)$$

where K_{rep} is repulsion coefficient, and it is a positive number, x_i and x_j is respectively the centroid of the sector area covered and formed by node S_i and, SD_i and SD_j is respectively the size of area covered by node S_i and S_j . Therefore, the vector sum of the repulsion which the node S_i suffers from its K neighboring centroids, namely virtual resultant force $F_{rep}(i)$ is defined as:

$$F_{rep}(i)=\begin{cases}\sum_{j=1,j\ne i}^{K}F_{rep}(i,j), & K\ge 1\\ 0, & K=0\end{cases} \quad (11)$$

2) Gravity between node's centroid and the path curve point

In the wireless multimedia sensor network, path curve points have gravity to some nodes' centroid when these points are not covered by these nodes, therefore it can improve the convergence of the algorithm. When these points on the path curve are within the perception range of these nodes, that is when these multimedia sensor nodes can sense these target points by adjusting their perception directions, farther the distance from target points to the nodes, bigger the gravities they suffered, which can help the nodes to adjust to cover the target points quickly. However, if the points on the path curve have already been covered by nodes, the gravity does not work. Whether the points on the path curve are covered by the sensor nodes is determined by Eq. (3).

The gravity is proportional to the distance value, for special circumstances, such as when the distance is 0, we can set the gravity to 0. Therefore, the size of the gravity which the point j on the path curve gives to the node S_i can be expressed as:

$$\mathbf{F}_{att}(i,j)=\begin{cases}k_{att}d(S_i,j)^2, & \varphi_s(j)=0\\ 0, & \varphi_s(j)=1 \text{ or } d(S_i,j)=0\end{cases} \quad (12)$$

where k_{att} is called as the gravity coefficient, we define the sum of the gravity which multiple points on the path curve give to S_i as:

$$\mathbf{F}_{att}(i)=\begin{cases}\sum_{j=1}^{K}\mathbf{F}_{att}(i,j), & K\ne 0\\ 0, & K=0\end{cases} \quad (13)$$

For the sensor node S_i near the path curve, the total force it suffered is consist of the resultant repulsions from the centroids of its neighbor nodes and the resultant gravities from the path curve points, seen as in Eq. (14).

$$\mathbf{F}_{total}(i)=\mathbf{F}_{att}(i)+\mathbf{F}_{rep}(i) \quad (14)$$

B. Nodes Scheduling State

When the target point comes to the path curve, multimedia sensor nodes change their states as the target point moves. In order to facilitate the calculation, we divide the states of the sensor nodes into three types:

1) The active state: the target point is covered by the sensor node, and the node is selected as the master monitoring node;

2) The sleep state: the sensor node doesn't cover the target point, or the node covers the target point but it is not selected as the master node, the node only retains simple communication function at this time;

3) The critical state: when the target arrives at the boundary of the area which the sensor node covers, the master node selection criteria mentioned in the section 3.2 would be executed to decide whether the node is selected as the master monitor.

Switch of each state is shown in Fig. 4.

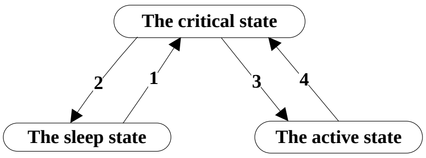

Fig. 4.The switch of multimedia sensor nodes' states.

The interpretation of the each switch is listed as follows:

Step 1: when the monitored target arrives at the area which the multimedia sensor node covers, the sensor node comes to the critical state and start to judge in terms with selection criteria.

Step 2: after the judgment of the critical state, the nodes which are not selected as the master active node enter the sleep state one more time.

Step 3: the selected node will enter the active state and monitor the activity of the target point.

Step 4: when the target enters the overlapped area between two nodes, the sensor nodes come to the critical state and re-execute step 1.

