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CHARACTERISTICS OF CLUSTERING PROTOCOLS OF WIRELESS AD HOC NETWORK: A COMPARITIVE ANALYSIS

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ABSTRACT

A need for a self-organising reliable network structure was felt that can be maintained under changing connectivity without the support of a central controller. The classical hidden terminal phenomenon of a wireless communication increases the radio channel transmission conflict because of the widespread disperse of nodes. Scalability is of particular interest to ad hoc network designers and users and is an issue with critical influence on capability and capacity.

Where topologies include large numbers of nodes, routing packets will demand a large percentage of the limited wireless bandwidth and this is exaggerated and exacerbated by the mobility feature often resulting in a high frequency of failure regarding wireless links. Owing to a variety of benefits, clustering is becoming an active branch of routing technology in Wireless ad hoc Networks. Clustering is a key technique used to extend the scalability, reliability and lifetime of ad hoc network by reducing energy consumption.

We analytically study a few distinguishable WSN clustering routing protocols and equated these different approaches according to several significant metrics.

KEYWORDS: Cluster, Cluster Head, Cluster Member, Gateway, Wireless ad hoc Network, Routing Protocols

INTRODUCTION

Equated to the Routing Protocols generally used in immobile networks, the Routing Protocols for ad hoc networks must have surplus properties in order to survive with the new challenges forced by the mobile and wireless environment. Communication over wireless channels is comparatively less reliable as compared to wired networks, the protocol must be strong and should not display inconsistent behavior if packet carrying routing information are lost. Energy conservation, Constrained and limited resources, global addressing scheme, high probability of data redundancy, many-to-one communication scheme and time- constrained applications are WSN inherent characteristics that makes routing, a challenging task.

Clustering provides a convenient framework for the development of important features such as channel access, routing, power control, code separation, and virtual circuit support and bandwidth allocation. Aim of the Clustering algorithm is to discover a realistic interconnected set of Clusters covering the entire node population.

An efficient Clustering algorithm should be steady to the radio motion, i.e. it should not change the Cluster Configuration too drastically when a few nodes are moving and the topology is slowly changing. Otherwise, the Cluster Heads will not control their Clusters efficiently and thus lose their role as local coordinator.

Figure 1

One hop means that the Cluster Head can reach all its members in one hop. One hop clustering algorithm is much stable than the lowest ID and highest degree algorithms in both low mobility and high mobility scenarios. Stability of the highest degree algorithm is the worst. This is due to the fact that the degree of one node is changing frequently under mobility. By using Multihop clustering, grouping of mobile nodes and partition the whole network into different subnets and approximately control the subnet size becomes easy.

