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Hybrid energy aware clustered protocol for IoT heterogeneous network

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Abstract

IoT diverse applications face many challenges. The main challenge is to have efficient energy aware communication protocols that utilize the diversity and heterogeneity of the connected things through Internet. Saving energy is a vital requirement in the limited battery energy nodes and also for the outsourced energy nodes for green computing. IoT milieu has many diverse devices that are heterogeneous in their energies, their Internet availability, etc. These devices are usually distributed into regions with different heterogeneity levels; ranging from homogeneous to near homogenous, till reaching to the high heterogeneous regions. Many existed protocols efficiently treated either the homogenous devices or heterogeneous devices. This paper defeats the gap between the physical wireless sensor network environment and the real heterogeneous Cyber IoT milieu. This paper targets not only providing an efficient hybrid energy aware clustering communication protocol for green IoT network computing; Hy-IoT, but also provides a real IoT network architecture for examining the proposed protocol compared to commonly existed protocols. Efficient cluster-head selection boosts the utilization of the nodes energy contents and consequently increases the network life time as well as the packets transmission rate to the base station. Hy-IoT uses different weighted election probabilities for selecting a Cluster-head based on heterogeneity level of the region. Simulation shows that Hy-IoT prolongs the network life time and increases the throughput compared to the SEP, LEACH and Z-SEP. Hy-IoT provides prolonging for the network life time ranging from 47.8% to 92.5% based on the heterogeneity level and also the average throughput was boosted ranging from 11.5% to 70.1% based on the heterogeneity level.

Keywords: Internet of things; Clustering protocols; Sensors; Heterogeneity; Energy limited devices

1. Introduction

Internet of Things (IoT) is the communication networking to sense, control and integrate non-smart and smart objects (things). IoT with many new enabling technologies such as the Cloud computing, SDN, NFV, etc. provides many new applications. IoT environment has many diverse devices (things) such as sensors, actuators, mobile phones, Radio Frequency Identification (RFID) readers and tags, etc. These things/devices are heterogeneous in their characteristics such as available energy budget, connectivity type, Internet access, etc. Some of the devices have limited energy since they are powered by batteries but others don't have this problem. The devices sense/gather data and send them to the controller which is called gateway, base station, or sink. Real world IoT physical process has all kind of communication; machine to machine, machine to human as well as human to human. IoT network environment usually has layers in their computing which physically interpreted in regions; as for collecting data (e.g. sensors, RFID tags), aggregated data and forwarding (e.g., RFID readers, gateways), Controllers (e.g. servers, SDN controllers), Computing platform (e.g. Fog, Cloud) and applications interfaces [1−3]. Many challenges face the IoT applications on the coming era [1,4,5]. One of the main challenges is the energy aware efficient communication among all the devices type not only for unchangeable/uncharged limited battery sensors but also for the energy outsourced devices such as smartphones for sake of green computing. Therefore, developing the protocols that prolong the network lifetime is always hot topic in IoT research [1,4,6−8].

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Although, many energy efficient WSN protocols were developed, they shallowly consider the heterogeneity among limited battery sensors [9−13]. IoT environment requires consideration of the diversity in energy content and energy consumption of the heterogeneous nodes. In wireless sensor networking, the LEACH (Low Energy Adaptive Clustering Hierarchy) protocol [14,15] was the most commonly used protocol and many modified versions were developed [14,16−18]. LEACH was developed to deal with *homogeneous* sensor networks, since it considers all nodes have same amount of energy. SEP was developed as a heterogeneous-aware protocol [19,20]. SEP elects cluster-heads with the election probabilities that are weighted by the initial energy of a node relative to other network nodes. Zonal-Stable Election Protocol (Z-SEP) provides a zonal heterogeneous protocol which is more near for the IoT multiregion real environment without utilizing this heterogeneity to boost the IoT network performance. Z-SEP divides network field; by locating base-station near to normal-nodes that transmit their data directly to base station. On the other hand, advanced-nodes which were considered away from the base station, use clustering technique in transmission to base-station in order to save energy [21]. LEACH proves its efficiency in the homogenous environment; on the other hand the SEP performs well in the heterogenous environment. Although the heterogeneity is always presented, IoT regions may characterized as more likely homogenous or more likely heterogeneous.

This paper proposes a new hybrid heterogeneous energy-aware IoT protocol for complex IoT network with multiple level of heterogeneity located in different regions. The paper introduces an efficient hybrid protocol; Hy-IoT that is suitable for the mixed heterogeneous dominating zones and the homogenous dominating zones in IoT environment. A new real cyber IoT architecture deployment is also proposed in this paper instead of simple random distribution of nodes to overcome the gap between the physical wireless sensor network environment and the real Cyber IoT. The proposed protocol comparison with the commonly used protocols has extensively examined in the new deployed architecture. The IoT proposed architecture provides two main features; ability to have zones based on the dominant level of heterogeneity and also having interaction among multiple levels of heterogeneity. Extensive testing proves the promising performance of the proposed protocol Hy-IoT compared the commonly used protocols. The impact of different heterogeneity levels is extensively examined especially in cases that have more devices has extra energy; which is the case in some of IoT applications.

The paper is organized as follows; Section 2 presents the IoT heterogeneous model and requirements. Section 3 provides the background on clustering based protocols and related work. Section 4 defines the proposed protocol. Section 5 shows the simulation and its results. Section 6 discusses the conclusion and the future work.

2. IoT heterogeneous network model

The Internet of Things (IoT) is a communication − computing system of various devices, animals, or human with unique addresses in order to transfer data/activate action over a network. However, developing IoT services is carried out over the existing IoT systems, It faces inefficiency due to the very heterogeneous devices and systems [1,3]. Things or devices have many important criteria that need to be considered in designing any IoT application framework. Criteria are such as; available energy budget, communication link type, Internet access connectivity, application type, etc. The integration of a wide variety of constrained devices in the IoT requires new protocols. These protocols need to consider devices communication types and enabling technologies such as heterogeneous big data, SDN, Cloud Computing, Fog Computing, etc. [1−3,5].

Available energy budget; Some devices are battery-limited powered devices and others are mains-powered devices. Battery-powered devices: are the things that have energy limited by the used battery size. They need to use all the ways to conserve energy by using low-energy communication protocols, sleeping for unused periods. Sensors are the main example for this kind of limited non rechargeable batteries. Other devices might be mains-powered or easy to recharge, such as intelligent devices (e.g., smartphones, control devices), RFID, etc. RFID tags may be active tags (battery powered), semi-active and passive tags (without a built-in battery). Tracking of RFID systems can be active or passive. There are various RFID tracking applications such as patient tracking, child/elder tracking, supply chain and security. *Internet Access Connectivity;* Some devices might be occasionally connected Internet such as sensors and some mobile nodes. Other devices might have an always-on connection to Internet. Internet connectivity may vary in case of mobility [1,22].

