A NOVEL AND RELIABLE ATTRIBUTE RATIO CONGESTION CONTROL TECHNIQUE FOR WSN (ARCC)

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Abstract— Effectiveness of a Wireless Sensor Network (WSN) is determined by its performance and any WSN can lose packets when it is congested. Sinks collecting information from other nodes are most likely to be less efficient when there is congestion. There are many congestion control algorithms while congestion detection and control are major research areas. There are various congestion control techniques in WSN's based on many factors but controlling congestion becomes mandatory in WSN's for better performance. The main contribution of this paper is a congestion control mechanism for reliability and management in a WSN. This paper presents a novel technique to overcome congestion and improve performance of a WSN while detailing other routing and congestion algorithms.

Index Terms—WSN, Congestion in WSN, Congestion Control, Algorithm, Reliability, WSN Management, Performance in WSN.

1 Introduction

Wireless sensor nodes act autonomously and interface with actuators to communicate by using wireless transmitters. A large number of sensor nodes are scattered into wide geographical regions. They form a logical network to route packets towards managing nodes called sinks or base stations. They can be used effectively in areas difficult to like environmental monitoring. They operate on very less loads, but become active when a related event occurs. Though targeted for military application they are being deployed in civilian applications like health monitoring [1], habitat study [2], object tracking [3]. WSN usage in mission-critical applications [4] demand performance controls for accomplishment thus making node placement an essential for sensing coverage. The traffic in a WSN can be both ways i.e. to and fro from the sink. The innumerous nodes in a WSN can be imagined as subnets with a sensor node for each subnet. Directed diffusion for structured data was proposed [5]. The communication between the nodes forwarded named-data. The nodes were equipped with memory and processing ability. A node requests data by sending a query on named-data and on finding a match the results are transferred to the querying node. Intermediate nodes aggregate data and redirect them to nearby nodes. Each probe consists of a type, duration and interval called an interest. The sink periodically broadcasts interests with the latest time stamp (exploratory interests) to check on node for the required data. Based on a node's confirmation, gradients are setup and data transfer occurs us ing an optimal path from a source to the sink. This paper proposes a NOVEL congestion avoidance technique (ARCC) for better and efficient congestion management.

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2 Congestion in WSN's

The main objective of a WSN is to achieve reliable event detection while minimizing packet losses in transmissions from sensors to the sink. The nodes sense and transport different types of information triggered by events, thus leading to overcrowded information. This overcrowding called congestion results in d an increase in data losses. The nodes suddenly burst into action due to events thus flooding the sink with sudden bursts of information causing packet losses. Though many schemes have been proposed for event detection and data transmission in WSN's, the issues of reliable data transfer needs more attention. Mechanisms providing a general set of components which can be plugged into applications, are needed. Congestion can be managed with detection and control. Congestion control study is an important part of research in WSN congestion and alleviating congestion using various techniques enhances the output of a WSN. Collision occur when all packets are sent through the same medium and when if a protocol handles collisions, it helps improve congestion control in a WSN. Applying directed diffusion in WSN's has its own drawbacks. The nodes need to be equipped with some amount of computational capabilities and memory for storing interests with various time stamps, thus causing major overhead for sensor networks [6]. Directed diffusion's guaranteed data delivery becomes less significant, since data flows from several source nodes in event detection [7]. Moreover, the limited storage capacity of the nodes are static, while congestion control techniques need more storage while making nodes sleep and or when efficient congestion control protocols need to be employed to overcome congestion. Campbell et al. in their study observed that WSN's were generally tolerant to loss of data packets[8]. In spite of this observation there exists an amount of vulnerability in message losses, when the data flows from the sink to source. Their proposed Pump Slowly Fetch Quickly (PSFQ) mechanism for WSN's supported a simple and scalable yet customized transport scheme to meet the requirements of reliable data transfer. PSFQ is based on propagation of data from source node by injecting data at relatively low speed and nodes experience data loss and fetch missing data packets from immediate neighbors by requesting for retransmission. The problem with PSFQ is that the authors assume that packet loss based on poor quality of wireless links, while the traffic congestion is not considered making it an unrealistic assumption for WSN's [7]. Event to Sink Reliable Transport Protocol (ESRT) , proposed in [7], was designed for reliable event detection in WSN's. It necessitates a multipoint flow to a sink opposed to the point-to-point transport protocols. Data flow from several source nodes to a single sink are loss tolerant increasing the reliability. The objective of ESRT is to achieve reliable event detection in WSN with low energy dissipation and maximum congestion control. The reliable transfer of an event from source to sink is measured in terms of number of data packets received at the sink within a given time interval. In ESRT, the sink does not try to optimize the number of nodes required to sense the data for a given task. Further it transfers raw data to the sink and does not reduce redundancy of data from the source nodes [6]. WSN nodes get loaded or become idle based on event occurrences. Any occurrence experiences a sudden burst of data transports within a WSN leading to congestion at various stages. Retransmission of data lost in congestion incurs additional energy cost. Congestion Detection and Avoidance (CODA) proposed in [9], attempts to address these challenges by using energy efficient heuristic mechanisms in the network and avoids congestion. Though CODA tries to achieve congestion control, the extra messaging required in controlling congestion leads to higher energy dissipation. The above discussed approaches achieve individual packet reliability in packet retransmissions without considering the effects of buffer limitations of sensing devices.

