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Comparison of Energy Efficiency and Routing Packet Overhead in Single and Multi Path Routing Protocols over S-MAC for Wireless Sensor Network

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Abstract—**Wireless Sensor Network (WSN) is a type of intelligent wireless network composed by tens to thousands of nodes. WSN can communicate each other as well as to modify the configuration by itself. In their communication process, WSN needs energy to forward some data packet. Energy of WSN is limited with batteries are not rechargeable. Energy efficiency is an interest case to be analyzed more on WSN. Obviously, With reduce cost of routing process we can save energy on WSN. In this paper, we analyze energy consumption of WSN and routing packet overhead on routing protocol based single path AODV and multipath AOMDV over SMAC in order to find out the most energy efficient between both. By performing simulation with Network Simulator NS-2, the study found that AOMDV perform better in terms of energy efficiency in among intermediate node but overal wasteful of energy with average large number of routing packet overhead compare to AODV.**

Keywords: S-MAC ; AODV ; AOMDV ; Energy Efficiency ; Wireless Sensor Network

I. INTRODUCTION

Wireless Sensor Network (WSN) is a type of intelligent wireless networks composed by tens to thousands of sensor nodes with sensing capabilities, communication and ability to self organize [1]. WSN has many advantages particularly in obtaining data and its ability to be applied in different situation, time, places, such as military and national defence, medical health, environmental monitoring, traffic management and many others.

Unfortunately, it comes with several limitations such as lack in storage capacity and limited communication capabilities of sensor nodes, which in turn leads WSN faces many challenges in practical applications, especially in increasingly complex network topology structures combined with rapidly changing network topology. A typical sensor node generally takes power from the battery that it is insufficient in terms of energy capacity and in many applications where they are put randomly sometimes in inaccessible locations, battery replacement is very difficult to do. In this case, the quality of WSN dropped.

As a result, the entire network can be affected by one or more nodes stops working. Therefore, the life of the nodes in such network is considered as very critical in WSN.

A WSN network with long survival life and low power consumption is a challenging field of research in this area [2]. Several studies have been proposed to deal with this issue.

One of the most widely used protocols is called S-MAC, designed specifically for low energy consumption of WSN sensor node.

Considering inability of nodes to replenish their energy consumption, S-MAC protocol is sometimes combined with single path routing protocols such as Ad-hoc On-Demand Distance Vector (AODV) routing protocol [3] or multi path routing protocols such as Ad-hoc On-demand Multipath Distance Vector (AOMDV) routing protocol [4].

In single path, routing protocol is intended to find a single route from source to destination, while in multi-path, routing protocol finds some route to compensate for the dynamic and unpredictable of network both energy and network bandwidth constrained sensor network [5].

One of the design of multipath routing is for load balancing, split the traffic between the source to destination across multiple path. Data are sent along different paths. With load balancing can distribute energy utilization accross intermediate nodes in a network [6].

This study aims at comparing energy efficiency and routing packet overhead of S-MAC in both single and multi path routing.

It is performed through computer simulation based on NS-2 to analyze four aspects: average of energy consumption, energy consumption on intermediate node, packet delivery fraction, and routing packet overhead.

The rest of this paper is organized as follows. Section 2 presents literature review of S-MAC and routing protocol. Next, in the following section, we explain the simulation scenario and perform analysis of the simulation results according to the given aspects. Finally, concluding remarks and future research directions are provided in last section.

II. TECHNICAL BACKGROUND

A. S-MAC

S-MAC protocol was proposed by Ye et.al [7][8] as a robust MAC protocol with low power consumption designed for use only in WSN, to solve the energy consumption related problems of idle listening, collisions and overhearing

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in WSN using only one transceiver. In [9 : 27] it is stated that "S-MAC considers that nodes do not need to be awake all the time given the low sensing event and transmission rates".

In addition, it has many other characteristics such as no loss packets, except in the case of changing topology, fixed period of idle/wake up between the nodes and changes in the inter-node operations is performed after each data transmission [8][10].