Every IoT application system design needs a different approach for data aggregation from different types of things. Things (sensors/detectors/legacy devices) are such as temperature, flow sensor, pressure, humidity, acoustic noise level, water level detectors, lighting conditions, accelerometers, biological and chemical agents, vehicle movement, the presence/absence of the object, camera, etc. Usually, these things have the role of sensing and they sent their data to other things with more capabilities (mainly power) regularly or event based. Sometimes these later nodes could be just more powerful sensors, gateways, readers in case of RFID, etc. Sensors sense, measure, collect data from the surrounding environment. The availability of the sensors and the actuators as well as low power wireless sensor networks technologies open up many more wide coverage IoT applications. Usually most of IoT systems need devices as gateways in close proximity to sensors and actuators to provide some kind of aggregation, processing. For instance, dozens of temperature and humidity sensors are distributed on agriculture field gathered by many gateways located on the edge of the field which aggregate, process and forward the data. On the other hand, Transportation road Technologies that include vehicles sensors and roads sensors provide safety driving by using safety messages. It is consists of RFID, road reflectors, to identify the vehicles speed [1].

IoT Network typically provides wired/wireless communications of a large number of nodes with diversity in cost, power, and functions and supporting wide computation capabilities. In the IoT network architecture, nodes are commonly considered as sensors with very limited in their resources (memory, computational power, communication range, energy battery powered) [5]. Also, Sensor nodes are usually considered distributed in a random manner with varied density and autonomous configuration with communication network protocol. Although, the IoT network architecture is designed based on the required application, sensor with limited resource is the main component in addition to some rechargeable nodes as well as the gateways and base stations that are required to stream the collected data into the Internet.

Routing protocols that are utilized in IoT topology environment are developed and extensively examined to measure their performances with a common assumption of randomly distributed nodes. This assumption doesn't provide a chance to efficiently utilize the energy of the nodes especially in case of IoT applications that has some kind of multiple level of energy heterogeneity nodes such as passive RFID, sensors, mobile phones etc. Therefore, this paper proposes a new practical IoT architecture that provides dividing the network into regions based on their dominant energy level in each region. For example, a heterogeneous region may have randomly distributed of regular nodes which mostly include normal limited energy nodes and few advanced-nodes. Other region may have nodes with higher contents of energy; rechargeable, main-powered, etc. Fig. 1 shows the IoT network architecture.

3. Related work: heterogeneous and homogenous communication protocols

Design of Routing protocols for low budget energy devices can affect the network lifetime. Clustering strategy proved good performance because of its reduction in communication and consequently the consumed energy. Clustering algorithm used in these protocols constitutes clusters with a head node and nodes as members. Clustering improves the network lifetime and stability period especially in large network. Cluster-head (CH) aggregates and access as a relay by having the data from the members and send it to the base-station (BS). Clustering efficiently helps in solving congestion and collusion that have high drainage effect of the energy. CH may be regular sensor or another device with more high resources such as mobile phone, camera,. etc [8,14,23,24]. This section briefly surveys the main clustering based protocols in order to cover their concepts, cons and pros for IoT applications which have mix of heterogeneous and homogenous nodes regions. LEACH is a hierarchical based energy clustering algorithm that employs randomized rotation of the local cluster head. LEACH is designed for the homogeneous environment [14]. For heterogeneous environment, SEP introduces two level heterogeneous protocols with two energy based types of nodes; normal-nodes and advanced-nodes [20]. Weighted probability to become Cluster-head is treated differently based on the energy of the node in addition to the random selection that offers more chances for the advanced-nodes to be Cluster-head than other normal-nodes. The randomness of the nodes and their distances away from the base-station affects the stability periods and the overall throughput of the network. The far the normal-node, the more energy is consumed to transmit to base station. Z-SEP provides a zonal heterogeneous protocol by dividing network field; by locating base-station near to normal-nodes that transmit their data directly to base station. On the other hand, advanced-nodes which were considered away from the base station, use clustering technique in transmission to base-station in order to save energy [21].

3.1. LEACH (low energy clustering hierarchy) protocol

LEACH establishes/re-establishes the clusters and elects the Cluster-head in each round. This provides load balancing among the network nodes. Moreover, it saves communication cost to sink node since each node transmits to the closest Cluster-head. LEACH has no optimal percentage of nodes to become CHs in each round assuming uniform distribution of nodes in space [14,15]. It distributes the energy load by dynamically elects cluster-heads and its associated cluster according to a priori optimal probability. Cluster-heads responsible for aggregating data from cluster members and forward to Base station/sink. Hierarchal clustering based protocol uses randomized rotation of CHs in order to evenly distribution the energy load among sensors in network. Each round has 2 phases; set up and steady phases. Setup for formation cluster and randomly elect the Cluster-head by a node based on generated random number chosen between 0 and 1. If it is less than a thresholds T, node becomes CH, else it become regular node. P_{opt}, is the desired percentage of CHs. r is the current round number. G is the set of not being CH in previous rounds, otherwise, T = 0; $1/P_{opt}$ rounds in the same epoch.

$$T(n) = \frac{P_{opt}}{1 - P_{opt}\left(r.mod\left(\frac{1}{P_{opt}}\right)\right)} \qquad if\ n \in G \tag{1}$$

Each elected CH advertises to rest of nodes. Transmission is done using CSMA-MAC. Assume all CHs use the same transmission energy in transmission. Nodes join the selected.CH. CH informs its associated cluster member's nodes of the time schedule of their transmission. Each node (non CH/regular) can utilize the sleeping period to save energy. Then CH aggregates and compresses the data coming from its members and sends it to the base-station [15]. This protocol assumes equal energy in all nodes which is a theoretical assumption, especially in cases such as IoT heterogeneous devices. This introduces imbalance in battery based devices. It provides instability in the network; shortened the stability period as well as instability period.

3.2. SEP (Stable Election Protocol) protocol

SEP (Stable Election Protocol) is a heterogeneous protocol based on weighed election probability of each node to be CH according their energies. It randomly elects CH based on the fraction of energy in each node. It improves the stable region using the heterogeneity parameters, namely the fraction of