3 Effects of congestion in WSNs

As demonstrated in this document, the numbering for sections upper case Arabic numerals, then upper case Arabic numerals, separated by periods. Initial paragraphs after the section title are not indented. Only the initial, introductory paragraph has a drop cap Congestion avoidance is mandatory in WSN applications. For example, hundreds of sensors can be scattered over a flat area in an environmental monitoring system, to support periodic sensing. Applications with high data-rates are susceptible to congestion problems, especially at intermediary nodes near the sink and detection of congestion is necessary to avoid congestion collapse. MAC protocol has to ensure correct delivery of packets to one-hop neighbors using various techniques An important effect of network congestion is the increase of packet collision at the MAC layer due to sensors overhearing other radio transmissions when they are densely populated. When each sensors buffer is full, it creates retransmissions, traffic and results in increased contention or decreased packet delivery ratios. Applications requiring high levels of transmission can use tiered networks [10] or [11] for imaging. Routing in a WSN has to focus on energy efficiency which is a key metric, as the transport layer has to synchronize with the routing protocol for minimum use of node energy. The routing schemes can be separated into categories based on attributes or network models [12]. Multipath routing techniques focus on multiple paths from a source to a destination to circumvent invalid links or failed nodes [13], [14]. When a single link fails, a secondary route is available to re-route packets to the destination. Multiple routes can help avoid congestion by re-routing packets when neighbor nodes' queues are filled up. For packet drops, due to broken links or buffer overflow, multiple routes allow an alternate routing decision, thus creating a self-regulating system for load balancing in a WSN.

4 Proposed Technique ARCC for Congestion Management

Tilak et. al. [15] study on the effect of congestion in a WSN, one of the earliest, determines probable techniques for avoiding congestion. They increased the sensor density and network load through simple experiments, thus demonstrating deployment infrastructure as the base for avoiding congestion. Rangwala et. al. [16] presented an interference based control technique to monitors queue lengths for detecting congestion. CODA [17], Fusion [18], and Phase-divided tcp congestion control schemes were proposed for WSN's to recover from congestion. This paper proposes a queue monitoring technique in which the packet forwarding decision is based on the number of downstream nodes with their queue sizes. Congestion avoidance is done with multi-path routing in a WSN using the characteristics of upstream and downstream flows. The method is also compared with existing protocols. The scheme assumes a WSN with sensors and multiple sinks with static positioning of sensors distributed in a rectangular area which are collision free at the MAC level, thus abstracting packet losses due to collisions.

4.1 ARCC Congestion avoidance

Queue monitoring checks congestion levels of nodes in the network thus implementing congestion avoidance. Fig. 1 depicts the example scenario

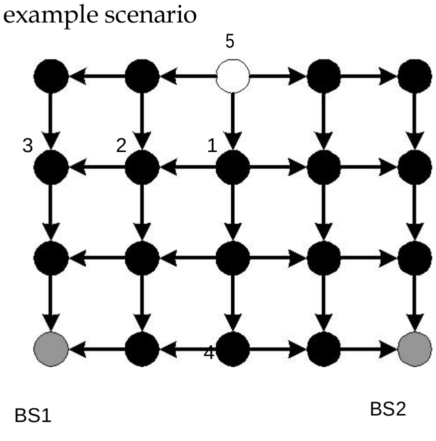

Fig. 1. A grid of sensor nodes with one source (5) and two base stations

ARCC congestion avoidance model requires a set of steps at each node for congestion avoidance. Each node maintains a list of streaming nodes used to calculate the Attribute Ratio

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(AR) value at each node.The nodes regularly publicize their prevailing queue sizes for the neighbor nodes to update their respective queue sizes in tables. The congestion is avoided by using the AR values at each node along with the targeted node's queue lengths to forward packets to appropriate candidate nodes.

