A Novel Routing Protocol For Wireless Sensor Networks With Improved Energy Efficient LEACH

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Abstract: **Wireless Sensor Networks (Wsns) Have Been Widely Considered As One Of The Most Important Technologies For The Twenty-First Century. A Typical Wireless Sensor Network(WSN) Used For Environmental Condition Monitoring, Security Surveillance Of Battle-Fields, Wildlife Habitat Monitoring, Etc. Cluster-Based Hierarchical Routing Protocols Play An Essential Role In Decreasing The Energy Consumption Of Wireless Sensor Networks (Wsns). A Low-Energy Adaptive Clustering Hierarchy (LEACH) Has Been Proposed As An Application-Specific Protocol Architecture For Wsns. However, Without Considering The Distribution Of The Cluster Heads (Chs) In The Rotation Basis, The LEACH Protocol Will Increase The Energy Consumption Of The Network. To Improve The Energy Efficiency Of The WSN, We Propose A Novel Modified Routing Protocol In This Paper. The Newly Proposed Improved Energy-Efficient LEACH (IEE-LEACH) Protocol Considers The Residual Node Energy And The Average Energy Of The Networks. To Achieve Satisfactory Performance In Terms Of Reducing The Sensor Energy Consumption, The Proposed IEE-LEACH Accounts For The Numbers Of The Optimal Chs And Prohibits The Nodes That Are Closer To The Base Station (BS) To Join In The Cluster Formation. Furthermore, The Proposed IEE-LEACH Uses A New Threshold For Electing Chs Among The Sensor Nodes, And Employs Single Hop, Multi-Hop, And Hybrid Communications To Further Improve The Energy Efficiency Of The Networks. The Simulation Results Demonstrate That, Compared With Some Existing Routing Protocols, The Proposed Protocol Substantially Reduces The Energy Consumption Of Wsns.**

Keywords: **Wireless Sensor Networks (WSN); Low-Energy Adaptive Clustering Hierarchy (LEACH); Cluster Heads (CHs); Improved Energy Efficiency -LEACH (IEE-LEACH);**

INTRODUCTION

The Manual Operation of the Network Is Highly Difficult, Which brings Some Challenges Regarding The Application Of Wsns [4–6]. To Remedy These Drawbacks, The efficient Use Of The Battery Energy Of Sns Should Be Considered As A Primary Goal When Researchers design Protocols And Hardware Architectures [7]. Therefore, Several Routing Protocols Have Been proposed To Render the Sensor Network More Energy Efficient [8, 9].

The Cluster Formation and Various Communication Modes of Transmitting Data Have Been The Most emphasized Approaches. In General, Compared With Non-Clustering Protocols, Cluster-Based Routing protocols Can Efficiently Use the Sns in the Network [10]. A Cluster Leader, Called The Cluster Head (CH) Is In Charge Of Eliminating The Correlated Data That Can Decrease The Final Data Volume. Afterwards, The CH Will Transmit The Aggregated Data To The BS [11–13]. In Cluster-Based Routing Protocols, Sns Are Divided Into Many Clusters to Decrease energy Consumption for Long Distance Communication.

The Clustering Can Minimize The Overall Energy Consumption And Balance The Nodes' Workload, Which Is Caused By The Large Difference In The Energy Depletion Between The Chs And Other Nodes. Therefore, Clustering Is An Energy-Efficient Solution For Increasing Network Longevity And Improving Energy Efficiency. Moreover, Most Clustering Protocols Adopt Optimal CH Selection To Avoid The Premature Death Of The Sns And Further Extend The Lifetime Of The Network [14–16].

Many Clustering Models Like Hierarchy Clustering Protocol, Scalable Energy-Efficient Clustering Hierarchy (SEECH), A Learning Automata-Based Multilevel Heterogeneous Routing(LA-MHR) Scheme, LEACH-Mobile(LEACH-M) Protocol, Optical LEACH (OLEACH) Protocols, LEACH-Xmpv protocols, Etc., These Protocols Aim To Merely Distribute The Energy Consumption Between The CH And Its Assistant At The Beginning Of The First Round. This Distribution Will Result in a Reduction In The network Lifetime.

To Overcome The Drawbacks Of Conventional Methods And Further Prolong The Lifetime Of Wsns, We Propose A Novel Improved Energy-Efficient LEACH (IEE-LEACH) Routing Protocol In This Paper.

In The Proposed Protocol, The Threshold Setting Introduces Four Parameters Including The Initial Energy of Nodes, Residual Energy Of Nodes, Total Energy Of The Network, And Average Energy Of The Network.