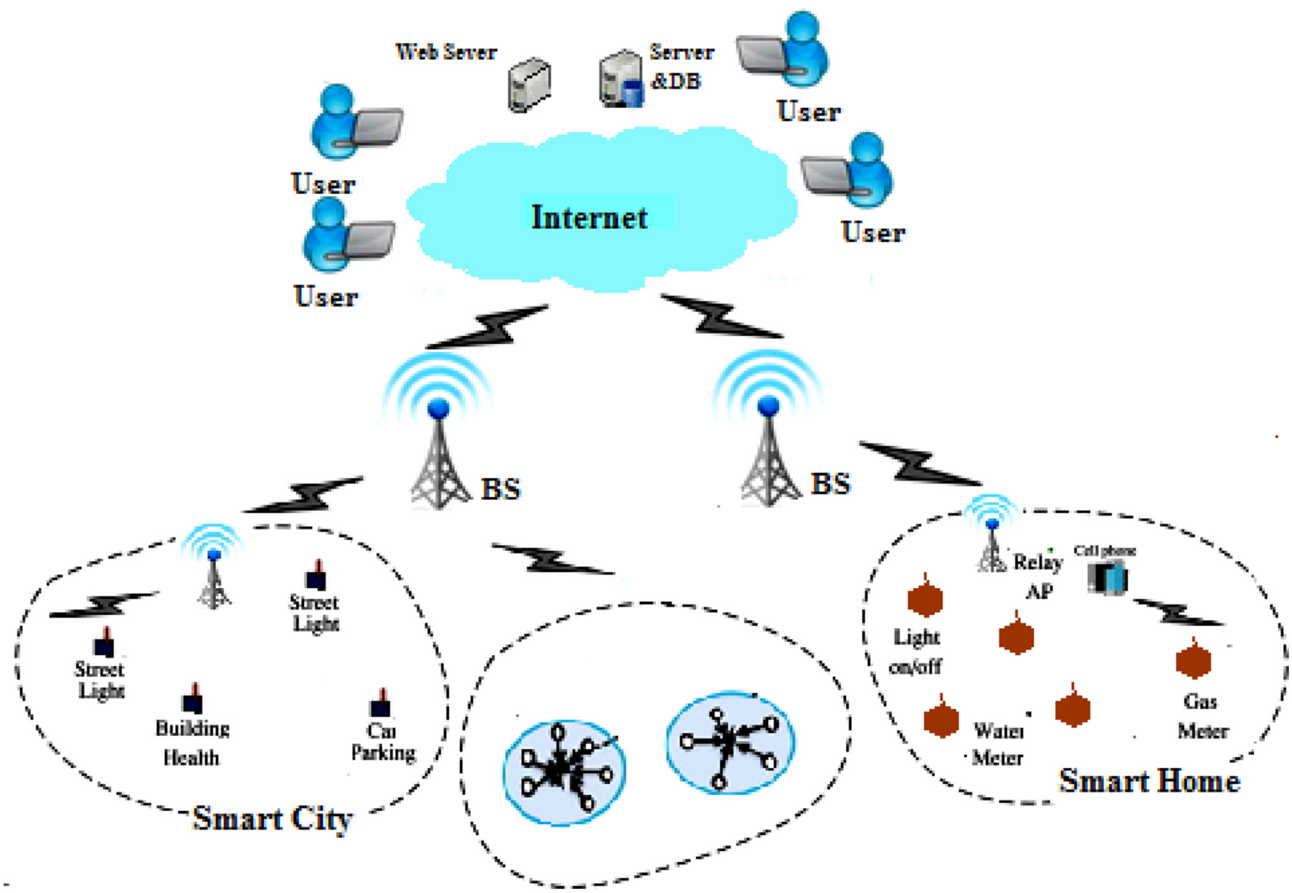

Fig. 1. IoT Network architecture.

advanced-nodes ***m*** and the additional energy factor ***a*** for the advanced-nodes than the normal-nodes. SEP uses two weighted probability for normal and advanced-nodes with considering the random number and the nodes which were elected before as CHs. Advanced-nodes become cluster-heads over than the normal-nodes. This is done by considering weighted probabilities for normal and advanced-nodes. The base-station can check the heterogeneity in the field by examining whether one or/more nodes reach this energy threshold. Base-station could broadcast to cluster-heads in that round the values for weighted probabilities for normal and advanced-nodes and then CH unicast these values to nodes in their clusters. Assume an optimal number of clusters *Kopt* and *n* is the number of advance nodes. According to SEP optimal probability of CH is $P_{opt} = K_{opt}/n$. Every node decides becoming CH in current round or not. A random number between 0 and 1 is generated for node. If this random number is less than or equal threshold *T(n)* for node then it is selected as CH. Threshold *T(n)* was illustrated in equation 1. Probability for advance nodes to become Cluster-head is P_{adv} and accordingly the threshold for advance nodes is T_{adv}, G' is the set of not being CH in previous rounds, otherwise, $T_{adv} = 0$; [21]. Equation 2 and equation 3 show the threshold for advance nodes is T_{adv}, Probability for advance nodes P_{adv} respectively;

$$P_{adv} = \frac{P_{opt} \cdot (1 + a)}{1 + (a.m)} \tag{2}$$

$$T(adv) = \frac{P_{adv}}{1 - P_{adv}\left(r.mod\left(\frac{1}{P_{adv}}\right)\right)} \qquad if\ adv \in G' \tag{3}$$

3.3. Z-SEP (zonal-stable election) protocol

Hybrid protocol on basis of energy level and y coordinates. Z-SEP assumes 3 zones; 0,1 and 2. Zone 0 has randomly normal-nodes [21]. Zone 1 and Zone 2 have the advanced-nodes divided equally and distributed randomly in both zones. Z-SEP uses two techniques for data transmit to the base-station; direct communication which was used by normal-nodes directly, send to the base-station BS and on the other hand, transmission via CH is used in zone 1 and zone 2, CH is selected. In a round, each node decide to be CH or not based on comparison a chosen random number (between 0 and 1) with the threshold value that consider the probability of advanced-nodes [21].

4. Proposed hybrid protocol for heterogeneous devices in IoT (Hy-IoT)

IoT environment has many diverse devices that are heterogeneous in their energies, their Internet availability, etc. Although, IoT environment has many heterogeneous devices, it is usually distributed into zones. Each of these zones usually is dominated by one type of devices in addition to few of the other types. Many developed protocols treated efficiently either the homogenous devices or heterogeneous devices. This paper proposes a heterogeneous-aware IoT protocol; Hy-IoT. The proposed protocol introduces an efficient hybrid protocol that is suitable for the mixed heterogeneous dominating zones and the homogenous dominating zones in IoT environment; Hy-IoT. Hy-IoT proposed protocol provides prolonging the stability period. Hy-IoT uses different weighted election probabilities for being a Cluster-head based on heterogeneity of the zone. Simulation shows that Hy-IoT prolongs the stability period compared to the SEP, LEACH and Z-SEP. Extensive examination is carried out for the impact of heterogeneity especially in cases that have more devices has extra energy; which is the case in most of IoT applications. The radio model utilized in Hy-IoT is the commonly used in wireless sensor networking [20,21].

Routing protocols that are utilized in IoT topology environment are developed and extensively examined to measure their performances with a common assumption of randomly distributed nodes. This assumption doesn't provide a chance to efficiently utilize the energy of the nodes especially in case of IoT applications that have some kind of multiple level of energy heterogeneity nodes such as passive RFID, sensors, mobile phones etc. Therefore, this paper proposes a new practical IoT architecture and provide the adaptation in selecting the routing based on providing two regions one has the gateway/sub-controller (in case of SDN) devices which always have enough energy to manage, and the other region has the normal randomly distributed regular nodes which includes normal limited energy nodes and advanced-nodes. Fig. 2 shows graphically the proposed IoT network architecture. For deployment, there is an assumption of having ***m*** advanced-nodes of the total nodes ***n*** which have ***a*** multiple more energy of normal-nodes and ***k*** superior nodes of the total nodes ***n*** which have ten times the energy of normal-nodes. ***k*** superior nodes are randomly concentrated in a region, all the other nodes; regular and advanced are randomly distributed in the remaining part of the deployed IoT network architecture.

