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Improved Wireless Sensor Networks Localization Algorithm Suit for Underground Coalface Environment

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Due to complex environment and multi influencing factor of coalface, Wireless Sensor Networks (WSN) based safety monitor system is an effective solution for coalface environmental monitoring and underground miner positioning. Based on analysis of environmental features of coalface, a WSN node deployment method is proposed in this paper, and DV-HOP localization algorithm is determined to be coal miner location solution. Due to low accuracy of DV-HOP algorithm on condition of uneven structure of coalface WSN and big distance gap between adjacent nodes, a RSSI-based weight DV-HOP algorithm is proposed in this paper. In the algorithm hops of adjacent node is weighted by RSS value of flooding packets transmitted between adjacent nodes, which can associate hops with distance of adjacent nodes. Simulation results show that under the same experimental accuracy of our algorithm is better than DV-HOP algorithm, and can meet localization requirement of coalface environment much better.

Key words: Wireless Sensor Network, Localization, DV-HOP, RSSI, Coalface.

In China coal mine has complicated geological conditions, underground coal mining often faces the threat of disasters, which has brought a great security risk to safety of coal mine, and effective safety monitoring and personal location technology on coal face will greatly reduce the incidence of coal mine accidents (Gangzhu Q *et al.*, 2012). There are poor working conditions on underground coal face, larger concentration of dust, a large number of coal mining equipments in the space, wiring is extremely difficult, traditional wired monitoring system can not meet requirements of full range of mine safety monitoring. Wireless sensor network has the features of low-cost, low power, simple to deploy, without on-site maintenance, etc, can achieve a variety of low-cost unmanned continuous monitoring of hazardous areas (Kai *et al.*, 2012),and can solve the problem of coal mine face deployment and maintenance effectively .

As location information is foundation of Wireless sensor network application, lack of location information will make WSN applications meaningless. Establishing a reliable and practical coal mine localization algorithm is the key of underground wireless sensor network application, which has important practical significance for improving mine safety level and production management level. Due to poor working conditions on underground coal face, which is replete with high concentration of dust and a large number of coal mining equipments in the space, these factors have a great interference on underground radio transmission, and traditional wireless sensor network node self-localization algorithm can not

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be directly applied on underground wireless sensor network. So, it is very necessary to study wireless sensor network node self-localization algorithm suitable for underground coalface environment.

Underground position algorithm

Existed study

Recent year lots of node self-localization algorithm have been proposed. Zhang (ZhiBin Z *et al.*, 2009) has proposed a weighted Centroid algorithm based on RSSI ranging; Wang (Yang W *et al.*, 2009) has proposed a positioning algorithm using distance of adjacent beacon nodes and RSSI value to adjust weight of each mobile nodes and beacon nodes; Wang (Sheng W *et al.*, 2006) designed a new node location algorithm based on DV-HOP algorithm and Probability Grid scheme; Han (Ping H *et al.*, 2007) has proposed a underground tunnel positioning algorithm based on TOSP(Time of Signal Propagation) algorithm; Tian (Hong-xian T *et al.*, 2008) proposed a RSSI value matching localization algorithm with RSSI strength of combination between experience of signal strength and channel estimation value; Abdellah (Abdellah *et al.*, 2009) proposed a mine location algorithm based on TOA(Time of Arrival) algorithm; Liu (Xiaowen L *et al.*, 2012) proposed a signal strength interpolation algorithm based on RSSI algorithm by combine related theory with experiment.

DV-HOP algorithm is a range-free localization algorithm (FuBao *et al.*, 2005), which do not need to measure distance or angle information of nodes and can overcome shortcomings of direct trilateral localization algorithm. It estimates distance through exchanging connectivity information and multi-hop routing information between nodes, and eventually estimates location of node. The algorithm takes product of average distance of hop and hops between unknown nodes and beacon nodes as distance from unknown nodes to beacon nodes. Having got more than 3 distance information to beacon node, blind node can use triangular positioning algorithm or maximum likelihood estimation to work out its location information. Simulation results has shown that when average connectivity of network is 10, average positioning accuracy of DV-HOP algorithm can reach 33 percent, which has reached requirements of WSN positioning applications (FuBao *et al.*, 2005).

Localization algorithm

Stopping method is widely used in underground coalface recent years, whole coalface can be seen as square structure with one side opening, shown as Fig. 1. Along with the push of coal mining, coalface move forward constantly (Lijuan *et al.*, 2010), and shape of coalface changes constantly (Hengshen *et al.*, 2010). In view of this situation, beacon nodes could be deployed at both sides of coalface, bracket and mining machine. Through WSN of coalface, the environmental data of coalface can be reported to surface safety control center constantly. Surface safety control center can also locate and track position of equipment and miner in coalface area through coalface WSN localization technology. To ensure effectiveness of WSN node communication, beacon nodes can be deployed at three sides of coalface with interval of 20 meters.

