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Energy Aware Distributed Protocol for Heterogeneous Wireless Sensor Network

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Abstract

In WSN (Wireless Sensor Network) every sensor node sensed the data and transmits it to the CH (Cluster head) or BS (Base Station). Sensors are randomly deployed in unreachable areas, where battery replacement or battery charge is not possible. For this reason, Energy conservation is the important design goal while developing a routing and distributed protocol to increase the lifetime of WSN. In this paper, an energy aware distributed protocol (EADP) for heterogeneous WSN has been reported. Proposed paper considers energy heterogeneous WSN to increase the lifetime of the network. An algorithm is proposed in the form of flow chart and based on various clustering equation proved that the proposed work accomplishes longer lifetime with improved QOS parameters. A WSN implemented and tested using Raspberry Pi devices as a base station, temperature sensors as a node and xively.com as a cloud. Users use data for decision purpose or business purposes from xively.com using internet.

Keywords: *Heterogeneous WSN, Advanced node, Distributed Energy-Efficiency, Longer Network Lifetime*

1. Introduction

WSN is composed of various low powered, low storage and short range communication devices/nodes. Each continuously sense the region in its range and transmit data to its neighbour’s node or cluster head using low power wireless links. A Sensor node is composed of power, sensing, processing and communication unit typically. Deployment of sensors are random and static, but in proposed work few sensors are dynamic [1], hence localization technique plays an important role.

In homogeneous WSN, sensors would have the same lifetime if they have the same energy consumption rate. In heterogeneous WSN, each sensor has different capabilities in terms of storage, processing, sensing, and communication. In Computational heterogeneity a heterogeneous node has a more powerful microprocessor and large memory compare to normal node. In Link heterogeneity a heterogeneous node has high bandwidth and longer transmission range and provides more secure & reliable data transmission. In Energy heterogeneity a heterogeneous node has different energy level or it may be line powered, or its battery is replaceable. These types of heterogeneous nodes called advanced nodes.

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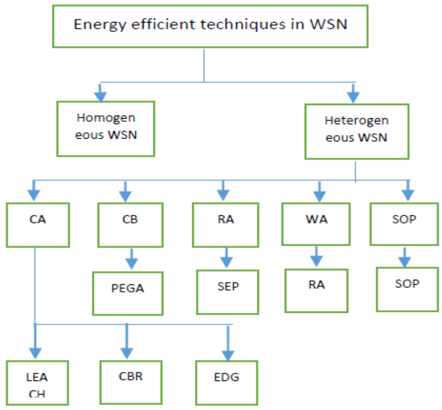

Figure 1. Energy Efficient Taxonomy of Heterogeneous WSN

Using Heterogeneous WSN, network lifetime, reliability of data transmission will increase while latency of data transportation will decrease. To evaluate the performance of heterogeneous WSN we considered network lifetime, number of cluster heads per round, number of alive (total, advanced and normal) nodes per round, and throughput as evaluation parameters.

In figure 1, taxonomy of heterogeneous WSN is given and among of various techniques cluster based approach is best for solving the sensors energy constraints by reducing the cost of data transmission and aggregation of sensed data before transmitting data to base station [2]. In a cluster, there is a cluster head which is selected randomly based on available energy so that the energy load can be evenly distributed in sensor network [2]. All the sensor node sense the data and transmit it to the cluster head and after aggregation it passes the data to the base station. The base station (Raspberry Pi) is a larger computer or mote where data from the sensor network will be aggregated, compiled and processed. The base station may communicate with any cloud services via Internet or Satellite [1, 2]. Human operators controlling the sensor network send commands and receive responses through the base station. Raspberry pi device can be used as base station and forward all the data at cloud (Xively.com site) for decision making or various business purposes.

