Stateless Data Flow Approach with Void Avoidance for Wireless Ad Hoc and Sensor Networks

Mujdat Soyturk, D. Turgay Altilar
Istanbul Technical University, Department of Computer Engineering
Maslak, TR-34469, Istanbul, Turkey
msoyturk@itu.edu.tr, altilar@itu.edu.tr

ABSTRACT

In this paper, we propose a void avoidance algorithm for the Stateless Weight Routing (SWR) algorithm which is recently developed stateless geographical routing protocol for wireless sensor and ad hoc networks. In order to demonstrate the efficiency of the method we started with the illustration of transmission coverage of relay nodes during the course of routing in the SWR protocol. The threshold value to retransmit a packet defined in the SWR may be used for several purposes including elimination of the void problem. It can be shown that the threshold value provides a tool to balance the tradeoff between energy consumption and reliability..A number of scenario has been considered to test the performance of the void avoidance (recovery!) algorithm. The initial simulation results indicates the proposed algorithm works with the SWR and providing it with an additional feature of adaptivity for wireless ad hoc and sensor networks.

I. INTRODUCTION

Geographical routing protocols use local topology information and have not any overhead because of continuous process of update [1]-[8]. Therefore, they provide scalability in mobile networks with respect to conventional routing protocols. On the other, energy resource limitation requires energy-efficient approaches. Stateless geographical protocols can be used to provide energy efficiency. They do not require local topology information. However, the stateless geographical routing protocols in the literature propose solutions to be implemented at the MAC layer and generally have local minima problem. On the other hand, only a few ones propose solutions for void problem, while the solutions are too complex to implement and costly.

The Stateless Weight Routing (SWR) protocol [9] proposes a stateless routing solution to be implemented at network layer, independent of the MAC-layer used beneath. SWR provides scalability by not using routing tables, and by not beaconing. SWR introduces a weight metric to be used in routing decision phase. Weight metric simplifies the routing process and decreases the calculations, the delay, and the resource requirements (such as processor and memory). Reliability is provided by carrying data on multiple-paths. A threshold value in metric of weight is used to regulate the transmissions.

In this paper, we propose a void avoidance algorithm for SWR protocol. The algorithm is peculiar to SWR and guarantees the delivery of data to the destination. We also describe the usage of threshold value to shape the data flow toward the sink. Threshold usage aids the void avoidance algorithm implicitly and explicitly.

In the next section, we review the related works. We give the approaches and algorithms for void avoidance in section 3. Performance evaluations are given in Section 4. In the last section we conclude the paper.

II. RELATED WORK

The taxonomy for position based routing algorithms for ad hoc networks is given in [2] and [8]. Surveys of the proposed protocols are given in [2]-[4], [10], [11]. Formerly proposed position based routing protocols use greedy approach either distance or angle as metric. In greedy approaches, there is a possibility that they may not find the route due to the local topology knowledge, even if there is a path to destination that can be found with global topology knowledge. Besides that, beaconing-based greedy approaches consume excessive energy due to beaconing and introduce control traffic overhead. Furthermore, as the topology changes, providing proactively local topology knowledge reduces the performance and the scalability. Therefore, stateful protocols are not suitable for these types of networks, e.g. ad hoc and sensor networks. However, stateless (table-free) protocols are not affected too much from the topological changes and network dynamics. But, they use broadcasting to find routes as in flooding which wastes resources. However, they use MAC-layer integrated approaches to achieve this and introduce delay. MAC-layer integrated approaches make them dependent to the MAC-layer used. Challenges and the approaches of the stateful and stateless geographic routing is surveyed in [11]. Approaches and algorithms for void problem in geographical routing in sensor networks are well defined in [12]-[14].

III. VOID AVOIDANCE IN SWR

Stateless Weight Routing (SWR) protocol [9] is a stateless and beaconless routing algorithm for wireless sensor and ad hoc networks. The difference of SWR from other stateless protocols is that routing is completely achieved in network layer rather than MAC-involved solution. No routing table and beacon messaging is used. The SWR uses a weight

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metric instead of geographical positions in routing decisions. Each node derives its *weight* dynamically from its current position. The use of weight metric makes the routing simple and minimizes both delay and energy consumption. Moreover processing requirements at nodes is limited by those done in routing decision phase.

When a node has data to transmit, inserts its own and the destination's weight into the packet, and broadcasts the packet. As soon as a node receives a packet, it compares its weight with ones in the packet. If its weight is between the transmitting node's weight and the destination's weight, it rebroadcasts the packet after replacing the transmitter's weigth with its own. If node's weight is not between the weights of transmission and destination, node simply drops the packet.

