SOPHIS Project No.4. “Development of technologies for secure and reliable smart-city” (GudPils)

Smart cities technologies: a long-term prognosis for R&D directions developed in the project

Smart cities are defined in different ways; however, most of the definitions include the effective employment of information and communications technologies (ICT) for solving various problems that the cities are facing due to rapid urbanization and for providing fast and expected services to citizens. For example, IBM Smarter City Solutions follow three directions to make cities smarter, namely making them more instrumented, integrated and intelligent (ftp://public.dhe.ibm.com/la/documents/imc/la/cl/news/events/infrastructure summit/smarter_city_solutions.pdf). Here, ‘instrumented’ means equipped with different sensors that provide data for making decisions, ‘integrated’ emphasizes fusion of the collected information for analysis of real-world behaviour, and ‘intelligent’ means processing of collected data using mathematical algorithms and statistical tools that facilitate informed decision making. It is also emphasized that, to solve city problems, technology aspects should be considered together with human and institutional aspects (see https://www.ieee.org/publications_standards/publications/periodicals/ieee-smart-cities-trend-paper-2017.pdf), and a smart city is a complex ecosystem including all these. Multiple interconnected technology areas are involved to make cities smart, ranging from sensors to collect data, communications to gather them in processing centres, data analysis and exploitation in various applications.

The following vision can be generated on the future smart city: its infrastructure objects will be interconnected in a large network of sensors and devices and monitored by the artificial intelligence. The roads will be filled with self-driving cars and autonomous public transport. Smart traffic light will adapt to the traffic flow, pedestrian crossing will sense human presence and automatically control the traffic lights. The street lighting system will be part of a traffic and safety monitoring system. It will automatically adapt and lower the brightness if no humans and cars are on site. The public transportation will be interconnected and besides fulfilling their primary function will also help to monitor the city road quality by scanning the road surface and subsurface with on-board sensors. The buildings of the smart city will be also “smart”, each equipped with its own artificial intelligence and sensor grid and will adapt to the people needs and even mood. Also, the integrated sensors will be used to perform the self-diagnosis and monitor the construction stability and state. Human movement tracking and vital sign monitoring will also be monitored in real-time, so in case of emergency (fire, heart attack) the corresponding services will be informed automatically.

Smart city technologies market shows stable growth (Fig.1), mainly driven by urban population growth that imposes huge challenges to city governments (see report from Navigant Research: https://www.navigantresearch.com/wp-assets/uploads/2014/06/SCIT-14-Executive-Summary.pdf).

Smart solutions are currently under development in more than 140 smart cities around the globe (see https://www.sciencedirect.com/science/article/pii/S0040162513002187). Multiple directions of making city ‘smarter’ are pointed out e.g. smarter transportation, smarter water, smarter energy, smarter buildings, smarter government, smarter public safety, smarter healthcare, smarter social services and the like. These directions are related to major tasks of the municipalities and regional governments. The key to further development of smart cities is innovative technologies, coupled with strong engagement of citizens in defining the needs, collecting input data for analysis of city

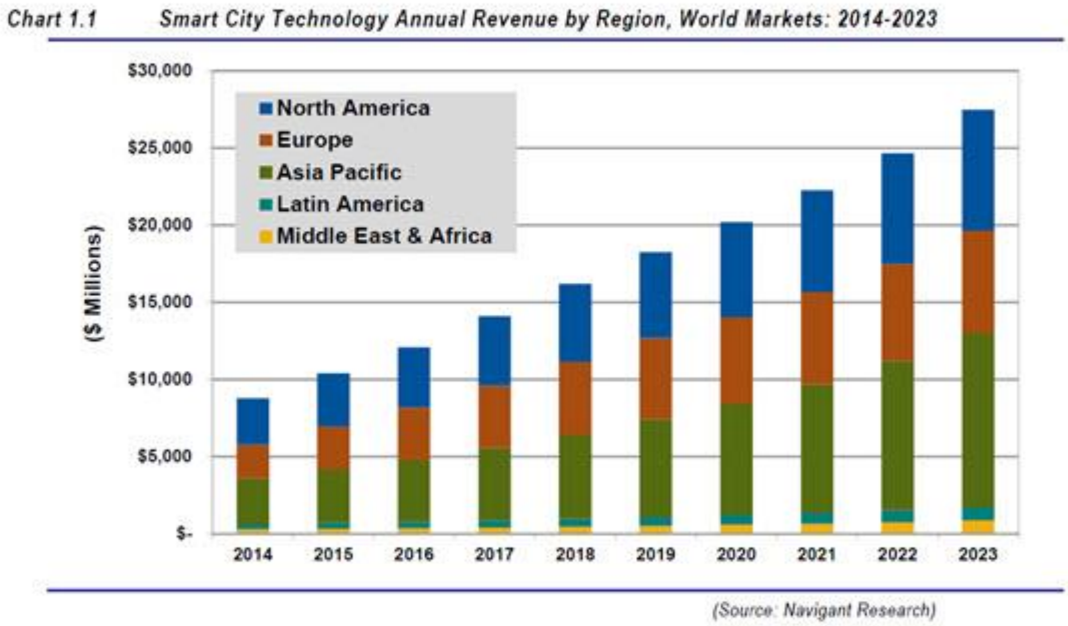

Fig. 1. Revenue forecast for smart city technologies.

processes, and bringing the developed solutions into life. The report "Smart Cities: An Overview of the Technology Trends Driving Smart Cities" (https://www.ieee.org/publications_standards/publications/periodicals/ieee-smart-cities-trend-paper-2017.pdf) points out the following trends and recommendations:

- At present, smart city developments focus on specific infrastructure needs, e.g. improving transportation through monitoring. It is necessary to integrate them to provide aggregate efficiencies and create new services;
- It is necessary to increase data collection via sensors and big data analytic capabilities of them;
- It is necessary to adapt to different problems and solutions specific to different regions;
- Collaboration of technology companies is crucial; few companies can provide full solutions;
- Smart city solutions should be developed with engagement of citizens; such solutions will have advantages over alternatives.