The proposed protocol is a multilevel energy based clustering Protocol. The proposed Protocol deliberates the IoT heterogeneous environment, therefore it is called Hy-IoT protocol. Hy-IoT considers randomly deployed things with multiple energy levels at the start. The IoT heterogeneous milieu that is proposed in this paper consists of two regions; regular region; R_{ra} and superior region R_s. The first regular region R_{ra}, has regular nodes as the majority and some advanced-nodes. In IoT applications, commonly this kind of regions is widely applied as some kinds of sensors, actuators, RFIDs, etc. The second superior region R_s has superior nodes with high advanced-nodes which correspond in the IoT applications to some mobile phones, smart controllers, etc. The proposed protocol provides an adaptive hybrid usage for the SEP and LEACH. Nodes/things are randomly distributed. Nodes in regular region and superior region transmit data to base-station through clustering algorithms. Cluster-head selection is carried out in superior region and regular region based on LEACH and SEP respectively. Nodes in regular region may either using the announced CH by SEP in the same region or the announced CH by LEACH in superior region which are the adjacent based on the distance and energy consumption. Each CH collects and aggregates data from its member nodes and then transmits it to BS. CH selection is the most significant step since it affects the whole network life and performance. BS checks the heterogeneity in the field by examining number of nodes reach the energy specified threshold. BS broadcasts to CH in each round the values for weighted probabilities for different types of nodes and then CH unicast these values to nodes in their clusters.

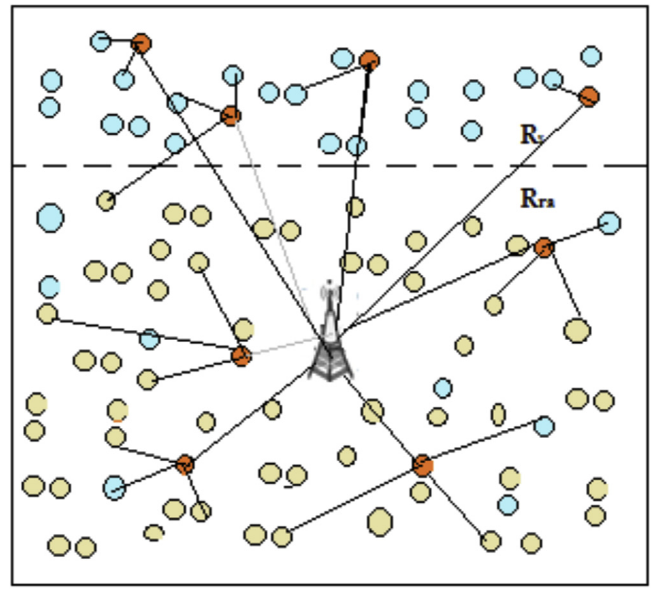

Fig. 2. IoT Network deployment.

4.1. Cluster-head selection phase

Conventionally, all the clustering based protocols have bounded rounds and each round has three phases cluster-head selection, cluster creation and transmission steady state phase. The CH selection phase is the main perturbing phase in the heterogeneous milieu. In Hy-IoT, nodes picks the suitable Cluster-head according to many criteria; its region belonging, its residual energy, its distance from CH; unlike LEACH which uses CH selection threshold having fixed probability of CH selection and SEP uses weighed election probability of each node to be CH according their energies. To form the cluster, For N number of nodes in the network, number of cluster heads; K is different in each round, the length of each cluster is varied C_r; C_r =N/K. In Hy-IoT, CH selection is carried out differently on the different regions not only to cope with the multiple levels of heterogeneity but also to utilize the difference in heterogeneity in order to elongate the network life time as well as increasing the network throughput. Superior region R_s uses the LEACH algorithm in CH selection since this region is much like as homogenous region. On the other hand, the regular region R_{ra}, uses the SEP algorithm in

CH selection, since the nodes have some that can be characterized as advanced-nodes. When the instability period starts, the nodes may associate either with the announced CH from the superior region R_s or from the regular region R_{ra} based on the distance and its associated consumption of energy.

4.1.1. Superior cluster-head selection

Since, Superior region has heterogeneous superior nodes with high energies; they are considered power stable devices. The superior nodes are usually located in a specific region R_s. The selection of the Cluster-head is carried out using the LEACH in a random way [14] along the whole process. Although they are energy positive nodes, it is always recommended to reduce even the consumption for green computing. There is required of cluster-heads percentage; p for entire network, which is used to calculate a threshold T_s that is used in a comparison with a random elected number between 0 and 1. As illustrated in equation 1, this comparison specifies whether the node will behave as cluster-head or regular node in this current round; r. Each superior node that wasn't cluster head before, has equal probability p in each Cluster-head selection process.

4.1.2. Regular cluster-head selection

Regular region R_{ra} has majority of normal-nodes/things with minority of advanced-nodes distributed in a random way. The selection of the cluster-head is carried out by using the SEP in order to consider the remaining of energy content in each round [20]. There is required of cluster-heads percentage; p for entire network, which is used to calculate a threshold (equation 3) that is used in a comparison with a random elected number between 0 and 1. This comparison specifies whether the node will behave as cluster-head or regular node in this current round; r. Each node that wasn't a cluster head before, has equal probability p in each Cluster-head selection process. Since each node has different residual energy in each round, normal-nodes with low energy usually die faster than those with higher energy whether they are advanced-nodes or superior nodes. The network status is affected with the global residual energy content and consequently the life time of the network as well as its throughput. Therefore, the local energy of nodes in the regular region is considered in selecting the CH by using SEP protocol till starting of the instability period. Then, it may consider associating the CH formed by LEACH and located in the Superior region based on the required its consumed energy and distance to new CH. This will elongate the stability period of the network.

4.2. Cluster formation phase

Once the cluster-head is selected, it broadcasts an advertisement message to the nodes. Nodes receive these messages to know which cluster-head they will be belonged to in this round. The distance as well as the received signal strength are the main required parameters for the nodes to decide which cluster-head they will associate with. Nodes associate to the nearest CH to minimize the energy consumption. The proposed protocol facilitates using the CH that has much energy even it is far from the node unless it is within the nodes transmission range. However, Hy-IoT may not elect the nearest CH, in case it is saturated with the maximum number of members or in case of there is another CH has higher residual energy in its transmission range. This strategy enhances the overall network lifetime. Each node checks its most three next nearest CH within its transmission range and sort them in a list with their residual energies in descending order, if the highest -nearest CH; the first on the list reaches to its maximum members then assigns the node to its next CH in the list to minimize data transmission latency, ensure load balance, increase the network life time and throughput. Each node sends a request message to the selected cluster head to join its cluster. The requesting message contains node id, cluster-head id and same spreading code using CSMA as a MAC protocol. The selected CH uses CSMA as a MAC protocol to broadcast an advertisement message containing its ID, header to indicate it as an announcement message and a spreading code necessary to reduce inter cluster interference. Also, after cluster formation, each CH announces its TDMA schedule for its nodes to facilitate receiving data from nodes in the cluster in their time slots. Each node wakes up only during its TDMA time slot to transmits its data to CH and goes into sleep mode again.

