Design, Implementation and Simulation of WirelessHart Network

Miroslav Kostadinovic[1], Mile Stojcev[2], Zlatko Bundalo[3], Dusanka Bundalo[4]

Abstract – **In this paper has been presented the way of design and implementation of WirelessHart in the work with the modified TrueTime simulator based on the MATLAB/Simulink, which can simulate the regulating and control mechanism in the execution of tasks in real-time systems, networks and dynamic plants. WirelessHart MAC protocol has been designed and implemented with some C++ functions with the suitable MATLAB MEX interfaces. For better understanding of MAC protocol in the work has been implemented the algorithm of pseudo-code.**

Keywords – **WirelessHart, TrueTime, MATLAB/Simulink**

I. Introduction

WirelessHart protocol has relatively low speed of data transfer in the comparison with the IEEE 802.11g standard for computer wireless networks. This protocol works on the frequency of 2.4GHz in the ISM radio range using the Time Division Multiple Access (TDMA) for access to communication medium [1]. The complete time of communications executes inside predetermined time slots of 10 ms. Series of the time slots form superframe for the data transfer and WirelessHart makes possible the hopping between communication channels in order to avoid interference and reduce multi-path fading effect. One or more appliances or devices which send data and one or more appliances or devices which receive data can be determined that communicate mutually in one beforehand envisaged time slot. Time slot may be reserved for communication of only one appliance or can support dividing of data transfer across one time slot. WirelessHart is communication protocol that is organized like the ISO/OSI 7 communication model. Data transfer from all communication appliances in WirelessHart network passes across the gateway (Fig. 1). It can be seen that gateway must direct packages towards beforehand quoted destination. Gateway uses standard HART commands for communication with network devices and host applications. The network manager creates start superframe and configures Gateway [1], [2].

[1]Miroslav Kostadinovic is with the Faculty of Traffic and Transportation, University of East Sarajevo, Vojvode Misica 52, 74000 Doboj, Bosnia and Herzegovina, E-mail: kostadinovicm@gmail.com

[2]Mile Stojcev is with the Faculty of Electronic Engineering, University of Nis, Aleksandra Medvedeva 14, 18000 Nis, Serbia, E-mail: stojcev@elfak.ni.ac.yu

[3]Zlatko Bundalo is with the Faculty of Electrical Engineering, University of Banja Luka, Patre 5, 78000 Banja Luka, Bosnia and Herzegovina, E-mail: zbundalo@etfbl.net

[4]Dusanka Bundalo is with the UniCredit Bank, Banja Luka, 78000 Banja Luka, Bosnia and Herzegovina, E-mail: dusanka.bundalo@unicreditgroup.ba

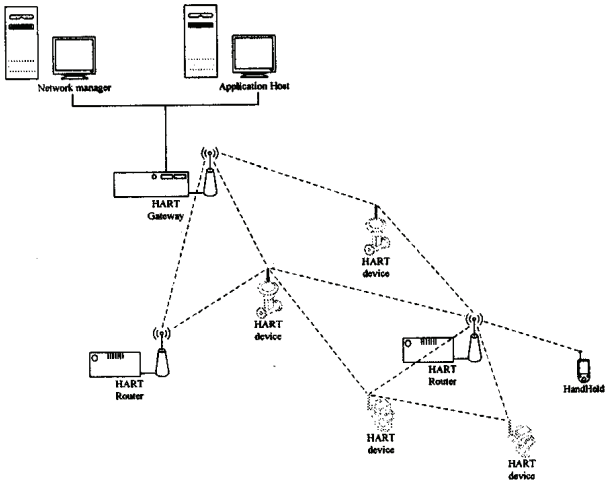

Fig. 1. Structure of WirelessHart network

II. Short Description of True Time

A. Simulator Description

Here is described the usage of original simulator (dissembler) TrueTime based on the MATLAB/Simulink, which simulates regulating and control mechanism in execution of tasks in real-time systems, networks (wired or wireless) and dynamic plants.