Project No.4 "Development of technologies for secure and reliable smart-city" (GudPils) of the SOPHIS programme was mainly targeting the following R&D directions for making cities smarter by using ICTs:

- Development of highly efficient optical fibre transmission technology for transmission of high volume sensor data to processing centres;
- Development of artificial neural network- based solutions for analysis of large-scale urban data (mainly video) related to city security;
- Development of methods for monitoring of urban environment using remote sensing (RS) data;
- Development of urban infrastructure security monitoring technologies using ultra-wideband (UWB) sensors;
- Development of the bacteriological quality control system for the city water supply network.

The present forecast focuses on these five areas and describes potential development and usage potential of ICT technologies in these directions.

1. Optical fibre transmission technologies

Nowadays, information transmission technologies using the optical fibre as the medium of information transmission bear a major importance in the field of telecommunications. The rapidly increasing volume of data flows to be transmitted demand a faster introduction of technologies in the telecommunications sector. Services like high-speed Internet, video on demand, ultra-high definition television, cloud computing, etc. which are ensured using one and the same client connection, demand ever increasing data transmission speeds. Estimated growth rates by different telecommunications industry companies vary, but undoubtedly it is projected that there will be an overall increase in the amount and transmission rates of data. The analysis performed by the company Cisco forecast that the global IP traffic will nearly triple from 2016 to 2021. Overall IP traffic is expected to grow to 278 EB per month by 2021, up from 96 EB per month in 2016, with a compound annual growth rate (CAGR) of 24 percent (see Fig. 2). This growth represents a slight increase in expectations over last year's forecast, which projected a CAGR of 22 percent from 2015 to 2020, driven by an increase in expectations for fixed traffic [1]. This rate of increase will also continue further on and it is expected that in 2018 the amount of data transmitted in access and metro networks will amount to 62 % of the total transmitted data amount [2].

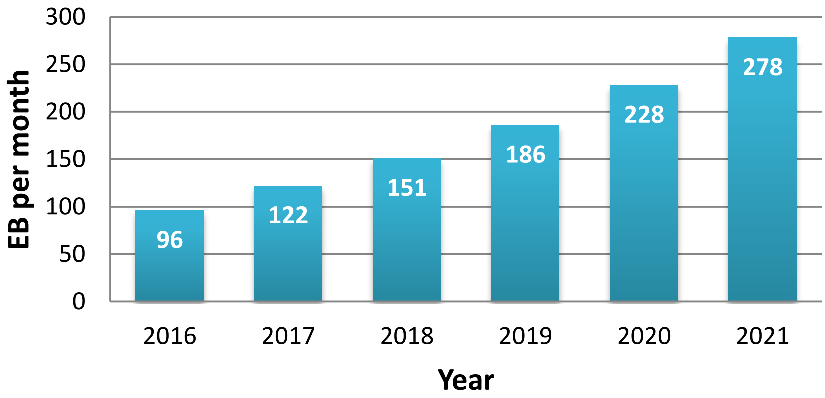

Fig. 2. Cisco global transmitted traffic forecast for the time period from 2013 to 2018 [2].

Bearing in mind the fact that the largest increase in the transmitted data amounts is observed at the access level, particular attention must be paid specifically to optical access networks that are one of the most promising data transmission technologies. Most often, information transmission in these optical access lines right to the client's apartment or house is ensured using a single optical fibre (OF). Currently optical fibres are increasingly being used in metropolitan area networks (MANs) and even local area networks (LANs) since this technology can provide very high data transmission rates (more than 10 Gbps per one wavelength channel) and it becomes more cost effective compared to its beginnings when it was used mainly in backbone networks. From these aspects it can be concluded that optical access networks will be one of the main data transmission mediums in the context of future smart city concept.

The subject-matter examined in the national research program "Cyber-physical systems, ontologies and biophotonics for safe&smart city and society" (VPP SOPHIS) is topical because currently Latvia is undergoing a rapid development of the communications sector. As of now, the existing optical access communications systems are using time division multiplexed passive optical network (TDM-PON) technology, but within the upcoming five years, as the need for bigger data transmission speeds increases, it will be necessary to update the existing network infrastructure and to introduce a high-speed wavelength division multiplexed passive optical network (WDM-PON) technology, which can ensure higher data transmission speeds (over 10 Gbit/s) at a longer distance (at least 20 km) than the current TDM-PON technology can provide (transmission speeds of up to 2.5 Gbit/s).