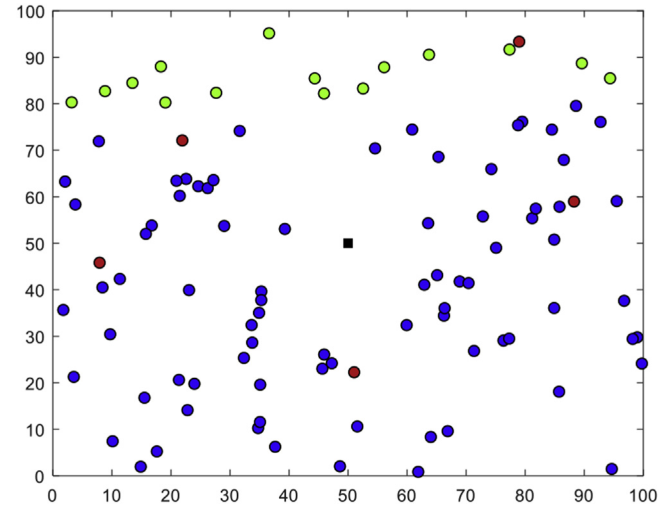

Fig. 3. A sample of randomly deployed nodes in the two regions; regular and superior.

Table 1
Simulation parameters.

Parameter	Value
Network size	100 m × 100 m
Number of Nodes	100,50
Packet size	4000 bit
Initial energy E_o	0.15 J
Energy for data aggregation EDA	*5 nJ/bit/signal*
Transmitting and receiving energy E_{elec}	*5 nJ/bit*
Amplification energy for short distance E_{fs}	*10 Pj/bit/m2*
Amplification energy for long distance E_{amp}	*0.013 pJ/bit/m4*
Probability P_{opt}	*0.1*

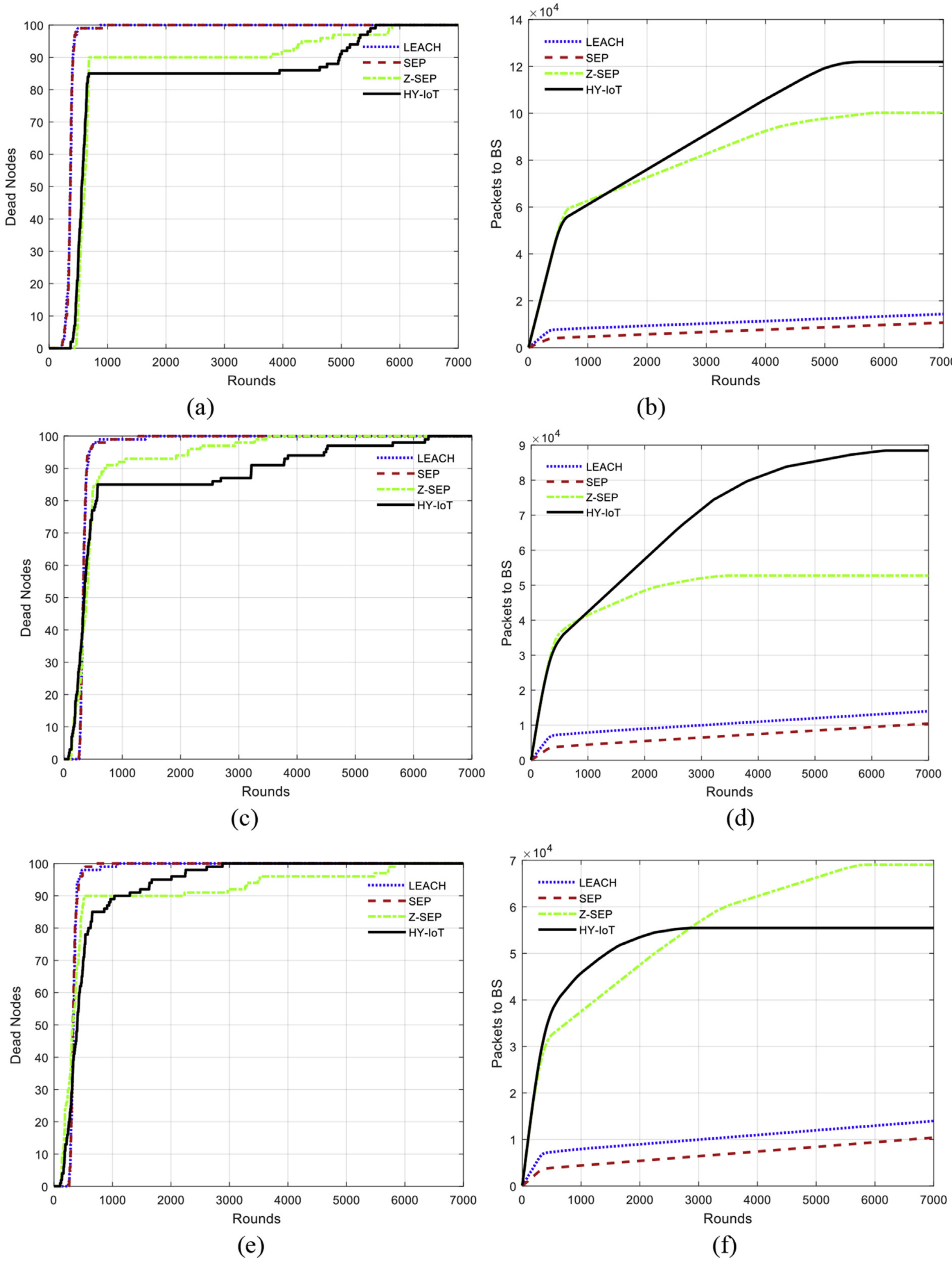

Fig. 4. 1st scenario network performance measures; column (a,c,e) for network life time, column (b,d,f) for network throughput. First row for BS centered, second row for BS upper corner, third row for BS lower corner.

4.3. Data transmission phase

After the CHs election phase and cluster formation phase, transmission the data from nodes to the base-station through the CH is taking its part. Since, the proposed protocol considers the region based IoT applications, data transmission could be done either through the CH located within same region; intra-zone communication or via CH with more energy content that locates in its associated superior region; inter-zone communication. Then CHs transmit the aggregated data to BS. This strategy ensures less energy dissipation especially on limited energy nodes.

5. Simulation experiments and results

Simulation is carried out for the proposed protocol. MATLAB 2017a is used in implementation of the simulations. The proposed Hy-IoT protocol in addition to the already developed and commonly used protocols LEACH [15], SEP [20], and Z-SEP [21] are implemented in order to have comparison among their performances in the proposed real world IoT region based environment. Thoroughly examination is carried out by proposing a heterogeneous network architecture more like the real IoT that has some energy limited nodes and others energy rechargeable nodes. A real world cyber IoT region based environment is considered as shown in Fig. 3.

