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Position-based Wireless Sensor Network Routing Protocol for Strip Area

Abstract. *Limited by the terrain, lots of Wireless sensor network (WSN) applications have to be deployed in a narrow strip area. Due to the narrow and strip network structure, traditional WSN routing algorithms such as LEACH and PEGASIS can not be applied in such applications directly, it's very necessary to develop a new routing protocol suit for the strip WSN. In order to improving communication efficiency of the strip network and saving the energy of the nodes, in this paper a Position-based Cluster routing (PBCR) protocol is proposed, which combines the clustering techniques with the chain routing techniques. The PBCR protocol divided the strip WSN into many belt-shaped region clusters and elected the cluster head through the position and dump energy of the nodes in the cluster, and forward data by cluster head chain. Simulation results show that the PBCR protocol can ensure a balanced use of node energy and prolong lifetime of the network, and has the obviously advantages in the narrow strip area than the LEACH and PEGASIS protocol.*

Streszczenie. *Przy wąskich pasku przestrzeni tradycyjne metody routing bezprzewodowej sieci czujników takie jak LEACH czy PEGASIS nie zdają egzaminu. W artykule zaproponowano nowy protokół PBCR – position based wireless network routing który łącz w sobie technikę klastrów i technikę łańcucha routingu. (**Uwzględniający pozycję nowy protokół routingu bezprzewodowych sieci czujników w zastosowaniu do wąskich obszarów**)*

Keywords: Wireless Sensor Network, Routing protocol, Cluster, Chain, Strip area.
Słowa kluczowe: bezprzewodowa sieć czujników, routing

1. Introduction

Energy consumption is one of the key research questions of Wireless Sensor Networks (WSN)[1,2]. Due to the large amount of nodes, with limited energy, and energy supplement inconvenience, how to extend the network life cycle and use node energy efficiently is very important for WSN design. The WSN route protocol is closely related to the application[2], the WSN Routing protocol[3, 4] which suit for the application will improve communication efficiency and save the communication energy, and ensure a balanced use of energy of the network. As the deployment and external environment of the WSN plays a decisive role to monitoring quality and survival time of WSN, it's very imperative that routing protocol should be researched and developed in accordance with the characteristics of wireless application.

Recent years WSN are widely used in lots of different strip environment such as coal mines, bridges, tunnels, canyons and so on, whose length is typically longer and width is often very narrow. In aforesaid application WSN has to be deployed into a narrow strip structure and base station is normally deployed in one side of the area. Due to narrow and strip network structure, traditional routing algorithms such as LEACH[2, 5, 6] and PEGASIS7 can not be directly applied in such strip WSN, it very necessary to develop a new routing protocol which suit for the strip WSN.

To increase lifetime of the strip sensor network, after having analyzed characteristics of the strip WSN, a Position-based Cluster routing (PBCR) protocol is proposed, the simulation shows that the PBCR protocol can improve network performance and can meet monitoring needs of a variety of WSN application scenarios.

2. Requirement of routing protocol

2.1. The Network Model of the Strip WSN

Deployment of strip WSN is shown as figure 1. In order to describe the strip WSN accurately, according to the Characteristics of the WSN application environment, the following strip WSN model is proposed: the network is composed of M uniformly deployed nodes, whose application scene is for periodic data collection. The s_i is expressed as the ith node, the corresponding node set is $S= \{s_1, s_2, \dots, s_m\}$,$|S|=M$, and based on the below supposition:

1. The monitor area is a rectangular region, whose length is L and width is N and L>>N.
2. The WSN consists of one base station, which has plenty of energy, memory and computing resources, and is often far away from the network and cannot move.
3. The nodes is deployed in monitoring area uniformly, each node in the network have same initial energy, computing and communication capabilities and plays same role in the network. The position of node cannot change having been deployed.
4. Each node can obtained its own position information through location mechanism, and can estimate distance to the sending node through Received Signal Strength(RSS).
5. Each node has capacity of adjusting its wireless transmission power, and can adjust size of transmission power according to the distance to the destination node.
6. Each node in the network can calculate its current dump energy.

