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Hidden Nodes Problem Solution in Wireless Sensor Networks: A Review

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Abstract: *Wireless sensor networks consist of a large number of sensor nodes with limited energy. Sensor energy limitations and hidden node are the basic challenges in these networks and reduce network lifetime as well. Hidden node problem is a critical and significant issue in wireless sensor networks (WSNs). Large amount of data and energy are wasted due to this problem. In addition, the throughput degradation and the time delay to successfully send data is increased. A lot of researchers tried to overcome hidden node problem in WSNs using different solutions, nevertheless till now there are no complete sufficient solution. This paper provides an overview for the existed solutions of this problem, we divided them to three sections grouped based, busy tone multiple access and other solutions. we describe and discus each of them.*

Keyword: *Busy Tone; Handshaking Mechanism; Hidden Node Problem; Multiple Access; WSN*

1. INTRODUCTION

Wireless sensor networks is consider a promising technology that can be many very significant scopes like tactical systems, industrial process monitoring, environmental monitoring, tracking and target detection. Wireless Sensor Networks (WSNs) combine one or more sensor devices which are battery-operated with an small memory, embedded processor and a low power transceiver. Nodes in a wireless sensor network work together to execute a common design goal. One reason of the limited coverage and communication range is the low power capacities of sensor nodes. Therefore, a lot of sensor nodes which are geographically dispersed to cover the entire area of interest are needed. To prolong the life of the network, a recharge node battery periodically is insistent, nevertheless nodes may be spread in a rough or a hostile area that very difficult or impossible to reach. Security is an important and a critical design factor in wireless sensor network, the nature of wireless communication is broadcast so any one can intercept the sent data and view, modify or even change it, a lot of strategies are suggested to resolve security issue in WSNs [1]. Accordingly, novel protocols for energy efficient are requirement.

In general, the energy consumption is involved in three main activities which are sensing, processing and communication. The largest amount of energy is consumed during the transmission and reception of information. Routing could play important factor to consume or reserve energy in WSNs, a good path choosing for sending data mean more energy conserving [2]. A successful data transmission means a higher energy saving and a long-life network. The most communication failure happening because a collision due a hidden node problem. In wireless contention based medium access control (MAC) protocols, when two nodes that are not visible to each other transmit to a third node that is visible to the former, there will be a collision this is called hidden-node or blind collision [3]. An example for hidden node problem is illustrated in Fig. 1. Node A can sense node B since it is in its radio range but can't sense node C because it is lie outside its radio range, the same is for node C, it can sense node B but can't sense node A for the same causes. If in the same time node, A and node C try to send a packet to node B there will a collision, this situation is called hidden node or blind node problem.

The rest of this paper is arranged as follow, in section 2 the properties of a good MAC protocol needed for WSNs are illustrated, in section 3 we illustrate the existed solutions for hidden node problem, in section 4 we conclude this paper.

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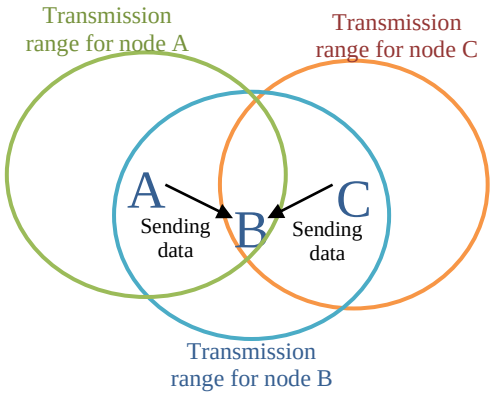

Figure 1 Hidden Node Problem

2. MAC LAYER IN WIRELESS SENSOR NETWORKS (WSN)

WSNs are typically composed of a large number of cheap, battery powered, multifunctional wireless devices scattered over a wide area in an ad hoc fashion and without a predefined planning. Individually, sensing devices have strength resource constrained so that they are only capable of a limited amount of processing and communication. WSNs devices need to share the allocated bandwidth fairly. Medium access control protocols have direct impact on channel utilization among nodes. So, a good MAC protocol will lead to efficient channel utilization. As a result for the nature of WSNs, MAC protocols have a number of challenges to overcome, the spatial distribution of communication nodes mean that additional exchanging packets are needed to allocate and confirm the winning node to utilize the communication link .this packets overheads will use the channel and denying efficient use to it, and also will cause undesired loss in energy.

