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Extended Support with Level Based Hierarchical Management Model for WSN: Survey and Conceptual View

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Abstract: Wireless sensor network is a set of wireless sensor nodes without a fixed network structure. The sensor nodes are constrained with limited battery energy to operate with. These nodes are used in gathering environmental data and used in military operations, forests search or count operations and many other operations where human monitoring is difficult and impossible. The nodes maintenance is also absolutely difficult due to the deployed locations inaccessibility and lack of continuous power supply. To overcome these difficulties many research attempted to achieve the maximum network lifetime and batter efficient wireless sensor infrastructure through efficient routing, system design and architecture. In this study, we present a survey of such system designs to understand the network organization and functionality and analysis of the limitations to propose a better theoretical model of network management which helps to perform the network in efficient way.

Key words: WSN management, wireless sensor network, clustering, human monitoring, theoretical model

INTRODUCTION

Wireless sensor nodes became cheaper, smaller and light weight and hence the main energy source, i.e., the battery size is also smaller with the recent evolvement and advancement of microelectronics theory and concepts. The continuous monitoring and sensing of the environments of a specific area is the most important reason for wireless sensor networks as it is almost impossible due to extreme environmental conditions for human beings to stay and monitor the environmental change and detect the changed behaviors. The environments where the wireless sensor nodes are deployed are in the area of active volcano, difficult terrain border lands, bridges, battlefields, roads, sluices, etc. where it is often low possibility to replace or recharge the dead nodes as well. The continuous monitoring nature of sensor nodes drops the battery energy and hence reduces the network lifetime. Therefore, energy management and conservation is a serious and critical issue in designing of sustainable and elongated wireless sensor networks infrastructure. Energy conservation should be gained by wisely management of energy resources. The first step to reduce the energy consumption of WSNs is to know the most energy consuming parts of these networks which are important in choosing the appropriate method. Energy consumption of communication subsystem is much more than that of computation subsystem. It is shown that transmitting of a bit of data needs to same amount of energy as running of a few thousands of instructions (Das and Misra, 2015). So, there should be always a competition between communication and processing tasks which will lead to a better conservation of battery energy. Thus, many researchers found it reasonable to turn off the radio as long as it could be and should be used when actual transmission is required. On the other hand, sensory subsystem also found to consume energy substantially. However, the research is still on to reduce the energy consumption through sensory and also the advanced device is getting into picture to reduce the energy consumption through sensory unit. It is observed that many research studies around the world hav been done to reduce the energy consumption of radio communications. So far, a number of energy conservation methods have been suggested in the various literature, most of them focused on special layer ofprotocol stack such as several MAC protocols that have been proposed in the literature and comprehensive survey studies on them as by Heinzelman *et al*. (2000) or several routing protocols and survey studies on them (Xu *et al*., 2001; Lee *et al*., 2006). But, more comprehensive survey studies on energy conservation approaches of WSNs with a different viewpoint have been presented by Kamila *et al*. (2010, 2015. Researchers in (Anastasi *et al*., 2009) also presented a perfect taxonomy which divides all energy efficient approaches into three main groups: duty-cycling, data reduction and mobility based approaches, etc.

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MATERIALS AND METHODS

System organization: The management system organized based on 3 models:

- Centralized
- Distributed
- Hierarchical

Before we discuss the management system organization model let's discuss briefly the different management operations that provides to choose the competetitive system model (Fig. 1).

Passive monitoring: The system collects the static data of the network health and node energy state.

Fault detection monitoring: The management system collects information to identify whether there is any fault in the network system.

Reactive monitoring: The management system to gather the information to reconfigure the network in case of the event of necessity.

Proactive monitoring: The management system to analyze collected data and predict the future events. Now let's discuss on the 3 types of management model (Fig. 2).

Centralized model: The base station controls the network completely by collecting the information from the network. This centralized manager is performing all network operations as it has all the capacity to execute the management task and to reduce the management operation task on the nodes.