Using heterogeneity in proposed work, energy will optimize while performance will remain same. Nodes deployed closely therefore multi-hop and low power communication is desirable. A node joins a cluster which is very near to it depending upon signal strength. A sleep state has been presented during the cluster formation process which further increases the network lifetime and optimize energy in heterogeneous WSN. Here a multi-hop and clustering scheme are combined together with advanced node capabilities in distributed environment and proposes a new EADP to improve sensor network lifetime with reduced delay. In Section 2 cluster based related protocols are described. In section 3 problem statement is defined which is related to energy efficient designing in WSN. Section 4 describes the heterogeneous network model and various equations are defined for energy calculation in clustered WSN, section 5 describes the proposed EADP protocol, section 6 shows a WSN implementation and finally the paper is concluded in section 7.

2. Related Work

Low Energy Adaptive Clustering Hierarchy (LEACH) is a clustering protocol where cluster head responsibility is rotated to balance the energy in WSN. The LEACH works on how to define cluster and cluster head (CH).The idea is to form clusters for the sensor nodes based on the received signal strength (RSSI) and use local cluster heads as routers to the base station. All the data processing such as data fusion and aggregation are local to the cluster. All CHs directly communicate to the BS using star topology. Since CH are randomly chooses in LEACH algorithm so there is some probability to form a low-energy normal node as a CH. The node becomes a cluster head for the current round if the number is less than the following threshold:

$$(n) = [p/ (1-p \times (rm(1/p)))] \text{ if } n \in G \ otherwise\ 0.$$

Here G denotes the set of nodes that are not selected as a cluster head in last $1/p$ rounds and r is the current round.

Power-Efficient Gathering in Sensor Information Systems (PEGASIS) [4], is a near optimal chain-based protocol. The basic idea of the protocol is that in order to extend network lifetime, nodes need only to communicate with their closest neighbours and they take opportunities in communicating with the base-station. To locate the closest neighbour node in PEGASIS, each node uses the signal strength to measure the distance or location to all neighbouring nodes and then adjust the signal strength so that only one node can be heard. The chain in PEGASIS will consist of those nodes that are closest to each other and form a path to the base-station. The aggregated form of the data will be sent to the base station by any node in the chain and the nodes in the chain will take turns in sending to the base-station.

Hybrid Energy Efficient Distributed clustering Protocol (HEED) protocol proposed in 2004 [5]. It extends the basic scheme of LEACH by using residual energy as primary parameter and network topology features (e.g. node degree, distances to neighbours) as secondary parameters. The clustering process is divided into a number of iterations, and in each iteration, nodes which are not covered by any cluster head double their probability of becoming a cluster head. Since these energy-efficient clustering protocols enable every node to independently and probabilistically decide on its role in the clustered network, they cannot guarantee optimal elected set of cluster heads.

Threshold-sensitive Energy Efficient sensor Network protocol (TEEN) [7-8]is a reactive protocol where sensor nodes sense the medium continuously, but the data transmission is done less frequently. A CH broadcast its members a hard threshold (HT), which is the absolute value of an attribute and a soft threshold, which is a small change in the value of the sensed attribute that triggers the node to switch on its transmitter and transmit. The HT tries to reduce the number of transmissions by allowing the nodes to transmit only when the sensed attribute is in the range of interest. The ST further reduces the number of transmissions when there is little or no change in the sensed attribute. A smaller value of the ST gives a more accurate picture of the network, at the expense of increased energy consumption.

Stable Election Protocol SEP [9] used two level heterogeneous network. Weighted probabilities of normal and advanced nodes are used to determine the thresholds for the election of cluster head in a round.

DEEC [11, 13] is a multilevel heterogeneous network where CH are elected by a probability. The node with higher initial and residual energy has greater probability to become a CH. DEEC as in LEACH rotates the role of CH among all the nodes to expend energy uniformity in WSN.

Elbhiri *et al.* [10] proposed a distributed energy efficient clustering scheme where initial and residual energy level defines the CH.

