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# Energy-Aware Routing in Wireless Sensor Network Using Modified Bi-Directional A*

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**Abstract**: Energy is a key component in the Wireless Sensor Network (WSN)[1]. The system will not be able to run according to its function without the availability of adequate power units. One of the characteristics of wireless sensor network is Limitation energy[2]. A lot of research has been done to develop strategies to overcome this problem. One of them is clustering technique. The popular clustering technique is Low Energy Adaptive Clustering Hierarchy (LEACH)[3]. In LEACH, clustering techniques are used to determine Cluster Head (CH), which will then be assigned to forward packets to Base Station (BS). In this research, we propose other clustering techniques, which utilize the Social Network Analysis approach theory of Betweeness Centrality (BC) which will then be implemented in the Setup phase. While in the Steady-State phase, one of the heuristic searching algorithms, Modified Bi-Directional A* (MBDA *) is implemented. The experiment was performed deploy 100 nodes statically in the 100x100 area, with one Base Station at coordinates (50,50). To find out the reliability of the system, the experiment to do in 5000 rounds. The performance of the designed routing protocol strategy will be tested based on network lifetime, throughput, and residual energy. The results show that BC-MBDA * is better than LEACH. This is influenced by the ways of working LEACH in determining the CH that is dynamic, which is always changing in every data transmission process. This will result in the use of energy, because they always doing any computation to determine CH in every transmission process. In contrast to BC-MBDA *, CH is statically determined, so it can decrease energy usage.

**Kata Kunci**: Energy; Routing; Wirelss; Sensor, Network; Betweenness Centrality; Searching; Modified Bi-directional A*.

## 1. INTRODUCTION

Internet of Thing (IoT) is a concept whereby an object has the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. IoT has evolved from the convergence of wireless technologies, micro-electromechanical systems (MEMS), and the Internet[4]. Based on a survey of IoT analysis, 10 popular IoT applications are Smart Home (100%), Wearable (63%), Smart City (34%), Smart Grid (28%), Industrial Internet (25%), Connected Car 19%), Connected Health (6%), Smart Retail (2%), Smart Supply Chain (2%), and Smart Farming (1%). This application works automatically by utilizing Wireless Sensor Network (WSN) technology.

Although there are many WSN applications, this network has some limitations that should be considered when deciding what protocol to use. Some of these limitations are first, WSN is limited energy supply, WSN has limited energy supply, thus required energy-saving communication protocol. Second, Limited Computation, node sensors have limited computing capabilities so that WSN can not run sophisticated network protocols. Third Communication, limited bandwidth, so that often inhibit intersensor communication[4].

In contrast to traditional wireless networks such as cellular networks, prioritizing quality of service and bandwidth efficiency, energy consumption and network lifetime are important in wireless sensor networks (WSN). In this research, we apply clustering based routing protocol for WSN. Various protocol clustering has been widely developed[8],[9],[10],[11],[12],[13],[14],[15],[16], such as LEACH[5] and its various modifications, PEGASIS, TEEN and so on. The clustering process will generate nodes designated as cluster head (CH). CH is tasked to forward packet data to Base Station. This method will make CH overloaded, affecting energy usage. If one node or CH die, it will disrupt the work function of the network.

Low Energy Adaptive Clustering Hierarchy (LEACH) is one of the most popular WSN routing protocols. CH is selected periodically each time it sends data (per round), while the energy supply consumed by each large node is fixed[5].

## 2. THEORY

This chapter describes the supporting theories of this research, which will be described in detail in subsequent chapters.

### 2.1 Wireless Sensor Network

Wireless Sensor Network (WSN) is a collection of hundreds or thousands of wirelessly connected sensors. The sensor device contains a complex set of electronics capable of performing sensing functions, performing simple computing processes and having the ability to communicate with other peers (other sensor nodes) or directly communicate with the base station (BS). Deployment of sensor node can be either randomly or manually planted (static). Components of sensor node are generally shown Figure 1, and Figure 2 show the wireless sensor network architecture.

