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A Chain Routing Algorithm Based on Traffic Prediction in Wireless Sensor Networks

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ABSTRACT

As a representative of chain-based protocol in Wireless Sensor Networks (WSNs), EEPB is an elegant solution on energy efficiency. However, in the latter part of the operation of the network, there is still a big problem: reserving energy of the node frequently presents the incapacity of directly communicating with the base station, at the same time capacity of data acquisition and transmission as normal nodes. If these nodes were selected as LEADER nodes, that will accelerate the death process and unevenness of energy consumption distribution among nodes. This paper proposed a chain routing algorithm based on traffic prediction model (CRTP). The novel algorithm designs a threshold judgment method through introducing the traffic prediction model in the process of election of LEADER node. The process can be dynamically adjusted according to the flow forecasting. Therefore, this algorithm lets the energy consumption tending to keep at same level. Simulation results show that CRTP has superior performance over EEPB in terms of balanced network energy consumption and the prolonged network life.

Keywords: Wireless Sensor Networks; A Chain Routing Algorithm; LEADER Node; Traffic Prediction Model

1. Introduction

Wireless Sensor Networks (WSNs) is a technology combined with computer, micro sensors and wireless communication [1]. The self organization characteristic, also the reliability, dynamicity and anti-destroying ability, make WSNs suitable for battlefield target positioning [2], physiological data collection [3], intelligent transportation system [4] and ocean exploration [5], etc. [6].

Energy problem is one of the key problems in WSNs [7]. Because battery capacity is low and not easy to change, cognitive nodes should be scraped once energy depleted. Therefore, improving energy efficiency, balancing the node energy consumption and prolonging network life time have become a judgment in WSNs routing protocol [8].

Chain routing algorithms characterized by energy efficient have been proposed in recent years. PEGASIS [9] uses the greedy algorithm to build the chain, as a typical algorithm that shortens the commutation distance between the nodes. However, PEGASIS has some inherent flaws: there are large numbers of long chains between neighbor nodes that increases the energy consumption in data transmission. The method of rotating the LEADER of the chain among the nodes will result in unbalanced energy consumption of each node. In recent years, international and domestic academics have put forward improved algorithms from different angles to avoid long chains [10-14]. When these algorithms select the LEADER of the chain, they only consider the factor of the residual energy or the same as PEGASIS, and still can't avoid the problem of inconsistent energy consumption of the nodes. [15] avoids long chains between neighbor nodes by employing a distance threshold; through comprehensively taking into account of node residual energy and the distance between the nodes and base station, selecting the LEADER of the chains. EEPB algorithm makes a better performance in balancing of node energy consumption and prolonging the network life cycle. However, after running a long time, nodes in network are not strong enough to send the fusion of data to base station, but still can be used as data acquisition or transmission nodes among chains. If these nodes were chosen as the LEADER of the chain, it would cause the waste of node energy, not only weaken the network robustness but also shorten sur- vival time. This situation is particularly serious in the monitoring area far away from base station.

This paper proposes a chain routing algorithm based on traffic prediction, CRTP. This model was applied to the selection of the LEADER, implementing replacement of the LEADER through forecast. At the end of this paper, simulation results show that, CRTP makes better performance in terms of balanced network energy consumption and prolonged the network life.

2. Traffic Prediction Model

The nodes in Wireless Sensor Networks periodically sensor monitoring area and transmit the collected data to the remote Sink. ARMA model can effectively analyze the serial correlation of these stable data sequence, so the ARMA prediction model is applied to forecast network traffic in this paper.

Suppose that the raw data flow sequence is $X_0^{'}, X_1^{'}, \cdots, X_i^{'}, \cdots, X_n^{'}$, taking the method of differencing or logarithm, we get a smooth sequence $X_0, X_1, \cdots, X_i, \cdots, X_n$. This algorithm uses ARMA (2, 1) to predict the traffic. The model can be described as follows:

$$\varphi(B) X_i = \theta(B) a_i \tag{1}$$

$$\varphi(B) = 1 - \varphi_1 B - \varphi_2 B^2 \tag{2}$$

$$\theta(B) = 1 - \theta_1 B \tag{3}$$

B is backward shift operator, a_i is flat noise. φ_1, φ_2, θ_1, σ_a^2 (flat noise variance) are the estimated parameters. Since the sensor node is limited by its computing power, we get the value of $\hat{\varphi}_1$, $\hat{\varphi}_2$, $\hat{\theta}_1$, $\hat{\sigma}_a^2$ through the method of least squares estimation. ARMA fitting model is:

$$X_t = \hat{\varphi}_1 X_{t-1} + \hat{\varphi}_2 X_{t-2} + a_t - \hat{\theta}_1 a_{t-1} \tag{4}$$

