Integrated Energy Efficient Clustering Strategy for Wireless Sensor Networks

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Abstract: The foremost compensations of clustering are the communication of combined information to the base station, bids scalability for enormous quantity of nodes and lowers down energy depletion. Essentially, clustering could be categorized into centralized grouping, distributed grouping and hybrid grouping. In centralized grouping, the cluster head is immovable. The rest of the sensor nodes in the group deed as participant nodes. In distributed clustering, the cluster head is not stationary. The cluster head retains on fluctuating form node to node within the group on the foundation of some restrictions. Hybrid clustering is the mixture of both centralized clustering and distributed grouping contrivances. A distributed clustering procedure, the integrated energy efficient clustering (IEEC) mechanism has been anticipated. The anticipated procedure is a well dispersed and energy effectual grouping procedure which engages relay nodes, capricious communication power and solitary message communication per node for group set-up. The enactment of the projected procedure is associated with two prevailing distributed grouping procedures LEACH and HEED. The projected procedure portrays an upgrading in average communication energy and overall system energy intake. Eventually, the complete network lifetime is considerably extended in IEEC procedure

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1. Introduction:

Wireless Sensor system inter-networks with an Internet Protocol (IP) central system through a quantity of gateways. A gateway routes probes or commands to suitable nodes inside a sensor network. It correspondingly routes sensor information, at times combined and abridged to operators who have demanded it or are predictable to exploit the data. An information mine or storage provision is offered at the gateway, in adding to data classification at each sensor. The mine may support as an intermediate amid the users and sensors thus providing obstinate data storing. Furthermore, one or additional information storage strategies are involved for the IP network to record the sensor information from a quantity of superiority sensor networks. One of the chief compensations of WSN is their aptitude to function in unattended, severe environments in which current human-in-the-loop observing structures are indeterminate, incompetent and occasionally dreadful. Consequently, wireless sensors are probable to be positioned arbitrarily in the prearranged area of attention by a comparatively unrestrained method. Assuming the enormous area to be enclosed, the petite lifetime of the battery-operated wireless sensors and the likelihood of having dented sensor.

Nodes during disposition, enormous population of sensors are predictable in the majority of wireless sensor applications. A WSN contains numerous sensor nodes that are used to intellect the target information and collaborating them to the Base station (BS) sited abstractedly left from the sensing ground. The primary sorts of these systems are reduced amount movement, a slighter quantity of hardware competences, abridged memory and augmented populace compactness in the target zone, when associated to ad-hoc networks. Frequently, a wireless sensor node encompasses squat power processor, tiny memory, radio frequency constituent, copious kinds of identifying devices and inadequate powered batteries. Considerable energy depletion proceeds throughout the wireless transportations. The energy depletion when assigning one bit of data equivalents to numerous thousands of sequences of CPU instructions. Hence the energy effectiveness of a wireless communication procedure expressively distracts the energy competence and period of the scheme. Numerous investigators have projected plentiful measures for WSNs to progress energy ingesting and network period. The regarding procedures in WSNs can be characterized into three modules: routing processes, sleep/awake scheduling processes and clustering processes. Since these devices are power-constrained, long-distance transportations are not fortified (Heinzelman et al., 2002; Manjeshwar & Agrawal, 2001; Youssef et al., 2006).

Thereby conventional communication amid the nodes and BS is escaped. An effective technique is to position the network into frequent groups and each distinct cluster has a cluster-head (CH). CH is one of the sensor nodes which are comfortable in possessions. Sensor nodes direct their sensed information to the CH during their TDMA time-slots. The CH performs information accumulation procedure and onwards the merged information to BS. Clustering tracks some compensations like network scalability, restricting route arrangement within the group, preserves communication bandwidth and abuses network lifetime.

Since in clustering practices the contrivance of information accumulation, unwanted communication amongst the sensor nodes, CH and BS is equivocated.

