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SCALING CHALLENGES OF HIGH-TECH SMES DEVELOPING INTERNET OF THINGS TECHNOLOGY

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ABSTRACT

This paper is a review of the organizational structure and challenges that a technological enterprise faces during scaling, from the perspective of the engineering management. After expanding operations internationally, the distributed engineering teams developing hardware and software for internet of things applications, face issues regarding culture, communication, leadership, project planning and management. Relevant literature addressing these issues is presented. We elaborate on already implemented measures for improving the overall efficiency and propose further processes introduced in recent literature that can be beneficial for further optimizing the new product development. Potential knock-on effects by such implementation are also discussed.

KEYWORDS: *Organizational Challenges; Scaling; Engineering Management; Manufacturing; Internet of Things.*

I. Introduction

The nowadays widespread use of technology covering all aspects of everyday life, sparked the proliferation of high-tech small and medium-sized enterprises (SMEs) developing IoT (internet of things) platforms. Though traditional SMEs may focus on steady growth, securing market share and establishing their local presence, high-tech SMEs commonly follow the "start-up route" focusing on exponential growth and rapid scaling. This key difference between start-ups and traditional SMEs is mentioned in [1] with reference to how each structure gains access to funding opportunities. The exponential growth is typically tied with establishing international presence for various reasons beneficial to the organization.

A series of studies conducted by the European Commission confirm internationalization as a success factor for high-tech SMEs within Europe [2]. This is primarily because a multitude of technological products address niche markets and therefore accessing a broader potential customer base can be secured by expanding to international level. Moreover, by expanding internationally, an organization can gain access to skilled personnel or cost-effective labor, infrastructure, favorable political conditions, etc. that are otherwise unavailable to the primary location / head office. A typical example here would be a company designing clothing in a country famous for its fashion-designers and producing in an industrialized country with developed manufacturing infrastructure.

Any technological SME requires since its conception at least a few engineering roles (software, hardware, systems, sales, etc.) and a few functional roles (customer service, marketing, sales, human resources etc.). During international expansion, the former smaller team is now required to cooperate with other individuals or teams, which are more than often geographically separated and from different cultures. While there are processes and management models to accommodate a smooth integration, these are hard to implement when the expansion is rapid or are often overlooked by managers concentrated in the financial key performance indicators [3]. This can induce several fundamental organizational issues regarding communication, leadership and decision making.

II. Organizational Structure, Growth State and Current Issues

The company examined herein is an IoT-electronics manufacturer founded in the United Kingdom. The product portfolio comprises a series of electronic devices used in various industries, including oil and gas, military, car manufacturing, space exploration, data centers and logistics operators. The management team quickly established corporate presence in the United States, as it was considered a key market, and approached a venture capital firm while seeking funds for a rapid expansion. This led to the assembly of several functional teams spread all over the globe to serve the needs of the organization as illustrated in figure 1.

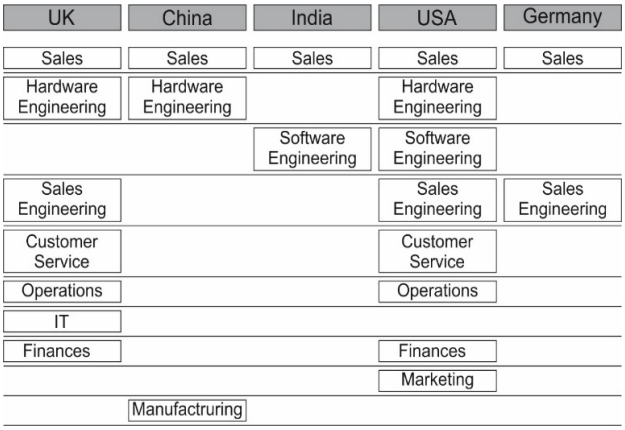

Figure 1. Organizational structure after initial growth stage

The company's initial head office located in the United Kingdom comprised two functional teams, namely a hardware engineering team and another for key administrative roles, employing a total of approximately 20 staff. The company eventually settled to the structure illustrated in figure 1, employing roughly 300 full-time staff, with all major restructuring taking place in a 12-month timeframe. Though quantifying the growth level of the organization may not be very straightforward, by projecting the organizational structure onto the Greiner growth model, we can observe that the organization is running through phase 3 i.e., delegation [3]. This is tied with the creation of "profit centers", as illustrated by the establishment of regional sales offices in figure 1. Also, each regional structure tends to act more independently, focusing on their own performance. Moreover, senior management become less involved in the day-to-day business and communicate less frequently through formal corporate communication. As anticipated, this rapid restructuring resulted in leadership, communication, and decision-making conflicts, during the assembly of the regional units.

Though there are a few different perspectives, we will be focusing on the challenges faced by the distributed engineering teams. It is noteworthy that the product portfolio consists of 3 main categories:

- Active devices (hardware)
- Passive devices (hardware)
- Software

Active devices are battery supported electronics, while passive devices use ambient electromagnetic waves to operate. Software is sold either as a service (SaaS) supporting customer needs or as a product (SaaP), and mainly to assist applications for the electronic devices.

Figure 2 illustrates a simplified diagram of the new product development process, which is either driven by a market need as identified by senior management including operations, sales, and marketing (internal), or it is driven by a customer need as communicated to the engineering team through various channels including sales and sales engineering (external). Regarding the new product development process, the distributed engineering department follows the stage-gate model for hardware products, where the actual workload is split in different phases at the end of which continuation of the project is decided upon [4].

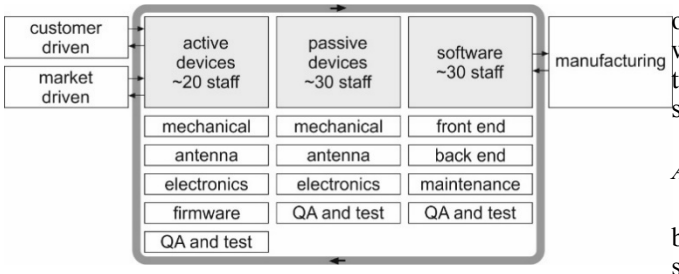

Figure 2. Engineering structure and new product development diagram

For software development the scrum model for the agile methodology is followed, where customer input (internal or external) is constantly fed to the engineering team and the product specifications are adapted accordingly [5].

