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Destination-based Greedy Routing Protocol for Wireless Sensor Networks

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Abstract

In recent years a lot of focus has been done on establishing wireless sensor networks (WSN) for environment monitoring, natural disaster management, military and remote medical systems. When it comes to WSNs, the major problem faced is the implementation of efficient routing protocol that is fault tolerant and can avoid obstacles. An obstacle is a region that does not provide any sensing or communication capability and thus adds up to the delay overhead and impacts the performance of the WSN. Here in, we propose a simple and yet effective routing protocol uses greedy algorithm, with a few tweaks that help to cover the major limitations faced while still respecting the constraints of WSNs. The routing protocol is a reactive protocol that does not compromise on path length efficiency and delay overhead.

Index Terms- **WSN. obstacle . greedy algorithm. reactive. Proactive . routing protocol . forbidden region**

I. INTRODUCTION

Wireless sensor networks (WSN) have emerged as a concrete tool for monitoring the environment, employing the use of self-sustaining networks of wireless sensors which are battery powered and are capable of sensing, processing, storing and communicating. The system sensor-wireless networks explained by Biradar *et al.*[1], its functioning explained by few others[2,3] and constraints as well[4].Apart from the network of sensors, a WSN also comprises of a sink node which acts like an interface between the user and the WSN. Most of the protocols that have been developed recently are able to overcome majority of the constraints and limitations. On a general note, any region which is either incapable of sensing or communicating in a WSN, is called an obstacle. As mentioned in[5], obstacles can be formed dynamically due to many reasons, like- random deployment causing non-uniform distribution of WSN; energy exhaustion in nodes after continued use; physical obstacles like hills, buildings; animus signal interference causing abnormal functioning; animals passing or strong breeze blowing the sensors away causing node failure. Because of the existence of obstacles, packets will get blocked and further delay overhead will be incurred leading to inefficient performance. This paper proposes a reactive algorithm called *Destination-based Greedy Routing Protocol* (DGRP) that aims at providing a simple yet effective WSN routing procedure. Before getting into the design details of the protocol, we need to understand the design issues involved in designing WSN protocols.

Design Issues

As stated in [1], for designing routing protocols, the following major design issues need to be considered. The general approach towards diversification there are reports for design issues [3, 6] of the sensor network have to be taken care off.

Fault Tolerance, Scalability and Power Consumption

There may be node failure or blockage due to power exhaustion, physical damage or interference. In such a situation, the failed node or cluster of nodes is an obstacle and, thus, should be excluded from the routing path. The fault tolerance, consume less quantity of power, faster and programmable using software, prompt, have capacity for quicker data acquisition, dependable and accurately perfect over long term, cheaper and can be maintained easily. Sometime sensor nodes may get fail and/or blocked due to deficiency of power. Fault tolerance is the technical ability to manage sensor network functioning without any failure/break down due to sensor node non-functioning. The basic design of sensory network are controlled by various factors [1, 7,8]. The basic design of sensory network are controlled by correct scalability demonstrated by

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many authors [1,7]. The multi-hop routing introduces important overhead for design management and access control system and the direct routing would better perform if all the nodes are close to the sink [9].

Data Delivery Models

As it would be evident later, the new protocol would be best suited for Query driven model, however, it can be slightly modified to support all the aforementioned models. The suggested modifications would be mentioned later. The basic physical layer is actually responsible for the selection of frequency, simple and strong modulation, detection of signal, encryption of data, transmission, and receiving of data. This primary layer also explains the requirement of a modulation technique to modify the power consumption [10, 11].

Quality of Service (QoS)

Quality of Service (QoS) determines the quality of transmission as required by the application. In few applications the data has to be delivered within a specific period of time from the momentary time it is sensed by the sensor. Review of routing and quality of service is demonstrated by few authors [12, 13]. In the present concept, the paper proposes a simple yet elegant solution to WSN routing problems which are useful and can be extended to other data delivery models, through constant transmission path details in every node and transmitting data using these paths.

II. RESULTS AND DISCUSSION

Node Deployment

The deployment of node is dependent on the application and the type of the WSN and is in self-organizing networks, that, a reactive protocol is highly beneficial and so will be the proposed protocol DGRP. However, since the formation of obstacles can also occur in deterministic networks, DGRP can also be implemented in deterministic networks, but, as expected, the delay overhead will be more than other deterministic proactive routing protocols. Considering the constraints mentioned above, this article proposes a reactive protocol that aims at obstacle avoidance while still providing shortest path routing. Considering a Query driven wireless sensor network, firstly, the *Path Determination Phase* initiates which aims at determining the best path from the sink to the concerned node, using flooding algorithm. Fig.-1 depicts the optimum path selection. After that, the *Path Selection Phase* is initiated, where in the most optimum path is chosen from the set of determined paths using Greedy algorithm. The data is routed along this path and the sensor waits for an acknowledgement from the sink. If the acknowledgement is received within the expected time, the transmission ends, else, the next best path is chosen for routing. Figure 2 shows one such example of multiple possible paths. The designing of wireless sensor network elaborated by Singh et al. [14]. The basic approach of DGRP is as mentioned below.