Grouping may be centralized or distributed, centered on the construction of CH. In centralized grouping, the CH is immovable and the enduring nodes of the group deed as associate nodes. Distributed grouping has no stationary construction for CH and this retains on altering from node to node grounded on nearly few pre-assigned constrictions like lingering energy, communication cost and weight. Distributed grouping construction is used for some detailed motives like sensor nodes disposed to disaster, better congregation of information, diminishing redundant information and providing backup in case of disaster of the principal node. As there is no centralized figure to assign the possessions, these distributed grouping processes have tremendously self-organizing proficiency (Manjeshwar & Agrawal, 2001; Akkaya & Younis, 2005; Al-Asadi, 2016; Al-Asadi et al., 2010a; Al-Asadi et al., 2011a; Alasadi et al., 2010b)

In this paper, a distributed grouping technique IEEC is projected which is based on variable communication power, relay nodes and solitary communication per node for cluster-setup. The prime objective of the projected technique is to attain energy efficiency and protracted network lifetime. The performance of the projected technique is assessed in contradiction of two present procedures, specifically Low Energy Adaptive Clustering Hierarchy (LEACH) and Hybrid Energy-Efficient Distributed Clustering (HEED). The respite of this paper is agreed as follows. An assessment of prevailing distributed grouping processes is conversed in Section II. The exemplary of the projected procedure is labeled in Section III. Section IV expounds the clarification of the projected procedure. Simulation consequences and their deliberations and elucidated in Section 5. Finally, Section 6 gives the supposition.

2. Review of Existing Distributed Clustering Algorithms

Distributed clustering is the mechanism in which there is no static central cluster head and the cluster head keeps on varying from node to node based on some pre-assigned constraints (Younis & Fahmy, 2004; Al-Asadi, 2013; Al-Asadi et al., 2011b; Al-Asadi et al., 2011c).

Low Energy Adaptive Clustering Hierarchy (LEACH): LEACH is a grouping mechanism that dispenses energy feasting all alongside its organization, the scheme being isolated into groups and the CHs are virtuously distributed in approach, and the haphazardly designated CHs assemble the information from the nodes which are coming underneath its cluster as projected by (Heinzelman et al. 2000). LEACH procedure comprises of four chief stages for each round: Advertisement stage, Cluster set-up stage, Schedule creation and Data transmission.

Fixed number of Clusters LEACH (LEACH-F): Heinzelman et al. (2000) projected a distributed clustering procedure LEACH-F in which the quantity of clusters will be enduring all-through the network lifetime and the cluster heads are alternated within the individual clusters. Steady state stage of LEACH-F is equivalent to that of LEACH. LEACH-F might or might not compromise energy tradable and does not compromise flexibility to sensor node movement.

Centralized LEACH (LEACH-C): Heinzelman et al. (2000), approved out few alterations in the original LEACH protocol and was projected as LEACH-C. The original LEACH cluster formation procedure has the difficulty of having no declaration about the quantity of cluster head nodes. As the clusters are adaptive, there is disadvantaged clustering set-up during a round. However, by means of a central control mechanism to form clusters can generate better clusters by distributing the cluster head nodes all-through the system, which forms the rudimentary idea behind LEACH-C.

Heterogeneous-LEACH (LEACH-HPR): LEACH-HPR is an energy efficient cluster head selection method, and uses the modified Prim's algorithm to form an inter-cluster routing in heterogeneous wireless sensor network. LEACH-HPR is more effective in dropping and balancing the energy consumption and therefore validates an enhanced network lifetime.

3. The Analytical Model of IEEC:

The projected process (figure 1), integrated energy efficient clustering (IEEC), is a well dispersed grouping process where the sensor nodes are positioned haphazardly to sense the object surroundings. The nodes are detached in to groups with each group partaking a CH. The nodes through the information throughout their TDMA timeslot to their corresponding

CH which ferocities the information to dodge redundant information by the procedure of information aggregation. The combined information is advanced to the relay nodes which in turn routes the information to BS furthermore directly or forwarding through additional relay nodes. Figure 1 portrays the enunciation of IEEC clustering procedure

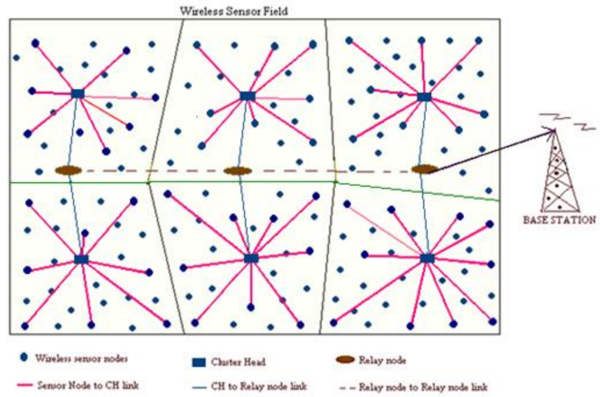

Figure 1. An articulation of IEEC clustering procedure

In a network of N nodes, every node is assigned with a solitary Node Identity (NID) n, where n=1, 2, 3…., N. The NID evenhanded helps as an identification of the nodes and has no association with position or grouping. The CH will be placed at the midpoint and the nodes will be prearranged in to frequent layers about the CH and these layers are owed with Layer Number (LN). LN is an integer figure beginning from zero. CH acquires LN0, nodes adjacent to the CH in the next layer are allocated LN1, and so on. The nodes in the farthest layer get the uppermost LN. Nodes in primary layer use slighter transmission power. The nodes in the last layer use supreme transmission power. The power transmission is adjustable and virtuously based on the layers, thus IEEC achieves outstanding power conservation.

