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Using adaptive clustering scheme with load balancing to enhance energy efficiency and reliability in delay tolerant with QoS in large-scale mobile wireless sensor networks

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Abstract

Purpose – Load balancing is an effective enhancement to the proposed routing protocol, and the basic idea is to share traffic load among cluster members to reduce the dropping probability due to queue overflow at some nodes. This paper aims to propose a novel hierarchical approach called distributed energy efficient adaptive clustering protocol (DEACP) with data gathering, load-balancing and self-adaptation for wireless sensor network (WSN). The authors have proposed DEACP approach to reach the following objectives: reduce the overall network energy consumption, balance the energy consumption among the sensors and extend the lifetime of the network, the clustering must be completely distributed, the clustering should be efficient in complexity of message and time, the cluster-heads should be well-distributed across the network, the load balancing should be done well and the clustered WSN should be fully connected. Simulations show that DEACP clusters have good performance characteristics.

Design/methodology/approach – A WSN consists of large number of wireless capable sensor devices working collaboratively to achieve a common objective. One or more sinks [or base stations (BS)] which collect data from all sensor devices. These sinks are the interface through which the WSN interacts with the outside world. Challenges in WSN arise in implementation of several services, and there are so many controllable and uncontrollable parameters (Chirihane, 2015) by which the implementation of WSN is affected, e.g. energy conservation. Clustering is an efficient way to reduce energy consumption and extend the life time of the network, by performing data aggregation and fusion to reduce the number of transmitted messages to the BS (Chirihane, 2015). Nodes of the network are organized into the clusters to process and forwarding the information, while lower energy nodes can be used to sense the target, and DEACP makes no assumptions on the size and the density of the network. The number of levels depends on the cluster range and the minimum energy path to the head. The

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proposed protocol reduces the number of dead nodes and the energy consumption, to extend the network lifetime. The rest of the paper is organized as follows: An overview of related work is given in Section 2. In Section 3, the authors propose an energy efficient level-based clustering routing protocol (DEACP). Simulations and results of experiments are discussed in Section 4. In Section 5, the authors conclude the work presented in this paper and the scope of further extension of this work.

Originality/value – The authors have proposed the DEACP approach to reach the following objectives: reduce the overall network energy consumption, balance the energy consumption among the sensors and extend the lifetime of the network, the clustering must be completely distributed, the clustering should be efficient in complexity of message and time, the cluster-heads should be well-distributed across the network, the load balancing should be done well, the clustered WSN should be fully connected. Simulations show that DEACP clusters have good performance characteristics.

Keywords Wireless sensor network, Energy saving, Distributed algorithm, Load balancing

Paper type Research paper

1. Introduction

A wireless sensor network (WSN) consists of a large number of wireless capable sensor devices working collaboratively to achieve a common objective. One or more sinks [or base stations (BS)] collect data from all sensor devices. These sinks are the interface through which the WSN interacts with the outside world. Challenges in WSN arise in implementation of several services, and there are so many controllable and uncontrollable parameters (Chirihane, 2015) by which the implementation of WSN is affected: *energy conservation*. Clustering is an efficient way to reduce energy consumption and extend the life time of the network, by performing data aggregation and fusion to reduce the number of transmitted messages to the BS (Chirihane, 2015). Nodes of the network are organized into the clusters to process and forward the information, while lower energy nodes can be used to sense the target, and distributed energy efficient adaptive clustering protocol (DEACP) makes no assumptions on the size and the density of the network. The number of levels depends on the cluster range and the minimum energy path to the head. The proposed protocol reduces the number of dead nodes and the energy consumption to extend the network lifetime. The rest of the paper is organized as follows: an overview of related work is given in Section 2. In Section 3, we propose an energy efficient level-based clustering routing protocol (DEACP). Simulations and results of experiments are discussed in Section 4. In Section 5, we conclude the work presented in this paper and the scope of further extension of this work.

2. Related work

In the paper Rana *et al.* (2015), the authors proposed a clustering mechanism that implements two fuzzy logic levels (FEMCHRP). In the first level, CHs are elected based on energy and the distance between the nodes. In the second level, CH leaders are elected based on the energy level of the CH and its distance to the BS. This mechanism has more computational load and complexity in a fuzzy inference system (FIS). Also, Sajjanhar and Mitra (2007) proposed a distributive energy efficient adaptive clustering (DEEAC) protocol. This protocol is adaptive in terms of data reporting rates and residual energy of each node within the network. The DEEAC protocol has spatio-temporal variations in data reporting rates across different regions. DEEAC (Sajjanhar and Mitra, 2007) selects a node to be a CH depending upon its hotness value and residual energy.

Athreya and Tagu, (2011) proposed a routing mechanism that uses cross-layer strategies. The cross-layer strategy involves incorporating feedback and information from layers below the network layer to make decisions at the network layer. It works well for small networks. In Xing *et al.*, 2015, the authors proposed network coding condition with QoS constraint proposed, which provides proof for coding opportunity detection. To facilitate the evaluation of discovered routes, a novel routing metric, called coding aware QoS routing metric, is presented, which jointly considers link quality, node congestion and coding opportunity. They proposed a path evaluation mechanism for the paths returned by multi-path routing mechanism.

3. Distributed energy efficient adaptive clustering protocol with data gathering for wireless sensor networks

3.1 Motivations

There are several requirements for our clustering algorithm:

- DEACP clustering should be completely distributed because a centralized control manner is not practical in a large-scale sensor network;
- the CHs should be well distributed to make energy consumption be well-balanced among all sensor devices; and
- our algorithm has the advantage of minimizing the routing control messages and therefore can safely operate from an energy efficient perspective.

3.2 Radio model

We used the following equations for calculating the communication energy dissipation. The free space (d^2 power loss) channel model is used, depending on the distance between the transmitter and the receiver. The energy spent for the transmission of the k-bit packet over distance d is given by $E_{TX:}$

$$E_{Tx}(K, d) = KE_{elc} + KE_{amp}d^2 \tag{1}$$

$$E_{Rx}(K) = KE_{elc} \tag{2}$$

E_{elec} is required energy for activating the electronic circuits. E_{amp} are required energy for amplification of transmitted signals to transmit a one bit in open space and multi-path models, respectively. Energy consumption to receive a packet of k bits is calculated according to equation (2). The residual energy of a node Ni, after transmitting a message of "k" bits at distance d from the receiver, is calculated by equation (3):

$$E_{ri} = E_{initial} - (E_{TX}(k, d) + E_{RX}(K)) \tag{3}$$

We can compute the total initial energy equation (4) of the networks by the given equation:

$$E_{total} = NE_{initial} \tag{4}$$

equation (5) denotes the average energy of all live micro sensor nodes in the WSN, which is calculated as follows:

$$E_{average} = \sum_{n=1}^{n} E_{residual}(i)/n \quad (5)$$

equation (5) is the total energy dissipated in the network during a round, which is equal to:

$$E_{round} = \lambda[NE_{DA} + 2NE_{elect} + NE_{fs}d^2_{neigh} + E_{amp}d^4_{ChtoBs}]$$

where E_{DA} is the data aggregation cost spent in each node, d_{CHtoBS} is the average distance between the CH and the BS, d_{neigh} is the average distance to the next node in the chain, λ is the total size of transmitted data, E_{fs} and E_{amp} depend on the transmitter amplifier model used (Boubiche and Bilami, 2011).

3.3 Network model

In the network studied in this paper, we assume a homogeneous WSN, where nodes are uniformly randomly dispersed throughout the area. The nodes in the network are scattered within a square area, where the length of the sides are represented by M in this paper. We assume that all the nodes can communicate with the BS with enough energy, and also can use different power levels for communications (Figure 1).