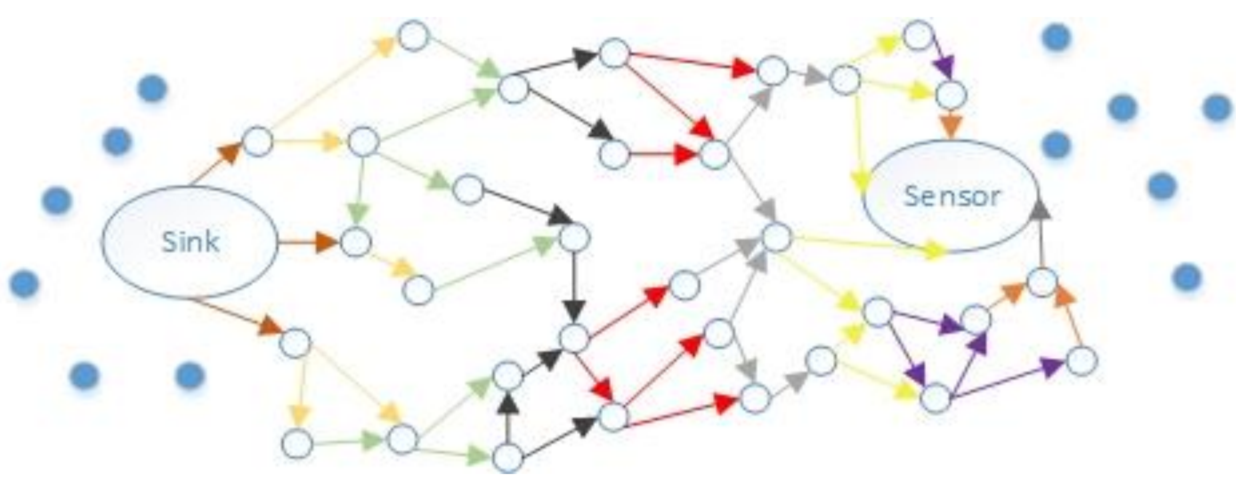

Fig.1: DGRP uses flooding at every node in the vicinity and keeps a track of the arrival time at the destination to determine optimal paths. The differently colored arrows indicate different nodal levels.

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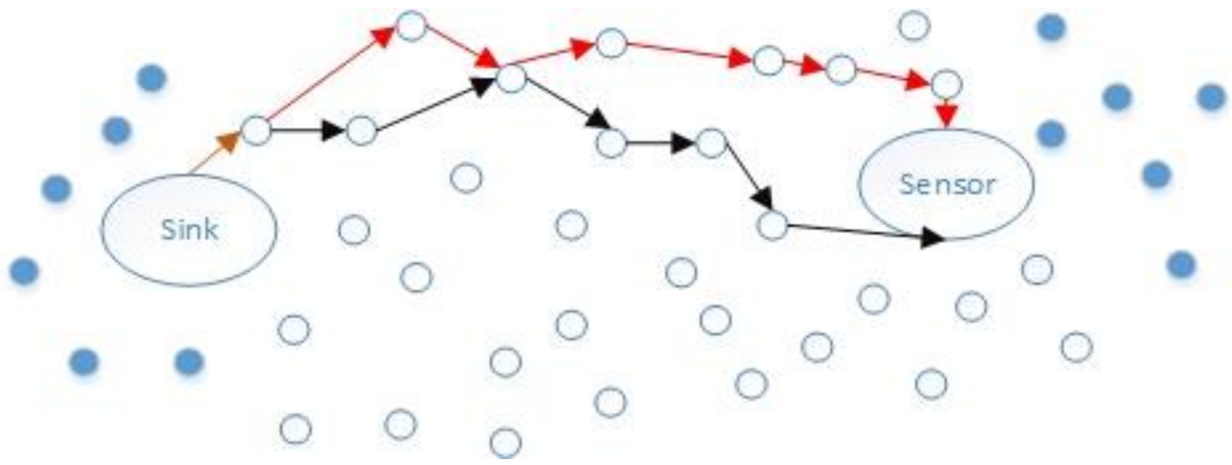

Fig. 2: Two possible optimal paths have been shown. Considering the "red" path to be more optimal, DGRP would first route data through the "red" path, in case, transmission is successful the sink would send an acknowledgement; else, the black path would be chosen for routing.

