Energy Aware Sensor Node Design

Ms. Prajakta Ananda Kharote. Prof. M. P. Satone.

***Abstract*—Wireless sensor network (WSN) have been identified as one of the most important technology for 21st century. But the energy consumption is the major problem for the implementation of wireless sensor network now days. This paper presents the design and software based implementation of an energy aware sensor node which helps to solve above mentioned problem about WSN. The proposed design helps to construct energy efficient WSN. The strategy used in this is useful for sensor node level as well as for network level design. For energy efficient communication, distance between transmitter and receiver is estimated and then required lowest transmission power is calculated at available data rate. After that actual communication takes place. Between two consecutive measurements sensor nodes are set to sleep mode for energy saving purpose under normal operating conditions. It is observed that energy consumption within whole network under different network configurations giving better results. It can give best results by choosing most efficient from one of them is also useful.**

***Index Terms*— Energy efficiency, Central monitoring unit (CMU), Central Processing Unit (CPU), Periodic sleep/wake up method, Received signal strength (RSSI), Wireless sensor network (WSN).**

I. Introduction

Compact system and wireless communication are recent trends and having rapid development in this embedded world [1]. Wireless sensor technology having wide area of applications [2] like industrial system monitoring [3], [4], environmental sensing [5] etc. WSN are real life applications and its development is future continued in next year's [[6], [7].

Although batteries can be rechargeable and many other recharging facilities are available [8], energy consumption still remains major obstacle for exploitation of this technology. Previous researchers studied various approaches for reducing energy consumption such as duty cycling and data driven technology [9]. For duty cycling sleep/wake up and MAC protocol is used with low duty cycle. Some redundant nodes can be set to sleep mode to improve network life has been proposed in [10]. If sensor is not working in transmitting or receiving mode it is considered that sensor is in low power idle mode with MAC protocol [11]. In data driven technology approaches to data compression and energy efficient data acquisition technique [12]. In other research data transmission decreased with only higher level communication. Here network is divided into various subsystems. As data transmission is reduced the energy consumption is also reduced [13]. Optimal energy sampling is obtained by using an adaptive sampling algorithm [14]. Other energy optimization options are also studied like modulation sampling method [15], [16], multihop routing schemes [17], network sectioning [18], [19], and low power hardware [20] is used. Combination of block transfer with sleep/wake up scheduling is also developed in [21].

II. Sensing methods

For reducing energy consumption in WSN node level and network level energy saving are basic constraints. As mentioned in [22] RF power setting in adaptive network configuration strategy is used in this paper. Also periodic sleep/wake up technique is used to achieve further energy saving.

A. Energy Consumption Calculation

In order to communicate between two or more nodes required energy consumption for data transmission can be expressed as [25]

$$E_{TX} = E_{e\_tx} . k + \varepsilon_{amp} . d^{\alpha} \quad (1)$$

Here k is number of data bits to be transmitted, ε_{amp} is environmental factor ranging from 2 to 5, d is the distance between communications, α is amplification factor and E_{e_tx} is the dissipated energy used to operate transreceiver [26].

$$E_{w\_tx} = V_{cc} . I_{TP} / K_{data\_rate} \quad (2)$$

Where V_{cc} is the operating voltage, I_{TP} is transmitting current K_{data_rate} is the rate of data transmission. Whereas receiving energy can be expressed by equation 3.

$$E_{RX} = E_{e\ rx} . k \quad (3)$$

Equation 1 [26] shows that consumed energy is moreover dependant on distance between communication and rate of data transmission.

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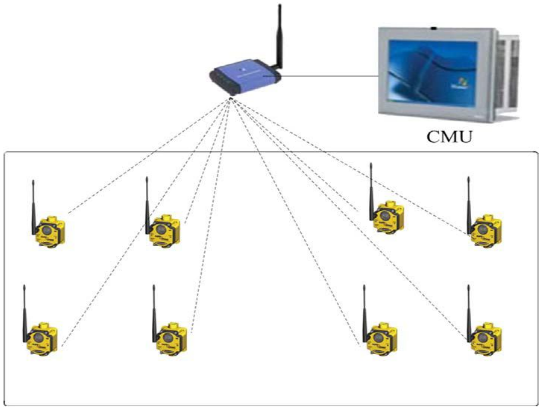


Fig. 1. Distributed method used in network system.

B. Sensing Methods

To ensure efficient operation of entire WSN, power supply plays an important role in the system. Therefore to design energy efficient network is difficult task. As this paper suggests nodal as well as network level energy saving, the network level energy saving can be implemented with different approaches.

