Some ICT Systems for Increasing Occupational Safety with a Reference to the Seaport Environment

ICT sustavi za poboljšanje sigurnosti na radu u okviru morskih luka

Sanja Bauk
Durban University of Technology
Faculty of Accounting & Informatics
Durban, South Africa
e-mail: bsanjaster@gmail.com

DOI 10.17818/NM/2018/2.5
UDK 004.4:331.45
656.615 (262.3 Bar)
Preliminary communication / *Prethodno priopćenje*
Paper accepted / *Rukopis primljen:* 11. 12. 2017.

Summary

The paper presents some commercial ICT (Information and Communication Technology) solutions for increasing workers' safety in invasive environments (e.g., steel industry, mining, construction, oil and gas rigs, seaports, etc.). It has been pointed to the need to increase safety measures, primarily because of the necessity to protect human lives and health, as well as to increase productivity and reduce the costs, which companies and insurance agencies have to cover in the case of accidents. The article also briefly describes some alternative solutions that have been examined at the level of simulations, in accordance to the actual needs and available resources at the Port of Bar (South Adriatic Sea). This seaport has been operating during the decades in the transitional conditions and it has been permanently faced with the impediments in providing sophisticated and expensive ICT solutions for occupational safety purposes.

KEY WORDS

occupational safety
ICT (Information and Communication Technology)
harsh environments
Port of Bar (South Adriatic Sea)

Sažetak

U radu su prikazana komercijalna ICT (informacijske i komunikacijske tehnologije) rješenja za poboljšanje sigurnosti na radu u invazivnom radnom okruženju (npr. industrija čelika, rudnici, gradilišta, naftne i plinske platforme, morske luke, itd.). Pokazuje se potreba poboljšanja sigurnosnih mjera, ponajprije zbog zaštite ljudskih života i zdravlja, kao i zbog povećanja produktivnosti i smanjenja troškova koje kompanije i osiguravateljske kuće moraju pokriti u slučaju nezgoda. U članku se također ukratko opisuju alternativna rješenja koja su ispitana na razini simulacija u skladu sa stvarnim potrebama i raspoloživim resursima u Luci Bar (južni Jadran). Ova morska luka djeluje desetljećima u uvjetima tranzicije i stalno je suočena s preprekama u pružanju sofisticiranih i skupih ICT rješenja za potrebe zaštite na radu.

KLJUČNE RIJEČI

zaštita na radu
ICT (informacijske i komunikacijske tehnologije)
zahtjevno radno okruženje
Luka Bar (južni Jadran)

1. INTRODUCTION / *Uvod*

According to the official data of the International Labor Organization (ILO, URL: http://www.ilo.org) every 15 seconds, 151 workers worldwide experience an accident at workplace. At the annual level, in global proportions, the number of injuries without a fatal outcome is 317 million. That worries far more is the fact that on average 321 000 people die in the world yearly due to injuries at workplace. Even those work-related injuries without a fatal outcome have negative impacts on workers, i.e., on their general health conditions. Not only do workers suffer, but injuries also cause great productivity damages, and therefore companies have big financial losses. Only at USA level these losses are about 220 billion $ a year, corresponding to a loss of about 27 million working hours [25]. This, additionally, affects negatively insurance companies.

Regardless of security regulations and procedures, there is a necessity to reduce the number and intensity of the injuries. In this respect, the paper gives a brief overview of some actual, sophisticated ICT solutions developed for these purposes. Then, the descriptions of some of the alternative ICT systems in the context of the individual needs and preferences of the Port of Bar have been given, while secondary and primary literary resources have been used. It is to be said, that the Port of Bar is an invasive working environment, which has been operating for decades in unfavorable transitional economic and administrative conditions.

The rest of the paper is organized as follows: Section 2 provides a description of some advanced ICT occupational safety systems used in the steel, construction, gas and oil industries. Section 3 shows the results of some experimental attempts to develop the appropriate ICT safety at work wireless network models that would be in line with the Port of Bar needs and capabilities. This has been done with the clear intention to avoid the usage of Internet of Things technology, in order to reduce the costs of investments. Therefore, some of the simulation experiments have been carried out by using different models of RFID (Radio Frequency IDentification) technology, MANET (Mobile Ad hoc NETwork), ZigBee, RFID/ZigBee hybrid systems, and V2V and V2I (Vehicle-to-

Vehicle and Vehicle-to-Infrastructure) vehicular communication networks. The simulation experiments have been done in Matlab, Opnet, Omnet++ and PIROPA simulation environments. At the end, in Section 4, some conclusion remarks are given, along with some directions for further research work in the field.

2. SOME COMMERCIAL ICT SYSTEMS FOR ENHANCING OCCUPATIONAL SAFETY / *Komercijalni ICT sustavi za poboljšanje sigurnosti na radu*

In this section, functional features of some commercial ICT systems for securing occupational safety at the harsh working environments are described, since their technical features were unfortunately not available from the used on-line resources. Firstly, a ready-made safety system employed in steel production industry is described in terms of its functionality, and then, some similar safety systems available at the labor market are briefly described in the similar manner.

2.1. On the Employee Wellness and Safety Solution / *O rješenju vezanom uz dobrobit i sigurnost zaposlenika*

The IBM Haifa (Israel) research team is working on a new system for employees' safety management. Namely, IBM's Employee Wellness and Safety Solution (EW&SS) is a new platform for monitoring vital workers' parameters and their safety. The EW&SS is primarily intended for the needs of the *Northstar Bluescope Steel* production corporation, with companies in Australia, New Zealand and North America. The system collects data from almost all types of sensors, as well from those which capture key environmental parameters. Based on the data collected and processed, workers and security personnel are warned in the case of danger. The focus is on each individual worker, with the aim to reduce the scale of accidents. The solution being offered by IBM is a kind of technological *guardian angel* of workers, who work in dangerous conditions. The new platform works as a warning system in real time. It analyzes large amounts of data collected from the sensors, which are embedded in the protective equipment (wearables) of workers, i.e., in the protective hard helmets, vests, shoes, as well as in the smart phones. The sensors continuously record the pulse of the worker, her/his motions, body temperature, hydration level and environmental factors like: temperature, noise level, presence of toxic gases, etc. [19].

