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ENERGY EFFICIENT CHARGING TECHNIQUE USING RADIO FREQUENCY (RF) FOR WIRELESS SENSING NODES IN UNTIDY AREAS

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Article Info

Abstract

Wireless Sensor Networks (WSNs) are widely used in various areas, including medical, battlefield, agricultural, industrial, and defence automation. In recent decades, numerous research studies have been conducted successfully in this area. However, after a thorough study of the recent work, it is concluded to more improve the power feeding and accuracy of the constraint nodes. This research focuses on the power consumption of sensor nodes, aiming to prolong their lifespan, especially in challenging environments such as untidy areas, mountains, hills, or underwater scenarios. In such an environment, the sensing capabilities of sensor nodes become weak and ultimately increases the data lost due to the non-availability of continued energy/power sources. This work aims to propose the technique to raise the ability of power consumption, the operational lifespan of each sensor, and the efficient selection of cluster heads. It fully concentrated on the signal of Radio Frequency which is transmitted by the RF transmitter and performs modulation on power consumption to enhance the variable energy for sensor nodes ultimately. Also, with the optimal cluster heads, the data is routed towards Base Station. RFHC (Radio Frequency based on harvesting cluster head) protocol is being proposed with a simulation scenario, compared with other standard solutions in terms of varying nodes. Simulation results show that RFHC improves overall performance by 25.3% over LEACH, 78% over LEACH-C, and 78.5% over Stat-Clus.

Keywords:
Energy Efficient, Radio Frequency (RF), Wireless Sensing, Charging Technique, Wireless Sensor Networks (WSN).

1. INTRODUCTION

WSNs are crucial and widely utilized due to their exceptional capabilities and efficiencies.) Wireless Sensor Networks have become indispensable in various fields, including (Security & Surveillance of Smart Houses, Environmental changes monitoring, etc.) (França et al. 2020; Radhappa et al. 2018). It is used not only in the plan surface but also used in remote areas, non-accessible and untidy areas, like mountains, under the water, underground, forests & snowy areas. WSNs operate in diverse environments, from plan surfaces to remote and inaccessible areas. WSN nodes have 4 MHz of its processing frequency, 4KB of RAM for storage, and the distance of short transmission about 30 meters in Communication. Wireless sensing nodes possess limited processing power, storage, and transmission capabilities, operating on RF frequency. For increasing the energy of each node in WSN and its lifetime, the energy harvesting techniques are very important and used widely with best operations. Energy harvesting techniques, such as (thermodynamics techniques, vibration, thermal, Radio Frequency (RF), and solar), are essential for maintaining node lifetime and accuracy in WSN (Tang et al. 2018; Ghomian & Mehraeen. 2019).

Several studies (Choi et al. 2020; Quwaider. 2017; Al Shehri. 2017) have investigated the monitoring of Wireless Sensing Nodes and surveillance cameras for security purposes, leveraging a single link to interconnect various surveillance equipment, including (single board computer memory (SBC) and remote alarming system via remote buzzing for fire and security breach). These systems enable features like (smoke deductive early warning system on SMS to your handset) and real-time video capture. The collected data is then uploaded on the FTP web server and saved for later access across the globe. This research focuses on connecting devices to a single network with high accuracy. Previous research (Ramya et al. 2016) has emphasized the importance of (energy harvesting, energy transferring, and energy conservation) to maintain node functionality. Another study (Aoudia et al. 2016) discussed power management in Energy Harvesting Wireless Sensor Networks (EH-WSNs), proposing a dynamic energy harvesting approach that prevents power failures. The authors also introduced Fuzzyman, a power manager fuzzy switch scheme, which demonstrated efficiency in harvested energy management. Researchers have proposed various methods to optimize energy consumption in WSNs to ensure hierarchical efficient routing protocols (Bansal et al. 2014) with effective management of energy consumption. A comparative analysis of LEACH and PIGASIS HIERARCHAL protocol demonstrated the effectiveness of hierarchical class protocols in achieving stability, scalability, and energy efficiency. In (Ren et al. 2015), many approaches have been discussed for clustering and enhance energy efficiency for constrained nodes. Furthermore, zone-based energy-efficient hierarchal clustering (ZEEHC) protocol (Kaur & Mittal. 2016) has been designed to divide the network into limited zones, increasing node lifetime. They have investigated the performance of WSNs, highlighting their potential for routing protocol and approving ability of to maintain network lifetime. Additionally, researchers have explored BLOAD mechanism (Azam et al. 2017) to optimize node network period stability by adapting power fractions in various simulation scenarios. It logically adjusted the transmission range of sensors and uniform distributes the data fractions between neighboring nodes of next hop.

