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Systems Structure Based on Wireless Sensor Networks for Monitoring the Transportation Pipelines of Oil and Gas

This paper presents some results of our own doctoral research on the structure of transportation systems for monitoring oil and gas pipelines using wireless sensors networks. Wireless sensor networks (WSN in English) are a new area of research which is growing rapidly due to the development of the new sensor technologies which are cheaper and cheaper. In this paper we analyze some linear structures and we propose a new hierarchical structure of WSN monitoring systems.

Keywords: *Linear structures of WSN systems, pipeline oil and gas transportation monitoring systems, hierarchical structures of WSN monitoring systems*

1. Introduction

Wireless sensor networks captured the attention of a great number of researchers from the moment when in 1999 Business Week review has announced the 21st technologies most important for the 21st century [1].

Among them there is the technology based on wireless sensors networks, architecture which is composed of micro sensors of unique use. WSN have a topology based on high density of distributed sensors along the pipeline and are organized in clusters (groups) of nodes which control some portions of the pipeline imposing a large scale of safety by collaborating each other in order to ensure a good function of the whole ensemble[2].

2. The causes which decides the development for systems monitoring of transportation pipelines of gas and oil

The energy crisis determined the acceleration of development of a lot of investments in oil and gas industry and the investments in WSN represents a key domain in the whole chain for the supply with oil and gas. The transportation of oil and gas is usually realized by pipeline mounted on fields which offers severe weather conditions fact which make difficult the verification of the status of the pipelines along all the direction of thousand of kilometers. In the table 1 there are presented some of the most famous pipeline of that kind. The attention regarded to the investments in monitoring the pipelines of oil and oil products and natural gas is determined by the danger which represents the accidental leaks from pipelines toward the environment and the enormous looses in case of accidents.

Table 1. Oil&Gas Pipeline examples

Trans-Alaska	Length=500Km; Transport oil from North Alaska to maritime ports and then with ships to cities of the USA.
Russia-China	Length=600 km; transports oil from Siberia to China
Russia- from Baltic Sea	Length=890Km, transports natural gas to Sweden , Norway, Germany .
Trans-Afghanistan	Length=2000Km, transports natural gas from Turkmenistan, through Afghanistan, towards Pakistan and India

Pipelines can be the target of **vandalism, sabotage**, or even terrorist attacks. In war, pipelines are often the target of military attacks, as destruction of pipelines can seriously disrupt enemy logistics.

Obviously, the likelihood of accidents can be significantly reduced, through monitoring and strict control of the state of infrastructure and process parameters of the pipeline transport system. Transport safety depends largely on the safety monitoring and control system. Taking into consideration all the above, the focus of our scientific research on increasing the security of energy supply nodes is justify because this affects the operational safety of the entire sensor network systems for the monitoring of pipelines transport systems of oil and gas from extraction areas to the storage or processing areas.

3. Topological structures of the systems of WSN type targeted for monitoring

A pipeline monitoring and inspection system has a long list of tasks to accomplish. For example, [6], for natural gas pipelines, these tasks include: ***measuring*** wall thickness; ***detecting*** gas contamination in pipeline; ***measuring velocity and flow*** of gas; ***detecting presence of gas leaks***; ***determining the variation in pipe cross-section***; ***determining structural defects in pipes***, etc.

To be able to perform these functions WSN nodes are distributed along the transport pipeline as shown in figure 1. Geographical distribution of WSN nodes depends on the geometry of the area being monitored. In figure 1 there are presented some variations of such distributions. It is obvious that the linear distribution (figure 1C) is suitable for pipeline infrastructure monitoring using WSN systems.

It must be noted that there are times when some of the components of a sensor node can be disconnected from the power source when they are listed in the so-called "sleep" mode. For example, the time during which the components of the radio transceiver transmit data stored in RAM to the central dispatcher (CD) of the WSN, the sensor component can be put into "sleep" which totally disconnects it from the power supply. This shift into "sleep" mode is used in order to save energy from the battery which can not be recharged locally.