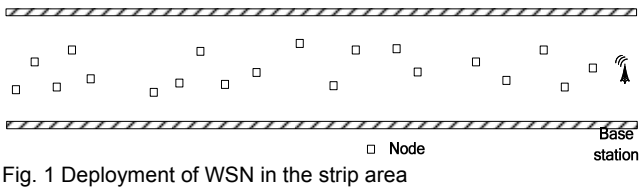


Fig. 1 Deployment of WSN in the strip area

2.2. Propose of PBCR Protocol

Due to limited energy, the node in the strip WSN usually has to forward data to base station through multi-hop. As the distance to base station is different, energy consumption of node is unbalance. In srip WSN the data far away from base station flows together to base station, the node near base station has to receive and forward massive data, which will exhaust its energy very quickly and lead to the node failure. This will reduce survival time of Strip WSN and aggravate the "hot spot" question of the network.

In WSN routing protocols LEACH protocol is a typical and widely used clustering routing protocol[2,5,7] and can be widely used in many applications. In LEACH, cluster head which is a designated node in every cluster is responsible for collecting and aggregating data from sensors in its cluster and eventually transmitting result to base station, which can reduce energy consumption of data transmission. However, as LEACH protocol does not take the position of cluster head and member node into account during the cluster head election period, it will lead to uneven

energy dissipations in strip network. During cluster formation period, as e cluster head is elected randomly, its position is not always nearest to base station which will lead to a negative data transmission away from base station and result in unnecessary energy dissipations. Furthermore LEACH protocol assumes that each cluster head can communicate directly with base stations, but it can not be guaranteed in strip WSN, as base station is usually deployed at one end of strip area and is often far away from most nodes in strip area.

Another typical routing protocol is PEGASIS, in PEGASIS every node choose the nearest adjacent node which is nearer to base station than it as its relaying node, one by one all the nodes finally form a routing chain and will send data with it. In PEGASIS protocol as data transmit distance of every hop is very short, every node' energy dissipations is very low, however it also lead to large data transmit delay. So PEGASIS protocol is also not suitable for strip WSN application.

Based on communication requirement and deployment characteristic of the strip WSN, in this paper a Position-based Cluster routing (PBCR) protocol is proposed, which has combined position information and cluster routing on the basis of LEACH protocol and PEGASIS protocol.

3. PBCR protocol

PBCR protocol is composing of Cluster Divide phase, Cluster Head Elect phase, Cluster Head Chain Establishment phase and Steady-state phase.

3.1 Cluster Divide phase

Having deployed WSN in strip area, the WSN in the strip area will be divided into several belt-shaped regions which are same size and next to each other with no overlap. The length of belt-shaped region should be less than or equal to half of node' communication distance in order to ensure that every node of current region can communicate directly with the node in adjacent area. The nodes in a belt-shaped region form a cluster, and cluster-heads will be elected only from those nodes which are in current belt-shaped regions, shown in Fig 2.

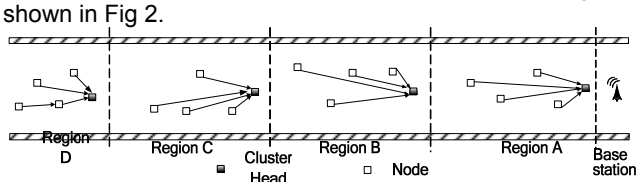


Fig. 2 Formation of cluster

3.2 Cluster Head Elect phase

In each round of PBCR protocol, cluster head of every cluster will be elected based on topology of strip WSN. In LEACH protocol, there is no limit to energy of cluster-head, in order to avoid this kind of situation, PBCR protocol has set up energy threshold value of cluster head, only the node whose dump energy is bigger than the threshold value can be elected as cluster head.

In this phase, every member node whose dump energy is bigger than the threshold value calculates distance between it itself and base station periodically, the node with the nearest distance in this cluster will be elected as the cluster head at curren round. After cluster head has been elected, it will broadcast a packet including its id and position to other node in curren cluster. After member nodes of the cluster have received that packet, they can send their data to cluster head, shown in Fig 2. Cluster head can reduce amount of upload information through data fusion technology after data from member nodes have been received. If dump energy of every node in the cluster is smaller than energy threshold, the energy threshold value will be reduced according to actual need.

