Self-Organization Configuration Models for Wireless Sensor Network Applications

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Abstract: Normally many human made systems exhibit the property of self-organization, components having interaction among themselves lead to system-wide patterns of behaviour. This review paper mainly concentrates on the current, scientific understanding of self-organizing systems and then discuss about some important models investigated by computer scientists looking to apply self-organization to design large, distributed systems. In this paper self-organization models associated with wireless sensor networks are mainly targeted, because they are used to provide various functions such as conserving power; synchronizing time; reconfiguring software components; adapting behaviour associated with routing.

Key words: *Wireless Sensor Networks – Self Organization - Routing*

1. Introduction

Wireless networks must become adept at *self-organization*—allowing devices to investigate their surroundings, cooperate to form topologies, and monitor and adapt to environmental changes, all without human intervention. Self-organization applied to wireless networks is not a new concept. There are lot of surveys performed earlier in the area of wireless sensor networks, and each survey resulted in a new concept at the end. [1]

Self-organization is a natural phenomenon of distributed systems, where components interact on a microscopic level leading to global behaviours that emerge on a macroscopic level. Such emergent behaviours are not deliberate and thus may be undesirable. For example, unintended self-organizing phenomena have been observed in the Internet [2], cellular wireless networks [3], and computing grids [4]. The paper identifies selected approaches to stimulate deliberate self-organization for allocating spectrum, band-width, and processing capacity; for forming structures, disseminating information, and organizing tasks; for configuring software, synchronizing time, and conserving power; and for repairing faults and resisting attacks.

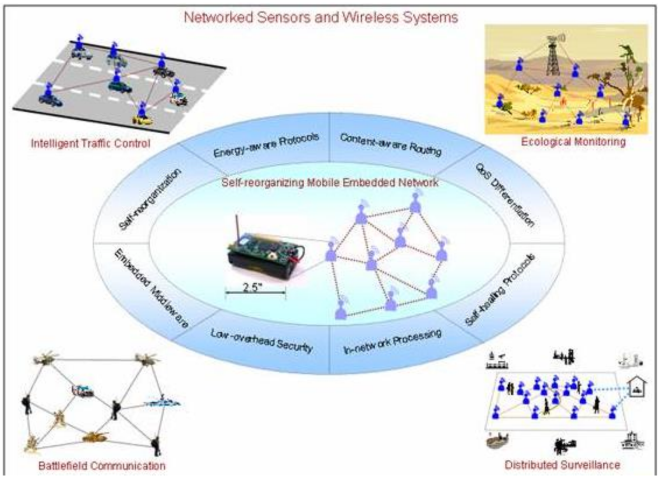

Fig 1. Wireless Sensor Networks & Systems

As shown in the Fig.1, a system with many simple components can exhibit behaviors of the whole that appear more organized than behaviours of the individual components [5]. These so-called emergent behaviours arise naturally through a process of self-organization, which appears in complex natural and man-made systems (e.g., biological organisms, ecosystems, food webs, geological systems, metabolic networks, transportation networks, and stock markets [6–12]). Complex systems encompass jumbles of positive and negative feedback loops that cascade the effects of changes in each component through an increasing number of interconnected components. Through such interactions, system state tends toward some coherent pattern. This is the essence of self-organization: patterns arise from many interactions spread over space and time. Such patterns are known as emergent properties because they have no meaning for individual components. For example, gas (a collection of molecules) exhibits both temperature and pressure, which measure strength of interactions among molecules as shown in the Fig.2 below, remote sensing based urban areas can also be detected and self organized using the wireless sensor networks.

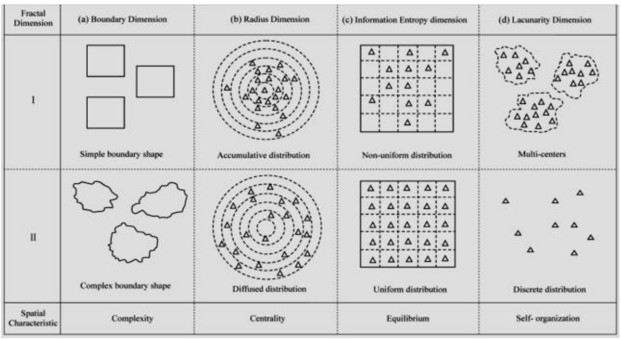

Fig 2. Self Organization of molecules

2. Self-Organization in Wireless Sensor Networks

Self-organization might allow adaptation to changing user density and traffic patterns in fixed wireless networks, where only users move. Self-organization could help reconfigure topologies as nodes move in and out of range in mobile ad hoc networks, where all nodes may move. Self-organization could form an initial topology among large numbers of sensor nodes dropped across a geographic area, and then adjust the topology as sensors exhaust power and replacement sensors are injected.

2.1 Self Organization Problem

The BOOTUP algorithm provides a means for a random collection of nodes to determine, collectively, local versions of the connectivity matrix of the network, and to establish links based on this information. The nodes do not have any prior information about the time reference, or location of other nodes or total number of nodes when the algorithm starts.

