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Components for sensor nodes and transducers

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Editor(s):	***Karel Charvat, Zbynek Krivanek, Petr Kubicek, Maneesha V. Ramesh, Rehna Raj T, Joshua D Freeman, Vijay Selvan, Sangeeth Kumar***
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Abstract:

This document defines the WINSOC project deliverable D.2.2 and deals with the description of required sensors component. The purpose of the document is to provide description of requested functionality and their comparison with COST components. The analysis define requirements on development of Winsoc sensor nodes.

Key words:

Sensor, node, transducer,

CONTENTS

1 INTRODUCTION

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2 SELECTED CONTEXTS FOR SENSORS DEPLOYMENT IN ENVIRONENTAL RISK MANAGMENT

Forest Fire Scenario: Deliverable D2.1 Sensor Network Scenarios, Services, and Requirements analysed requirements on sensors and sensors networks from the point of view of three different contexts for forest fires:

- Fire preparedness and prediction
- Fire detection and response
- Post-fire assessment

and from the point of view of an end user scenario for landslides.

On the basis of analysis of possible behaviour of sensors networks we suggested dividing the first context into two separate ones:

- Estimation of the probability of forest fire risk
- Forest fire detection

The reason for dividing is that first case is much more suitable for testing of Winsoc algorithms. Estimation of forest fire risk is focused on large area assessment and there will be a stronger request for consensus in the network. Detection of forest fires is usually oriented on one concrete point of limited scale (we need to allocate the forest fire in the initial stage) and then the function of the network will be more oriented on the building of ad hoc connectivity and retranslation of information from the sensor detected forest fire to the dispatcher. The third context is technologically combination of first two scenarios.

For later stages of project Winsoc, we would like to also recommend simulating a second scenario. The experiences from the last days in Greece demonstrate the importance of such a solution. Also, this second scenario is interesting from the point of view of the Winsoc algorithm. It is necessary to look for fast consensus in network and it also has to be expected, that the topology of network is dynamically changing. This solution also requested additional functionality and it is calculation of position of every sensor in network on the base of known position of few sensors. This update of requirements doesn't have influence on the parameters of sensors and sensors networks described in D2.1, it only defines new requirements on software components.

The deliverable D2.1 Sensor Network Scenarios, Services, and Requirements, discussed the requirements for sensors and sensors networks for Landslide prediction, based on many natural inherent causative factors (Slope, Water content variations, Water pore pressure etc.) and external causative factors (Shocks and vibrations, Rainfall etc.) for the occurrence of landslides. The geological sensors monitors the vital geological parameters and enables us to establish the expected threshold values, at which landslides will happen. We aim in developing an early warning system for predicting the high risk landslides. In the landslide scenario, the low level nodes sample data from the geological sensors and transmit it to the higher levels after consensus among the group members.

The contexts for sensors deployment in landslide scenario will aim to obtain the most sensitive measurement parameters that will change significantly at the onset of the landslide event. Typical situations for which various sensors have been used are the following :

- Determination of absolute lateral and vertical movements within a sliding mass.
- Monitoring of groundwater levels or pore pressures associated with landslide activity so that effective stress analyses may be performed.
- Determination of the rate of sliding (velocity) and thus provision of a warning of impending danger.
- Monitoring of the activity of marginally stable natural or cut slopes and identification of effects of construction activity, rainfall infiltration, contour bounding etc.
- Provision of remote information to be sent to a remote alarm system using a wireless sensor network, which integrates environmental and physiological sensors in a scalable, heterogeneous architecture.
- Real-time monitoring and assessment of sites with high landslide risk

2.1 Components of WINSOC Architecture

Here are described the sensors components of the WINSOC architecture. The text explains the role and functionality of single components.

2.1.1. Forest fire Scenario

Context I: Fire preparedness and prediction

The basic infrastructure for collection of data is formed by a human distributed network of sensor nodes monitoring fuel moisture content, weather variables, air temperature, wind, rainfall , relative air humidity, and the presence of COx. Every sensor node could measure one or more parameters

- Sensors nodes are “alert ready” and able to communicate with other sensors nodes of level 1 and with one nodes of level 2

- Every sensor node has to be able to communicate with all others sensors node of level 1 in one cluster - Distance of two sensors node of level 1 in one cluster is from ten meters to maximum hundred meters
- Every sensors node of level 1 has to communicate directly with one node of level 2 in its cluster or has to be guarantee retranslation trough other sensors node on level 1 The communication is one directional
- Sensors node on level 1 need to know their geographic position. It is expected, that this position will be fixed, so it could be determined one time.

This basic level of sensor network communicates trough human distributed network of level 2 nodes, which don't measure environmental parameters, but guarantee transfer of communication in the wireless network. The distance of two communicated node of level 2 is upto one kilometre

- Node of level 2 know their own position (or its position is stored on the dispatchers server). It is enough to measure the exact position one time, the position will not change
- Node of level 2 are "alert ready" and able to communicate with dispatcher server or terrain worker by sensor web notification services. The communication is one directional
- Node of level 2 are able to collected information from all sensors nodes of level 1 in cluster and transfer relevant information on dispatcher server
- Node of level 2 need to communicate with other nodes of level 2 (not with all). The distance of two communicating nodes is expected to be up to one kilometre
- Nodes of level 2 need to have the capability to transmit information from other nodes of level 2 to the dispatch server or to terrain workers. There is no guarantee that all nodes of level 2 will have permanent access to a public network.

Context II: Forest fires detection and response

An airplane traverses a fire region and deploys massive numbers of small sensors (sensors of level 1). There is minimum one sensor node per 100 m^2. These sensors nodes provide temperature or Cox monitoring. Below are the next requirements on sensors.

- The sensors nodes of level 1 randomly scatter spatially as they land
- The sensors nodes of level 1 self-organize into an ad hoc network such that information can be transmitted in a multi-hop route to a nodes level 3 - The sensors could be destroyed during the fire. This possibility has to be monitored
- Sensors node of level 1 are continuously monitoring the situation and are able to communicate with other sensors nodes of level 1 and directly or through other sensor nodes on level 1 with a minimum of one node of level 3
- Every sensor node has to be able to communicate with more other sensors nodes of level 1 - Distance of two sensors nodes of level 1 is approximately 10 meters

- Every sensor of level 1 has to communicate directly or indirectly with at minimum one node of level 3. The communication is uni-directional
- Sensors nodes on level 1 need to know their geographic position (calculated from network parameters)
- The sensors monitor and report forest fire front contour

Second part of system is network of sensors node level 2, which is distributed human, measuring under surface (ground) temperature. The sensors node measure temperature in three different depths. They will be in three lines around fire front. The distance between two sensors node will be ten meters. The sensors nodes of level 2 self-organize into an ad hoc network such that information can be transmitted in a multi-hop route to a node of level 3 - The sensors could be destroyed during the fire. This possibility has to be monitored by the network. Basic requirements on sensors:

- Sensors node of level 2 continuously monitor the situation and are able to communicate with other sensors nodes of level 2 and directly or through other sensors nodes on level 2 with a minimum of one node of level 3
- Every sensor node has to be able to communicate with more other sensors nodes of level 2 - Distance of two sensors nodes of level 2 is approximately 10 meters
- Every sensor node of level 2 has to communicate directly or indirectly with a minimum of one node of level 3. The communication is uni-directional
- Sensors node on level 2 need to know their geographic position (calculated from network parameters)
- The sensors nodes of level 2 monitor and report under ground forest fire

Both networks communicate with human distributed network of nodes of level 3, which don't measure environmental parameters, but, which guarantee transfer of communication in the wireless network. The distance of two communicating nodes of level 3 is up to 500 meters. There are next requirements on this network:

- Nodes of level 3 know their own position, they are equipped with GPS. Their position could be changed during a forest fire
- Nodes of level 3 are "alert ready" and able to communicate with the dispatcher server or terrain workers by sensor web notification services. The communication is bi-directional
- Nodes of level 3 are able to collected information from all sensors of level 1 and 2 and transfer relevant information on dispatcher server and to terrain workers
- Sensors of level 3 need to communicate with other sensors of level 3 (not with all). The distance of two communicating sensors is expected to be up to one kilometre
- Sensors of level 3 need to have capability to transmit information from other sensors of level 3 to the dispatchers server or to terrain workers. There is no guarantee that all sensors of level 3 will have permanent access to a public network

Large-scale sensor networks impose energy and communication constraints, thus it is difficult to collect data from each individual sensor node and process it at the sink. The expected solution will be based on the well-known representation of data – contour maps, which trade off accuracy with the amount of samples. There will be a need to build:

- distributed spatial and temporal data suppression,
- contour reconstruction at the sink via interpolation and smoothing, and an efficient mechanism to convey routing information over multiple hops.

2.1.2 Landslide Scenario / Context IV

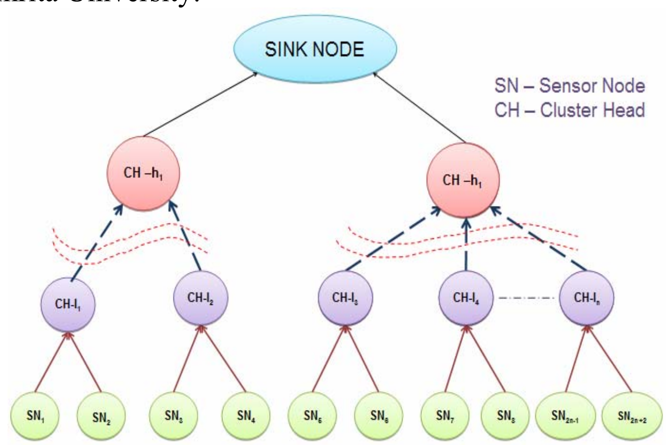
In the Indian Scenario, the main landslide triggers are intense rainfall and earthquakes. The principal parameters for monitoring rainfall induced landslides are pore water pressure of the soil and the slope movement.

