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Study of Network Layer in Internet of Things Case Study on Wireless Hart Using Network Simulator 2

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Abstract - Automation and process monitoring in the secondary sector till now are based on wired connection between devices. The proportionality of wires used increases as the complexity of the industry increases. The time taken for installation is also more. These expensive installations and their maintenance also consume too much of time and man power. Repairing a faulty connection due to technical failure, accident or any other reasons is difficult. The down time of the system will occur in huge loss to the industry. The solution to the above-mentioned problem is by using open, interoperable wireless standard like WirelessHART. It is a wireless communication protocol which is used in monitoring in the industrial sectors.

To carry out the performance evaluation in a low cost and a scalable way, we propose a module of Network Simulator 2 for the WirelessHART. Network Simulator (NS) is a discrete event simulator targeted at networking research that provides substantial support for simulation of various networks. This paper presents the implementation of WirelessHART in the NS-2 to work with the pre-simulation TCL file and post simulation trace file evaluation and also parameter calculation.

Keywords- Awk script, NS-2(Network Simulator 2), Simulation, Tcl, WirelessHART

I. INTRODUCTION

In 2007, the HART (Highway Addressable Remote Transducer) Communication Foundation [1] developed WirelessHART, the first open, international standard to fulfill industrial requirements. Using self –organizing and self healing mesh network architecture, it establishes a secure and reliable wireless communication protocol. It is backward compatible with the widely –used wired HART protocol: the global standard for sending and receiving digital information over analogue wires between monitoring and control systems. After gaining the confidence of the industry, the Wireless HART has been increasingly adopted over the last few years. [2]

Wireless HART can be conveniently evaluated by implementing the Wireless HART protocol in a network simulator. This serve as a basis for further extensions and improvement of the protocol itself. Simulation provides a good alternative to the expensive testbeds that need to be setup in real industrial environments and helps to test and analyze easily. These factors encourage us to work on implementing the Wireless HART simulator protocol. Here we choose one of the network simulators, NS-2 [3] for our implementation.

The typical WirelessHART network is shown in figure 1. The WirelessHART network consist of following devices:(1) Field Devices that are attached to the plant process,(2)Wireless Handheld used for device configuration, diagnostics and calibration,

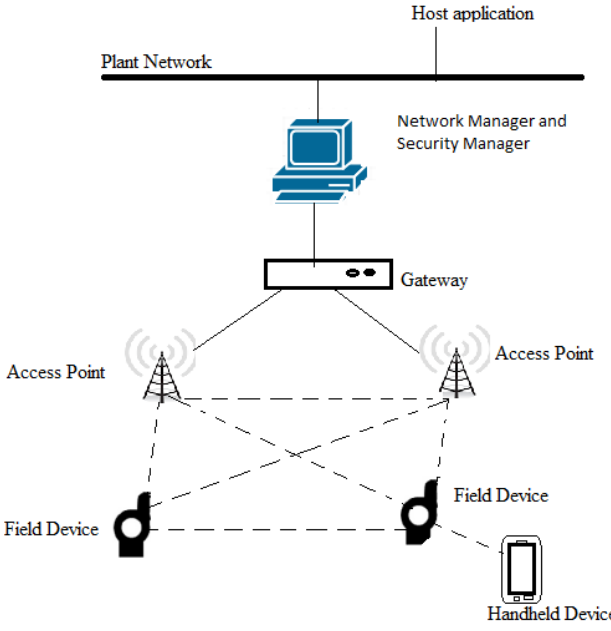

Figure 1: Wireless HART Structure Example

(3) a gateway that connects host applications with field devices, (4) a network manager responsible for network configuration, scheduling and communication management

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between WirelessHART devices, and (5) a security managers that manages and allocates security encryption keys, and also keep track of devices approved to join the network.[4]

The WirelessHART is based on the Open Systems Interconnection model (OSI) and it adopts the IEEE 802.15.4 as the physical layer. It also operates in the near globally available unrestricted 2.4 GHz Industrial Scientific and Medical (ISM) radio frequency band using 15 different channels (11-26)[4].A key difference between WirelessHART and other similar standards like ZigBee is that it specifies its MAC layer which is time –synchronized. The MAC header is designed to support the co-existence of other networks, such as ISA 100 Wireless, ZigBee, Wi-Fi,etc. The communication between the devices is accomplished using Time Division Multiple Access (TDMA) with a strict 10 ms time slots in a super frame. WirelessHART implements several mechanisms to ensure data confidentiality, authenticity and integrity in both hop-by-hop and end-to-end transmissions. As WirelessHART builds a mesh network, sensors are located several hops from the network manager. Thus, there sensors reply on their neighbors to forward their packets from/to the network manager. The several forwards of packets between neighbor devices are called by hop-by-hop transmission and the communication between the sending sensor and the network manager is called the end-to-end communication.