A. Threshold Usage

In order to reduce the number of rebroadcasting nodes, a threshold value is used which is also transmitted with the packet. Only the nodes of which weight difference is greater than the threshold value is allowed to rebroadcast the packet. In other words such an approach prevents nodes closer to transmitting node to rebroadcast. Although the weight metric includes Euclidian distance the flexibility of the algorithm comes from the other additional values. As shown in Algorithm 1, function *Diff(x,y)* returns (signed or absolute) weight difference between node *x* and node *y*.

Algorithm 1 Simplified Data Flow Algorithm

```
Diff(x,y)= |w_x-w_y| (absolute value?)

if((w_sender> w_i > w_destination)and
  (Diff(sender,i) >= threshold) then
    rebroadcast;
```

Threshold is used for several purposes. First of all, the threshold value can be adjusted to save energy by limiting the number of retransmitting nodes since the number of nodes actively contributing to retransmission vary as depicted in Fig.1 and Fig.2. Increasing the threshold value provides fewer nodes in number to relay the data packets and decreasing the threshold value provides more nodes in number to relay the data packets (Fig. 1). Shaded areas in the figure show the covered area by transmissions when the Algorithm 1 is applied. Only the nodes in these areas retransmit the received packets according to the Algorithm 1. Secondly, the threshold value can be adjusted for reliability (Fig. 3-4). More relaying in number causes the data to flow over multiple paths (Fig. 4). Data transportation over multiple paths provides reliability. Reliability requirements challenges with the energy saving requirements. Therefore, threshold value can be used to balance these requirements as needs. Thirdly, the threshold value can be adjusted for void avoidance (Fig. 5-6). In case of void detection, the transmitting node decreases the threshold value allowing more nodes to be in data flow algorithm (Fig. 6). By this way, nodes that may circumvent the void are forced to relay the data packets. Fourthly, the threshold value should be adjusted according to the node density in the network. In dense networks, the threshold value can be set to be high by default to limit the retransmitting nodes. In non-dense networks, the threshold value can be set to be low to allow enough nodes to participate in data flow.

B. Multipaths

SWR applies the Algorithm 1 to make the broadcast decision constructing multiple paths. Constructed multiple paths are disjoint braided paths which are shorter and more robust than other possible paths between the source and the destination. Number of rebroadcasting nodes, therefore, the number of multiple paths can be determined by adjusting the threshold value as required. Using multiple paths provides robustness and reduces the bad effects of mobility, link failures, node terminations, node state transitions and works at uncertainty.

C. Voids

Algorithm 2 Void Avoidance Algorithm

```
if (threshold > 0) then
    set threshold to 0 (zero);
    rebroadcast;
if (the packet cannot be relayed) then
    set the w_sender to w+w' in header;
    rebroadcast;
```

Without any effort, the void problem is eliminated substantially due to multiple route construction in SWR. Even if one of the paths encounters a void that it cannot pass around, the other paths remain toward to the destination. For the case of large gaps in the topology, we propose a void elimination algorithm to solve the void problem.

Nodes can understand the existence of a void by the *non-retransmission* of the packet with the same parameters by the nodes those have lower weight values. The void problem is solved by two different ways. In the first one, the interference of the void is removed implicitly by multi-path usage. By adjusting the threshold value, data can be carried over multiple paths. Therefore, the threshold value variations determine the range of the area that data disseminates. However, due to size of the void, nodes still may encounter a void. In this case, an explicit void elimination approach is used. On encountering a void, the node executes the void elimination algorithm given in Algorithm 2. The algorithm is consisted of two steps. In the first step, the algorithm tries to transcend the void by decreasing the threshold value to 0