Furthermore, we use inverse function to carry out one-step prediction. The ARMA inverse function $I_1, I_2, \cdots, I_n$ are:

$$\left.\begin{aligned} I_1 &= \hat{\varphi}_1 - \hat{\theta}_1 \\ I_2 &= \hat{\varphi}_2 - I_1 \hat{\theta}_1 \\ I_3 &= I_j \hat{\theta}_1 \cdots (j > 3) \end{aligned}\right\} \tag{5}$$

One-step prediction model is:

$$\hat{X}_t(1) = \sum_{j=1}^{m} I_j X_{t+1-j} \tag{6}$$

Where m is m times before the X_t observations, it can be decided in accordance with the requirements of the prediction accuracy values. Multi-step predictive model is:

$$\hat{X}_t(l) = \hat{\varphi}_1 \hat{X}_t(l-1) + \hat{\varphi}_2 \hat{X}_t(l-2) \tag{7}$$

We use Matlab 7.0 to simulate. **Figure 1** shows a real traffic flowing through a sensor node during the 150 s of sensor network operation. Its fitting model is:

$$X_t = 0.86579 X_{t-1} - 0.07356 X_{t-2} + a_t - 0.68954 a_{t-1} \tag{8}$$

Further, One-step prediction model is:

$$X_t(1) = \sum_{j=1}^{3} I_j X_{t+1-j} \tag{9}$$

Multi-step predictive model is:

$$\hat{X}_t(l) = 0.86579 \hat{X}_t(l-1) - 0.07356 \hat{X}_t(l-2) \tag{10}$$

Starting from any time in the 150 s (round), its estimated value can be calculated by the use of this model every second, its chart of one-step prediction shows in **Figure 2**. From above figure, one-step prediction curve is similar with the raw data flow. This because the ARMA is a short model, its related structure appears exponential decay and decay rate is faster than actual observation value. Therefore, one step prediction could have better prediction accuracy.

3. CRTP Algorithm

Assume a random distribution of sensor nodes in a square

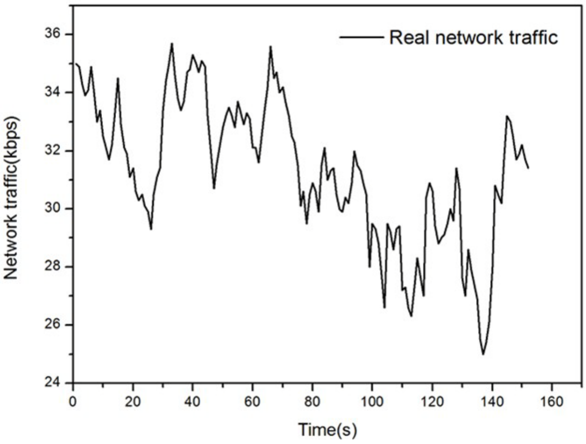

Figure 1. Example of a real flowing.

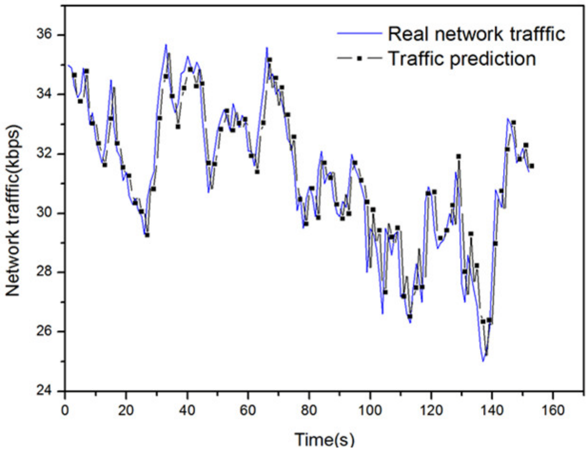

Figure 2. One-step prediction.

monitoring area, and this sensor networks have the nature as follows:

- The location of the base station is fixed, which is far from the monitoring area. The base station has a strong computing and storage capability, and unlimited energy.
- All sensor nodes are immobile, homogeneous, the same initial energy value.
- According to the receiver's distance nodes can control their transmit power for different transmission ranges.
- All nodes can be informed the coordinates of their location.

3.1. Chain-Building Stage

Similar with EEPB chain-building method, CRTP also starts a chain from the nodes which is the furthest from the base station. In order to determine whether the chain is long, we set a distance threshold, in terms of $d_{threshold}$. If $d_i \le d_{threshold}$, said that the chain between node $i+1$ and node i is not a long chain. Then the node $i+1$ join the chain by directly connected to the node i. If $d_i > d_{threshold}$, said that the chain between node $i+1$ and node i is a long chain. Here, node $i+1$ can't directly connect with the node i, node $i+1$ will find the nearest node from the chain.

