WirelessHART Routing Analysis Software

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Abstract. *Reliability and robustness are critical parameters in choosing a wireless protocol to be used in industry. Nowadays, WirelessHART is the most adopted wireless industrial protocol. However, there are only a few number of analysis tools for industrial networks, specially for WirelesHART, which implies in a lack of information about the health network to its end users. In this paper a software to obtain network data from a WirelessHART network is presented. The developed software allows to identify relevant issues to the verification and maintenance of WirelessHART networks. One of the advantages is the ability to customize the tests, being allowed to evaluate data of most interest for a particular purpose. In a case study, the obtained data allowed to identify the mostly used routes of the network which lead to the identification of bottlenecks.*

1. Introduction

Advances in electronics allowed the growth of high tech automation devices for industrial processes monitoring and control. The equipments are more robust, reliable and integrated processors with greater computational power promote greater flow of information. Now, they can make use of wireless modules to surpass cables and related infrastructure needs. This leads to reduced costs and reliable access to each site of the plant. These advantages and others are discussed by [Willing, Andreas et al. 2005] and [Khakpour and Shenassa 2008] in previous works. Also, some industry organizations have promoted the use of wireless technologies in the industry. Several attempts were made to launch a standard for industrial use, including Bluetooth, WiFi, Zigbee and Wina which did not receive a final acceptance by the industry primarily by the strength of standard [Svensson and Lennvall 2008], [Horjel 2009]. On the other hand, WirelessHART (WH) standard have been adopted because of its reliability, scalability and low cost. Recently, the International Electrotechnical Commission certified WH communication protocol as the first wireless communication standard for process control. With the certification of the protocol, several manufacturers are developing devices that support and meet the standard specification. In these circumstances it can be seen that there is still a great lack of computational tools that allow a monitor and a clearer analysis of the behavior and characteristics of these networks. Many of these tools become essential as soon as the full operation of the network depends and varies according to the aspects of the environment as well as the distribution of devices.

This paper describes a software tool that allows the analysis of the main characteristics and behavior of the WH protocol. This tool aims to enable a better analysis of the behavior of the network topology between WH devices in order to identify possible interference between devices, device malfunction and even identification of bottlenecks in the network. Next section will briefly present the main features of the WH protocol, addressing details about some of the developed tools. Section four presents a case study and the main results. Finally, the conclusions are presented in Section five.

2. The WirelessHART Protocol

The WH is the first open standard for wireless communication and control measurement in industrial processes and is part of version seven of the HART specification [Kim, Anna et al. 2008], [Song, Jianping et al. 2006]. It features a secure network and operates in the 2.4 GHz ISM (Industrial, Scientific and Medical) radio band. The standard uses the IEEE 802.15.4 physical layer in which direct sequence spread spectrum is employed [IEEE-SA 2007]. WH network supports a variety of devices from several manufacturers, including: field devices, adapters, portable devices, access points, network manager and a gateway to connect to a host. The protocol allows multiple access and media arbitration by means of time division multiple access (TDMA) [Rappaport. 1996]. The vast majority of communication is directed along routes in graphs [Song, Jianping et al. 2008]. Scheduling is performed by a centralized network manager that uses the network information in combination with the reporting requirements provided by the devices and applications. Links among devices are programmed and divided into time slots by the network manager that later are sent to individual devices. The network manager continuously adapts all the routing and schedule changes in network topology and demand for communication [Chen, Deji et al. 2010].

3. Routing Analysis Software

One of the WH protocol associated characteristics are reliability and security of is the dynamics in the network formation between different devices. The network manager contains a complete list of routes, connections and network devices. When devices are added to the network, the network manager stores all neighbor entries including information of the signal level reported for each device on the network. This information is used to build the complete graph of the network. An important function of the network manager is to configure the connection information and graphs on each network device [Song, Jianping et al. 2007]. Concerning WH analysis software, there are only few related works available. A hybrid simulation framework for WH networks in a controlled environment is discussed by [Konovalov, Igor et al. 2009]. Also, commercial software available from Emerson (AMS Snap-on) is used especially in WH. In comparison with these, the proposed tool in this paper is the only one that allows an analysis directly connected on the WH network, with the flexibility to customize different kinds of tests at anytime. The developed application uses UDP protocol in order to communicate with a WH network manager. The network manager is connected to an access point that communicates with the field devices on the network. Figure 1 depicts the whole system. The application is based on HART commands which are used to obtain the desired data [Hart Comm. 2007]. The commands are encapsulated on the standard UDP and sent to the network manager that responds to the request after sending and receiving data from the devices.

