EFFICIENT ENERGY CONSERVATION ALGORITHM FOR MOBILE SENSOR NODES IN WIRELESS SENSOR NETWORKS

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Abstract – **In this era, the wireless sensor networks has become more attractive for industrial applications, environmental monitoring, research units and so on. Coverage, delay and power management are the key constraints that degrade the performance of the wireless sensor networks. In this paper, we propose an energy efficient algorithm to resolve these constraints. We also present a square grid method for deploying mobile sensor nodes more efficiently. The particle filter algorithm is used to done the localization system more accurately. The deepest sleep state in asynchronous awakening algorithm used to decrease the power consumption of mobile sensor nodes. The power conservation is done by utilizing the power conservation modes such as active mode, idle mode and deep sleep mode. This algorithm also increases the lifetime of wireless sensor network. The simulation results show that the proposed system is more efficient in increasing the energy conservation.**

Index Terms – Square grid deployment, Coverage, energy conservation, wireless sensor networks (WSNs), delay, sleep state.

INTRODUCTION

Wireless sensor networks are an emergent trend that finds many applications in the field of healthcare assistance, data logging, forest fire detection, machine health monitoring and so on. A sensor network comprises of multiple sensor nodes that communicate with each other through a wireless network. The sensor nodes contain one or more low-power sensors, a processor, a memory, a battery and some kinds of actuators. A mobile sensor node makes the system more flexible.

An efficient way to conserve energy in WSN is to keep the sensor nodes in sleep state whenever there is no need to transmit packets. This mechanism is called as sleep-wake scheduling. The sleep-wake scheduling consists of synchronous sleep-wake scheduling and asynchronous sleep-wake scheduling protocols. In synchronous sleep-wake scheduling, the clock messages are exchanged periodically among the sensor nodes. But this synchronization clock messages causes additional overhead and it consumes significant amount of power. Asynchronous sleep-wake scheduling is proposed in this paper. It is highly efficient, since it does not require any clock messages to synchronize the node and wake up autonomously and hence this dynamically reduces the power consumption. Some studies have been made for the design of mobile nodes and it achieves good usage of their mobility. The important part of sensor network is assigning nodes' location and lots of research going on in finding different deployment methods. Luo and Chen et al [1] proposed the systematic method for auto deployment of mobile nodes. By this the coverage and uniformity of nodes can be raised by placing a mobile node in the monitored environment without changing the previous distribution of nodes. Corke et al [2]proposes a deployment method which finds the gaps in connectivity and rectify it, and that completes the connectivity.

An energy efficient dynamic power management by Zhang and Huo[3] present a sensor network that uses sleep state policy combined with OGDC (Optical geographical density control) will reduce the energy consumption. Coverage is an important criteria for the wireless sensor network applications. The full coverage of the node depends on both the sensing range and the deployment method of nodes. The network lifetime and network fault tolerance can be increased by the availability of redundant nodes shown in Fig 1.

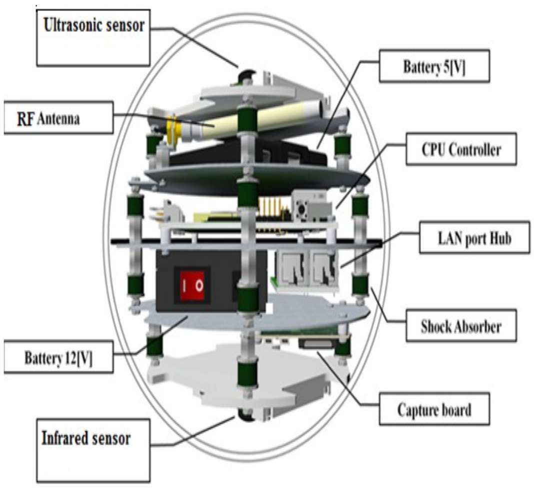

Fig 1. "Robomote" mobile sensor node

The selection of active nodes provides full coverage and connectivity. A distributed coverage can be obtained by the process of selecting active nodes[4-6]. Network delay is a very essential performance characteristic of a wireless network. Processing delay is the delay that is caused by data-rate of the link and the time it takes to process the packet header. The delay-sensitive sensor networks in[7] is essential for its efficient operation. The reliability of network can be improved by dynamically reducing the retransmission of packets in wireless sensor network. One of the major issues in military application and surveillance are the resistance to fear. The reliability problem does not exist in the adhoc peer-to-peer configuration. The efficiency of operation in wireless sensor network depends on the connectivity and coverage offered by the deployment of nodes. The first approach in [8-10] illustrate the different deployment topologies that includes star, circular, square, triangular, hexagonal and grid deployments.

