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Duty Cycle Control Using X-MAC Protocol and Reduction of End to End Delay using Transmission Power Control Techniques for Rechargeable Wireless Sensor Networks

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Abstract - A main problem in rechargeable wireless sensor networks is nodes have to adjust their duty cycle continuously. Because the energy harvested from the environment is not sufficient to power the sensor nodes continuously. So the nodes have to operate in low duty cycle. X-MAC is a asynchronous mac protocol for wireless sensor networks (WSNs). Other asynchronous MAC protocols involved in extended preamble sampling. Long preamble introduces excess latency at each hop. The receiving node has to wait for the reception of full long preamble message even though it comes to wake state in the middle of the transmission. X-MAC proposes solution to this problem. It uses strobed preamble to interrupt the preamble message as soon as it wakes up and determines it is the target receiver. So the duration of sending preamble message is reduced. The transmission power control technique is used to adjust the power level of the node to improve the transmission range. Thus the end to end delay is reduced by improving the transmission range.

Keywords: X-MAC protocol, Transmission power control technique, Rechargeable wireless sensor networks.

I.INTRODUCTION

Wireless sensors are used to monitor and report data in various application scenarios. As nodes are energy constrained ,the battery must be used carefully by using efficient power management techniques. For rechargeable wireless sensor networks (RWSNs), the power manager plays the imortant role of balancing energy harvested from the environment with the energy consumed by the node.

. To extend the lifespan of sensor nodes that has to be embedded with rechargeable technologies [20], which convert sources such as body heat [2], foot strikes [4], and finger strokes [3] into electricity. The energy harvested from the environment is not enough to power the sensor node continuously. So the nodes have to operate in low duty cycle [19]. Duty cycle is the ratio between active period to the lifetime of the node. Duty cycling extends the lifetime of the wireless sensor node. However, it incurs an additional delay because the nodes may be asleep [15].

Idle listening state of the node is the major source of energy wastage. In fact, it can consume almost the same amount of energy as required for receiving. By applying duty cycling to the node reduces the power consumption by tuning the radio to off .

Synchronous MAC protocols such as S-MAC [5] and T-MAC [6] need to frequently exchange their duty cycle information among neighbors to find neighbor node’s state. On the other hand asynchronous MAC protocols such as B-MAC [7] sends long preamble message to find other node states. In this paper X-MAC protocol [14] is used.It is an enhanced version of B-MAC is proposed to reduce the power consumption by incorporating two features. The first one is to reduce the duration of sending the preamble message by allowing the receiver to inform that it is ready to accept even in the middle of transmitting the preamble. Instead of continuously sending a long preamble message, it transmits one short preamble after another with the gap during which the awaken receiver can send an early acknowledgement [14]. The second feature is to embed the target node’s address in each preamble to let other nodes awaken go back to sleep if they are not the destination [14].

II. RELATED WORK

Duty cycle MAC protocols for WSNs are classified into synchronous and asynchronous classes based on whether or not senders know the exact wakeup time of their receivers. Synchronous classes have to exchange their duty cycle information among their neighbours; and asynchronous classes depend on low poewr listening.

S-MAC is a synchronous MAC protocol that makes use of synchronization among nodes to allow for duty cycling in sensor networks. At the start of the awake period, a node exchanges synchronization information to its neighbors to ensure that the node and its neighbors wake up concurrently. After exchanging synchronization message, the node sends Request To Send (RTS) and Clear To Send (CTS). In [9], the authors introduce adaptive listening to reduce delay. When a node hears an RTS or CTS from its neighbor, it will wake up at the end of the transmission to check the channel. If the node is the next hop on the data path, waking up at the end of the transmission leads to low delay as the packet can be transmitted immediately without having to wait until the next scheduled awake period.

T-MAC [10] is an extended version of S-MAC by shortening the awake period. In S-MAC, the nodes remain awake through the entire awake period if they are neither sending nor receiving data. While compared to S-MAC, T-MAC listening to the channel for only a short time after the synchronization phase, and if no data is received during this window, the node goes to sleep mode. But T-MAC was not able to handle as heavy load as LPL.