Other features of the WirelessHART include channel hopping to avoid interferences and minimize multi-path fading effects, channel blacklisting and for security of the network it employs the use of industry standard AES-128 ciphers and keys. The self-organizing and self healing mesh networking of network layer is supported by WirelessHART. The methods of routing packets through the network here is through graph routing and source routing which is controlled efficiently by the network manager and continuous communication is ensured between devices. Although Wi-Fi standard operates on the same 2.4GHz unrestricted ISM radio frequency band as the WirelessHART, the two operates on two different standards of IEEE 802.11 for the former and IEEE 802.15.4 for the later. However, Wi-Fi is targeted at WLAN, it consumes a lot more power and uses only one channel hence does not support channel hopping like WirelessHART that uses 15 channels. Furthermore, Wi-Fi supports star topology as against WirelessHART mesh topology thus making the Wi-Fi unreliable and therefore unsuitable for industrial environment. [4]

Ns-2 is designed for rapid performance simulation of networks. It is a discrete event simulator targeted at networking research. Ns-2 provides substantial support for simulation of many protocols over wired and wireless (local and satellite) network [9]. The wireless model includes support for node movement and energy constraints. By NS-2 wireless sensor network designer we can build the simulation models quickly for the application and get the performance of the target network.

The outline of this paper is as follows. Section 2 discuss regarding the literature review. Section 3 describes the methodology how these tools can be used to evaluate WirelessHART network. Section 4 contains results of work which has been concluded in Section 5.

II. RELATED WORK

This work focuses on finding delay, general throughput, overhead and packet delivery ratio with the help of Network Simulator.

Sabo Miya Hassan et al. (2016) [4] discuss regarding the problems associated with the wired connection in the processing and automation industry. To overcome high down time, expensive installation etc. we require a open, interoperable wireless standard like WirelessHART. This is used for monitoring and to apply control. Mesh topology helps to reroute the communication to another possible route in case of any interruption in the available route. The basic elements of WirelessHART is field devices, hand held devices, gateway, network manager and security manager. The application of WirelessHART in both practical and simulation environment is discussed.

Pouria Zand et al. (2014) [5] discuss regarding implementation of WirelessHART using NS-2 network simulator. The usage of sniffed traffic from test bed is used for validation of correctness of the simulation in NS-2. Analysis shows that results obtained from the real network and simulated results are almost comparable. The author describes the architecture, protocol stack of WirelessHART in detail. The joining process, routing, communication procedure, service request procedure is included in network management algorithms. Energy consumption in the network is also calculated. Multi hop mesh network analysis is used to demonstrate the usability of the simulator. Further evaluation results can be achieved with diverse scenarios.

M. Chernyshev et al. (2018) [6] discuss regarding comparative analysis of different simulation tools available categorized based on the scope of coverage of the IOT architecture layers and comparison between test beds is also performed. The survey was conducted on the 30 WSN simulators indicating its application, limitation and its advantages. Discussion is done on several open challenges of current IoT simulators and testbeds that need to be addressed by the IoT research community to conduct large-scale, robust and effective IoT simulation, and prototype evaluations.

Yanjun Zhang et al. (2012) [7] discuss regarding the performance of IEEE 802.15.4 is analyzed based on NS-2

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simulator. The scenario is built based on Ns-2 and some experiments are taken for investigating the performance of IEEE802.15.4. Obtaining the performance based on different parameters of the desired network by building the simulation model we use NS-2 simulator. The packet reception ratio and packet routing load are measured over different sending interval time and packet size.

III. METHODOLOGY

A simulation scenario is built to test performance of the network. First part contains Tool Command Language (TCL) file simulation in NS2 and second part consists of algorithm for performance evaluation of trace file which is output of simulated TCL file using AWK scripts.

A. Protocol testing using NS2 (Tcl script)

The first step is to acquire the instance of the simulator class. New and delete method is used to create and destroy the instance of the objects. The building blocks of network topology are nodes, links and agents. To create, configure the building blocks there are many methods in the simulator class. The Tcl scripts are used in simulation which consists commands and parameters for simulator initialization, node creation and configuration.