DGRP

In the present scenario, the system uses a query-driven approach, all the nodes are stationary and each node is aware of its neighbor. Any obstacle or path related information is unavailable to any node whatsoever. DGRP comprises of two phases, Path Determination and Path Selection, which will be executed in order.

Phase I: Path Determination Phase

This phase aims at determining the "best" path from the sink to the concerned node. Since communication is a reversible process, the "best" path from sink to the concerned node will also be the best path from the node to the sink. The phase employs the use of flooding algorithm for determining the shortest path. The critical points to note here are:

- The sink initiates a request packet and sends it to all the nodes in its vicinity. The packet essentially contains a timestamp that would help in measuring the time taken by the packet to reach the concerned destination node.
- The nodes upon receiving the request packet add their node id to the packet. This shall help in recognizing the path taken by the packet and also the number of hops. (Note: The path with an optimal number, neither too many nor too less, of hops is more preferred because having too many hops complicates the topology management system and having too less leads to more energy consumption).
- The node then transmits copies of the modified to all the nodes in the vicinity. The process continues till the packet is received by the concerned destination node.

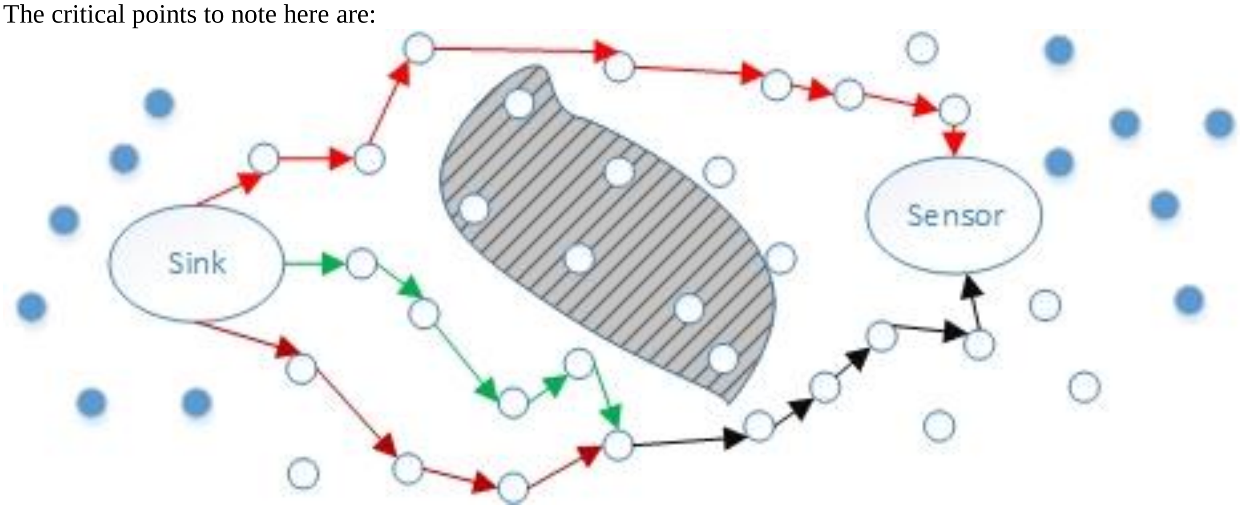

Fig. 3: The shaded area marks the obstacle. The nodes transmit along the boundary to reach the concerned sensor.

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- Since each node transmits packets to the nodes in the vicinity of itself, even if an obstacle does exist, the nodes will keep transmitting along its boundary and thus the packet will reach the destination. Fig.-3 depicts such a scenario.
- The destination node maintains a table of the paths followed by the packets along with the time take taken by them.
- In this case, as depicted in Fig-1, there will be backward transmission as well. This is against the energy consumption constraint of WSN as nodes in the backward direction will be routing data unnecessarily, even though it is 100% sure that they will not produce any optimal path in any case whatsoever. This could be overcome totally by following the location aware routing technique as shown in [15]. However, such a case might either totally ignore the possibility of a changing network structure due to environmental interference or use GPS systems that consume more power. This article proposes the computation of a *"timeout"* function that computes the maximum lifetime of a packet in the network. This way we can still do away with most of the redundant packet routings will not compromising on the possible dynamicity, that may exist, or the energy consumption constraint. The design issues for routing protocols in WSNs based on classification by Mehndiratta *et al*. [16].

