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Gallery: A Self-healing Topology Model for Pervasive Sensor Networks

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Abstract

Pervasive Sensor Network(PSN) is identified as rapid dynamic network. PSN environment is viable only through Sensor networks. Fault-tolerance is expected high when handling speedy movements of sensor nodes. Henceforth, we propose a novel self-healing topology named Gallery; a placement model for Pervasive WSNs with dynamic topology control functions. The topology model ensures the localization of sensor nodes and guarantees the scalability by increasing its tracks and slices. The 2D and 3D deployment methods are Gallery is discussed. A wait-n-relay method is introduced for mobility nodes. An informal clustering of nodes within a region is identified as track region. The careful design of track region and relevant parameters are done. A covering map of mobility enabled relay sensor is calculated. The simulation is done with omnetpp simulator. Self-healing is promising by exact data aggregation by relay sensor if an desirable event raised within the region of interest.

KEYWORDS

Gallery Topology, Self-healing, Topology Control, Pervasive Sensor Networks

1. INTRODUCTION

Pervasive Networks synonymly known as ubiquitous computing networks formed by tiny sensing devices. To achieve pervasiveness, the network must be fault-tolerant particularly self-healing. Self-healing is one of the most desired operational properties that, the ability of a network to effectively combat coverage, routing holes, and topology control and network disconnection. Topology control identifies the shape of the active network over a certain period of operation, in which the coverage holes are re-arranged automatically. Most of the Pervasive environments require Wireless Sensor Networks implemented in reality. Perhaps the network must inherit the qualities of WSN such as placement structure which need not be ad-hoc in nature. Rather an initial and firm placement method should be followed even the network is rapidly dynamic. Aggregation and fault-tolerant methods can be carefully adjusted to heal the network. Additional nodes are deployed in some networks to overcome energy constraints, in spite of that the nodes may deplete. Recent trends in energy management to have self-powered or solar batteries avoid placing additional nodes. Some special nodes are introduced with mobility to aggregate data in high dense and fault-tolerant regions. Hence the proposed deployment model enhances the network performance in faulty scenarios and focus on some specific out door domain applications like agricultural fields.

1.1 Pervasive WSN

Wireless Sensor Networks has flourished as a promising enabler for Pervasive computing. Rather than computers being the centre of attention always, pervasive networks aims for calm computing. Here, the computing is surrounded all around us and have to be pro-active. The Objective of Pervasive network is to design computing infrastructures in such a manner that they integrate seamlessly with the environment and become almost invisible. "The technologies weave themselves into the fabric of everyday life until they are indistinguishable from it", known as Pervasive (Weiser, 1991). Pervasive computing networks will change the computing landscape enabling the implementation of new applications that were never imagined. Self-Organization is an inherent property of Wireless Sensor Networks since the deployment region is outdoor environments most of the time. Self-adaptive, Self-tuneable, Self-healing are the most desirable properties according to the placement. The basic idea is to implement WSN in precision agricultural regions that are helpful activities such as weather monitoring, crop monitoring, Irrigation techniques and all other possibilities. An effective initial deployment will guarantee for future occasions even when the network becomes faulty and error-prone. Both static and mobile node deployment is required for better performance of the entire network over the period of operations. The continuous sensing of a specific physical phenomenon will make a node tired of battery life, communication range and due to other obstacles. It is commonly known as routing holes; here we define them as sensing voids. These voids are filled with many mechanisms often by researchers.

We propose a promising way of node placements with a blend of static nodes and mobility nodes. The mobility nodes are assumed with high-energy and long-battery life. These nodes are responsible to aggregate the sensing data to relay them to the base station synchronously. A wait-n-relay method is introduced in the mobility nodes with a flash-memory of course, for not missing any real data.

2. RELATED WORK

The researchers actively find various standards and solutions for pervasive environments probably to the deployment scenarios, protocol findings, middleware services and so on. The vision and challenges of pervasive enlisted and long-standing design assumptions is one of the challenges in pervasive computing environments [1]. The Social and technical challenges were revised with Environment Sensor Networks [2]. Self-organisation is the process of nodes in the network imposing some simple scalable organization of the network. Energy efficiency is being concentrated by the researchers enormously. LEACH proposes the way of creating clusters with two level hierarchy i.e. sensors to cluster-head and cluster-head to base station [3]. Coverage problems and topology model is addressed using Voronoi diagrams with Best case coverage and maximal support path [4].

