SHIV SHAKTI

International Journal of in Multidisciplinary and Academic Research (SSIJMAR)

Vol. 3, No. 4, August-September (ISSN 2278 – 5973)

Collision Free MAC Protocol in WSN Network

Mudit bansal
S.I.T.M,Rewari. Mobile no. 9468040229
Mr. Pushpender Sarao
Dean,S.I.T.M. Rewari

Impact Factor = 3.133 (Scientific Journal Impact Factor Value for 2012 by Inno Space Scientific Journal Impact Factor)

Indexing:

1.1 INTROUCTION

Recent years have seen the applications of wireless sensor networks (WSN) in a variety of tasks including habitat monitoring, border surveillance and structural monitoring. Wireless sensor network consists of large number of sensor nodes that are randomly distributed in a region. Wireless Sensor Network consists of three functional units' viz. computational circuit, transmission circuit and sensor circuit as in figure 1.1.

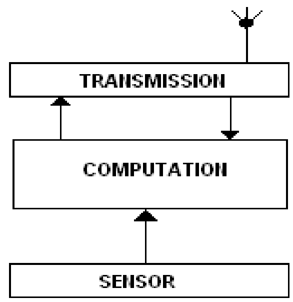


Figure 1.1: Architecture of WSN

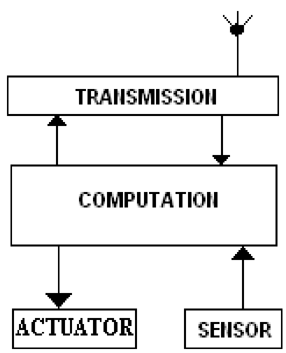


Figure 1.2: Architecture of WSN with additional part, actuator

However, there may be application where we need to install another functional unit called actuator figure 1.2. This works as a device which responds to the environmental changes in the way the response comes from the sink node. The nodes are equipped with limited battery power, inexpensive short-range radio communication and low power computation circuit. In order to enable the long-lasting operation of such networks i.e. the issue of survivability of network, the proper integration of power-efficient hardware entities and protocols is one of the major challenges to be addressed.

Another important aspect of WSN is the distributed nature of the channel. To address the problem of channel utilization as well as collision we can use TDMA and its variants. However, the efficiency can still be maximized since there are places which need modification to improve the channel utilization. The recent advancements in the hardware technologies for WSN made it possible to implement FDMA also. Hence, we reached the position where we can use a suitable mix of these technologies to generate better output. Another limitation faced by traditional design of WSN is, it uses the basic OSI or TCP/IP reference model which follows the strict layered architecture. The solution to this problem appeared in the form of development of Cross-Layer Technology.

Medium access is a major consumer of sensor energy, especially for long-range transmission and when the radio receiver is kept on all the time. Energy consumed for radio transmission is directly proportional to distance squared and can significantly magnify in a noisy environment. Energy-aware routing typically pursues multi-hop paths in order to optimize the transmission energy 910. On the other hand, time-based medium access control (MAC) saves transmission energy by limiting the potential for collisions and minimizes the energy consumed in the receiver by turning the radio off when it is idle 1112. Generally, an efficient MAC layer protocol for sensor networks should have the following attributes:

• The protocol should be scalable since most applications of sensor networks involve a large set of sensor nodes.

• Collisions among the transmissions of various nodes should be avoided. Collisions lead to packet drop and thus reduce throughput and cause energy wastage.

• Energy consumed by the radio circuit in idle mode is almost equal to that consumed in active state. Consequently, idle mode of operation and transmission overhearing among sensors should be minimized.

• To limit energy consumption during idle time, the sensors are typically switched to a sleep mode when not in use.

However, active to sleep transitions and vice-versa consume considerable amount of energy. Therefore, an efficient protocol should minimize such transitions 8.

• The protocol should not be contention-based. Control packets overhead and active sensing of the medium, typically performed by contention-based protocols, are inefficient in terms of energy consumption.

• Packet drop due to limited buffer capacity should be prevented.