Distributed management systems: This management model deploy multiple manager stations and these manager stations will execute the management tasks and may communicate with other manager stations. The communication cost is low but to maintain the distributed system model is complex and high computation is required to manage the management stations.

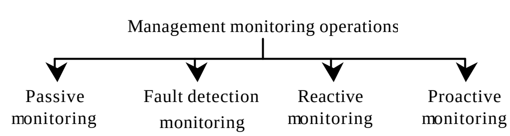

Fig. 1: Management operation

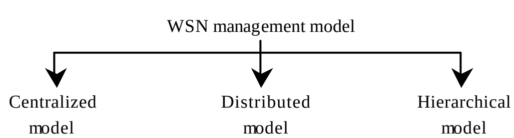

Fig. 2: Management system nodes

Hierarchical network management: It is a hybrid system between centralized and distributed system. Intermediate managers execute management tasks and directly report to the centralized manager.

System design: There are some criteria as discussed below, based on which wireless sensor network management system performances are evaluated.

Lightweight operation: Management system should avoid running on the cost of sensor nodes battery energy. If the management system design consumes more energy then it will degrade the network operations and the lifetime of network will be reduced.

Robustness and fault tolerance: A network management system should be resilient to reconfigure the network in instance of node dying, packet loss, etc.

Adaptability and responsiveness: A system should be able to get the network state and adaptive to the network topology change. As wireless sensor network is not based on the fixed network structure, so adaptiveness is very much necessary for a well performed WSN network.

Minimal data storage: The data model for the management system is to be minimal as to respect the WSN memory constraints.

Scalability: The network management system should not be constrained to operate only on small sized networks or only on big sized network. It should be capable to perform if network size changes dynamically.

Review of WSN management models: We discussed here three different types of models, i.e., functionality based, routing based and fault detection based models. All these models are briefly discussed as below.

Functionality based protocols: There are mainly two functionality based protocols, MANNA and BOSS.

MANNA: This is based on multidimensional plane for physical, informational and functional. The physical plane responsible for interfacing different network connectivity based on to the protocol profile. The informational plane is responsible to collection of information and processes them. The functional plane is responsible for configuration of application specific data and environments.

BOSS: BOSS (Bridge of Sensor S) is an architecture based on standard service discovery protocol. UPnP (Universal Plug and Play) is a set of protocol where devices in the network will discover the devices seamlessly and communicate with each other. Researcher Song found that the sensor nodes are not suitable to use UPnP protocol as it consumes lot of energy and hence it was addressed by implementing the UPnP agent at the base station and hence creating the bridge between managed sensor network and the UPnP based network. The proposed system by researcher has 3 main components UPnP control point, BOSS and the non-UPnP sensor devices. The control unit is continuously power supplied and having sufficient resources to run UPnP protocol and could communicate with the non-UPnP protocol based sensor nodes using BOSS architecture implemented on base station. Base station is also a continuous power supplied divice and is capable to run the UpnP agents.

Routing protocols: Routing protocol also alternative approach to monitor and control the wireless sensor network. In this context four different protocols could be taken into considerations are LEACH, PEGASIS, DD and RTRA.

LEACH: One of the most important hierarchical routing protocols is LEACH (Heinzelman *et al*., 2000). In this protocol with one node acting as a cluster head, sensors organize themselves in local clusters. To balance energy consumption, a randomized rotation of cluster head is used. The figure below shows that the simulation results shows the LEACH network lifetime is significantly more approximately 40%) than the conventional flood based routing.

GAF: GAF (Xu *et al*., 2001) which stands for geographic adaptive fidelity focuses its architecture on the extension of the lifetime of the network by exploiting node redundancy. This node redundancy is achieved by switching off unnecessary sensor nodes in the network without any effect on te level of routing fidelity.

DD: The other is Directed Diffusion (DD) (Ma *et al*., 2010) in which sinks broadcast an interest message to sensors, only interested nodes reply with a gradient message. Hence, both interest and gradients establish paths between sink and interested sensors.

RTRA: In RTRA, researchers have approached a reverse transmission approach where the repetitive transmission towards the cluster-head from intermediate-nodes and again from intermediate nodes to same cluster-head is reduced. This approach has effectively managed the energy consumption which could be applied extensively on other hierarchical protocols.