The EW&SS discovers and notifies the supervisor or worker about any irregularity and potential risk in real-time. In combating heat stress, which is the most commonly occurring negative phenomenon at work in the steel production, the EW&SS collects data from various sensors that continuously record worker's skin temperature, heartbeat, galvanic skin response, activity level, etc., comparing collected information with those of ambient temperature and humidity.

The system can alert a supervisor/worker to a particular workplace hazard or send an alert in the event of a worker's injury. For example, the system gives a warning when the worker is in the workplace without a mandatory safety vest, safety glasses or headset. It displays a warning message if the worker is too close to a machine or on a slippery ground. Also, a warning is sent when the worker is exposed to harmful toxins or noise longer than the prescribed time. When the worker's organism has reached the critical point of dehydration, even in situations where (s)he is not concentrate enough, or when (s)he is too tired. The platform identifies instances of urgency, type of worker fall or faint at work place, when the report is sent directly to the assistance provider and/or the nearest employee who can assist. Sensors' information on smart protective equipment are stored directly in the employees smart phones, which process the data. Some of the collected information is kept in the Cloud, for further analysis and improvement of security regulations and procedures, as well as for adapting them to the individual needs of employees.

Progress of Internet of Things has enabled the connection of workers [13]. A worker who is aware of the situation, thanks to sensors controlling her or his vital parameters and the parameters of the environment, has a certain influence on the safety of the work environment. Wearable sensors are used in Internet of Things to collect, integrate and analyze the data. Thanks to the integration and presentation of contextual information to the workers, they become more aware of the situation in the environment. In this case, non-intrusive, always active, *conscious* about the environment state sensor devices pass critical information in time to the right place and person.

Although the fitness bracelets offer individual solutions for consumers for a while, i.e., inform the user about the amount of calories (s)he consumes, the EW&SS in addition offers a platform, which uses the benefits of *cognitive computing* for analysis of the information collected from many sensors. By collecting and analyzing information in this way, it becomes possible to detect what really is happening in the work environment, so that an indicative combination of dangers can be identified, while it could be overlooked in the case of individual observations. For example, the combination of increased body temperature, increased pulse rate, and the absence of the worker's normal-usual movement over a few minutes, indicates that the worker most likely experienced heat stress. Any of these indicators, viewed separately, will not activate the alarm, but if they are taken into account integrally, the system will point to a serious situation, which requires intervention.

It should be noted that the EW&SS provides individual advices to the worker, for instance, to take a 10-15 minute break in the shade, take liquids, etc., if her/his physiological parameters exceed the normal values. Also, the EW&SS includes sensors for the determination of threshold values of radiation, noise, toxic gases, etc. The presence of harmful gases, e.g., can be detected by using sensors embedded in the protective equipment of workers and communicating with base stations via Wi-Fi or Bluetooth technology [19].

2.2. On some other commercial ICT occupational safety systems / *O drugim komercijalnim ICT sustavima zaštite na radu*

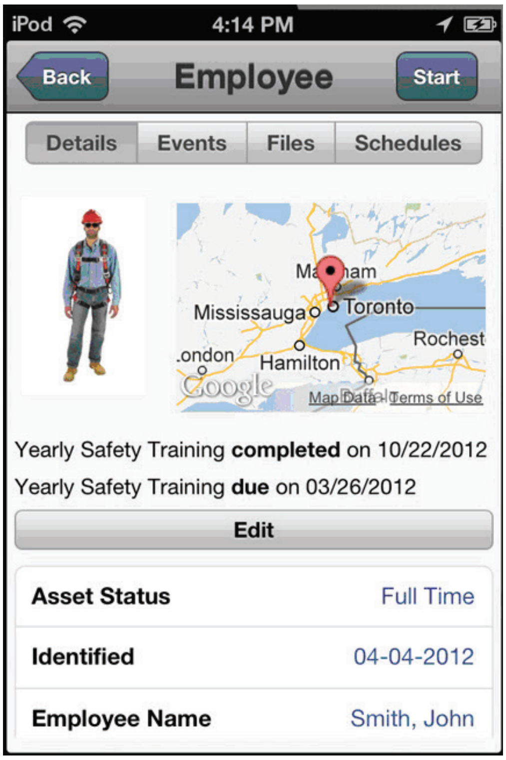
Besides the EW&SS smart solution for tracking and tracing workers in invasive environment with the aim to increase the safety, there are some other ready-made solutions, which have been offered at the market. Some of them, such as: MasterLoch Field ID [16], 3M Science Applied to Life™ [1], Honeywell [18], RFIDentity [28] and RFIDNordic [27] are shortly described in terms of their functional features.

The *MasterLoch Field ID* software allows the PPE (Personal Protective Equipment) to be monitored in terms of its use and functionality [16]. The Field ID app for Google Android, Apple iOS or Windows Mobile can capture the PPE position in real time and notify the PPE status, in terms of its functionality. The system is synchronized in real-time with RFID and GPS devices, anywhere and at any time, with the use of Cloud services. By controlling the safety belts (harnesses) of the worker, the system provides proactive protection against falling at the workplace (Fig. 1.a and 1.b). If the system had the WISP (Wireless Identification and Sensing Platform) capabilities, ID, and harness's functionality check option, a detector and alarm could also be associated with a worker's fall (the related sensors usually work on the principle of paired accelerometers).

Source: Author

Figure 1 a Workers with tagged harnesses on harbor-coastal construction

Slika1.a. Radnici s označenim pojasevima na lučkom obalnom gradilištu



Source: [16]

Figure 1 b Field ID app for monitoring the worker's protective harness

Slika 1 b Aplikacija terenske iskaznice za nadzor sigurnosnog pojasa radnika

The *3M Science Applied to Life™* uses RFID technology to mark each individual piece of PPE, track its use, functionality, history, and location. The system runs on desktop and mobile devices. The EHS (Environmental Health and Safety) engineers use this system for inventory, inspections, to capture the efficiency of using PPE, etc. [1].

The *Honeywell* solutions use UHF RFID chips as *birth certificates* that include information on each serial number of the PPE component, date of production, manufacturer, etc. Thanks to this system, it becomes possible to actively collect and monitor important safety information about every worker and her/his PPE, at any location covered by the system at any time. Through online portals, users can log in, scan each PPE peace, perform inspection or maintenance tasks, create and send reports, trigger (notice) alarms, etc. [18].