As a result, S-MAC is among limited WSN protocols included in TinyOS, a free and open source component-based operating system and platform targeting wireless sensor networks (WSNs) [11].

However, it comes with several limitations such as inability of node to replenish the energy they consume. Consequently, a solution should be made to deal with this issue. One passive way to save energy is a mode of sleep/wake up. When sensor nodes in a state of sleep, the energy are consumed based on the most likely. And wake up when running a particular task. Because S-MAC protocol is always in a position to control the transmission of sensor data node, it means that S-MAC protocol can make the decision when the sensor nodes in a state of sleep mode or wake up mode. S-MAC reduces the idle listening state by turnicng the radio OFF and ON periodically, so the time spent on idle listening can be significantly reduced, which accordingly saves a lot of energy.

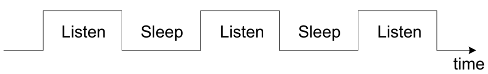

Figure 1. Periodic listen and sleep S-MAC protocol

The following are several important points related to the issue of energy consumption of WSN that gets serious attention by scholars [11]:

- *Collisions*: it occurs when two nodes transmit at the same time. Packages can be damaged and may need to be resent. So much time and energy is wasted during transmission and reception.
- *Overhead*: this is not contained application data. But it is very important for communication. Transmission and receipt of this package is overhead in sensor networks. Message control and the header length should be avoided as much as possible, because it will add an additional cost in communication.
- *Overhearing*: in which the sensor node can receive packets that are not addressed for him. These nodes can turn off the radio to save energy. Overhearing is the energy consumed by a node continuous and frame decoding is not directed to the node. This is a consequence of using media where the node does not know the priority whether the delivery of the package is for them or not.
- *Idle listening*: idle listening refers to the energy expended by a node in the circuit they have ON and ready to receive them at the moment there is no activity in the network.
- *Complexity*: complexity refers to the energy expended as a result of algorithms and protocols.

In essence, WSNs use only one transceiver only to deal with five energy consumption issues above. Therefore, by S-MAC it is assumed that nodes do not need to remain on stand-by at any time, given the low event rate sensor and transmission. Based on the CSMA/CA, that self configuration energy conservation is a primary goal, while fairness and latency is not so important. To provide energy conservation, S-MAC tries to reduce the depletion of unwanted energy due to collisions, overhearing, packet overhead and idle listening is based on fixed duty cycles.

Another drawback of S-MAC is the use of fixed duty cycles can waste a lot of energy since the communication subsystem activated, although there is no communication occurring [11].

B. *Routing Protocol*

1) Ad hoc On demand Distance Vector (AODV)

AODV is a distance vector routing protocols are included in the classification of reactive routing protocol, which is only to request a route when needed. Standard AODV was developed by C. E. Perkins, E.M. Belding-Royer and S. Das in RFC 3561 [12].

AODV has route discovery and route maintenance. Route Discovery is Route Request (RREQ) and Route Reply (RREP). Whereas Route Maintenance in the form of data, Router Update and Route Error (RERR). AODV initiates route discovery whenever a route is needed by the source node or whenever a node wishes to join a multicast group. Routes are maintained as long as they are needed by the source node or as long as the multicast group exists and routes are always loop free through the use of sequence numbers. AODV maintains a route table in which the next hop routing information for destination nodes is stored [13].

AODV adopts a very different mechanism to maintain routing information. AODV uses a single routing table entry for each destination. Without the use of source routing, AODV relies on routing table to disseminate route reply back to the source and sequentially will lead toward the goal. AODV also uses a sequence number to maintain any routing information purposes in order to obtain the latest and to avoid routing loops. All packages are geared to bringing this sequence number. The main feature of AODV is to maintain timer based state at each node according to the use of routing tables. Routing table will expire if it is rarely used. Routing path of AODV is illustrated in Figure 2.

