CAPACITY CONSIDERATIONS FOR SENSOR NETWORKS WITH MOBILE AGENTS

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Abstract— We study the capacity of sensor networks with mobile agents. We look at the problem from information theory perspective, and optimize various network parameters such as coverage area, flying altitude, and the trajectory of mobile agents. Multiple mobile agents and the possibility of cooperation among them are also considered.

1. INTRODUCTION

We consider sensor network with mobile agents (SENMA)—a network architecture for low power and large scale sensor networks [1]. SENMA has two types of nodes: sensors and mobile agents. Sensors collect the data, and mobile agents retrieve the information from sensors. A distinguishing feature of SENMA is that communication takes place only between mobile agents and sensors; sensors do not talk to each other.

Sensors are low power and low cost nodes that have limited processing and communication capability. They are deployed in large quantity, perhaps randomly through aerial drop. Mobile agents are powerful hardware nodes, both in their communication/processing capability and in their ability to traverse the network. Mobile agents perform information retrieval and post processing. Examples of mobile agents are manned/unmanned aerial vehicles, ground vehicles equipped with sophisticated terminals and power generators, or specially designed light nodes that can hop around in the network. These mobile agents may have connections to satellites, allowing reachback to remote command control centers. Mobile agents need not always be present or operational along with the sensors in SENMA; they may be called upon for data collection, or they may be embedded in the network, operating mostly in a passive and energy conserving state and being put in action only when necessary.

2. FORMULATION AND MAIN RESULTS

We first consider a single mobile agent (MA). It is assumed that the MA flies at an altitude d, and it can receive packets from angle 2θ (Fig. 1). The angle and altitude determines the the coverage area of MA, which is a circle with radius $d \tan \theta$. The MA continuously transmits a *beacon* to inform about its location. The sensors within the coverage area hear the beacon, wake up and send their data.

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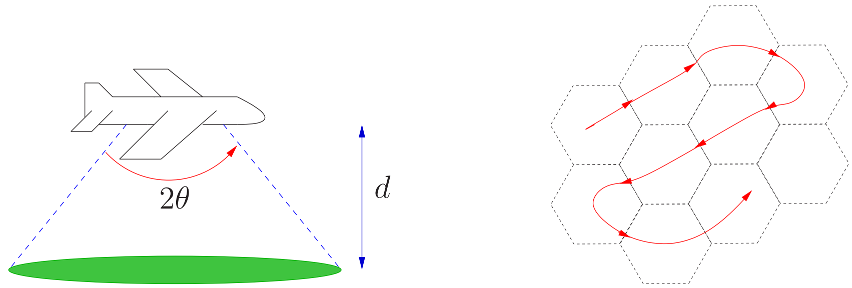

Fig. 1. Mobile agent (*on the left*), and its trajectory within the field (*on the right*).

For convenience, we approximate the coverage area with a hexagon with side length $d \tan\theta$. The sensor field is divided into non-overlapping hexagonal regions (or, *cells*) each with area same as the coverage area of the MA. The MA moves inside the field according to some trajectory and collects sensor data from each region one after another. The MA activates only the cell right below itself.

There are several interesting tradeoffs in SENMA. When the MA flies low, signal strength improves, yet the MA has fewer sensors to talk to. Conversely, flying high means larger coverage, and more sensors, but poorer signal quality. We use a standard block-fading model, and the sum-capacity as the performance metric to analyze this tradeoff. Previously, the sum-capacity of symmetric cellular networks has been derived and analyzed by Shamai and Wyner [2]; our work follows their methodology, and use some of their techniques.

Among our interesting findings, we show that flying as low as possible, and receiving only from one sensor is optimal in terms of maximizing the network capacity. Flying low maximizes the signal strength, and advantages of flying high doesn't compensate for the signal attenuation when the MA flies high. However, flying as low as possible is not optimal when there is channel fading and/or the number of sensors in each cell is random; in such cases, the optimal altitude is, roughly, the one at which the MA covers half a dozen sensors on the average.

When there is multiple MAs, the issue of receiver cooperation becomes critical. When the MAs do not cooperate and treat signals transmitted to neighboring MAs as noise, it is best to make MAs fly as distant as possible. However, if the MAs cooperate (they have access each others signals, and decode jointly), it can be shown that there is a critical signal-to-noise (SNR) threshold below which the MAs should fly in neighboring locations forming a group. Above this critical SNR, keeping MAs apart is the best as in the non-cooperative case. Further details are provided in [3].

3. REFERENCES

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