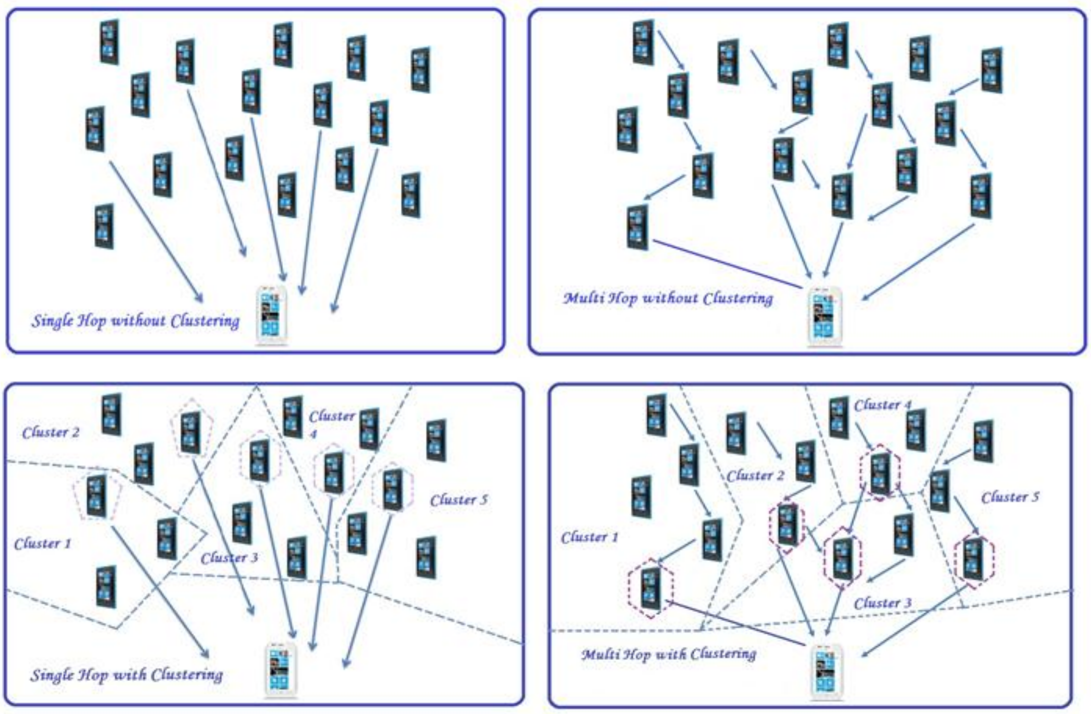

Figure 2

RELATED WORK

Innovative designs to simplify the route construction process are used Control overhead reduction-based protocols to enhance the energy efficiency with the goal of extending network longevity.

Dynamic event clustering, multi -hop communication, cooperative communications are the different methods can consume the energy appropriately and avoid wasted energy in Energy consumption mitigation-based protocols. Uniform objective of energy balance is achieved by assigning redundant and repetitive missions appropriately between nodes in Energy balance-based protocols.

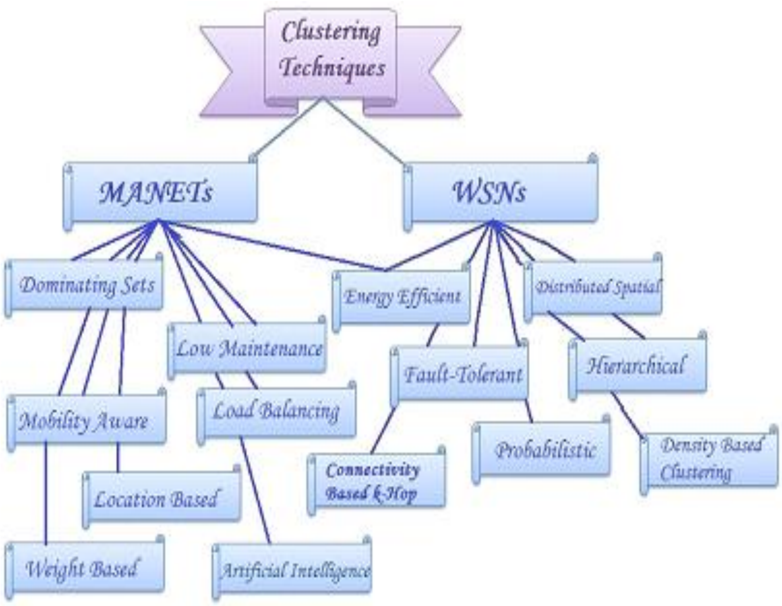

Figure 3

Data packets, which are, waiting to be forwarded, neighbor information, cluster information, route information of ad hoc network requires efficient memory management. Due to the limited memory capacity of the large -scale ad hoc networks, efficiently utilization of storage resources is of great significance for enhancing the scalability of the routing protocols. Diminishing the number of control messages, reducing the average end-to-end delay and satisfying data aggregation parameters are the achieved by DECROP. Initialization with distributed cluster formation, data transmission and route maintenance are three processes to accomplish the functioning of DECROP.

A survey of clustering algorithms for WSNs was presented by Abbasiet al. The authors of that survey presented a taxonomy and classification of typical clustering schemes, then summarized different clustering algorithms for WSNs based on classification of variable convergence time protocols and constant convergence time algorithms, and highlighted their objectives, features, complexity, etc. Finally, these clustering approaches were compared based on a few metrics such as convergence rate, cluster stability, cluster overlapping, location-awareness and support for node mobility.