• The protocol should adapt to changes in the network topology and all sensors should have a fair chance of transmitting.

1.2 PROBLEM OUTLINES

MAC layer attracted most of the research work because it is considered as an important source of energy wastage that we summarize as follows:

Overhearing: A sensor node receives packets that are transmitted for other nodes. This is due to the radio transmission nature forcing every node of the neighborhood to waste energy when receiving this radio.

Collision: since radio channel is shared by many nodes, a collision take place every time, two nodes try to transmit in the same time. Collisions increase energy consumption and latency due to retransmissions.

Control packets: packet headers and control packets (RTS/CTS/ACK) used by a MAC protocol do not contain application data, thus they are considered as supplementary data (pure overhead). Still they are considered to be important since most applications use data packets with reduced size.

Idle listening: when a node is not active, leaves listening the signal carrier to knowing if it is the receiver of an eventually traffic. Researches show that in this situation, the amount of energy wasted is equal to the energy dissipated by a normal reception.

Over emitting: This case arrives when a sensor node receives a packet while is in a sleep mode. This situation forces the sender to perform new retransmissions since it has no way to know it is needed to wake up.

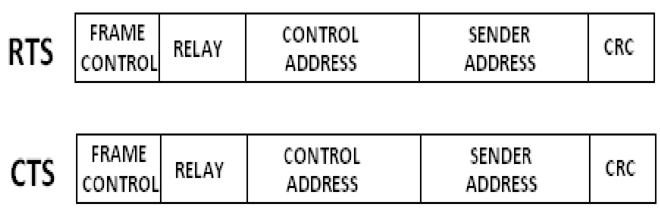
1.3 OBJECTIVES

In this dissertation, we first try to evaluate the efficiency of the network according to the CL-MAC protocol and then calculate the efficiency of our proposed protocol with same assumptions. The efficiency is calculated assuming that the time required for establishing the communication is negligible, as it increases the time linearly in both the cases. Also, that the nodes always starve for channel and have data to transmit.

Considering one routing path the CL-MAC protocol busies four nodes for one communication as shown in the figure, however every node is common in two consecutive transmissions so we count the nodes required for each communication is three. And, each communication wastes two channels.

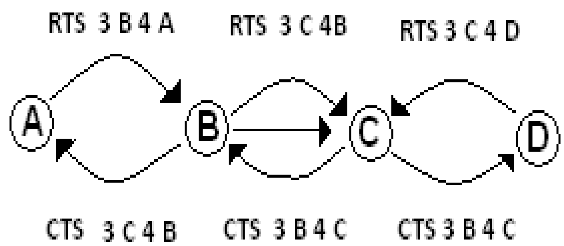
PROPOSED WORK

The protocol is deployed as another protocol in the category of those utilizing routing information. The neighborhood list established by each node contains information about neighboring nodes i.e. identifier, position, and calendar, and the routing table maintained by the network layer same as in CL-MAC. Some modifications made in RTS and CTS message structures without violating the IEEE 802.11 standard are done. The Sink node address is supposed to be known at the level of each node of the network in case of a mono-Sink WSN. I try to improve the mode of operation of CL-MAC protocol. It improves the channel utilization by implementing the concept of FDMA along with already implemented TDMA and cross layer architecture already proposed in CL-MAC. The modification in the format of RTS and CTS packets is given in figure 5.1.