The growing amount of Internet users and data flows (from such services as online video games, high resolution video streaming, telemedicine services, video conferencing, computerised high frequency trading systems and others) pose several challenges for the communications network operators, and they are forced to improve the infrastructure of the fibre optical network. Therefore, optical access networks must be capable of ensuring ever higher data transmission speeds (2.5 and 10 Gbit/s) with lower signal latency, by using the existing electrical and opto-electrical components inasmuch as possible. It must be mentioned that an ERDF project “Next Generation Electronic Communications Networks in Rural Areas” is being implemented in Latvia since 2012; its aim is to develop next generation networks (NGN) in the remote rural areas of Latvia and to promote the achievement of the Europe 2020 strategy targets (by 2020, to ensure that all households have an option to receive access to Internet at a minimum speed of 30 Mbit/s and 50 % of households in 2020 will have the Internet with the access speed of at least 100 Mbit/s) [3]. The project provides for developing a 7000 km long optical line which would ensure optical network access at 500 connection points. Thus, it will be necessary to ensure access technologies that perform “last mile” data transmission, which is the network from the service provider’s access point to an individual telecommunications service user. The technologies and solutions developed by Riga Technical University (RTU) Telecommunications Institute (TI) within the framework of the GudPils project can be fully used for successful implementation in the existing access optical networks and for ensuring communications services from the service provider to the end-user.

Research performed by RTU TI can be divided into two sections. One direction is study of different access network topologies and selection of the most suitable for smart city applications. The other direction is optical transmission system component-level studies.

In the scope of network topology it was found out that smart city application requires networks with a high degree of branching to connect a large number of end-users. From the point of physical realization the most appropriate solution is passive optical network (PON) with wavelength division multiplexing (WDM). Such a system block diagram is given in Fig. 3. Here for each subscriber (optical network terminal - ONT) a certain wavelength channel has been assigned.

By this it is possible to increase optical fibre use efficiency. Such a solution requires a different splitting device (for example, arrayed waveguide grating (AWG) optical filter) compared to traditional time domain multiplexing PON networks. It was also studied how to enable different modulation format simultaneous use. This is essential to expand the applicability of a system which therefore could be used for wide variety of services. It is also important to mention that proposed technical solutions can be implemented into existing optical access network infrastructure.

Research in the field of optical components resulted in creation of reconfigurable add/drop multiplexer. It allows detaching and attaching a single wavelength channel to an existing WDM system completely in the optical domain (without demultiplexing of all channels). This multiplexer is also completely passive device (does not require power supply) so it can be located in places where power supply is not available. Application of such a device is to add new subscribers to existing optical cable infrastructure. Such a component could be also used to expand the applicability of optical access networks, for example, by transmitting various sensor data using optical signals. In such a case add/drop multiplexer makes possible connection of sensor to fibre infrastructure. This application is very topical in the context of smart cities because remote sensors and automated monitoring systems is one of the upcoming development directions that goes under Internet of Things (IoT) and Tactile Internet (TI) concepts. Extremely low latency in combination with high availability,

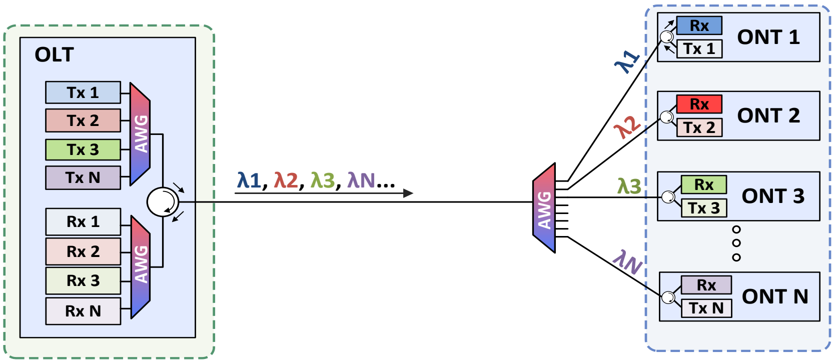

Fig.3. Block diagram of a WDM-PON transmission system.

reliability, and security will define the character of the TI. It will have a marked impact on business and society, introducing numerous new opportunities for emerging technology markets and the delivery of essential public services [4]. That would make possible to provide such a services like remote control video surveillance systems, security systems, environment pollution monitoring systems, etc. in various locations where fibre infrastructure is available as illustrated in Fig. 4.

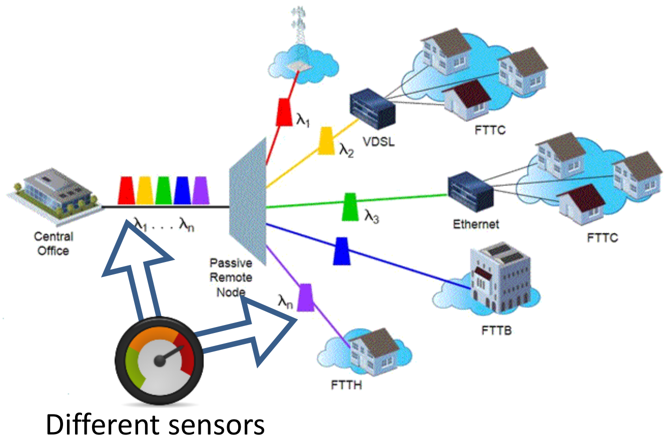

Fig. 4. Optical access network structure with possible sensor connections.

A prototype of the aforementioned add/drop multiplexer has been created as a result of the GudPils project. The future work would be to create optimized (size, performance, costs etc.) component that could be tested and eventually applied in real working conditions.

