Traffic-Aware Dynamic Routing to Alleviate Congestion in Wireless Sensor Networks

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Abstract

Congestion is one of the problems encountered in Wireless Sensor Networks (WSNs). Many algorithms came into existence. They all focused on the solution by reducing the number of packets to be sent by the sender node. This solution is not ideal as it cause decrease in overall throughput in the WSN. This paper focuses on a dynamic aware routing algorithm which is aware of network traffic and probability of congestion. This solves problem of congestion in WSNs through optimal use of idle nodes in the network. Though congestion areas, the algorithm sends less packets while it sends more packets through many paths that contains idle nodes or the nodes that have less load. The proposed algorithm can overcome obstacles created by congestion and provide best throughput performance in WSNs.

Keywords: *WSNs, congestion, traffic-aware routing, idle nodes*

1. Introduction

Congestion problem decreases throughput in WSNs besides causing degradation in performance and also increasing in utilization of resources such as energy [1]. As mobile devices have less resources, this is a potential problem and also the real time applications in WSNs expect high throughput which is not possible when congestion is not alleviated. This problem in WSN is not same as that of wired networks. This is because in the traditional networks traffic flows are different. They can go in any direction to any receiver in the network. In case of WSN, all nodes which are meant for collecting data in the sensed area should send the data to a common sink. As it is a new traffic phenomenon, just reducing the traffic by using traffic controlling algorithms is not effective as it results in reduction of throughput which is highly required by applications that run in WSNs. Wireless Sensor Networks can be employed in emergency situations also. In that case data loss due to congestion or slow in performance causes many problems in the real world scenarios. That is the reason congestion control in WSNs is to be given utmost importance as it has its impact in the real world applications which are based on WSNs. Many algorithms came into existence for solving congestion problem WSNs. Unfortunately they were focusing on traffic control instead of really finding a best solution to congestion problem. Many such algorithms were borrowed from wired networking making them not suitable for WSNs. Those algorithms try to control traffic when congestion is encountered which is not ideal solution for WSNs [2], [3], [1]. Especially those solutions are not ideal for WSNs for reasons such as alleviating traffic from source in cases of emergency and thus controlling congestion is not a desirable solution; the congestion due to bursts in traffic is temporary. Instead of following these less than ideal solutions it is better to increases resources and achieve high throughput in the network. Fortunately WSNs support elastic resources which can be increased dynamically. Though this will provide flexibility, the real problem of congestion needs to be addressed through an ideal algorithm. The core problem has to be solved and even capacity planning schemes can be utilized for employing additional resources on demand. When WSN cases temporary bursts of traffic in emergency situations, it is not suitable solution to control the traffic while it needs to be resolved differently. Many congestion control solutions are available. They include buffering, connection admission control, hop-by-hop traffic control, and capacity planning. The selection of a particular mechanism for congestion control has to be used based on the nature of congestion encountered in WSNs [4].

We propose an algorithm that takes care of traffic aware routing. It does mean that it sends packets through areas where congestion is encountered and excess packets are sent through many routes where nodes are either idle or they have less load experienced. This helps in smooth data transfer even in case of short bursts in the network. This is achieved by using fields that take care of providing basic routing mechanism and also traffic awareness.