Here the principal level nodes employ power (P1), the second layer nodes exploit power (P2) and so on. It is to be renowned that the transmission power upsurges with growth in layer number. The communication power required for a node in level M is,

$$P_M = M.\ P_1 \qquad (1)$$

Where PM is the communication power of a node in level M, P1 is the communication power of a node in first level and M is the layer figure.

A relay node is just a node which is wealthier in possessions like battery, memory, etc. In the projected procedure, the relay nodes accomplish only one purpose: routing of the information to BS either straight or progressing through other relay nodes. In IEEC, the foremost circumstance to be considered is that the relay nodes closer to BS necessitate more communication power as they have to onward all the information packets from the previous relay nodes.

4. IEEC Algorithm Description:

In the projected procedure IEEC, the network contains N nodes, Node Identity (NID) n and the quantity of clusters formed is signified as K, K=1, 2…., (N-1)/2. The complete procedure performs in four phases: cluster-setup, data aggregation, relay node's maneuver and CH re-election.

In IEEC, the node with uppermost residual energy has the supreme likelihood of becoming a CH. Originally PCH associates the residual energy of the cluster nodes and handovers the CH to the node partaking uppermost residual energy within a cluster. If it does not discover any node having advanced residual energy PCH itself will develop as a CH. It broadcasts join-request to the sensor nodes within R meters, where R is equivalent to the cluster radius. The broadcast message comprises of the NID of the CH, the overall number of layers in the cluster l_T and local communication radius R_{COMM}. The objective of this message is to suppress other nodes revolving into CH. Nodes getting this message will halt their interest to develop a CH and links to that CH. As deliberated previously, the clusters are organized in concentric layers, the sensor nodes will make use of messages in the packet and with the subsequent equation to estimate the bound B_K of the K^{th} layer, where K=1, 2…...., l_T.

The expression for B_K is,

$$\begin{cases} 0 \text{ for } & K \le 0 \\ b_{K-1}+R_{COMM} & \text{otherwise} \end{cases} \qquad (2)$$

Where b_{K-1} is the typical distance between CH and the cluster member in the $K-1^{th}$ level. Here b_{K-1} is articulated as,

$$b_{K-1} = \frac{B^2_{K-1}+B^2_{K-2}}{2} \qquad (3)$$

The cluster members will make use of received signal strength indicator (RSSI) and the link quality indicator (LQI) of the CH to the evaluation of their expanses from CH and computes their corresponding layers. Variable power can be thus successfully engaged for transmitting information from nodes to CH and vice versa.

A CH will fuse all the inward information packets together, those received from the sensor nodes in order to evade redundant information transmission of extremely correlated data. The merged information is then progressed to relay nodes. In case when a node deceases or does not communicate the information during its time-slot, it is observed as unreachable and can be hopped from the information collection procedure. The aggregation is achieved by spatial correlation measurement by gauging the offset amongst the two sensor interpretations. If the error is within the bearable range, then the two interpretations are correlated.

In IEEC the relay nodes are stationary and only onward the information to BS. Every relay nodes have similar initial energy and transmission range. The MAC protocol places the radio of the relay node in sleep manner if it is not the transmitter or receiver of the packet. The relay nodes are alienated into dissimilar zones beginning from the BS. The relay nodes in the zone closer to the BS prerequisite to relay more packets and henceforth number of relay nodes are to be located in the region closer to BS. The region farther from BS necessitates less number of nodes as there is requirement for only tiny quantity of information to be forwarded. Also the power depletion of the relay nodes closer to BS will be extra related to the relay nodes far away from BS. The BS will occasionally broadcast a beacon message to the relay nodes. The relay nodes use the RSSI and LQI of the beacon message to guess its distance from BS in order to uphold the transmission power.

The CH computes the lifetime of the member nodes based on their residual energies. The CH uses the lifetime data to guess the lifetime of the cluster. If any node is found with residual energy superior than that of CH, that precise node is re-elected as new CH. All wireless sensor nodes which have stretched their own predictable lifetimes will be deliberated themselves as dead and becomes indolent. An indolent node will not contribute in any of the forthcoming operations.

