A Network Management Approach for Implementing the Smart Sensor Plug and Play

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Abstract – **Sensor networks are used in the industry extensively. Most of these networks are static and do not provide standardized and systematic network management capabilities. There is no intelligence associated with the sensors and they behave as mere sensing elements. There is a need to monitor the sensor networks with the classical elements of network management : fault, configuration, performance, accounting, and security. However, most of the sensor networking approaches lack a standardized method of handling these classical elements. This paper is on the demonstration of plug and play of smart sensors using a standardized internet network management protocol (SNMP – Simple Network Management Protocol) method with IEEE 1451-based TEDS capabilities. It also demonstrates plug and play capability at different levels to provide network and sensor management in a dynamic fashion. To our knowledge, this is the first demonstration of three-level plug and play in a standardized way using SNMP and IEEE 1451.**

Keywords - SNMP, Plug-and-Play, smart sensor, sensor networks, IEEE 1451.

I. Introduction and Background

Transducers are used in large numbers in various industries. Management of these transducers over a network is a challenge while meaningful and reliable information is gathered from then. Unlike the traditional networks which are more static in nature, sensor networks are dynamic and need strict monitoring in order to detect any anomalies. Maintaining good health of a sensor network is important in order to get reliable sensor data.

A. Plug and Play

A network becomes dynamic when all the elements in the network have Plug and Play (PnP) capablility. A node is PnP when it becomes operational and networked immediately after turned on and is physically connected to a network. Thus PnP plays a very important role in managing a dynamic network. In order to be PnP capable, a node has to:

- Announce its presence to other nodes in the netowrk.
- Configure itself to the default settings during a startup.
- Acknowledge to clients/servers in the network, of its availability to report sensor readings or to perform actuator functions.

There can be multiple levels of PnP in a system. While managing a sensor network involves detecting anomalies in the sensors, detecting different events and alerts is also desirable. Thus, a node has to be intelligent in order to provide good management support.

B. Smart Sensor Node

A node becomes intelligent (or is a smart sensor) if:

- It can provide data, a measure of the quality of the data, and a measure of the health of the node/sensor possibly using configurable /programmable intelligent algorithms. (E.g.: battery life, received signal strength in wireless communications, sensor reading)
- It embodies specification/identification information as in the IEEE 1451 standards for Transducer Electronic Data Sheet (TEDS) in embedded form on the physical sensor or virtually on a remote node. TEDS should be accessible through Internet connections whenever the sensor network is on the Internet.
- It can communicate through a network using common internet protocols such as the TCP/IP to support configuration and operation activities in adherence with the IEEE 1451 standards for smart sensors and actuators.

It would not be possible for nodes on the network to communicate with each other if they are not interoperable. To be interoperable, the application layer protocol should be standardized. Such a standard should be independent of the underlying layers and the data link layer communication protocols as has been conceptually proposed in the IEEE 1451.1 network neutral model [1].

C. IEEE 1451 Standards Suite

In order for sensors to integrate successfully, they must embody networking capabilities that provide information flow and control. Currently, there is no defined common digital interface standard between transducers and how they should provide information flow. However, there is a strong push in the industry to harmonize the standards that enable networking and data acquisition of sensors. One such effort is the creation of the IEEE 1451 Standard for Smart Sensor Networks to combine data acquisition control systems with networking.

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There are many examples of implementations of IEEE 1451 based smart sensor networks.

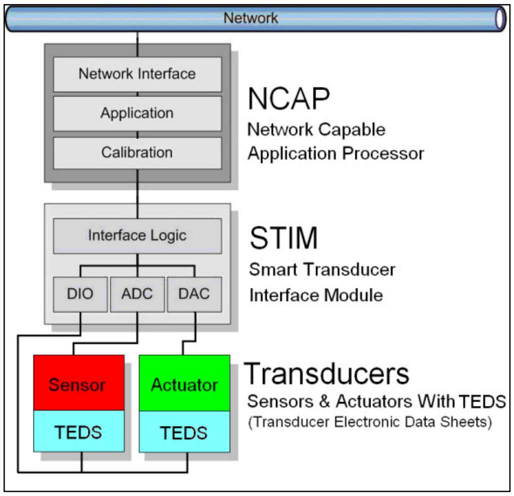


Figure 1: Conceptual diagram of IEEE 1451

Applications include using IEEE 1451 smart sensors to control traffic signal lights in a metropolitan area, [2]. Another application has IEEE 1451 smart sensors used to monitor automobile controls, [5]. Other applications include large-scale urban monitoring where wireless sensor nodes are used to monitor the environment, roadways, civil structures, and animal habitats, [6]. There has also been interest in IEEE 1451 from NASA's Integrated System Health and Management (ISHM) group [2], as well as from NIST, [3].

