Mobile Agent-based Policy Management for Wireless Sensor Networks

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***Abstract*—Wireless sensor network is a revolution of information sensing and collecting. This kind of networks is composed of hundreds and thousands of sensor nodes in small size with ubiquitous sensing and computing capabilities. The task of management of Wireless sensor networks in environments with hundreds and thousands of sensor nodes is very complex. Until now, wireless sensor networks and their applications have been developed but with the management research in the germinal stages. In this paper, we describe a management architecture for wireless sensor network that combines mobile agent with policy technologies, and take into account the restrict physical resources of this type of network in the form of policies, such as energy and computing power, imbalance of network flow, and faults caused by nodes unavailable. Then the paper proposes the hierarchical architecture of policy management and mobile agent-based network management structure.**

Keywords-Wireless sensor network; Mobile Agent; Policy; network management

I. INTRODUCTION

Wireless sensor network is a revolution of information sensing and collecting. It combines sensor technology, embedded computing, distributed information processing and wireless communication technology all together, to realize monitoring, sensing and collecting various environmental data in the monitored area. A wireless sensor network consists of hundreds and thousands of sensor nodes, which are tiny, low-cost, low-power radio devices dedicated to performing certain functions such as collecting data and sending them to infrastructure processing nodes. They buildup the wireless sensor networks based on their collaborative efforts as shown in Fig.1 [3]. The sink node can be considered to be an access point, and it communicates between task manager node with sensor nodes by Internet or satellite.

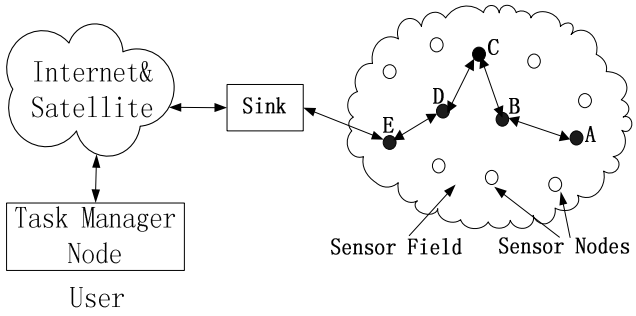

Figure 1. Model of wireless sensor network

Nowadays, a wireless sensor network is becoming an increasingly important technology that will be used in a variety of applications. The large use of wireless sensor networks depends on the design and development of a scalable, low-cost sensor network architecture. This kind of networks is highly dynamic in nature, as sensor networks are formed over wireless links. So, the task of management of wireless sensor networks in environments with hundreds and thousands of sensor nodes and the dynamic nature of the network is very complex.

Until now, wireless sensor networks and their applications have been developed but with the management research of wireless sensor networks in germinal stages [10]. This will definitely be a critical problem when the applications for wireless sensor networks require a large number of sensor nodes. The need to coordinate such large networks as well as their inherent limitations like power constraints, limited bandwidth, distributed coordination and deployment lead to a number of challenges in the design and deployment of a wireless sensor network.

In order to simultaneously satisfy these requirements and constraints, and improving the overall efficiency, we need the management operations of wireless sensor networks. In this paper, we present a mobile agent-based policy network management system for wireless sensor networks, which aims at providing effective management mechanism in the form of policies, in order to satisfy the networking requirements and have them automatically realized in the network by mobile agents, and

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keep the wireless sensor networks running in a normal, stable and reliable way with high efficiency.

II. MOBILE AGENT TECHNOLOGY

In this paper, we introduce mobile agent technology into the network management architecture. Mobile agent is a section of code that can implement user tasks autonomously. A mobile agent can suspend its execution on a node, and then migrate and transfer its code, data state, to another node on the network, and resume execution and access the resources on the new node. When completing the task, the mobile agent returns the results to the source node. Each host provides an execution environment for one or more agents, and the underlying physical network provides the means for agents on different hosts to communicate and migrate [6].

Mobile agent is the combination of distributed and artificial intelligence technologies and it is a kind of intelligent agent with mobility, the main concept of it is to execute in distribution. It can distribute the local tasks to be executed on the nodes with data or nearby nodes, and finally return the executing results. In this way, there is no need to collect all the data executed on only one node. Thus, it can save the network communication bandwidth effectively, and improve the degree of parallelism and real-time performance of the task execution.