In The Proposed IEE-LEACH Protocol, The Node Closer to the BS than the CH Does Not Take Part in The cluster Formation. Thus, The Protocol Can

Balance The Energy Load And Decrease The Energy Consumption.

Furthermore, the Proposed IEE-LEACH Protocol Compares the Energy Consumption of Single Hop And multi-Hop Communication Modes in the Data Transmission Phase. The Communication Mode With The least Energy Consumption Will Be Adopted. Therefore, The Proposed Approach Decreases the Overall communication Cost and Significantly Improves the Network Lifetime.

IMPLEMENTATION MODEL

***Energy Consumption Model*:** The Radio Hardware Energy Consumption Model Is Shown In Figure 1. The Radio Electronics And The Power Amplifier Are Run By The Transmitter, And The Radio Electronics Are Also Run By The Receiver. Both Operations Consume Energy. The Energy Consumption Model Adopts The Free Space Channel With D^2 Energy Consumption And The Multipath Channel With D^4 Energy Consumption Depending On The Distance Between The Transmitter And The Receiver [16–20]. Thus, To Transmit A Packet Of M Bits At A Distance D, The Energy Consumption Is Given By The Following Equation:

$$E_{TX} = \begin{cases} m * E_{elec} + m * \varepsilon_{fs} * d^2 & d \le d_0, \\ m * E_{elec} + m * \varepsilon_{mp} * d^4 & d > d_0, \end{cases}$$

Where D_0 Can Be Calculated By $D_0 = \sqrt{\varepsilon_{fs} / \varepsilon_{mp}}$. The Electronic Energy E_{elec} Is Used Depending On The Digital Coding, Modulation, Filtering, And Spreading Of The Signal. The Specific Energy Function Of Receiver Is The Reverse Of The Transmitter, As Depicted In Figure 1. The Parameters E_{fs} And E_{mp} Are The Amplification Factors Of The Transmitting Circuit When $D \le D_0$ And $D > D_0$, Where D_0 Is Threshold. To Receive A Message Of M Bits, The Receiver Expends Energy As Follows: $E_{RX} = M * E_{elec}$.

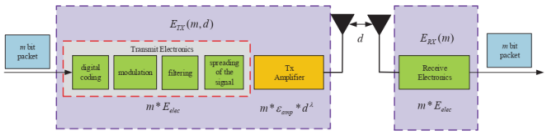

Fig. 1: Radio Energy Dissipation Model

***LEACH Protocol*:** The LEACH Protocol Plays An Important Role In The Field Of Wsns [26,27]. In The CH Election phase, The CH of Every Cluster Compresses the Data collected From the Member Nodes and Then Sends them To the Sink Node [9]. The Mechanism Of selecting The CH Is Determined By The threshold Value$t(N)$ And The Rand Function. The SN Generates A Random Number $M(0 \le M < 1)$. If It Is Satisfied With $M \le T(N)$, The Node Is Elected As The Head Node Of The Cluster For The Current Round. The Limit value $t(N)$ Is Calculated As Follows:

$$T(n) = \begin{cases} \frac{p}{1-p*(r* \bmod (1/p))}, & n \in G, \\ 0, & \text{otherwise}, \end{cases}$$

Where P Is The Ratio Of The Total Number Of chs To Sns And Represents The Probability Of Each Node becoming CH During Round 0 [4],R Is The Current Number Of Rounds, G Is The Set Of The Nodes That will Not Be Elected As A CH In A Recent $1/P$ Round, And Mod(·) Denotes The Modulus Operator. The power Amplifier energy Consumption to Total Energy consumption Ratio versus the Distance Is Shown In Figure 2. The Power Amplifier Energy Consumption to Total Energy Consumption Ratio Can Be calculated by:

$$ratio = \begin{cases} \frac{m*\varepsilon_{fs}*d^2}{m*E_{elec}+m*\varepsilon_{fs}*d^2}, d \le d_0, \\ \frac{m*\varepsilon_{mp}*d^4}{m*E_{elec}+m*\varepsilon_{mp}*d^4}, d > d_0. \end{cases}$$

The LEACH Protocol Adopts the Concept of Clustering and Periodic Data Collection, Which Can reduce The Data Transmission between the Nodes and the BS. Therefore, This Protocol Can Not only reduces The Energy Loss, But Also Can Extend the Network Lifetime. In Addition, The CH Uses The Method of Data Aggregation, Which Can Reduce Correlated Data Locally. This Method can also optimize the amount Of Data in the Network and Reduce Energy consumption. Moreover, The Time Division Multiple accesses (TDMA) Schedule Used by LEACH Allows the Member Nodes to Go into Sleep Mode, And This mechanism Holds Back the Collision between Clusters and Extends the Sensors' Battery Life [28–30].

