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ABC: ADAPTIVE BANDWIDTH CONTROL FOR FAIRNESS IN WIRELESS SENSOR NETWORKS

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Abstract- Wireless sensor network (WSN) is a group of number of sensor nodes. Nodes are spatially distributed to monitor physical and environmental conditions. Multi-hop communication is significantly predictable in WSN, because of limited transmission range and energy saving purpose. Traffic load in multi-hop wireless sensor network is not distributed uniformly over the nodes; hence energy consumption is different at different levels. This unfairness reduces network lifetime. To maximize the network lifetime, it is important to adjust resources according to their utilization at particular point. Nodes which are one hop away from sink carry the entire network traffic and hence congestion occurs at near sink. These nodes may die earlier than nodes which are far away from sink. That means resources are not equally utilize and later on it may result in to reduction of network lifetime and functionality. Adaptive Bandwidth Control (ABC) algorithm is proposed to avoid the congestion and to reduce the probability of packet loss. It maintains the energy as well as traffic fairness by varying bandwidth. Projected scheme shows good results in terms of fairness which reduces the congestion and increases the network lifetime.

Keywords- Wireless Sensor Network, Quality of Service, Energy Fairness, Traffic Fairness, Network Performance, Adaptive Bandwidth Control, Packet Delivery Ratio, Throughput

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Introduction

Wireless sensor network (WSN) consists of sensor nodes. Sensors are of many types like pressure, temperature, humidity, etc. Sensor node senses physical and environmental conditions in the form of information [1]. The collected information is forwarded by intermediate nodes towards base station called as sink. Sensor network have one or more sink node.

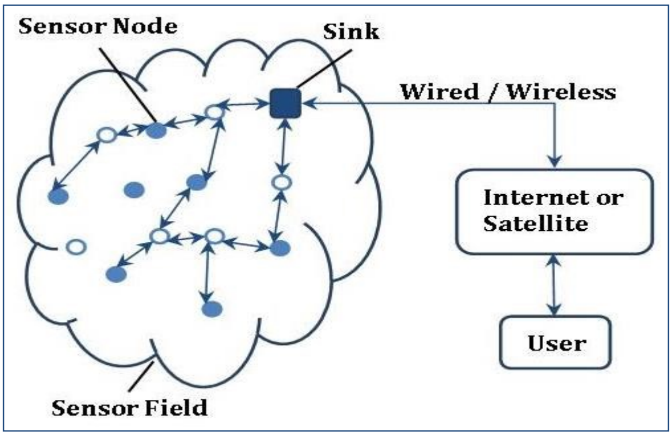

Fig. 1- Wireless Sensor Network

Sink node gather data from all nodes and with the help of internet or satellite send that data to user as shown in [Fig-1].

Wireless communication is done by either one-hop node communication or multi-hop node communication. But multi-hop communication is significantly predictable in WSN, because of limited transmission range and energy saving purpose [2]. In this communication traffic flows in two directions. First direction is sensor-to-sink, means sensor node sends data to sink called as upstream flow. The second is downstream flow means in reverse way (sink-to-sensor) [3]. The necessity of application decides the flow of communication. But generally, upstream flow is more important than downstream flow. WSN serves the demands of applications like sound monitoring, earth monitoring, agriculture purpose, location tracking, habitat monitoring, security surveillance, target tracking, etc.

Wireless sensor network has many qualities of service parameters which are reliability, throughput, congestion control, fairness, delay, loss recovery, network lifetime, etc. Achievement of these parameters upgrades performance of WSN, specifically at transport layer [4]. To perform flow control and congestion control with low energy consumption is the essential purpose of transport layer protocol in WSN. It is also important that resources should be utilized fairly to increase network lifetime.

The reliability of transport layer can be addressed into two ways which are hop-by-hop and end-to-end [5]. In either of communication (hop-by-hop or end-to-end) reliable data transfer is important. Reliability feature is concerned with reliable data delivery in all means of communication. For reliable data transfer, it is essential to control the congestion. When sensor node receives more number of packets than it forwards, then there is possibility of congestion.

There are two possibilities of congestion, i.e. node level congestion and link level congestion [6]. Congestion in WSN can lead to drop of packets [3]. Then loss recovery is needed to find out loss information. Then energy is wasted in recovery of loosed information which reduces network lifetime. To increase network lifetime resources should be utilized fairly or allocated fairly [7].

