Mao *EURASIP Journal on Embedded Systems* (2016) 2016:25
DOI 10.1186/s13639-016-0063-5

EURASIP Journal on Embedded Systems

RESEARCH Open Access

Crowd cloud routing protocol based on opportunistic computing for wireless sensor networks

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Abstract

We proposed a crowd cloud routing protocol based on opportunistic computing to improve the data transmission efficiency, reliability, and reduce routing overhead in wireless sensor networks. Based on the analysis of the demand of big data processing in wireless sensor network, the data analysis and processing platform for wireless sensor network are designed based on the combination with the cloud computing. The cloud platform includes the main nodes, the nodes, and the core nodes. There are the engine and the drive between the wireless sensor network and the cloud server. Secondly, aiming at the problem of data transmission in the cloud platform, we design an opportunistic computing model which is suitable for wireless sensor networks to minimize the weight of routing management and network overhead. Then, we design an opportunistic calculation model to guarantee the data transmission scheme of the cloud platform. Finally, by eliminating the factors that may cause the link instability, the crowd cloud routing protocol is proposed. The experimental results show that the proposed crowd cloud routing protocol has the functions of real-time and reliability and reduces the cost of routing request.

Keywords: Crowd routing, Cloud, Opportunistic computing, Fusion, Wireless sensor networks

1 Introduction

With the rapid development of large data applications and the increasing demand for wireless mobile computing, [1] it has become the key to provide integrated service quality for wireless sensor networks [2]. Emerging big data applications [3] put forward a new and higher request to the communication network. The application of large data transmission in wireless sensor networks requires smooth real-time data transmission and reliability guarantee [4]. However, providing reliable and efficient routing for these novel applications in wireless communication environments is much more complex than wired networks for [5].

The energy-efficient routing protocols were classified into four main schemes: Network Structure, Communication Model, Topology Based and Reliable Routing by Pantazis N A et al. [6]. The comprehensive review on atypical hierarchical routing was provided by the article [7]. They also offered a classification of atypical hierarchical routing of wireless sensor networks and gave the detailed analysis of different logical topologies. The E-STAR for establishing stable and reliable routes in heterogeneous multi-hop wireless networks was proposed by Mahmoud M M E A et al. [8]. Ledy J et al. [9] had compared the common reactive, proactive, hybrid, and geographic routing protocols using a simulation platform integrating a realistic physical layer and mobility models. A secure and intelligent routing protocol was proposed by Bhoi S K et al. [10] to transmit the data in a quickest path through the authenticated vehicles.

The study of the article [11] proposed the core network supported multicast routing protocol, which is a stateful-based distributed multicast routing protocol for sensor networks. The performance of the protocols was measured in terms of packet delivery, delivery cost, and average packet delay [12]. They also compared the protocols' performance together with the results of optimal routing using real-life scenarios of vehicles and pedestrians roaming in a city.

The above results did not do in-depth research about cloud platform to build relations with routing protocols. At the same time, they ignored how to improve the

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computational efficiency of wireless sensor network in the process of data packet transmission. As a result, we proposed the crowd cloud routing protocol based on opportunistic computing for wireless sensor networks.

The rest of the paper is organized as follows: Section 2 describes the wireless sensor network cloud platform. In Section 3, we discussed the opportunistic computing model for wireless sensor networks. The cluster intelligence cloud routing protocol for wireless sensor networks has been shown in Section 4. Performance analysis of routing protocols is given by Section 5. Finally, the conclusions are given in Section 6.

2 Wireless sensor network cloud platform

In recent years, the scale of data in wireless sensor networks has been growing and varied continuously. In order to satisfy the requirements of big data processing, the data analysis and processing platform should be applied to wireless sensor networks.

In the cloud platform, we designed the main nodes, the nodes, and the core nodes. The main node is composed of sensor nodes with strong communication ability. The primary node directly forwards the actual data that should be stored. The master node records all the metadata information and log information. In order to facilitate the reading and writing operation of sensing data in wireless sensor networks, the main node has to obtain the storage path and operation authority of the target sensing data through query and log information.

