PLANNING AND ANALYSIS TOOL FOR LARGE SCALE DEPLOYMENT OF WIRELESS SENSOR NETWORK

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ABSTRACT

In this paper the importance of tool-suite for large scale Wireless Sensor Network (WSN) deployment scenario has been investigated. This tool-suite is classified depending on the required feature for WSN deployment. Here both pre-deployment and post deployment has been considered for classification. Planning tool is used in pre-deployment phase and diagnostic tool is used in post-deployment phase. To enable a good planning for WSN, a proper model of WSN and the number and position of sensor nodes are required. In post deployment phase, the diagnostic tool will monitor the health of the deployed network status. In this paper, a direction of development of this type of tool has been presented and the challenges of building this type of tool are also discussed.

KEYWORDS

WSN, simulation, deployment, planning, tools.

1. INTRODUCTION

Wireless is a key enabling technology to offer reliable, flexible and cost effective automation solutions. Wireless introduces cost reduction and ease of maintenance and commissioning in industrial plant. Now-a-days wireless technology has become so familiar to human life that industrial plant is planning to move towards wireless automation systems. WSN is a wireless network which is consisted of different wireless devices with attached sensors. This type of sensor network plays an important role in low-range communication. The main applications of this type of network are monitoring, tracking and control. It helps to wirelessly connect the physical world to their information systems for better visibility and control. The sensor nodes attached to field devices detect the event being monitored or tracked and report the information to high-end devices using small, low power radio for further control.

When an industrial plant uses WSN which requires large numbers of nodes, the planning for WSN becomes most important issue. For planning, the accurate model of real environment is very important. Good planning also predicts the suitable plan of how many sensor nodes are required for a certain coverage area. The prediction should also suggest where these nodes will be placed so that end-to-end connectivity exists between all the nodes. For modelling the real world environment we require the simulators which can accurately predict the behaviour of it. In industrial plant, field devices with sensor nodes are deployed for monitoring and control purpose. If some nodes are not within the coverage area, then it is required to change the position of nodes and see the connectivity and coverage again. This is a cumbersome process and for large scale deployment it is a big issue. Moreover, in wireless domain, there are different technologies which operate in the same frequency range. To reduce interference issues, proper placements of nodes are required. This in turn ensures the co-existence of different technologies. Beside this, after deployment it is also important to know the performance of already deployed network by monitoring the network health in terms of energy consumption and performance of successful packet delivery. For this it is required to directly connect already deployed network and accumulate the information from there.

In 2004 and 2005, ZigBee standard was the buzz of the industry. ZigBee is a specification for a suite of high level communication protocols using small, low-power digital radios based on the IEEE 802.15.4-2003 standard. But in [1], Tomas Lennvall, Stefan Svensson and Fredrik Hekland showed that the ZigBee standard is not suitable in industrial environments. The industry demands secure and reliable communication, but static and multi-path fading sometimes blocks ZigBee due to its use of one static channel [2]. For industrial application new wireless communication standard, named WirelessHART has evolved. WirelessHART is a secure and robust mesh networking technology operating in the 2.4GHz ISM radio band and it utilizes IEEE 802.15.4 compatible DSSS radios with channel hopping on a packet by packet basis.

This paper investigates the need of tool for large scale deployment and categorizes them depending on their application. This paper also presents the development procedure for these types of tool.

Remainder of this paper is divided into three sections. Section II classifies the tools depending on their required feature. Section III gives a direction to develop the tools with those features. Challenges to build this type of tool are given in Section IV. Based on our work the conclusion is derived in Section V.

2. CLASSIFICATION OF TOOLS

This section classifies the taxonomy of the tools which are required for large scale deployment in industrial plant. In different phases of the life-cycle of deployment different features are required in tools. This classification is done according to the required features of planning and diagnosis. Fig. 1 shows the taxonomy of Tool support for WSN. In pre-deployment phase tools are required for planning and after deployment tools for diagnosis are required.

