

Energy Management of Context-aware Cold Chain Vehicle Nodes

Ronling Hu*, XiangLi, YangLou, Wei Yan

Faculty of Computer and Software Engineering, Huaiyin Institute of Technology,
Huai'an 223003, Jiangsu, China
*e-mail: 2237797605@qq.com

Abstract

In view of the question that the energy-constrained sensor nodes affect the normal operation of the whole system due to the short survival period, in this paper we present a new solution of adaptive energy management from the angle of context-aware computing. In different scenario modes, we take different environment acquisition and communication strategy according to scenario parameters, and thus build the context-aware energy management model. Finally, we extend the whole system life by lowering energy consumption of single internet of things vehicle node. Experimental data show that the energy management plan of context-aware wireless sensor nodes effectively reduces the energy consumption of nodes and extends the system life under the premise of providing reliable services.

Keywords: context-aware, internet of things, cold chain logistics, energy management

Copyright © 2016 Universitas Ahmad Dahlan. All rights reserved.

1. Introduction

For the production, processing, transportation, sales of cold chain logistics, the normal operation of the whole system needs to monitor the temperature, humidity and other logistics environment [1], while the transportation environment monitoring is the most difficult and critical, because this continuous monitoring needs an equipment [2] to continue working. However, due to the limitation of special conditions, the environmental monitoring nodes inside refrigerator van usually use the battery power that is not easy to change or refuel. This limited energy of nodes will seriously affect the service life of the whole cold chain logistics monitoring system [3]. Therefore, the low-power design is particularly important for the wireless sensor environment monitoring system [4]. At present, the research on sensor node energy management mostly still stays in the basic routing protocol selection or algorithm optimization, few studying the design optimization of energy management from the perspective of the whole system. The development of computer science and communication technology makes the context-aware technology arise at the historic moment. In 1994, Schilit and Theimer have put forward the concept of context, and defined it as: location, nearby people and object identification as well as the change of these objects [5]. Context awareness [6, 7] is a calculation model using the environment context information to help the decision optimization, which generally involves the information acquisition, context modeling and intelligent processing aspects [8].

At present, in view of the energy consumption optimization problem of wireless sensor nodes, the researchers mainly study from two aspects of system architecture and routing algorithm. Reasonable system architecture can reduce the node energy consumption to a certain extent, but if we need to save energy consumption in a deeper level, we also need to do in-depth research on routing algorithm. We solve the energy problem from routing algorithm, such as in literature [9] we propose minimum hops energy-adapted protocol (MHEP) through the analysis of the minimum cost routing algorithm. The algorithm uses the minimum path node residual energy and the minimum hop count of sink nodes as the selection routing metrics to complete data forwarding; In literature [10] we use energy-saving optimization energy management strategy of sleeping and awakening strategy, to transform the sleeping and awakening probabilistic certainty problem into a bargaining game, and thus achieve the balance of energy and performance; In literature [11] we present a new distributed positioning tracking strategy based on dynamic power management, which uses the wavelet de-noising and

autoregressive prediction algorithm, to realize the node dynamic awakening in the dormant state, extend the sleep time, and reduce the energy consumption. These methods analyze from the routing algorithm and other perspectives, and thus reduce the energy consumption of nodes to a certain extent, but all node states are switched from the perspective of probability or forecast, not rigorous and precise, and reduce the quality of service to a certain extent, so we need to find a more reasonable and effective mechanism for energy optimization. In literature [12] we apply the context-aware method to monitor the environment of medicine management place, and realize the distributed multiple source environment context awareness. At present, some researchers also apply the context awareness to the energy management of sensor nodes. Wood et al. [13] using the bidirectional data flow, analyze and study the resident activity pattern and feed back to the network, to realize the context-aware power management; For the study on energy consumption optimization problem of indoor environmental quality monitoring sensors, V Jelicic et al. [14] put forward the context-aware node energy management method, to decrease the activities of nodes and reduce energy demand.

The above work has verified the effect of context awareness on saving energy consumption of the wireless sensor nodes, but the current study is only limited to the network of fixed place. Considering the good performance of context awareness in energy management. This paper has proposed the energy management plan of context-aware cold chain logistics van sensor nodes. According to different application contexts, it takes different information acquisition and data transmission strategies, to effectively reduce the energy consumption of the nodes and extend the life cycle of the whole system without affecting the normal operation of system.

