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Mobile agent based event discovery in wireless sensor networks

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Abstract: Advances in micro-sensor and wireless sensor network (WSN) technology will enable small but smart sensors to be deployed for a wide range of environmental monitoring applications. This requires flexible and adaptable methods for distributing queries (queries generated by sink nodes to relevant sensor nodes that have observed interesting events in the network) and getting responses in a WSN. The paper proposes an agent based method to perform following: 1) generate an event path from the source node (where the event has occurred) to end node placed at either the adjacent or opposite boundaries of the area of WSN, 2) generate a query path from the sink node to discover an event by using an event path. The proposed method is simulated in various network scenarios and performance is analyzed in terms of successful real-time event (route to event) discovery and agent overheads. It is noticed that performance improved with more number of event paths. Agents offer flexible and adaptable services and also support component based software development.

Key–Words: mobile agents, sensor networks, event paths, query paths,

1 Introduction

The individual devices in a wireless sensor network (WSN) are inherently resource constrained, i.e., they have limited processing speed, storage capacity, limited power and communication bandwidth [4]. WSN may have either mobile or static nodes. For environment monitoring applications such as soil moisture, humidity, temperature, etc., static sensor nodes will be deployed. All the sensor nodes are battery driven and draw their operational power from solar energy. Due to limited power capability it is advisable to perform asynchronous communication (not necessary to have permanent connection for data transfer/exchange). Manually configuring large WSNs of small devices is impractical, the nodes must organize themselves and provide a means of programming and managing the network as an ensemble, rather than administering individual devices [1,2].

Applications of WSNs include environmental and habitat monitoring, precision agriculture, indoor climate control, surveillance, treaty verification, intelligent alarms, structural monitoring, ecophysiology, condition-based equipment maintenance, medical diagnostics, urban terrain mapping, monitoring complex interactions, wildlife habitats, disaster management, emergency response, ubiquitous computing environments, asset tracking, healthcare, and manufacturing process flow [5,6].

Some of the issues in WSNs are micro-sensor developments with more memory and processing capability, real-time information query and retrieval with reliable and dynamic routing techniques, flexible and adaptable sensor network operating systems, enhancing battery capacity, power management, security, programming abstractions, etc. This paper deals with real-time event query and retrieval by using suitable agent based technique. Agents are the autonomous programs situated within an environment that senses the environment and acts upon it using its knowledge base, and learns so as to act in future. Flexible and adaptable services in real-time can be offered by an agent based system. Mobile agent theory is based on ant colony optimization technique [3], where colony of ants can find shortest paths to the food from nest.

Some of the related works on sensor networks are as follows. Building a cost field towards a particular node, and then reliably routing queries across a limited size mesh toward that node is presented in [7]. Energy efficient routing protocols that conserve energy by finding energy aware paths are presented in [8]. Work in [11] provides reliable network broadcasts probabilistically and nodes flood message to some of the neighbors. An agent based routing algorithm is modeled after ant behavior [13]. Directed diffusion, geo-routing [9][10] provide a mechanism for doing limited flood of a query towards the event, and then setting up reverse gradients to send data back along

the best route. Diffusion results in high quality paths, but requires an initial flooding of the query for exploration. Data-Centric Storage in sensornets [12] allows access to named data by hashing the name to a geographic region in the network.

The proposed work is motivated by theory on straight lines, i.e., possibility of intersection of two straight lines in a given plane is 67%. If there are five lines the possibility is about 99.67%. Our work utilizes this theory as well as position coordinate information of the nodes (with reference to bounded area of WSN) to establish a query route in a static WSN. Any event (sensing critical data) generated by a node is spread across the nodes in the event path where event path is a path leading from source to a node at adjacent or opposite boundaries of the area of WSN. We assume WSN area to be either square or rectangular. Mobile agents are used to create event paths. The sink querying for a particular event information uses mobile agents to reach an event path and acquire the event information from event creation node.

Remainder of the paper is organized as follows. Section 2 describes the proposed work. Section 3 presents simulation model. Section 4 discusses results. Finally, conclusions are given in section 5.

