Aware-Routing Protocol using Best First Search Algorithm in Wireless Sensor

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Abstract: *Wireless Sensor Networks (WSNs) are recently spread widely because of their practical use in different applications and areas; this led to ubiquity wireless sensor networks everywhere. Energy consumption is considered as the biggest challenge to determine the WSNs lifetime, due to the limited power source in the batteries that are integrated into these sensor nodes. This paper proposes a new routing protocol based on BFS algorithm. Simulation Results show that the proposed protocol is efficient in terms of reducing energy consumption and increase the WSNs lifespan and achieves better performance than well-known protocols in terms of transmission delay, throughput, and packet delivery ratio.*

Keyword: *Aware-Routing Best First Search (AR-BFS), heuristic function, Wireless Sensor Networks (WSNs), load balancing.*

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1. Introduction

Wireless Sensor Networks (WSNs) are rapidly emanating as an important and influential factor in mobile computing, wireless systems, and vehicular- ad hoc networks [4, 17]. Which consists of a vast number of sensor nodes collaborate with each other to accomplish a common task, and therefore report the collected data to a center node (sink node [6, 11, 15, 17].

Wireless Sensor Networks (WSNs) may have a significant number of sensor nodes, which have been deployed over a particular sensing area. These Nodes broadcast their link quality, which is depending on radio frequency environment [14, 17]. The primary purposes of WSNs are to monitor, analyze, combine, and respond to the data which has been gathered by hundreds or thousands of nodes. There are many practical examples of WSNs applications, such as habitat monitoring, civil structure monitoring, Healthcare monitoring, inhospitable terrain, military use, and factory maintenance, etc., [10, 12].

The power of WSNs lies in the capability of deploying significant numbers of tiny nodes that have been configured by themselves, each of this sensing node contains a processing unit, sensing unit, external memory, power unit, and transceiver, sometimes it has a power generator. Figure 1 shows the sensor node architecture [24].

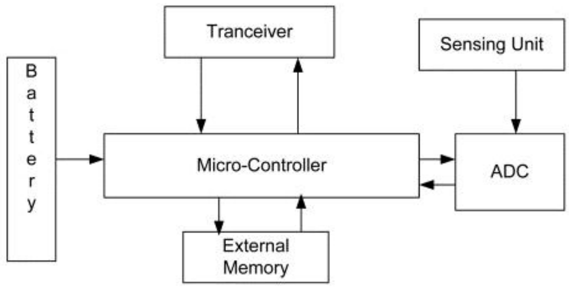

Figure 1. Sensor Node Architecture.

Wireless sensor networks suffer from different resource constraints, such as energy and memory size [7].

Energy consumption of each sensor node during the routing process in wireless sensor network considered as the most common problem in this type of systems, Because of its effect on the WSNs lifetime, and reliability, so that, find a solution to this problem is a big challenge[18, 22, 23, 24].

Energy consumption in wireless sensor networks can becategorized into two types: power consumption in communications (Data transmission), and power consumption in computations [9]. Data transmission consumes more energy if it is compared with the energy consumption in computations. Therefore, minimizing data transmission cost will lead to minimize the energy consumption in WSN which in turn will extend the network lifetime, so that many of researchers proposed different approaches of routing techniques to achieve this goal [8, 23].

The proposed protocol (AR-BFS) takes into consideration the effect of this problem on the reliability and network lifetimeso that it was built to mitigate the impact of this issue on WSNs.

AR-BFS will be used to minimize the power consumption rate at each sensor node in the wireless sensor network, and ensure the reliability of the system, extend the network lifetime, and also increase the average of packet delivery rate, all these objectives will be achieved by finding the optimal path during the routing process.

The practical procedure to find this route in this paper is based on select in gmulti-variable heuristic function with Best First Search (BFS) algorithm which means that any sensor node wants to pass data to next node must take into consideration this heuristic which is; straight line distance (SLD) from any sensor node to the sink node, the residual energy for this node, and also the minimum amount of the energy that must be held by this node to be in the path, this technique will save the energy for all sensor nodes in the network, which in turn will increase the WSN lifetime and reliability.