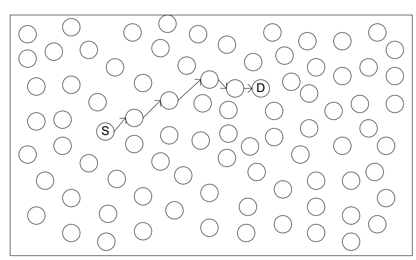

Figure 2. Single path routing

2) Ad hoc On-demand Multipath Distance Vector Routing (AOMDV)

AOMDV is an extension of AODV protocol which is able to find multiple paths to get to the destination and use as a backup path and use them concurrently and simultaneously.

The purpose of the multi-path routing protocol is to find multiple paths from source node to destination node. Then, sensing data can be transmitted from the source node to the sink node along this path [4]. Routing path of AOMDV is illustrated in Figure 3.

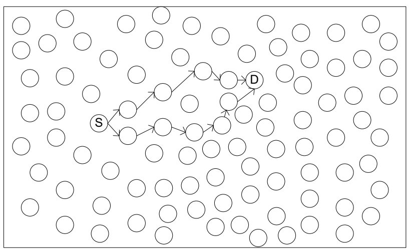

Figure 3. Multi path routing

AOMDV can be used to find node-disjoint or link-disjoint routes. To find node-disjoint routes, each node does not immediately reject the Reply Request (RREQ) duplicates. Each RREQ arriving via a different node from the specified source node-disjoint path. This is because the node cannot broadcast RREQ duplicate, so that every two RREQ arrives at an intermediate node through other nodes different from the source, cannot pass the same node. In trying to get some link-disjoint routes, destination RREQ duplicate replies, to answer the RREQ that arrived through other nodes are unique. After the first hop, Route Reply (RREP) which follows the best path, which then becomes a link-disjoint from the node disjoint. Trajectories of each RREP intersect at an intermediate node, but each will take a different path from the source link-disjoint.

By using AOMDV it is possible for intermediate nodes to reply to a RREQ, while still on the selected track. However, AOMDV has more overhead messages for discovery of new routes and because it is a multipath routing protocol [12].

III. SCENARIO AND SIMULATION

A. Scenario

In our study and evaluation for comparison the two scheme routing protocols single path AODV and multi path AOMDV we have used the SMAC as the MAC layer protocol.

The table below presents all parameters used in our simulation. While some parameters stay fixed others are varied in order for us to observe the changing behaviour of the network.

TABLE I. SIMULATION SCENARIO

Description	Scenario
Network simulator	NS2-2.35
Simulation time	1000 seconds
Data Link Layer	SMAC
Routing protocol	AODV and AOMDV
Number of node	10
Initial energy	1000 Joules
Idle Power	1.0w
Receiving Power	1.0w
Transmission Power	1.0w
Transition Power	0.2w
Sleep Power	0.0001w
Transition Time	0.005s
Max packet in ifq	50
Traffic	CBR
Packet size	100
SMAC synFlag	1
SMAC dutyCycle	80
Interface queue type	Queue/DropTail/Priqueue

The simulation scenario of path of forwading data from source to destination on AODV and AOMDV are presented in Figure 4 and Figure 5. It consists of ten nodes, where the source node of 0 generates packets while node 3 acts as destination node that receives the packets.

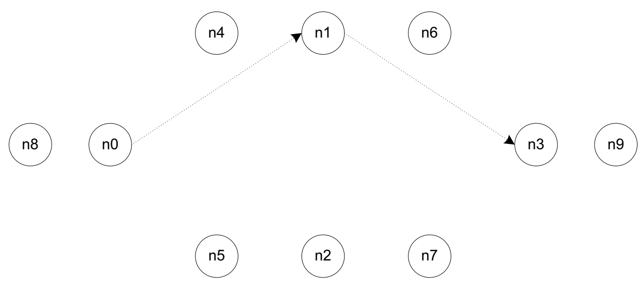

Figure 4. Path of forwading data from source to destination on AODV

Other nodes act as intermediate node that will forward data from source to destination. In this scenario, AODV routing protocol has only one route to destination, while AOMDV routing protocol have three paths to destination.