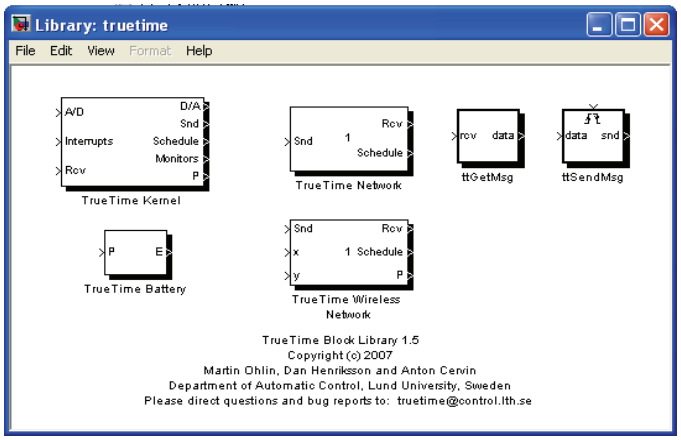

Fig. 2. The TrueTime 1.5 block library

TrueTime do not compose only library blocks (Fig. 2) but also collections of C++ functions with the suitable MATLAB MEX interfaces. Some of the functions make possible by simulation designing of tasks, manually interrupting, surveillance, timers, etc. The other function are real-time which are called by the code during execution of task and enable AD/DA conversion, sending and receiving of

messages, etc. TrueTime has been developed on Simulink, which takes care of the managing system in the meaning of performances, stability and endurance, and primarily has been intended for usage together with the MATLAB/Simulink [2].

B. Work of Wireless Network Block

Wireless network block simulates access to the medium and transporting of packages. Originally in TrueTime have been implement two kinds of communication protocols, 802.11b/g (WLAN) and 802.15.4 (ZigBee). Usage possibility of WirelessHart is later added and makes possible simulation of lost packages using the package error probability [3]. Here will be described new functions in Wireless Network block and possibilities of WirelessHart.

C. New Functions in Wireless Network Block

Here is described new utility program implemented to improve behavioral and usability of Wireless Network block in TrueTime. By study and research of problem of loss of packages in wireless control networks and comparing results of different solutions, possibility of establishing of time interval in which packages have been lost also has been added. WirelessHart uses the same parameters as for Wlan and ZigBee with the addition of three fields to set the number of channels, the size of the slot and the superframe length.

Simulation is used for the surveillance of position of lost package and for this reason has been included new graphic function. It emphasizes on the graph when the package has been lost because of the collision. It allows study of simpler way how to influence on the control performance.

The first useful functionality is 3D location of network nodes which makes possible more realistically setting of appliances and devices in the environment. The second useful functionality is comprised in possibility to present the outside noise source. Improved usability of the tool gives possibilities for information when has been lost the package. Modification in TrueTime graphic interface and Wireless Network block has been made for usage of WirelessHart protocol. For more realistic behavior of appliance MAC level has been relocated from Wireless Network block and is implemented in the special function that may be called from every appliance and device.

III. Description of MAC Protocol

Here is explained the way of implementation of WirelessHart in work with modified TrueTime simulator. WirelessHart MAC protocol has been implemented with some C++ functions with suitable MATLAB MEX interfaces and the main function applies algorithm which allows the access to the medium. Later have been described all technical details. The main task of MAC protocol is:

1. Synchronizations of slots.
2. Identifications of appliances and devices which demand the access to transmission medium.
3. Transmission of messages accepted from the network layer.
4. Listening of packages transmission of neighboring nodes.

Farther has been presented WirelessHart MAC protocol. WirelessHart uses TDMA and hopping technique between transmission channels for access control to the medium. Every appliance and device has table in which are determined all information that is necessary for the communication [4]. When the device wants to transfer message it must call MAC function (Fig. 3) which reads the table and checks is the device permitted to transfer message. In other words the MAC protocol checks is valid slot reserved by the appliance which has called the MAC function. If the slot is reserved then the transfer is allowed, in opposite case the transfer is blocked.