2. Material and Methods

In WSNs, power management is a significant challenge, particularly in harsh environments such as underwater, remote, or untidy areas. The hostile climate substantially impacts network performance by depleting energy resources.

To address this issue, we utilize the Powercast-2110-EVB RF Harvesting Device, a widely adopted tool among researchers for conducting WSN experiments. This device leverages radio frequency (RF) transmission, featuring a transmitter with a wave oscillator and antenna, operating at a frequency of 915 MHz. As the RF wave travels, its strength diminishes with distance. Upon reaching the receiver, the transmitter converts the RF signal to DC current, which charges capacitors or batteries in the nodes, providing a continuous power supply. Notably, smaller capacitors charge rapidly but offer only short-term power, whereas larger capacitors provide longer-term power but charge more slowly.

3. Local Information Processing Drawbacks

The LEACH protocol's approach to selecting cluster heads based solely on local node information has several limitations. By allowing each node to decide whether to become a cluster head probabilistically, there is a risk of multiple cluster heads being chosen in close proximity, leading to increased energy consumption. Additionally, the number of cluster heads formed can fluctuate, deviating from the optimal number in certain rounds. Furthermore, the chosen cluster head may be located near the network's edges, requiring adjacent nodes to expend more energy to transmit data. Moreover, each node must perform threshold calculations and generate random numbers for every round, consuming valuable CPU cycles.

The proposed system involves attaching a Powercast device to each node in the Wireless Sensor Network (WSN), depending on the hardware module used for the network or individual nodes. The technique then introduces a clustering method for WSN nodes, which includes efficient selection of cluster heads and next-in-line cluster heads. When the voltage signal reaches a threshold value of 1.2V, a booster circuit generates an output pulse signal ranging from 1.2V to 3.3V. This extracted energy enables uninterrupted power supply to the network, ensuring optimal performance. Notably, the Powercast device features a unique power management system, which ceases operation and enters sleep mode upon task completion. This approach enhances the stability of the deployed network depicted in Figure 1, and facilitates data retrieval for application users connected to the base station. Figure 2 shows the schematic interaction among sensing devices, base station, and cluster heads, integrating the capabilities of RF energy harvesting. In (De & Singhal. 2012) the author determined practical vision about the said technology and available products by Powercast Inc. (Pittsburgh, PA, USA); with charging kits and for academic & research communities. The P1110-B is designed to charge an external storage element, including batteries and capacitors for each node in the WSN.

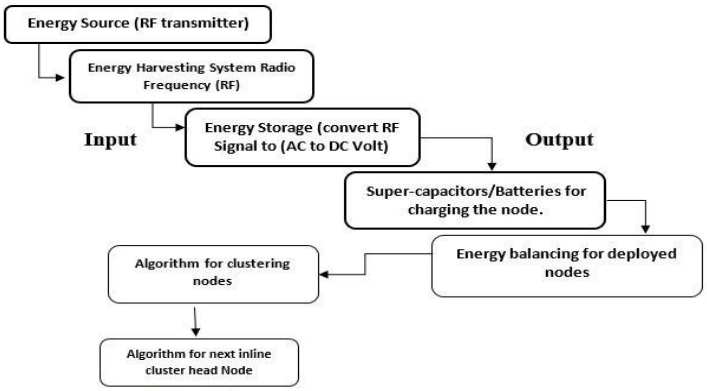

Figure- 1 Illustrates the block diagram of the proposed methodology.

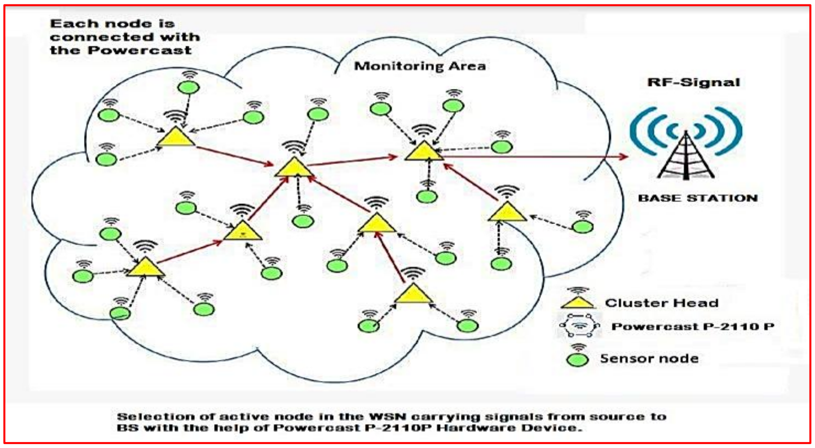

Figure- 2: Schematic diagram of the proposed methodology.