Fairness plays vital role in upgrading the performance of WSN. In ABC algorithm, course tuning is done by adjusting bandwidth to sidestep link level congestion and fine tuning is carried out according to buffer occupancy to avoid node level congestion. The proposed scheme shows better results in terms of fairness which sidesteps the congestion. Maintaining fairness leads to energy efficient sensor network.

The rest of this paper is organized as follows: Section II briefly covers related work. Section III introduces the proposed ABC scheme. Section IV consists of experimental setup. The performance evaluation of ABC is carried out in Section V. Finally, Section VI concludes the paper.

Related Work

Work reported in this paper [2], provides analysis on traffic load distribution over the randomly deployed nodes in wireless sensor network. Author divides network along x axis in three parts. Analysis is done on the basis of position node along x axis. The scheme reduces the traffic load by applying probability distribution function during node scattering. If node n_x, is near sink node and no other node which is nearer to sink than node n_x. Then probability distribution function shows that the probability of having more traffic to forward for node n_x. Results of this paper shows that changing the node distribution over the network can result in decreasing the load over bottleneck nodes and also increases lifetime of network. It also distributes energy over nodes according to their traffic distribution to assure all nodes in network have same lifetime. Time and energy is wasted in finding traffic load according to probability distribution formula. It took more time to reach entire information at destination.

Authors in [6] present the congestion control scheme for wireless sensor network. It consists of two components congestion detection and rate adjustment. To detect congestion it considers unoccupied buffer size and traffic rate of each node. According to buffer occupancy it adjust rate of each node. First it will set node priority and congestion index. When congestion is detected then according to node priority rate is adjusted. Upstream hop-by-hop congestion control (UHCC) protocol achieves better priority based fairness and throughput. It mitigates congestion hop by hop hence quick response. But UHCC considers source traffic priority on all conditions. And also energy will be wasted in assigning priority to nodes.

In this paper [8] analysis is done for each node traffic load in multi-hop wireless sensor network. It presents analytical model which find out traffic load of each node. According to model state transition probability is evaluated. Means, if node x is near to sink than node y then state transition probability of node x depend on node y. According to this probability per node traffic load is calculated. Results shown in this paper confirm that the traffic load of a node increases as distance of node from sink decreases. This is beneficial to find out hop spots in network. To extend the operational lifetime of the network, additional sensor nodes can be deployed at these hot spots. But environmental impact may vary results. Also during an emergency time is wasted in finding the traffic load.

Congestion control and fairness (CCF) [9] figure out total change in aggregate traffic required. Congestion is detected according to packet service time and rate is adjusted. It also uses utility control and fairness control module for utilization of network and to achieve fairness among different flows. It provides stability with the guarantee of efficient use of network resources. CCF reduces oscillation with achievement of simple fairness. As packet service time is used for congestion detection, it may lead to low utilization when traffic is low.

In [10], the authors propose fairness aware congestion control (FACC) scheme. Paper consider single sink scenario, where in between nodes are split in to two parts. First part contains node which are near to source or source node itself, called as near source node. Second part consists of nodes which are near to sink called as near sink node. During upstream communication when packet is dropped at near sink node. Then near sink node produces warning message. That message will be forwarded to in between nodes. Then in between nodes recalculate rate according to traffic and forward the new rate to source node. Then new rate is adjusted by source node. FACC gives better performance in case of handling congestion. During packet loss after some time it will become stable. It may increases end to end delay. Throughput may degrade.

Proposed Algorithm

The ABC algorithm mainly runs on each sensor node. At the beginning, the source node will generate traffic as per the rate provided to that source node. Then intermediate node process packets and try to forward it to the next node in the hop. Then, if the processing speed of node is good and link is free the packets are going to be processed with normal and forwarded to destination node.

But, if the incoming packet flow rate is too much high than the packet processing speed of node then condition becomes worst. Traffic in network becomes unfair and near sink node have to process mode packets as compare to other nodes. It increases buffer occupancy as compare to expected limit and leads to the drop of packets in the network and wastage of energy. It reduces the network lifetime and increases total time requires, reaching data at destination. So to avoid this unfairness, proposed algorithm runs continuously on the node and whenever the buffer occupancy is going to cross certain threshold value, algorithm should adjust bandwidth according to threshold.