2. Analysis of large-scale urban data using Deep Learning

During the GudPils project, Deep Learning (DL) of artificial neural networks was recognized as the most perspective approach for carrying out video analysis tasks with the potential impact of a significant change in the future of technological development. Within the framework of this project, specific DL-based neural networks were developed/ adapted to fit the defined tasks. A system for identification of the person from the image and an effective object counting system in a video signal were created. DL is the most advanced approach in Machine Learning and currently driving the fast progress of Artificial Intelligence (AI), in other words, the ability of computerized systems to perform functions that are typically attributed to humans. This forecast is mainly devoted to the development of DL. Forecasts in this area are mostly prepared using the documents available from McKinsey &

Company (see https://www.mckinsey.com), which is a global management consulting firm that provides advice to leading companies, governments, non-governmental organizations, and non-profit organizations.

Basically, there are two scenarios for development. The first is scenario A - no significant evolution of AI (including Deep Learning) technology into a better method is expected. The second is scenario B - a breakthrough in unsupervised DL methods occurs. This scenario requires the continuation of large investment in the scientific fields dealing with artificial intelligence and recognition systems. Rooting from https://www.mckinsey.com, the current forecast is also mainly based on development scenario A. Even this scenario suggests significant changes and progress in many areas. Apparently, in the case of the scenario B, the efficiency and impact of artificial intelligence will increase.

It is expected that, in the years to come, DL will become the main tool for video analysis, recognition system, and other tasks. Due to it, DL will affect many areas, exceeding the applications for smart cities. The prediction is that within 10 years the DL would change even the meaning of those tasks.

2.1. Workplaces in future cities

The expectations are that DL and work automation will affect most of the world's employees. They will do most of the work in complementary collaboration with artificial intelligence systems. These systems can be developed by already available technologies (in other words, scenario A). Below is a study of the potential of automation for current workplaces, compiling work that requires repetitive operations and is automatable: https://public.tableau.com/profile/mckinsey.analytics#!/vizhome/InternationalAutomation/WhereMachinesCanReplaceHumans .

Data shows that automated systems can manage about 50% of the operations, so job automation will continue to increase over the next 10 years.

For more information, see: https://www.mckinsey.com/global-themes/digital-disruption/harnessing-automation-for-a-future-that-works.

2.2. Mobility in future cities

This forecast is based on the information found in the website of McKinsey: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/disruptive-trends-that-will-transform-the-auto-industry and https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/how-the-convergence-of-automotive-and-tech-will-create-a-new-ecosystem.

The use and installation of DL technology in new cars will be a commonplace event. DL is one of the technologies next to auto electrification (which is not analysed in this document) that will change the car industry and the car completely. McKinsey predicts that by 2030 up to 15% of newly sold cars will be self-driving.

It is also worth mentioning that there are various aspects in the field of transport that are expected and need to be solved in the future smart cities. One of such aspects is the interconnection of all devices on the network. This will open new opportunities for communication, a cooperation of devices, and services. Another aspect is an expectation of diversity in human mobility (or diversity of available transportation ways) in smart cities. As the sharing-based-economy grows, citizens will increasingly prefer not to own vehicles but instead rent them or use public transport. This paradigm shift is facilitated by such factors as urbanization, the technological development of self-driving cars, and Internet of Things (IoT). These factors will change the infrastructure of cities, in parallel with the traditional infrastructure, developing urban data mining and sensor networks, creating opportunities for new innovations, new traffic services and new business models and services.

2.3. Artificial Intelligence in stores

The forecast is based on the information available at https://www.mckinsey.com/~/media/McKinsey/Industries/Advanced%20Electronics/Our%20Insights/How%20artificial%20intelligence%20can%20deliver%20real%20value%20to%20companies/MGI-Artificial-Intelligence-Discussion-paper.ashx.

Retail companies are already starting to apply AI, machine training, and robotics to key parts of the supply chain. Three areas with the greatest potential are ads, assortment, and replenishment. Major retailers are experimenting with AI in all these areas. Leading companies use AI to predict trends, optimize warehouses and logistics, set prices and personalized ads. Some even aim to fully predict purchases of customers by delivering goods before the order is made.

In the future, artificial intelligence will help to predict and automate the decision-making of retailers in real time. There are bulk data that cover many different sources (past business, weather forecasts, social media trends, shopping models, online viewing history, analysis of facial expressions, seasonal shopping patterns). Using these data, AI will obtain and learn the buying habits of people. In this way, AI can help companies adapt and even control the increasingly dynamic market environment. By improving prediction accuracy, machine learning and computer vision can help to meet consumer preferences by optimizing and automating contracts with suppliers.

2.4. Electricity supply

The forecast is based on the information available at https://www.mckinsey.com/~/media/McKinsey/Industries/Advanced%20Electronics/Our%20Insights/How%20artificial%20intelligence%20can%20deliver%20real%20value%20to%20companies/MGI-Artificial-Intelligence-Discussion-paper.ashx.

In the coming years, there is a great potential for the inclusion of AI in the electricity services sector. At each stage of the supply, from power generation to final consumers, there are opportunities for machine learning, robotics, and decision-making automation. These opportunities can help electricity companies to make better predictions in supply and demand, balance the net in real time, reduce downtime, increase profitability and improve the user experience.

One of the most critical cases of AI applications in the field of electricity is the prediction of demand and supply. An inaccurate prediction of the load in the power grid will affect many stakeholders. The reasons are the following. Firstly, energy production determines the allocation of energy sources for the next 24 hours based on one or two-day forecasts. Secondly, transmission networks divide resources based on electricity transmission requirements. Thirdly, electricity retailers calculate energy prices based on their estimated demand.