Each product family requires the engagement of roughly 20 to 30 engineers, spanning various specializations as listed in figure 2. An engineering director is responsible for managing and distributing the engineering workload of each product family. The passive devices are managed by the UK Engineering Director, the active devices by US Engineering Director and the software products by the Software Engineering Director also located in the United States. The UK and US Engineering Directors report directly to the Chief Operations Officer (COO), while the Software Engineering Director reports to the US Engineering Director, who oversees all engineering functions in the US office (hardware and software).

However, not all engineering roles required for a specific product family are collocated. For example, all antenna engineers are part of the UK engineering team i.e., their work schedule is managed by the UK Engineering Director. Furthermore, software engineering is managed through the US office, whereas there is another team located in India as shown in figure 1. It is also apparent that the hardware engineering team in China mainly acts as an interface between the UK-US teams and manufacturing. Their goal is to assist the manufacturing team by transferring the development teams' designs into DFM specifications (design for manufacture) during the last stages of the new product development process.

The main issues arising due to this structuring are listed below:

- Engaging different cultures into collaborating
- Effective communication between distributed engineering teams
- Leadership - Deciding on engineering resource allocation
- Project planning and technology management

III. Organizational Culture

A fundamental issue that multinational companies face, regardless of size, is defining their organizational culture. Since the different regional structures are co-dependent and are required to work together, it is important to firstly quantify the individual organizational culture of each regional office and then based on the outcomes to define the culture of the organization as a whole. However, a summary of several studies indicates that quantifying organizational behavior is not straightforward and depends heavily on the industry [6].

A. Effective Communicaiton

A make-or-break factor that is crucial to the synergy between teams in international organizations is the spoken language. While a team of employees from different countries may not communicate as effectively as a team of employees from the same country, a study indicates that opting for informal language and face-to-face meetings can help bridge the communication and cultural gap [7]. This study moreover recommends that the manager of a subsidiary be familiarized with the culture of the foreign country. A mixture of local and foreign employees within functional teams can also help increase productivity.

Another key factor for communication issues between the geographically separated teams is commonly the time zone difference. In some cases, this can work to the organization's advantage, as one team can pick up where the other one left off, whereas in other cases even a 1-hour difference can be detrimental to the organization's operations [8].

B. Leadership

The effectiveness of the manager responsible for each regional team is crucial to the success of the that team. A study confirms that the member-site (regional structure) leadership is a critical factor influencing site culture and site performance, and that high-performing sites are more prone to initiating collaborative activities with other sites [9].

Though a management structure may be well defined, leadership is more important for achieving positive results and accomplishing goals in engineering projects. A study concluded that members from within the engineering team, demonstrating leadership behavior, are more important in agile environments for successful completion of development work [10]. A further study demonstrates that the performance of individual teams is directly affected by shared leadership within the teams, which is especially important for the overall prosperity of large organizations [11]. The driving factors fostering shared leadership within a team are trust, empowerment, age and maturity, fair reward, disposition and beliefs.

Therefore, it is necessary for managers to nurture product and project ownership among the individual members of the engineering teams for improving performance.

C. Project planning and technology management

The adoption of processes and digital tools is of paramount importance for facilitating the efficient execution of engineering projects. Employing highly skilled personnel is moreover crucial for these processes to be effective, as confirmed by an analytical study reviewing the degree of adoption of Industry 4.0 tools by Italian manufacturing SMEs [12].

Regardless of size, high-tech enterprises providing cutting-edge products or services have the intrinsic need for innovation to remain competitive on local or global scale. Though large multinational enterprises often

allocate resources specifically for research and development purposes with dedicated departments, personnel and budget, smaller enterprises rely heavily on "open innovation' as introduced by [13]. This includes both the influx of innovation from external sources referred to as "technology acquisition", as well as the outflow of innovation incorporated in products and services referred to as "technology exploitation" [14]. Hence, the success of a high-tech SMEs is commonly tied with the exchange of relevant technical information with other organizations.

IV. Recommendations

A significant issue arising in the examined enterprise is the communication between the hardware engineering teams and manufacturing. As mentioned in section (1.2), to alleviate this issue, a hardware engineering team was established inside the production facilities in China. This enabled the hardware engineering teams located in the UK and the US to effectively communicate their designs and receive feedback regarding manufacturing issues. Online meetings were arranged between the engineering teams so that issues and solutions could be communicated. Within this framework, we moreover suggest that these meetings be carried out more often and senior management allow more flexible working hours or home-officing to accommodate for the time zone difference between sites.

The engineering team in China was also given permission to independently solve design-for-manufacture issues whenever possible, for avoiding time wasted until the team responsible for the initial design was available for revisions. Furthermore, the general manager of the Chinese site, who was originally employed in the UK office and offered long engineering experience was assigned to direct the local engineering team.

Among implemented tools and processes, we can identify the use of a global digital parts' database and the Stage Gate model for the development of hardware products, already showing a positive net effect and the scrum for the agile methodology proven to work effectively for software development.

The distributed software engineering teams in the US and India appear to work efficiently, with most issues being solved through regular online meetings, email communications and the use of business communication platforms, as for example "slack". A further tool that could be implemented to improve effective communication of project goals, deliverables and customer requests is the Obeya wall methodology. An excellent use this technique by Siemens, demonstrated improved performance of the development teams and higher engagement of all stakeholders [15].

Moreover, a combination of the Stage Gate and the Agile models could improve quality and reduce the overall time required for the development work for both hardware and software products, as indicated by [16]. This combination enables the segmentation of the development work through the Stage Gate model. Thus, the work is regularly reviewed to verify whether milestones have been met and senior management act upon to approve further allocation of resources. But also, by combining these features with the agile model, the development work shall be easier to adapt when customer feedback and requests are submitted to the engineering teams, thus leading to quicker convergence with customer expectations and higher customer satisfaction.

It was noted that the decision-making process during the initial phases of the new product development process could many times be convoluted. Though this is a common byproduct of the blue sky thinking that is an integral part of the brainstorming process leading to innovation, we propose the garbage can model for decision making. As originally proposed by [17] for better managing day-to-day issues, this model assumes a mix or random yet independent streams of problems, solutions, decision makers and choice opportunities to make decisions on any issue. A revised garbage can model using queues as introduced by [18] could be adapted for use within engineering team meetings.