Distributed Method: In this method each node is acting as separate data transmitting or receiving device. The energy consumption Edr can be calculated by equation 4 given below [26]

$$E_{dr} = \sum_{n=1}^{N} \left[\left(E_{e\_tx} + \varepsilon_{amp} \, . \, d_n^{\alpha} \right) . k_r \right] \tag{4}$$

Numbers of sensor nodes are denoted by N in this equation d_n is distance between sensor node and CMU, k_r is the number of bits to be transmitted or received [1].

Clustered Method: All sensor nodes are grouped into different number of clusters. Each cluster is having its own cluster head which collects the data from other sensor nodes of same group. After that the cluster head will transmit the data to CPU. In this method the energy consumption can be calculated by following equation 5 [26]

$$E_{ds} = \sum_{m=1}^{M} \left[\sum_{j}^{N_m - 1} \left(E_{e_{tx}} + \varepsilon_{amp} \, . d_j^{\alpha} + E_{e_{rx}} \right) . \, k_r + \left(E_{e\_tx} + \varepsilon_{amp} \, . \, d_m^{\alpha} \right) . \, k_m \right] \tag{5}$$

Here M are the number of clusters, N_m is the number of sensor nodes present in the respective cluster, distance between sensor node and its cluster head is given by d_j, d_m is the distance between cluster head and CPU and number of bits used in transmission /reception is given by k_m.

III. DESIGN OF ENERGY AWARE SENSOR NODE

The designing of energy aware sensor node is dealing with various parameters. The designing is described as follows.

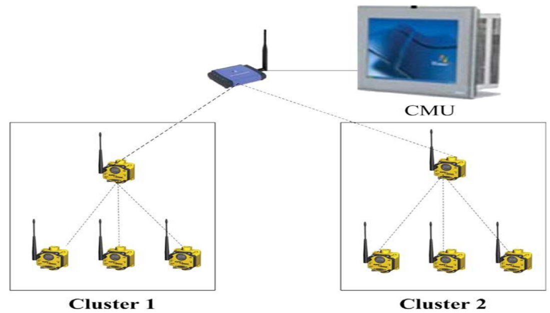


Fig. 2. Clustered method used in network system.

A. Communication Module

For communication module transmitted power and received power are important values. To calculate these values the antenna signal gain is assumed to unity. To transmit 1 bit to the receiver transmitted power and received power is given by equation 6 and 7 [26]

$$P_{Tx} = \left(\varepsilon_{amp} \, . \, R \right) . \hat{d}^{\alpha} \tag{6}$$

$$P_{Rx} = \frac{P_{Tx}}{d^{\alpha}} = \left(\varepsilon_{amp} \, . \, R \right) . \left(\frac{\hat{d}^{\alpha}}{d^{\alpha}} \right) = P_S \, . \left(\frac{\hat{d}^{\alpha}}{d^{\alpha}} \right) \tag{7}$$

The rate of data transmission is given by R, $\hat{d}$ is the estimated distance between transmitter and receiver, d is the actual distance between transmitter and receiver.

If $\hat{d} < d$, due to underestimation transmission will fails as there is incorrect identification of receiver node. If $\hat{d} > d$, overestimation will takes place which will results in loss of energy as more than sufficient energy is received. It will not energy efficient communication. The remedy of above problem can found with the consideration of received signal strength indication (RSSI) one can estimate actual distance. For example by using clustered method, the sample code is transmitted to sensor node by cluster head with maximum power P_{Tx} max and received power is P_{Rx} then the distance can be calculated with equation 8 [26]

$$\hat{d}^{\alpha} \geq P_{Tx\_max} \, / \, P_{Rx} \tag{8}$$

Therefore minimum power required for data transmission is expressed as given in equation 9 [26]

$$P_{Tx} = P_S \cdot (\frac{P_{Tx\_max}}{P_{Rx}}) \tag{9}$$

The format of data packet shown in fig. 4 can be constructed with following contents

1) Header………………………… 4 bytes
2) Synchronous word……………. 2 bytes
3) Size of packet………………… 1 byte
4) Address of packet…………….. 1 byte
5) Data…………………………… n bytes
6) CRC word……………………... 2 bytes

HEADER (11010…10)	SYNCH. WORD	PACKET SIZE	PACKET ADDRESS	DATA	CRC WORD
4 BYTES	2 BYTES	1 BYTE	1 BYTE	n BYTES	2 BYTES

Fig. 3. Data packet format for transmitter.

