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DEVELOPMENT OF ARCHITECTURE OF EMBEDDED DECISION SUPPORT SYSTEMS FOR RISK EVALUATION OF TRANSPORTATION OF DANGEROUS GOODS

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Abstract. The analysis of the risk of transportation processes shows that transportation of hazardous materials is complex process and causes a risk quite a different than that of a fixed facility. Sustainability of surroundings depends on a safe transportation, especially on the safe transportation of dangerous goods by different auto transport kinds. The aims of our research concern an approach for development of the architecture of decision support system with integrated embedded components for monitoring and evaluation of transportation processes of dangerous goods. Mobile technology provides a potentially convenient and truly ubiquitous platform for detection of the objects and the contextual information such as the location, region awareness, etc. A location-based reminder application runs on wireless equipments. Reminders can be more helpful when rich contextual information is used to present necessary information at appropriate time moments in appropriate places. Devices sense and interact with their physical environment through sensors. In general terms, any aspect of the device that enables it to sense and interact with its physical environment may be considered as a sensor. The combination of web service protocols (e.g. SOAP) with session initialization protocol (SIP) enables P2P accessibility by introducing sensor's listener and context retriever as programming components in the developing communication architecture of servers and users. We are using an appropriate interface structure (components, scenarios) for service control, and integrate data-mining, knowledge-based techniques for recognizing a concrete situation of the moving object. The integration of distributed information systems and the means of wireless communication systems (i.e., programming components, protocols, sensors, and devices) are needed. The paper describes an approach of designing the architecture of the system that uses wireless technologies for monitoring dynamic objects with implementation of probabilistic methods for evaluation of risk of possible types of scenarios of accident events which can occur in transportation of dangerous goods. Some wireless protocols are used in establishing the object's geographical coordinates, monitoring and fixing the state behavior of the moving dangerous transportation objects.

Keywords: decision support system, componential architecture of embedded systems, wireless technology, risk evaluation, transportation of dangerous goods.

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1. Introduction

When considering the risk as a complex phenomenon of transportation of dangerous goods we understand that transport by road is more hazardous nowadays. The recent EEC Directive 96/82/EC implies the evaluation of risk in highly industrialized areas by means of Quantitative Area Risk Analysis techniques. It should be stressed that certain dangerous substances are transported along particular road routes in quantities that would exceed the threshold for safety notification or declaration. The analysis of risks caused by the transportation of hazardous materials influence the evidences. The possibilities of pollution during accidental events are related with safety of moving objects. Possibilities to move in differently protected regions have a different risk. The means for evaluation dynamic objects are quite complex and differ from the evaluation means of fixed facilities and stationary established objects (Pine and Marx 1997; Dzemydienė *et al.* 2008) until complex evaluation means of dynamic objects (Zhang *et al.* 2007; Batarlienė 2007).

The related works that deal with the evaluation of risk of transportation of hazardous materials is presented by (Fabiano *et al.* 2001, 2005; Milazzo *et al.* 2010) where a site-oriented risk analysis is made and tested in a pilot areas. Road designing approaches integrating the geographic information systems (GIS) (Jakimavičius and Burinskienė 2009) and multi-criteria based analysis of sustainable development of transportation zones (Zavadskas *et al.* 2007; Kavaliauskas 2008; Kaklauskas *et al.* 2009) influence the safety of transportation in extremely engaging regions and junctions (nodes) of transport networks.

The problem concerns the development of decision support systems (DSS) which enable to assist in complex, operatively control processes of hazardous transportation. Related works started from an in-depth inventory of transported hazardous materials and the statistical analysis of traffics and accidents observed in the areas (List *et al.* 1991; Leoneli *et al.* 2000; Batarlienė and Baublys 2007) and continuous in recently implemented projects for safety transportation such as eCall (eSafety iniciative 2007), Intelligent transport (Jarašūnienė and Jakubauskas 2007), etc. For design of embedding DSS components the knowledge-based methodologies are needed with deeper multi-dimensional evaluation methods of situation recognition and decision making (Brauers and Zavadskas 2009; Minalga 2007; Kavaliauskas 2008; Zavadskas *et al.* 2007; Kaklauskas *et al*. 2009; Bielskis *et al.* 2009).

The aims of our research are related with the problems of sustainable development in the area of the transportation, considering several directions:

- Evaluation possibilities of the risk of transporting of goods with hazardous materials, especially evaluation of the risks after pollution during accidents in ground, air and water reservoirs;
- Development possibilities of mobile technologies with including the sensor systems, that can record data from moving objects in the distributed information systems (DIS);
- Development of componential architecture of embedded decision support system (DSS) that can assist in abnormal situations, by integrating an interface reaction and control

according to abnormal situation evaluation which can cause the accidental events in the transportation processes of dangerous goods.

Implementation of some applications of layered protocols, used in mobile technologies by locating moving objects as transportation of dangerous goods in time and geographical dependencies can be helpful in the evaluation processes of the risk (Dzemydienė and Dzindzalieta 2009). Mobility support of peer-to-peer (P2P) applications is back grounded by charging of P2P applications. Solutions of P2P technology are widely implemented nowadays. Mobile web services (as clients) and server as the mobile terminal can be realized on the session initialization protocol (SIP) for mobility, presence, and session management. Some interesting examples of such sensors include: built-in cameras, motion/gesture sensors, location-sensing capabilities (e.g., GPS hardware), etc.

The location detection service (LDS) has made a real time location detection system using one of the certain techniques. The accuracy depends on the method chosen (Rosenberg *et al.* 2002). Location may be expressed in text or spatial descriptions. Descriptions of the spatial location may be expressed as latitude, longitude and altitude coordinates. Contextual information can be simply expressed as addresses, population density, risk of the rout, etc. (Gudgin *et al.* 2006).