2 Proposed work

This section describes concept of agents, system model, definition of event, event path, query path and the proposed event path based query scheme.

2.1 Software agents

Agents are the autonomous programs situated within an environment, which senses it and acts upon it using its knowledge base, and learns so as to act in future. They have certain special properties which make them different from the standard programs such as mandatory and orthogonal properties. Mandatory properties of the agents are: *autonomy, reactive, proactive and temporally continuous*. The orthogonal properties are: *communicative, mobile, learning and believable* [14]. Agents can be classified based on properties they posses: *local or user interface agents, networked agents, distributed AI (Artificial Intelligence) agents and mobile agents*. The networked agents and user interface agents are single agent systems whereas other two agents are multiagent systems. The agents of a single agent systems never cooperate or communicate with each other. Mobile agents are the multiagent systems which posses the mandatory properties and some or all of the orthogonal properties specified for an agent. It is an itinerant agent dispatched from source computer which contains program, data, execution state information, migrates from one host to another host in the heterogeneous network and executes at remote host until they accomplish their task.

The mobile code should be platform independent, so that, it can execute at any remote host in the heterogeneous network environment. They communicate and cooperate with other agents to achieve their goals. Agent can update its information base while interacting with other agents during its travel. Inter-agent communication can be achieved by message passing, RPC or common knowledge base (black board). In general, there are several good reasons for using agents: they reduce network load; overcome latency; encapsulate protocols; execute asynchronously and autonomously; adapt dynamically; provide aggregate functionality of several individual protocols and support component based software development.

2.2 System model

The system environment considered is a wireless sensor network as shown in figure 1. The coverage region of WSN is a rectangular area wherein smart sensors are deployed randomly throughout the area. An event may occur randomly some where in the rectangular area. The sensor nodes are capable of wireless communication with the symmetric range. All sensor nodes very well know about their coordinates and the boundaries of WSN. All the nodes are assumed to have an agent platform. Agent platform services are agent creation, reception, execution, migration and security with fault tolerance. However nodes can communicate using traditional message exchange mechanisms in case of non-availability of agent platform.

2.3 Definitions

Here we define an event, event path, query and query path that are essential to understand the proposed work. *Event*: An event is described as an occurrence of certain activity which is critical to the application and needs certain attention from the decision support system or the user.

Event path: It is a path created by mobile agents upon occurrence of certain event. Path leads from source to node either placed at the edge of adjacent boundary or opposite boundary.

Query: A query is generated by a sink node requiring certain critical event information. It consists of event type/id, node id (optional) and the time bound of response delivery.

Query path: It is path generated by mobile agent from the source upto a node in the event path.

Figure 1 depicts the static sensor nodes, event generating node, event paths, query generating node and a query path. It is observed that two event paths are generated from event generating node that reaches nodes at adjacent and opposite boundaries of WSN.

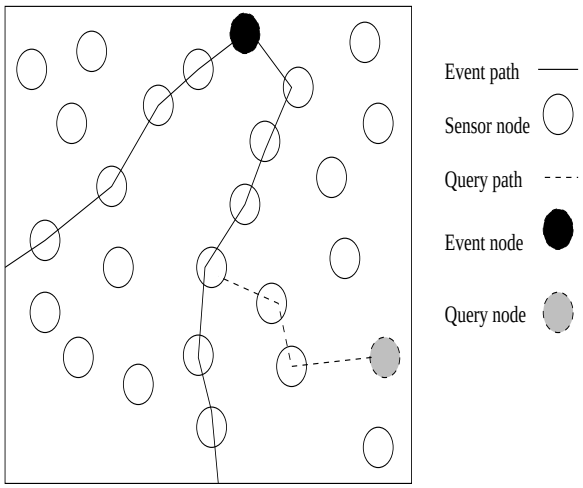

Figure 1: Event and Query paths

Event path table: This is present at every node in the path. It consists of event id, node id (node generating the event), next-hop to reach the node for acquiring event information.

2.4 Agencies

An agency for event path generation and query-response generation is located at the source and sink nodes, respectively. Agency in a source node comprises of static event manager agent and a set of event path generation mobile agents. Similarly agency in a sink node comprises of static query agent and a set of query-response mobile agents. Every node in WSN will have event knowledge base and event path table which will be updated by event path generation mobile agents.

