University of Petrosani
DOCTORAL SCHOOL

PHD THESIS SUMMARY

CONTRIBUTIONS REGARDING PROCESSING THE INFORMATION AND THE ARCHITECTURE OF SENSOR NETWORKS WITH SPECIAL APPLICATIONS

SCIENTIFIC COORDINATOR:
P.H.D. mat. Emil POP

PHD STUDENT:
Ing. POPA Ionuț- Alin

PETROȘANI
2019

TABLE OF CONTENTS SUMMARY

1. INTRODUCTION

At present, WSN sensor networks have become increasingly important in all areas of activity ranging from household to industrial or strategic. As regards the structure of sensor networks, a number of technological developments can be observed as they are more robust, cheaper, with adaptations to changes in network topology and environmental conditions.

Sensor networks are based on SCADA technology that is still operational, enabling the operator to collect information from remote equipment (valves, sensors, pumps, etc.) and to send a limited set of instructions to them for the purpose of monitoring and command of processes technological in a centralized version.

WSN's contemporary technology has superior and totally different features to SCADA: it is a stable industrial solution and fast technical support, flexibility in further development of the system to integrate into other systems including SCADA technology, collaborative local software, environmental integration, distributed monitoring and remote control and, providing users with an easy way to operate, increasing the life of equipment and machinery through proper operation (automatic operating mode), rapid diagnosis of alarms and preventive maintenance, optimization of operational consumption/ costs, etc.

The WSN networks began in the US in 1980 at Defense Advanced Research the Project Agency (DARPA), which set up a demonstration application of a helicopter tracking system (Myers 1984) using a distributed range of acoustic microphones via signal abstractions, but sensors were quite large like a shoe box and the number of applications was limited so recent developments advances in computing, communication and microelectromechanical technology have led to a significant change in research and have contributed to microminiature of sensors.

Moreover, sensor nodes have become much smaller (similar to a card or dust particles) and much cheaper as price, so that new applications of networks sensor such as environmental monitoring, sensor network for vehicles and sensor network attached to human body.

Sensor networks were launched in Europe in March 2006 by the European Agency for Monitoring, Structural Assessment and Control, with the objective of establishing a monitoring network and a European integrated infrastructure by the end of 2020. However, WSN developments have prompted smart strategic applications for cities, water, transport, energy, and the emergence of an Internet of things (IoT), considered one of the major technological challenges.

IoT devices have as a starting point WSNs to extend this concept with the proposal of applications where embedded devices with an Internet connection help to automate user tasks. So IoT devices have ideas in many applications from the usual to the special ones.

The term internet of things was developed by Kevin Ashton in 1999 and refers to identifiable and virtual objects, representations in an "Internet-like" structure. These objects can be anything from large buildings, industrial, plants, planes, machines of any kind, goods, certain parts of a larger system for beings, animals and plants, and even parts specific to the human body.

We can say that WSN represents the path of the future, being universally omnipresent computers (ubiquitous), which will penetrate into all areas, including sensitive ones, as is the case with special applications.

2. MOTIVATION AND OBJECTIVE OF THESIS

The motivation of the PhD thesis is related, on the one hand, to the provision of safe locations for the personnel carrying out activities in potentially dangerous environments and for the military domain to find alternative sources of security that can be deployed, configured or self-configured in any location regardless of the conjuncture or situation.
The main objective of the thesis is to contribute to the processing of information and the architecture of sensor networks in special applications with applications in the underground coal mining field and with a specific reference to strategic areas such as: energy, intelligent transport, water, smart cities and military operations theaters.
The above main objective was achieved by reaching other specific objectives such as:

- the need for research has started from the steady increase over the past decade in the use and popularity of wireless communication systems and especially in environments where wired communication is not possible;
- improvement the protection of electrical equipment in explosive atmospheres; observance of the types of protection according to current standards;
- improvement the current state of control and monitoring of processes from potentially explosive environments.
- integration of a WSN network that has the ability to detect gas emissions and the transmission of remote results through IoT to take action of eliminate a disaster.
- designing a network of ad-hoc sensors that can be autoconfigured for explosive atmospheres, functionally compatible with remote transmission environment;
- the research was capitalized by supporting and publishing papers, in conferences / symposium proceedings and validation by modeling / simulation and prototyping on the Arduino platform.

3. KEY WORDS

From the title of the doctoral thesis ″Contributions regarding processing the information and the architecture of sensor networks with special applications″ there are some key words that have given a specific direction to this research.
These are: information processing, wireless sensor networks (WSN), control, transmission parameters, modeling / simulation, special applications, experiments. In principle, it is about creating systems for detecting, monitoring and controlling systems and processes that, through their specifics, take place in places where staff can be adversely affected by occupational health and safety through accidents. These are Locations with accidents potential, and in the case of explosive gas mixtures such as methane, these are called explosive potential location. Activities are only allowed in Safe Locations, without any risk. In this thesis we analyze, using mathematical methods, modeling / simulation and experimentation the possibilities of transforming the explosive potential locations into secure locations using WSN networks.