The *RFIDentity* provides advanced analytical capabilities for users, in the processes of ordering, replacing, and/or repairing tagged parts of PPE. The PPE Intelligent Module enables users to define their own rules and track the time of use, worker's habits, as well as the need to repair or purchase a new PPE garment. The system offers optimal solutions for companies, which are looking for scalable RFID infrastructure, reducing operating costs, increasing productivity, and so on [28].

The *RFIDNordic* is an occupational safety support system, for hundreds of oil platform and onboard ship workers. The system uses UHF Gen 2 tags installed on the workers' protective helmets. By installing the RFID reader at the entrance to the ship, e.g., the system provides the supervisor with information about that how many workers are onboard, so that (s)he can optimize the ship's abandonment plan in the case of danger. At oil rigs, this system is used in combination with sensors for measuring the concentration of harmful and flammable gases and for planning the platform evacuation in hazardous situations. It is also used to alert workers if they are near a restricted (dangerous) zone(s). This system connects users, suppliers, administrative bodies, research institutes, so it allows designing and implementing security solutions tailored to the individual needs [27].

In addition, the safety system implemented at the Port of Cagliari (Italy) it is to be mentioned. Assuming that the worker has passed the identification and PPE control at the entrance gate, the CCTV (Closed Circuit Television) system installed at the terminal provides continuous monitoring with the intention to discover if the worker properly wears the PPE at the working place. In the case of non-use, or improper use of PPE, the technician responsible for the video surveillance will warn the worker by sound or text message alarm via the port wireless network (Wi-Fi) and PDA (Personal Digital Assistant) device attached to the worker's belt. Wearable sensor network in this case consists of passive RFID and WISP (Wireless Identification and Sensing Platform) devices which provide the ID and ambient light and temperature (helmet), as well as worker's plantar pressure (shoes) data [32-34]. It is an example of a possible port workplace safety solution, but it hasn't been recommended for application in the case of the Port of Bar. The centralized monitoring system of the CCTV connecting with the port Web GIS maps, RFID/WISP sensors and readers, might be too complicated for implementation at the present stage of the Port of Bar development [12]. This model employed at the Port of Cagliari has been recently re-engineered towards the Internet of Things [24]. In this regard, it excludes workers' PDA devices and provides direct communication between worker's clothing with embedded RFID tags and readers placed at the strategic port's locations. A smart software system is used for locating workers, checking their

PPE functionality, and helmet position, thanks to the accelerometer installed in it. The segment of this safety solution that provides periodical communication between tags and readers through the virtually intelligent software back-end system might be partially implemented in the Port of Bar, in the manner presented within the first part of the next section.

3. THE ICT MODELS FOR ENHANCING PORT SAFETY WITH THE REFERENCE TO THE PORT OF BAR / *ICT modeli za povećanje sigurnosti u luci, primjer Luke Bar*

The above described commercial solutions for increasing safety of workers in invasive working areas, in real time, as well as those developed at the Port of Cagliari, are based on periodic locating (pinpointing), or continuous monitoring of workers, checking whether they carry the prescribed PPE, whether it is functional, etc. All of these solutions are very complex and usually expensive ones. According to some sources (e.g., OpenRTLS, URL: https://openrtls.com), installing such system(s) costs \$ 3-11 per m^2 of working space. This practically means that if some of these systems would be applied, e.g., over the container and general cargo terminal of the Port of Bar, which occupies about 7 hectares, it will cost about half of million \$. Thus, the implementation of any of the solutions described afore would be too expensive in the considered case.

In the attempt to overcome this problem and to familiarize the managers and stakeholders with some of the alternative options for enhancing safety of the on-port workers and pedestrians, some simulation experiments have been carried out. The simulations are performed over the layout of the container and general cargo terminal at the Port of Bar, since it has been assumed that harbor workers and pedestrians at this terminal are at most exposed to the risks, like: outdoor work, proximity to heavy manipulation and transport mechanisms, heavy goods handling errors, etc.

The research firstly goes into the direction of using PPE with active UHF Gen 2 RFID chips, readable at a distance of several hundred meters from readers connected to the local network. The back-end info-communication system would provide periodic location of the workers (i.e., when they are in the range of readers), as well as check whether they carry the PPE, and whether it is functional. Due to some preliminary calculus, the costs of implementation of such system at the Port of Bar should be approximately \$ 1.2 per m^2.

Based on simulations in the Matlab, Opnet and Omnet ++ simulation environments, with ten readers at the terminal and about twenty to twenty-five workers (per shift/per berth), the system operates well at distances greater than 500 m, in terms of SNR (Signal to Noise Ratio) and BER (Bit Error Rate) for characteristic WLAN, Wi-Fi and White-Fi frequencies [12]. The main disadvantage of such a system is the inability to monitor workers, the use and functionality of their protective equipment at work in real time.

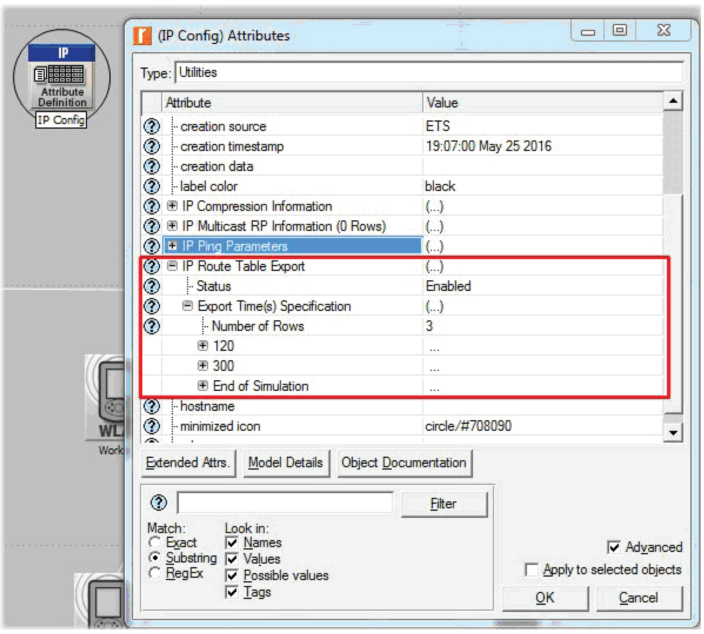
Additionally, a series of experiments for MANET and ZigBee technologies, as particular communication channels for increasing safety of port workers, has been done. The MANET scenario is based on the idea that workers and supervisors communicate via the PDA devices; while in the case of ZigBee scenario, BCUs (Body Central Units) are treated as end-nodes of the network that communicate with fixed and mobile routers (mounted on forklifts) [10]. The entire network and traffic related to security is managed by the coordinator placed at the strategic location of the port terminal. Simulations were made for different routing algorithms in MANET (OLSR, TORA, AODV and DSR) and for different ZigBee topologies (star, tree and mesh). The results of the simulation analysis are given in Table 1.