Assume there are R orthogonal channels available to our network. (e.g. through some combination of time, frequency, or code division). Consider a network of N nodes, with connectivity matrix C = [cij]. A link lij exists from i to j, if j is able to receive signal from i and cij = 1. Otherwise cij = 0. Let this network have a total of L links, numbered from 1 to L . Two links l1, from node i to node j , and l2, from node k to node m , are de ned to be interfering if at least one of the members of the following set ckj; cim is equal to one. Now an interference free organization of the network will be a mapping, such that in the entire network no two interfering links have the same channel r assigned to them. The size of this organization is the total number of distinct channels assigned. Finding a mapping where the total number of assigned channels is minimum in an NP complete problem for general topologies. Fortunately, we only require an interference-free mapping, regardless of its size. The important constraint is that this mapping must be found using minimal energy. Since the major energy cost is due to communicating messages between nodes, our algorithm must nd ways to reduce the number of passed messages.

To summarize, the self organization procedure must form a connected multi-hop network, starting with no connectivity information or timing reference. The algorithm must also save energy. In order to do this, the algorithm enables nodes to their neighbours by means of exchanges of a limited number of messages over the air. The messages enable nodes to change local information, and assign channels to the discovered link in a distributed fashion.

2.2 Channel Access Mechanism

Before description of the BOOTUP algorithm is given, the channel access mechanism for the sensor network must be described. In the sensor network nodes communicate intermittently, and their radios, which are a major energy consumer, need not be turned on at all time. This leads to a TDMA-like channel access mechanism for the sensor network. Unfortunately, generic TDMA systems are synchronous systems, where all the nodes are slot synchronized (a costly endeavour). However, since node only needs to know the transmission and reception epochs of its neighbours and since these coordinate are determined at the time a link is formed, there is no need to form network wide synchronization, nor for a single TDMA schedule. Thus nodes do not reckon their frame structure on a single frame epoch. Also the internal structure of this frame structure, which we call a "SUPER FRAME", will be different for each node. Figure 3 illustrates the concept of the "SUPER FRAME".

SUPER FRAME

TDMA	BW assigned on demand	BOOTUP	TDMA	BW assigned on demand	BOOTUP	node i

TDMA	BW assigned on demand	BOOTUP	TDMA	BW assigned on demand	BOOTUP	node j

Figure 3: SUPER FRAME structure.

This paper discuss the uses of self-organization in wireless networks to accomplish specific functions: sharing resources (processing and communication capacity); forming and maintaining structures; adapting behaviour associated with routing, with disseminating and querying for information and with assigning tasks and configuring software components; managing resources (synchronizing time and conserving power); and providing resilience by repairing faults and resisting attacks. These functions reflect increasing levels of abstraction: sharing physical resources, forming collectives, shaping collective behaviour, managing collective resources, and ensuring collective survival under duress. [13]

2.3. Sharing of Resources in a Wireless Network

Nodes in a wireless network must share a number of resources, such as electromagnetic spectrum, transmission bandwidth, and processing capacity. The task becomes difficult when the number of nodes and traffic demands are unknown or fluctuate. Self-organization can be used to discover participants and demands, to determine how best to allocate resources, to monitor changes, and to reallocate resources are needed. [14]

2.4 Processing

Most sensor networks require nodes not only to act as data sources and sinks but also as relays that forward packets among neighbouring nodes. Assuming nodes have finite power, tradeoffs arise between network throughput (which should be as high as possible) and lifetime (which should be as long as possible). Complete cooperation with forwarding minimizes a node's lifetime, while completely uncooperative behaviour drives throughput to zero. [15]

2.5 Information query

Query protocols allow consumers to pull data from relevant sources, e.g., an intrusion-alarm controller within a building might periodically check readings maintained by motion sensors attached to various doors and windows. Given an estimate of location, they wish to choose a sensor to query in order to increase estimate accuracy. They propose querying the sensor with information that would yield the largest reduction in uncertainty, represented as *entropy* associated with the probability distribution of the target's location. Simulation results show that entropy-based, sensor selection, with its lower computational demand, works nearly as effectively as more computationally demanding approaches. [16]

2.6 .Task assignment

Sensor networks may require a subset of nodes to host or provide particular services, such as translating between incompatible protocols or aggregating, caching or filtering data. Deciding which nodes should perform particular functions may require consideration of the capabilities or state of individual nodes, the network topology and variations in demand. These factors suggest the need to dynamically assign tasks, roles, or services to specific nodes and then to reassign them as conditions change. [17]

2.7. Software reconfiguration

Wireless nodes may operate in a heterogeneous environment where channel conditions and protocols vary with place and time. This suggests need for nodes to sense the environment and reconfigure platform software as necessary. Such reconfiguration may involve dynamically loading and unloading appropriate software modules or tuning parameter settings to achieve desired performance. [18]