The proposed methodology provides RF frequency to convert DC power, increasing energy efficiency and prolonging WSN network lifetime. It generates clusters based on received signal strength, assigns unique addresses to prevent multiple cluster membership, and uses a cluster head selection algorithm to send data or detect intrusion activity to the base station.

4. NORMALIZATION PARAMETERS FOR CLUSTER HEAD SELECTION.

In this section, the process of normalization is explained to select the role of cluster heads among candidate nodes. It is based on the following factors.

1. Battery Power (BP_i) = Remaining battery power of node i
2. LEACH check= Node close to the base.
3. D_{BS} = Distance from Base
4. D_c = Distance from centroid
5. $MaxCoverage_{Limit}$ = Maximum coverage area of node

Each potential contestant node i for the cluster head is assigned a weight based on its battery power, distance, and coverage area factors, as shown in Equations 1 and 2.

$$BP(CH_i) = (BP_i) \quad (1)$$

$$Distance\_Weight(CH_i) = \frac{\frac{((D_{BS}+D_C)-MaxCoverage_{Limit})}{MaxCoverage_{Limit}-1}\times 100}{2} \quad (2)$$

In this study, we give equal importance to both battery power and the distance weightage of the node, as shown in Equation 3.

$$CH_i = \frac{(BP_i)}{2} + \frac{\frac{((D_{BS}+D_C)-MaxCoverage_{Limit})}{MaxCoverage_{Limit}-1}\times 100}{2} \quad (3)$$

The cluster head role is rotated among member nodes, and each node stores information in its local table, which is updated when a new cluster head is selected. To balance battery power and stabilize system performance, the proposed technique introduces the concept of a next-in-line cluster head, which is selected based on the RSSI range and battery power consumption. The methodology consists of three main steps: (1) using RF frequency to charge WSN nodes, (2) clustering nodes using RSSI, and (3) selecting cluster heads and next-in-line cluster heads to prolong network lifetime and balance energy resources. The process continues until data is transmitted to the base station, either through direct communication or multi-hop paradigm.

5. Experimental Setup

The proposed RFHC protocol is compared to LEACH, LEACH-C, and Stat-clus schemes in terms of average energy consumption and network throughput. The comparison was done using Network Simulator-2 software, and the simulation parameters are presented in Table 1.

Table 1: SIMULATION CONFIGURATIONS

S/NO.	Parameters	Values
1	Network size	670 × 670 meters
2	Initial energy of nodes	200 Centijoules (2 Joules)
3	Number of Base Station	1
4	Pause Time	1 Seconds
5	Random Seed	1
6	Traffic Type	Constant Bit Rate (CBR)
7	Simulation	20
8	Packet Size	512 Bytes
9	Mobility Speed	3 meters/second
10	Number of Nodes	Varying 20 to 150
11	Simulation Time	1000 Seconds
12	Mobility Model	Random Way Point

Average Energy Consumption

Energy consumption means the Total Energy consumed by the network to perform transmission, reception and data aggregation as shown in Equation 4.

$$\text{Energy Consumption} = E\_Transmit + E\_Reception + E\_Data\_Aggregation \quad (4)$$

6. RESULTS

In this section, we represent the analysis of the data collected during the evaluation and evaluate the performance results. In the first part of the analysis, data were gathered from standard LEACH, LEACH-C, Stat-Cluster, and our proposed RFHC by measuring the average energy consumption of nodes in different trials. The trials contained the following aspects:

- **i.** In the first trial **20** nodes.
- **ii.** In the second trial **40** nodes.
- **iii.** In the third trial **60** nodes.
- **iv.** In the fourth trial **80** nodes.
- **v.** In the fifth trial **100** nodes.

Figure 3: The Average Energy Consumption of 20 Nodes Scenario represents the comparison with LEACH, LEACH–C, Stat-Clus, with RFHC. LEACH average consumption energy 28.8, LEACH-C 45.13, Stat-Clus consumed 44.09, while our RFHC consumed the minimum energy of 14.49.