EEHC [13] is an energy efficient scheme for WSN. By setting powerful node EEHC increases the life of the network by 10 % as compared to LEACH.

EECDA [7] used three layerin heterogeneous networks such as advanced nodes, super nodes and normal nodes.

DBCP [11] selects the CH according to initial energy and average distance.

3. Problem Statement

In wireless sensor network various issues need to be dealt while designing an energy optimization techniques distributed environment. Some are:

- Selection of cluster head.
- Number of active sensors between sensor node and cluster head.
- Distance between cluster head node and gateway node.
- Mobile beacon trajectory path (A node has moving capability with and GPS enabled, used in localization so that other sensors find out their coordinates).
- Cost metrics (Prorogation delay, processing delay, and queuing delay) in communication between sensors.
- Interoperability capability between the sensor nodes (heterogeneous environment).
- Reliability of data transmission or security in WSN.
- latency of data transportation

In this proposed work, we are considering heterogeneous environment to reduce the energy in distributed WSN.

4. Heterogeneous Network Model

This section defines the heterogeneity in proposed work. Parameters for proposed work are as:

- Nodes are deployed randomly and uniformly in the sensing region.
- Base station and nodes become stationary after deployment OR base station has limited mobility.
- Nodes are location unaware i.e. they do not have any information about their location. Localization technique can be used for awareness of location/coordinates.
- Nodes continuously sense the region and they always have the data to send the base station.
- Battery of the nodes cannot be changed or recharged due to harsh environment deployment.

Proposed work used the concept of advanced and normal nodes, where energy of normal nodes is E0, advanced nodes initial energy [E0 × (1 +α)], where AN have α times more energy than normal node. Heterogeneous network total initial energy is given by equation 1 in table 1.

Free space (d^2 power loss) and the multipath fading (d^4 power loss) channel both techniques are used based on the distance between the transmitter and receiver. When distance is less than specific a threshold value then free space model are used otherwise multipath loss model is used with conditions. The amount of energy required to transmit L bit packet over a distance d is given by Equation 2 in table 1.

I. Proposed Eadp

In EADP to calculate energy parameters in heterogeneous WSN a table is given below.

Table I. Equations used in EADP Heterogeneous WSN

Eq. No	Contents	Equation
1	Heterogeneous network total initial energy	$ETotal = N \text{ x} E0\ (1 + \alpha m)$
2	Energy required to transmit L bit packet over a distance d, $Eelec$ is the electricity dissipated to run the transmitter or receiver	$ETx(L,) = L \times Eelec + L \times \varepsilon fs \times d^2 if\ (d<d0)$ $L \times Eelec + L \times \varepsilon mp \times d^4 if\ (d \geq d0)$

3	For receiving an L bit message the energy expends by radio	$ER(L) = L \times Eelec$
4	Energy dissipated in the cluster head during a single round	$ECH = (n/k - 1) \times L \cdot Eelec + (n/k)L \cdot EDA + L \cdot Eelec + L \cdot \varepsilon fs \cdot d^2 toBS$
5	Energy dissipated in a non-cluster head	$ENCH = L \times (Eelec + \varepsilon fs \times d^2 toCH)$
6	Energy consumed in a round	$ECluster = ECH + ((n/k)ENCH)$
7	Total energy dissipated in the network	$ET = L \times (2nEelec + nEDA + k\varepsilon fsd^2 toBS + n\varepsilon fsd^2 toCH)$
8	Average distance from cluster head to the BS	$dtoBS = 0.765(M/2)$
9	Normal and advanced node weighted probability	$pnrm = popt/(1 + \alpha \cdot m)$ $padv = [popt/(1+\alpha \cdot m)] \times (1 + \alpha)$
10	Optimal number of clusters	$kopt =$ $(M/ d^2 toBS)$
11	Node's optimal probability to become cluster head in round	$popt = (kopt/ n)$
12	Normal and advanced nodes weighted probability	$pnrm = popt/(1 + \alpha m)$ $padv = [popt/(1 + \alpha \cdot m)] \times (1 + \alpha)$
13	Average probability pi	$pi = [popt \times Ei\ r] / [(1 + \alpha \cdot m) \times Ei\ t]$ $if\ si\ is\ the\ normal\ node$ $pi = popt\ (1+\alpha)/ (1 + \alpha \cdot m)$ $if\ si\ the\ advanced\ node$
14	The probability threshold $T(si)$ which node si uses	$T(si) = pi /[(1-pi)\ r\ mod\ (1/ pi)]\ if\ si\ \varepsilon\ G'$ $0\ \ otherwise$