4.2 ARCC Congestion avoidance Algorithm

```
   Setup the Node neighborhood list for NLi
   while packets forwarded in WSN do
      if packet received for forwarding then
      Buffer packet
      Update NLi with received info
      Check NLi length (leni) and compare with nlth
      if leni ≥ nlth then
      Run neighbor table management algorithm
      end if
      Calculate Attribute Ratio Ri
      if Ri > 1 then
      forward packets
      else if Ri < 1 then
      Use technique to reduce sending rate
      else if Ri = 1 then
      Check downstream nodes from NLi
      Route traffic through these nodes
      end if
      end if
 end while
```

The Congestion Avoidance Algorithm and terms are described below

Attribute Ratio: Using neighbor discovery protocol, each sensor node knows its streaming neighbors including nodes closer to the source and nodes near the sink. Intermediate nodes, based on its location will gauge the flowing nodes, both ways. Source nodes and sinks are special nodes with no streaming nodes. The Attribute Ratio (AR), Ri, is the ratio of the number of streaming nodes of a node in the network. In Fig. 1, '5' denotes the sensing node and the arrows denote the various paths possible to the sinks, since multiple paths could exist from the source. The nodes '1', '2' and '3' are the intermediate nodes for the hops from the source to the sink. Node '1' has four streaming nodes (three downstream and one upstream), with an AR of 3 for R1as listed in Table 1. Similarly, R2 and R3 becomes 1 and 0.5 respectively. Sensor nodes may have zero streaming nodes, implying they are disconnected. The AR at a particular node presents useful information of the network state, since they have the capability to measure incoming traffic and decide on the output route for the traffic. This technique balances load in WSNs. Table 1 lists some of the AR values for various nodes in the assumed network.

4.3 Congestion avoidance with multiple paths

The individual AR values at each node can be used to forward sensed data. A node checks on the Ri value before forwarding a packet, where Ri > 1 implies it has multiple, it means that the node has multiple streaming nodes and implement any of the

TABLE 1
ATTRIBUTE RATIO VALUES

Node ID	Number of Streaming nodes down	Number of Streaming nodes up	Attribute Ratio (AR)
1	3	1	3
2	2	2	1
3	1	2	0.5
4	2	1	2
5	3	0	Source
Base stations (1,2)	0	2	Sink

paths in forwarding packets. Ri < 1, means there are no more nodes up. When Ri = 1, the node checks streaming nodes down and routes packets through them fairly avoiding congestion.

4.4 Attribute Ratio Importance

The AR usage represents decisions at the nodes for forwarding, especially in times of collisions or incipient congestion. The AR value helps a forwarding node to take an informed decision on forwarding information down and balancing load. Conventional congestion control mechanisms aim at recovering from a congestion collapse after a bottleneck occurs. This scheme would produce the best output when there is a mixture of AR values in nodes

It can be applied to randomly deployed WSNs. Pseudo code for the congestion avoidance algorithm and Neighbor Table Updation Algorithm is presented below

4.5 ARCC Neighbor Table Updation Algorithm

```
  Receive packet from NND
                  // neighbor node NND
  for all Records Ri of NND header table NNDTQ do
                  //Que size Table NNDTQ
        Check for Ri in existing
                  // Ri Attribute Ratio of Current Node
         if Ri < NNDRi then
         delete record with minimum queue size (Ri)for NND
         end if
 end for
```

4.6 ARCC Rate Reduction

The AR usage represents decisions at the nodes for forwarding, especially in times of collisions or incipient congestion. The AR value helps a forwarding node to take an informed decision on forwarding information down and balancing load. Conventional congestion control mechanisms aim at recovering from a congestion collapse after aSince current node queue sizes are advertised to neighbor nodes for regular updates of the neighbor tables, they are advantageous in controlling packet overhead, leading to reduced processing and frequent updates. A node forwards a packet after ensuring the next hop will be accommodated in the neighbors queue else it holds the packet in its queue. In times of extreme congestion, the node finds a neighbor with least queue to accommodate the packet in its next hop thus reducing congestion, The packet is not forwarded unless it finds a neighbor which can accommodate the forwarded packet, thus stopping the transmission tempo-