2. The System Architecture of Energy Management

With the advancement in networking and multimedia technologies enables the distribution. Although encryption can provide multimedia content once a piece of digital content is decrypted, the dishonest customer can redistribute it arbitrarily.

The system architecture of cold chain logistics internet of things is shown in Figure 1. The system consists of three parts: information acquisition network, remote monitoring center and the QR code traceability system.

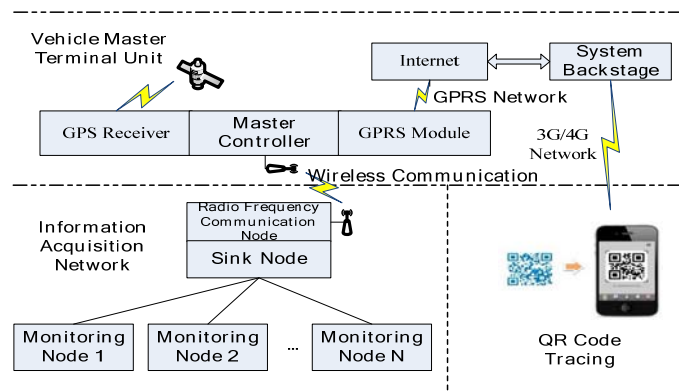


Figure 1. The system architecture of cold chain logistics internet of things

The information acquisition network in the refrigerated van including radio frequency communication module, gathering node and some nodes of environmental monitoring, implement the data acquisition of car environment, and interact data with vehicle master terminal; Vehicle control terminal, including the main controller, GPS module, GPRS module, power supply module, etc., realize the real-time environmental monitoring of refrigerated car and interact data with the system background; System background is the control and dispatching center of the whole cold chain logistics system, responsible for the storage and analytical calculation of main data information. At the same time, the system background is the main source of context information. The framework of context-aware energy management

system is shown in Figure 2. The system framework consists of the context information acquisition, context-aware modeling and context-aware application, and is centralized context information management architecture.

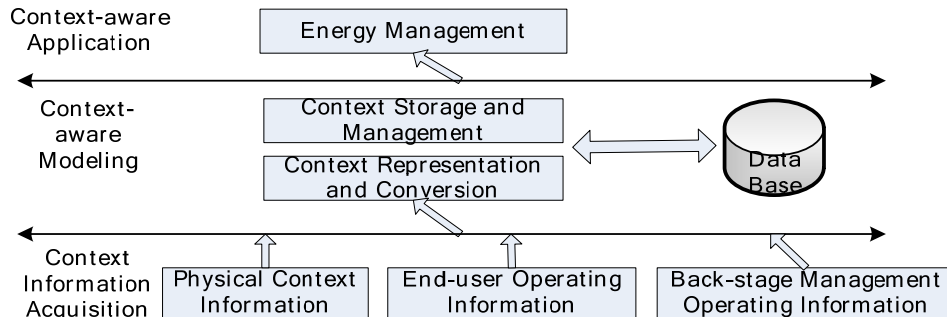


Figure 2. The framework of context-aware energy management system

Context information acquisition is mainly responsible for acquiring all kinds of context information, and converting into appropriate data format after pretreatment. In this system, the acquired context information includes three aspects of contents: the physical scene information, the end-user operating information and the background management operation information. The context information provides a data basis for context-aware modeling.

Context-aware modeling plays a crucial role in the whole system. The system efficiently extracts meaningful information from vast context information that is acquired from the underlying, and can effectively organize and present information, namely context representation and transformation. Database is used for helping the system reason out the current context types, storage context and context usage.

Context-aware application is the final purpose of context awareness. The establishment of context-aware model is to provide users with more intelligent service, and provide personalized services according to different contexts. In this paper, the context-aware system is mainly engaged in low-power optimization problem of sensor nodes. According to different application contexts, it tries to reduce the power consumption of each node without affecting the data accuracy and efficiency, and extend the life cycle of the system. Of course, the energy management is just one aspect of context-aware application, and it also can be used in vehicle scheduling, crisis management and other aspects. In this paper we are committed to looking for effective means of sensor node energy management, and the context-aware application is the energy management.