Timeout Function

The article proposes a timeout function to compute the maximum lifetime of a packet in the network once it starts from the sink. Once the time runs out, the packet is dropped from the network and no further routing takes place. This way any further nodes are not activated for the process of path determination and thus their energy is conserved. The timeout function depends on a number of factors, namely- average density of nodes in the WSN, a possible heuristic function for determining the lower bound of the packet lifetime, the minimum available bandwidth of WSN at that time (depends on network load). We shall now illustrate how each factor effects the timeout function. *Density (d)* - Since transmission time is directly proportional to the number of nodes, the more the number of nodes the more will be the transmission time and hence the more should be the timeout value. Also, since DGRP considers the nodes in the vicinity of the transmitting node, the more the number of nodes in the vicinity the more will be the number of the hops. Hence, average density of nodes is a deciding factor and as observed the timeout function (Γ) is directly proportional to the average density (d) of nodes. That is, $\boldsymbol{\Gamma \propto d}$.

Heuristic Function (h(x)) - In order to estimate the lower bound on Γ, we need to use a heuristic function, h(x).Here, we consider h(x) to be defined as time taken for a packet to travel from the sink to the destination node, x, traversing through a straight line path from the sink to x. This is a trivial heuristic choice as no other path would be smaller in length than the straight line path and thus packet would take minimum time while traversing through this straight line path. As observed, $\boldsymbol{\Gamma \propto h(x)}$. **(**<u>Note:</u> Here, while initially calculating the values of h(x) for ever node, the minimum possible (not available) bandwidth will be considered). ***Minimum Available Bandwidth (B)*** - While transmitting the packet it is nothing but obvious that we need to consider the bandwidth of the network. Since the maximum delay will be caused with the node utilizing the minimum available bandwidth, the minimum available bandwidth (B) also acts as a deciding factor. Through trivial speculation it can be realized that Γ will be inversely proportional to B. That is $\boldsymbol{\Gamma \propto 1/B}$. Combining the three equations we get-$\boldsymbol{\Gamma = (k * d * h(x))/B + C}$ Where-$\boldsymbol{k}$ is the proportionality constant. $\boldsymbol{C}$ is the normalization factor used to normalize Γ to a valid time value. The normalization factor will be calculated ta the deployment of the system. Since, the equation involves the use of the density of the WSN, which is dependent on the number of sensor nodes, it also scales the protocol according to the network size, with the value of Γ being lesser for less dense networks and more otherwise This ensures the packets do not get dropped until and unless the packet traversing the shortest path reaches the destination node. The Γ calculated will be appended to the packet as the maximum lifetime of the packet and once the time runs out, all the packets will be dropped. By this time, a considerate number of packets (k≥1) would have reached the destination, following the k optimal paths. Also, since the packets get dropped after maximum lifetime is achieved, no further redundant nodes are disturbed and thus energy of those nodes is conserved.

Phase II: Path Selection Phase

Once k packets have been received by the concerned node and it has made a table of the corresponding k transmission times, paths and hops, the node needs to select the best path to transmit the data to the sink. Although one might simply assume that the node usually chooses the path with the least transmission time, this may not always be the case considering the constraint on energy consumption. As mentioned earlier, the more the number of hops the lesser will be the transmission power required by the node to transmit further and thus, the more the energy consumption. Keeping this in mind the path with more hops (but not too many) and comparable (to the

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shortest path) transmission time is given preference. Following the same rules, each path is given a rank and then the best ranked path is chosen using Greedy algorithm. Once the path has been chosen, the node transmits the data and waits a specified time, T (T is decided depending on the transmission time of the chosen path), for the acknowledgement from the sink. If it receives an acknowledgement, the transmission process is halted. However, if it does not, then it selects the next best path using the same procedure as before and sends the data again. The process is repeated until an acknowledgement is received or a HALT signal is sent from the sink. The tutorial of routing protocols in wireless sensor networks is very well defined by Chaudhary and Vatta [17]. Edge based networks [18], location-based energy efficient network [15], and geography-informed energy conservation for ad-hoc routing [19], recursive data dissemination networks [20] and energy efficient adaptive r networks [21] are very well defined. The lifetime maximizing dynamic multi hop wireless networks using queue-based [22, 23], hybrid Wi-Fi and Wi-MAXnetwork routing networks explained [24, 25, 26]. The Energy efficient differentiated directed diffusion (EDDD) in wireless sensor networks [27] and QoS-aware multi-hop routing in wireless sensor networks [28] explained the working system of WSN's. The polynomial-time algorithms in wireless [29] and ad-hoc networks are demonstrated by authors [30, 31]. However, the present finding is a simple yet elegant solution to WSN routing problems.

III. CONCLUSION

This paper proposes a simple yet elegant solution to WSN routing problems. The protocol keeps in mind the dynamic nature of the WSN networks and tries covering as many prospects as possible while still respecting the WSN constraints. There is still room for improvement and it can improvise using backward pruning as to enhance its efficiency. Also, it can be extended to other data delivery models, such as continuous model, by maintaining a constant transmission path details in every node and transmitting data using those paths.

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