VILNIUS UNIVERSITY

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DEVELOPMENT OF A SYSTEM FOR MONITORING OF THE
MOVING OBJECTS BY USING THE SESSION INITIATION PROTOCOL

Summary of Doctoral Dissertation

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VILNIAUS UNIVERSITETAS

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General Characteristic of the Dissertation

Relevance of the topic. Software development often becomes complicated when it is required to combine several heterogeneous systems into a unified new whole to ensure a single communication. Information technology users desire new ways and opportunities to exchange, process and obtain the necessary data from moving objects. The rapidly developing technologies require continuous integration of new devices into existing systems by adding new functionalities instead of changing the overall system architecture. That has raised the necessity to design a system which, being integrated into the existing traditional and Internet Telephony system, with software support, extends the communication protocol functionality, i.e., a neccesity of a development of session initiation protocol (SIP). The modern software development is based on the rapid improvement of the Internet networks.While gaining popularity, different mobile devices such as mobile phones, laptops and other specialized wireless mechanisms together with developed communication networks and software support enable interaction with one another. The development of these technologies deal with distributed systems work and the organization of their interaction for the application of mobile network technology platforms. Distributed systems allow users to efficiently perform complex tasks, collaborate and coordinate their actions. The advantage of such systems is resource sharing and the ability to scan the parametric data from remote heterogeneous systems.

The development of technologies has increased the number of different types of devices. Utility programs or even technology platforms are usually designed for each type of device just to enable them to communicate with each other and exchange data. This is not always a convenient and even an urgent problem for the users who cannot use all the provided functionality. These users must have adapters (technical equipment needed to ensure the communication among different devices). However, it is not always possible to give an adapter for each new user, especially in the situation of their ongoing occurrence.

The dissertation contains a proposal how to avoid these problems without using different adapters. The dissertation offers the ways of using a single extended communication protocol for any user with a mobile phone.

The principal of an extended SIP is based on a call, that is, an invitation to share data is simultenously sent to the server. As soon as the server receives the request, it does not initiate the call but just carries out additional functionality installed in it.

There is a wide spread of existing infrastructure networks in which mobile devices are connected to the base stations via a fixed network infrastructure. Such a connection method is based on the centralized network topology in which the transmission of the user data takes place over a fixed network infrastructure. Such a data transmission is relatively slow and does not always meet the needs. As a result, the Internet connection is increasingly used nowadays. For example, the user connects to the access points providing Internet data services and can transfer data faster.What is more, the connection to these access points enables a direct transfer of audio and video material.

One of the most used technologies in such cases is GPRS, but this technology is for data communication rather than for interoperability.

In order to organize interoperability among remote devices, it is necessary to find ways to integrate them and provide opportunities to combine them into a single operating system using a single protocol. This paper deals with the problem of integration of SIP capabilities that would help remote heterogeneous devices to interact and communicate with each other and thus SIP would become a single protocol for these devices. Information systems users would be provided with sensor data via the real-time interface. If necessary, data would be available on wireless devices (such as a mobile phone, iPad, etc.). The usage of one unified protocol for communication among all remote objects prevents from creating a lot of different applications allowing to scan or control remote objects.

This principle has been applied in this paper in order to connect four different types of devices using a single extended protocol, thus allowing them to communicate with each other. There are other technologies allowing different types of devices to communicate, but

using the SIP protocol we can not only integrate new devices into the system but also to combine them or even provide access to all fixed communications.

Statement of the problem

Mobile (wireless) technologies allow us to track moving objects throughout the geographical area, but the systems enabling the analysis of object states require a development of supplementary means to be integrated into the infrastructure of these systems. Hardware that reads data from sensors is the key component of data gathering in data repositories.the values of the relevant parameters of sensory hardware (sensors) can be transmitted to remote servers, where data is systematized and applied to the analysis and information regarding further object control actions.

To properly manipulate remote objects, we need to link contextual information with the incoming data, and with the help of that to diagnose and evaluate the state of the object. Since remote sensing devices can be of different types, frequently there emerges a problem of their integration. The problem lies in compatibility of different devices being integrated into a single system as well as in other unforeseen technical disturbances. As a result, solution of these problems involves extra costs. The dissertation examines a universal data exchange bus, based on the SIP performance capabilities. This raises questions in what way the solution regarding moving objects data exchange will be realized by choosing a universal bus.

The object of research

The object of research is the development of decision support system architecture which enables us to ensure the interaction of heterogeneous systems by integrating the capabilities of the SIP functionality as well as to monitor and evaluate the remote mobile objects.

The target of the research work is to analyze the communication methods of remote objects and propose a decision support system architecture that would integrate the extended capabilities of the SIP functionality to monitor and evaluate remote moving objects by applying the principles of a universal data exchange bus operation.

The problems tasks of research

The following tasks should be performed to achieve the aim of the dissertation:

1. To address the methods that ensure the communication of remote moving objects by applying the SIP, to identify SIP capabilities in ensuring the interaction among Peer-to-Peer and third-generation 3G networks.

2. To examine the SIP functionality which allows us to implement the communication among remote moving objects as well as data exchange among remote heterogeneous devices of different types.

3. To evaluate the communication and data exchange capabilities of SIP connecting remote moving objects applying Colored Petri Nets (CPN) modeling tools.

4. To propose the decision support system architecture with the integrated extended capabilities of the SIP functionality allowing us to carry out the monitoring and evaluation of remote objects.

5. To propose hardware and software tools of the experimental system that would allow remote objects to communicate with each other by using the capabilities of extended SIP functionality, and to experimentally evaluate the proposed hardware and software tool suitability for communication of different heterogeneous devices.

Research methodology

This study used recent scientific literature sources from science databases. Therefore, the author examined other authors' material regarding equal-rank device interaction and communication methods, the mode of operation of data transmission as well as the methods of interaction and integration of the SIPmultilayer architecture.

After analyzing the literature, this paper developed the data exchange method among heterogeneous devices to match and link with the SIP model, the methods of the use of conceptual modeling, Colored Petri Nets, systematic process analysis as well as the methods of the system engineering and modeling processes. To this end, the methods of data exchange among heterogeneous devices using the SIP protocol, and the methods for improving the work efficiency have been applied.

To carry out the experimental research, the prototype hardware model, developed for dissertation research was used consisting of a microcontroller allowing us to combine four different types of remote devices for ensuring their communication and enabling a successful work of a universal data exchange bus.

The queueing theory methods were applied to compare the experimental results that helped determine the load of the server, message retransmission capabilities and compare them quantitatively.

Scientific novelty

While preparing the dissertation have been got these results as a novelty in Informatics Engineering science:

• The analysis of dense networks, local area networks , 3G networks, occasional (ad-hoc) networks and equal-rank Peer-to-Peer networks showed that remote devices communication uses a great variety of communication protocols, but for different devices new, supplementary devices (adapters) have been developed, enabling remote devices to communicate with each other under different protocols.

• The Colored Petri Net model of SIP protocol allows us to examine operations to be carried out and monitor the states to be performed in the imitating model. The SIP protocol operating model enables us to analyze the information structure transmitted through communication channels necessary for changing one state to another as well as to see how the transfer of controlling information and flow of information are performed.

• The decision support system architecture proposed allows us to combine different types of remote SIP-based devices excluding additional adapters. That provides a possibility to integrate new moving objects into a system without making changes in the overall architecture.

It has been developed the system architecture that allows to combine different devices into a single whole using the SIP protocol of choice as the main one for their communication. To facilitate the communication, devices were classified into four types according to the SIP capability to initiate the session interoperability.

Practical significance of the work

The system architecture has been developed allowing us to combine devices into a single new network using a unified SIP protocol. This Technology Architecture was developed to monitor moving objects while scanning their sensor data.