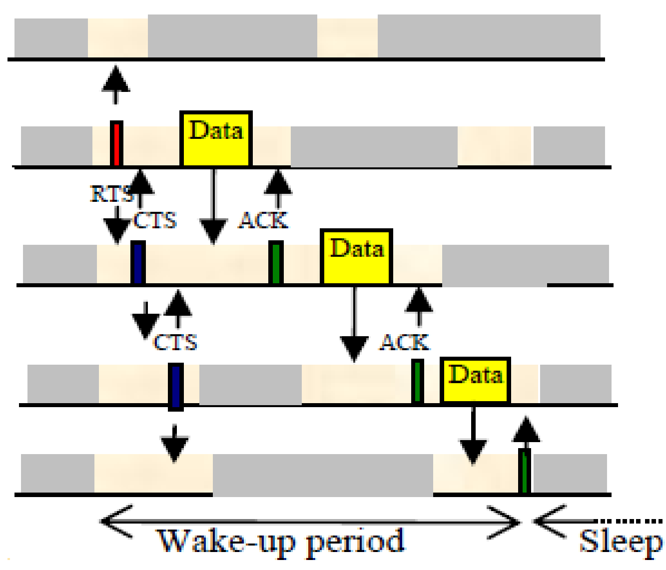
RTS/CTS frame format

Here also as in CL-MAC protocol, the formats of RTS and CTS packet is same, but different in interpretation by the receiver of the packet. The receiver of the data is determined by the transmitter by looking into the routing table available from the routing layer. This approach basically helps to remove need of flooding along with establishment of alternative routes in cases of failure of some node.

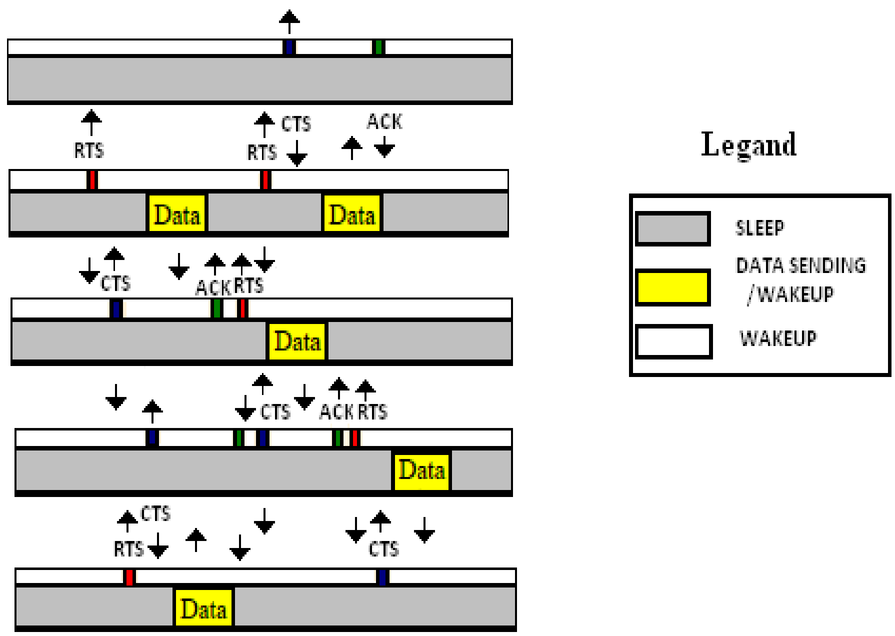


mode of transmission of RTS/CTS packets

In figure 5.2 for B TO C communication B sends a RTS to C, C returns CTS to B. Now B checks if (CTS->3==RTS->4) then acceptance. It starts communication with C. Meanwhile a RTS from A reached B, it sends the CTS which is checked at A for if (CTS->3==RTS->3) which is not so hence rejection. If same sort of request reaches C from D Then same condition is checked and a rejection for the same reason. Figure 6 (b) Now, We can send these control packets on the control channel and hence this would allow the nodes to communicate its status even if busy in transmission as follows:



transmission in CL-MAC protocol



HYBRID of TDMA/FDMA and Cross Layer

The control channel has short sleep/wakeup periods and hence it continuously checks the channel for control packets. There may arise following cases enumerated and explained one by one.

For idle node: If node has data to transmit it sends the RTS packet.

For transmitter: If it receives a RTS meanwhile in transmission it rejects the request.

For receiver: If it receives a RTS packet, and already receiving it sends inability.