2. Related Work

Congestion control is given more importance is WSNs. Congestion is of two types namely link level and node level. The former causes loss of packets and delay in data transfer and it is due to buffer overflow while the latter causes collisions and it is due to the sharing of wireless channel by many nodes at a time especially in case of protocols such as CSMA/CA. Link level congestion is taken care of by MAC protocols while the node level congestion needs research and solutions further. Most of the existing solutions were focusing on traffic control mechanisms that are not ideal to be used with WSNs. The ideal solution was first investigated in [1] where detection and avoidance of congestion was proposed. This solution is based on the observations on the queue usage and also the sampling approach. According to this scheme, when a node encounters congestion, it sends signals upstream nodes to alert them. Thus the upstream nodes will push less number of packets through that route. Afterwards in [2] three mechanisms for congestion control were introduced. They are known as prioritized medium access control, limiting source rate, and hop-by-hop flow control. It reduces congestion by alerting source node and nodes up the line to send less packets through the route. The problem with these schemes is that they have to monitor the parent nodes' sending patterns and also observe congestion severity to ensure smooth transmission of packets in WSNs. These schemes also tend to consume more energy resources of WSN. [3] introduces a protocol for controlling congestion. Here the sink plays an active role while allocating traffic to avoid or reduce congestion. IFRC [2] uses thresholds to control congestion. In this scheme also sink takes care of congestion control based on the static thresholds provided. When congestion is encountered, the router takes steps to reduce traffic in that route. Priory's concept is introduced in [6] to alleviate source traffic when WSN encounters congestion problem. DPCC is another protocol proposed in [7] which makes use of channel estimator and queue for reducing congestion on detecting congestion. Adaptive enforcement of rate flow is used in DPCC for reducing congestion. Another reliable protocol for WSNs is RCRT [8] which employees a loss recovery mechanism at the sink which controls traffic and minimizes congestion. Light weight buffer management technique is used in [9] for avoiding congestion in network. It is another hop-by-hop flow control mechanism that stop latent nodes to cause the congestion problem.

Obviously there is negative impact of congestion control mechanisms as they do not solve the problem in an ideal way. Instead, they choose less than ideal approach to reduce congestion but can't improve throughput in the network. Other than traffic control mechanisms, some attempts were made to invent other aproachches. SPEED [10] reroutes traffic when congestion is suspected. The problem with this is that the new route may again cause congestion if it is not having that channel capacity. In [11] virtual sinks concept is introduced. According to this packets are routed towards sink by bypassing WSN protocol's congestion situation. Ee and Bajcsy [12] invented a distributed approach for congestion control. This scheme is based on the notion of hop-by-hop repeat request done automatically. The service time used in this scheme might be misleading and can't increase the throuput ideally. Moreover it also needs information about topology of network. Wang et al. [13] proposed priority based protocol for congestion control by using weighted fairness concept at each node in WSN. Priotity index and congestion degree measure play key role in this scheme. To discover congestion zone [14] proposed a new routing approach which gives high priority to truly prioritized data. In [15] Kang et al. proposes increase in the resources of the network instead of just controlling the traffic. They used algorithms for resource control and thus achieved maximum throughput by avoiding congestion. In [16] and [17] source control schemes were proposed which were able to reduce congestion. In [16] the bursts in traffic is effectively managed using new nodes turning on in the WSN when situation demands. It needed local knowledge and also the topology details to achive this thus causing more overhead causing less scalability. In [17], multiple paths are found suitable for data transfer in order to reduce congestion. Same kind of work is done in [18], [19] and [20] also. Popa et al. [17] proposed a new scheme for avoiding costs of using multiple paths which are obtained using GPS. However, it also causes extra burden on the network.

The GBR proposed in [19] has many drawbacks but its idea is considered suitable to solving congestion problem in WSNs. This is because its approach is dynamic routing and desired by WSNs for achieving congestion control with less cost. From this understanding this paper presents an algorithm that takes care of congestion. It basically follows philosophy which thinks about reducing congestion besides increasing throughput required by the real world applications. The idea is very intuitive in nature. The protocol is built on the fact that when a node encounters congestion, its excess traffic is to be redirected to destination through other nodes which are either idle or less overloaded. To achieve this proposed protocol used two fields. They are meant for basic routing and traffic awareness. This is the key for the proposed solution.

3. Proposed Algorithm

As discussed in the previous section, the proposed algorithm is based on the philosophy that, the network congestion control does not mean reducing throughput. The congestion control mechanism should increase the overall throughput of WSNs. The throughput is increased by sending excess packets through multiple paths while making use of the routes that caused congestion. This will be done by identifying alternative routes with multiple paths where nodes are either idle or less overloaded.