3. The System Architecture of Energy Management

3.1. Energy Consumption Analysis of Wireless Sensor Nodes

The structure of wireless sensor nodes usually consists of power management unit, sensor, microcontroller and radio frequency module, as shown in Figure 3.

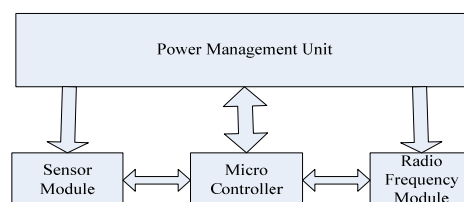


Figure 3. Structure of wireless sensor nodes

The energy consumption of nodes mainly comes from the following aspects:

1) Sensor module

The sensor module is data acquisition module, mainly responsible for sampling, recuperating, converting various physical environments, and its energy consumption can be shown as follows:

$$P = W * N + E \quad (1)$$

Wherein, W is the energy consumption for single sampling, N is the number of sampling, E is the energy consumption during idle time. From the formula, the sampling frequency of lower nodes can reduce energy consumption.

2) Microcontroller

The microcontroller as data processing unit, is responsible for controlling signal acquisition, data processing and wireless communication of the whole nodes. The microcontroller typically has various work states, including normal, idle, low power consumption and other modes.

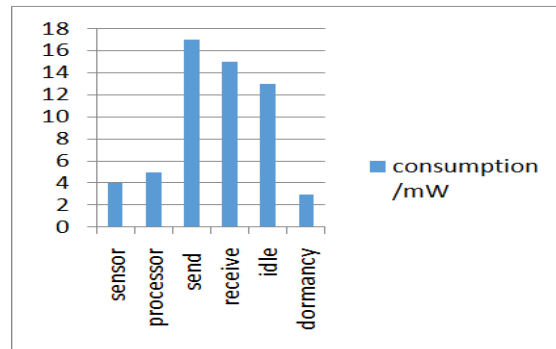


Figure 4. Value comparisons of wireless sensor node power consumption

3) Radio frequency module

Radio frequency module as the wireless communication interface of sensor nodes, is responsible for the wireless communication task with other nodes or gateways. It can be seen from the figure 4, sensors and processors consume very little energy, while the radio frequency module consumes a large percentage of energy in the node energy consumption. Radio frequency module consumes roughly the same energy in sending, receiving and idle state, while the power consumption is low in dormant state. Therefore, the nodes should make radio frequency module keep in dormant state without communication.

3.2. The Design of Energy Management Plan

The acquisition of system context information includes the physical context information, the end-user operation information, and the background management operation information. The sink nodes converge, pretreatment and pack the gathered temperature, physical context data, and send to the gateway nodes in driving cab, the gateway will upload to the remote monitoring center after further processing. The vehicle scheduling and management operation information in the background are sent to the monitoring center through the Internet.

The monitoring center represents and converts the input context information, and describes these context information in the same form, establishing the context-aware model.

According to the established context model, the system outputs a specific application strategy, namely the energy management strategy. The gateway nodes receive instructions from the monitoring center, and send to the sink nodes and acquisition nodes through the wireless way. Through the related parameters of the control software, it intelligently changes the frequency of sink nodes and collected signals, the number of data storage the frequency of radio frequency communication, the volume of wireless communication data, and thus

effectively reduces the energy consumption of nodes, and extends the life cycle of the whole system. In the practical application, we also need to consider different control strategies according to different transported goods, realizing the balance of intelligence and energy saving. Table 1 shows the context-aware energy management strategy.

Table 1. The context-aware energy management strategy

Context model	Microcontroller	Sensor module	Radio frequency communication
Loading	Activity alternates with dormancy	Acquisition interval is t1	Each acquisition n1 times
In transportation	Activity alternates with dormancy	Acquisition interval is t2	Each acquisition n2 times
Unloading	Activity alternates with dormancy	Acquisition interval is t3	Each acquisition n3 times
Empty idle	Dormancy	Closed	Closed
Parking rest	Activity alternates with dormancy	Acquisition interval is t4	Each acquisition n4 times
Breakdown maintenance	Activity alternates with dormancy	Acquisition interval is t5	Each acquisition n5 times

According to different contexts, we make corresponding adjustments for the working modes of sensor nodes, such as adjusting the temperature acquisition, the time interval of radio frequency communication, etc. In the stage of loading, unloading, parking rest and breakdown maintenance, the values t1 and n1 should be reduced accordingly as it is easy for the car temperature to have anomalies, we should upload the van temperature to the monitoring center at a higher frequency. But in transportation, the abnormal temperature has small occurring probability, we can increase the t1 and n1 correspondingly.