The characteristics of mobile agent are dynamic execution, asynchronous computation, parallelism, intelligent routing. In the heterogeneous network, mobile agent can migrate to and interact with the outside autonomously. The advantages of mobile agent are listed as follows:

1) Reduce the flow quantity, connecting time and number of times in network: one the one hand, mobile agent can execute many tasks in right server autonomously and locally, so the flow quantity through the network will reduced to the lowest. On the other hand, mobile agent can execute asynchronously, and reduce the unnecessary network connecting time.

2) Integrate with distributed structure seamlessly: the strongpoint of mobile agent lies in its supporting for distributed structure. Mobile agent can be distributed in many servers, instead of only two servers in tradition, and distribute the tasks properly. Mobile agent will lead the work in resource concentrated node to the node with less work. In the period of peak-load in the network, mobile agent will delay its own tasks or execute the work with smaller load only.

3) Pervasive computing: mobile agent technology keeps away from the bottleneck of network and processing power in pervasive computing. It transfers the interaction and information processing to be executed in host with strong processing ability and security, which is one of the pervasive computing technologies with good applied cost.

III. POLICY TECHNOLOGY

Policy-based networking[2], is a powerful approach to automating network management, as evidenced by the numerous industry efforts in this area dealing with diverse networking domains, e.g., configuration management, quality of service control [1], [9], traffic engineering [6], etc. A policy implies a pre-determined action pattern that is repeated by an entity whenever certain system conditions appear [4].

More recently, in the area of distributed systems management, work in [8] outlined an approach to providing automated support for analysis of policy hierarchies for the management of very large distributed systems. Then, the use of policy-based management for QoS management in wireless ad hoc networks has been studied.

The architectural components of the Policy Framework include a Policy Decision Point (PDP) and Policy Enforcement Points (PEP), and a policy repository. The policy rules stored in the policy repository are used by the PDP, which defines the processes and results of policy rules. It interprets and translates the policy data of logical entities to a device-dependent format and configures the relevant PEPs. The PEP enforces the logical entities decided by policies, including active PEPs and passive PEPs.

Once policies are defined, they are automatically enforced by the management system. These capabilities can provide powerful functions to configure and control their network, and to re-configure their network in response to network conditions, with the highest possible level of automation.

Network management functionality can be realized by policy agents that are organized in a hierarchy to provide both scalability and autonomy. Survivability is achieved by enabling any component to take over the management role of another component in the case of failure.

IV. ARCHITECTURE OF WIRELESS SENSOR NETWORK MANAGEMENT

A. Structural model of network management

Based upon the information collection and communication strategy, there are three types of network management structural models: centralized, distributed, and hierarchical [3]. In a centralized network management system, there is a single manager station that collects information from all nodes and controls the entire network. This is an easy implementation but with some potential problems. For example, the manager station is a single point of failure. Also, if a network partition occurs because of some kind of failure, the portion that is disconnected from the manager is left without any management functionality. In a wireless sensor network, a centralized model will suffer from a high message overhead in data collection. A distributed management system has multiple manager stations; each manages a subnetwork and communicates with other manager stations in a peer-to-peer manner. Using the distributed approach, a network management system could achieve higher reliability

and efficiency as well as lower overhead both on communication and computation resources [7]. Thus, in a large telecommunication network, a distributed model is a better choice. But it is complex to realize and control.

Hierarchical network management systems shown in figure 2 integrate the advantages of the first two management models [5], and use intermediate managers to distribute the manager tasks. Each intermediate manager has its domain called cluster; it collects and processes node information of its domain and passes the information to the upper level manager if necessary, and the intermediate manager is called cluster head. It also distributes the messages from the upper level manager to nodes in its domain. There is no direct communication between intermediate managers.

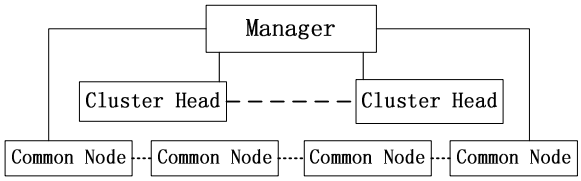

Figure 2. Structural Model of WSN management

However, there is also a problem in the imbalance of network flow, if this structural model above used for wireless sensor network management, because the information flow from to cluster head and nodes to the manager is obviously less than that in opposite direction. Therefore, we can apply two technologies to the management of wireless sensor network, one is mobile agent, and another is policy management.