The scanning of SIP protocol messages and initiating sessions among devices supporting the SIP protocol, and development of a SIP adapter for devices that do not support the SIP protocol and do not exist in the IP network. It was proposed a prototype architecture model of remote sensing monitoring system. Has been his model allows us to integrate sensory components supporting the relationship among different types of mobile devices by transmitting data captured by sensors and assessing the state of a moving object.

The methods and software for wireless systems used in this work allow the exchange of most possible data formats (e.g., text, images or voice) and provide real time state information of the object. The main advantage is an expanded architecture in order to receive data via mobile internet services.

Before turning to the description of a wireless communication protocol system, have been examined the options of the SIP extension. This research paper addresses problems related to communication among different devices, using a single protocol, in this case, - the SIP.

The author directly contributed to the development of the project based on the SIP protocol. This system initiates and manages the calls without the use of telephones. More information about this system is available on the website: http://www.teoverslas.lt/pokalbiai/paslaugos/greitasis_skambutis.

Defended propositions

• The proposed decision support system architecture will allow the integration of SIP functions and enable us to perform the monitoring of moving objects, and to store data in remote data warehouses.

• The hardware prototype will allow us to experimentally test the communication of remote objects and to improve the functions of a universal SIP bus.

• The proposed hardware and software enable us to ensure and test the communication of remote objects as well as to integrate and assess the capabilities of the extended SIP functionality and a universal data bus.

• The models created with Colored Petri nets allowed us to analyze the information structure transmitted through communication channels, necessary for changing from one state to another, as well as to see how the transfer of controlling information and flow of information via these channels is performed.

Approbation and publication of the research

The main results of this dissertation were published in 14 scientific papers: 1 article in a journal abstracted in Thomson ISI Web of Sceince database; 3 articles in scientific publications indexed in Thomson ISI Proceeding database; 7 articles in journals indexed in international databases approved by Science Council of Lithuania. 3 articles in the proceedings of scientific conferences. The main results of the work have been presented and discussed in 5 international and 3 national conferences.

The scope of the scientific work

The work is written in Lithuanian. It consists of 5 chapters, and the list of references. There are 83 pages of the text, 35 figures, 5 tables and 123 bibliographical sources.

INTRODUCTION

The relevance of the problem, the scientific novelty of the results and their practical significance are described as well as the objectives and tasks of the work are formulated in this chapter.

1. METHODS AND MEANS ENSURING COMMUNICATION OF MOVING OBJECTS IN WIRELESS NETWORKS

The establishment of the SIP protocol initiating the communication allows us to use not only centralized, but also decentralized network infrastructures. Users with their own devices connect wirelessly to a network through access points. Users' network devices connected in such a way form Wireless Local Area Networks (WLAN). Even being close to each other, users devices connect to the access points and send the data only through them (Plestys, 2009, Andziulis, 2012).

Initially, in order to connect to the local area network a mobile device sends a registration message indicating its current location and other data that allow us to initiate a session. An access to other types of networks and the Internet from the local area network is available through access points.

In the areas where it is required to maintain high-bandwidth and the fixed network installation is too expensive, high-density networks are implemented which, being of limited mobility, are used for fixed wireless services. High-density network routers use different frequency bands and have several wireless communication modulations. High-density networks use devices with integrated technology standards (Ghazisaidi, 2009) for example, IEEE 802.16 (WiMAX) (IEEE 802.16-2009). That allows us to combine individual IEEE 802.11a/b/g/n networking standards by providing a high bandwidth.

Location Services are designed for the dissemination of location of the devices in the network. There are two main types of these services (Lee, 2002) - location database systems and location dissemination systems. Network devices transmit update messages of location coordinates to a database server. Location service databases are copied in order to increase the probability of a successful response to a query. One of the examples of such systems is a distributed location service – Grid Location Service (GLS) (Pleštys, 2010).

The article (Acker, 2010) introduces the concept of home management, using VoIP media backend advantages the controlled devices of which use the KNX bus. KNX bus combines a variety of device management technologies: trunk cable, co-axial cable, the Internet, infrared signals and radio waves. Home management is based on the KNX technology. This allows the transmission of data over the Internet Protocol. The article (Acker, 2010) also emphasizes the idea that the remote device management contributes significantly to environment protection by reducing energy consumption. Kim in her article (Kim, 2007) proposes the data scanning and delivery to the consumer by using the UDP protocol. Also, the SIP protocol was chosen to ensure the communication between devices and users. Kim proposes a monitoring system for observing the interaction and real-time data transfer, using the SIP protocol and ZigBee network integration. Jung in his article(Jung, 2008) introduces the integration of ZigBee devices for data transmission via a GPRS network.

Peer-to-Peer networks. Peer-to-Peer networks (referred to as P2P) have evolved from the client-server paradigm (Li, 2008). This paradigm focuses on clients' possibility to access remote server resources. The development of wireless technologies is necessary to facilitate multi-component functions by providing the performance of new service capabilities that would be available to the user at any time and from any location. These technological capabilities are based on an open services delivery platform and introduced to mobile users.

The SIP communication capabilities of moving objects in the 3GPP network.

With the increasing demand of telephone users to use the Internet, simultaneously emerged the need to use phone lines to access the Internet. The mobile equipment operators can no longer afford to offer only voice and ever faster Internet access because these items are becoming mere commodities. Operators should provide attractive services that can be bundled with their basic access offer. Mobile carriers cannot offer their customers to mix multimedia components (text, pictures, video, audio) within one call (Gurbani, 2011). A two party voice call is impossible (i.e., video conference is impossible) (Barbosa, 2011). But IMS overcomes such limitation. IMS scalability allows data and telecommunications services mixing (Chu, 2012, Homayouni, 2009). In order that we could take the advantages of the Internet following the minimum modifications to existing architectures, the IMS architecture has been developed (Yeganeh, 2011) the main advantages of which as follows:

Integration into widespread existing architectures that allows IMS to mix GSM, VoIP, standard and other telephone networks.

Transmission of data through the Internet Protocol (IP) and the SIP allowing us to provide other online telecommunication services over the network (e.g., conference, video telephony and other services).

IMS is the IP multimedia subsystem. IMS is an IP-based network that connects to different access points for providing one service for wireless, linear and cable network users. IMS provides a flexible IP multimedia management and session control platform that operators can layer over the existing network infrastructure. To control the calls, IMS uses the SIP during which a call (session) is transferred among different call control elements. IMS is a network functional architecture that facilitates multimedia services development and deployment as well as supports interactions (Chu, 2012).

Common call control and transport layers provide users with a variety of services among multiple access networks. All signaling sessions are transmitted to each subscriber via the internal networks. Remote users of mobile devices can communicate with each other as shown in Figure 1.1
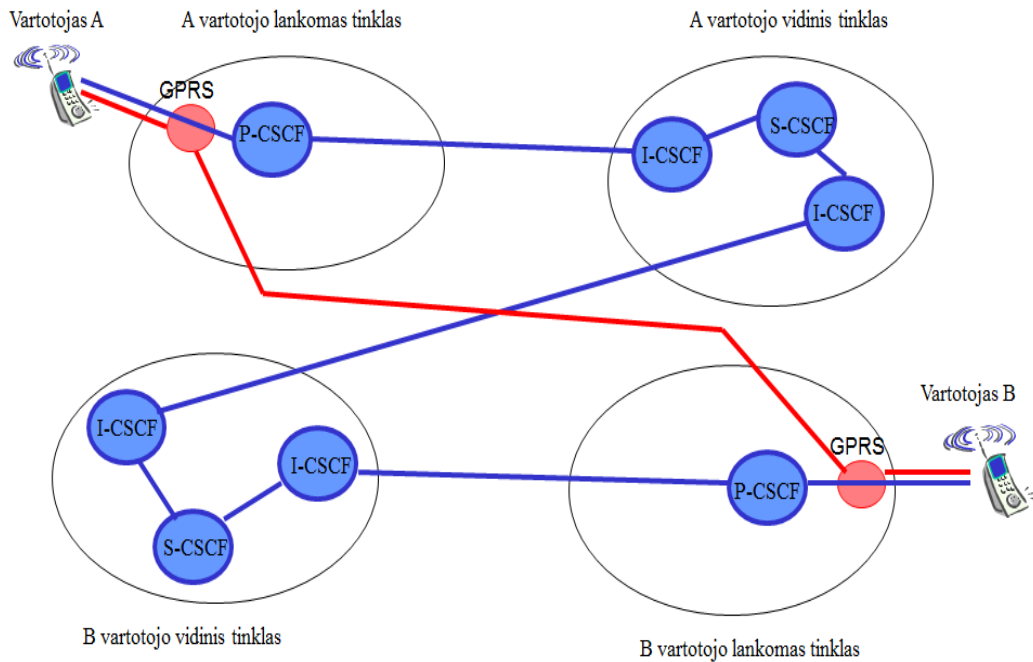
Fig. 1.1 Diagram of mobile device communication

The red line shows data transmission via GPRS services (see Figure 1.1). The blue line is used to show the SIP and SDP.