3.4 Distributed energy efficient adaptive clustering proposed protocol

One of the important factors to improve lifetime of WSN is the design of network. In this section, we describe the proposed *DEACP* approach. The *DEACP* approach uses adaptive clustering scheme. A clustering scheme is called an adaptive scheme if, over time, the number of clusters vary and the nodes membership evolves. In *DEAC*, the BS is assumed to have unlimited energy residues and communication power. It is also assumed that the BS is located at a fixed position, either inside or away from the sensor field. Nodes with special high "Cch" condition can act as CH to burden the pressure of data transmission. To prevent early death due to excessive energy expenditure, all

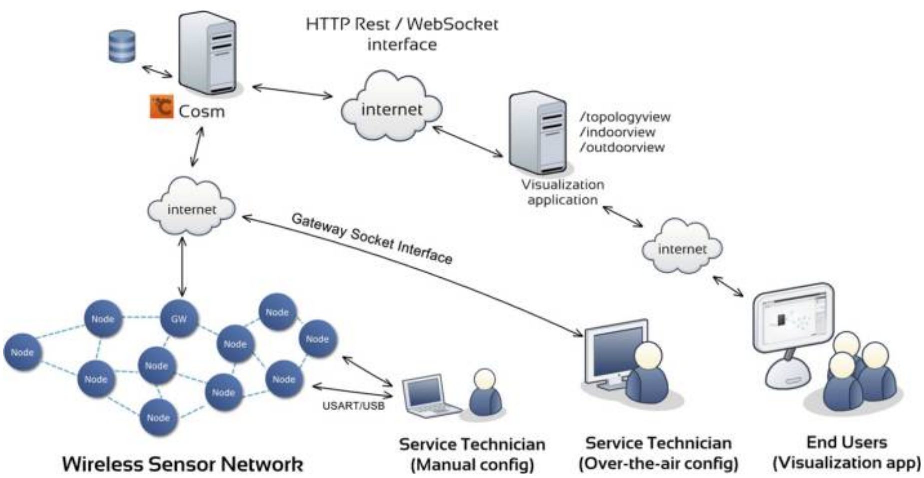


Figure 1.
Network model

nodes should alternately take turns to become CH. CH election need to consider many factors. In *DEACP*, the following factors are considered: node-weight, residual energy, condition distance between nodes, condition distance with SB. The *DEACP* protocol achieves a good distribution of clusters (unresolved problem with many protocols). The *DEACP* protocol takes place in "rounds" that represent time intervals determined in advance. Each round consists of four phases, the initialization phase, phase decision, phase of group formation and phase transmission (Chirihane *et al.*, 2015).

3.5 Distributed energy efficient adaptive clustering protocol initialization phase:
3.5.1 Distance (N,BS). Initially the sensor nodes are randomly deployed in a capture zone. There are many techniques used to conserve WSN energy, to prevent its premature death. Longer distance transmission, involving a number of relaying nodes, increases energy consumption very quickly. It strives to receive a message from nodes located as close as possible to a BS. The nodes are deployed, and we have no possibility to change its location. To achieve energy saver effect, more rational seems to be having mobile BS especially that in real life there is usually only one. Typically, in WSN, there are a lot of sources of messages. BS should be moved to the location where messages flow evenly from all directions. If this condition is met, it prevents unnecessary BS movements in other directions. Furthermore, such BS location reduces consumption of energy spending for communication but, as a drawback, it reduces the WSN lifespan (Nikodem *et al.*, 2012).

The initialization phase is to broadcast an announcement message "*BS-Msg*", by the BS, at a certain power level to all the sensor network nodes. Thus, each node can calculate the approximate distance from the BS, according to the received signal strength.

3.5.2 Node weight. The neighborhood discovery is a component of the WSN construct algorithm. During the WSN construct, each node in the network performs at least one neighborhood discovery. The objective of the neighborhood discovery is to collect as much information as possible about other nodes in the vicinity to provide a good basis of decision-making for choosing neighbors. For that reason, messages of different types have to be exchanged between the discoverer and neighboring nodes to transmit information and to notify the chosen neighbors. Finally, the neighborhood discovery ends with the construction of a neighbor table. Each node to calculate the node-weight sends a message "Discov-neigh-msg" which contains its identifier. Each node receiving the message sends immediately a "Discov-neigh-msg" message of the same type, and then each member has its neighbors table, allowing him to know its cost is that the size of the latter (Figure 2).

The objective of this phase is to collect as much information as possible about other nodes in the vicinity in order to provide a good basis for decision-making in choosing neighbors. In our DEACP protocol, two aspects are crucial for the choice of the neighbors. On the one hand, neighbors with a good link quality are important. If messages to or from a neighbor are received only rarely and require many retransmissions because of a bad link quality, a lot of energy of the batteries is wasted and the reliability of the network function is decreased. Thus, it is energy-efficient and more reliable for the network function to choose the nodes with the best link quality as neighbors.

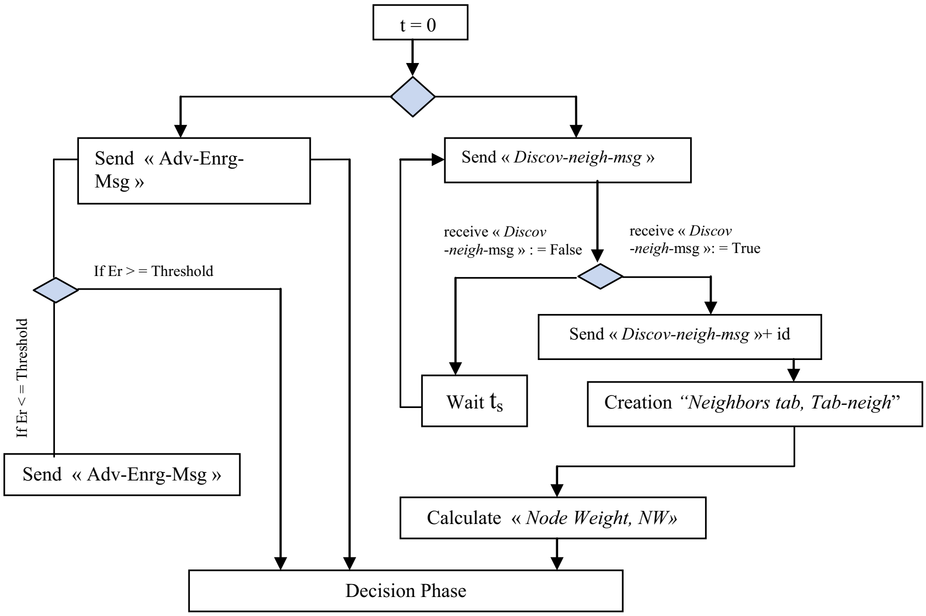


Figure 2.
Neighbor discovery (node weight)

At the beginning of the neighborhood discovery, the discoverer transmits a *Discov-neigh-msg*. By the time the discoverer transmits the first broadcast, a timer *ts-discov* is started simultaneously. While the timer is running, the node waits for *broadcast received messages*, a node receiving a notification adds the source as neighbor to the neighbor and transmits an ack notification back to the discoverer. As a reaction to receiving an ack notification, the discoverer adds the source as a neighbor as well. Upon having received all ack notifications, the discoverer a neighbor table and thus the neighborhood discovery is completed (Figure 3).

The neighborhood discovery is completed with the construction of the neighbor table, whether it could be filled up with neighbors or remains empty. The choose neighbors procedure is a component of the neighborhood discovery. The procedure chooses neighbors among all nodes which are discovered during the neighborhood discovery.