3.3 Cluster Head Chain Establishment Phase

As every cluster heads often away from its adjacent cluster heads, if adjacent Cluster heads connect each other, energy consumption of cluster head will increase greatly. In cluster head chain establishment phase, cluster head randomly selected an adjacent node in adjacent cluster, whose position is much near to base station than current cluster head, and make it as relay station to establish the Cluster Head Chain with adjacent cluster head.

Shown in Fig 3, cluster head of region C will send a Cluster Head Information packet (CHIP) to region B after cluster head of region C has been elected. After node in region B received the CHIP, it will forward it to the cluster head of region B. Having received the CHIP, then cluster head chain between region B and C is set up. The cluster head of other regions can be interconnected with the same method to establish cluster head chain, which forms the backbone of strip WSN to transmission data between clusters. Having established the cluster head chain, the protocol enters Steady-state phase.

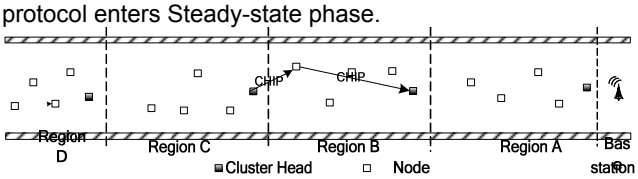


Fig. 3 cluster head chain of adjacent region

3.4 Steady-state phase

The last phase of PBCR protocol is steady communication phase, in this phase the member nodes, the cluster head and base station forward data each other. Data from the member nodes are gathered together and forward to cluster head. Having fused the data from cluster member and other clusters, cluster head forward the fused data to adjacent cluster node nearer to base station. One by one, the data will reach base station eventually through cluster head chain of Strip WSN, shown in Fig 4. Data forward method of PBCR is similar with the PEGASIS protocol.

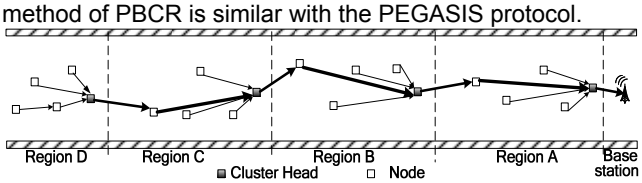


Fig. 4 Cluster head chain of whole strip area

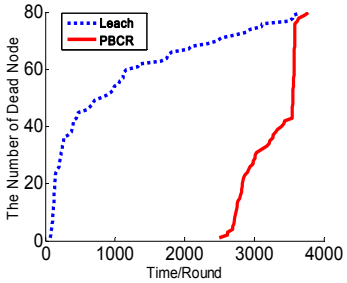
4. Simulation and results

In order to assess performance of PBCR protocol, we simulate the strip WSN with Matlab. The application scenarios of simulation are as follow: a certain amount of nodes are random deployed in a narrow and strip area, base station is 10m far away from strip area, shown as Fig 2. The initial node energy is 1J, the length of broadcast packet is 50 bytes and the length of the data packet is 2000 bytes and the parameters of simulation experiment are as follows: distance threshold d0 is 75m, energy consumption parameter of wireless transmission εfs is 13 pJ/b/m^2, energy consumption parameter of amplifier Etr is 0.0013 pJ/b/m^4, energy consumption parameter to launch the transceiver circuit Eelec is 10nJ/bit, and energy consumption parameter of data aggregation Efusion is 5nJ/bit. To compare with original LEACH protocol, a model has also been built for LEACH with the same parameter.

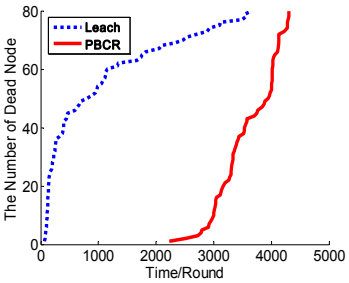
The round of the first node failure during the course of routing protocol process is important parameters to measure lifetime of WSN[8], here the round of first node failure is defined as the lifetime of the WSN. Energy consumption of nodes is also an important evaluation index of routing protocol, so we designed lots of simulation

scenarios to evaluation lifetime and node's energy consumption of the two protocols.