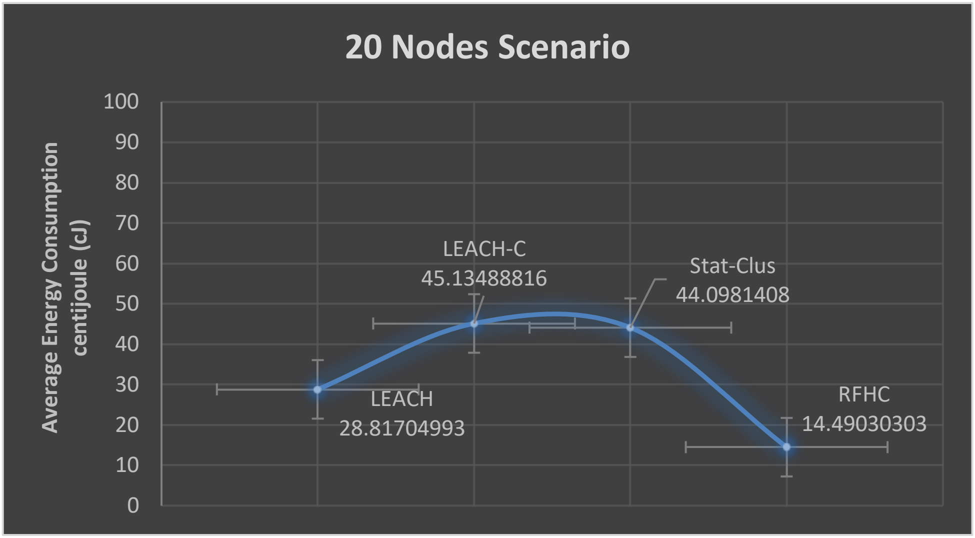

Figure-3: Average Energy Consumption of LEACH, LEACH-C, Stat-Clus and RFHC in scenario of 20 nodes

Figure 4: The average energy consumption of 40-nodes scenario represents a comparison with LEACH, LEACH-C, Stat-Clus, and RFHC. The average consumption energy of LEACH is 30.4, LEACH-C is 86.2, Stat-Clus is 85.09, while our RFHC consumes less energy at 14.9.

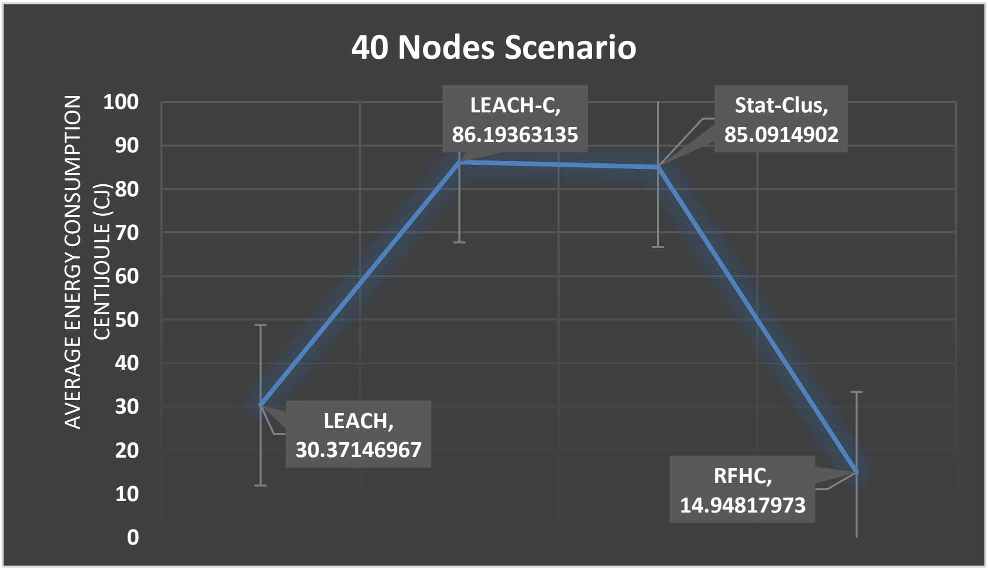

Figure-4: Average Energy Consumption of LEACH, LEACH-C, Stat-Clus and RFHC in scenario of 40 nodes

Figure 5: Average Energy Consumption of 60 Nodes Scenario represents the comparison with LEACH, LEACH–C, Stat-Clus, with RFHC. LEACH average consumption energy 30.9, LEACH-C 153.9, Stat-Clus consumed 153.7 while our RFHC consumed less energy of 28.5.

