A Wireless Sensor Networks with Self-Organization Capabilities

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Abstract

We present a suite of algorithms for self-organization of wireless sensor networks, in which there is a scalable large number of mainly static nodes with highly constrained energy resources. The protocols further support slow mobility by a subset of the nodes, energy-efficient routing, and formation of Ad-hoc sub networks for carrying out cooperative signal processing functions among a set of the nodes. We define a self-organizing system as one where a collection of units coordinate with each other to form a system that adapts to achieve a goal more efficiently. We then lay out some conditions that must hold for a system to meet this definition and discuss some examples of self-organizing systems. Finally, we explore some of the ways this definition applies to wireless sensor networks. Keywords: Wireless Sensor Network Architecture, Tiny OS, Ad-Hoc Networks.
1 Introduction

This wireless sensor network is depends on a simple equation: Sensing + CPU + Radio = Thousands of possible applications. A wireless sensor network is a type of wireless network. It is small and infrastructure less. Basically, wireless sensor network consists a number of sensor node, called tiny device and these are working together to detect a region to take data about the environment. Wireless sensor network has two types: structured and unstructured. If we talk about unstructured so is a collection of sensor nodes. And these deployed in Ad-hoc manner into a region. Once deployed, the network is absent unattended perform monitoring and reporting functions. In other structured wireless sensor network, the all sensor nodes are deployed in predesigned manner. The benefit of structure wireless sensor network is that some nodes can be deployed with lower network maintenance and management cost. Fewer nodes can be deployed now since nodes are placed at specific locations to provide coverage while ad-hoc deployment can have uncovered regions. Wireless sensor network aim is to provide efficient connection among the physical environmental condition and internet worlds. The sensor nodes of the wireless sensor network is allows random deployment in inaccessible terrains, this means protocol of the wireless sensor is self-organized, another important feature of the wireless sensor network is cooperative effort of the sensor nodes. Sensor nodes are collecting data about environment, after collecting it they process it and then transmit to the base station. Base station provides an interface between user and internet. Basic characteristic of the wireless sensor network are limited energy, dynamic network topology, lower power, node failure and mobility of the nodes, short-range broadcast communication and multi-hop routing and large scale of deployment. In the wireless sensor network architecture includes both a hardware platform and an operating system designed. TinyOS is a component based operating system designed to run in resource constrained wireless devices. It provides highly well-organized communication primitives and fine grained concurrency mechanisms to application and protocol developers. Basically TinyOS is the use of event based programming in conjunction with a highly efficient component model. TinyOS enables system-wide optimization by providing a tight cou-
pling among hardware and software. TinyOS has been designed to run on a generalized architecture where a single CPU is shared between application and protocol processing. Fig.1 shows the basic architecture of the wireless sensor network in which sensor nodes deployed in the sensor fields and they communicate with each other to collect the information from the environment, or directly send to the base station. Basically, the base station acts as a gateway. With the help of a gateway, data is transmitted to the internet. Because users are directly connected to the internet. Analyzing the set of requirements for a sensor network and the state of the art, it seems that the problem to face is extremely challenging, if not impossible to solve with the current approaches. Nevertheless, the analysis of many biological organisms reveals that in nature there are many systems meeting those requirements. One example is heart beating. In our bodies, there is no master clock operating with great precision; nevertheless, our heart beats in a very regular fashion and is also capable of self-adapting to external solicitations, with very limited energy consumption. Each natural pacemaker cell, contributing to the cardiac rhythm, is by itself unreliable and its life cycle is much shorter than our average life. Nonetheless, it is the interaction among nearby pacemaker cells that gives rise to a very robust system. Driven by this inspiring example, it can be guessed that the mathematics of a population of mutually coupled oscillators could provide an important model to synthesize novel types of sensor networks capable of satisfying the demanding requirements.

Fig.1 Architecture of the Wireless Sensor network.