The main components used are:

- Sensor Column
    - *Pore Pressure transducers*
    - *Geophones*
    - *Strain Gauges*
    - *Inclinometers (Tiltmeters*
    - *Accelerometrs*
    - *Dielectric Moisture Sensors*
    - *Rain gauges*
- Wireless Sensor Nodes
- The gateway (Stargate)
- Satellite Network

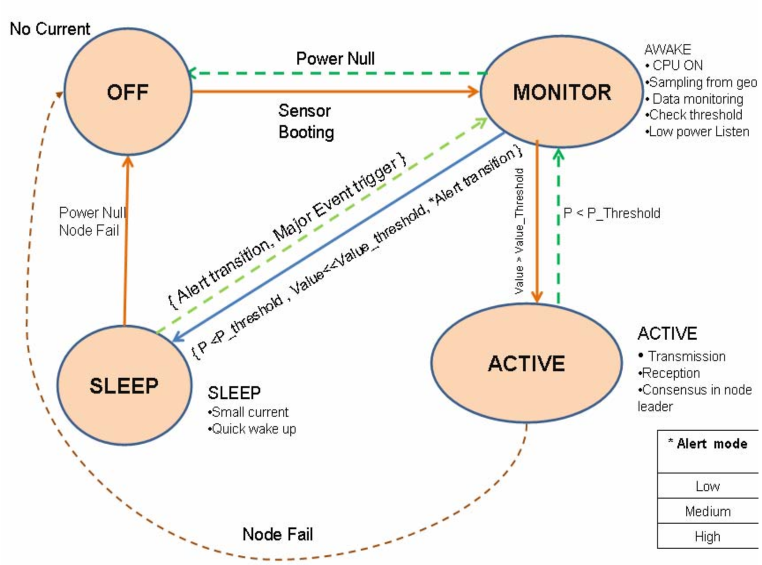
The primary geotechnical sensors being used are pore pressure transducers, tilt meters, strain gauges, accelerometers, and geophones. One or more of these geological sensors are connected with a wireless sensor node to form a sensor column. The sensor column will be buried underneath the earth for monitoring the various parameters like soil pore water pressure, earth movements, in situ stresses and strains, etc. The rain gauge will be placed above ground and will allow us to correlate rainfall rates and values with pore pressure values observed in the earth by the sensor columns.

The wireless sensor network used in the landslide scenario has three levels of nodes: low level nodes, cluster heads, and the sink node (the gateway node). The lower level wireless nodes are connected to the sensor column comprising the geological sensors. The low level nodes coming under each cluster head are allowed to communicate each other and arrive at a consensus on the parameter values. The consensus value will then be forwarded to the cluster head. No processing is done in any of the cluster heads. All of the higher level nodes will be receiving the data from the lower nodes and transmitting it to the successive higher level nodes. The cluster heads transmit the data to the sink node, which will then further forward the data via TCP/IP (possibly over WiFi) to a local analysis computer. From there, it is transmitted via a satellite link to a more sophisticated landslide data processing and modeling center located at Amrita University.



Initially all of the Lowest level Sensor Nodes, the Cluster Heads, and the Sink Node start their own clock. The Sink Node will make all Cluster Heads to time synchronize with each other. The Cluster Heads will then pass the synchronization on to the Sensor Nodes.

Energy consumption in each node can be achieved by using appropriate node transition states like OFF, SLEEP, MONITOR and ACTIVE. In the OFF state, the nodes are initially off, in which they consume no energy. In the SLEEP state , the nodes will consume very little energy. In the MONITOR state, the nodes will be allowed to gather the data from the geological sensors and compare it with the available threshold values. In the ACTIVE state, nodes can transmit and receive data. In this scenario, the nodes will talk with each other to reach a consensus on the data. Power consumption is also a maximum in the ACTIVE state.



Once the network is running, the nodes go into the MONITOR state, in which the entire time is utilized for data collection. The data is sampled from the geological sensors and is compared with threshold values. Once a threshold is reached, the node enters into the ACTIVE state, and the data will be transmitted to its neighbors in the group. The node that has crossed the threshold can send a digital signal, activating the rest of the group members. The group will then try to reach a consensus on the data received from all the members. The consensus value will be compared to the threshold, and if that is reached, the alert state of the entire network will be changed.

The thresholds will be determined on a site by site basis from a combination of data from the lab experiments (using the same soil as at the deployment site), accumulated data collected from the Wireless Sensor Network deployment site itself, computer simulations, and the expert guidance of scientists familiar with the local geology and landslide history of the region. Furthermore, there exists the possibility of adding an adaptive element to the thresholds, such that if thresholds are initially set, they are crossed, and no further activity takes place, the threshold could be increased slightly to save energy.

In this context, the WSN architecture can be described in short as,

- The network of in-situ wireless sensors will collect and collaboratively process measurements from the field before forwarding them to an analysis station co-located with the VRC satellite stations.
- The analysis station will execute more computationally-intensive algorithms and will act as the end-user interface to the system

2.2 Coverage area and sensor network hierarchy

Context I: Fire preparedness and prediction

- The network will have multiple hierarchy
- A large area could be covered, up to 50 km2, allocated on the basis of previous geographical analysis of forest typology. It is expected, that in average, there will be maximum or 4 sensors clusters (node 2) per km2.
- The area will be covered by network clusters with one node of level 2 and more sensors node of level 1 in one cluster. Every sensor node of level 1 will communicate with more sensors nodes of level 1 and with exactly one node of level 2 (could be trough retranslation on nodes level 1]. Every node of level 2 will communicate with more nodes of level 2. There is no guarantee, that all nodes of level 2 will have access to public network, so the network of nodes of level 2 has to guarantee the transmission of information among nodes of level 2 to the external world.

Context II: Forest fires detection and response

- The network will have multiple hierarchy
- There area covered could be a relatively smaller area, usually up to 5 ha. Only in the case of large disasters will the covered area be more than km2. It is expected, that there will be on average 1 sensor node of level 1 and 2 per 100m2.But they will not cover the whole area, but only the area surrounding the forest fire. The density of nodes of level 2 will be maximally 1 node per one hectare
- The area will be covered by two independent ad hoc networks of sensors nodes(level 1 and 2), which both communicate with one node from network on level 3. Every sensor node of level 1 (2) communicates with more sensors nodes of level 1 (2). Sensor node of level 1 (2) communicates with 0 to n nodes of level 3. If there is no direct communication of sensors nodes of level 1 (2) with any node of level 3, then the information has to be transferred through other sensors nodes of level 1 (2). There is no guarantee, that all nodes of level 3 will have access to public network, so the network of nodes of level 3 has to guarantee the transmission of information among nodes of level 3 in order to guarantee communication with the external world.

Context IV: LandSlides

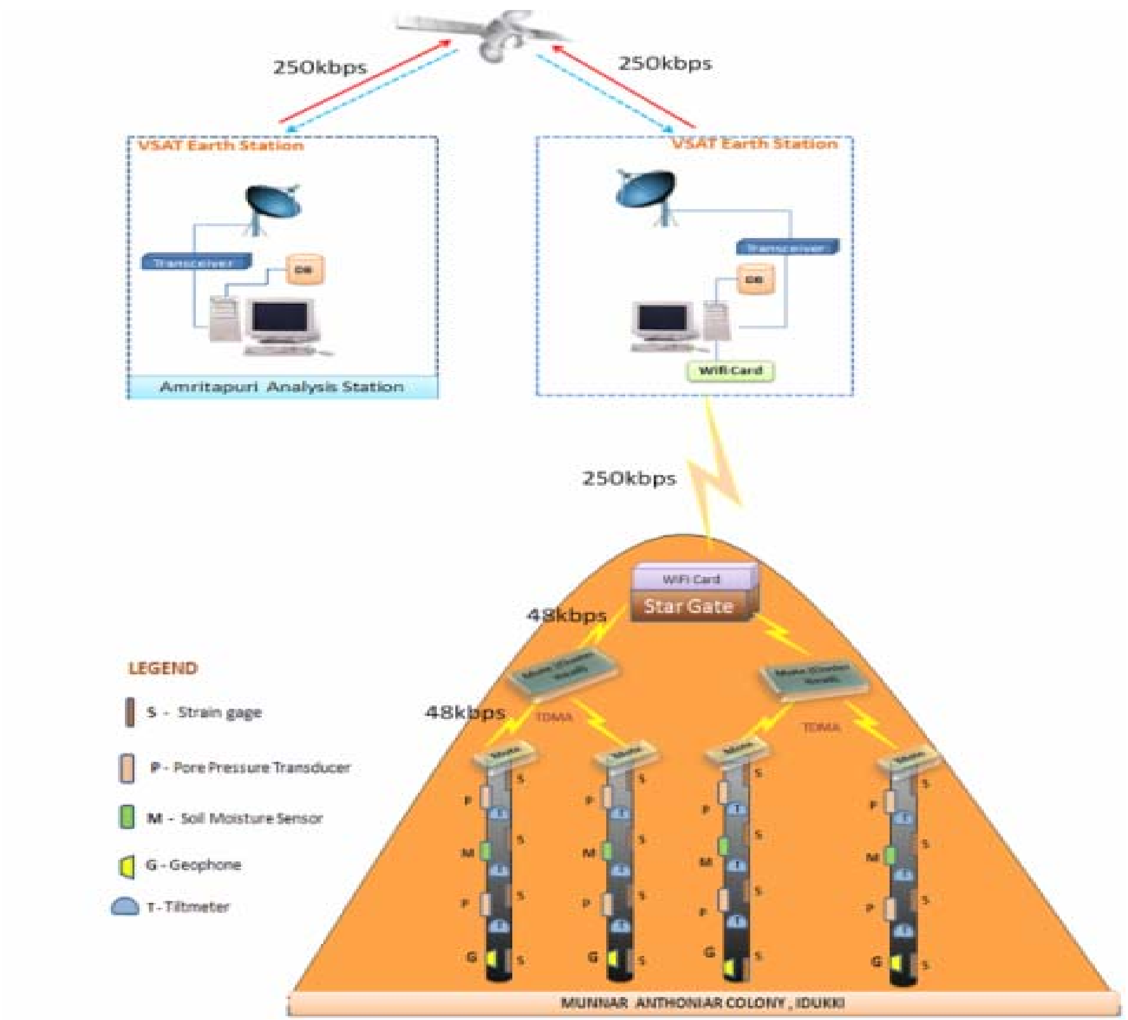
The proposed wireless sensor network is planned for deployment in the landslide prone site at Government college in the Idukki district of the state of Kerala, with a coverage radius of approximately one-half square km.