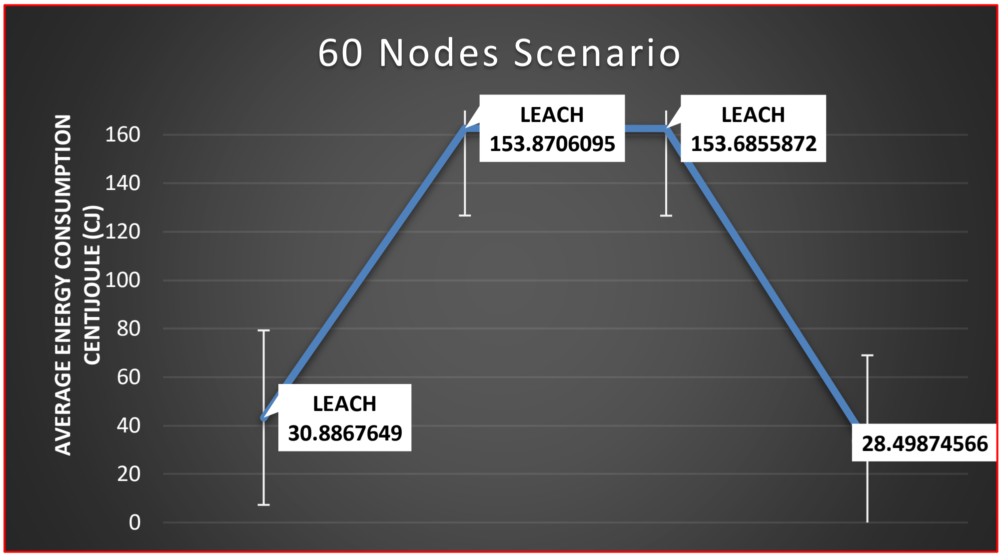

Figure-5: Average Energy Consumption of LEACH, LEACH-C, Stat-Clus and RFHC in scenario of 60 nodes

Figure-6: Average Energy Consumption of 80 Nodes Scenario represents the comparison with LEACH, LEACH–C, Stat-Clus, with RFHC. LEACH average consumption energy 58.06, LEACH-C 200, Stat-Clus consumed 199.2 while our RFHC consumed less energy of 44.2.

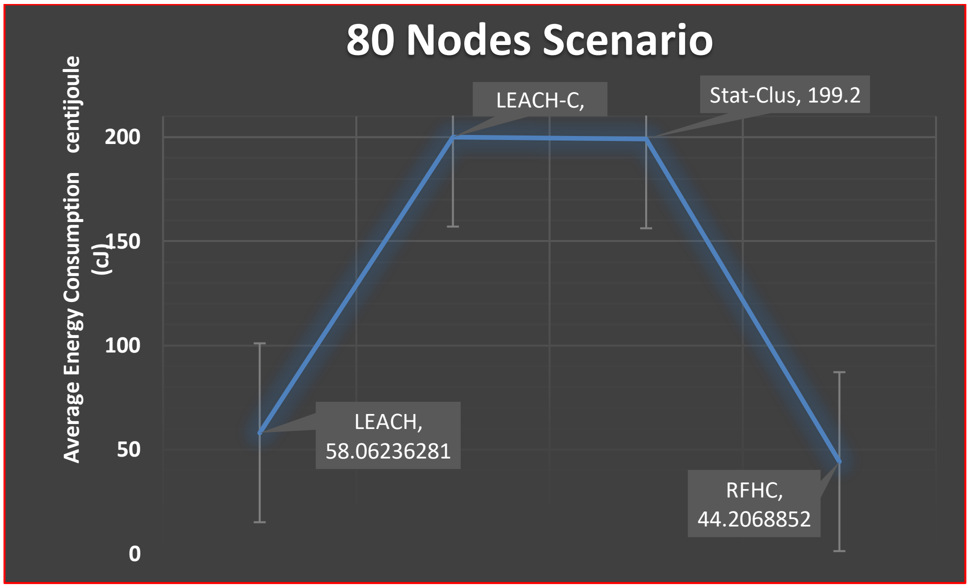

Figure-6: Average Energy Consumption of LEACH, LEACH-C, Stat-Clus and RFHC in scenario of 80 nodes

Figure 7: Average Energy Consumption of 100 Nodes Scenario, representing a comparison with LEACH, LEACH-C, Stat-Clus, and RFHC. LEACH average consumption energy 58.1, LEACH-C 200.0, Stat-Clus consumed 199.2, while our RFHC consumed less energy of 44.2.