B-MAC [12] utilizes low power listening and an extended preamble to achieve energy efficiency. In B-MAC each node can have an independent schedule. Schedule message contains the node's wake and sleep period. If a node desires to transmit, it sends preamble that is slightly longer than the sleep period of the receiver. During the awake period, a node checks the medium and if a preamble is detected it remains awake to receive the data. While B-MAC performs quite well, it suffers from the overhearing problem. Transmission of long preamble dominates the energy usuage.

Wise MAC [8] uses preamble sampling to achieve low power communications in infrastructure sensor networks. Wise MAC uses a technique that are used in S-MAC protocol but the sender knows the schedules of the receiver awake periods and schedules its transmission to reduce the length of the extended preamble. To achieve this, the receiver adds the time of its next awake period in the acknowledgement frame. If the transmitter wants to send to that receiver next time it can begin the preamble only a short time before the receiver will awaken, taking into account possible clock skew. This reduces the energy consumption when sending the preamble.. Receivers process the data frame and if it finds that it is not the intended receiver it returns to sleep. If the node is the intended receiver, it remains awake until the end of the transmission and sends an acknowledgement. Wise MAC solves many of the problems related to low power communications but does not adapt to changing traffic patterns.

Transmission Power Control (TPC) techniques are used to achieve high link reliability [8], high throughput [1], and efficient energy utilization [13]. Transmission power of the node determines the range over which the packet can be reached correctly. To address the above issues various protocols have been proposed for wireless sensor networks. In [8], the transmission power of a node is increased to improve the reliability of a link when it is below a threshold level. The delay decreases if the transmission power of the node increases and vice versa. TPC techniques are used to reduce the delay because of fixed and limited energy supply in WSNs.

III. X-MAC PROTOCOL FOR LOW DUTY CYCLE

Asynchronous duty cycling classes have more advantages over synchronous classes in terms of energy consumption, latency, and throughput. Asynchronous classes do not have overhead due to synchronization. In asynchronous classes the awake period is shorter than that of synchronized methods. However extended preamble leads to higher energy consumption per packet as latency tolerance, and thus the receiver's sleep period increases. In comparison with other existing protocols X-MAC reduces the power consumption and delay by sending series of preamble message.

A. EMBEDDIND THE ADDRESS OF TARGET INTO PREAMBLE

A key limitation of low power listening is that non intended receiver who wake and sample the medium while the preamble transmission must wait until the end of the extended preamble before finding that they are not the target receiver and should go back to sleep. This is named as the overhearing problem. This leads to higher energy consumption in current asynchronous techniques.

In X-MAC the overhearing problem is reduced by dividing the one long preamble into a series of short preamble packets, each containing the ID of the target receiver. When a node receives a short preamble packet, it looks at the target node ID that is embedded into the packet. If the node is the intended receiver, it remains awake for the subsequent data packet. If the node is not the intended receiver, it returns to sleep mode immediately. Thus avoiding the overhearing problem.

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B. REDUCTION OF EXCESSIVE PREAMBLE USING STROBING

In traditional asynchronous techniques, the sender sends the entire preamble even though the receiver node wake up in the middle of the transmission of the long preamble. The full preamble packet needs to be sent before the data transmission because the sender does not that the receiver has woken up.