5. Simulation Study and Discussions:

All the simulations were approved using the network simulator NS-2. For energy consumption, the first-order radio model, delineated in (Heinzelman et al., 2002) was engaged. Conferring to this model, the energy mandatory to transmit k bit message over distance d meters is specified by E_{TX} (k, d),

$$E_{TX}(k, d) = E_{TX} - elec(k) + E_{TX} - amp(k, d) \quad (4)$$
$$E_{TX}(k, d) = E_{elec} \times k + E_{amp} \times k \times d^2 \quad (5)$$

Where E_{amp} characterizes the energy expended by the amplifier to attain an adequate SNR and E_{elec} is the energy expended by running the transceiver circuitry. The energy depletion can be considered using the subsequent equations,

$$E_{RX}(k) = E_{RX} - elec(k) \quad (6)$$
$$E_{RX}(k) = E_{elec} \times k \quad (7)$$

Where $E_{RX}(k)$ signifies the energy necessary to receive a k bit message.

Table 1: *Simulation parameter setup*

Parameter	Acronym	Values
Cluster topology (m)	C_t	100 x 100
Tx/Rx electronics	$E_{tx/rx}$	m^2
constant Amplifier	E_{amp}	50nJ/bit
constant	P	$10pJ/bit/m^2$
Path loss exponent	E_{th}	2
CH energy threshold	p	$10^{-4}J$
Packet size	b	50 bytes
Packet rate	N	1packet/s
Number of nodes	R_{bc}	20
Transmission range	R_{sense}	70m
Sensing range	$R_{cluster}$	15m
Cluster range		30m

For simulation, nodes were positioned arbitrarily on the basis of the constraints outlined in table 1. The projected distributed clustering procedure is simulated with 20 nodes and at each time the energy consumption, node's residual energy, etc., are documented. Lastly IEEC is associated with two prevailing procedures LEACH and HEED based on the abovedocumented interpretations. The chief purposes of simulation are: Construction of clusters. Selection of CHs. Gathering information from cluster members. Combination of collected information by CH. Transporting the fused information to relay nodes. Progressing of information by relay nodes to remote BS. Re-electing the CHs. An information collection procedure is said to be accomplished when all the relay nodes in the sensor network onwards the information to the BS.

Sensor nodes are arranged in a square sensing field (x, y) of 100 x 100 meter2. Once deployed the sensor nodes are expected to be motionless. For simulation perseverance the BS is positioned at the midpoint of the field but in real-world applications BS will be situated far away from the target atmosphere. The BS comprises of adequate energy and at any cost energy scarcity does not occur.

In this paper, regularized number of wireless sensor nodes is used to assess the lifetime of the network. The projected procedure IEEC is simulated and the results are documented for average communication energy against time, normalized total system energy consumption and node death rate. These constraints are then associated with the two prevailing procedures LEACH and HEED. The association between average communication energy and time for LEACH, HEED and IEEC are exposed in figures 2 and

3. In LEACH (Figure 2), the initial communication energy is 2.2 J then upsurges to 2.6 J and again decreases to 2.2 J with continuation in time.

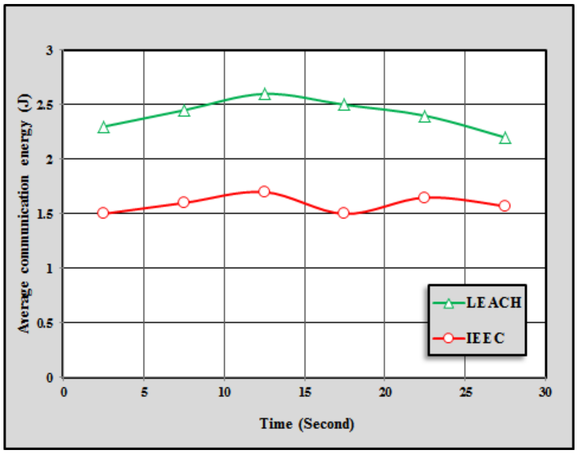

Figure 2. Average communication energy against time (LEACH versus IEEC)

For IEEC, the initial communication energy is 1.5 J, increases to 1.7 J and then reduces to 1.6 J. In case of HEED (Figure 3), the initial communication energy is 4.2 J, increases to 4.5 J and then reduces to 4.4 J. For IEEC, the initial communication energy is 1.5 J, increases to 1.7 J and lastly decreases to 1.6 J. From figure 2, the average communication energy of LEACH is 2.33 J and IEEC is 1.6 J. IEEC displays 0.73 J improvement in average communication energy compared to LEACH for every 27.5 seconds. From figure 3, the average communication energy of HEED is 4.37 J and for IEEC is 1.6 J. IEEC displays 2.77 J improvement in average communication energy compared to HEED for every 27.5 seconds. This is because LEACH and HEED uses number of needless communications between sensor nodes, CH and BS while IEEC avoids redundant communications.