To obtain the current location coordinates, we can use one of the following methods:

- The use of mobile networks (MRI). While being in an unknown geographical location, the exact location can be detected with the help of base stations. The user of mobile device identification (m–ID) situated in a certain geographic location gets into a mobile station's coverage area, therefore the user's location can be detected by using mathematical methods.
- The use of satellites, as compared with the mobile network positioning method, has more advantages because the accuracy of localization reaches 4-40 meters (Johnson *et al.* 2004). However, the greatest imperfection is that mobile devices must have an additional Global Positioning System (GPS) receiver, which was unnecessary for the first MRI method. Another shortcoming is that a mobile device uses a phone battery and it must be visible to satellites. So the mobile phone can use the area's information only after receiving the GPS data.

There is no single answer to decide which method is the best. It depends on the accuracy requirements.

The target of our research is integration of some components in the decision support system (DSS), which will allow to use the mobile services, to control and recognize the concrete situation of the moving objects (i.e., automobile transport), using distributed information systems and the means of wireless communication systems (i.e. programming components, protocols, sensors, and devices). We propose to use some wireless protocols for establishing the object's geographical coordinates, monitor and fix the state of behavior of the moving dangerous transport objects.

2. Principles of risk evaluation of unsafe transportation of hazardous goods

The risk is related with a probability that an accidental event e_t can occur. The road of transportation as well has different levels of ecological danger, i.e., environment protection.

Selection of the best route has been widely investigated (List *et al.* 1991; Jakimavičius and Burinskienė 2009; Zavadskas *et al.* 2007) and recently formulated as a "minimum cost flow" problem. The problem consists of determining, for a specific hazardous substance, the cheapest flow distribution, honoring the arc capacities, from the origin vertices to the destination vertices (Leonelli *et al.* 2000). Some factors related to road conditions such as the road class, set speed limits, traffic density, as well as the population characteristics, are likely to result in a risk assessment insensitive to route specifics and over- or underestimating the overall level of risk (Fabiano *et al.* 2005).

The goods become wastes after an accidental event e_t of transportation at the time moment t.

We have based our consideration on the classification of wastes according to the Technical Directive for Hazardous Substances (TDHS) – i.e. Directives 201 (July 2002). TDHS is meant for the classification and labeling of wastes for disposal purposes (Hazardous Substances Ordinance 2004). The basis for the assessment of wastes by the ordinance for dangerous goods is the dangerous properties (Evaluation... 2010), which these materials can have:

- Flammability (combustibility);
- Oxidizing properties;
- Toxicity;
- Corrosiveness;
- Formation of flammable gases in contact with water;
- Contamination with infectious and pathogenic materials;
- Radioactive radiation;
- Water polluting properties;
- Release of hazardous dusts.

A further differentiation among the classes of dangerous goods can be made by substance registers. The classification and assessment of hazardous wastes are made according to their physical-chemical properties (solid/liquid, boiling point, ignition point, and toxicity data), etc.

The assignment of wastes to one of the listed hazard categories is difficult, if they are mixtures of solids or liquids (solutions). The dangerous goods ordinance gives some guides how to classify. But to this end, it is necessary to know the constituents and hazardous properties of the waste. We restricted the scope of our consideration to the properties of water pollution, because the phenomenon of wastes is of an unlimited character which can change in the course of time, as well as the properly to have evaporate into the air of the surroundings, etc.

The initial task of expertise is data gathering, resulting in the set $\{Ob_t\}$ – observed findings and storing in the temporal database of distributed information warehouses.

The materials are classified by the rate of their harmfulness. Such materials, which are ecologically dangerous, are the main decision variables of the water analysis task. We have established 4 grades of pollutant harmfulness:

- Set of pollutants of the first rate of harmfulness in water bodies, which are especially dangerous – $\{H^1_{j1}\}$;
- Set of pollutants of the second rate of harmfulness, which one less dangerous – $\{H^2_{j2}\}$;
- Set of pollutants of the third rate of harmfulness – $\{H^3_{j3}\}$;

- Set of pollutants of unidentified effect, which can be harmful or non harmful and very dangerous in the chemical reaction with other materials – $\{H^{4}_{j4}\}$.

The DSS has the assistance properties for improved performance models for dispersion of chemical substances in complex universe of discourse (UoD). The DSS integrates a GIS platform in order to calculate and assist the regional/local decision making process for managing the transportation processes, related with e_t and recognized as chemical accidents. The means of calculating the exposure-related lifetime risk are complicated, and, for simplicity, we can calculate the additional risk as a difference between the risk of the exposed persons and the risk of the non-exposed control group as:

$$PA\ (x) = P(x) - P(0),$$

with $PA\ (x)$ – additional risk during exposure x, $P(x)$ – lifetime risk of the exposed persons, and $P(0)$ – "background risk" (lifetime risk of a non-exposed control group).

We have the problem there with two different objectives/goals. The goal of the transport enterprises is a rational development for economic benefit (Radžiukynas 2007; Žvirblis *et al.* 2008). It means that enterprises must guarantee the economic value growth. But, such transportation must be of minimal pollution of the environment and damage to the nature, not exceeding the permissible standards. It means an ecological clean transportation. Thus we have:

$$G(x) = \langle \begin{matrix} \max \vec{E}_{b,i}, \\ \min \vec{P}_{terj,\Delta k}, \end{matrix}$$

where $\vec{E}_{b,i}$ is the vector evaluating the economic benefit b of the transport enterprise i under consideration to increase in capacity and profit, $\vec{P}_{ter,k}$ is the vector evaluating pollution of the territory ter_j of environment during the time duration Δk.