In the approximately 1/2 km square coverage area, the network will employ a maximum of 9 sensor columns placed inside vertical holes drilled in the ground and arranged approximately on a matrix grid pattern. If the worst case transmission distance of the lowest level wireless sensor nodes is insufficient to cover the entire landslide when only 9 sensor columns are used, then relay nodes will be employed to pass data from one sensor to the other. The worst case scenario is especially important to consider in landslide applications because the heavy rainfall which often precedes landslides also attenuates the strength of the wireless sensor network's communications. Borehole depth will be based on the depth of the soil (the distance between the surface and bedrock) and other soil conditions obtained from a detailed soil survey. Thus, the sensor column length will vary depending on the soil depth selected.

Each sensor column can have a maximum of 8 individual channels of data. Each sensor column is made up two or three pore pressure transducers, tilt meters (uniaxial and biaxial) or strain gages, and optionally a geophone. The field deployment will only require around two geophones total due to the ready transmission of large vibrations through the earth. The sensors are placed in a distributed fashion along the length of the sensor column with an average separation of 2 to 3m. For example, a sensor column can have two or three pore pressure transducers placed a quarter distance above the bottom and a quarter distance below the top, three or four single axis inclinometers (tilt meters) and one geophone at the bottom. The sensor tube (typically made of thick wall ABS plastic) having a diameter slightly larger than the size of the sensors, is used for the sensor column. The sensing part (sensors) of the column is under the ground and the wireless sensor node (processor + radio module) stays above the ground.

The data from the sensors (attached to the level one nodes) at each portion of the landslide (top, middle and bottom or 'toe'), will be aggregated together and transmitted to the Cluster Heads (level two sensors). The cluster heads will transmit the data to the Sink Node Gateway. The Sink Node will then transmit data via WiFi TCP/IP to the local analysis station. The local analysis station will store the data in a local database and then forward the data through the Satellite connection to the Amrita Analysis Station located at our university.

This sensor network hierarchy is shown below:



3 THE REQUEST ON COMPONENTS

3.1.a Basic description of sensors components in Forest fire prediction

For a single node of level 1, we expect that it will have four components: a sensory transducer(s), a radio transceiver, a power unit and a processing unit, to guarantee its operation in the sensor network. Certain nodes in the network may possess only the latter three components: these are relay nodes meant to process and pass information from other sensors to the monitors. We assume that heterogeneity of transducers can exist in the sensor network, and that most sensors have limited computational power and storage space.

Request on analytical sensors

Air

Temperature	measuring range		-30 +70°C
	accuracy		1%
	working condition	IP54	-40 +80°C
Absolute humidity	measuring range		0 – 150g/m3
	accuracy		2%
	working condition	IP54	-40 +80°C
Specific humidity	measuring range		0 - 150g/kg
	accuracy		2%
	working condition	IP54	-40 +80°C
Relative humidity	measuring range		0%-100%
	accuracy		2%
	working condition	IP54	-40 +80°C
Dew point	measuring range		-30 +50°CDP
	accuracy		2%
	working condition	IP54	-40 +80°C
COx	measuring range		0 – 2500 ppm
	accuracy		2%
	working condition	IP54	-40 +80°C
NOx	measuring range		0 – 200 ppm
	accuracy		2%
	working condition	IP54	-40 +80°C

Wind

Speed	measuring range		0 – 40 m/s
	accuracy		10%
	working condition	IP54	-40 +80°C
direction	measuring range		0 – 360 °
	accuracy		5%
	working condition	IP54	-40 +80°C
wind gust speed	measuring range		0 – 40 m/s
	accuracy		10%
	working condition	IP54	-40 +80°C
wind gust direction	measuring range		0 – 360 °
	accuracy		5%
	working condition	IP54	-40 +80°C

Soil

temperature	measuring range		-20 +50°C
	accuracy		1%
	working condition	IP54	-40 +80°C
moisture	measuring range		5 – 50 %
	accuracy		5%
	working condition	IP54	-40 +80°C

Rainfall	accuracy		0,5 mm H20
	working condition	IP54	-40 +80°C

Wireless Sensor Nodes 2

Wireless Sensor Nodes consist of 4 block: power block, interface / bus block, processor block and Tx / Rx block. The interface / bus block is connected with the external analytical sensors. The processor block collect data, control net management and cooperate with Tx / Rx block. Tx / Rx block transmitted and receipted data to and from other wireless sensor nodes The base station connected wireless network to Internet via GPRS/EDGE.

3.1.b Basic description of sensors components in Forest fire monitoring

A forest service could use sensor nodes to monitor for fires in a forest. In this scenario, forest service personnel would drop the dust from an airplane and then count on the sensors to self-organize into a network. In the event of a fire, a mote that notices unusual temperatures in its zone would alert neighbouring motes that would in turn notify other motes in the network. In this way the network of motes would notify a central monitoring station of the fire and the location of the mote that noticed it. Equipped with prompt notice of the fire and its approximate location, fire fighters could race to the scene and fight the fire while it is small. By linking similar networks of motes to a central fire reporting system, the system can be extended to monitor an enormous region in a national forest.

For other purposes, different kind of sensors could be used, but smart dust seems to be a solution also for other level of sensors.

For a single node of level 1 and 2, we expect that it will have four components: a sensory transducer(s), a radio transceiver, a power unit and a processing unit, to guarantee its operation in the sensor network. Certain nodes in the network may possess only the latter three components: these are relay nodes meant to process and pass information from other sensors to the monitors. We assume that heterogeneity of transducers can exist in the sensor network, and that most sensors have limited computational power and storage space.

Request on analytical sensors on level 1

Air

Temperature	measuring range		-30 +70°C
	accuracy		1%
	working condition	IP54	-40 +80°C
COx	measuring range		0 – 2500 ppm
	accuracy		2%
	working condition	IP54	-40 +80°C
NOx	measuring range		0 – 200 ppm
	accuracy		2%
	working condition	IP54	-40 +80°C

Request on analytical sensors on level 2

Air

Temperature	measuring range		-30 +70°C
	accuracy		1%
	working condition	IP54	-40 +80°C
Absolute humidity	measuring range		0 – 150g/m3

	accuracy		2%
	working condition	IP54	-40 +80°C
Specific humidity	measuring range		0 - 150g/kg
	accuracy		2%
	working condition	IP54	-40 +80°C
Relative humidity	measuring range		0%-100%
	accuracy		2%
	working condition	IP54	-40 +80°C
Dew point	measuring range		-30 +50°CDP
	accuracy		2%
	working condition	IP54	-40 +80°C
COx	measuring range		0 – 2500 ppm
	accuracy		2%
	working condition	IP54	-40 +80°C
NOx	measuring range		0 - 200 ppm
	accuracy		2%
	working condition	IP54	-40 +80°C

Wind

Speed	measuring range		0 – 40 m/s
	accuracy		10%
	working condition	IP54	-40 +80°C
direction	measuring range		0 – 360 °
	accuracy		5%
	working condition	IP54	-40 +80°C
wind gust speed	measuring range		0 – 40 m/s
	accuracy		10%
	working condition	IP54	-40 +80°C
wind gust direction	measuring range		0 – 360 °
	accuracy		5%
	working condition	IP54	-40 +80°C

Soil

temperature	measuring range		-20 +50°C
	accuracy		1%
	working condition	IP54	-40 +80°C
moisture	measuring range		5 – 50 %
	accuracy		5%
	working condition	IP54	-40 +80°C
Rainfall	accuracy		0,5 mm H20
	working condition	IP54	-40 +80°C

Wireless Sensor Nodes 2

Wireless Sensor Nodes consist of 4 block: power block, interface / bus block, processor block and Tx / Rx block. The interface / bus block is connected with the external analytical sensors. The processor block collect data, control net management and cooperate with Tx / Rx block. Tx / Rx block transmitted and receipted data to and from other wireless sensor nodes The base station connected wireless network to Internet via GPRS/EDGE/WIFI

3.1.c Description of Sensors used in Landslide Detection

A multi functional Data Acquisition Board with up to 8 channels of 16-bit analog input, is used to sample the geological sensors. This can be interfaced to the wireless module which contains a low power processor and a radio module with high data rate.

The sensors used are Pore Pressure transducers, Geophones, Strain Gauges, Inclinometers, Dielectric Moisture Sensors and Rain gauges.

Ground Water Pore Pressure transducers – The ground water levels and pore pressures in a landslide prone area can be measured by a variety of commercially available piezometers. We are evaluating vibrating wire and strain gauge type piezometers since they are extremely sensitive and have a negligible time lag. For short term observations in the laboratory set up, where data transmission is over limited distances, strain gauge type piezometers can be used. But the vibrating wire piezometers exhibits better long term stability and can be used in field deployment for monitoring ground water pore pressure. Piezometric heads can be obtained with respect to the amount of rainfall and other data that may influence the pore pressure.