Algorithm 1: Pseudo code of the BFS.

OPEN = [initial state]
CLOSED = []
while OPEN is not empty
do
1. Remove the best node from OPEN, call it n, add it to CLOSED.
2. If n is the goal state, back trace path to n (through recorded parents) and return path.
3. Create n's successors.
4. For each successor do:
a. If it is not in CLOSED and it is not in OPEN: evaluate it, add it to OPEN, and record its parent.
b. Otherwise, if this new path is better than previous one, change its recorded parent.
i. If it is not in OPEN add it to OPEN.
ii. Otherwise, adjust its priority in OPEN using this new evaluation.
done

This algorithm operates by finding the optimal route of the data transmission on the wireless sensor network during the routing process, the factor that determines finding path mechanism is the heuristic function that is applied on the Best First Search. Figure 2 below shows an example of finding an optimal path using BFS algorithm based on the heuristic function that has been determined before.

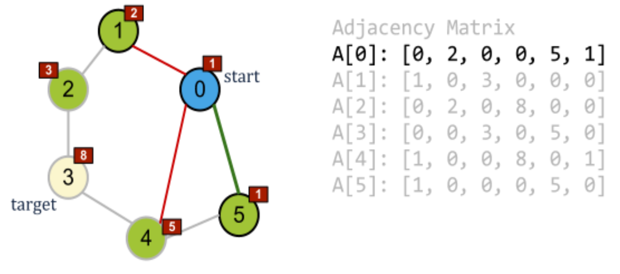

Figure 2. Finding optimal path using BFS with heuristic.

The rest of the paper isarranged as follows: section 2 describes the Literature Review. Proposed System is discussed in section 3, Simulation results are presented in section 4. Finally, the conclusion is listed in section 5.

2. Literature Review

All routing protocols can be categorized into three approaches [7], as shown in Figure 3:

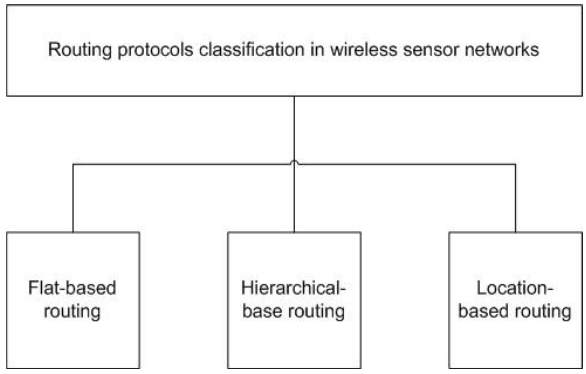

Figure 3. Routing protocols classification for WSN.

Many of current routing protocols and algorithms try to mitigate the impact of the energy problem in the WSNs lifetime and reliability, but all of these protocols face different types of challenges because of the poor resources of the sensor nodes, this problem has received a considerable interest from WSNs researchers [24], who proposed many protocols and mechanisms to overcome this issue, here are some of these protocols:

The new hybrid routing protocol in [19] which is called State Aware Link Maintenance Approach that is abbreviated by (SALMA) is proposed, this protocol based on two protocols the first one is Dynamic-Source Routing DSR and the second one is Optimized Link State Routing (OLSR). This protocol focuses on the activeness of sensor nodes in the WSN operations, and it is defined three states of sensor nodes, that is, black, white, and grey. The conclusion of this work proposed protocol gives enhancements in some QoS metrics such as lesser routing overhead than OLSR, smaller delay than DSR, and low-energy-consumption for all sensor nodes in the network. But the improvements of this protocol was at the activeness side of nodes in the network, but it does not achieve enhancements in the power efficiency for WSN.

Sequential Assignment Routing (SAR) was proposed as new routing protocol that is a concern in routing protocols that support some quality of service. Sequential Assignment Routing is working as multiple paths routing protocol that assists in routing decisions; it is based on three phases: quality of service on each path, energy resources, and the priority level of the packet. This protocol suffers from the overhead of routing tables and quality of service metrics at each sensor node [13].