The highest permissible contents or interim permissible concentrations of these substances in the surrounding are established depending on some types of characteristics: the territory (ter_j) characteristics; the type of water reservoirs, etc.

Harmful materials, and their models of distribution during transportation processes, are the main subsystems and the resulting information units that may be established in DSS and analyzed dynamically.

3. The architecture of DSS with embedded subsystems for monitoring and localization of moving objects

We describe the basic design principles and introduce a conceptually layered framework, with a view to associate the functionality of implemented components of the subsystems in the existing framework of the DSS, divide into various layers. We depict different context models used for representing, storing and exchanging sensing and contextual information.

A real-time subsystem is embedded in the target system as a concurrent computing system related with the monitoring of data (Fig. 1).

The monitoring subsystem connected with the expert subsystem must detect the faults of process performance. The time for obtaining a solution is often strictly limited. These

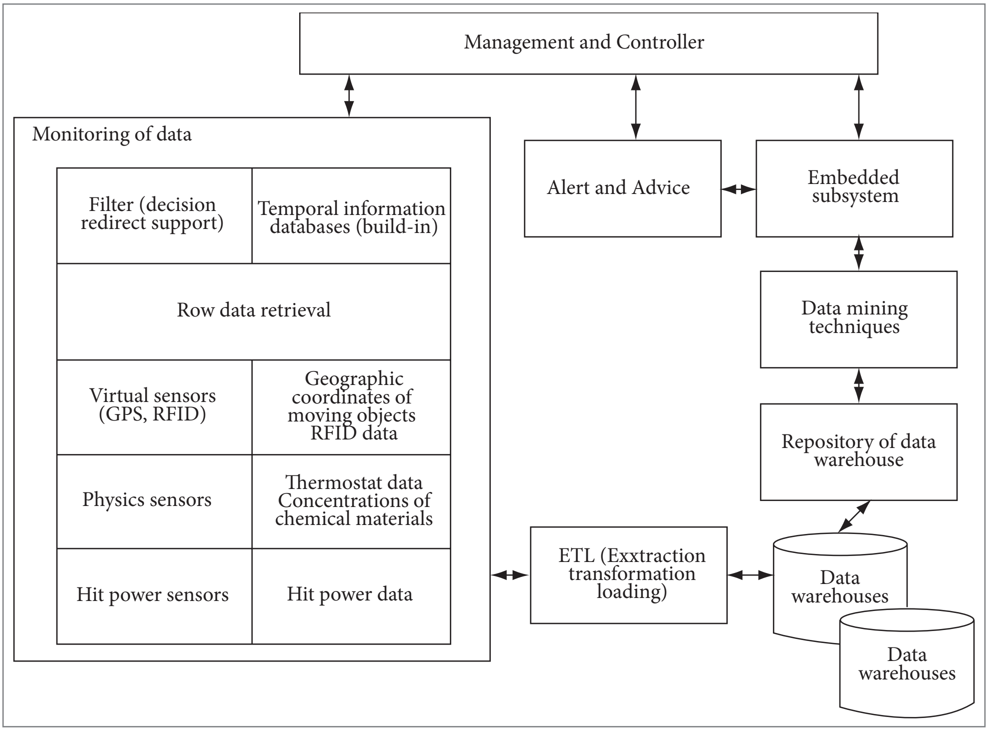

Fig. 1. Architecture of main components of the DSS

conditions impose strict deadlines on the obtaining a decision and maintaining the functioning correctness. The system behavior defines a set of temporal dependencies, dynamic evaluation of situations, adaptively control feedbacks and complexity management, which must be implemented in the embedded DSS, according to related works (Dzemydienė *et al.* 2008; Dzemydienė and Tankelevičienė 2009; Bielskis *et al.* 2009). The system works as a multiple agent system.

The monitoring component of the system integrates several sensor systems which observe the transportation means and indicate possible conditions of the state. Such sensors are aimed at localization of the object, observing the main physical parameters inside the object, which can characterize multiplex state evaluation. The types of sensors are represented in Fig. 1. Such data became row data for transforming them in the data warehouses. The metadata represented in the conceptual schema of the repository of data warehouses are introduced in our system for a better understanding of data semantics and contextual information (see Fig. 2). The extraction transformation loading (ETL) engine is used for revealing and storing such row data into the data warehouses. Data mining techniques are introduced in the DSS as the components for extraction of the main rules and patterns of the situation recognition which can help to integrate multi-dimensional parameters into decision support processes and control processes of the accident event situation.

4. Description of the risk of road stretch characteristics in the DSS

The route is divided into road stretches and each is characterized by different characteristics. Risk is related with scenarios of accident events, influenced by types of dangerous goods, and surroundings. The approaches of multiple complex description of scenarios influence the classification them by types and can be based on the ontology of this phenomenon. Federal and provincial legislation provide for the regulation of an extensive list of products, substances or organisms classified as dangerous. The products fall into one of nine classes: explosive, flammable, radioactive, etc. The model is focused on evaluation of a proper frequency of accidents.

The set $S = \{s_k\}$ represents types of scenarios of accident events of transportation which we can to recognize, where $k = \overline{1,n}$.