The problem that is still remaining to be discussed is the sleep/wakeup cycle of the control channel. Since the control packets are transmitted at any time the channel should always be ready to sense the control which causes the channel to be in wakeup mode for all the time resulting in excessive power loss. This can be solved by applying the same schedule of CL–MAC figure 5.3(a) protocol of time synchronized sleep/wakeup cycle for control channel. Hence if any control packet i.e. RTS/CTS packet is to be sent the node will wait until the next wakeup of control channel. For such a synchronization of time various protocols are already working in network.

The main advantage of this protocol is it establishes the best utilization of channel in the conditions when the data travelling on the network has two way natures. The data may travel in both the directions if the nodes send the sensed information to sink as well as sink sends some data for actuators on the nodes to adapt themselves to the conditions or some sort of control messages to change the behavior of the nodes. Theoretically this can be deduced that the data travelling in the network using this schedule has same speed in both the directions.

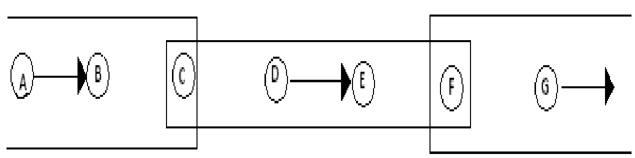
The reason of using ACK message is to ensure the reliable delivery of the data. Only after reception of ACK a new connection can be made by transmitter and after delivery of ACK by the receiver. Hence, here receiver gets a chance to request the transmission first thereby giving it a chance to avoid limited buffer problem since every node is facilitated with one reception/transmission cycle.

RESULT AND PERFORMANCE EVALUATION

Results

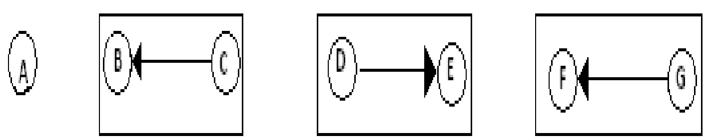
We first try to evaluate the efficiency of the network according to the CL-MAC protocol and then calculate the efficiency of our proposed protocol with same assumptions. The efficiency is calculated assuming that the time required for establishing the communication is negligible, as it increases the time linearly in both the cases. Also, that the nodes always starve for channel and have data to transmit.

Considering one routing path the CL-MAC protocol busies four nodes for one communication as shown in the figure, however every node is common in two consecutive transmissions so we count the nodes required for each communication is three. And, each communication wastes two channels.



the range of disturbance in CL-MAC

In case of our proposed protocol the nodes busied in each communication is two and the channels wasted in each communication is just one. As shown in the figure:



the range of disturbance in our proposed scheme

Hence calculating the efficiency of channel utilization when only forward traffic is considered as in figure 6.1 and figure 6.2.

Utilization = used channel/(used channel +idle channel)

For CL-MAC=1/ (1+2) =0.33 i.e. 33%

For our proposed protocol = 1/ (1+2) = 0.3 i.e. 33% Hence the same.

However, as a matter of fact wastage of one channel is obvious hence in that case

For CL-MAC Utilization =1/ (1+1) = 0.5 i.e. 50%

For our proposed protocol Utilization = 1/ (1+1) = 1.0 i.e. 50%

The assumption of obvious wastage of one channel is considered because avoidance of that would require multiple channels in the network which should be equal to the maximum degree of some node in the network so that communication to each node can be established at a time.

The protocol proves more efficient for carrying maximum amount of bi directional traffic. Any network applying only TDMA and Cross Layer can withstand is calculated as follows.

Utilization =1/(1+1) = 0.50 i.e. 50%

For our proposed scheme it is

Utilization=1/ (1+0) = 1.0 i.e. 100%

Till the above discussion somebody may not feel the existence of neighborhood knowledge worth keeping however it is important since there may exist many such routing chains that may interfere with each other and also for the situation when the nodes are mobile the routing information serves the purpose of changing the current neighborhood table when triggered.