3.6 Decision phase

3.6.1 Cluster-head election phase. The most important part of each clustering scheme is the CH election. In the clustering-based protocol, the nodes are arranged into local clusters. Each cluster consists of one CH and a number of member nodes which belong to the same cluster. All non-CH nodes should transmit their data to the CH, while the CH must forward the received data from all the cluster members to the remote BS after performing data aggregation. Therefore, being a CH is much more energy consuming than being a non-CH member node. For the CH election, the proposed *DEACP* uses a hybrid scheme of residual energy and distance among the CHs, distance between node and Bs, Weight-node. The CH election phase is done in two steps: the local competition and the distance condition (Chirihane, 2015).

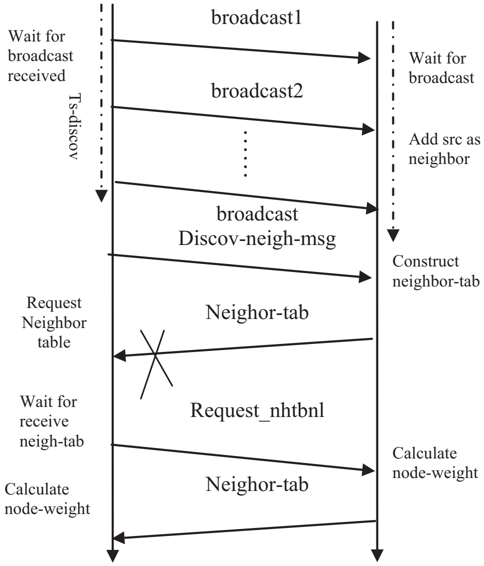


Figure 3.
Create neighbor table and calculate node weight

In our proposed method, the nodes compete in a competition scheme to be elected as the CH candidate. The CH election and cluster formation in DEACP protocol has four primary objectives: prolonging network lifetime by distributing energy consumption, terminating minimizing control overhead (to be linear in the number of nodes), the clustering process within a constant number of iterations and producing well-distributed CHs. At first, the condition of each node being selected as the CH candidate is found. To do so, this condition "*Pch*" "equations (6)-(8)", is determined proportional to the remainder energy of node "Ni" as:

$$\beta_1(i,j) = 1 - \alpha_1(1 - D_{Bs,i}/D_{Bs,j}) \tag{6}$$

DBs,i: the distance between the node "i" and the base station Bs. *DBs,j*: the distance between the node neighbor "j" and the base station Bs:

$$\beta_2(i,j) = 1 - \alpha_2(1 - Nw_i/Nw_j) \tag{7}$$

Nwi: Node-weight of node ≪ i ≫.

Nwj: Node-weight of node neighbor ≪ j ≫:

$$\beta_3(i,j) = 1 - \alpha_3(1 - E_i/E_j) \tag{8}$$

Er,i: Residual energy of node ≪ i ≫.

Er,j: Residual energy of node neighbor ≪ j ≫:

$$Pch_{(i,j)} = Max\left[1 - \sum_{i,j=1}^{n} \beta_1(i,j), \beta_2(i,j), \beta_3(i,j)\right]$$

Pch(i,j): condition to be CH for node "CH" $\alpha 1$, $\alpha 2$, $\alpha 3$: constant coefficient ≪ 0 ≫ or ≪ 1 ≫.

Each sensor node (Ni) in the network calculates its condition Pch, and then broadcasts a message to the other nodes, called CH-ADV. This message includes the node ID and the value of condition Pch. In the proposed competition scheme, we define a competition range called Rcomp; *Cluster range (cluster radius)*, "*Rcomp*" this parameter specifies the radius of a cluster, i.e. the farthest a node inside a cluster can be from the CH. The cluster radius is a system parameter and is fixed for the entire network, this range should be reasonable, that it is should not be too long to overload the network and should not be too short to increase the number of CH candidate advertisements. The node "*Ni*" waits for "t_{wait}" seconds and receives the message "*Pch-msg*" from all its neighbors. Note that the waiting time "twait" should not be too short as some nodes may not receive the message "*Pch-msg*", and it should not be too long as it increases the time complexity.

Then it compares its condition value "Pch" with that of its neighbors. If it found its condition "*Pch value*" greater than "*Pch value*" of all its neighbors, then it elects itself as CH candidate. Else, it sends a join message to the neighbor that has the highest condition "*Pch*" to become a member of the cluster. The number of selected CHs varies according to the specified cluster radius. The smaller the radius, the larger the required number of CHs to fully cover the entire network (Figure 4).

Algorithm 1: The pseudo algorithm of DEACP
The pseudo algorithm of DEACP is given as follow:

***Phase 1**: "Initialization phase"*
 # Distance D(Ni,Bs).
The BS broadcast "BS-msg".
***IF** the message "BS-msg" is received fromNi.*
The node Ni Calculate D(Ni,Bs)
ELSE
***wait t**$_{wait}$ seconds to receive "BS-msg" message*
EndIf
 # Node weight.
N_i Broadcast "Disc-neigh-msg" in Rc
***IF** the "Disc-neigh-msg" message I received from N_j THEN*
***Add** identifier "id" and send msg "Disc-Neigh-msg";*
***Create** table of neighbors "neigh-tab";*
Weight-node=length of neigh-tab;
ELSE
***wait** for t_{wait} seconds for the "Disc-neigh msg";*
EndIF
Phase 2: "Decision phase"
"Ni" sends msg {WN, Er, Dbs,D_{i-j}};
***Ni** calculates the condition $P_{Cch(i);}$*
Evaluate the condition cluster head Cch (i);
***For** each node neighbor*
If** Pcch(i) > Pcch(j) **THEN
Ni ← CCH(i); // Ni is the cluster head
***broadcast** the CCH-ADV messages to the higher power levels*
Else
Nj ← CCH(j); // Nj is the cluster head

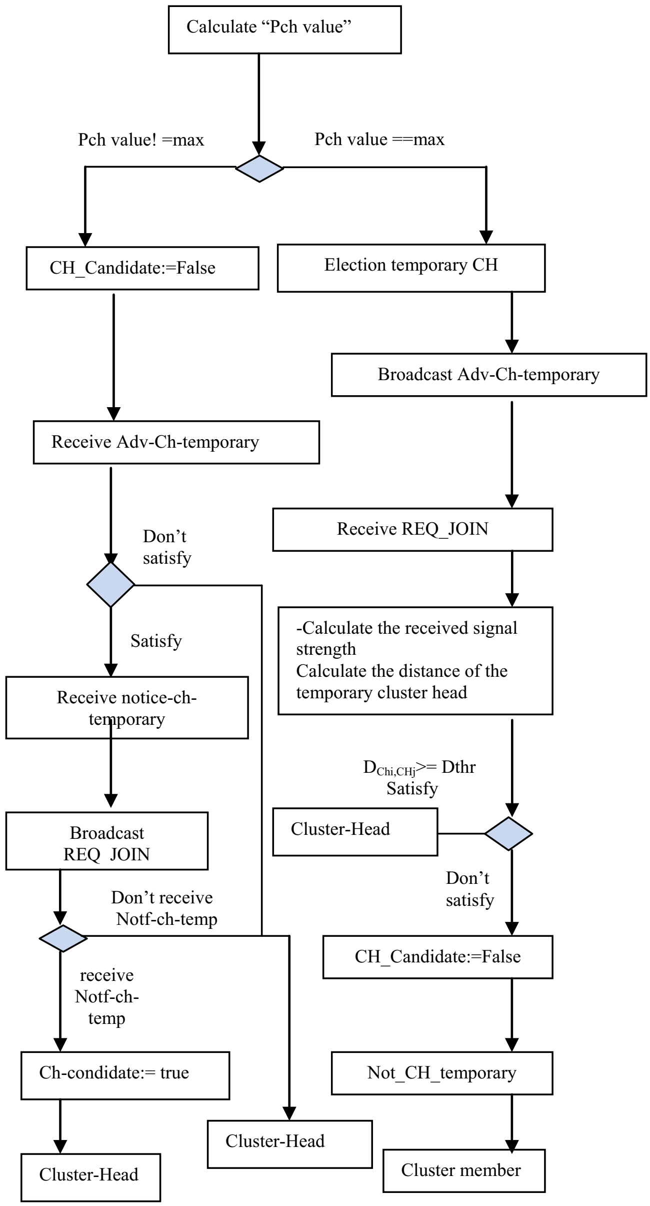


Figure 4.
CH election

wait *t_{wait} seconds for the CH-ADV message*
send *a Join-Req message to the CH candidate*
EndIF
Condition distance
IF *the current node is a cluster-head candidate* ***THEN***