In Addition, Under The Multipath Fading Channel Model, The Power Amplifier Energy Consumption to Total Energy Consumption Ratio Is About 80% When $D \approx 112$ M. Therefore, Looking towards Real Applications, It is necessary To Develop an Energy-Efficient Protocol to Decrease the Energy Loss of the WSN.

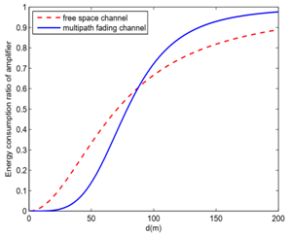

Fig.2: The Power Amplifier Energy Consumption to Total Energy Consumption Ratio.

Improved Energy-Efficient LEACH Protocol: To Decrease the Energy Loss and Increase the Energy Efficiency of the Wsns, We Propose a Novel improved Energy-Efficient LEACH Protocol Called IEE-LEACH in This Section.

Energy Consumption Model Of The IEE-LEACH Protocol: The Energy Consumption Model Of The Proposed IEE-LEACH Protocol Is Introduced In This Section.

Unlike The LEACH Protocol, In Which Nodes With The Same Initial Energy Are Considered, Each SN In the IEE-LEACH Protocol Is Assigned A Different Initial Energy. It Is Assumed That There Are *N* Nodes That

Are Placed In An $L \times L$ Region, And The Proposed IEE-LEACH Protocol Takes Two Models Into Accounts, I.E., The Free Space Model And Multipath Model.

When The BS Is Close To the Nodes, The Energy Dissipated Follows the Free Space Model (D^2 Power loss) [17]. Thus, the Energy Consumption of the CH per Round Is

$$E_{CH} = (\frac{N}{k} - 1) * m * E_{elec} + \frac{N}{k} * m * E_{DA} + m * E_{elec} + m * \varepsilon_{fs} * d_{toBS}^2,$$

Where *K* Is The Number Of Clusters Per Round In The WSN, *N*/*K* Is The Average Node Of Each Cluster, *EDA* Is the Energy Consumption Of The CH Receiving A Message Of 1 Bit, And D^2_{tobs}denotes The Expected Squared distance Between The CH And BS.

Cluster Head Selection Algorithm of the IEE-LEACH Protocol: Although There Are Advantages of Using the LEACH Protocol, It Cannot Guarantee the Current residual Energy of the CH. The Selection of the Threshold *T*(*N*) Used By Conventional LEACH-Based

Protocols Only Consider Whether the Nodes Will Be Selected to Be the CH, Without Considering The node's Energy. Therefore, The Chs Are Randomly Selected, And, If A Node With Less Energy Is Chosen Asch, Then They Will Quickly Die. To Balance the Energy Consumption and Prolong the Network Lifetime, We Propose a New Threshold *T*(*Si*), Which Is Defined By

$$T(s_i) = \begin{cases} \frac{p_i}{1 - p_i(r \bmod (1/p_i))}, & s_i \in G, \\ 0, & \text{otherwise}, \end{cases}$$

Where $S_i$is the Node And I [2][1, *N*]. The Energy Adjustment Parameter $P_i$is Given By

$$p_i = \frac{p * s_i * E_r^i * E_i}{E_t * E_a},$$

Where *P* Is The Proportion Of Selecting The Optimal CH, $E_r^i$is The Current Residual Energy Of The *I*th node, *Ei*is The Initial Energy Of The *I*th Node, *Et* Is The Total Energy Of The Whole Network, And *Ea*is The average Energy Of All Sns In The WSN. It Can Be Seen From Equation That The Initial Energy Of Nodes,

Residual Energy Of Nodes, Total Energy Of The Network And Average Energy Of All Nodes Are All Used to Calculate The Energy Adjustment Parameter.

Cluster Formation Algorithm Of The Proposed IEE-LEACH: Once The Election Of Chs Is Completed, The Chs Will Inform The Other Nodes Of The Information that They Have Become The CH In This Round. To Complete This Function, Each CH Node Will Send An Advertisement Message To All The Other Nodes In The Form Of Broadcast With A Non-Persistent Carrier-Sense Multiple Access (CSMA) MAC Protocol.