There are many factors affected on wireless communication at coalface, existing range-based localization algorithm can not be used in face which is limited by cost and accuracy. Among range-free positioning algorithm, as Centroid algorithm is strict with layout and node density of network, it can not meet localization requirements of rapidly changing structure of underground network. Among range-free positioning algorithm, as DV-HOP algorithm has the features of easy realization and is less influence by environment factors, it has been widely used in WSN node localization.

DV-HOP algorithm has low requirement to deploying density of beacon nodes and only requires that beacon nodes should be deployed at edge of network, which can meet very well by coalface WSN, so DV-HOP algorithm is selected as node self-localization algorithm in this paper.

Existed problems

As DV-HOP algorithm uses straight line distance between beacon nodes to estimate curve distance of beacon nodes, when DV-HOP algorithm calculates minimum-hop distance, no matter physical distance between adjacent nodes is far or near, value of hops only increase by 1, which can not reflect difference of distance degree.

If structure of WSN is uniform, this hop distance calculation method has little affection on positioning error. However if structure of WSN is non-uniform or is sparse, it will increase node localization error. Limited by terrain and equipment, deployment of underground coalface WSN is a typical non-uniform structure, in which at the area near device distribution of nodes is comparatively centralized and at both sides of coalface distribution of nodes is sparse, which will lead to large location error for DV-HOP algorithm.

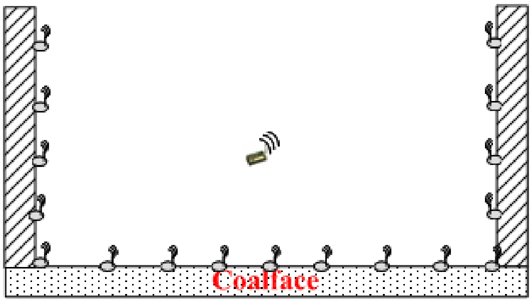

Fig. 1. Beacon nodes deployment at coalface

Shown as figure 2, L1, L2, L3 are three beacon nodes, other nodes are unknown nodes. Actual distance from C to L3 is 5 and actual distance from C to B is 25. Because hops from node B to L3 is only 2, when calculates with DV-HOP algorithm, estimated distance from node C to L3 is 10 and that from node B to L3 is 20, there is bigger error compared with actual distance. So when network architecture is uneven in which gap of nodes distance is large, these have great influence on locating accuracy. About this problem, a weighted DV-HOP algorithm based on RSSI is proposed in this paper, which uses weighted processing based on RSSI value of the neighbor nodes hop, to improve localization accuracy and reduce positioning errors caused by uneven network problem.

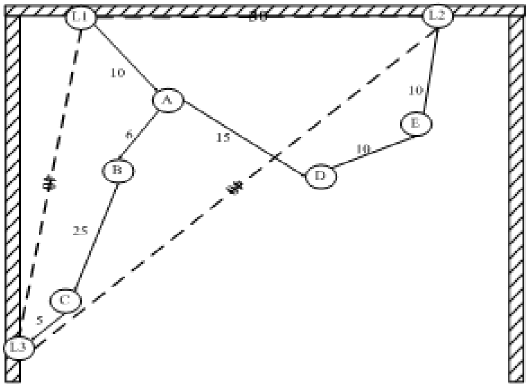

Fig. 2. Distance estimation error schematic diagram

Improved localization algorithm

As DV-HOP algorithm dose not consider difference of each hop when it counts hops of adjacent node, localization error will increase greatly if difference of distance between adjacent nodes is obvious. If distance factor is taken into account when calculating number of hops, localization error will reduce and localization accuracy will improve. Because vast majority of nodes have radio signal strength detection hardware, and signal strength can be seen as distance feature, so we can use radio signal strength(RSS) to weight hops of adjacent nodes. In this paper the hop statistic method of DV-HOP algorithm is improved. The improved algorithm uses RSSI value of first hop from beacon nodes to adjacent nodes as benchmark, count of this hop is 1, and adds RSSI value to beacon nodes location information tuple to broadcast in network. After other receiving nodes receive message tuple, it will use the quotient of RSSI value of receiving tuple divide reference RSSI value as weighted hop count of that hop. Tuple in number of hops weighted with hops and record location of beacon nodes and number of hops, and forward its tuple to other neighbors. If the node receives a number of groups which come from same node, then nodes retain only minimal information group tuple of distance information. In this way each node in network can get location of beacon nodes and least number of weighted hops from it to every beacon node. The second and third phases still conform to DV-HOP algorithm method to calculate hop distance. The proposed algorithm flat is as follows:

Step 1. beacon nodes generate a tuple {ID, (x,y), Hopcount, RSSILevel}, ID is the number of beacon nodes; (x,y) is position of beacon nodes; Hopcount is the hop, whose initial value is 0; RSSILevel is radio signal strength(RSS) value when nodes receive the tuple, whose initial value is 0. Beacon nodes will broadcast tuple to its neighbor nodes.

Step 2. when neighbor nodes receive the tuple, HopCount will be set as 1, and RSSI value of receiving tuple will be set to RSSILevel.