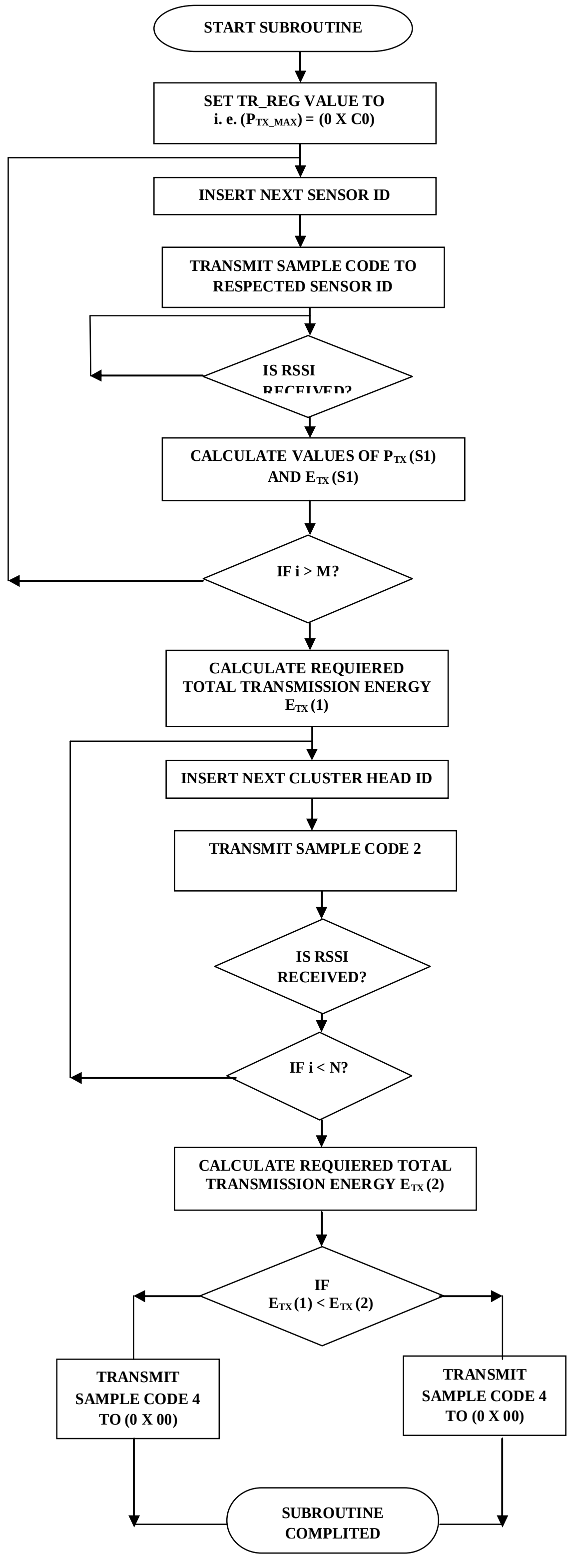


Fig. 4. Flowchart for method selection and energy estimation of a network.

As a result each sensor node transmit (10+n) bytes data at a time. Therefore its energy consumption can be calculated as equation 10.

$$E_{Tx} = P_{Tx} \cdot \frac{(10+n).8}{R} \quad (10)$$

Where n is the number of data bytes to be transmitted and R is rate of data transmission.

B. Periodic Sleep/wake up Technique

The application of WSN can be possible in remote areas where the recharging of batteries is not easily possible. In such cases for energy saving purpose some sensor nodes can kept in sleep/wake up mode with specified timer. Timer is used to set sleep period, when it overflows, it interrupts sleep mode of respected sensor node. And node will wake up to perform its defined operation. In this way energy saving can be done efficiently.

C. Network Level Energy saving

Only reduce energy consumption at nodal level is not sufficient, to reduce energy consumption at network level is an important part of designing of system. The operation of sensor nodes within network is carried out under given steps.

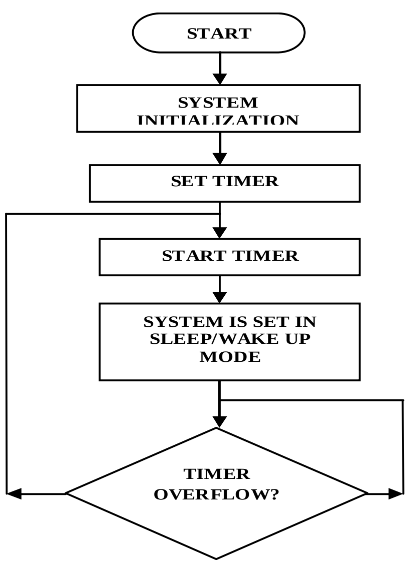


Fig. 5. Flowchart for sleep/wake up method.