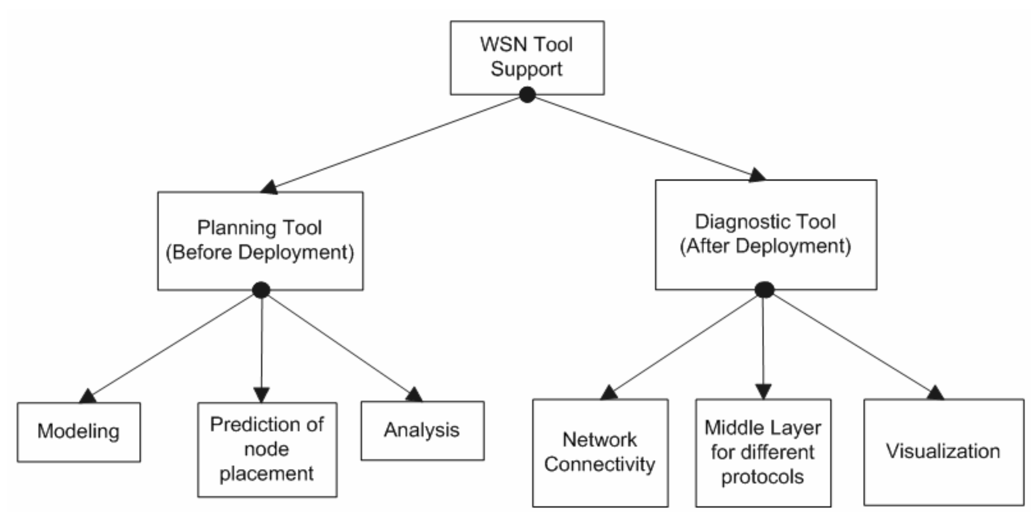

Figure 1. Taxonomy of Tool Support in WSN

2.1. Planning Tool

The traditional way in deployment of wireless sensor networks is mostly placing sensor nodes by ad-hoc or random method which is convenient and suitable for outdoor applications [3]. But in industrial environment a sensor or device is planned to be placed at the same spot for many years. So the luxury of placing nodes in random manner can not be entertained. Moreover the coverage and connectivity are very important to successfully send information to the destination. A poorly designed network will suffer from coverage holes, poor service areas, slow response, and improper connectivity. These challenges can be eliminated with an efficient design and planning. Planning reduces the time and cost required to design a WSN. For this, it is required to simulate and plan the WSN system before its deployment. Planning tool requires the feature of modelling the environment in industrial plant and behaviour of WSN. It also requires a feature to predict the number of nodes and their positions required for certain coverage area in the plant. This prediction must ensure full connectivity in the plant. Coverage requires that every location in the sensing field is monitored by at least one sensor. Connectivity requires that the network is not partitioned in terms of nodes' communication capability. The sensing field can be modelled as an arbitrary-shaped region possibly with obstacles [4]. Moreover, in order to optimize sensor node placement, sensor nodes may be deployed as a grid, where all devices are meticulously and evenly spaced according to their monitoring/transmitting range [5]. The planning tool also requires an analyzing feature to verify the result ensuring coverage and connectivity. This analysis generates reports that contain locations of nodes and expected coverage. It generates the deployment plan and predicted results which in turns save time. When this result is presented to the user, he/she can modify the positions as their requirement and the feature of predicting node placement, generates new plan depending on new constraint of position.