3.2. LEADER Node Selection Algorithm Based on the ARMA Model

LEADER node selection in EEPB considers the residual energy of nodes and the distance from nodes to the base station. Under the condition that nodes' residual energy is equal, EEPB algorithm is priority to select nodes near the base station as the LEADER node, in order to save energy when transmitting data to the base station. Similarly, under the condition that distances from nodes to the base station are the same, EEPB algorithm is priority to select nodes with more residual energy as the LEADER node, in order to avoid nodes with less residual energy to death.

In the LEADER node selection based on ARMA model, when the energy consumption exceeds the threshold, the node broadcasts its withdrawing the competition of LEADER node in this round to neighbors, neighbor nodes updates its routing table after receiving the message. The key issue is to design a judgmental forecasting method based on threshold. Suppose the threshold is Max, the probability that the prediction exceeds the threshold value in the L-step is

$$P_t(l) = (y(t) > Max \mid X_t, X_{t-1}, X_{t-2}, \cdots, X_{t-m}) \quad (11)$$

According to the Equation (8), X_t is conditioned by a_t, if a_t is normal distribution and so is X_t. Standardize the Equation (7), we get

$$\begin{aligned} P_t(l) &= 1 - P(X_{t+l} \le Max) \\ &= 1 - \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{x} \exp\left(-\frac{Max - \hat{X}_t(l)}{2\sigma(l)}\right) dx \end{aligned} \quad (12)$$

4. The Simulation and Analysis

In order to verify the proposed idea, we use MATLAB to simulate and compare EEPB and the improved routing algorithm CRTP. The wireless commucation energy cost model is the Heinzelman model. Simulation environment goes as follows (**Table1**).

First of all, let's analyze the number of the survival nodes: the number is an important indicator of the energy efficiency. From **Figure 3**, we know that 1) the first dead node emerges at the 900r in EEPB but at the 1600r in CRTP, improve 77.8%; 2) attenuation curve in CRTP is faster than EEPB; 3) the slope of CRTP's curve is greater than EEPB after 1900r. This is because as the network round increases unceasingly, the LEADER selection according to flow prediction is more reasonable.

Figure 4 is a comparison between our algorithm and EEPB in average residual energy each round, we can get

Table 1. Table type styles (Table caption is indispensable).

Parameters	Value
Network Field	100 m × 100 m
Nodes numbers	100
Sink coordinates	(50,250)
Nodes Initial energy	1.0J
Eelec	50 nJ/bit
Efs	100 pJ/bit/m^2
Emp	0.0013 pJ/bit/m^4
Packet length	3000 bit
α	1.2

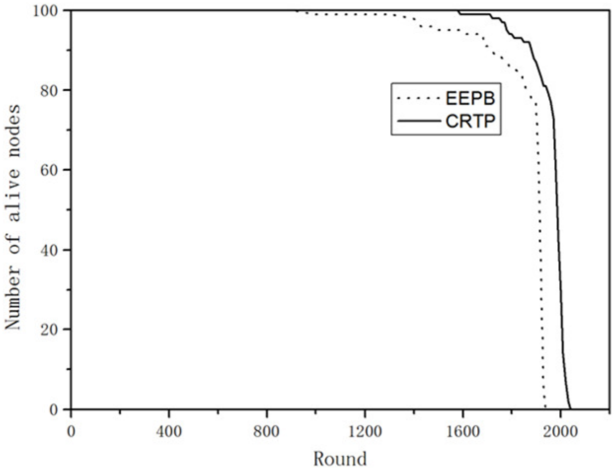

Figure 3. Life time of the network.

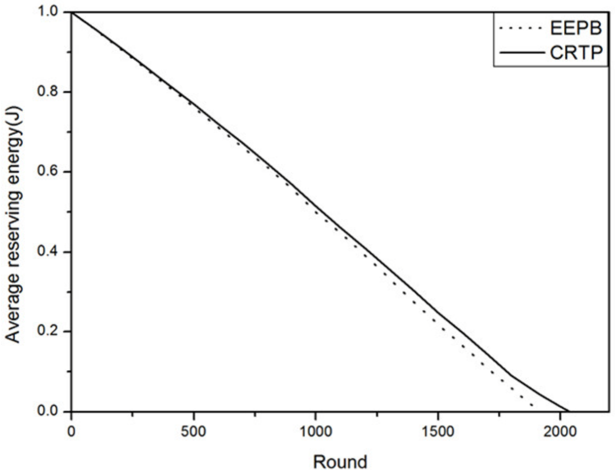

Figure 4. Average residual energy of the network.

that the average residual energy in improved algorithm is more than EEPB as network running, at the same time the network energy cost is lower. That's because we take a more reasonable method to select the LEADER node in a chain and take into account the energy balance when we established routing link, so life cycle of the network is extended.

