Challenges and Prospects for Sensor Networks

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May 14, 2006

Abstract

I raise a number of problems and challenges in distributed computing, in particular in the context of sensor networks. The main concern is the identification of clear scenarios and problems.

1 Our Distributed World

We live in a world that is full of distributed structures: our organisms, brains, societies, political systems, economic structures, scientific communities do not only work *despite* of the absence of central control; virtually all these structures function *because* they are organized in a distributed fashion, largely driven by and relying on local interaction and information [1]. This makes them both robust and flexible, at the same time allowing better use of resources.

The mere existence of distributed structures everywhere we look is proof by itself for their superiority: most of them evolved under adverse conditions, competing with other designs or entitities.

2 Algorithms

Classical computing (and hence: algorithms) follows a different paradigm. They are based on *one* central processor that (1) collects all necessary information, (2) carries all all necessary computations, and (3) distributes and implements the results. This reflects the availability and capabilities of computing devices, as well as the limited insight into systems for which algorithms are developed [2].

In recent years, the field of distributed algorithms has started to develop. However, most of the problems and methods still refer to the well-established, classical paradigm of centralized computing.

3 Sensor Networks

Over the last five years, the area "sensor networks" has become one of the standard hot topics. It is remarkable that this topic has received attention from a number of very different communities, covering engineering aspects as diverse as sensors, wireless communication, or ad-hoc networks, applied computer science problems like protocols, middleware, etc., but also theoretical, algorithmic issues.

On one hand, this makes sensor networks an excellent focus point for interdisciplinary research; on the other hand, the standard approaches and cultures from different areas are at times quite diverse, causing a different level of communication problems. It should also be noted that the standard approach to writing grant proposals leads to

[1] Despite of strong efforts by many top executives, bureaucrats, or politicians, healthy companies, universities, or parties share many of these properties.

[2] Notwithstanding the complexity of algorithms and data structures that have been developed for many problems of centralized computation.

visions that ignore aspects not from the applicant's immediate community; this is aggrevated by the push for success within the respective scientific community. This means that different scientists may think of themselves as working on "sensor networks", but mean quite different things. At the same time, there is still a lack of clear, well-defined scenarios that could lead to stronger scientific interaction.

4 Scenarios

Fulfilling many of the visions of sensor networks that have been promised in recent years requires strong efforts from all sides. The fact that so many different scientists use this bandwaggon as an excuse to work separately on their particular aspects poses the imminent risk of the field growing apart, rather than together. At the same time, each subregion needs to be able to concentrate on their particular strengths in order to achieve progress. In my opinion, the most promising approach to dealing with this dilemma is the formulation of several clear scenarios; pursuing particular aspects of these scenarios will automatically lead to specific research problems within different fields, tied together by the scenario itself. In this respect, "scenarios" is half-way between "visions" and "problems"; note that traditionally, an algorithms person is happy with just a number of problems.

5 My Favorites

After taking the global view, I will now focus on three particular aspects I care about.

5.1 Geometry

Having a preference for geometric problems, I like to think of a sensor network as being placed in a geometric environment, possibly modeled by an appropriate graph. This may or may not imply dealing with coordinates; my talk will present a particular set of assumptions, which is clearly not the only possible one: a large number of nodes are scattered over a geometric street network (i.e., a polygon with many holes), without access to localization devices such as GPS. What are other people's favorites?

5.2 Network Dynamics

In most scenarios I know, nodes are assumed to be immobile. This puts some restrictions on network capabilities, but it also simplifies some tasks. But even if nodes are mobile, there may be inherent dynamics in the networks, either because of node failure (which may be temporary or permanent), fluctuations in wireless connections, or the result of other events in the network (including energy-saving protocols.)

However, it should be worth our while to discuss aspects of mobile nodes: some of my favorite scenarios (e.g., traffic) benefit greatly from mobile nodes.

5.3 Objectives

What does a sensor network actually measure? This may give rise to quite diverse problems; it may also lead to the identification of interesting scenarios.

6 Problems

I can see two separate approaches to identifying interesting problems; both may be interesting.

(1) Set up a classification scheme for scenarios and assumptions, based on key parameters; this leads to a situation where problems simply are the result of a combination of picking specific parameters and assumptions.

(2) Agree on specific scenarios and discuss which choices of parameters and assumptions are most relevant.