As the amount of water in the ground and its pressure is directly related to the soil cohesion strength, this parameter is one of the most important for slope stability and for landslide prediction. Pore pressure values in landslide prone soil are typically in the range of up to 10 kg/cm2) and can be slightly negative at times. A minimum resolution of 0.010 kg/cm_2 needs to be measured.

Geophone - A geophone used for earthquake detection needs to detect frequencies of 1-10 Hz. However, a landslide has much different characteristics from an earthquake. In this case, frequencies of up to 250 Hz need to be measured. Since we are also monitoring for earthquake induced landslides, geophones with a frequency response of 1 to 250 Hz will be used. The resolution should be within 0.1 Hz. These measurements need to be collected when they occur, therefore, the geophone response will be used as a trigger to collect other measurements. This is possible, as a geophone does not require an external power source.

Strain Gauge – A strain gauge can theoretically be used to measure the movement of a bore well pipe buried in the ground. As part of the pipe moves due to surrounding earth movement, it will stress the strain gauges attached to the pipe. Deflections in the pipe of 0.5 mm per meter need to be detected. For a strain gauge that is 50 mm long, this corresponds to a resolution of 0.025 mm.

The rugged construction and flexibility of the selected pre-wired strain gauges are suitable for static and dynamic measurement with a high degree of accuracy. These standard strain gauges have their temperature coefficients matched to either steel of aluminum. However, soil temperate at depth does not vary much, therefore it should be possible to attach the strain gauges to our sensor tube without too much concern for the different expansion rates of the strain gauge and the sensor tube.

Inclinometer (Tiltmeter) – Inclinometers or tiltmeters measure the ground's movement. Because the ground can creep very slowly over a long period of time, extremely high accuracy is required. A inclinometer is fixed inside the sensor tube. Because of it's length and due to the fact that the sensor tube is anchored in the solid bedrock below the soil, only part of the sensor tube will move as the slope slowly deforms. This will cause part of the tube to become bent. The tiltmeter measures this bend in the tube. Trigonometric formulas can be applied to determine the amount of movement of the slope. The sensor tube movement is very slight. Ground velocities in the range of millimetres per hour need to be detected.

The selected inclinometer combines the function of two inclinometers in one package. The unique dome shaped design features a capacitance based sensor which produces output signals directly proportional to the relative tilt in two axes.

Dielectric Moisture Sensor - We have selected the capacitance-type soil moisture sensors that measure the dielectric constant or permittivity of the soil in which they are buried. Since the most common triggering mechanism of the landslide is the combination of heavy rainfall, steep slopes and loose or soft soil, it is very important to know the soil moisture at which the soil loses sheer strength and eventually triggers failure in response to the intense rainfall. The cohesive properties of the soil change with varying moisture content. Analysis of soil moistures at critical locations where seepage pressures are likely to develop is important.

Rainfall – Rainfall of up to 5000 mm per year can fall in the Idukki District. The effect of rainfall infiltration on a slope can result in changing soil suction and positive pore pressure, or the depth of the main water table, as well as raising soil unit weight and reducing the anti-shear strength of rock and soil. For deep seated landslides, their stability states are mostly affected by the rising of the main water table and rock and soil softening by rainfall infiltration. For shallow landslides, their stability behaviors and styles are dominated by transient pore pressure in response to rainfall process, combined with water washing or soil erosion. When rainfall occurs, the factor of safety of a slope varies as a function of transient pore pressure, depth and time. The landslide response process to rainfall is a time-varying process, which determines the landslide stability, landsliding depth, timing, style or scale. Therefore rainfall measurements are very important information for landslide prediction.

Here we use a "tipping bucket type" of wireless rain gauge in which the tipping event is counted as .001 inch of rainfall. In other words, the rain gauge has a resolution of .001 inch.

Wireless Sensor Nodes –

Wireless Sensor Nodes consist of three sub systems, a transceiver module, a processor module, and a data acquisition module. The data acquisition module is interfaced with the external geological sensors such as the pore pressure piezometers, geophones, tiltmeters, dielectric moisture sensors and strain gauges. The processor module samples the data acquisition system at specific intervals and sends the data to the transceiver module which handles the transmission and reception of data. The transmission and reception of data to and from other wireless sensor nodes is handled by the transceiver module. The wireless sensor nodes are grouped into different clusters, with a base station as the root node. The root node process the incoming sensor network data and sends the compressed data to the Analysis station through the VSAT satellite connection.

3.2 BASIC DESCRIPTION OF COMPONENTS NEEDED FOR INTERFACING VARIOUS SENSORS

3.2.a Interfacing of Geological Sensors with Wireless Nodes-----

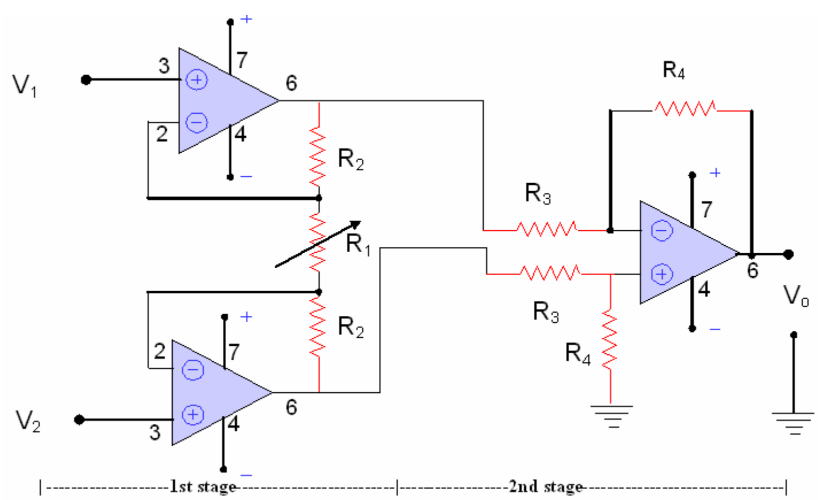
Many of the geological sensors we are using do not provide an output that is suitable for input into the wireless sensor nodes. For this reason, we need to modify the sensor outputs. They may either be too low of voltage range, have negative voltages, be of too high a voltage, or have excessive noise.

The circuits we are using involve optionally level shifting circuits, filters, and instrumentation amplifiers. In addition, sensor excitation and power circuitry needs to be used with some of the geological sensors.

- Voltage Amplifiers and Filters are used for most of the sensors.
- Summing Amplifiers are used only in geophone, tilt meter and accelerometer to raise (level shift) the signal so that it is entirely positive.
- Voltage Divider circuits are used in some cases so that the output voltage does not exceed 2.5 V.

Amplifiers

The signals produced from the sensors are analogue and may need to be amplificatied before the signals can be processed by the motes. Instrumentation amplifiers can be used to amplify the signal produced by a transducer such as a thermocouple or a strain gauge. An instrumentation amplifier is a difference amplifier i.e., it amplifies the voltage difference between its two input terminals, neither of which is required to be a signal ground. An instrumentation amplifier should have the following characteristics: high input resistance, high voltage gain, and high common-mode-rejection-ratio (CMRR).



Instrumentation Amplifier

We have designed an **instrumentation amplifier** for a variable gain from 2 to 500 by using a variable 100 KΩ (kilo ohm) potentiometer. The volltage gain of the instrumentation amplifier is given by :

$$G = 1 + \frac{2R_2}{R_1}\left(\frac{R_4}{R_3}\right)$$

Common Mode Rejection Ratio :

$$CMRR_{AMP} = 1 + \frac{2R_2}{R_1} CMRR_O$$

Design for a variable gain from 2 to 500

$$G = 1 + \frac{2R_2}{R_1} = 2 \; to \; 1000$$

$$ie \; 1 + \frac{2R_2}{R_{1f} + R_{1v}} = 2 \, (when \; pot \; is \; set \; to \max imum)$$

$$Therefore \; \frac{2R_2}{R_{1f} + 100K} = 1$$

$$2R_2 = 50K + R_{1f} \; ------ \; (a)$$

$$Selecting \; \frac{R_4}{R_5} = 0.5 \cdots \; for \; \sec ond \; stage$$

$$1 + \frac{2R_2}{R_{1f}} = 1000 \, (when \; pot \; is \; set \; to \; zero)$$

$$\frac{2R_2}{R_{1f}} = 999$$

$$2R_2 = 999 R_{1f} \; ----------(b)$$

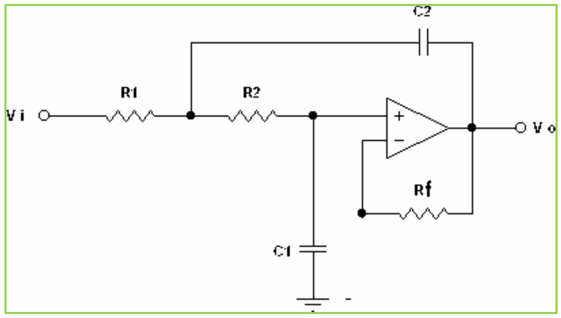
By substituting (b) in (a), we get,

$$R_2 = 50K\Omega$$
$$R_1 = 100\Omega$$

In this design , by Selecting Vcc = ± 2.5 Volts , the maximum output from stage I will be always less than 5 V peak to peak. Since the output from stage I is halved in the second stage, the maximum output from the amplifier will become 0 to 2.5 Volts always.

Filters

It is sometimes desirable to have circuits capable of selectively filtering one frequency or range of frequencies out of a mix of different frequencies in a circuit. A circuit designed to perform this frequency selection is called a filter circuit, or simply a filter.

