Poster Abstract: CONCERT: aggregation-based CONgestion Control for sEnsoR neTworks

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1. APPLICATION SCENARIO AND DESIGN CHALLENGES

Sensor networks are commonly deployed to monitor natural phenomena in the physical world. The sink uses data collected by sensors to build a map of the spatial propagation or the temporal evolution of the phenomenon under study. Recently, it has been observed that, even under normal operating conditions, data funneled toward the sink lead to large packet losses due to congestion. This congestion problem is accentuated because of the *funneling effect* (i.e., many-to-one multi-hop communications).

While the funneling effect makes communications problematic, another innate characteristic of sensor networks provides a key to efficiently solving the congestion problem. In fact, traffic generated by sensor network applications is typically characterized by a high degree of spatial-correlation [3] between data events because all the sensors located in the area where the phenomenon occurs, will notify the sink of the same event information. We believe such spatial-correlation can be exploited to efficiently mitigate network congestion in sensor networks. In addition, temporal correlation, where sensors frequently send data packets which do not differ very much over time, also contributes towards congestion. However, temporal correlation is not such a critical issue since it can be solved locally by nodes that detect redundant data events and self-regulate their transmission rate accordingly.

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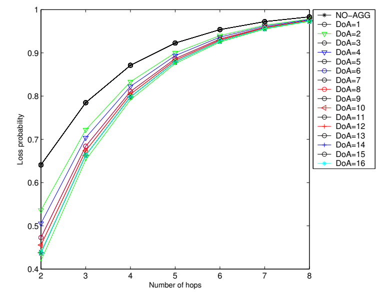


Figure 1: Impact of using static aggregation on the loss probability.

2. BASIC IDEA

We propose a new approach to solving the congestion problem in sensor networks. Rather than using a back-pressure approach to regulate sources' transmission rate every time congestion occurs, as proposed by a number of previous papers [4, 2], we use adaptive data-aggregation in order to reduce the amount of information traveling throughout the network. While the positive effect of using data-aggregation has been discussed in the literature in response to observed congestion, there has been no proposed solution to this. Usually, data-aggregation has been regarded mostly as a tool for minimizing energy consumption and thus increase network lifetime. The impact of aggregation techniques on network load has been discussed in the literature but not as a response to solving the congestion problem. In this work, we propose to specifically use data-aggregation as a way to counteract network congestion. We believe this is a synergistic approach because it leverages a unique characteristic of sensor networks to solve the congestion problem; more specifically, we exploit correlated events to mitigate congestion rather than use conventional back-pressure or rate regulation techniques as proposed by existing work on congestion control in sensor networks.

The use of adaptive data-aggregation is aimed at trying to guarantee a certain degree of fidelity in the network. More specifically, the fidelity could be estimated through the use of some metrics, such as *packet loss probability* and *number of events per unit of time being notified to the sink.*
To efficiently deal with network congestion, spatial aggregation could be exploited; more specifically, we propose that

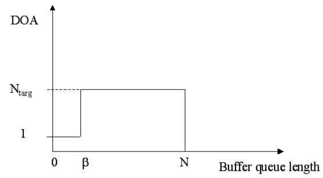
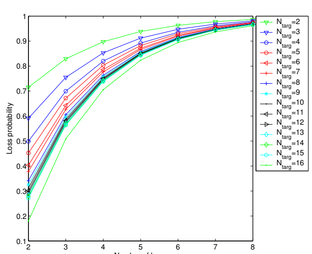
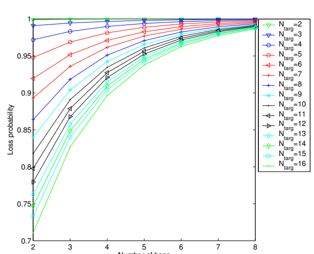


Figure 2: Data-aggregation step function.

nodes use a dynamic network aggregation technique which takes into account the buffer queue length the relay node experiences. As a more stable indication of network congestion, channel loading could also be considered. Accordingly, the combination of channel loading and queue length monitoring guarantees an accurate detection of congestion at each relay node, as observed in [4].

In designing such a congestion control scheme, one of the key question is how many aggregator nodes to choose. Introducing a certain number of data aggregator nodes in the network can help reduce the amount of traffic which would stress the nodes in the closest vicinity of the sink, as confirmed by studies on small-world dynamics [5], but can increase the delivery time due to data processing. Accordingly, we propose to use data-aggregation only at certain nodes which are more likely to be congested during the phenomenon notification phase. In scenarios where the monitored area is accessible, the data aggregator nodes can be placed in appropriate positions where congestion is expected to occur; instead, in scenarios where the area is not accessible, mobile aggregator devices could be used, e.g. [1].





(a) β=1

(b) β=10

Figure 3: Loss probability when using a step data-aggregation function.

Our objective is to define a methodology for congestion avoidance in sensor networks where the adaptive data aggregation curve implemented by the aggregator nodes uses a unique and agreed metric chosen by the sink (e.g. average, min/max, standard deviation) and communicated to the aggregator nodes. The aggregation curve should allow to vary the degree of aggregation (DOA), i.e. the number of data packets whose information should be aggregated, based only on the information on the congestion level experienced at each aggregator node.

To this purpose, we propose to use an approach similar to Random Early Detection (RED) since this methodology used for queue management in wired networks, showed to be very efficient for congestion avoidance purposes.

Preliminarly, we have chosen to investigate on the effect of adding an aggregator node performing a fixed data-aggregation procedure. We estimated through ns-2 simulations the loss probability experienced at the sink of a sensor network when M packets travel throughout the network. A grid sensor area, divided into sub-areas, was considered. Sensors located in the same sub-area were assumed to send correlated data to the sink. The results are shown in Fig. 1 and confirm the good effect of using data-aggregation for network performance improvement.

Then, we introduced a simple adaptation in the network aggregation process and investigated the effect of using a data-aggregation step function like the one shown in Fig. 2.

The results are shown in Figs. 3 [a-b]. In these figures it can be observed that, as soon as the value of β increases, the loss probability increases as well because the aggregation action is not timely. Moreover, we investigated the effect of using a variable maximum degree of aggregation, N_{targ}, at the aggregator node. From our findings we derived that the use of a dynamic aggregation allows for the reduction of the loss probability, being responsive to network congestion. Moreover, the use of a moderate maximum degree of aggregation gives better results when compared to the case when a more drastic but fixed aggregation is performed.

The algorithm used for data-aggregation works as follows. Let us assume that the required degree of aggregation is $\hat{D}$, i.e. the information stored in the incoming buffer of the aggregator node should be transmitted in $\frac{1}{\hat{D}}$ data packets of the ones stored. If in the buffer there are packets sent by the same node, they will be supposed to be correlated and, thus, their information will be aggregated. If the amount of data sent should be additionally reduced, if there are packets sent by sensor nodes located in the same sub-area, their information will be aggregated. Finally, if the amount of data sent should be additionally reduced due to a high level of congestion in the network, information sent by sensors will be aggregated independently of the sub-areas.

3. WORK IN PROGRESS

In order to further evaluate our basic ideas, we are studying the impact of using other adaptive data-aggregation functions on the performance of the system in terms of loss probability and network fidelity. Finally, we will define some meta-aggregation functions, depending on the metric chosen by the sink, and implement our adaptive data-aggregation mechanism in a MICAZ sensor testbed for further proof of concept.

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