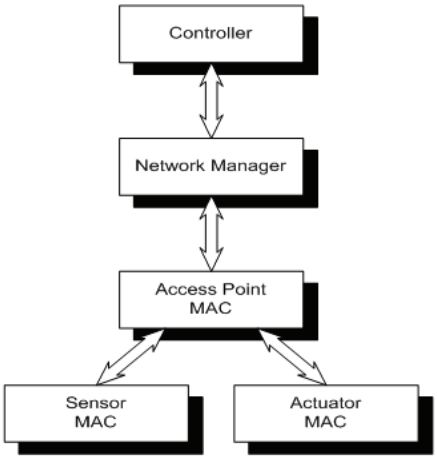

Fig. 3. MAC protocol location in a real environment

WirelessHART communication uses TDMA technique for the organization of communications across the transfer channel. All communication in the network are prepared according to already beforehand defined size of time slots of 10 ms. If it comes to the loss of package, it will be tried repeated sending of package that reserves additional time slot. In the case of sharing of time slot it can happen the appearance of collision, back-off counter will reduce value on 0, as long as it comes the repeated sending of package. Back-off counter decrements the value only once for one time slot. Because of these reasons MAC sublayer will not try communication more often then for time interval of 10 ms.

All communication appliances support multiple superframes, formed from time slots where the size and number of slots is fixedly determined. Sending of superframes is constantly repeat according to beforehand defined time interval [3]. For successful and efficient TDMA communication the key is synchronisation of tact (clock) between appliances in the network, in order to appliances know when appears the start of slot. Inside slot beforehand is defined interval between the start of slot and start of sending of original message, what makes possible source and destination nodes adjustment of frequencies of communication channels and allows the receiver listening of required transfer channel. Since exists the tolerance in tact generators, receiver must start listening of transfer channel before the start of time for ideal transfer of the package and after this it must continue listening of transfer channel. When

the transfer has been finished the direction of communication is turned and destination machine sends to the source confirmation of successful reception of message (ACK).

To increase reliability it is used technique of jumping (hopping) between transfer channels which makes possible the work on different frequencies i.e. that different appliances transfer messages in the framework of same time slot using different transfer channels. I this way is avoided appearance of interferences and is decreased multi-path fading efect [3]. When the appliance tries transfer in the framework of common slot, MAC function checks the status of channel and if the channel has been occupied it estimates back-off time.

IV. Control Performances of WirelessHart

Already two decades HART communication presents the standard for the simplicity, safety and reliability in the process industry. WirelessHart has been designed primarily to cover very wide range of needs in the process industry from the simple supervision to the control in closed loops [4]. Testing and experiments in the field with wireless appliances and devices have shown that these appliances provide correctness of communications, stability, reliability and that can satisfy all needs of supervision and control in industrial processes.

Control applications require periodical samples and on this occasion appear disturbances and delays which especially appear in WirelessHart technology. Actually, control performances with WirelessHart can be compared with the wired system that uses conventional field bus highway. Farther have been presented the some of the factors which appear in uses of WirelessHart.

A. Selection of Time Slots

Sampling speed for WirelessHart is determined from the condition that needs to be fulfilled on the basis of the requirement of concrete control loop while it is necessary at the same time to minimize influence of energy consumption of field appliances which can be supplied using batteries. Usual rule based on experience from practical systems of control is that the feedback control information is taken 4 to 10 times faster than is the speed of process response, where the time of response of process is equal to sum of time constant and dead time of process.

Measuring systems are often unsynchronized with the control system and measured values are usually sampled 2 to 10 times faster than is the answer of process on the change of parameter. In wireless systems it is desirable to reduce the sampling frequency and speed of communication with the measuring device in order to extend the life cycle of battery.

Communication using WirelessHart protocol is realized without endangering the reliability of control [4]. Fig.4. shows two methods that are used by the sampling:

1. *Synchronized*. Samples are taken only when it is necessary control above the process.
2. *Synchronized with exception reporting*. Samples are taken for beforehand envisaged intervals, for example 4 to 10 times faster than is the response time of process, but transfer is performed only if it is changed measured value or if it is run out the time which was beforehand defined as the time between sending of two messages.