Following the recommendations of approaches by (Marti 1996, 2005; Rubinstein and Shapiro 1993; Fabiano *et al.* 2005), the expected number of fatalities as a consequence of an accident occurred on the road stretch r and evolving according to a scenario s_k, can be expressed as:

$$B_r = \sum_{k=1}^{n} f_r N_{r,s_k} P(s_k), \tag{1}$$

where f_r is the frequency of accident in the r-th road stretch [accident·year^{-1}], N_{r,s_k} is the number of fatalities according to a scenario s_k in the r-th road stretch [accident fatalities^{-1}], $P(s_k)$ is the probability of evolving scenarios of type s_k, following the accident initialises (i.e. collision; roll-over; failure, etc.).

The transportation network can be considered as a number of junctions (nodes) linked one to another by a number of arcs (Fig. 2).

The junctions represent the cross roads, towns, tool-gates, storage areas, etc. in the transportation network. An arc between two junctions can be characterized by a different number of road stretches and the expected number of fatalities for the arc is:

$$B = \sum_{r} \sum_{s_k} f_r N_{r,s_k} P(s_k). \tag{2}$$

The frequency of an accident involving the scenario s_k, on the r-th road stretch, can be expressed as:

$$f_{r,s_k} = f_r P(s_k), \tag{3}$$

$$f_r = \gamma_r L_r n_r, \tag{4}$$

where:

$$\gamma_r = \gamma_{0,r} G, \tag{5}$$

where γ_r is the expected frequency on the r-th road stretch [accident·km^{-1}·vehicle^{-1}·year^{-1}], L_r is the road length [km], n_r is the number of vehicles through the road r-th stretch in [vehicle], $\gamma_{0,r}$ is the regional accident frequency [accident·km^{-1}·vehicle^{-1}·year^{-1}], according to (Prekopa 1995).

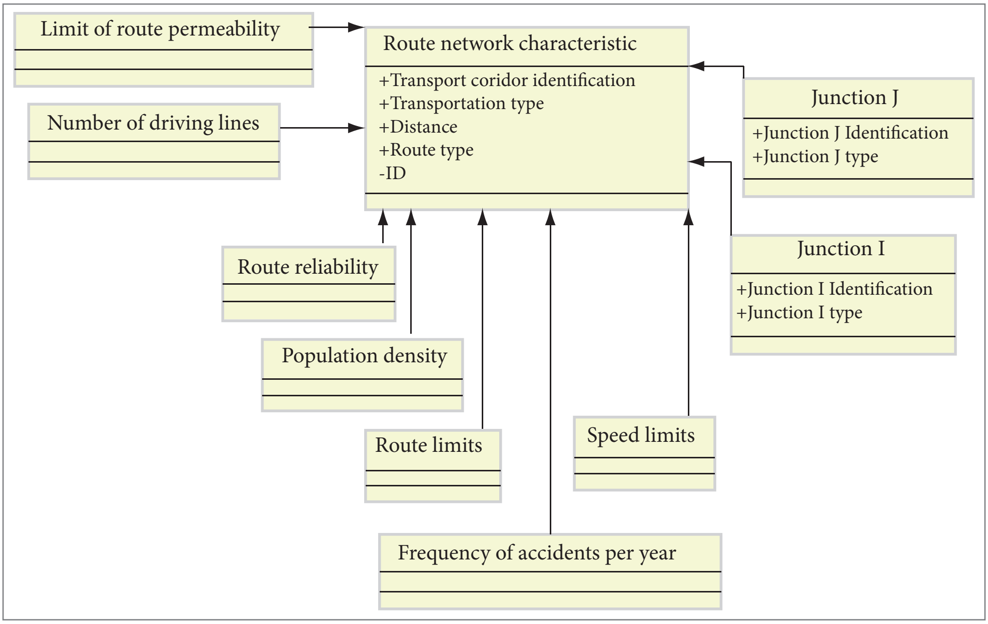

Fig. 2. The example of conceptual representation of main parameters of route stretch of the transportation network in the repository of data warehouse

G is probabilistic parameter, characterized as a common evaluation parameter of environment. Various factors influence the accident events: environmental, behavioural, physical, mechanical. Road intrinsic descriptors are described by these parameters.

$$G = \prod_{j=1}^{m} G_j, \tag{6}$$

where *G* is the local enhancing/mitigating parameter. The main types of these parameters we can describe as: G_1 is a parameter depending on temperature, G_2 is a parameter that depends on the inherent factor (such as tunnel, bend radii, slope, height gradient, etc), G_3 is a parameter that depends on the metrological factor (such as snow, sun, rain, ice, etc), G_4 is a parameter that depends on the wind speed and wind direction, and others until such parameter that we can recognize G_m.

N_{r,s_k} is the total number of fatalities according to Eq. (2):

$$N_{r,s_k} = \left(\Phi_{s_k}^{in} \circ^{\Delta t} v_r + \Phi_{s_k}^{off} d_r\right) P(F, s_k). \tag{7}$$

Being the in-road and the off-road number of fatalities calculated, respectively, as:

$$N_{r,s_k}^{in} = \Phi_{s_k}^{in} \circ^{\Delta t} v_r P(F, s_k), \tag{8}$$

$$N_{r,s_k}^{off} = \Phi_{s_k}^{off} d_r P(F, s_k), \tag{9}$$

where $\Phi_{s_k}^{off}$ is a consequence of the in-road area associated with scenario s_k [m^2]; $\Phi_{s_k}^{off}$ is a consequence of the off-road area associated with scenario s_k [km^2]; $P(F,s_k)$ is a probability of fatality F for accident scenario s_k; $o^{\Delta t}$ is the average vehicle occupation factor during specific time period Δt , which can depend on the seasons or day time; v_r is the vehicle density on the road area [vehicle·m^{-2}]; d_r is the population density of the *r-th* road area environment [inhabitants·km^{-2}].