A. Best Method of Performance of Proposed Scheme

Nodes are distributed spatially in network. The term level is used to redefine the hops from sink. Level of node is discovered by counting the number of hops from sink. Initially bandwidth is assign linearly according to level of sensor node. Course tuning is done by linear assignment of bandwidth. Then proposed algorithm uses Buffer Occupancy as a method of Congestion Detection. Higher threshold is defined. Depending on threshold value we prepared fine tuning.

The best method of performance of invention is as follows. It contains three steps.

Step 1: Level Detection: Level detection will be done by finding the number of hops of sensor node from sink. If node is one hop away from sink then it will be included in level 1, and it will be included in level 2 if it is two hops away.

Step 2: Bandwidth calculation and Assignment: According to level of node initial bandwidth will be allocated.

Step 3: Bandwidth Control: Bandwidth control comes in to picture when node crosses their buffer occupancy over the higher threshold.

B. Detail Description of the Invention

Algorithm: Adaptive Bandwidth Control (ABC)

1. Discover the level (number of hops) from sink
   a. Find out larger hop count
   b. Split it in four margins.
   c. According to margins define node level
2. According to node level *l*, assign bandwidth linearly.
3. Initially we assign a bandwidth according to level from sink. Then we adjust bandwidth as *ΔB* depends on buffer occupancy of that sensor node. Initially we define buffer occupancy range as Buff_window and according to control bandwidth as

if (Current buffer occupancy > T_h)

$$B = \frac{\text{Normalized Bandwidth (bw)}}{l} \times c$$

Where *c* = constant of proportionality,

T_h = Higher threshold and

l = node level

Experiment Setup

Network simulator 2(ns2) is selected for simulation as scenario consists of huge network. It is single sink scenario.

Radio propagation model is two ray ground. IEEE 802.11 media access control protocol is used. Transmission range of sensors is 250 meter. Ad-hoc on demand routing protocol is used. Each node can store maximum 100 packets in queue. Packet size is 50 bytes. And packet generation rate is 10 pkts/sec. Initial energy of all nodes is 5 joules. Bandwidth is 0.4 Mb and topography is variable (chain topology, grid topology, random topology, hierarchical topology). Error model is introduced as 20%. ABC algorithm consists of two additional simulation parameters i.e. Constant of proportionality and bandwidth variation. Constant of proportionality is 2 and linear variation of bandwidth.

To find fairness factor for each graph, "Jain's Fairness Formula" is used. It rates fairness of a set of values. Suppose sensor network contains *n* number of sensor nodes. Suppose X_i is the value of quality of service parameter of i^{th} node. Then fairness factor for that particular quality of service parameter is as follows

$$X(1,2,\ldots\ldots,n) = \frac{(\sum_{i=1}^{n} X_i)^2}{n\sum_{i=1}^{n} X_i^2}$$

The result ranges from 0 (worst case) to 1 (best case). When resources utilization of all nodes is fair then fairness factor will be good.

Considering all these parameters, simulation was carried out for without using ABC (without-ABC) algorithm and with ABC (with-ABC) algorithm. Performance analysis is done for both with and without ABC. The results are compared against quality of service for checking the performance of ABC algorithm.

Performance Analysis

[Fig-2] shows the performance of energy consumption as a function of distance from sink. Level 1 contains the nodes which are one hop away from sink. Similarly, level 2 contains the node which are two hop away from sink and likewise. If node density increases level 1 may contains node which are one or two hop away from sink and correspondingly number of hops increased.

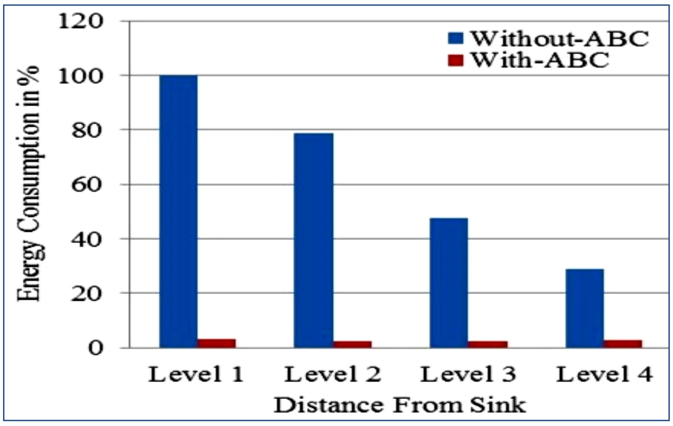

Fig. 2- Energy consumption as a function of Distance from sink.