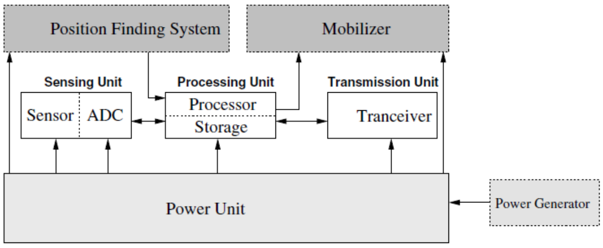



**Figure 1. Components of *sensor node***

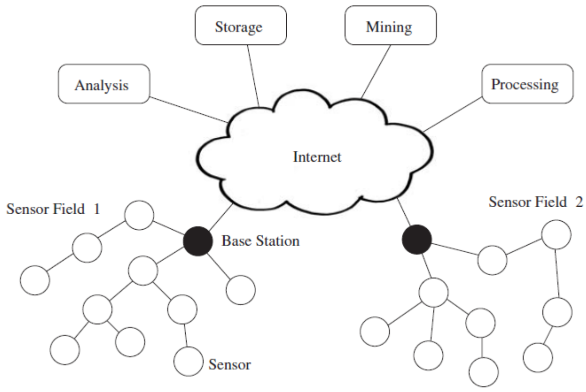



**Figure 2. Architecture of *Wireless Sensor Network***[5]

In Figure 1 it can be explained that components of node sensor generally consist of four main parts, namely sensing unit, processing unit, communication unit, and power unit. Sensing unit consists of sensor and ADC (Analog Digital Converter). The function of the ADC is to change the data output from the sensor that is analog data into digital data which will be entered into a digital component that is microcontroller. Sensor classification and sensor samples are shown in Table 1.

**Table 1. Classification and sample of sensors**[1]

| **Type** | **Example** |
|---|---|
| *Temperature* | *Thermistors, thermocouples* |
| *Pressure* | *Pressure gauges, barometers, ionization gauges* |
| *Optical* | *Photodiodes, phototransistors, infrared sensors, CCD sensors* |
| *Acoustic* | *Piezoelectric resonators, microphones* |
| *Mechanical* | *Strain gauges, tactile sensors, capacitive diaphragms, piezoresistive cells* |
| *Motion, vibration* | *Accelerometers, gyroscopes, photo sensors* |
| *Flow* | *Anemometers, mass air flow sensors* |
| *Position* | *GPS, ultrasound-based sensors, infrared-based sensors, inclinometers* |
| *Electromagnetic* | *Hall-effect sensors, magnetometers* |
| *Chemical* | *pH sensors, electrochemical sensors, infrared gas sensors* |
| *Humidity* | *Capacitive and resistive sensors, hygrometers, MEMS-based humidity sensors* |
| *Radiation* | *Ionization detectors, Geiger–Mueller counters.* |

The Communication protocol for low power devices can be shown in Table 2.

**Table 2. Communication protocol for low power devices**

| | ***GPRS/GSM 1xRTT/CDMA*** | ***IEEE 802.11b/g*** | ***IEEE 802.15.1*** | ***IEEE 802.15.4*** |
|---|---|---|---|---|
| ***Market name for standard*** | *2.5G/3G* | *Wi-Fi* | *Bluetooth* | *ZigBee* |
| ***Network target*** | *WAN/MAN* | *WLAN and hotspot* | *PAN and DAN (Desk Area Network)* | *WSN* |
| ***Application focus*** | *Wide area voice and data* | *Enterprise applications (data and VoIP)* | *Cable replacement* | *Monitoring and control* |
| ***Bandwidth (Mbps)*** | *0.0064 – 0.128+* | *11 – 54* | *0.7* | *0.020 – 0.25* |
| ***Transmission range (ft)*** | *3000+* | *1 – 300+* | *1 – 30+* | *1 – 300+* |
| ***Design factors*** | *Reach and Transmission Quality* | *Enterprise support, scalability, and cost* | *Cost, ease of use* | *Reliability, power, and cost* |

## 2.2 Routing Protocol in WSN

In sensor networks, energy conservation, directly related to network lifetime, is relatively more important than network performance in terms of quality of data that can be transmitted (QoS). As the energy will be exhausted, the network may be needed to reduce the quality of the results in reducing dissipation energy at the node and thus can extend the network lifetime. Therefore, energy conservation is considered more important than network performance. In general, the division routing protocols in WSN can be shown Figure 3.