EADP deployed Base station like Raspberry pi in the middle of deployment area. The distance of normal or advanced node should be ≤ d0 from its CH.

Important factor when we are creating CH is that they should not overlap each other hence the distance between them must be defined. Using localization technique or RSSI, selected cluster head will cover all the deployment area.

In a round when normal node become cluster head, it aggregates the data and then try to find out any advanced instead of sending data directly to sink. Advanced node selected if following 2 conditions met.

- Node is not a cluster head in this round.
- Distance between normal CH and AN is less than compare to distance between normal CH and BS, AN should not be very near to CH or BS.

If the normal cluster head find such an advanced node that is not a cluster head in this round r and also its distance is less than distance between normal CH and BS, and not very near to CH or BS, then normal CH instead of sending the data to the BS directly, CH sends its data to AN which further send data to the BS. If normal cluster head does not find any such AN who fulfils the above mentioned two conditions then it will try to send the data to the BS itself. Thus by introducing a gateway concept or three tier architectures for normal cluster head, EADP has optimize the energy to prolong the WSN lifetime and stability period. Moreover, when the CHs are selected, each node joins to the closest (considering the transmission power) CH. However this may not be the optimal choice because, there may be a sensor node whose distance from the BS is less than all the nearby cluster-head distance.

Let us consider the figure 2, where the node N1 has to transmit L-bits to BS. The closest CH to N1 is CH1, and then it spends energy.

$E1 = L \cdot Eelec + L \cdot \epsilon d2 \cdot d2^x$

But if the node N1 does not belong to any CH and its distance is near to BS then it spends energy:

$E2 = L \cdot Eelec + L \cdot \epsilon d3 \cdot d3^y$

Energy dissipation model defined by using x and y. Clearly E2 < E1, but in this case lot of uncompressed data is collected at the BS. As in figure 2, sensor node N3 transferring its data to BS and uncompressed data at base station is not a problem, as at BS power & space is not a constraint. When E1 > E2, it is not an optimal choice for saving energy and transmit data and we can avoid transmission for particular time as sensor will go to the sleep mode for three rounds. For these three rounds if node itself become CH then it can transmit the data otherwise after three rounds, sensor node sends data to the near CH directly where E1 < E2. As in figure 2 sensor node N1 transferring its data to CH1 and then CH1 to BS.

ForE1 < E2, if a node neither a CH nor a member of CH then node can transmit the data to near AN (distance of AN is less compare to BS), then AN will transfer data to BS. As in figure 2, N2 transfer data to AN then AN to BS. If no AN between node and BS then after three rounds, node will transfer data directly to BS, as N4 in figure 2.

For E1 < E2 Sensor nodes send data to near cluster head and cluster head compress all the data received from its sensor members. To reduce the energy at cluster head level, it will not send data directly to base station it will follows some steps:

- If there is an advanced node between cluster head and base station then cluster head send data to advanced node then advanced node forward it to base station.
- If AN is very near to BS then cluster head first send data to AN which is not a good choice because AN first receive the data then forward it to the base station hence total energy consumption (receiving and sending) more compare to directly transmission of data from CH to BS.
- If AN is very near to CH then first AN receive all the data and then forward it to BS hence more energy consumption at AN (as long transmission will consume more energy). Delay is another parameter for QOS, if data transmission happens directly from CH to BS then minimum delay occur otherwise delay will increased.