The second approach(Shown in fig 2) in[11] uses the principle of voronoi diagram that moves the sensor from heavily deployed region to dispersedly region. It also helpful in discovering the coverage vacancies and designing the movement-assisted deployment protocols like VOR (Voronoi based), VEC (vector based) and minimax. The third method in [12] discusses the virtual forces that are used to find the deployment of all sensor nodes.

The author Ghosh A in[13] proposes an event based power management technique where the node can periodically update the probability of event generation. One of the energy efficient power saving mechanism is to use ASLEEP protocol [14]. It reduces the power consumption by dynamically adjusting the duty cycle. But this protocol regulates the power conservation only for static sensor nodes and not for the mobile sensor nodes.

This paper is organized as follows. The hardware design of the mobile sensor node is discussed in section II. Section III illustrates the localization method. Section IV describes the efficient method of Square grid deployment of mobile sensor nodes. Section V proposes asynchronous energy conservation that can increase the efficiency of the sensor network system. The simulation and experimental results are demonstrated in section VI.

HARDWARE ARCHITECTURE

The main design consideration for the mobile sensor node includes low cost, small size, and Ultra-low power consuming. Under these specifications the sensor node MSP340 with a wireless communication module fabricated by Texas Instrument connected to the mobile platform is developed. Fig. 1 shows a Rob mote mobile sensor node measures 17 cm in height, 14 cm in width, 17 cm in length. The US and IR sensor are useful in obstacle avoidance. The data from these sensors are transmitted to 8051 and the path can be changed dynamically. Since the Ultrasonic waves have a larger wavelength and slower rate of propagation compared with EM waves, it is very useful in measuring distances ranges from few millimeters to several meters without any contact. The optimization of the ultrasonic sensors results in reducing the inaccuracy in measurement.

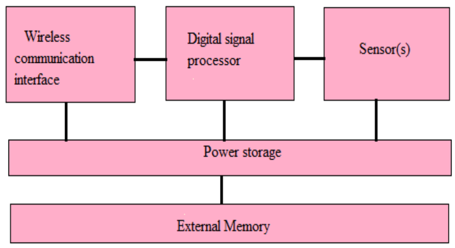

Fig 2. Block diagram of sensor node.

Due to flexibility, ease of programming, low power consumption, and low cost the microcontroller are often used in sensor nodes. The sensor node consumes more power for sensing and data transmission compared to other process. Sensor nodes are battery-operable that is either rechargeable or non-rechargeable. The two energy saving process used are Dynamic power management (DPM) and Dynamic voltage scaling (DVS)[15]. DPM saves energy by shutting down the hardware module of sensor node that are currently active. A DVS algorithm changes the power levels within the sensor node depending on the non-deterministic overloads. To improve the communication, the interface facilities align the portable wireless device with another device. The on-chip memory is the most useful from an energy-perspective of a microcontroller. Flash memory is widely preferred due to their low cost and storage capacity.

LOCALIZATION STRATEGY

The localization method of Robomote uses the USS, RSI, and DR information to establish the coordinates of mobile sensor node. The location of mobile sensor node can be found accurately and efficiently using the particle filter algorithm.RSI - The RSI circuit is used to measure the voltage of the received signal. The sensor collect data from moving object and measure the voltage from the RSI circuit and convert into distance. By extending the lifetime of the system energy can be saved. This method does not need any external energy for localization.US Localization – Ultrasonic sensors have a larger wavelength and slower rate of propagation compared with EM waves, it is very useful in measuring distances ranges from few millimeters to several meters without any contact. The optimization of the ultrasonic sensors results in reducing the inaccuracy in measurement[16].Typically, the sensing range of ultrasonic sensors ranges from 2 to 300 cm. The preceding map location is needed for US localization system. The grid map is used for researched .The present position can be obtained from past orientation and speed over the ground with help of a navigator. Dead reckoning also used to determine its future position by projecting its present orientation. Particle filter algorithm is an nonparametric parameter of the Bayes filter. The goal of particle filter algorithm is to approximate the sequence of hidden parameters. All particles are distributed at same position in the initialization stage. The weight of all nodes becomes unity. DR used to update the position of each particle by a control input. Each particle will produce effective sensor data. The factors can be calculated from relative to the distance between the measurement data and virtual sensor data. The weight of each particle is normalized and then resample to get a uniform weight distribution.