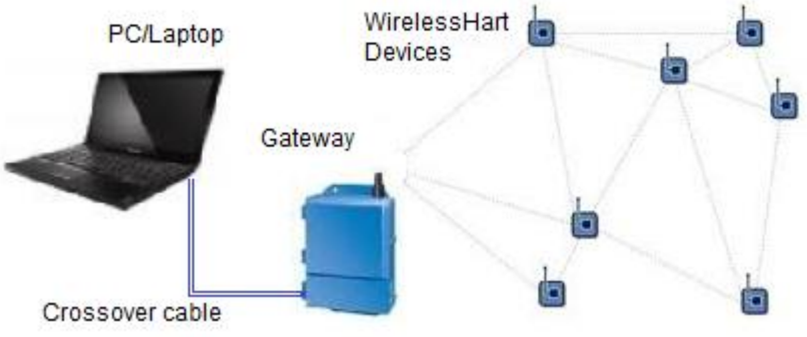


Figure 1. Connections among computer, network manager and WH field devices.

4. Case Study

In order to evaluate the developed system, a case study is conducted with the proposed tool. The network used in the tests is consisted of the following devices: a network manager, access point and gateway from Emerson model 1420A; temperature sensors also from Emerson; prototypes: a previously WH compatible developed prototype [Muller, Ivan et al. 2010] and a development kits from Freescale's MC13224 [Freescale 2009].

The tests are carried out inside a lab to guarantee adequate spacing between the field devices and the network manager. The field devices are deployed in order to communicate directly and indirectly with the network manager. This permits to identify possible routes of data determined by the network manager. In Figure 5, a representation of the devices distribution as well as the obstacles is shown. The software connects to the network manager via gateway and records the various data associated with the protocol commands. The data pertain to the distribution of the proposed network and several conclusions about the network health can be retrieved. The dynamics of a WH network can be now studied.

4.1. Obtained Results: Network Health

The devices are deployed at various locations in a process plant. An important feature as a result of this distribution in space is the quality of the radio signal. A WH device keeps in memory a list of other devices which can communicate. The signal quality variations may lead to the discovery and addition of new neighbors, loss of neighboring devices or in the choice of different routes for communication. Graphs that identify neighboring devices are obtained by the analysis of the device and the signal strength between them. In the graph of Figure 2 for device nicknamed 6, we can see that all the measured intensities showed little variation. The data is related to the RF signal intensity received by the device 6 from devices 1, 2, 3 and 4. Another data retrieved from the network, are the lists of the active superframes, network links and information related to the devices. The links represents the parameters required to move a package in a hop (between adjacent nodes). The links are addressed by their position in the link list of devices. Figure 3 shows a sample table of links recorded in the device nicknamed

5. It is noticed that the device number 5 has links with the access point (nickname 1), the network manager (nickname F980) and link broadcast address (nickname FFFF).

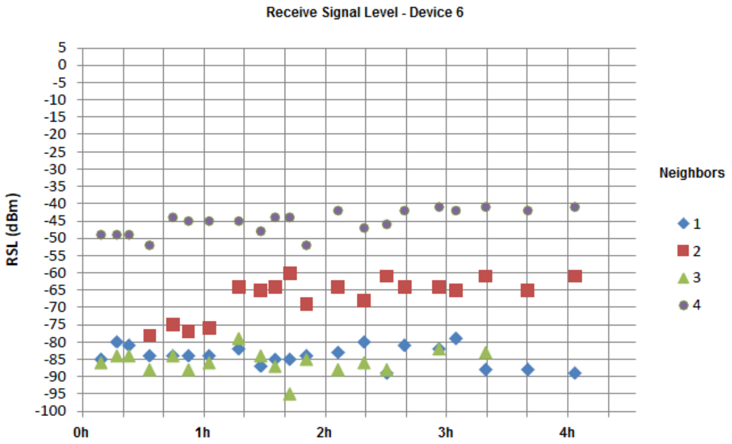
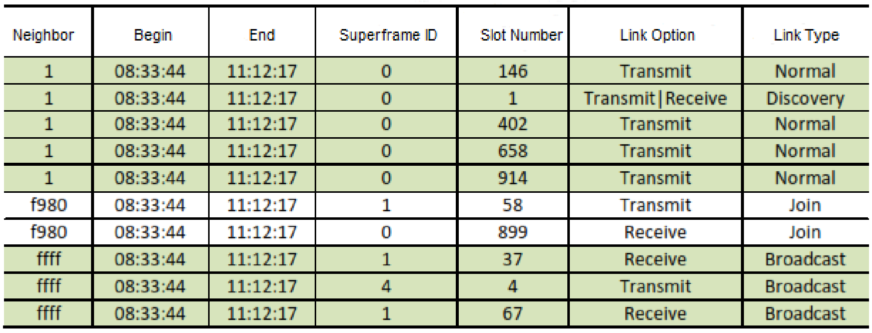


Figure 2. Graph of RF signal intensity received by the device 6 from devices 1, 2, 3 and 4.