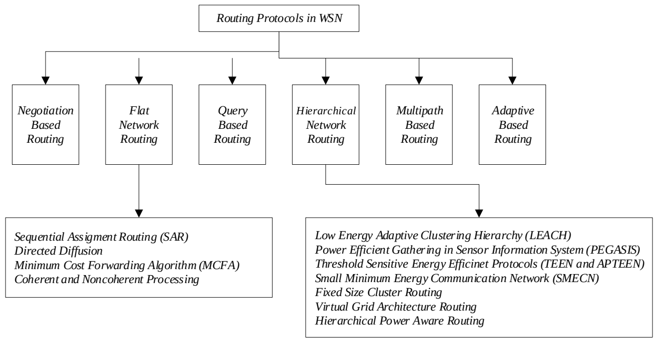



**Figure 3. *Routing Protocols in WSN***[4]

## 2.3 Modified Bi-Directional A*

The Modified Bi-Directional A * is algorithm uses heuristic functions with slight modifications. The heuristic function for n vertices in the forward search of Source (S) to Destination (G) is shown in equation (1)[6].

$$f = g\,(S,n) + \tfrac{1}{2}[h_s\,(n) - h_g\,(n)] \qquad (1)$$

While the heuristic function for n vertices in the search return (from Destination (G) to Source (S)) is shown equation (2)

$$f = g\,(G,n) + \tfrac{1}{2}[h_g\,(n) - h_s\,(n)] \qquad (2)$$

S : origin node or initial state

G : destination node or goal state

g (S, n) : the actual cost of S to n

g (G, n) : the actual cost from G to n

h_s (n) : approximate cost from n to G

h_g (n) : approximate cost from n to S

## 2.4 Heuristic Search

In the methods included in the heuristic search, heuristic functions play a decisive role. A function may be accepted as a heuristic function if the estimated cost generated does not exceed the actual cost. When a heuristic function gives an estimated cost that exceeds the actual cost (overestimate), the search process can get lost and make the heuristic search to be not optimal. The heuristic function is said to be good if it can provide approximate costs that are close to the actual cost. The closer the actual cost, the heuristic function more better. The heuristic function that can be used for the problem of finding the shortest route is a straight line distance on Cartesian coordinates which can be calculated using equation (3)[6].

$$h_s(n) = \sqrt{((x_n - x_s)^2 + (y_n - y_s)^2)} \quad (3)$$

With $d_{ab}$ is the distance between node a and node b. $x_a$ and $y_a$ are the coordinate values of node a on the x and y axes respectively. $x_b$ and $y_b$ are the coordinate values of node b on the x and y axes respectively.

## 2.5 Betweeness Centrality

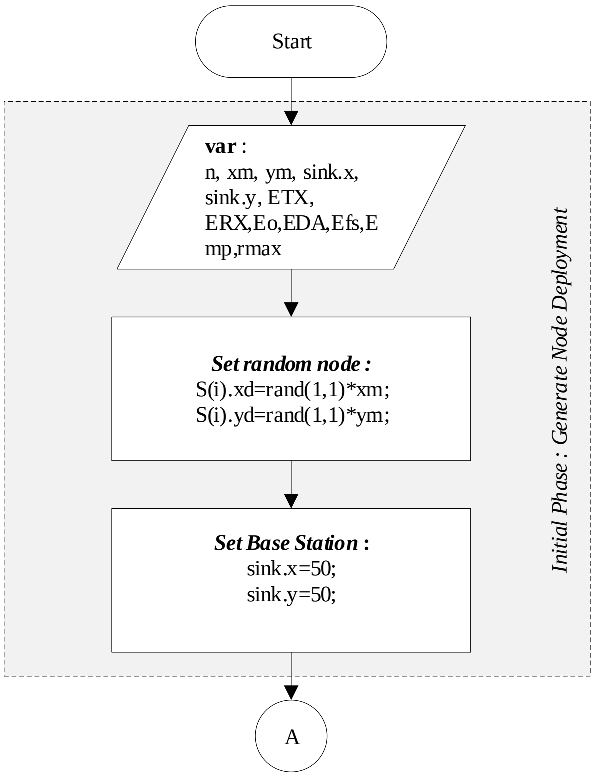
In graph theory and network analysis, the centrality indicator is used to identify the most important nodes in the graph. Usually used to identify the most influential people in social networks, the key key infrastructure on the Internet or urban networks, and the major disease spreaders.