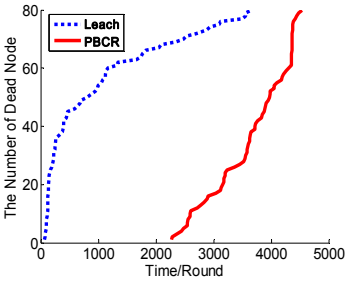
Scenario 1: In order to compare influence of length of belt-shaped region on performance of protocol, 100 blind nodes are randomly deployed in a 500m long and 10m wide strip area. We carry out simulation with 3 variable lengths of belt-shaped region, which are 20m, 50m and 100m. Result of simulation is shown in Fig. 5 and Fig. 6. In order to reflect the impact on node's energy consumption accurately, we randomly choose a specified member node for reference to evaluate its energy consumption in simulation.



(a)length of belt-shaped region is 20m

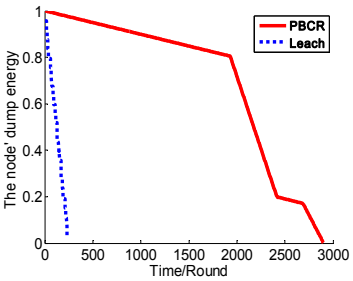


(b) length of belt-shaped region is 50m

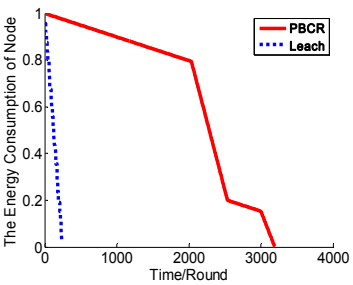


(c) length of belt-shaped region is 100m

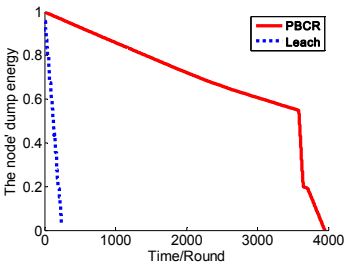
Fig. 5 Lifetime of 500m long strip WSN



(a) length of belt-shaped region is 20m



(b) length of belt-shaped region is 50m

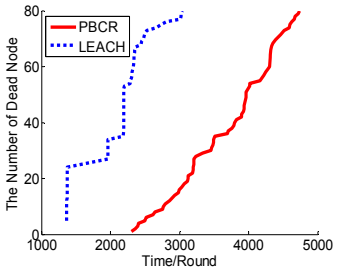


(c) length of belt-shaped region is 100m

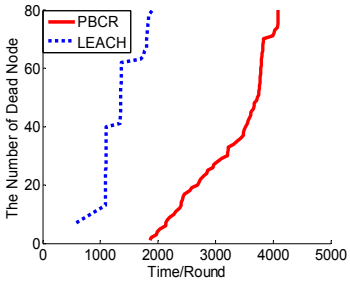
Fig. 6 Node dump energy of 500m long strip WSN

It can be seen from Fig. 5 that lifetime of PBCR is last a lot longer than LEACH, and node's energy consumption is far less than LEACH. Result shows that PBCR protocol can ensure equably usage of node energy, and with an obvious advantage in strip WSN, which is more energy-efficient than LEACH protocol. We can see from Fig.5 and Fig.6 that performance of our protocol is stable on condition of different belt-shaped length.

Scenario 2: In order to compare influence of the length of strip area on protocol's performance, 100 blind nodes are deployed randomly in two 10m wide strip areas, one is 1km long, and another is 500m. We carry out the simulation with 2 variable lengths of belt-shaped region: 50m and 100m. The result of simulation in 1km long strip area is shown in Fig. 7 and Fig. 8.



