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Review Article

Enhancing Wireless Sensor Networks Routing Protocols Based on Cross Layer Interaction

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ABSTRACT

Wireless sensor networks (WSN) aim to develop a smart city based on sensing environment. The routing protocols of WSN are important to transfer the data in smart cities since sensor nodes have limited power and transmission range. The aim of this research is to enhance WSN routing protocols based on proposed cross-layer interaction between physical layer and network layer also a proposed routing table information of wireless sensor nodes is developed to consider the transmission power of neighbor's nodes to determine the next hop. Cross-layer interaction provides a useful information and effective adaptation for WSN routing protocols. As a result, the proposed routing protocol shows an improvement in network performance when number of intermediate nodes is minimized.

Keywords: Transmission power, wireless sensor node, routing protocol, cross-layer interaction

INTRODUCTION

Wireless sensor networks (WSNs) are under growth and revolution technology in wireless communication since it is the most widely used in smart cities to monitor or to sense the environment.[1,2] There are two types of wireless sensor nodes: Fixed wireless sensor nodes and mobile wireless sensor nodes. In fixed wireless sensor nodes, the nodes are placed in strategic and suitable positions while, in mobile wireless sensor nodes, the nodes are moving and sensing for data collection.[3,4]

Wireless sensor nodes have different applications that are used on land, underground or under water or even in human body and each one of them face different problems and challenges.[5,6]

WSNs can be classified into homogeneous (identical mobile sensor nodes) and heterogeneous (different abilities in node property).[7,8]

The traditional layered approach concerning OSI layered model is not suitable to be used in the mobile wireless sensor nodes design due to the unstable conditions of mobile nodes and wireless links reliability changing. The dynamic environment performance can be improved by considering cross interaction between the layers. These cross-layer interactions provide an exchange information to control the dynamic environment and will allow improvement of network performance.[9]

In this research, an interaction of the physical layer with the network layer is used with different parameters that result in a new physical-network cross-layer design, the new physical-network cross-layer design is elaborated to implement the proposed WSNs routing protocol that will effect and improve network performance.

The main contributions of this research are as follows:

1. Design an efficient routing protocol for WSNs with reliable intermediate nodes that participate in the routing process.
2. The development of a new structure for wireless sensor nodes routing table to consider cross-layer interaction parameters.
3. Minimize the flooding problem when sending information from source to destination.

The remainder of this research will be as follows. We present some of the work related to WSNs concepts; we present the WSN routing protocols based on cross-layer interaction; we evaluate the proposed routing protocol in an urban scenario; and finally, we conclude this work.

LITERATURE REVIEW

In the literature, WSNs use routing protocols with cross-layer interaction to exchange information over wireless sensor nodes to find the path from source to destination.

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Urmila *et al*.[9] proposed a cross-layer design with fewer intermediate sensor nodes and keep others in the sleep mode to maximize the lifetime of sensor nodes and to manage sensor node energy efficiently.

Azlan *et al*.[10] proposed a cross layer design of medium access control MAC and routing, to deliver sensing data from wireless sensor nodes to the sink. When wireless sensor node has data to transmit, it broadcasts the packets to all its neighbors, and this will affect the efficiency of the routing algorithm when flooding problem will happen.

Nabil *et al*.[11] used cross-layer design parameters and exchanged between different layers to ensure efficient use of energy. The stored energy system is used to take decisions for the wireless sensor node state and then in the routing protocol.

MOBILE WIRELESS SENSOR NODE ARCHITECTURE

In general, wireless sensor node architecture includes processing unit, sensing unit, power unit, and transceiver unit while mobile wireless sensor nodes have additional unit relate to positioning, mobility, and power generation, as shown in Figure 1.[12,13] In Jung *et al*.,[14] they developed a sensor node hardware that has processor of 8 MHz, RAM of 8 KB, and storage of 116 KB, the nodes are limited in its specification due to their small size.

UNDERSTANDING TRANSMIT POWER OF WIRELESS SENSOR NODE

In WSNs, use the radio frequency (RF) signals for transceiver unit in wireless sensor nodes. Wireless sensor nodes transceiver operates at the high frequencies and high sampling rates to have specific RF signal processing.[15,16] The distance that a RF signal can be transmitted depends on several hardware factors of wireless sensor nodes, includes:

1. Transmitter power: The power of the signal is measured in dBm (decibels) or mW (mill watts).[17]
2. Cable losses between the transmitter and its antenna and cable losses between the receiver and its antenna.[18,19]
3. Antenna gain of the transmitter and receiving antenna gain.[18,20]
4. Localization of the two antennas: The distance between sender and receiver is important and a better data transfer will be gain when there are no obstacles between both antennas and when both antennas are in line of sight. Free space path loss problem refers to power lost, it happened when energy of RF disperses into the air.[21]
5. Receiver sensitivity: Receiver sensitivity is the minimum signal power level that is necessary for the receiver to accurately decode a given signal it is measured in dBm or mW.[18]

