A Utility-Based Sensing and Communication Model for a Glacial Sensor Network

Paritosh Padhy [a] Rajdeep K. Dash [a] Kirk Martinez [a]
Nicholas R. Jennings [a]

[a] *School of Electronics and Computer Science, University of Southampton, Southampton, SO17 1BJ ,UK.*
{pp04r,rkd02r,km,nrj}@ecs.soton.ac.uk

Abstract

Multi-sensor networks are being deployed in a wide variety of application areas and, in particular, they have recently been advocated for a number of environmental monitoring applications [5]. Moreover, there is an increasing interest in controlling these networks using multi-agent system techniques [4]. In this vein, we consider a particular sensor network, GLACSWEB [5], that we have deployed in the Brikdalsbreen glacier in Norway, and examine how it can be modelled as a (cooperative) multi-agent system. In this case, the two main tasks performed by the sensors (agents) are gathering data from the environment and communicating it towards a central sink node (i.e. an agent that harvests data from all other agents). In general, the agents work towards the predefined system goal of maximising data collection (hence the cooperative nature of the system). However, they are invariably constrained in at least one of the following dimensions: their available power, their communication bandwidth, their memory storage and their processing capability. Of these, power is the most important since it is required for everything else. Thus, it directly influences the life-span of the agents and, hence, that of the system as a whole. Given this, we focus on developing a communication and a sensing protocol for this network. Nevertheless, the solution we develop is also more broadly applicable to networks that have any form of limited power supply.

In more detail, the purpose of the GLACSWEB multi-sensor network is to monitor sub-glacial behaviour in order to understand climatic change. Figure shows GLACSWEB's central base station that is located on top of the glacier and figure 2 shows a typical GLACSWEB node. The individual nodes each sense their own data and then communicate it directly to this sink node. As such, the system's communication protocol is energy inefficient since it lacks the energy savings that a multi-hop approach would provide [8] (i.e. one in which agents relay data for one another). Furthermore, at present, sensing in GLACSWEB is carried out at a pre-determined constant rate which is blind to the actual variations in the environment. This decoupling results in unnecessary sampling because, given the same energy expenditure, the information gained by sensing a slowly varying environment is less than what could be gained in a more dynamic situation.

Against this background, the paper [6] develops a Utility-based Sensing and Communication protocol (called USAC). Now, the concept of utility has previously been used in the context of sensor networks for both cooperative [1, 3] and selfish agents [2, 7]. In the latter case, the concept of selfishness arises mainly in those applications where agents are individually owned by different stakeholders (which is not true in our case). The focus of our work is however on cooperative agents (since all nodes are owned by one stakeholder, the University of Southampton) and differs from existing research by combining the sensing and communication protocol via the utility function

The USAC protocol consists of a sensing and a routing protocol that uses the cost of transmission and the value of observed data as utility metrics in the agents' decision-making process. In doing so, we advance the state of the art in the following ways :

- We develop a novel mechanism for adaptive sampling. In this, each agent adjusts its rate depending on the rate of change of its observations and a valuation function (based on a sound information theoretic foundation) that the agents use for assigning a value to the data they observe.

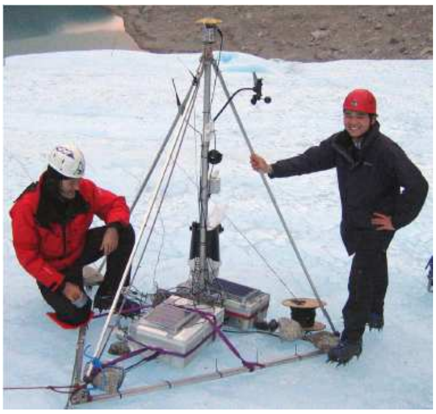

Figure 1: GLACSWEB base station

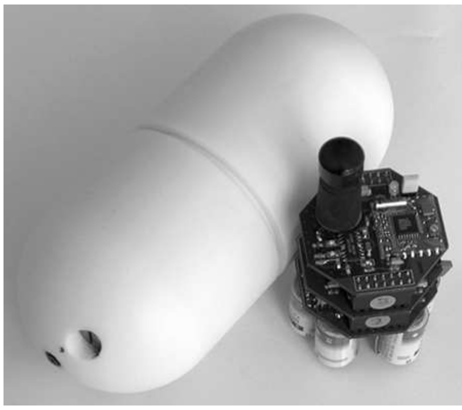

Figure 2: A GLACSWEB sensor probe

- We devise a new routing protocol that finds the cheapest cost route from an agent to the centre. Here, the cost of a link from one agent to another is derived using the opportunity cost of the energy spent relaying the data (i.e. the value that a relay could have gained by using the energy in sensing instead of relaying).
- We empirically evaluate the USAC protocol against the current GLACSWEB protocol by examining the impact on efficiency of the network topology, the size of the network, and the degree of dynamism of the environment. In so doing, we demonstrate that the efficiency gains of our new protocol, over the currently implemented method over a 6 month period, are 470%, 250% and 300% respectively.

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