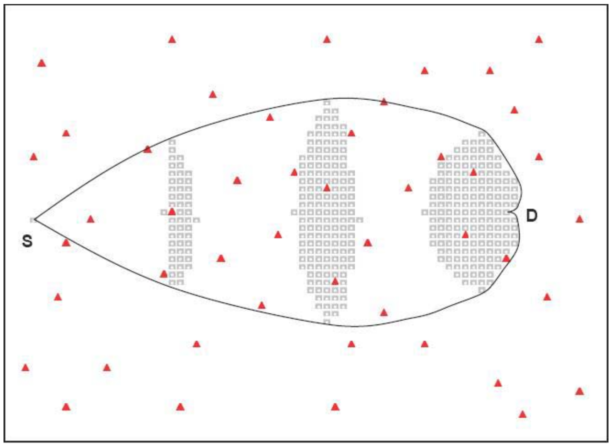

Fig. 1 Active retransmission area and nodes for a high threshold value

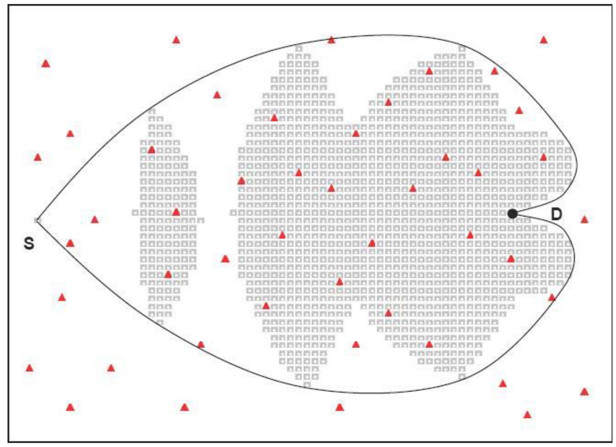

Fig. 2 Active retransmission area and nodes for a lower threshold value with respect to the one in Fig 1.

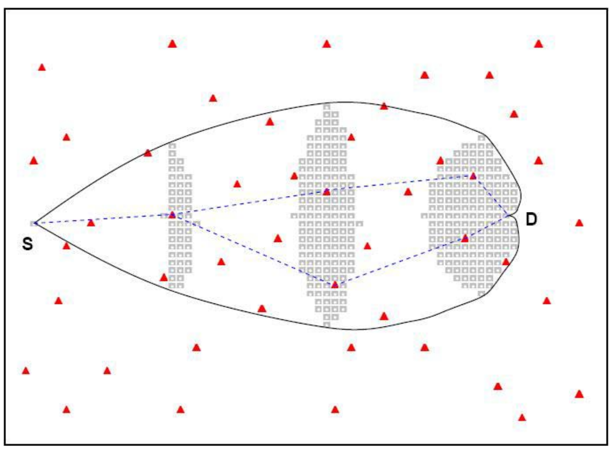

Fig. 3 Threshold value affects the number of possible paths.

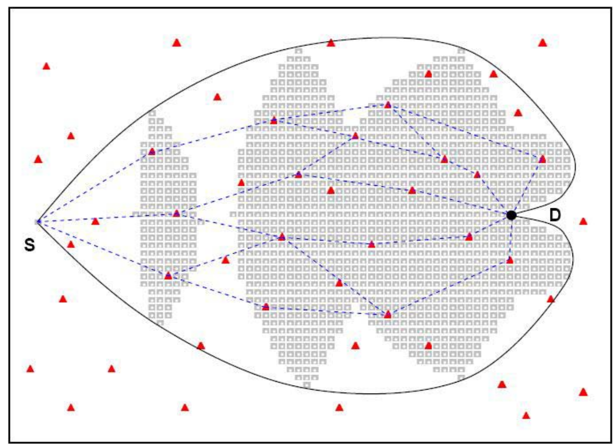

Fig. 4 Data is carried on multiple paths to the destination.

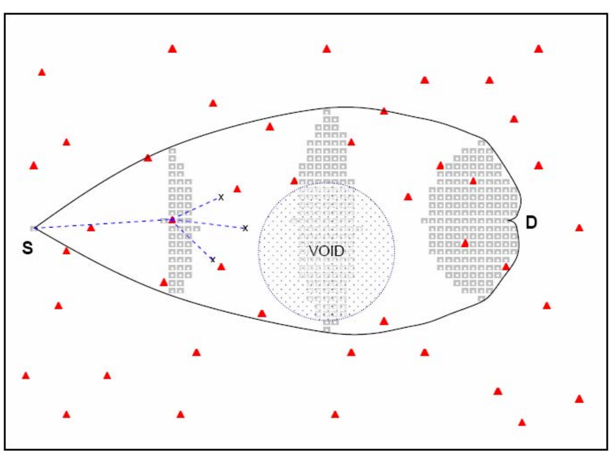

Fig. 5 Multiple paths help the packets arrive to the destination even if there are voids. But in case of no available path, void avoidance approach should be used.