It is noteworthy that the engineering management decision-making process could be optimized when allocating resources into the individual projects. As per a previously mentioned example in section (1.2), the US Engineering Director technically requires approval by the UK Engineering Director for using antenna engineers in active hardware development projects. The Balanced scorecard method with strategy maps as introduced by [19], could be implemented by senior and engineering management for long-term planning, assessing overall performance, deciding upon resource allocation, and communicating the organization's goals to the engineering teams.

V. Implementation Concerns

The establishment of the engineering team in China had a positive net effect, where the average time from design to finished product and the iterations required were significantly shortened, that led to the Chinese engineering team making even more independent decisions and to be recognized as an integral part to the new product development process. This is considered a positive implementation that helps with waste management, by reducing time required for production, used materials and other inefficiencies that eventually add cost to the final product [20]. We moreover proposed an increased participation in decision making by all engineers through shared leadership and better processes. A potential knock-on effect here would be the negative influence of team members, perceived to be more competent than they are.

A recent study shows that the general perception of competences is directly related to influence in decision-making on different types of issues [21]. Though this study focuses on employee representatives influencing management decisions and resolving issues when they arise, this illustrates that the perceived competence of team members plays a crucial role in decision-making, which may potentially have a negative effect. A typical example here would be a team member fluent in the organizations' formal communication language with less experience and technical skills, perceived to be more competent and thus having more influence in decision making than a counterpart not as fluent in the same language.

We furthermore proposed the introduction of a combined Stage Gate and Agile process for the new product development process, based on its merits as described by [16]. However, sales or field application engineers are required for regular engagement with internal or external customers to provide input to the development team. [22] elaborate in their study on the concerns by senior managers regarding the required additional resources in sales engineering.

VI. Conclusions

We herein review the organizational structure of a high-tech SME developing and manufacturing IoT hardware devices and software products. The reviewed enterprise underwent through the typical rapid expansion backed by venture capital, thus reaching a multinational status in a short period. This exponential growth incurred issues regarding culture, communication, leadership, project planning and management, which are commonly encountered in similar cases. The senior and engineering managers introduced several good practices, digital tools, and processes to address the key issues, with positive signs already showing. The enterprise appears to be on the right track to reach an initial public offering, an objective commonly shared by technological start-ups.

We propose some further improvements based on recent literature that should complement the existing processes by improving the overall efficiency of the organization. Though there are some potential knock-on effects, the proposed measures should be beneficial to the operation of the engineering teams and add value to the enterprise.

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MULTI-FACTOR AUTHENTICATED SECURE DIGITAL LOCKER USING GSM

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ABSTRACT

In this time and age, technology is on an ever-developing trend, bringing with it a plethora of new advancements to daily life and common activities, but with these advancements, a whole new set of issues and vulnerabilities become present. This paper aims to discuss and propose a solution to the vulnerability of physical security lockers, a facet of security that many organisations tend to neglect. It aims to provide an elevated level of security for companies who use physical lockers to secure sensitive information or important contents. More specifically, the paper discusses the plausibility and the advantage of utilising multi-factor authentication with dynamic passwords or OTP code for short and facial recognition to access physical lockers. The proposed system will require employees to have accounts in their respective locker by entering their respective ID and passing the facial recognition feature. The system will then provide the employee with an OTP code, allowing the company an extra layer of security from intruders or malicious individuals.

KEYWORDS: *physical locker security, sensitive information, multi-factor authentication, facial recognition, OTP*

I. INTRODUCTION

Security is one of the most concerning and pressing issues at hand for any organisation. Due to the continuous increase in security breaches every year, it becomes more and more necessary to make our systems less vulnerable to any potential future breaches. An individual can attempt to compromise or even steal property which could threaten the integrity of the capital, information or even persons in homes, banks and offices. Securing physical lockers has become one of the more pressing concerns in need of a solution. Nowadays, lockers are prone to various attack types and multiple threats, particularly physical item theft. To reduce this threat, most companies opt for the implementation of dual authentication systems and alarms on their digital lockers. These digital lockers are composed of electronically secured locking systems that work according to the signals received via the corresponding input keyboards. They are unaffected by tampering attempts and offer the user a variety of security options. The utilisation of an electronic keyboard as the entry lock offers several advantages, such as reliability, strength and ease of use. These digital lockers also offer much flexibility in their setup. They can be programmed to automatically enter lockout mode when left idle for longer than a previously specified amount of time. Moreover, they can also temporarily lock the system for a predetermined duration in the cases when a wrong code input has been received multiple times as a result of an intruder attempting to brute force the code.

It is invaluable for any company, business, or even government organisation to implement a secure system that accounts for any possible attacks, discovers vulnerabilities, and ensures ongoing compliance cost-effectively and safely. This is often not easy to achieve, but it can be possible with secure wireless technologies. In the words of Bruce Schneider: "Security is a process, not a product". This well-known quote is well reflected in the case that while there exist an innumerable amount of security ensuring techniques and best practices nowadays, none of these methods manages to single-handedly achieve all of the security goals for any given organisation, there is always room for more advancements and more secure systems. In this work, the proposed system uses facial recognition as well as a One-Time Password (OTP). As is known, OTP is a dynamically allocated password that is used for a single login session. So, OTP allows the system to overcome several shortcomings present in traditional or static authentication methods such as password-based. This paper proposes a smart locker implementation to ensure secure access and authorisation. This system can implement in a variety of companies, banks, or even for personal use. This is why a mix of facial recognition and OTP is used to subdue unauthorised access attempts. In this proposed system, any registered user can log in by using their identity credentials, and after the face recognition of the valid person as additional authentication, the user sends a request for OTP in order to activate access to their respective locker. The password is then sent to the established individual via Global System for Mobile Communication (GSM) based messaging service, which is currently the most secure cellular telecommunication system. GSM security methods are standardised. It also guarantees end-to-end security by maintaining the confidentiality of messages and the anonymity of the GSM subscriber. The OTP session is set to 15 minutes. OTP offers a primary benefit over static passwords seeing as it is not vulnerable to repeated assaults. OTP has one predefined validity consultation, making it not vulnerable to abuse via hackers or other intruders. Another major benefit of OTP is that it circumvents the vulnerability present when a person uses the same login credentials to access multiple systems seeing as even if passwords are the same, authenticating through OTP will provide an extra layer of security. This paper aims to propose the design and development of a multi-factor authentication based secure digital locker system.