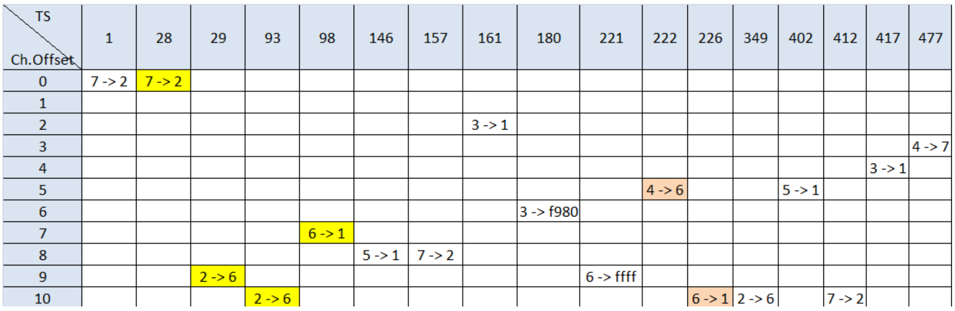
From the data obtained we can identify the list of links used by the device and thus the definition of some possible routes. In this analysis, one can see in the Figure 4 the used RF channels and packet switching. Also, we observe time slots that are obtained sequentially and data fragmentation. For example, a packet is transferred from device 7 to 2 to 6 and finally to the access point device (1).



Neighbor	Begin	End	Superframe ID	Slot Number	Link Option	Link Type
1	08:33:44	11:12:17	0	146	Transmit	Normal
1	08:33:44	11:12:17	0	1	Transmit|Receive	Discovery
1	08:33:44	11:12:17	0	402	Transmit	Normal
1	08:33:44	11:12:17	0	658	Transmit	Normal
1	08:33:44	11:12:17	0	914	Transmit	Normal
f980	08:33:44	11:12:17	1	58	Transmit	Join
f980	08:33:44	11:12:17	0	899	Receive	Join
ffff	08:33:44	11:12:17	1	37	Receive	Broadcast
ffff	08:33:44	11:12:17	4	4	Transmit	Broadcast
ffff	08:33:44	11:12:17	1	67	Receive	Broadcast

Figure 3. Typical superframe and link information.

Other data are related to route identification through the graph or origin. Information about the established sessions between the devices is also taken from network manager. Sessions are addressed by their positions on the device and multiple sessions are supported. A session provides a private and secure communication between a pair of network addresses.



TS Ch.Offset	1	28	29	93	98	146	157	161	180	221	222	226	349	402	412	417	477
0	7 -> 2	7 -> 2															
1																	
2								3 -> 1									
3																	4 -> 7
4																3 -> 1	
5											4 -> 6			5 -> 1			
6									3 -> f980								
7					6 -> 1												
8						5 -> 1	7 -> 2										
9			2 -> 6							6 -> ffff							
10				2 -> 6								6 -> 1	2 -> 6		7 -> 2		

Figure 4. Map of utilized links.

Through the test and interpretation of data obtained we found the network typology for the deployed devices. This topology is recorded by evaluating the data when all the network devices are associated with the main parameters. These parameters are discovered neighbors, links established between the devices. Devices nicknamed 2, 4 and 7 are used to establish intermediate devices and to exchange data packets to the gateway. The used paths are shown in Figure 5.

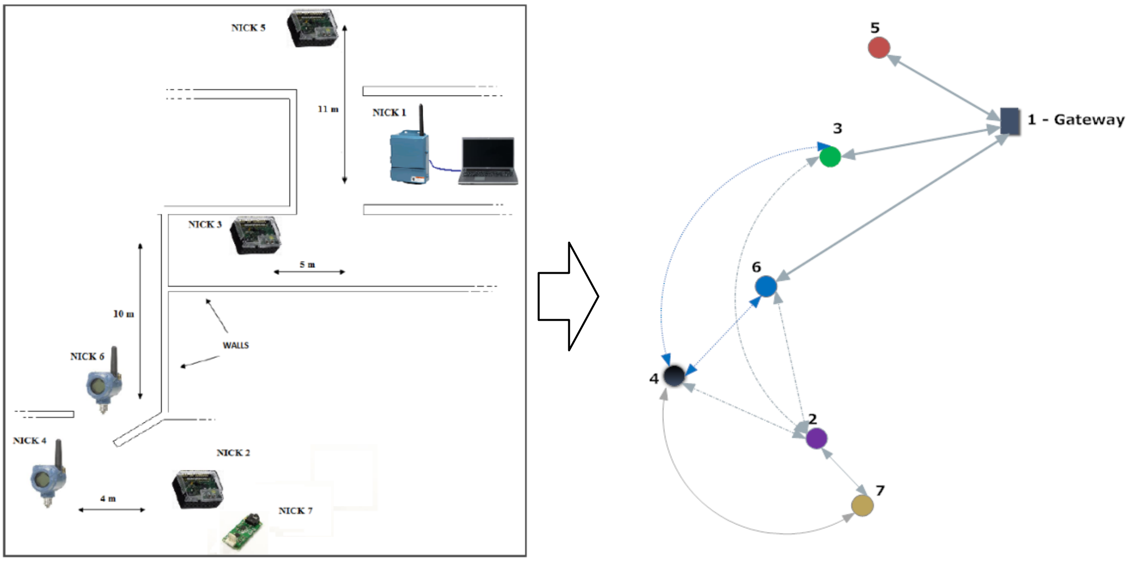


Figure 5. Deployment of the devices for the test scenario and network topology obtained by the developed software.