The typical clustering routings protocols in WSNs include Algorithm for Cluster Establishment (ACE), The Adaptive Threshold sensitive Energy Efficient sensor Network protocol (APTEEN), Base-Station Controlled Dynamic Clustering Protocol (BCDCP), energy efficient cluster-based service discovery protocol (C4SD), Concentric Clustering Scheme (CCS), Distributed Weight-based Energy- efficient Hierarchical Clustering protocol (DWEHC), Energy Efficient Clustering Scheme (EECS), Energy-Efficient Uneven Clustering (EEUC) algorithm, Hybrid Energy-Efficient Distributed clustering (HEED), Hierarchical Geographic Multicast Routing (HGMR), Low-energy Adaptive Clustering Hierarchy (LEACH), Position-based Aggregator Node Election protocol (PANEL), Power Efficient Gathering in Sensor Information Systems (PEGASIS), Two-Level Hierarchy LEACH (TL- LEACH), Unequal Clustering Size (UCS) model, Threshold sensitive Energy Efficient sensor Network protocol (TEEN), Two- Tier Data Dissemination (TTDD), etc. Clustering routing is becoming an active branch of routing technology in WSNs on account of a variety of advantages, such as more scalability, data aggregation/fusion, less load, less energy consumption, more robustness, etc.

Chan and Perrig presented Algorithm for Cluster Establishment (ACE) allows a node to evaluate its potential as a CH before becoming one and retire if it is not the best CH at that instant. Spawning of new clusters and the migration of existing clusters are two logical parts of the ACE. ACE employs an emergent algorithm, which is any computation that achieves formally or stochastically predictable global effects, by communicating directly with only a bounded number of immediate neighbors and without the use of central control or global visibility. One of the main distinguishing characteristics of emergent protocols over other localized protocols is the existence of feedback during protocol operation. The Adaptive Threshold sensitive Energy Efficient sensor Network protocol (APTEEN) introduced by Manjeshwar and Agrawal, aims at both capturing periodic data collections and reacting to time-critical events. When the base station forms the clusters, the Cluster Heads broadcast the attributes, the threshold values, and the transmission schedule to all nodes. Cluster Heads also perform data aggregation in order to save energy. APTEEN supports three different query types: historical, to analyze past data values; one- time, to take a snapshot view of the network; and persistent to monitor an event for a period of time. Base-Station Controlled Dynamic Clustering Protocol (BCDCP), introduced by Muruganathan et al. is a centralized clustering routing protocol where each CH serves an almost equal number of MNs to balance CH overload and uniform CH placement throughout the network with the BS being capable of complex computation.

Marin et al. addressed energy efficient cluster-based service discovery protocol (C4SD) reduces the workload of the resource constrained devices, where a set of nodes are selected, based on their capabilities and each node is assigned a unique hardware identifier and weight (capability grade). Higher the capability grade more suitability for CH role and act as a distributed directory of service registrations for the nodes in the cluster.

The proposed clustering algorithm reacts rapidly to topological changes of the sensor network by making decisions based only on the 1-hop neighborhood information, avoids chain reactions and constructs a set of sparsely distributed CHs. The Concentric Clustering Scheme (CCS) has been proposed by Jung et al. to enhance the performance and to prolong the lifetime of the network. Changmin Duan and Hong Fan proposed Distributed Energy-Balance Clustering algorithm (DEBC), a probability based clustering elects Cluster Heads based on the knowledge of the ratio between remaining energy of node and the average energy of the network. Qing, Zhu, and Wang proposed Distributed Energy-Efficient Clustering Algorithm (DEEC) elects the Cluster Heads with the help of probability based on the ratio between residual energy of each node and the average energy of the network.

Two levels of heterogeneous nodes are considered in this algorithm and the ClusterHead role is rotated among all nodes to expend energy uniformity. When a new epoch begins, each node is computes the average probability pi by the total energy Etotal, while estimate value R of lifetime is broadcasted by the base station. Now pi is used to get the election threshold T(si). This threshold decides node is to be a cluster-head in the current round.

Distributed Weight-based Energy-efficient Hierarchical Clustering protocol (DWEHC), proposed by Ding et al., main objective is to improve HEED by building balanced cluster sizes and optimize the intra-cluster topology using location awareness of the nodes. Energy Efficient Clustering Scheme (EECS), proposed by Ye et al. partition the network into several clusters and single-hop communication between the CH and the BS better suits the periodical data gathering applications.