C. Moving Target Based Path Coverage-Enhancing Algorithm

MTPCA(Moving Target based Path Coverage-enhancing Algorithm) will be described in detailed. Firstly, some relevant definitions are provided as follows:

Definition 5 The ratio of regional coverage: the ratio of the area *Cs* practically covered by the set of nodes S to the area A which needs to cover is marked as $C_r(C_S, A)$.

$$C_r\left(C_S, A\right) = \frac{\int_A v\left(p\right)dp}{V\left(A\right)} \tag{15}$$

where $V\left(A\right)$ is the measure of the deployed are A, for an arbitrary point $p \in A$, has:

$$v\left(p\right) = \begin{cases} 1, C_S\left(p\right) \geq 1 \\ 0, otherwise \end{cases} \tag{16}$$

The CS (p) represents the number of nodes covering the point p. Where, the more of $v(p)$ the better of the ratio of regional coverage.

Definition 6 Coverage impact factor: coverage impact factor μ represents the impact on the ratio of the network coverage caused by one time moving of the nodes, seen as in Eq.(17), where $C'_r(C_S, A)$ is the ratio of the new regional coverage after the nodes move one time.

$$\mu = \begin{cases} 1, C'_r(C_S, A) > C_r(C_S, A) \\ 0, C'_r(C_S, A) \leq C_r(C_S, A) \end{cases} \tag{17}$$

The detailed description of the MTPCA algorithm is given in Table I.

TABLE I: STEPS OF MTPCA ALGORITHM

//initialization
1) t←0 // set the initial step length.
2) Set the relevant parameters and coefficients of the multimedia sensor nodes, and deploy the sensor nodes in the coverage area randomly.
3) Initialize the set of the path curve points and the set size *Ccount*, and acquire the collection of the positions of the multimedia nodes which are near the curve.
4) Set the maximum number of loops *tmax*;
while(t<tmax)do
{
5) Calculate the resultant forces suffered by node S_i according to Eq. (12)~(14), including repulsions and gravities.
6) Calculate the component force in the tangent direction of sensor node S_i, and finally determine the rotation direction of S_i.
7) Calculate the coverage ratio after the rotation of one step according to Eq. (3), and decide whether the sensor node rotates again according to the coverage impact μ.
8) t←t+1;
}
9) Set trace point counter *iNodeCount*=0;
while(*iNodeCount*<*Cconut*)
{
10) Calculate the set of the sensor nodes which cover the *iNodeCount*-th *path curve point*.
}
11) Select the master active sensor node which covers the *iNodeCount*-th path curve point according to the selection criteria, and record it.
12) *End*.

V. THE SIMULATION AND VERIFICATION OF MTPCA ALGORITHM

The simulation experiments of MTPCA algorithm use VS2010 to develop and implement. Matlab2009 is used to display the data, also verify the effectiveness and superiority of the MTPCA algorithm.

A. Parameters Settings

In the simulation experiments, we set the target region as a 500m × 500m square, with a number of mobile nodes randomly distributed in the region. The repulsion coefficient k_{rep} between two nodes is 1, the gravity coefficient k_{att} between the node and the target point is 0.025, the parameter β in the probability model is 1.

B. Analysis of Algorithm Convergence

The convergence of the algorithm is a necessary premise for the validity of the algorithm.

The MPTCA algorithm uses random generating function to generate 8 different topologies with the different scale of nodes, and records the loops' number until the coverage trends to stable, the detailed data is shown in Table II. Other experimental parameters are set as: R_1=20 m, R_2=40 m, α=π/4, the distance between two path curve points is 5m.

Apparently, according to Table II, the following conclusions can be drawn by analyzing the data of the experiments: the average number of loops while obtaining convergent coverage ratio is usually in the range of [5], [7], it is not affected by the size of the network. Therefore, the MTPCA algorithm has good convergence; it can complete the coverage enhancement process within a relatively short period.

