The Optimum Configuration of Vehicle Parking Guide System based on Ad Hoc Wireless Sensor Network

Myoung-Seob Lim*, Yihu Xu*, Chung-Hoon Lee*

Abstract

The wireless sensor network (WSN) based on ad hoc network is applied to vehicle parking guide system without parking guide man at area or building with large scale of parking lots. The optimum number of cluster heads was derived for getting the minimum power consumption as well as time delay. Through the theoretical analysis of power consumption and time delay with the number of cluster heads in wireless sensor network, it was found that there exists the minimum point in the variation of power consumption and time delay according to the number of cluster heads.

Keywords : vehichle parking guide, Ad Hoc, WSN,

I. INTRODUCTION

Recently, the wireless sensor network based on ad hoc network is being widely spread in various environments to monitor and collect information [1]. A wireless sensor network consists of a large number of low-cost sensor nodes which can be self-organized to establish an ad hoc network via the wireless communication module equipped on the nodes. These functional parts enable sensor nodes to be easily and rapidly deployed to cooperatively collect, process, and transmit information. In a multi-hop ad hoc sensor network, each node plays the dual role of data originator and data router. The malfunctioning of a few nodes due to power life time can cause significant topological changes and might require rerouting of packets and reorganization of the network [2]. The research about the relationship between the end-to-end delay and the capacity was motivated by the results of Gupta and Kumar. It was shown that, in an ad hoc network of size n, the capacity per node goes down with n thus making large networks impractical [3].

As reviewed in the above references, energy consumption and time delay are vital factors of wireless sensor networks which should be considered. Therefore in some specific application based on ad hoc wireless sensor network, different design approach should be considered deliberately while managing successfully energy conservation as well as capacity maximization like other ad hoc wireless sensor applications with mobility.

In this paper, we applied the Ad Hoc WSN to vehicle parking guide system without parking guide man at area or building with large scale of parking lots, where the total number of wireless sensor nodes are divided into some cluster group and cluster head in each group will do the role of relaying the sensing information from nodes and transmit it to base station which is far away from cluster head [4].

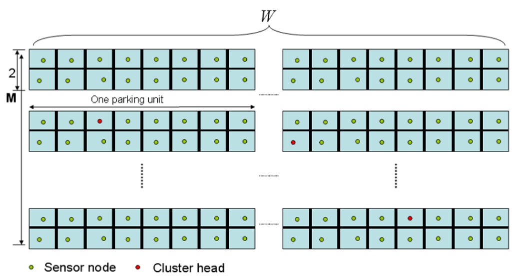

Fig. 1. Parking area with Ad Hoc wireless sensor nodes

Because the power consumption and time delay occur mainly at cluster head in the car parking guide system, the analysis was focused in deriving the power consumption and time delay according to the number of cluster heads.

II. THE MODEL OF CAR PARKING SYSTEM BASED ON WSN

We present the model of the car parking guide system based on the Ad Hoc WSN in Fig. 1.

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From Fig. 1, we can see directly that the nodes were fixed at every parking unit in parking area. Wireless sensor nodes are deployed to the parking lots to monitor and detect the occupation status of the parking unit, and to cooperatively process and transmit the information through a base station to the computer data service management system in Fig. 2.

It is necessary to locate the cluster head in each group of cluster for relaying the information of the occupation status of the parking lots to the parking guide management system.

The parking guide management system will send the parking information with direction arrow signal to the local display panel located at each corner for drivers.

Now it is required to decide how to divide the total number of sensor nodes in parking area.

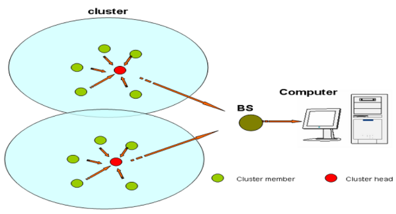

Fig. 2. Model of car parking guide system based on Ad Hoc WSN

Ⅲ. RELATION BETWEEN POWER CONSUMPTION AND THE NUMBER OF CLUSTER HEADS

It is necessary to make a design of power efficient system when car parking system is configured. Referring to the method such as Wendi [5] or Heed [6], it is assumed that each node has a radio power enough to directly reach the neighboring nodes.

Here we defined that all nodes are not cluster heads and only communicate with the cluster head in a TDMA fashion, according to the schedule created by the cluster head.