In EECS, CH candidates compete for the ability to elevate to CH for a given round. This competition involves candidates broadcasting their residual energy to neighboring candidates. If a given node does not find a node with more residual energy, it becomes a CH. Energy-Efficient Uneven Clustering (EEUC) algorithm, proposed by Li et al. is an unequal clustering approach for the purpose of balancing energy consumption among CHs and solving the hot spots problem. H. Zhou et al. proposed a protocol named Energy Dissipation Forecast and Clustering Management (EDFCM) algorithm balances the energy consumption round by round, which will provide the longest stability period for network. Type1 nodes vary in capabilities of sensing, energy and software have the responsibility of sensing events, while the management nodes perform management of both types of nodes during cluster formation. EDFCM is specially proposed for heterogeneous networks to provide the longer lifetime and more reliable transmission service.

Hierarchical Geographic Multicast Routing (HGMR), is a location-based multicast protocol optimizes energy efficiency and scalability by incorporateing the key design concepts of the Geographic Multicast Routing and Hierarchical Rendezvous Point Multicast protocols. Hybrid Energy-Efficient Distributed clustering (HEED) introduced by Younis and Fahmy, is a multi- hop WSN clustering algorithm which brings an energy-efficient clustering routing with explicit consideration of energy. Different from LEACH in the manner of CH election, HEED does not select nodes as CHs randomly. The manner of cluster construction is performed based on the hybrid combination of two parameters. One parameter depends on the node's residual energy, and the other parameter is the intra-cluster communication cost.

In HEED, elected CHs have relatively high average residual energy compared to MNs. Additionally, one of the main goals of HEED is to get an even distributed CHs throughout the networks. Moreover, despite the phenomena that two nodes, within each other's communication range, become CHs together, but the probability of this phenomena is very small in HEED. In HEED, CHs are periodically elected based on two important parameters: residual energy and intra-cluster communication cost of the candidate nodes. Initially, in HEED, a percentage of CHs among all nodes, Cprob, is set to assume that an optimal percentage cannot be computed a priori.

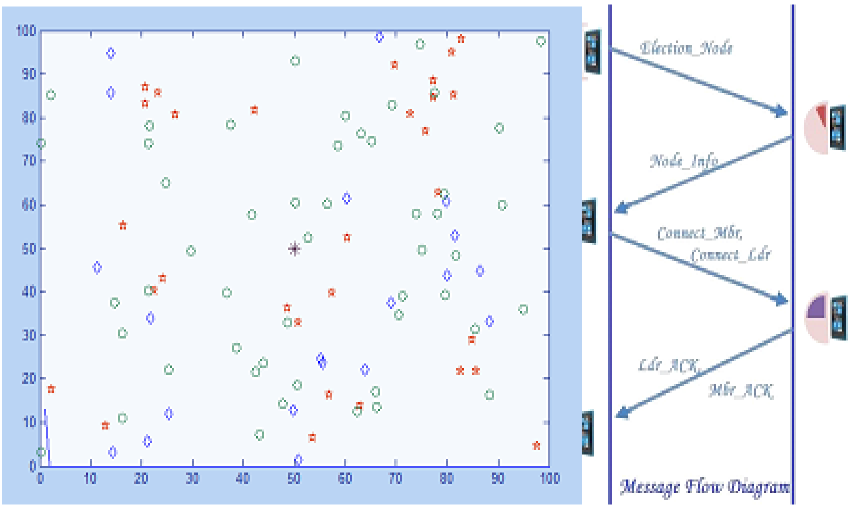

Figure 4

Low-Energy Adaptive Clustering Hierarchy, the sensor nodes will be organizing themselves into local clusters, with one of the nodes acting as the Cluster Head (CH) improve the fact that a node in the network is no longer useful when its bat tery dies. Leach utilizes the randomized rotation of Cluster Heads to evenly distribute the energy load among the sensors in the network. To enhance the network life time, not only the Cluster Heads have the responsibility of collecting data from their clusters, but also to aggregate the collected data for reducing the amount of messages to be sent to the Destination. The sensor nodes elect themselves to be CHs at any given time with a given probability. The decision of whether a node elevates to cluster head is made dynamically at a time interval. The elevation decision is to be made solely by each node independent of other nodes.