B. Hierarchical Architecture of policy management for WSN

Policy management is the supply, implementation and verification of the policies. It allocates the resources for user-workgroups and applications.

The hierarchical architecture of policy management for WSN is shown in Figure3. As shown here, corresponding to the structural model above, three levels of this hierarchical architecture begin from the access point. They are Policy Manager (PM) at the highest level, Cluster Policy Agent (CPA), Local Policy Agent (LPA).

The node with best configuration and most dump energy usually acts as the cluster head. An LPA manages a node. LPAs perform local policy-controlled configuration, monitoring, filtering, and reporting, thus reducing management bandwidth overhead, discovering the topology change and improving the network performance. A CPA can manage multiple LPAs. A PM manages multiple CPAs; it is also a policy agent actually. A PM is equivalent to a global PDP, and a CPA is an intermediate PDP, and a LPA is a PEP.

These collections of Policy Agents manage all the nodes in the wireless sensor network. Policies are disseminated from the PM to CPAs to LPAs, or from CPAs to LPAs. Policy Agents react to network status changes on various levels (globally, locally, or domain-wide) by automatically reconfiguring the network as needed to deal with fault and performance problems. In this architecture, any node can dynamically take over the functionality of another node to ensure survivability. A flexible agent infrastructure allows dynamic insertion of new management functionality.

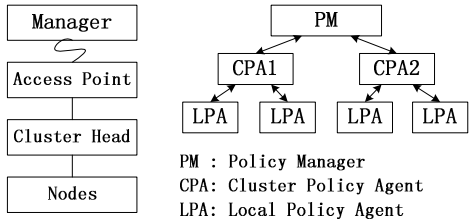

Figure 3. Hierarchical architecture of policy management

C. Mobile Agent-Based Network Management Structure

The policy manager and policy agents of the two levels can all be viewed as an agent with capability of policy enforcement. A complete node in the network includes agent execution environment, policy agent and the real managed node. The execution environment supplies necessary conditions for policy enforcement and agent migration. A policy agent is the key part for management, and the managed nodes are common sensor nodes. The structural of a policy agent is shown in figure4.

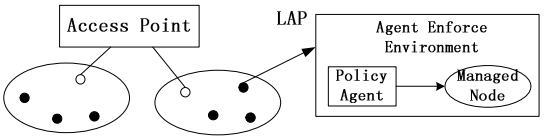

Figure 4. Structure of a Policy Agent

In the structure, the policies are rules, which define the standard of resource access and usage. A policy is an aggregation of rules for devices selection in network, and each policy rule is composed of a series of conditions and relevant operations. The conditions define the validity of this rule. Once this rule is activated, the relevant operations will be executed in a specific rule. The can be defined to executed while the conditions prevail, or not. The policy information base (PIB) is an ordered set representing data types, the structure of which is similar to that of SMI in SNMP.

In original, the wireless sensor network is self-forming, clustering and self-configuration. When the user is to execute some management function, the network manager firstly sends the relevant policy to access point. The access point puts it into PIB, and sends the policy for relevant management function to the cluster head. Then cluster head sends the policy to common nodes, and the common node informs the agent with data to the cluster head after received information. If the agent finds that is not the target node, then returns to access point and be destroyed, with data backup in access point.

Because each agent is kept on standby any time, so the real-time performance is improved effectively, and the data

transmission by agents reduces the communication flow in the network.

V. SUMMARY

Wireless sensor networks represent a new frontier in the development of technology to be used in a variety of applications in the future. But presently, most researches of wireless sensor networks are concentrated on energy efficiency, routings, and locations and so on; the research on management of wireless sensor networks is just at starting stage. In this paper, we propose a mobile agent-based policy management for wireless sensor network. The management system described in this paper shows that a reduction in management traffic overhead can be achievable by mobile agents and policy management. This architecture reduces the network management requirement for bandwidth, and upgrades the imitativeness, adaptability and reconfigurability of network management system. It has a good practical and research value for geographically distributed network environment.

The wireless sensor networks management is very complex, and there is a great deal of scope for further research in this area. It would be interesting to explore the security communication between manager station and cluster heads, the setting of management functions of manager station, the survivability of the network, and so on.

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