A HYBRID ALGORITHM FOR EFFICIENT CONGESTION CONTROL IN WIRELESS SENSOR NETWORKS

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ABSTRACT

As applications in Wireless Sensor Networks (WSNs) are evolving, congestion control remains an open and, in several cases, a critical problem. A lot of research has been performed on this issue and two general approaches seem to be the most prominent for its solution: traffic control and resource control. Each of these two methods presents specific advantages and disadvantages under different scenarios. In this paper we present HRTC, a dynamic scheme capable of bridging these two methods for congestion control and provide the best solution, based on the prevalent network conditions.

Index Terms- Wireless Sensor Networks, Congestion Control, Traffic Control, Resource Control, Hybrid Solution

I. INTRODUCTION

Congestion is a problem that affects all types of networks. Especially for the low-powered, unreliable WirelessSensor Networks (WSNs), the occurrence of congestion could negatively affect not only the performance of the network (throughput, delay, packet loss), but also its lifetime as well as its mission. Currently, research converges in two methods for the solution of the problem of congestion in WSNs: traffic and resource control [1].

Traffic control (TC) is the method that has been employed by the majority of congestion control algorithms in WSNs the last few years. Algorithms that employ this method, attempt to limit the data rate of the sources until congestion is mitigated [2]–[12]. On the other hand, algorithms that employ resource control (RC) take advantage of the dense and redundant placements of nodes on the field and create alternative and multiple paths in order to avoid the congested regions.Both methods present specific advantages and disadvantages under different scenarios and network conditions. TC is more efficient than RC in cases where transient congestion occurs, as well as in cases where the network is sparsely deployed. On the other hand, RC, although in general it exhibits better attitude than traffic control, in terms of throughput and power consumption it presents the disadvantage that it can only function in fields where alternative paths can be created (i.e.placements where nodes are densely deployed [13]).

In particular, in [14] the authors show that when RC applies, the throughput of the sink is higher, while there is morebalanced energy consumption in the network. Conversely, there is an increment in the end-to-end packet delay fromthe source to the sink, since packets need to bypass the congested node which is normally part of the shortest pathfrom the source to the sink, using alternative paths. Similar studies show [15] that the lifetime of the networks can be severely degraded in cases where heavy data load exists and a congestion control algorithm that adopts traffic control method is employed. The reason lies on the fact that this type of algorithm constantly utilizes the shortest path to the sink and this drives the network to the creation of routing holes(network becomes disconnected).

In this work we present HRTC, an algorithm that provides a complete solution to the congestion problem. By complete, we mean that the nodes in the network are able to understand whether they can apply resource or traffic control, at any level. Thus, if RC cannot be applied, the source node applies TC until it achieves congestion alleviation. In particular, by applying this hybrid scheme, the network gives priority to RC and in case it is not able to so, it applies TC. The obvious advantage of this scheme is the fact that the assumptions made in RC algorithms like [13], [16], [17], that the network needs to be densely deployed, is canceled.The rest of the paper is organized as follows. In Section IIwe present the proposed hybrid algorithm, then we evaluateits performance in comparison with pure traffic and resourcecontrol algorithms in Section III and we finally close with theconclusions in Section IV.

II. HYBRID RESOURCE AND TRAFFIC CONTROL METHOD- HRTC

The basic design philosophy of HRTC is based on thefact that the conditions in WSNs are possible to changedynamically. Thus, it is possible for a densely deployednetwork to initially exist, but after some time this to transforminto a network full of routing holes or disconnected partseither due to network issues, like heavy traffic, or other issueslike destruction of nodes due to physical phenomenon's (rain, floodingetc.).In either case, the target of this work is to find a solution that maximizes the efficiency of the network in terms of throughput and lifetime, using effectively the available network resources. The application of the aforementioned congestion control methods should be seamless, attempting to minimize any extra overhead to the network. Hence, we propose a hybrid algorithm that aims to exhibit only the positive traits of both individual methods. In thisalgorithm, when a node faces congestion, it attempts to inform the **source node** from which it receives packets with the lowest data rate, to suppress its data rate. To achieve this, it transmits a backpressure message, hop-by-hop, to the source. We intentionally choose to limit the transmission of the source node with the lowest data rate, since we prefer to keep serving the nodes with higher data rate(s) in order to affect throughput the least. Now, when each node in this reverse hop-by-hop path receives this packet, it checks whether it can apply **resource control** before the message reaches the source. If it can, it applies RC and stops transmitting this backpressure message. Otherwise, it keeps transmitting the backpressure message and if finally this message reaches the source, it(the source) applies traffic control. Thus, it adjusts its data rate and simultaneously adds a specific bit in each packetheader it transmits indicating that its data rate is throttled.Since the network dynamics are constantly changing, the nodesthat receive packets from this source node are now aware thatits data rate is throttled. Therefore, if they are able to applya resource control method again, they ask the source nodethrough a subsequent backpressure message to transmit witha full data rate. When the source node receives this secondmessage, it removes this specific bit and transmits in full datarate. Then, the specific node that initiated this new transactionreceives the full flow of packets and splits the traffic betweenthe initial node and the alternative path. Hence, even if theduration of the event is very small the overall gains of thenetwork are high.