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rarily, but lessening the chances of collision or congestion. The implementation considers the flows up and down to be the same. the forwarding rates for upstream and downstream nodes to be the same. Multiple nodes forwarding packets to bottleneck nodes, do not actually forward, unless the bottleneck is down. The nodes only check the queue size and availability instead of forwarding the entire packet, thus stopping packet drops and congestion.

5 Simulation Environment and Metrics

The effectiveness of ARCC congestion avoidance technique was analyzed with 150 sensor nodes, placed randomly in a 600 x 600 area with a transmission ranges of [35, 70]. The number of active sources were varied from 1 to 35 with each source generating on-off traffic at a maximum sustainable rate of 20 packets per second. Each data packet was 35 bytes long and buffer sizes at each node is set to 20 packets. It was assumed that two sinks were present, one at the right of the simulation grid while the other on the left bottom edge of the grid. It was also assumed that multipath shortest paths from the source to sink were present. . Table 2 summarizes the simulation parameters used in the experimental setup. From the simulations, the effect of the proposed algorithm using Attribute Ratio with respect to delivery ratio, were studied. The proposed protocol was compared with global rate control protocol [9] and lightweight buffer management [7] protocol.

TABLE 2
ARCC SIMULATION PARAMETERS

Number of nodes	160
Total area	600x600
Active sources	1-35
Traffic type	Variable rate
Data packet size	3 5 bytes
Node density (η)	1 5
	1
Buffer size	0 packets

Packet delivery ratio: On increasing the number of active sources the packet delivery ratio for the proposed algorithm hardly varied. Figure 3 depicts the average packet delivery ratio with varying number of active sources in the network, while Table 3 lists the packet delivery rations. The comparative algorithms show a decrease in the packet delivery ratio with an increase of active nodes in the network. Though an increase in the active sources could result in a greater number of packet drops, the proposed technique makes full use of the available queues in the network by monitoring queue sizes of neighbors before forwarding packets. As a result, packets are transmitted only if there is an availability of a route to carry forward and do not get dropped due to congestion.