II. LITERATURE SURVEY

Previous research on the topic already exists, with many new and relevant advances made every day. This section discusses some of the mention-worthy papers related to this domain and proves the ever-increasing necessity for more secure systems.

Dey S. et al. [1] presents a home-based web security system that utilises an Arduino microcontroller in conjunction with the Wi-Fi switch. In this case, a simple router is utilised to offer an internet protocol (IP) address to the end-user devices via a corresponding ethernet module.

Shaligram A. et al. [2] introduced a security system for home/office based on GSM technology. The paper proposes different methodologies to utilise for a home security framework. One of these methodologies uses web cameras to alert the owner of a security issue, while another method dispatched a SMS through the usage of GSM and GPS modules. In this case, an atmega644p micro controller became utilised, capturing signals from sensors based totally on making decisions and sending intimation via the use of SMS.

Sharma R. K. et al. [3] proposes an Android based home security system. In this case, an android application used to interpret the message information and in turn provide an answer through SMS, which would light up the light-emitting diode. The signal would then go to mobile as a SMS alert through the use of a GSM modem. Afterwards, the android application would initiate a pop-up alert notifying about the security issue in the house. In this case, as the additional security feature, the authors have also used facial recognition.

MD. Wasi-ur-Rahman et al. [4] describe an approach that uses GSM technology to achieve communication in a remote metering system with devices through the use of SMS. The research demonstrates a method that remotely accesses the electricity meters reading by making use of SMS. Data gathering based on SMS can work very easily and efficiently. Thus, post-paid and pre-paid are both possible to implement utilising this architecture.

Kunal M. et al. [5], the paper discusses the design and the development of a locking system for vehicles. Moreover, it discusses the conception and implementation of an automobile system for theft control and circumvention. The proposed system is made possible through the use of GSM technology in conjunction with an embedded system which is installed onto the vehicle with the cellular-related to the corresponding microcontroller linked to the vehicle engine. If the automobile happens to be stolen, the relevant information is then sent through SMS to the system responsible for central settlement insurance. The microcontroller unit then extracts the SMS information and forwards it to the Global Positioning System (GPS) module, which in turn commands it to be locked or the engine to be switched off. As for the owner of the vehicle, they provided with an account to which they only need to enter the password to access their automobile. Once the valid password has been entered, the microcontroller forwards the SMS to the cell phone number of the account's holder. The individual holding the account can then send the password via a mobile phone with GSM to the relevant microcontroller which in turn compares the passwords received via the mobile phone and entered via the keyboard. If both passwords happen to be correct then the microcontroller will provide the signal required for opening the lock.

Niaz M. et al. [6] presents an IoT based approach to Smart Lockers with the additional use of OTP and facial recognition. First, the user would have to log in and send an (OTP) request code to unlock the locker. After he has received a corresponding feedback e-mail with OTP, he can access the locker's contents. The article also suggests using a facial recognition feature to augment the existing locker security system.

Ajay K. et al. [7] proposes developing a security system for Bank Lockers, which permits the manager to monitor any occurrences and probably catch the applicable frame relying on its benefit. The paper proposes achieving this through properly structuring and organising the application as well as planning of the pages for the site which will then be connected to their corresponding database, capturing pictures through the use of raspberry pi, facial acknowledgment, and facial discovery, thus allowing or denying acces to the clients as neccesary.

Dhoot A. et al. [8] proposes a model for Smart Online Banking Systems (SOBS), which uses biometric authentication and digital signatures to make transactions possible for customers of a bank. The article discusses methods such as machine and data learning, biometric recognition as well as hybridised methods in creating this system, and how they can further help reduce threats and detect intruders.

D.-M. Turner et al. [9] discuss the importance and implications of utilising secure wireless technologies in healthcare and the difficulties faced when implementing them into this particular environment. It uses a case-study approach to investigate these challenges and proposes better practices for secure wireless access for the studied organisations based on the collected data.

Tariq, F. et al. [10] proposes a model for home and industrial automation, which discusses the automation over the GSM-based messaging service. This article discusses multi-factor authentication for home automation, in which the installed system can switch on or off any home appliances via a microcontroller after the verification of the used encrypted key sent via GSM messaging service.

III. AUTHENTICATION TECHNIQUES

In any given system, authentication provides the first line of defence. This is the process in which a system determines if a user or individual is who they claim to be through digital identification so that individuals can have the corresponding level of access or permission necessary to act.

There exist a wide variety of authentication methods, such as fingerprints as well as passwords used to access an individual's identity before allowing them access. It helps add a layer of protection and prevents security issues such as breaches of data. It is worth mentioning that the most secure system reinforcement against possible threats is usually only achieved by combining different authentication methods.

a. Password-based

Passwords are by far the most common authentication method. They can be numbers, a string of letters or special characters, but a secure password generally incorporates all three of these forms. This being the most common form of authentication also makes it the least secure when utilised in a single-factor authentication system as brute force attacks easily bypass it.

b. Biometrics

The term biometrics defines the measuring of any unique personal characteristics like fingerprints, face, voice, retina as well as iris. Nowadays, this term is often used when refering to a method of securing stored data, systems or computers which requires the user to scan the corresponding body part in order to gain authentication. Biometrics are very difficult to fake, but in order to use them, specialised scanning equipment is often necessary, which is often not ideal for projects or industries.

c. Token Authentication

A token refers to a physical device that used in order to access secure devices or systems. Some of the common forms of tokens include an RFID chip, card, or dongle. Tokens make it harder for a malicious individual to gain access to an account since they need to have both the credentials and the physical device itself. Similar to biometrics, tokens are also difficult to fake. The unique digital identification of a token in the form of an RFID chip or key based on more sophisticated security standards attackers cannot easily forge. Nevertheless, tokens themselves are very secure. They can still be easily lost or stolen.

d. Transaction Authentication

The basic idea regarding transaction authentication is its context. This authentication method looks out for reasonable mistakes which can make when one compares the known data regarding an individual with the corresponding information of the current transaction. An example of this would be a user living in one given country, but several purchases made from them logged in from an IP address in a different country. This authentication method is thankfully not dependent on the users, as it is usually outsourced to third-party monitoring teams. However, if a criminal manages to spoof a user successfully, they can fraudulently approve of transactions occurring under false pretences.

e. Multi-Factor Authentication (MFA)

Multiple factor authentication uses a combination of several authentication techniques, all necessary to gain access to the system, thus providing a high-assurance method to verify users. MFA uses factors such as biometric, additional passwords, confirmation based on the device, location, or even behaviour based on information in conjunction with each other to confirm the individuals' identity. This layering of authentication methods allows for increased security as if any of the given methods are bypass. The attacker would still have to deal with the additional authentication methods to gain access to the system.