Table 1. MANET vs. ZigBee advantages
Tablica 1. Usporedba prednosti - MANET i ZigBee

No. of nodes	Technology	Topology	Routing protocol
5	ZigBee	star	-
10	ZigBee	mesh	-
15	MANET	-	OLSR
20	MANET	-	AODV

It is obvious that MANET has better performances for greater number of nodes. The router forwarding table and IP route table export parameters being set in Opnet are shown in Fig. 2 and 3.

Since MANET's AODV routing protocol shows the best



Source: Author

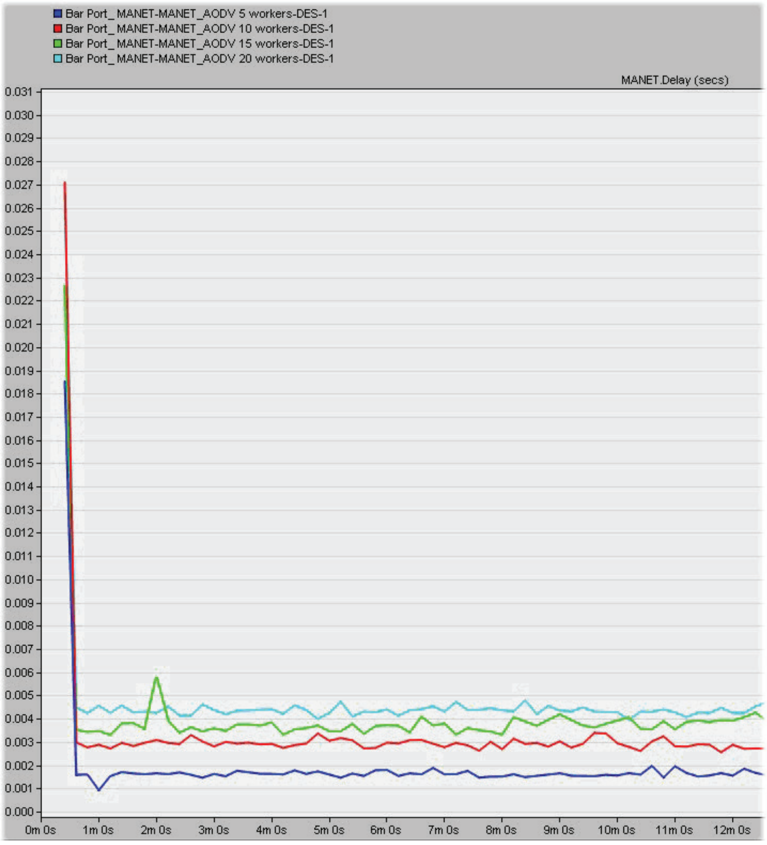
Figure 2 IP route table export parameters in Opnet
Slika 2. Izvoz parametara IP tablice usmjerivača u Opnetu

	Destination	Source Protocol	Route Preference	Metric	Next Hop Address
1	192.168.1.2/32	AODV	1	1	192.168.1.2
2	192.168.1.4/32	AODV	1	3	192.168.1.10
3	192.168.1.6/32	AODV	1	3	192.168.1.8
4	192.168.1.8/32	AODV	1	1	192.168.1.8
5	192.168.1.9/32	AODV	1	1	192.168.1.9
6	192.168.1.13/32	AODV	1	3	192.168.1.10
7	192.168.1.14/32	AODV	1	3	192.168.1.10
8	192.168.1.15/32	AODV	1	3	192.168.1.8
9	192.168.1.16/32	AODV	1	1	192.168.1.16
10	192.168.1.19/32	AODV	1	2	192.168.1.8
11	192.168.1.20/32	AODV	1	1	192.168.1.20
12					
13	Gateway of last resort is	not set			

Source: Author

Figure 3. The router forwarding table in Opnet

Slika 3. Tablica usmjeravanja u Opnetu



Source: Author

Figure 4 MANET global delay for AODV routing protocol

Slika 4. Globalno kašnjenje MANET-a za AODV protokol usmjeravanja

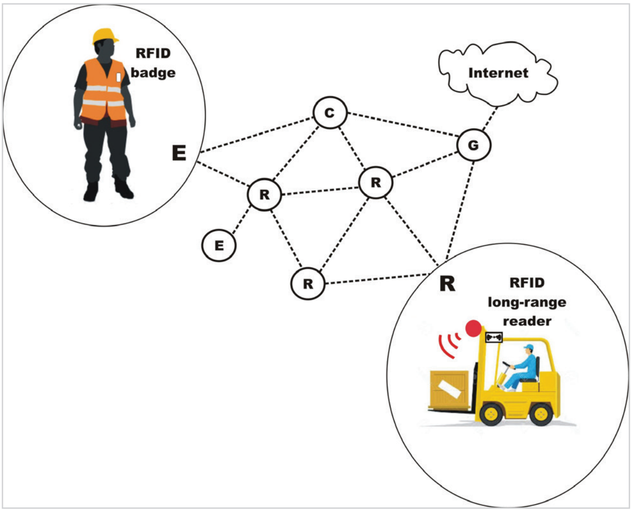
performances in the examined case, the delay in receiving packages is negligible in all analyzed cases for 5, 10, 15 and 20 end-nodes (Fig. 4).

A preliminary study has also been conducted towards the implementation of the Cloud services for easier resolving the safety issues at the Port of Bar [11]. This analysis is based on the secondary literary resources and the theory developed so far in the field of the methodological framework for the adaptation of the Cloud services [21,23]. It has been found that as a potential solution could be considered a model of *outsourcing as a service*. This model implies that the providers of ICT system for increasing occupational safety are at the same time its owners. Responsibility for implementation, maintenance and development of the system is also on the side of the supplier. Of course, before making the final decision about an eventual outsourcing model in the Cloud, the market and strategic orientation of the Port of Bar management, regarding the role and place of ICT in the port's functioning and business affairs, are to be analyzed in more detail.