Wait *for t_{wait} seconds to receive the CCH-ADV message*
IF *the CCH-ADV message received* ***THEN***
Evaluate *the received messages and calculate the Distance*
If

$$\sqrt{(Xcch\,(i)-Xcch\,(j))^2+(Ycch\,(i)-Ycch\,(j))^2} >\; = Dth$$

THEN
Broadcast *the CH-ADV message to all nodes in Rc*
ELSE
Send *the CH send a Join-Req message to the cluster head candidate*
ENDIF
Cluster head ***final*** *"Ch" is defined*
Phase 3: "Steady phase"
Cluster head node fixes and sends a TDMA to all its cluster members.
Each *cluster member sends its data packets in allocated TDMA s*
CH collects the data from all the nodes in its cluster multi-hope communication inter-cluster r.
CH transmits the data with multi-hope communication inter-cluster to the Sink node.
For *each* ***(level i)***
for *each CH*
CH receives the data from the cluster member
The CH ***Aggregate*** *the data.*
IF *(i ==1) //* ***level I***
CH transmits data to the BS.
Else
CH broadcasts data in the next level.
End if
End for
End for
End

3.6.2 Temporary and final cluster head distributed energy efficient adaptive clustering protocol. Each elected CH temporary should broadcast *CCH-ADV* message contain its node ID and the *PCCH(i)* probability. When a CH temporary receives this message, it calculates the distance between the sender and itself. If this distance is greater than or equal to a threshold distance, $D_{threshold}$, it ignores the message, but if the distance (d_{chx},d_{chy}) is less than $D_{threshold}$ and if it found PCCH(i) value of sender greater than its own PCCH(j), then the receiver CH temporary becomes an ordinary node and sends a "Join-msg" message to the sender CH. If two temporary CH are in the same level, the distance between them is less than D-threshold, and they have the same PCCH, then the temporary CH with the higher PCCH value is elected as a final CH (Figure 5). The pseudo code of the CH election phase of the proposed DEACP is presented in Algorithm 1.

3.7 Cluster formation step

After the election phase, is the cluster formation phase. In this phase, the CHs broadcast the Adv_Msg to neighbor nodes. Other non-CH nodes receive the Adv_Msg and estimate "*Join-cond* (*i,CHj*)", and then join clusters by sending a "*JOIN_ Msg*" to their respective CH:

$$Join_{cond(CH,j)} = Max\left(1 - \frac{Pchj}{D_{i,chj} + D_{chj,bs}}\right)$$

Where: D (chj,bs) the distance from chj to the bs.

D(i, chj) the distance from node i to chj.

Join cond (CH,J) $\rightarrow$ max, $pch_j \rightarrow$ max, and D(chj, bs) +.

d(i, CHj) $\rightarrow$ Min allows the node to choose the CH that has the greater *Pch* and that is closer to the BS.

Due to inherent resource constraints in communication and energy consumption, node clustering techniques have been widely used by WSN applications to achieve energy efficiency and scalability. Clustering provides an efficient and scalable network structure for collaborating sensor nodes by grouping them into a hierarchy. Such hierarchical structures are constructed by various clustering approaches at different network layers such as the Data Link layer and the network layer. Clustering offers many advantages in improving the performance of WSN. Clustering keeps network traffic local and thus reduces energy dissipation of long-distance transmissions as well as the amount of routing information stored at each sensor node. DEACP clustering can further conserve energy by using CHs to perform local data aggregation and activity scheduling among local members. Inactive members can stay in the sleeping mode or low-power operations. Furthermore, clustering also helps in reducing the cost of topology maintenance as a reaction to dynamic topology changes. To be responsive to dynamic phenomenon changes, a collaborative structure needs to be configurable and adaptable to phenomenon dynamics. With a clustered network, topology reconfiguration is only performed on the CH level and does not affect local cluster nodes. Thus, the overhead of dynamic topology adaptation can be greatly minimized (Marròn *et al.*, 2010):

- *DEACP Optimized resource utilization*: Clustering techniques have been successfully used for time and energy savings. These optimizations essentially reflect the usage of clustering algorithms for task and resource allocation.
- *DEACP improved scalability*: As clustering helps to organize large-scale unstructured *ad hoc* networks in well-defined groups according to application specific requirements, tasks and necessary resources can be distributed in this network in an optimized way. DEACP clustering can be considered the most

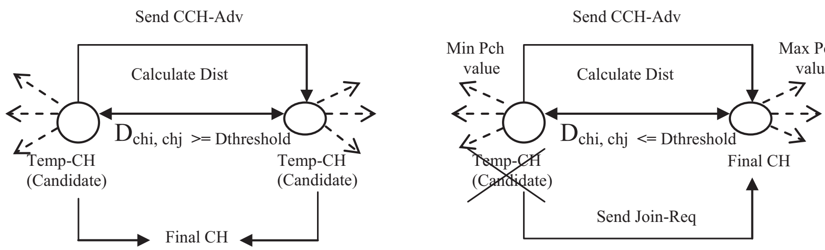


Figure 5.
Temporary and final CH

important unsupervised learning problem; so, as every other problem of this kind, it deals with finding a structure in a collection of unlabeled data.

3.8 Steady phase

After the cluster formation phase, the CHs establish a time division multiple access (TDMA) protocol, and send a time schedule to each of their members (Figure 6). In this DEACP protocol, a transmission time slot is assigned to each node, during which the nodes can send their messages. In a wireless transmission, as the signal from a sender propagates over the channel, it attenuates with distance; it also suffers from physical propagation due to interactions with the physical environment (e.g. passing through obstacles). A receiver receives the signal after attenuation and other propagation effects, and it attempts to decode the signal. If the received signal strength is sufficiently higher than the sum of the noise and signal from interfering signals, the signal can be decoded successfully (with low error rate); otherwise, the transmission cannot be received. Thus, interference from concurrently transmitting nodes plays an important effect in determining whether correct reception or a collision occurs.

3.9 Distributed energy efficient adaptive clustering protocol network transmission time

One the clusters are formed and TDMA schedule is fixed in all clusters of the network. In network transmission time (NTT), all nodes send their data to their PCHs, in assigned time slots. CHs receive the data from its cluster and aggregate the data. Data aggregation is key technique to compare data amount. CHs only send meaningful information to BS to prolong the battery lifetime. One of the primary challenges in multi-hop wireless networks is the routing problem; how to construct efficient routes for a network that is self-configuring.