SQUARE GRID DEPLOYMENT METHOD

Square grid method is used to find the exact destination of the sensor node. A map is divided into individual multiple grids and is known to the control centre in our system. Each grid is a square shape with same edge and its size is adaptive[17] . Each individual grid can achieve better solution when larger grids can reduce the complexity of computing. The weighting value of each grid is estimated by grid deployment method and also calculates the minimal region.

Grid will be marked when a static node is placed within its range. Other grids calculate their weighting values and form the weighting field of this node at the same time. The length of each grid is defined in one unit and it is helpful in computing the difference of (m, n) and find the square between the marked grid. The weighting value of each grid can be obtained by taking the inverse of the evaluated value.

The sensor node coverage will be composed next to the boundary and the mobile node may hit against the wall due to inaccuracy of mobility. Obstacle effect avoids from being deployed inside the obstacle[18] . To avoid over imbalanced disposition we can assign smaller values to hot zone and larger value to other regions. Hot zone effect should not exceed the range between 0 and 0.4. This means that more nodes are required to be placed in this region. After considering all weighting fields caused by environmental factors such as node effects, boundary effects, obstacle effect and hot zone effect. The total weighting field is obtained by adding these factors.

$$Vtot (i) = \sum Vj (i) + Vb (i) + Vo (i) + Vh (i)$$

Where Vtot(i) is the total weighting value of grid, Vj(i) denotes predeployed nodes, Vb (i) denote boundary effect, Vo(i) denotes obstacle effect,Vh(i) denotes hot zone effect.

ASYNCHRONOUS POWER MANAGEMENT

Asynchronous power management achieves the aim of power conserving by shutting down the individual components of wireless sensor node. The design of efficient power management algorithm for resolving the problem of coverage, optimization, energy saving, and reliability is discussed.

The tradeoff between the communication and power consumption has an impact on the transmission rate. The sleep-wake scheduling decides when the node has to wake-up. This can be categorized by the following factors: a) how recurrently the node has to wake up; b) the dissemination of the wake-up interval. These two factors defines the wake-up rate and wake-up pattern and can be controlled independently to regulate the sleep wake scheduling .During the deepest sleep state, the sensor node not able to sense any event or received messages from another node. Hence it is essential to define the deepest sleep state period and deepest sleeping probability. The deepest sleep state period Ts can be given as

$$Ts = \mu \times e^{(V_{swv} - V_{pwv})} \qquad (1)$$

Where μ is the factor of mobility, V_{swv} denotes the standard working voltage of the battery and V_{pwv} is the present voltage of the battery. The deepest sleeping probability is given as

$$Ps (Tth,0) = e^{(-Pei + \lambda_{ttl} + T_{th})} \qquad (2)$$

The sensor generates an interrupt and awakens the CPU whenever there is an event like rapid change in temperature, or any signal generated by the moving object [20]. The use of counter interrupt also enables node awakening during the sleep state. The deepest sleeping period can be obtained by the battery status and mobility parameter μ. The Operating Power conservation modes are 1) Active mode, 2) Idle mode, 3) Deep sleep mode

Active state : In active state, the devices are continuously powered and in running state. The average power requirement is about 1050 milliwatts and is directly limits the performance of the device. The active power consumption can be reduced by dynamically reducing the synchronization rate.

Total power used = Total transmitted power + Total received power.

Stand by state : In this state, the device is either on or in a low power inactive mode. It can retain all of its internal state and contents of its memory, since it is still powered.

Many of the device spend most of their time in this low power mode. But it also requires the fast startup capabilities.Deep sleep state : In this state, the device is either active or in extreme power saving mode. This mode achieves the maximum energy saving by shutting down the hardware. The memory parameter requires to be reinitialized after wake up.

State	MSP430	Sensor	Radio	Pd(mW)
Active	Active	Idle	Sleep	1050
Idle	Sense	Sense	Sense	450
Sleep	Tx, Rx	Rx	Off	12

