Smart Sensor Network System For Environment Monitoring

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ABSTRACT

SSN (Smart Sensor Network) systems could be used to monitor buildings with modern infrastructure, plant sites with chemical pollution, horticulture, natural habitat, wastewater management and modern transport system. To sense attributes of phenomena and make decisions on the basis of the sensed value is the primary goal of such systems. In this paper a Smart Spatially aware sensor system is presented. A smart system, which could continuously monitor the network to observe the functionality and trigger, alerts to the base station if a change in the system occurs and provide feedback periodically, on demand or even continuously depending on the nature of the application. The results of the simulation trials presented in this paper exhibit the performance of a Smart Spatially Aware Sensor Networks.

Key Words: **WSN, SVR, Location Aware Sensing, Smart Spatially Aware Sensor Networks.**

1. INTRODUCTION

The advances in technology has brought a whole new change in the way things are done in today's world, processing is faster, memory is larger and storage space is in abundance. With the resources available tasks seem easier to approach and for a single problem several solutions exist. However the problem arises where the resources are limited.

Sensor nodes are assumed to be energy constrained, as they are small in size, with little processing capability and battery storage. Where size is not an issue the battery storage would not be a concern and processing abilities and memory could be tailored to the application. Sensor nodes being deployed over a large scale are likely to be small in size, as the nature of the job requires them to monitor various phenomena such as buildings, production plants, environmental conditions, natural habitat, battle fields, etc.

Smart spatially aware sensor systems [1] could be employed to carry out distributed tasks. The general application area could be distributed environments such as buildings, transport interchanges, and manufacturing plants which require a variety of sensing and actuation duties and typically share an intrinsic spatial organisation. Smart sensor systems are designed to provide the network with an ability to carry out smart tasks. Research has been carried out to see how nodes could benefit from inter-node cooperation among nodes [2-8]. Most of the present work relates to the improved communication among the nodes. There is still a need to investigate the application benefits, which could be achieved by inter-node cooperation pivoting upon location information.

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SSNs could carry out an array of event driven, on demand queries using sensed and local data to update the network even on the slightest change within the network. Smart networks even possess the ability to differentiate between an actual change in the network and a false positive. Such systems have the capability to determine whether the network is functioning properly, whether the system is in its normal limits and if there is an error in the system, its origin could be located. With location information networks could be divided into regions to carry out tasks on their own and to perform as stand alone systems. The core of a distributed smart system is based on the routing protocol employed to route data throughout the network. The routing protocol acts as the driving force for such smart systems. In order to reap the application benefits from smart systems an energy efficient routing protocol is desirable.

2. SMART SENSOR NETWORKS

SSNs [9-10] are emerging with time to provide a cost effective, scalable, mobile and flexible solution for monitoring various phenomena. SSNs could offer increased and independent functionality, for example a task downloaded to a region could continue to monitor a complex phenomenon even when communication is lost with a sink. SSNs may formulate compound data results in conjunction with nearby nodes.

SSNs have opened up an entirely new dimension for research and in the coming age these SSNs could turn out to be a part of our daily lives. Although SSNs provide an efficient means of sensing, there are some key parameters and criticalities in sensor network applications [11-12], which are worth considering.

- ☐ The first key feature is the ability of nodes to cooperate and to realise a specific element of a task, for example to compare their sensor values and to determine which has the highest value.
- ☐ The second key feature is an intrinsic knowledge of an estimate of node location, so that the network could in effect infer distributed information.

As sensor nodes are usually small in size they have less processing capabilities and with the introduction of smart sensor nodes that have the ability to sense, process and communicate there is a need to reduce the energy consumption to maximise the networks life time. Inter-node cooperation in wireless sensor networks exploits the ability of sensor nodes to cooperate with each other, and utilises it to accomplish tasks that could not be performed by stand alone individual nodes on their own.

