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Overview of WSN Infrastructure Models, Design & Management

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Abstract:-Network management for Wireless Sensor Network Infrastructure is a challenging area where the management operation is to run on very minimal or zero cost. The network data packets routing costs more, hence managing this unstructured network improves the network efficiency and extend the network life time. The deployed sensor nodes have a fixed battery life and there are also some attempts made to manage this WSN network efficiently. In this paper we focus on different networking parameters used to measure efficiency, different network functionality and different design structure evolved in this area.

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1. Introduction:

Wireless Sensor Network is a sensor network infrastructure which stands without the fixed network structure. The network is self-build and traces the route of its own over the time and network communication. The sensor nodes capable to sense the environmental change and then broad cast the data through their antenna. The other nodes within the antenna range will receive the data and again broadcast the data through its antenna. In this wat the sense data moves forward and finally reaches to the base station from where the fixed network structure starts and the data will be send through the fixed networks. So the management of this individual discrete network based structure is highly sensitive and the mismanagement would lead to the destruction of the network. 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. A network management system designed for WSNs should provide a set of management functions that integrate configuration, operation, administration, security, and maintenance of all elements and services of a sensor network. We focus on applications that provide management schemes in terms of monitoring and controlling WSNs. Security management is beyond the scope of this chapter. Monitoring individual nodes in a large sensor network may be impractical. It is sufficient to control the network by ensuring specific network coverage. Furthermore, sensor nodes are typically deployed in remote or harsh conditions and the configuration of nodes in WSNs changes dynamically. Thus, a sensor network management system should allow the network to self-forming, self-organize, and ideally to self-configure in the event of failures without prior knowledge of the network topology.

2. Node Types:

There are mainly three types of nodes in Wireless Sensor Networks. They are described briefly as follows.

a. Common Nodes:Common nodes are executing main task e.g. collecting the sensed data and cluster with neighboring nodes. They run on very limited battery energy and have very limited memory space to hold the sensed data. Hence as soon as they collect the sensd data, they forward to the neighboring node. These nodes may involve sample application processing, but avoids complex data processing.
b. Sink Nodes:Sink nodes are special category of common nodes and are responsible for receiving and aggregating the data sent from the common nodes. These sink nodes are hardly involved in collecting the sensed data.
c. Gateway Nodes:Gateway nodes are mainly involved in connecting the link between the sink nodes to the application servers where the actual data processing happens and these servers sometimes called as observers.

The brief description of three different types of nodes' behavior as follows.

2.1 Application-Specific :

WSNs nodes are different from other non-WSN nodes in terms of power usage, processing speeds and memeory storage. The non-WSN nodes are having sufficient source of powers, memory and storage area on the other hand, the WSN nodes are having fixed size on these parameters. Hence WSN nodes are application-dependent [4]. The design and architecture of applications which intends to run on WSN nodes should be optimized to run with minimal energy, limited memory and less processing speeds. Hence the application developer have to build the application keeping these factors in mind while developing the application for the sensor nodes.

2.2 Resource Constrains :

As mentioned previously, resource-constrains of sensor nodes is another unique feature of WSNs. Sensor nodes areconstituted of four basic components; sensing unit, processing unit, a transceiver unit, and a power unit. The power unit takes care all the activities e.g. communication, data processing, sensing, etc. The network lifetime is deends on the battery ower of each nodes, and the replacement of battery is not feasible for wireless sensor nodes especially for some of the critical area such as battle fields, war or hazardous zone etc.

2.3 Fault Tolerance :

The WSN nodes are to be self-capable to recover from the fault situation. A fault is a node failure or communication failure. The WSN applications would also have considered the application failure recovery feature. However, in either of the case, WSN nodes need to recover from the fault behavior and re-configure the network in such a way that it is resilient to the internal and external network systems.

3. Management Functionality :

Management functionality is the scope of the functionality based on which the WSN nodes and infrastructure to be managed. These are also set of key features which could be used to calibrate the management efficiency.

3.1 Fault detection

Fault Detection is to monitor the fault occurred in the system and recovered incase fault occurred. TP [13], Sympathy [14], MANNA [15], and WinMS [12] which focus on this fault detection mechanism. In Two Phase Monitoring mechanism, each node monitors its own health and the health of nearest neighbor. This mechanism is called as local fault detection. The debugging technique to detect the faults is shown in Sympathy [14]. In case of MANNA[15], the system detect the fault at centralized level. In WinMS, there is a scheduled period in which the node will listen to the network and will start re-configuration in case any change in the network state. WinMS also provide the centralized fault management scheme that analyses network states.