The algorithm performs a Breath First Search (BFS) constructing a tree having the base node as its root. As each node Ni is traversed by BFS, it is assigned a default time slot and a frequency. Then the possibility of having an interference2

with any of its same-height previously-visited one-hop AND two-hop neighbors is checked. If a conflicting neighbor Nj is found for Ni, the algorithm checks whether Ni and Nj are siblings. If so, Ni will be assigned a different time slot than that of Nj . If they are not siblings then Ni will be assigned a different frequency than that of Nj , allowing both Ni and Nj to send

messages to their parents at the same time slot but in different channels. When BFS is about to start a new level (height) of
nodes the default time slot number will be increased by one.
Once all nodes are processed according to the above heuristic, all of the time slot assignments will be inverted such that the slot number assigned to every node is smaller than that of its parent. This inversion is done as following:

tnew = tmax − tcurrent + 1

Algorithm 1

HyMAC Scheduling Algorithm Require: A Graph of Sensor Network Topology

Ensure: An scheduled Tree of the Given Network

```
1: ENQUEUE (Q, S)
2: while Q is not empty do
3: v   DEQUEUE(Q)
4: timeSlot[v]   currentTimeSlot
5: channel[v]   1
6: for all Visited same-height 1-2-hop nbr n of v do
7: if parent[n] == parent[v] or
#Channel >= available chnls then
8: if timeSlot[v] = timeSlot[n] then
9: timeSlot[v]   timeSlot[n] + 1
10: end if
11: else
12: if timeSlot[v]=timeSlot[n] and
channel[v]=channel[n] then
13: channel[v]   channel[n] + 1
14: end if
15: end if
16: end for
17: for all unexplored edge e of v do
18: let w be the other unvisited endpoint of edge e
```

```
parent[w]   v
height[v]   height[w] + 1
end for
end while
```

where tnew is the new inverted assigned slot, tcurrent is the current slot number assigned to the node and tmax is the total number of assigned slots. Note that such an assignment allows the data packets to be aggregated and propagated in a cascading manner to the base station in a single TDMA cycle. The complete steps of the overall process are presented in algorithm 1. Figure 6.1 shows a sample run of the scheduling on a graph of sensor networks.

PERFORMANCE EVALUATION

In this section we provide an evaluation of the performance of HyMAC and give a comparison of it with the performance of already proposed MAC protocols for sensor networks. We use the number of potential conflicts as a performance metric. This number is defined to be the total number of node pairs in the network which satisfy the following condition: if the two nodes are within each other’s two communication hops and are assigned the same time slots, they share the same frequency. Since HyMAC operation does not only depend on the number of available frequencies, its performance remains unaffected by a varying number of them.