IEEE 1451.1 defines a network-independent information model enabling transducers to interface to network capable application processors (NCAP). It provides a definition for a transducer and its components using an object-oriented model which consists of a set of object classes with specified attributes, actions, and behaviors chosen so as to provide a clear, comprehensive description of a transducer.

Figure 1 shows a conceptual block diagram for the solutions using IEEE 1451.1 (which depicts the NCAP) and IEEE 1451.2 (which defines the STIM and TEDS). IEEE 1451.2? describes the STIM (Smart Transducer Interface Module) giving rules for organizing the transducers in channels, the definition of a standard connector (signals and timings) and the TEDS (Transducer Electronic Data Sheets). The TEDS includes complete information about the transducers and allows for plug-and-play and hot swap (startup) connections of nodes in the network, [5].

II. Sensor Network Management

A network management system consists of one or more management stations (managers) and several managed nodes. The manager should be able to:

- Discover the network topology using the discovery messages obtained from all the managed nodes.
- Request information from the managed nodes.
- Track various asynchronous events and alerts initiated by the managed nodes.

For such a management, all the manager stations and the manged nodes in the netowrk should be made interoperable by using a standard application layer protocol as explained above. Various existing application layer protocol can be used for the network management. This paper presents network management approaches using two such protocols – SNMP and HTTP.

A. SNMP

SNMP is a network management protocol that is used to manage the networks for a long time since its inception in early 1990s [8]. In an SNMP system, one or more administrative computers are called "manager"s with the task of monitoring or managing a group of nodes or devices, where each managed node executes a software component called an "agent" and reports information via SNMP to the manager systems. As the name suggest, SNMP is a very simple protocol with only five operations. SNMP provides the following features:

1) SNMP network topology discovery

The protocol provides a way to discover various SNMP managed nodes in the network using SNMP ping. The manager systems can discover and map the SNMP managed nodes in the network. Thus, the manager can request information using SNMP protocol from any of the discovered nodes.

2) SNMP information exchange

An agent maintains information about the predefined management variables and reports to the manager when requested. The managing system can retrieve the information through the "GET", "GETNEXT" and "GETBULK" protocol operations. Management systems can also change the configuration or control variables through the "SET" protocol operation to actively manage a system.

3) SNMP alert/event monitoring

The agent also has the capability of reporting asysnchronous messages to manager systems using "TRAP" (SNMP versions 1 or 2 [10]) or INFORM (SNMP version 3[11]). These messages are used to notify the manager about the alerts or special events that are to be monitored.

B. Management Information Base (MIB)

SNMP by itself does not define which information or variables a managed system should offer. Instead, SNMP uses an extensible design, where the available information is defined by management information bases (MIBs). MIB stems from the OSI/ISO network management model and is a type of database used to manage the devices in a communication network. It comprises of a collection of objects in a database (virtual) used to manage entities.

Since the network consists of components manufactured by multiple vendors, commonality in the definition and relationship of component attributes is needed. MIBs describe the structure of the management data of a device subsystem.

They use a hierarchical namespace containing object identifiers (OID). Each OID is unique and identifies a variable that can be read or set via SNMP. The MIB is used by both agent and management processes to store exchange management information. A manager MIB consists of information on all the network components that it manages, whereas an agent MIB needs to know only its local information.

III. Demonstration of SNMP Management of a Sensor Network

The implementation of network management in a sensor network needs intelligent nodes. Such a node should provide data processing and networking capability. In this paper, the intelligent nodes called "MobeeNet®" manufactured by Mobitrum Corporation are used. The SNMP agent software for the defined MIB is developed and is run on the MobeeNets. The sensors are connected to a Transducer Interface Module (TIM). This module is also manfactured by Mobitrum Corporation and is called a "Mobee®". The MobeeNet communicates with the Mobee using ZigBee as the data link layer protocol in order to obtain the sensor TEDS in IEEE 1451.4 format. The figure 2 shows the architecture for demonstrating the SNMP network management.