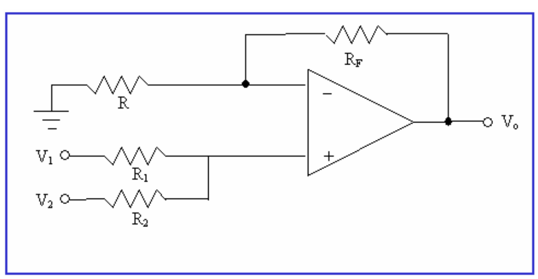


Circuit Diagram of a active low pass filter

The frequency cut-off control selects at which frequency the filter should start operating, and the resonance control creates a peak just before it starts filtering out frequencies. Here we have designed Low pass filters for a cut-off frequency of 15 Hz.

Level Shifting

Some sensors, such as the Geophone, Accelerometer, and Tilt meter, have outputs varying from +v to –v with respect to ground they need to be level shifted before giving it to the mote, because all the motes have input range varying from 0 to +2.5 Volts DC (Eight analog input ports). In order to achieve this a level shifting circuit is added after the filter stage to these sensors. A level shifting circuit is nothing but a adder circuit (summing amplifier circuit) which adds a positive voltage to a varying signal so that the output voltage will be always positive but varying one. We use non-inverting type summing amplifier for our level shifting purposes.



Circuit diagram of Non Inverting summing Amplifier

Our design aimed to add a +1.25 Vdc voltage to the 2.5 Vp-p signal from the filter circuit. Also it was assumed that current flowing into the summing amplifier is zero . By writing KVL (Kirchhoff's Voltage Law) equation at the inverting and non inverting pins and also by equating these equations we get the output voltage (Vo).

Solution

KCL, non-inverting input (out = +):

$$\frac{V^+ - V_1}{R_1} + \frac{V^+ - V_2}{R_2} + \frac{V^+ - V_3}{R_3} + I^+ = 0, \text{ where } I^+ = 0$$

$$V^+\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right) = \frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}$$

$$V^+ = \frac{\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}\right)}{\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)} \quad \text{(Eq. 1)}$$

KCL, inverting input (out = +): (using $V^- = V^+$)

$$\frac{V^+ - 0}{R} + \frac{V^+ - V_o}{R_F} + I^- = 0, \text{ where } I^- = 0$$

$$V_o = \left(1 + \frac{R_F}{R}\right)V^+ \quad \text{and now substituting Eq. 1:}$$

$$\boxed{V_o = \left(1 + \frac{R_F}{R}\right)\frac{\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}\right)}{\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)}} \quad \text{(Eq. 2)}$$

Special case: If $R_1 = R_2 = R_3 = R$ and $R_F = (n-1)R$

where n = number of inputs, then Eq. 2 reduces to:

$$\boxed{V_o = V_1 + V_2 + V_3}$$

Basic description of sensors network components

Large-scale sensor networks impose energy and communication constraints, thus it is difficult to collect data from each individual sensor node and process it at the sink. The expected solution will be based on the well-known representation of data – contour maps, which trade off accuracy with the amount of samples. There will be need to build:

- distributed spatial and temporal data suppression,
- contour reconstruction at the sink via interpolation and smoothing, and an efficient mechanism to convey routing information over multiple hops.

It is not possible to make general assumptions on the node density of the network, except that events are sensed by more than one sensor. By reducing the number of transmissions required to convey relevant information to the sink, the proposed contour mapping scheme saves energy and improves network lifetime. In a sharp contrast to related work in this area, the scheme does not require all nodes to explicitly share information.

It will be considered a network of fixed sensor nodes that are deployed in a 2 or 3 dimensional space. A set of monitoring nodes, defined as sinks, are responsible for collecting data reports from sensor nodes.

It is assumed that knowledge of sensor node locations will be calculated from position of sensors with GPS and from the network. The location information need not be precise. It could be computed even after deployment.

4 MAIN PRODUCERS OF COTS SENSORS COMPONENTS

4.1 What sensor components are considered?

4.1.1 Cirronet

Since 1987, Atlanta-based Cirronet has created high-performance components for industrial wireless applications. They started with our own frequency hopping spread spectrum (FHSS) technology, which has been continually optimized. They have also focused on emerging standards, incorporating the best of them into our product mix. Their product lines today encompass the industry's broadest range of technologies and options, ensuring that they meet their customers' needs precisely.

In 2001, Cirronet put their technology to work in a wireless Internet access system designed for broadband delivery in remote settings and over challenging terrain. That system is currently deployed in 21 U.S. states and 35 countries, in areas that would otherwise be underserved by Internet access.

Solutions Driven, Technology EnabledSM

Cirronet was acquired in September 2006 by RF Monolithics (RFM) and is now a wholly owned subsidiary of this 25 year-old leader in low-power wireless sensor networks and high performance RF components (NASDAQ: RFMI). RFM is helping to provide connections that will extend the edge of the Internet in machine-to-machine connectivity through its Solutions Driven, Technology EnabledSM approach.

RFM also acquired Aleier, a well established enterprise asset management solutions provider. With both acquisitions, RFM is now the first company to provide a complete family of end-to-end industrial wireless sensor networking with enterprise asset management and computerized maintenance management systems. For more information on RFM visit www.rfm.com and www.wirelessis.com.

Cirronet is an ISO 9001:2000 certified company.

Cirronet, Inc.

3079 Premiere Parkway

Suite 140

Duluth, GA 30097

4.1.2 MeshNetics

MeshNetics is a leading provider of short-range wireless sensor technology. They offer market-ready solutions for wireless sensing applications that are based on IEEE802.15.4 / ZigBee standards. Their goal is to help their partners establish a solid footprint in the emerging M2M market and we achieve that with our MeshNeticsTM product family.

The MeshNeticsTM product portfolio includes wireless ad-hoc mesh-networks software, hardware designs, and customization services that enable M2M applications, based on open systems and standards.

MeshNetics offers low power, high sensitivity ZigBee Modules adding wireless connectivity to a sensor device;

The platform-independent ZigBee Embedded Software configurations that provide various levels of ZigBee Standard compatibility for the wireless sensor products;

The ZigBit Evaluation Kit and ZigBit Development Kit contain hardware and software that you need to quickly prototype and test wireless sensor network (WSN) applications.

4.1.3 Moteiv corporation

Moteiv is a venture-funded company that provides wireless sensor networking solutions to enterprises worldwide. They sell hardware, software and services to innovative companies. Our customers leverage wireless sensor networks to create business value and expand market leadership. Moteiv's mission is to accelerate the integration of physical world data and processes into the enterprise, by removing the existing barriers to mass wireless sensor adoption.

Moteiv's founding team has several decades of collective experience leading the implementation of the world's largest wireless sensor network deployments from UC Berkeley. They have leveraged our domain and technology expertise to build innovative solutions that address the real-world problems and barriers we've encountered working with customers around the globe.

201 Marshall Street

Redwood City, CA 94063

4.1.4 MaxStream

MaxStream is a premier manufacturer of high-performance wireless device networking solutions. MaxStream's patent-pending wireless designs have garnered multiple awards and thousands of design wins for the innovative technological advances. MaxStream's highly reliable data radios are deployed worldwide in an array of industrial and commercial applications, creating easy-to-implement wireless connectivity

MaxStream, Inc.

355 South 520 West Suite 180

Lindon, Utah 84042

4.1.5 IntelliSensing LLC

IntelliSensing LLC is a young technology company that stems from a solid footing in the aerospace market. With a strong background in sensing instrumentation design, embedded development and information technology, they combine the trusted methods of physical measurement with advanced wireless technology to produce sensors that interface directly with control and measurement systems, using no external power or wiring.

Their mission is to design, manufacture and support wireless sensor products that enable advanced applications in demanding markets. Their slogan, The Network is the Sensor, highlights our commitment to provide a system solution not only incorporating sensors, but also the infrastructure responsible for transporting the measurement data to the destination.

With an increase in the global demand for quality at a reduced cost, a world of ubiquitous sensors is imminent. The integration of wireless intelligence inside the sensor increases the accuracy of the measurement while simultaneously lowering the cost of the system. By reducing cabling and eliminating individual channels of data acquisition, the density of the measurement array becomes less constrained by cost and more driven by the desire for a comprehensive data set

IntelliSensing LLC not only produces the sensor, but provides the means to transport the measurement data to the destination. This is accomplished through the careful selection and implementation of key layers of the Open System Interconnection (OSI) networking model, and the development and support of XML-based Web services

IntelliSensing LLC

4 Centre Drive

Orchard Park, New York 14127

4.1.6 Vulcanic Inc

Vulcain, a leader in the gas detection industry, designs and manufactures technologically superior products in order to provide clear solutions to ensure clear air.

4005 Matte Blvd., Unit G

Brossard, QC, Canada

J4Y 2P4

4.1.7 Crossbow

Crossbow Technology, Inc. is the leading end-to-end solutions supplier in wireless sensor networks. Crossbow provides a scalable product portfolio comprised of hardware and software development platforms, complete product designs, manufacturing and professional services that enable OEMs and system integrators to bring end-to-end wireless sensor network systems to market quickly.

The MICAz MPR2400 (2400MHz to 2483.5 MHz band) uses the Chipcon CC2420, IEEE 802.15.4 compliant, ZigBee ready radio frequency transceiver integrated with an Atmega 128L micro-controller.

We are using motes from Crossbow because of our previous expertise using their MICA2 motes. The MICAz motes differ from MICA2 motes in that the MICAz is Zigbee compliant.

5 CHARACTERISTICS OF EXISTING WIRELESS COTS COMPONENTS

5.1 COTS components based on IEEE 802.15.4 technology

Crossbow's TelosB mote is an open source platform designed to enable cutting-edge experimentation for the research community. The TelosB bundles all the essentials for lab studies into a single platform including: USB programming capability, an IEEE 802.15.4 radio with integrated antenna, a low-power MCU with extended memory and an optional sensor suite.

Crossbow's Imote2 (IPR2400) is an advanced wireless sensor node platform. It is built around the low power PXA271 XScale processor and integrates an 802.15.4 radio (CC2420) with a built-in 2.4GHz antenna.