In the future, machine and deep learning technologies will predict demand and supply in real time and optimize load transfer, thus saving energy and costs. On a network which demands from 10 to 18 GW, the savings can reach 100 MW over a period of one to four hours per day. Safer forecasts would allow utilities to delay or even prevent the use of fossil fuels in powered stations. It would also offer cost-effective alternatives to entrepreneurs who are currently considering building new power plants in order to face seemingly impossible variability.

2.5. Healthcare

The forecast is based on the information available at https://www.mckinsey.com/~/media/McKinsey/Industries/Advanced%20Electronics/Our%20Insights/How%20artificial%20intelligence%20can%20deliver%20real%20value%20to%20companies/MGI-Artificial-

Intelligence-Discussion-paper.ashx, as well as https://blogs.nvidia.com/blog/2017/04/17/ai-to-predict-brain-tumor-genomics/.

Healthcare is a promising AI market. There is a huge potential for AI to draw conclusions and recognize patterns in related data. It consists of patient history, medical imagery, epidemiological statistics, and other data that is available on a large scale. AI can help doctors improve their diagnosis, expect the spread of diseases and adapt treatments.

There are benefits in combining artificial intelligence with the digitization of healthcare. It lets medical service providers to remotely check or diagnose patients. AI also allows transforming the way we treat chronic diseases, which forms a large part of healthcare budgets.

Hospitals could also improve the use of their capacity through AI solutions. These solutions would optimize many common business tasks. Virtual agents could automate the routine interaction of patients. Customer service employs AI as speech recognition software. This software handles routine tasks such as scheduling specialist visits and registering people when they arrive at a hospital. This reduces patient treatment costs.

An important field is natural language processing. It can analyse medical records and other documents by summarizing their content so that doctors can quickly access it. These types of applications can have a significant impact, without the need for regulatory alignment.

An important task in medicine is an interpretation of magnetic resonance and X-ray images. Even in this task, an application of AI succeeds by detecting more details than human eyes can record. For example, there are different types of glioblastoma. The treatment of glioblastoma depends on its type. But radiologists cannot identify genetic abnormalities of these brain cancers from images alone. Even with the help of tissue test the accuracy of diagnosis is low. But, the Mayo Clinic has developed a machine learning program that can quickly and reliably identify the abnormalities with the help of MRI. AI-based automation, which facilitates the day-to-day operation of doctors and nurses, has the potential to increase healthcare productivity. One day, chat-bots equipped with DL algorithms could help the work of emergency medical staff by taking care of patients who are not in immediate danger.

2.6. Summary

From the above, it can be seen that the role of data collection, and especially data processing, will increase. The effective use of data collection and processing even now allows automation in many areas. The artificial intelligence will be able to handle more tasks, and even more efficiently than humans.

3. Remote sensing for smart cities

Remote sensing is used as a tool to collect data for monitoring of the city, analysis of its status and planning operations accordingly. Remote sensing data considered are collected using different means: satellites, airplanes, drones, which are taking hyperspectral images, multispectral images, synthetic aperture radar (SAR) or LiDAR data. These data are of different physical meaning, characterized by different spectral contents, different spectral and spatial resolution so that they are suitable for solution of different tasks.

Recent advances in European Copernicus programme related with the launch of Sentinel satellites and its policy of providing free and open data to everybody has currently made a strong accent on satellite-based Earth Observation (EO) (see http://copernicus.eu/news/earth-observation-europe-silicon-valley). Multiple start-up companies are created to provide different services based on processing satellite data. It is expected that satellite EO market in Europe will grow exponentially (see Fig.5, from http://earsc.org/file_download/43/Business+in+Earth+Observation+eoVOX080508.pdf). This growth will partially be related

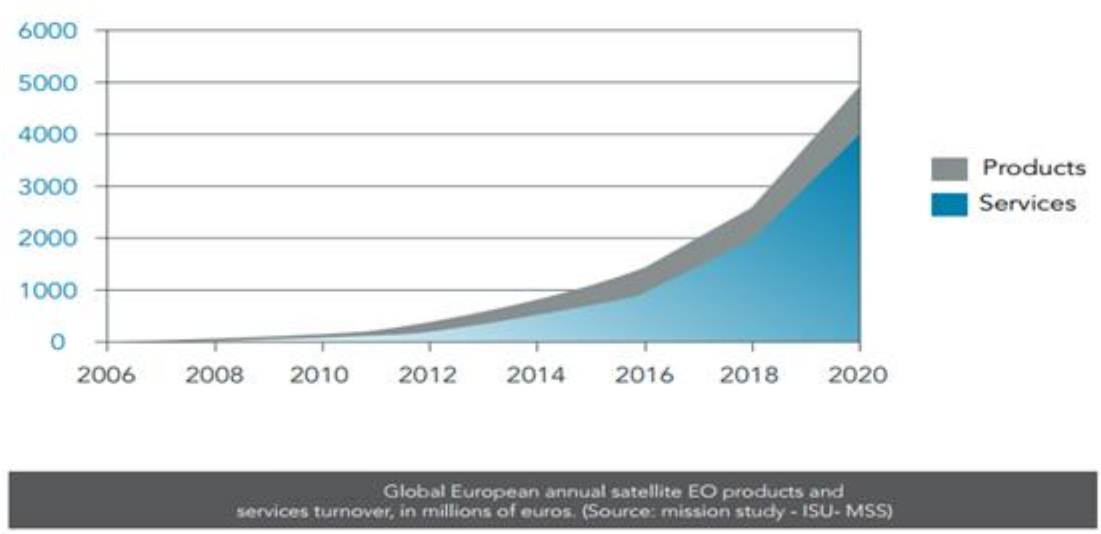

Fig.5. Turnover forecast for satellite EO products in Europe.

to applications for smart cities (e.g. disaster monitoring, climate prediction, remote surveillance etc.).