Fig. 2.1 illustrates how this mechanism functions.

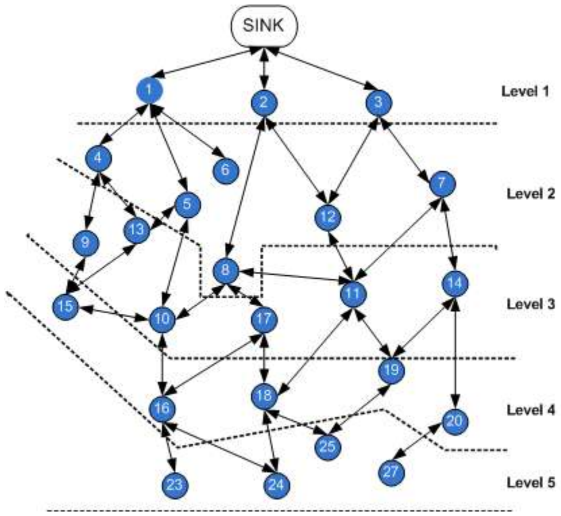

Fig. 2.1. Initial Network Connectivity.

We consider that node 14 is the congested node. This node receives packets from nodes 19 and 20, which are connected to sources 25 and 27. We also consider that node 19 transmits packets to node 14 with a lower data rate than node 20. In such a case, the congested node (node 14) it informs through a backpressure message node 19 to limit its transmission in order to alleviate its congestion situation. When node 19 receives this backpressure message, it checks whether it can create alternative paths to the sink (resource control). If it can, it creates this alternative path and stops transmitting the backpressure message to the source (node 25), solving the issue locally. Otherwise, it forwards the backpressure message to the source (node 25) and the source reduces its data rate byapplying atraffic control mechanism. Concurrently, the source, adds a bit in the packet header of the subsequent packets it transmits, indicating that its data rate is throttled. In this case, if also another node receives these packets (e.g. node 18) and is able to handle this data rate without a problem, it asks the source to transmit with full data rate and the throughput increases again.In the next paragraph we explain how a node is capable to Understand whether it can apply a “resource control” method or not.

2.1 Understanding of Whether A “Resource Control” Methodcan Be Applied

Nodes that apply resource control take advantage of the plethora of unused nodes in the network and try to establishAlternative paths towards the sink, in order to forward the excess traffic. Algorithms that apply resource control for congestion control [13], [16], [17], argue on the importance of the existence of an efficient topology control scheme. Topology control is required since it reduces the connections between the nodes while, concurrently, it provides the required number of redundant paths. Thus, this hybrid scheme should definitely employ a topology control algorithm. A very simple topology control scheme is to place nodes in levels from source to sink. This scheme has been employed in [16] and [17] and results show that it is a simple yet efficient scheme.

Moreover, it should be assured that there is always at leastone available path from source to sink. This preconditiondid not appear in previous efforts that apply resource control method [13], [16], [17] since in those cases it was assumed that the network was densely deployed and available paths always existed. In the cases we examine we consider any nodeplacement. Thus, in a sparse placement it is possible that paths from the source (or splitting node) to the sink are not always available.To secure this precondition we “borrow” the “flag decision”mechanism, proposed in the DAlPaS [17] algorithm, but with a significant variation. In the DAlPaS algorithm the flag decision mechanism assured that there was always at least one available node in a level higher than the congested node. In this case, it is not enough to assure that there is always one node available at a higher level above the congested node, since it is possible, in sparse placements have one available node a level above,but not an available path towards the sink. Hence, this issue cannot be solved locally.Thus, we consider that each node sets its flag field to“TRUE” when it is sure that there is a least one available path (not just a node in a level higher than itself) to the sink. To enable this, the”Flag Decision” algorithm is altered.Specifically, according to the DAlPaS [17] algorithm flag field is set to “TRUE” when the following conditions are satisfied:

- The buffer occupancy is above the pre-specified limit.
- The remaining power of the node is above the prespecifiedlimit.
- There is at least one node available to accept packets ata level higher than this node.