3.1. The ZigBee/RFID hybrid safety system / *ZigBee/RFID hibridni sigurnosni sustav*

In addition to the simulation experiments with RFID [11,12], MANET and ZigBee [10] technologies, some ZigBee/RFID hybrid system [9] analysis are performed, too. For these analyses, Opnet simulation modeler has been used. The layout of the Port of Bar container and general cargo terminal for different scenarios with five, ten, fifteen and twenty wireless network end-nodes has been used as a background for the simulations. The end-nodes symbolically present info-communication devices on the side of port workers and forklifts. The number of end-nodes varies and it is mostly in accordance with the daily needs (per shift) of the Port of Bar.

In the hybrid ZigBee/RFID system, workers are equipped with RFID badges, while forklift trucks are equipped with RFID transponders (long-range RFID transceivers). Workers' tagged badges represent the end-nodes of the ZigBee network, while forklift transceivers represent ZigBee network communication routers. In addition to the forklift, as a moving router, in the simulations, three fixed routers were used in the appropriate positions within the perimeter of the port. As a link between the RFID devices and the ZigBee network, XBee devices [9,15] have been deployed. A scheme of this hybrid ZigBee/RFID safety system is shown in Fig. 5. The system triggers alarm/warning when the worker and forklift are close to each other, and in such way prevents a potential crash.



Source: Author

Figure 5 A scheme of the ZigBee/RFID hybrid alerting system

Slika 5. Shema ZigBee/RFID hibridnog sustava uzbunjivanja

The simulations have been performed in the Opnet Modeler (Riverbed Modeler ver. 17.5.A) on a PC (Intel CoreTM i7, 2.50 GHz, 8GB RAM), while the following network properties were used: packet interval time: constant (1); package size: constant (32); start time: constant (30); stop time: infinite, and transmition power: 5 mW. After a set of the experiments, the following results are obtained [9,10]:

- As the number of end-nodes increases from 15-20, the traffic received on the coordinator side decreases, from 12-7 packs per second, but there is no break in the sense that the coordinator does not receive traffic;
- The experiments show that the performances of the ZigBee communication network are much better at 2.45 GHz than at 868 MHz. This is because of the higher transmission speed at 2.45 GHz and more complex modulation scheme (QPSK instead of BPSK for 868 MHz);
- Better performance in the case of the 2.45 GHz carrier frequency relates to the higher number of packets received in the time unit on the coordinator side, as well as to the less end-to-end delay of received signal;
- Some variations of received power are observed, depending on the dynamics and the mutual positions of the end-nodes and routers at certain time intervals. The received power is in all cases higher for carrier frequency of 2.45 GHz; and,
- In all analyzed cases, the received power is above the predetermined threshold of -85 dBm.

Further research in the field should certainly be carried out over larger number of end-nodes and routers, and also, RFID devices on the side of workers and forklifts, as well as XBee devices linking them to the ZigBee network, should be more precisely specified. Also, it would be advisable to do some experiments in the real port environment, taking into account the physical barriers. Besides, the willingness of the manager and stakeholders to secure the funds for implementing such or similar occupational and environmental safety system should be explored in some more detail, preferably through in-depth interviews.

It is worth to mention that workplace accidents, which involve moving vehicles (e.g., fork-lifts) cost ports huge amounts of money in terms of expensive downtime, investigations and increased insurance premiums [26]. Above all are fatal injuries and loss of human lives. In 2014, e.g., the number of casualties in the transportation sector in the USA was 734, according to the Bureau of Labor Statistics [17]. Fortunately, the fatal accidents have not been recently recorded in the Port of Bar, but this should not be excluded as a potential danger and should be prevented.

There are several ready made, commercial solutions for reducing the risk of collision between moving vehicles and workers/pedestrians at the workplace, such as: Forklift Safety RFID Solutions [31], BodyGuard [26], Pedestrian Alert System [20], EGOpro Safety Move Proximity Warning Systems [3], etc. They all improve safety through a proximity alert system for forklifts and workers/pedestrians. The main operating features of these systems are: the detection of workers/pedestrians in frontal (0.5-6.5 [m]), back (0.5-6.5 [m]), and side area (up to 4 [m]) of the forklift in operation to warn the forklift's driver (while maximum detection range can be adjusted to smaller). They also alert the worker/pedestrian by visual and/or audible alarms and automatically reduce the speed or stop the forklift, while its maximum speed is limited to 10 [km/h] [20]. These systems help in overcoming the typical risks caused by factors such as driver inattention, poor visibility (e.g., blind entry/exit, warehouse aisles, etc.), worker's non-compliance with exclusion areas around vehicles, collision between a worker and moving vehicle at a common working area, etc.

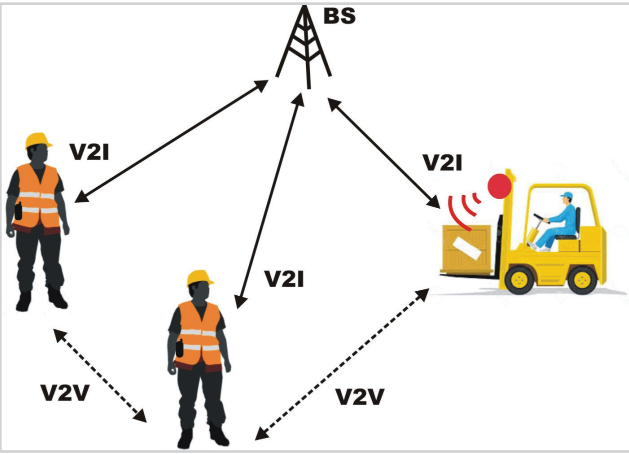
Since the insight into technical characteristics of these commercial systems are not widely available, in this paper are given some results of simulation experiments, which reveal basis technical features of such systems at physical and communicational layers. At the current state of the research, upper layers conceiving and deploying is leaved to the managers and stakeholders preferences and real needs, as well as to ICT architects decisions.

3.2. The vehicular communication safety system / *Sigurnosni sustav kolne komunikacije*

When it comes to enhancing on port workers and pedestrians safety, one should undoubtedly take into account the potentials of emerging vehicular communication technology.

