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ENHANCING ROBUSTNESS IN WIRELESS SENSOR NETWORK IN NUCLEAR POWER PLANT USING WIRELESSHART

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Abstract

WirelessHART is an efficient and robust wireless sensor networking technology where HART stands for Highway Addressable Remote Transducer Protocol. WirelessHART extends the successful HART field devices by providing the possible means of communication via wireless channels. The protocol operates in the 2.4 GHz ISM band and utilizes a time synchronized, self-organizing, and self-healing mesh architecture and supports operation using IEEE 802.15.4standard radios.WirelessHART has an efficient two-way communication between a host application and smart field instruments, providing access to diagnostics, configuration and process data. The WirelessHART standard is designed to offer simple configuration, flexible installation and easy access of instrument data, and at the same time, ensure robust and reliable communications mainly in industrial applications. In this paper we are going to deal with the implementation of WirelessHART technology among the Wireless sensor components to continuously sense the nuclear power plant operations and to periodically send the data to the servers via gateways.

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1. INTRODUCTION

The vulnerability of nuclear plants is of concern in the area of nuclear safety and security. Physical security at nuclear power plants involves the threat that could directly or indirectly endanger public health and safety through exposure to radiation. Security measures in Nuclear plant concerns and protects three primary areas of vulnerabilities:

- controls on the nuclear chain reaction,
- cooling systems that prevent hot nuclear fuel from melting even after the chain reaction has stopped,
- Storage facilities for highly radioactive spent nuclear fuel.

Special sensors are used to monitor and observe the chain reaction in the nuclear reactors by considering parameters like radiation and temperature. These sensor readings are further forwarded to the base station where the data are periodically stored and predictions are done by comparing the values to a static threshold value. When the values seem to increase than usual the alert messages are sent to the higher authorities and also to the recovery team. The WirelessHART[10] in this case provides a more secure and reliable communication between the sensor and the gateway.The following is the architecture diagram of WirelessHart.

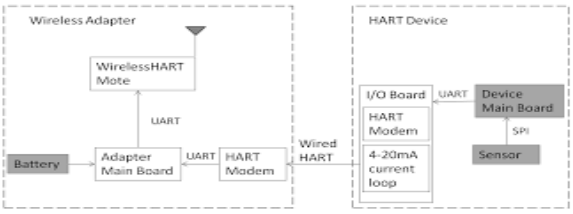

Figure 1: Architecture of WirelessHart Device

The wirelessHART protocol is widely implemented in industrial applications like in leakage detection, health care monitoring etc.

2. NUCLEAR POWER PLANT STRUCTURE

Nuclear plants produce electricity by boiling water into steam. This steam then turns turbines to produce electricity. The boiling of water into steam is done using uranium fuel, consisting of solid ceramic pellets which generate the required amount of heat to evaporate water into steam. The energy from the nuclear core is obtained by the nuclear fission reaction where enormous amount of energy is dissipated.

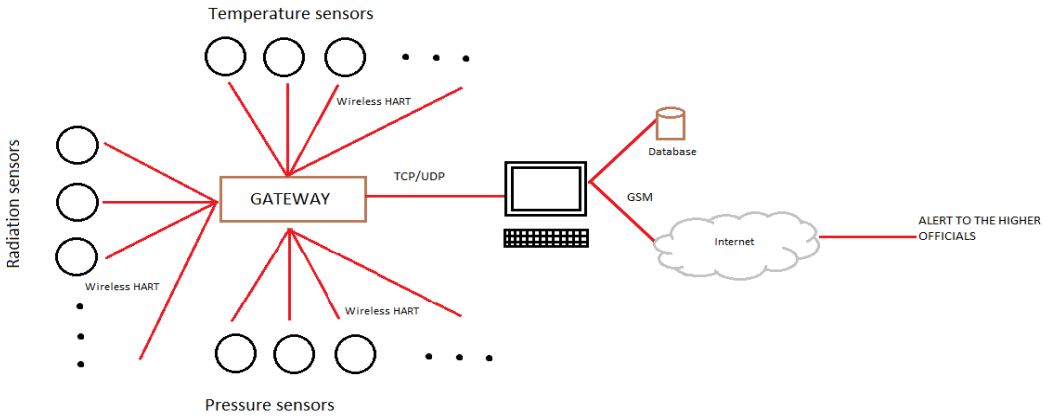

Figure2: High level architecture diagram

3. INSTALLATION OF WSN USING WIRELESS HART IN NUCLEAR POWER PLANT

Installing the wireless sensor technology to the nuclear power plant can increase the robustness of the plant against vulnerabilities by constant monitoring and prediction of states. Deploying sensors mainly concern the areas like the pressure valve, coolant and nuclear core[17]. Preferable sensors for this case includes

- Bragg grating (FBG) temperature sensors
- The Geiger counter radiation detectors.
- Pc-1210 low pressure sensor

These sensors are deployed as specified in fig.3 and on installing wireless HART it provides higher reliability by switching sensors on failures.