5. Representation of localization data of the transport objects using mobile technology

Moving objects are constrained by a road network and they are capable to obtain their positions from an associated GPS receiver. Moving objects (termed as mobile clients) are recognized by their location information. Location server and the central data warehouse are in the server site. The relationship is possible via a wireless communication network (Booth *et al.* 2004). The disconnection between client and server is realized by other mechanisms in the network than the tracking. The disconnection occurrences activate mechanisms which notify the server which appropriate actions are needed. After each update from a moving object, the position is represented in the data warehouse and the system informs the moving object about the location. The moving object issues an update when the predicted position deviates by some threshold from the real position obtained from the GPS receiver (Hofmann-Wellenhof *et al.* 1997; Johnson *et al.* 2004; Gudgin *et al.* 2006; Huang *et al.* 2006a,b).

The client initially obtains its location information from the GPS receiver and from the physical and virtual sensors. This possibility allows collection of the data from the sensors and processes them on-line. The data of sensor parameters are exchanged, and then the event e_{ti} influence changes in reality. If the data are changed critically, DSS gets a signal or message. The architecture of these components is represented in Fig. 3.

A temporal database efficiently stores time series of data, typically by having some fixed timescale (such as seconds or even milliseconds) and afterwards storing changes only in the measured data. The temporal database is often used in real-time monitoring applications or when we lose the connection with the main databases.

The second layer is responsible for the retrieval of raw context data. It makes use of appropriate drivers of physical sensors and APIs of virtual and logical sensors. The query functionality is often implemented in reusable software components which make low-level details of hardware access transparent by providing more abstract methods such as *getPosition()*.

While using the location J2ME programming interface, the location of user can be determined (White and Hemphill 2002; Mahmoud 2004; Kreiensen and Kyamakya 2004). This service can be adapted in other applications or other services in mobile devices such as limited mobile devices and PDA phones (Location API for J2ME 2003). Also, the functionality can be extended in them.

```
Criteria crit = new Criteria();
crit.setHorizontalAccuracy(500);
LocationProvider locpro = LocationProvider.getInstance(crit);
Location loc = locpro.getLocation(60);
Coordinates cor = loc.getQualifiedCoordinates();
if (cor! = null) (
double lat = cor.getLatitude();
double lon = cor.getLongitude();
```

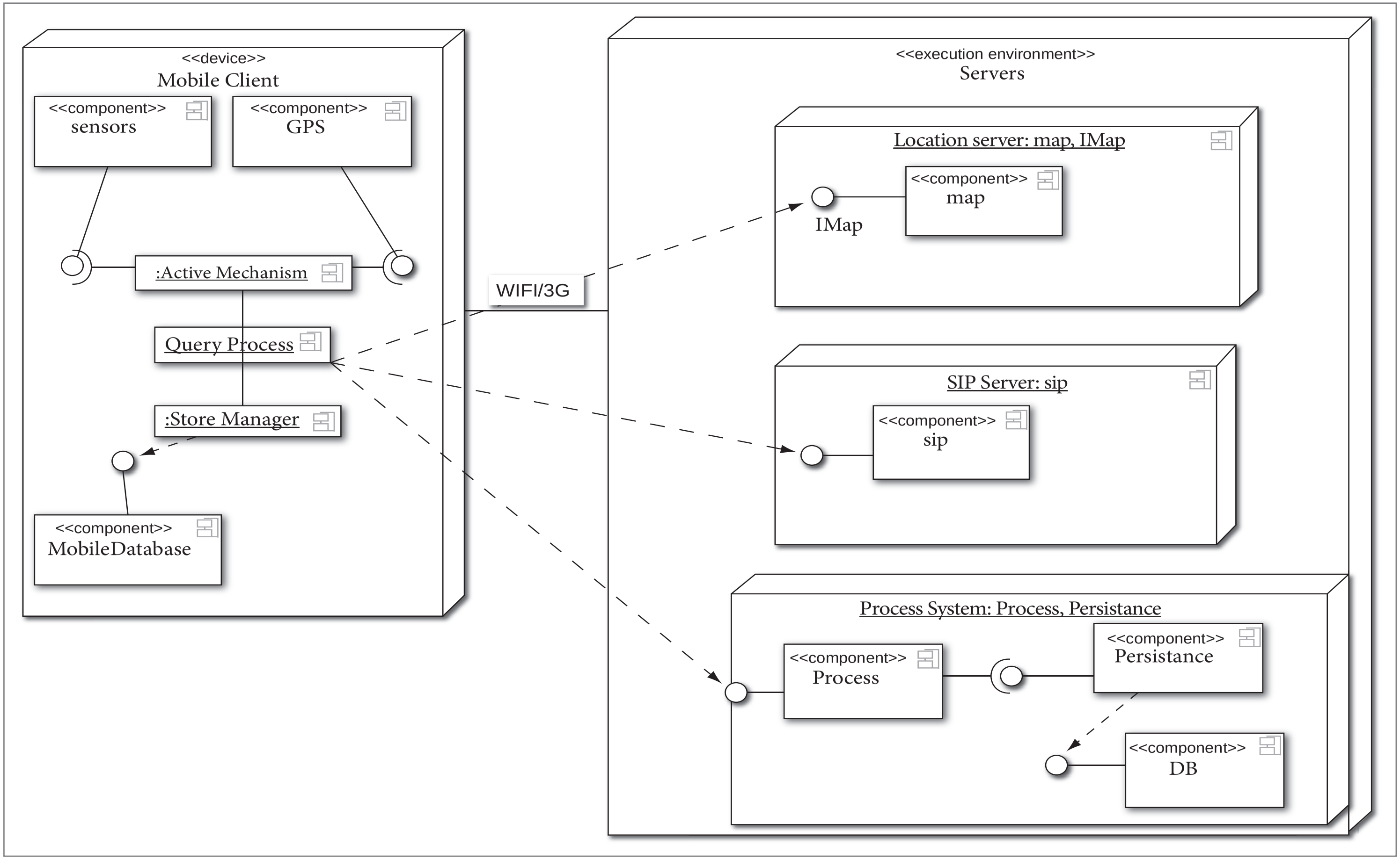

Fig. 3. Communication architecture enabling interoperability of mobile objects and servers