IV. Proposed Model

This project aims to provide an effective, low cost and more reliable locker security system. The proposed system needs multi-authentication from the user to verify the legitimate access and access only the verified user. After passing the user ID to the locker and after verifying the coordinates of the user's face via the facial recognition method, the microcontroller generates a randomly suitable OTP through the GSM module based on the defined parameters. After passing the OTP code generated via the GSM module, the microcontroller gives the response to the relay and finally opened the locker. The user ID and the OTP code required to open the door must enter into the system via the keypad.

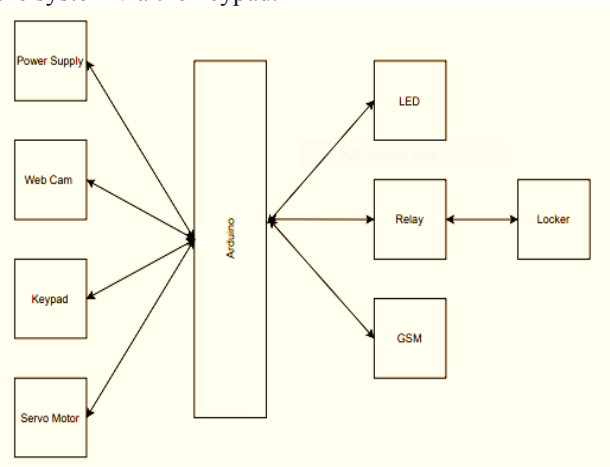

Figure 1: The proposed model

The following Fig. 1 shows the proposed system in the form of a block diagram.

a. Arduino controller

Arduino is simply an Integrated Development Environment (IDE) which runs on a PC and allows users to write C, C++ or any other high-level languages. All programs are installed in the Arduino controller. Arduino is an electronics platform based on easily used and implemented hardware and software while also being open-source. The program is written in Arduino IDE software and burnt onto the Arduino board.

b. Servo Motor

The servo position control method uses a potentiometer. Arduino writes every position value to angular position according to the input change. This method provides not the exact servo position as input, or the user cannot write this Servo position in exact degrees, unless the values entered via the serial keypad. This is an easy way to move the servo motor's position by specifying the degree of the angle as a numerical value. So, we used a servo motor in this paper for better detection of both the face movement and the position of the keypad.

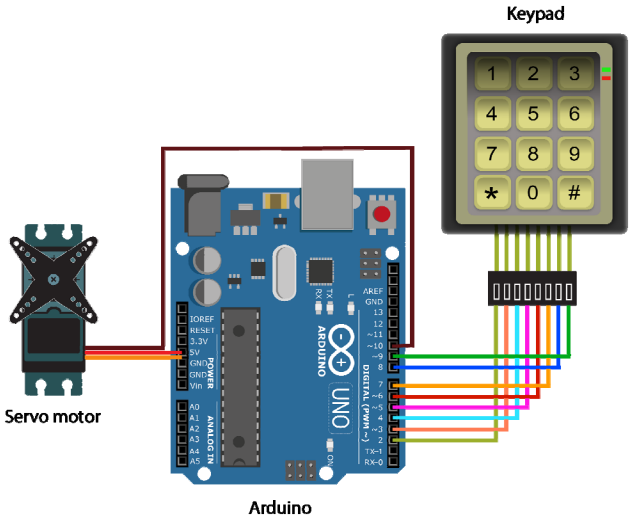

Figure 2: Servo Motor

c. GSM Module

GSM Module is used to provide data transfer to a remote network. After entering the correct user password and detecting the face, the microcontroller generates a random OTP based on the defined length and transmits it via GSM Module to the user's defined cellular network. So, the microcontroller is only switched on the relay after the verification of the respective OTP.

d. Facial Recognition

Facial recognition is a biometric technique used by digital locker systems because it is secure and controls overlocker access. Many algorithms have developed and proposed to achieve facial recognition, including Evolutionary Pursuit (EP), Principal Component Analysis

(PCA), Kernel methods, 3-D face recognition, Independent Component Analysis (ICA), Active Appearance Model (AAM) and Support Vector Machine (SVM).

e. Evolutionary pursuit (EP):

This is an adaptive eigenspace-based approach which appears for the superior set of projection axes to maximise the fitness feature when calculating type accuracy and the system's capability to generalise. Since the dimension corresponding to the solution space for this issue is very large, it is resolved utilising a certain genetic algorithm called Evolutionary Pursuit (EP).

f. Principal Component Analysis (PCA):

It is derived from the Karhunen-Loeve transformation and provided with a s-dimensional vector instance of every face present in the set of training images. PCA tries to determine t-dimensional subspace whose base vectors speak with the full existing variance path in the initial image space.

g. Kernel methods:

Here the facial distributor present in the subspace does not necessarily have to be linear. Kernel methods can be thought of as a generalisation of linear methods and may conceptualise as instance-based learners: instead of learning a fixed set of given parameters relating to the features of their inputs, they rather "remember" the example in training and learn the corresponding weight for it. For studying this nonlinear distribution, direct nonlinear distribution schemes have studied.

h. 3-D face recognition:

The principal innovative element provided with the aid of this approach is its capability in evaluating surfaces independently of any natural deformations taking place on facial expressions. Firstly, the distance image, as well as the face texture, is captured. The image has to delete then preprocessed by removing certain parts that can needlessly overcomplicate the recognition process, such as hair. Lastly, the canonical shape presented by the front surface has calculated. This representation is not sensitive to head orientation or facial expression, which greatly simplifies the process of recognition that occurs on canonical surfaces.

i. Independent component analysis (ICA):

Independent component analysis (ICA) enables the minimisation of the second and higher-order dependencies present within the input information, even when trying to find a basis on which the statistics can be statistically impartial.

j. Active Appearance Model (AAM)

The Active Appearance Model(AAM) provides an integrated model which intertwines the shape replacement version with a shape change model in a form-normalized structure. AAM consists of a statistical version of the appearance and the shape of the interesting object in grayscale that is generalized to almost every possible legitimate instance. Image acquisition includes the acquisition of version parameters which reduce the difference between the images and the synthesized model shown in the picture.

k. Support Vector Machine (SVM):

For a chain of factors that belong to two distinct training, Support Vector Machine (SVM) will discover a hyperplane that shares the maximum capable fraction of points of the equal corresponding class on one side, while also maximising the space between both pieces of training as well as the hyperplane itself. PCA is first utilised inside the extraction of functions from facial images and afterwards during the use of recognition features in-between each pair of pictures found out with the help of the SVM.

