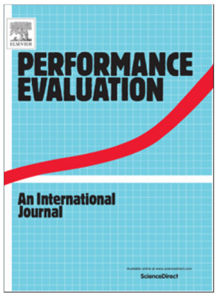

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A two-queue model for optimising the value of information in energy-harvesting sensor networks

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Abstract

We study the optimal transmission policy of a sensor node in an energy-harvesting wireless sensor network. We consider a hybrid wireless sensor network in which a mobile sink is used to collect data. Taking cues from recent works on the value of information (VoI), we posit that the optimal policy maximises the VoI that can be sent for the node to the sink. We model this system as a discrete-time queueing model with two coupled queues. In particular, the sensor node under study operates energy neutral and harvests energy according to a Bernoulli process. Discretising energy into "energy chunks", the battery is modelled as a first queue, whereas a second queue is introduced to hold the VoI at the sensor node. From the vantage point of the sensor node, this means that the sensor can only send when the sink is sufficiently close. When this is the case, the sensor decides whether to transmit its data or not depending on the amount of available energy and the value of the information. Focusing on the optimal transmission policy, we formulate the optimal control problem as a Markov Decision Process with a level-dependent block-triangular transition probability matrix. We find the optimal policy which maximises the mean VoI transmitted from the node in the long run and numerically show that it is of threshold type. Further, we assess the value function at optimal policy analytically and provide some properties. Finally, we investigate the structure of the optimal policy and the mean VoI collected from the node for different system parameters by means of some numerical experiments.

Keywords: Sensor network; Energy harvesting; Value of information; Markov decision process;

1. Introduction

Wireless sensor networks (WSNs) have attracted considerable research interest over the past few years because of their wide range of applications in health care, utilities, remote monitoring and in diverse industrial contexts [1]. WSNs majorly consist of three components: gateways, relay nodes, and sensors (also referred to as sinks). Gateways act as an interface between wireless sensor nodes and the application platform. Relay nodes, sometimes referred as routers, are used to extend the coverage area. Finally, sensors can sense, measure and collect the information from the environment. The information sensed at the sensor node is analysed and the node can then decide whether to transmit the data or not. WSNs can be used in many applications that require close monitoring of the physical world which explains the wide range of areas in which it is applied.

Wireless sensor nodes are low power devices [2] equipped with a small battery and on-board memory. Currently, the primary source for sensor nodes is a small on-board battery which limits the lifetime of sensors. Since they are often installed in hostile terrain, it is very expensive and difficult to replace the battery due to environmental and terrestrial challenges. To overcome this problem, more efficient energy consumption and power management are active areas of research and development. Some research focuses on energy conservation by controlling the communication system. A recent survey [3] shows that the energy consumption in the sensor node is mostly due to the WSN operations such as sensing, computing, switching, transmission etc. Raghunathan et al. [4] studies the energy consumption in

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