The working state of nodes can be described as an orderly state sequence, such as [S1→S2→S3→S4→...→Sn], n work states circulate continuously. We assume that the corresponding power consumption of each state is respectively P1、P2...Pn, the working time of each state is respectively T1、T2...Tn. The energy consumption of nodes is calculated as follows (ignoring state switch time).

$$E = \sum_{i=1}^n (P_i * T_i) \quad (2)$$

In the process of actual use, the working state of sensor nodes is constantly switching. When nodes do not need the temperature acquisition and wireless communication, the sensor module and radio frequency communication module should be closed, to make nodes keep in the state of low power consumption as far as possible. Under each context of loading, transportation, etc, the working state of nodes is changing constantly, and the circulated time interval of this state is also changing as the context changes.

4. Experimental Design and Simulation Analysis

4.1. Experimental Environment Design

The vehicle terminal system designed in this paper consists of 1 gateway node, 1 sink node and 4 acquisition nodes.

This paper makes the power consumption contrast experiment on acquisition nodes. The voltage of acquisition nodes is 3.3 V, the wireless transmission frequency is 2.454 GHz, and the output power of radio frequency is 1 DBM. We measure the current of experimental nodes in different working conditions, and the Table 2 shows the test results. With the advancement in networking and multimedia technologies enables the distribution and sharing of multimedia content widely. In the meantime, piracy becomes increasingly rampant as the customers can easily duplicate and redistribute the received multimedia content to a large audience. critical [1]. Although encryption can provide multimedia content once a piece of digital content is decrypted, the dishonest customer can redistribute it arbitrarily.

Table 2. The measured parameters of different states of nodes

State	Parameters	Node energy consumption	Condition
S1	Activation	3.515mA	The internal crystal oscillator as system clock, only CPU works.
S2	MCU+ Sensor module	4.525mA	Sensors acquire, convert and send data to MCU.
S3	MCU+ Radio frequency transmission	29.015mA	External 32M clock, in the sending state, the power is 1dBm.
S4	MCU+Radio frequency receiving	25.846mA	External 32M clock, in the receiving state.
S5	Dormancy	0.109mA	It can enter the normal working mode by interruption

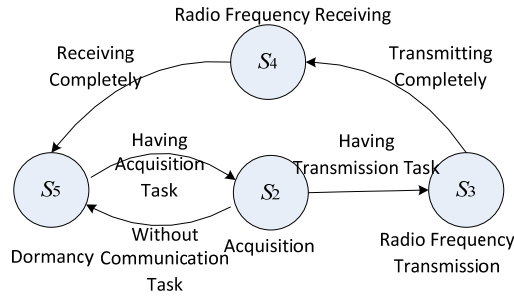


Figure 5. Working state transition diagram

The nodes immediately enter a dormant state after each acquisition data and radio frequency communication, and the next round of state circulates automatically when it's the time for the set sleep timer. According to the state setting of Table 2, the Figure 5 shows the working state transition model of the design nodes.

The A node acquires temperature and uploads data on 6 minutes as a cycle. The B node uses the context-aware energy management plan, intelligently controlling the temperature acquisition and the frequency of data uploading, namely the values of t and n in Table 1. The node energy consumption can be calculated as follows:

$$E = E_1 + E_2 + E_3 + E_4 \tag{3}$$

In the above formula, E_1 , E_2 , E_3 , E_4 are respectively loading, transportation, rest, the unloading phase of the energy consumption. The Table 3 lists the context-aware energy management strategy of the B node for each stage, in table T_w expresses the interval of temperature acquisition, and C_t is the temperature acquisition interval of radio frequency communication.