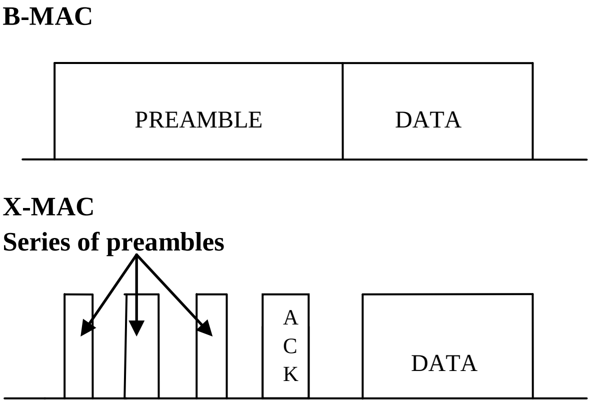

Fig.1.Preamble in B-MAC and X-MAC protocol

Instead of sending a long preamble message, X-MAC insert small pauses between packets the series of short preamble packets, during which time the transmitter node pauses to listen to the medium. These small gaps enable the receiver to transmit an early acknowledgement packet back to the sender. When a sender receives an acknowledgement from the target node, it stops sending preambles and sends the data packet.

C. ADAPTATION TO TRAFFIC LOAD

. Nodes with different traffic loads consequently have different ideal sleep schedules. It is difficult for a developer to hand tune all of the node's radio to sleep according to the changing traffic loads. X-MAC protocol adapts its duty cycle schedules to varying the traffic load.

IV. METHOD AND DESIGN

A. X-MAC DESIGN

If the probability, $P_{d(t)}$, of receiving a packet in any given interval is known then sender and receiver tunable parameters can be set to optimal values. Assume P_{Tx}, P_{Rx}, and P_s are the power required to transmit, receive, and sleep, respectively. S_p, S_{al}, and S_d denote the duration of the sender's preamble, acknowledgement listen, and data transmission periods. R_l and R_s denote the receiver listen and sleep periods. The expected energy to send a packet is given by:

E_s = (preamble energy+ energy per ACK listen) * (expected preamble-listen iterations required) + (energy to send packet)

$$= (P_{Tx}S_p+P_{Rx}S_{al}) \left(\frac{1}{\left(\frac{R_L-S_P}{R_L+R_S} \right)} \right) + S_dP_{Tx} \quad (1)$$

The protocol implementation adds a post-packet-reception delay R_{qpl} to catch queued packet trains. This extra wake time changes the expected number of preamble listen iterations required, giving:

$$E_s = \frac{P_{Tx}S_p+P_{Tx}S_{al}}{1-(1-P_dR_{qpl}) \left(1 - \frac{R_l - S_P}{R_l + R_s} \right)} + S_dP_{Tx} \quad (2)$$

The expected energy to receive a packet is given by:

E_r = (listen cycle energy + sleep cycle energy) * (expected iterations for a preamble to arrive) + (energy to send an ACK) + (energy to receive packet)

$$= \frac{P_sR_s + P_{Rx}R_l}{1-(1-P_d(t))^{(Rl+Rs)}} + P_{Tx}R_a+R_dP_{rx} \quad (3)$$

The expected latency for a single hop is:

L_{at} = (duration of preamble + ACK listen) * (expected number of iterations required) + (duration to send packet)

$$\left(\frac{1}{\quad} \right) *(S_p+ S_{al})+S_d$$

$$= \frac{R_l - S_p}{R_l + R_s} \quad (4)$$

$$= \frac{(S_p+S_{al})(R_l+R_s)}{R_l - S_p} + S_d$$

B. TRANSMISSION POWER CONTROL DESIGN

The E2E delay that a packet is delivered from a sensor node to the sink is reduced by the method of improving transmission power of nodes if they have enough energy to support the action. The method is explained in an example for several nodes in an linear network as shown in fig.2. The E2E delay from node a to node c is 13 units of time, where the period duration is 10 units of time.

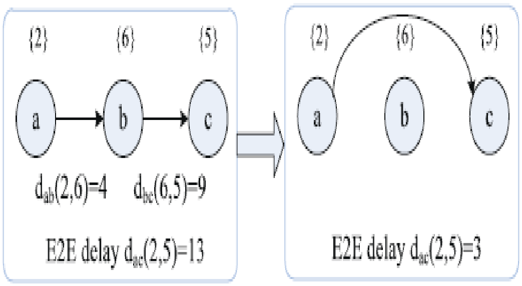

Fig.1 Reduction of end to end delay using transmission power control mechanism

If node a has enough energy to increase its transmission range and communicates with node c directly without forwarding to node b. So the E2E delay from node a to node c is 3 units of time. The new E2E delay from node a to node c is 3 units of time. So the E2E delay reduces 10 units of time. The transmission power controlling technology greatly reduces the E2E delay.