2.1.1. Modelling

Models play an important role in many different disciplines. The broad scope of applicability of models, results in a wide range of "types of models" for a given system component, a "range of system components" that are of interest to be modelled, and an assortment of "levels of detail" provided in models [6]. In modelling two major sensing schemes are trigger-driven modelling and schedule-driven modelling [7]. In trigger-driven operation, the sensors are managed by a low-power pre-processing unit that continuously samples the sensors. This pre-processor performs a first-order filtering of the data and wakes up a more powerful main processing unit if certain criteria are met. In schedule-driven operation, the node's sensors are connected directly to the node's main processor. To conserve energy, the processor follows a schedule that alternates between a low-power mode (e.g. sleep, deep-sleep or shutdown) and a short, full-power mode in which the processor (or its ADC) samples the sensors for interesting activity. In WSN modelling of hardware, environment, standard and application are very important for planning. Hardware modelling gives detailed description of nodes. It models the basic physical layer of nodes along with radio propagation and antenna. Modelling of environment gives the sensing range and coverage area for WSN. Planning tool should also be able to model the standard protocol. This feature is used to model the physical and MAC layer which supports the specific standard. For WSN physical layer and MAC layer supports 802.15.4 standard. Modelling of application depending on the behaviour of WSN is also important. The WSN is used for short range communication and nodes have limited battery power. So, energy consumption model is required in WSN application [8].

2.1.2 Prediction of node placement

This feature is used to predict the number and the suitable position of nodes in the plant environment. This helps to design WSN for large scale deployment. With the help of modelling feature, it recommends the number of nodes and their position assuring the network coverage and connectivity. It gives an overview of where to place the wireless sensor nodes or devices. This is the most important feature in planning. In this procedure, the sensing area of industrial plant environment in which sensors must be deployed will be given as input to the plan generation procedure. This floor plan will have specification details of the industrial plant. Each sensor has a communication range and a sensing range. Sensors can transmit packets to other sensors within this communication range. Sensors can correctly monitor the events in the environment within sensing range. This information is mainly user-defined and stored in the specification details. The goal of plan generation procedure is to deploy sensors in the sensing area, so that both the connectivity and coverage are ensured. Generally if the number of nodes is increased, the connectivity and coverage become better. The objective of the plan generation is to give an optimum number of sensor nodes which can produce the required coverage and connectivity.

2.1.3. Analysis of generated plan

This feature is used to analyze the behaviour of the overall network. It verifies whether the plan is optimum with proper network connectivity and coverage. By this analysis it is easier to sort out network connectivity and coverage related problem in planning. It helps to check the interference issues to ensure co-existence in the industrial environment. This feature of analysis also allows user to add/delete nodes or modify the position and verifies the result. Thus it plays an important role in planning. This analysis feature gives a visual representation of number of nodes and their position on the floor-plan. It is easier to check that connectivity and coverage from the visual presentation.

2.2. Diagnostic Tool

Diagnostic Tool is used to monitor the network status and health after deployment of WSN in industrial plant. This information is used to make appropriate modifications in the network. This tool should be connected to gateway or any network adapter to have the information about the network and presents the result to the user. Now, following the WirelessHART standard [9], the gateway can support different protocols and WirelessHART standard does not restrict the implementation of particular protocol in gateway. So to make the diagnostic tool compatible with different protocols, it is required to have one middle layer which takes each protocol and extract data from it. The data is passed to the Diagnostic Tool which processes the data and show the processed diagnostic information to the users.

2.2.1. Network Connectivity

The diagnostic tool gets the information from network, so there must be a proper connection to gateway or any network adapter which can pass the data to the tool. WirelessHART gateway generally supports different connection and protocols to its host application. So, the tool can be connected to gateway either on Ethernet, Wi-Fi or serial connection with different protocol like TCP/IP, Modbus, ControlNet. For this, tool must have different interfaces to be connected to the gateway.

2.2.2. Middle Layer for Different Protocols:

A middle layer for different protocols is used to extract data from standard or proprietary protocol of one device and to pass the data to other device or tools for achieving the interoperability. Now WirelessHART gateway supports different protocols to its host application and each vendor is free to implement any one protocols supported by WirelessHART standard. The diagnostic tool can be implemented following one particular format considering the required data for diagnostic processing. Thus the middle layer is required to extract data from the gateway and pass it to the diagnostic tool.

2.2.3. Visualizer:

The diagnostic tool provides a visualizer which is used to provide the graphical view of network topology. Presenting graphically the voluminous data that are collected is important in any type of diagnosis [10]. For large scale deployment, it is very important to know that how many nodes are connected in the WSN. This feature gives an overview of connected nodes in the network, which helps in diagnostic. It helps in quickly understanding the problem whether some nodes are not working properly or the radio connectivity is inactive between nodes. When a WSN is deployed it is also required to know the performance of the network in terms of successful packet delivery, stability and reliability. This feature presents the network related information. In diagnostic, this network information is most important. With all these information visualization improves diagnostic.

