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A Study of Heterogeneity Characteristics over Wireless Sensor Networks

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Abstract: Wireless Sensor Networks (WSNs) have the potential to build novel IOT applications to monitor and track the physical activities in the fields of wild life, smart homes, disaster recovery, battle fields, and so on. WSNs are purely application-specific; by behavior, they broadly classify into two categories, namely homogeneous and heterogeneous. All sensor nodes in homogeneous networks are the same type, have the same energy and link capabilities, and so on, whereas in heterogeneous networks, these parameters vary depending on the application. In this paper, we primarily focus on the elimination of overlapping results from existing surveys and propose extensive survey results in terms of the potential performance of various clustering and routing protocols in heterogeneous WSNs. The overall survey was carried out based on the three types of heterogeneity, namely link, energy, and computational and evaluated protocol capability with various network parameters, which are presented in the survey results.

Keywords: WSN's, Heterogeneity, IOT (Internet of Things), Low-energy adaptive clustering hierarchy

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1. Introduction

Wireless sensor networks (WSN) are a collection of homogeneous and heterogeneous sensor nodes that are spatially scattered to observe an environmental or physical condition such as sound, pressure, temperature, etc. [1] [2]. These sensors collect information from the environment and forward the data to the nearest nodes, where it finally reaches the base station. Sensor nodes are equipped with a small battery and limited memory and processing capability. For sending and receiving data, sensor nodes consume resources like energy, storage, and computational capacity. Typical wireless sensor network applications are natural calamity relief operations, biodiversity mapping, smart buildings, industrial surveillance, precision horticulture, and health care [3–6]. One of the major research challenges is developing efficient clustering and routing algorithms to maintain large-scale sensor networks. Some of the current research challenges are real-time data scheduling, energy management, protocol programming abstraction, privacy and security, and localization aspects [7]. As per functional and technical metrics, wireless sensor networks are broadly classified into two types, namely homogeneous and heterogeneous, as extensively presented in [8-10].In homogeneity, all sensor nodes have the same type, energy, link capability, and other characteristics, whereas in heterogeneity, these characteristics vary depending on the application. Many researchers in previous decades concentrated on and contributed efficient techniques for homogeneous conditions, which lagged in heterogeneous conditions. Efficient clustering, energy optimization, scalable routing, node deployment strategies, and data fusion and aggregation are the major research goals, and some are still open issues.

The remaining paper is organized as follows: Section 2 represents a literature review; Section 3 presents a proposed model; Section 4 presents a result analysis; and Section 5 presents concussion.

2. Related Work

We investigated the properties of cluster-based routing protocols under heterogeneous conditions in this paper.

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Low-energy adaptive clustering hierarchy (LEACH) by Heinemann addressed efficient clustering and node energy constraints in a homogenous environment [11].

LEACH is an adaptive and self-organizing clustering algorithm that selects the cluster heads randomly based on the residual energy. LEACH prolongs the network's lifespan by significantly reducing energy utilization. LEACH protocol execution has two steps, namely the setup and study state phases. In the setup phase, each node is organized and forms a cluster by selecting one cluster head. In each round, the possibility of the node becoming the cluster head is 1/total number of rounds, and the cluster head will change the node's energy balance, which prolongs the network's lifetime. LEACH, a dependable protocol, performs computations locally with the help of MAC, routing under difficult conditions. LEACH, the first cluster-based routing protocol, and its variants (LEACH-C, Multi-hop LEACH, Vice LEACH (VLEACH), RECHS, Energy Aware Centralized LEACH (EA-LEACH), Energy-Efficient Adaptive Protocol for Clustered Wireless Sensor Networks (EEAP), EDRLEACH, Two Level Low Energy Adaptive Clustering Hierarchy (LEACH-TLCH), Quadrature-LEACH (QLEACH),The extrapolation technique in LEACH enhancements improved throughput and network life span by minimizing larger packet losses.[12]. PEGASIS [13] is a homogeneous protocol that adapts a chain-based approach; each node works with its neighbor node and transmits the aggregation data to the sink node.