This is done to minimize overhead in cluster head establishment. This decision making is a function of the percentage of optimal cluster heads in a network (determined a priori on application) in combination with how often and the last time a given node has been a cluster head in the past. The Threshold function is defined as- Where n is the given node, P is the a priori probability of a node being elected as a cluster head, r is the current round number and G is the set of nodes that have not been elected as cluster heads in the last 1/P rounds. Each node during cluster head selection will generate a random number between 0 and 1. If the number is less than the threshold (T (n)) the node will become a cluster head.

In Set-up phase, Sensors may elect themselves to be a local Cluster Head at any time with a certain probability. If this random number selected by node between 0 and 1 is less than the threshold T (optimal is 5%), the sensor node becomes a cluster-head. Each node accesses the network through the Cluster Head that requires minimum energy to reach. Once the nodes receive the advertisements, the nodes inform the appropriate Cluster Heads that they will be member of the cluster. Finally, the cluster heads assign the time slot on which the sensor nodes can send data to them. Sensors begin to sense and transmit data to the Cluster Heads which aggregate data from the nodes in their clusters during Steady-phase. After a certain period of time spent on the steady state, the network goes into start-up phase again and enters another round of selecting cluster heads.

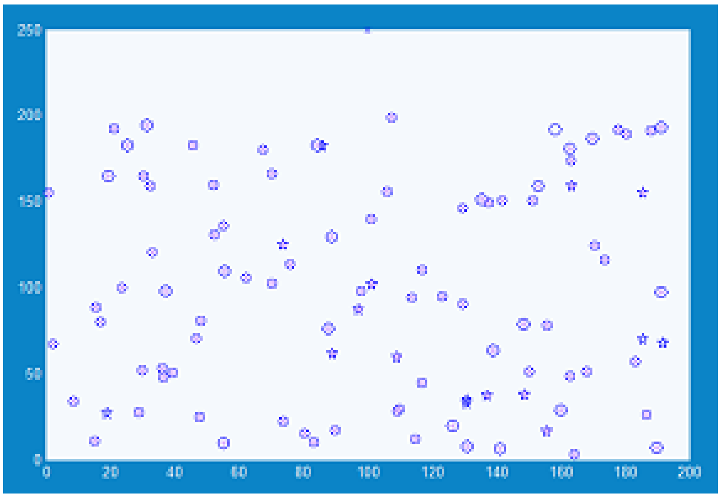

Figure 5

Position-based Aggregator Node Election protocol (PANEL) presented by Buttyan and Schaffer with main goal is to elect aggregators CHs, for reliable and persistent data storage applications supports asynchronous sensor network. PANEL assumes that the nodes are deployed in a bounded area, which is partitioned into geographical clusters. The clustering is determined before the deployment of the network, and each node is pre-loaded with the geographical information of the cluster to which it belongs. PANEL introduces a notion of reference point. At the beginning of each epoch, a reference point Rj is computed in each cluster j by the nodes in a distributed manner in terms of the epoch number. Lindsey et al. proposed Power- Efficient Gathering in Sensor Information Systems (PEGASIS) distributes Energy load evenly among the sensor nodes in the network. In PEGASIS, the nodes are organized to form a chain, which can either be concentratedly assigned by the sink and broadcast to all nodes or accomplished by the nodes themselves using a greedy algorithm.

The main idea of PEGASIS is for each node to only communicate with their close neighbors and take turns being the leader for transmission to the sink. In PEGASIS, the locations of nodes are random, and each sensor node has the ability of data detection, wireless communication, data fusion and positioning. If the chain is formed by the nodes themselves, they can first get the location data of all nodes and locally compute the chain using the same greedy algorithm. During the process of chain formation in PEGASIS, it is assumed that all nodes have global knowledge of the network and the greedy algorithm is employed. The chain construction is commenced from the furthest node from the sink and the closest neighbor to this node will be the next node on the chain. When a node on the chain dies, the chain will be reconstructed in the same manner to bypass the dead node. For gathering data from sensor nodes in each round, each node receives data from one neighbor, fuses the data with its own, and transmits to the other neighbor on the chain. By moving from node to node, the fused data eventually are sent to the sink by the leader at a random position on the chain. The leader is important for nodes to die at random locations, in respect that the idea of nodes dying at random places is to enhance the robustness of the network. Alternatively, in each round, a control token passing approach initiated by the leader is used to start the data transmission from the ends of the chain. The scheme of data transmission in PEGASIS. If node C2 is the leader, it will pass the token along the chain to node C0 at first. Then, node C0 will pass its data toward node C2. After node C2 receives data from node C1, it will pass the token to node C4, and node C4 will pass its data towards node C2 with data fusion taking place along the chain.