4. SYNTHESIS OF THE WORK

The structure of the thesis contains 6 chapters, with Introduction, a chapter of Conclusions, contributions and proposals, totaling 165 pages, of which 120 pages represent the actual thesis and 45 pages represent the Bibliography and the Annexes. The bibliography has 81 positions and the Annexex contributes to a better understanding of the thesis and its objectives.

The first chapter, entitled "Introduction", presents general considerations, the main objectives, the motivation of the thesis and a brief review of the paper as presented above. Sensors are technical devices that have the ability to gather information about systems or physical processes. They can act in different environments: in the underground, inside the buildings, in the free space, in aggressive environments or with hard accessibility, in water or under water.

In the near future, WSN sensor networks will become increasingly important in all areas of activity ranging from domestic to industrial or strategic.

A problem of great importance in recent years is the increasing security and safety of personnel carrying out activities in potentially aggressive environments such as chemistry, mining, military, oil, construction etc. Personnel activities must only be admitted if the work environment is safe. These domains are special applications for WSN networks.

Chapter 2, "The actual stage of Wireless Sensor Network Development," presents a brief evolution and development of wireless sensor networks (WSNs) as ubiquitous computers. Networks sensor wireless or WSN are part of the ubiquitously distributed computing systems category (Ubiquitous computing) and were introduced by Mark Weiser under the ubicomp acronym in 1991.

Today's science has created a relatively new and exciting field - systems with artificial intelligence. Her forerunner is considered to be Norbert Wiener, the parent of cybernetics based on the university's mathematics, biology and philosophy, and has succeeded in forming a new domain of meta-science called Cybernetics or the science of control and communication in machines and living organisms. It is good to recall here the Romanian Ştefan Odobleja, who prior to Wiener published in French the book ″ Psihologia consonantista″ in which he presented the principles of cybernetics, being rightly considered the precursor of cybernetics. One can assume that WSN is a class of cooperative sensors with software that gives them a particular quality "a level of artificial intelligence".

In this chapter, classical applications related mainly to disaster monitoring and then some of WSN’s smart applications are presented like: Intelligent Electricity Network, Intelligent Urban Transport, Intelligent Water Networks, Intelligent Buildings, Network Centric Warfare, with the benefits and challenges it implies.

One of the special applications to which the thesis refers is represented by locations with " explosive potential atmospheres" such as chemistry, mining, army, etc.

Thus, in the mines with explosive atmospheres, a SCADA system for controlling and monitoring the parameters of the underground atmosphere called “Telegrizumetrics Central” has been used for decades. Note that SCADA is able to transmit information both by cable and radio over long distances. All of these systems have a common feature: data control and processing are centralized, requiring very expensive, energy-intensive hardware and software resources, and is not fully achieve safety. WSN structure are made up of nodes. A node is structured as 4 basic components: environmental sensors, data and program memory microcontroller, wireless communication interface, power supply. Sensor-free nodes have the quality of a router amplifying the signals and thus increasing the transmittance fully safe.

A first example of the node was the MICA Mote system, developed at Berkeley University, having the size of a matchbox with Atmega processor, transmission distance of 40 m, light sensors, temperature, seismic, acceleration, acoustic and magnetic source with 2 AA batteries enough for a few months. Uses the TOS operating system.

In 2001, the concept of Smart Dust (Smart Dust), consisting of millions of millimeters of sensors that are launched in the environment to monitor different phenomena, was launched. Each microdevices has all four elements of a node structure, can float in the air, can be embedded in the building plaster, configured and maintain themselves.

It has become a standard, the ZIGBEE family with XBEE variants, designed to equip sensor networks for monitoring and controlling building environments and beyond. In addition, ARDUINO technology provides accessible as price and configuration modules for testing sensor network applications, being a useful platform in the experimental prototype stage.

The operating systems and programming languages used by WSN represent an extensive category of information products called Middleware, providing environmental sensors and providing an infrastructure for interoperable applications. Among these are: SensorWare, DSWare, TOS, MAC etc. Generally, the programming languages used by WSN are restrictions of classical languages: C, C ++, BASIC, JAVA, etc.

The development of WSNs started as military applications in the US, in particular conflict surveillance, when the US called on the DARPA to develop the Distributed Networks of Sensors (DSNs) for the US Army. A wider list of applications is given below.

Regular (classic) WSN applications:

- disaster detection
- environmental quality control
- ecological control for the so-called geo mapping of biodiversity in certain habitats
- Surveillance of mechanical stress on buildings in seismic areas

Strategic WSN Applications:

- realization of the smart electric network
- online monitoring system for intelligent transport
- WSN applications in intelligent water network monitoring
- city logistics
- WSN applications for smart homes

Special WSN Applications:

- monitoring potentially explosive locations

This application is still at the beginning and is dealt with in detail in this thesis.