5. Conclusion

This paper proposes a chain routing algorithm based on ARMA traffic prediction for nodes' premature "death". It introduces ARMA prediction model into the LEADER node reelection in EEPB. Therefore it has not only avoided LEADER premature "death" because of the used-up energy, but also avoided the network topology reconstruction as well as the short life of the death of LEADER. Experimental results show that CRTP has a better performance than EEPB on balancing energy consumption and prolonging lifetime of Wireless Sensor Networks (WSNs).

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REFERENCES

[1] X.-L. Zhao, X.-L. Li and K.-Q. Li, "LEACH-Based Protocol Difference of Cluster-Based Routing Algorithm," Computer Engineering and Applications, 2012.

[2] F. Viani, P. Rocca, G. Oliveri, *et al*., "Localization, Tracking, and Imaging of Targets in Wireless Sensor Networks: An Invited Review," *Radio Science*, Vol. 46, No. 5, 2011. http://dx.doi.org/10.1029/2010RS004561

[3] E. E. Emeka and O. F. Abraham, "A Survey of System Architecture Requirements for Health Care-Based Wireless Sensor Networks," *Sensors*, Vol. 11, No. 5, 2011, pp. 4875-4898.

[4] L. Fernando, G. Antonio-Javier, G. Felipe, *et al*., "A Comprehensive Approach to WSN-Based ITS Applications: A Survey," *Sensors*, Vol. 11, No. 11, 2011, pp. 10220-10265.

[5] A. Cristina, S. Pedro, I. Andrés, *et al*., "Wireless Sensor Networks for Oceanographic Monitoring: A Systematic Review," *Sensors*, Vol. 10, No. 7, 2010, pp. 6948-6968. http://dx.doi.org/10.3390/s100706948

[6] Z.-H. Qian and Y.-J. Wang, "Internet of Things-Oriented Wireless Sensor Networks Review," *Journal of Electronics & Information Technology*, Vol. 35, No. 1, 2013, pp. 215-227.

[7] J.-H. Han, X. Ding, L. Shi, D. Han and Z.-C. Wei, "Research on the Time-Varying Charging and Dynamic Data Routing Strategy for Rechargeable Wireless Sensor Networks," *Journal on Communications*, Vol. 33, No. 12, 2012, pp. 1-10.

[8] Y.-H. Luo, S.-Q. Chen and J.-X. Wang, "The Energy-Efficient Routing Algorithm in Mobile Ad-Hoc Networks," *Engineering and Application of Computer*, 2004, Vol. 36, pp. 15-21.

[9] S Lindsey and C. Raghavendra, "PEGASIS: Power-Efficient Gathering in Sensor Information Systems," *Proceedings of IEEE Aerospace Conference*, Big Sky, Montana, 2002, pp. 1125-1130.

[10] K.M. Du, J. Wu and D. Zhou, "Chain-Based Protocols for Data Broadcasting and Gathering in the Sensor Networks," *Proceedings of Parallel and Distributed Processing Symposium*, Nice, 2003, pp. 1926-1933.

[11] S. L. Hu, Y. Zhang, X. Y. Jin, *et al*., "Improvement of PEGASIS Algorithm in Wireless Sensor Networks Using GA," Journal of Jiangnan University (Natural Science Edition), Vol. 7, No. 4, 2008, pp. 0420-0424

[12] L. P. Wang and Z. Cai, "Improved Algorithm of PEGASIS Protocol Introducing Double Cluster Heads in Wireless Sensor Network," 2010 *International Conference on Computer*, *Mechatronics*, *Control and Electronic Engineering* (*CMCE*), Changchun, 2010, pp. 148-151.

[13] W.J. Guo, W. Zhang and G. Lu, "PEGASIS Protocol in Wireless Sensor Network Based on an Improved Ant Colony Algorithm," *The* 2nd *International Workshop on Education Technology and Computer Science*, Wuhan, 2010.

[14] Zhang Z., Yan L.-S., Pan W., *et al*., "Routing protocol based on cluster-head-chaining incorporating LEACH and PEGASIS," *Chinese Journal of Sensors and Actuators*, Vol. 23, No. 8, 2010, pp. 1173-1178.

[15] Y.-C. Yu and G. Wei, "An Improved PEGASIS Algorithm in Wireless Sensor Network," *ACTA Electronica Sinica*, Vol. 36, No. 7, 2008, pp. 1309-1313.