Fault detection based models: WinMS and sympathy (Ramanathan *et al*., 2005) are two such important models under fault detection model of wireless sensor network. In order to provide self-stabilization and self-configuration.

WinMS: This uses systematic resource transfer and capable to establish the self configuration and stabilization in local and global layer of wireless sensor network. With this implementation, the nodes in the network will listen the network activities for a specific period of time and then with the data collected with this listen process will be used to self configure. WinMS uses the TDMA-based (Time Division Multiple Access) MAC protocol in order to support resource transfer among nodes in the network. So, through the mechanism of central recovery, it adjusts the network topology.

Sympathy: Sympathy protocol, on the other hand, only provides support to debug and detect the failures in wireless sensor networks. It does not provide support to automatic reconfigure the network. By detecting the failure nodes, it able to identify which nodes deliver insufficient data to the sink node or base station. The major disadvantages are that it has to share the intermediate neighbors' information which is a cost effective and consumes maximum energy. Figure 3 describes different WSN key functions or activity.

WSN key functional

Configuration management: It is a management activity to set the network and based on the

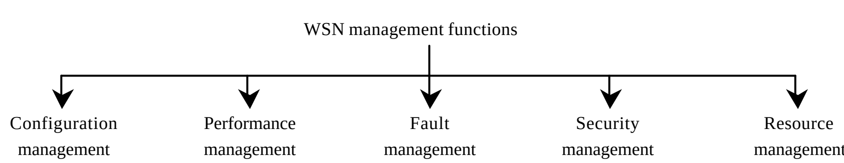

Fig. 3: Types of management functions

Table 1: Resource management

SN systems	Arcitecture	Model	Energy efficient	Memory efficiency	Scalability
BOSS	Centralized	Management function	Yes	Yes	Yes
MANNA	Hierarchical	Management function	N/A	N/A	N/A
LEACH	Distributed	Routing protocol	Yes	Yes	Yes
PEGASIS	Centralized	Routing protocol	Yes	Yes	Yes
DF	Distributed	Routing protocol	Yes	Yes	Yes
RTRA	Distributed/centralized	Routing protocol	Yes	Yes	Yes
WinMS	Hierarchical	Fault detection	Yes	Yes	Yes
Sympathy	Centralised	Fault detection	Yes	Yes	No

necessity to re-set the network in such a way that the network is alive. Configuration management is to get the data from the sensor nodes based on which it will be able to re-configure the network.

Performance management: This is a management task to keep monitoring the nodes to ensure the smooth network operations. It will collect performance data, record the historical data and monitor the power consumptions. Through this, the network is able to sense the health and could able to analyze the network state.

Fault management: This management enhances the network reliability. Fault detection used to identify the network device error or any unwanted event due to which the network is not able to operate as usual.

Security management: This facility ensures that there is no theft of data and the network data is not erroneous. In order to establish this, the policy is set to restrict the network access and limiting the network resources access to the external network.

Resource management: This is a derived concept which introduced in this study in later sections. The network is capable to execute the management task but may lead to get dried out soon as due to the additional execution of management task. Hence, the resource management is adopted to introduce the additional supportive resources which will support the management as an additional resource (Table 1).

Proposed design model: Existing design models such as centralized, distributed and hierarchical based model has performed based on the network size and configuration complexity. In this context, we propose a new system design model called Extended Support Level based Hierarchical model (SELH) where all hierarchy responsibility is based on level of management and each hierarchy level there is a supportive individual or group who could share the load of management task in order to avoid the fast dry out of residual energy.

RESULTS AND DISCUSSION

Level of management: There are basically three level of management, low-level, middle level and top level management. Each level of management in wireless sensor network, there will be a supportive station or node (s) as shown in Fig. 4 which will share the load of performing network and management task. In this way the nework will achieve the following advantages:

- The load of primary node or station is shared with secondary node/station. The energy consumption will be shared and hence the energy dry-out will be delayed and the network will active for an extended time period
- The information always available with the other support (secondary) station/node. So in case of primary station/node failure, the secondary node/station will always take the responsibility and delay time will be reduced

Let's discuss on the responsibility of each level of management.