4.2. Data Analysis and Result

According to the experimental condition setting, we use MATLAB to generate the simulation data, and get 6 groups of random experimental data as shown in Table 4. Combined with the actual production conditions, the nodes need 2s for a data acquisition, and both the radio frequency receiving and sending need 30 ms.

Table 3. Power consumption optimizing strategy of B node for each stage

Time interval	T_w /min	C_t /time
Loading	1	1
Transportation	5	2
Stopping to rest	3	1
Unloading	1	1

To save energy, the nodes immediately enter a dormant state without data acquisition and radio frequency transmission and receiving task. According to the power consumption

parameters shown in the Table 2, combined with the formula 2 and formula 3, we calculate the power consumption of the node B. We also calculate the power consumption of A node by formula 2 and formula 3, and set each parameter according to the context-aware energy management strategy in the Table 4.

Table 4. Each time period distribution of randomly generated transportation task

Experimental group	Total transportation duration /h	Loading duration /min	Rest duration /min	Unloading duration /min	Cycle count of A node activity	Acquisition times of B node temperature	Times of B node radio frequency communication
1	11.97	13.45	22.84	24.50	120	140	85
2	23.67	11.81	51.71	14.60	237	263	151
3	10.92	15.11	26.37	21.52	109	130	81
4	28.94	27.17	54.18	26.21	289	325	189
5	20.51	28.22	54.77	18.08	205	239	145
6	20.01	23.99	49.37	29.77	200	234	143

For the nodes of using context-aware energy management strategy, in order to calculate conveniently, we carry on the statistics at various stages of transportation. We select group 3 and 6 groups of experimental data, to list the energy consumption curves. From the picture, we can see more intuitively the context-aware energy management strategy has very obvious energy saving effect. The Figure 6 and Figure 7 show the simulation results.

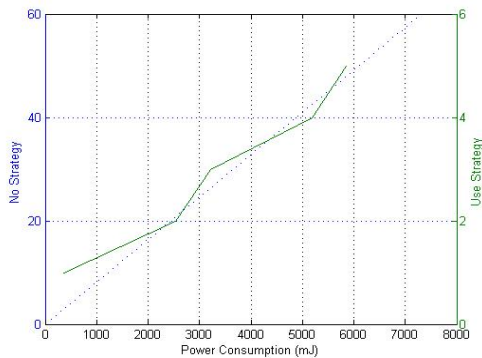


Figure 6. Comparison of two running results in the 3rd group

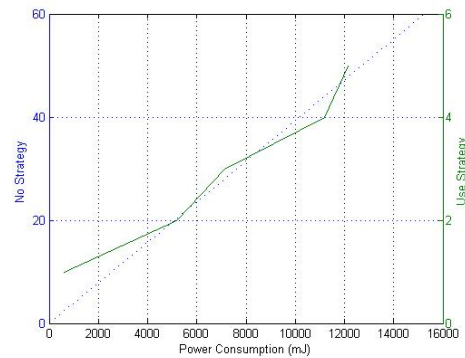


Figure 7. Comparison of two running results in the 6th group

For the simulation results of 6 groups of experiments, we analyze the energy consumption, as shown in Table 5. Through the analysis contrast, the context-aware energy management plan make the average energy consumption of nodes reduce by about 21%.

Table 5. Comparative analysis of all 6 groups experimental results

Experimental group number	Node energy consumption under operation without strategy	Node energy consumption under operation of context-aware strategy	Saved energy consumption	Energy saving proportions /%
1	8384.72	6731.99	1652.73	19.71
2	16574.50	12226.61	4347.90	26.23
3	7650.30	6335.53	1314.77	17.18
4	20264.18	15258.33	5005.85	24.70
5	14362.09	11452.20	2909.89	20.26
6	14011.94	11289.43	2722.52	19.43
	Mean value			21.25

The experimental results have achieved the expected effect, and verified the context-aware energy management method can more effectively reduce the power consumption and extend the life of the limited energy nodes. Moreover, as the transportation distance (or time) increases, the nodes, which use the context-aware strategy for energy management, will have more obvious advantages of low power consumption.