Consider three sensor nodes are in sequence {i, i+1, i+2}, which means node with serial number of i+2 is more closely than i+1 to the sink node and the node with serial number of i+2 is more closely than i+1 to the sink and the node with serial number of i is farthest away the sink. For clarity, node with the serial number of i is replaced by node i. Assume node i delivers packets at time t_k^i, which is one of active instances of working schedule of node i. For adjacent node i+1, the active instance t_k^i+1 is the closest active instance to node i, which means di,i+1 (t_k^i+1,t_k^i)≤|t_ni+1-t_ni|, n=1,2,....n, n≠k. The minimum delay from node i to the node i+1 is

$$d_{i,i+1}(t^k_{i+1},t^k_i)=t^k_{i+1}-t^k_i \quad (5)$$

In this paper $t_i<t_{i+1}$ if there is a k and the value of active instance of node i and node i+1 meets the requirement $t^k_i<t^k_{i+1}$. Therefore,there are six possibilities comparing the value of active instances for three nodes i, i+1, i+2.

For a nodes sequence {i,i+1,i+2}, if the value of active instance meets $t_i<t_{i+1}<t_{i+2}$,the E2E delay does not decrease while using transmission power control scheme. By analyzing the six possibilities, the E2E delay only can be reduced in three cases by improving transmission power of nodes contains{i, i+1, i+2 |$t_i<t_{i+2}<t_{i+1}$, $t_{i+1}<t_i<t_{i+2}$, t_{i+2}<ti+1<t_i}. Nodes sequence {i,i+1,i+2} satisfy ϕ(i, i+1, i+2). However,the E2Edelay does not decrease in other three cases.It is called as φ(i, i+1, i+2)={i, i+1, i+2|$t_i<t_{i+1}<t_{i+2}$, $t_{i+2}<t_i<t_{i+2}$, $t_{i+1}<t_{i+2}<t_i$}. Therfore, if we want to reduce the E2E delay, the relationship of every three adjacent nodes which are in an ordinal sequence {i, i+1, i+2} has to satisfy the ϕ(i, i+1, i+2).

B.1 E2E delay

For a packet ready at source node i,the delay to reach the sink node s is the sum of single-hop sleep latency. Consequently, it can be formulated as:

$$d^0_{is}(i,s)=\sum_{i=1}^{i=n-1} di,i+(i,i+1) \quad (6)$$

B.2 The times of controlling transmission power

For a packet at source node i, the E2E delay bound B is the expected transmission delay to reach the sink node s. Assume τ denote the units of time of duration. The least times of controlling transmission powe For a packr of nodes can be formulated as:

$$h = \frac{d0is(i,s)-B}{\tau} + 1 \quad (7)$$

In order to meet theE2E delay bound requirement, at least h number of nodes to improve their transmission power in the networks. Assume there are at least p ordinal sequences {i, i+1, i+2} can satisfy the ϕ(i, i+1, i+2) in the networks, where p≤n-1. When h≤p, after improving h times transmission power, the new E2E delay can be expressed as:

$$d^h_{is}(i,s) = \sum_{i=1}^{i=n-1} di,i+1(i,i+1) - \tau * h \quad (8)$$

V. SIMULATION RESULTS

A. POWER CONSUMPTION FOR B-MAC AND X-MAC

The energy consumption for X-MAC protocol and B-MAC protocol is evaluated. The B-MAC protocol sends long preamble message to find the neighbor modes of transmission. If the neighbor node wakes up at the middle of the transmission of the long preamble the receiver node cannot signal about the states. So the receiver node has to wait for the reception of full preamble. So B-MAC protocol spents more energy for sending preamble message.