2. DATA EXCHANGE AMONG REMOTE HETEREGENEOUS SYSTEMS USING SESSION INITIATION PROTOCOL CAPABILITIES

Description of SIP operation. SIP protocol was designed by the IETF Multi-Party Multimedia Session Control Working Group, known as the MMUSIC. The protocol achieved the proposed standard status and was published as RFC 2543 in 1999, In 2001 it was refined and the final version was published. SIP is a standard that facilitates the establishment, modification and implementation of communication between two or more participants, approved of the Internet Engineering Task Force (IETF). Participants can be individuals (video conferencing), automated device (voice mail servers) or communication apparatus.

SIP can be divided into three separate protocols:
1. SIP (RFC2543) (Sends messages).
2. Session Description Protocol (RFC2327) (Session Description Protocol (SDP)).
3. Data Transfer Protocol.

SIP consists of five components:
1. Calling party (User Agent Client (UAC));
2. Called party (User Agent Server UAS);
3. Proxy server;
4. Redirect server;
5. Registrar server.
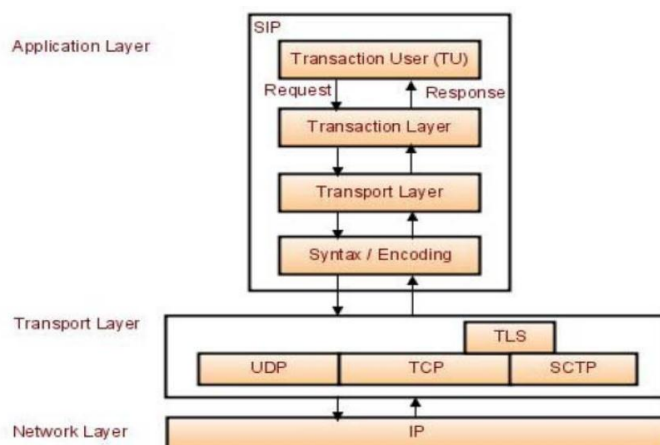
Fig. 2.1 Layers of SIP

The SIP is divided into three layers with each layer adding its own set of related functions:

The SIP protocol uses a structure of the traditional network (IP), transport (UDP,TCP, TLS) and application layers (Barnawi, 2012). The application layer consists of (Fig. 2.1):

- request syntax and encoding;
- transport layer;
- transaction layer and transaction user layer.

The syntax and encoding layer specifies the SIP message structure. The transport layer transmits or receives SIP messages from the underlying transport medium. The SIP transport layer is a transaction layer consisting of a client transaction sending requests and a server transaction responding to requests (Khoury, 2007, Wu, 2010). The top layer is the Transaction User layer which creates and destroys SIP transactions, and utilizes services provided by the transaction layer (Zou, 2007). Among all the SIP layers, the transaction layer is the most important one since it is responsible for request-response matching and retransmission handling when the transport medium is unrealiable (Wu, 2007). SIP messages are transmitted as requests from a client to a server and are responded from a server to a client. Each request message is implemented using methods such as INVITE or ACK to invoke a particular operation on a server. Each response has a status code which can be used to identify the acceptance, rejection and redirection of SIP requests. The first message transmitted to SIP transaction is always an INVITE transaction message or other transactions (if it is not an INVITE or ACK request messages). The INVITE transaction is used to invoke a session while other non-INVITE transactions are used to destroy or maintain sessions for some time. The INVITE client and server transaction method is defined in RFC 3261 specification using the description of state machines (Fig. 2.2.). When a transaction client initiates a session on the client side, it creates an INVITE method in the client transaction.
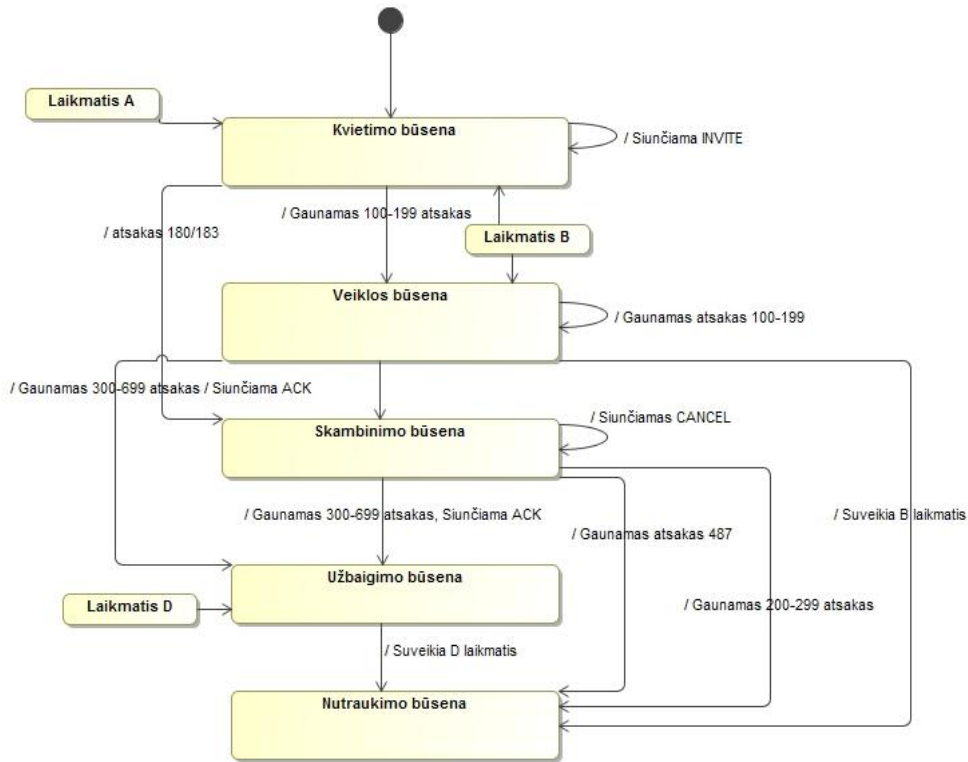
Figure 2.2 State machine defining the SIP on the client side

The client transaction (Fig. 2.1) has five states:

1. Calling;
2. Proceeding;
3. Ringing;
4. Completed;
5. Terminated.

2.2. Universal Communication Bus solutions

SIP platforms are widely used in a variety of forms, including dedicated IP telephony or other systems, and have become the standard for IP telephony.

SIP can be embedded in an increasing number of devices and software systems.It is proposed to use the SIP protocol as a universal communication bus. It is examined how different remote devices need to be adapted to connect them to the universal SIP communication bus.

To adapt each class of devices, different SIP adapter software components are required. The particular component to be chosen will depend on the type of device. This paper classifies remote devices into four types (see Table 1).

