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Battery Capacity Management in Wireless Sensor Network Rechargeable Sensor Nodes

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***Abstract*- A Wireless Sensor Network (WSN) consists of distributed autonomous sensors to monitor physical or environmental conditions and to cooperatively pass their data through the network to a main location. Each node and sensor is capable of computation, communication and sensing. Size and cost constraints on sensor nodes result in corresponding constraints on resources such as energy and memory. Sensor Node battery capacity management improves to a considerable extent the challenges of recharging nodes and prolonging WSN lifetime. The energy allocation according to wireless node charge level along with energy harnessing, Optimal decision of node sampling rate and Time determination of natural energy utilization are methods by which Node battery capacity can be maintained in an energy efficient way thereby saving energy during WSN working and data transmission by sensor nodes . This paper gives an overview of energy saving in WSN, objectives leading to conservation of power in Wireless nodes, challenges and constraints in WSN working and methods to maintain battery reserves of WSN sensor nodes.**

Keywords—Wireless Sensor Networks, Sensor Node recharging, Node battery reserve limitation, Natural energy harnessing, Energy Allocation by node charge level, Optimal Sampling Rate control, Appropriate external energy utilization time, Node energy saving

I. INTRODUCTION

A. *Wireless Sensor Network (WSN)*

A WSN consists of nodes that are spatially dispersed and there are dedicated sensors for monitoring and recording the physical and environmental conditions and the collected data are organized at a central location. The development of wireless sensor networks was motivated by military applications and today such networks are used in many industrial and consumer applications. Some unique characteristics of WSN are: Small-scale sensor nodes, Limited power they can harvest or store, harsh environmental conditions, node failures, mobility of nodes, dynamic network topology, communication failures, heterogeneity of nodes, large scale of deployment and unattended operation.

B. *Energy Management in WSN*

Sensor nodes are typically powered by batteries with a limited lifetime. Energy harvesting, less power consumption during data transmission and Node battery charge conservation techniques help in optimal utilization of Sensor node power thereby saving energy and improving the network lifetime.

C. *Need for sensor node energy saving and benefits*

Energy constraint is a challenging bottleneck for advancement of wireless sensor networks. Sensor nodes usually have limited capacity batteries. Sensor networks need to be left unattended and perpetually run without interruption. Natural energy harvesting can extend the lifetime of rechargeable sensor nodes and battery powered wireless sensor networks and can be stored for future use. Solar and Wind energies can be used by the rechargeable sensor nodes.

D. *Challenges of wireless sensor nodes*

The harnessed energy is time varying and unreliable. The other challenge is to get the right sampling rates to increase efficiency and performance of the wireless sensor nodes. Management of energy use wisely in nodes is also a challenge.

E. *Shortcomings of less battery level in Wireless sensor nodes*

The sensor node may use up too much energy in the past and run out of energy and stop at a time slot thereby currently it gets short of energy due to aggressive allocation. The above kind of energy allocation scheme means the sensor node has used too much energy in the past and is currently short of energy. The battery level of some sensor nodes may reach the maximum and also not much energy may be depleted whereby the recharging opportunity can be missed and is conservative. In the above scheme the sensor node does not deplete much energy so the sensor nodes cannot store all the harvested energy due to the limited capacity of the battery. Both the above kinds of cases limit the potential to improve the WSN and sensor node performance.

F. Some general means of reducing energy consumption in Sensor Nodes

The general means are energy scavenging, reduction of transmission data, energy conserving sampling techniques, efficient analog to digital conversion techniques.