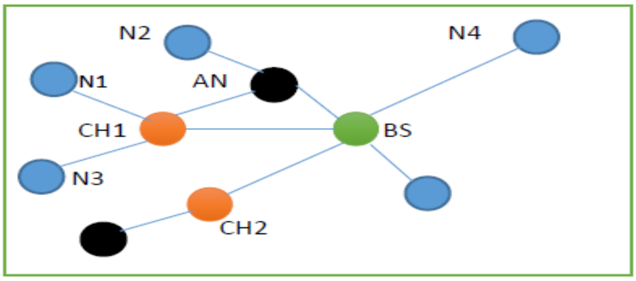

Figure 2. Cluster Head Formation & Selection

- For best result A should be approximately between CH and BS. Hence uniform consumption of energy at AN, CH, and minimum delay will occur.

The performance of the WSN evaluated on the basis of, stability period, network lifetime, number of CH per round, number of live nodes per round and based on throughput. Based on above equations in table 1, it is identified that if transmission is in short distance compare to longer then energy consumption is low for corresponding CH. AN has more energy and it will help CH for longer transmission, hence lifetime of CH is increased and approximately at the same time full network will die. Simulation results is still due to claim the same.

5. Testing and Implementation of WSN

A WSN is implemented using Raspberry Pi Kit and temperature sensor nodes. Raspberry Pi device working as base station and connected to a temperature sensor and xively.com using Wi-Fi internet. To get started with Raspberry Pi you need an operating system. NOOBS (New out Of the Box Software) is an easy operating system install manager for the Raspberry Pi. The easiest way to get NOOBS is to have an SD card with NOOBS preinstalled, if we have an SD card (8GB recommended), then download NOOBS for free and install it on your card. It is best to format your SD card before copying the NOOBS files on to it. Once your SD card has been formatted, drag all the files in the extracted NOOBS folder and drop them onto the SD card drive. The necessary files will then be transferred to your SD card. When this process has finished, safely remove the SD card and insert it into your Raspberry Pi. Plug in your keyboard, mouse and monitor cables. Now plug in the USB power cable to your Pi. Your Raspberry Pi will boot, and a window will appear with a list of different operating systems that you can install. We recommend that you use Raspbian – tick the box next to Raspbian and click on Install. Raspbian will then run through its installation process. Note this can take a while. When the install process has completed, the Raspberry Pi configuration menu (raspi-config) will load. Here you are able to set the time and date for your region and enable a Raspberry Pi camera board, or even create users. You can exit this menu by using Tab on your keyboard to move to Finish. The default login for Raspbian is Username: pi, Password: raspberry. To load the graphical user interface type startx.