In the case of the HRTC algorithm, the third condition “at least one available node” is changed to “at least one available path”. To assure that there is at least one available path, the process is reverse and begins from the nodes that communicate directly with the sink. Nodes that communicate with the sink, set their flag to”TRUE”. This means that they have enough free space in their buffer to receive packets, their power is sufficient, and they can definitely communicate with this sink. This condition, (“TRUE Flag”) is communicated to the nodes that are a level lower than them using a backpressure message. These nodes are now sure that if they have a packet to forward, they can safely forward it through the nodes that are at a level higher than themselves and have their flag field set to “TRUE”. This procedure iterates in a backward fashion. Thus, each nodethat has in its neighbor table at least one node in a level higher that itself, with its flag set to true, is aware that it has at leastone available path to the sink.

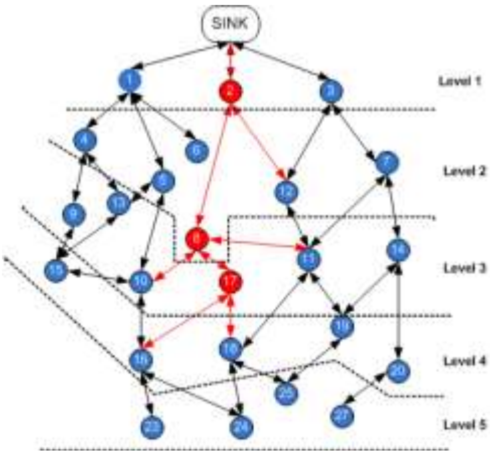

Fig. 2 2. Network Connectivity after failure of Node 2.

III. PERFORMANCE EVALUATION

To evaluate the performance of this hybrid scheme, a seriesof simulation have been performed using the Prowler [18]simulator, a probabilistic wireless network simulator. Prowlerprovides a radio fading model with packet collisions, static anddynamic asymmetric links, and a CSMA MAC layer servingas a contention based MAC protocol. For comparison, wecompared this hybrid scheme with a pure resource and a puretraffic control scheme.

To perform the simulations we have used the radio propagationmodel provided by Prowler. The transmission model is

Given by:

$$P_{rec,ideal}(d) \leftarrow \boldsymbol{P}_{transmit}(1/1 + d_{\gamma}) \quad (1)$$

Where, $2 \leq \gamma \leq 4$. Equation (1) presents an ideal transmissionfunction with no errors. In order to provide realistic conditionsto our simulations we add fading effects to the radio propagationmodel according to

$$(2): Prec(i, j) \leftarrow Prec,ideal(di,j)(1 + a(i, j))(1 + \beta(t)) \quad (2)$$

Where Ptransmitis the signal strength at the transmitter and*Prec,ideal* (*d*) is the ideal received signal strength at distance*d*. Variables a and β are random variables with normaldistributions $N(0, \sigma a)$ and $N(0, \sigma\beta)$, respectively. A node *j*can receive packets from node *i*if $Prec(i, j) > \Delta$ where Δ isthe threshold

A. Simulator Setup

30 nodes were uniformly deployed in a 100m x 100m field.The average radio range of transmission for each node is aradius of 10m. In our simulations we employed the defaultvalues of Prowler simulator, a choice made by several authors [19]–[22]. Specifically, we set $\sigma_a = 0.45$, $\sigma_\beta = 0.02$ andthe reception threshold is set to $\Delta = 0.1$. Also we set

$p_{error} = 0.05$. This parameter (p_{error}), models the probabilityof a transmission error caused for any other reason. Thesevalues add fading effects to the ideal transmission function. Inparticular, they model an imperfect circle.

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The rest of the parameters we employ represent the Mica-Znode and the most important of them are presented in TableI.

TABLE I
SIMULATION PARAMETERS.

Max Data Rate (kbps)	250
Transmission Power (dbm)	2
Receive Threshold (dbm)	-74
Transmission Current (mA)	17.4
Receive Current (mA)	19.7
Packet Size (bit)	1024
Buffer Size(Bytes)	512K
MAC layer	CSMA/CA

3.1 Results

In the first scenario, sources transmit at maximum data rateand we plot the throughput of the sink until the end of thelifetime of the network (throughput reaches zero).