5. Conclusion

In view of that the energy-constrained nodes in the system affect the service life of the whole system due to the short life cycle, in this paper we propose a method of context-aware energy management. The data acquisition, processing, storage, transport of nodes change as the context changes, and also greatly reduce the energy consumption of nodes when meeting the intelligent work. In this paper, the method is applied to the vehicle system of cold chain logistics internet of things, which has well solved the defect that the vehicle nodes has a short cycle, improved the efficiency of the logistics transportation, and greatly reduced the logistics cost. In this paper, our further work is to explore a more scientific context-aware modeling method on the basis of the existing system, and further expand the application range of context awareness.

Acknowledgements

This work was supported by the Science and Technology Projects of Huaian (HAG2014028) and the University Science Research Project of Jiangsu Province (15KJB520004, 13KJB510004) and the Science and Technology Project of Jiangsu Province (BE2015127) and the Scientific Foundation Project of Huaiyin Institute of Technology (HGC1412) and the Internet of Things Development Special Fund of China in 2013 and the Small and Medium Enterprise Technology Innovation Fund of China in 2013.

References

- [1] Defraeye Thijs, Cronje Paul, Berry Tarl. Towards Integrated Performance Evaluation of Future Packaging for Fresh Produce in the Cold Chain. *Trends in Food Science & Technology*. 2015; 44(2): 201-225.
- [2] García LR, Elorza PB, Rodríguez-Bermejo J, et al. Monitoring the Intermodal, Refrigerated Transport of Fruit Using Sensor Networks. *Spanish Journal of Agricultural Research*. 2007; 5(2): 142-156.
- [3] Bachmann C, Ashouei M, Pop V. Low-power Wireless Sensor Nodes for Ubiquitous Long-Term Biomedical Signal Monitoring. *IEEE Communications Magazine*. 2012; 50(1): 20-27.
- [4] Sari, Lydia. Routing Raptor code for energy-efficient wireless body area network data transmission. *TELKOMNIKA Telecommunication, Computing, Electronics and Control*. 2015; 13(1): 277-283.
- [5] Gamecho Borja, Silva Hugo, Guerreiro Jose. A Context-Aware Application to Increase Elderly Users Compliance with Physical Rehabilitation Exercises at Home via Animatronic Biofeedback. *Journal of medical systems*. 2015; 39(11): 296-302.
- [6] Perera C, Zaslavsky A, Christen P, Georgakopoulos D. Context Aware Computing for the Internet of Things: A Survey. *IEEE Communications Surveys & Tutorials*. 2014; 6(1): 414-454.
- [7] Tong En-dong, Shen Qiang, Lei Jun, Liu Yu. Study on Context-aware Technologies for Internet of Thing. *Computer Science*. 2011; 38(4): 9-14.
- [8] Rosmawarni Neny. A mobile ecotourism recommendations system using cars-context aware approaches. *TELKOMNIKA Telecommunication, Computing, Electronics and Control*. 2013; 11(4): 845-852.
- [9] Yu Lei-lei, CHAI Qiao-lin, WANG Chun-lei. Energy Adaptive Routing Algorithm for WSN based on Min Imum Hops. *Application Research of Computers*. 2007; 24(11): 236-238.
- [10] Yunfeng Ling, Hongtao Zhang, Guiru Gu. A Printable CNT-Based FM Passive Wireless Sensor Tag on a Flexible Substrate With Enhanced Sensitivity. *IEEE Sensors Journal*. 2014; 14(4): 1193-1197.
- [11] Lin Jin-zhao, Li Guo-jun, Zhou Xiao-na. DPM-based Method for Tracking Maneuvering Targets in Wireless Sensor Networks. *Journal on Communications*. 2010; (12): 90-96.
- [12] Li Zheng, Ma Yong-tao, Liu Kai-hua. Design and Implementation of Environmental Context Awareness System Based on Internet of Things. *Computer Engineering*. 2012; 38(17): 1-4.
- [13] Wood A, Stankovic JA, Virone G, Selavo L, He Z, Cao Q, et al. Context-aware Wireless Sensor Networks for Assisted Living and Residential Monitoring. *IEEE Network*. 2008; 22(4): 26-33.
- [14] Jelcic V, Magno M, Brunelli D, Paci G. Context-adaptive Multimodal Wireless Sensor Network for Energy-Efficient Gas Monitoring. *IEEE Sensors Journal*. 2013; 13(1): 328-338.