In the power consumption model of a wireless sensor node in Fig. 3, power is calculated with the parameter in the view of distance and message length as like the following parameters.

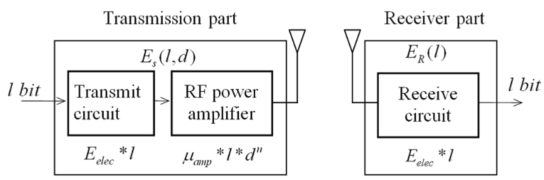

Fig. 3. power consumption model of a wireless sensor node

$E_s(l,d)$: The power consumption of transmission part
$E_R(l)$: The power consumption of receiving part
E_{elec} : The electronic power consumption
μ_{amp} : The constant parameter of amplifier
l: The size of message

In wireless communication, sometimes the signal fading was affected by distance [7], where free space fading has the attenuation parameter as d^2 and in case of multi-path fading, the attenuation parameter is d^4. It is assumed that the node sends l bit data in the time slot and the distant threshold value is d_n.

So in the transmission part, the power consumption is

$$E_s(l,d)=\begin{cases} lE_{elec}+l\mu_{fs}d^2 ......d<d_0 \\ lE_{elec}+l\mu_{mp}d^4 ......d\ge d_0 \end{cases} \quad (1)$$

,where μ_{fs} and μ_{mp} represent free space fading parameter and multipath fading parameter respectively.

In the receiving part, the power consumption is

$$E_R(l)=lE_{elec} \quad (2)$$

Assuming that there are K clusters in the car parking area and N nodes are distributed evenly in the car parking lot (W*M), the average number of node for one cluster is N/K. Every cluster has (N/K)-1 cluster members. The total power dissipated at cluster head is caused by three parts:

$lE_{elec}+l\mu_{mp}d^4_{toBS}$: Transmitting power consumption

$lE_{elec}((N/K)-1)$: Receiving power consumption

$lE_{DA}(N/K)$: Data-fusion consumption

So the power consumption of cluster head is:

$$E_{CH}=lE_{elec}((N/K)-1)+lE_{DA}(N/K) +lE_{elec}+l\mu_{mp}d^4_{toBS} \quad (3)$$

The power consumption of cluster member nodes is:

$$E_{not-CH}=lE_{elec}+l\mu_{fs}d^2_{toCH} \quad (4)$$

Every cluster occupies WM/K area. Assuming that $\rho(x,y)$ is the uniform distributing probability density of cluster member and the cluster head in the center of cluster, the mean of d^2_{toCH} can be defined [8].

$$E[d^2_{toCH}]=\iint d^2_{toCH}\rho(x,y)d\sigma=\iint(x^2+y^2)\rho(x,y)dxdy =\iint r^2\rho(r,\theta)rdrd\theta \quad (5)$$

With the radius of cluster, R

$$WM/K=\pi R^2 \Rightarrow R=\sqrt{\frac{WM}{\pi K}} \tag{6}$$

Putting (6) into (5), we can get:

$$E[d^2_{toCH}]=\rho\int_{\theta=0}^{2\pi}\int_{r=0}^{\sqrt{\frac{WM}{\pi K}}} r^3 dr d\theta=\frac{\rho(WM)^2}{2\pi K^2} \tag{7}$$

And because $\rho(r,\theta)$ is uniform distribution, so

$$\rho=\frac{1}{WM/K} \tag{8}$$

Putting the (8) into (7), finally we can get

$$E[d^2_{toCH}]=\frac{WM}{2\pi K} \tag{9}$$

Putting (9) into (4), we can get the power consumption of single cluster member node:'

$$E_{not-CH}=lE_{elec}+l\mu_{fs}\frac{WM}{2\pi K} \tag{10}$$

From all above equations, we can say that the power consumption in one cluster is defined as follows:

$$E_{cluster}=E_{CH}+((N/K)-1)E_{not-CH}$$
$$\approx E_{CH}+(N/K)E_{not-CH} \tag{11}$$

Putting (3), (8) into (11), we can get the total power consumption as like:

$$E_{total}=K*E_{cluster}$$
$$=l(2E_{elec}N+E_{DF}N+K\mu_{mp}d^4_{toBS}+\mu_{fs}N\frac{WM}{2\pi K}) \tag{12}$$