Betweeness Centrality is an indicator of the centrality of the nodes on a computer network. BC or Betweeness Centrality works by counting the number of paths that pass through that node. Betweeness Centrality of the node (v) is formulated by equation (4)[7].

$$BC_i = \sum_{s \neq d} \frac{\sigma_{sd}(i)}{\sigma_{sd}} \quad (4)$$

# 3. Routing Protocol

In this chapter, we will explain in detail the designed routing protocol, which can be described in the step of process with a flowchart in Figure 4.



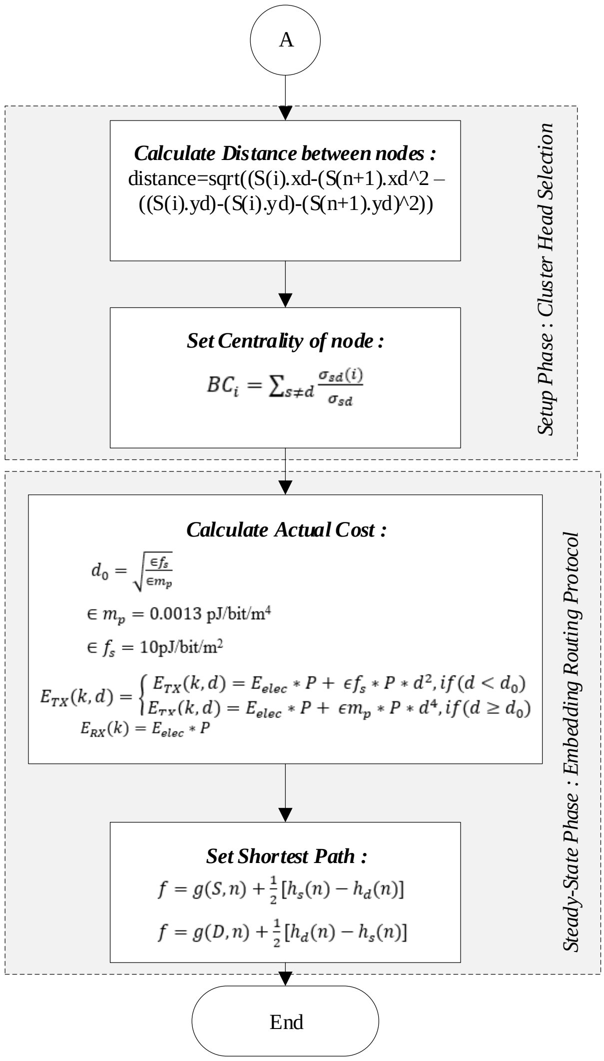




**Figure 4.** ***Flowchart BC-MBDA****

The variables used in this research are shown in Table 2.

**Table 2. Identification of Operational Variables**

| No | Name of variable | Kind of Variable | Function |
|---|---|---|---|
| 1. | n | Input | Number of node. |
| 2. | xm | Input | Coordinat max value x axis of field dimension. |
| 3. | ym | Input | Coordinat max value y axis of field dimension. |
| 4. | sink.x | Input | Coordinat value x axis of Base Station. |
| 5. | sink.y | Input | Coordinat value y axis of Base Station. |
| 6. | $E_{TX}$ | Input | Energi for Transmit packet data. |
| 7. | $E_{RX}$ | Input | Energy for Receive packet data. |
| 8. | $E_{elec}$ | Input | Energy of sensor node for computation process. |
| 9. | $E_o$ | Input | Initial energi for each node. |
| 10. | $E_{DA}$ | Input | Data aggregation energy. |
| 11. | $E_{fs}$ | Input | Energy free space loss (direct). |
| 12. | $E_{mp}$ | Input | Energi multipath (deflective). |
| 13. | $r_{max}$ | Input | Rounds max. |
| 14. | $x_d$ | Output | Coordinat value x axis of node. |
| 15. | $y_d$ | Output | Coordinat value y axis of node. |
| 16. | $d_o$ | Output | Distance of Base Station to Cluster Head. |
| 17. | C | Output | Node to become Cluster head. |
| 18. | E | Output | Energy of Cluster Head. |
| 19. | first_dead | Output | Number dead node. |

