Competition: Dynamic Alternative Path Selection in Wireless Sensor Networks

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Abstract

As applications in Wireless Sensor Networks (WSNs) are evolving, performance control remains an open, and in several cases, critical issue. Dynamic alternative path selection, could be become a solution in guaranteeing stable performance under the requirement that there are enough available nodes capable to accommodate the traffic that can't be routed though the initially established source to sink path. Our proposal for participation on the EWSN2017 dependability competition lies on a modified version of Dynamic Alternative Path Selection Scheme (DAlPaS), that has been initially developed for facing congestion in WSNs.

1 Introduction

Performance control in WSNs is a difficult task since many, mostly unpredictable reasons can negatively affect the performance of the network. Due to their unreliability, wireless sensor nodes are frequently redundantly deployed. For this purpose we have developed a dedicated algorithm capable to initially balance the traffic between the majority of nodes and, in case of congestion, to find the least congested path in order to route the traffic, thus guaranteeing the performance. DAlPaS [2] is a dynamic algorithm capable of adopting to the variable conditions of the network. For this particular competition, a special feature had been added in this algorithm to also identify and avoid interference spots.

2 Dynamic Alternative Path Selection Algorithm

In this section we briefly describe the DAlPaS algorithm. The DAlPaS algorithm consists of the four phases described below.

Setup Phase: The Setup phase runs only once, during the initialization of the network. In this phase, the nodes, after their random or deterministic deployment, discover each other and built their neighbor tables where they keep specific information for each neighbor node they can communicate bi-directionally with. Specifically, this phase initiates from the sink node. The sink broadcasts a "hello" message along with its level which is zero. The level value indicates the hop distance of a node from the sink. The node that receives this message is aware that it can communicate directly with the sink. Thus, this node becomes a level 1 node, while it updates its neighbor table with the Sink ID as well as its level (Figure 1). This procedure iterates until all nodes discover each other. During this phase, CSMA MAC protocol is being used.

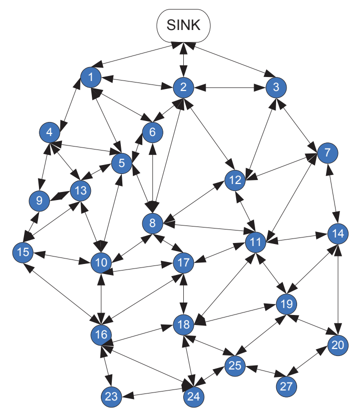

Figure 1. Initial Network Connectivity (Before Topology Control Algorithm Applies).

Topology Control Phase: Topology control schemes are critical for the successful operation of densely deployed WSNs, since they can handle the redundant number of nodes. Problems like interference, maximum number of possible routes, use of maximum power to communicate to distant nodes directly, etc., may arise. The DAlPaS algorithm employs a dynamic way to control topology without adding any extra load to the network. To do this, it employs data from the neighbor tables that have been created during the setup phase, and especially the level that a node resides. Thus, every node that is going to transmit data searches in its neighbor table, finds the node with the lower level (which is closer to the sink) and transmit its data through this node. As a re-

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sult, a dynamic spanning tree is being created and each node transmits its data through the shortest path (Figure 2).

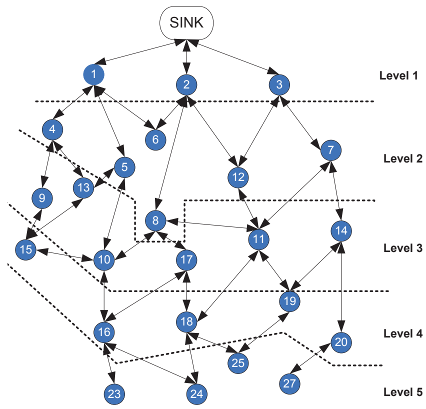

Figure 2. Network Connectivity After Topology Control Algorithm Applies.