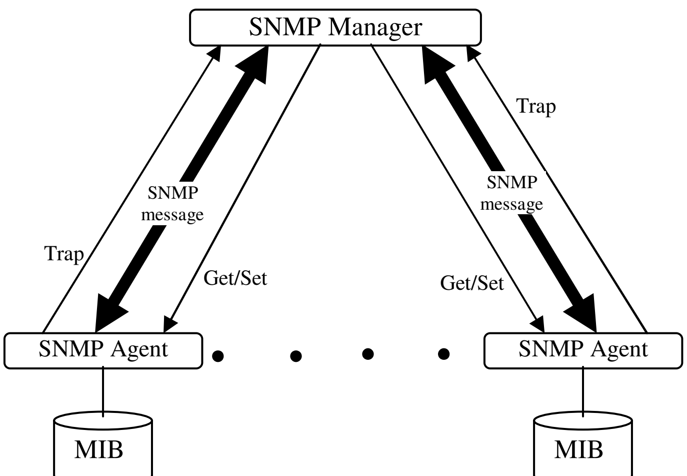


Figure 2. SNMP Architecture

The MIB structure used in this demonstration accomdates the information about the various system-related variables such as battery status, system architecture used, number of Mobees connected, etc. It also provides information about the Mobees and their health information in a table. The MIB also accommodates the TEDS (Transducer Electronic Data Sheet) information of the senors that are connected to the different Mobees in another table. TEDS are used to identify the sensor and its capabilities and are defined in IEEE 1451.4.

A. *Three Levels of Plug and Play*

There are three levels of PnP management possible using SNMP. These are shown in figure 3 with a small snapshot of the SNMP manager screen of the demonstration.

MobeeNets run the SNMP agent. They can be discovered by the Manager systems using the SNMP ping. Once the manager discovers all the MobeeNets running SNMP in the network, they can form a map showing the network topology. The discovery is done periodically and thus the manager detects the new MobeeNet in the network.

Mobees do not provide SNMP agent capablities and makes use of the MobeesNets MIB to accommodate all its SNMP management information. Thus, MobeeNets act as Proxy/ Virtual SNMP agents to the Mobees. The MIB provides a table for indicating the Mobees connected to MobeeNet and also present its health information such as battery status, received signal strength index (RSSI), etc. Whenever a Mobee is turned on, it broadcasts its information to the MobeeNet. The MobeeNet updates the Mobee table in the MIB structure indicating its presence. When a Mobee is turned off its corresponding entry is deleted from the MIB. Thus, there is also a plug and play management possible at the TIM level. Again, each TIM can be mobile or static. The Mobee can then be detected as a non-SNMP device in the network and be accommodated on the network map.

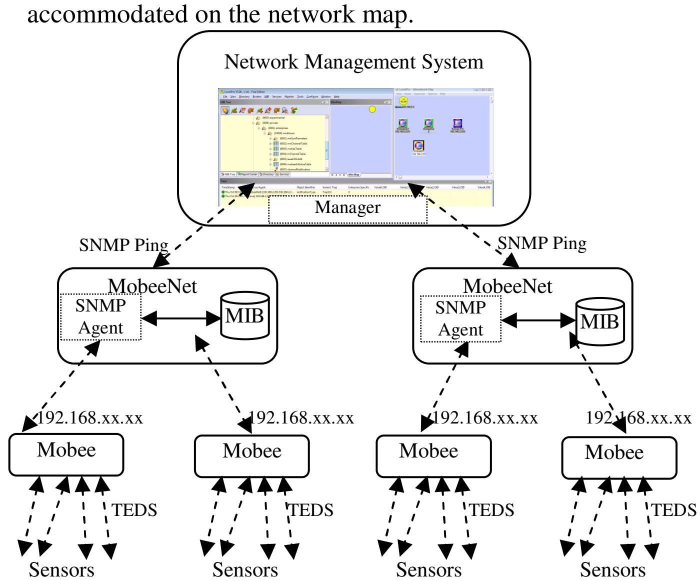


Figure 3: Three levels of PnP

There is one more level of plug and play capability that can be achieved at the sensor level. Mobees provide interface for sensors to connect. Whenever a sensor is connected to it, a Mobee would report the TEDS corresponding to the sensor to the MobeeNet and vice-versa. The MobeeNet in turn updates the TEDS table in the MIB indicating the presence of a new sensor at the reporting Mobee thus achieving PnP capability.

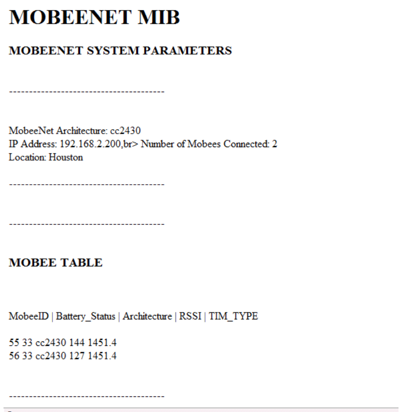
Using the PnP provides a dynamic management capability to the system. Also, the agent can report asynchronous alert messages to the manager stations: e.g., Low battery, Low RSSI, Anomolous sensor, sensor failure etc. requesting attention.