G. Architecture of Sensor Node

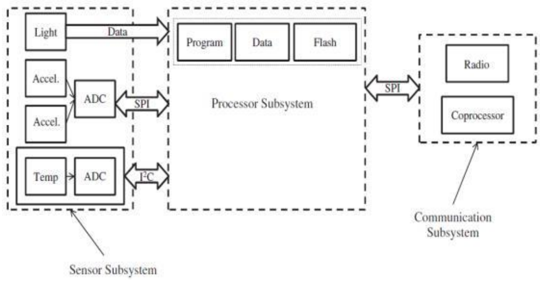

Fig.1. Sensor Node Architecture

The wireless sensor nodes are the central element in a wireless sensor network. It is through a node that sensing, processing, and communication take place. It stores and executes the communication protocols and the data-processing algorithms. The quality, size and frequency of the sensed data that can be got from the network are influenced by the physical resources available to the node. Therefore the design and implementation of a wireless sensor node is a critical step.

II. CHALLENGES AND CONSTRAINTS IN WSN WORKING

A. Energy

The constraint most often associated with sensor network design is that sensor nodes operate with limited energy reserves. Typically, they are powered through batteries, which must be either replaced or recharged when depleted. Some nodes simply are discarded once their energy source is depleted. Whether the battery can be recharged or not significantly affects the strategy applied to energy consumption. As a result the important design challenge for a WSN is energy efficiency. This requirement permeates every aspect of sensor node and network design.

B. Self Management

It is the nature of many sensor network applications that they must operate in remote areas and harsh environments without infrastructure support or the possibility for maintenance and repair. Hence sensor nodes must be *self-managing* in that they configure themselves, operate and collaborate with other nodes and adapt to failures and changes in the environmental stimuli without human intervention.

III. OVERALL OBJECTIVES TO SAVE ENERGY IN WIRELESS NODES

First is to allocate energy to sensor nodes based on its charge reserve, second is to assign sampling rate for each sensor node taking remaining energy of node into consideration, third is to store available or harvested energy for future use, fourth is taking into consideration the battery capacity limitations of the sensor nodes that can recharge, then the objective is to account for longer working of sensor nodes with uninterrupted sensor data flow along with improvement of the network utility and efficient working of sensor nodes.

IV. SIMULATOR NS2 QUICK FACTS

NS2 is a discrete event simulator that provides for simulation of networks. It can be used to simulate packets, links, nodes, queues and protocols. It has the Network Animator (NAM) and Trace Playback components. Simulation programs of NS2 are written in C or C++ and TCL scripting is used.

V. FUNCTIONAL REQUIREMENTS

Nodes and energies initialization module is needed. There should be setting of available or harvesting energy to be used by nodes. Data transmission between selected nodes must be there. Nodes with energy below threshold are selected. Energy allocation determination module and Optimal and adaptive Rate assignment modules are implemented. Appropriate time slot to harvest energy gives appropriate time to use external energy.

VI. HARDWARE REQUIREMENTS

Development system to run NS2 Simulator must be there. 64bit or 32 bit systems capable of running NS2 applications can be used. Processor speed can be P4 2.4 GHz. Memory of 2GB at least and extra RAM would be useful. A set of Sensor Nodes can be set up in real time which are connected wirelessly to form a WSN but this is cumbersome and expensive to carry out hence been simulated. Each node in the above set should have a solar panel to harvest solar energy in real world. The node battery capacity management algorithms are stored in the memory and run in the processor unit of the Sensor Nodes. Algorithms can also be implemented on Mobile android phones with sensors.

VII. SOFTWARE REQUIREMENTS

NS2 Simulator has been used for the algorithms implementation. MATLAB can also be used for the algorithms. NS2 coding has been done using C, C++ and TCL scripting. A small wireless sensor network of the real world with some number of Sensor Nodes has been simulated using NS2. A small sensor network using few sensor nodes can be set up but is cumbersome and expensive so this wireless sensor network has been simulated. Values got by the run are plotted by simulator and the data transmission and technique is simulated. Data values after the algorithms have executed are shown in the graphs generated. A comparison of these algorithms has been done with an earlier existing algorithm.

VIII. ALGORITHMS IMPLEMENTED

A. Energy allocation method

This is to allocate the energy for each sensor node such that it uses the harvested energy wisely according to the current available energy.