From a routing perspective, clustering allows to split data transmission into intra-cluster (within a cluster) and inter-cluster (between CHs and every CH and the sink) communication. This separation leads to significant energy saving, as the radio unit is the major energy consumer in a sensor node. In fact, member nodes are only allowed to communicate with their respective CH, which is responsible for relaying the data to the sink with possible aggregation and fusion operations. Moreover, this separation allows

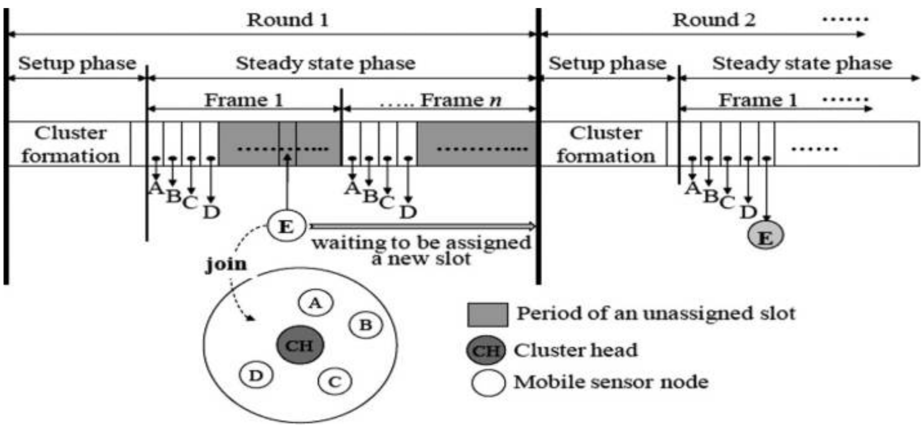


Figure 6. Time line showing DEACP-based clustering protocol

to reduce routing tables at both member nodes and CHs in addition to possible spatial reuse of communication bandwidth. The sink is usually located far away from the sensing area and is often not directly reachable to all nodes due to signal propagation problems. A more realistic approach is multi-hop inter-cluster routing that had shown to be more energy efficient. In DEACP protocol, sensed data are relayed from one CH to another until reaching the sink. Inter-cluster communication in several proposals is achieved through organizing the CHs in a hierarchy figure allows better energy distribution and overall energy consumption. However, maintaining the hierarchy could be costly in large and dynamic networks where nodes die as soon as their y supply is completely discharged.

Algorithm 2: DEACP Inter Cluster Multihop
The pseudo algorithm of DEACP Inter cluster routing is given as follow:

ChID: *CH identifier* ***bsID*** *:BS identifier*
nexthopID_ *: neighbor ID*
clusterheadChoices_*: list containing all the current CHs*
Begin
Specify the ***max –dist*** *CH compared to SB*
in clusterheadChoices_ list.
Calculate *the rays of levels from the maxCH.*
For *(each ChId belongs to* ***level N_)***
IF *(ChId has a nearest neighbor in Level N)* ***Then***
Search *(nexthopID_) in level N.*
Else
Search *(nexthopID_) in* ***Level N-1.***
EndIF
EndFor
IF *(ChId belongs to level 1)* ***Then***
IF *(ChId has a nearest neighbor in Level 1)* ***Then***
a. ***Search*** *(nexthopID_) in Level 1.*
Else
a. ***The nexthopID****: BsID*
b. SendDataToBS
EndIF
EndIF
End

3.10 Performance evaluation

In this section, we evaluate the performance of the proposed DEACP via several simulation experiments. At first, the simulation setup is explained, and then the results are presented, a comparison between the simulation results in DEACP, DEEAC and FEMCHRP algorithms is performed via NS2 simulator. We used the ns2 simulator for the following motivations: ns-2 stands for Network Simulator version 2. Is a discrete event simulator for networking research, work at packet level, provide substantial support to simulate bunch of protocols like TCP, UDP, FTP, HTTP and DSR, simulate wired and wireless network, is primarily Unix based, Use TCL as its scripting language, and the ns-2 is a standard experiment environment in research community. We use two scenarios for simulations. In the first scenario, 100 nodes are uniformly and randomly dispersed in a field of size 200 × 200 m. To study the effect of scale on the performance of DEACP, in the second scenario, 200, 400, 600, 800 nodes are uniformly and randomly dispersed in a field of size 200m_200m. We assume that the BS is located at the center of the field. The other simulation parameters are summarized in Table I (Figure 7):

- Configuration of DEACP protocol.

3.10.1 Distributed energy efficient adaptive clustering protocol energy consumption of sensor nodes. Figures 8 and 9 show the results for the energy consumed by sensor nodes in DEACP, DEEAC and FEMCHRP protocols. The energy consumed by sensor nodes for each round in DEACP is much lower than that in DEEAC and FEMCHRP. According to the data presented in this figure, DEACP has less energy consumption than the other two protocols because this protocol periodically selects CHs according to a hybrid of their residual energy distance between node and BS, weight-node: number of neighbor nodes, such as node proximity to its neighbors or node degree. The main reason for this result is the suitable number and distribution of the clusters in the network. As expected, FEMCHRP has variant energy consumption, relevant to the pendulous number of its clusters in consecutive rounds. Although, DEEAC has distributed clusters across the network properly, as the number of clusters in DEEAC is large, energy consumption in the whole network increases.

Parameter	value
Area	200 × 20m
Data paquet size	4000 bits
Control packet size	512 bits
Number of sensor nodes	100 or more
Initial energy	2J
Base station location	(100,100)
Distance d_0	87 m
E_{elec}	50 nj/bit