The slave nodes of cloud platform are almost distributed from nodes in wireless sensor networks. The slave nodes are responsible for storing the data from the sensor nodes. The slave nodes store the perceived data with block. According to the data request from the node and the data type released by the wireless sensor networks, the slave node scheduled the cloud platform. The scheduling includes the distributed sensing and centralized retrieval. Each node periodically sends its own management data to the master node. The data consistency and friendliness of the whole cloud platform system can be guaranteed from the cycle of the node and the main node.

The core node of the cloud platform is the engine and the drive between the wireless sensor network and the cloud server. The wireless sensor network can carry out parallel data processing of multisensor nodes through the node. The core node is composed of mapping module and driving module.

The main function of the one mapping module is to assign the data processing task of the master node to the node from the node. In order to ensure the I/O efficiency of the cloud platform, according to the data of the primary node and the data storage information from the node, the mapping module allocates the data transfer task to the core node of the communication ability. In order to avoid the cross cloud platform node transmission of wireless sensing data, the routing management of data forwarding is completed by the drive module.

Two drive modules are responsible for the specific implementation of data forwarding routing management. The driving module and all the sensor nodes of the cloud platform are to establish a drive relationship. Sensor nodes send data transfer to the drive module periodically. It is easy to control and manage the data management module of all physical nodes and the distribution of the bottom routing of the cloud platform (Fig. 1).

The delay solution method for each node of the cloud platform is shown in formula (1). Delay of all nodes is the work delay of the cloud platform.

$$\begin{cases} \mathrm{tD_M} = N_\mathrm{M}\dfrac{3}{t}\sqrt{t} \\ \mathrm{tD_S} = N_\mathrm{S}\dfrac{2}{t}\sqrt{N_\mathrm{M}t_\mathrm{M}} \\ \mathrm{tD_C} = \dfrac{N_C}{\sum_{i=1}^{N_\mathrm{M}+N_\mathrm{S}} i\sqrt{t}} \end{cases} \tag{1}$$

Here, $\mathrm{tD_M}$ represents the work delay of the master node. $\mathrm{tD_S}$ represents the work delay from the node. $\mathrm{tD_C}$ represents the work delay of the core node. t represents a physical sensor node in wireless sensor networks for the job delay. N_M represents the number of main nodes. N_C represents the number of core nodes. N_S represents the number of nodes from the node.

3 Opportunistic computing model for wireless sensor networks

Aiming at the problem of data transmission in the cloud platform and lightweight routing management, we design an opportunistic computing model to minimize the network overhead, for wireless sensor networks. Opportunistic calculation can protect the data transmission scheme of the cloud platform to deal with some of the more extreme network. In extreme cases, the opportunistic calculation of the cloud platform and wireless sensor networks can reduce the transmission load and get rid of resource constraints. In order to give a full play to the opportunistic advantage, we need to ensure that the probability of occurrence of extreme cases is less than the overall level of confidence in the cloud platform. We construct a mathematical model for data management and forwarding in wireless sensor networks based on chance computing. The constraint conditions and paradigms of the opportunistic calculation framework can be updated at any time. The mathematical model formula (2) for data