3.1. Design of Fields

Depth and length fields are identified as potential fields which are corner stone of the proposed algorithm. The depth field is meant for basic routing functionality while the depth field is meant for traffic awareness. The combination of these two with other mechanisms makes it a robust scheme that can cope with bursts of traffic without causing congestion and at the same time do not compromise on throughput requirements demanded by real time applications. The depth field and its force from given field are deduced into equation 1 and 2.

$$V_d(v)=Depth(v), \qquad (1)$$

$$F_d(v,w)=\frac{nVd(v)-Vd(w)}{Cvw} \qquad (2)$$

To avoid dropping packets at congestion points, the following rule is used. It is known as rule1.
If $Q(w)=1$, $w \in nbr(v)$, w should not be selected as the parent in any case.

3.2 Routing Algorithm

1. If update message is from neighbor node then
2. Insert routing table
3. For each entry in routing table
4. $F_d(w)$=(Local_Depth-d) / c;
5. $F_q(w)$=(Local_QueueLength – q) / c;
6. $F_m(w)=(1-\alpha) F_d(w)+\alpha F_q(w)$;
7. End for
8. Select lowest depth
9. Set local depth
10. Choose the next hop node
11. IF timeout THEN
12. Send update message
13. Else
14. Updatemsgpending = true
15. End if

Listing 1 shows broad outline of proposed algorithm

4. Simulation and Evaluation

The proposed algorithm is implemented and simulated using NS2 running in Linux environment. The simulation considers one sink and many sensor nodes in WSN. The proposed algorithm is applied and tested. The results reveal that the proposed algorithm is effective in coping with congestion and at the same time ensuring the throuput requirements of real time WSN applications. The experimental results with queue levels are presented here.

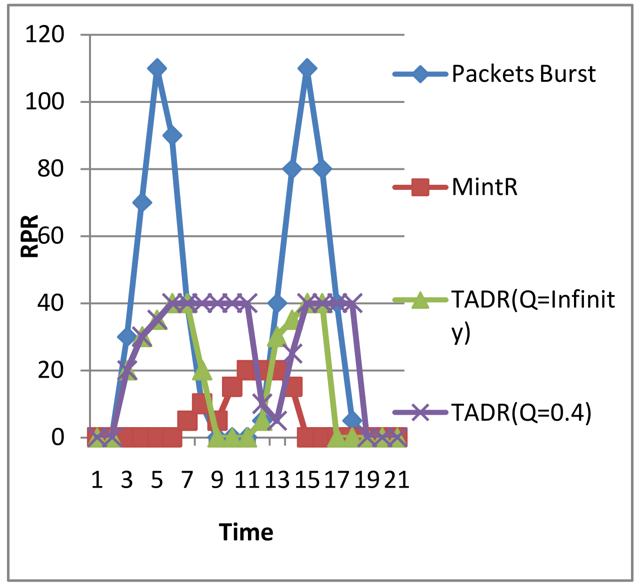

Fig. 1 – Distribution of transmission over time

As can be seen in fig. 1 the horizontal axis represents time while the vertical axis represents RPR. It does mean that the vertical axis denotes the rate of received packets while the distribution of transmission over time is shown in X axis. The figure shows temporal spreading of the proposed algorithm.

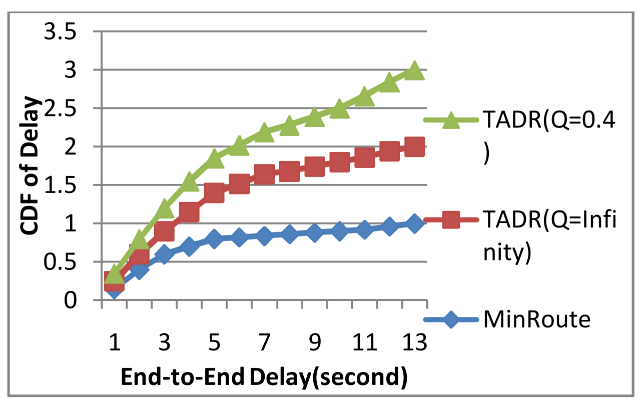

Fig. 2 – Distribution of hops

As can be seen in fig. 2 the horizontal axis represents end to end delay in seconds while the vertical axis represents CDF of delay.