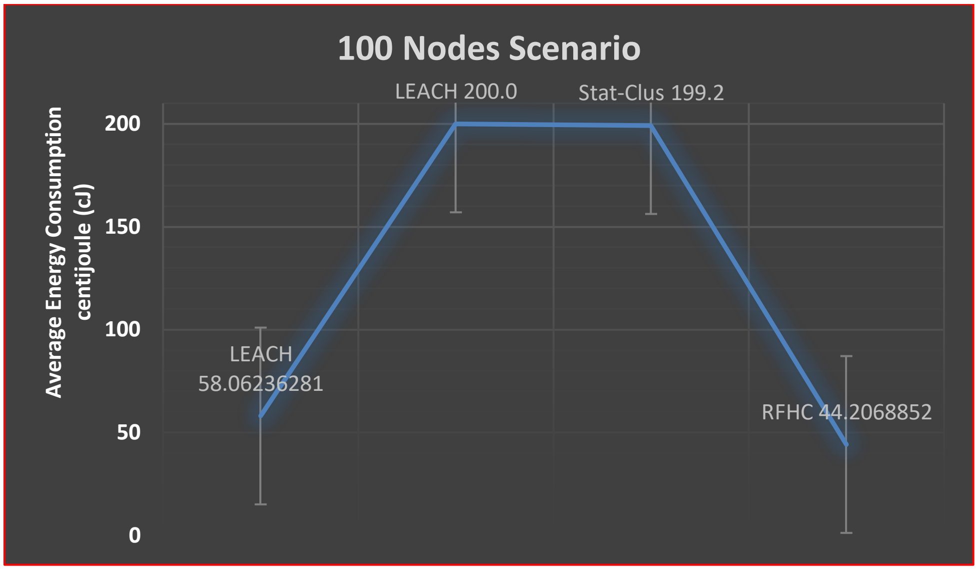

Figure-7: Average Energy Consumption of LEACH, LEACH-C, Stat-Clus and RFHC in scenario of 100 nodes.

Figures (8-12) illustrated the performance of RFHC with LEACH, LEACH-C and Stat-Clus approaches in terms of network throughput under varying nodes from 20 to 150.

	20 NODES			
	LEACH	**LEACH-C**	**Stat-Clus**	**RFHC**
AVERAGE	**12340.7**	**6136.0**	**11940.7**	**12629.8**

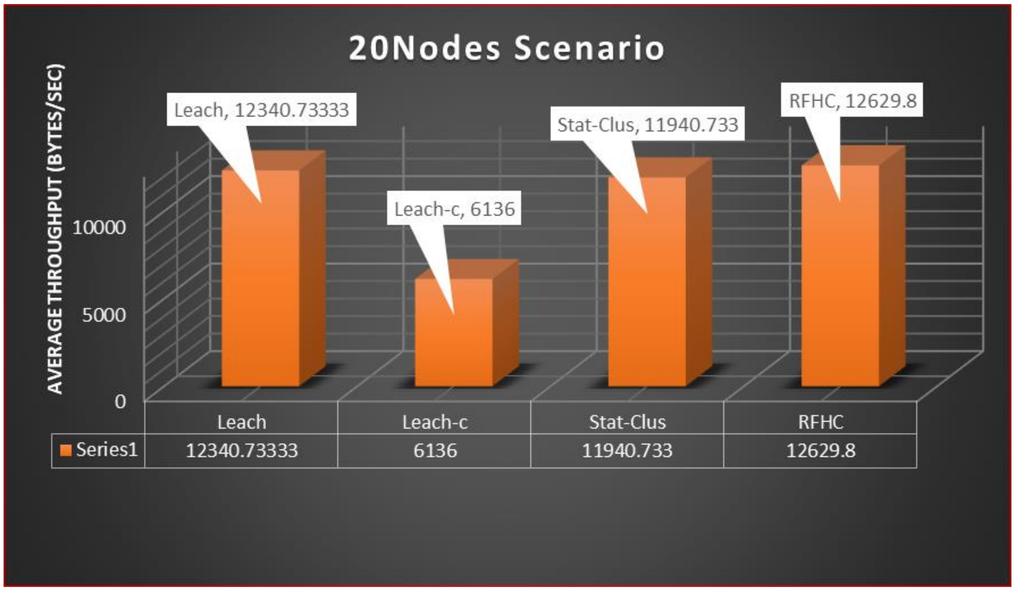

Figure-8: Average Throughput of LEACH, LEACH-C, Stat-Clus and RFHC in scenario of 20 nodes.

