Delay - based end - to - end Congestion Control for Wireless Sensor Networks

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***Abstract:*-In wireless sensor networks, commonly used networking protocols may not necessarily function well due to the stringent requirements of such networks. A transport layer protocol for this environment must work well over shared wireless connections that are prone to packet errors. TCP's burstiness due to its aggressiveness in probing for available capacity and multiplicative back off in response to congestion yields a traffic profile that may not be suitable for wireless sensor networks. This work investigates how LEDBAT, a delay-based less-than best- effort protocol, would behave in a wireless sensor network. Although LEDBAT was designed to yield to TCP when sharing a bottleneck link, simulations showed that under certain conditions, LEDBAT obtains a fair share of wireless bandwidth, ensuring able to provide a steadier flow than TCP even as the number of hops to its destination increases.**

Index Terms— Wireless sensor networks, less-than-best-effort

I. INTRODUCTION

Future networks are envisioned to deliver services and information from thousands of smart objects, devices and sensors embedded in the environment. Therefore, wireless sensor networks (WSNs) will become major building blocks of these future ubiquitous networks. WSNs however follow a different paradigm from that of common user networks due to their very stringent requirements. Wireless sensor nodes operate on very limited resources (e.g. limited energy supply, communication bandwidth, computational power, and memory capacity) and communicate over lossy wireless networks. To ensure reliable data transport and congestion control capability, common sense would dictate that TCP, the most commonly used transport layer protocol, also be used for WSNs. Unfortunately, TCP's performance degrades significantly in lossy wireless networks due to its congestion control mechanisms [1].

When congestion is inferred, TCP reacts by cutting down its sending window in half. Using packet losses (inferred from timer timeouts or triple duplicate acknowledgments) as its indication of congestion has two flaws: (1) it does not detect congestion early enough for it to avoid the point where packets begin to be dropped; and (2) in networks where losses are not necessarily due to congestion, such as wireless networks, TCP can easily incorrectly conclude that the network is congested and reduce its sending rate unnecessarily. A protocol that does not aggressively drive the sending rate up to the point where packet losses occur may deliver better performance in a wireless environment. Less-than-best-effort (LBE) protocols are a class of protocols designed to detect and react to congestion earlier than TCP. These protocols are useful as scavenging protocols because they can opportunistically make use of additional resources when available and back off at the earliest inference of congestion. As such, they are expected to be less aggressive than TCP such that they yield to TCP when sharing a bottleneck link [2]. Low Extra Delay Background Transport (LEDBAT) is a recently standardized delay-based LBE protocol [3]. It regulates its sending rate such that it achieves and maintains a target queuing delay throughout the connection lifetime. Although LEDBAT's behavior has been studied thoroughly in the wired scenario [4], [5], [6], [7], [8], there is little work that looks into LEDBAT over wireless. This paper evaluates LEDBAT's behavior over wireless connections, in the context of typical WSN scenarios and topologies. Using simulations, we provide an analysis of LEDBAT's behaviour over wireless, focusing on three common characteristics of a wireless sensor network: contention over the wireless channel, multihop forwarding and packet error rates. We examine whether LEDBAT's congestion avoidance algorithmis affected by channel contention. In a wired topology, LEDBAT maximizes the capacity of a link so long as there is no competing flow.

In a wireless setting, however, even disjoint flows may impact one another if they are contending typically depend on multihop forwarding to move data across the network. Since increasing the number of hops increases a packet's forward delay, we test whether LEDBAT can tolerate this increase in forward delay while still being sensitive to the changes in delays caused by congestion. We also investigate how LEDBAT fares against packet errors compared to TCP. If LEDBAT were to be used in a wireless sensor network, it must be able to deliver acceptable throughput even with increased packet error rates.

Paper Contributions: This paper provides the following contributions: (1) We have analyzed the performance of LEDBAT in Wireless Sensor Networks; (2) We show, through simulations, that LEDBAT's LBE algorithms still react to congestion when sharing common paths with other flows, but do not react to channel contention alone; and (3) We demonstrate that LEDBAT can deliver steadier traffic than TCP with increasing number of intermediate hops. To our knowledge, the applicability of LEDBAT's congestion avoidance algorithm to the wireless environment, particularly wireless sensor networks, has not yet been studied quantitatively in this context.