B. Optimal sampling rate assignment

This technique uses energy allocation method as basis to find the dynamically the optimal sampling rate for each of the sensor nodes.

C. External energy utilization time determination

This technique makes better the energy allocation method by reducing the effect of incorrect assessment of external natural energy by deciding upon the optimal time to utilize this energy.

IX. METHODS IMPLEMENTED TO EFFECTIVELY MANAGE SENSOR NODE ENERGY

A. Energy allocation algorithm

This algorithm involves allocation of Natural Energy to each sensor node so that it uses this external energy wisely according to its present energy reserve [4]. This method allows the sensor node to manage efficiently use of available energy based on battery level. External energy is variable so wise allocation helps maintain charge balance. Specific energy amounts are allocated taking present node capacity into consideration. This maintenance allows for uninterrupted network working. Current power level is compared with the amount needed and balance can be assigned. Sensor node does not fall short of power.

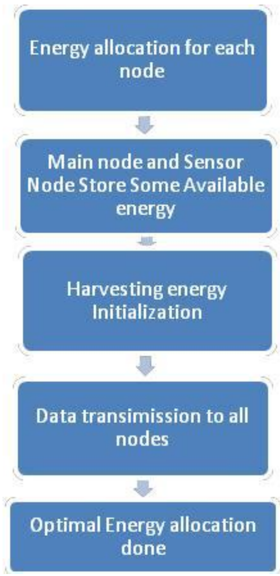

Fig.2. Flow of steps involved in Energy allocation method

This method allows the sensor node to manage its energy use efficiently and allocates available or harvested energy based upon node energy or battery level. Available or harvested energy varies over time so wise allocation helps the sensor maintain balance of energy reserve. Specific amounts of energy are allocated considering the current energy reserve in the sensor. Since energy is maintained this allows for uninterrupted network working. Each node is checked for battery level and compared with the required and available energy and the balance is allocated. This allocated amount can be used in future by the sensor node and it does not fall short of power. This method allows the sensor node to manage its energy use efficiently.

B. Optimal Sampling rate assignment

This algorithm involves finding the optimal sampling rate for each sensor node [4]. This method enables the sensor node to pass data at the right sampling rate such that its energy is not depleted. This adaptive sampling rate reduces energy loss during transmission. The sampling rate of each node is changed or configured depending upon the current sensor energy and the external energy it would utilize. Information transmission takes place without interruption. This allows for data transmission and communication between nodes at the optimal sampling rates assigned to the sensor nodes. The energy reserve of these nodes is considered. Less energy depletion during data passing is needed