Here the criteria fields (*Criteria*) include: accuracy, response time, height and speed. *Criteria crit = new Criteria (); cr.setHorizontalAccuracy(500)* – means that the horizontal accuracy is 500 meters. The location class extracts local results. Its object contains coordinates, speed if reached, and address where the text is reached and the time marker, which shows the dimensions of the space.

By using interfaces of the components responsible for equal types of context these components become exchangeable. Therefore, it is possible, for instance, to replace a RFID system by a GPS system without any major modification in the current and upper layers.

The fourth layer (Storage and Management) organizes the gathered data and offers them via a public interface to the client. Clients may gain access in two different ways: synchronous and asynchronous. In the synchronous manner, the client is polling the server for changes via remote method calls.

The use of mobile web services in a P2P manner is enabled by establishing a SIP session between the devices. The mobile web service endpoints are SIP URIs, the Web Service endpoints of both clients are URIs containing the current IP address.

To combine the web service protocol, e.g. Simple Object Access Protocol (SOAP), with SIP is very important for securing the communication between server systems and mobile devices (Mitra 2003). SOAP is a transport neutral mechanism for exchanging messages (Booth *et al.* 2004). SOAP can be used on the top of SIP or in parallel with the same layer (Rosenberg *et al.* 2002). The use of SOAP on the top of SIP on the user (data) plane enables transmission of SOAP messages within the SIP message. SIP is defined to be used only as a signaling protocol in the application layer. Thus, work is focused on the use of SIP on the control (signaling) plane in parallel with SOAP on the user plane. Separation of the user and signaling plane has advantages with respect to protocol design, communication software design, and performance. SIP is used to transmit "application layer" signaling messages. User data are transmitted over SOAP on top of various alternative underlying Internet protocols using different SOAP bindings. In order to communicate between two different mobile devices via Web Service there must be a mobile web service endpoint. The mobile web service endpoint is a SIP URI (URI is based on the IP address). Each web service must have ID which is used to easily identify and register for the mobile web service.

The SIP URI is as follows: *sip:user_name@server_name:port*. This URI is used in each SIP message exchanged between devices to identify the sender and the recipient. For example, e-mail addresses traditionally are assigned by a SIP provider to SIP users to enable them to receive and initiate communication sessions.

In general, each terminal is able to provide and use Mobile Web Services (MWS) at the same time and within the same SIP session. SOAP is a transport mechanism for exchanging messages. The use of MWS in a P2P manner is possible by establishing a SIP session between the devices. The MWS endpoints are SIP URIs, the web service endpoints of both clients are URIs containing the current IP address. First, we need a set of building-blocks of web services. They are common basic web services required by most mobile-service applications. The MWS and proxies have to register with the SIP agent in order to be notified about URI (IP address) changes.

The *SensorListener* listens to updates from sensors which are located in distributed computers called sensor nodes. Then the collected information is stored in the database by the *SensorListener*.

The *ContextRetriever* is responsible for retrieving the stored context data. Both of these classes may use the services of an interpreter. The *ChangeListener* is a component with communication capabilities that allows a mobile computer to listen to the notification on context change events. Sensor and *LocationFinder* classes also have built-in communications capabilities. Mobile clients connect to the server via wireless networks. To reduce the impact of intermittent connections local caching is supported on the client side.

These agents can be as applications hosted by mobile devices that a user carries or wears (e.g., cell phones, PDAs and headphones), services that are provided by devices (e.g., temperature controller) and web services that provide a web presence for people, places and things in the physical world (e.g., services keeping track of peoples and object whereabouts).

Registration is not required for the agents using a proxy server for outgoing calls. It is necessary, however, for an agent to register the receipt of income calls from proxies. The user mobile device must share its physical address with the registrar in the network. Along with this "registration" is the public identity that is to be bound to the physical address. Keep in mind that the public URI can change physical addresses many times as a subscriber moves about the network, so the binding of addresses may change frequently.

The request for a session typically consists of sending an *INVITE* message. However, requests are not limited to this method. The connection of two participators is able to start by sending a SIP *INVITE* message after starting the SIP session between two devices (or conference). This session is initialized by request that enables a virtual connection between two or more entities for exchange of user data (voice calls, data, e-mail, etc.). This method is used to set up a session between the identified entities.

The *ContextRetriever* is responsible for retrieving stored context data. Both of these classes may use the services of an interpreter. The *ChangeListener* is a component with communication capabilities, which allows a mobile computer to listen for notification of context change events. Sensor and *LocationFinder* classes also have built-in communications capabilities. Mobile clients connect to the server over wireless networks. To reduce the impact of intermittent connections local caching is supported on the client side.

6. Analysis of monitoring data and feedback management

The sensor's subsystems work as agents in parallel and the important information is written on the temporal information registration window (TIRW). The process control subsystem of DSS must detect the following facts: what the maximum value was at a concrete time interval, the number of times a value exceeded a predefined reference value (i.e., the limitation of concentrations of harmful materials in the surrounding, sewerage water, etc.), a temporal delay between the maximum of a variable, and the maximum effect on another variable.