Table I. Parameters of simulation

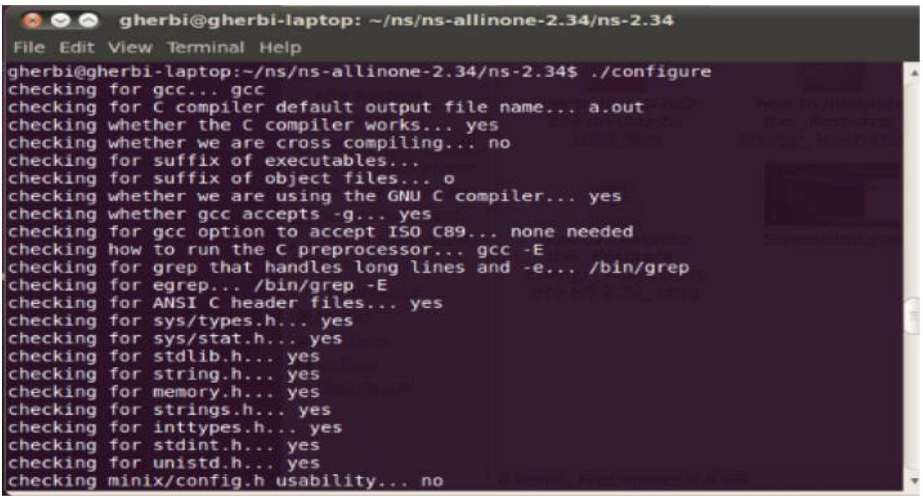


Figure 7. DEACP configuration in NS2.34 simulator –

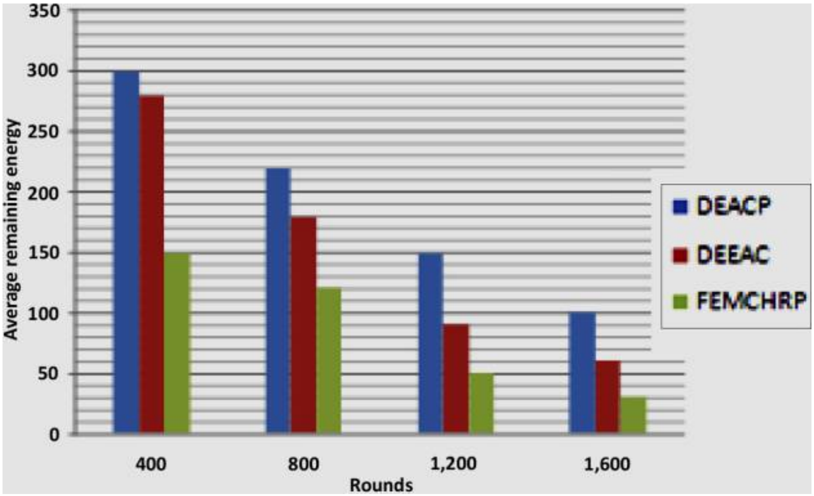


Figure 8.
Average remaining energy

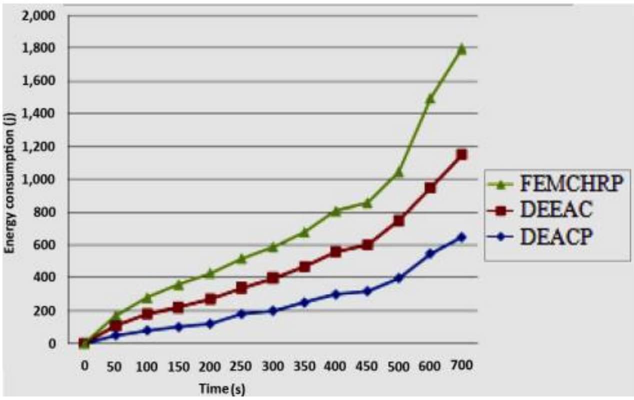


Figure 9.
Comparison of energy consumption

Therefore, DEACP has the lowest energy consumption among the two protocols and has more energy consumption in contrast with the other protocols. Other main reason, DEACP uses a multi-hop communication inter-cluster and intra cluster. Each parent node polls its direct children and forwards the data to its parent node until the data reaches the CH and a multi-hop communication between CH and BS. Figure 8 plots the total remaining energy per round and total remaining energy per round is more in DEACP as compared to DEEAC.

3.10.2 Distributed energy efficient adaptive clustering life time for wireless sensor network. The network lifetime for three protocols is depicted in Figures 10 and 11. The result between the number of nodes alive, and the number of rounds is shown by "Figures 10 and 11". The result obtained by measuring the time until the first node dies to the time until the last node dies appear the DEACP has a better lifetime than the other protocols DEEAC and FEMCHRP because the DEACP method elects the nodes with the highest condition CH "Cch". Also, in this approach, the load balancing in the network is

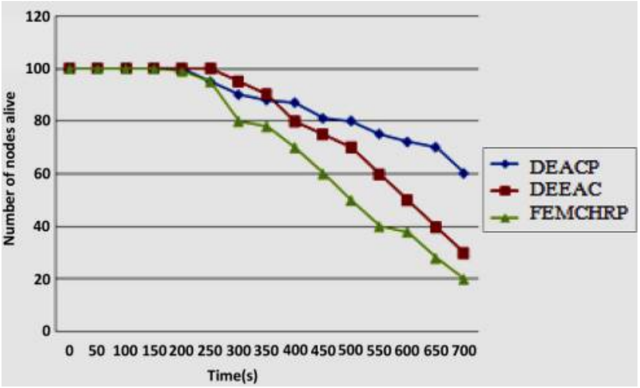


Figure 10. Comparison of network life time with 100 nodes

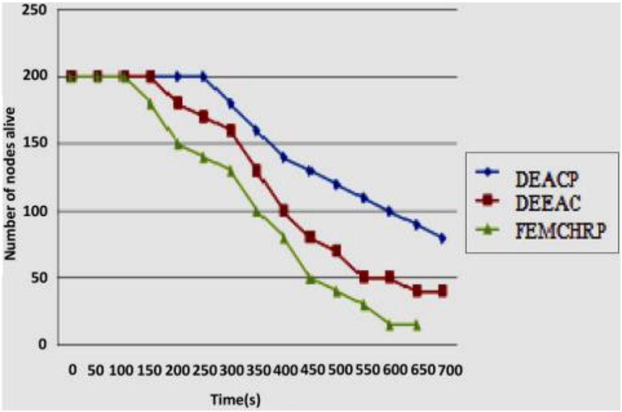
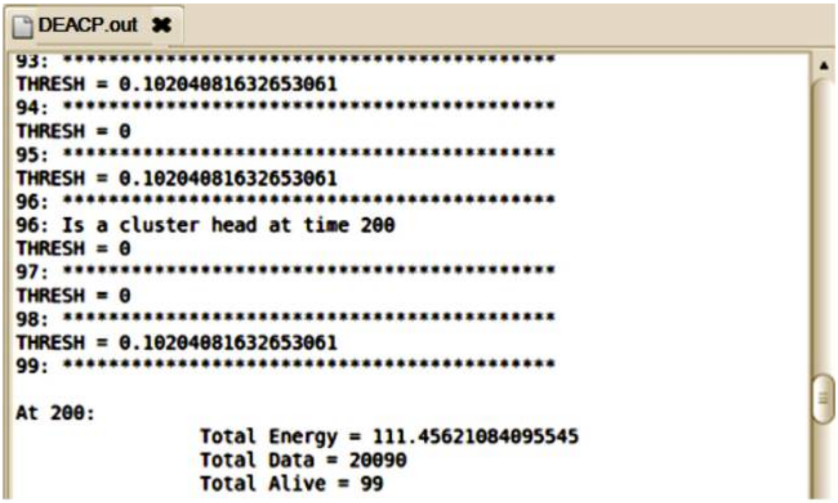


Figure 11. Comparison of network life time with 200 nodes

performed properly, which provides a longer time between the beginning of the operations until the time the first node die. Figures 10 and 11 shows the total numbers of nodes (*100-200 devices*) that remain alive over the simulation time. The result shows that DEACP performs better than DEEAC and PEAGSIS. In DEEAC [Figure 11 200 nodes], the first node death occurs after 210 rounds. And near to 800 rounds, almost all the nodes are dead in FEMCHRP. While in DEACP, the first node dies after 310 rounds. So DEACP performs best for 100 and 200 sensor devices. In Figure 12, we measured in DEACP.out file the total energy, total data and total alive in round 200, this file DEACP.out was automatically generated when we execute our algorithm DEACP in ns2.34 – ubuntu 12.04.

In Figure 13, we measured the nodes' death percentage throughout the duration of simulation, which gave us the result as shown in the Figures 10 and 11. Based on the simulation results, we showed that DEACP increases the profit of energy and prolongs the network's lifetime because we used an adaptive clustering protocol, the CHs and next heads are elected based on residual energy of each node and the average energy of each cluster. Indeed, DEEAC based on dynamic chain clustering approach prolongs the network lifetime from 55 to 75 per cent compared to FEMCHRP protocol, and from 40 to



Note: 100 nodes

Figure 12.
DEACP.out file

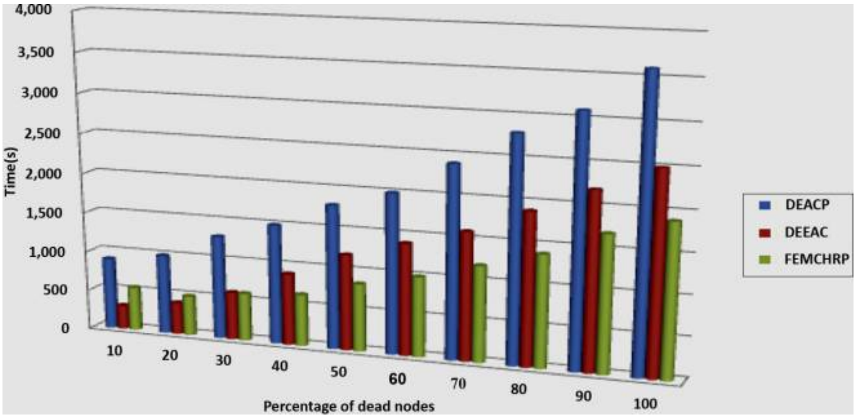


Figure 13.
Percentage of dead nodes in the network

50 per cent. We also note that the network's lifetime obtained is very close to that provided with DEEAC algorithm (from 10 to 15 per cent). In Figure 14, it is seen that network lifetime of DEACP is more than DEEAC as last node dies in DEEAC for 500 node is after 11,350 rounds and in DEEAC it dies after 6,140 rounds. Thus, the stability period of DEACP is more than DEEAC. This improvement is because the DEACP method elects the nodes with the highest residual energy as the CHs and *Pcch* election. Also, in this approach, the load balancing in the network is performed properly, which provides a longer time between the beginning of the operations until the time the first node dies. Figure 15 shows the network lifetime of DEACP, DEEAC and FEMCHRP with different sink node position, the increase of the distance between the sink node and the network, the energy consumption of the nodes that can directly communicate with the sink node will increase remarkably. In this case, the number of the nodes that can