MAC protocols in WSNs can be classified according channel reservation to contention-based MACs ,contention-free MACs and hybrid MACs as shown in fig 2 .In contention-based MAC protocols the nodes contend with each other to occupy the channel to send their packets ,this lead to efficient channel utilization since the channel is working all the time, as a drawback in this type some nodes may not have the chance to win communication link because there is some nodes have a lot of packet to send , as a result unfair channel distribution could occur .Conversely, contention-free MAC protocols will divide the channel to individual slots and allocate each node a number of slots to use for communication in exclusive manner, drawback for this MAC protocols is un efficient channel utilization ,since there are some nodes will have no packets to send in its exclusive time to send that made channel idle .Hybrid MAC protocols try to aggregate the benefits of the two previously mentioned types to produce efficient and effective MAC protocol .A comparative analysis between contention-based and contention-free MAC protocols by using four performance parameters which are end to end delay, throughput, packet delivery ratio and energy consumption are provided in [4].

Energy efficiency is major issues in designing WSNs MAC protocol. Sources of energy waste can be divided into four types idle listening, overhearing, control packet overhead and collisions. Idle listening happens when a node is listening to an idle channel in order to receive possible traffic. Overhearing happened when a node receives packets that are destined to another node. Control packet overhead is the additional packets needed for enabling data transmission. Collision is a major source of energy waste; it is happened when a node receives two distinct packets from two nodes at the same time or during the receiving interval. Hidden node problem can be classified as a main cause for collisions; therefore, a good MAC protocol should be maintaining this problem and mitigate or eliminate it successfully.

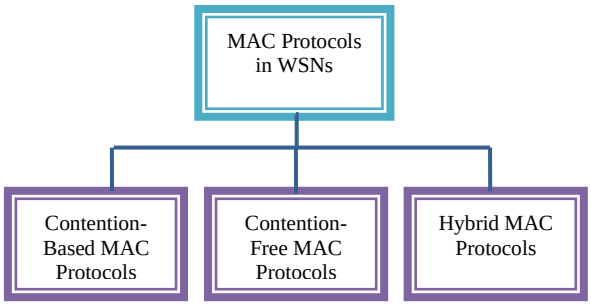

Figure 2 Classification of MAC Protocols for WSNs

3. SOLUTIONS TO HIDDEN NODE PROBLEM

In this section we illustrate and divide the existed solutions to three different groups, grouping based mechanisms, busy tone multiple access and other solutions.

3.1 Grouped Based Mechanisms

The authors in [5] propose Hidden-node Avoidance Mechanism (H-NAMe) as a sufficient protocol to mitigate hidden node problem. H-NAMe is targeted to synchronized cluster-based wireless sensor networks, it is based on a grouping strategy that split each cluster into disjoint groups of non-hidden nodes and after that handles the nodes between clusters via a cluster grouping strategy that must guarantees no transmission interference between overlapping clusters. In addition, the authors show how to apply H-NAMe mechanism to the IEEE 802.15.4/ZigBee protocols by using minor add-ons and ensuring backward compatibility with the standard specifications. The H-NAMe starts by grouping nodes in each cluster that have bi-directional link between them and then give them a different time window to compete for reserve the

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channel .Another grouping strategy have been proposed in [6] to dynamically assigns time periods for each group, the authors suggested to use the transmission periods in the group instead of the number of nodes in the group to use the bandwidth efficiently. In [7] a new grouping strategy is proposed for solving hidden node problem in IEEE 802.15.4 , it is consist of four phases, the first phase is hidden node situation discovery in which the coordinator test if the corrupting signal happened due to hidden node ,the second phase is hidden relationship collection in which coordinator collect information about the hidden nodes ,the third phase is nodes grouping where nodes that hear each other are arranged together and the final phase is bandwidth allocation where the coordinator distribute time periods among groups depending on group size.