It is connected with cooperative systems in which vehicles and pedestrians equipped with on-board units can *talk* to each other and also with the infrastructure through road-side units (RSU), base station (BS) or dedicated access sites [36]. Such cooperative sensing and controlling systems may exhibit more advanced behavior compared to vehicles, pedestrians and environments that do not communicate. Some large consortium projects such as: Connected Vehicles, Cooperative Vehicle-Infrastructure Systems, Cooperative Systems for Road Safety, Strategic Platform for Intelligent Traffic Systems, Car-2-Car, etc. [2,37], have shown the feasibility and advantages of DSRC (Dedicated Short Range Communications) technology, which is particularly important for smooth vehicular communication. It enables safety and infotainment applications by IEEE 802.11p standard in 5.850 GHz to 5.925 GHz, which allows the devices to transmit up to 1 km with 32 dBm power [38]. The main motivation for its deployment is to provide safety-related applications. By collecting up-to-date information about the status of the road, the driver/pedestrian assistance system can quickly detect potentially dangerous situations, and notify the driver/pedestrian about the approaching danger. A relatively small reduction in the driver's/pedestrian's reaction time may potentially avoid the trigger of an accident [39].

Within the seaport environment, e.g., driver might be a fork-lift driver, pedestrian might be an on-port worker or pedestrian, while road is an internal-dedicated road at the seaport transportation and operational areas with the appropriate number of base stations (Fig. 6).



Source: Author

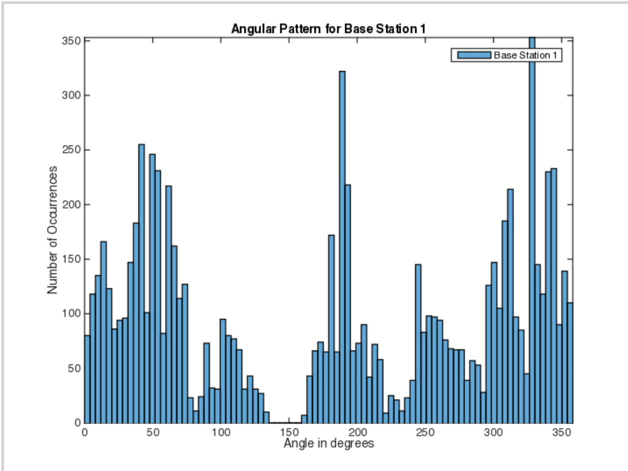
Figure 6 A scheme of the vehicular communication network
Slika 6. Shema kolne komunikacijske mreže

Some simulation experiments with vehicular communication at the seaport environment have been done over Intelligent Autonomous Vehicles (IAV) at the container terminal [5]. Additionally, there are some indices that vehicular communications will enter Automated Guided Vehicles (AGV) market [35]. The idea of deploying vehicular communication for enhancing safety at the seaport environment is firstly proposed by Bauk et al. [7,8] due to the best of the author's knowledge.

The simulation experiments in the case of vehicular communication ad-hoc network have been performed over the Port of Bar container and general cargo terminal, in PIROPA (Parallel Implemented Ray Optical Propagation Algorithm) environment [29], for different combinations of ten end-users (workers, pedestrians and forklifts), while the following general conclusions have been drawn [7,8]:

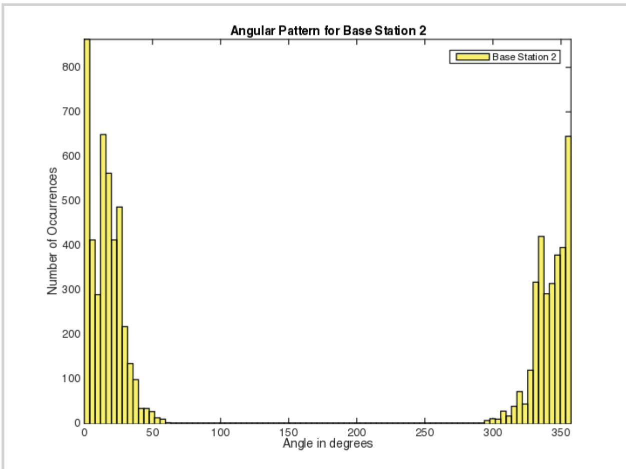
- Three arbitrarily positioned base stations (BS1, BS2 and BS3) cover well the entire surface of the terminal and provide smooth communication between all involved workers, pedestrians, and front-lifts. Their angular patterns are given in Fig. 7, 8 and 9, respectively;
- The power of the receiving signal is in all cases within the upper and down threshold boundaries (Table 2); and,
- The delays and Doppler's shifts are negligible (Table 2).

It should be noted that the observed port terminal has been approximated by a rectangle of 650x350 m. As obstacles, the blocks of containers, warehouses, and the robust horizontal and vertical port mechanization are taken into consideration. It is assumed that on-port workers and pedestrians are moving by an average speed of 1.4-2.5 m/s, while forklifts are moving by an average speed of 6 m/s. Simulations have been done on 2.6 GHz Intel Core i5 PC with 16 GB RAM.



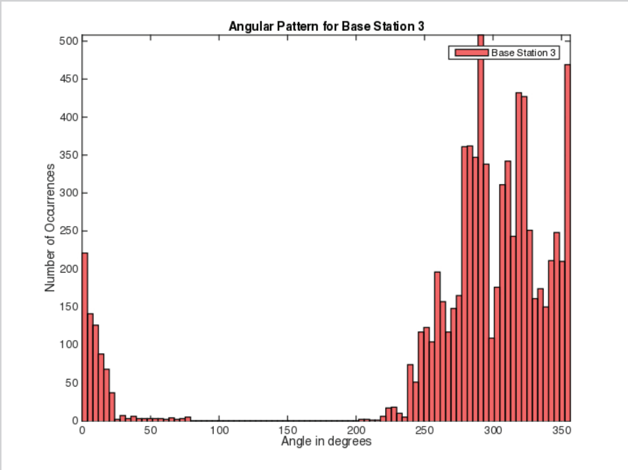
Source: Author

Figure 7 Angular patterns for BS1
Slika 7. Kutni obrasci za BS1



Source: Author

Figure 8 Angular patterns for BS2
Slika 8. Kutni obrasci za BS2



Source: Author

Figure 9 Angular patterns for BS3

Slika 9. Kutni obrasci za BS3

In accordance to the secondary literature resources, about 50 000 $ might be taken as a potential average cost for introducing such vehicular communication safety system per site [4,30]. This cost seems affordable for the implementation at the Port of Bar.