TABLE II: ANALYSIS OF ALGORITHM CONVERGENCE

The number of nodes N	The original coverage ratio %	The final coverage ratio %	The number of loops t
50	23.7346	42.2588	5.6
100	54.7342	87.4132	5.7
150	67.6025	95.4728	6.2
200	79.2651	98.8729	5.6

TABLE III: ANALYSIS OF EXAMPLE OF MTPCA ALGORITHM

Adjustment times	0	1	2	3	4	5
Coverage ratio	48.032	61.582	76.643	81.265	84.493	87.391

C. Analysis of Examples of MTPCA Algorithm

In this section, we will analyze an example, where the target area is a 500m × 500m square, with 80 rotatable multimedia sensor nodes be distributed in the area randomly. The repulsion coefficient k_{rep} between two nodes is 1, the gravity coefficient k_{att} between the node and the target point is 0.025, the distance between the path curve points is 5m, other parameters in the probability model are set as β=1, R_1=20 m, R_2=40 m, α=π/4.

After setting the parameters, we observe the convergence of the algorithm by simulating and the data is shown in Table III.

After setting the parameters, we observe the convergence of the algorithm by simulating and the data is shown in Table III. In this example, the coverage probability becomes stable after five adjustments, though the coverage increase is not obvious, at around 85% stably, compared with other classic algorithm such as PEPCE algorithm (Potential Field based Path Coverage Enhancement algorithm) proposed by Tao [4] et al. and IPFPCA algorithm (Improved Potential Field based Path Coverage-enhancing Algorithm) proposed by Xiao [5], the MTPCA algorithm can quickly obtain convergence due to the introduction of the coverage impact factor, which can be reflected in Fig. 5.

We will observe the influence on performance of the MTPCA algorithm by changing the main parameters such as the moving step length, i.e. the rotational angle each time, and the linear density of path curve points. They are shown respectively in Fig. 6 and Fig. 7.

We set the length of moving step as 5, 10, 15 respectively, and it can be seen that the coverage probability does not increase as the length increases from Fig. 6, that because the increase of the length only accelerates the convergence speed. The coverage probability may be volatile when it reaches a certain level, and it swings back and forth around the optimal value. In the simulation example, by contrast, it reaches the best level apparently when the step length is 10.

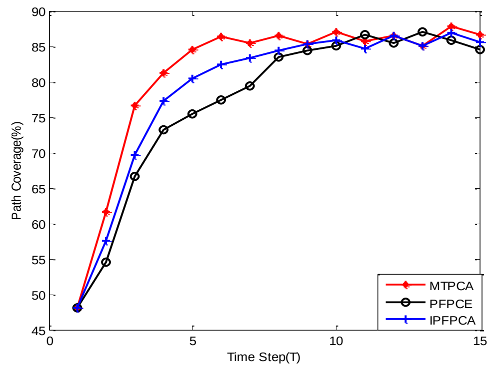

Fig. 5. The covering performance of MTPCA.

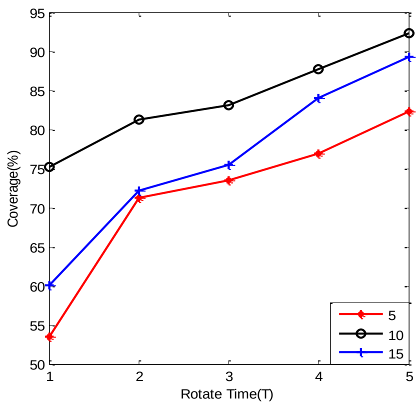

Fig. 6. The influence by the length of the step.

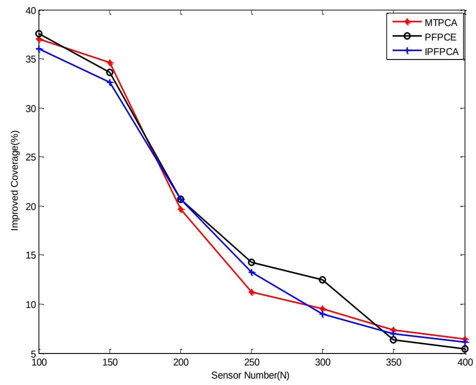

Fig. 7. The relationship between the coverage enhancement and the number of the nodes.