Project GudPils included mainly processing of hyperspectral images, multispectral images and LiDAR data for land use classification, vegetation change detection, and flooding simulation. SAR images can be employed by the developed classification algorithms as additional information layers similar to images taken in spectral bands.

3.1. Land use maps of urban areas

Development of land use maps is recognized as one of the major application areas of processing remote sensing data. As to urban areas, since 2006, European Environment Agency has provided Urban Atlas, a special part of the Copernicus Land Monitoring Service (see https://www.eea.europa.eu/data-and-maps/data/copernicus-land-monitoring-service-urban-atlas). Land use maps of E for years 2006 and 2012, together with change layers from 2006 to 2012 are freely available for download. This service is providing information on urban growth in Europe. With the launch of Sentinel-2 satellites, the data they provide will add valuable information for classifiers used in Urban Atlas and Copernicus High Resolution Layer Imperviousness services (see http://www.mdpi.com/2072-4292/8/7/606/htm). It is expected that these services will provide more precise and frequent information, namely spatial resolution will be improved to 10m, and land use maps will be provided by Urban Atlas each 3 years.

3.2. Using spectral images for detection of contamination or other environment features

Development of object classification techniques from multispectral and hyperspectral images will provide means for analysis of different characteristics of city objects. Hyperspectral data will provide information about contamination in city areas, health status of individual trees and parks. Thermal sensors will assist in finding leaks from heating systems and provide for analysis of urban heat islands. Multispectral and hyperspectral sensors will be mounted on drones and used much more frequently thus providing data for dynamic analysis of changes in city areas.

3.3. Using LiDAR data for 3D scanning of urban areas

LiDAR technology based on generating pulsed laser light, detecting reflected pulses from objects and measuring distance to them as well as intensity of the reflected signal. It is used from moving platforms (airplanes, satellites, cars, drones) and from stationary systems (laser ranging, 3D object scanners). There are numerous applications of LiDAR technology in different areas, ranging from precision agriculture, archaeology, atmospheric remote sensing to autonomous cars. It is widely used for making digital elevation maps and 3D models of buildings in cities. A number of countries (including Latvia) have organized LiDAR scanning of the whole territory in order to create digital elevation models.

It is expected that LiDAR technology will become more and more accessible and its application will constantly grow. The precision of elevation models created from LiDAR data will definitely improve. It is known that modern satellite laser ranging systems already provide measurements with sub-mm precision. Vertical precision of current systems used for airborne scanning (e.g. Optech ALTM Gemini) reaches about 5-10 cm and they can scan the surface of the Earth with density of several points per square meter. It allows to create rather precise elevation models of cities with good spatial resolution, which makes it possible to use them for planning of water drainage system, make flooding forecasts, create a virtual city 3D model. Such city models will be created in GIS software and will assist in decision making by the local governments as well as promote and assist tourism.

Another hot topic will be advanced driver assistance systems that are based on distance measurements using LiDAR technology. These systems will provide comprehensive information about obstacles on the road or provide input data for self-driving cars.

3.4. Using Geographical Information Systems in smart cities

Geographical Information Systems (GIS) are considered as one of the core information management tools in smart cities. They enable spatial planning of the cities that is crucial in the era of their fast growth. Images provided by remote sensing together with maps produced by processed remote sensing data form the background of GIS operations. The global CAGR of GIS market is expected at more than 10% during 2017-2023 to reach $17.5 billion in 2023 (see https://www.psmarketresearch.com/ press-release/global-geographic-information-system-market). India and China are expected to be the fastest growing GIS market during this period. 3D- based geographic information systems will become more and more popular in city planning and urban development. According to Environmental Systems Research Institute Inc. (ESRI), a major provider of GIS software ArcGIS, 3D based urban mapping is rapidly growing in smart cities. Apart from the urban planning, the 3D based GIS market is also witnessing fast growth in flood modelling, transportation, and census.

4. Ultra-wideband radar-based technologies for smart city infrastructure and security monitoring

4.1. Real-time location systems

According to the new market research report "Ultra-Wideband (UWB) Market by End-User (Healthcare, Automotive and Transportation, Manufacturing, Residential Retail), Application (RTLS/WSN, Imaging), and Geography (North America, Europe, Asia-Pacific, Rest of the World) - Global Forecast to 2022", it is expected to grow from USD 62.9 Million in 2016 to reach USD 85.4 Million by 2022. The highest growth rate is expected for the UWB-based Real-Time Location System (RTLS) market. The major advantage of the UWB-based RTLS solutions is their advantage of sustaining a good performance in walled environments.

4.2. Dynamic street lighting sensors

Dynamic street lighting control using presence sensors may help reduce energy in the future. Due to the high range resolution and robustness against destructive interference compared to conventional continuous wave (CW) systems, Ultra-Wide Band radar technology is well suited for such purposes. In addition to detecting presence and distance, other information like speed and direction may also be measured adding further value to the application.