2.4.1 Event path generation

Following steps illustrate the event path generation by using mobile agents (see figure 2)

1. An event is sensed by event manager agent of the sensor;

2. Event manager agent informs about the event to its neighbors;

3. Event manager agent creates n number of event path generation mobile agents and updates its event knowledge base, where n depends on number of event paths to be generated. Value of n is based on degree of importance of the event; (in figure 2 only two event paths are considered, maximum value of n is 5)

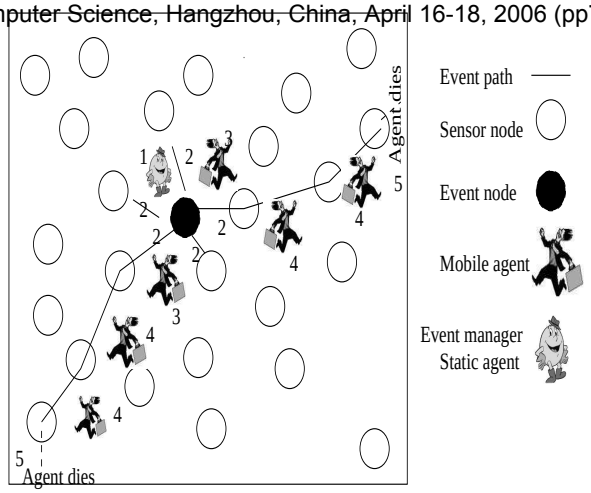

Figure 2: Event path generation by agents

4. The mobile agents move from one node to another node and updates the event path table to reach the event node, i.e., agents decide their migration to neighbors based on the coordinates of neighbors such that they reach the adjacent or opposite boundaries from one of its randomly chosen neighbors (of event source). Mobile agents travel in a loop free manner by using its stack of visited nodes [15]. Mobile agents on its travel may also carry other event information (given by other mobile agents) and carry aggregated information for updating event path table at the visited nodes.

5. Mobile agents destroys themselves once they reach the node at the edge of boundaries of WSN.

2.4.2 Event query-response

Following steps illustrate the query path generation and event access by using mobile agents (see figure 3)

1. Query agent in a node (sink) generates a query for an event with real-time access requirements as given by the user/process;

2. Query agent interacts with neighbors to get the response for queried event; If response is available then it does not go step 3.

3. We assume (in figure 3) that response is not available with neighbors, hence query agent creates

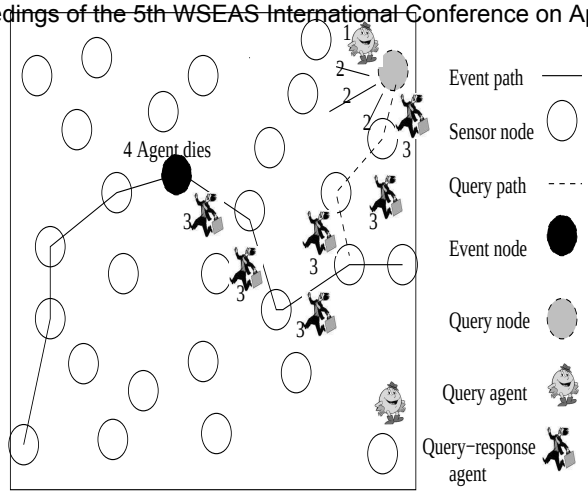

Figure 3: Query path generation and event access

a set of query-response mobile agents in opposite direction; (figure 3 depicts only one mobile agent)

4. Query-response agent moves from one node to another node by checking the event path tables. It moves in a loop free manner, i.e., it does not visit already visited nodes. Once it encounters a node with event information, uses that route information to reach the event node and accesses the information and passes on the information to sink node. The agent also may pick up some critical information on its way from visited nodes and aggregates the information with required event information;

5. Mobile agent destroys itself at the event node;

In case of any node failure in an event path, node that senses its neighbor node failure will send messages to other neighbors to establish path to neighbor of a failed node by using event path generation mobile agents.