| | | | |
|---|---|---|---|
| 20. | distance | Output | Distance intersensor node. |
| 21. | X | Output | Coordinat value x axis of cluster head. |
| 22. | Y | Output | Coordinat value y axis of cluster head. |
| 23. | min_dis | Output | Distance intercluster head. |
| 24. | id | Output | Node id. |
| 25. | Message | Input | Message size. |

## 3.1 Initial Phase

This phase is the stage process of the node deployment, WSN is modeled in two-dimensional graphics by placing 100 nodes scattered randomly in a 100x100 (m) area. The base station is located at the coordinates (50,50). The placement of node and base station is static. The initial energy Eo = 0.5 Joule per node, we assuming all nodes are homogeneous and 4000bit message size.

## 3.2 Setup Phase

This phase is the stage process of the node deployment, WSN is modeled in two-dimensional graphics by placing 100 nodes scattered randomly in a 100x100 (m) area. The base station is located at the coordinates (50,50). The placement of node and base station is static. The initial energy Eo = 0.5 Joule per node, assuming all nodes are homogeneous and 4000bit message size.

## 3.3 Steady-State Phase

In this process the system determines the centrality of the node function as a cluster head in charge of forwarding the ndata packet to the Base Station. In this process the author uses Social Network Analysis (SNA) theory approach that is Betweeness Centrality (BC), which is calculated by using equation (4). The distance between nodes will be determined using the heuristic function, according to equation (3). The output of this process is the node designated as the cluster head.

## 4. EXPERIMENTAL RESULT

In this chapter, we will discuss the results of the research from the scheme designed in the previous chapter. Discussion of test results includes the results of each process from the process of generating node deployment, embedding routing protocol, and routing protocol performance analysis. Parameters used to determine the performance of routing protocol in this research are network lifetime, throughput, and residual energy. The experimental results will be compared with LEACH.

## 4.1 Network Model

In Figure 5 it can be seen the network model of the experiment. In this experiment obtained the results of 21 nodes designated as cluster head.

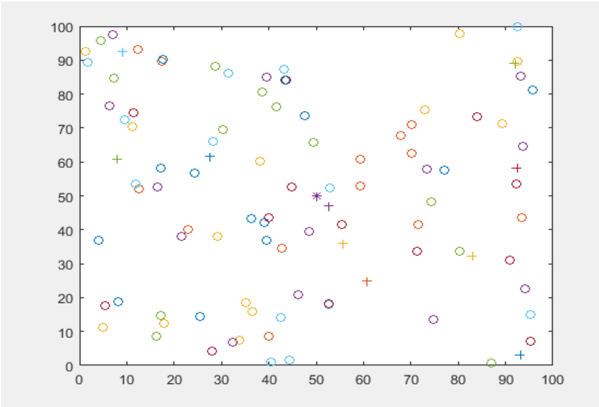


**Figure 5.** ***Node Deployment***

## 4.2 Performance Analysis

### *4.2.1 Network Lifetime*

Figure 6 shows a graph of the simulation results of routing protocol performance for network lifetime. In this experiment the node will die after consuming the energy of 0.5 Joule. BC-MBDA * ability to show Network lifetime better 3.22473% than LEACH. This is influenced by the way LEACH always uses dynamic clustering in every round, which will certainly result in the use of energy in CH. Different with LEACH, BC-MBDA * uses a semi dynamic clustering strategy. CH is determined in the setup phase, and is static after being determined as CH. This will reduce the computation process, so energy usage can be saved.