More frequent sending of measured values is possible as well as by the appliances and devices in the wired network. In the case of appliances which use batteries or the appliances where important is to preserve energy, WirelessHart offers users possibility to use the optimal balance at searching of compromise between speed of communication and lifetime of battery.

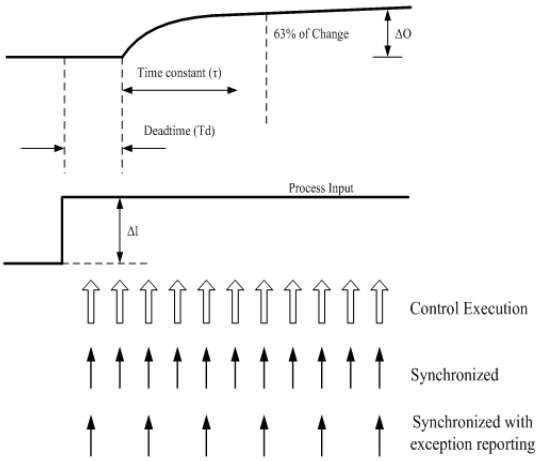

Fig. 4. Synchronized sampling of time slots

V. System Redundancy with WirelessHart

In the process of automation operators take decisions on the basis of available data, and when are not available one or more process variables they must make a decision without complete picture what happens in the control process. The same is valid also for control systems which have no all necessary entry data or in which output of control algorithm could not be able to provide the best functionality of control on the control process or even can lead to the exclusion and stopping of control of process [2].

Therefore control process sometimes use system of redundancy to minimize probability of loss of data. This is especially important for processes where control data are critical from standpoint of control process or where the failure of one component can result in the loss of large number of process variables. Redundancy can be doubled by any component of system, from the device to the controller and also to the level of communication. For example, wired communication system can have two special cables or wires for transfer of one the same communication. Wireless systems can also give the redundancy in order to prevent the loss of data. In the event of WirelessHart the redundancy is available at all levels of network system [1].

WirelessHart gives the redundancy in wireless sensors networks through a few mechanisms. Every communication can have:

1. Multiple transmission paths between field appliances and devices and network gateways (spatial diversity).
2. Multiple transmission radio channels (frequency diversity).
3. Multiple possibilities of measurement of time intervals (time diversity).

Here it is presented example shown in Fig. 5. If communication from the appliance TT101 towards gateway is not possible via path A-B-C the appliance will again in very short interval and via other transmission channel try to achieve the communication via other path, for example via D-E-F. If this also is not succeeded the appliance will try again via path D-G-C. System makes possible three attempts during establishing of communication towards destination. This redundancy has been enabled in both directions, from gateway towards the appliance and from the appliance towards gateway.

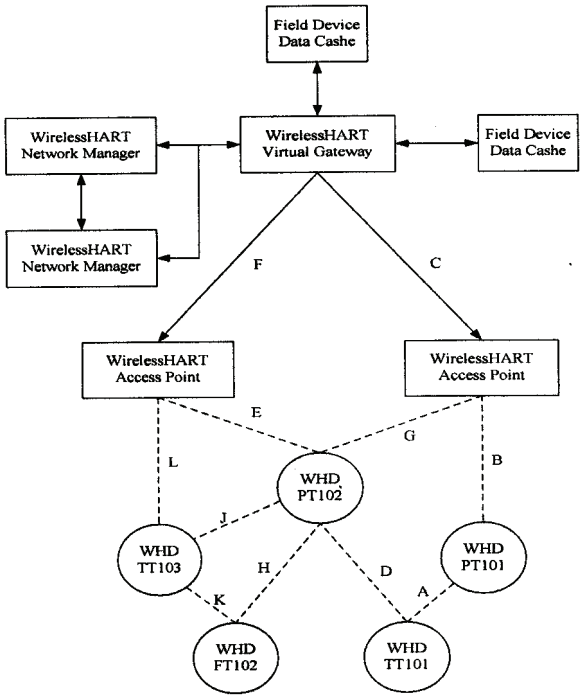

Fig. 5. WirelessHart system components and transfer paths

VI. Simulation of WirelessHart Network

To analyze WirelessHart protocol in the industrial plant it will be shown simulation of networked control system whose scheme has been presented in Fig. 6. Simulations have been made in the Simulink surrounding using the modified TrueTime dissembler.