3. Direction For Development

3.1. Planning Tool Development

Planning tool gathers the floor-plan and information about industrial plant. It includes information about physical properties of the present entities in the industrial plant.

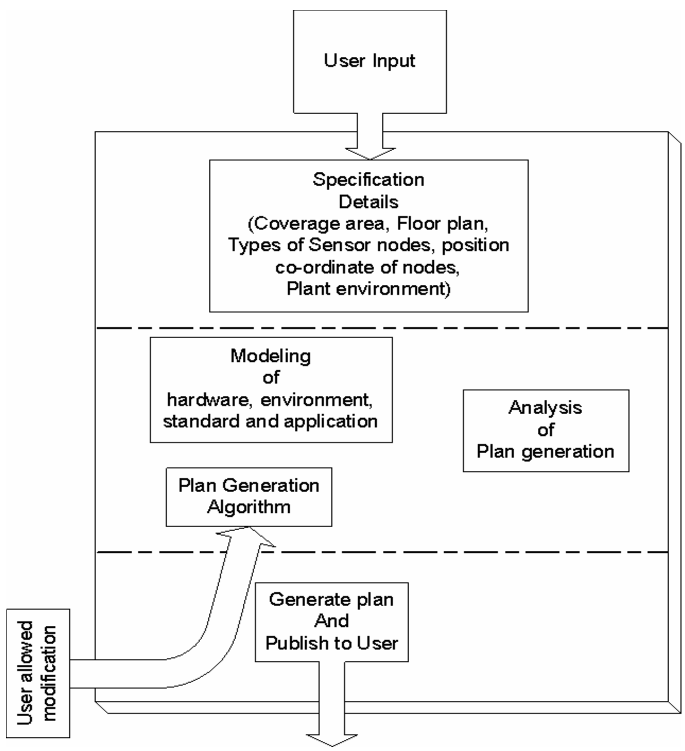

Figure 2. Planning Tool

With the model of industrial environment, it maps RF characteristics with the site-plan. Then it also includes the plant specific usage information like required coverage, required reliability etc. Considering sensor node model and all these information, planning tool recommends the optimum number and location of sensor nodes. This should ensure network connectivity so that packets are transmitted to the destination using the network and proper signal coverage. The signal coverage increases with the increase of sensor nodes which increases the design cost. So, planning tool should suggest suitable position of each node by minimizing the number of nodes used while expanding the network coverage to the industrial plant. The analyzer analyzes the coverage, RF environment and network connectivity to be sure that design satisfies connectivity and coverage. It can verify the connectivity and coverage by adding/deleting nodes or modifying the position of those. After analysis the plan for deployment is generated and published to the user of the tool. If user wants some more modification, the plan generation procedure will re-calculate the position and after analysis it will present the modified result to user.

Fig. 2 describes the planning procedure. The specification details like coverage area, floor plan, type of sensor nodes, position co-ordinates, and plant environment are taken as user input. The modelling of hardware, environment, standard, and different applications are done. Then depending on user input, the optimal number and position of nodes are predicted. To know whether the plan is optimum or not, the analysis of plan generation is done and plan is presented to the user. Users are allowed to give input and modify the plan.

3.2. Diagnostic Tool Development

When large scale WSN is deployed, the diagnostic tool helps to monitor the network health. The diagnostic tool is connected with gateway or network adapter which get the information from sensor network. This information is used to modify the network if there is any problem in network connectivity and coverage. The tool sends a query to the gateway or network adapter to know nodes information and which nodes are connected in the network. The tool also collects network topology from the network and presents which node is connected to other node by active radio connection between them. The tool also gives network information like percentage of data packets that the gateway or network adapter actually received or average percentage of data packets in the network that have successfully reached their destination. It also presents average time required for a data packet to travel from the originating nodes to the gateway or network adapter. The tool is able to log the information coming from the gateway about network. The diagnostic tool is used to monitor the network status and network health and presents the result to the user. This information is used to make appropriate modifications in the network.