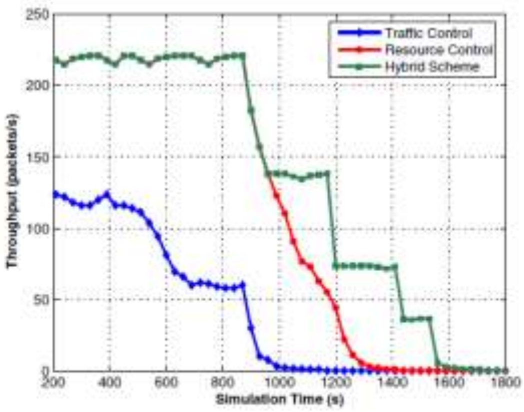

Fig. 3.1. Sink Throughput

Studying the results of Fig. 3.1, we notice that when the trafficcontrol method is applied, the throughput of the network isalmost half in comparison with the results of the resourcecontrol method, while the throughput reaches zero in less time.This is an indication that traffic control is not an effectivecongestion control method in terms of throughput since itreduces the data rate of the sources. Furthermore, the factthat packets travel through the shortest path to the sink, itdrains the power of the nodes that create this path and routingholes are created. Thus the lifetime of the network is reduced.When the resource control method is applied, throughput ismaintained at much higher levels. The reason lies on thefact that the data rate of the network is not reduced and theexcess data are being transferred to sink through alternativepaths. Moreover, we notice that the lifetime of the network isextended since there is uniform utilization of the power of thenodes. When the hybrid algorithm applies, the throughput aswell as the lifetime of the network is extended even more.This can be explained by the fact that when the resourcecontrol method is used and the network exhausts its alternativepaths (when it reaches the end of lifetime), sources keeptransmitting at the maximum data rate. In this case, the powerof the remaining paths is exhausted quickly and the networkceases its operation. But, if at the moment that no morealternative paths exist, the algorithm switches to the trafficcontrol method, the throughput is reduced (and diminishes)in a more linear way and the lifetime of the network extendseven more. To reinforce the previous results we present in Table II thepercentage of the remaining energy of the nodes when thenetwork is unable to transmit a single packet to the sink.

TABLE II

PERCENTAGE OF NODES REMAINING ENERGY (%).

Traffic Control	14.2
Resource Control	6.1
Hybrid Scheme	4.3

According to Table II when operating under traffic control, there is still 14.2% remaining energy to the nodes which cannot be used, since routing holes have been created andthe source node cannot find any routing path to forward data to the sink. On the other hand, when resource control is used this percentage falls to 6.1%, which indicates that the resource control method can uniformly utilize the energy ofthe nodes and extent the lifetime of the network. However, at the point where the resource control method cannot find any alternative paths to the sink, nodes apply the traffic controlmethod (Hybrid Scheme), and the network is able to utilizealmost 2% more energy. This percentage is able to extend the lifetime of the network as well as to increase the throughput at the sink.

Finally, in Fig. 3.2 we vary the data rate of the sourceand monitor how each scheme behaves. The results presented in this figure show the conditions in the network after the occurrence of congestion, when these method have been called by the application. The traffic control method maintains the data rate of the source stable, thus the average throughput doesnot alter. The resource control method increases the average throughput, since with higher data rate at the source there are more packets available in the network and since there are available alternative paths, the excess data can be forwarded to the sink. At the same time we note that when the data ratereaches 200 packets/s and more, the hybrid scheme presentsbetter attitude since the traffic control method complementsthe inefficiencies of resource control method when there are no more alternative paths.

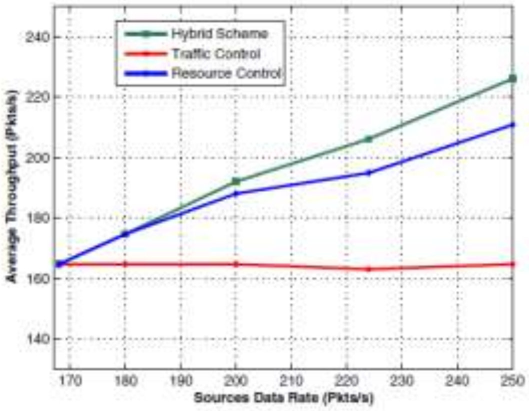

Fig. 3.2. Average Throughput Varying Source Data Rate

IV. CONCLUSIONS

In this paper we proposed HRTC, a hybrid scheme for congestion control in WSNs. This scheme attempts to complement the resource control method with traffic control. In particular, when resource control in unable to be effectively applied in a specific network instance, the algorithm employs the traffic control method. The advantage of this hybrid solution lies on the fact that due to the frequent variations that take place in WSNs topologies and node placements, each node is able to figure out which congestion control method is the most appropriate to apply at any moment, giving priority to resource control that extends network lifetime as well as throughput. Simulation results verify the efficiency of this hybrid scheme in terms of throughput and network lifetime.