2.8 Resource Management

Organizing a transmission schedule to limit interference requires that neighbouring nodes have a synchronized notion of period and phase. Similarly, choosing sleep and wake periods for a node demands sufficient inter-node synchrony. Alternating sleep and wake periods provide one means of conserving power. Several other options may also be implemented to extend network lifetime. [19]

2.9. Resilience

Potential attacks against sensor networks come in a variety of forms, such as injecting false sensor reports and draining network power. A statistical mechanism is investigated to detect and drop false information within a large, dense, sensor network where elected nodes aggregate and forward readings collected by nearby sensors. The mechanism requires that each data sink possess an indexed collection of keys partitioned into disjoint sets and that each sensor is randomly assigned a subset of index-key pairs from one partition. Any sensor report is forwarded along with a message has generated based on one of the keys within the sensor. [20]

3. Conclusion and Future Scope

Overall, this survey paper mainly concentrated on the self organization problem, different mechanisms in frames, current, scientific understanding of self-organizing systems and then concentrated on some important models investigated by computer scientists looking to apply self-organization to design large, distributed systems. In this paper self-organization models associated with wireless sensor networks are mainly targeted. The picture appears cloudy with regard to self-organization in wireless sensor networks. Researchers have yet to experiment with self-organizing designs that can simultaneously address multiple dimensions of performance, security, and robustness.

Further research is needed to develop techniques to measure, analyze, and visualize macroscopic behaviour. Without an ability to understand global consequences of particular design decisions, deploying self-organizing networks could prove to be risky.

4. References

1. Robertazzi TG, Sarachik PE. Self-organizing communication networks. *IEEE Communications* 1986; **24**(1): 28–33.
2. Floyd S, Jacobson V. The synchronization of periodic routing messages. *IEEE/ACM Transactions on Networking* 1994; **2**(2): 122–136.
3. Antunes N, Fricker C, Robert P, Tibi D. Metastability of CDMA cellular systems. In *Proceedings of the 12th Annual International Conference on Mobile Computing and Networking*, 2006, pp.206–214.
4. Mills K, Dabrowski C. Investigating global behaviour in computing grids. *Self-Organizing Systems* 2006; LNCS 4124: 120–136.

5. Hillis WD. Intelligence as an emergent behaviour or, the songs of eden. *Daedalus, Journal of the American Academy of Arts and Sciences* 1998; (winter): 175–189.
6. Kauffman SA. *The Origins of Order: Self-Organization and Selection in Evolution*. Oxford University Press: New York, NewYork, 1993.
7. May RM. *Stability and Complexity in Model Ecosystems*. Princeton University Press, 1973.
8. Cohen JE, Briand E, Newman CM. *Community Food Webs: Data and Theory*. Springer: Berlin, Germany, 1990.
9. Turcotte DL. *Fractals and Chaos in Geology and Geophysics* (2nd edn). Cambridge University Press: Cambridge, UK, 1997.
10. Bhalla US, Iyengar R. Emergent properties of networks of biological signallingpathways. *Science* 1999; **283**(5400): 381–387.
11. Yerra BM, Levenson DM. The emergence of hierarchy in transportation networks. *The Annals of Regional Science* 2005; **39**(3): 541–553.
12. Plerou V, Gopikrishnan P, Rosenow B, Amaral Lan, Guhr T, Stanley HE. Random matrix approach to cross correlations in financial data. *Physical Review* 2002; E 65066126.
13. Bak P. *How Nature Works—the Science of Self-OrganizedCriticality*. Copernicus: New York, New York, 1996.
14. Ito K. Punctuated-equilibrium model of biological evolution is also a self-organized-criticality model of earthquakes. *PhysicalReview* 1995;**E 52**: 3232–3233.
15. Stanley HE. *Introduction to Phase Transitions and CriticalPhenomena*. Oxford University Press: New York, New York,1971.
16. Kuramoto Y. *Chemical Oscillations, Waves, and Turbulence* Springer-Verlag: Berlin, Germany, 1984.
17. Roli A, Zambonelli F. Emergence of macro spatial structures in dissipative cellular automata. In *Proceedings of Cellular Automata: 5th International Conference on Cellular Automata for Research and Industry*, Springer: Berlin, Germany, 2002.
18. Erdos¨ P, Renyi´ A. On the evolution of random graphs. *Publ.Math. Inst. Hung. Acad. Sci*. 1960;**5**: 17–61.
19. Kay JJ. *Self-organization and the Thermodynamics of LivingSystems: A Paradigm* 1984; PhD Thesis, University of Waterloo.
20. Johnson NL, Rasmussen S, Joslyn C, Rocha L, Smith S, Kantor M. Symbiotic Intelligence: Self-Organizing Knowledge on Distributed Networks Driven by Human Interaction. In *Proceedings of the Sixth International Conference on Artificial Life*, MIT Press: Cambridge, Massachusetts, 1998, pp. 403–407.