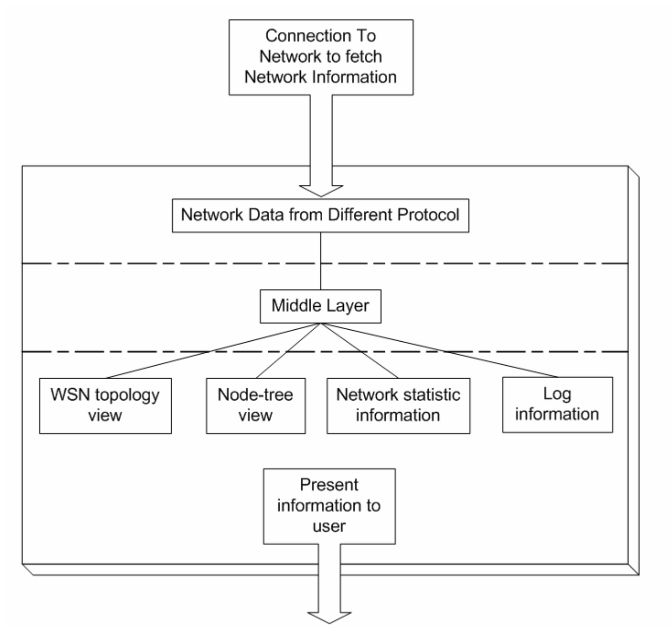

Figure 3. Diagnostic Tool

Fig. 3 describes the procedure for diagnostic. The tool collects the data from the network. The data from different tools can be from different protocol. The middle layer is used to extract the data from different protocol and processes for diagnostic. Then visualizer provides the graphical view of network topology along with network diagnostic information along with network statistics and log information.

4. Challenges Of Planning And Diagnostic Deployment

For planning first of all, a virtual WSN identical to real world network is required to be established. The modelling of the real world physical environment is a big challenge. In industrial plant there are different numbers of plant devices. These devices are made up of different type of metals which can destruct the wireless communication. Some devices can radiate electro magnetic wave which can cause interference. In industrial plant, there may be piles of metal sheet which are not always in the same position but can cause serious interference effect. Moreover, when real sensor nodes are in the network, they can behave differently depending on the plant environment. The model of WSN should be able to consider the interference effect from the plant devices. It should be able to analyze the constraints imposed by plant environment. Beside these, if new plant devices are added in the plant, the planning tool shall be able to include this information. The planning tools must gather the information related to the constraint imposed by the plant environment. Then using some empirical formulas the planning tool should calculate the EM (electro-magnetic) characteristics of the plant. This is a real challenging problem. After that suggesting the position, satisfying the coverage and connectivity are various challenging features for planning.

For diagnostic, the tool should collect information about network from the gateway or network adapter. There are different standards in WSN. The gateway/network adapter and tool must communicate with each other in same standard. This is very important for diagnostic for getting information from network. As discussed in Section II-B, the tool should support different connectivity options as one particular gateway can provide specific connectivity. The tool must be able to support different gateway following WirelessHART standard. Moreover, the middle layer, which takes data from all standard and extracts data, is also a big challenge as tool should have interface for all supported protocol of WirelessHART.

5. Conclusions

For any plant using wireless technology, specific tool support is required in all phases of the plant life-cycle. The tool support of WSN is classified in planning and diagnosis depending on the deployment phase. The planning phase is done in pre-deployment phase. Here we have analyzed, in pre-deployment phase it involves lot of challenging problems like interference analysis, EM characteristic calculation for industrial plant. It is very important to predict the suitable position of nodes considering coverage and connectivity. We have analyzed and found that the diagnosis is done in post-deployment phase. The tool presents the diagnostic results to the user and the user can do appropriate modification if it is required.

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