In X-MAC protocol each active node transmits series of short preambles spaced with gaps. When a receiver wakes up and receives a preamble, it transmits an ACK back to the sender to stop series of preambles, which reduces energy spent by the transmitter. So X-MAC protocol spents less energy for transmitting the preamble packets while compare with B-MAC protocol.

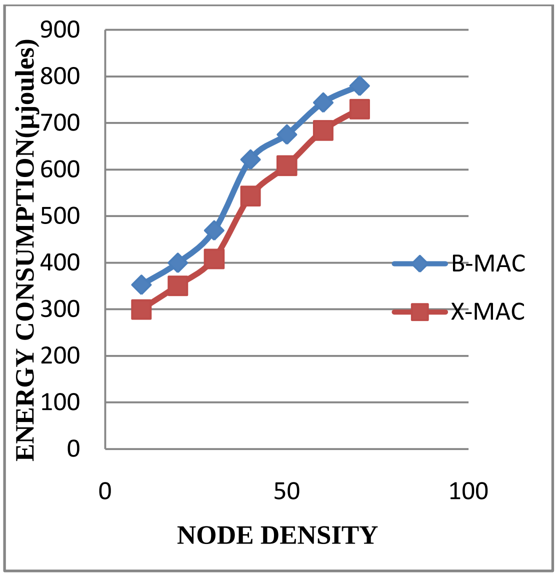

Fig.1 Energy consumption comparison between B-MAC and X-MAC

B. END TO END DELAY FOR X-MAC AND X-MAC WITH TPC

End to end delay refers to the time taken for a packet to be transmitted from source to destination. In X-MAC the sender node sends series of preamble packet to the target node until the receiver turned on and inform to the sender node. So the duration of sending preamble packet is reduced. Due to the duty cycling of the nodes the delay is increased. To reduce the delay transmission power control is used. By applying transmission power control in the networks node can adapts its transmission power to reach the multihop away node.

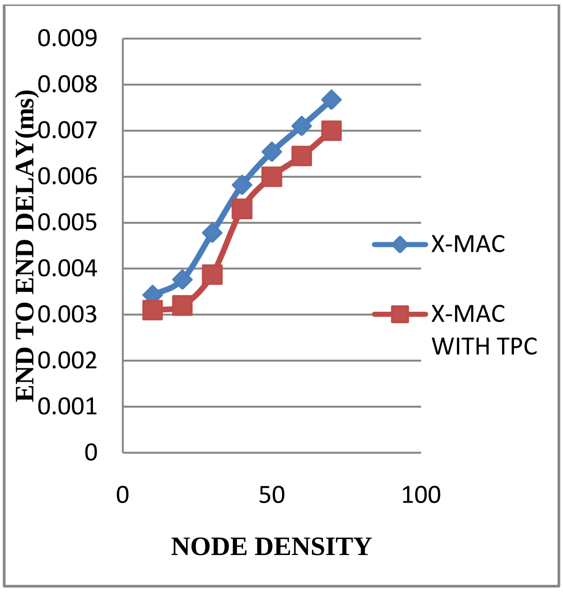

Fig 2.End to end delay comparison between X-MAC and X-MAC with TPC

This transmission power control algorithm mainly used in the case of link failure. If the packets are transmitted through all the relay node then the time taken for the packet to be transmitted from the source node to destination increases. This is undesirable. So the transmission power control aims to reduce the end to end delay between the source to destination. By improving the transmission power level the node can increase its transmission range. Instead of transmitting through all relay nodes it directly transmits to the far away node. Simulatlion result shows that the X-MAC end to end delay is reduced after applying transmission power control algorithm.

