# Survey Of A Network Management Architecture In Wireless Sensor Network

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*Abstract*: **Wireless Sensor Networks (WSNs) have become an emerging new research area in the distributed computing environment. It plays an important role in the pervasive computing to support a wide range of applications of our daily life in future. More specifically, such wireless network proposes a new monitoring and control model for applications to operate as environmental monitoring, public safety, medical, transportation and military. Most of those applications share similar features such as difficult to access because of geographical locations where the network has been deployed, the large scale of deployment, high mobility, and prone to failure. Accordingly, the traditional network maintenance and management approaches become impractical under such very dynamic conditions. Furthermore, features such as smart, autonomy, and self-awareness have also been considered as the ultimate vision for WSNs to continuously support various applications in a long period of time. Thus, network management becomes extremely important and vital in order to keep the whole network and application work properly. Until now, there still Doesn't emerge a considerable network management solution for WSN. Most of existing research addresses one or several application-specific problems in WSNs, approaches, and provides discussion and provision of some design issues and requirements for building efficient management architecture for WSN.**

## I. INTRODUCTION

Wireless sensor networks (WSNs) have promised us a new monitor and control model over the distributed computing environment. In general, these networks consist of a large number of sensor nodes densely distributed over the region of interest for collecting information or monitor & track certain specific phenomena from the physical environment. As in Figure1, each sensor node is typically battery-powered, and consists of a processor, sensor, transceiver and other modalities. As sensor nodes are always designed with small dimensions, the size impose. This project is sponsored by ESPRC restrictions on its resources (e.g. energy, communication, and processor capacities), and consequently limits sensor nodes to undertake too much complex tasks. In general, sensor nodes are expected to operate autonomously for a long period of time. Because of limited resource, they always split tasks into individual portions, and coordinate with each other to achieve a big objective. These days, WSNs are likely to operate under very dynamic and critical environment with applications such as environmental monitoring, public safety, medical, transportation and military. Sensor nodes are usually difficult in access because of the geographical locations where they are deployed or the large scale of network. Thus, network maintenance for reconfiguration, recovery from failure or technical problems becomes impractical. In early days, this problem can be ignored as WSNs were supposed to operate cheaply and ready to be disposed. If the system breaks or underperforms, more nodes will be deployed to cover the failure. While, researchers have recently found out that this vision is not always a case within our reach since resource (e.g. the sensor nodes, batteries on which they operate) are not that cheap. In addition, we would also like to get the most out of the system we have at hand, which requires the WSN to cooperate with various application rather than setting up a new network environment. Therefore, WSNs are indeed in need for some sort of management to continuously work without too much human being intervenes. Management of WSNs is a new research area that only recently started to receive attentions from the research community. It has already presented a set of significant management challenges. The operation of a WSN is greatly affected by different inter-related factors such as network traffic flows, network topologies, and communication protocols. The interactions among those factors are still not clear yet. The environment also imposes a deep impact on the wireless network performance. As a different enough from traditional computer network. This short survey paper first summarizes some unique features, which are most likely to be considered in design of management architecture in WSNs. Secondly, it provides some design provision and discusses of considering management architectures in WSNs. These ideas derive from several existing research prototypes. This paper also highlights some management features from current state of researches, which support WSN operation in various aspects.

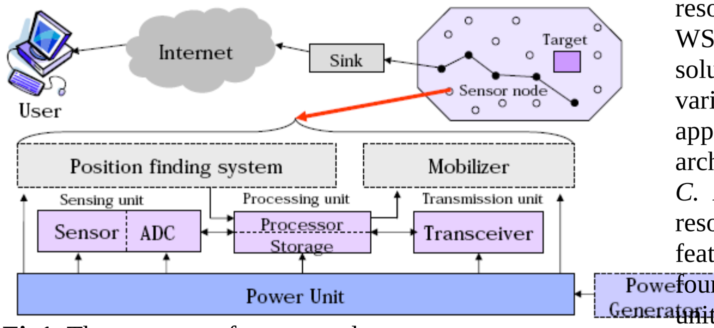


**Fig1.** The structure of sensor nodes

This paper is organized as follows: Section 2 presents some specific features of WSNs; Section 3 summaries several design issues and requirements for management architecture; Section 4 overviews some desirable features of future existing research approaches, which are catalogued into different aspects.