5.1. Simulation parameters

Field area with dimensions XxY is 100 m × 100 m and IoT nodes population n = 100 is distributed in the predefined regions with respect to the energy criterion. Assume, 20% of superior and advanced-nodes and 80% normal-nodes are deployed. Consider an initial network with n heterogeneous nodes. Field area has two regions. First regular region; R_{ar} with normal-nodes; aa where (aa∈M), and they are randomly located in region ($0 < X \leq 100$, $0 < Y \leq 80$), While the second superior region has superior nodes; bb where (bb∈N) and they are randomly located in region ($0 < X \leq 100$, $80 < Y \leq 100$). The IoT network devices n is equal to M + N. The radio characteristics and other simulation parameters that were used in the simulation are illustrated in Table 1. Fig. 3 shows a sample of randomly deployed nodes in the two regions; regular and superior.

5.2. Performance measures

Many measures usually used to evaluate the clustering protocols performance [20,21]. _*Network lifetime* consists of *Stability Period* and. _*Instability Period*. *Stability Period* is the interval from the start of network operation till the first node death. _*Instability Period* is the interval from the death of the first node till the last node death. _*Number of cluster-heads/round* is the number of nodes instantaneously sends that aggregated data from cluster members to the BS. *Number of Dead Nodes* is the number of nodes (*total, superior, advanced and normal*) that are lost its energy and dead. *Throughput/round* is the total data sent rate over the network; the data sent rate from CH to BS and the of data rate sent from the nodes to their CHs.

5.3. Simulation results

Same simulation is carried out with five experiments with different samples of randomly deployed nodes with the same parameters and then the average were taken to ensure more accurate results. Performance measures; network life time and throughput are used to evaluate the performance comparison between the different protocols (LEACH, SEP, Z-SEP and Hy-IoT) with the assist of some scenarios to highlight the behavior in some special cases as well as the general cases. Heterogeneity degree is also examined.

Scenarios are simulated to examine the performance in terms of network life time as well as the throughput of the networks in different level of heterogeneity located in the predefined regions. 1st simulation scenario renders the homogeneity impact on the network performance using the proposed protocol versus different existed protocols. 1st simulation scenario considers homogenous nodes in each region R_s and R_r with the base-station in different places; center of the deployment area, upper right corner of the deployment area, and lower left of the deployment area. Fig. 4 shows the 1st scenario network performance measures; left column has network life time and right column has the Network throughput Packets received in BS, rows correspond to BS position; firstly centered, secondly upper corner, thirdly lower corner. Fig. 4; left column; (a,c,e) shows the dead nodes through the different rounds in the 1st scenario. It demonstrates that the LEACH and the SEP have the same performance in case of almost homogenous environment, while the Z-SEP and the proposed Hy-IoT achieves longer network lifetime. For the BS being in *center*, the stability region is 249 rounds, 279 rounds, 503 rounds and 490 rounds for LEACH, SEP, Z-SEP and Hy-IoT respectively. On the other hand, the instability period till, 807, 1000, 5850 1nd 5500 for LEACH, SEP, Z-SEP and Hy-IoT respectively. The results show that the stability region of is double elongated in case of the proposed algorithm compared to the LEACH or SEP and it is slightly less than the Z-SEP, since Z-SEP uses direct communication on the majority on nodes near the BS which are homogenous in the assumed case. On the other hand, the overall life time of the Hy-IoT outperforms all the other protocols, since it can still use the superior nodes in case of instability period of regular nodes.

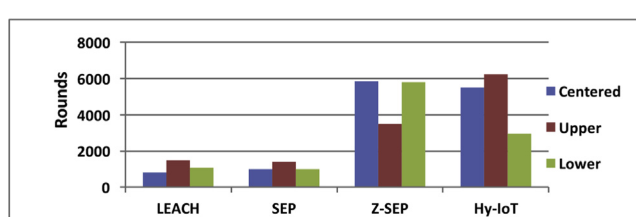

Fig. 5. Network life time in different cases in terms of rounds.

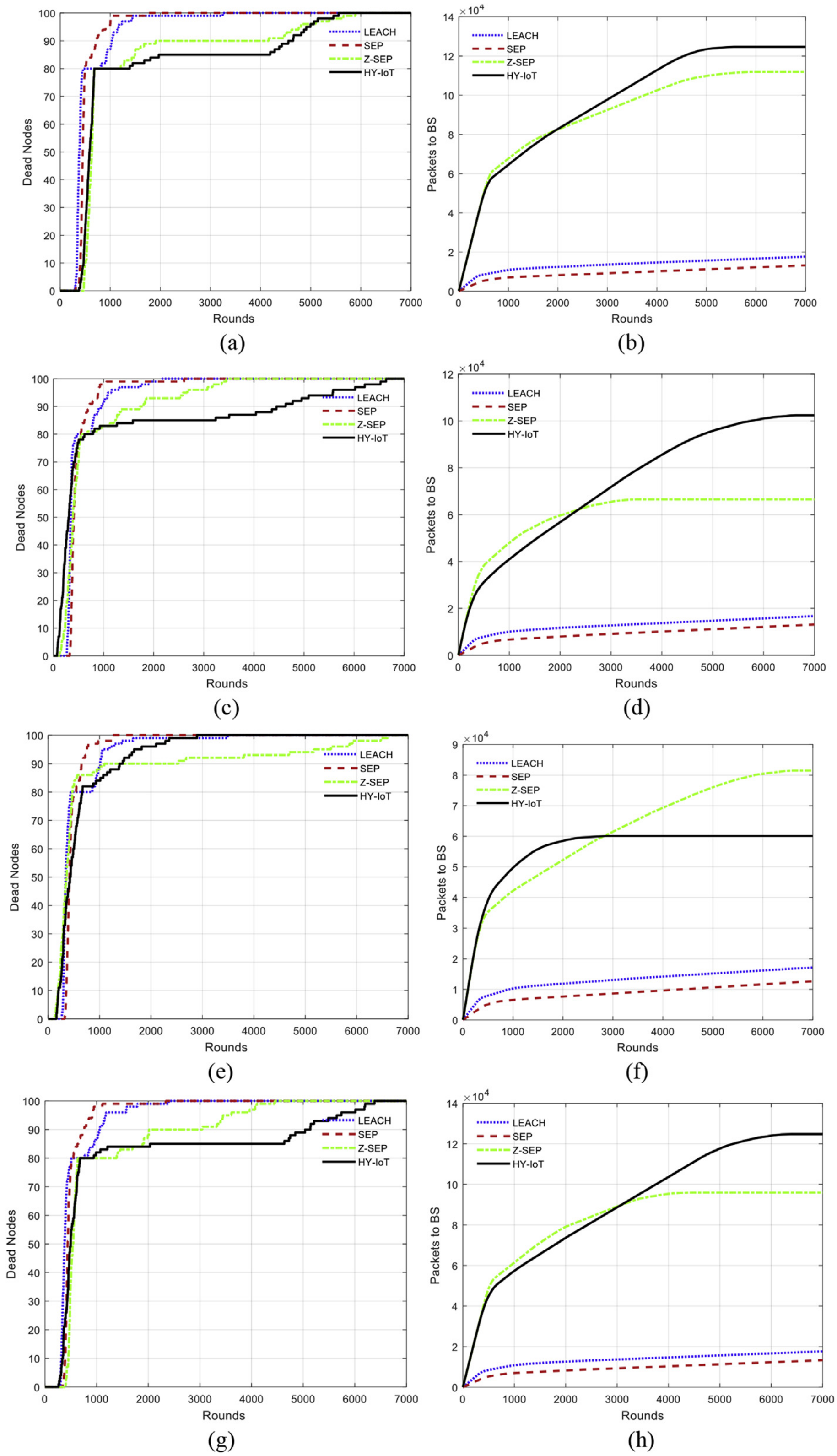

Fig. 6. 2nd scenario network performance measures; column (a,c,e,g) for Network life time, column (b,d,f,h) for Network throughput. First row for BS centered, second row for BS upper corner, third row for BS lower corner, third row for BS y80,x50.