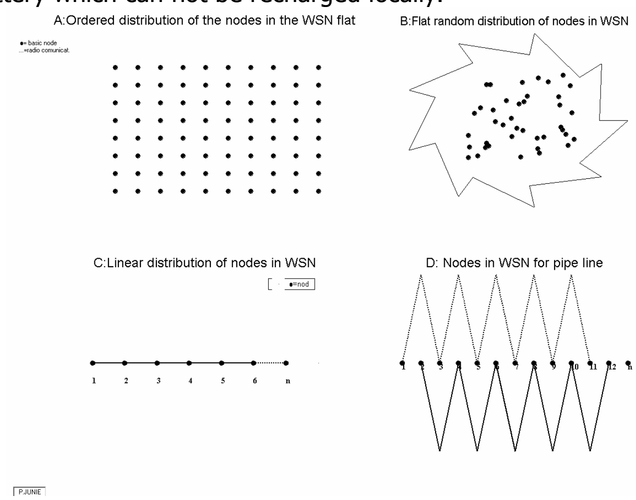

Figure 1. Geographic distribution of nodes in the WSN

4. Multi-hop communication technique in the monitoring systems based on WSN

Since the covering radius R of the radio wave emitted by a node is small (R <30m), a node can not communicate directly with the CD that are tens or hundreds of miles away. Therefore, we use the technique of multi-hop communications radio (one hop corresponds to a section of pipe between two neighboring nodes of the WSN). Multi-hop technique assumes that a node can only communicate with any of the nearest neighboring nodes. For example in figure 2 is considered a WSN composed of only three nodes whose locations are specified by coordinates (xi, yi, i = 1, 2, 3).

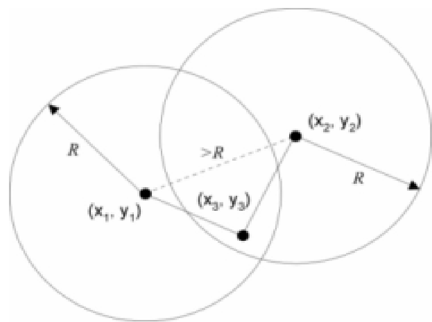

Figure 2. The communication between the node i=1 and node i = 2 can not be done directly because the distance between nodes d12> R, so node i = 3 is used as transit hub: hop-hop.

From figure 2 we can see that the node 1 can not communicate directly with node 2. The only possibility of communication between these two nodes involves using node 3 as a radio relay, applying hop-hop technique.

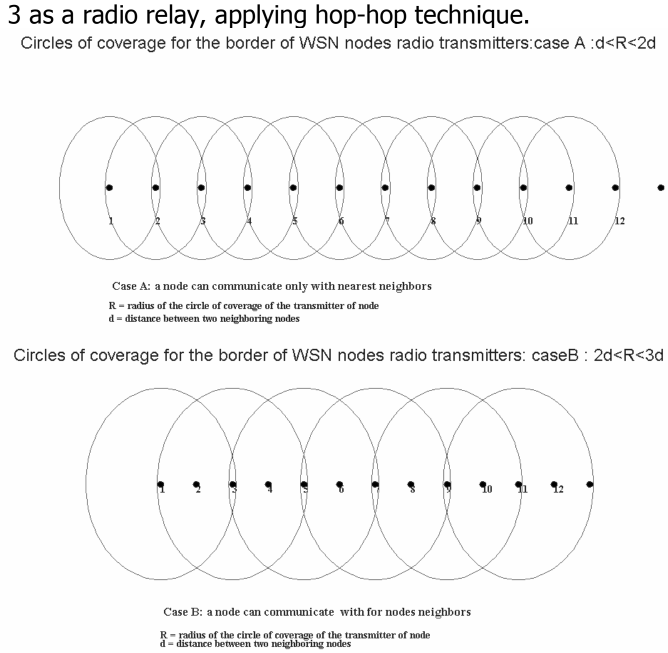

Figure 3. Number of nodes that can communicate directly with each oher on a WSN with linear distribution depends on the ratio between the radius R of the transmitter node and the distance between two consecutive nodes (R / d): Case A node can only communicate with a neighbor on the left and his right neighbor. Case B, each node can communicate with other 4 nodes