Each Member Node Decides Whether To Participate In Cluster Formation, According To The Signal intensity Of The Message That Is Transmitted From The BS And Each CH Node. Since The Symmetric propagation Channel Model Is Used By The Proposed IEE-LEACH Protocol, The Election Of A Cluster head Is Only Related To The Pure Signal Strength [15]. The Stronger The Received Signal Is, The Closer The distance Between Member Nodes To The Sink Node Or The CH Is. Comparing The Distance Of The Nodes to The Chs And That Of The Nodes To The BS, The Nodes Closer To The Base Station Do Not Participate In cluster Formation And Directly Send Data Information To The BS

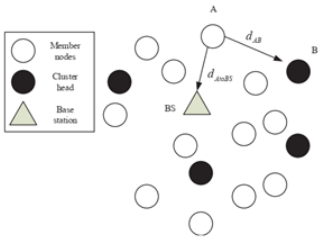

Fig. 3 Cluster Formation

In The Above Figure 3, The Cluster Head In The Network Is Elected And The Cluster Head broadcasts Messages To Other Nodes, The Non-Cluster Head Node A Finds The Nearest Cluster Head B According To The Received Signal Strength, And Calculates The Distance Between Them, I.E., Dab. Figure 3 Shows The Process Of CH Selection And Cluster Formation Of The Proposed IEE-Leach protocol. First, The Related Energy And The Distance To The BS Are Calculated. Then, The Threshold $t(S_i)$ In Each Round Is Determined By Equation (17). Each Node Closer To The CH Needs To Generate A Random Number And Then Compare It With $T(S_i)$. If The Result Is Less Than Or Equal To $T(S_i)$, Then The node Will Be Chosen As The CH. The Distance To CH Is

Calculated. The Nodes Whose Distance Is Closer to The BS Rather Than The CH Will Not Take Part In The Process Of Cluster Formation And Will Directly transmit Data To The BS. Finally, The Transmitted Data Adopt The Method Of Single Hop, Multi-Hop And hybrid Communications.

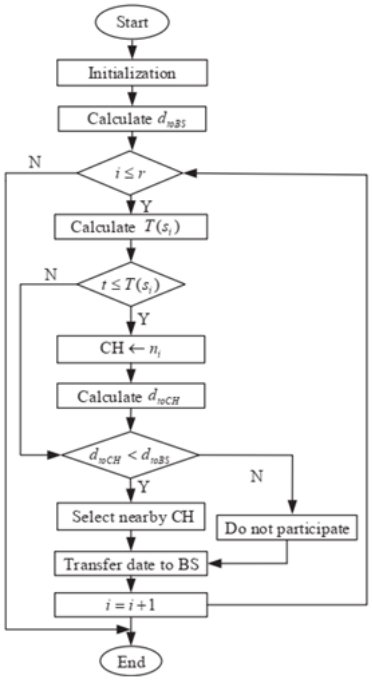

Fig. 4 Block Diagram Of Proposed Protocol

Data Transmission Scheme Of The IEE-LEACH Protocol: To Decrease Energy Consumption, The Radio Network Of The CH And Nodes Is Closed Until The transmission Slot Is Assigned. The Radio Network Of The CH And Nodes That Intend To Send The Data need To Be Activated. After Activating The Nodes, Non-CH Nodes Send The Data To The CH, While The ch Receives These Data And Sends Them To The BS [24, 25]. A Single Data Communication Approach Will increase The Energy Consumption Of The Nodes Because The Best Way To Transfer Data Are To Minimize The distance Between Nodes. Therefore, We Propose A Methodology That Provides A Single Hop, Multi-Hop and Hybrid Communication Network To Minimize The Distance.

It Is Assumed That The Cluster Head Node Transmits Data To BS By (N - 1) Hops And The Distance Of each Hop Is R In The Wireless Sensor Network With The Free-Space Channel Model. Therefore, To Transmit An M-Bit Message, The Energy Consumption For Signal Hop Is Given By

$$\begin{aligned} E_1 &= E_{TX}(m, n \times r) \\ &= m \times E_{elec} + m \times \varepsilon_{fs} \times (nr)^2 \\ &= m \times \left(E_{elec} + \varepsilon_{fs} \times n^2 \times r^2\right). \end{aligned}$$

The Energy Consumption For Multi-Hop Can Be Expressed As

$$\begin{aligned} E_2 &= n \times E_{TX}(m, r) + (n-1) \times E_{RX}(m) \\ &= n \times m \times \left(E_{elec} + \varepsilon_{fs} r^2\right) + (n-1) \times E_{elec} \times m \\ &= m \times \left[(2n-1) E_{elec} + \varepsilon_{fs} \times n \times r^2\right]. \end{aligned}$$