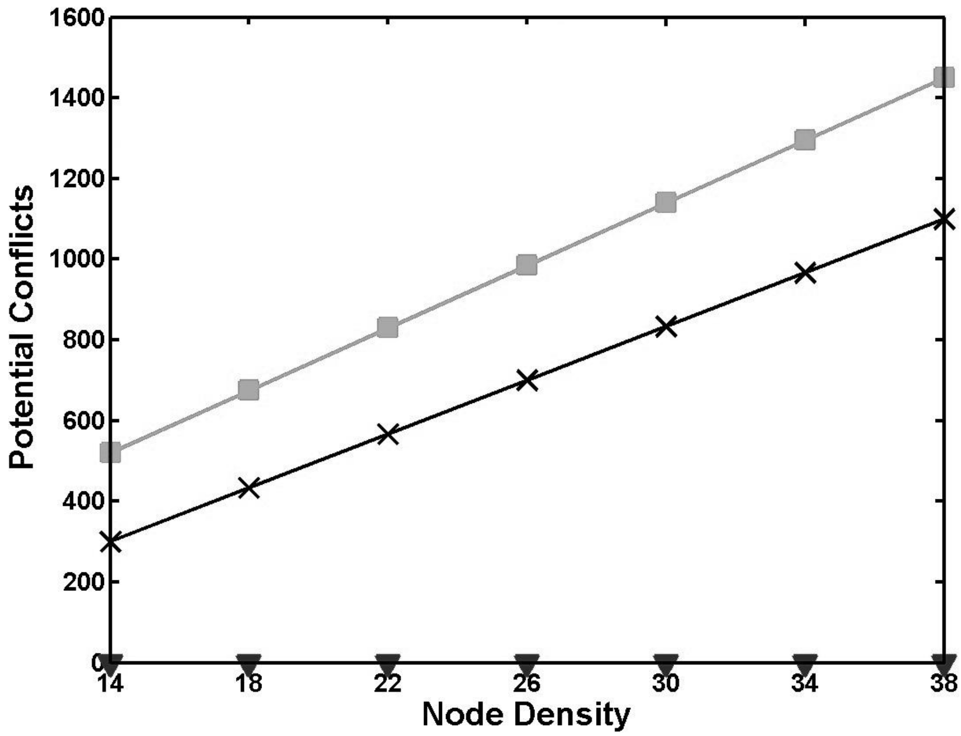
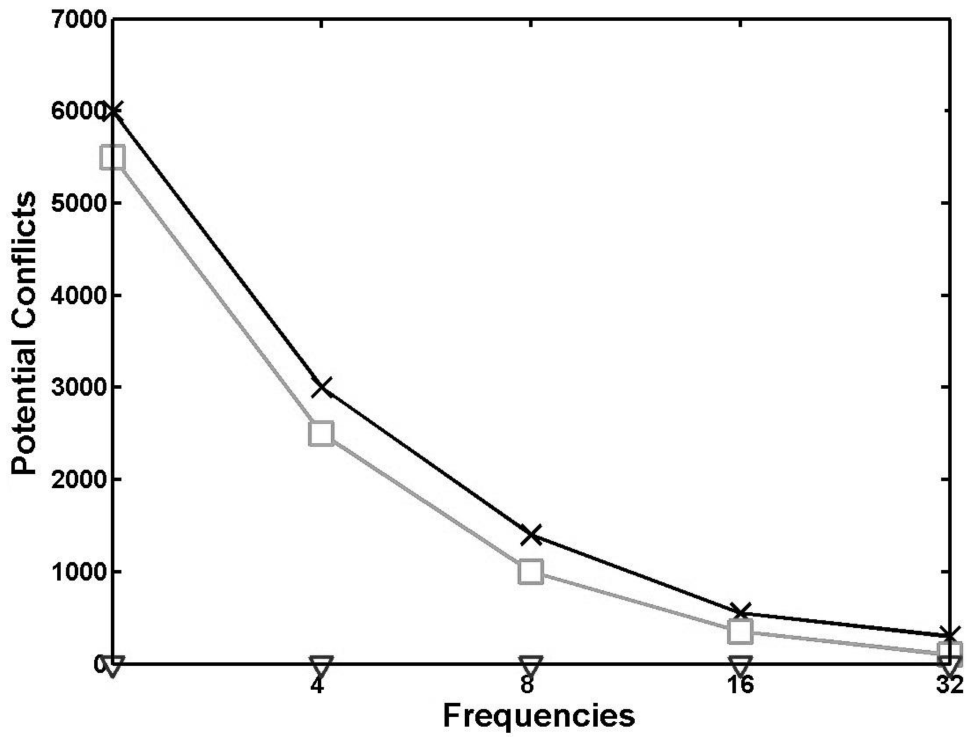


Fig. 6.3 Number of Potential Conflicts VS. Node Density

While the the Number of Frequencies is Fixed at 5



Number of Potential Conflicts VS. Number of
Available Frequencies

show the perfect performance of HyMAC which is interference-free even when there are only 2 frequencies available while MMSN suffers from the communication interference. The cost of this high performance, however, is the increase in the number of required time slots. This is because when a new frequency is needed to be assigned to a node while the maximum number of available frequencies is already reached, the node is assigned a new time slot instead in order to avoid the potential interferences.