Step 3. neighbor nodes of beacon nodes forward the tuple to their neighbor nodes, when the neighbor nodes receive the tuple, it will record the RSSI value of receiving tuple as R, and calculate their weighted number of hops with Eq.1 :

$$H=\frac{R}{RSSILevel} \quad ..(1)$$

update the HopCount value of tuple , and then calculate and store the product DIS of tuple, which equals Hopcount times RSSILevel. And continue to forward this tuple.

Step 4.if current node receives other tuple whose ID number is same with current tuple from other nodes, it will calculate the product DIS of new tuple, which is called DIS1, and compare DIS1 with DIS. If DIS1 is greater than DIS then ignore this tuple, otherwise turn to Step 2.

Simulation results

In order to evaluate performance of our algorithm, we simulate the improved weighted DV-HOP(WDV-HOP) algorithm with Matlab 7.0 under coalface environment and compare it with DV-HOP algorithm. First we deploy 20 unknown nodes randomly in the flat area of 100m*100m, and deployed a certain number of beacon nodes evenly on three edges of coalface to execute a simulation experiment. We compare our algorithm with DV-HOP algorithm of relative location error of two localization algorithms in different beacon nodes

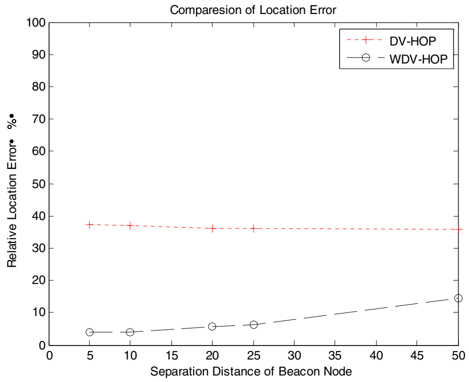

Fig. 3. Location accuracy in 100*100 area

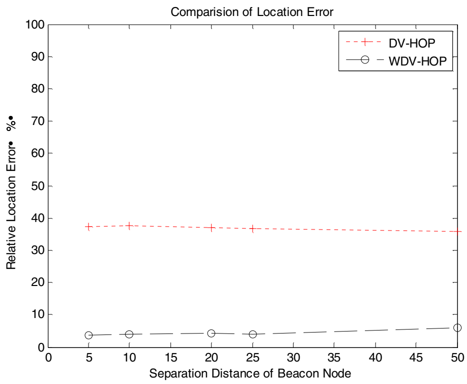

Fig. 4. Location accuracy in 200*200 area

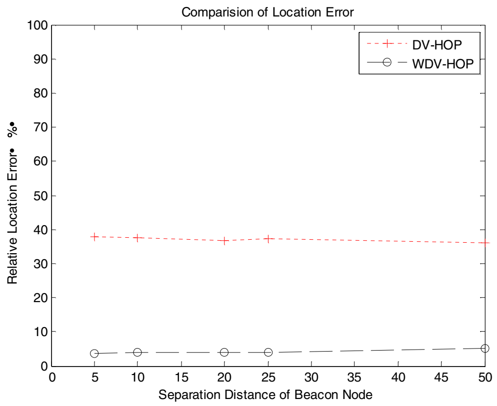

Fig. 5. Location accuracy in 300*300 area

Tabel 1. Average location error of two algorithms

	Interval of Beacon node(m)	Size of coalface area(m^2) 100*100	200*200	300*300
DV-HOP	5	37.41	37.18	37.88
	10	36.97	37.61	37.60
	20	36.06	36.94	36.79
	25	36.13	36.54	37.37
	50	35.89	35.93	36.22
Weighted DV-HOPalgorithm	5	3.89	3.58	3.78
	10	4.01	3.80	3.86
	20	5.58	4.26	3.93
	25	6.38	3.95	3.97
	50	14.50	6.11	5.06

intervals under the different circumstance of beacon nodes spacing: 5 meters, 10 meters, 20 meters, 25 meters, 50 meters, results shown as fig. 3.

Then we deploy 20 nodes randomly in flat area of 200m*200m, under circumstance of different beacon nodes intervals, relative location error of our algorithm and DV-HOP algorithm is shown as figure 4. At last we deploy 20 nodes randomly in flat area of 300m*300m, under t circumstance of different beacon nodes intervals, relative location error of our algorithm and DV-HOP algorithm is shown as figure 5.

It can be seen from those figures that in case of beacon nodes deployed sparsely, weighed algorithm has been greatly improved than DV-HOP algorithm in positioning accuracy. Under circumstance of different size and spacing, average location error results of two algorithms is shown in Table 1. Overall location accuracy of our algorithm can meet requirement of underground miner positioning much better than DV-HOP algorithm.

Summary

Due to complex environment of mine coalface, multi factors affect on wireless signal, frequent changes in network, traditional wireless sensor network location algorithm can not use directly. Because of low location accuracy caused by DV-HOP algorithm strained by uneven nodes distance, an algorithm of RSSI weighted DV-HOP based on the transmission of information between adjacent nodes on the number of hops weighted intensity is proposed in this paper. Compared with DV-HOP algorithm, positioning error of the algorithm is significantly lower, the simulation result show that the algorithm is better than the DV-HOP algorithm, improve the positioning accuracy greatly.

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