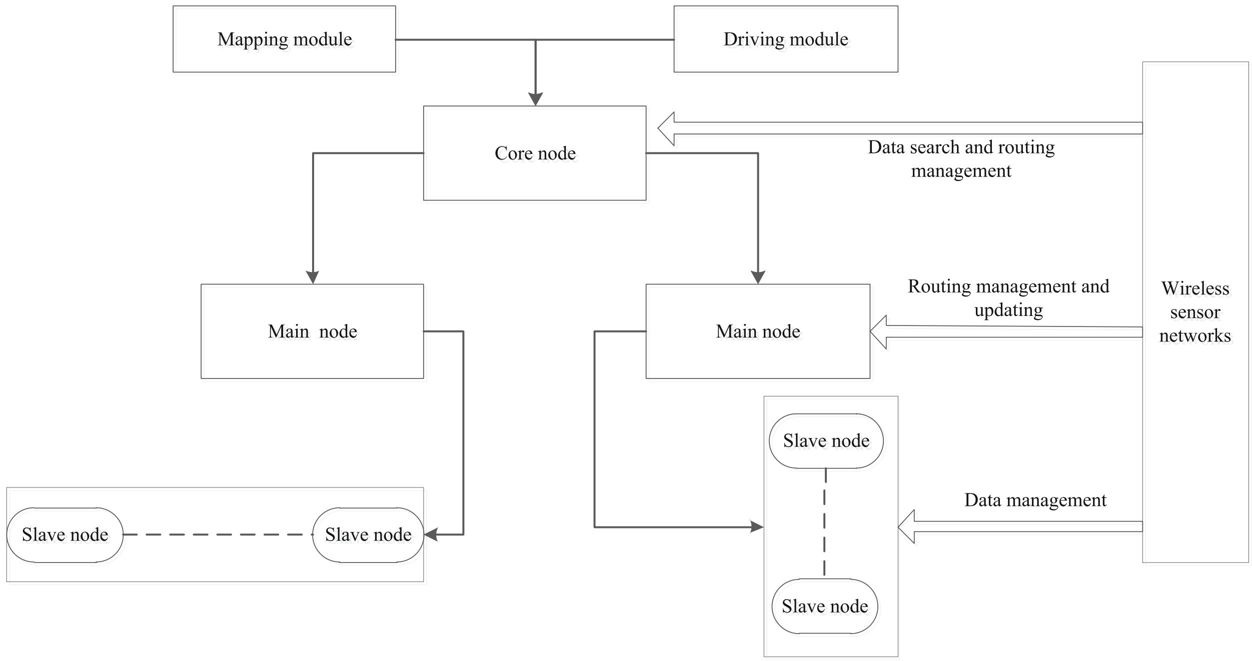

Fig. 1 Cloud platform architecture for wireless sensor networks

management and forwarding of wireless sensor networks is based on chance calculation.

$$\begin{aligned} &\min f(S) = \sum_{i=1}^{N_M} \mathrm{tD}_i C_i + \sum_{j=1}^{N_C} \mathrm{tD}_j C_j + \sum_{k=1}^{N_S} \mathrm{tD}_k C_k \\ &s.t. \quad P_S\{P_R \geq P_{SE}\} > \lambda \\ &\qquad P_R \leq \sum_{i=1}^{N_S} P_R(i)/N_S \\ &\qquad P_{SE} = \sin\theta \sum_{i=1}^{N_M} P_R(i) \end{aligned} \tag{2}$$

Here, C cloud platform node to represent the work overhead. P_S indicates successful transmission probability of sensing data. P_R represents the power of the sensor node to receive data. P_{SE} represents the power of sensor nodes to transmit data. This is the opportunistic calculation factor for cloud platform.

Combining the data forwarding and management requirements of cloud platform, the opportunistic of wireless sensor networks will be calculated to combine the objective function and driven constraints together and form the opportunistic planning function. The main solution steps for this opportunistic calculation model are as follows:

1. Enter the data stored in the cloud platform.
2. Input the requirements of the node deployment to candidate plan vector.
3. Based on the node crossover and failure probability, the initial deployment planning scheme is adopted. For each working node in the cloud platform, the opportunistic calculation method is used to obtain the resources to satisfy the constraint vector. Based on the optimal node vector and routing scheme, the network overhead and the probability of successful transmission are calculated.
4. Calculate the network overhead of all sensor nodes.
5. If the results do not satisfy formula (2) constraints on the cloud platform and sensor node, by chance, calculation sections dyed mapping fusion adjust and update. Mapping degrees are provided by the cloud platform. Fusion degree is provided by wireless sensor network.
6. The deployment of sensor nodes in wireless sensor networks is optimized and updated by the chance adjustment and random calculation method.
7. On the main node and core node of the cloud platform for cross and failure to judge, to get a new deployment scheme node set. Use the opportunistic calculation method to determine whether the set meets the opportunistic to calculate the constraint conditions.
8. Repeat steps 5 to 7, to achieve a given maximum allowable number of iterations so far.
9. To solve the problem in the process of finding the best sensor node set and cloud platform work node set as the final wireless sensor network data transmission system planning.