Stable Election Protocol (SEP), a heterogeneity-aware protocol does not require energy knowledge sharing but is based on assigning weighted election probabilities of each node to be elected cluster head according to their respective energy. In SEP normal and advanced nodes are considered based on weighted election probabilities of each node to become cluster head according to the remaining energy in each node. SEP ensure that the Cluster Head is randomly selected based on the fraction of energy of each node; this assures that each node’s energy is uniformly used which prolongs the stability period i.e. the time interval before the death of the first node.

Anjeshwar and Agrawal proposed Threshold sensitive Energy Efficient sensor Network protocol (TEEN) pursues a hierarchical approach along with the use of a data-centric mechanism. After the clusters are formed based on a hierarchical grouping, the cluster head broadcasts two thresholds to the nodes and this process goes on the second level until base station (sink) is reached.

The hard threshold allows the nodes to transmit only when the sensed attribute is in the range of interest, thus reducing the number of transmissions significantly. Once a node senses a value at or beyond the hard threshold, it transmits data only when the value of the attribute changes by an amount equal to or greater than the soft threshold. One can adjust both hard and soft threshold values in order to control the number of packet transmissions.

Two-Level Hierarchy LEACH (TL-LEACH), introduced by Loscrì et al. uses the randomized, adaptive, self-configuring cluster formation and localized control for data techniques to achieve energy and latency efficiency. In TL-LEACH, a CH collects data from MNs as original LEACH, but instead of transmitting data to the BS directly, it uses a part of CHs that lies between the CH and the BS as a relay station. TL-LEACH introduced two-level hierarchy: top CHs called primary cluster heads (CHi), second level represented from secondary cluster heads (CHij) and ONs. The algorithm is composed from four basic phases: advertisement phase, cluster setup phase, schedule creation and data transmission.

In the first phase, each node decides whether it become a primary CH, secondary CH or ON in each round which is the same as that of LEACH. If a node is elected a primary CH, it must advertise other nodes. The mechanism used in this phase is carrier sense multiple access (CSMA). Thereafter, secondary CH nodes send the advertisement to the ONs. In this phase, each secondary CH decides to which primary CH it belongs and sends an advertisement message to its primary CH.

In the same way, each ON must decide which secondary CH it belongs to and informs it through an opposite message. In the third phase, each primary CH creates a TDMA schedule assigning each node in its group a slot to transmit. Each primary CH chooses a CDMA code and informs all the nodes at second level in its group to use this code. In the same way, each secondary CH can transmit this information to

The Two-Tier Data Dissemination (TTDD) approach, presented by Luo et al. is a low-power protocol for efficient data delivery from multiple sources to multiple mobile sinks. It exploits a geographic routing based on grid of cells as the routing method. Instead of passively waiting for queries from sinks, sensor nodes can proactively establish a structure to set up forwarding information. Ultimately, the sensing field is figured as a set of grid points. In TTDD, a source divides the field into a grid of cells and each cell is square.

A source, at one crossing point of the grid, propagates data announcements to reach all the other crossings, called dissemination points. A source calculates the locations of its four neighboring dissemination points and sends a data announcement message to the four neighboring dissemination points using simple greedy geographical forwarding, i.e., it forwards the message to the neighbor node that has the smallest distance to the neighboring dissemination point. Similarly, the neighbor node continues forwarding the data announcement message till the message stops at a node that is closer to the dissemination point than all its neighbors. During this process, each intermediate node stores the source information and this process continues until the message stops at the border of the network. After this process, the grid structure is obtained.

Unequal Clustering Size (UCS) model was proposed by Soro and Heinzelman, is the first unequal clustering model for network organization in order to balance energy consumption of CHs, thus increasing the network lifetime. It is assumed that the positions of the CHs are determined a priori, with all CHs arranged symmetrically in concentric circles around the BS which is located in the center of the network, thus it's easy to control the actual sizes of different clusters.

In UCS, the sensing field is assumed to be circular and is divided into two concentric circles, called layers. In order to simplify the theoretical analysis, the authors approximate the sensing field as pie shaped field with a multiple-layer network.