B. Post Simulation Analysis

The simulation process gives the output in the form of trace file. In first column, four type of packets s: send, r: receive, d: drop, f: forward, are indicated. Second column is time when event was started. The third column indicates the node number. The event generated at "MAC" level is indicated by fourth column. Rest of the column of trace file gives information about packet size, packet type, source and destination MAC address and time to send data etc. We have to collect all the parameters from trace file and then by using AWK scripts of performance metrics parameters, insert the formula and extract the results from the generated trace file.

C. Performance Metrics

Packet delivery ratio:

PDF is the ratio of successfully received packets to the number of sent packets. A higher the PDF value indicates a good network performance with lower packet loss.PDR is calculated in % (percentage).

PDR= ((received packets total)/(total packets sent))*100 %.

End-to-end delay:

It is the time elapsed by a successful received packet from source to destination node, which includes route discovery delay, propagation time, data transfer time and in between queuing delays. It is derived in ms (mille second). Smaller value of end to end delay indicates improved performance.

Throughput:

Throughput is the amount of data transmitted from the source node to the destination node within a specified amount of time. It is the important indicator of the performance. Unit of Throughput is Kilobits per second (Kbps). Higher values of the throughput carries better performance.

Normalized Routing Load (NRL):

NRL is defined as the total number of routing packet transmitted per data packet. It is calculated by dividing the total number of routing packets sent by the number of received packets.

NRL= (Number of sent routing packets)/ (Number of data packets received)

Higher values of NRL provide reduced efficiency of the routing protocol in term of consumption of bandwidth.

D. Simulation parameters

Channel type	Channel/WirelessChannel
Radio-propagation model	Two Ray Ground
Antenna model	Omni Antenna
Network interface type	Phy/WirelessPhy
Interface queue type	Queue/DropTail/ PriQueue
Topology Size	1000X1000
MAC type	Mac/802_11
Routing Protocol	DSDV

IV. RESULTS

This section describes our implementation results of topology scenario representation of WirelessHART. The network topology, model used for simulation and parameters associated with simulation are described.

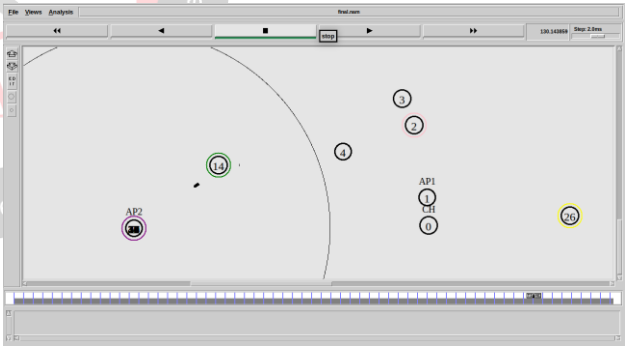

Figure 2: A scenario representation of network topology using NS-2 simulator (nam)

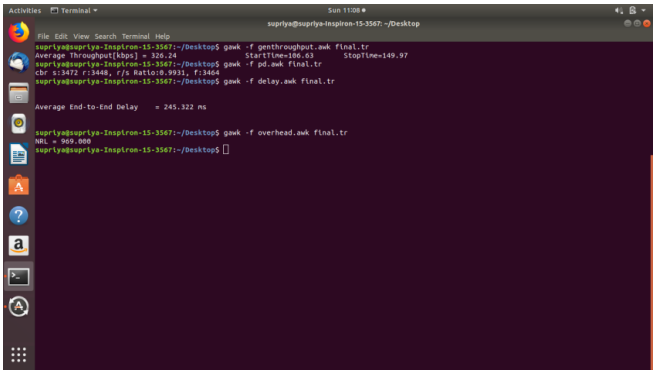

Figure 3: Snap shot of the result

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Performance Analysis:

Metrics	Values
Average Throughput	326.24 kbps
End to End delay	245.32 ms
NRL	969.000
Packet delivery ratio	0.9931

V. CONCLUSION

WirelessHART network is a sensor mesh communication system that simplifies network and device installation and allows the end user to tailor the installation and its topology to satisfy specific application requirements. The basic elements of WirelessHART network includes: Field Devices, A Gateway, A Network Manager. The implementation done can be used for parameter calculations like delay, overhead, packet delivery ratio and general throughput Simulation is done to analyze the pre-simulation and post-simulation using trace file generated and to check performance of the network topology. Analysis showed that the simulated results are quite close to the results obtained from real networks. Hence, we can make very realistic simulations with our implementation.

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