EDAL is the data collection protocol proposed by the authors in the paper [9], which stands for Energy Efficient Delay Aware Lifetime balancing data collection. The authors of this paper proposed both a centralized heuristic to reduce the computational overheadand also distributed heuristic to make the protocol compatible with large-scale networks. The drawback of this approach is the less remaining energy because of the extended period of time that EDAL was running.

In [8] a new routing protocol was proposed to achieve energy efficiency in wireless sensor networks by reducing energy consumption on each sensor node, extending WSN lifetime, ensuring reliability for the system, increasing WSN load balancing, and minimizing packets delay. This protocol considered as an intelligent routing algorithm, which is based on reinforcement learning approaches. This protocol suffers from the complicated way of finding CH for each cluster in the network.

Velmani and Kaarthick [20] presented a new routing protocol which is perfect for little energy and low-bit rate networks. The idea of this protocol is not complicated, the author of the paper supposed that using the least energy path cost is not always necessary to be the best for the long-term health of wireless sensor network. This protocol assumed that using different routes during routing will make using the resources more equitably, the drawback of this protocol that it focuses on the resources utilization more the energy.

An Energy Efficient Routing (EEHR) protocol using the A-star search algorithm was proposed to find the optimal path from the source node to the sink node in the network. Simulation results with MatLab show that the proposed protocol EEHR is efficient in terms of the total of energy consumption and network lifetime if it is compared with the fuzzy approach, EEHR suffers from the memory consumption at each sensor node participated in the route [3].

The Multihop-LEACH protocol was proposed in the paper [21], this protocol working to improve the mode of communication from single-hop to multi-hop between the selected cluster head and sink node (base station). The results of simulation show that the energy consumption of Multihop-LEACH protocol has better performance than LEACH protocols, but this protocol still suffers from the problem of selecting Cluster Head (CH) for each cluster in the network.

Agarkar and Kodole [1] proposed a new routing protocol, which is called Neighbour coverage based probabilistic rebroadcast (NCPR) protocol, NCPR reduces the packet duplication. Due to the contention and collision is decreased. Moreover, it maximizes the delivery ratio of the packet and minimizes end to end delay. However, the delay that results from total broadcasting is increased.

In [6], authors have proposed a Multi-Constrained QoS Multiple Path Routing (MCMP) protocol, the objective of this proposed protocol is to utilize the multi-path to increase the performance of the network with least cost of energy, but MCMP did not achieve a breakthrough with respect to reduce the consumption rate of energy in the network.

ELCEA protocol was proposed in [13], this protocol can be considered as new and updated version of (DIJKSTRA) algorithm. ELCEA working as routing protocol aims to find a list of the minimum cost paths, then select a path from the list that meets end to end delay requirement. This mechanism led to reducing the energy of the network, also maximize the throughput of WSNs.

Geographical and Energy Aware Routing protocol abbreviated as (GEAR), which is a new routing protocol that is presented by the authors of paper [16], the method of this protocol based on selecting the next hop of the path according to the geographical location closeness or cost.

Control and improve the undesirable behaviour of the Evolutionary Algorithm (EA) when used with the clustered-routing problem in WSN is the core idea of paper [2], the concept of this paper stands on suggesting a new fitness function that merges two clustering sides, namely separation and cohesion error. The results of Simulation over 20 random heterogeneous wireless sensor networks indicates that the author's evolutionary based-clustered routing protocol (ERP) always extend the WSN lifetime, minimize more energy as compared with the results obtained from other protocols, such as SEP, HCR, and LEACH.

In [5], authors presented a geographic routing protocol, LASeR, designed for use in WSN. The protocol uses location awareness to maintain an updated data. a blind forwarding technique is used to send packets towards the sink. The protocol utilises multiple paths simultaneously to create route diversity.