directly communicate with the sink node is, the more rapidly the performance of protocols degenerates. Therefore, DEAC use multi-hop-communication to communicate with the sink node, perform remarkably better than DEEAC. In DEACP, all the nodes should take turns to be a CH to communicate with the sink node, and as the distance between each node and the sink node is different, the energy consumption for each node is different. As a result, some nodes with higher energy consumption will die soon. As Figure 17 shows, the network lifetime of DEACP and DEEAC is over 200 rounds longer than that of FEMCHRP. Figure 16 shows the average number of cluster over number of nodes that means the total number of clusters that are formed in network space. The DEACP protocol provides about 32.81 per cent less clusters than DEEAC end 45.73 per cent than FEMCHRP. In DEACP protocol, we also used the load balancing, so for each CH can handle the same number of nodes at the same time. Figure 17 illustrates the variation of the average number of clusters with respect to the transmission range. We found that there is opposite relationship between clusters and transmission range. This is on the grounds that a CH with a considerable transmission range will cover a large area. (ex: Deacp cluster formation “for n = 800, Tr = 150, N.cluster = 4”, “for n = 600, Tr = 110, N.cluster = 8”, “for n = 200,Tr = 50, N.cluster = 12”). So, we conclude that when the transmission range increases; the average number of clusters is decreased.

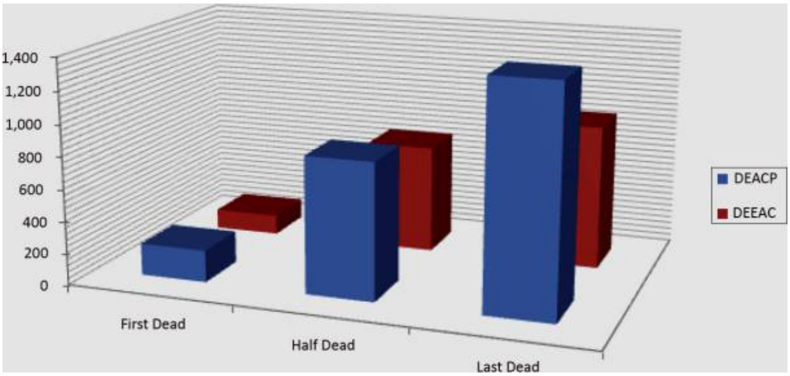


Figure 14.
Rounds for first, half and last node dead in DEACP and DEEAC

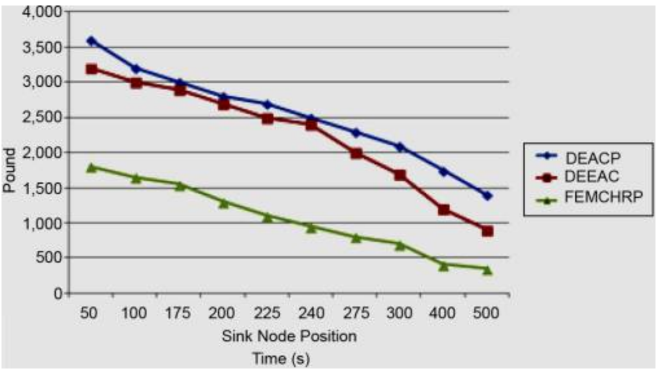


Figure 15.
Sink node position vs network life time

The possible reason for this kind of behavior is that a CH with a large transmission range will cover a larger area.

Figure 18 shows the DEACP CH distribution map, in area (200 × 200 m), our DEACP clustering algorithm completely distributed because a centralized control manner is not practical in a large-scale sensor network (with $n = 100$, $n = 200$, $n = 300$, $n = 400$) The CHs in DEACP are well distributed throughout the monitoring area to make energy consumption be well-balanced among all sensor nodes. Figure 19 illustrates the cluster formation in round = 140 for DEACP, we improving the load balancing and performing the stability in the network. The load balancing is accomplished by determining a pre-defined threshold on the number of nodes that a CH can cover ideally. This ensures that none of the CHs are overloaded at any instance of time. In our algorithm Load Balancing: that means for each CH can handle the same number of nodes at the same time.

Figure 20: shows the total number of data received at the BS as a function of time. The proposed protocol DEACP with the variable desirable number of CHs sends more data