VI. CONCLUSION

X-MAC introduces a strobed preamble approach by transmitting a series of short preamble packets, each containing the address of the intended receiver. Preamble packets spaced with the small gap that permit the target receiver to send an acknowledgement that stops the series of preamble packets. Truncation of preamble saves energy at both transmitter and receiver and allows for low latency. Non intended receivers which overhear the strobed preamble goes to sleep state immediately, rather than remaining awake for the full preamble as in conventional LPL. Actually duty cycling of node leads to delay. To overcome that transmission power control algorithm is used. It is used to adapt the node’s transmission power level. Transmission power control algorithm is used for link failure issues. By improving the node’s power level the transmission range can be increased. So the sensor node can transmit the data packets to far away node directly instead of transmitting to all the relay nodes. Thus end to end delay is reduced.

REFERENCES

[1] Karn P. A new channel access protocol for packet radio. In: American radio relayleague ninth computer networking conference. 1990.

[2]Starner T. Human-powered wearable computing. IBM Systems Journal 1996.

[3] Kymissis J, Kendall C, Paradiso J, Gershenfeld N. Parasitic power harvesting inshoes. In: Second International Symposium on Wearable Computers. 1998.

[4]Shenck N, Paradiso J. Energy scavenging with shoe-mounted piezoelectrics.IEEE Micro 2001.

[5] W. Ye, J. Heidemann, and D. Estrin. An energyefficient mac protocol for wireless sensor networks. In 21st International Annual Joint Conference of the IEEE Computer and Communications Societies (INFOCOM'02), New York, NY, USA 2002.

[6] T. van Dam and K. Langendoen. An adaptive energyefficient mac protocol for wireless sensor networks. In 1st ACM Conference on Embedded Networked Sensor Systems (SenSys), pages 171–180, 2003.

[7] J. Polastre, J. Hill, and D. Culler. Versatile low power media access for wireless sensor networks. In The Second ACM Conference on Embedded Networked Sensor Systems (SenSys), pages 95–107, November 2004.

[8]Gomez J, Campbell AT. A case for variable-range transmission power control inwireless multihop networks. In: Proceedings of the IEEE INFOCOM, 2. 2004. p.1425–36.

[9] W. Ye, J. Heidemann, and D. Estrin. Medium access control with coordinated, adaptive sleeping for wireless sensor networks. ACM Transactions on Networking, 12(3):493–506, June 2004.

[10]G. Halkes, T. V. Dam, and K. Langendoen. Comparing energy-saving mac protocols for wireless sensor networks. ACM Mobile Networks and Applications, 10(5):783–791, 2005.

[11]Kawadia V, Kumar PR. A cautionary perspective on cross layer design. IEEEWireless Communications 2005;12(1):3–11.

[12] A. El-Hoiydi and J. Decotignie. Low power downlink mac protocols for infrastructure wireless sensor networks. ACM Mobile Networks and Applications, 10(5):675–690, 2005.

[13] Ghosh A, Wolter DR, Andrews JG, Chen R. Broadband wireless access withwimax/802.16: current performance benchmarks and future potential. IEEECommunications Magazine 2005;43(2):129–36.

[14] M. Buettner et al., "X-MAC: A Short Preamble MAC Protocol For Duty-Cycled Wireless Networks," In Proceedings of ACM SenSys, Boulder, CO, November 2006.

[15]Kansal A, Hsu J, Zahedi S, Srivastava MB. Power management in energy harvesting sensor networks. ACM Transactions on Embedded Computing Systems2007.

[16] Du S, Saha AK, Johnson DB. RMAC: a routing-enhanced duty-cycle MAC pro-tocol for wireless sensor networks. In: Proceedings of the 26th annual IEEEconference on computer communications (INFOCOM). 2007. p. 1478–86.

[17] Fei Yang , Isabelle Auge-Blum. Delivery ratio maximized wakeup scheduling for ultra-low duty-cycled WSNs under real-time constraints. Elsevier journal 2010.

[18] He S, Chen J, Jiang F. Energy provisioning in wireless rechargeable sensor networks. IEEE Transactions on Mobile Computing 2013.

[19]Demin Gao, Guoxin Wu, Yunfei Liu, Fuquan Zhang. Bounded end-to-end delay with Transmission Power Controltechniques for rechargeable wireless sensor networks. International Journal of Electronics and Communications (AEÜ) 2014.