Comparing The Energy Consumption Of Two Communication Modes, If The Energy consumption of a Multi-Hop Is Less Than That Of A Single Hop, I.E.,

$$\begin{aligned} & m \times \left[(2n-1) E_{elec} + \varepsilon_{fs} \times n \times r^2\right] \\ & \quad < m \times \left(E_{elec} + \varepsilon_{fs} \times n^2 \times r^2\right). \end{aligned}$$

$$r > \sqrt{\frac{2E_{elec}}{n\varepsilon_{fs}}}.$$

Then, It Can Be Devised As

Note That E_{elec}= 50 Nj/Bit And # *F S* = 10 Pj/Bit/M2, When *N* = 2, It Can Be Found That *R* >70 M. Therefore, The Energy Consumption Of Multi-Hop Communication Is Less Than That Of Single Hop communication When *R* >70 M. This Mechanism Is Beneficial To The Average Energy Dissipation Of The network And Prolongs The Lifetime Of Network. The Algorithm 1 Of The Proposed Protocol Is Shown Below:

Algorithm

1. *N*-Number Of Nodes, *R*-Number Of Rounds.
2. The First Step Is To Initialize The Network Parameters For WSN.
3. The Second Step Is The Random Deployment Of The Nodes In The Network.
4. The Third Step Is The Deployment Of The BS In The Network.
5. Calculate D_{tobs}
6. For *I*= 1 To *R*
7. $E_a = E_t(1 - R_{\max} r)/N$
8. $Pi = P * N * Eri * Ei/(Et * Ea)$
9. $T(S_i) = P_i/(1 - Pi(R \bmod (1/Pi)))$
10. T=Random Number
11. If ($T \le T(Si)$)
12. CH *Ni*
13. Calculate D_{toch}
14. End If
15. If ($D_{toch} < D_{tobs}$)
16. Select CH And Join The Cluster;
17. Else
18. Nodes Do Not Participate In The Cluster
19. End If
20. Transfer To BS
21. I=I+1
22. Go To Step 6
23. End

SIMULATION RESULTS

In This Section, To Evaluate The Performance Of The Proposed IEE-LEACH Protocol In Thewsn, The Existing LEACH, LEACH-Centralized (LEACH-C) [18], LEACH-M [22], O-LEACH [23],Energy-Efficient LEACH (EE-LEACH) [36], Stable Energy Efficient Network (SEEN) [24], And LEACH-Extended Message-Passing (LEACH-XMP) [25] Protocols Are Used In Comparison In The simulation Experiments. Simulation experiments Were Carried Out Using MATLAB 2014a (Mathworks, Natick, MA, USA). A Wireless Sensor Network System Model Consisting Of 100 Homogeneous Sns [37] Randomly Distributed In 100 M × 100 M Square Area With Different Initial Energies Is Considered. The bs Is Placed At The Coordinate (50, 100). Therefore, The Maximum Distance Between The SN And The Bsis 50p5m (Approximately 111.8 M). We Run The Simulation For 3500 Rounds, And The Value Of The Time interval Between Rounds Is 20 S [4]. Table 1 Shows The Parameter Configurations In The WSN That Are employed In The Simulation.

Table 1. Simulation parameters.

Parameters	Values
E_{elec}	50 nJ/bit
E_{DA}	5 nJ/bit/signal
Transmitter Amplifier (ϵ_{fs}) if $d \leq d_0$	10 pJ/bit/m^2
Transmitter Amplifier (ϵ_{mp}) if $d \geq d_0$	0.0013 pJ/bit/m^4
p	0.05
d_0	87 m
Data Packet Size	4000 bits
Data Packet rate	1 packet/s

Comparison Of The Number Of Cluster Heads: To Demonstrate That It Is Necessary To Consider The Improvement When Nodes Closer To The Bs do Not Participate In Clustering Formation, The Simulation Results Of The Cluster Heads Number For the IEE-LEACH-B And IEE-LEACH Protocols Are Provided In This Section. Unlike The LEACH And iee-LEACH-A Protocols, IEE-LEACH-B And IEE-LEACH Consider The Energy When Selecting The CH.