Low level: The nodes are responsible of the following task executions (Fig. 5).

Data gathering: Each node performs their main task, i.e., gathering the environmental data.

Data forwarding: The sensor nodes are responsible to forward the data to the cluster head or next neighbor node based on the protocol selection. For instance in LEACH, the individual node will send the gathered information to the cluster head. In PEGASIS it will be forwarded to the nearest neighbor.

Self learn: The node should learn and becoming expert gradually based on the experience gained over the time. For instance, the nodes should not transmit the data which already transmitted and node should not transmit data to those nodes which already do not participate in the network.

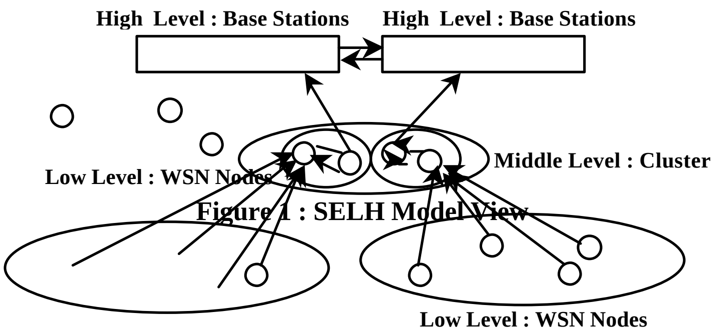

Fig. 4: SELH model view

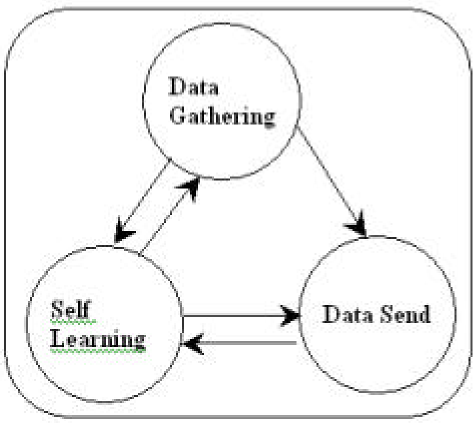

Fig. 5: Low level responsibilities

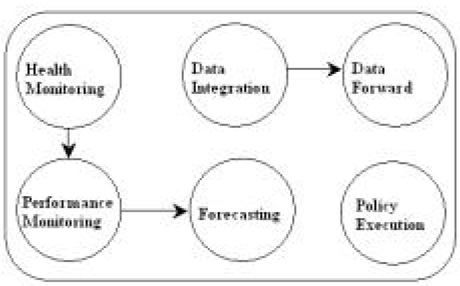

Fig. 6: Middle level responsibilities

Middle level: This level responsibility basically based on the group management. Here group refers a specific cluster or group of clusters based on the network density and topology. The following responsibility mainly included under this level (Fig. 6).

Health monitoring: This level nodes/stations monitors the individual node's health.

Data integration: Integrate the collected data from the set of nodes and send to the top level manager station in specified regular intervals.

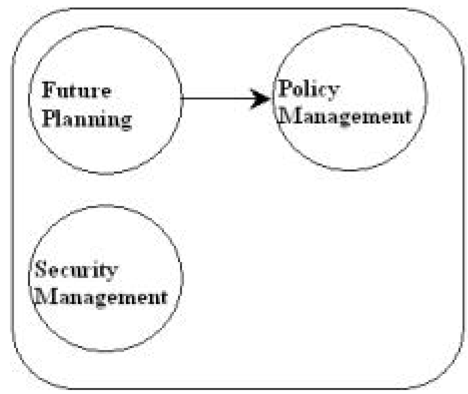

Fig. 7: Top level responsibilities

Performance monitoring: Based on the data received, their performance to be evaluated and sharing the information with the top level manager stations.