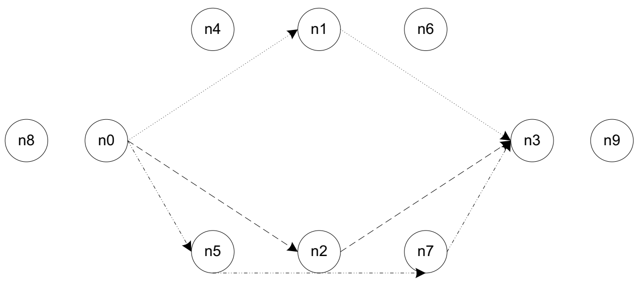

Figure 5. Path of forwading data from source to destination on AOMDV

B. Data Analysis

Based on the given scenario, the simulation was performed to obtain data according to four aspects to be measured. They are average of energy consumption, energy consumption on intermediate nodes, packet delivery fraction, and finally message packet routing overhead. The data based on four analysis are described below.

1. Average of energy consumption

The following charts show the energy consumption, span of time and average transmitted packets as parameters change. The energy of network is defined as the period from the beginning of simulation to the end of simulation when all nodes exhaust their energy. From data result of the trace file, has been defined the confidence interval [514, 534] time state. For detail information can be seen at Table II and Figure 6.

TABLE II. AVERAGE OF ENERGY CONSUMPTION

State (s)	AODV (Joule)	AOMDV (Joule)
514	514.0399	498.4926
518	510.2004	494.7013
522	506.3563	490.3354
526	502.5576	486.8515
530	498.8424	482.7468
534	495.0148	479.1413

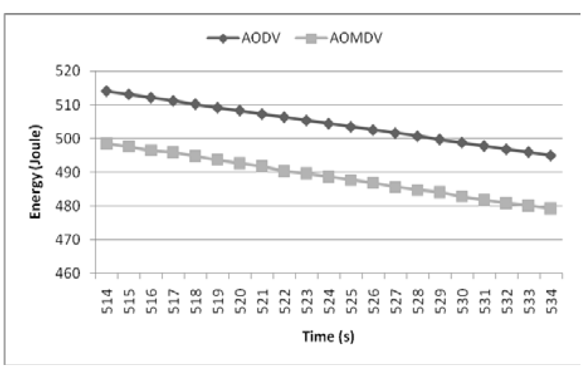

Figure 6. Average of energy consumption

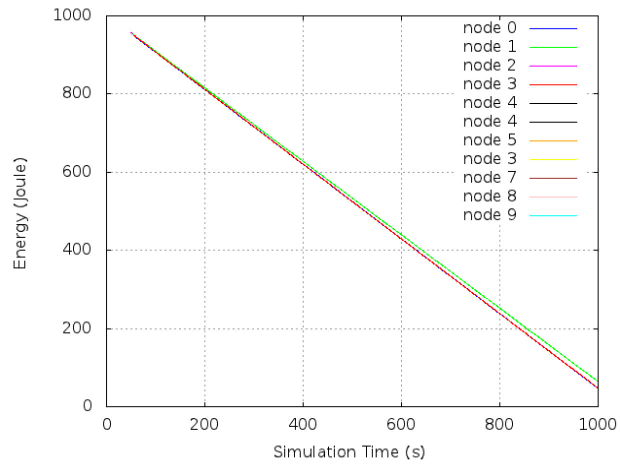

Figure 7. Distribution of the energy consumption of each node on the routing protocol AODV