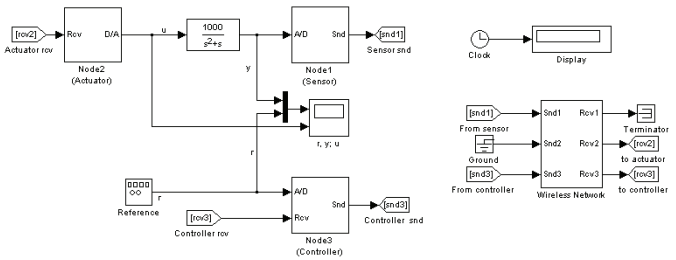

Fig. 6. TrueTime simulation model of the networked control system

Model of simulation may be described in the following way: Sensor periodically converts analog signal from the process into digital value and sends it to controller. Controller, after taking message from the sensor, calculates the output according to appropriate control algorithms and sends the control signal to the actuator using WirelessHart network. Actuator converts the control signal into analog and sends it in the process. Results of simulation of described model have been presented in Fig. 7.

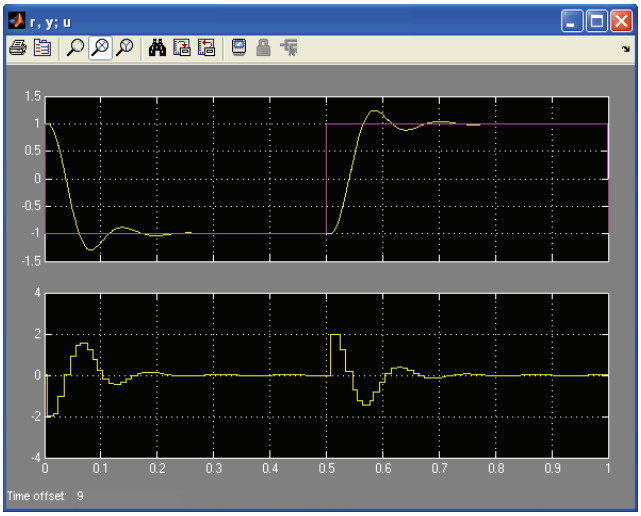

Fig. 7. Simulation results of simple TrueTime control

In order to use WirelessHART protocol in network control system it is necessary to check if the control system has the time constant of tenths of ms. If the system is faster then the WirelessHART can not be used.

VII. Conclusion

In the paper it has been described the new utility program implemented to improve behavioral and usability of Wireless Network block in TrueTime. Originally are implement two types of communication protocols, 802.11b/g (WLAN) and 802.15.4 (ZigBee) and the usage possibility of WirelessHart has been added.

WirelessHart makes possible the redundancy at all levels of the network. Total performances of WirelessHart networks are comparable with wire fieldbus networks. WirelessHart protocol makes possible secure, high reliable communication with small delay without influence on the throughput range and performances of process. All this possibilities are integrated in WirelessHart standard in order to enable: simplicity, reliability and safety.

References

[1] M. Kostadinovic, M. Stojcev, Z. Bundalo, D. Bundalo, "Control of WirelessHart Network", *INFOTEH'09, Symposium Proceedings*, Jahorina, Bosnia and Herzegovina, 2009 (in Serbian).

[2] M. Kostadinovic, "Application of Hart protocol for communication needs in process industry", *INFOFEST'08, Conference Proceedings*, Budva, Montenegro, 2008 (in Serbian).

[3] Andersson, M., D. Henriksson, A. Cervin "TrueTime 1.5—Reference Manual", *Department of Automatic Control*, Lund University, Sweden, January 2007.

[4] HART Field Communication Protocol, *Application guide*, HCF 2006.