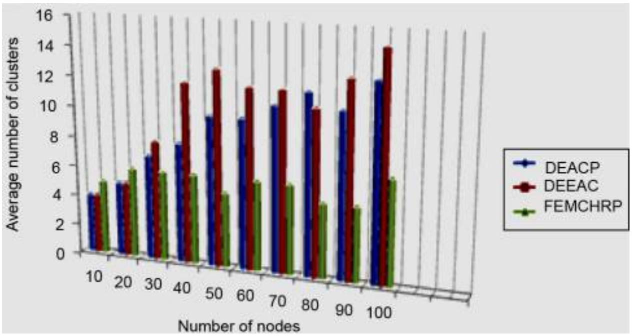


Figure 16.
Average number of clusters over number of nodes

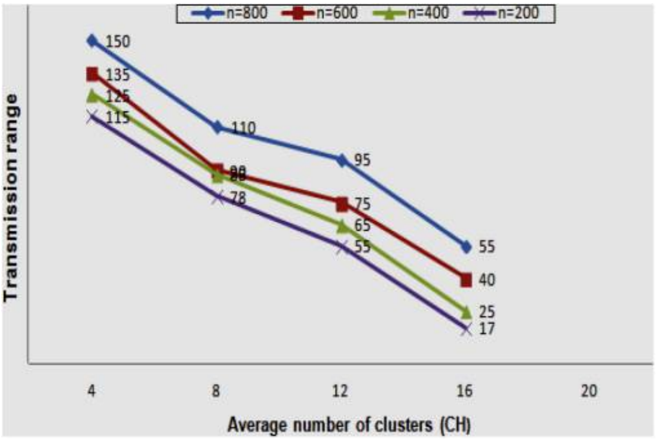


Figure 17.
Average number of clusters over transmission range

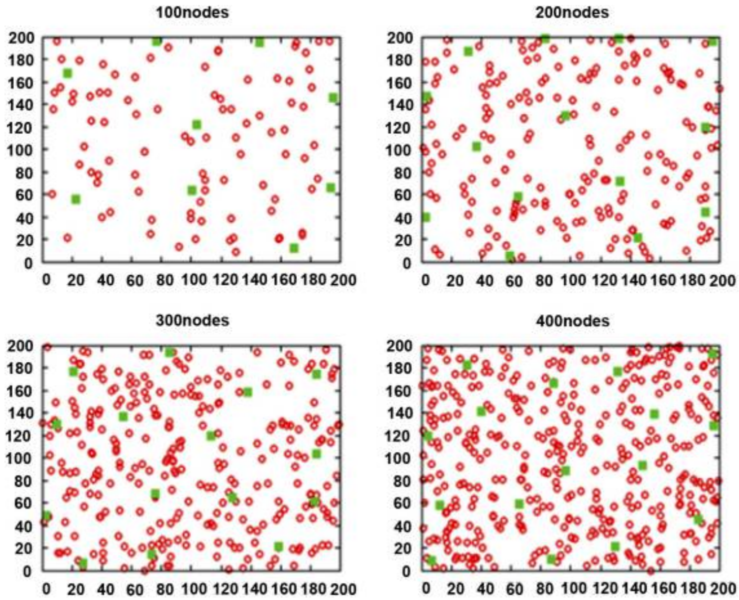


Figure 18.
DEACP CH distribution map

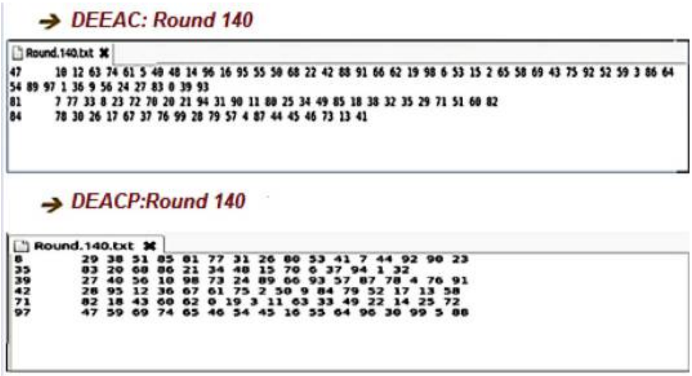


Figure 19.
DEACP load balancing

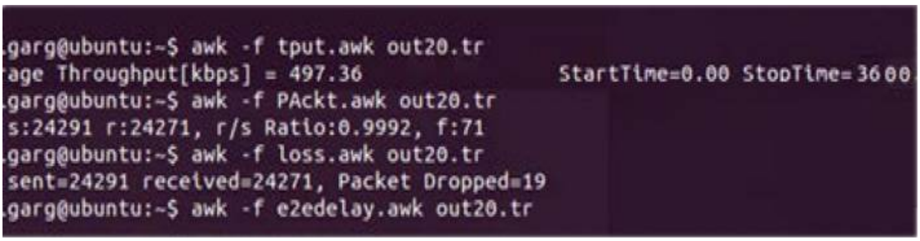


Figure 20.
Execution terminal for paquets sent, received and dropped

to the BS than DEEAC, as the lifetime of the sensor networks of the proposed protocol is longer than DEEAC. From the figures, it is evident that the performance of the proposed protocol is better than DEEAC when the number of CHs is variable. Thus, it can be seen that the number of CHs plays an important role in the overall performance of the energy-constrained sensor networks. We used these equations for calculating probability of packet sending (Figure 21). Figure 22 illustrates the latency per paquet over the number of nodes, the simulation results show that DEACP protocol offers better results in terms of reduction of latency than other protocols like DEACP and FEMCHRP. Figure 23: Number of packets = file size/packet size. Time = number of packets; this figure illustrates DEACP protocol with number of parquets sending (4 paq/s, 16 pqt/s, 32 pqt/s).

$$\text{Pqt} - \text{send} = \frac{\text{Number of successful sending paquet}}{\text{Total Number of sending paquets}}$$

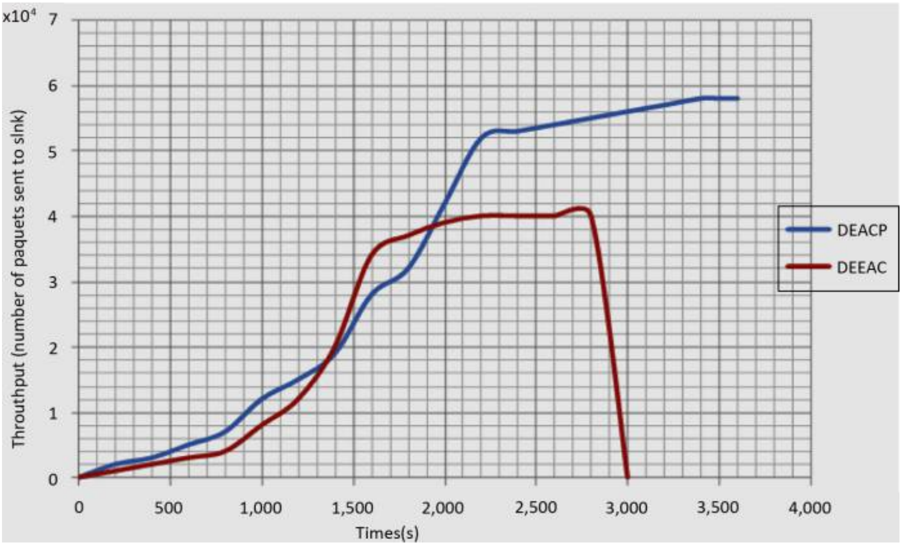


Figure 21.
Number of paquets sent to sin

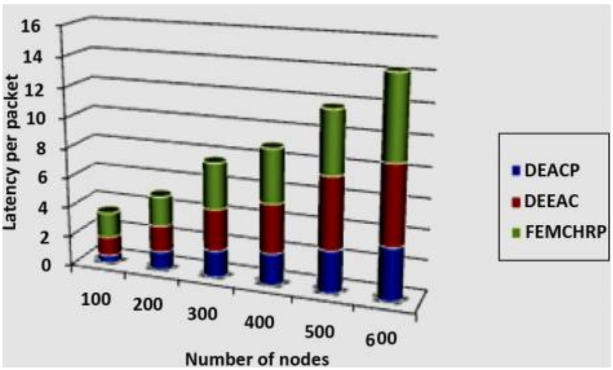


Figure 22.
The latency per packet over number of nodes

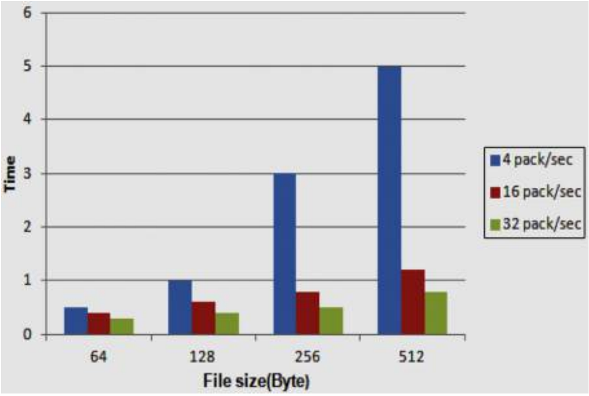


Figure 23. Transmitting time in different number of packets

$$Pqt - send_{DEACP} = \frac{Nb - succ - paquet}{Tot - Nb - send - paquets}$$

5. Conclusion and future work

In this paper, we proposed a DEACP with data gathering for WSNs. DEACP is well distributed, which is a major advantage in a power constrained sensor network. In this protocol, the distance among the CHs has been used to reach a well-distributed clustered WSN with suitable size clusters, and a load balancing is an effective enhancement to the propose d routing protocol. Selecting coordinators for clusters is a research issue in the area of wireless *ad hoc* networks. CH can be selected by computing quality of nodes, which may depend on connectivity, mobility, battery power, etc. Significant performance improvement can be achieved by combining the effect of several performance factors. The basic idea is to share traffic load among cluster members to reduce the dropping probability due to queue overflow at some nodes. Sharing traffic inside a cluster is reasonable because nodes in the same cluster have similar mobility pattern, and thus similar ability to deliver data messages. Our approach can be applied to the design of several types of sensor network protocols that require scalability, prolonged network lifetime, fault tolerance and load balancing. Our simulations demonstrated that DEACP generates well-balanced clusters. In the future, in addition to the energy efficiency, we will try to design the DEACP approach in a way that it meets the other WSN requirements, like the full coverage of the area and involves real-time implementation using wireless sensor motes and secure routing protocol in terms of memory.

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Further reading

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