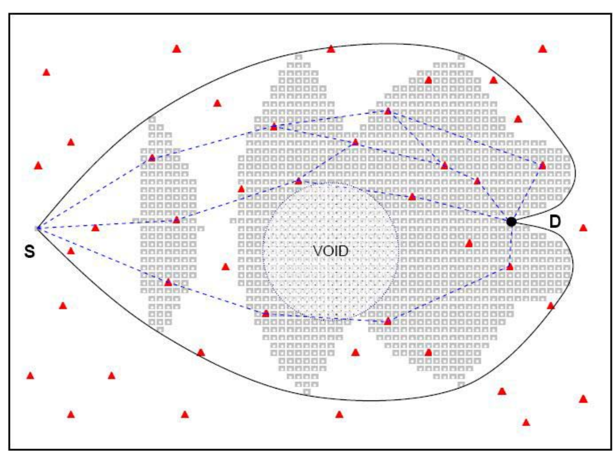

Fig. 6 A simple approach to eliminate voids, is decreasing the threshold value. By the way, more nodes involve in routing.

(zero). Therefore, more area can be covered to forward the packet. If the packet still cannot be forwarded due to void, second step is implemented. Transmitting node, retransmits the packet with a weight value greater than its weight (e.g. *w+w'*) embedded into the sender's weight field in the packet and the threshold value set to 0 (zero). By changing its weight value to a fake weight value, the transmitting node enforces the rearward nodes to participate into the routing with these new parameters. Therefore, a void can be passed by without any complex calculations.

IV. SIMULATION AND RESULTS

A. Simulation Parameters

In this section we present our simulation results. There is no packet loss due to transmission collisions in or simulation environment. We use the parameters given in [16] to make the results comparable with the proposed evaluations. To provide the double range property, nodes have a sensing range *(R_s)* 50m and a transmission range *(R_c)* 100m *(R_c/R_s =2)*. Unlimited energy is given to each node. Nodes are uniformly distributed in a well-defined topology [17] over an area 1000m x 1000m. Number of deployed nodes depends on the node density with 0.0005, 0,001, and 0.01. Nodes randomly generate packets with a probability of 0.05 pkt/min. Destination (gateway) is positioned at the center of the rectangular area.

We compare the proposed approach with the flooding and "GPSR without perimeter" algorithm. Parameters for GPSR are obtained from the results of [16] with 1 sec periodic beaconing. Default threshold value is set to $R_c/2$ for SWR protocol. The proposed results are the averages of 10 runs. We assume that energy consumptions are identical in receive and transmit states. We mainly focus on the energy consumption. The total energy consumption of the system is observed with the changing parameters of the system, such as node density and the threshold value.

B. Energy Consumption

Fig. 7 shows the energy consumption in GPSR protocol with different node densities. As expected, energy consumption increases as the number of he nodes increases. But, note that y-axis is a logarithmic scale. Energy consumption increases linearly in GPSR, due to beaconing that causes most of the energy consumption in GPSR.

We observe similar results in flooding (Fig. 8). However, it appears that flooding is better than GPSR with respect to energy consumption with these parameters. GPSR would have performed better than flooding when the beaconing time interval increased. But there is great consumed energy difference between the GPSR and flooding in Fig. 7-8. SWR performs better results than both GPSR and flooding (Fig. 9). In SWR, the energy is consumed only in routing processes and only the on-the-route nodes involve in routing process. Fig. 9 shows the results of SWR with a threshold value 0.5 of range. It would have performed better if the threshold would have increased. This is shown in Fig. 10.

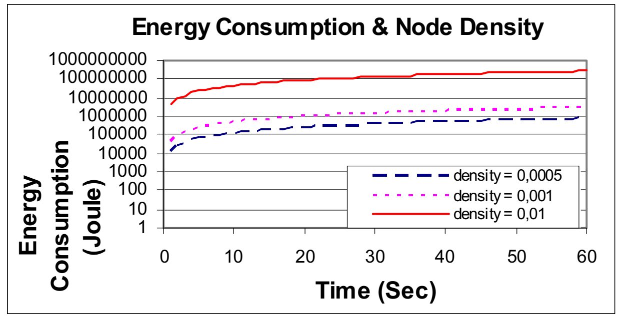

Fig. 7 Energy consumption in routing process in GPSR. Note that y-axis is a logarithmic scale

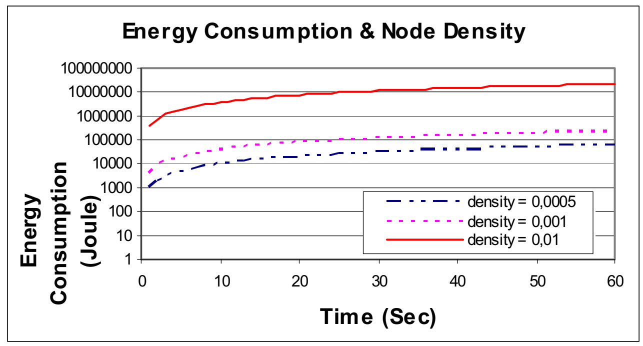

Fig. 8 Energy consumption in routing process in GPSR.