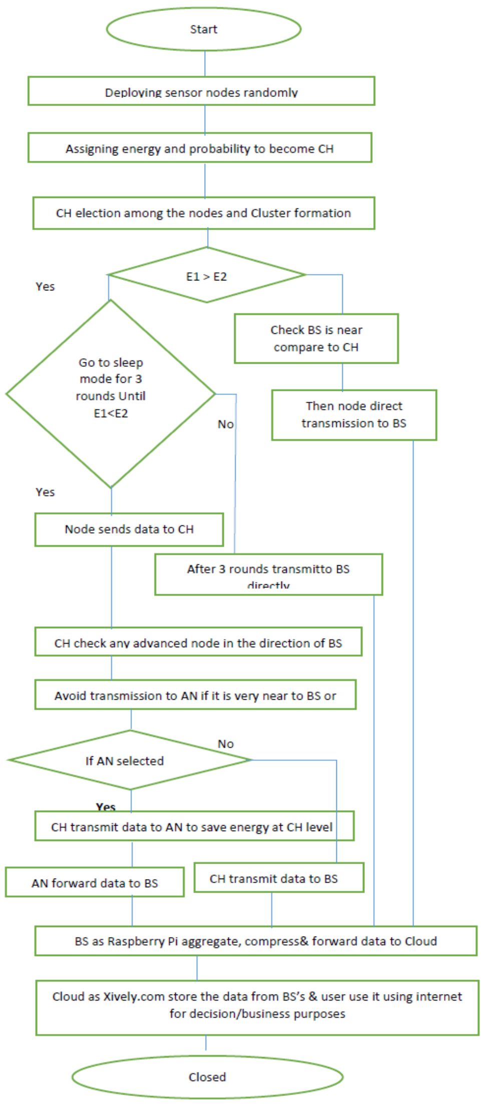

Figure 3. Flow Chart of Proposed Algorithm

Step 2: Configure Network using Wi-Fi Configuration

Select Terminal, Open interfaces files in nanoeditor:sudonano/etc/network/interfaces
•For wlan0 interface, write: auto wlan0allow hotplugwlan0 ifacewlan0 inetdhcpwpa-ssid“ENTER NETWORK NAME HERE”wpa-psk“ENTER PASSWORD HERE”
•Ctrl + X , Y , Enter to Save file & exit nano editor
•Restart networksudo/etc/init.d/networking restart
•Check Wi-Fi configurations with ifconfigcommand.

Step 3: Set up Remote Desktop

3.1. VNC Access (Remote Desktop)

•Install VNC Server using aptitude Package manager:sudoapt-getupdatesudoapt-get install tightvncserver
•RunVNC Server using the following command, set 12345 as password :vncserver:1
•Setup VNC Client on your PC, append :1 to the IP address of the Raspberry such as 192.168.2.34:1
•Install Enable vnc server to run at the boot-up of Raspberry-Pi:cd/home/picd.configmkdirautostartcdautostartnanotightvnc.desktop
•Contents of tightvnc.desktopfile:[DesktopEntry]Type=ApplicationName=TightVNCExec=vncserver:1StartupNotify=false
•Ctrl+Xand Y to Save and Exit nano editor, Reboot the Raspberry-Pi.

Step 4: Introduction about Wiring Pi C Library

• Download & Install Wiring Pi C Library using git: sudoapt-get install git-corecd/home/pigitclone git://git.drogon.net/wiringPi
•Build/Install WiringPiLibrarycdwiringPi./build
•Test your installation withgpio –v

Step 5: How to use GPIO Utility

Enables GPIO access from the command line. See the man page for the GPIO Utility man gpio
•Check version usinggpio –v
•This reads all normally accessible pins and prints a table of their numbers (Both WiringPi and BCM_GPIO) along with their modes and current valuesgpioreadall
•Read add Pins using gpioreadall

Step 6: How to Program with Wiring Pi

Include files:#include <wiringPi.h>
•CFLAGS:-I/usr/local/include-L/usr/local/lib-lwiringPi

Compile the program using

gcc–Wall –o blink blink.c-I/usr/local/include -L/usr/local/lib –lwiringPi

6. Conclusion and Future Work

EADP is a multi-hop energy efficient clustering algorithm for heterogeneous WSN. The proposed EADP takes the full advantage of computation and power heterogeneity. It improves the CH lifetime resulting increased network lifetime, stability period, throughput and reduce delay of WSN network. Clearly if CH select AN as an intermediary node then CH will save the transmission energy because transmission energy proportional to the distance. If AN near to BS or CH then only delay will increase. Implemented a WSN to show the working protocols and multi-path communication using Wi-Fi technology. In future work we try to implement WSN using ZigBee stack and WiMAX technology to provide heterogeneity in communication. Proposed work simulation is not done, but implemented a WSN, which successfully store all the data at cloud.

For future work, EADP can be simulated using NS3 and compare with all available algorithm, can be extended to deal with an energy efficient algorithm through data aggregation in a mobile sensor network.

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