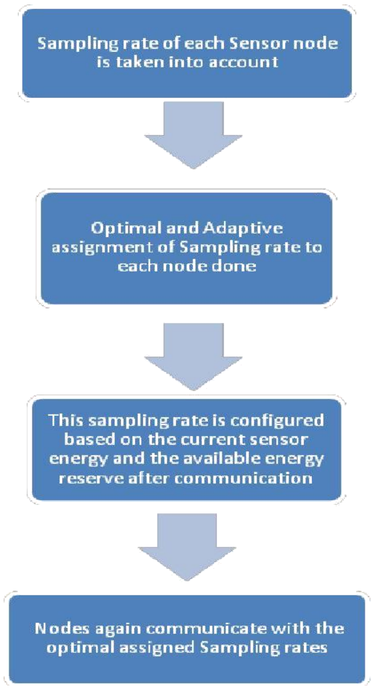

Fig.3. Flow diagram of the optimal sampling rate assignment

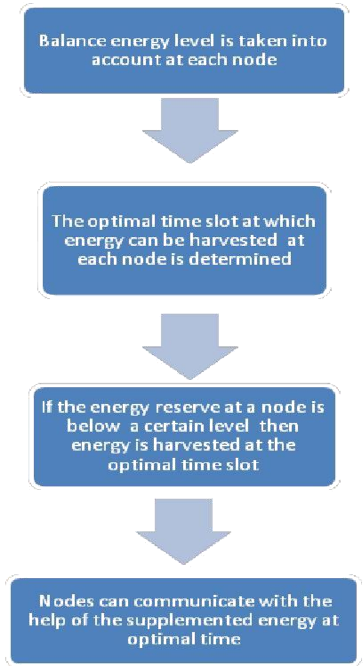

Fig.4. Flow diagram of the External energy utilization time determination

This enables to obtain the optimal sampling rate for each sensor node. This method decides adaptively the sampling rate for each node. The sampling rate of each node is changed or configured depending upon the current sensor energy and available energy. Also information transmission by nodes needs some power so this is taken into account.

C. *External energy utilization time determination*

This technique involves decision regarding the right time external energy harvesting [4]. This sensor decision making provides improvement to the previous methods in terms of time and energy estimation. The right time slot to use the available energy resource at each node is decided upon dynamically. In order to determine the balance needed by the node during energy allocation this technique prevents the inappropriate amount of natural energy being taken into account. This dynamic decision of time to recharge helps the WSN nodes to store the needed extra energy effectively. The right time to harvest energy is important as the Sensor nodes can only hold a certain amount of available or harvested energy and randomly using available energy might lead to exceeding of available store capacity at the node. Time decision helps in use of external resource by nodes when these can use appropriately without overusing or depriving themselves of the reserve.

This method provides improvisation to both the previous algorithms in terms of time determination for energy harvesting. There is precise estimation of available or harvested energy and the time slots at which harvesting of available energy can be done. In order to determine the balance needed by the node during energy allocation this technique prevents the incorrect level of available energy being estimated.

X. EXECUTION STEPS

To execute the project implementation the following is to been done: Ubuntu should be installed on the system in use. An appropriate version of the NS2 simulator must run on the Ubuntu platform. The project is saved in Ubuntu. The terminal is opened. Path is set which points to the location where the project implementation files are saved. The command ns "main file name".tcl is executed. This opens the network animator. When simulation animation is played the trace file is generated. At the end of the simulation the required graphs with data values got as algorithms run are generated. Needed information from the graphs can be got.

XI. SIIMULATION RUN

The set of nodes are deployed and configured. Low, medium and high energy nodes are set up.

Communication between a set of nodes occurs. The remaining energies of the communicated nodes are considered. The nodes with low energy among these are selected for energy allocation according to the delta or difference parameter and the remaining energies of these nodes. The different energy nodes are assigned optimal rates according to energy level left in nodes. Nodes communicate with the allocated energies and rates. Appropriate time slot for energy harvesting is taken into account

XII. ALGORITHMS TESTING PLATFORMS

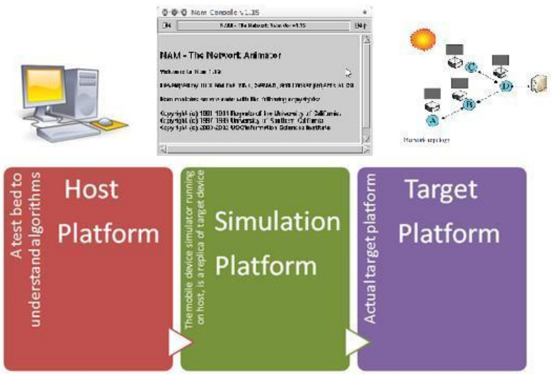

Fig.5. Platforms for algorithms testing

A. Host Platform

The algorithms can be developed or executed using any simulation tools which will run on the host system which could be the desktop or laptop in use.

B. Simulation Platform

The algorithms of this project have been implemented using the NS2 simulator running on the Ubuntu Platform. The run values of the algorithms have been plotted and shown in the graphs generated. These values have been compared with an earlier existing algorithm. These methods have resulted in more energy saving at the Sensor nodes.