The *SensorListener* listens to updates from sensors which are located on distributed computers called sensor nodes. Then the collected information is stored in the database by the *SensorListener*.

A direct sensor access approach is often used in devices with sensors locally built in. The client software gathers the desired information directly from these sensors, i.e., there is no additional layer for gaining and processing sensor data.

The first layer consists of a collection of different sensors. Note that the word "sensor" not only refers to sensing hardware, but also to every data source which may provide usable context information. In the view of the way data are captured, sensors can be classified in two groups.

The most frequently used types of sensors are physical and virtual sensors. Many hardware sensors are available nowadays which are capable of capturing almost any physical data. Possibilities to integrate such types of sensors are as follows:

- Light measurers – photodiodes, color sensors, IR and UV-sensors etc.;
- Visual context fixation – various cameras;
- Audio – microphones;
- Motion, acceleration – Mercury switches, angular sensors, accelerometers, motion detectors, magnetic fields;
- Location outdoors – Global Positioning System (GPS), Global System for Mobile Communications (GSM); Location Indoors: Active Badge system, etc;
- Touch measurers – touch sensors implemented in mobile devices;
- Temperature measurers – thermometers;
- Physical and chemical attributes measures – biosensors to measure skin resistance, blood pressure;
- Hit power sensors.

Virtual sensors source context data from different services or software applications. The monitoring subsystems are working as agents in parallel and the important information is written on the temporal information registration window (TIRW). The TIRW is organized for co-operation of agents at different levels of abstraction.

The topology of harmful materials constructed as a semantic model is used in the co-operation work of agents. The temporal information management requires handling the following kind of information as follows:

- past values will usually be "exactly known" in the used time scale and stored with time parameters (the temporal relations among them can be deduced using dates and time);
- current values are established at the current time moment and can be assumed as "partially known" and "dependent";
- future values are used to represent expected or predicted values (their management presents more difficulty due to the lack of knowledge about the exact instant at which they will be produced).

An example of TIRW for controlling some important parameters of sewage characteristic is shown in Fig. 4. The information is affected by the level of uncertainty. If the uncertainty is associated with the value itself, we analyze information with confidence measure, for instance, the concentration of copper (Cu) will be 0.04 mg/l with the confidence of 90% in time t_{k5}. If the uncertainty is associated with temporal occurrence of the values, we deal with another kind of information, for instance: in the next 60 min the concentration of Cu will be 0.04 mg/l. The temporal occurrences of values are important in constructing of rules of the knowledge base.

The accessible degree of values affects other parameters, which are time dependent. When the causal facts occur (e.g., the temperature of sewage exceeds the limits and/or the concentration of harmful materials reach as the greatest permissible limitations), the dependent fact gets a status (e.g., Alarm = on). Such a fact entered in TIRW activates another agent the function of which is to influence the assistance supporting processes. If such situation does not occur, then the dependent fact will not occur.

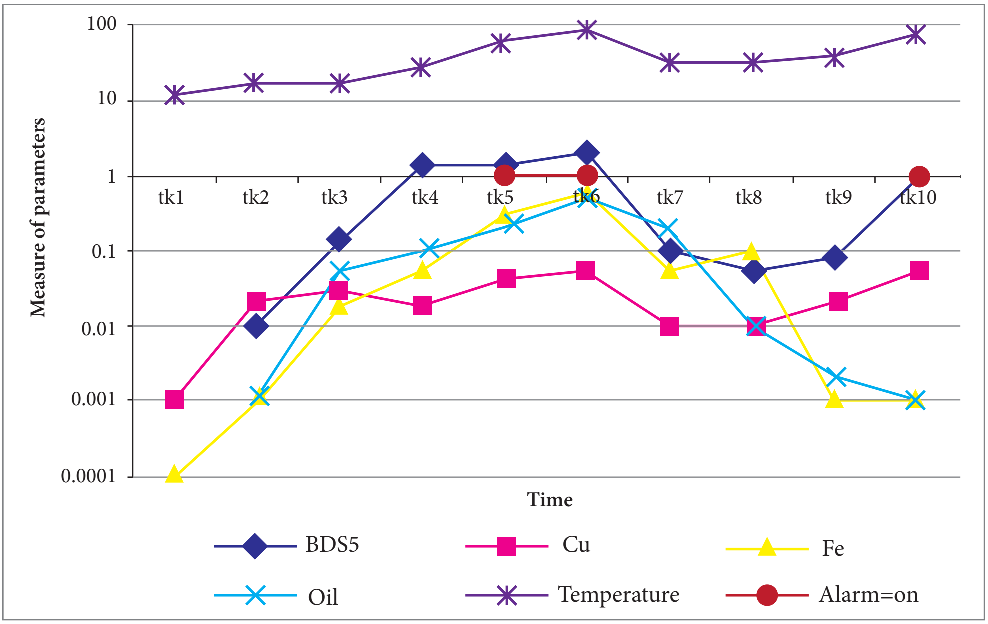

Fig. 4. An example of case study of representation and recognition of physical parameters of temporal information management in TIRW

In order to identify the necessary data, management and control structures, and information processing abilities, one has to imitate a cognitive task in the decision support system.

The courses of decision management and the basic sequences of functional reasoning are joined with information processes as a result of which the evaluation states are obtained. By a decision we mean reasoning (evaluation, determination, resolution, etc.) that has to follow certain actions. An ordinary determination – from certain assumptions to certain generalized conclusions may serve as a preliminary preparation for these actions.

Automatic generation of alternative solutions implies the use of semi-automatic methods for comparing these solutions. The complexity of the decision making task consists in finding the best decision under multiple criteria. As the number of alternatives increases, the multi-criteria evaluation involves a mechanism for rejecting a number of those alternatives.