The sensing field is partitioned into smaller sub regions. In each sub region, the sensors were arranged row by row such that each row guarantees continuous coverage and connectivity and that adjacent rows ensure continuous coverage [5]. Sensors were deployed on cattle as a part of habitat monitoring and created a smart-farm using Berkeley motes, Fleck-1, Fleck-2, Fleck-3. Multi-hop routing and node's position were the questions arose in the real implementation [6]. GLACSWEB system was proposed and the requirements of out-door WSN given as sensing, communication and computing [7]. An efficient broadcasting and a clustering algorithm was proposed and Gateway selection and mirror node selection were also discussed [8].

BNGRAZ, a grazing mobility strategy was introduced for mobile WSNs. A Coverage approximation algorithm was proposed [9]. A grid structured arrangement was suggested with coverage and connectivity trade-offs. 'n' nodes are placed over a unit area, defining r(n) as the transmitting radius of each node, and p(n) as the probability that a node is active at some time t, the active nodes are connected for a square region $p(n)r^2(n) \sim \log(n)/n$ [10]. BayesMob, a Bayesian self-healing algorithm was suggested for the coverage increase in Pervasive Sensor network structure [11].

OplaMoN, Optimal placement of a Mobile node within a routing hole of any arbitrary topology was given and deploying mobile bridge between nodes were calculated [12]. Sensor On-demand Multi-path Distance Vector Reliable (SOMDV-R) routing protocol was designed for Packet Delivery Ration (PDR) and mean latency [13]. The problem of, How many sensors are required for to cover a specific area was solved by reduced cover network with self-healing system using SUB algorithm [14]. The most helpful taxonomy of sensor faults was enlisted such as High noise/variance, Calibration fault, Connection failure and low battery [15]. A similar circular placement of sensors used in recent work on developing a MAC Protocol DGRAM, which focused on delay guaranteed routing for WSN.

3. PRELIMINARIES

3.1 Goals

The topological model designed for self-healing deployment with wait-n-relay mobility sensors. In order to gain the pervasiveness on the whole, the self* activities are focused. The aggregation is done by mobility enabled node to cover the entire region of interest which may reduce the dependency on static nodes. The goal can be extended for the deployment in a specific domain such as agricultural field is further concentrated.

3.2 Variable Assumptions

1. Radius of n^{th} track = $r(t_n)$
2. Radius of $(n-1)^{th}$ track = $r(t_{n-1})$
3. Track distance = $r(t_n) – r(t_{n-1})$
4. Area of a Torus = A_t
5. Area of a Quad-Torus = A_{qt}
6. Sensing range of a Sensor = R_s
7. Communication Range = C_s

4. GALLERY TOPOLOGY

4.1 Graphical Model

The Gallery is either 2-Dimensional or 3-Dimensional based on the deployment requirements. The region of interest is a hill-station, then the 3D Gallery is imperative. Otherwise, 2D flat Gallery is sufficient. Fig 1 illustrates the true perspective of Gallery Topology sliced with quadruples. The Topology can be sliced into 'n'-slices if, required by the designer. This centric circle is formed with a common centre-point with multiple radiuses.

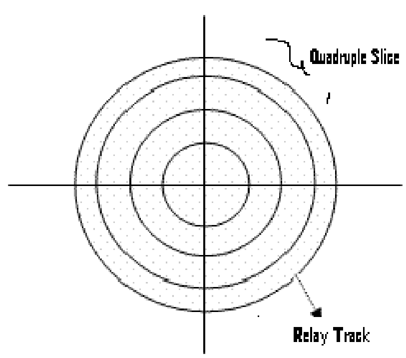

Fig 1 Gallery - A Bird's Eye View

4.2 Different Layouts

Gallery Topology is viewed on the basis of various understanding layouts. Fig 2 cuts-down the whole-view into the quadruple slice view. The number of sensors deployed in each track-region is given.

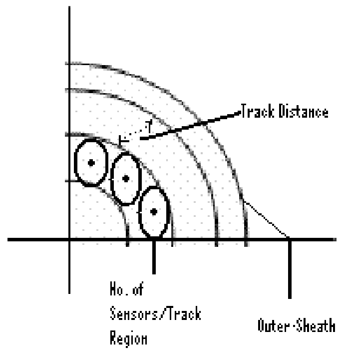

Fig 2 Gallery - A Quadruple Perspective

The overlapping of sensing region of individual sensor is assumed as zero or trivial. Fig 3 imagines the entire topology is framed inside a square and Fig 4 imagines for a Gallery framed inside a rectangle. The changes in ellipse shaped rectangle topology would reflect in circumference and radius which is out of focus of this paper.