Fig. 4(b,d,f) also shows the throughput of the network through the different rounds. It attests the improving of the total throughput of the network in case of using Hy-IoT compared to the LEACH and the SEP with outstanding ratios in all cases. Therefore, the comparison of throughput is focused on the Z-SEP, since it also has two communication protocols used. Hy_IoT performs better than Z-SEP in both BS being in the center and on the upper corner. Hy-IoT it can't perform well in case the BS is close to the regular region, since the choosing of using CH from the superior region after starting the instability period load them overhead communication energy than those in Z-SEP. Throughput is increased with using the proposed HY-IoT by 21.7% over the Z-SEP in case the BS in the center of the field and by 70.1% over the Z-SEP in case the BS in the outer upper corner of the field and decreased by 27.88% over the Z-SEP in case the BS in the inner lower corner of the field. Fig. 5 shows the comparison of the proposed protocol compared to the other protocol in terms of network life time in different cases. Life time of network is decreased with HY-IoT by 6% over the Z-SEP in case the BS in the center of the field and increased by 77.55% over the Z-SEP in case the BS in the outer upper corner of the field and decreased by 48.9% over the Z-SEP in case the BS in the inner lower corner of the field. These results show the outperforming of Hy-IoT in case of the base-station locates near the superior nodes region.

2nd scenario testifies the effect of presence of multiple level of energy heterogeneity on the network performance. Assume 20% of superior and advanced-nodes and 80% normal-nodes are deployed. 10% advanced with doubled energy are randomly distributed in the regular region R_{ar} and 10% advanced are randomly distributed in the superior region R_s.

Fig. 6 shows the 2nd scenario network performance measures; left column has network life time and right column has the Network throughput Packets received in BS, rows correspond to BS position; firstly centered, secondly upper corner, thirdly lower corner and fourthly center in the middle of the two regions (y = 80, x = 50). Fig. 6 left column; (a,c,e,g) shows the dead nodes through the different rounds in the 2nd scenario. It is clear that the more stability gained over than the others. LEACH is very sensitive to heterogeneity so nodes die at a faster rate. SEP performs better than LEACH because its weighted probability for selection of CH. Fig. 6(b,d,f,h) also shows the throughput of the network through the different rounds is highly improved using the Hy-IoT. Fig. 7 uses Log scale to show the Cluster heads in each round in case of the BS is centered. Lower number of selected CHs indicates the capability to forward more member nodes data, either in the early stage of battery consumption or after changing to use CH from superior region. A higher number of cluster-heads causes more network energy consumption. Throughput is increased with using the proposed HY-IoT by 11.5% over the Z-SEP in

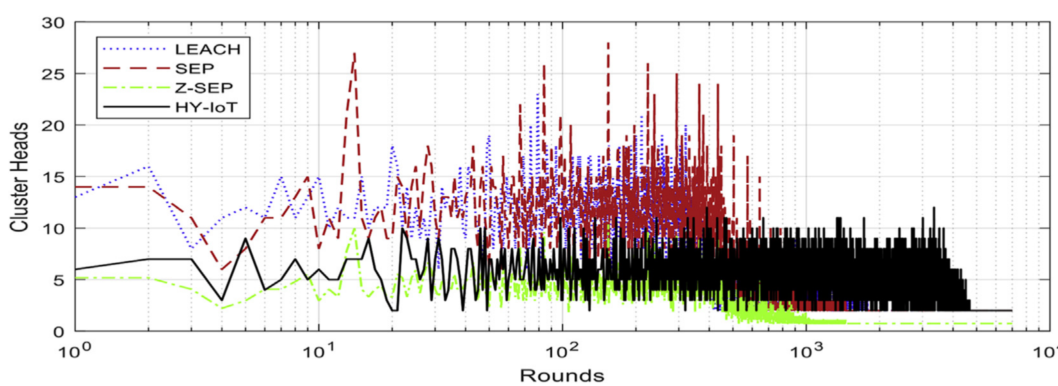

Fig. 7. 2nd scenario: Cluster heads in each rond BS centered using log scale.

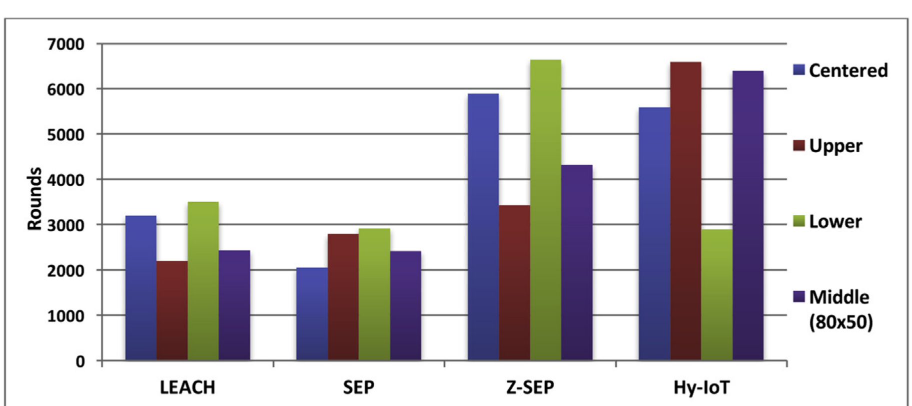

Fig. 8. Network life time in different cases in terms of rounds.