5.1.1 Modems, gateways

	company	unit	describe	Onboard sensors	I/O line	ADC line	DAC line	Wire com.	Range / power
1	Crossbow	TelosB	250 Kbps, TinyOS, USB,	Temp, Light, Humidity	Various	12 bit – 8 Channels	12 bit – 2 Channel	2.4 Ghz	Outdoor 75 to 100 m, Indoor 20 to 30 m
2	Crossbow	Imote2	250 Kbps,USB, Marvell PXA271 CPU	None	Various, Camera	Sensor Board has ADC	Sensor Board has DAC	2.4 Ghz	30 m

5.1.2 Sensors

	company	unit	describe	Onboard sensors	Wire com.	Range / power
1	Crossbow	ITS400	Sensor board that attaches to Imote2	Temperature, Light, Humidity, 3-axis accelerometer, 4 channel ADC		
2	Crossbow	IIB2400	Sensor board that attaches to Imote2	2 Serial Port		

5.1.3 Modules

N/A

5.2 COTS components based on ZigBee technology

The ZigBee protocol has been developed to provide low-power, wireless connectivity for a wide range of applications that perform monitoring or control functions. It is a worldwide open standard controlled by the ZigBee Alliance. The ZigBee standard overcomes the traditional limitations of low-power, wireless network solutions; short range and restricted coverage, as well as vulnerability to node and radio link failures. It achieves this by building on the established IEEE802.15.4 standard for packet-based, wireless transport. ZigBee enhances the functionality of IEEE802.15.4 by providing flexible, extendable network topologies with integrated set-up and routing intelligence to facilitate easy installation and high resilience to failure. ZigBee networks also incorporate listen-before-talk and rigorous security measures that enable them to co-exist with other wireless technologies (such as Bluetooth and Wi-Fi) in the same operating environment. Since the IEEE standard 802.15.4 specifies only the PHY and MAC layers, devices built on top of that are not necessarily interoperable. The ensure interoperability among multiple vendors an industry alliance was formed, the “Zigbee Alliance”. It is an association of companies (counting about 100 at this point of time) working together to enable reliable, cost-effective, low-power, wirelessly networked, monitoring and control products based on an open global standard. Any manufacturer that wishes to implement the ZigBee standard into his devices should first enroll in this Alliance. The ZigBee is a set of high level communication protocols for WPANs and is based upon the specification produced by the IEEE 802.15.4 task group.

5.2.1 Commercial / industrial ZigBee modems, gateways

	company	unit	describe	Onboard sensors	I/O line	ADC line	DAC line	Wire com.	Range / power
1	Cirronet	ZN2401	ZigBee modem	-	2	4	2	YES	
2	Cirronet	ZG2400M	ModBus Gateway					ModBus	
3	Cirronet	ZG2400E	Ethernet Gateway	-	-	-	-	TCP/IP	
4	MeshNetics	EGW-A1281	Ethernet Gateway					TCP/IP	

5	Moteiv Corporation	Tmote Connect	EthernetGateway					TCP/IP	
6	Vulcain Inc.	Vulcain 301C	control unit, Gateway					TCP/IP ModBus	
7	MaxStream	XBee PRO	RS 232 Modem					RS-232	
8	MaxStream	XBee Pro	USB modem					USB	

5.2.2 Commercial / industrial ZigBee sensors

	company	**unit**	**describe**	**Onboard sensors**	**Wire com.**	**Range / power**
1	Moteiv Corporation	Tmote Invent	sensor unit	Light, Temperature, Acceleration, Sound	-	
2	IntelliSensing LLC	PSI - Range	sensor unit	pressure gas pressure liquid	-	
3	Vulcain Inc.	Vulcain 301W	sensor unit	CO, NO2, O2	-	

5.2.3 ZigBee OEM modules

	company	**unit**	**describe**	**Onboard sensors**	**I/O line**	**ADC line**	**DAC line**	**Wire com.**	**Range / power**	**Expansion support**
1	Cirronet	ZMN2401	OEM	-	4	4	2	-		YES
2	Jennic	JN5139	OEM	temperature		4	2			YES
3	Jennic	JN5121	OEM	temperature		4	3			YES
4	Moteiv Corporation	Tmote Sky		temperature, humidity, light						
5	Moteiv Corporation	Tmote Mini				8	2			

5.3 COTS components based on Mica Z technologies

Short technology description: Crossbow provides a broad portfolio of wireless modules to meet the specific needs of applications for either end-user or OEM designs. A variety of Development Kits are designed to provide customers with all of the tools needed to evaluate, design and develop a wireless sensor network.

The MICAz MPR2400 (2400MHz to 2483.5 MHz band) uses the Chipcon CC2420, IEEE 802.15.4 compliant, ZigBee ready radio frequency transceiver integrated with an Atmega 128L micro-controller. It enables low-power, wireless sensor networks. It uses an Atmel processor to run the sensor applications and network/radio communications stack simultaneously. The radio offers both high speed and hardware security.

The IRIS is a 2.4 GHz Mote module used for enabling low-power, wireless sensor networks. The IRIS Mote features several new capabilities that enhance the overall functionality of Crossbow's wireless sensor networking products.

Crossbow's MICAz and Iris motes are compliant with IEEE 802.15.4/ZigBee.

5.3.1 Modems, gateways

	company	**unit**	**describe**	**Onboard sensors**	**I/O line**	**ADC line**	**DAC line**	**Wire com.**	**Range / power**
1	Crossbow	Micaz Mote – mpr2400	Atmega128L	Uses Sensor Boards Above	Digital I/O,I2C,SPI	10 Bit		2.4 Ghz	Outdoor – 75 to 100 m, Indoor – 20 to 30
2	Crossbow	Iris Mote –	Atmega 1281	Uses Sensor Boards	Digital	10 Bit		2.4 Ghz	Outdoor

		xm2110		Above	I/O,I2C,SPI				> 300 m, Indoor > 50 m
3	Crossbow	Micaz Mote – mpr2600 – OEM module	Atmega128L	Uses Sensor Boards Above	Digital I/O,I2C,SPI	10 Bit		2.4 Ghz	Outdoor 75 to 100 m, Indoor 20 to 30 m
4	Crossbow	Iris Mote – m2110 – OEM module	Atmega 1281	Uses Sensor Boards Above	Digital I/O,I2C,SPI	10 Bit		2.4 Ghz	Outdoor > 300 m, Indoor > 50 m
5	Crossbow	SBP200 Stargate Gateway	Communicates with: IRIS, MICAz, MICA2PCMCIA, USB, RS-232, Compact Flash, RS-232, Ethernet	None, uses sensor boards below	Various				
6	Crossbow	MIB510	Serial (RS232) Programming board for Mica2, Micaz, and Iris sensor nodes	None	RS-232	N/A	N/A	N/A	N/A
7	Crossbow	MIB520	USB Programming board for Mica2, Micaz, and Iris sensor nodes	None	USB	N/A	N/A	N/A	N/A
8	Crossbow	MIB600	Ethernet Programming board for Mica2, Micaz, and Iris sensor nodes	None	Ethernet	N/A	N/A	N/A	N/A

5.3.2 Sensors

	company	unit	describe	Onboard sensors	Wire com.	Range / power
1	Crossbow	MDA300	Fits MicaZ and Mica2 motes	GPIO (Digital), Temperature, Humidity, Actuator Relays, 12 Analog inputs 12 bits each		
2	Crossbow	MDA320	Fits Micaz and Mica2 motes	GPIO (Digital), 8 Analog inputs 16 bits each		
3	Crossbow	MDA100	Fits Micaz , Iris, and Mica2 motes, Includes prototype space	Analog inputs, 10 bits each, GPIO Photoresistor, Thermistor		
4	Crossbow	MTS300	Fits Micaz , Iris, and Mica2 motes	Light, Temperature, Acoustic and Sounder	N/A	N/A
5	Crossbow	MTS310	Fits Micaz , Iris, and Mica2 motes	Dual-Axis Accelerometer, Dual-Axis Magnetometer, Light, Temperature, Acoustic and Sounder	N/A	N/A
6	Crossbow	MTS400	Fits Micaz , Iris, and Mica2 motes	Temperature, Humidity, Barometric Pressure, Ambient Light Sensors, Dual-Axis Accelerometer	N/A	N/A
7	Crossbow	MTS420	Fits Micaz , Iris, and Mica2 motes	Temperature, Humidity, Barometric Pressure, Ambient	N/A	N/A

				Light Sensors, Dual-Axis Accelerometer, GPS receiver		

5.3.3 Modules

N/A

5.4 COTS components based on Mica 2 technologies

_

Crossbow's Mica2 Wireless Platform is designed for Low-Power Sensor Networks. They feature a 868/916 MHz Multi-Channel Radio Transceiver. The data rate is up to 38.4 kbps, They are designed for Deeply Embedded Sensor Networks with a multi-year battery life. Every node has the capability to be a wireless router.