60 NODES			
LEACH	LEACH-C	Stat-Clus	RFHC
14301.9	6676.0	12216.1	16301.6

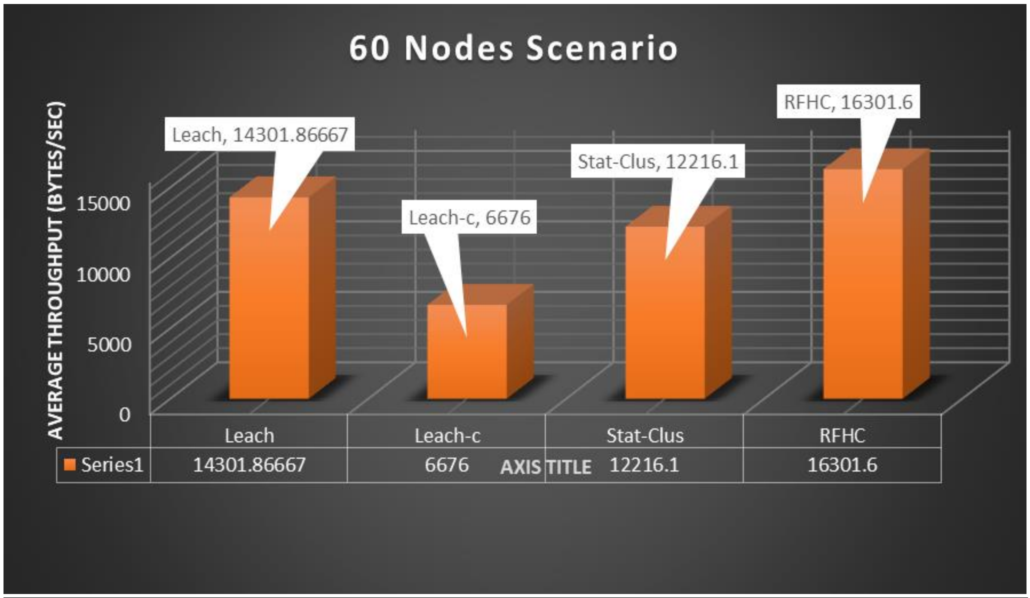

Figure-9: Average Throughput of LEACH, LEACH-C, Stat-Clus and RFHC in scenario of 60 nodes.

90 NODES			
LEACH	LEACH-C	Stat-Clus	RFHC
17719.4	12458.5	12533	19719.4

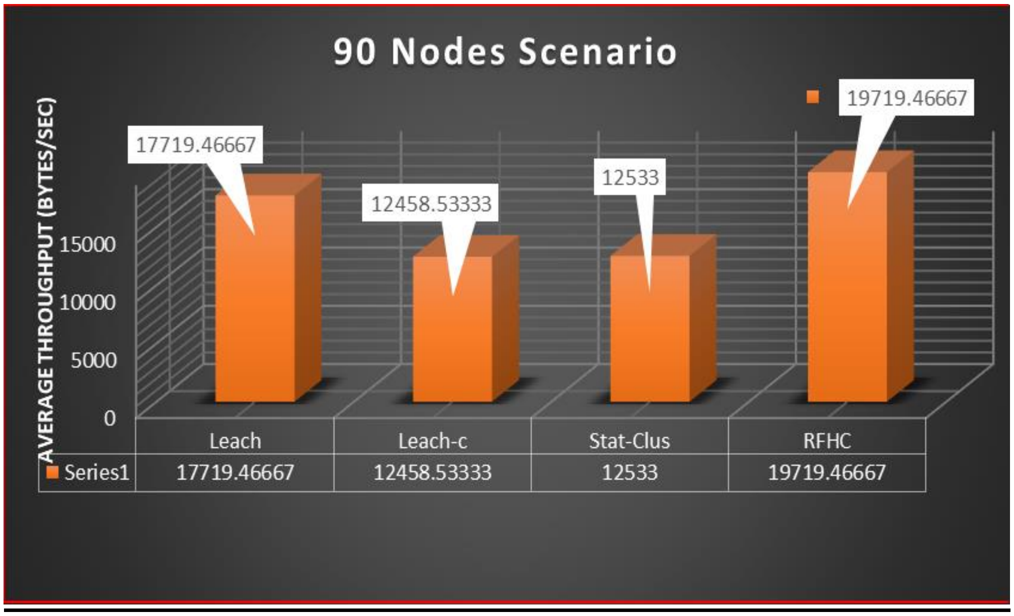

Figure-10: Average Throughput of LEACH, LEACH-C, Stat-Clus and RFHC in scenario of 90 nodes