When the density of the path curve points has a given value, the coverage ratio is mainly determined by the number of nodes which are deployed in the coverage area, larger the number of the nodes, higher the coverage ratio. However, the coverage enhancement is not necessarily improved as the number of nodes increases, as shown in Fig. 7, when the number of nodes is 100, the coverage enhancement is the best, and when the number is above 350, the improved coverage is tiny.

The MTPCA algorithm has a better energy-saving effect by introducing the master active node selection criteria. It is obvious that the MTPCA algorithm obtain the better efficiency on energy consumption than the algorithm without this selection criteria. Multimedia nodes are still distributed in a 500 m× 500 m square area randomly, the number is 100, 150, 200, 250, 300, 350 and 400 respectively, their initial energy is 10J, the energy consumption is 0.05J when the nodes move one step length, the nodes on active state consumes 0.01J every hour, and the nodes on the sleep state consumes 0.002J every hour. Shown as in Fig. 8, after 10 adjustments, there exists a gap of the average residual energy between the two algorithms. Because the coverage ratio increases most significantly when the number of nodes is 100, and meanwhile the moving steps is the most, to ensure and maintain the coverage ratio, the number of nodes on the active state is the largest, so the average energy consumption is the biggest, which will decline with the number of nodes increases. Obviously, the MTPCA algorithm using the sleep scheduling mechanism is more energy-efficient.

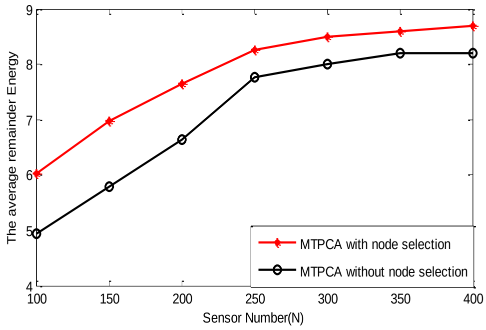

Fig. 8. Comparison of the energy consumption when the MTPCA takes the master node selection criteria or not.

VI. CONCLUSIONS

For this issue which the moving target crosses through the path covered by the wireless multimedia sensor network, based on the improved probability model and the virtual potential field, the MTPCA algorithm can decide the adjustment directions of sensor nodes according to the resultant force. Furthermore, after completing the initial deployment of the multimedia nodes, aimed at a target point in the path curve, the master active node would be selected in terms with a certain criteria, and meanwhile other nodes would sleep in order to save the energy. Finally, the effectiveness of the MTPCA algorithm is verified by simulation experiments. However, when the number of the nodes is too few to form the effective coverage area completely, and even no overlapped coverage areas exist, the MTPCA algorithm will lose its advantages, degenerate into a simple path coverage algorithm. Therefore, when the nodes' density in the monitoring region is relatively sparse, whether collecting all the nodes to detect the target path to improve the coverage ratio is the main problem we will study in the future.

ACKNOWLEDGMENT

This work was supported in part by grants from the National Natural Science Foundation of P. R. China (No. 61202355, 61201163, 61373138), Scientific and Technological Support Project (Industry) of Jiangsu Province (No.BE2012183), Natural Science Key Fund for Colleges and Universities in Jiangsu Province (No.12KJA520002), Postdoctoral Foundation (No. 2013T60536), Science and Technology Innovation Fund for Higher Education Institutions of Jiangsu Province (No.CXLX13_467).

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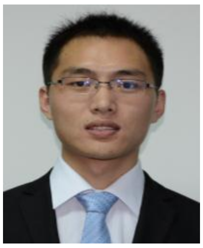

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