In figure 3 there are presented two cases (case A: $2d<R<3d$ and case B: $2d<R<3d$) of the linear distribution of the sensors used in pipeline infrastructure monitoring system using WSN in which the radius R of the nodes is different. From the figure it can be seen that the number of nodes that can communicate directly with each other depends on the ratio R/d. In A we have $1<R/d<2$, in which case a node can only communicate with two other neighboring nodes (neighbor from left and right). In case B we have, $2<R/d<3$, where one node can communicate with four neighboring nodes (two from the left and two from the right). In case A from figure 3 the multi-hop technique uses the first neighbor as a radio relay station which can transmit the received signal to the nearest next node and so on to the relay which is in direct contact with the WSN CD . From this point of view the linear version from figure 1C shows a poor reliability.

It is enough to fail one of the neighbors emitting node and the chain of radio relays will be broke; it remains a small number of nodes to communicate with the CD of WSN. A solution for increasing the reliability of WSN is as in figure 1D in which the communication protocol ensure 2 distinct communication paths with CD-WSN. Every node of WSN has a unique identification (ID), an address which can be ordinate numbers. For one of the two paths which communicate with CD sensors node with odd number which communicate with CD and on the other the even numbers. In this case if a path is broken it remains the other way what transmit to CD the information in the vicinity of failed nodes. Through interpolation we can estimate the information regarding to failed area nodes.

4. Hierarchical structure of a system for monitoring a pipeline infrastructure using WSN

From what we presented until now it is obvious that a pipeline infrastructure monitoring system using WSN is suitable to nodes hierarchy on levels:

- LEVEL 0: node-sensor (NS)
- LEVEL 1: node- Local Dispatcher (LD) collector date
- LEVEL 2: node-Zone Dispatcher (ZD)
- LEVEL 3: node-Central Dispatcher (CD)

Figure 4. A variant of in line distribution along pipeline of the hierarchical function

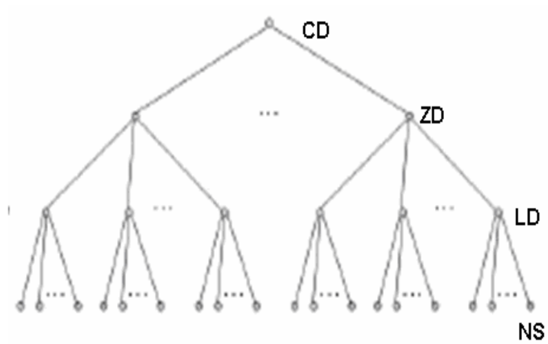

Figure 5. Tree model of functional hierarchy nodes in pipeline

The hierarchical model of a WSN in figure 5 is a graph of tree type; the root is a ***CD*** and the leaves are NS. The branches are determined by the ZD and ***LD*** (figure 5).

5. Conclusions

In the paper there are presented some of own scientific research resulting in:

1) procedure of increasing the reliability of pipeline infrastructure monitoring system using WSN by realizing 2 parallel paths of transmission multi-hop of information to odd and even nodes;
2) hierarchical structure of node functioning by the analogy with the hierarchical structure of monitoring the national energy system;

We appreciate that the results obtained can be developed much more in the future in the direction of optimization of WSN topology in what regard to the perspectives for continue this research.

References

[1] *21 technologies most important for the 21st century*, Business Week, 1999
[2] Borade S., Zheng L., and Gallager R., *Amplify-and-forward in wireless relay networks: Rate, diversity, and network size*, IEEE Trans. Inform. Theory, vol. 53, pp. 3302–3318, Oct. 2007.

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