Fig.2 denotes the overall high level architecture of the implementation of the protocol in the nuclear plant. The GSM is used in the case of sending the information from the host to the higher authorities on finding and predicting worst cases inside the core.

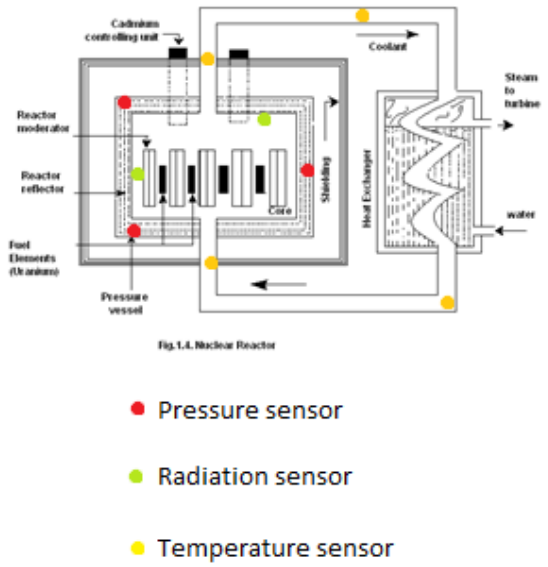

Figure3: Deploying sensors in the plant

These sensors periodically sense the environment and send the values to the base station via the gateway[4]. The sensor to the gateway uses wireless HART and the gateway to the host or server is done using TCP/UDP as preferred. All the period calculations are recorded and stored in the database and on prediction of vulnerabilities in the plant the intimation to the authorities is done using GSM.The figure below denotes the real time installation of WSN in the nuclear plant.

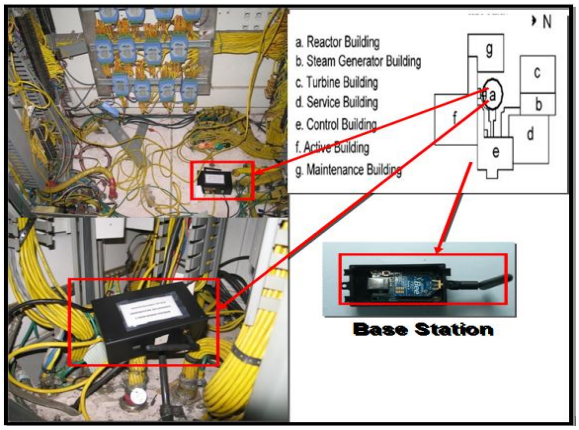

Figure4: Installing the wireless sensor network in the plant.

4. WIRELESS HART OVER OTHER PROTOCOLS

There are several reasons to consider WirelessHART rather than any other existing protocols likeZigbee and its significantly because WirelessHART[3] has

- Faster and easy device commissioning and loop troubleshooting

- Remote access to all device information and diagnostics
- Streamline maintenance procedures
- Enables predictive maintenance
- Increases plant availability
- Low cost access to stranded process information
- Large selection of devices that work together
- Industry standards reduce overall costs.

Further the few other aspects with respect to considering the most widely used protocol Zigbee[1] includes

Table 1: Comparision of WirelessHART to Zigbee

FEATURES	WirelessHART	Zigbee
Multi hop	Node hops every message, changing channels every time it sends a packet.	only hops when the entire network hops
At the MAC(Datalink) layer	Utilizes time division multiple access (TDMA), allotting individual time slots for each transmission.	applies carrier sense multiple access with collision detection (CSMA/CD)
the network layer	Represents a true mesh network, with each node capable of serving as a router. Thus, if one node goes down, another can "pick up the slack", ensuring a packet reaches its destination.	utilizes a tree topology, which makes nodes along the trunk critical
Compatibility	WirelessHART provides 100% back compatibility with wired HART. As a design principal, HART doesn't allow newer	They share the same basis for theirphysical layers, but Zigbee, Zigbee Pro, Zigbee RF4CE, and Zigbee IP are otherwise

	versions to erase or remove anything from older versions	incompatible with each Other
Reliability	More	Less

5.RESULTS AND EVALUATIONS

The evaluation of WirelessHART was done in a simulation environment using NS-2 simulator. The comparision of WirelessHART and Zigbee was done based on delay and throughput and under AES encryption mechanism to study the security and robustness in the network.Network parameters likeposition of nodes, number of trafficwere considered. WirelessHART components including Gateway, Network manager and Security manager along with their functions where also simulated and results were incurred.For the Zigbee network components including the ZigbeeCoordinatorwas included.