## II. SPECIAL FEATURES OF WSNS

This section discusses some unique features of WSNs, which need to be taken into account when designing management architectures in WSNs.

*A. Different types of nodes:*-WSNs involve with three types of sensor nodes: *common nodes* mainly responsible for collecting sensor data, or occasionally involving with collaborated tasks with neighborhood nodes. Due to constrained resource, common nodes don't have extra storage space to hold large amount of sensor data (or processed data). It may take simply data processing if necessary; *sink nodes* responsible for receiving, storing, and processing (e.g. Aggregation) data from common nodes; and *gateway nodes* that connect sink nodes to external entities (e.g. sensor applications, traditional enterprise application) called observers. In addition, *actuators* can also be introduced to control or actuate on a monitored area in WSNs.

*B. Application-Specific:* In general, WSNs are tightly application-dependent. The constrained resources (e.g. processing, storage and transmission range) limit sensor nodes in WSNs to accommodate a wide variety of applications as the traditional network does. The designs of applications and management architectures in WSNs are also dependent on application semantics (e.g. application-specific data processing combined with data routing). As a result, application designers have to develop many complex and special program to perform node localization, data routing and data aggregation tailored to specific sensor applications. Thus, it is not likely that those programs can carry over directly from one application to another, since the application-specific requirements on WSNs are varied in terms of resource usage and communication patterns. Recent WSN research has focused increasingly on the solutions that can accommodate the diversity of various sensor applications by integrating the application knowledge with management architectures in WSNs.

*C. Resource Constrains:* As mentioned previously, resource-constrains of sensor nodes is another unique feature of WSNs. Sensor nodes usually compose of four basic units as in 1: a sensing unit, a processing unit, a transceiver unit, and a power unit. The power unit supports all the activities on a sensor node, including communication, local data processing, sensing, etc. The lifetime of a sensor node is mainly determined by the power supply since battery replacement is not an option in sensor networks, especially in critical environments as battlefields or environment monitoring. The longer the lifetime of a sensor, the more stable the WSN. In order to save power, redundant activities should be reduced if not eliminated.

*D. Network Topology:* Network Topology represents the actual topology map and the reach ability of sensor nodes in the network. Note that the topology in WSNs may be dynamic due to the nodes changes. For example, nodes may fail (either from lack of energy or from physical destruction), and new nodes may join the network. Therefore, the network must be able to reconfigure itself periodically. As a result, network topology has been considered as an important feature when considering the management structure in WSNs.

*E. Fault Tolerance:* Failures are prone to happen in WSNs, which normally include sensor nodes failure (as discussed previously), and communication failures etc. Although the sensor application may have already considered this in their design, there is still a need for WSN to have the ability to reconfigure and recover itself without too much human being intervene, especially in inaccessible environment.

 

**III. NETWORK MANAGEMENT IN WSNs**

The unique characteristics and restrictions of WSNs make the management approach different enough from the traditional wired networks and the emerging mobile adhoc wireless network. Thus, it is necessary to take those unique features into account when proposing efficient management architectures for WSNs. This section discusses some design issues and requirements for proposing efficient management architecture in WSNs.

*A. Lightweight Management Architecture:* Sensor nodes in WSNs are generally operating with very tight resources. Thus, the management architecture should be designed as lightweight in terms of the computation and communication requirements. The traditional distributed approaches, which base on DCOM, CORBA etc., are normally heavyweight, and therefore not applicable in WSNs with scare energy and processing resources. In addition, those approaches mostly rely on "request/response" synchronous communication model, which is misfit for the nature of WSNs where the communication is mostly event-driven asynchronous, and also prone to fail due to unpredictable errors.