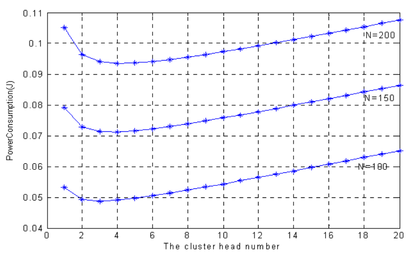

Fig. 4. Power consumption according to the number of cluster heads

Calculating the derivative of E_{total} with respect to the variable K, we can get the optimal number of K as like:

$$K_{optimal}=\sqrt{\frac{N}{2\pi}}\sqrt{\frac{\mu_{fs}}{\mu_{mp}}}\frac{\sqrt{WM}}{d^2_{toBS}} \tag{13}$$

In Fig. 4, we can see that there exists minimum point in the relation between power consumption and the number of cluster heads.

Ⅳ. RELATION BETWEEN THE TIME DELAY AND THE NUMBER OF CLUSTER

The structure of data transmission of sensor node in Ad Hoc WSN is shown in Fig. 5. The total time delay in Ad Hoc WSN includes detecting time delay, processing time delay, sending delay, and broadcasting delay.

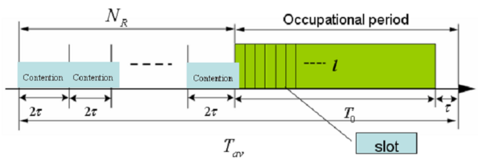

Fig. 5. The structure of data transmission in sensor node

Let's define the related parameters as follows.

τ: transmission time
2τ: contention period
L: length of data frame [bits]
R: data rate
$L/R=T_0$: transmission time of data frame
N_R: the number of retransmission
T_{CH-BS}: the average time delay from cluster head to base station
T_{av}: the average transmission time of one frame

In the cluster, the cluster members communicate with the cluster head in a TDMA fashion. The number of sensor in a cluster, N/K is slot number. Assuming the length of message which is sent by each cluster member is l_1. We set the slot length as 1.5 l_1 [9]. Therefore we can define the length of the message frame as:

$$L=1.5l_1\frac{N}{K} \tag{14}$$

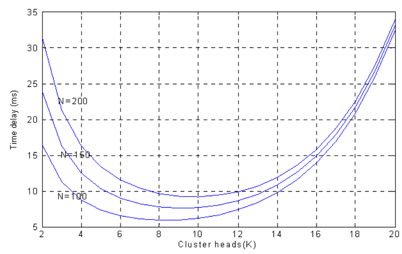

Fig. 6. Time delay according to the number of cluster heads

Assuming that the cost time of one slot, is

$$t_1 = \frac{1.5l_1}{R} \quad (15)$$

From (14) and (15), we can calculate the total time delay from cluster members to cluster head as like:

$$T_0 = \frac{N}{K} \times t_1 = \frac{N}{K} \times \frac{1.5l_1}{R} = \frac{1.5l_1 N}{KR} \quad (16)$$

Now let's calculate the time delay from the cluster heads to BS.

Here $\tau = \frac{E[d_{toBS}]}{C}$ is the contention time and N_R is the number of contention periods. The

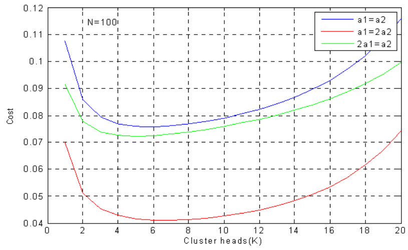

Fig. 7. Cost of power consumption and time delay vs the number of cluster heads

average time delay from cluster head to base station is defined as :

$$T_{CH-BS} = N_R \times 2\tau + T_0 + \tau \quad (17)$$

Next we calculate the number of contention periods, N_R , assuming that there are K cluster heads. The transmission probability of cluster head is p. The successful transmission probability is A. So we can express A as:

$$A = Kp(1-p)^{K-1} \quad (18)$$

The probability of transmission failure is 1-A.