Thus, IEE-LEACH-B And IEE-LEACH Can Select The Optimal Number Of Cluster Heads. Figure 5 Shows The Number Of Cluster Heads Versus The Number Of Rounds. The Maximum Number of Cluster Heads For IEE-LEACH Occurs After Approximately 700 Rounds, And The Number Of Cluster heads Is Zero After 2600 Rounds. However, The Maximum Number Of Cluster Heads For IEE-LEACH-B occurs In Approximately 500 Rounds, And The Number Of Cluster Heads Is Zero After 2300 Rounds. We find That The Number Of Cluster Heads Extends Up To 2600 Rounds For IEE-LEACH As Compared To2300 Rounds In IEE-LEACH-B, Which Is Due To The Improvement By Which The Nodes Closer To Bs do Not Participate In The Cluster Formation. The Number Of Cluster Heads For IEE-LEACH-A And leach Disappears After 2050 Rounds And 1800 Rounds, Respectively. It Is Obvious That IEE-Leach and IEE-LEACH-B Prolong The Network Lifetime Compared With IEE-LEACH-A And LEACH Because iee-LEACH-B And IEE-LEACH Consider The Energy Adjustment Parameter When Selecting The CH.

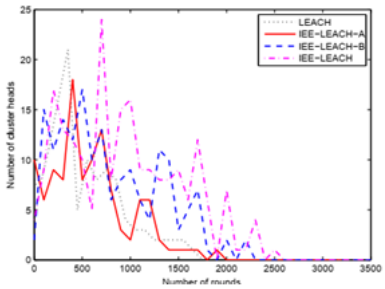

Fig. 5 Comparison Of The No. Of Cluster Heads

In Addition, The Proposed IEE-LEACH Protocol Generates More Chs Than IEE-LEACH-B Throughout the 3500 Simulation Rounds, Which Can Reduce The Energy Consumption Of The WSN Nodes. Thus, The proposed Scheme Is Efficient In Terms Of Saving Energy And Extending The Lifetime Of The WSN.

Comparison Of Total Energy Consumption Of The Network: To Prove That The Performance Of The Proposed Protocol Is Better Than That Of The Existing Protocols,
The Total Energy Consumption Of The Proposed Protocol Is Compared With That Of LEACH, LEACH-M,O-LEACH, LEACH-C [18], EE-LEACH [25] And SEEN, Under The Same Simulation Conditions. Figure 6shows The Total Network Energy Consumption Of The Protocols Versus The Number Of Rounds. As Shown in Figure 6, The LEACH-C Protocol Optimizes The Cluster Head Selection And Consumes Less Network energy Than The LEACH Protocol In The Same Round. The LEACH-C Prolongs The Network Lifetime To 2723 Rounds As Compared To 2267 Rounds Of The LEACH Protocol. In Addition, The LEACH-M Ando-LEACH Prolong The Network Lifetime To 2775 And 2972 Rounds, Respectively. Because The Residual
Energy Of Nodes Is Taken Into Account When Selecting Cluster Heads And The Multi-Hop Communication mode Is Applied In EE-LEACH, The EE-LEACH Further Prolongs The Network Lifetime To 3114 Rounds.
The Proposed IEE-LEACH Protocol Not Only Considers The Residual Energy And Initial Energy Of Nodes when Selecting Cluster Heads, But Also Considers The Average Energy Of All Nodes And The Total Energy Of Network To Further Optimize Cluster Head Selection. Thus, The Total Network Energy Consumption Of the IEE-LEACH Protocol Is Less Than That Of The

Other Protocols In The Same Round, And The Proposed iee-LEACH Protocol Prolongs The Network Lifetime To 3242 Rounds. Moreover, Because Single Hop,
Multi-Hop And Hybrid Communication Modes Are Adopted, And The Nodes Closer To BS Than To The CH Do Not Participate In Cluster Formation, The Proposed IEE-LEACH Protocol Further Extends The Lifetime
Of The Network.

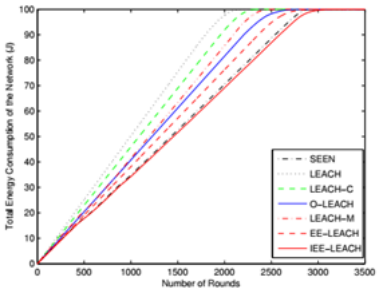

Fig. 6 Comparison Of Total Energy Consumption Of The Network.

CONCLUSION

In This Paper, A Novel Clustering Protocol, Named IEE-LEACH, Is Proposed To Reduce Energy Consumption And Improve The Lifetime Of Wsns. Compared With The Existing Routing Protocols, The Threshold Of The Proposed IEE-LEACH Protocol Introduces Four Parameters: The Initial Energy of Nodes, Residual Energy Of Nodes, Total Energy Of The Network And Average Energy Of All Nodes. This Mechanism Can Improve The Robustness Of The Network And Extend The Network Lifetime. In Addition, The Proposed Protocol Can Optimize The Number Of Chs And Their Distributions, Which Can Effectively Reduce The Energy Consumption. Furthermore, To Decrease The Energy Consumption, We Consider That The Nodes Closer To The BS Do Not Participate In Cluster Formation.