3. SPATIAL AWARENESS

Operational smartness could be defined as the ability of a network to carry out tasks, which reduce the energy overhead. Implementation of energy aware routing protocols could provide a platform to achieve operational smartness. Research has been carried out with major focus on energy saving [13-14] and it is also common to assume that nodes could be shut-down when not in use, but this could threaten network integrity [15]. A substantial amount of energy could be conserved by applying routing protocols that exhibit smart behaviour. Extensive research has been carried out to find ways to route data along least energy consuming paths. Operational smartness enables nodes to make decisions for them selves based on the available local data. Local data in this context is referred to the data obtained by a node while sensing a phenomenon on its own and data gathered from its neighbouring nodes. Where local data has a role to play, operational smartness could be achieved if the network is distributed in nature. Operational smartness also plays a vital role in achieving application smartness, required by a smart spatially aware sensor network. Equipping nodes with operational smartness it unveils a whole new dimension for SSNs.

At the core of a smart spatially aware sensor network system lays the routing protocol, which leverages the performance of the network. The SVR (Spatial Vector Routing) protocol uses a directional approach to route data throughout the network. The directional approach of SVR results in a greater network lifetime. The protocol could also be used to carry out spatial diffusion tasks within the network.

The idea of spatial awareness is demonstrated in Fig. 1 where the node in red represents the source or the originating node that sends the packet throughout the network using the neighbours to forward the packet. The yellow nodes represent the neighbouring nodes in Fig. 1. The concept of spatial awareness is the core for the foundation of SVR protocol. In Fig. 2 a possible traverse of the SVR protocol is shown.

The SVR protocol [16] is compared with some of the existing routing protocols for WSNs and location aware routing. The benefits reaped by the routing protocol in terms of communication, could be referred as the operational benefits, which is one of the important aspects of the application.

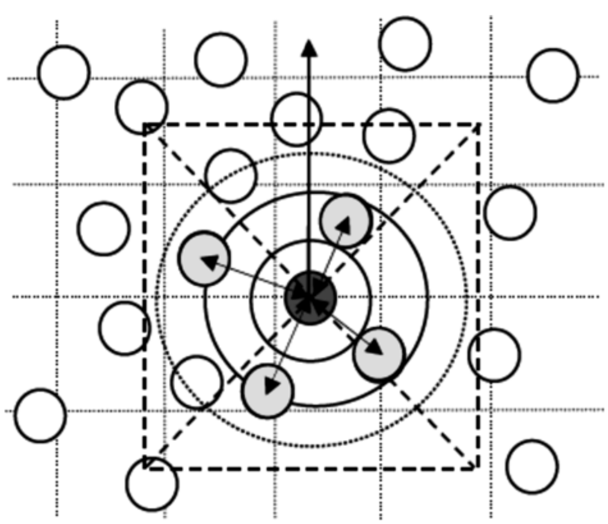

FIG. 1. SPATIAL AWARENESS

4. SPATIAL DIFFUSION

Spatial diffusion is a process of application smartness, which forwards a message to all the nodes of the network. The way a message is forwarded plays a vital role in how a task is performed and the need varies from network to network. Some networks may bid for reliable and robust message delivery. In such networks the energy consumption could be a trade off to the task being achieved within a specific time frame or within a specific number of attempts. In such cases a node would forward the message to all its proximate nodes and each node would receive a copy of the message from all its proximate nodes. This approach could turn out to perform well in irregular networks. While in other networks messages could be diffused in a more energy efficient way. Messages could be forwarded by the SVR mechanism, making sure that each node receives the query from at least a single node and in case of receiving it from other nodes, the message is discarded.

The spatial diffusion property allows nodes to cooperatively self organise themselves to get the message sent and meet the requirements of the task. Spatial diffusion