C. Target Platform

These algorithms can be directly implemented on a real world set up of the WSN Sensor nodes. For this project real world deployment has not been done as this is cumbersome and expensive to be carried out.

XIII. INTERPRETATION OF RESULTS

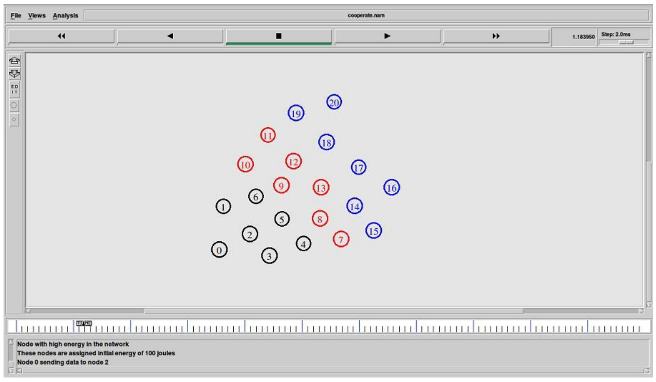

Fig.6. Low, Medium and High energy node

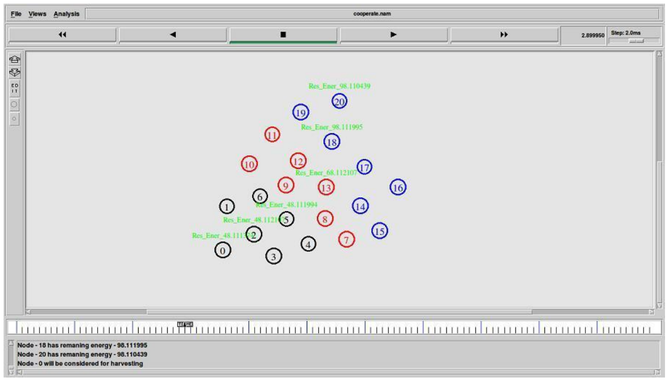

Fig.7. Remaining energies of nodes

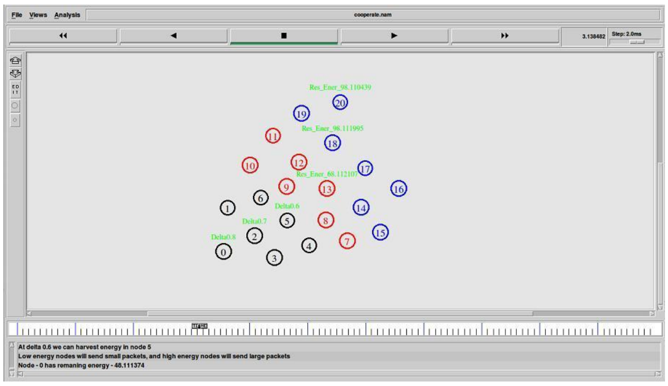

Fig.8. Energy allocations to nodes with low energy

The above figures show the nodes during simulation. The network contains low, medium and high energy nodes. The nodes communication and data transmission is there. Remaining energy values of nodes are considered after the data passing or node communication. Required energies are allocated to nodes with less energy from the reserve or available energy taking into account the remaining balance of nodes and the amount needed using the Energy allocation algorithm.