Moreover, The Proposed protocol Employs Single Hop, Multi-Hop, And Hybrid Communications Instead Of A Single Communication Mode In Data Transmission. Therefore, The Proposed Approach Decreases The Overall Communication Cost And Significantly Improves The Network Lifetime. The Simulation Results Demonstrate That The proposed IEE-LEACH Protocol Has A Better Energy Consumption Distribution And Is More Reliable And energy-Efficient Than Some Existing Protocols.

REFERENCES

1. Zhang, D.; Li, G.; Zheng, K.; Ming, X.; Pan, Z. An Energy-Balanced Routing Method Based On Forward-Aware Factor For Wireless Sensor Networks. IEEE Trans. Ind. Inform.. 2014, 10, 766–773.
2. Sobrinho, J.L. Correctness Of Routing Vector Protocols As A Property Of Network Cycles. IEEE Trans. Netw. 2017, 25, 150–163.
3. Mouapi, A.; Hakem, N. A New Approach To Design Autonomous Wireless Sensor Node Based On RF Energy Harvesting System. Sensors 2018, 18, 133.
4. Zhang, Y.; Liu, M.; Liu, Q. An Energy-Balanced Clustering Protocol Based On An Improved CFSFDP Algorithm For Wireless Sensor Networks. Sensors 2018, 18, 881.
5. Bahbahani, M.S.; Alsusa, E. A Cooperative Clustering Protocol With Duty Cycling For Energy Harvesting Enabled Wireless Sensor Networks. IEEE Trans. Wirel. Commun. 2018, 17, 101–111.
6. Li, X.F.; Xu, L.Z.; Wang, H.B.; Song, J.; Yang, S.X. A Differential Evolution-Based Routing Algorithm For Environmental Monitoring Wireless Sensor Networks. Sensors 2010, 10, 5425–5442.
7. Ma, T.; Hempel, M.; Peng, D.; Sharif, H. A Survey Of Energy-Efficient Compression And Communication Techniques For Multimedia In Resource Constrained Systems. IEEE Commun. Surv. Tutor. 2013, 15, 963–972.
8. Shen, J.; Wang, A.; Wang, C.; Hung, P.C.K.; Lai, C. An Efficient Centroid-Based Routing Protocol For Energymanagement In WSN-Assisted Iot. IEEE Access 2017, 5, 18469–18479.
9. Sohn, I.; Lee, J.; Lee, S.H. Low-Energy Adaptive Clustering Hierarchy Using Affinity Propagation For Wirelesssensor Networks. IEEE Commun. Lett. 2016, 20, 558–561.
10. Zhao, Z.; Xu, K.; Hui, G.; Hu, L. An Energy-Efficient Clustering Routing Protocol For Wireless Sensor Setworksbased On AGNES With Balanced Energy Consumption Optimization. Sensors 2018, 18, 3938.
11. Heinzelman, W.R.; Chandrakasan, A.; Balakrishnan, H. Energy-Efficient Communication Protocol For Wirelessmicrosensor Networks. In Proceedings Of The 33rd Annual Hawaii International Conference On Systemsciences (HICSS), Maui, HI, USA, 7 January 2000; Pp. 1–10.
12. Roy, N.R.; Chandra, P. A Note On Optimum Cluster Estimation In LEACH Protocol. IEEE Access 2018, 6,65690–65696.
13. Hosen, A.; Cho, G. An Energy Centric Cluster-Based Routing Protocol For Wireless Sensor Networks. Sensors2018, 18, 1520.

14. Sharma, D.; Bhondekar, A.P. Traffic And Energy Aware Routing For Heterogeneous Wireless Sensor Networks.IEEE Commun. Lett. 2018, 22, 1608–1611.

15. Kaur, T.; Kumar, D. Particle Swarm Optimization-Based Unequal And Fault Tolerant Clustering Protocol Forwireless Sensor Networks. IEEE Sens. J. 2018, 18, 4614–4622.

16. Behera, T.M.; Samal, U.C.; Mohapatra, S.K. Energy-Efficient Modified LEACH Protocol For Iot Application.IET Wirel. Sens. Syst. 2018, 8, 223–228.