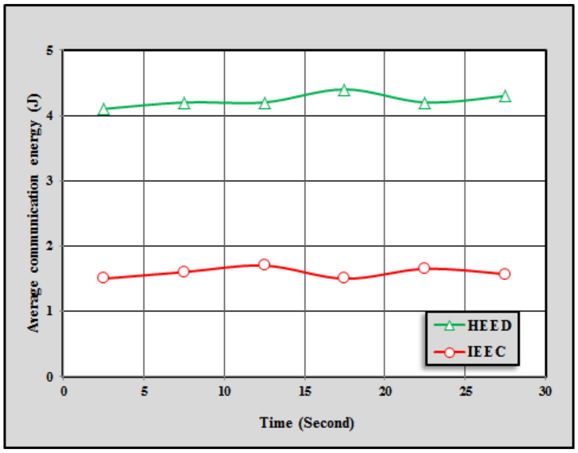

Figure 3. Average communication energy against time (HEED versus IEEC)

The assessment of normalized total system energy consumption of LEACH, HEED and IEEC is shown in figure 4. LEACH and HEED possess piercing declining slope. In figure 4, the initial energy consumption of LEACH is 10 J and in 700 rounds the energy consumption reduces to 0 J.

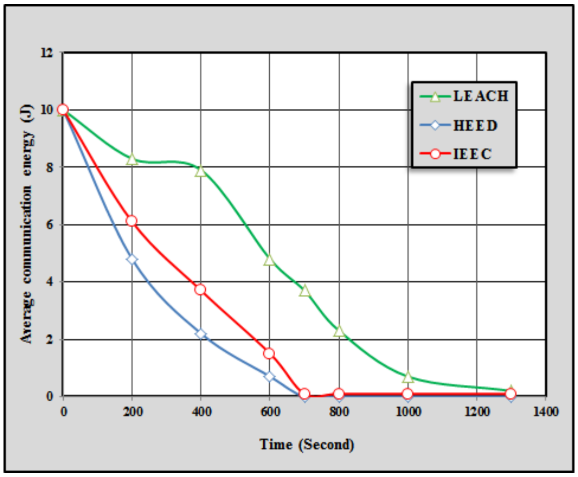

Figure 4. Comparison of proposed protocol with LEACH and HEED (Normalized total system energy consumption)

The preliminary energy consumption of HEED is 10 J and in 700 rounds the energy consumption is 0 J. The initial energy consumption is 10 J but only in 13000 rounds the energy consumption drops to 0 J for IEEC. Hence IEEC displays decent development in total system energy consumption compared to LEACH and HEED. From figure 5 it could be seen that the proposed procedure IEEC shows 46% enhancement in lifetime compared to LEACH and HEED. This is mostly because of the characteristic structures applied for IEEC which were deliberated in the former sections.

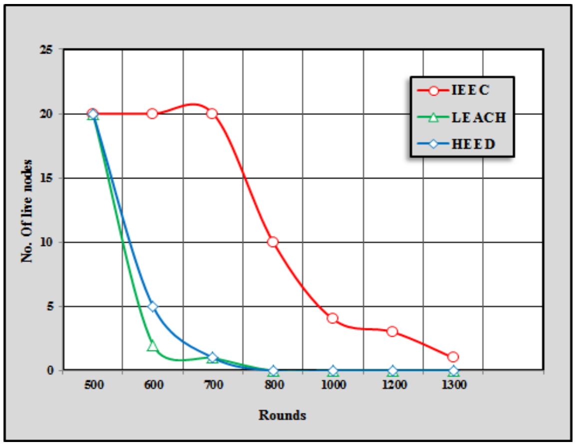

Figure 5: Node death rate (LEACH, HEED and IEEC)

6. Conclusion:

The projected distributed grouping method has shown much enhancement in communication energy over the two evaluated procedures. The performance of the proposed procedure shows an extreme improvement in the overall energy of the wireless sensor system. However, the proposed procedure can significantly diminish the node death rate and thus have extended network lifetime. This effort can be stretched to mobile wireless sensor networks when the nodes are in highly mobile atmosphere.

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