3. Proposed System

In wireless sensor network routing protocols classified into three approaches of routing protocols, which are hierarchical-based routing protocol, location-based routing protocol, and flat-based routing protocol. In this paper, the proposed Aware-Routing protocol based on Best First Search algorithm (AR-BFS) will be considered in flat-based approach, because it is more suitable than other routing protocols for the proposed topology and structure, especially for particular applications such as event detection. Data transmission arrives at the base station through multi-hop communication paradigm (the final destination will not be reached directly, the number of sensor nodes could be used to route any sensed data to the base station). AR-BFS will control this transmission in the routing process through applying multivariable heuristic function for each hop in the path. Figure 4 below shows the difference between Single-Hop and Multi-Hop communication.

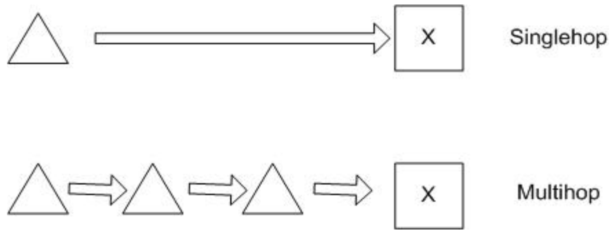

Figure 4. Single and multi hop communication.

When a sensor node wants to transmit a message, it selects the next hop from the list of active neighbour nodes using BFS algorithm, choosing a suitable heuristic in BFS is crucial, as bad heuristic will lead to low system performance and system short lifespan.

The proposed heuristic is a multivariable heuristic function (parameters) that will determine the selection process of the sensor node to participate in the path which is composed of three metrics in the WSN, which are:

1. The Straight Line Distance (SLD) which is the straight distance from the current node to the base station (sink node), also, SLD is previously known, fixed value, and describes the node value (goodness of the node, when the node far from base station the value will be high and the opposite is true).
2. The amount of energy at each sensor node, this valueis updated frequently from the base station, which means that weak nodes will not participate in path to avoid link break, and finally the threshold for the minimum amount of energy that must be available for each sensor node to be included in the path, the threshold is computed by the base station each time it receives a message.

Next Figure 5 shows how each node applies the multivariate heuristic to decide the next node among neighbours, where the node on the right below the threshold and thus ignored.

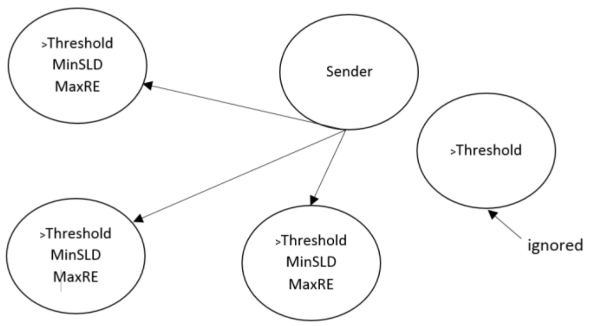

Figure 5. Heuristic example.

Taking all these parameters into account will be the only factor to select next node that will participate in the multi-hop process, the SLD value is fixed, the residual energy for the current node will be added to the message to inform the base station an updated information about the residual energy for this node.

When the base station receives any message, it updates its information with fresh information it gets from this message about the currently active nodes and their current energy, and thus, the threshold should be computed to prevent weak nodes from receiving a message and try to send it, as weaknode in energy, may have the energy to receive the message, but don’t have enough energy to send this message to the next node.

The threshold is computed in the base station by Equation (1):

$$T = \frac{\sum_{i=1}^{n} Er}{n} \tag{1}$$

Where T is the threshold, n is the number of active nodes, i.e., above threshold, Er is the residual energy for the whole system nodes, it is worth noting, that the threshold value after sometime should decrease in value, this means that when all the nodes that are having high residual energy became weak, and to not exhaust these nodes and to achieve more fairness and load balancing, the threshold will be updated and lowered to reflect the suitable value for the current network status, this new information about the threshold will be broadcasted to all nodes in the system, so each node will update information about the system threshold, furthermore, base station broadcasts the residual energy about each node participated in the message transaction to all nodes as well, each node will have an updated information about its neighbors and some of its node may become an active or inactive depending on the new value received from the base station and this will be the indicator in selecting nodes at next path. Figure 6 shows a sample of the multi-hop communication path.

