

Research Article

INDIGO: An In Situ Distributed Gossip Framework for Sensor Networks

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With the onset of Cyber-Physical Systems (CPS), distributed algorithms on Wireless Sensor Networks (WSNs) have been receiving renewed attention. The distributed consensus problem is a well studied problem having a myriad of applications which can be accomplished using asynchronous distributed gossip algorithms on Wireless Sensor Networks (WSNs). However, a practical realization of gossip algorithms for WSNs is found lacking in the current state of the art. In this paper, we propose the design, development, and analysis of a novel in situ distributed gossip framework called INDIGO. A key aspect of INDIGO is its ability to perform on a generic system platform as well as on a hardware oriented testbed platform in a seamless manner allowing easy portability of existing algorithms. We evaluate the performance of INDIGO with respect to the distributed consensus problem as well as the distributed optimization problem. We also present a data driven analysis of the effect certain operating parameters like sleep time and wait time have on the performance of the framework and empirically attempt to determine a *sweet spot*. The results obtained from various experiments on INDIGO validate its efficiency, reliability, and robustness and demonstrate its utility as a framework for the evaluation and implementation of asynchronous distributed algorithms.

1. Introduction

Sensor networks are becoming an important part of monitoring activities across various interdisciplinary domains. They have been successfully applied to solve problems like seismic activity monitoring and tomography [1], exploratory geophysics [2], and wild fire and wildlife monitoring [3] among many things. Extracting optimal performance from sensors has always been a challenge [4] and it has led to a flurry of active research in recent times. Sensor networks come with their own set of constraints which cannot be overlooked. For instance, sensor networks often come with a very limited energy source, which makes it imperative to use system resources judiciously and keep communication costs as low as possible. It is also quite likely that due to energy constraints the sensor network might be able to provide only limited amount of bandwidth for data transfer, which makes communication a more precious affair.

Therefore, recent state-of-the-art research in the area of sensor networks suggests that the trends appear to be focusing on striking a balance between power consumption

attributed to communication and system utilization. With sensor nodes becoming computationally more powerful and less resource hungry, the bottleneck of communication as a barrier for efficient utilization of system resources seems to persist. Due to the rise of increasingly powerful sensor nodes it now makes more sense in some cases to delegate computation based tasks to the nodes themselves than to have them use up precious resources to depend on a central entity for computation. In recent times, the interleaving of the computational aspect of sensor networks with that of physical processes such as sensing has opened up new research avenues like *Cyber-Physical Systems* [5] and *in-network computing* [6].

One such research problem in which the centralized approach to problem solving is less efficient than an in-network approach is that of achieving consensus in a sensor network. Sensor nodes are heavily reliant on batteries. Wireless transmission of sensed data requires bandwidth which consumes considerably more energy than processing data locally [7, 8]. In some cases, for example, in seismic networks, the sensed data at a particular node does not vary drastically