Soft Stage Phase: Due to the ad-hoc nature of WSNs, it is possible for just two flows to congest a specific route, even when the residual network is completely under-loaded [1]. In such a case, applying traffic control techniques will force the sources to reduce their data rates while the resources of the rest of the network are under-utilized. The DAlPaS algorithm manages these cases with a lightweight scheme called soft-stage, described here. Each node enters in a soft-stage alert condition when it receives packets from more than one flows. Under this condition, the node attempts to stop receiving data from more than one flow. The node that receives this backpressure message is programmed to check for an alternative path. For performance reasons, then each node chooses to keep serving the flow with the higher data rate.

Hard Stage Phase: When the soft stage scheme runs, a node is just "advised" to change its routing path. Thus, it is possible for the sender to decide to keep sending packets to the same target/forwarding node. If this is completely unacceptable (e.g. it exceeds application-set performance thresholds) the flag decision algorithm starts. The Flag decision algorithm is a very simple scheme and its purpose is to change the value of the field "Flag" in the neighbor table from True to False - or vice-versa when the conditions are suitable. The Flag field indicates whether a node is available to receive packets or not. Whenever a node alters the value of the flag field, it immediately informs its neighbors through a modified ACK packet it transmits. A node can become unavailable either when its buffer occupancy is reaching its upper limit or its power is low or when there are not available nodes at a higher level.

An enhanced feature of our algorithm, customized for this competition, incorporates the detection of radio interference that can decrease the lifetime of sensor nodes and increase end to end latency. Depending on the frequency of radio signal interference, it may block a sensor node from executing its intended functionality by either denying the chance to transmit packets or by decreasing its energy [3].

We monitor sensor activity at the CSMA MAC level and detect abnormalities. We investigate possible parameters which provide useful information of possible intervention and use them to create a normal sensor profile. The normal activity profile is set up locally at each sensor and upon deployment, any deviation from what is considered normal sensor activity is taken as that sensor node is interfered. A sensor node notifies its neighbors and enter the hard stage such as it will not accept any packages.

Alternative Path Creation

Since the algorithm is dynamic, the number of hops to the sink may change when the state of nodes at a level closer to the sink changes. The choice of the next node to forward data, after avoiding the congested (or interfered) node, depends firstly on its availability (Flag) and the number of hops to the sink. Using this tactic each node can, with an easy and simple way, find the next node with minimum computation. It just sorts the number of available nodes in ascending order with respect to their number of hops from the sink and forwards the packets to the first node in the list. If the first node becomes unavailable for any reason (e.g soft or hard stage algorithms apply) the transmitting node immediately chooses the next node in the list. When more than one nodes are at the same level (same number of hops to sink), the table is sorted based on the remaining power (above or below some specific thresholds). Finally, when more than one nodes are above these thresholds, nodes are sorted based on their remaining buffer occupancy. In the extreme case where even this value is the same for more than one nodes, the algorithm randomly chooses a node to forward the packet.

The algorithm gives priority to the maintenance of performance metrics, like the mean time for the transmission of packets from a source to the sink, as well as to the network's uniform energy utilization, thus avoiding the creation of energy and routing "holes". Depending on the application a "weighted function" could be implemented, concerning the choice of the alternative path.

3 Conclusions

In this paper we provide a short description of the main features of Dynamic Alternative Path Selection (DAlPaS) algorithm, initially designed for avoiding congestion hotspots in WSNs. We extend DAlPaS functionality, in order to identify and avoid interference spots. Finally, we adapt the functionality of DAlPaS to match the specific application and traffic requirements of the competition.

4 References

[1] C. Sergiou and V. Vassiliou. Estimating Maximum Traffic Volume in Wireless Sensor Networks Using Fluid Dynamics Principles. *Communications Letters, IEEE*, 17(2):257–260, 2013.

[2] C. Sergiou, V. Vassiliou, and A. Paphitis. Congestion Control in Wireless Sensor Networks through Dynamic Alternative Path Selection. *Computer Networks*, 75, Part A:226 – 238, 2014.

[3] W. Xu, W. Trappe, Y. Zhang, and T. Wood. The feasibility of launching and detecting jamming attacks in wireless networks. In *Proceedings of the 6th ACM International Symposium on Mobile Ad Hoc Networking and Computing*, MobiHoc '05, pages 46–57, New York, NY, USA, 2005. ACM.