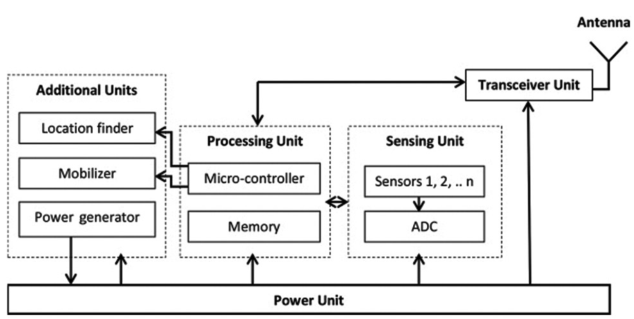

Figure 1: Architecture of the mobile wireless sensor node

PROPOSED WSN ROUTING PROTOCOLS BASED ON CROSS LAYER INTERACTION

Flooding in network is the process of broadcasting packets form one node to all other nodes. In WSN routing protocols, the wireless sensor node broadcasts the receiving packet to discover the route to all neighbors, in which each intermediate wireless sensor node will rebroadcast the packet again that will cause a broadcasting storm and a flooding problem.[22]

Based on these analyzes, we propose a new protocol which interacts between the different layers: Physical layer and network layer, at the aim of: Improving the routing protocol and minimizing the broadcasting storm problem for intermediate nodes.

The transmit power range of the sensor node is a parameter that will be considered from the physical layer to be crossed to network layer. This parameter will affect the performance of the network layer and the proposed routing protocol, as shown in Figure 2. A new routing algorithm is proposed and implemented to send information from source to destination with minimum number of intermediate nodes.

Communication link in wireless sensor node will has unreliable wireless link, unreliable links need to prevent from the use.[19,23]

The wireless sensor node will detect all the neighbor nodes to find next hop to send the information, as shown in Figure 3, where S_0 coverage area and its neighbors S_1, S_2, and S_3 are detected (S_4 is outside its range). The routing table will be updated whenever the wireless sensor node is moving from point to point or every *t*-time and the next hop will be chosen according to the maximum transmit power range and transmission direction to reach to the destination.

The proposed routing table structure needs to be developed to consider the physical layer parameter (Transmit power range of wireless sensor node), as shown in Table 1:

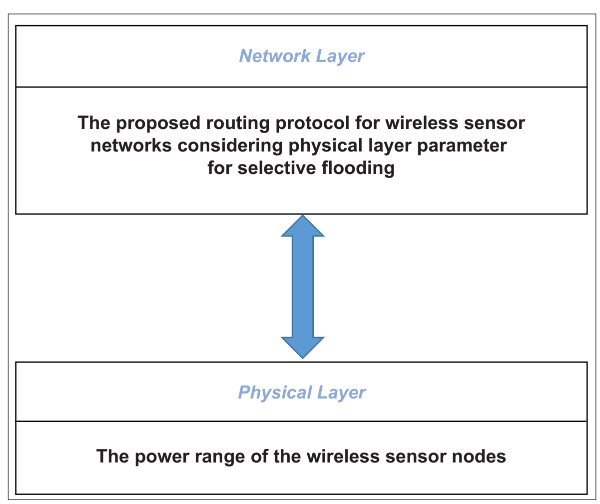

Figure 2: The proposed physical-network cross-layer parameters

According to the proposed routing table for wireless sensor node S_0 that is shown in Table 1, the next hop to be selected will be the wireless sensor nodes: S_1 or S_3 since they have high power range relate to S_0.

Algorithm 1: *Proposed* WSN *Routing Protocols*

Input:

Source wireless sensor node (S), destination wireless sensor node (D), and

Transmit power range of (T) wireless sensor nodes (N)

Table 1: Proposed routing table for wireless sensor node S0

Wireless sensor node (WSN)	Transmit power range of wireless sensor node	Next hop
S1	High	S1
S2	Medium	-
S3	High	S3
S4	Low	-

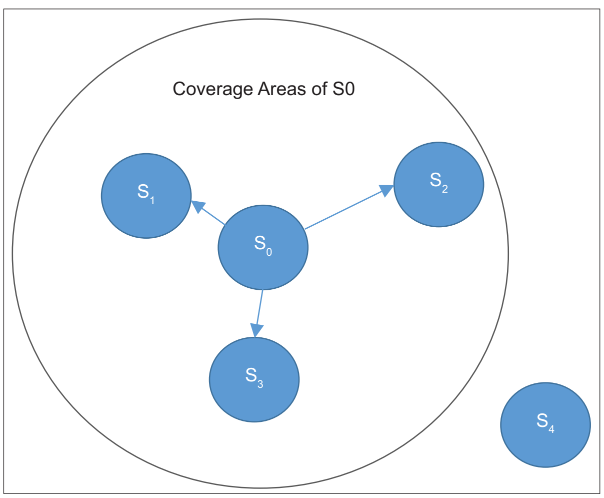

Figure 3: Coverage area of wireless sensor node S_0 and neighbor nodes. ● - Wireless sensor node, ⟶ - Wireless link