Table 1. SIP adapter possible device types and their examples

Adapting devices to SIP types		Device examples
1 type	Communication devices using SIP interface	SIP phone, IP phone, Skype phone, SIP video camera
2 type	Communication devices requiring reprogramming	e-calendar, Smart phone (PDA, iphone)
3 type	Non- programmable devices	IP video camera, Printer,
4 type	Devices without IP capability	Sensors, ZigBee, X10

Type 1 devices, supporting the SIP protocol as the main communication, are adapted to SIP without additional embedded functions, entrance to SIP functionality via SIP-accepting mechanisms is supplied. To provide the access to SIP subject's functionality, three

interaction modes available in SIP are defined: commands (status query and control of subjects), events (event publishing and event subscription), and sessions (invitations and data stream). These interaction modes need to pass and receive data that may have different formats: command parameter value (e.g., SOAP), estimates value (using XML-based format), and session description (SDP description).

Type 2 devices are devices with software that supports the SIP. This functionality allows the device to harness the SIP Internet telephony functions. Software installation includes the full SIP stack as well as integrated online control services that allow one to create and receive SIP messages.

The adapter layer is responsible for the device functionality. As shown in Figure 2.3, for the devices that do not support SIP, a programmable SIP adapter is implemented to ensure device connection to the SIP communication bus. The type 2 device is a programmable SIP adapter that resides in the same device (e.g., smart phone) making it autonomous.

Devices of 3 and 4 types being non-programmable have to be connected to a SIP adapter to integrate them into a universal bus communication based on the SIP protocol. A hardware gateway can also be used for the type 2 devices to improve the communication performance by reducing the energy consumption or increasing the quality of service. A hardware gateway is necessary for type 4 devices as they support neither IP nor SIP capabilities.

First type device capabilities

To associate these devices with a SIP interface it has been designed a device middleware so that devices could directly interact via the SIP native protocol. The application code of the middleware software must be described in order to allow a direct communication if these devices are of type 1. This situation allows a direct connection to the existing SIP infrastructure (e.g., it could be Sailfin or OpenSER server) and entities (e.g., SIP phones and SIP video cameras).

Second type device capabilities

Currently there is a variety of devices with programming SIP capabilities ranging from smart phones to the e-mail software. In our case, it would be the development in the Java programming language with the SIP capabilities supporting framework to create the invocation layer and to connect device functionalities to the SIP communication bus. Programming is based on high-level operations to register and lookup devices, implement and invoke entities functionality.

Third type devices capabilities

This type of device is non-programmable without the software supporting SIP, but with one supporting the IP protocol (e.g., it could be IP video camera). In order to address this type of devices by the SIP protocol, it is necessary to design an adapter, mapping the device communication protocol into SIP. To implement this type of applicability, it is necessary to build the Internet gateway. To design the network gateway, ATMega Board with the Ethernet shield was chosen.The ATMega board is programmed in the C programming language. It can be used the GNU oSIP library which was ported to the board. Then a SIP user agent was transferred to register each device it serves.

Fourth type devices capabilities

The majority of these devices consist of small devices and sensors with low-level functions when reading individual parameters. Since they do not support the IP network and are non-programmable, a gateway is required.
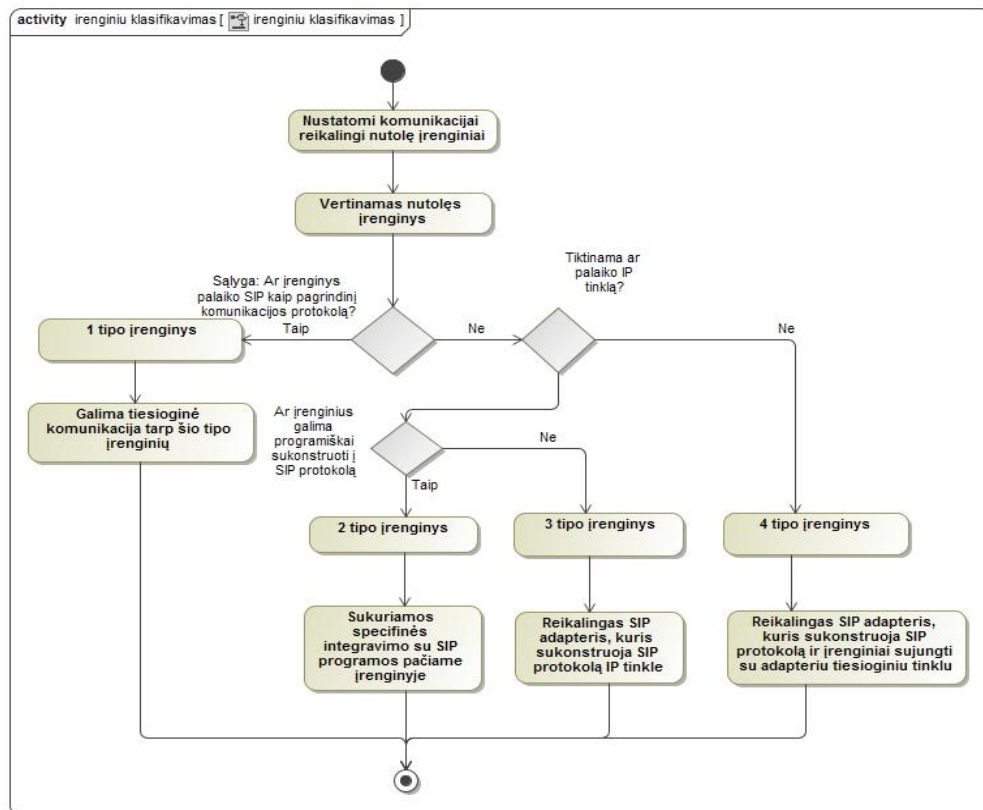
Figure 2.3. SIP adapter architecture

3. DESCRIPTION AND MODELLING OF SIP COMMUNICATION PROCCESSES USING COLORED PETRI NETS

Colored Petri nets (CPN). Colored Petri nets (CPN) allow us to analyze the system quite in detali, because each system step is described by individual components. To create the proper algorithm for a real situation in each system phase, the corresponding Petri network architecture model is applied, according to which a routing scenario is used. Each subsystem of the system is divided into components - operations and states. The CPN model the states of the system. Communication channels transmit control information as well as that required for changing one state in to another, and/or perform material flows. The state of the system is defined as "state marking" and is fixed in a certain position. State changes are represented by marking changes. Marking flows match the changes of parameters of the objects (resources, signals, data) and are modell in the system through the set of marking parameters and operators.

Colored Petri nets modeling language allows the description of large and complex systems (Liu, 2011). The main reasons why CPN should be chosen for modeling CPN are as follows:

1. The model created using Colored Petri nets, renders a possibility to practically explore a not yet implemented system, that is, a modell description of the system has been used for the requirements or future system introduction purposes.

2. Model performance analysis is based on simulations.

3. We get more information, better understand the modell system while making the system description and analysis.

4. Colored Petri Nets are representational graphs attractive to those, who do not have enough knowledge about this type of networks. Another reason is that these nets are similar to the majority of informal drawings designed by engineers and designers.