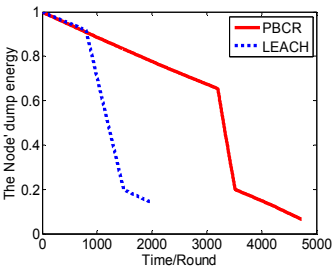
(a)length of belt-shaped region is 50m



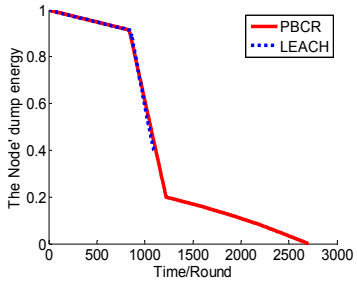
(b)length of belt-shaped region is 100m

Fig. 7 Lifetime of 1km long strip WSN

It can be seen from Fig.5, Fig.6, Fig.7 and Fig.8 that with the increasing of the strip area' length, the lifetime of network and the node's energy consumption decreased slowly with PBCR protocol. It can be seen that performance of our protocol is stable on condition of different strip area length.



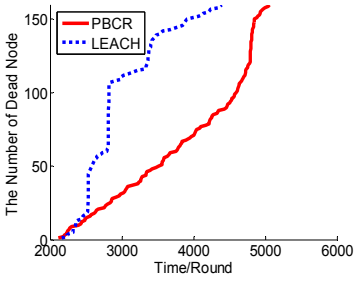
(a)length of belt-shaped region is 50m



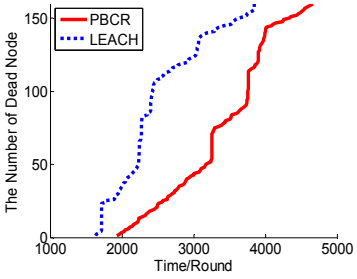
(b)length of belt-shaped region is 100m

Fig. 8 Node's dump energy of 1km long strip WSN

Scenario 3: In order to compare influence of amount of nodes on protocol's performance, 200 blind nodes are deployed randomly in 500m long and 10m wide strip area. We carry out the simulation with 2 variable lengths of belt-shaped region: 50m and 100m. The result of simulation is shown in Fig. 9 and Fig. 10.

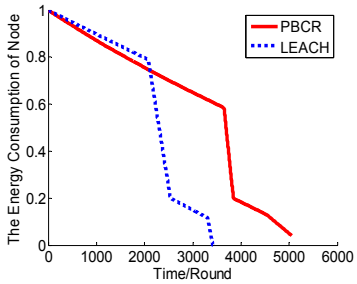


(a)length of belt-shaped region is 50m

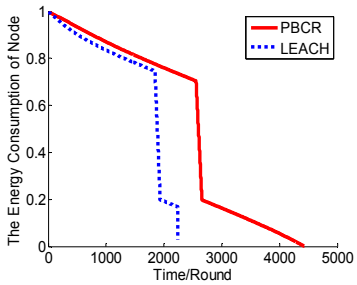


(b)length of belt-shaped region is 100m

Fig. 9 Lifetime of 500km long strip WSN with 200 nodes



(a)length of belt-shaped region is 50m



(b)length of belt-shaped region is 100m

Fig. 10 Node dump energy in 500km long strip WSN with 200 nodes

It can be seen from Fig.5 and Fig.9, Fig.6 and Fig.10 that with the increasing of the node' number the improvement of lifetime of network and node's energy consumption are not noticeable with the PBCR protocol, this suggest that our protocol has a distinct advantage under the condition of sparse nodes, and performance of our protocol is stable.

The result shows that PBCR protocol can ensure equably usage of node energy, and is with an obvious advantage in strip WSN, which is more energy-efficient than LEACH protocol. Compared with PEGASIS protocol, time delay of the PBCR protocol is also much smaller, for example, in Figure 4, every nodes in bar area A can transmit data to base station only with 2 hops, the hops can be 4 in bar area B to transfer data to base station, however the hops of the same node to transfer data to base station will increase a lot if PEGASIS protocol is used in strip WSN.

5. Summary

Based on analysis of routing requirement of strip WSN in strip WSN, we proposed the PBCR protocol, which divided the strip WSN into many belt-shaped region cluster and elected cluster head through node' position and dump, and set up a cluster head chain as the backbones of strip WSN to forward data from nodes. The PBCR protocol can reduce energy consumption and latency of network effectively and balance the load of node. Simulation experiment result indicated that our protocol is more suitable for strip WSN than LEACH and can prolong lifetime of network effectively.

Acknowledgments

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