Typically, the sensor will be mounted within the lighting source and facing downwards. The sensor will detect cars, pedestrians and similar objects that should trigger the light to turn on. Small objects like cats, birds, etc., should leave the light off. Since the sensor is facing down it will not detect the presence before the object is relatively close to the sensor, which could be impractical. This will be handled through wireless communication between light sources to allow one light source to trigger another just in time for the object to approach.

According to the PRNewswire report "Global LED & Smart Street Lighting Market (2015-2025)" there are currently 304 million total streetlights in the world. This number will grow to 352 million total streetlights by 2025. The public outdoor lighting market is currently undergoing a period of change where legacy streetlights are being replaced with new and more efficient LED, or solid-state lighting technology. Taking this new technology a step further, these LED streetlights are also being networked together with communications to become "smart" streetlights. The estimated market opportunity is 63.5 billion USD.

See: http://www.currentbyge.com/cities/ and http://www.comlight.no/home.

4.3. Smart cities parking system sensors

In large cities, drivers seeking an available parking space represent a significant pollution source. In addition, time is wasted and traffic jams may occur. To improve logistics and help to reduce pollution, intelligent infrastructure systems for smart cities have started to evolve. An important component of such systems is a sensor capable of detecting if a parking lot is occupied or not. Current technology is mainly based on inductive sensing which has some limitations under certain conditions reducing its reliability. By introducing standalone UWB based sensors or dual technologies including UWB sensor, the error rate will be significantly reduced.

The report "Smart Parking Systems - Sensor and Communications Hardware, Software, Services, and Smart City Applications: Global Market Analysis and Forecasts" from Navigant Research analyses the evolution of smart parking technology and the smart parking systems market, including global market forecasts for smart parking systems hardware, software, and services through 2024. Today, the parking industry is being transformed by new technologies that are enabling cities to reduce levels of congestion significantly. Sensor networks that detect vehicle occupancy are providing the basic intelligence behind smart parking systems, which provide real-time parking availability information to make it easier for drivers to find a parking space. According to this report, the installed base of sensor-enabled on-street smart parking spaces is expected to surpass 1 million worldwide by 2024.

See: http://www.fastprk.com.

4.4. Train crossing security sensor

Vehicles or persons may unintentionally be located on the railway track at train crossings, either stuck between the gates or at crossings without gates which are not uncommon outside larger cities. Every year many incidents are reported representing a high cost for the society. There are radar products available in the market today, but the relative short range and wide coverage angle makes UWB sensors a good alternative. The purpose is to develop a system that detects unwanted obstacles at the crossing and alerts the train driver or automatically forces the train security system to stop the train to avoid a collision.

5. Early warning system technology for drinking water microbiological quality monitoring

Approximately 66 % of the world population could live in the cities by 2050 (WEF, 2016). Regarding drinking water (DW) supply, growing population and growing cities will require not only increased water and energy consumption, but this will also imply increased health risks – more people will be affected in case of water contamination that results from accidents during drinking water supply process. While these events should be prevented by proper water supply system planning and management, the probability of unforeseen and extraordinary circumstances, and, consequently, the risk of water contamination should not be underestimated. Moreover, most of the DW supply networks in modern cities have been developed during 1970`s and 1980`s. Despite the DW network renewal strategies and policies, this process is slow, and water pipelines are aging, which also means that pipes will get more vulnerable to breakage, and DW quality deterioration risk will increase. Hence, smart solutions for prompt contamination detection to ensure fast emergency response should be involved.

Smart solutions will require modern and reliable methods for DW microbiological quality monitoring. Currently, water quality is analysed manually with conventional cultivation-based methods. Despite the serious drawbacks – long time required for analysis and detection of only 1 % of DW bacteria – these methods are the only officially accepted and regulated methods in the majority of the countries [5, 8]. Specificity and requirements of the cultivation-based methods, namely, sterile environment for samples preparation, incubation facilities, and at least 24 h before obtaining results, seriously obstruct feasibility of process automation. In turn, manual sampling implies low sampling frequency and a limited amount of samples that could be collected. It means that if contamination did not happen just before sampling, it would be detected after several hours or days, or it could even not get detected with analytical methods.

The overall objective of the GudPils project was to develop a world-class expertise in the area of "smart" city technologies, which can be used for monitoring of environment and urban infrastructure to ensure a safe and reliable living environment for citizens, thus creating the basis for development of competitive services and products. Tthe specific task of Water Research Laboratory group was to develop and adapt the DW monitoring technologies to on-line monitoring and early warning system (EWS) to detect deliberate and accidental bacterial contamination.

5.1. Technology description

The smart technology presented in the current project is the EWS for DW biological contamination detection. Generally, EWS consists of a DW quality sensors, data collection and analysis system and alarm triggering algorithm. Most of the EWS available in the market are based only on physical-chemical measurements and are generally focused on chemical water contamination [12]. Moreover, only limited amount of data is available on response to microbiological contamination of such systems. Thus in the project, we tested and compared both relatively simple and cheap sensors for various physical and chemical parameters determination, and novel microbiological methods to evaluate an ability of microbiological contamination detection specifically. Mahalanobis distances were used for contamination detection and identification as well as for evaluation of the algorithm performance.

Innovative methods for drinking water microbiological quality and stability assessment were used for the EWS development. In short, flow cytometric (FCM) TCC and ICC measurements are based on DNA staining with specific fluorescent dyes: SYBR Green I alone (TCC) or together with propidium iodide (ICC) [10]. After staining, samples are analysed with a flow cytometer, which counts bacteria that cross a laser beam. Emitted fluorescence allows to distinguish bacteria from the background, and to determine bacteria with intact and damaged bacteria. ATP is a molecule, which is present in all living cells. Thus ATP measurements could detect potentially viable biomass [7].