Fig 3. State table of sensor node

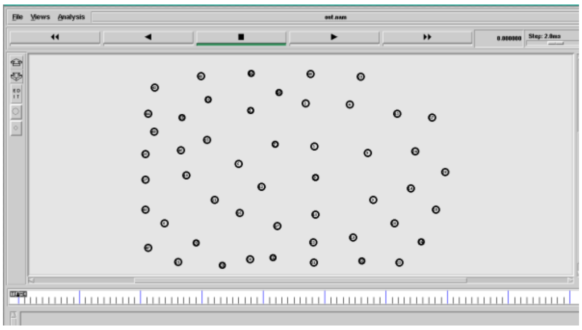

Figure (a) Node deployment of mobile nodes

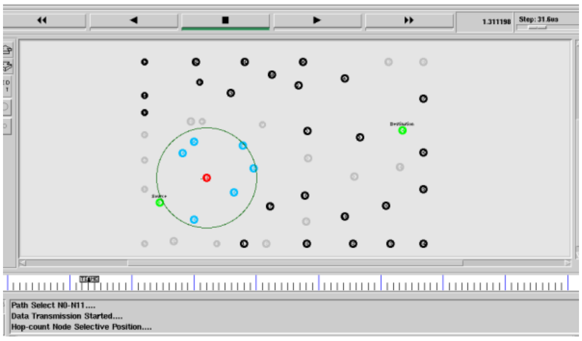

Figure (b) Data transmission between node0 and node11

SIMULATION RESULTS

The simulation result shows good uniformity after distributing certain number of nodes. More nodes make uniformity better according to this algorithm. It helps to improve the system efficiency, energy conservation and decreased packet loss.Node coverage is more important factor to evaluate the deployment performance. The better coverage, higher the probability that the event can be detected in this field. The policy becomes more powerful when it covers more region. Initially we have created 50 nodes.

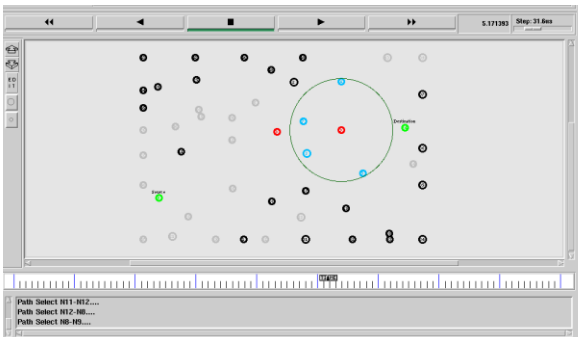

Figure (c) packet reaches the destination through the intermediate nodes N11,N8,N9

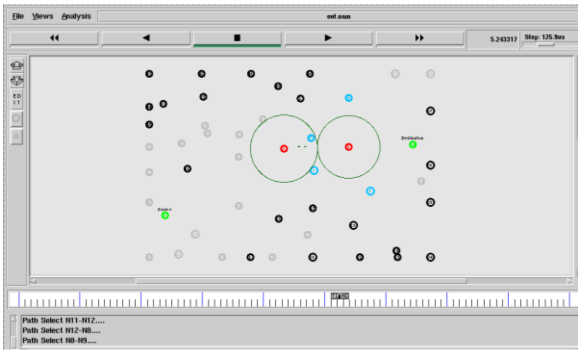

Figure (d) packet reached the destination N24

In that source and destination are static nodes, and remaining are mobile nodes. The figure 3(a) shows the node deployment of mobile nodes. Figure 3(b) shows the data transmission between node0 and node11 (N0-N11) and it can be started by the hop-count node selective position. The packet reaches the destination through the intermediate nodes N11,N8,N9 and is showed by figure 3(c). Each grid has the same length of 1m. Now the packet had reached the destination N24 is shown in figure3(d). The graph shows power saving comparison in random and grid deployment methods. The power consumption is about 23Mw in all nodes shown in table 4.

The implementation of the energy conservation algorithm depends on the hop-count routing. Hop - count routing is nothing but the node – node count. The energy conservation modes is processed through hop – count. When the hop-count is one from the packet transmitting node (shown by red colour), then the nodes around the coverage are in the active state (shown in blue colour). Next, if hop-count is two, then the nodes are in the idle state (indicated in grey colour) and when it is greater than two, the nodes are in deep sleep state (indicated in black colour).

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Parameters	Existing system	Proposed system
Throughput	0.83	0.94
Packet Delivery Ratio	94.52	96.02
Energy level	32 joules	25 joules
Average delay	43.67 ms	23.67 ms

Fig 4. Comparison table.