Both the networks consists of 35 nodes excluding the other components. The simulation area is 150m × 150m, the neighbors distance is 10 meters and the transmission range islimited to 15 meters[7]. In each scenario, the number of trafficsis increased (5, 10, and 15) in order to evaluate the end to end

delay and the packet loss rate. The packet data size is equal to50 and 70 bytes. Note that, the packets are sent periodically,every 2s [5], from the nodes (sensors) to the gateway (orcoordinator) or from the gateway (or coordinator) to the nodes(actuators)in the WirelessHART and in the Zigbee network. The so obtained calibrated values of throughtput, delay and Jitter are comparitatively represented into a graph.

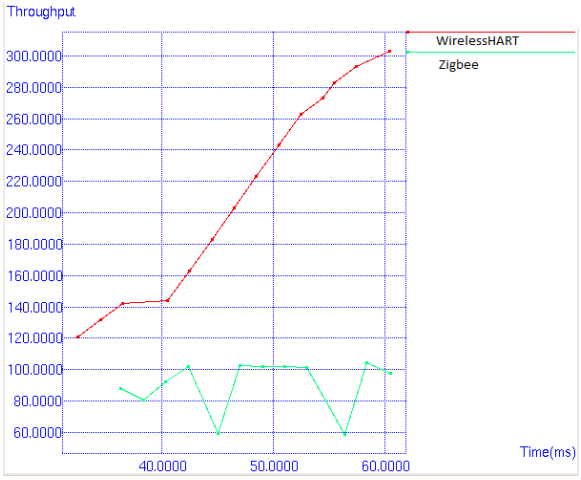

Figure5: Throughput graph

From Fig 4 it is observed that the throughput and data consistency is very high for WirelessHART when compared to the Zigbee network. Hence the network consistency provides a much robust. When considering delay and jitter it is a little higher than that of Zigbee.

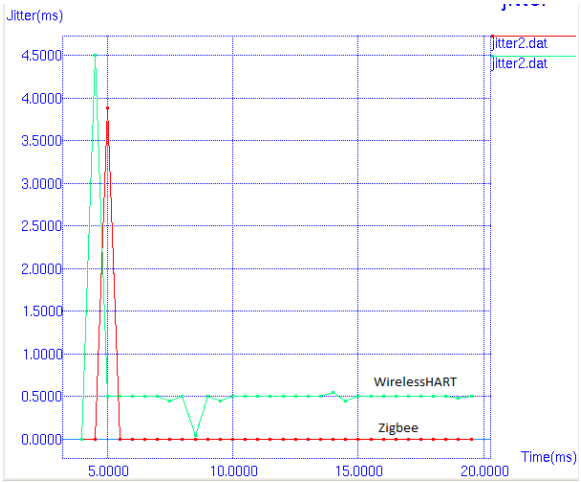

Figure6: Jitter Graph

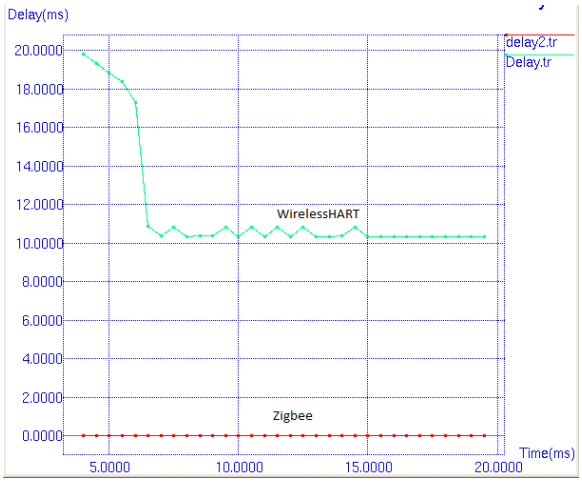

Figure6: Delay Graph

.6. CONCLUSION

This paper is about how WirelessHART protocol can be in the nuclear power plant ensuring secure and reliability at comparatively lower cost than wired sensors installation. Also as the messages are sent as radio waves there is a possibility of losing the message due to the large walls and metals surrounded in the plant.This can be overcome by using WirelessHART as the it is self configuaring and has a mesh structure which will pass the message from transmitter to transmitter until it reaches the gateway.

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