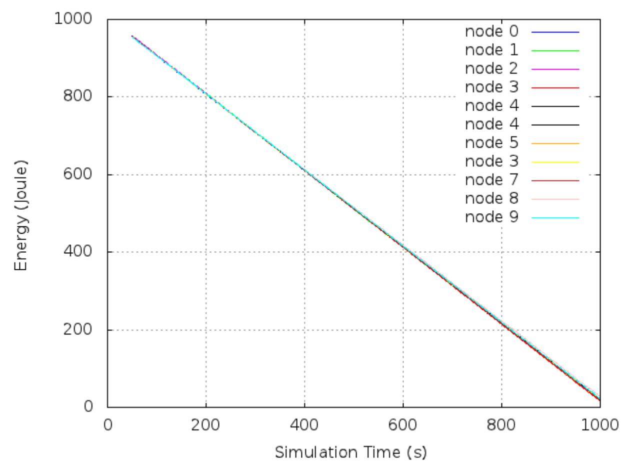

Figure 8. Distribution of the energy consumption of each node using the routing protocol AOMDV

It is found that there is a significant difference between both types in terms of energy consumption. While AOMDV accounted for around 479.1413 Joules, AODV only about 495.0148 Joules. As a result, it is clear that AOMDV consumes more energy than AODV.

The detail of energy consumption of each node every routing protocol of AODV and AOMDV are presented in Figure 7 and Figure 8.

Based on our findings, only three nodes found active for AODV routing protocol (node 0, node 1 and node 3) during the simulation process. In other words, only these three active nodes consume energy. Other seven nodes called inactive nodes or passive nodes are those that do not consume energy.

On the contrary, as depicted in figure 8, there is no single passive node for AOMDV. In other words, all nodes actively consume energy. This findings lead to us to justify that AOMDV has more energy consumption than AODV.

2. Energy consumption on intermediate nodes

In this aspect, we simulate how both AODV and AOMDV may differ in terms of energy consumption on the intermediate node. Both Figure 9 and Figure 10 represent the simulation results.

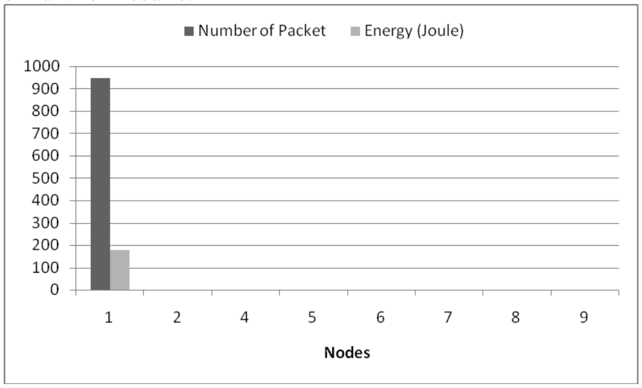

Figure 9. Distribution of the energy consumption of each intermediate node using the routing protocol AODV

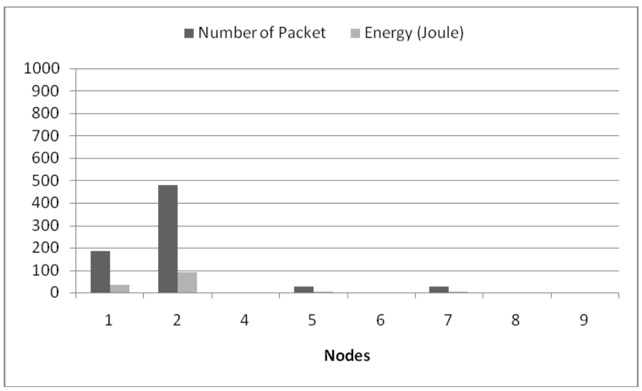

Figure 10. Distribution of the energy consumption of each intermediate node using the routing protocol AOMDV

The detail distribution energy consumption of each intermediate sensor nodes as a function of number packet in routing protocol AODV and AOMDV is indicated in Table III.