The facial recognition algorithm aims to detect and extract the features of the user's face and save them into the database for future matching. After narrowing down the different algorithms for face recognition, we select a PCA based face recognition algorithm. We divided it into phases: the training phase and the recognition phase.

Face recognition is the most important part of this paper because, without accurate recognition, the system would not give access to a given user's locker. The human face is a very complex multi-dimensional structure. So, there is a need to use a more effective technique. We picked the Eigenface technique.

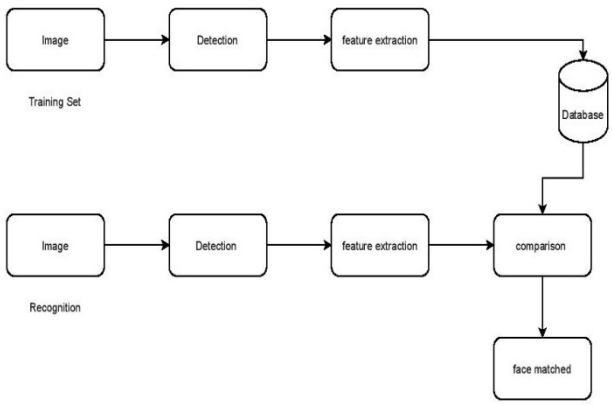

Figure 3: Face recognition steps

V. PROPOSED ALGORITHM

The microcontroller gets inputs from the web to verify the user's verification via facial recognition method and the keypad used to enter the required user ID, giving a suitable output response to LED and GSM. The microcontroller generates a random suitable OTP through the GSM module. After passing the password generated via GSM, the microcontroller passed the relay's response and finally opened the locker.

a. Algorithm 1: Face Recognition Algorithm

Step 1: Facial image **conversion** tested by n*n size into a column vector $v_{i\ n^2}$

Step 2: Facial image **normalisation** as an input to training images to evaluate its value for distinct matrix x_{input} by reducing the average value to its train images.

Step 3: Compute the weight of trial images by multiplying Eigenval Transpose Matrix $\underset{V}{\rightarrow} t$ to the matrix

$x_{input}\, matrix\ (W_{input})$

$W_{input} = \underset{V}{\rightarrow} t\ x_{input}$

Step 4: Evaluate different image's distance for testing images with the train face image by using Euclidean distance.

$$\varepsilon_i = \sqrt{||W - W_{input}||^2}$$

Where i = 1……N

The result to identify face is the image with the minutest distance with its test image to display by the system.

b.

c. Steps for the System Testing

It determines the system is working, whether it is working properly or not. It is important to the test system is running properly or not to identify the images.

Step 1: Training: In this process, the system is in the training stage. In this, it aims to generate value's weight for each existing training image.

Step 2: Image Recognition: This process occurs after the successful implementation of the training process. In this stage, image recognition carries out to recognise and test all the required images properly. It contains two sub-stages

- The training image is similar to the testing image
- The training image is not similar to the testing image

These training data will assure a 100 per cent identification system. Therefore the proposed system has precise value and provides security from the authentic user. It saves the system from various unknown attacks and protects the user's crucial data.

VI. Conclusion

This work proposes a multi-factor authenticated secure digital locker to enhance the security of valuable assets. The proposed system ensures security by providing an OTP on top of the dual-authentication. In the first step, an individual's identity credentials in conjunction with facial recognition techniques are utilised to authenticate the user. After the dual-authentication of the user, the system generates an OTP for their corresponding personal device and sends it via the GSM module, thus providing an extra layer of security for ensuring the authentication of the valid user. Moreover, the PCA algorithm is utilised for face detection because it is easier for the classifier to extract faces when data is spread out instead of grouping them. The proposed digital locker is more secure than traditional digital lockers because it provides a dynamic key via OTP on top of dual-authentication instead of traditional keys used in unlocking lockers. It provides a highly reliable and secure system alternative to amplify the security of valuable assets.

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CHAPTER 7. DIGITAL TRANSFORMATION AND DATA RISK MANAGEMENT IN ICT/TELECOMMUNICATION

CHAPTER 8. DEVELOPING PERSONAL SKILLS FOR LEADING INNOVATION INITIATIVES

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BCH CODES DECODER BASED ON EUCLID ALGORITHM

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ABSTRACT

In the process of algebraic decoding of BCH codes over the field GF(q) with the word length n = qm-1, correcting t errors, both in the time and frequency domains, it is necessary to find the error locator polynomial ?(x) as the least polynomial for which the key equation. Berlekamp proposed a simple iterative scheme, which was called the Berlekamp-Messi algorithm, and is currently used in most practical applications. Comparative statistical tests of the proposed decoder and decoder using the Berlikamp-Messi algorithm showed that they differ slightly in decoding speed. The proposed algorithm is implemented in the environment in Turbo Pascal and can be used for the entire family of BCH codes by replacing the primitive Galois polynomial.

KEYWORDS: *Berlekamp-Messi algorithm, Euclidean algorithm, BCH codes, Galois polynomial, decoder*

I. INTRODUCTION

In the process of algebraic decoding of BCH codes over the field *GF(q)* with the word length $n = q^m-1$, correcting t errors, both in the time and frequency domains, it is necessary to find the error locator polynomial $\Lambda(x)$ as the least polynomial for which the key equation [1]

$$\sum_{k=0}^{n-1} \Lambda_k e_{j-k},\ j = 0,1,...,n-1. \qquad (1)$$

The degree of the polynomial $\deg \Lambda(x) \le t$ and $\Lambda_0=1$, so (1) takes the form:

$$e_j = -\sum_{k=1}^{2t} \Lambda_k e_{j-k},\ j = 0,1,...,n-1,$$

and it is possible to cyclically obtain all e_j and Λ_k components.