- Network Centric Warfare (NCW), the term network-centered operations refers to military operations, operations activated through the Military Force network.

As the development of WSNs has been made, we will present some elements of it.
NCW is the new military strategy in which WSN's special applications are fully utilized starting with the soldier (the future, the universal), continuing with the military technique and command center. The fighter's equipment will be made with advanced technology, the outer layer will be heat-insulated and waterproof, will be able to change the color according to the environment of the fighter. The surface of the suit will be treated with nanoparticles of carbon nanotubes, so it is believed they will be able to detect the approaching of the bullet, generating a shield electric field that will stop or deviate the projectile, the whole body and especially the vital organs will be protected. The military helmet is also performing with integrated gas mask that adapts to detectable noxes or germs, night-vision stereoscopic cameras, tactical images and data projected inside the weatherproof and shockproof visor, high-security satellite communications, voice control for other applications.

- German version of the future soldier called Gladius.

Supplied by Rheinmetall company, he was interested in a partnership with a Romanian company, for such equipment to be produced for the infantry forces of the Romanian Army. Gladius helps the infantries to identify the targets more precisely, which is vital for their own protection, but also for the civilian population. The system is modular, does not overload it, and energy consumption is minimal. Ballistic equipment protection reaches level 4, according to German military standards. Strengths are steel helmet and the so-called "electronic backbone" - a computer worn by soldier who controls the other subsystems and sensors in the equipment, giving the soldier information about his current situation and the position of the allied forces.

- The Universal Soldier Concept was launched by the Pentagon and is a development of the Future Soldier launched by the Advanced Defense Research Agency using genetic manipulation.

This wants to create the genetic manipulation of the perfect soldier able to resist for days without food or sleep, to run as fast as Olympic champions and even to regain his limbs lost in battle. One of his first projects was to build an exoskeleton to allow soldiers to run very fast and be able to carry enormous loads.
Genetic mutations target the body's ability to turn fat into energy and to last for days without food. The shocking thing is, however, the ability of organs to grow back by replacing the lost limbs in battle. The agency has spent a lot of money to find out which gene can trigger this phenomenon of regeneration, and have already studied cases in which the fingers of children have grown back.

- In Romania, an important thing is the Center of Excellence, which is responsible for the simulation of CILFT combat operations.

CILFT features real-time simulation, virtual simulation VBS2 and JCATS simulation. CILFT provides military training using the various simulation types but can integrate them into so-called LVC simulation federations. In the latter case, exercises distributed at brigade level can be

carried out. The future soldier in the German version could be a starting point for equipping the Romanian Army's infantry forces.
At the end of the chapter are listed the main types of sensors in WSN for special applications, namely:

- Air quality sensor SGP30;
- Gas Sensor MQ-2;
- Methane Sensor MQ- 4;
- Motion and vibration sensor;
- Temperature sensors;
- Inductive speed sensor;
- Presence and pressure sensors;
- Current, voltage, proximity sensors;
- NI-WSN, WSN Multiple Node.

Chapter 3 called "Special Applications of WSN Wireless Networks", in this chapter is a brief definition of the concept of "special applications" as "the use of WSN in areas with potential for accidents to provide locations safe work ". Such areas are potentially explosive: mining, oil, chemical, food, marine, etc.
The characterization of a location with aggressive potential is made by three conditions defining the accidents triangle:
1. If the environment facilitates the production of accidents;
2. If there are event conditions;
3. If there are sources that can trigger accidents;
Particularly for coal mining, this is called the explosion fire triangle.
The safe area, the potentially explosive zone, the explosion risk area are then defined. It shows how a potentially explosive zone turns into a safe area using intrinsically safe equipment, positive safety remote control devices, and explosive atmosphere monitoring through SCADA and more recently WSN systems. At the end of the chapter are listed the qualities of WSN networks that make them useful in monitoring and control applications in underground coal mining, with application to distribution of WSN networks in cut coal.
Transforming potentially explosive location into a safe location is done by two actions:
• Remove any sources of explosion initiation.
• Maintaining the percentage of methane in the air of the location below 1%, which is non-hazardous.
The first condition is ensured by the use of anti-explosive construction equipment and the second by aerating the locations and permanent control of the methane percentage.
One single problem remains sensitive, namely the communication between the equipment and staff that needs to be done through intrinsically safe and positive protective devices.
An example of this is the remote-control device with intrinsic protection and positive security and which, as presented in the thesis, can be achieved by software.

Regarding the special applications in the coal mines, the thesis presents at the beginning the geological-mining conditions for the extraction of coal, the location named production working, which is made by various exploitation methods such as:

• slice mining;

• drilling-blasting mining;

• undercut mining.

Methane also called mine gas is present in coal layers, but also in surrounding rocks, reaching underground workplaces with exploitation and a permanent hazard, especially if they accumulate in flammable or explosive concentrations.