It is clear that the system, albeit the small number and speed of moving nodes, works properly. However, one should bear in mind the obstacles that can be encountered along the way of implementing this emerging technology at a relatively small seaport, which operates in rather rigid transitional (economic and administrative) conditions. In this regard, there is a need to raise awareness of the seaport management in terms of *innovative culture*. Also, there is a need to create an appropriate marketplace that would enable the integration of knowledge, new technological opportunities and user needs in the considered environment. The pro-active communication between the seaport administration and stakeholders on one side, and the research and development institutions and the ICT architects on the other one, is to be developed and nurtured.

By adapting and routinizing one of the previously proposed ICT occupational safety wireless network models, the Port of Bar should become better ranked at the users' perception map, i.e., it will be positively re-positioned on the global market of seaport (added value) services as safe and *green*.

4. CONCLUSIONS / *Zaključak*

In the paper are presented some ready-made ICT solutions for increasing workers' safety in invasive working environments, i.e., EW&SS, MasterLoch Field ID, 3M Science Applied to Life™, Honeywell, RFIDentity, RFIDNordic, etc. It has been pointed to some of their similarities and differences, while it can be concluded that these systems are highly sophisticated, with a global coverage and high precision, e.g., they work at the level of individual PPE parts, in real time. All these solutions are flexible and scalable. Besides, they are based on the concept of the Internet of Things and oriented towards contextual computing.

The paper also proposes some alternative ICT occupational safety models based on wireless networks, which have recently been considered at the logical and simulation levels in the context of real needs and capacities of the developing Port of Bar, in order to increase workers' safety and reduce environmental impacts. The backgrounds and the simulation results of conducted research studies in this domain are described in more detail in the references [7-12], while the summary of simulation experiments at physical and communication layers are given in this paper. Further research, in addition to these of rather technical-engineering nature, should be focused on: (a) testing the level of the seaport's managers' and stakeholders' willingness to adopt such wireless networks to reduce the risk of workers injuries and environmental impacts; and, (b) testing the port workers and supervisors, in terms are they willing to become constituent parts of such smart (wearable) safety networks.

Also, one has to bear in mind that it is about emerging technologies, which adaptation and routinization are always connected with the impediments on the path towards innovation success. The last stated should certainly be taken into account in further research endeavors in the field. The innovations in general, and even these related to enhancing the safety of humans and ecosystems, can not be limited to adopting new technologies. They should also involve creative use of technologies, primarily in terms of knowledge and market integration. Likewise, the culture of innovation [14] should be nurtured through the development and promotion of *innovative networks*, by gathering seaport administration, research and development centers, industry representatives, seaport operators, on-port workers, pedestrians and seaport customers. Only after the fulfillment of all the above mentioned prerogatives, it could be expected success of the innovations related to the deployment of emerging technologies in improving occupational safety and the environmental management system within the developing seaport ecosystem.

ACKNOWLEDGEMENT / *Zahvale*

The author would like to express her gratitude to M.Sc. Jose Angel Leon Calvo and M.Sc. Diego Garcia Gonzalez from the Institute for Theoretical Information Technology at RWTH Aachen University (Germany) for their support in realization of the simulation experiments.

Table 2. Doppler shift, delay and power analysis

Tablica 2. Doplerov učinak, kašnjenje i analiza jakosti

Features vs. Interplays	max_DS	min_DS	max_Delay	min_Delay	max_Power	min_Power
BS/FL-W	negligible	negligible	13.941 ms	0.202 ms	-75 dBm	-108 dBm
W/FL-W/FL	3.969 Hz	-3.455 Hz	1.652 ms	35.967 ms	-30 dBm	-110 dBm

Legend: DS – Doppler shift; BS – base station; W – worker (or pedestrian); FL – front-lift

REFERENCES / *Literatura*

[1] 3M Science Applied to LifeTM (2017), Workers Health & Safety - PPE Safety Solutions, URL:

[2] Alexander P., Haley D., Grant A. (2011), Cooperative intelligent transport systems: 5.9-GHz field trials, Proc. IEEE 99 (7), pp. 1213–1235. https://doi.org/10.1109/JPROC.2011.2105230

[3] AME – EGOpro Safety Move Proximity Warning Systems (URL: http://www.ameol.it/en/egopro-safety/anticollision/?gclid=CN6875b1-coCFQkIwwodTZ0EbA, last access, October, 2017)

[4] American Association of State Highway and Transportation Officials and DOT, "GAO-15-775 Intelligent Transportation Systems Report", p. 40., (URL: http://www.gao.gov/assets/680/672548.pdf, last access, October, 2017)

[5] Bahnes N., Kechar B., Haffaf H. (2016), Cooperation between Intelligent Autonomous Vehicles to enhance container terminal operations, Journal of Innovation in Digital Ecosystems, 3, pp. 22-29. https://doi.org/10.1016/j.jides.2016.05.002

[6] Barro-Torres S., Fernández-Caramés T.M., Pérez-Iglesias H.J., Escudero C.J. (2012), Real-time personal protective equipment monitoring system, Computer Communications, 36, pp. 42-50. https://doi.org/10.1016/j.comcom.2012.01.005

[7] Bauk S., Calvo J.A.L., Mathar R., Schmeink A. (2017), V2P/I Communication for Increasing Occupational Safety at a Seaport, Proc. of the 59th IEEE International Symposium Electronics in Marine (ELMAR), Zadar, Croatia, 18-20 September, 2017, to appear.

[8] Bauk S., Calvo J.A.L., Schmeink A., and Mathar R. (2017), Enhancing on Port Safety by Vehicular Communication Approach - Port of Bar (Montenegro) Case Study, Proc. of the 6th IEEE Mediterranean Conference on Embedded Computing (MECO), Bar, Montenegro, 11-15 June, pp. 338-341.

[9] Bauk S., Gonzales D.G., Schmeink A., Examining some ZigBee/RFID safety system performances at the seaport, Proc. of the 58th IEEE International Symposium Electronics in Marine (ELMAR), Zadar, Croatia, 12-14 September, 2016, pp. 133-137 https://doi.org/10.1109/ELMAR.2016.7731771

[10] Bauk S., Gonzalez D.G., Schmeink A., Avramovic Z. (2016), MANET vs. ZigBee: Some simulation experiments at the seaport environment, Journal of Information Technology and Applications, 6(2), pp. 63-72.