In formula (2) constraint function to add an opportunistic to calculate the driver. Opportunities for linear constrained optimization functions can be expressed as follows:

$$\begin{cases} F=\sum_{i=1}^{N_{\mathrm{M}}}\frac{f(T)t_iC_i}{(1-\lambda)^N}+\sum_{j=1}^{N_{\mathrm{C}}}\frac{f(T)t_jC_j}{(1-\lambda)^N}+\sum_{k=1}^{N_{\mathrm{S}}}\frac{t_kC_k}{\sqrt{(1+\lambda)}} \\ N=N_{\mathrm{M}}+N_{\mathrm{S}}+N_{\mathrm{C}} \end{cases} \tag{3}$$

Here, F represents the opportunistic to add the driver to calculate the function. N is the cloud platform node scale. Function $f(T)$ represents the computational complexity evaluation function of wireless sensor networks, as shown in formula (4).

$$f(T)=\begin{cases} 0, P_{\mathrm{S}}>\lambda \\ \lambda f(S), P_{\mathrm{R}}\leq\sum_{i=1}^{N_{\mathrm{S}}}P_{\mathrm{R}}(i)/N_{\mathrm{S}} \end{cases} \tag{4}$$

4 Cluster intelligence cloud routing protocol for wireless sensor networks

In wireless sensor networks, the energy signal strength of the cloud platform node can represent the end-to-end distance between the sensor node and the receiving node. The delay jitter of the node of the cloud platform reflects the quality and stability of the wireless sensor network link. The distance of the end to end can be judged through the signal strength of the sensor node in the opportunistic calculation, but the error of the distance is larger. By detecting the attenuation degree of the crowd signal, the mobile behavior and link quality of sensor nodes are deduced. It is difficult to accurately reflect the relative position of nodes in the wireless transmission hop count information, which is a single cloud platform. When the wireless transmission path is complex and the distance between the adjacent nodes is larger, the elimination of the link instability may lead to the elimination of the link between the crowd signal and the cloud platform.

In wireless sensor networks, the data transfer path which does not conform to the constraint condition is transformed by the cloud platform which is exhausted by the active resource depletion. This transformation can avoid the loss caused by the use of multiple paths. In addition, the wireless sensor network through the sensor node physical layer signal receiving strength and the cloud platform to map the fusion degree of the main node of the rational planning of wireless sensor network cluster intelligence cloud routing.

In wireless sensor network cloud platform, the wireless signal transmission driven model of the core node has two kinds of opportunistic space model and crowd mapping model. The opportunistic space model is used to detect the non-blocking distance between the sender and the receiver. In wireless communication, the path between the transmitter and the receiver is random. Crowd mapping model is based on the combination of end-to-end wireless path and crowd cloud propagation path. In the fusion crowd cloud routing, the signal power received by the receiving party is as follows:

$$\begin{cases} P_r=\dfrac{\sum_{i=1}^{N}\mathrm{tD_i}P_{\mathrm{R}}G_{\mathrm{r}}}{h_{\mathrm{t}}^2h_{\mathrm{r}}^2\sum_{i=1}^{N}C_i}\sqrt{f(T)} \\ f(T)=P_{\mathrm{R}}\leq\sum_{i=1}^{N_{\mathrm{S}}}P_{\mathrm{R}}(i)/N_{\mathrm{S}} \end{cases} \tag{5}$$

The crowd cloud platform receiver antenna gain is G_{r}, h_{t}, and h_{r} as the transmitter and the pick-up of the crowd antenna height. The crowd mapping model, the attenuation of the signal power along the crowd cloud path distance. Thus, the distance between sender and receiver is as follows:

$$\begin{cases} d=\dfrac{\mathrm{LG_r}\sqrt{\sum_{i=1}^{N}\mathrm{tD}_iP_{\mathrm{R}}}}{h_t^2h_r^2} \\ L=\dfrac{2N}{T}\sqrt{Nt} \end{cases} \tag{6}$$

The parameter values are determined by the wireless sensor nodes and the cloud platform server. Wireless sensor network and wireless mobile nodes in the network interface configuration are exactly the same.