5.4.1 Modems, gateways

	company	unit	describe	Onboard sensors	I/O line	ADC line	DAC line	Wire com.	Range / power
1	Crossbow	SBP200 Stargate	Communicates with: IRIS, MICAz, MICA2PCMCIA, USB, RS-232, Compact Flash, RS-232, Ethernet	None, uses sensor boards below	Various				
2	Crossbow	MICA2	Atmega128Lm, 38.4 kbps	None, uses sensor boards below	Various			900Mhz 866Mhz 433Mhz	150 m Outdoor
3	Crossbow	MCS410 (Cricket)	Mica2 based, uses ultrasonic sensors and transmitter to obtain locating capability to within 1 cm resolution, Atmega128Lm, 38.4 kbps,	None, uses sensor boards below	Various			900Mhz 866 Mhz 433 Mhz	150 m Outdoor

4	Crossbow	MIB510	Serial (RS232) Programming board for Mica2, Micaz, and Iris sensor nodes	None	RS-232	N/A	N/A	N/A	N/A
5	Crossbow	MIB520	USB Programming board for Mica2, Micaz, and Iris sensor nodes	None	USB	N/A	N/A	N/A	N/A
6	Crossbow	MIB600	Ethernet Programming board for Mica2, Micaz, and Iris sensor nodes	None	Ethernet	N/A	N/A	N/A	N/A

5.4.2 Sensors

	company	**unit**	**describe**	**Onboard sensors**	**Wire com.**	**Range / power**
1	Crossbow	MDA300	Fits MicaZ, Iris, and Mica2 motes	GPIO (Digital), Temperature, Humidity, Actuator Relays, 12 Analog inputs 12 bits each	N/A	N/A
2	Crossbow	MDA320	Fits Micaz, Iris, and Mica2 motes	GPIO (Digital), 8 Analog inputs 16 bits each	N/A	N/A
3	Crossbow	MDA100	Fits Micaz , Iris, and Mica2 motes, Includes prototype space	Analog inputs, 10 bits each, GPIO Photoresistor,	N/A	N/A

				Thermistor		
4	Crossbow	MTS300	Fits Micaz , Iris, and Mica2 motes	Light, Temperature, Acoustic and Sounder	N/A	N/A
5	Crossbow	MTS310	Fits Micaz , Iris, and Mica2 motes	Dual-Axis Accelerometer, Dual-Axis Magnetometer, Light, Temperature, Acoustic and Sounder	N/A	N/A
6	Crossbow	MTS400	Fits Micaz , Iris, and Mica2 motes	Temperature, Humidity, Barometric Pressure, Ambient Light Sensors, Dual-Axis Accelerometer	N/A	N/A
7	Crossbow	MTS420	Fits Micaz , Iris, and Mica2 motes	Temperature, Humidity, Barometric Pressure, Ambient Light Sensors, Dual-Axis Accelerometer, GPS reciever	N/A	N/A

5.4.3 Modules

N/A

5.5 Experimental components to be considered

Since January 2005 a standard for UWB wireless personal area networks is being developed (IEEE 802.15.4a). At first, more that 25 companies and institutions sent their proposals based on various technologies and on various variants of these technologies. The main technology was then chosen based on sequences of ultra short pulses . In the same document an optional solution, based on UWB chaotic signals, was also adopted. Thus, after many years of investigations in the field of applying chaos to communications, international scientific and engineering community has come to a conclusion that chaotic signals are competitive information carriers for wireless communication systems and committed this in this document.

Prof. Dmitriev attitude (UWB) –whole technology is described in Annex 1, others according to the partners proposal.

6 CHARACTERISTICS OF EXISTING COTS WIRE ANALYTICAL SENSORS

6.1 What analytical sensors are considered?

Edinburgh Instruments Ltd

Since its establishment in 1971, Edinburgh Instruments Ltd has become recognised as a leading light in the photonics and electro-optics industries. It is now located in purpose built 12,800 sqft facilities just outside Edinburgh, where it employs 40 people. The company is involved in the development, manufacture and sale of a wide range of high technology products for the scientific research and industrial markets. Product ranges include lasers, analytical spectrometers and gas detection and monitoring products supplied by its Sensors Division. Of the current annual turnover of ca £3.4M (ca $5M) over 85% is exported world-wide.

Edinburgh Instruments Ltd. can be considered the blue print for on-campus industry in the UK. Formed in 1971 as a spin-off from Heriot-Watt University, it was the first private company on Britain's first "Research Park".

Following rapid expansion, by the 1980's, a full range of infra-red gas lasers, both sealed and flowing, cw and pulsed CO2, CO and FIR lasers were brought to the market.

In 1978 the company developed a Fluorescence Lifetime Spectrometer system based around the successful nanosecond flash lamp. This product range has culminated in the development of the latest computer controlled, combined Steady State and Fluorescence Lifetime Spectrometers hitting the market in the new millennium: the FLS920 is truly a world beating, state of the art fluorescence laboratory in a single instrument.

Product diversification continued with the development of CO, CO2 and CH4 gas sensors. Based on non-dispersive infra-red (NDIR) technology these devices are available as OEM or complete monitoring and detection packages, supplied through the Sensors Division of Edinburgh Instruments Ltd.

Over the years Edinburgh Instruments has continually sought to diversify and develop new and innovative products, winning many international designs, technology and export achievement awards. Its products are used world-wide in industries as diverse as medical, bio-physical, plasma and semiconductor research, chemical analysis, forensic science, to cutting and marking in industrial applications. As well as offering precision products, our in-house staff are available to provide advice and consultation to comprehensively help meet the demands of the discerning user.

Vaisala Group

Vaisala develops, manufactures and markets products and services for environmental and industrial measurement. Vaisala's markets are global. The mission is to provide basis for better quality of life, environmental protection, safety, efficiency and cost savings.

The major customer groups are meteorological and hydrological institutes, aviation organizations, defence forces, road and rail organizations, weather related private sector, system integrators and industry worldwide. Vaisala's competitiveness in environmental measurement is based on premium value products. The company is the global market leader in many of its core businesses.

Vaisala had more than 1 000 employees and achieved net sales of EUR 220.8 million in 2006. Vaisala serves customers around the world. Operations outside Finland accounted for 97% of net sales in 2006.

Parent company Vaisala Oyj, domicile in Vantaa, Finland, is listed on the Helsinki Exchanges in Finland. The Vaisala Group has offices and operations in Finland, Northern America, France, United Kingdom, Germany, China, Sweden, United Arab Emirates Malaysia, Japan and Australia.

6.2 Industry / outdoor analytical sensors

	company	unit	quantity	range	wire com.	type	
1	Edinburgh Instruments Ltd	Gascard II Plus	CO2	0 – 100%	Analog	OEM	
2	Edinburgh Instruments Ltd	Gascard II	CO	0 – 100%	Analog	OEM	
3	Edinburgh Instruments Ltd	GasCheck	CO2	0 – 10%	Analog	OEM	
4	Vaisala Group	GMM221	CO2	0 – 20%	Analog	OEM	
5	Vaisala Group	GMM222	CO2	0 – 10000ppm	Analog	OEM	
6	Vaisala Group	GMM20W	CO2	0 – 20000ppm	Analog	OEM	
7	Vaisala Group	GMM111	CO2	0 – 20%	Analog	OEM	
8	Vaisala	GMM112	CO2	0 – 2000ppm	Analog	OEM	

	Group						
9	Vaisala Group	WXT510	Wind Temperature Humidity Rainfall Barometric Pressure	0...60 m/s -52 … +60 °C 0...100 % 0.01 mm 600...1 100 hPa	digital	Sensor unit	
10							

7 REQUIREMENT FOR COMPONENTS DEVELOPMENT

The all context differs in principal functionality, but the requirements on low level sensor node could be generalised.

Winsoc Node - Requirement components:

- Power block – for power management Winsoc Node and analytical sensors
- Interface / bus block – for analytical sensors connection – it is expected that there could be connected one or more sensor components for measuring physical parameters
- Procesor block and memory – for data collection, net management, etc.
- Tx / Rx block - for wireless mesh connection, the connectivity is expected till 100 m

Winsoc Node – Analytical sensors requirement:

Connection via wire industry bus standard (RS485) and/or wireless standard (ZigBee)

Winsoc Node - Requirement for data transfer

- Frequency of measurement: from 30s till 30 min
- Number of analytical sensors connected to Winsoc Node: max 15
- Data sentence from each analytical sensor 50Byte

Data transfer

Winsoc Node Level1 – connect directly maximum with 1 Winsoc Node Level2 and more nodes of level 1

Winsoc Nodes Level2 – connect to Internet

There is no guarantee, that all sensors of level 2 will have access to public network, so the network of sensors of level 2 has to guarantee the transmission of information among sensors of level 2 to Internet.

8 CONCLUSION

The report analyse Winsoc scenario requirements on the sensor node on different levels and also on the requested sensors component for measure concrete physical parameters. These requirements were compared with existing technologies on level of sensor nodes and also on sensors for measurement concrete physical parameters. As result is recommendation for design and implementation of Winsoc sensor node.

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List of acronyms

COTS	Commercial off-the-shelf
CH	Cluster Head
CM	Cluster Member

ANNEX 1

UWB wireless personal area networks (WPAN) and sensor networks based on chaotic signals

Dmitriev A.S., Laktushkin A.M., Andreyev Yu.V.

Institute of Radio Engineering and Electronics, Russian Academy of Sciences

Mokhovaya st. 11-7, 125009, Moscow, Russia

e-mail: chaos@cplire.ru

Introduction

Since January 2005 a standard for UWB wireless personal area networks is being developed (IEEE 802.15.4a). At first, more that 25 companies and institutions sent their proposals based on various technologies and on various variants of these technologies. Then the main technology was chosen based on sequences of ultrashort pulses [1]. In the same document [1] an optional solution, based on UWB chaotic signals, was also adopted. Thus, after many years of investigations in the field of applying chaos to communications [2–12], international scientific and engineering community has come to a conclusion that chaotic signals are a competitive information carriers for wireless communication systems and committed this in this document.

Main application area of UWB signals are wireless wireless personal area networks (WPANs), for which low cost and low power consumption of the devices are very important. Such networks are developed, in particular, in the framework of IEEE 802.15.4a standard, devoted to transmission of information with rates up to 1 Mbps (aggregate rate up to 10 Mbps) at distances up to 50 m. Besides, deices of this standard must be able to determine their location within the network. To implement the goals of the standard, several types of signals are proposed: ultrashort pulses and sequences of such pulses, spread spectrum signals, chaotic radio pulses and signals with linear FM (sweep-frequency modulation).