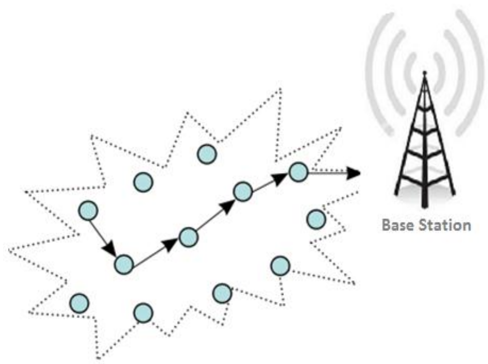

Figure 6. Multi-Hop communication path.

Figure 7 below shows the flowchart of the proposed protocol (AR-BFS):

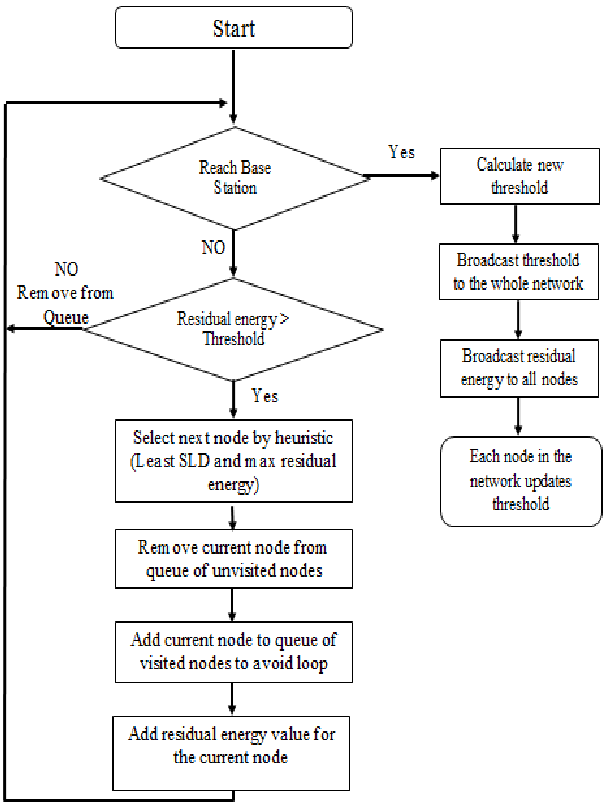

Figure 7. Proposed flow chart

Next is the AR-BFS Algorithm.

Algorithm 2: AR-BFS.

Start
If not (reach destination) then
If (Residual energy > Threshold) then
Select next node: heuristic (Lowest SLD and max residual energy)
Remove current node from queue of unvisited nodes.
Add current node to the queue of visited nodes to avoid loop
Add residual energy value for the current node
Else (Remove from the queue) and go to line 2
Else
Base station calculate threshold from the received message
Broadcast threshold to the whole network
Broadcast residual energy to all nodes
Each node in the network updates threshold

4. Simulation and Results

To prove the correctness of the proposed protocol, an intensive simulation was conducted using Matlab R2017a which presents an interactive environment for WSN; the comparison included transmission delay, throughput, and packet delivery ratio.

The AR-BFS was compared with OLSR and LASeR protocols [5], the simulation environment and parameters used in [5] were adopted to create same conditions and same experiment for the LASeR.

The number of nodes used in the simulation is 100nodes, randomly distributed; all nodes have equal power at the start of the experiment.

Figure 8 shows the results for the end to end delay simulation between OLSR, LASeR, and AR-BFS were AR-BFS achieves less delay than the other protocols as it visits only the un-visited nodes after applying the heuristic, which limits the options for the multi hop when selecting next node and thus reduces the delay, while LASeR tries to find a suitable route by discovering multi-paths which need more time to achieve.