Event detection was based on the trade-offs between false positive and false negative decisions as a function of the detection methods, or in other words, by its ability to place the current measurement of water quality parameters into one of two classes: background – clear and safe water, and event – contaminated water. Mahalanobis distances method is based on the assumption that similar objects have close values in multidimensional space (Liu et al., 2015). The values from 6 sensors were read once a minute and then compared to previously classified DW parameter values, which represent clean DW properties or specific water contamination. Manual measurements with microbiological methods followed the same algorithm. Our tests showed that biological methods were the most sensitive to various types of contamination. Therefore, a combination of biological DW monitoring methods with the Mahalanobis distances- based method is suggested as a potential EWS technology.

5.2. Performance, future applications and development

EWS based on microbiological methods has a high potential for drinking water monitoring and drinking water quality control. Both microbiological methods take only about 5-20 min per measurement depending on the method, and the methods detect all bacteria or viable biomass in the sample. Moreover, in combination with different physical or chemical sensors, the technology could generate different fingerprints and recognize the type of contamination, e.g., groundwater, wastewater, untreated water or bacteria, cultured in the lab as in case of terrorist attack.

In our study, we only tested the ability of the certain methods and Mahalanobis distance- based algorithm to detect bacterial contamination. However, the technology has a potential to be fully automated. Flow cytometer with automation block has proved to be accurate and reliable for collecting high-resolution microbiological on-line data [6] and now is available commercially. ATP measurements have not been automated yet. Although the method is technically simple, interference of extracellular ATP (dissolved ATP molecules in extracellular environment) is an issue for a method that we used in our study. A technique for extracellular ATP removal or separation should be improved before it could be successfully implemented into EWS.

The technology will be demanded for DW monitoring at water treatment plants and in distribution networks. However, it should be noted that this type of EWS is expensive at the moment, and it will take time before it gets affordable enough be installed everywhere in the critical points in the distribution network. We believe that at the beginning, the technology could be used for short-time monitoring purposes, for example, during large public events such as sports competitions, festivals and meetings, when an increased risk of deliberate water contamination exists.

Further development of microbiological methods, including ATP and flow cytometric methods will reduce operational costs and make the technology available for wide use by water utilities. Another issue that should be solved during the next years is legislation. As was mentioned before, drawbacks of conventional monitoring methods have been proved, and it is only a matter of time when this problem will be recognized at legislation level, and alternative DW monitoring methods will become regulated and accepted. It will also accelerate the technology development and production of the EWS. The increase of EWS products and new manufacturers in the market will also reduce prices and make the technology more affordable.

Continuous monitoring in several locations implies the very large amount of data, which should be collected and processed. Since digital technologies are developing rapidly, solutions for large data set storage and processing optimization will improve over time. It is important not only for instant system response to contamination but it will allow creating statistical data for long time periods. For example, DW quality can fluctuate over time: often water quality parameters change during different seasons, and uneven water consumption could also lead to daily fluctuations [11]. Nevertheless, these changes are normal and usually do not indicate DW contamination. Therefore, long-term data could give a possibility to define a baseline and the limits for acceptable DW quality parameters. Moreover, the longer is observation period; the more accurate is the baseline. In other words, the performance of the technology will improve with time and amount of data. Moreover, synchronizing the data from different locations in distribution network will allow tracing the source and location of contamination.

The algorithm itself could be used in various types of applications. It could be based on a single parameter monitoring or developed into multi-parameter technology. The EWS can be combined with the technologies for water leaks detection in the network. In turn, leaks detection and prevention is one of the main challenges for sustainable smart water city development, since this will help to reduce water loss, preserve water resources and prevent water stress due to climate changes and growing urban population (Wong and Brown, 2009). With minor modifications, it can also be adapted to natural water, wastewater and air quality parameters control and pollution detection. Although microbiological methods proved to be more reliable for microbiological water quality monitoring than chemical and physical sensors, the latter could also be considered in case of high contamination risks from specific contamination types (e.g., wastewater) and inability to use modern microbiological methods. For example, we showed that electrical conductivity, turbidity and redox potential are effective for detection of wastewater intrusion. Thus, this could be used as an alternative in developing countries with low income or small DW supply systems. While primarily EWS is meant to be used for water utilities, it is very probable that communication with customers will be considered. Customers could receive notifications of possible water contamination via emails or smartphone applications together with the guidelines with necessary actions. It can also be combined with "smart house" technologies and applications, where the end user can be updated about DW quality and can control other building facilities performance according to that.

One of the potential problems that could arise with smart technologies development and implementation is a lack of properly educated and qualified personnel. The technologies develop very fast, regarding both DW quality monitoring approaches and information technologies (IT). Ideally, water professionals should know IT or IT stuff should have an understanding of DW system operation and risks.

The DW safety plans and risk assessment have to be introduced in many countries within the next 20 years and this will definitely raise a question of effective DW monitoring. Technically, EWS is one of the best solutions for that, and this smart technology has a high probability of becoming a common part of a modern DW supply system in a smart city. EWS for DW system will improve the safety of urban citizens and their confidence to water utilities. Moreover, the data it generates will give a better understanding of every individual water supply system and processes in the distribution network. It will help to improve and optimize DW treatment and DW system management and bring knowledge for the further development of technologies.

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