In this paper we describe architecture for self-organizing wire-

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less sensor-networks [1]. These are wireless ad-hoc networks that connect deeply embedded sensors, actuators, and processors. This combination of wireless and data networking will result in a new form of computational paradigm which is more communication centric than any other computer network seen before. Wireless sensor networks are part of a growing collection of information technology constructs which are moving away from the traditional desktop wired network architecture towards a more ubiquitous and universal mode of information connectivity [2].

2 METHODS AND DISCUSSION

Self-organization is often referred to as the multitude of algorithms and methods that organize the global behavior of a system based on inter-system communication. Most networking algorithms work like that. Therefore, self-organization in this context is not a new solution. Nevertheless, most of these algorithms are based on global state information, e.g. routing tables. In the networking community, it is commonly agreed that such global state is the primary source of scalability problems of the particular algorithms. Especially in the area of ad hoc and sensor networks, new solutions were discovered that show the properties of the new definition of self-organization.

A. Methods and Techniques

Self-organizing systems completely rely on localized decision processes. Three basic methods can to be distinguished that enable the desired behavior. These are the building blocks for all approaches that should self-organize as depicted by our definition of self-organization.

Positive and Negative Feedback:

The local state of an individual system can be adapted to changing environments based on adequate feedback on its own actions. Feedback can be divided into positive and negative feedback. Positive feedback provides amplification capabilities, to act efficiently and in real-time to particular changes. The amplifying nature may lead to snowballing effects and overloading amplifications. Negative feedback is used for keeping positive feedback under control. Such feedback can be created in form of rules that have
been developed to keep the system state within a given parameter range. In other cases, such an inhibition arises automatically, often simply from physical constraints. Positive and negative feedback must be strictly coordinated. If these mechanisms are used uncontrolled, the system will either tend to do nothing, over-react, or to oscillate between multiple states. Different terms are used in the literature, for example, positive feedback is equal to reaction, amplification, and promotion, and negative feedback is often described as diffusion, suppression, and inhibition.

**Interactions Among Individuals and with the Environment:**

In our discussion of self-organization and self-organizing system, we outlined as a main characteristic that the operation and control, i.e. the organization, arises entirely from multiple interactions among their components. We need to distinguish between two kinds of information transfer: Information transfer between individuals, i.e. direct communication between neighbouring (in time and space) individuals via signals, and interactions with the environment, i.e. indirect information flows via cues arising from work in progress (stigmergy).

**Probabilistic Techniques:**

A third component for successfully building self-organizing systems is probability. Basically, all self-organizing systems include probabilistic techniques. Such mechanisms can be either used to entirely organize the local behavior of a single system or at least for parameter settings of other deterministic algorithms. In the following, we discuss some of these open issues that can be seen as starting points to conduct further research on self-organization and distributed control.

- Controllability as shown in Fig.2, the predictability of the behavior of a self-organizing system is rapidly decreasing while increasing its scalability. This problem is directly related to the controllability of the system. For example, classical network management solutions cannot be employed in self-organizing networks because the necessary state information cannot be retrieved. Therefore, the operability of the network can only be estimated or approximated. Even harder is the guarantee of quality of service parameters.
• Cross-mechanism interference The composition of multiple self-organizing mechanisms can lead to unforeseen effects. For example, different energy aware methods implemented at MAC and network layer may interfere and lead either to reduced throughput and reliability or to much higher energy consumption compared to the non-optimized behavior. Cross-layer design and cross-method validation techniques are needed to identify such interferences and to eliminate them.

• System test The test of the system, its components, and the installed software becomes a complex task. It is not possible to create a lab environment showing exactly the properties of the desired deployment scenario. The same holds for field tests because it is not possible to predict future conditions influencing the system. Fig.2 depicts the main problem of self-organizing systems, the reduced determinism. The more scalable a system becomes by using self-organization techniques, the less control of individual entities is possible. The primary conclusion is that the predictability of the system behavior must be reduced for such a self-organizing system.

Fig.2. Scalability vs. determinism in centralized controlled and self-organized systems.