For non-binary BCH codes, in addition to the error locator equation, it is necessary to find a polynomial of error values *E(x)* in the frequency space, which is associated with $\Lambda(x)$ and the error syndrome *S(x)* equation, which in this case is also a key equation [2].

$$E(x) = (\Lambda(x) \cdot S(x)) \bmod x^{2t}, \qquad (2)$$

at that, $\deg \Lambda(x) \le t$, and $\deg E(x) \le t-1$.

II. FORMULATION OF THE PROBLEM

In the first published procedures for solving the key equation, standard matrix inversion methods were used. However, later, Berlekamp proposed a simple iterative scheme, which was called the Berlekamp – Messi algorithm, and is currently used in most practical applications [1, 3]. More recently, it was shown that the solution of a key equation can also be obtained using the Euclidean algorithm. **The purpose of this work** is to develop an algorithm for decoding BCH codes based on the Euclidean algorithm, which is simple and versatile, and software for experimental research and comparison with the Berlekamp-Messi algorithm.

III. ALGORITHM FOR SOLVING THE KEY EQUATION

The solution of equation (3) can be obtained using the Euclidean algorithm.

The Euclidean algorithm is a recurrent method for determining the greatest common divisor of two polynomials (or two integers) over the field *GF(q)*.

For example, if $\deg s(x) \ge \deg r(x) \ge 0$, then in accordance with the Euclidean algorithm

$$\begin{aligned} s(x) &= d_1(x) \cdot r(x) + r_1(x), \\ r(x) &= d_2(x) \cdot r_1(x) + r_2(x), \\ r_1(x) &= d_3(x) \cdot r_2(x) + r_3(x), \\ &\ldots\ldots\ldots\ldots\ldots\ldots \\ r_{n-2}(x) &= d_n(x) \cdot r_{n-1}(x) + r_n(x), \\ r_{n-1}(x) &= d_{n+1}(x) \cdot r_n(x) + 0. \end{aligned} \qquad (3)$$

As a consequence, it turns out that

$$r_n(x) = a(x)s(x) + b(x)r(x), \qquad (4)$$

where $a(x)$ and $b(x)$ - polynomials over the field *GF*(*q*).

From intermediate iterations (4), it can be noted that each subsequent equation is obtained from the two previous ones according to the following rule

$$r_i(x) = r_{i-2}(x) - q_i(x) \cdot r_{i-1}(x),$$

where $d_i(x)$ - quotient from dividing polynomials $r_{i-2}(x)$ by $r_{i-1}(x)$ for non-negative degrees x

$$d_i(x) = \left| \frac{r_{i-2}(x)}{r_{i-1}(x)} \right|. \qquad (5)$$

The connection of the Euclidean algorithm with the problem of solving the key equation (3) becomes obvious if we represent equation (4) in the form

$$b(x)r(x) \equiv r_n(x) \bmod s(x).$$

Then, assuming that $s(x) = x^{2t}$, and $b(x) = S(x)$, $r(x) = \Lambda(x)$, $r_n(x) = E(x)$, get the key equation (2) in the form $\Lambda(x)S(x) \equiv E(x) \bmod x^{2t}$.

Thus, to solve the key equation, the Euclidean algorithm should be applied until the condition $\deg E_i(x) < t$. The description of the method for solving the key equation is summarized for the BCH codes correcting t errors:

1. Apply the Euclidean algorithm to $s(x) = x^{2t}$ and $b(x) = S(x)$,
2. Adduc

$$d_i(x) = \left| \frac{r_{i-2}(x)}{r_{i-1}(x)} \right| = \left| \frac{E_{i-2}(x)}{E_{i-1}(x)} \right|,$$

$$E_i(x) = E_{i-2}(x) - d_i(x) \cdot E_{i-1}(x),$$

$$\Lambda_i(x) = \Lambda_{i-2}(x) - d_i(x) \cdot \Lambda_{i-1}(x);$$

3. Use initial conditions:

$$\Lambda_{-1}(x) = 0, \Lambda_0(x) = 1,$$
$$E_{-1}(x) = x^{2t}, E_0(x) = S(x);$$

4. op, when $\deg E_i(x) < t$;

5. Adduc $n = i,\ \Lambda(x) = \Lambda_n(x),\ E(x) = E_n(x)$.

To calculate $d(x)$ in algorithm (5), we use the simplified iterative procedure proposed in [2]

$$d_{b-a-i} = \frac{1}{r_a}\left(S_{b-i} - \sum_{j=0}^{i-1} d_{b-a-j} r_{a-j-i}\right) = \left|\frac{E_{i-2}(x)}{E_{i-1}(x)}\right|,$$

where $b = \deg s(x),\ a = \deg r(x)$, and the degree of the quotient $d(x)$ is (*b*-*a*) and depends on $r(x)$ only through the coefficients of this polynomial $r_a, r_{a-1}, ..., r_{b-a}$.

This procedure for calculating the quotient must be repeated at each step of the Euclidean algorithm so that at the first step it has the form:

$$d_1 = \frac{S_{2t}}{E_{(2t-1)}};\quad d_0 = d_1 \cdot \frac{E_{(2t-2)}}{E_{(2t-1)}};$$

and on the intermediate and last iteration steps:

$$d_{(j-i)} = \frac{E_{(b-i)}^{(n-2)} - \sum_{ii=0}^{i-1} d_{(b-ii)} \cdot E_{(a-i-ii)}^{(n-1)}}{E_a^{(n-1)}},$$

where $b = \deg[E^{(n-2)}(x)],\ a = \deg[E^{(n-1)}(x)]$; $j = (b-a)$; $i = 0, ..., j$; the superscript of the coefficients $E_{(i)}^{(j)}$ indicates the iteration number, and the lower one the degree of x of the equation $E^{(j)}(x)$, at which this coefficient should be taken.

After solving the key equation using the Euclidean algorithm, the positions and error values in the received codeword are determined as usual by the solution of $\Lambda(x)$ and $E(x)$ [2]. In the first case, the roots of the equation $\Lambda(x)$ are found using the Chen procedure [2], given that the ith symbol is erroneous if $\Lambda(\alpha^{-i})=0$ or:

$$\Lambda(\alpha^{-i}) = \sum_{k=0}^{t} \Lambda_k \alpha^{-ik} = 0. \qquad (6)$$

It remains to find all values of *i* for which equality (6) is satisfied.