5. Conclusions

The process control industry has undergone many technological advances. Among all of these technologies wireless communication networks are those that have undergone bigger advances. As a consequence, wired networks are gradually being substituted by their wireless equivalents. This change of paradigm augmented the automation degree allowing more data, higher performance and efficiency. The networks now can be easily upgraded by demand, as the wireless devices don’t need any cable infrastructure. On the other hand, the employed wireless protocol has to be robust, flexible and reliable. The WH standard is the most prominent protocol available, ready to use. Once a wireless protocol is adopted, we need to know the behavior of the network and its health along the time. In order to do this, a complete set of tools need to be developed. Concerning WH, this includes tools to supervise the network manager, tools to supervise devices directly and tools to supervise the networks, without any network interference by means of sniffers.

In this work a PC software was developed in order to obtain WH network data. These data were used to analyze a test bed network and the results confirmed the usability of the developed system. Initially we attempted to monitor the dynamics of the network topology, so that one of the standout features of this protocol (the ability to form mesh topologies and so, redundant paths) was verified and confirmed. Following tests permitted the observation the completeness of the information received by the equipment used in the tests. Through these tests and results we can go for a next step in the development of this protocol. Future works are the improvement of this application by the inclusion of a graphical interface that allows more friendly interaction with the user. Also, automated data retrieving, based on triggering events will be possible.

References

Willing, A. Matheus, K., Wolisz, A. (2005). “Wireless Technology in Industrial Networks”. Proceedings of the IEEE, Vol. 93, No. 6.

Khakpour, K., Shenassa, M. H., (2008). “Industrial Control using Wireless Sensor Networks”. Information and Communication Technologies: From Theory to Applications, ICTTA.

Svensson, S., Lennvall T., (2008). “A Comparison of WirelessHART and ZigBee for Industrial Applications”. ABB Corporate Research. Factory Communication Systems, WFCS. IEEE. p. 85-88.

Horjel, A., (2001). “Bluetooth in control”, Department of Automatic Control, Lund Institute of Technology, Lund, Sweden, Available online at www.control.lth.se/publications/msc/2001/documents/5659.pdf.

Kim, A. N., Hekland, F., Petersen, S., Doyle, P., (2008). “When HART Goes Wireless: Understanding and Implementing the WirelessHART Standard”. In Emerging Technologies and Factory Automation. IEEE, International Conference.

Song, J., Mok, A. K., Chen, D., Nixon, M., Blevins, T. and Wojsznis, W. (2006) “Improving pid control with unreliable communications”. In ISA EXPO Technical Conference.

Konovalov, I., Neander, J., Gidlund, M., Österlind, F., Voigt, T., (2011) “Evaluation of WirelessHART Enabled Devices in a Controlled Simulation Environment”. In IEEE International Symposium.

IEEE 802.11. Available online at: http://grouper.ieee.org/groups/802/11/.

Rappaport, T. S., (1996), “Wireless Communications – Principles & Practice”, Prentice Hall Communications Engineering and Emerging Technologies Series.

Song, J., Han, S., Mok, A. K., Chen, D., Lucas, Nixon, M., and Pratt, W. (2008) “WirelessHART: Applying Wireless Technology in Real-Time Industrial Process Control”. In IEEE Real-Time and Embedded Technology and Applications Symposium.

Chen, D., Nixon, M., Mok, A., (2010) “WirelessHART: real-time mesh network for industrial automation”, Springer, England.

Song, J., Han, S., Mok, A. K., Chen, D., Lucas, and Nixon M., (2007) “A study of process data transmission scheduling in wireless mesh networks”. In ISA EXPO Technical Conference.

HART Communication. Available online at: http://www.hartcomm2.org/index.html.

Muller, I., Pereira, C. E., Netto, J. C., Fabris, E. C., Algayer, R. (2010) “Development of WirelessHART Compatible Field Devices”. In: 2010 IEEE International Instrumentation and Measurement Technology Conference, Austin, TX. New Tork : IEEE PRESS, v. 1. p. 1430-1434.

Fresscale, (2010). “MC1322x. Technical Data”. Revision 1.3, Available online at: http://www.freescale.com/