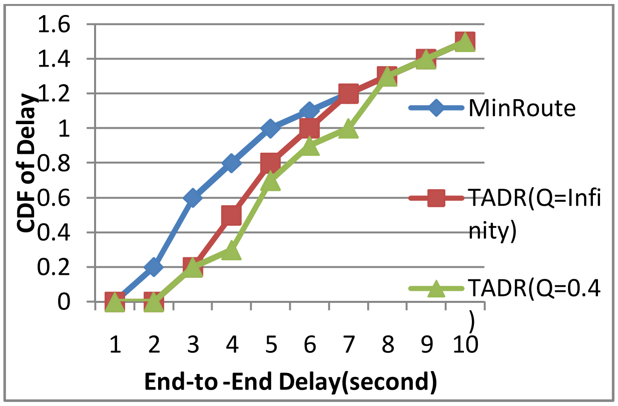

Fig. 3 – under less load end to end delay

As can be seen in fig. 3 the horizontal axis represents end to end delay in seconds while the vertical axis represents CDF of delay under les load.

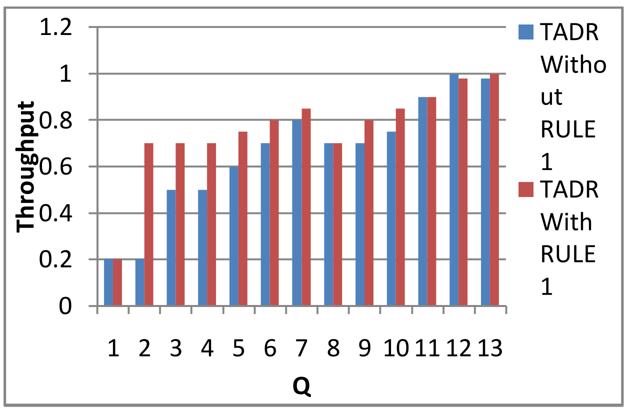

Fig. 4 – Throughput under different parameters

As can be seen in fig. 4 the horizontal axis represents Q while the vertical axis represents throughput. The graph shows results of throughput with and without rule1.

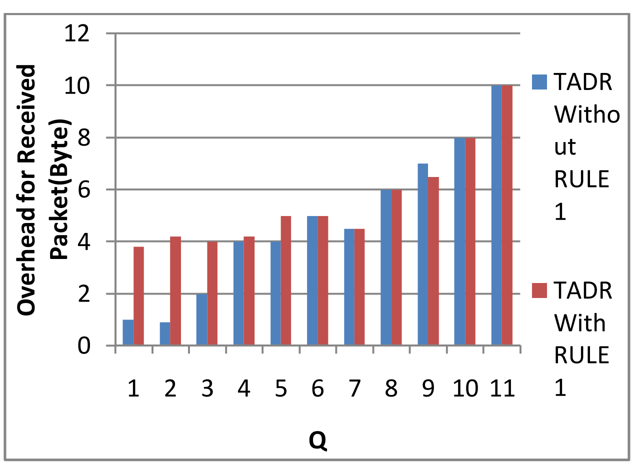

Fig. 5 – Overhead vs. Queue variations

As can be seen in fig. 5 the horizontal axis represents Q while the vertical axis represents overhead for received packets. As Q is increased overhead is more.

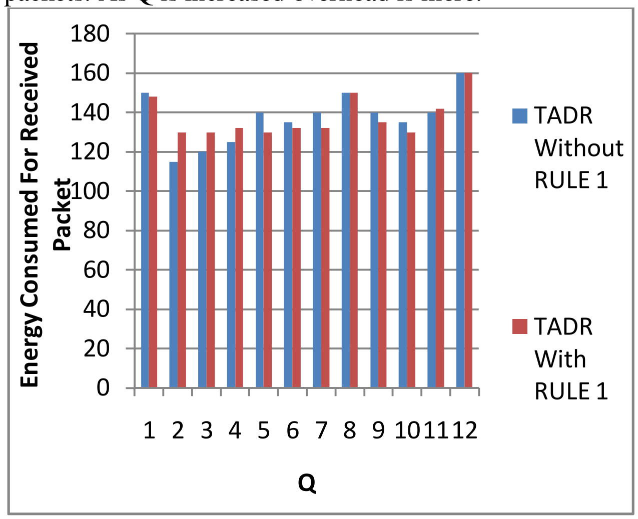

Fig. 6 – Average energy consumed by received packet

As can be seen in fig. 6 the horizontal axis represents Q while the vertical axis represents average energy consumed by received packets. The experiments are done with and without rule 1.