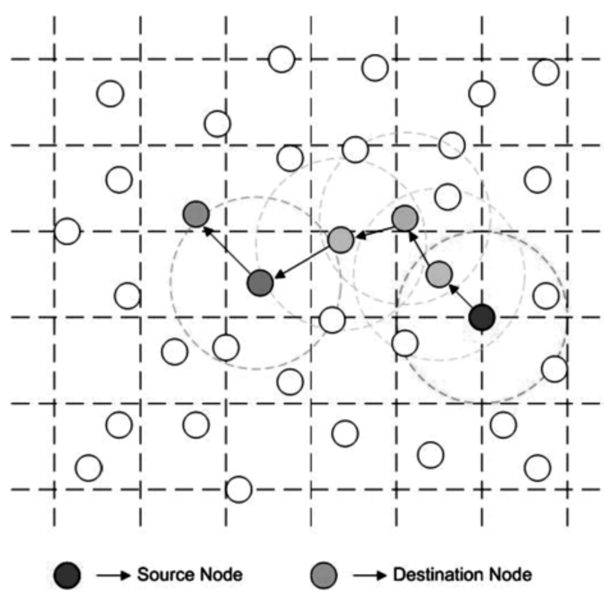

FIG. 2. SPATIAL VECTOR ROUTING

is all about how a certain message is diffused within the network. Critical criteria associated with spatial diffusion could be the maximum time taken to relay a message, and the degree to which energy is wasted or messages repeated.

5. SPATIAL DIFFUSION MECHANISM

The spatial diffusion process is responsible for forwarding the query message generated by a task to all the sensor nodes. Different approaches could be taken to propagate the message throughout the network, but one thing is common in all of the approaches the basic concept of an *Initial Node(s)*. In and a *Terminal Node Tn*. In order to propagate a message it is first sent to the In, which then ensures the message, traverses through the application depending on the nature of the application. As discussed above messages could be forwarded such that a single sensor node receives a message from a minimum of one proximate node, or from all. Fig. 3 shows both the scenarios.

In Fig. 3(a) the In is located in the top left corner and the Tn is located in the bottom right corner. The location of the nodes (initial and terminal) may vary depending on the network topology. Fig. 3(a) depicts a network where a single node receives the message from at least one proximate node and the traverse of the message is from top to bottom. This diffusion methodology is preferred when the networks prime object is to increase the network lifetime by conserving energy. Where as in Fig. 3(b) the methodology adapted differs from Fig. 3(a). In this case reliable delivery of the message is the prime objective, densely populated networks could benefit from such an approach. However, the reliable delivery comes with a trade off, which is increased energy consumption. Though the messages traverse is the same as in the latter, which is from top to bottom and left to right. There will always be a trade off between the node energy usage and the transmission reliability.

6. SIMULATION TRIALS

The simulation test bed was designed using NS-2 [17-18] and further augmenting it with the Mannasim Framework [19-20]. The framework further extends the node class of the network simulator to a sensor node, allowing nodes to be turned off, to sleep and turned on again. A property associated with sensor networks mostly used for event driven simulation where the energy is very scarce. The second addition made to the Network Simulator-2 was adding a new routing protocol SVR [16] and the spatial diffusion properties to create a smart spatially aware sensor network. The simulations were carried out on two different scenarios shown in Figs. 4-5. The scenario shown in Fig. 4 is a network of uniformly regular sensor nodes consisting of around 800 sensor nodes in a 1000x1000m network where as Fig. 5 is its counterpart with an irregular random network.