It is assumed that all clusters in one layer have the same size and shape, but the sizes and shapes of clusters in the two layers are different. The position of a CH within the cluster boundaries determines the overall energy consumption of nodes that belong to the cluster.

To keep the total energy dissipation within the cluster as small as possible, every CH should be positioned at the center of the cluster. CHs are deterministically deployed in the network and are assumed to be super nodes which are much more expensive than MNs. Zone- Based Residual Energy and Energy Consumption Rate developed and analysed a protocol based on residual energy and energy consumption rate which improves the stability period. Balancing the energy consumption is a very tough task and leads to instability, is solved in ZREECR by dividing the network into fixed-size zones, depending upon distance and orientation from destination.

CONCLUSIONS

Heterogeneous wireless ad hoc networks are more suitable for real life applications as compared to the homogeneous counterpart. Clustering heuristics, usually, can well co-operatee the constraints and the challenges of Wireless ad hoc networks. Clustering is a decent method to moderate energy consumption and to be responsible for stability in wireless ad hoc networks. In past few years, consistent and substantial effort have been made in adressing the techniques to formulate an effective and efficient Wireless ad hoc Network clustering routing protocol.

This is very much clear from the number of protocol designed in the last few years and subsequent improvements done in them to overcome the shorcomings in them. All the protocols have tabulated alphabetically irrrespective of the their time of design. Further classification of all protocols has been done according to the network stability and energy efficiency. Strenths and weakness have been sumarrized with each of the schemes. Based on clustering attributes a novel taxonomy of clustering routing methods for Wireless ad hoc Networks has been developed.

An extensive survey has been conducted on Clustering routing protocols to get a better understanding and compared these different approaches based on our taxonomy and some primary metrics. As the number of nodes in large-scale wireless ad hoc networks increases, the density of the network is increased. Therefore, more redundant information is created and this makes the network congestion more serious. On the other hand, in some inclement and unstable environments, a certain degree of redundancy may be desirable to provide the network with reliability.