In the process of the request message and the response message of the crowd cloud routing, the cloud platform is effective from the node according to the resource loss and propagation distance opportunistic to calculate the weight of the cloud path W, that is, the cloud platform:

$$\begin{cases} w=\int_{i=1}^{N}\dfrac{\varphi-L}{\varphi} \\ L=\dfrac{\prod_{i\to N}\frac{2N}{T}}{\sqrt{Nt}} \end{cases} \tag{7}$$

Here, parameter i represents the sensor node. φ represents the transmitting radius of the crowd cloud node signal. In the reliability of w measurement path and real-time path, we use the value of intellectual property group.

5 Performance analysis of routing protocols

This section analyzes and evaluates the performance of the proposed crowd cloud routing protocol based on

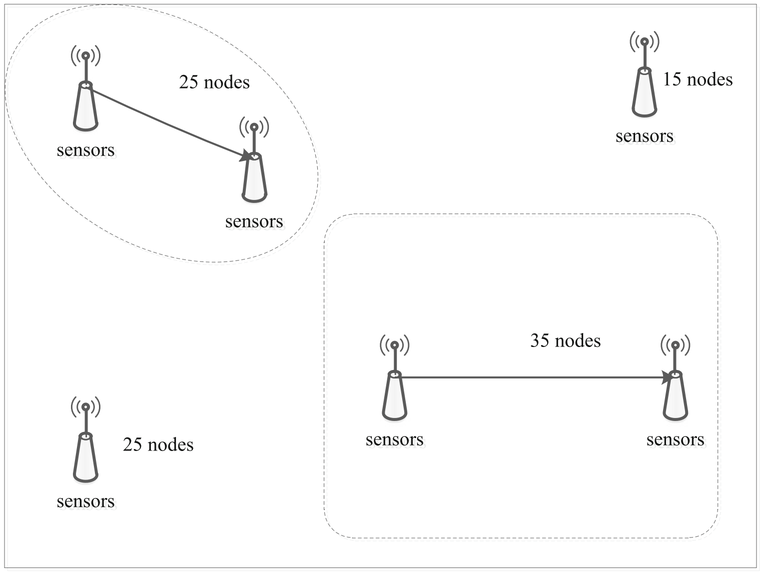

Fig. 2 Network topology

opportunistic computing denoted as CCRPOC and the energy-driven routing protocol denoted as EDRP through simulation method. At first, the paper introduces the configuration of the simulation environment and network parameters, and then formulates the performance evaluation standard. Finally, the performance of the routing protocol is analyzed and evaluated. The experimental network topology is given by Fig. 2.

The performance of the network is studied by comparing with the energy-driven routing protocol. Table 1 records the network parameter setting.

In order to quantitatively evaluate the performance of CCRPOC, this section has developed the following three routing performance evaluation criteria:

1. The end-to-end delay of packet from the source node to the destination node sends the received time interval;

Table 1 Parameter settings

Parameter	Value
Time	1200 s
Distance with one hop	200 m
Scale of topology	850 m×850 m
Number of sensors	100
Number of clouds	50
Load occurrence mode	Randomly
Packet size	1024 bytes
Packet transmission rate	5 packet/s
Moving model	Random moving
Moving speed	5, 10, 15, 20, 25 m/s

2. The packet loss rate: the total number of packets received cannot be correctly divided by the number of packets sent;
3. The route request overhead: sending request messages per unit time of crowd cloud routing or forwarding number.

Figures 3, 4, and 5 show the routing performance under the change of the node movement speed. We are thinking of the node's persistent moving scene.

CCRPOC significantly improve the end-to-end delay, as shown in Fig. 3. The reason lies in the cloud platform-aware routing mechanism to improve the robustness of the path, while extending the path life. In addition, CCRPOC can better control the mapping and integration