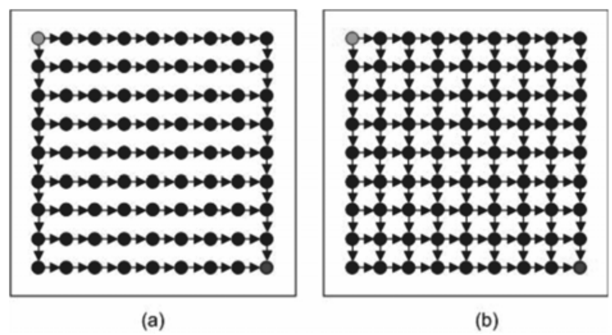

FIG. 3. SPATIAL DIFFUSION

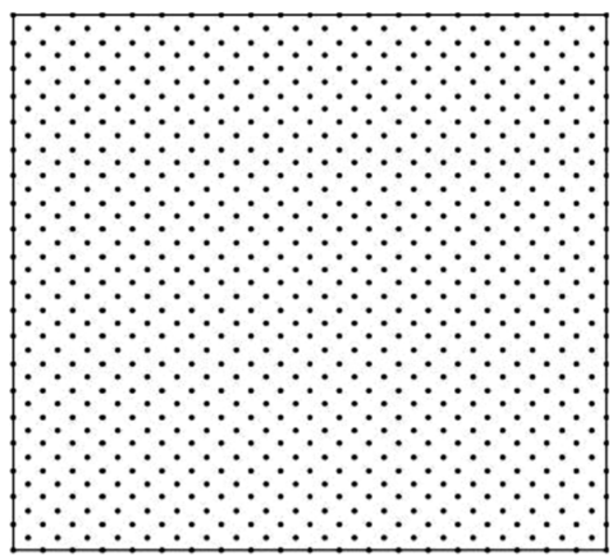

FIG. 4. REGULAR SCENARIO

Tables 1-2 show the different parameters used in the simulation. In the first table the network parameters used in NS-2 are mentioned. In the second table the simulation parameters are listed including, the number of nodes used, initial energy of each node, the network size, the simulation time and the power consumed in receiving and transmitting.

7. RESULTS

The results were achieved from the simulation trials carried out on two scenarios, a uniformly regular sensor node distribution and an irregular deployment of sensor nodes. The results obtained investigate the application benefits of a smart spatially aware sensor network in terms of cardinality, sense specific and location specific attributes of sensor nodes.

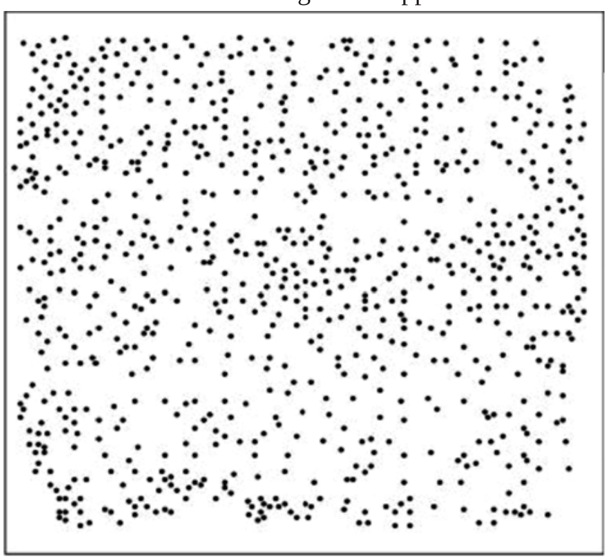

FIG. 5. IRREGULAR SCENARIO

TABLE 1. NETWORK PARAMETERS

Parameter	Type Used
Channel Type	Wireless Channel
Radio-Propagation Model	Two Ray Ground
Network Interface Type	WirelessPhy
MAC Type	802_11
Interface Queue type	PriQueue
Link Layer type	LL
Antenna Model	Omni Antenna
Max packet in ifq	200
Sensing Power	0.015W
Processing Power	0.026W
Instructions per second	8000000

Attributes of a smart spatially aware sensor network like cardinality, sense specific and location specific could improve the performance of WSNs. Temperature monitoring in a greenhouse could be a real time example of monitoring where the likes of cardinality, sense specific and location specific attributes of a sensor node could be used. Another example could be of a production plant, cardinality could be used to find whether the system is about to congest.

7.1 Cardinality

The simulation trials investigate the cardinal values (highest and lowest). In the simulation trials the phenomena being sensed is temperature within a closed environment. The results shown in Figs. 6-7 shows the cardinal values (highest and lowest) for a regular and irregular node distribution respectively. The cardinal values appear at the nodes in the topmost left corner and lowest right corner of the simulated environment. However, the nodes with the cardinal value could be at any point depending on the temperature distribution throughout the network.

The cardinal values could be used to set threshold values. The system could be designed to allocate tasks when the cardinal values reach a certain point and could be greatly beneficial in the case, where the temperature needs to be regulated within a specific range in a closed environment.