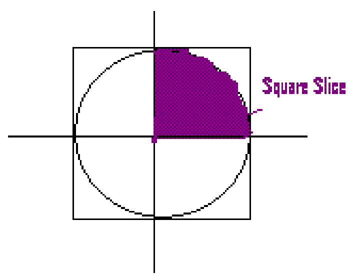

Fig 3 A Gallery within a square

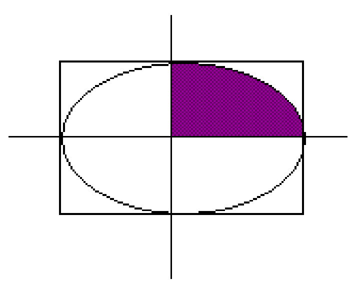

Fig 4 Gallery within a rectangle

4.3 Handling Uncertainty

The fault-types of a Pervasive WSN is described in Kevin et al. [15] and missing of data aggregation at cluster head level is accounted here. If a node is transmitting packets of a node is unable to reach the relay sensor/cluster-head, the wait-n-relay method is adopted by individual nodes. The following list of attributes may cause uncertainty.

Table 1Attributes cause Uncertainty

Sno	Attribute Name
1	Scalability
2	Flexibility
3	Controllability
4	Routing Complexity
5	Reliability
6	Storage & Forward
7	Delay & Media usage efficiency

Scalability and Storage and Forward is the key focus of our paper. The mobility enabled relay sensor/track hopper is then transmitting to the base station placed at the center point. Every track region is surrounded with an inner track and a outer track of the concentric Gallery. The region between two tracks is a Track-region (T_r), where 'r' is the r^{th} track of the concentric circle. This shape around the center point is referred as Torus (T). Fig 5 shows the Torus shaped track region. The map p: R→S1 given by the equation :

$$p(x) = (\cos 2\pi x, \sin 2\pi x) \quad \rightarrow (1)$$

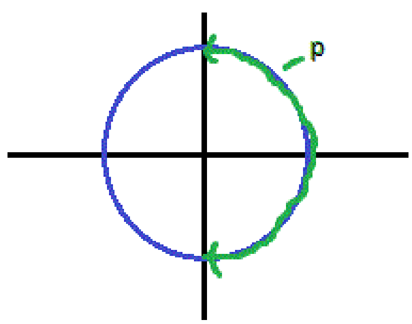

Fig 5 Cover map function p

is a covering map and in the process maps each interval [n,n+1] onto S1. p is a covering map comes from elementary properties of the sine and cosine functions. Let E be the space X x {1..n} consisting of n disjoint copies of X. The map p:E → X given by p(x,i) = x for all i. If p: E→ B and p':E'→B' are covering maps, then
p x p' : E x E' → B x B'. Consider the space T = S1 x S1; it is called as Torus. The product map p x p :R x R → S1 x S1 is a covering of the torus by the plane R2, where p denotes the covering map of (1). Fig 5 illustrates 'p' as a function that wraps the real line R around the circle S^1, and in the process maps each interval [n,n+1] on to S^1. Gallery topology uses the covering map to determine the distance of a track circumference. A track circumference is a covering space

between positive x and y coordinate. A mobile relay sensor shuttles between the intervals requires the exact distance of travel around.

4.4 Self-Healing

The relay sensor node is placed in every upper track of the track region. The design of a relay sensor is to collect the data from every appropriate track region. Henceforth, the relay node with mobility is taken charge as cluster-head if, the track region is assumed as a cluster. Self-healing is vital in pervasive environments and Gallery topology guarantees for self-aggregation of data during mobility period of relay sensor with wait-n-relay technique. We introduce wait-n-relay as a method of aggregate data from sensing region of interest when it comes into communication range of a sensor. A buffer is mounted in relay sensor to keep collected data for a certain period of time.

4.5 Topology Control

One of the greater assumptions is that the nodes are deployed as ad-hoc fashion inside every track region. The no. of sensor nodes deployed is as follows

1. Radius of n^{th} track = $r(t_n)$
2. Radius of $(n-1)^{th}$ track = $r(t_{n-1})$
3. Track distance = $r(t_n) - r(t_{n-1})$
4. Area of a Torus = A_t
5. Area of a Quad-Torus = A_{qt}
6. Sensing range of a Sensor = R_s
7. Communication Range = C_s
8. No. of sensors/track region = y

$$A_{tn-1} = \pi r2(t_{n-1}) \rightarrow (2)$$

$$A_{tn} = \pi r2(t_n) \rightarrow (3)$$

A_{tn} denotes the area of a circle for every outer track whereas A_{tn-1} denotes area of every inner track. The area of required torus region is

$$A_t = A_{tn} - A_{tn-1} \rightarrow (4)$$

Thus, Area of quadruple region of torus is

$$A_{tq} = A_t / 4 \rightarrow (5)$$

Case (i)

If $A_{tq} = R_s$, then ‘y’ no. of sensors placed within a track region.