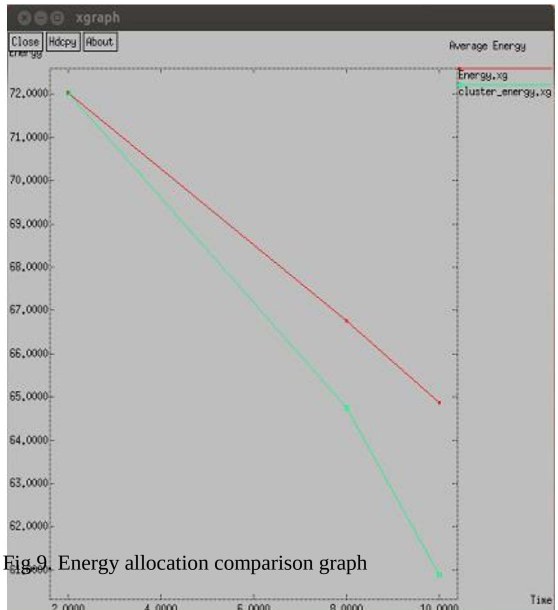

Fig.9. Energy allocation comparison graph

The graph shows energy saving over time for the Energy allocation method and an older cluster energy saving method. There is more energy saving with time for the prior method.

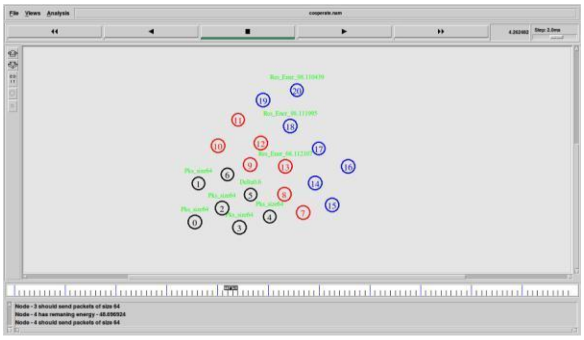

Fig.10. Rate or packet size assignments to low energy nodes

The Nodes communicate using the allocated energy from the energy allocation method. Nodes with low energy values after transmission are considered and appropriate rates or packets sizes are assigned to these using optimal sampling rate assignment method and they can utilize their energy balance optimally with using the rates to send data. The optimal time to utilize the external energy reserve is given by the external energy utilization time determination method. This displays the time slot during simulation in a window at the bottom of the display. Energy is allotted in this slot to the less energy node.

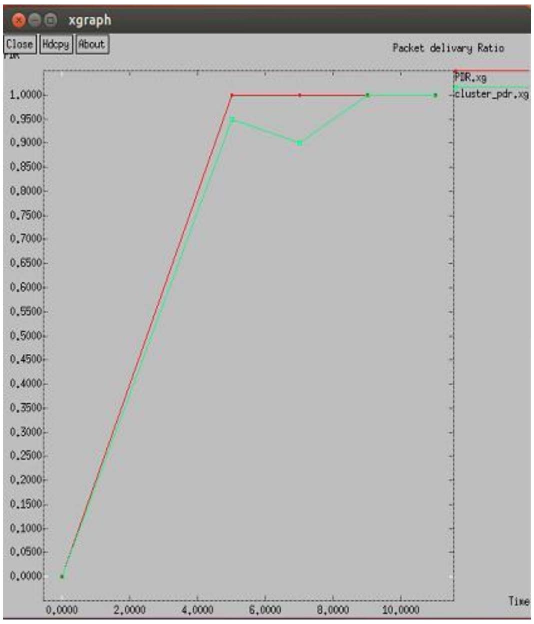

Fig.11. Packet delivery comparison graph

There is steady packet delivery to time throughput using optimal sampling rate assignment algorithm than the older method.

XIV. CONCLUSION

The Sensor Nodes can be connected by wireless means thus making up the wireless sensor networks. The Sensor Nodes are the central communication means. The energy allocation according to power content enables sensor nodes to manage their energy usage and replenish their charge level effectively. Optimal decision of WSN node sampling rate allows sampling based on the current resource level and node capacity thereby enabling sensor nodes to maintain their battery reserves during data transmission. Dynamic determination of time to harness external energy reduces the impacts of harnessing insufficient energy amounts. These techniques improve efficiency of the wireless sensor network by effective management of battery capacity in rechargeable sensor nodes thereby saving energy in the sensor node.

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