Generally, nodes at level 1 consume more energy because they have to forward more traffic as compare to other levels, hence energy consumption at level 1, without-ABC is near about 100% as in [Fig-1]. ABC algorithm assign more bandwidth to near sink node, hence most of the time link will be free to transmit the traffic. It decreases the probability of packet loss and energy wastage in in drop of packets or retransmission is saved. As a result, energy consumption of nodes at level 1 is very less. ABC assign bandwidth according to level from sink, energy consumption of nodes at different level is fair. Throughput is also fair at all levels as shown in [Fig-3].

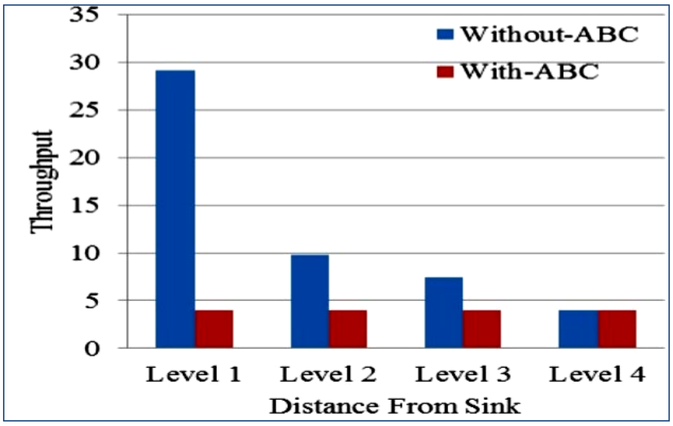

Fig. 3- Throughput as a function of Distance from sink.

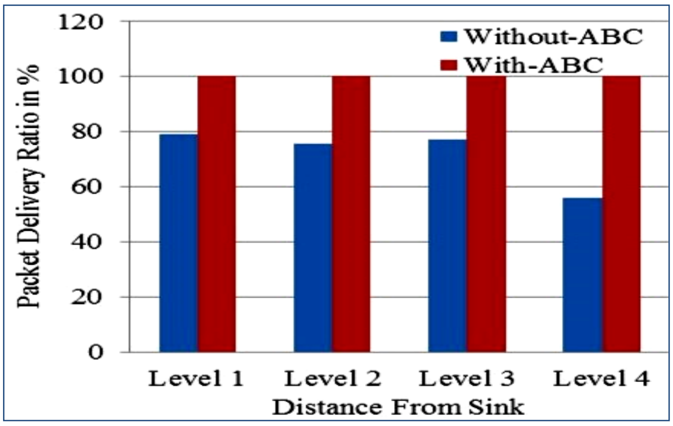

Fig. 4- Packet Delivery Ratio as a function of Distance from sink.

ABC assigns bandwidth according to level from sink which decreases possibility of drop of packets. Hence packet delivery ratio of nodes at all level is good as equal to 100% (as shown in [Fig-4]). With-ABC gives good packet delivery ratio at all level than without-ABC. PDR is also fair to all level with-ABC.

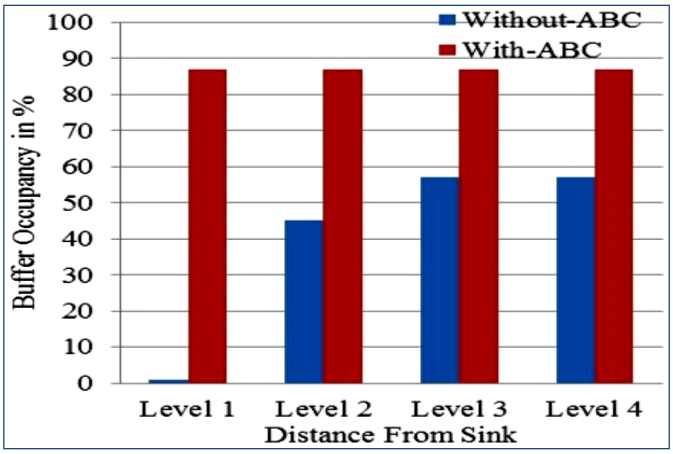

Fig. 5- Buffer Occupancy as a function of Distance from sink.