Wireless UWB communication tools for “smart home and office” are considered as one of the most interesting products that can boost the market of personal communications WPAN. Besides, many supplementary communication devices must also be wireless and unified with, e.g., mobile phones for convenient use.

When speaking about direct chaotic systems, we imply systems in which chaotic carrier is formed directly in communication band, e.g., in RF or microwave frequency range. Useful information is put into the chaotic signal and is then retrieved from chaotic signal directly in this frequency band. With certain reservations, the term “direct chaotic” can also be attributed to systems in which chaotic carrier signal in RF or microwave band is obtained by means of a transformation of initial (low frequency) chaotic signal, e.g., using it to modulate VCO.

In this report problems of implementing wireless networks and their components with transceivers based on UWB direct chaotic platform [13–14].

Why UWB WPAN?

UWB WPAN is expected to bring inexpensive wireless communication structure for hone and office applications. This infrastructure must be more user-friendly than Bluetooth and ZigBee, must have higher transmission rate and be able to substitute most part of wire interfaces. Such infrastructure is sometimes called «Internet for things», thus emphasizing its importance in future human environment.

Direct chaotic transceiver

The first version of small-size UWB transceiver was designed in a project devoted to experimental verification of the concept of direct chaotic communications and application of wireless direct chaotic technology in UWB WPANs. It was composed of a chaotic generator, a switch–modulator, power amplifier, envelope detector, LNA and digital board [13–14]. This testbed was made on several PCBs, some were made of RF material. The transceiver's antenna was also pronted on a separate PCB.

The transceiver discussed in this report (Fig. 1) is a next-gen device. As the previous-generation transceiver, this transceiver operates in 3,1…5,1 GHz frequency band. But instead of microstrip chaotic generator and external modulator, here a lumped-element chaotic generator with internal modulation is implemented, all device is built on single PCB, made of low frequency material. Omni-directional printed antenna is also implemented on this board and requires no tuning.

Not only the construction but also capabilities of the transceiver were changed.

Use of internal modulation in transmitter allowed to decrease power consumption. For example, the first generation transmitted consumed 600 mW at rate 2.5 Mbps and approx. 25 mW at rate 100 Kbps. New transmitter consumes 25 mW at maximum rate 2.5 Mbps and about 1 mW at rate 100 Kbps. This saving is achieved by means of: (1) using more economic generator; (2) turning generator on only during generation of radio pulses and turning it off on time intervals between the pulses (due to internal modulation).

Also, a more economic receiver is used that consumes 120 mW instead of 400 mW of the first version at maximum transmission rate, and about 5 mW at rate 100 Kbps.

Capabilities of the transceivers are extended. Now they can be used as:

1. Transceivers of data.
2. Active RFID.
3. Data re-transmitter.
4. Ranging devices.
5. Tools of communication with sensors.

Set of these functional capabilities allows to use these transceivers in зуук-topeer systems, as well as in personal communication networks.

Fig. 1. The transceiver itself (top) and set of transceivers(bottom).

Examples of direct chaotic UWB WPANs

What makes wireless communication network different from a pair of transceivers operating in peer-to-peer mode? First of all, the presence of MAC layer and protocols that provide joint cooperative functioning of set of devices, thus ensuring integral realization of communication system functions.

At present there is a number of operation systems intended to provide WPAN functioning, such as TinyOS, Bluetooth, ZigBee, etc. Specification of MAC layer for IEEE 802.15.4a standard networks is under development. So, when a question of development of MAC layer for UWB wireless networks based on chaotic signals was asked, it was necessary to decide which way to move. Note that, as was stated in decision of the IEEE 802.15.4a Standard Committee [1], for homogeneous chaotic networks MAC must (can) be made different from that designed for the main solution. Besides, when designing the structure of the system, we must take into account that application areas of direct chaotic personal communication systems step over the bounds of the goals solved by the standard. For example, regarding transmission rates. In direct chaotic networks with above transceivers it can be as high as 30…50 Mbps.

So, we decided first to implement several simple network structures based on "common sense", and then to formulate general requirements.

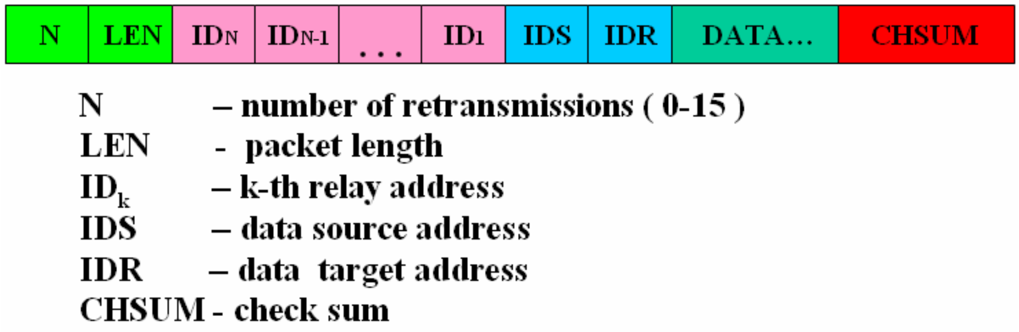

Fig. 2. The packet structure.

In all below described networks asynchronous packet data transmission is used. The packet structure for all the cases is shown in Fig. 2. The packet consists of a header, data field and a tail. The first byte of the header is for the number of re-transmitters *N* \through which the packet passed, the second byte is for the size of the entire packet, then in the next *N* bytes the addresses of the passed-through re-transmitters are written. Then go two bytes with addresses of transceiver, source of information, and of transceiver, receiver of information. Then goes a data field tha can have up to 60 bytes. The packet is closed by two bytes with CRC sum.

Let us consider implemented network structures (Fig. 3).

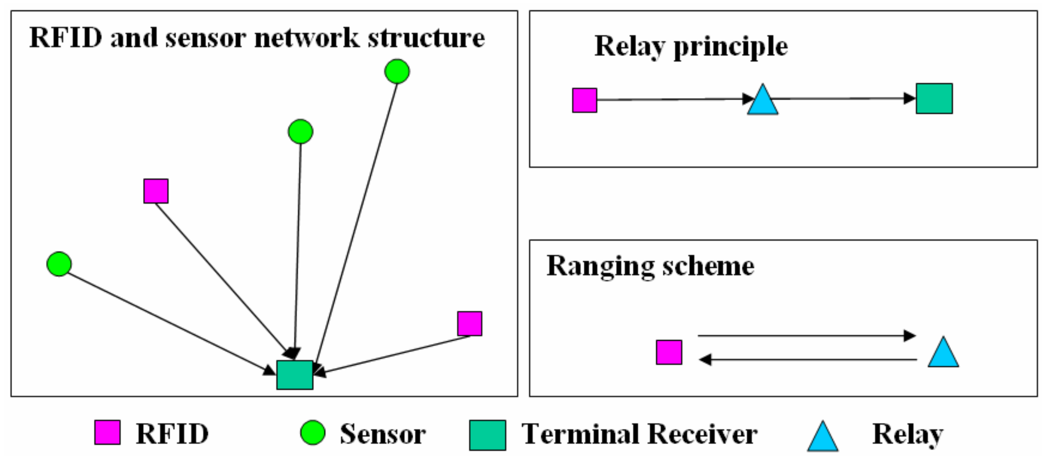

Fig. 3. Implemented network structures.

System of active RFID labels. Before including in the network each device is assigned an ID number and data field is filled with useful information about an object. After mounting on the object the label is activated and it begins to periodically transmit packets. Typical time between packets is 2…3 sec. During each session up to 480 ишеы ща data about the object is transmitted. One session lasts for ~200 µsec. All RFIDs are turned on independently of each other. Receiver gets the signals from the labels and puts information on screen about the presence of signal from concrete label, and marks its activity with color. After receiving a message the label is considered active for time T_a, even if no other signals come from it during this time. If time interval after the last message becomes larger than T_a, the label on screen is marked as having “no activity”. Duty cycle of each RFID signal is less than 1/10000, hence simultaneous receiving of messages or message overlapping is hardly probable. Therefore, no special collision avoidance measures are necessary in case of small or moderate number of label.

Data re-transmitters. The function of transceiver in re-transmitter mode us to receive packets from one transceiver and to send useful information part of the packets to another, preliminary assigned device. For this purpose, the address field of the initial packet is filled with the address of re-transmitter and the address of the destination transceiver. Information transmission in reverse direction is performed similarly. If information must be sent through several re-transmitters, all the route is written in address field. Besides, in each re-transmitter information is written about devices with which it can connect.

In process of re-transmission the packet is written in the memory of re-transmitter, a new packet is formed and emitted, so the operation of re-transmission adds a delay of approx. 0,5 msec.

Ranging. In these transceivers a function of measuring distance between two devices is implemented. During operation of ranging one transceiver emits a packet with special data structure. The second transceiver receives this packet and re-transmits it to the first transceiver. The first one receives it and by delay between emitting own signal and receiving the signal from the second transceiver it estimates the distance between the devices. Ranging accuracy is about 30…50 cm. Ranging procedure is described in detail in [15].

Wireless sensors. The mode of wireless sensor is implemented by means of attaching a sensor to microcontroller using a ADC built in microcontroller. At certain moments data is taken from the sensor (e.g., luminance intensity, temperature, pressure, etc.), packet containing the taken parameter value is formed and emitted. Taking data and emitting packets can be performed either periodically, or by request from another transceiver. As in the case of a network of RFID labels, each sensor operates independently of other elements of sensor network. If the network is sparse or moderate-size, collision probability is small.

Conclusion

In this report we presented results of development of direct chaotic transceivers for UWB WPAN and considered implementation of some simple structures of wireless networks based on these transceivers.

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ANNEX 2 – DATA SHEETS