5. In Colored Petri Nets semantics is clearly defined that describes the exact operation.

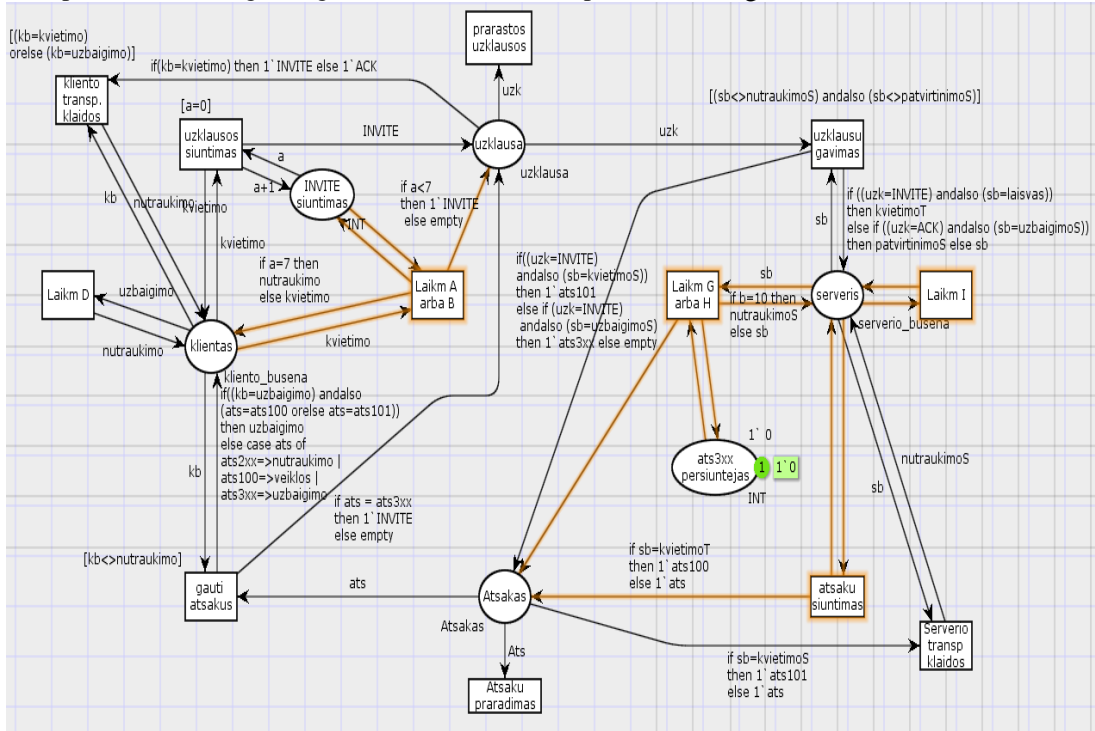SIP protocol modeling, using Colored Petri Nets, is presented in Fig. 3.1.

Fig. 3.1 Simulation model of the SIPusing CPN.

4. ARCHITECTURE OF A DECISION SUPPORT SYSTEM FOR MONITORING AND STATE EVALUATION OF TRANSPORTATION OF DANGEROUS GOODS USING MOBILE TECHNOLOGIES

This chapter presents an architecture system which uses wireless technologies to monitor hazardous transport means. DSS architecture with embedded subsystems is describedfor monitoring and localization of moving objects. The decision Support System (DSS) is a computer-based system that helps decision makers to form the tasks, to accomplish them and make decisions using information technologies, data, models and knowledge. DSS is an interactive information system designed to compile necessary information for decision making and help system users to solve unstructured problems using data and models. DSS can be understood as a system of data acquisition from different sources and data processing to help system users to address specific, unstructured or partially structured problems. When examining DSS it can be understood that it not only helps to make decisions, but also selects the most acceptable option from the provided alternatives or from that to be formed by it (Dzemydienė, 2006).

The following requirements must be completed for developing DSS systems: ensuring system-user interaction; combination of access to the models and data and search for them into a single whole; consideration of user preferences and environmental changes (Batarliene, Baublys 2007).

The developed DSS system must perform the following functions: user interface; problem identification; offer of identified problem solving. DSS functions are as follows: 1) interaction with the solver; 2) problem identification; 3) offer of solutions to the problem, 4) justification for the proposed solution.

The DSS system provides the information needed to create alternatives, analyze, evaluate, suggest the most appropriate solutions and provide an opportunity to further develop the system by selecting problem solving ways (Kaklauskas, 2002).

DSS – is a set of measures which, in a concrete case, refers to the described sources of information in order to obtain and process information as well as to provide users with its appropriate form. The aim of the DSS system is to allow the user to receive and evaluate possible alternatives as the system does not make decisions itself. The DSS system consists of:
- the data processing subsystem that stores all the required data;
- the model management subsystem that stores user-created models and model components;

- in our case, when observing dangerous goods and diagnosing their status at a given time, the models will be created and completed by experts;
- user interface is an important part of the system, because the user is part of the decision-making process;
- a user (decision maker) is part of the system, and decisions are made when communicating with the system.

The monitoring subsystem is connected with the DSS subsystem that can detect deviations of the predefined reference values of the observed object. If the deviations exceed the described limits, the monitoring subsystem is informed. The time for obtaining the right solution is often limited. The system behaviour is defined by temporal dependence, dynamic evaluation of the situation and adaptively feedback control which must be implemented in the embedded DSS subsystem.

The monitoring system component integrates some sensor systems that observe and indicate possible conditions of the state. These sensors are aimed at localization of the object and observing its physical parameters. Sensor types are represented in Figure 4.1. Several important sensor examples are built-in camera, motion sensors, global positioning system (GPS) used to track the object.
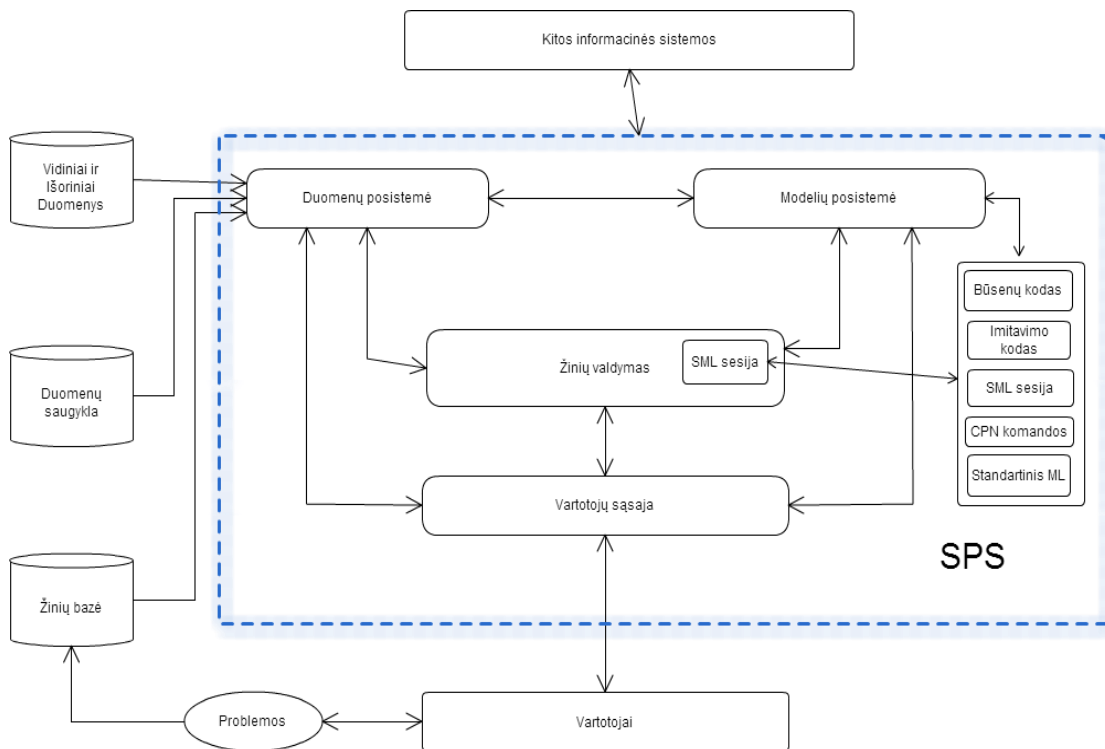
Figure 4.1 Architecture of the main components of DSS

Sensor data are delivered to the DSS system which diagnoses the occurred state. For the diagnosis of the occurring state, the SIP will be used as the main protocol for data exchange. The sensor's subsystems work as an agent and collect data in parallel. The process control subsystem of DSS must find the facts such as the data that exceed the predefined reference value at a concrete point of time (material permissible temperature, impact force, etc.) (XIE, 2011).