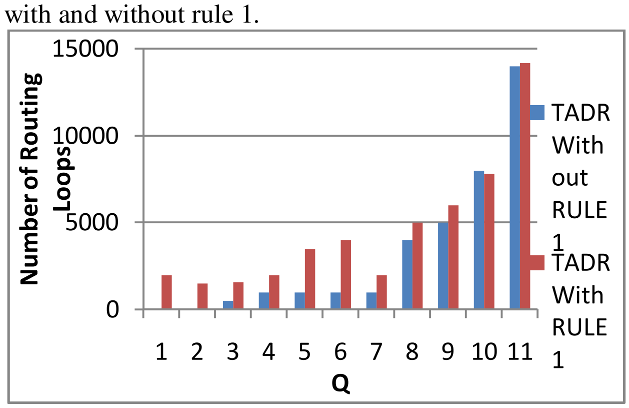

Fig. 7 – Routing loops under different queues

As can be seen in fig. 7 the horizontal axis represents Q while the vertical axis represents number of routing loops. As queue is increased, number of routing loops increased.

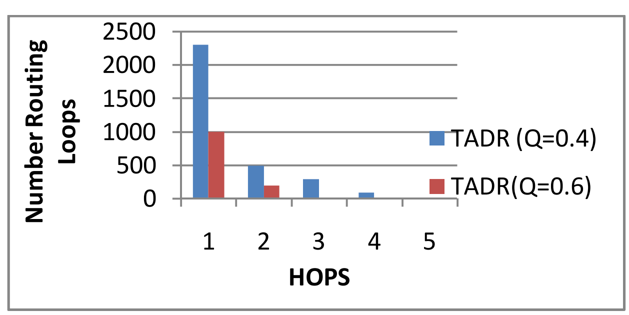

Fig. 8 – Distribution of hops in routing loops

As can be seen in fig. 8 the horizontal axis represents hops while the vertical axis represents number of routing loops. When hops are less, routing loops are more.

4. Conclusion

The traffic control mechanisms existed for WSNs were pure traffic control mechanisms. They can only reduce the traffic but can't increase throughput which is the need for real time applications in WSNs. As congestion problem in WSNs is different when compared with other networks, it needs different solution. This paper proposes a new traffic aware algorithm which can dynamically estimate the capacity of routes and also finds the idle of under loaded nodes in the network to solve the problem. The algorithm contains fields providing basic routing mechanism and also traffic awareness. When congestion is encountered, the algorithm routes excessive packets through nodes which are idle in the network or the nodes which experience no congestion or in other words under loaded nodes. This will improve throughput besides reducing congestion in WSN. This algorithm is scalable as it needs information which is available with all nodes in the network. Further optimization of the proposed algorithm is the work to be continued in future.

References

[1] C.Y. Wan, S.B. Eisenman, and A.T. Campbell, "CODA: Congestion Detection and Avoidance in Sensor Networks," Proc. ACM Int'l Conf. Embedded Networked Sensor Systems (SenSys '03), pp. 266-279, 2003.

[2] B. Hull, K. Jamieson, and H. Balakrishnan, "Mitigating Congestion in Wireless Sensor Networks," Proc. Int'l Conf. Embedded Networked Sensor Systems (SenSys '04), pp. 134-147, 2004.

[3] Y. Sankarasubramaniam, O. Akan, and I. Akyildiz, "ESRT: Eventto- Sink Reliable Transport in Wireless Sensor Networks," Proc. ACM Int'l Symp. Mobile Ad Hoc Networking and Computing (MobiHoc '03), 2003.

[4] R. Jain, "Congestion Control and Traffic Management in ATM Networks: Recent Advances and a Survey," Computer Networks and ISDN Systems, vol. 28, no. 13, pp. 1723-1738, 1995.