When analyzing the possible choice mechanisms (under lack of information on the importance of criteria, or assuming the criteria are equivalent), the acceptable decision variant seems to be not so easily chosen. It is expedient to make a choice according to a weighed criterion. Then the basis for choosing the decision variant is qualitative information on the relative importance of each separate criterion.

The essential part of a decision support system is the model of a decision process. Referring to the decision support performance analysis, it is important to represent the relationships between the individual steps in decision-making and the control network ensuring a proper application of the information environment and the knowledge base. The description of this meta-model must include the model of goals, plans and must represent the practice and strategy of reasoning of specialist-experts in making a decision. At the stage of analysis and evaluation of the enterprise performance, the use of this meta-model could be of use:

- to recognize what changes in the environment may induce changes in decision goals;
- to decide whether the situation is relevant to the ready application of the existing rules or not;
- to specify the process of identification of possible courses of actions and alternatives and to control the choice of a concrete variant of these actions by evaluating the attractiveness of consequences of each action.

The multiple objective decision making level deals with the analysis of information obtained from the static sub model, taking into account all the possible measurement points revealed in a dynamic sub-model of such a system. The modeled system is regarded as a direct mapping of the real enterprise system, and decisions can be based on decisive facts and followed rather deterministic rules.

7. Conclusions

A dynamic environment has significant dynamic components that should be evaluates in accordance with correct well working assistances, such as DSS. On-line working sensors can help in the recognition of abnormal situations of transport means, by using mobile technologies. Some issues are presented for integrating mobile technologies into DSS under development. The location detection service enables a holder of mobile devices to receive and provide information on the geographic location of a moving object. We have developed this service adding a new functionality. An approach for developing the interaction architecture of mobile devices and remote server systems with additional functionalities for contextual information transmission is proposed. The paper has presented an architecture based on the MWS and the SIP infrastructure. The proposed context modeling mechanism assures an always up-to-date context model that contains information on the transport device and location. We offer mobile internet services to extend the users interaction with architecture. The main advantage is the extensible architecture so that you can get the data to a mobile devises through web services. In this way, we try to solve the data integration of heterogeneous systems and compatibility issues.

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SPRENDIMŲ PARAMOS SISTEMOS ĮTERPTINĖS ARCHITEKTŪROS PLĖTOTĖ PAVOJINGŲJŲ KROVINIŲ TRANSPORTAVIMO RIZIKAI VERTINTI

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Santrauka. Transporto srautų ir avarijų keliuose daugėjimas verčia nagrinėti pavojingųjų krovinių transportavimo problemą sisteminiu – daugiakompleksiniu požiūriu, nustatant galimos rizikos sritis ir pasiūlant operatyvaus valdymo metodus. Transportuojant krovinius, vežančius pavojingas, taršias medžiagas, išauga aplinkos taršos rizika, susijusi su judančių transporto objektų įvykių pasireiškimo tikimybiniu padidėjimu ir atitinkamų pasekmių galimybėmis. Tikėtinos taršos rizika įgyja daugiafunkcį pobūdį ir yra sudėtingesnė nei rizikos vertinimas stacionarių objektų aplinkoje. Darnios aplinkos vystymo reikalavimai verčia užtikrinti saugius transportavimo procesus ir ypač saugų pavojingųjų krovinių transportavimą skirtingose autotransporto priemonėse ir teritorijose. Todėl gana svarbu sukurti tinkamą sprendimus palaikančią aplinką, kuri padėtų stebėti ir operatyviai vertinti transporto objektus, vežamų cheminių medžiagų būklę, kelio ruožų avaringumą. Ypatingą reikšmę įgyja transportavimo kelyje išsidėstančių teritorijų statusas ir padėtis. Šiam tikslui tenka ieškoti metodų, tinkamų vertinti pavojingųjų krovinių transportavimo procesus ir juos aprašyti sprendimų paramos sistemoje (SPS). Mobiliosios technologijos padeda nustatyti objekto buvimo vietos informaciją, leisti sieti ją su vietovės informacija, taikyti atitinkamus jutiklių rodmenis. Vietovės nustatymas grindžiamas priminimų paslauga ir veikia belaidžiuose įrenginiuose. Priminimai gali būti naudingi, kai kontekstinė informacija pateikiama tinkamu metu ir tinkamoje vietoje. Prietaisų jutikliai sąveikauja su fizine aplinka per sensorius. Straipsnyje siūlomi sprendimai, kaip projektuoti atitinkamas sąsajos struktūras – sprendimų paramos sistemų įterptinius komponentus, scenarijus, vykdymo paslaugų kontrolę judančio objekto konkrečiai situacijai atpažinti ir valdyti. Įmontuotoje SPS taikomi išskirstytųjų informacinių sistemų ir belaidžio ryšio sistemų sąveikos komponentai, t. y. programavimo moduliai, protokolai, sensorinių duomenų analizė. Straipsnyje aprašomas SPS projektavimo procesas, pasitelkiant belaides technologijas dinaminiams objektams stebėti, susijusiems su pavojingųjų krovinių transportavimu. Siūloma taikyti bevielio ryšio protokolus nustatant geografines objekto koordinates, pateikiant įspėjimus apie judančio pavojingojo transporto būseną ir galimų prognozių rezultatus panaudoti operatyviam objekto valdymui.

Reikšminiai žodžiai: sprendimų paramos sistema, įterptinė komponentinė sistemos architektūra, rizikos vertinimas, darnus vystymas, pavojingųjų krovinių transportavimas, belaidės technologijos.

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