5. EVALUATION OF SIP INTEGRATION CAPABILITIES BY CONNECTING EXPERIMENTALLY DIFFERENT HETEROGENEOUS SYSTEMS

This study proposes a universal communication bus which enables us to monitor the location of the object and its different states at different points of time. The main objective is to offer a platform that would be integrated into the widespread VoIP platform, i.e., it would be serve as communication among all the SIP-based devices. In this environment there is a variety of installed devices, from the telephony devices to the smallest sensors that measure environmental parameters. To combine all these different devices and sensors an interpreter is

required. To design an interpreter, the Atmega board was selected and oSIP Application Programming Interface (API) used. This is an interface that a computer system, library or program provides for the programmer, that he/she can take advantage of its functionality via an other program or to exchange data. The software was written using this programming interface. With the help of it, the sensor parameters were converted to SIP standards compatible with messages in the interpreter. The intepreter software is written in the C language. The oSIP supports basic transport protocols such as TCP, UDP and TLS (Transport Layer Security). The oSIP software is written in C and does not require any library dependencies except the standard C library. The software was implemented using libosip2parser library (see http://www.gnu.org/s/osip/), which had been modified to allow us to compile as well as have an interpreter on the Atmega board. The opportunity is provided for devices that support the SIP functionality but do not have a direct connection with distributed systems, to take advantage of SIP proxy capabilities.

The platform discussed above can be used as a vehicle to experiment with various scenarios. For this purpose, a prototype system was developed that involves smart phones, IP cameras, ZigBee sensors and X10 controllers. Combining different devices into a single protocol (Figure 5.1)
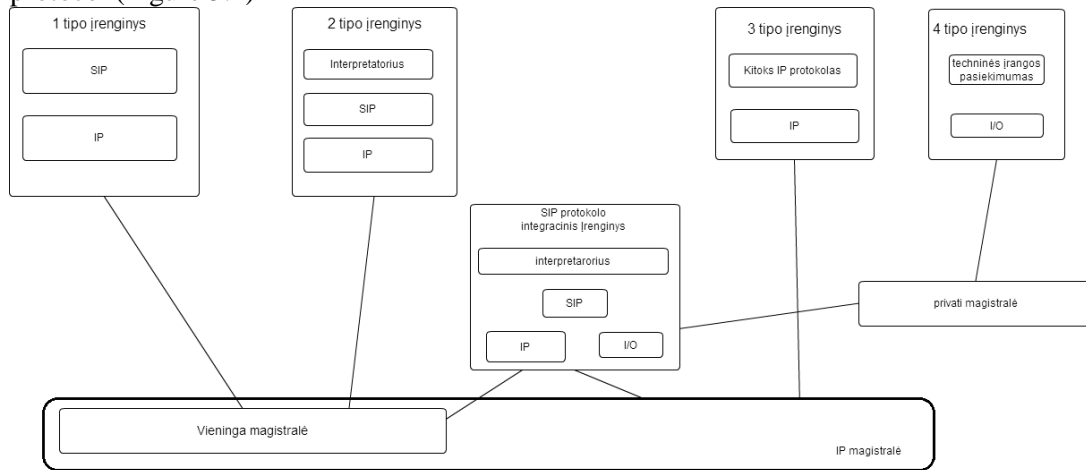
Figure 5.1 Diagram of a combination of four different devices

The SIP is used as a communication bus for data exchange between sensors and distributed devices.

General conclusions
1. The analysis made of dense networks, local area networks , 3G networks, occasional (ad-hoc) networks and Peer-to-Peer networks has showed that the remote device communication uses a great variety of communication protocols, but for different devices new, supplementary devices (adapters) that are developed enable distributed devices to communicate with each other under different protocols. For this reason the feasibility study of SIP was conducted, as a universal protocol ensuring communication. The analysis of the architecture of SIP has indicated that it is possible to ensure the communication in Peer-to-Peer, 3G and other networks of higher generation by using a single SIP protocol to initiate, maintain and terminate sessions. It has been found that this technological solution allows us to refuse a number of different protocols currently used to ensure the communication.
2. The SIP location services behaviour architecture was analyzed and expanded SIP functionality, e.g. identifying the end mobile device through the IP address and , the capabilities of discovery of the path between the nodes in the network. When using device identification through the SIP research there can be another way to determine the geographical position of a moving object, which can be applied even when the GPS unit does not receive the signal, for example, when a moving object hides behind natural barriers (in a tunnel, between the mountains or inside the building).

3. The SIP protocol operating model created using Colored Petri nets allowed us to analyze the operations performed and monitor the states obtained in the imitation model, during each phase of the system to determine the required real situation parameters, to describe appropriate algorithms.The models, created using Coloured Petri nets anables us to analyze the information structure transmitted through the communication channels that is necessary for changing the state from one to another as well as to see how the transfer of managment information and flow of information is performed.

4. The decision support system architecture with integrated extended SIP functionality has been proposed. With the help of the proposed architecture the information has been analyzed concerning the necessity of how to keep sensor data of the monitoring moving objects in remote data depositories using, embedded sensory systems. This technology has enabled the use of a universal data bus, as an integrated SIP function allowing the exchange of the data used for the monitoring and assesment of remote moving objects. The proposed decision support system architecture has allowed us to combine different types of remote SIP-based devices refusing supplementary adapters. All that has provided an opportunity to integrate new moving objects into the system without making changes in the overall architecture.

5. The proposed hardware and software prototype system allowed us to ensure and test the remote moving object communication, integrate and evaluate the expanded SIP functionality and universal data bus capabilities. The designed experimental stand under real network conditions allowed to combine four different types of devices into a single whole. The experiment accuracy was tested by delivering message stream which was successfully processed by all the four types of devices. The study has defined session initiation capabilities by incorporating four different types of devices into a common network, using a single SIP protocol.

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About the Author

Ramūnas Dzindzalieta was born in Lithuania in Šiauliai on the 13th of December 1982.
In 1999 earned a Bachelor's degree of Fundamental Sciences at the Siauliai university
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Since 2009 Ramunas Dzindzalieta was employed as a lecturer at the Communication and information institute of MRU.
Since 2009 Ramunas Dzindzalieta has been employed in the development and application at TEO LT traditional and Internet Telephony department of Network Development and Management.

Reziume
   Temos aktualumas
   Programinės įrangos kūrimas neretai tampa komplikuotas, kai norima sujungti keletą heterogeninių sistemų į visumą bendrai komunikacijai užtikrinti. Informacinių technologijų vartotojai pageidauja vis naujų būdų ir galimybių keistis, apdoroti ir gauti reikiamus duomenis iš judančių objektų. Technologinių įrenginių spartus vystymasis verčia nuolat integruoti naujus įrenginius į jau egzistuojančias sistemas, nekeičiant visuminės sistemos architektūros, bet prijungiant naujas funkcines galimybes. Atsiranda poreikis projektuoti sistemą, kuri integruojama į jau esančią interneto telefonijos sistemą, išplečiant funkcines komunikacijos protokolo galimybes programinės įrangos dėka. Šiuolaikinės programinės įrangos kūrimas grindžiamas sparčiu interneto tinklų tobulėjimu. Įvairūs mobilieji įrenginiai, tokie kaip mobilieji telefonai, nešiojamieji kompiuteriai ir kiti specializuoti belaidžiai mechanizmai kartu su išvystytais komunikacijos tinklais populiarėja, suteikia galimybes bendrauti įrenginiais tarpusavyje, pasitelkus programinę įrangą. Šių technologijų išvystymas susiduria su išskirstytų sistemų darbu, jų sąveikos organizavimu, mobilių tinklų technologinių platformų taikymui. Išskirstytų sistemų dėka vartotojai gali efektyviau atlikti sudėtingas užduotis, bendradarbiauti ir koordinuoti savo veiksmus. Tokių sistemų privalumas – dalinimasis savo resursais ir gebėjimas nuskaityti parametrinius duomenis iš nutolusių heterogeninių sistemų.