1) Initialization of system and timer is set for particular period .When timer overflows sensor node will wake up and collects data for transmission or reception if needed.

2) Before communicating sensor node will estimate minimum required transmission power P_{Tx} for each sensing method.

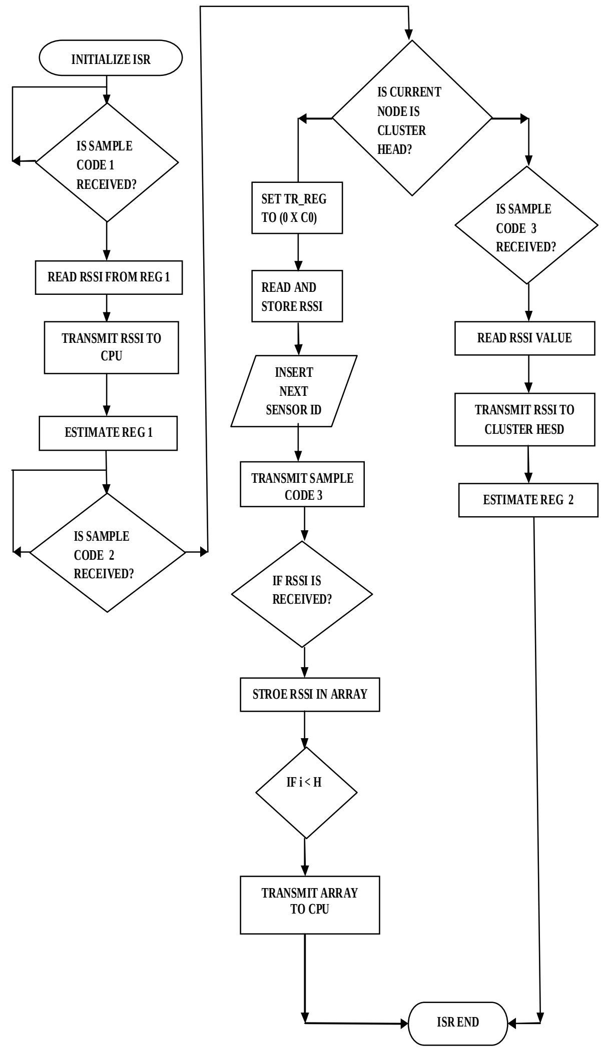


Fig. 6.Flowchart for conceptual arrangement of networking system.

3) Total energy consumption is calculated by CPU and selects the best method among both for best energy efficient to construct network.

The basic concepts are implemented with algorithms are shown in fig. 4, fig. 5 and fig. 6. Fig. 6 shows flowchart which is used to collect all data related to energy and to select appropriate and efficient method of networking.

Now the question arises if any node wish to communicate between sleep periods, for that purpose an interrupt service routine is set (ISR). This ISR will calculate the total energy estimation and most efficient method of networking. The flowchart gives detail information about ISR.

IV. EXPERIMENTAL RESULTS

For energy efficient communication nodal level and network level different strategies are implemented using software. Here all the results gathered from simulation and for this purpose network simulator is used. In this paper to achieve results NS-2 software is used.