TABLE 2. SIMULATION PARAMETERS

Parameter	Properties
Number of Nodes	800
Scenario Size	1000x1000m
Simulation Time	200s
Node Energy	1J
Transmission Power	0.034W
Receiving Power	0.026W

7.2 Location Specific and Sense Specific

The system also possesses the ability to determine the specific location of a node knowing the temperature and vice versa. In Figs. 8-9 the specific location of a node is computed knowing its temperature for a regular and irregular node distribution respectively. Where as in Figs. 10-11 the temperature of a node is calculated knowing its location.The ability of a system to compute the location and the attribute of a phenomena (temperature in this case) adds smartness to the system. Knowing the specific location or sensed value could be used to trigger events if a threshold is set. Specific location could also be beneficial when the nodes are mobile.

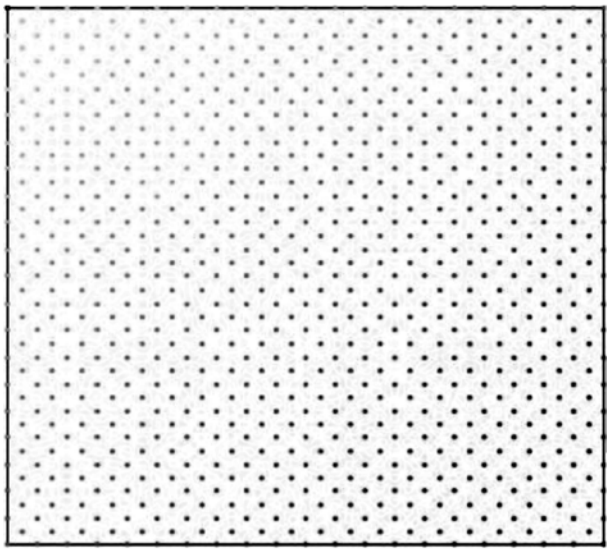

FIG. 6. CARDINALITY REGULAR SCENARIO

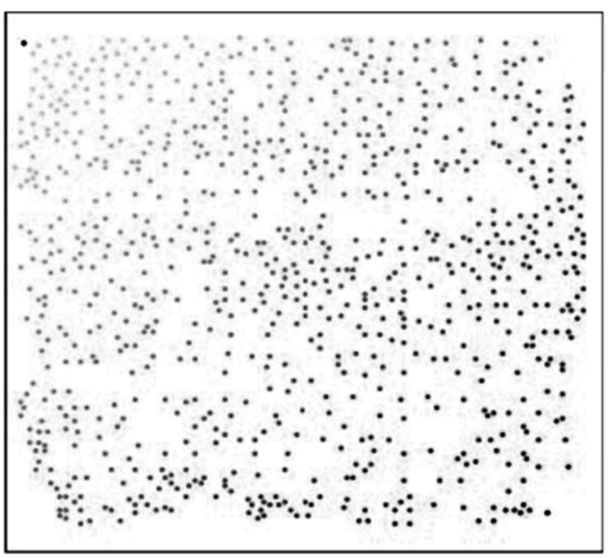

FIG. 7. CARDINALITY IRREGULAR SCENARIO

8. CONCLUSIONS

The paper outlines the benefits of spatial awareness and spatial diffusion in a SSN system. It further addresses the importance of communication in a SSN and stresses on the selection of an effective routing protocol and the basic functionality of the SVR protocol is highlighted. The