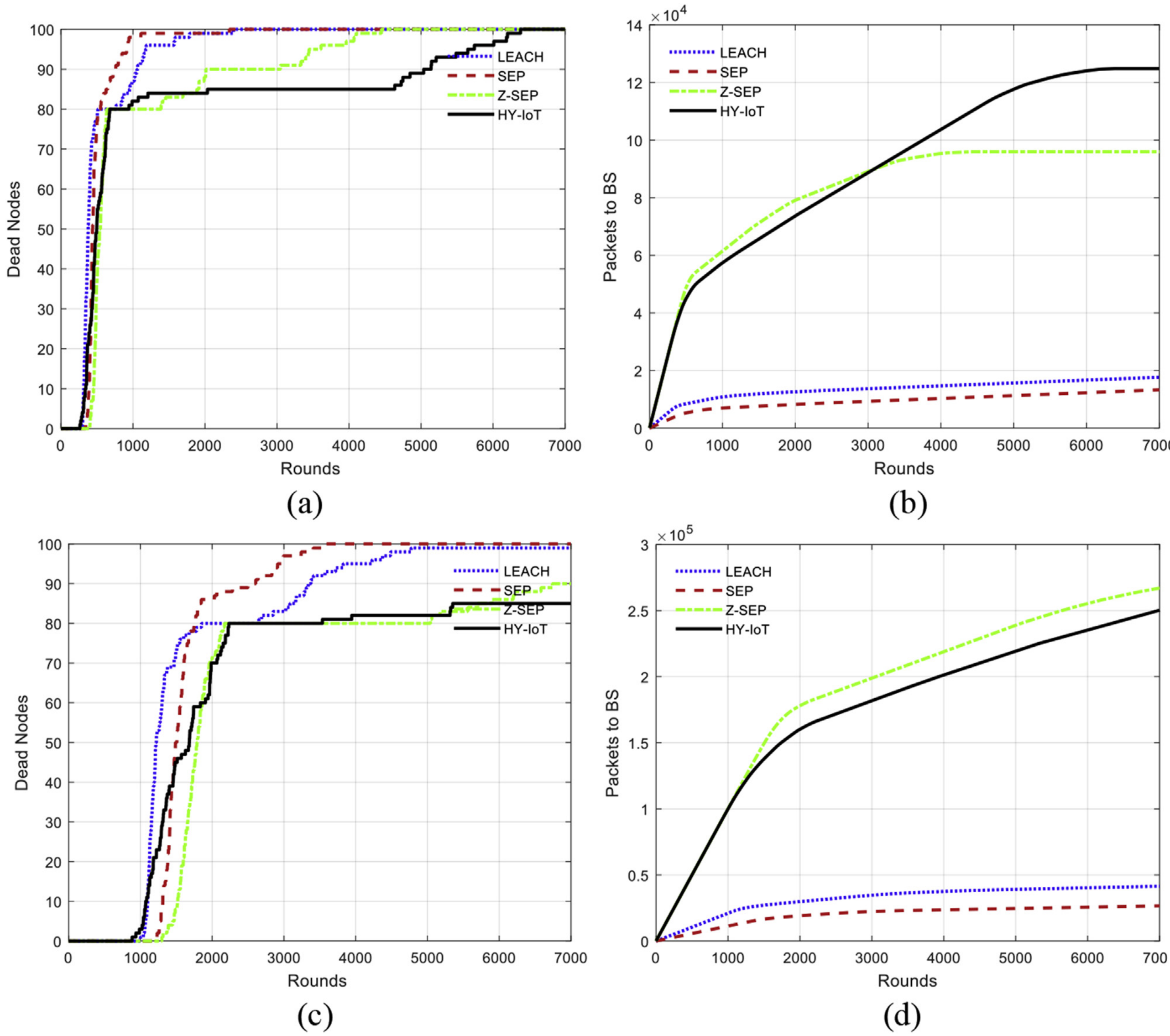

Fig. 9. 3rd scenario network performance measures (a,c) Network life time: its stability and instability zones (b,d) Network throughput: Packets received in BS, rows correspond to E0 = 0.15, E0 = 0.5. BS in 80 × 50.

case the BS in the center of the field and by 54% over the Z-SEP in case the BS in the outer upper corner of the field and decreased by 26.2% over the Z-SEP in case the BS in the inner lower corner of the field and increased by 30% over the Z-SEP in case the BS in middle of the regions at y80, x50. Fig. 8 shows the comparison of the proposed protocol compared to the other protocol in terms of network life time in different cases. Life time of network is decreased with HY-IoT by 5.16% over the Z-SEP in case the BS in the center of the field and increased by 92.5% over the Z-SEP in case the BS in the outer upper corner of the field and decreased by 56.33% over the Z-SEP in case the BS in the inner lower corner of the field and increased by 47.8% over the Z-SEP in case the BS in the middle area at y = 80 and x = 50. These results proved the outperforming of Hy-IoT in case of the base-station locates near the superior nodes region.

3rd scenario testifies the effect of presence of higher level of initial energy from 0.15 to 0.5 on the network performance. Assume nodes are distributed as was proposed in the previous scenario. The base-station is located in middle of the two areas y = 80, x = 50. Fig. 9 shows 3rd scenario network performance measures; Network life time and Network throughput with initial energy E0 = 0.15 and E0 = 0.5. Throughput is increased with using the proposed HY-IoT by 30% over the Z-SEP in case the energy 0.15 and decreased by 6.29% over the Z-SEP in case the energy 0.5. This means the Hy-Iot outperforms in case of the high with low initial energy heterogeneity.

6. Conclusion

This paper proposes an energy aware IoT cluster communication protocol. The main focus was to enhance Cluster-head selection process in real world IoT network architecture. Traditional Clustering protocols LEACH and SEP and their modified versions are mostly used to deal with energy homogenous sensor network or theoretical heterogeneous energy nodes respectively. Practically in IoT real world applications, energy heterogeneity of the things are completely different. IoT applications usually contains of things type (e.g. sensors) that are pauper in energy and other things type (e.g., camera, mobile phones) that are considered sated in energy with direct power connection or rechargeable. Although, the need for energy saving is a mandatory for the things that are poor in energy, it is also highly required even in the rechargeable devices/things for green computing. IoT network architecture has nodes with different heterogeneous levels of energy that usually distributed in regions. Level of heterogeneity affects the selection of used protocol, LEACH for homogenous and SEP for heterogeneous for instance. The proposed Hy-IoT provides considering the real world cyber IoT architecture based region in managing the clustering. This is carried out by considering different and dynamic update of the weighted election probability based on the residual energy, distances and the current heterogeneity condition to utilize the usage of CH vicinity. As discussed before in the results, Hy-IoT provides some advantages over the commonly existed protocols LEACH, SEP and Z-SEP protocols. The allotment of the deployed area into regions based on the majority of nodes and their degree of heterogeneity equally distributed sub-areas helps to balance the network traffic. Energy efficiency is managed by dividing the network into regions with a degree of heterogeneity, dynamically the load can be balanced to prolong the network lifetime. Consequently, Hy-IoT increases the throughput. Z-SEP performs well in case of the Base-station located inside the region of the normal-nodes region. Hy-IoT provides prolonging for the network life time ranging from 47.8% to 92.5% based on the heterogeneity level and also the average throughput was boosted ranging from 11.5% to 70.1% based on the heterogeneity level. Future work; (1) Consider efficiently merging the proposed protocol with the MAC to have an efficient approach.(2) Consider GPS in clustering topology to resolve the optimization dilemma of the regions partitioning (3) Scalability issue in both the population of nodes and the density.(4) Using network coding for efficient data aggregation and communication with the manipulation of the correlation or redundancy level. (5) Consider a specific energy based protocol for RFID. (6) Examine and adapt the proposed protocol incase of tied with SDN controller.

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