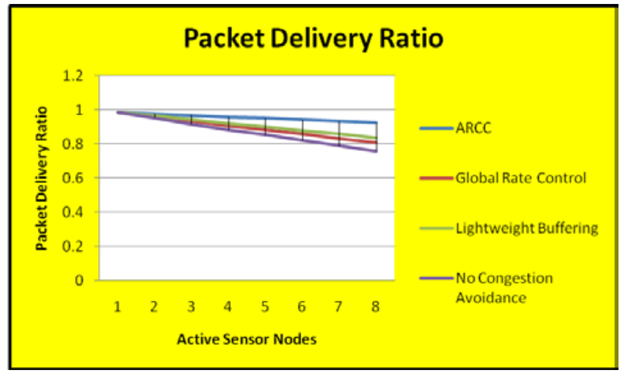

Fig. 2. Number of active sources vs. packet delivery ratio

Average queue occupancy: On monitoring the average queue

TABLE 3
PACKET DELIVERY RATIO'S IN CONGESTION ANALYSIS

Active Sources	ARCC	Global Rate Control	Lightweight Buffering	No Congestion Avoidance
1	0.987	0.987	0.987	0.987
2	0.985026	0.981078	0.982065	0.979104
3	0.983056	0.975192	0.977155	0.971271
4	0.98109	0.96934	0.972269	0.963501
5	0.979128	0.963524	0.967408	0.955793
6	0.977169	0.957743	0.962571	0.948147
7	0.975215	0.951997	0.957758	0.940561
8	0.973265	0.946285	0.952969	0.933037
9	0.971318	0.940607	0.948204	0.925573
10	0.969375	0.934963	0.943463	0.918168
11	0.967437	0.929354	0.938746	0.910823
12	0.965502	0.923778	0.934052	0.903536
13	0.963571	0.918235	0.929382	0.896308
14	0.961644	0.912725	0.924735	0.889137
15	0.95972	0.907249	0.920111	0.882024
16	0.957801	0.901806	0.915511	0.874968
17	0.955885	0.896395	0.910933	0.867968
18	0.953974	0.891016	0.906378	0.861025
20	0.952066	0.88567	0.901846	0.854136
21	0.950162	0.880356	0.897337	0.847303
22	0.948261	0.875074	0.892851	0.840525
23	0.946365	0.869824	0.888386	0.833801
24	0.944472	0.864605	0.883944	0.82713
25	0.942583	0.859417	0.879525	0.820513
26	0.940698	0.854261	0.875127	0.813949
27	0.938816	0.849135	0.870751	0.807438
28	0.936939	0.84404	0.866398	0.800978
29	0.935065	0.838976	0.862066	0.79457
30	0.933195	0.833942	0.857755	0.788214
31	0.931328	0.828938	0.853467	0.781908
32	0.929466	0.823965	0.849199	0.775653
33	0.927607	0.819021	0.844953	0.769447
34	0.925752	0.814107	0.840728	0.763292
35	0.9239	0.809222	0.836525	0.757186

sizes with varying number of active sources of the sensor nodes in the network, depicted in Fig.3

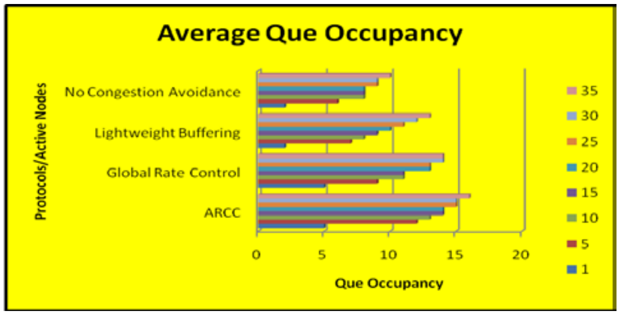

Fig. 3. Average Que Occupancy

It is evident from fig. 3, that the proposed scheme makes greater use of the available queues in the network. This result also explains the average delivery ratio remains more or less constant in Figure 2 even with an increase in the number of active sources. Comparative schemes show a gradual increase in the average queue occupancy, the proposed mechanism consistently uses the extra available resources to minimize the packet drops due to congestion. A consistently high queue occupancy rate would be desirable for the network (provided there are fewer packet drops), as it shows greater resource utilization and a higher degree of fairness. It avoids a common drawback of overloading specific bottleneck queues while other neighboring nodes which could participate in the packet forwarding process are left with largely unused queues. From Figure 3, it can be observed that the lightweight buffering scheme also uses large parts of its available buffer space since it simply waits on a packet before transmission. However, our scheme has a better overall memory usage since the packets are forwarded based on not only the neighbor queue characteristics, but also the number of downstream and upstream nodes. Load balancing in such a scenario is more effective with the proposed algorithm. Comparing the instantaneous queue sizes of neighbors of a particular node during the entire simulation run for the proposed AR scheme, only source node ids were varied for one quarter of the total number of nodes in the network. The memory requirements in a WSN node can be calculated by using the following equations:

$$M r = N \times p_l \times q_l$$

where, pl is the packet length, N is the total number of queues, and ql is the size of each queue. In the proposed technique the queue sizes converge to a more constant size and hence represent a greater network resource utilization which leads to a better congestion control in the network. Though in the beginning, high neighbor queue occupancies throughout the network operation seems to defeat the purpose of an avoidance algorithm as higher queue sizes inevitably lead to congestion. However, there is an upside to this characteristic if we monitor the net packet loss ratio obtained. As it is evident from Figure 2 the proposed scheme accounts for an improved delivery ratio compared to other existing mechanisms even though Figure 4 shows a higher queue occupancy. Using available memory at each node throughout the network in an effective manner is definitely more advisable than leaving queues unfilled in some nodes while others overflow and ultimately drop packets

6 CONCLUSION

Designing congestion avoidance algorithms for WSNs is a challenging task, since the frequency of events sensed is a deciding factor for the occurrence of congestion. Multiple sensors transmitted sensed information increase the probability of congestion and eventually packet drops. This paper proposes a novel congestion avoidance algorithm based on Attribute Ratio, where multiple yet reachable paths to a destination are pre-informed. Simulated studies indicate a better packet delivery ratio in comparison with other mechanisms

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