Pure chemical methane is a colorless, odorless and insipid gas, not detected by human senses. The ignition temperature of the methane is quite low, 650-750 ° C and drastically reduces when mixed with air. In this sense, gas releases that could create an explosive atmosphere must be controlled and maintained in a perceived percentage as non-hazardous and the equipment, installations and machinery to be anti-explosive and periodically controlled.

The advantages of WSN that make them very useful in special applications including underground are:

• WSN forms a control loop with the real world;

• WSN are a set of simple nodes that cooperate as one unit;

• WSN nodes process environmental data integrating human experience with the real world;

• Nodes operate on the principle of energy conservation;

• WSNs are automatically located in space and synchronized in real time;

• WSNs are tired architecture platforms as a local / global compromise.

As presented above, the solution proposed in this chapter is: the combined use of sensor networks with the SCADA scanning system.

Besides, some mining companies have announced that they are in the advanced phase of implementing mining sensor networks, so we have presented a prototype produced by Australia's MST.

WSN consists of two main components: the remote telemetry unit (RTU) and the network connection port of the mine called gateway. RTUs form their own WSN network at 802.15,4 MHz.

The chapter is largely original, some concepts and examples have been published by the author in the prestigious journals and Proceedings ISI, indexable in Thomson Reuter / Web of Science.

The 4th chapter is titled "Modeling and simulations of special applications with Wireless Sensor Networks".

In this chapter is presented the modeling/simulation-algorithm for the special applications of the WSN sensor networks.

In case of using WSN in special applications it is necessary to have modeling / simulation platforms capable of doing the following:

• Designing the accidents with potential location;

• Configuring individual SCADA sensors (if any) and WSN;

• Establishment of hazardous routes and installation of WSN networks;
• Adjustment of WSN sensor parameters;
• Network programming;
• Simulation and extraction of results;

Among the modeling and simulation platforms, CupCarbon is one of the most complete and performing software products.

In this paper we used the CupCarbon simulation/modeling platform, which was briefly presented below, with an example of a real case, namely the extraction of coal from a production working.

CupCarbon is the result of the French project ANR PERSEPTEUR which aims to develop algorithms for simulating WSN applications in a 3D environment.

Networks can be designed and prototyped through an easy-to-use ergonomic interface, using the OpenStreetMap (OSM) graphics application.

Energy consumption can be calculated and displayed based on simulated time.

The CupCarbon grafic interface is composed of five main parts:

• Location map
• Menu bar
• Toolbar
• Parameters panel
• Console

Sen Script is used to write programs necessary for the operation of the sensor nodes of the CupCarbon simulator, the language used is a simplified processing of the Java script.

Below we presented an example of modeling / simulation in the case of a classic underground working location with combine and conveyor so that such an approach limits the risk of global accidents through the SCADA scanning system of the S sensors and ensures a safety location at the local level through the network WSN, W sensors.

The model is a concept to simulate the scenario described below.

If the methane is detected, the appropriate sensor processes the information data of other WSN sensors and sends a synthesis of the situation to the receiver sensor.

Of course, in dangerous situations, the Scada and WSN systems will react by activating the feedback to disconnect the electricity in order to protect the hazardous space.

Finally, the result model is simulated and the Arduino code can be generated for practical testing.

Such an approach limits the risk of accidents through the SCADA scanning system of the S sensors and provides a more secure location locally through the WSN W sensor network.

The modeling / simulation was implemented on the CupCarbon platform as follows:

- the real world of the mining site was designed based on the technological model presented with the SCADA S sensors;
- based on human experience, methane from free space, coal front, bunker and conveyor were determined.
- a mobile element was introduced, simulating the evolution of methane, running on methane evolution;

- Three WSN Wi (i = 1, 2, 3) node sensors are introduced, arranged in a star topology and each is transmitting to an intermediate router and final router which then connects to the gateway receiver connected to IoT.

The simulation results are presented for two situations: first, when the intermediate sensor detects methane in the coal layer after combine cutting and the second when methane from the bunker and belt conveyor infiltrate. The two sensors are programmed to receive data from the work environment, cooperate, and transmit them to the gateway's final receiver. The receiver is programmed to retrieve data and upload it to the internet.

Thus, process managers and coordinators receive real-time information and decide what steps they need to take to ensure a safe working environment. Finally, the model for the simulation results is run and the code is generated for implementation on the Arduino platform.

In the thesis we can see the implementation with Arduino technology for 3 WSN gas nodes together with 2 routers and a gateway receiver for each node with a total of 6 routers and 3 gateways. Gateway receivers to connect to Internet or Internet of Things, can all have 3 channels in the same end device.

Chapter 5 "Special Applications and Experiments on Using Wireless Sensor Networks" presents some WSN prototyping applications and experiments such as the realization of methane sensor nodes, the transceiver as a radio transmitter / receiver using the Arduino platform and a C / C ++ communication program.

This chapter is largely original and contributes to the validation of the theoretical results presented in the doctoral thesis.