120 NODES			
LEACH	LEACH-C	Stat-Clus	RFHC
20081.1	18970.7	19080	28744

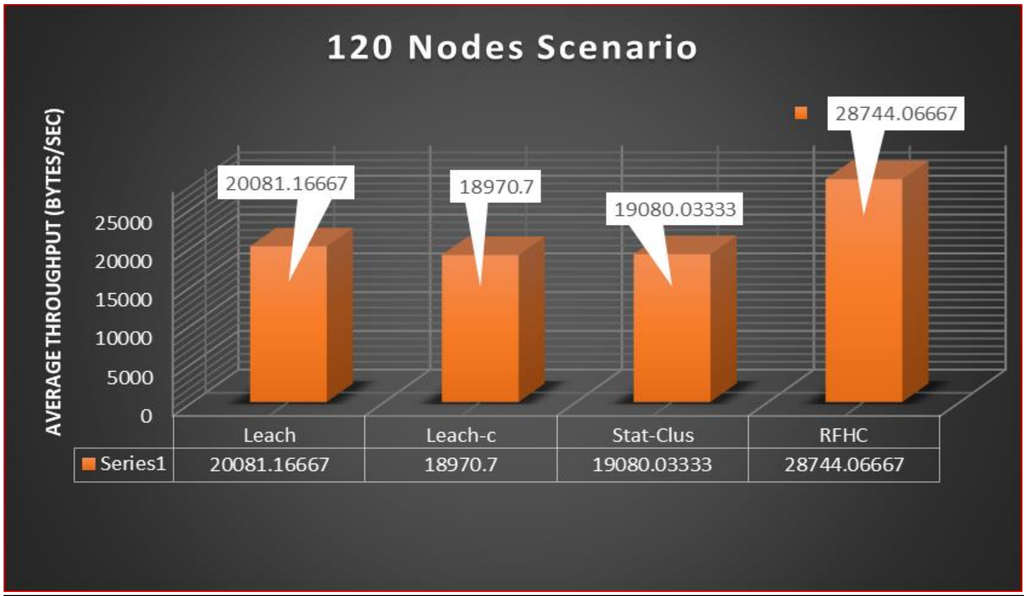

Figure-11: Average Throughput of LEACH, LEACH-C, Stat-Clus and RFHC in scenario of 120 nodes

150 NODES			
LEACH	Leach-c	Stat-Clus	RFHC
21265.5	19842.3	20265.5	24785.8

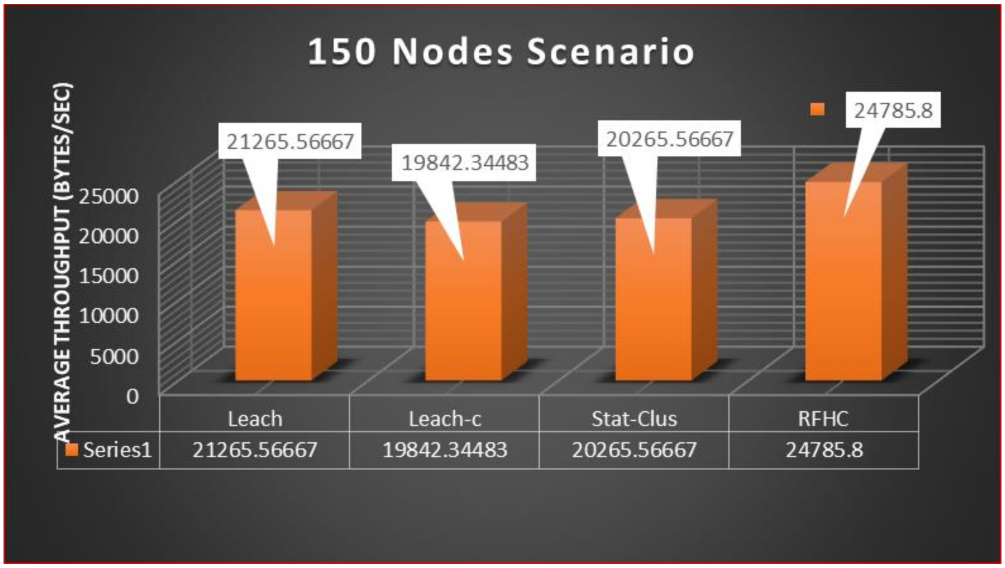

Figure-12: Average Throughput of LEACH, LEACH-C, Stat-Clus and RFHC in scenario of 150 nodes

7. CONCLUSION

This study concludes that the proposed Radio Frequency Based Harvesting Clustering (RFHC) protocol reduces overall network performance by 25.3% compared to LEACH, 78.06% compared to LEACH-C, and 78.5% compared to Stat-Clus. By normalizing the selection cluster heads, the proposed protocol also enhances the network throughput and stability of the constrained environment. The rotation of cluster heads and the provision of an energy harvesting solution make it more feasible to untidy conditions, thereby increasing the reliability of nodes in critical circumstances. RFHC improves network performance and stability with increasing node density. Future research directions include investigating statistical probability for selecting multiple next-in-line cluster heads, incorporating node location, and optimizing Powercast device usage for improved efficiency.

8. ETHICAL STATEMENT

No ethical issues were raised during the course of study.

9. AKNOWLEDGEMENT

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10. AUTHORS` CONTRIBUTION

Concept: MSK, KH. Plan: MSK, KH. Data analysis: NA, FNK, ZJ, SK. Writing, review and editing: MSK, KH, NA, FNK, ZJ, SK. All authors have reviewed and consented to the final version of the manuscript for publication.

11. CONFLICT OF INTEREST

The authors declare no conflict of interest.

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