Node joining and grouping scheme (NJ-GS) for avoiding hidden node problem is proposed by authors to be a proactive scheme instead of being a reactive scheme [8]. The authors proved that NJ-GS reduce the time complexity to collect hidden node relationship from $O(N^2)$ to (~O(N)), they define the access period for each group according to the number of nodes in that group, the regroup will not initiated when node leaving or joining a group, NJ-GS have four phases hidden node relationship collection, nodes grouping ,access period allocation and grouping result and notification .

3.2 Busy Tone Multiple Access

This mechanism take advantage of busy tone signals for keeping hidden node silence and overcome collisions. It takes their advantage from being easily detected by all nodes in range. The bandwidth is divided into two channels ,one for message exchange and the other for busy tone signal .When node need to transmit a packet it sense for the existence of busy tone signal , if no signal are sensed the node send the packet and send a busy tone signal on the busy tone channel [9]. Receiver-initiated busy-tone multiple access protocol is proposed in [10] to let the receiver send the busy tone instead of the sender, the sender start to send a preamble which contain the receiver identification on the data channel, the receiver answer with a busy tone signal to acknowledge the sender and to reserve the channel and deny hidden nodes from sending their preambles. The authors in [11] proposed Dual Busy Tone Multiple Access (DBTMA), They utilized an RTS packet and a receiver busy tone, the sender after sensing no busy tone start sending RTS packet and also a busy tone on busy tone channel to protect RTS packet, the receiver acknowledge the received packet by sending a busy tone on busy tone channel this will notify all nodes in the range of the sender and receiver about the transmission.

The use of busy tone signal is enhanced and developed in Enhanced Busy-Tone Multiple Access MAC Protocol (EBTMA) [12], the busy tone is a non-interfering signal that generated for a short period of time ,before sending RTS packet the sender node generate busy tone signal on busy tone channel that its range cover twice data signal transmission range to notify all hidden nodes about the transmission, the busy tone stay on until the end of sending RTS packet ,the busy tone signal is transmitted for a short time period to overcome the exposed node problem .

3.3 Other Existed Solutions for Hidden Node Problem

The researchers investigate a lot of solutions to mitigate hidden node problem, a novel solution for mitigate hidden node problem with an efficient energy usage is directional based antenna [13], the authors suggested to make node communicate with other nodes in a unidirectional way ,this will reduce hidden nodes and also exposed nodes, to make a node communicate with all other nodes in the other directions they suggest to rotate the antenna in idle states ,this rotation is scheduled to allow the node communicate with all other node in its range .

Hidden node problem could be avoided by managing the value of contention window [14]. The authors targeted wireless multi-hop sensor networks and proposed adjusting contention window according to number of existed hidden nodes to be larger enough to reduce the probability of hidden node collisions, the nodes alternate between sleeping and active periods, and they follow a mechanism like IEEE 802.11 DCF for channel access.

The authors introduce a new handshaking signal (COL) that could be sent by the receiver node to inform the sender about the collision instantly [15] ,the proposed protocol fall in Packetized-preamble MAC protocols , this protocol is designed to detect collision in the early stage of connection establishment, during exchange handshaking signals. The receiver can send two signals as an answer for RTS packet either CTS or COL, if there is no collision the receiver node send CTS, if it detect a collision it send a COL signal to all neighbors.

An attempt to apply RTS/CTS handshake mechanism to alleviate hidden node problem in IEEE 802.15.4 wireless network is discussed and explained in [16], IEEE 802.15.4 is the standard for low data rate and energy consumption sensitive network, it doesn't provide any protection against hidden node problem, so the authors try to mix RTS/CTS handshake signals with it to provide a protection for hidden node problem ,the authors applied the idea successfully but they notice a reduced capacity in the network when compared with the original IEEE 802.15.4 standard, this is because a high packet overhead as a result for exchanging RTS/CTS packets ,the authors also noticed a longer end-to-end delay in the proposed protocol ,this as a result for longer transmis-

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sion sequence which requires sending additional RTS and CTS frames.