Output:

Path from (S) node to (D) node and updated routing table

Begin

For each wireless sensor node in the region *N*

Discover neighbor wireless sensor nodes

Get transmit power range for each neighbor wireless sensor node by exchanges information every 3 s

If *D* = neighbor wireless sensor nodes

Send data from *S* to *D*

Else

Find next hop with the higher transmit power range *T* from the neighbor wireless sensor nodes to send data

Update the routing table with next hop and new transmit power range from the neighbor wireless sensor nodes

End

IMPLEMENTATION AND RESULTS

In this section, we present the implementation of the proposed WSN routing protocols using MATLAB R2016a (9.0.0.341360). We proposed a heterogeneous mobile wireless sensor node, where the sensor nodes are mobile and have a different hardware specification that relates to transmit power and energy management.

The evaluation of the results is shown as line plots using pyplot module of matplotlib library in Python programming language. For this purpose, Python 3.8 was used.

Figure 4 shows neighbors' discovery of sensor nodes. We observed that proposed selective flooding based on cross-layer interaction shows better performance compared to broadcasting to all neighbors since fewer number of neighbors for sensor nodes will deliver packets over routing protocols because only high power transmit wireless sensor node will be considered in routing protocols.

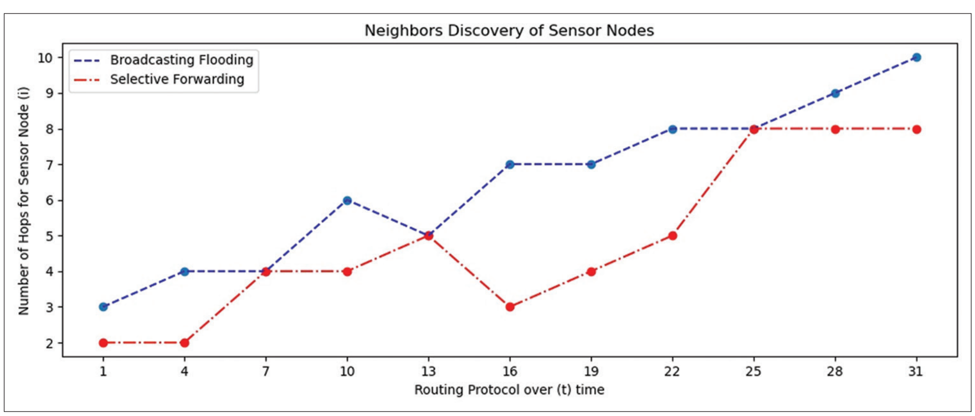

Figure 4: Compares neighbors' discovery of sensor nodes of broadcasting flooding with proposed selective flooding based on cross-layer interaction

CONCLUSION

In this research, we propose a new routing table is updated with physical layer parameter relate to power range of wireless sensor nodes that aimed to enhance the reliability of WSN routing protocol.

The proposed cross-layer interaction of WSN routing protocols will minimize the number of sensor nodes that will deliver the packets in routing protocol when selective forwarding neighbors with the high power range will participate in routing compared to broadcasting flooding of packets to all neighbors. Furthermore, reliable transmission in routing protocol will improve the performance of WSNs when weak power range of wireless sensor nodes will not be considered to be as an intermediate node in routing.