Table 1

Clustering Routing Protocols	Cluster Characteristics: Cluster Count/Sizes	Cluster Characteristics: Intra/Inter-Cluster Routing	CH Existence	ClusterHead Characteristics: Capabilities	ClusterHead Characteristics: Mobility	Role	Clustering Process: Control Manners	Clustering Process: Execution Nature	Clustering Process: Convergence Time	Clustering Process: Parameters for CH election	Proactivity	Objectives	Entire Proceeding of the Algorithm	Energy Efficiency	Cluster Stability	Scalability	Delivery Delay	Load Balancing	Algorithm Complexity
ACE	V/E	1-hop/1-hop	☑	Homogenous	Stationary	Agg.	Dis.	iterative	Constant	Adaptive	☑	Load Balancing	Cluster Construction	moderate	very low	moderate	small	moderate	very high
APTEEN	V/E	1-hop/m-hop	☑	Homogenous	Stationary	Agg.	Dis.	Prob.	Constant	Adaptive	proactive reactive	Proactive & Reactive scenes	Data Transmission	moderate	very low	low	small	moderate	very high
BCDCP	V/E	1-hop/m-hop	☑	Homogenous	Stationary	Agg.	Cent.	iterative	Constant	Adaptive	☑	Load Balancing	Cluster Construction	very low	high	very low	small	good	very high
C4SD	V/E	m-hop/m-hop	☑	Hetrogeneous	☑	Relay	Cent.	iterative	Constant	Adaptive	☑	Lifetime Extension	Energy and Link	high	mod erate	very low	small	bad	mod rate
CCS	V/UE	m-hop/m-hop	☑	Homogenous	Stationary	Agg.	Dis.	Prob.	Constant	Adaptive	☑	Lifetime Extension	Data Transmission	low	Low	low	large	very bad	mod rate
DEBC	V/E	1-hop/1-hop	☑	Hetrogeneous	Micro-Mobile	Fus./ Rel	Dis.	Prob.	Constant	Adaptive	☑	Lifetime Extension	Energy and Link	high	good	moderate	moder ate	Good	high
DEEC	V/E	1-hop/m-hop	☑	Hetrogeneous	Micro-Mobile	Agg.	Dis.	Prob.	Constant	Adaptive	☑	Lifetime Extension	Energy and Link	high	mod erate	moderate	moder ate	Good	mod erate
DWEHC	V/E	m-hop/1-hop	☑	Homogenous	Stationary	Agg.	Dis.	iterative	Constant	Adaptive	☑	Load Balancing	Cluster Construction	very high	high	moderate	moder ate	very good	mod erate
EDFM	V/E	1-hop/m-hop	☑	Hetrogeneous	Stationary	Agg.	Dis.	Prob.	Constant	Adaptive	☑	Lifetime Extension	Energy and Link	low	V.G	low	small	Good	mod erate
EECS	V/UE	1-hop/m-hop	☑	Homogenous	Stationary	Agg.	Dis.	Prob.	Constant	Adaptive	☑	load balancing periodical data communication	Cluster Construction	moderate	high	low	small	moderate	very high
EEHC	V/E	1-hop/m-hop	☑	Hetrogeneous	Stationary	Agg.	Dis.	iterative	Constant	Adaptive	☑	Lifetime Extension	Cluster Construction	high	mod erate	moderate	moder ate	Good	high
EEUC	V/UE	1-hop/m-hop	☑	Homogenous	Stationary	Agg.	Dis.	Prob.	Constant	Adaptive	☑	Load Balancing	Cluster Construction	high	high	high	moder ate	good	high
HEED	V/E	1-hop/m-hop	☑	Homogenous	Stationary	Agg.	Dis.	iterative	Constant	Adaptive	☑	Load Balancing	Cluster Construction	moderate	high	moderate	moder ate	moderate	mod erate
HGMR	V/E	1-hop/m-hop	☑	Homogenous	Stationary	Agg.	Dis.	Prob.	Constant	Adaptive	☑	Lifetime Extension	Data Transmission	low	high	very high	modra te	bad	low
LEACH	V/E	1-hop/1-hop	☑	Homogenous	Stationary	Agg.	Dis.	Prob.	Constant	Adaptive	☑	Load Balancing	Cluster Construction	very low	mod erate	very low	very small	modearte	low
PANEL	F /E	1-hop/m-hop	☑	Homogenous	Stationary	Agg.	Dis.	Prob.	Constant	Adaptive	☑	Load Balancing	Cluster Construction	moderate	low	low	moder ate	good	high
PEGASIS	V/E	m-hop/1-hop	☒	N/A	N/A	N/A	Dis.	Prob.	Constant	Adaptive	☑	Load Balancing	Data Transmission	low	low	very low	very large	moderate	high
SDEEC	V/E	1-hop/m-hop	☑	Hetrogeneous	Micro-Mobile	Agg.	Dis.	Prob.	Constant	Adaptive	☑	Lifetime Extension	Energy and Link	high	mod erate	moderate	moder ate	Good	mod erate
SEP	V/E	1-hop/m-hop	☑	Hetrogeneous	Stationary	Agg.	Dis.	Prob.	Constant	Adaptive	☑	Lifetime Extension	Energy and Link	low	good	moderate	moder ate	bad	low
TEEN	F/E	1-hop/m-hop	☑	Homogenous	Stationary	Agg.	Dis.	Prob.	Constant	Adaptive	reactive	reactive scenes Lifetime exten.	Data Transmission	very high	high	low	small	good	high
TL-LEACH	V/E	1-hop/m-hop	☑	Homogenous	Stationary	Relay Agg.	Dis.	Prob.	Constant	Adaptive	☑	Load Balance Lifetime Exten.	Cluster Construction	low	mod erate	moderate	small	bad	low
TTDD	V/E	1-hop/m-hop	☑	Homogenous	Stationary	Agg.	Dis.	Prob.	Constant	Adaptive	☑	scenes of multiple mobile sinks	Data Transmission	very low	very high	low	very large	Good	low
UCS	V/UE	1-hop/m-hop	☑	Hetrogeneous	Stationary	Relay Agg.	Dis.	Prob.	Constant	Adaptive	☑	Load Balance Lifetime Exten.	Cluster Construction	very low	high	low	small	bad	mod erate
ZREECR	F/E	1-hop/m-hop	☑	Homogenous	Stationary	Agg.	Cent.	Prob.	Constant	Adaptive	☑	Computational and Energy	Cluster Construction	low	good	low	small	good	mod erate

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