*B. Localized Management and Coordination:* In order to reduce redundant activities and thus save power of sensor nodes, localized approach has been well considered as the solution. It can intelligently select and group a subset of sensor nodes to participate specific objectives such as communication or coordinated computation tasks. The participating nodes only need to coordinate with their neighbor nodes. This reduces a large amount of redundant data instead of always routing management messages back to the sink node (e.g. base station) over the network. Thus, it can prolong the lifetime of WSNs by saving sensor nodes' power energy. Localized approach can also provide sensor applications and management architecture with good scalability and robust distributed sensor coordination, especially within large scale of network environment. In particular, clustering as shown in Figure 2, is a good example of localized management. It forms the virtual backbones for managing wireless sensor network and ad-hoc wireless network by grouping sensor nodes into each individual group / vicinity. The cluster-based architecture can localize the interaction and communication of sensor nodes, and hence reduces the amount of communication messaged flooding over the network. Although clustering appears more application-specific (e.g. especially on data routing and data aggregation etc.), the essential concept from this decentralized structure is still applicable in design of network management architecture in wireless network. The project ANMP has distinguished its cluster formation for management purpose from application-specific routing and data aggregation purposes. Proposes a cluster-based hierarchical structure for designing self-organization management in WSNs, in which the lower-level cluster nodes are managed and organized by the higher-level ones. Moreover, in a cluster-based middleware framework, adopts the cluster as a basic function unit for distributed resource management in a dynamically changing wireless environment. Thus, the middleware architecture acts as a distributed software composed of multiple clusters. In particular, clustering is also used in the fault tolerance management, which supports hierarchical based network with enough fault-tolerance or redundancy ability to recover from node failures

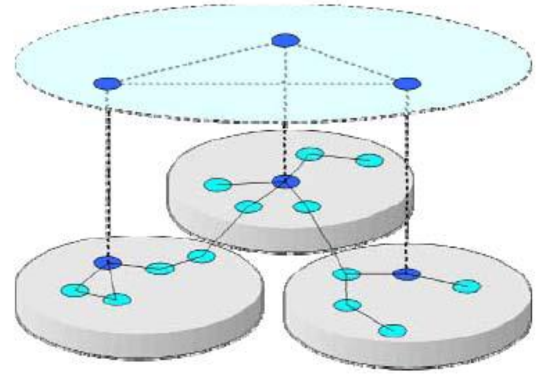

**Fig2. Cluster structure in WSNs**

*C. Generic Management Functions*

It is most likely the structure of today's WSNs is application-dependent. The design of traditional WSN management architectures also encapsulates application specific tradeoffs in terms of data routing, resource utilization and communication patterns. Hence, it becomes unfeasible to carry out the existing management architecture directly from one application to another as the requirements on WSNs are varied. In order to continuously support and coordinate various concurrent applications in WSNs, a degree of generic for different applications with common interface has come to a need. Recent WSN research has already started on the separation of application semantics from the underlying hardware, operating system, and network infrastructure. In particular, a generic role assignment framework has been motivated to support various sensor applications to self-configure nodes on taking specific functions or roles (e.g. clustering, data aggregation) in the network without manual intervention. A reconfigurable middleware service proposes the generic group management of sensor nodes, which varies either from service to service (e.g., security, fault-tolerance, power management) or according to dynamic system conditions (e.g., power level, connectivity). Moreover, Stefan also studied on a generic abstraction for the definition of groups of nodes, which bridges the gap between high-level application specific query requests and underlying WSN resources. The ongoing MANNA architecture has started considering a three-dimension management architecture, which consists of function areas, management levels, and WSN functionalities. More generic network management functionalities will derive and abstract from those management dimensions. While, a particular generic architecture still doesn't emerge yet which mostly concerns and leverages the unique features of WSNs and also accommodates the diversity of various sensor application.