Consequently, fewer number of available frequencies results in a larger number of time slots. Figure 6.3 shows the variation of the number of required time slots based on the number of available frequencies for three different node densities. It

is important to observe that by employing a higher number of frequencies, a denser network can operate interference-freely without any dramatic increase in the total number of required time slots. In spite of the fact that the increase in the number of needed time slots results in a larger TDMA cycle and therefore a longer end-to-end delay, the worst case performance of HyMAC (where only a single frequency is available) will be the same as that of RT-Link which is shown to be high-quality enough to support real-time streaming for voice over sensor networks. Furthermore, given a fixed cycle length, HyMAC supports denser networks with higher number of nodes -and thus a higher throughput- than RT-Link is potentially able to; thanks to its use of multiple available frequencies. Figure 6.4 compares the total number of assigned time slots by HyMAC and RT-Link protocols when they both operate on FireFly platform which uses CC2420 radio. This radio component provides up to 16 different channels within the 2.4 GHz band in 5MHz steps according to IEEE 802.15.4 specifications. We have also measured the maximum number of required frequencies for operation in dense networks in order to study the feasibility of HyMAC in practice. Figure 6.3 shows the variations of the number of assigned frequencies based on the changes in the number of nodes of a dense network where each node has 7 neighbors. As it can be observed, the number of needed frequencies is well below the number of provided channels in practical WSN radio components. Even in an extreme case where 900 nodes are presented in the network each of which having 90 neighbors, our simulation results showed that the total number of required frequencies will not be more than 14. In addition, it is important to note that HyMAC is practically adjustable according to the exact number of frequencies that user specifies employing suitable number of time slots. 5MHz steps according to IEEE 802.15.4 specifications. We have also measured the maximum number of required frequencies for operation in dense networks in order to study the feasibility of HyMAC in practice. Figure 6.4 shows the variations of the number of assigned frequencies based on the changes in the number of nodes of a dense network where each node has 7 neighbors. As it can be observed, the number of needed frequencies is well below the number of provided channels in practical WSN radio components. Even in an extreme case where 900 nodes are presented in the network each of which having 90 neighbors, our simulation results showed that the total number of required frequencies will not be more than 14. In addition, it is important to note that HyMAC is practically adjustable according to the exact number of frequencies that user specifies employing suitable number of time slots

CONCLUSION

Here, in this dissertation we propose and study our TDMA/FDMA/Cross Layer hybrid MAC protocol for wireless sensor network. To the best of our knowledge this is the first sensor network protocol using the properties of three different approaches to eliminate the problem of collision, lowered delay and maximized efficiency with facilitating the application of two way data transfer for applications where actuators are integral part of nodes. The protocol assumes the availability of hardware to provide two channel simultaneous transmission. The protocol also uses only moderate amount of energy because of its sleep/wakeup cycle. In view of the above described advantages of the protocol it deserves a thorough study and implementation on a test bed for evaluating its best result.

FUTURE SCOPE

This protocol causes a bit more energy usage and a technology where two channels can simultaneously work which is no doubt a costly affair. However, such hardware is developed and there are protocols using more than two frequencies also. Research in this field could still be done to optimize the energy consumption and to develop hardware of low cost. Another field for research is that for calculation of our results we assumed an obvious wastage of channel which can be utilized if we make two data channels.

