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Evaluation Performance of Hybrid MAC Protocol in Wireless Sensor Network

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Abstract. The implementation Wireless Sensor Network (WSN) in generally can be applied in any environment where the important MAC layer plays vital. Researchers discover that the major power consumption of wireless sensor network nodes are related to their radio transceiver's activities on MAC. This paper explains the implementation expected system that can be used in the WSN system. It focuses on the comparison some MAC protocol in order to discover the performance of each protocol. Therefore, this paper is benchmarking with other MAC protocol to identify the capability of the proposed hybrid protocol in term of some parameter. Then, this paper determines the proposed hybrid protocol that is compared with other protocol based on evaluation of some parameter chosen.

1. Introduction

Wireless Sensor Network (WSN) is the most commonly well-known technology, especially in communication industry. It consists of tiny particles that consume some number of energies from irreplaceable batteries that is named sensor nodes. Sensor nodes gather packet data from worldwide networks, process it, and transmit the packet data via radio frequency transmitter to the sink node [1]. WSNs are usually static nodes that send data to a server or a sink node for processing.

Currently, WSNs are going into real deployments covering various areas, e.g., military industry [2], industrial application [3], environment monitoring [4] and health care [5, 6] for humanity. Moreover, sensor-networking communication manage is the main role in development of Internet of things (IoT) [5-8].

Wireless sensor network has limited battery. Most of researcher's efforts that discover the major power consumption of WSN nodes are related to their radio transceiver's activities have proved it. Then, running in the idle mode (switched on, or also called ready-to-receive mode) as when transmitting or receiving data is also significantly consume high energy consumption. Hence at the MAC layer that control the operation of radio, should avoid the frequent switching. Moreover, the problems of study about struggle to achieve power efficiency can be solved by the relevant technique in MAC layer called duty cycle.

Most of the existing Duty Cycle for MAC protocols in WSN use synchronous and asynchronous technique. In this paper, it proposes a hybrid asynchronous MAC protocol by combines the TDMA concept (L-MAC protocol) with the adaptive wake up preamble (WiseMac protocol). In order to improve end to end delay while ensuring energy efficiency, first each node allows to choose different timeslot, which is not interfering with the communication between other nodes in the network. Then, after finished choosing slot and it will check the medium by using preamble sampling to alert the receiver node, after receiving the current frame. A wake-up preamble of size equal to the sampling period is transmitted, in front of every data frame. It ensures that the receiver will be awake when the data portion of the packet arrives. Therefore, by combine Scheduling mechanism (LMAC) and Preamble Sampling (WiseMac), it is possible to reduce the delay and energy of the node.



2. Proposed Hybrid MAC

There is a direct trade-off between energy efficiency and latency, it is because lowering the energy consumption may result in high latency. Conceptual model of this research is a hybrid MAC protocol combines the concept L-MAC protocol with the advantages of adaptive wake up preamble of WiseMAC protocol. In the first phase by use scheduling mechanism, each node allows to choose different timeslot, which is not interfering with the communication between other nodes in the network. The free timeslots of each channel are calculated by performing the OR operation between the s local vector and the vector found from its neighbor. A node is allowed to transmit by using its controlled timeslots and can receive from any timeslot of any channel by switching the interface between different free timeslot as well. In the next phase, after a node finished choosing slot and it will check the medium by using preamble sampling mechanism. It ensures that the receiver will be awake when the data portion of the packet arrives.

3. Performance Result

In this section is elaborated the result value of four protocols in term of energy consumption, throughput, latency and packet delivery ratio which formula as follow.

- Energy consumption per bit: defined as the energy that being used by total number of bits transmitted. Energy efficiency unit is joules / bit. The formula for energy consumption per bit is given below:

$$\text{Energy Consumption per bit} = \frac{\sum \text{energy consumed}}{\sum \text{bits transmit}} \quad (1)$$

- Average Network Throughput is throughput per unit of time (number of packets received by the sink node). The formula for Average Network Throughput is given below:

$$\text{Network Throughput} = \frac{\sum \text{number of packet receive}}{\sum \text{time}} \quad (2)$$

- Average Packet Latency is the amount of time delay between the sending of packet to the time when the packet reaches the sink node. The formula for the packet latency is given below:

$$\text{Packet Latency} = \frac{\sum (\text{arrive time} - \text{send time})}{\sum \text{Number of connections}} \quad (3)$$

- Average Delivery Ratio is the percentage of data packets received by the number of packets sent overall average node. The formula for packet delivery ratio is given below:

$$\text{Packet Delivery Ratio} = \frac{\sum \text{Number of packet receive}}{\sum \text{Number of packet send}} \quad (4)$$

3.1. Energy Consumption

Energy consumption values are the main focus in this simulation. In this simulation is calculated energy consumption value of the prototype realistic model. The result of energy consumption. The result of energy consumption is shown in Table 1.

In Table 1 showed the obtain result of energy consumption-based simulation implementation with different nodes. The highest achieve the energy consumptions in any nodes is L-MAC that reach 0.1626 in 10 nodes and in nodes 50 get until 0.2582. For second highest is B-MAC that reach until 0.1584 and in 50 nodes until achieve 0.2548 value. However, the lowest is different among each node between WiseMAC and Hybrid ADC MAC. In nodes 10 and 20 the lowest is WiseMac where for nodes 10 the value is 0.1551 and nodes 20 the value 0.1922. Meanwhile, in other nodes WiseMAC is higher energy consumption than Hybrid ADC MAC. The Hybrid ADC MAC has the lowest energy consumption in nodes 30 that reach 0.2128, nodes 40 with 0.2334 and nodes 50 with value 0.2497. In averages, the Hybrid ADC MAC has the lowest energy consumption compare with other:

Table 1. Result of Energy Consumption of Proposed MAC

| MAC Protocol | Node(s) | | | | |
|--------------|---------|--------|--------|--------|--------|
| | 10 | 20 | 30 | 40 | 50 |
| WiseMAC | 0.1551 | 0.1922 | 0.2148 | 0.2347 | 0.2507 |
| Proposed MAC | 0.1554 | 0.1930 | 0.2128 | 0.2334 | 0.2497 |
| L-MAC | 0.1626 | 0.2027 | 0.2230 | 0.2415 | 0.2582 |

3.2. Throughput

It calculated to get the value of network throughput. The simulation results are emphasized to get the value of the rate of successful message delivery over the prototype model realistic that used. The result of network throughput is measured in bits per second (bit/s or bps). Below is the value of network throughput of each MAC Protocol obtained from the simulation results in Table 2:

Table 2. Result of Network Throughput of Proposed MAC

| MAC Protocol | Node(s) | | | | |
|--------------|----------|-----------|-----------|-----------|-----------|
| | 10 | 20 | 30 | 40 | 50 |
| WiseMAC | 51946.14 | 110046.79 | 209743.23 | 251531.23 | 324813.45 |
| Proposed MAC | 52233.28 | 121261.44 | 219743.36 | 266535.89 | 334316.83 |
| L-MAC | 53573.57 | 132326.16 | 228243.74 | 287591.44 | 347253.14 |

In the Table 2 is described the result of throughput in each network. In throughput simulation L-MAC is the highest that has values around 53573.57 bps in nodes and in the highest nodes 50 L-MAC reach until 347253.14 bps. The second highest throughput result in simulation is Hybrid ADC MAC that the lowest nodes (node 10) the result is 52233.28 bps and in nodes 50 the value is 334316.83 bps. Following the WiseMAC as the third highest with 51946.14 bps in nodes and in highest nodes is 347253.14 bps. Furthermore, the lowest of throughput simulation is B-MAC that achieved 51934.72 in nodes 10 until 314003.84 in nodes 50.

3.3. Latency

Latency measured from time interval between the stimulation and response, or, from a more general point of view. The result of energy consumption value is measured second (s). Below is the value of latency of each MAC Protocol obtained from the simulation results, as followed:

Table 3. Result of Latency of Proposed MAC

| MAC Protocol | Node(s) | | | | |
|--------------|---------|--------|--------|--------|--------|
| | 10 | 20 | 30 | 40 | 50 |
| WiseMAC | 0.0060 | 0.0144 | 0.0114 | 0.0110 | 0.0119 |
| Proposed MAC | 0.0046 | 0.0135 | 0.0111 | 0.0101 | 0.0113 |
| L-MAC | 0.0015 | 0.0120 | 0.0091 | 0.0082 | 0.0100 |

Table 3 showed the latency from simulation that B-MAC has the highest latency in any nodes from nodes 10 with value 0.0067 until nodes 50 with value 0.0127, following by WiseMAC that nodes 10 achieve 0.0060 and nodes 50 (0.0119). The third highest network is Hybrid ADC MAC value with nodes 10 is 0.0046 and in nodes 50 around 0.0113. Then, the lowest latency in this network is L-MAC

with 0.0015 for nodes 10 and 0.0100 for nodes 50.

3.4 Packet Delivery Ratio (PDR)

The last is Packet Delivery Ratio (PDR) value also be taken from the result of this simulation. PDR defined as the ratio between the received packets by the destination and the generated packets by the source. The result of PDR value is measured in percentage (%). The PDR value of each MAC Protocol obtained from the simulation results, as follows:

Table 4. Result of PDR of Proposed MAC

| MAC Protocol | Node(s) | | | | |
|--------------|---------|--------|--------|--------|--------|
| | 10 | 20 | 30 | 40 | 50 |
| WiseMAC | 0.9998 | 0.9971 | 0.9993 | 0.9969 | 0.9977 |
| Proposed MAC | 0.9988 | 0.9928 | 0.9932 | 0.9937 | 0.9940 |
| L-MAC | 0.9955 | 0.9885 | 0.9832 | 0.9867 | 0.9882 |

In Table 4 the highest and the lowest are slightly different in packet delivery ratio (PDR). In nodes 10 the highest value is WiseMAC 0.9998 and the lowest is L-MAC with 0.9955. Then, in nodes 20 the highest is also WiseMAC with 0.9971 and the lowest in this node is L-MAC is 0.9885. Meanwhile, in nodes 30 the highest value is 0.9994 and the lowest also L-MAC with value 0.9832. Furthermore, in nodes 40 the highest PDR value is WiseMAC with 0.9969 and the lowest is also L-MAC with 0.9867. Then, in nodes 50 the highest PDR value is also WiseMAC 0.9977 and the lowest is L-MAC with value number 0.9882.

4. Conclusion

This paper is describing the evaluated of MAC protocols of WSN that used parameters in term of Energy Consumption, throughput, latency and PDR. Then, the MAC protocol that used compared the evaluation is WiseMAC, L-MAC, Hybrid ADC MAC and B-MAC.

The comparison values of the MAC protocol are different that achieved high rate based on each parameter. In energy consumption, the highest achieve the energy consumptions in any nodes is L-MAC. Hybrid ADC MAC has the lowest energy consumption compare with other. Meanwhile, in throughput performance, the highest value is L-MAC the lowest value simulation is B-MAC that achieved. Then, in latency the highest is also L-MAC and the lowest latency is B-MAC. Furthermore, in PDR parameter the average highest value is WiseMAC and the lowest is L-MAC.

The expected contribution on this paper is more towards of comparing the performance MAC protocol that can use to identify efficiency of WSN implementation. For future work, another parameter is anticipated to propose in order to obtain the effectiveness MAC protocol performance.

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