It has been started from the general block scheme of a WSN terminal node consisting of: Microcontroller & Memory Environment Sensors, Antenna Radio on the chip, Power Source, Input / Output Ports.

For the WSN application used in underground mining exploitations, using existing devices such as sensors, circuit elements, dedicated plates produced by Arduino, etc.

The Arduino Platform was used as follows:

• the gas sensor and the Arduino connection interface were selected;

• Arduino board has been used that has Online C programming language adapted for reading, writing ports and making radio communication;

• An appropriate plate for Radio and Antenna has been selected and used;

• Wireless module incorporating integrated circuit the nRF24L01 works in the 2.4 GHz standard ISM band, capable of up to 2 Mbps transfer speeds, can send and receive data from free space up to 150 m.

For experimentation, Arduino motherboard interface was designed for both sensors and radio, these interfaces were able to connect several types of sensors (gas, motion, vibration, etc.) without loss of transmission or errors.

Further, these routers will communicate via radio on different channels without being disturbed to the main reception node, which has a more complex equipment, as follows:

• an Arduino Nano that takes the data from sensors nodes and other routers;

• an Arduino Uno equipped with an Ethernet shield for the gateway;
• For connecting to the web interface, was used an adapter made as a shield connected to an internet router to generate a web page, these modules can also work offline where we can view the state of the input parameters without accessing the web page directly from a work station .

Having two or more Arduino can communicate with one another wirelessly over a large distance and with a transmission speed of 2Mb / s. To an Arduino module it can be attached and other types of sensors: distance, temperature, vibration, motion with which we can remotely monitor various underground activities and send centralized results through IP communication via IoT.

Also, in this chapter was treated an original application the statistical-probabilistic analysis of rare catastrophic explosions using the Large Numbers Law, which will be presented below.

Investigations on underground mining and geological research have concluded that systematic real-time monitoring, as well as maintaining machine and plant safety, is a good way to prevent accidents and disasters.

These systems have greatly reduced the explosion hazards, but have not completely eliminated them, so unfortunately there are still accidents.

The above shows that in underground mining, including abstraction, there may be "Probabilistic Event Fields" in which the Bernoulli Probability Law, known as the "Large Numbers Law", is applied.

From a practical point of view: The Law of Large Numbers affirms that a certain rare event will certainly occur, influenced by an arbitrary but very large number of other elementary events, some of which are favorable, even if each of them has a minor influence on the phenomenon considered as a whole.

For example, tossing a coin of n times and recording the number of occurrences of the "tail" m leads to m / n = 1/2 if n is large enough. The experiment by Pearson, who threw a coin over 11500 times (n = 11500) and obtained the tails over 6000 (m = 6000). A frequency of m / n = 0.5217 was obtained, close to the probability of 0.5.

Chapter 6 "Conclusions, Contributions and Proposals" highlights the conclusions, contributions and proposals for improving the architecture of sensor networks with special applications, including the possibility of using them in armed conflict.

5. CONCLUSIONS

The need to use the described sensor networks as well as the processing of information is justified by the increase of the technological and safety level in all fields but especially in those with special activities. There are currently many sensor networks that diagnose much of the deviations from the normal limits of different processes such as disaster monitoring, natural disasters, and military systems. For industries with potentially explosive atmospheres such as underground coal mining, the problem is right at the beginning. The Law of Large

Numbers indicates the possibility of preventing or even eliminating catastrophes if an appropriate strategy is chosen and WSN could favor this.
For some underground mining processes by using WSN, the following would be obtaining: making and using more compact and robust automation systems by removing classic long wire wires; proposing a command and control strategy based on WSN; the use of equipment's with intrinsic protection by software, resetting the cycle of probability events that ultimately would be catastrophic one.
This knowledge was acquired in the Department of Automatics, Computers, Electric and Power Engineering of the University of Petrosani, Faculty of Mechanical and Electric Engineering. To this knowledge is added the over 12 years of activity in the Ministry of National Defense, namely the Special Telecommunications Service.
The proposed IT system brings a new approach to the use of intelligent WSN sensor networks for special areas with highly affordable detection capabilities that can help facilitate wireless use on the one hand and secure locations on the other hand. The classical approach consists in the fact that information is transmitted to the process through a large number of cables and requires the use of complicated, costly and even heavy equipment that primarily affects safety and security of activities, creating fields of potentially dangerous events that conform to Laws of Large numbers can lead catastrophic accidents.
It was also considered that sensor networks must be as affordable as possible, have a high transmission capacity, be scalable and reconfigurable. The need for the described sensor network as well as the processing of information is justified by increasing the technological level in all systems worldwide. This is justifiable if one takes into account that sensor networks are in continuous research and development, each contribution being a breakthrough to those described above.
The main objective of the thesis is as follows: ″contributions regarding processing the information and the architecture of sensor networks with special applications″
Currently, there are many sensor networks that diagnose much of the deviations from the normal limit of the different processes. These have been widely applied in theaters of military operations, then in the surveillance of natural disasters, and they have now begun to be applied to industries with potentially explosive atmospheres, as in the case of the underground mining industry where this thesis is the first approach in country of its kind. This is the main motivation for the development of a system based on ad-hoc WSN networks using even anti-explosive PLCs with intrinsically safe software ports that can be used in underground for potentially explosive atmosphere monitoring or control or intrusion detection, enemy troop movements or terrorism, and remote transmission of information to decision centers through modern wireless communications.
Modern methods and simulation methods were used to analyze, improve and validate the results of the use of the created network, along with the optimization of the parameters of the automation models. The CupCarbon platform was used for this purpose. Monitoring is done using a program written in C / C ++.