Another approach is suggested in [17] ,the authors suggested an improved S-MAC protocol by dividing scheduling duty into multiple micro-duties so that the nodes collision probability are reduced .Also by using different back-off algorithms depending on buffer queue length Fast-Binary Exponential Backoff and Conflict-Avoid-Binary Exponential Backoff are applied , adaptive micro-duties depending on residual energy, this applied techniques reduced collisions probability which led to high throughput and low latency.

TABLE I SUMMARY OF CONCLUDED PROTOCOLS IN THIS PAPER

References	Summary of Work Performed
Tobagi, F. and Kleinrock, L., 1975	They take advantage of busy tone signals for keeping hidden node silence and overcome collisions
Wu, C.S. and Li, V., 1987.	the busy tone is sent by receiver as an acknowledgement for sender RTS packet, and to let other nodes know about transmission.
Haas, Z.J. and Deng, J., 2002.	DBTMA is proposed utilizing RTS and busy tone technique to mitigate hidden node problem two busy tone signals are used.
Hwang, L.J., Sheu, S.T., Shih, Y.Y. and Cheng, Y.C., 2005.	A solution for hidden node problem that utilize grouping strategy and consist of four phases: hidden node situation discovery,hidden relationship collection, nodes grouping and bandwidth allocation.
Bachir, A., Barthel, D., Heusse, M. and Duda, A., 2005.	Adjusting contention window according to number of hidden nodes in network to reduce the probability of collision.
Koubâa, A., Severino, R., Alves, M. and Tovar, E., 2009	They proposed H-NAMe protocol as a grouping mechanism for mitigate hidden node problem.
Kwon, C.H., Tek, R.J., Kim, K.H. and Yoo, S.H., 2009.	Grouping strategy for solving hidden node problem that allocating channel for group according to data rate of group instead of number of nodes in it.
Abdullah, A.A., Cai, L. and Gebali, F., 2010.	EBTMA is proposed as energy efficient MAC protocol to solve hidden node problem, busy tone signal is transmitted for short period and twice the carrier sense range of the node.
Adere, K. and Murthy, G.R., 2010.	Directional antenna is proposed as a solution for hidden and exposed node problems.
Choobkar, S. and Dilmaghani, R., 2011.	A new handshaking signal (COL) was introduced to detect collision in early stages of communication.
Tseng, H.W., Sheu, S.T. and Ou, S.Y., 2013.	NJ-GS is a proactive scheme for avoiding hidden node problem, they reduced time complexity for collecting hidden node relationship from $O(N^2)$ to (~O(N)) .
Pešović, U., Mohorko, J., Ranđić, S. and Čučej, Ž., 2013.	An attempt to apply RTS/CTS handshake mechanism to alleviate hidden node problem in IEEE 802.15.4 wireless network.
Ke Wang, Xiaohu Zhao, Yao Shi, Donghong Xu, and Ruoyu Li.	Adaptive micro-duty cycles are applied with different backoff algorithms to reduce collision probability.

4. CONCLUSION

Hidden node problem is a serious issue in wireless networks, its impacts could degrade the overall performance of the network. In this paper we discussed and illustrated a number of existed solutions to mitigate hidden node effects, showing their advantage and disadvantage. The search result is there is no perfect solution to overcome hidden node problem completely until now in wireless sensor network.

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Kaeed Ketab, is a PG Student in University of Mosul, Mosul, Iraq. He completed his B.Sc. in Computer Engineering at Diyala University, Engineering College, Diyala, Iraq. He is an employ in directorate of agriculture in diyala governorate. He is working to achieve M.Sc in Computer Engineering from University of Mosul. His research interests are artificial intelligence, wireless sensor networks, wireless technologies, integrated circuit design.

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