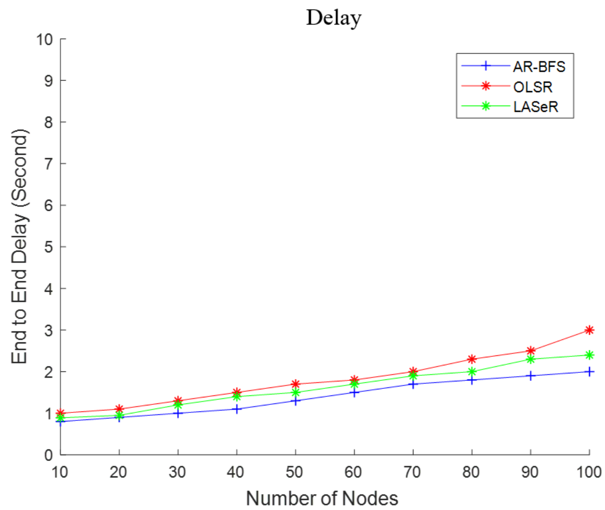

Figure 8. End to end delay.

Figure 9 represents the results of the throughput; were OLSR, LASeR achieves almost the same performance. However, AR-BFS achieves better throughput in the dense network as it has better awareness, and thus better decisions and better performance, it is worth noting that selecting next node in AR-BFS is carefully done and this means that only nodes who can receive and send the message to the next node to reach the destination are selected while the other protocols didn't consider this case.

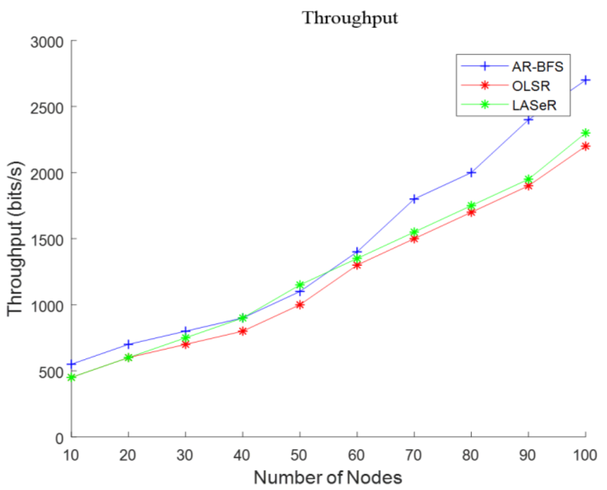

Figure 9. Throughput.

Figure 10 represents the results of the packet delivery, the AR-BFS achieves better packet delivery, as it achieves packet delivery with no broken links and thus more packets received successfully.

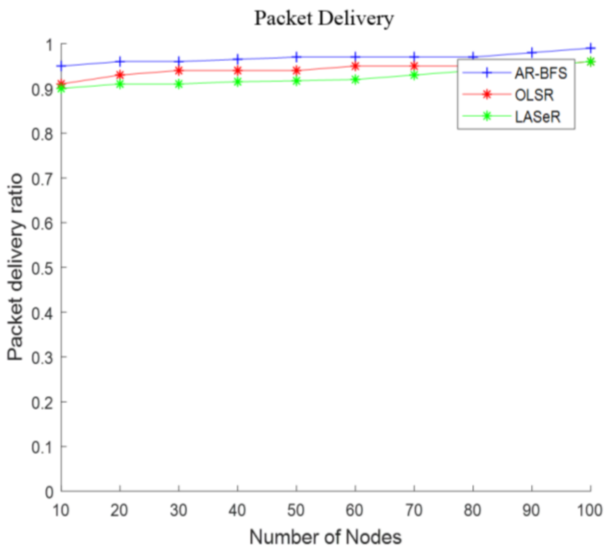

Figure 10. Packet Delivery.

5. Conclusions and Future Work

This paper proposed an Aware-Routing protocol based on Best First Search algorithm; this protocol used the multivariable heuristic function in the process of selecting the next hop communication path. AR-BFS computes an optimized route to transmit the packets from any sensor node in the network to the base station (sink node).

Since the data are transmitted using an optimal route, the required energy for this transmission will be minimized; thus, the wireless sensor network lifetime is maximized. Also, the reliability of the system and average of packet delivery rate will be increased.

Simulation results show that the AR-BFS achieves better performance than OLSR and LASeR protocols.

In the future work, another artificial intelligence algorithms will be tested like: A* or Knapsack to test the system performance.

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