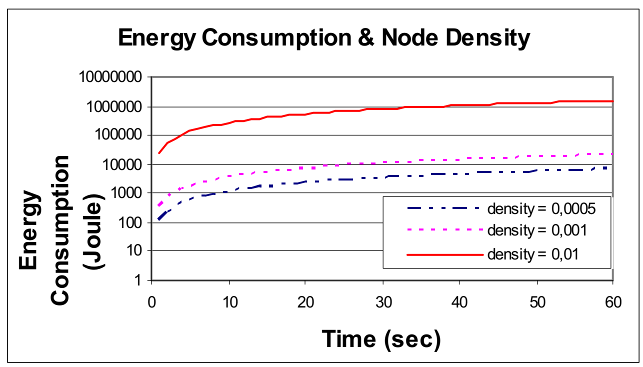

Fig. 9 Energy consumption in SWR.

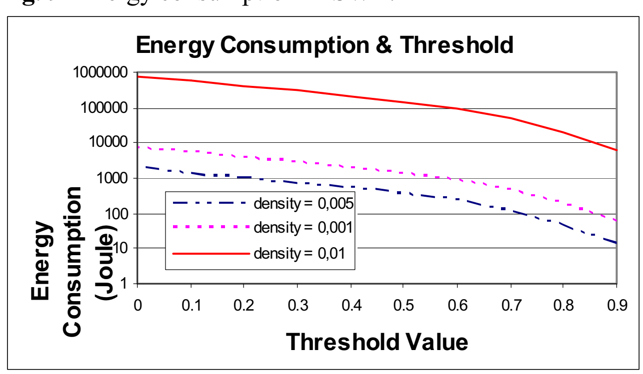

Fig. 10 In SWR, energy consumption .decreases as the threshold value increases. Note that y-axis is a logarithmic scale

In SWR, the possible relay node area decreases as the threshold value increases, as illustrated in Fig.1-6. Therefore, fewer transmissions occur as the threshold value increases Note that the y-axis is a logarithmic scale. There is great amount of energy gain when the threshold increases. Increase in range and increase in threshold, reduces the energy consumption (Fig. 11). It is seen in Fig. 11 that a small change in threshold value causes a great amount of energy gain.

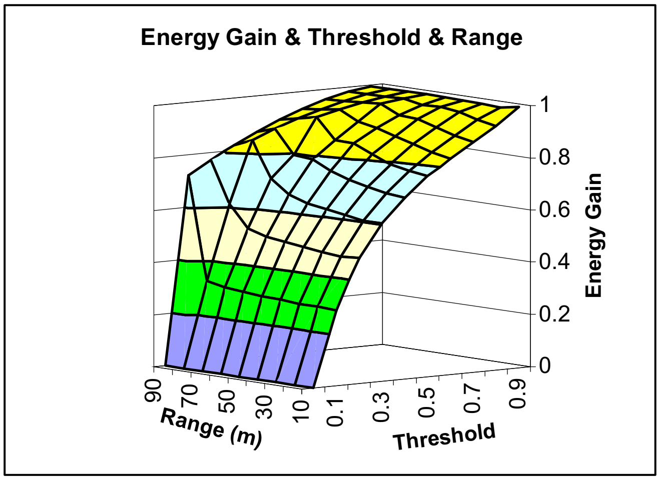

Fig. 11 Increase in range and increase in threshold reduces the energy consumption.

V.CONCLUSION

In this paper, we propose a void avoidance algorithm for Stateless Weight Routing (SWR) protocol. SWR protocol [9] is a new novel stateless and beaconless routing algorithm for wireless sensor and ad hoc networks. It is simple to implement SWR on nodes. SWR introduces a weight metric to forward packets instead of the location information. SWR also introduces a threshold value in metric of weight to shape the data flow toward the destination. Void elimination algorithms proposed in this paper use these weight and threshold values to circumvent voids. We demonstrated that without any topology information, SWR forwards the packet to the destination over multiple-paths to provide reliability. Performance results show that the SWR prolongs the network lifetime longer than flooding and GPSR, and has lower energy consumption. On the other hand, SWR provides a basis for real-time traffic by means of delay and reliability.

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