II. RELATED WORK

Transport layer protocols have been designed specifically for WSNs due to the incompatibility of TCPs congestion control with the characteristics of wireless sensor networks. In general, these new WSN congestion mechanisms use any of four techniques: monitoring buffer occupancy or queue length; channel sampling; packet loss recovery time; and reporting rate or fidelity measurements.

The buffer occupancy / queue length approach, used for example in Fusion [9], infers congestion when buffer occupancy ets/second) than expected. A negative trend even when the occupancy is above the threshold would indicate that congestion has been resolved. One disadvantage with occupancy-based approaches is the reliance on link-layer ACKs packets–which may get lost due to interference and fading–to signal information about queue length. This is appropriate for data driven WSN protocols such as ESRT [10]. This approach is inherently slow and end-to-end in nature. Thus, it may not be able to cope with localized congestion hotspots.

Channel sampling, such as in CODA [11], anticipates congestion when the estimated channel utilization is high. Although this may accurately detect local congestion, it will not reflect network-wide congestion. Furthermore, the method to estimate congestion from channel utilization depends on the type of MAC protocol used (e.g. TDMA or CSMA-based).

III. PROPOSED WORK

In the proposed system, the congestion control sub-problem can easily be solved at the source node of each flow by only using local information, and following a back pressure framework, the routing/scheduling sub-problem is converted into a weight scheduling problem where the weight information can be illustrated as some scale of the queue length at each node. However, as mentioned earlier, previous work has shown that the link scheduling under a binary interference model is an NP-hard problem and under the SINR model as NP-complete, both with and without SIC, and polynomial-time approximation algorithms are presented.

The system studies the problem of scheduling wireless links in a model where successive interference cancellation is combined with the physical interference model and uniform power assignment. Successive interference cancellation is based on the observation that interfering signals should not be treated as random noise, but as well-structured signals. By exploiting this structured nature, the strongest signal can be decoded and subtracted from a collision, thus enabling the decoding of weaker simultaneous signals. The procedure can be repeated iteratively as long as the collided signals differ in strength significantly. It has been shown that the problem of scheduling wireless links with successive interference cancellation is NPhard.

In this work, we propose a polynomial-time scheduling algorithm that uses successive interference cancellation to compute short schedules for network topologies formed by nodes arbitrarily distributed in the Euclidean plane. We prove that the proposed algorithm is correct in the physical interference model and provide simulation results demonstrating the performance of the algorithm in different network topologies. We compare the results to solutions without successive interference cancellation and observe that throughput gains of up to 20% are obtained in certain scenarios. In this work we build upon the results. We consider the model where successive interference cancellation is combined with the SINR model and uniform power assignment.

Successive interference cancellation is based on the observation that interfering signals should not be treated as random noise, but as well-structured signals comprised by modulated data. By developing a data-dependent model of the signal, the strongest signal can be decoded and subtracted from the sum of the interfering signals and noise, thus enabling the decoding of the remaining weaker signals. The procedure can be repeated iteratively as long as the collided signals differ in strength significantly.

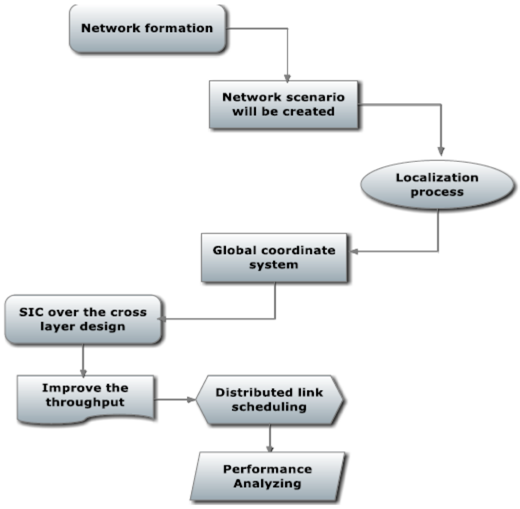

Figure 1: System Architecture

IV. SIMULATION AND RESULTS

Simulations were conducted using NS-2 to study LEDBAT's behavior over wireless in the context of wireless sensor networks. Three common scenarios found in wireless sensor networks were modelled and observed: contention over the wireless channel, forwarding over multiple hops, and increased packet error rates. For all the simulations, 802.11b wireless nodes with a transmission range of 250 meters were used.