[Fig-5] reports variation of buffer occupancy as a function of distance from sink. Buffer occupancy is increases when there is more number of packets to transmitte. As there is no drop of packets, buffer occupancy increases. When we see [Fig-5], buffer occupancy of nodes at all level is more with-ABC as compare to without-ABC. At level 1, buffer occupancy is near about 5% which is very less. Without-ABC gives unfairness in terms of buffer occupancy. But, in case of with-ABC buffer occupancy at all level is fair.

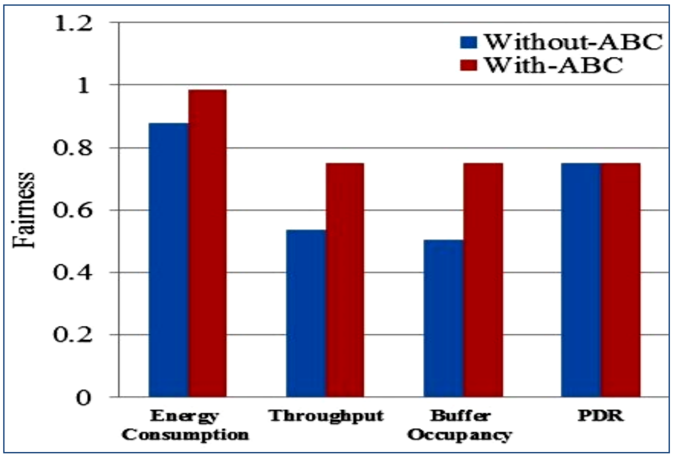

Fig. 6- Fairness w.r.t. Parameters

Fairness performance of with and without ABC algorithm is shown in [Fig-6]. As the parameters are equally utilized, fairness factor is good. Fairness factor for energy consumption without-ABC is 0.87 i.e. 87% and with-ABC is 0.98 i.e. 98%, means fairness is improved by 13% for energy consumption. Proposed scheme achieve fairness about 75 % for other parameters. The scheme advances fairness of throughput, buffer occupancy, and packet delivery ratio by 22%, 25%, and 1% respectively. The result demonstrates that ABC algorithm is able to achieve much better fairness than without-ABC.

[Fig-7] depicts the average values w.r.t. parameters. ABC outperforms the without-ABC, reducing the value of average energy consumption by about 60%. Buffer occupancy is more by 40% and packet delivery ratio is 99%.

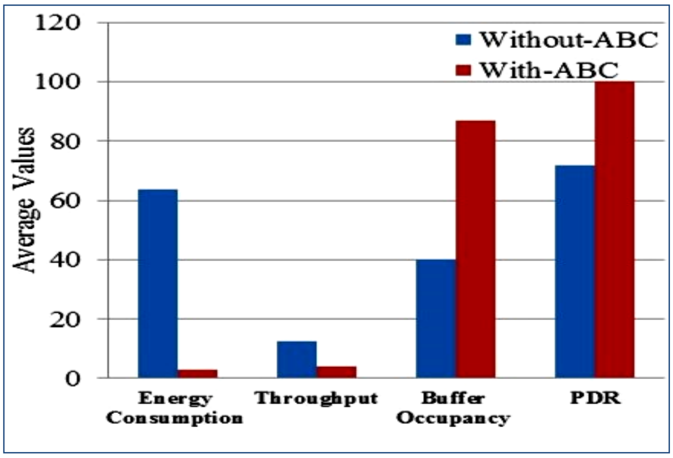

Fig. 7- Average Values w.r.t. Parameters.

Conclusion

According to results of proposed ABC algorithm, we conclude that consumption of energy of all nodes is same. Hence, *energy fairness* can be achieved using Adaptive Bandwidth Control with reference to results of fairness factor against different parameters. This strategy can be used for any topology and also work irrespective of number of nodes or node density.

The scheme shows better performance in terms of fair utilization of resources with better packet delivery ratio. Fairness is improved by 13% to 25%. Concluding that scheme ABC can achieve the traffic and energy fairness, and both network lifetime and packet delivery ratio are improved significantly.

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