*D. Integration with Application-knowledge*

In order to design a generic management architecture, applications-specific semantics and complexities are required to separate from the core management structure. While, such generic management structure still needs the application-knowledge to direct its operations in order to tailor to the special needs from one application to another. It is thus important to seek an efficient mechanism to inject application knowledge into the infrastructure of management architecture in WSNs and also integrate it with the management services. A cluster-based middleware architecture has proposed a "virtual machine" to compose the operations of the middleware with injected application knowledge for diverse applications.

*E. Adaptive Reconfiguration*

In recent years, wireless sensor networks have gradually appeared to be the long-running computer systems rather than temporary or emergency usages after first deployment. They are required to continuously work in the same environment to gather information for various sensor applications. This requires robust adaptation ability of the underlying management architecture. In which case, the management architecture needs to reconfigure its operations and functions (even its structure) reflective to the changes of environments and circumstances. Those changes may vary due to the requirements from sensor applications, application migration from one to another, or even underlying sensor nodes which typically operate with very tight computation and energy constraints.it has looked into this research problem by use of modularity-based approach to update / change programs in remote sensor nodes. Sensor nodes are thus able to load with various application protocols for routing data back to the base station whenever these applications are applicable under different conditions. Subsequently, sensor network can discern the needs of individual applications and adjust itself automatically.

## IV. DESIGN OF NETWORK MANAGEMENT ARCHITECTURE IN WSNs

In this section, we present some visions for the design of an efficient management architecture for WSNs after surveying several relevant ongoing research prototypes. We think such architecture should be the lightweight design, adopting a layered architecture and have the robust ability and knowledge to adapt its behaviors and operations, which is supported by the policy-based management. The concept of service from Service Oriented Architecture (SOA) can also contribute to designing more flexible management services by integrating a or a set of existing management function units in the WSN.

*A. Layered System Structure*

The layer-based system is a common approach adopted by existing management architectures in WSNs. It has several significant advantages against the monolithic approach. First, it is easier to precisely program individual functional components for various sensor applications and management functions rather than designing a super system with static integrated functions. Second, software changes such as adding, removing, or modifying a management function can be simpler because it only involves local code changes within a selected layer. By contrast, in a monolithic approach, even small changes may have global repercussions elsewhere in the whole architecture. The layer-based approach can also efficiently support management architecture in terms of lightweight design. As a result, energy-constrained sensor nodes can selectively choose essential function layers to load into their management architectures according to the role assignment in networks (e.g., cluster-head, or common sensor nodes) or even energy levels. In particular, application components in the upper layer of Impala middleware architecture are programmed separately without affecting each other. Agents in the lower layer take care of the switching decisions among those application components. In a lightweight cluster-based middleware approach, sensor nodes are implemented with different functional layers (e.g. Cluster Layer, Resource Management layer). Due to their roles in the network, cluster-heads will implement all the functions layers as they have extra resources. MiLAN middleware approach provides an abstraction layer for low-level network specific plug-ins to convert MiLAN commands to protocol-specific commands. Thus, MiLAN can sit on top of multiple network plug-ins for handling various physical networks. Tiny Cubus also encourages a cross-layer framework design rather than strict layering-based communication model, in which components can flexibly get the information provided by others in the system.

*B. Distribution of Management Function*

Traditional centralized sensing architectures mainly support specific applications such as location systems in a small WSN. However, it becomes impracticable when the network size has dramatically grown up. One main reason is the traffic concentration problem, which is caused by the fact that all the measurement and decision messages have to come from or back to the centralized base station. Such approach is not energy-efficiency, as the network data transmission is much expensive than the localized computation operations in WSNs. Thus, management operations and decision-making are most likely to perform in a distributed way within the resource-constrained WSNs. For example, Yu etc. considers the distribution of cluster forming and control protocol to every sensor nodes in the network as information of node status measurement (including data accessibility, node capability or network connectivity etc.) is more efficient to handle locally by sensor nodes. Specific commands and requirements from application-related knowledge can further be passed down to sensor nodes from their cluster heads. In MANNA, it describes a decentralized management approach, which distributes management functionalities among manager and agent in WSN, each of them takes individual role to maintain the network with different functionalities. It is likely to have a diversity of managers and agent locations in such architecture. Therefore, it minimizes the traffic generated by management, as all the measurement and decision messages can thus be dealt with in the local region or locally by individual sensor node.