Case (ii)

If $A_{tq} > R_s$, then no. of sensors are 3y. (three multiples of y).

Case (iii)

If $A_{tq} < R_s$, then no. of sensors are y.

Henceforth, scaling up and down of Gallery Topology is to increase/decrease the track regions appropriately. The center point of the concentric circular gallery is assumed as base station. The slicing of Gallery depends on the deployment field structure. The quadruple slice is given as minimum required structure for common deployments whereas unpredictable outdoor environments are designed with even little slices. In such case, either ‘x’ coordinate or ‘y’ coordinate stands stable. The $\theta°$ of quadruple may change due to further divisions. Dynamic Topology Control aimed when pervasive deployments understand context, location, user and moving regions. The relay sensor/track hopper designed to move on the track for aggregating sensing data of a phenomenon. The self-adjustable and tuneable property of identifying sensors of track region is pervasive.

4.6 Wait-n-Relay Technique

During the aggregation of sensing data, a relay sensor may store and forward to the base station not immediately transmit as designed so far. With this idea, low-memory enabled sensors are deployed with high energy. The data stacked at track hopper takes FIFO order. The waiting time is predicted as random that depends on event raised at every track region. In maximum event occurred regions may hold for less period of time obviously less event occurred regions may hold for longer period.

5. SIMULATION

The Gallery topology is simulated in Omnet++ for the initial placement of nodes and the mobility node and sensing is simulated in Mixim module. A Center node is assumed as a base station for the entire network. And Every track region is divided for convenience into Torus and further Quad-Torus(Aqt). The nodes are placed inside the torus region as real-time field. The data is aggregated by the mobility node placed on the torus boundary line. It is assumed to move only on the track and the aggregated data transmitted to the Base station through the edges known as radius lines. Figure 6 shows the simulated result of Gallery Topology.

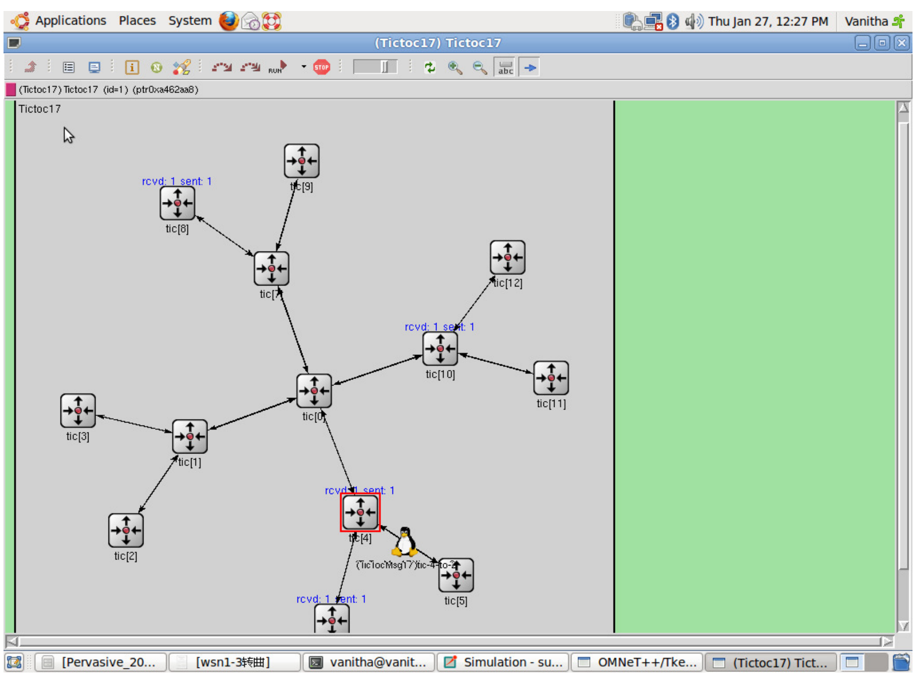

Figure 6. Gallery deployment Scenario

6. CONCLUSION AND FUTURE WORK

A topological structure for pervasive Wireless Sensor Network is suggested with valid notations and parameters. Self-healing is derived by aggregating the exact sensing data with mobility enabled relay-sensors. Overlapping between sensing range of nearest track region nodes is a future issue of this paper. Physical death of a node due to energy depletion may be focused with additional no. of nodes deployed in each track region with sleeping mode. Then automatic activation and deactivation of nodes would be an interesting issue.

Then, the no. of slices is restricted in this Gallery as four and defined as quadruples. If the deployment region in real time is unpredictable polygon then, slicing is done with add-on patterns. Our focus is to deploy this mixed infrastructure with both static and mobiles nodes in real time.

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