3.2 Power Resources management :

WSN nodes are constrained with power resources as there is no continuous power supply. Hence power management is the key feature of the WSN management functionality. SenOS[9], Agent-based Power management [16] AppSleep [17] and Node-Energy level management[18] utilizes intelligent mobile agents to manage the sub-networks. . It can reduce the sampling rate of nodes with critical battery and reduce node transmission power. Other systems such as SenOS, AppSleep, and Node-Energy Level Management [18] use common sensor nodes to perform power management.

3.3 Traffic management:

Traffic management is also equivalently a major management function. The network congestion, data packets delay as the receiver antenna is not aligning to the sender's send data information.], DSN RM [20] and WinMS [12] . Siphon [19] uses multi-radio nodes to redirect traffic from common nodes in a network in order to prevent congestion at the central server and in the primary radio network. In contrast, DSN RM [20] uses single-radio common-nodes to evaluate each of their incoming and outgoing links and apply delay schemes to these links when necessary in order to reduce the amount of traffic in the network.

4. System Organization :

There are mainly four category of management monitoring operations based on which all other management operations will be decided and executed. They are as follows.

- Passive monitoring:In this, the system gathers the network state data information and also analyzes the gathered data to find the network and individual nodes' health.
- Fault detection monitoring:In this category, the system collects the information to identify if there is any issue or error occurred. This helps the management to re-configure the network to make the network system resilient to external network(s).
- Reactive monitoring:The system collects the information to snoop the error events and reacts accordingly based on the occurred event to reconfigure the network.
- Proactive monitoring:The system collects the network state past events and analyzing the data to predict about the future events.

4.1 Centralized Management

In centralized management system, there is a central manager who manages network management. All the nodes in the system will report to the central manager for all the management activities. Sympathy [14], SNMS [16], BOSS [28], MOTE-VIEW [29] are few systems under this management category. The centralized manager is having continuous power supply and high processing capacity processes complex task and reduces the processing task of the resource constrained sensor nodes. The centralized manager is communicated by all the sensor nodes and hence it has all the network state information and hence it is capable of taking management decisions according to the necessity. The difficulty in this model is the the limit of scalability due to bandwidth congestion. And other disadvantage is the failure of backup model i.e. if the centralized manager fails then there is no other central manager to recover and monitor the network management.

4.2 Distributed management

In Distributed environment, there are multiple number of managed stations available and each managed station communicate with each other. The other nodes in the network will communicate to their respective managed stations. In this way, the management task is shared by a set of managed stations and managed station also capable to managed fewer number of nodes than the centralized management system The network efficiency is increased and power consumption is reduced. However the disadvantages of this model are the complexity of the processing task and inter management station synch communication. The algorithm used in distributed management system is too expecive for the resource constrained nodes. Few example of this model are AppSleep [24], DSN RM [20], sensor management optimization [21] and Node-energy level management [25]. Another disadvantage of the distributed system is the memory usage. The Two Phase Monitoring

Ststem[13], Node-Energy level management [25, Agilla[22] are name of few system which uses significant memory .

4.3 Hierarchical management

Hierarchical is a mixture of above discussed two management systems. In this model, there is multiple numbers of managed stations available andeach node will communicate to one of the respective managed stations. Instead of managed station to managed station communication, in this model , the managed station will directly report to centralized manager. For example, in SenOS [9], TopDisc [5], AppSleep [24], and STREAM [10] some common-nodes are selectively elected as cluster heads to act as distributed managers. Agent-based policy management [24] uses mobile agents as distributed managers.In RRP [11], it is shown that individual nodes have different roles: either acquiring raw sensor data, transporting data, or filtering data. The intermediate managers will monitor and control the state of the individual group of nodes. After data collection happens, these intermediate nodes/stations forwards the message packets to the central processing manager. This way the distribution algorithm used in distributed management system would not require in this model and hence network operates smoothly.

.Network Management System Design Criteria

A network management system designed for WSNs must take into account the unique properties of WSNs. The following criteria are generally used to evaluate the sensor network management systems.