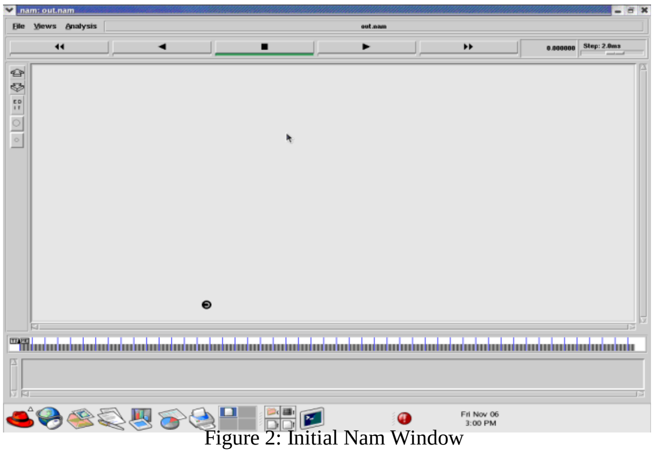

Figure 2: Initial Nam Window

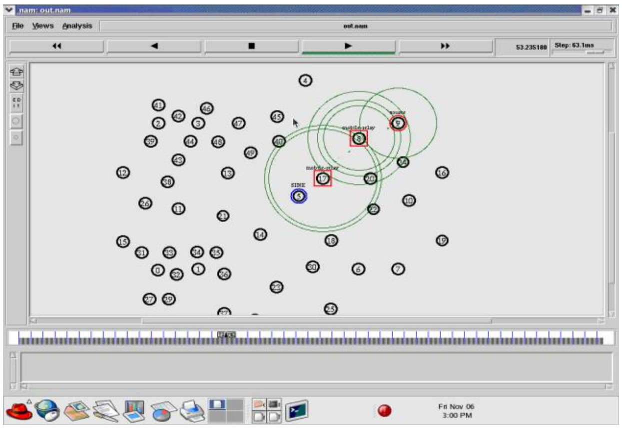

Figure 3: Node localisation

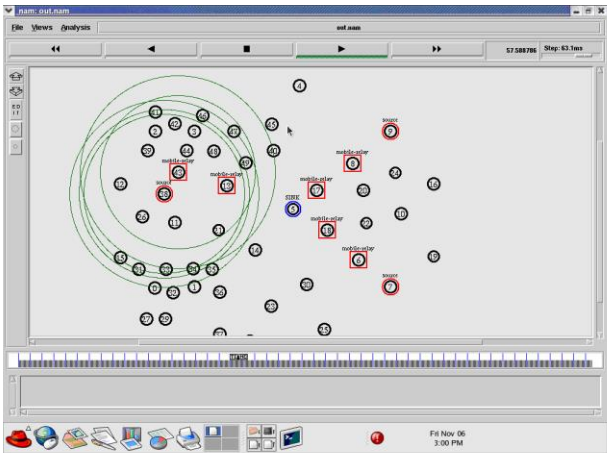

Figure 4: Data transmission

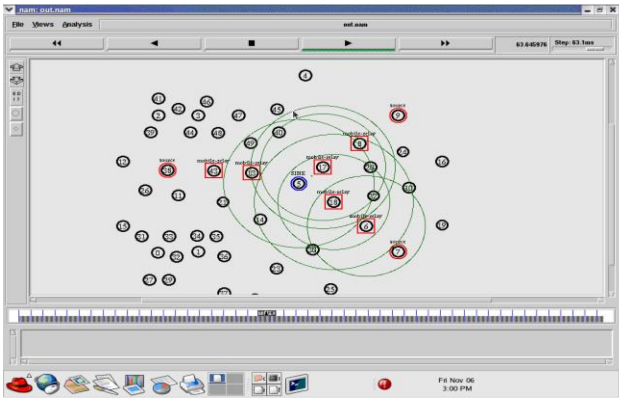

Figure 5: Congestion Control Process

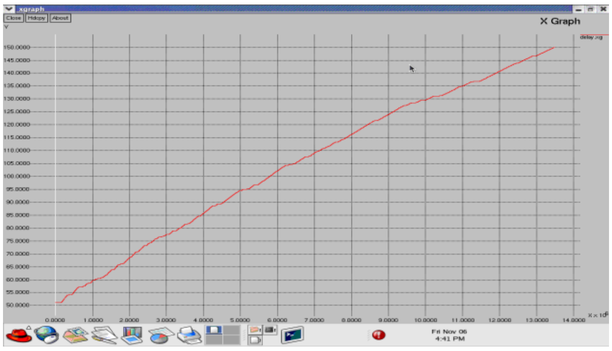

Figure 6: DELAY GRAPH

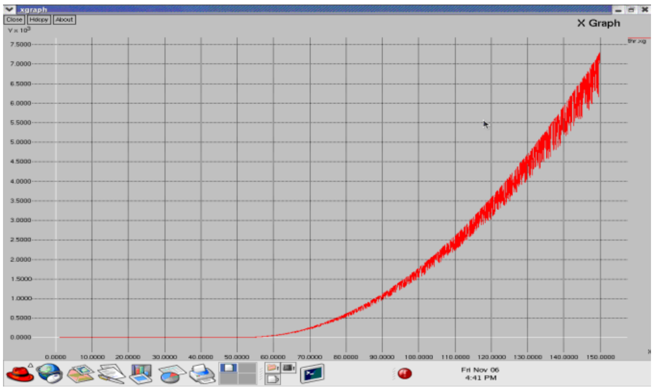

Figure 7: Throughput graph

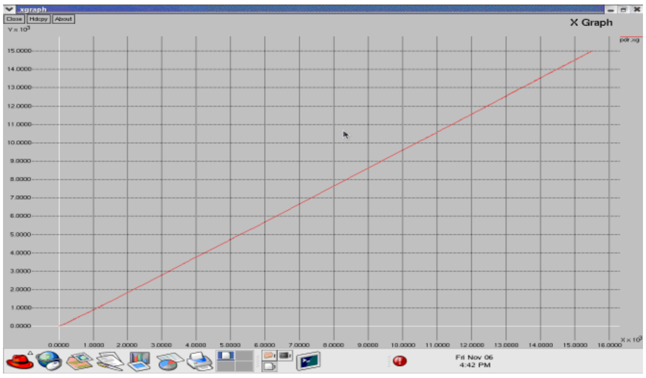

Figure 8: Packet delivery ratio graph

CONCLUSION

The system has studied the benefits of SIC in improving the performance of wireless networks. We considered solving an NUM problem in the context of cross-layer optimization of the joint congestion control, routing, and scheduling problem under the SINR interference model. Through dual decomposition, we divided our design problem into a congestion control sub problem and a routing/scheduling sub problem. Given the complexity of the scheduling sub problem, we presented a decentralized method for solving the link scheduling problem. Dual algorithms for convex optimization formulations of generalized network utility maximization have found many applications recently for both deterministic and connection-level stochastic models. We show that, for a large class of such convex optimization problems, stability and average performance are not affected by channel-level stochastic models. This provides a general technique to carry out optimization-based network designs in a time-varying environment. Further research steps stemming out of this paper include the following. First, unique features in our algorithm f or practical implementations need to be further leveraged. Second, we will extend the results to networks with more general interference models and/or node mobility. Third, scheduling problem is always a challenging problem for ad hoc network, and continued exploration of distributed scheduling protocols will further enhance the performance gain from cross-layer design involving link layer. Fourth, we will formally quantify the interesting observation that channel variations in fact help mitigate the overall system‘s degradation due to suboptimal design in one layer.

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