Forecasting: These level nodes to forecast the network state based on the individual nodes health and their performance. These forecast data is shared with the high level nodes for future planning.

Policy execution: These level nodes are responsible for the policy execution which is set by the top level manager stations.

Top level: In this level, the responsibility is based on to provide support to the middle level and implement policies to enhance the coordination and performance of the network. These include the following responsibility (Fig. 7).

Future planning: Based on the network state and individual nodes performance data shared by the middle level, the high level could forecast and reconfigure the network.

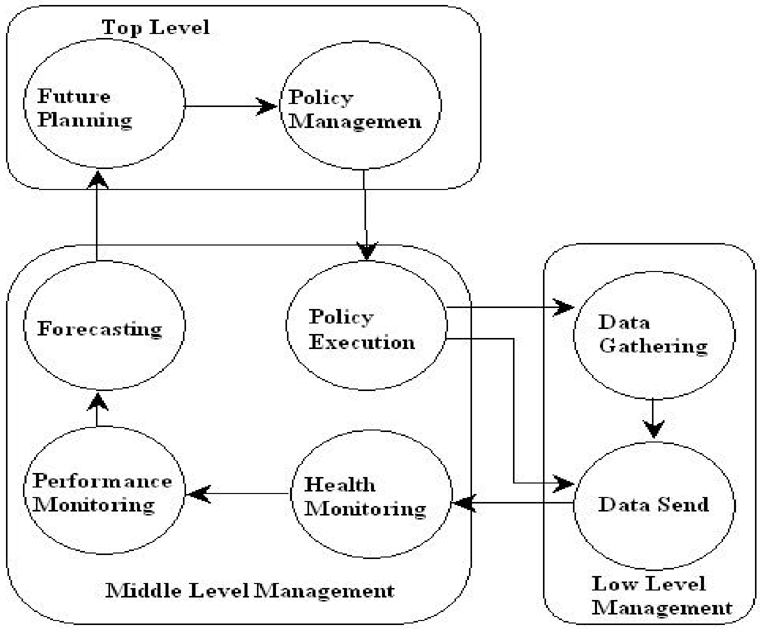

Fig. 8: Inter level message flow

Policy decisions: The high-level stations will determine different policies, e.g., whether nodes to adopt active or inactive for certain time interval or traffic to be off from certain regions, etc.

Security management: Top level manager stations should protect the network from outside attackers and should able to not disturb the network structure due to external disturbances.

Message flow: The important management task message flow is shown in below figure. The basic proposed SELH management data flow is as follows (Fig. 8).

Low level nodes are responsible to send their health monitoring information (residual energy) to the next middle level management nodes or management stations. As we earlier discussed, they are also in process of self learning to gain expertise on their basic task, i.e., data gathering and data send.

Middle level management nodes will gather the health monitored data and evaluate the performance. Based on the evaluation, the forecasting will be made and the forecasting report will be shared with the top level management. The forecasting task could also be part of the top level management task if extended support is necessary. These levels also make policy executed on low-level nodes on their regular task, i.e., Data gathering and data send. These policy may include, only data gather but do not send for certain time or regular interval data send or do not gather and do not send. These policies are adopted by the high level management station in order to extend life time and for network security.

Top level nodes will receive the performance evaluated data and will generate the performance report based on the extended support required level. This report will help to determine the future forecasting and planning the network management and whether network reconfiguration is required or not. Based on this inputs, the management will find the strategy and frame the policies to acquire the target goal, i.e., network efficiency, extended network life time maintenance, secured network, etc. This policy frame information will be dissipated to middle level for execution and middle level will execute this policy by sending the information to low level nodes.

CONCLUSION

Researchers have reviewed the Wireless Sensor Network Management different models in this study. The proposed Extended Support and Level based Hierarchical model (SELH) is a derived concept to re-organize the management structure based on the level of management. With this model, the self built wireless sensor network infrastructure will be more managed and efficient. The extended support model will make the management load balanced and hence will prevent the individual nodes to get dried out due to management task load. The implementation of this derived concept is the future scope of the work.

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