Rather, we will opt out of that debate and narrow our discussion to engineered systems where we can unambiguously designate the
goals of the system ourselves. This definition of self-organization can be enumerated into a list of features.

- The system is composed of units which may individually respond to local stimuli.
- The units act together to achieve a division of labour.
- The overall system adapts to achieve a goal or goals more efficiently.

For these features to hold, the following are some of the conditions that must be met.
- The system must have inputs and some measurable output.
- The system must have a goal or goals.
- The units must change internal state based on their inputs and the states of other units.
- No single unit or non-communicative subset of units can achieve the systems goal as well as the collection can.
- As it gains experience in a specified environment, the system achieves its goals more efficiently and/or accurately, on average.

A. Examples of Self-Organized Systems

Several engineered systems have been described as self-organizing and studied sufficiently well that they can serve as models. These include:

- self-organizing neural networks;
- swarm intelligence;
- self-configuring wireless networks; and
- cultural acquisition of a common language.

B. Self-Organizing Neural Networks

Neural networks come in many flavors, some emphasizing biological realism, some designed for engineering efficiency, and others for ease of theoretical analysis. In general, SOM are unsupervised learning systems employed to map high dimension inputs to a lower dimension output where similar inputs are mapped near each other. Imagine a two-dimensional lattice of output neurons all connected to a common input. The input is in the form of an n-dimensional
vector, and each neuron contains a single model vector of the same dimensionality. This configuration is illustrated in Fig.3. When an input comes into the system, each node computes the distance between that input and its model vector. The node with the closest model vector is chosen to fire either by a master control, a decentralized inhibition scheme, or something in between. Learning is accomplished by the firing node moving its model vector closer to the last input vector by some delta. The firing node then communicates to each of its neighbors prompting them to do the same with a smaller delta. As those neighbors communicate to their neighbors and so on, a wave of decreasing adjustment toward the last input vector propagates across the network. Typically, the wave of communication is limited to a certain radius centered on the firing node to reduce communication costs, and the delta value decreases with time so that the network is guaranteed to converge.

Fig.3. (a) The topological configuration of a Self-Organizing Map. (b): An example of a SOM mapping uniformly random 3-dimensional (RGB colour) input vectors to a 2-dimensional map.

The output of the system is the identity of the node that fires given a certain input. The two-dimensional lattice in our example is not a real constraint as a huge number of output topologies can be constructed simply by changing how neighbours are defined. Starting from random connections and completely without being informed of what are correct or incorrect responses aside from their own recognition, the system acquiring a feature map, ', that takes spatially continuous input vectors, x from a space H and maps them to a discrete space, A, the topology of which is determined by the
spatial array of the output neurons. Fig. 3(b) shows an example of such a mapping, taking uniformly drawn random RGB colour values (3-dimensional) to a discrete 20 by 10 2-D plane.

Swarm Intelligence: Swarm intelligence is a technique for designing optimization algorithms modelled after the apparent self-organization of social insects. There is a great deal of literature on these sorts of algorithms as well as dedicated conferences.

Self-Configuring Wireless Networks: The challenge of producing a well-connected network on small wireless devices leads to some of the clearest examples of self-organization available. Limited power, low radio range, potentially high density, and an ever changing environment all push for a distributed and adaptive solution.

Cultural Acquisition of a Common Language: Acquisition of a common language by a collection of units is a less well explored self-organizing system. One instantiation of such a system is a network of sensors developing a high-level language among them to communicate observed events. Among the motivations for the use of such a learned language include the ability to communicate using very short transmissions as opposed to sending the raw data of observations and the ability to express observations that were not anticipated by the designer of the system.

3 CONCLUSION

This paper contributes to the networking community by providing a broad introduction and classification to the concepts and ideas of self-organization. After outlining the basic methods of self-organization, we presented a general definition and classification of self-organization mechanisms in ad hoc and sensor networks. We expect that engineered self-organizing systems will become more common and important as computation becomes more ubiquitous, as computational explanations become more accepted by the general scientific community, and as principles of self-organization become better understood.
References