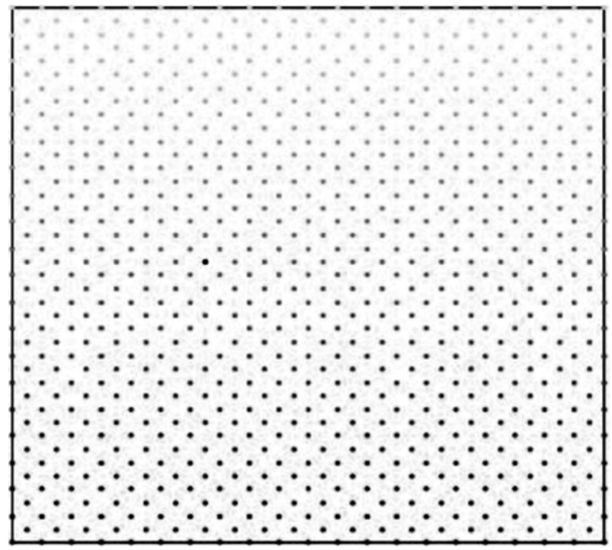

FIG. 8. LOCATION SPECIFIC REGULAR

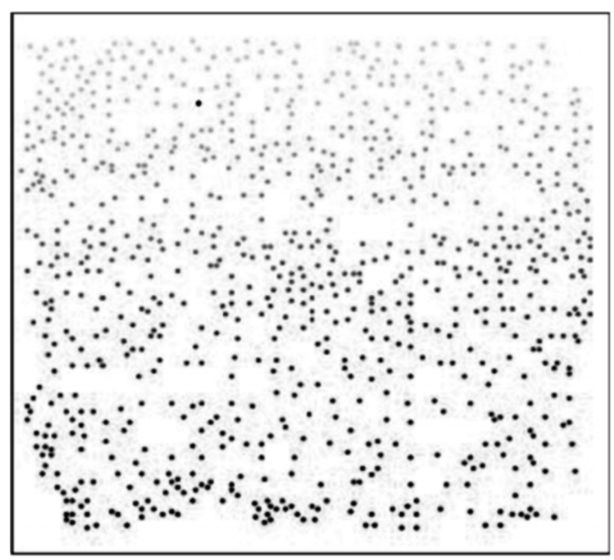

FIG. 9. LOCATION SPECIFIC IRREGULAR

different spatial diffusion techniques, reliable delivery of messages and the energy conserving approach are explored in detail. The paper focuses on the significance of various attributes of a sensor node and how their performance could directly affect the network on a whole. The sensor node attributes of cardinality, location specific and sense specific are tested on the simulation platform and the results are presented.

In the future the system could be easily implemented for mobile nodes by slightly augmenting the SVR protocol, currently the system is only capable to deal with static nodes. Adding mobility to the system would certainly broaden the scope of the application.

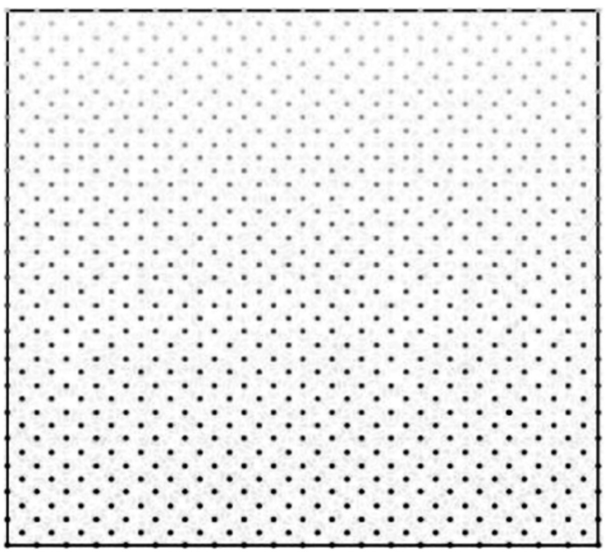

FIG. 10. SENSE SPECIFIC REGULAR

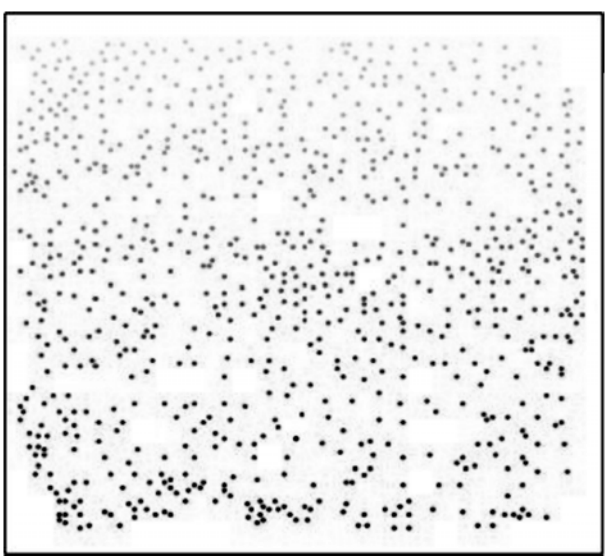

FIG. 11. SENSE SPECIFIC IRREGULAR

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