The foregoing justifies the necessity of establishment of a network of ad hoc sensors that can be used for potentially explosive environments as well as other special areas such as early detection systems for natural disasters or even modern military applications.
The Arduino Uno, Arduino Mega platforms, NRF 24 L01 transmission modules, PIR sensors, vibration sensors, gas and smoke sensors MQ-2, all were used for the PhD thesis. These equipment's have been used to prototype an experimental, error-free, solid platform that can be autoconfigured according to the environment in which it is used. In this paper we also presented the simulation of some processes characteristic of the potentially explosive atmosphere, namely:

• Remote command via PLC with intrinsically safe and positive ports through software for underground operation;
• simulation of a complex application using the CupCarbon platform;
• the need for an ad hoc network in potentially explosive environments;

Actuality and justification of theme

The qualities of WSN networks, the flexibility of architecture, their modeling and simulation, local programming and the possibility of integrating human experience, etc., show us the significant potential they have in applications in general and in special application in particular, contributing fully to and for development durable and sustainable. These support the need to know the field as best as possible, justify the motivation, timeliness, setting the main objectives, the choice of theme, the processing of information and the architecture of the sensor network with special applications.

6. CONTRIBUTIONS

In the following we will present a list of the main contributions resulting from the research carried out for the thesis entitled: Contributions regarding processing the information and of the architecture of sensors networks with special applications.

- Performing a bibliographic documentation research in the field of sensor nodes and WSN networks, in order to determine the level of implementation and their applications.
  In this way, it was possible to appreciate the possibilities of introducing WSN networks and choosing the strategy of application even in special fields, in particular underground coal mining.
- Rigorous definition of concepts used in research in the work, such as: Special applications, Triangle of accidents from which the Explosion Triangle derives, Location with explosive potential, Explosive location, Safe location, Intrinsic safety, Positive safety, Barrier safety, etc.

- Enunciation of the principle that generates the explosion in potentially explosive locations as follows: coincidence between the Explosive Atmosphere and the Source of Explosive Initiation Energy, mathematical definition and justification through the Large Numbers Law, two strategies to prevent them, the deterministic and the probabilistic strategy.
- Defining and using the concept of intrinsic protection and positive control controlled through software and exemplifying when using a PLC.
- Justification of the deterministic strategy and its limits, mainly used in underground, consisting of the following: Severe methane removal measures taken by ventilation, maintaining a lower non-dangerous limit, the atmosphere being monitored by continuous scanning through a centralized SCADA system. Similarly, removing any sources of ignition and equipment and installations being inspected periodically to maintain unaltered safety standards. This strategy has led to the elimination of long-term explosions but has not completely eliminated them.
- Defining the Probabilistic Events Field, where events that justify the probabilistic strategy can occur: Complexity of underground processes, equipment density, narrow workspace, hard to avoid natural phenomena, machine imperfections, non-collaborative operation of the SCADA scanning system, allowing for existence of security breaches between detectors, non-use of human experience or some human errors, etc. Random phenomena are treated by "The Laws of Hazard", of which here were used: Gauss's Bell and the Law of Large Numbers.
- Defining the Probabilistic Strategy results from the Laws of Hazard as follows: In a potentially explosive location even secured, if there is a probable event field, a rare incident (explosion) event may occur if a sufficient number of attempts m ($m \geq 1$) are successful attempts. This approach allows the extension of staff safety beyond the limits of the deterministic strategy.
- Establishing the implementation of Strategies in the event of a coal mining extraction locations, using the conveyor, combine and the SCADA system, together with the WSN networks.
- Establishing the Modeling / Simulation Algorithm and the application of CupCarbon Modeling / Simulation Platform for the exploitation of coal underground.
- Identify the qualities of WSN networks that make them useful in special applications, of which we mention: The network is a set of simple nodes that cooperate as one unit; Processes environmental data integrating human experience with the real world; The nodes function on the principle of energy conservation; They are automatically located in space, synchronized in real-time and self-configuring.
- Realization of WSN nodes with methane sensors, remote communication applications and internet connection, programmed in C / C + language and experienced for validation using the Arduino platform. Making various variants of interfaces for connection between

the Arduino board and various sensors. We have modeled / simulated, using CupCarbon medium, a complex application to monitor the potentially explosive atmospheres in the underground coal mine extraction, using the strategies developed in the thesis, by combining SCADA with a WSN network.