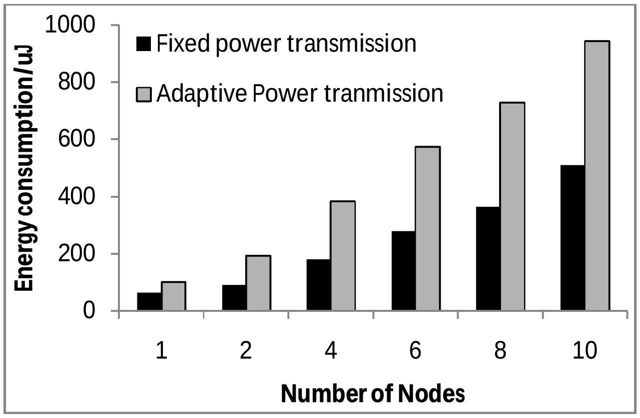
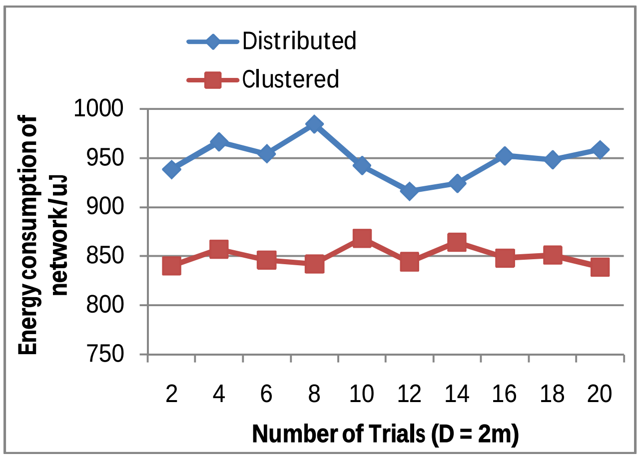
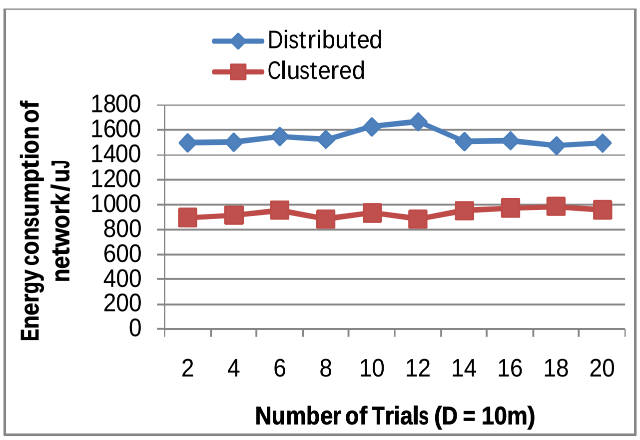


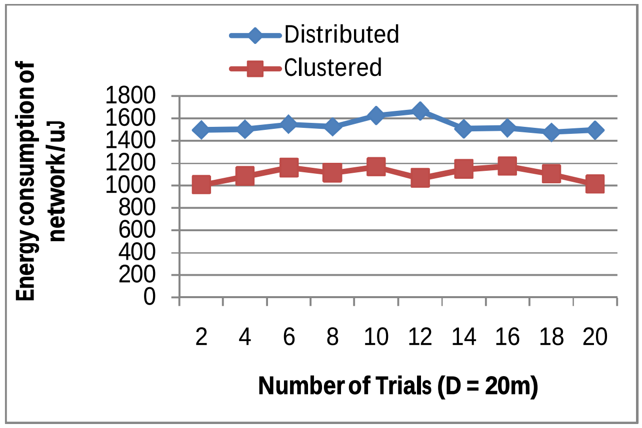
Fig. 7.Energy consumption of different networks while data transmission.



(a)



(b)



(c)

Fig. 8.Energy consumption between Distributed method and clustered method. (a) D = 2m. (b) D= 10m. (c) D = 20m.

Figure 7 shows energy consumption takes place in network with different approaches. It can see that as number of sensor nodes is increasing energy saving is increasing. Figure 8 shows performance of both methods under sleep/wake up mode. The energy estimation is calculated by considering different communication distance. Whereas figure 9 shows energy estimation done by Distributed method and clustered method for communication distance D =2m, 10m and 20m. It can summarize that as number of nodes and communication distance is increased, maximum energy consumption gets reduced.

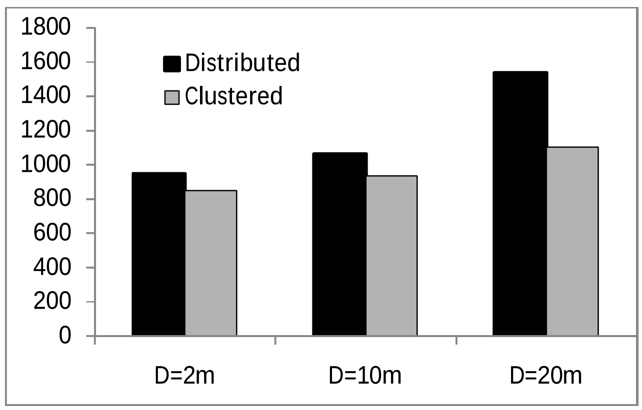


Fig. 9. Performance of distributed method and clustered method for different communication distance.

V. CONCLUSION

In WSN the performance of network is dependent on efficient communication and consumed energy by sensor nodes. In this paper we have presented design and implementation of an energy saving (aware) sensor node. The work is carried out under node level and network level energy saving with sleep/wake up mode. By approaching distributed method and clustered networking methods it is possible to achieve energy saving for WSN.

For further study smallest path finding algorithm can be used with energy saving protocols.

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