3 Simulation

The proposed scheme is simulated extensively with various network scenarios by using C programming languages on a Pentium-IV machine.

3.1 Simulation model

A WSN of num nodes is considered in an area of $m * n$ sq. mts. The area is divided into g grids. Nodes are randomly placed in the grids. Bandwidth of each grid is C mbps. Nodes generate events randomly with probability varying from 0.2 to 0.6. Each event node creates E event paths. Q number of queries are randomly generated by nodes placed at edges of WSN. Agent sizes are defined to be Ae and Aq kbytes for event path generation and query-response mobile agents, respectively. Propagation time of information and processing time of agent together is randomly distributed between 100 to 200 msec., as given in [19]. Time required to get response for the query is randomly distributed between x to y seconds.

3.2 Simulation procedure

Following inputs are considered for simulation: num=10 to 400, Q= 20 to 40, m= 400, n= 400, g= 400, C= 2, E= 1 to 4, Ae = 4, Aq = 5, x= 1, and y=3.

Performance parameters evaluated in the simulation are as follows.

- *Successful real-time route discovery*: It is the ratio of responses to queries obtained in real-time to the queries generated. The successful of the response is considered only when the response is returned within desirable time.

- *Agent overheads*: It is the average bandwidth occupied by mobile agents in a grid for event path generation and getting response to the queries.

Simulation procedure is as follows: 1) Generate WSN, 2) Generate events, 3) Apply the proposed scheme and 4) Evaluate performance parameters.

Figure 4 depicts that the route discovery improves with increase in event paths and the number of nodes. This is because, as the network becomes denser, nodes participating in the event paths will be more. Also, as more event paths are created, there are more chances of intersection of query paths and event paths.

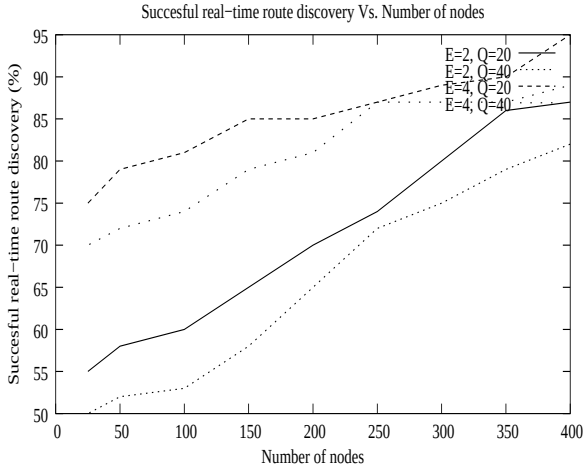

Figure 4: Successful real-time route discovery (%) Vs. Number of nodes for Q= 20, 40

Agent overheads increase with number of queries and the number of nodes as shown in figure 5. This is due to fact that agents travel more number of hops for each kind of query to get the responses.

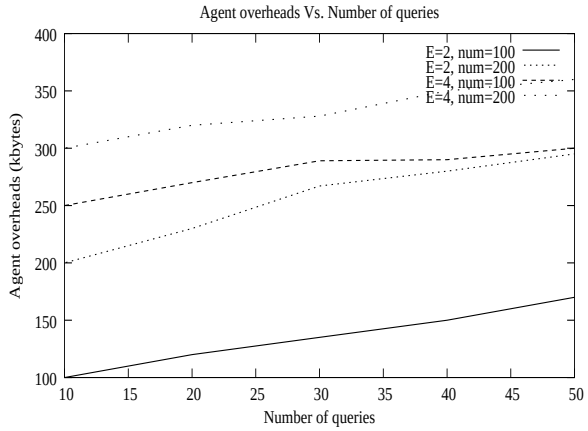

Figure 5: Agent overheads (Mbps) Vs. Number of queries for num= 100, 200

Agents offer flexibility in accessing any kind of events and are programmable to perform any tasks in WSN on behalf of a user/process. Adaptation is inherent feature of agents where it communicates and interacts with other visited query-response agents to know about certain interesting events happened in WSN and may initiate some other agents to take some critical decisions.

4 Conclusions

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