This protocol forms the chain from lower levels of nodes to higher levels, i.e., the base station. Every node in the chain works like a transceiver (sense and transform). To form a chain, the protocol employs a greedy-based heuristic technique, and data transmission occurs in both single-hop and multi-hop modes. Sensor nodes follow single-hop transmission, whereas the base station works on multi-hop. C4SD [14]. SEP (Stable Election Protocol) [15] environment aware and extends the table region's lifespan before the first node dies. SEP is a hierarchy protocol that maintains a certain level of hierarchy, namely "normal advanced" (more energy than normal) and allows a very small number of nodes to act as a cluster headset in dynamic and scalable environments. There is no global knowledge or distribution level required.

E-SEP [16]: E-SEP is a residual energy-aware protocol that does not calculate the remaining energy of the nodes at each round like LEACH. Due to this, sometimes a low-energy node may also become a cluster head and, being located at the edge of the network, will not be able to perform reliable data aggregation, which impacts faster energy depletion.

T-SEP [17]: T-SEP is an active routing protocol that achieves higher throughput by maintaining multiple levels of heterogeneity. T-SEP CH selection is based on node threshold and will include three levels of energy nodes: advanced, intermediate, and ordinary.ET-SEP is abbreviated as "enhanced threshold." SEP outperforms SEP and T-SEP in terms of delay, packet loss, and throughput. ET-SEP sets the threshold based on the clusters and residual energy of the nodes. RFL-SEP [20]: RFL-SEP adopts a five-level heterogeneity, hybrid data aggregation approach rather than a three-level approach, and improves T-SEP performance in terms of packets sent to the base station.AT-SEP, Z-SEP (Zonal SEP), AT-SEP , ELB-SEP , and M-SEP are other variants of SEP. M-SEP is a modified SEP suitable for multi-level power transmission. Distributed energy efficient clustering (DEEC) bases cluster head selection on probability based on the ratio of the average energy of the network and the residual energy of each node. Usually, nodes with high initial and residual energy form cluster heads. DEEC outperforms SEP, LEACH, and LEACH-E in terms of the number of alive nodes and packets sent to the base station.

D-DEED [18], E-DEEC [19], and Distance-Energy Cluster Structure Algorithm (DECSA) [20] consider nodes' residual energy and distance to enhance cluster head selection, formation, and data transmission. DECSA effectively focuses on the non-uniform distribution of nodes in the network and avoids the direct communication between the sink and cluster head, which leads to a balance in energy consumption and prolongs the lifetime. DECSA has better performance than the original LEACH protocol. LESCA (Location-Energy Spectral Clustering Algorithm) [21] adapts spectral clustering for cluster formation. The work of LESCA with residual energy and the distances between nodes to sink and nodes to cluster cancroids allow for the network's consumed energy to be minimized.LESCA provides better performance improvement in terms of energy and lifetime gains compared to the others. LEACH-C [22]. Ajay and Sushil proposed energy-efficient clustering (E2C), which handles multilevel heterogeneity by predicting residual energy and the optimal probability of a sensor. The E2C protocol improves throughput and network life by optimizing packet losses with the extrapolation technique.E2C outperforms DEEC and SEP [30].

AM-DICNT [23]. IAM-DICNT, DCCNT [24]. The Joint Clustering and Routing (JCR) protocol is suitable for larger sensor networks and performs better in terms of clustering and routing. JCR adopts back-off timer heuristics and follows gradient-based routing. JCR improved the inter-cluster communication by following a multi-hop routing approach. JCR prolongs the network life compared with BSC.

The EEHC (Energy-efficient Heterogeneous Cluster) [25] scheme for wireless sensor networks assigns a weighted probability to each and every node. Based on the probability value, nodes become a CH.EEHC outperforms leaching in terms of network life extension. BCDCP , EDFCM is a stable election protocol designed with an energy dissipation forecast method for clustered heterogeneous wireless sensor networks. It is a self-adaptive clustering routing protocol, with CH selection done using a one-step energy consumption forecast method. The network's stability is maintained by calculating the energy of each node in each round. EDFM balances energy utilisation better than conventional routing protocols and prolongs the lifetime of networks. The Algorithm for Cluster Establishment (ACE) [27] selects the CH by migrating to the existing clusters. It is scale-independent and does not require geographic capability for node location. ACE[28] is fast, robust against packet loss and node failure, and good in terms of communications. Base Station-Initiated Clustering resolved base station location issues and provided an efficient routing mechanism for heterogeneous wireless sensor networks. ZREECR [29] deals with node energy consumption based on initial energy and message size. The overall network area is subdivided into smaller zones based on the network size and transmission range. Based on the sink location, clusters will be formed and are usually located at the centre of the network. ZREECR balances the energy consumption of all network nodes and performed slightly worse than REECR. DMAC [30].