If there were j contention periods, which also means that after j times re-transmission, the data was successfully transmitted at j+1 times, we can express the probability as follows:

$$\begin{aligned} \mathrm{P}[j \text{ contention periods}] &= \mathrm{P}[j \text{ failures}, (j+1)_{th} \text{success}] \\ &= (1-A)^j A \end{aligned} \quad (19)$$

So we can get the number of contention periods, N_R . It is also equal to the number of re-transmission times.

$$N_R = \sum_{j=0}^{\infty} j(1-A)^j A = (1-A)/A \quad (20)$$

So the average time delay in Ad Hoc WSN is as follows.

$$\begin{aligned} T_{av} &= T_0 + T_{CH-BS} \\ &= T_0 + (N_R \times 2\tau + T_0) + \tau = N_R \times 2\tau + 2T_0 + \tau \\ &= (1-A)/A \times 2\tau + 2 \times \frac{1.5l_1 N}{KR} + \tau \end{aligned} \quad (21)$$

If equation (18) is inserted into (21),

$$\begin{aligned} T_{av} &= (1-A)/A \times 2\tau + 2 \times \frac{1.5l_1 N}{KR} + \tau \\ &= \frac{1-Kp(1-p)^{K-1}}{Kp(1-p)^{K-1}} \times 2\tau + 2 \times \frac{1.5l_1 N}{KR} + \tau \end{aligned} \quad (22)$$

So we get the average time delay as :

$$T_{av} = \frac{1-Kp(1-p)^{K-1}}{Kp(1-p)^{K-1}} \times 2\tau + 2 \times \frac{1.5l_1 N}{KR} + \tau \quad (23)$$

Ⅴ. OPTIMUM CONFIGURATION BASED ON POWER CONSUMPTION AND TIME DELAY

If we design the car parking guide system considering both power consumption and time delay, the cost function can be defined as follows.

$$\text{cost} = \alpha_1 T_{av} + \alpha_2 E_{total} \quad (24)$$

Setting the value of weighting parameters α_1 and α_2 in the system, we can get the Fig. 7 which shows the optimum point with respect to cost of power consumption and time delay.

$E_{elec} = 50nJ/bit,$	$E_{DA} = 5nJ/bit/signal$
$\mu_{mp} = 0.0013pJ/bit/m^4$	$\mu_{fs} = 10pJ/bit/m^2$
$E[d_{toBS}] = 100m$	$M = 100m$
$W = 150m$	$R = 1Mbps$
$l_1 = 100b$	$l = 4200b$
$p = 0.25$	

Ⅵ. CONCLUSION

In order to find the optimum configuration of Ad Hoc wireless sensor network for vehicle parking guide system without parking guide man at area or building with large scale of parking lots, the power consumption and time delay with the number of cluster heads theoretically are analyzed. Through the analysis, we found the optimum number of cluster heads which can make an optimum configuration of vehicle parking guide system without parking guide man with low power consumption and short time delay.

REFERENCES

[1] I. Akyildiz, W. Su, Y. Sankarasubramaniam, E. Cayirci. "A survey on sensor networks." IEEE Communication Magazine, 40(8): 102-114, 2002.

[2] Ian F. Akyildiz, Weilian Su, Yogesh Sankarasubramaniam and Edral Cayirci, "A survey on sensor networks", IEEE communication magazine,August,2002:102~114

[3] Piyush Gupta, P.R.Kumar, "The capacity of wireless networks", IEEE transaction on information theory,vol.46,no.2, March,2000:388~403

[4] 이준구, 임명섭, "빈 주차공간 확인 및 안내 방법", 특허 제 10-0988314호, 2010년10월11일

[5] Wendi Rabiner Heinzelman, Anantha Chandrakasan, and HariBalakr -ishnan. "Energy-Efficient Communication Protocol for Wireless Micro sensor Network". The proceedings of the Hawaii International Conference on System Science. IEEE, January 4 - 7, 2000.

[6] Ossama Younis and Sonia Fahmy. Heed: "A Hybrid, Energy-Efficient, Distributed Clustering Approach for Ad Hoc Sensor Networks". IEEE transaction on mobile computing, vol.3, NO.4, October-December 2004

[7] Rappaport T. Wireless Communications: Principles & Practice[M]. NJ: Prentice-Hall, 1996

[8] ZHANG Hai- bo, CHEN Di, LI Qi,WANG Wei Lowest- Energy Protect Clustering Algorithms for Wireless Sensor Networks

[9] Andrew S. Tanenbaum 'Computer Networks, Fourth Edition' Publisher: Prentice Hall Pub.; Date: March 17, 2003; ISBN: 0-13-066102-3

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