B. *Standardized MIB for Sensor Networks*

There are numerous vendors in the industry manufacturing various types of network components. As such there is a much needed requirement for an existence of some commonality in the definition and relationship of network component attributes [9]. MIB is a type of a database that can be used to manage the sensors and other elements in the sensor network. Since the nature of the network is dynamic and also implements the PnP feature, if we have a standard MIB defined for all the components that make up a sensor network then it will be simple and easy to identify them and will not be constrained by the manufacturing vendor of the product. This helps in making the process of managing them in a straight forward manner.

In the diversity of network technologies, standardization takes on a particularly important role; it can help prevent the duplication of effort and ensure interoperability between the resulting solutions. Standardization will also help create trust and confidence in the products and increase market relevance.

C. Web Access



MOBEENET MIB

MOBEENET SYSTEM PARAMETERS

MobeeNet Architecture: cc2430
IP Address: 192.168.2.200,br> Number of Mobees Connected: 2
Location: Houston

MOBEE TABLE

MobeeID | Battery_Status | Architecture | RSSI | TIM_TYPE

55 33 cc2430 144 1451.4
56 33 cc2430 127 1451.4

Done

Figure 4: We service output displays the MobeeNet (NCAP), the Mobees connected, and Mobee signal/health quality.

Web-based access also accomplishes all the functions of a dynamic management system. This approach is similar to the SNMP except that there is no requirement of a MIB structure. All the information related to a node can be displayed in a web page on the manager station (Figure 4). The protocol used to transfer information from a node to the Manager station is Hyper Text Transfer Protocol (HTTP). IEEE 1451.0 (Dot0) outlines the usage of HTTP to access parameters of TIMs and NCAPs over the network. HTTP and Dot0 by themselves do not provide any means to discover the nodes in the network. But, there are several off-the-shelf network discovery tools that make use of ping protocol in order to discover the IP nodes in the network.

In this approach, each MobeeNet has to run a web-server to reply to the requests sent by the Manager station. The web-server retrieves information about all the management information from the MobeeNet and replies back with the updated information on an html page. This approach can also accommodate the TRAPS / INFORM function of SNMP using the push method of http. Three levels of plug and play can also be presented in this approach. In figure 5, the architecture of a sensor network management web system is presented.

IV. CONCLUSION

This paper is on the demonstration of three levels of plug-and-play achieved through standards such as the IEEE 1451 and SNMP. IEEE 1451 has been used to identify and discover smart sensors, and their corresponding TIMs. SNMP protocol and its management information base (MIB) are used to achieve PnP from one access point such as a manager on the network. SNMP usage with IEEE 1451 has been proposed in order to achieve greater standardization base that includes widely-accepted internet technologies and to make use of the tools that enable better visualization of networks.

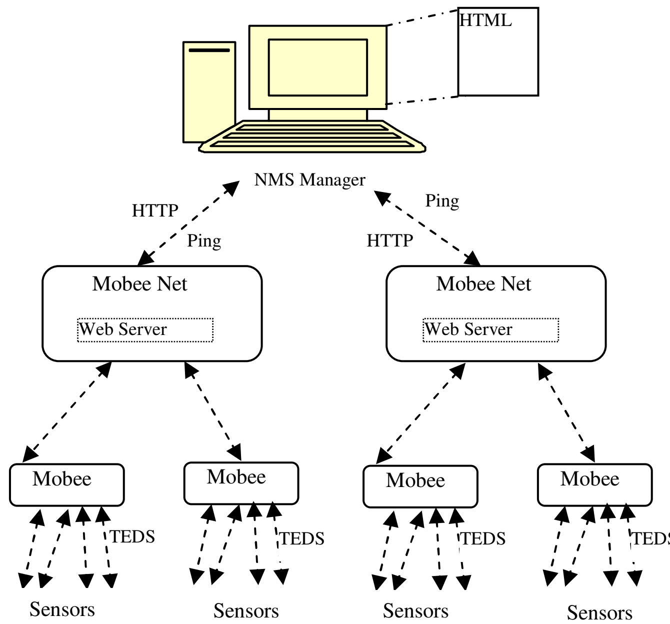


Figure 5: Web Services approach

This presentation will include a demonstration of the 3-level PnP during the conference with smart sensor nodes.

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