   Vystantis technologijoms, didėja skirtingų tipų įrenginių skaičius. Kiekvieno tipo įrenginiui dažniausiai kuriamos pagalbinės programos ar net sukuriamos technologijos platformos vien tam, kad jie galėtų tarpusavyje keistis duomenimis ir komunikuoti. Tai nėra visada patogu ir tai aktuali problema vartotojams, kurie negali pasinaudoti kitoje platformoje teikiamu funkcionalumu. Šie vartotojai privalo turėti adapterius (techninę aparatūrą, kuri užtikrintų skirtingų įrenginių bendravimą). Tai nėra labai patogu ypač tais atvejais, kai vartotojai kiekvienu atveju vis nauji ir kiekvienam įsigyti adapterį ne visada įmanoma.

   Darbe pateikiamas pasiūlymas, kaip išvengti šių problemų nenaudojant skirtingų adapterių. Darbe pasiūlomas būdas naudotis vieningu praplėstu komunikacijos protokolu, kuriuo galėtų naudotis, bet kuris vartotojas turintis mobilųjį įrenginį. Tokio sesijos iniciavimo protokolo su išplėstomis galimybėmis veikimo principas pagrįstas skambinimu, kai siunčiant kvietimą keistis duomenimis, pasiunčiama serveriui užklausą. Gavęs tokią užklausą, serveris neinicijuoja skambučio, o tiesiog vykdo jame įdiegtą papildomą funkcionalumą.

   Plačiai paplitę esami infrastruktūriniai tinklai, kuriuose mobilieji įrenginiai jungiasi prie bazinių stočių per fiksuoto tinklo infrastruktūrą. Toks prisijungimo būdas yra paremtas centralizuota tinklo topologija, kurioje vartotojų duomenų persiuntimas vyksta per fiksuotą tinklo infrastruktūrą. Toks duomenų persiuntimas yra pakankamai lėtas ir ne visada tenkina poreikių. Todėl dabar pradėta vis plačiau naudotis internetiniu ryšiu. Pavyzdžiui, vartotojas prisijungia prie internetinių duomenų paslaugas teikiančių prieigos taškų ir turi greitesnes galimybes parsisiųsti duomenis. Prisijungimas prie šių prieigos taškų įgalina tiesiogiai perduoti garso ir vaizdo medžiagą.

   Viena dažniausiai naudojamų technologijų tokiais atvejais yra GPRS, bet ši technologija yra labiau skirta duomenims pateikti, o ne tarpusavio komunikacijai užtikrinti.

   Norint organizuoti sąveikumą tarp nutolusių įrenginių, tenka ieškoti būdų juos integruoti ir suteikti galimybes sujungti į vieną bendrą veikimo sistemą, taikant vieningą protokolą. Šiame darbe sprendžiama SIP galimybių integracijos problema, kad galėtų sąveikauti ir komunikuoti nutolę heterogeniniai įrenginiai ir tokiu būdu SIP taptų šių įrenginių komunikacijai vieningu protokolu. Informacinių sistemų vartotojams per sąsają realiu laiku būtų pateikiami sensorių duomenys. Reikalui esant duomenys būtų pasiekiami belaidžiais įrenginiais (pvz.: mobiliuoju telefonu, planšete ir kt.). Visų nutolusių objektų komunikavimą sujungiant vieningu protokolu taip stengiamasi išvengti daugybės skirtingų dalykinių programų kūrimo, leidžiant nuskaityti ar valdyti nutolusius objektus.

   Naudojantis šiuo principu darbe buvo apjungti keturių skirtingų tipų įrenginiai vieningu išplėstu protokolu, taip leidžiant jiems tarpusavyje komunikuoti. Yra ir kitų technologijų leidžiančių skirtingo tipo įrenginiams komunikuoti, bet naudojantis SIP protokolu mes taip

pat galime integruoti naujus įrenginius į sistemą, juos apjungti ar net suteikti prieigą visiems fiksuoto ryšio įrenginiams.

Problemos formulavimas

Mobiliosios (belaidės) technologijos leidžia stebėti judančius objektus geografinėje vietovėje, tačiau sistemos, įgalinančios analizuoti objekto būsenas, reikalauja papildomų priemonių kūrimo ir integravimo į šių sistemų infrastruktūrą. Technologinė įranga, skaitanti duomenis iš sensorių, yra pagrindinis komponentas šių duomenų surinkimui į duomenų saugyklas. Sensorinės įrangos (sensorių) atitinkamų parametrų reikšmės gali būti perduodamos į nutolusius serverius, kuriuose šie duomenys yra sisteminami ir taikomi analizei bei informacijai dėl tolimesnių objekto valdymo veiksmų.

Norėdami tinkamai valdyti nutolusius objektus, turime susieti kontekstinę informaciją su gaunamais duomenimis ir gaunamų duomenų pagalba diagnozuoti ir vertinti objekto būklę. Kadangi nutolę sensoriniai įrenginiai gali būti skirtingų tipų, dažnai iškyla problemų juos integruojant tarpusavyje. Integruojant daugybę skirtingų įrenginių į vieną sistemą, kyla suderinamumo problemos ir kiti nenumatyti techniniai sutrikimai. Dėl tos priežasties atsiranda papildomų darbo sąnaudų tas problemas išspręsti. Disertacijoje nagrinėjama vieninga duomenų apsikeitimo magistralė, grindžiama SIP protokolo veikimo galimybėmis. Iškyla klausimai kokiu būdu judančių objektų duomenų apsikeitimą realizuoti pasirenkant vieningą duomenų mainų magistralę ir sesijos iniciavimo protokolo funkcines galimybes.

Tyrimų objektas

Tyrimų objektas – sprendimų paramos sistemos architektūra, kuri įgalina heterogeninių sistemų sąveikos užtikrinimą, integruojant sesijos inicijavimo protokolo funkcines galimybes ir leidžianti stebėti ir vertinti nutolusius judančius žemės paviršiumi objektus.

Disertacinio darbo tikslas Išnagrinėti nutolusių objektų komunikavimo metodus ir pasiūlyti sprendimo paramos sistemos architektūrą, kuri integruotų sesijos inicijavimo protokolo išplėtotas funkcines galimybes nutolusių judančių objektų stebėsenai ir vertinimui, taikant vieningos duomenų mainų magistralės veikimo principus.

Darbo uždaviniai

1. Išnagrinėti metodus, kurie užtikrina nutolusių judančių objektų komunikaciją, taikant sesijos inicijavimo protokolą (SIP), nustatyti SIP galimybes užtikrinant sąveiką lygiarangiuose (Peer-to-Peer) ir trečios kartos 3G tinkluose.
2. Išnagrinėti SIP funkcines savybes, kurios leidžia realizuoti nutolusių judančių objektų komunikaciją ir duomenų keitimąsi tarp heterogeninių nutolusių skirtingo tipo įrenginių.
3. Išnagrinėti metodus, leidžiančius modeliuoti ir imituoti sudėtingų sistemų komunikacijos procesus ir įvertinti sesijos iniciavimo protokolo savybes nutolusių judančių objektų komunikacijai ir duomenų keitimui užtikrinti pasinaudojus ir pritaikius spalvotųjų Petri tinklų modeliavimo priemones.
4. Pasiūlyti sprendimo paramos sistemos architektūrą, kurioje būtų integruotos SIP išplėtotos funkcinės galimybės, leidžiančios vykdyti nutolusių objektų stebėseną ir situacijos vertinimą.
5. Pasiūlyti techninę ir programinę įrangą, kuri leistų nutolusiems objektams komunikuoti tarpusavyje, naudojant SIP išplėtotas funkcines ir vieningos duomenų perdavimo magistralės galimybes bei eksperimentiškai įvertinti pasiūlytos techninės ir programinės įrangos tinkamumą skirtingų heterogeninių įrenginių komunikacijai.