- Lightweight operation:The application and network operation should have simple application feature which does not consume too much battery energy. The lightweight operations extends the network lifetime.
- Fault Tolerance & Robustness:the following are the possible cause of fault tolerance.
  a. dropped packets
  b. disconnected
  c. nodes dying
  d. new nodes joining the network
  e. powering on or off

  A management system in WSN should capable to resilient to such dynamic behaviors of nodes and able to adjust the network to operate smoothly.
- Responsiveness & Adaptability:The network should be able to responsive immediately inspite of multiple failures and network errors. Also the network system should be capable to adapt the dynamic network topology changes.
- Minimal data storage:As WSN nodes are memory constrains, so the data models designed for WSN application for management operation should be capable to operate with less memory usage. The management system that intends to operate on WSN nodes especially on common nodes which are limited on power sources must respect the WSN's memory constrains.
- Scalability:Sensor network infrastructure should capable to operate on high scalable mode as the nodes dying is a very common feature of the wireless sensor network and also occasionally node additions would happens due to the following reasons.
  a. New nodes deployment on to existing network area
  b. New nodes joins from one cluster to another clusters

There multiple existing system designs have been evolved till today. We have briefly described the existing designs as below.

4.4 Layered System Structure

Layered System architecture is now considered as an advanced architecture in most of the application field. In layered architecture the system is operate on several layers instead of operating on single layer(monolithic approach). The disadvantage of monolithic approach is that whenever any application change or configuration changes, it has global consequences and hence more analysis involvement required to access the global impacts. On the other hand the layered system design allows changing the system in one of required layer and it has no global impact on the whole system. Hence the layered based design supports the management light weight operations features and based on the network role such as cluster head, sensor (common) nodes etc. chose the appropriate opration and executes based on the role. There is no dependency to load all the components i.e. common nodes need not to load the cluster head components and hence the energy usage in layered based system architecture is optimized.

4.5 Distribution of Management Function:

Distributed system is another competitive approach in WSN management field. In WSN field due the traffic congestion and the nodes availability, it is difficult achieve efficiency in centralized processing. If nodes are dying in regular fashion which is common in WSN environment, then centralized management operation will be likely unfeasible or delayed (as network to get reconfigured to get a path to central processing system/base station) to get executed. Thus, in a distributed way the management operations and decision-making are most likely to perform resource-constrained WSNs. For example, the distribution of cluster forming and control protocol is considered by Yu[6] to every sensor as information of node status measurement (including node capability , data accessibility, or network connectivity etc.) is more efficient to handle locally by sensor nodes.

4.6 Policy-based Management :

Policy based management is based on certain policies which need to be agreed on for the network management. There is a manager and agent based structure(MANNA [26]) where the agent will work manager cooperatively to accomplish certain management task such as group formation, control density of network, monitor and keep the network coverage etc. There are some research work attempted in this field

such as reconfigurable group management service [25], Mire [24] which are setting some pre-defined behaviors for managing service for dynamic group formation in runtime. Similarly TinyCubus [23] approach the generic way of reconfiguring the network framework and distributed role usages for sensor nodes.

4.7 Information Model :

Certain management functions in WSN largely depend on the network state information which help in smooth execution of management operations. A network system can be of two states as it changes from time to time in real-time scenario, static and dynamic. In particular, the MANNA architecture describes these two kinds of management information (static and dynamic) to represent the network status. In static status, the network information does not change rapidly where as in case of dynamic criteria, the network information changed dynamically and based on the dynamic change the network should be able to adapt the change and reconfigure accordingly.

4.8 Service-Oriented Management:

Service oriented architecture (SOA [27]) is appealing design architecture since a decade in field of software applications where it diversified the applications into unit components and make the system low coupling to achieve a well build reliable system structure. This SOA design ensure the high scaling and adaptability due to the standardize inter communication protocol (soap based protocols for service messages). Thus the application developers will only focus on the specific operation development and hence the management operation development, enhancement and maintenance will be fast. SOA can also specifically deal with the WSN features e.g. mobility, dynamic network topology, node heterogeneity etc. and offers tointegrate seamlessly for various management operations.

5. Conclusion:

In this paper, we have seen different network parameters, functionality and the design architecture that have been evolved to address the network management in Wireless Sensor Network. The different management models such as central, distributed and hierarchical models have their advantages and disadvantages. However the routing protocols and appropriate model selection in specific model deployment enhance the network life time. A model which solves the network management problems and provides a unique design structure is our next future scope of study.

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