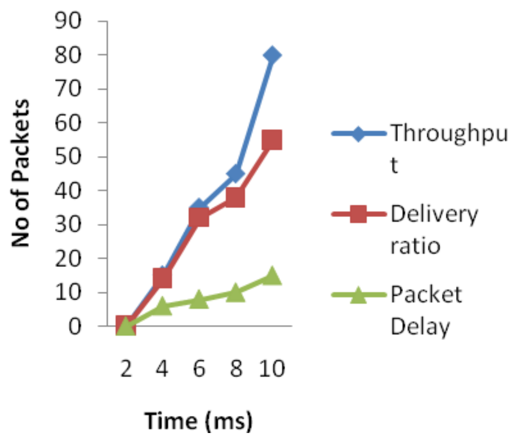

Fig 5. Time Vs No.of packets

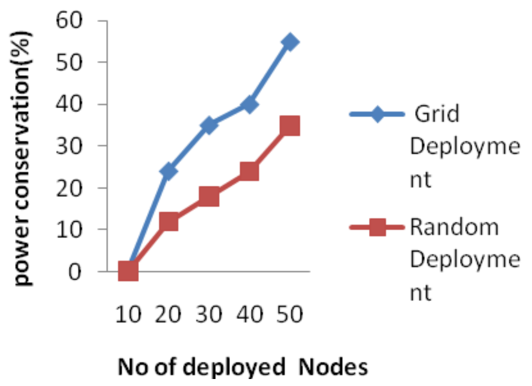

Fig 6. No of deployed nodes Vs power saving.

The nodes that are present outside the coverage acts as sleeping nodes. The sleep nodes wake up if any event occurs and it is determined by the event statistics, timer-driven and also using wake-up scheduling.

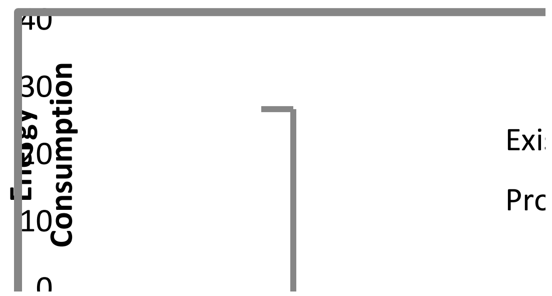

Fig 7. No of nodes Vs Energy consumption

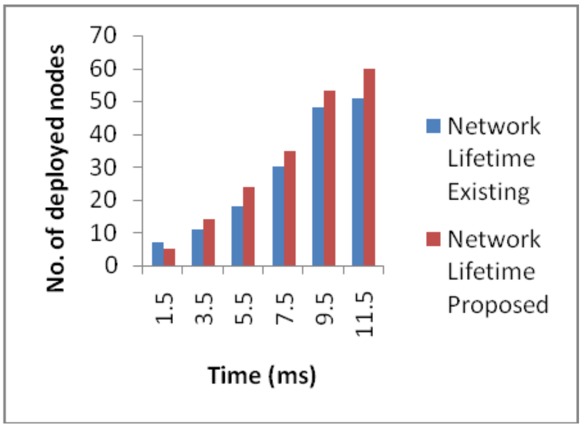

Fig 8. Time Vs No of deployed nodes.

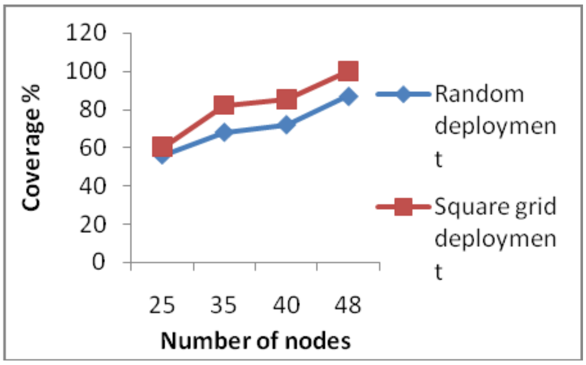

Fig 9. Number of nodes Vs coverage

By integrating these algorithms, the power consumption gets reduced efficiently. The reason behind using the mobile nodes is that it reduces the number of nodes necessary to provide the coverage and by this average coverage gets enhanced and lifetime of network also increased showed in fig 5-8.

CONCLUSION

In this paper, we developed localization mechanism to locate the mobile sensor nod using US, RSI, DR with a particle filter fusion approach. With accurate location information automatic grid deployment and dynamic power management can be achieved with high accuracy .The results of grid deployment method shows high performance of coverage, accuracy, low delay, scalability, self-healing, with lower implementation cost. The previously deployed nodes do not change their status and the mobile sensor node is adjusted. Asynchronous power management is efficient in reducing the power consumption on a sensor network. The n-duplicate covered algorithm is also used to maximize the sensing region. The k-perimeter algorithm reduces the queuing and energy consumption.

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