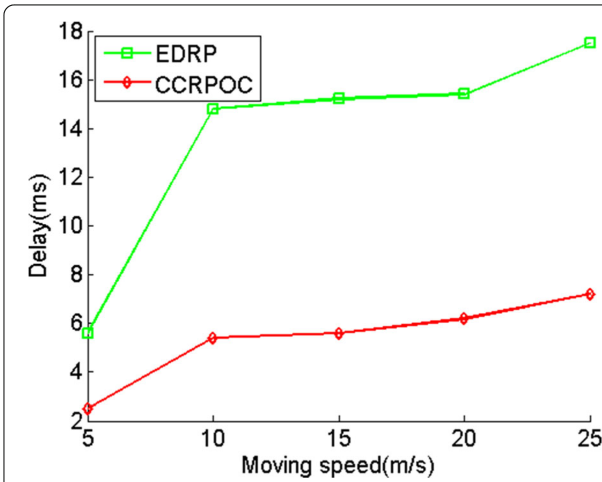

Fig. 3 Delay

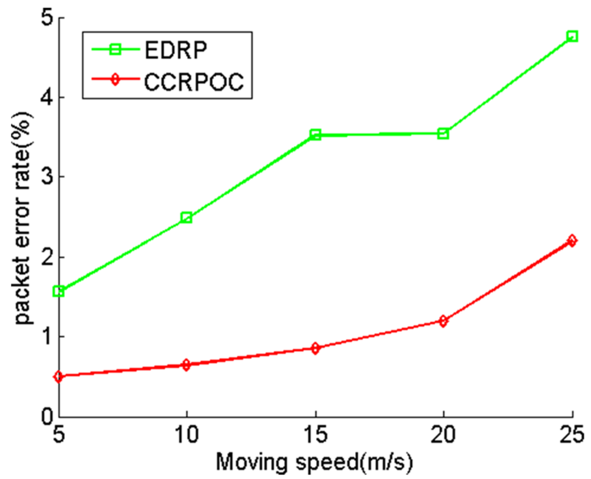

Fig. 4 Packet error rate

of the cloud platform and wireless sensor networks and improve the link bandwidth utilization. When the node moves faster, the performance of CCRPOC and energy-driven routing protocols is not obvious. This is due to the link outage probability and the node's moving speed into a certain proportional relationship. The results in Fig. 4 show the effect of the change of the node's movement speed on the packet loss rate. With the increase of the speed of the node movement, the frequency of the path is increased, and the packet loss rate presents a rising trend. Because the quality of the cloud path is improved, CCRPOC significantly reduces the packet loss. Due to the extension of the path life of crowd cloud, the overhead of CCRPOC routing is significantly reduced, which can save the network resources effectively, as shown in Fig. 5.

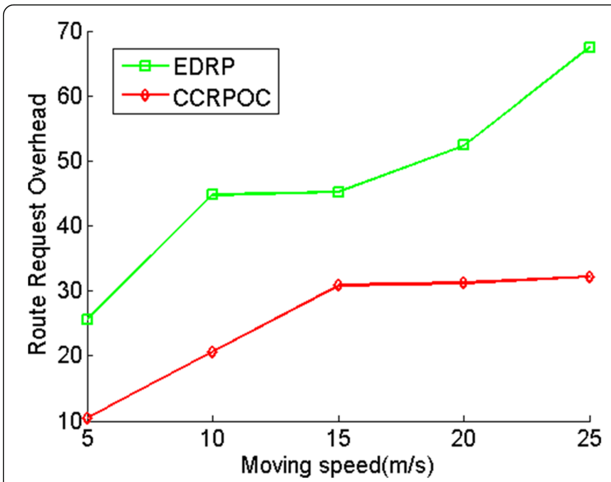

Fig. 5 Route request overhead

6 Conclusions

In order to improve the efficiency and reliability of data transmission in wireless sensor networks, we proposed a cluster routing protocol for wireless sensor networks. Firstly, in order to satisfy the requirements of big data processing, the data analysis and processing platform for wireless sensor networks are designed. In the cloud platform, we designed the main nodes, the nodes, and the core nodes. The engine and the drive between the wireless sensor network and the cloud server are designed. Secondly, aiming at the problem of data transmission in the cloud platform, we design an opportunistic calculation model which is suitable for wireless sensor networks. Opportunistic calculation can protect the data transmission scheme of the cloud platform to deal with some of the more extreme network. Finally, by eliminating the factors that may cause the link instability, the crowd cloud routing protocol is proposed. The experimental results show that compared with the energy-driven routing protocol, the proposed crowd cloud routing protocol can significantly improve the transmission delay, routing request overhead, packet delivery ratio, and other performance indicators.

Competing interests

The author declares that he/she has no competing interests.

Received: 28 July 2016 Accepted: 23 November 2016
Published online: 08 December 2016

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