REFERENCES

1. Yuebin Bai, Shujuan Liu, Mo Sha, Yang Lu, Cong Xu, An Energy Optimization Protocol Based on Cross-Layer for Wireless Sensor Networks, journal of communications, Vol. 3, No. 6, November 2008.
2. Zheng Peng, Zhong Zhou, Jun-Hong Cui, Zhijie Shi, Aqua-Net: An Underwater Sensor Network Architecture —Design and Implementation.
3. Haiming Chen, Changcheng Huang and Li Cui, Lightweight Protocol Suite for Wireless Sensor Networks: Design and Evaluation, July 2007.
4. Tommaso Melodia, Mehmet C. Vuran, Dario Pompili, The State of the Art in Cross-layer Design for Wireless Sensor Networks.
5. Bouabdellah KECHAR, Ahmed LOUAZANI, Larbi SEKHRI, Mohamed Faycal KHELFI, Energy Efficient Cross-Layer MAC Protocol for Wireless Sensor Networks.
6. Mastooreh Salajegheh, Hamed Soroush, and Antonis Kalis, HYMAC: HYBRID TDMA/FDMA MEDIUM ACCESS CONTROL PROTOCOL FOR WIRELESS SENSOR NETWORKS, The 18th Annual IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC'07).
7. Li Deliang, Peng Fei, Energy-effi cient MAC protocols for Wireless Sensor Networks.
8. Ye Wei, Herdemann John, Estin Deborah, An Energy-Efficient MAC Protocol for Wireless Sensor Networks[C]// Proc. of the INFOCOM 2002, San Francisco: IEEE Computer Society, 2002, 3:1567-1576.
9. Dam T, Langendoen K, An Adaptive Energy-Efficient MAC Protocol for Wireless Sensor Networks[C]// Proc. of the first ACM Conf. on Embedded Networked Sensor Systems (SenSys), New York: ACM press,2003: 171-180.
10. Rhee I, Warrier A, Aia M, et al, Z-MAC: a Hybrid MAC for Wireless Sensor Networks[M]. Networking, IEEE/ACM Transactions, 2008, 16(3):511 – 524.
11. J. Polastre, J. Hill, and D. Culler, Versatile low power media access for wireless sensor networks, SenSys'04,2004, pp.95-107.

12. Suh., C., Young-Bae, K. and Dong-Min, S. , An Energy Efficient Cross-Layer MAC Protocol for Wireless Sensor Networks. Graduate School of Information and Communication, Ajou University, Republic of Korea. APWeb 2006, LNCS 3842, pp. 410–419I,2006.
13. F. Akyildiz, M. C. Vuran, and O. B. Akan, Cross-Layer Module (XLM) for Wireless Sensor Networks, to appear in CISS ’06, March 2006.
14. G. Zhou, C. Huang, T. Yan, T. He, J.A. Stankovic and T.F. Abdelzaher, MMSN: Multi-Frequency Media Access Control forWireless Sensor Networks, in IEEE INFOCOM2006.
15. Mihail, L. Sichitiu.“Cross-Layer scheduling for power efficiency in Wireless Sensor Networks”. In Proceedings of the IEEE INFOCOM’04, 2004, pp.1740-50.
16. W. Ye, J. Heidemann, and D. Estrin. “An energy-efficient mac protocol for wireless sensor networks ” . In Proceeding of the IEEE INFOCOM,02, 2002, pp. 1567- 1576.
17. J. Haapola, Z. Shelby, C. Pomalaza-Raez, P. Mahonen. “Cross-layer energy analysis of multi-hop wireless sensor network”. In EWSN’ 05, 2005, pp. 33-44.
18. R. Wattenhofer, L. Li, P. Bahl and Y.-M. Wang. “ Distributed topology control for power efficient operation in multihop wireless ad hoc networks ” . In Proceeding of the IEEE INFOCOM’01, 2001,pp. 1388- 1397.
19. D. Estrin, D. Culler, K. Pister, and G. Sukhatme, “Connecting the Physical World with Pervasive Networks,” *IEEE Pervasive Computing*, vol. 1, pp. 59-69, Jan. 2002.
20. J Hill, P Bounadonna, D Culler, “Active message communication for tiny network sensors”, in *Proceedings of INFOCOM*, 2001.
21. X. Zeng, R. Barodia, and M. Gerla, “GloMoSim: A Library for Parallel Simulation of Large–Scale Wireless Networks,” In *Proceedings of Workshop on Parallel and Distributed Simulation*, pp. 154–161, 1998.
22. P. Levis, N. Lee, M. Welsh, and D.Culler, “TOSSIM: Accurate and Scalable Simulation of Entire TinyOS Applications,” In *Proceedings the 1st ACM Conference on Embedded Networked Sensor Systems(SenSys03)*, pp. 126–137, 2003.
23. J. Elson, L. Girod, and D. Estrin, “EmStar: Development with High System visibility,” *IEEE Wireless Communication*, pp. 70–77, December 2004.