[5] S. Rangwala, R. Gummadi, R. Govindan, and K. Psounis, "Interference-Aware Fair Rate Control in Wireless Sensor Networks," Proc. ACM SIGCOMM, pp. 63-74, 2006.

[6] M.H. Yaghmaee and D.A. Adjeroh, "Priority-Based Rate Control for Service Differentiation and Congestion Control in Wireless Multimedia Sensor Networks," Computer Networks, vol. 53, no. 11, pp. 1798-1811, 2009.

[7] M. Zawodniok and S. Jagannathan, "Predictive Congestion Control Protocol for Wireless Sensor Networks," IEEE Trans. Wireless Comm., vol. 6, no. 11, pp. 3955-3963, Nov. 2007.

[8] J. Paek and R. Govindan, "RCRT: Rate-Controlled Reliable Transport for Wireless Sensor Networks," Proc. ACM Int'l Conf. Embedded Networked Sensor Systems (SenSys '07), 2007.

[9] S. Chen and N. Yang, "Congestion Avoidance Based on Lightweight Buffer Management in Sensor Networks," IEEE Trans. Parallel and Distributed Systems, vol. 17, no. 9, pp. 934-946, Sept. 2006.

[10] T. He, J. Stankovic, C. Lu, and T. Abdelzaher, "SPEED: A Stateless Protocol for Real-Time Communication in Sensor Networks," Proc. IEEE Int'l Conf. Distributed Computing Systems (ICDCS '03), 2003.

[11] C. Wan, S. Eisenman, A. Campbell, and J. Crowcroft, "Siphon: Over-Load Traffic Management Using Multi-Radio Virtual Sinks in Sensor Networks," Proc. ACM Int'l Conf. Embedded Networked Sensor Systems (SenSys '05), pp. 116-129, 2005.

[12] C. Ee and R. Bajcsy, "Congestion Control and Fairness for Manyto- One Routing in Sensor Networks," Proc. ACM Int'l Conf. Embedded Networked Sensor Systems (SenSys '04), 2004.

[13] C. Wang, B. Li, K. Sohraby, M. Daneshmand, and Y. Hu, "Upstream Congestion Control in Wireless Sensor Networks through Cross-Layer Optimization," IEEE J. Selected Areas in Comm., vol. 25, no. 4, pp. 786-795, May 2007.

[14] R. Kumar, R. Crepaldi, H. Rowaihy, A.F. Harris, G. Cao, M. Zorzi, and T.F.L. Porta, "Mitigating Performance Degradation in Congested Sensor Networks," IEEE Trans. Mobile Computing, vol. 7, no. 6, pp. 682-697, June 2008.

[15] J. Kang, Y. Zhang, and B. Nathg, "End-to-End Channel Capacity Measurement for Congestion Control in Sensor Networks," Proc. ACM/IEEE SANPA, 2004.

[16] J. Kang, Y. Zhang, and B. Nath, "TARA: Topology-Aware Resource Adaptation to Alleviate Congestion in Sensor Networks," IEEE Trans. Parallel and Distributed Systems, vol. 18, no. 7, pp. 919-931, July 2007.

[17] J. Kang, B. Nath, Y. Zhang, and S. Yu, "Adaptive Resource Control Scheme to Alleviate Congestion in Sensor Networks," Proc. First Workshop Broadband Advanced Sensor Networks, 2004.

[18] P.P. Pham and S. Perreau, "Performance Analysis of Reactive Shortest Path and Multipath Routing Mechanism with Load Balance," Proc. IEEE INFOCOM, 2003.

[19] L. Popa, C. Raiciu, I. Stoica, and D.S. Rosenblum, "Reducing Congestion Effects in Wireless Networks by Multipath Routing," Proc. IEEE Int'l Conf. Network Protocols (ICNP '06), 2006.

[20] J. Teo, Y. Ha, and C. Tham, "Interference-Minimized Multipath Routing with Congestion Control in Wireless Sensor Network for High-Rate Streaming," IEEE Trans. Mobile Computing, vol. 7, no. 9, pp. 1124-1137, Sept. 2008.