Performance Evaluation of the Protocols:

Link Heterogeneity						
Protocol Name	**Bandwidth/latency**	**Single /Muti hop**	**Through put**	**Service Discovery**	**Path Loss Rate**	**RELAY NODE**
LEACH & its Variants	AVERAGE	Multi-Hop	High	MEDIUM	LOW	NO
DMAC	LOW	MULTI-HOP	HIGH	HIGH		YES
SLDMAC	LOW	MULTI HOP	LOW			YES
PEGASIS	LOW	Multi-Hop				YES
C4SD		Multi-Hop		LOW		YES

Computational Heterogeneity			
Protocol Name	**Cluster Stability**	**Packet Loss Rate**	**Level of heterogeneity**
BCDCP	HIGH	LOW	One
EDFCM	HIGH	LOW	Three
BASE STATION INTIATED CLUSTERING	LOW	HIGH	Two
ZREECR	LOW	HIGH	Two
EDFM	MODERATE	MEDIUM	Two
BSIDR	LOW	HIGH	Two

Energy Heterogeneity				
Protocol name	**Residual energy**	**no of alive nodes**	**Nodes Send to Sink**	**Throughput**
SEP & Its Variants ()	HIGH	HIGH	GOOD	HIGH IN E-SEP
DEEC & its Variants	MEDIUM	HIGH IN EDEEC	GOOD	HIGH IN EDEEC
LESCA	HIGH	HIGH	GOOD	MEDIUM
LEACH-E	MEDIUM	HIGH	GOOD	MEDIUM
LEACH-C	LOW	LOW	POOR	LOW

DECSA	LOW	LOW	POOR	LOW
E2C	MEDIUM	MEDIUM	very good	HIGH
AM-DICNT	HIGH	HIGH	very good	MEDIUM
IAM-DICNT	HIGH	HIGH	very good	HIGH
DCCNT	HIGH	HIGH	very good	High
JCR	HIGH	HIGH	very good	High
EDFCM	Low	MEDIUM	GOOD	MEDIUM
DEBC	MEDIUM	MEDIUM	GOOD	GOOD
C4SD	Low	Low	GOOD	Low
DEECIC	NA-	NA-	NA-	NA-
EHE-LEACH	NA-	NA-	NA-	NA-
WBCHN	HIGH	HIGH	GOOD	MEDIUM

3. Conclusion

The research survey carried out on the heterogeneity of wireless sensor nodes and their corresponding network protocols the heterogeneity of the sensor nodes is designed and implemented by three metrics, namely linkage, energy, and computation. Link heterogeneity is useful for multichip data transfer in large-scale WSN to achieve a higher reception success rate. Due to unwanted obstacles or events, nodes lose links quickly, causing high congestion in the network. Surge reliability is used to maintain link stability and the quality of the network to achieve reliable data transfer. Survey results state that when nodes are less than 3 meters apart, the reception success rate is high and gradually decreases as the distance is increase. Efficient Link Heterogeneity addresses the routing and data transfer issues of context-aware HWSN applications. The existing link heterogeneity protocols did not address all types of dynamic events fired in the network environment. Energy heterogeneity is useful to prolong the network's life span by calculating the nodes' residual energy in each round. To prolong the network life, heuristic techniques are used to develop efficient cluster head election and cluster formation approaches to save the energy of nodes. LEACH, SEP, and DEEC are some of the popular protocols to maintain energy efficiency. Computational heterogeneity is useful to achieve minimum power consumption and improve the bandwidth of the network.

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