- The majority of the results in the thesis were the subject of scientific papers sustained and published in the journals and international databases, Proceedings of Foreign Conferences (some ISIs), two are indexable in Clarivate Analytics Web of Science.

7. PROPOSALS

- The research carried out in the elaboration of the thesis can be a bibliographic source for implementable projects with systems based on networks of wireless sensor, systems which can be easily configurable and very useful, especially in limit situations;
- The whole work can be the base of a university course dedicated to sensor networks using Arduino modules or other sensor connection modules, and applications can be developed in the laboratory;
- The result of research in special areas can be used through cooperation with educational centers or companies and services;
- The use of WSN in special applications, based on the new technological requirements, like in the modernization of the infrastructure, ensures the conservation of the necessary natural resources for future generations which are a major objective of our time.

8. SELECTIVE BIBLIOGRAPHY

[1] Amar N. S., Ravi R., K., Vijay K., Vipin G.- Safety of Underground Coal Mine Using Artificial Intelligence and Wireless Sensor Network, Published: International Journal of Advanced Trends in Computer Science and Engineering, 11 November 2016.

[2] Abrudean M. -Systems theory and automatic regulation, Editura MEDIAMIRA, Cluj-Napoca, 1998.

[3] Allen Bradly, Rockwell Automation- SCADA System Application guide, Pub. AG-UM08C-EN-C, February, USA, 2005.

[4] Baker, N. – Zigbee and Bluetooth, Computing and Control Engineering, Aprilie-Mai 2005, Vol.16, Issue 2, Pag.20-25

[5] Baker, N. – Zigbee and Bluetooth, Computing and Control Engineering, Aprilie-Mai 2005, Vol.16, Issue 2, Pag.20-25

[6] Bogdanffy L., Pop E., Ilcea G, - HIL Simulation as Rapid Prototyping Method in Control Engineering, International Journal of Control Systems and Robotics ISSN: 2367-8917 Volum1, 2016.

[7] Emil Pop, Gabriel-Ioan Ilcea, **Ionut-Alin Popa** - *Distance Control and Positive Security for Intrinsic Equipment Working in Explosive Potential Atmospheres.* - Engineering, 16 March 2018, 10, 75-84, ISSN Online: 1947-394X ISSN Print: 1947-3931 DOI: 10.4236/eng.2018.103006. Pag. 75-84.

[8] Festilă Cl., Dulf E.H., Baldea A., *Observer Based Safe Operation of the 13C Cryogenic Separation Column*, 2010 International Joint Conference on Computational Cybernetics and Technical Informatics (ICCC-CONTI), Digital Object Identifier: 10.1109/ICCCYB.2010.5491250, 2010.

[9] https://www.researchgate.net- Centrala telegrizumetrică CTT 63/40 U, 2016

[10] https://datasheet.octopart.com, The Arduino Uno is a microcontroller board based on the ATmega328

[11] Ilcea Gabriel Ioan, Pop Emil, **Popa Alin- Ionuț** - Intrinsic safety and Positive Security with Embedded Software Solution for Equipment's Used in Spaces with Explosive Potential Atmosphere.- CBU-International conference UDC Classification 004.35;DOI:http://dx.doi.org/10.12955/cbup.v6.1297, Prague, Czech Republic, 1077, MARCH ISI Proccedings pag: 21-23, 2018

[12] Ilcea, G., Dobra, R., Păsculecu, D. and Buică, G. (2014) Decision Support System Based on Fiber Optic Technology Applicable to Mining Industry. Proceedings of International Conference on Circuits, Systems, Signal and Telecommunications, Tenerife, 10-12 January 2014, 148-151.

[13] **Ionut-Alin Popa**, Emil Pop, Gabriel-Ioan Ilcea - Using Wireless Sensors Networks in special Applications for Mining with Accident Potential Location International Journal of Science and Research (IJSR) ISSN 2319-7064, Impact Factor (2017): 7.296, Vol. 7 Issue 8, August 2018, pg. 229-235

[14] **Ionuț-Alin Popa**, Emil Pop- SENSORS AND SENSORS WITH SPECIAL APPLICATION Annals of the „Constantin Brancusi" University of Targu Jiu, Engineering Series, No. 4/2016, Issue 4, p113-118

[15] K. Holger, A. Willig "Protocols and Architectures for Wireless Sensor Networks". JohnWiley & Sons, 2012.

[16] Keith Stouffer, J Falco, Karen Kent - Guide to Supervisory Control and Data Acquisition (SCADA) and Industrial Control Systems Security, NIST Special Publication 800-82, 2006.

[17] Leba M., Pop E., Sochirca B., Vanvu P. - Modeling, simulation and design of the intrinsic protection using safty barriers, Proceeding of the 8th WSEAS International Conference on CIRCUITS, SYSTEMS, ELECTRONICS, CONTROL AND SIGNAL PROCESSING (CSECS `09), Perto de la Cruz, Tenerife, Canary Islands, Spain, ISBN 978-960-474-139-7, ISSN 1790-5117.