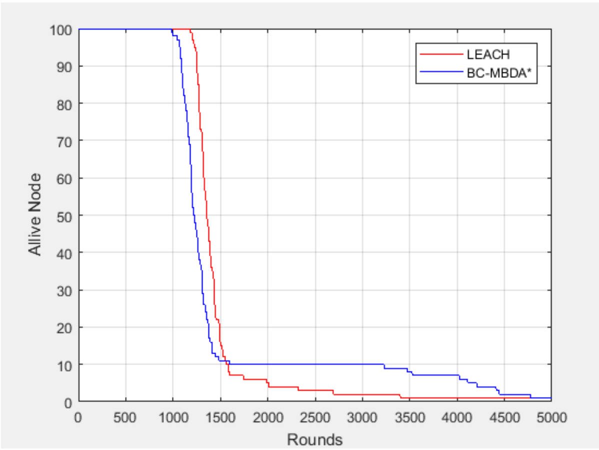



**Figure 6. Network Lifetime analysis result**

### *4.2.2 Throughput*

To evaluate throughput performance, the amount of packet data received in BS is compared to the number of packets sent by the nodes on each round. The BC-MBDA* throughput performance can be shown with the graph in Figure 7. The graph shows that BC-MBDA * throughput performance is 1.692883% better than LEACH. This is influenced by the ability of CH in delivering packets to BS. When CH is overloaded, it causes CH to die because the energy availability has been exhausted. When CH is off then the node will not be able to forward packets to BS. This resulted in disruption of the performance of the WSN system.

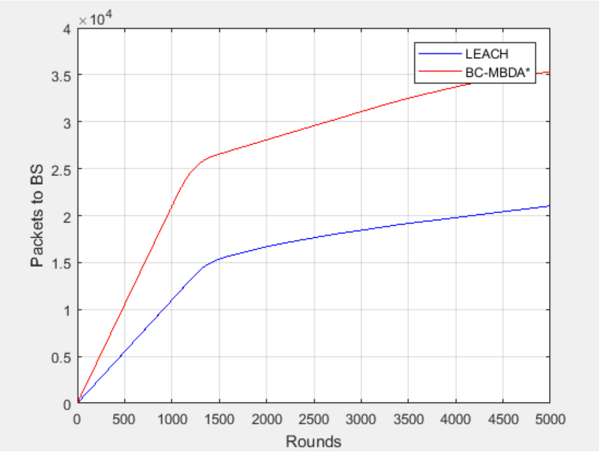



**Figure 7. Throughput analysis result**

### *4.2.3 Residual Energy*

Figure 8 shows the results of the analysis of the number of dead nodes in the experiment. The experiment was carried out as much as 5000 rounds, with an initial energy of 0.5 Joule / node. So the total energy of 100 nodes is 50 Joules. The graph shows that BC-MBDA * is better 0.879459% than LEACH.

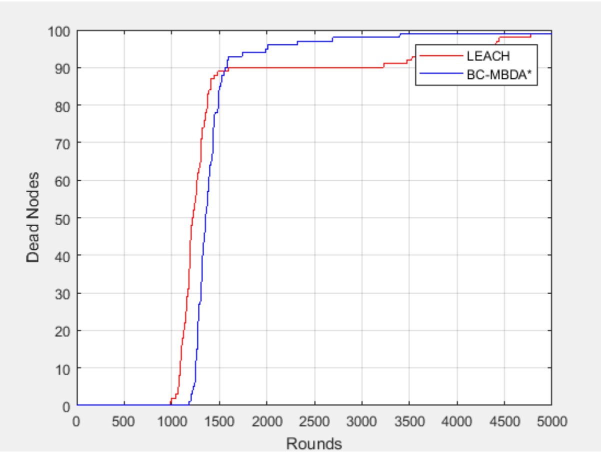



**Figure 8. Residual Energy analysis results**

## 5. CONCLUSION

Performance metrics analyzed in this research are network lifetime, throughput, and residual energy. The test results show that the performance of the designed routing protocol is better than LEACH. 1.692883% for Network Lifetime, 1.692883% for Throughput and 0.879459% for Residual Energy.

In the next study, we will develop a combination of K-NN method with MBDA*. In setup phase we will use K-Nearest Neighbors algorithm for cluster head selection, and for Steady-State Phase used MBDA*.

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