TABLE III. DISTRIBUTION ENERGY CONSUMPTION OF EACH INTERMEDIATE SENSOR NODE

Node	AODV		AOMDV	
	Packet	***Energy (Joule)***	***Packet***	***Energy (Joule)***
Node 1	950	178.6	187	35.156
Node 2	-	-	480	90.24
Node 4	-	-	-	-
Node 5	-	-	26	4.438
Node 6	-	-	-	-
Node 7	-	-	26	4.438
Node 8	-	-	-	-
Node 9	-	-	-	-

In routing protocol AODV only have one route to distribute traffic from source to destination, so from the existing scenario only through node 1 to forward data. AOMDV is multipath algorithm routing protocol where in traffic distribution can create more than one route, herewith for forward data from source to destination can through node 1, node 2 and node 5 – node 7 so there is load balancing and energy balancing on intermediate node. Based on the data, it can be concluded that energy consumption on intermediate node is more efficient by AOMDV rather than AODV.

3. Packet delivery fraction

Packet delivery fraction is the ratio of total data packets successfully received to total ones sent by CBR sources. It describes the loss rate that will be seen by the transport protocol. This metric tells us how much reliable the protocol is. Table IV gives results of packet delivery fraction each routing protocol.

TABLE IV. PACKET DELIVERY FRACTION

Routing Potocol	Send	Receive	Loss %
AODV	950	950	0
AOMDV	950	693	0.2705

As can be seen in Figure 9, AODV can effectively improve packet delivery fraction, consequently the original AODV would give higher performance with respect to the packet delivery fraction.

4. Routing packet overhead

Routing overhead is the total number of routing packets transmitted during the simulation. Based on our simulation, data comparison of routing overhead between AODV and AOMDV can be obtained as shown by Table V and Figure 11.

It is clear that packet routing overhead of AODV are always lower than of AOMDV especially in total packet send and received.

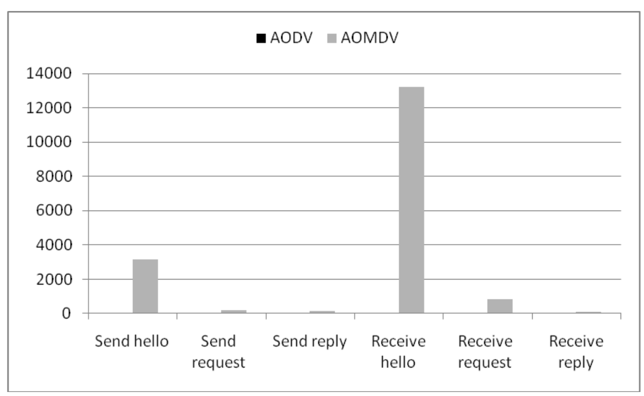

Figure 11. Comparison of packet routing overhead between AODV and AOMDV

Note: The number of packet routing overhead of AODV is not appear because insignificant.

TABLE V. NUMBER OF MESSAGES ROUTING OVERHEAD

Routing	Send hello	Send request	Send reply	Receive hello	Receive request	Receive reply
AODV	0	16	3	0	66	2
AOMDV	3164	210	144	13219	824	78

IV. CONCLUSION

Simulation of single path and multi path routing protocols over S-MAC for Wireless Sensor Network was performed to analyze energy efficiency and routing packet overhead. Based on the analysis, several main findings can be concluded as follows:

1. AOMDV is better than AODV in terms of energy consumption for sending or forwarding packet data traffic, although AOMDV have more packet routing overhead than AODV.
2. The amount of routing overhead each node needs, the type of protocol definitely affects the energy performance of the system.
3. The routing overhead affects the amount of energy used for sending and receiving the routing packets affects which nodes will have a faster decrease in energy.
4. From routing protocol perspective, both AODV and AOMDV require intermediate node to pass the packet. It is found that AOMDV requires less energy distribution of each node for sending the packet routing compare to AODV.
5. AOMDV has more number of drop packets than AODV which means packet delivery fraction of AODV is better than AOMDV.

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