Tyrimų metodai

Darbe buvo panaudoti analitiniai palyginamieji metodai analizuojant naujausią mokslinę literatūrą iš mokslinių duomenų bazių. Išsiaiškinti kitų autorių pateikiami lygiarangių prietaisų sąveikos ir komunikavimo metodai, duomenų perdavimo magistralės

funkcionavimo būdai. Analizuoti sesijos inicijavimo protokolo daugiasluoksnės architektūros sąveikos bei integravimo metodai.

Išanalizavus literatūrą, buvo pasiūlytas duomenų keitimosi tarp heterogeninių įrenginių būdas, šių įrenginių suderinimui bei susiejimui į bendrą duomenų mainų magistralę. Taikyti sesijos inicijavimo protokolo veiklos modeliai, grindžiami baigtinių automatų modeliavimo, konceptualaus modeliavimo spalvotųjų Petri tinklų modeliavimo priemonėmis. Tam tikslui sisteminės procesų analizės, sistemų veiklos procesų modeliavimo ir imitavimo metodai bei įrankiai (pvz.: CPN Tools, TCPDump, Wireshark, Hpink3). Pritaikyti duomenų apsikeitimo tarp heterogeninių įrenginių metodai, pasinaudojus SIP protokolo funkcinėmis galimybėmis.

Eksperimentiniam tyrimui atlikti sukurtas ir panaudotas prototipinis techninės įrangos maketas, kurį sudarė Atmega plokštė (mikrokontrolelis), interneto lizdas, nutolę sensoriai, leidžiantis apjungti 4 skirtingų tipų nutolusius įrenginius, skirtingai komunikacijai užtikrinti, vieninga duomenų perdavimo magistralė ir kt., įgalinantis įvertinti komunikacinės sistemos darbą. Ekperimento rezultatams palyginti taikyti eilių teorijos metodai, kurie leido nustatyti serverio apkrovų, žinučių retransliacijos pajėgumus ir palyginti juos kiekybiškai.

Mokslinio darbo naujumas

Rengiant disertaciją buvo gauti šie informatikos inžinerijos mokslui naudingi rezultatai:

- Atlikta tankiųjų tinklų, lokaliųjų aprėpties tinklų, 3G tinklų, proginių (ad-hoc) tinklų ir lygiarangių (Peer-to-Peer) tinklų galimybių analizė parodė, kad nutolusių įrenginių bendravimui naudojama didelė įvairovė komunikacijos protokolų, o skirtingiems įrenginiams kūriami vis nauji papildomi prietaisai (adapteriai), leidžiantys nutolusiems įrenginiams komunikuoti tarpusavyje esant skirtingiems protokolams. Todėl siūloma spręsti šią problemą praplečiant SIP galimybes ir įgalinant komunikuoti hetorogeninius nutolusius įrenginius tokių būdu, kad SIP taptų šių įrenginių komunikacijos vieningu protokolu.

- Išnagrinėtos sudėtingų dinaminių sistemų modeliavimo ir imitavimo priemonės (Petri tinklai, Spalvuotieji Petri tinklai, baigtiniai automatai ir kt.) leido įvertinti spalvuotuosius Petri tinklus kai vieną šių sistemų modeliavimo ir imitavimo priemonių. Spalvuotųjų Petri tinklų pagrindu sudarytas SIP protokolo daugialygis modelis sudarytas SIP protokolo veikimo modelis leidžia ištirti atliekamas operacijas ir stebėti imitaciniame modelyje vykdomus procesus ir būsenas. Šis SIP protokolo veikimo modelis leido išanalizuoti ryšių kanalais perduodamos informacijos struktūrą, kurią reikalinga įvertinti keičiantis protokolo būsenoms, bei matyti, kaip yra atliekami valdančios informacijos perdavimai ir informacijos srautų judėjimai.

- Pasiūlyta sprendimo paramos sistemos architektūra, kuri integravo tradicinius SPS sistemos komponentus ir mobilių technologijų pagrindu kuriamos įterptines posistemes (nutolusių sensorių įranga ir kt.), kuri integravo ir leido apjungti nutolusius skirtingo tipo įrenginius SIP pagrindu, atsisakant papildomų adapterių. Tai suteikė galimybių integruoti naujus sensorinius įrenginius į sistemą, nedarant pakeitimų bendroje architektūroje. Įrenginiai buvo suklasifikuoti pagal jų veikimą į keturis tipus ir nustatytos techninės ir programinės jų komunikacijos sąlygos pagal SIP galimybes užmegzti tarpusavio sesijas. Išplėtota sistemos architektūra leido apjungti skirtingus įrenginius į visumą, jų tarpusavio komunikacijai pasirinkus SIP, kaip pagrindinį protokolą.

Darbo praktinė svarba

SIP protokolo žinučių nuskaitymas ir sesijų inicijavimas tarp SIP protokolą palaikančių įrenginių ir SIP adapterio sukūrimas įrenginiams praktiškai galės būti pritaikomas ir tiems, kurie nepalaiko SIP protokolo ir nėra IP tinkle. Pasiūlytas nuotolinės sensorinės objektų stebėsenos sistemos prototipinės architektūros modelis. Šis modelis leidžia integruoti sensorines komponentes palaikančias ryšį tarp skirtingų tipų mobiliųjų įrenginių, perduodant sensorių užfiksuotus duomenis ir įvertinant judančio objekto būklę.

Naudojami metodai ir programinė įranga belaidėse sistemose leidžia keistis dauguma įmanomų duomenų formatų (pvz., tekstiniais, balsiniais ar vaizdiniais), suteikia informacijos

apie objekto būseną realiuoju laiku. Pagrindinis privalumas – išplečiama architektūra, kad galėtume gauti duomenis mobiliuoju telefonu per interneto paslaugas.

Autorius tiesiogiai prisidėjo prie projekto, vykdomo TEO LT ir vykdė darbus, susijusius su SIP protokolo galimybių išvystymu. Ši sistema inicijuoja ir valdo skambučius. Plačiau su šios sistemos galima susipažinti interneto svetainėje (
/paslaugos/greitasis_skambutis).

Pasiūlyta SPS sistemos architektūra įgalins pereiti prie belaidžių įrenginių komunikavimo ir informacijos vertinimo taikant SIP išplėtimo galimybės. Šiame tiriamajame darbe yra sprendžiamos problemos, susijusios su ryšio palaikymu tarp skirtingų įrenginių, pasinaudojus vieningu protokolu, šiuo atveju – sesijos inicijavimo protokolu.

Ginamieji teiginiai

- Pasiūlant sprendimo paramos sistemos architektūrą, kuri leistų stebėti judančių žemės paviršiumi objektus ir vertinti jų būklę, tikslinga SPS sistemą projektuoti kaip tradicinę, integruojant įterptines posistemis, kurios užtikrintų judančių sensorių stebėseną, duomenų saugojimą nutolusiuose duomenų saugyklose ir komunikaciją taikant vieningą SIP protokolą sesijos užmezgimui, palaikymui ir nutraukimui.

- Sesijos inicijavimo protokolo (SIP) architektūrinių sprendimų galimybių analizei atlikti tikslinga taikyti modeliavimo ir imitavimo priemonę - Spalvotuosius Petri tinklus. Sukurti modeliai leidžia išanalizuoti ryšių kanalais perduodamos informacijos struktūrą, kuri reikalinga keičiant vieną būseną kita, bei matyti, kaip jais atliekami valdančios informacijos perdavimai ir informacijos srautų judėjimai.

- Hetorogeninių nutolusių sistemų komunikacijai užtikrinti lygiarangiuose (Peer-to-Peer), 3G ir aukštesniuose tinkluose tikslinga suklasifikuoti įrenginius į keturis tipus ir jų komunikacijos valdymui taikyti SIP išplėtotas galimybes.

- Pasiūlyta techninė ir programinės įranga, leidžia užtikrinti ir išbandyti nutolusių objektų komunikavimą ir integruoti bei įvertinti SIP praplėstas funkcines ir vieningos duomenų perdavimo magistralės galimybes, bei pagerina SIP vieningos magistralės funkcijas.

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