REFERENCES

1. K. Z. Ghafoor, M. Guizani, L. Kong, H. S. Maghdid, and K. F. Jasim. Enabling efficient coexistence of DSRC and C-V2X in vehicular networks. *IEEE Wireless Communications*, vol. 27, no. 2, pp. 134-140, 2020.
2. M. K. Faaeq, N. K. N. Mat, A. K. Faieq, M. M. Rasheed, and Q. H. Al-Salami. Towards of smart cities based on the sustainability of digital services. *International Journal of Engineering and Technology*, vol. 7, no. 4, p. 28, 2018.
3. M. Carlos-Mancilla, E. López-Mellado, and M. Siller. Wireless sensor networks formation: Approaches and techniques. *Journal of Sensors*, vol. 2016, p. 2081902, 2016.
4. H. F. Hasan, A. A. Mahdi, and V. Zira. *Cost and Energy Efficient Hybrid Wireless Optical Networks: FiWi Access Network*. Massachusetts: LAP LAMBERT Academic Publishing, p. 978, 2019.
5. L. Chelouah, F. Semchedine, and L. Bouallouche-Medjkoune. Localization protocols for mobile wireless sensor networks: A survey. *Computers and Electrical Engineering*, vol. 6, no. 4, pp. 1-19, 2017.
6. A. N. Abdulfattah, C. C. Tsimenidis, and A. Yakovlev. Ultra-low Power m-sequence code generator for body sensor node applications Integration. *VLSI Journal*, vol. 12, no. 3, pp. 89-93, 2019.
7. C. H. Wu, and Y. C. Chung. Heterogeneous wireless sensor network deployment and topology control based on irregular sensor model. In: C. Cérin, and K. C. Li, (Eds.), *Second International Conference on Grid and Pervasive Computing. GPC 2007. Lecture Notes in Computer Science*. Paris, France: Springer Berlin, Heidelberg, pp. 78-88, 2007.
8. S. Sankar, H. Ranganathan, and S. Venkatasubramanian. A study on next generations heterogeneous sensor networks. In: *2009 5th IEEE GCC Conference and Exhibition; 17-19 March 2009*. Kuwait: IEEE, pp. 1-4, 2009.
9. U. Patil, A. V. Kulkarni, R. Menon, and M. Venkatesan. A novel AEB-AODV based AADITHYA cross layer design hibernation algorithm for energy optimization in WSN. *Wireless Personal Communication*, vol. 117, pp. 1419-1439, 2020.
10. A. Awang, X. Lagrange, and D. R. Sanchez. A cross-layer medium access control and Routing Protocol for Wireless Sensor Networks. *Journées Doctorales en Informatique et Réseaux*, vol. 4, p. 02161417, 2009.
11. N. A. Alrajeh, S. Khan, J. Lloret, and J. Loo. Secure routing protocol using cross-layer design and energy harvesting in wireless sensor networks. *International Journal of Distributed Sensor Networks*, vol. 9, no. 1, p. 374796, 2013.
12. V. Ramasamy. *Mobile Wireless Sensor Networks: An Overview*. India: IntechOpen, 2017.
13. N. Sabor, S. Sasaki, M. Abo-Zahhad, and S. M. Ahmed. A comprehensive survey on hierarchical-based routing protocols for mobile wireless sensor networks: Review, taxonomy, and future directions. *Wireless Communications and Mobile Computing*, vol. 2017, p. 2818542, 2017.
14. W. Jung, S. Hong, M. Ha, Y. J. Kim, and D. Kim. SSL-based lightweight security of IP-based wireless sensor networks. In: *International Conference on Advanced Information Networking and Applications Workshops*, Toronto, Canada: Leonard Barolli Laboratory, 2009.
15. Á. Lédeczi, and M. Maróti. Wireless sensor node localization. *Philosophical Transactions of the Royal Society A*, vol. 370, pp. 85-99, 2012.
16. L. R. Flaih, and S. A. B. Al-Deen. Machine to machine measurement (M3) framework for web of things. *Journal of Xi'an University of Architecture and Technology*, vol. 11, no. 11, pp. 118-125, 2019.
17. G. A. Qasmarrogy. Improving VoIP transmission for IEEE 802.11 n 5GHz MANET. *Zanco Journal of Pure and Applied Sciences*, vol. 33, no. 1, pp. 157-162, 2021.
18. *RF Power Values*. United States: Cisco Systems Inc., 2008. Available form: http://www.cisco.com/en/US/tech/tk722/tk809/technologies_tech_note09186a00800e90fe.shtml. [Last accessed on 2021 Jun 01].
19. D. Son1, B. Krishnamachari, and J. Heidemann. Experimental study of the effects of transmission power control and blacklisting in wireless sensor networks. In: *1st Annual IEEE Communications Society Conference on Sensor and Ad Hoc Communications and Networks*. United States: IEEE, 2004.
20. G. A. Qasmarrogy. Optimizing video transmission performance in 5GHz MANET, *Journal of Duhok University*, vol. 23, no. 2, pp. 402-411, 2020.
21. A. H. M. Al-Dalawie, and F. M. Zeki. Design and implementation a non-uniform helical antenna in frequency range of 450-850 MHz for ultra-high-frequency television application. *Cihan University-Erbil Scientific Journal*, vol. 3, no. 2, pp. 75-79, 2019.
22. S. Yamazaki, Y. Abiko, and H. Mizuno. A simple and energy-efficient flooding scheme for wireless routing. *Wireless Communications and Mobile Computing*, vol. 2020, p. 8832602, 2020.
23. G. A. Qasmarrogy, and Y. S. Mahmood. Capacity analysis of multiple-input-multiple-output system over rayleigh and rician fading channel. *Cihan University-Erbil Scientific Journal*, vol. 3, no. 2, pp. 70-74, 2019.