[11] Bauk S., Schmeink A. (2016), RFID and PPE: Concerning workers' safety solutions and Cloud perspectives - A reference to the Port of Bar (Montenegro), Proc. of the 5th IEEE Mediterranean Conference on Embedded Computing (MECO), Bar, Montenegro, 12-16 June, pp. 35-40. https://doi.org/10.1109/MECO.2016.7525756

[12] Bauk S., Schmeink A., Colomer J. (2016), An RFID Model for Improving Workers' Safety at the Seaport in Transitional Environment, Transport, 31(1), pp. 1-11. https://doi.org/10.3846/16484142.2016.1233512

[13] Borgia E. (2014), The Internet of Things vision: Key features, applications and open issues, Computer Communications, 54, pp. 1-31. https://doi.org/10.1016/j.comcom.2014.09.008

[14] De Martino M., Errichiello L., Marasco A., Morvillo A. (2013), Logistics innovation in Seaports: An Inter-organizational perspective, Research in Transportation Business & management, 8, pp. 123-133.

[15] Digi (2017), Digi – XBee products, URL: http://www.digi.com/products/xbee (last access: 31st August 2017)

[16] eCompliance/Field ID (2017), Field ID joins the eCompliance family!, URL: http://fieldid.com/ (last access: 31st August 2017)

[17] Grayson W. 2015. Construction deaths up 10% in preliminary 2014 report; total leads all industries, Equipment world

[18] Honeywell (2017), Enabled Safety Protection – Products Overview (URL: http://www.enabledsafetyproducts.com/, last access, August 2017)

[19] [IBMIsrael (2016), Using the Internet of Things to boost employee safety, YouTube (URL: https://www.youtube.com/watch?v=wJbAKeLGzrs, last access, January, 2017)

[20] IcnitaSafety – Pedestrian Alert System - PAS (URL: http://en.icnitasafety.com/, last access, February, 2016)

[21] Johansson B, Muhic M. (2013), Explaining Sourcing Motives from Sourcing Decisions: The Sourcing Motive Framework, Procedia Technology, 9, pp. 64-73. https://doi.org/10.1016/j.protcy.2013.12.007

[22] Kelm A., Laußat L., Meins-Becker A., Platz D., Khazaee M.J., Costin A.M., Helmus M., Teizer J. (2013), Mobile passive Radio Frequency Identification (RFID) portal for automated and rapid control of Personal Protective Equipment (PPE) on construction sites, Automation in Construction, 36, pp. 38-52. https://doi.org/10.1016/j.autcon.2013.08.009

[23] Muhic M. (2013), Sourcing motives behind sourcing decisions exposed through the Sourcing Decision Framework, International Journal of Information Systems and Project Management, 2(1), pp. 5-17.

[24] Musu C. 2015. Wearable sensor networks for safety applications in industrial scenarios, PhD Thesis, University of Cagliari, Italy.

[25] O'Connor C. (2016), Improving worker safety with wearables, IBM: Internet of Things blog (URL: https://www.ibm.com/blogs/internet-of-things/worker-safety-and-wearables/, last access, October, 2017)

[26] Orbitscom – BodyGuard (URL: http://www.orbitcoms.com/BodyGuard.php, last access, February, (2016)

[27] RFID Nordic (2017), RFID Journal, URL: http://www.rfidnordic.se/ (last access: 31st August 2017)

[28] RFIDentityTM (2017), RFID Industrial Solutions – Advanced RFID Solutions, Software Development and API Integration, URL: http://www.rfidentity.com/ (last access: 31st August 2017)

[29] Schröder F., Reyer M., Mathar R. (2012), Field Strength Prediction for Environment Aware MIMO Channel Models, Proc. of the 6th European Conference on Antennas and Propagation (EUCAP), Praque, Czech Republic, March, pp. 2384-2387. https://doi.org/10.1109/EuCAP.2012.6206142

[30] Simpson B. 2017. "Each V2I Site Could Cost $51,650", Driverless Transportation, (URL: http://www.driverlesstransportation.com/tag/infrastructure/page/2, last access, October, 2017)

[31] Silent Partner Technologies, The Silent Partner Technology RFID Forklift Safety Solution (URL: https://www.silentpartnertech.com/rfid-solutions-applications/forklift-solution/, last access, October, 2017)

[32] Sole M. (2014.) Communication technologies and data processing for safety, Doctoral Dissertation, University of Cagliari, Italy.

[33] Sole M., Musu C., Boi F., Giusto D., Popescu V. (2013a.) Control system for workplace safety in cargo terminal, Proc. of the 9th IEEE International Wireless Communications and Mobile Computing Conference, 1st-5th July, Sardinia, pp. 1035-1039. https://doi.org/10.1109/IWCMC.2013.6583699

[34] Sole M., Musu C., Boi F., Giusto D., Popescu V. 2013b. RFID sensor network for workplace safety management, Proc. of 18th IEEE Conference Emerging Technologies & Factory Automation - ETFA, 10th – 13th September, Cagliari, Italy, pp. 1-4. https://doi.org/10.1109/ETFA.2013.6648157

[35] VDL Containersystemen (2015). VDL towards new generation AGV (Daniels M., Publication date: 4-5-2015), (URL: http://www.vdlcontainersystemen.com, last access, July, 2017)

[36] Wang M., Daamen W., Hoogendoorn S.P., Arem B. (2014), Rolling horizon control framework for driver assistance systems. Part II: Cooperative sensing and cooperative control, Transport Research Part C, 40, pp. 290-311. https://doi.org/10.1016/j.trc.2013.11.024

[37] Weiß C. (2011), V2X communication in Europe – From research projects towards standardization and field testing of vehicle communication technology, Computer Networks, 55, pp. 3103-3119. https://doi.org/10.1016/j.comnet.2011.03.016

[38] Yan G., Rawat D.B. (2017), Vehicle-to-vehicle connectivity analysis for vehicular ad-hoc networks, Ad Hoc Networks, 58, pp. 25-35. https://doi.org/10.1016/j.adhoc.2016.11.017

[39] Zhon H., Xu S., Ren D., Huang C., Zhang H. (2017), Analysis of event-driven warning message propagation in Vehicular Ad Hoc Networks, Ad Hoc Networks, 55, pp. 87-96. https://doi.org/10.1016/j.adhoc.2016.09.018