[18] Lorand Bogdanffy, Emil Pop, **Ionuț-Alin Popa**- Rapid Prototyping for Optimal Control of Electrical Drives International Journal of Circuits and Electronic, http://www.iaras.org/iaras/journals/ijce, ISSN: 2367-8879 88, pg. 83-88, 2016

[19] Manolea Gh., Popescu Gh., Draghiciu M.A., Botezatu N. - Acționări electromecanice Universitatea, Craiova, 2000.

[20] Manolea Gh. - Sisteme automate de acționare electromagnetică, Editura Universitaris, Craiova, ISBN 973-8043-525-5, 2004.

[21] Mândrescu C., Pană T., Stoicuța O.- The control system analysis of the coal flow on the scrapers conveyor in a longwall mining system IEEE Applied and Theoretical Electricity (ICATE), 2016.

[22] Muresan V., Abrudean M. - Control of rotary hearth furnace, using a programmable controller, Automation, Quality and Testing, Robotics, 2008. AQTR 2008. IEEE International Conference, Pag. 262-266.

[23] Nedelcu, A., Sandu, F., Machedon-Pisu, M., Stoianovici, V. – Wireless-based Remote Monitoring and Control of Intelligent Buildings, International Workshop on Robotic and Sensors Environments, Lecco, Italia, Noiem. 2009

[24] Păun F., Părăian M., Sicoi S., Ghicioi E., Lupu Le.- Petricolul de aprindere a atmosferei explozive prin descărcări electrostatice de la om, INSEMEX, Petroșani 2008.

[25] Polastre, J., Szewczyk, R., Culler, D. – Enabling Ultra-Low Power Wireless Research, Proceedings of the Fourth International Conference on Information Processing in Sensor Networks (IPSN/SPOTS), Aprilie 2005

[26] Pop Emil, Alexandrescu Cristina, Ilcea Gabriel, **Popa Ionut-Alin**- POSSIBILITIES OF USING BLENDED LEARNING IN CONTROL ENGINEERING WITH APPLICATION AT SYSTEMS THEORY Conference name**:** 10th International Conference on Education and New Learning Technologies, EDULEARN18 Proceedings, ISBN**:** 978-84-09-02709-5, ISSN: 2340-1117, Location: Palma, Spain, Pages**:** 435-445,doi: 10.21125/edulearn.2018.0188, 2-4 July, 2018, (Indexing in WOS)

[27] Pop E., Ilcea G., **Popa I.A.**, Bogdanffy L. - Increasing the Safety of People Activity in Aggressive Potential Locations, analyzed through the Probability Theory, Modeling/Simulation and Application in Underground Coal Mining. Engineering Journal

ISSN 1947-394X ISSN Print: 1947-3931, DOI:10.4236/eng2019.112008, pag: 103-106, http://www.scirp.org/journal/eng.

[28] Pop M., Pop E. - Conducerea automată a combinelor miniere, Editura Didactica si Pedagogica, Bucuresti 1997.

[29] Pop E., Leba M. - Microcontrollere și automate programabile, Editura Didactica si Pedagogica,Bucuresti 2003.

[30] Poantă, A., Dojcsar, D. and Sochirca, B. (2009) System Command of a Pump Instalation Based on a Programmable Controller. Revista Minelor, 15, 15-18.

[31] Regulamentul de securitate şi sănătate în muncă. CNH SA Petroşani, 2007.

[32] Sochirca B. - Analiza echipamentelor electronice și a PlC-urilor pentru automatizări în medii potențial explozive. Raport de cercetare nr 2, 2009.

[33] Stefan Odobleja – Psychologie consonantiste, Lugoj, Librairie Maloine, Paris, 1937-1938.

[34] SR EN 60079-11:2007, Aparate electrice pentru atmosfere explosive gazoase. Partea 11: Protecția echipamentului prin securitate intrinsecă ”i”.

[35] SR EN 60079-1:2008, Atmosfere explosive. Partea 1: Echipamente protejate prin carcase antideflagrante ”d”.

[36] Vasilescu G., D., Ghicioi E., Kovacs A., Gheorghiosu E., Rus D., Jitea C., Bordoș S.-Ghid de evaluare a riscului de explozie la infrastructurile tehnice destinate depozitării explozivilor de uz civil., ISBN 978- 606-8761-03-9, Editura INSEMEX, 2017, Petroșani.

[37] www.iec.ch, International Electrotechnical Commission, Internet of Things: Wireless Sensor Networks, Geneva, Switzerland 2014.

[38] www.mining.com- Mine Site Technologies (MST)- New Wireless Sensor Network sets the benchmark for IoT in Mining, 19 October, 2016.

[39] Woo A.- MICA: The Commercialization of Microsensor Motes, Sensors expo 2018.