REFERENCES

[1] J. Al-Karaki and A. E. Kamal, “Routing Techniques in Wireless Sensor Networks: A Survey,” IEEE Wireless Communications, vol. 11, pp. 6–28, 2004.

[2] C.-Y. Wan, S. B. Eisenman, and A. T. Campbell, “CODA: Congestion Detection and Avoidance in Sensor Networks,” in SenSys ’03: Proceedings of the 1st international Conference on Embedded Networked Sensor Systems, 2003, pp. 266–279. [Online]. Available:
http://portal.acm.org/citation.cfm?id=958523

[3] A. Woo and D. E. Culler, “A Transmission Control Scheme for Media Access in Sensor International Conference on Mobile Computing and Networking (Mobi-Com’01), 2001, pp. 221–235. Networks,” in Proceedings of the 7th annual

[4] C. T. Ee and R. Bajcsy, “Congestion Control and Fairness for Many-to-One Routing in Sensor Networks,” in SenSys ’04: Proceedings of the 2nd international Conference on Embedded Networked Sensor Systems,2004, pp. 148–161.

[5] B. Hull, K. Jamieson, and H. Balakrishnan, “Mitigating Congestion inWireless Sensor Networks,” in SenSys ’04: Proceedings of the 2nd International Conference on Embedded Networked Sensor Systems,2004, pp. 134–147.

[6] R. Vedantham, R. Siva Kumar, and S.-J. Park, “Sink-to-sensors congestioncontrol,” Ad Hoc Networks, vol. 5, no. 4, pp. 462 – 485, 2007. [Online].Available: http://www.sciencedirect.com/science/article/B7576-4JM0T76-1/2/14742f9f889d550dc3a041349294e3d5

[7] K. Karenos, V. Kalogeraki, and S. V. Krishnamurthy, "Cluster-BasedCongestion Control for Supporting Multiple Classes of Traffic in SensorNetworks," in EmNets '05: Proceedings of the 2nd IEEE workshop onEmbedded Networked Sensors, 2005, pp. 107–114.

[8] C. Wang, K. Sohraby, and B. Li, "SenTCP: A Hop-by-Hop CongestionControl Protocol for Wireless Sensor Networks," IEEE INFOCOM (Poster Paper), March 2005.

[9] C. Wang, K. Sohraby, V. Lawrence, B. Li, and Y. Hu, "Priority-basedcongestion control in wireless sensor networks," International Conferenceon Sensor Networks, Ubiquitous, and Trustworthy Computing,vol. 1, pp. 22–31, 2006.

[10] G. Wang and K. Liu, "Upstream Hop-by-Hop Congestion Control inWireless Sensor Networks," in IEEE 20th International Symposium on Personal, Indoor and Mobile Radio Communications, 2009, pp. 1406–1410.

[11] X. Yin, X. Zhou, R. Huang, Y. Fang, and S. Li, "A Fairness-AwareCongestion Control Scheme in Wireless Sensor Networks," IEEE Transactionson Vehicular Technology, vol. 58, no. 9, pp. 5225 –5234,November 2009.

[12] P. Antoniou and A. Pitsillides, "A Bio-Inspired Approach forStreaming Applications in Wireless Sensor Networks Basedon the Lotka-Volterra Competition Model," Comput. Commun.,vol. 33, pp. 2039–2047, November 2010. [Online]. Available:http://dx.doi.org/10.1016/j.comcom.2010.07.020

[13] J. Kang, Y. Zhang, and B. Nath, "TARA: Topology-Aware ResourceAdaptation to Alleviate Congestion in Sensor Networks," IEEE Transactionson Parallel and Distributed Systems, vol. 18, no. 7, pp. 919–931,2007.

[14] V. Vassiliou and C. Sergiou, "Performance Study of Node Placement forCongestion Control in Wireless Sensor Networks," in 3rd InternationalConference on New Technologies, Mobility and Security (NTMS), Dec.2009, pp. 1 –8.

[15] C. Sergiou and V. Vassiliou, "Study of Lifetime Extension in WirelessSensor Networks through Congestion Control Algorithms," in IEEE Symposium on Computers and Communications (ISCC), July 2011, pp.283 –286.

[16] C. Sergiou, V. Vassiliou, and A. Paphitis, "Hierarchical Tree AlternativePath (HTAP) Algorithm for Congestion Control in Wireless Sensor Networks," Ad Hoc Netw., vol. 11, no. 1, pp. 257–272, Jan. 2013.[Online]. Available: http://dx.doi.org/10.1016/j.adhoc.2012.05.010