*C. Policy-based Management*

Policy-based management has presented its robust ability to support designing of self-adaptive decentralized management service in WSNs. In MANNA, policies describe a set of desired behaviors of management components (e.g. manager and agent) for indicating the real-time operations. Based on polices, managers and agents can interact with each other in a cooperative fashion to achieve a desired overall management goal such as form groups of nodes, control network density, and keep the coverage of the WSN area. The reconfigurable group management service integrated with Mire project adopts the policy-based approach to describe the set of predefined behaviors for its dynamic group management service at runtime. TinyCubus, the generic reconfigurable framework, also uses distributed roles (similar to policies) to describe the tasks of sensor nodes in WSNs.

*D. Information Model*

In general, policies or roles discussed previously also specify the conditions that should be satisfied before executing management operations for any desired goals. In this way, applications can select the most appropriate policy to tackle requests or changes from the network. The conditions for executing certain management functions largely depend on the information reflected from the real-time network state. A network state can usually be viewed from different perspectives and varies from time to time. In particular, the MANNA architecture describes two kinds of management information: static and dynamic to represent the network status in different aspects. Static information describes the management service configuration in details, and both the network and network element information including network connectivity and organization etc. Such information is organized by an object-oriented information model. Based on this model, managers and agents in WSNs can exchange management information. Dynamic information in MANNA covers aspects including sensing coverage area map, communication coverage area map, network topology etc. They are described by special WSN models, which are retrieved periodically for tracking the state changes of network. MANNA also uses those WSN models as a reference to the management functions. While, the acquisition of those information in WSNs is still energy consumption. Therefore, an important aspect is required to determine the adequate moment, frequency, and fidelity for updating that information.

*E. Service-Oriented Management*

In decades, service-oriented architecture (SOA) has been well proven as the next generation of software architecture in the distributed computing environment. It decomposes the design of large complex application, and middleware architecture into various reusable services or function units. Those services and function units can be flexibly combined or integrated in a loosely coupled manner at either design or run time. The standardized service interface and communication protocols (including standard data format as messages) also hide a way the diversity of implementations of various services and functions units from end-users. Thus, the application developers only need to concern the operational description of the service. Furthermore, SOA can specially deal with WSN unique aspects such heterogeneity, mobility and adaptation, and offers seamless management integration in the wireless environments. Although the special features of SOA are marvelous, there is still a large amount of research challenge needed to address before the concepts of SOA can be appropriately applied into WSNs. One main research challenge is to leverage the heavy-designed SOA into the resource-constrained WSN. So far, the implementation and design of SOA is mostly dependent on Web Services with standardized web technologies such as WSDL, OGSA. As a result, it is not applicable to directly implement all of those complex technologies on those resource-constrained sensor nodes.MANNA has presented some initial ideas of using the concept of service semantics from SOA. In MANNA, all the management function units sit at the lowest level of management architecture. They are designed with specific implementation for individual objectives in consideration of unique features of WSN. A service, at the top layer, can use one or more of those management functions. Different services can share the same functions, but still concern each individual given aspect based on the polices and network state obtained from WSN models.

**V. CONCLUSION**

As a new research area, wireless sensor network has represented its robust usage in the future distributed computing environment. However, there still needs significant work to address a set of technical challenges. One of the biggest challenges is the designing of efficient network management architecture to continuously support WSNs for providing services for various sensor applications. The unique features of WSNs make the design and implementation of such management architecture different enough from the traditional networks. As pointed out earlier, there is still no particular generic network management architecture emerged, which can provide network management independent of application-specific. In this paper, it first presents several principles for designing a network management architecture in WSNs. It then overviews some ongoing research work of management architectures in WSNs from different aspects. Finally, it summaries several management features which will appear in the future management architecture.

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