17. Obaidat, M.S.; Misra, S. Principles Of Wireless Sensor Networks; Cambridge Univ. Press: Cambridge, UK, 2014.

18. Alnawafa, E.; Marghescu, I. New Energy Efficient Multi-Hop Routing Techniques For Wireless Sensor Networks:Static And Dynamic Techniques. Sensors 2018, 18, 1863.

19. Jadoon, R.; Zhou, W.; Jadoon, W.; Ahmed Khan, I. RARZ: Ring-Zone Based Routing Protocol For Wirelesssensor Networks. Appl. Sci. 2018, 8, 1023.

20. Tarhani, M.; Kavian, Y.S.; Siavoshi, S. SEECH: Scalable Energy Efficient Clustering Hierarchy Protocol Inwireless Sensor Networks. IEEE Sens. J. 2014, 14, 3944–3954.

21. Tanwar, S.; Tyagi, S.; Kumar, N.; Obaidat, M.S. LA-MHR: Learning Automata Based Multilevel Heterogeneousrouting For Opportunistic Shared Spectrum Access To Enhance Lifetime Of WSN. IEEE Syst. J. 2019, 13, 313–323.

22. Kim, D.S.; Chung, Y.J. Self-Organization Routing Protocol Supporting Mobile Nodes For Wireless Sensornetwork. In Proceedings Of The First International Multi-Symposiums On Computer And Computationalsciences (IMSCCS'06), Hangzhou, China, 20–24 June 2006; Pp. 622–626.

23. Yan, L.; Pan, W.; Luo, B.; Li, X.; Liu, J. Modified Energy-Efficient Protocol For Wireless Sensor Networks In Thepresence Of Distributed Optical Fiber Senor Link. IEEE Sens. J. 2011, 11, 1815–1819.

24. Priyadarshi, R.; Singh, L.; Singh, A.; Thakur, A. SEEN: Stable Energy Efficient Network For Wireless Sensornetwork. In Proceedings Of The 2018 5th International Conference On Signal Processing And Integratednetworks (SPIN), Noida, India, 22–23 February 2018; Pp. 338–342.

25. Kang, J.; Sohn, I.; Lee, S. Enhanced Message-Passing Based LEACH Protocol For Wireless Sensor Networks.Sensors 2019, 19, 75.

26. Heinzelman, W.B.; Chandrakasan, A.P.; Balakrishnan, H. An Application-Specific Protocol Architecture Forwireless Microsensor Networks. IEEE Trans. Wirel. Commun. 2002, 1, 660–670.

27. Tümer, A.E.; Gündüz, M. Energy-Efficient And Fast Data Gathering Protocols For Indoor Wireless Sensornetworks. Sensors 2010, 10, 8054–8069.

28. Cheng, H.J.; Su, Z.H.; Xiong, N.X.; Xiao, Y. Energy-Efficient Nodes Scheduling Algorithms For Wireless Sensornetworks Using Markov Random Field Model. Inf. Sci. 2016, 329, 461–477.

29. Hoang, D.C.; Yadav, P.; Kumar, R.; Panda, S.K. Real-Time Implementation Of A Harmony Search Algorithm-Based Clustering Protocol For Energy-Efficient Wireless Sensor Networks. IEEE Trans. Ind. Inf. 2014,10, 774–783.

30. Noh, Y.; Lee, D. Bcops: An Energy-Efficient Routing Protocol With Coverage Preservation. IET Commun. 2017,11, 1933–1940.

31. Miao, H.; Xiao, X.; Qi, B.; Wang, K. Improvement And Application Of LEACH Protocol Based On Genetic Algorithm For WSN. In Proceedings Of The 2015 IEEE 20th International Workshop On Computer Aidedmodelling And Design Of Communication Links And Networks (CAMAD), Guildford, UK, 7–9 September 2015; Pp. 242–245.

32. Singh, S.K.; Kumar, P.; Singh, J. P. A Survey On Successors Of LEACH Protocol. IEEE Access 2017, 5, 4298–4328.

33. Zhang, W.; Wei, X.; Han, G.; Tan, X. An Energy-Efficient Ring Cross-Layer Optimization Algorithm For Wirelesssensor Networks. IEEE Access 2018, 6, 16588–16598.

34. Zheng, H.F.; Guo, W.Z.; Xiong, N. A Kernel-Based Compressive Sensing Approach For Mobile Data Gathering In Wireless Sensor Network Systems. IEEE Trans. Syst. Man Cybern. Syst. 2017, 48, 2315–2327.