The error values in the *i* positions can be determined using the Forney algorithm

$$e_i = -\frac{E(\alpha^{-i})}{\Lambda'(\alpha^{-i})} = -\frac{\sum_{k=0}^{t} E_k \alpha^{-ik}}{\Lambda'(\alpha^{-i})},$$

where $\Lambda'(\alpha^{-i})$ - derivative $\Lambda(x)$ at $x = \alpha^{-i}$ for a binary Galois field is

$$\Lambda'(x) = \Lambda_1 + \Lambda_3 x^2 + \Lambda_5 x^4 + ...$$

The decoding algorithm for non-binary BCH codes (Reed Solomon codes) using the Euclidean algorithm for solving the key equation is shown in Figure 1. The most complex operations are Fourier transforms at the beginning and at the final stage of decoding (Forney procedure). Therefore, the BCH binary decoder is faster.

The decoding process requires the computation of Galois field elements and the multiplication of field elements. Since the multiplication operation is reduced to the summation of the exponents of the elements, the elements of the Galois field should be defined both in the form of the exponents of the powers of the elements and in the binary representation.

IV. Research results

Consider the decoding process of the binary BCH code (63,51), which corrects ≤ 3 errors in the Galois field $GF(2^6)$ over a primitive polynomial

$$p(x) = x^6 + x^5 + 1.$$

Three errors occurred in the channel in the 42nd, 21st and 16th symbols and the error polynomial has the form

$$e(x) = x^{42} + x^{21} + x^{16}.$$

1. Calculating the syndrome of errors in the frequency space:

$$S(x) = \alpha^{33}x^5 + \alpha^3 x^4 + \alpha^{48}x^3 + \alpha^6 x^2 + \alpha^{47}x + \alpha^{33}.$$

2. nding the solution of the key equation using the Euclidean algorithm:

$$E_0(x) = S(x),\ \text{a}\ V_0(x) = 1.$$

The process of solving the iterations is shown in Table 1.

Table I

Process of calculation of error locator equation

r	0	1	2	3
Deg $[E_{r-1}]$	5	5	4	3
$d_r(x)$		$\alpha^{30}x + \alpha^{44}$	$\alpha^{20}x + \alpha^{40}$	$\alpha^{60}x + \alpha^{24}$
$V_r(x)$	0	$\alpha^{30}x + \alpha^{44}$	$\alpha^{50}x^2+\alpha^2x+\alpha^{42}$	$\alpha^{47}x^3+\alpha x^2+\alpha x+\alpha^{31}$
$E_r(x)$	$S(x)$	$\alpha^{13}x^4+\alpha^{28}x^3+\alpha^5x^2+\alpha^{17}x+\alpha^{14}$	$\alpha^{16}x^3+\alpha^{33}x^2+\alpha^{33}x+\alpha^{12}$	$\alpha^{28}x^3+\alpha^{48}x^2+\alpha^{17}x+\alpha^{36}$

3. Transform the resulting error locator equation into a temporary space (Fourier transform). We obtain an equation $v(x)$, it values of the field elements of which

from x^{63} to x^{0} (from left to right) are shown below in decimal representation:

(29, 39, 44, 32, 36, 45, 33, 23, 40, 41, 47, 49, 22, 50, 43, 24, 42, 12, 50, 46, 0, 33, 57, 2, 52, 32, 19, 3, 39, 18, 57, 21, 45, 4, 56, 1, 50, 12, 2, 42, 14, 0, 45, 17, 20, 12, 0, 31, 39, 25, 60, 33, 57, 5, 30, 40, 5, 6, 8, 48, 32, 40, 2).

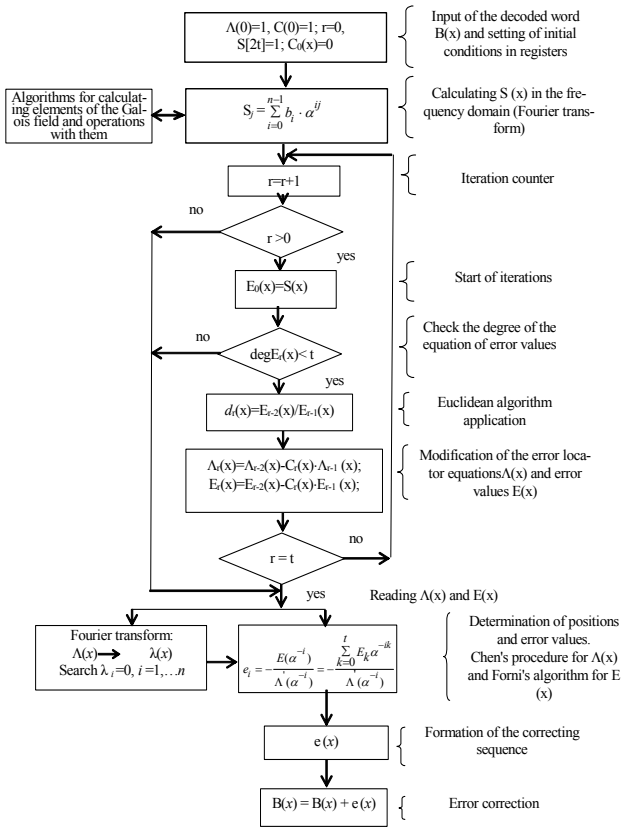

Fig. 1. Algorithm for decoding BCH codes by the Euclidean algorithm for non-binary codes

4. Zero val s of field elements occur at x^{42}, x^{21} and x^{16}, which indicates the position of errors.

V. Conclusions

Comparative statistical tests of the proposed decoder and decoder using the Berlikamp-Messi algorithm showed that they differ slightly in decoding speed. The algorithm proposed in Figure 1 is implemented in the Turbo Pascal environment and can be used for the whole family of BCH codes by replacing the primitive Galois field polynomial.

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EFFICIENT IMPLEMENTATION OF FPGA-BASED FORWARD ERROR CORRECTING COMBINATION AND BIT TO CELL WORD DE-MULTIPLEXER FOR A SECOND GENERATION DIGITAL TERRESTRIAL TELEVISION BROADCASTING SYSTEM

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ABSTRACT

This report focus on the implementation of FEC part. The motivation of the design is that FEC is an effective tool to mitigate problems associated with OFDM which stem from multipath fading channel, high speed data rate. One of the key features of BCH codes is that during code design, there is a precise control over the number of symbol errors that are correctable by the code. BCH coder proccesses parralelly with high-speed operation. 8-bit parallel data input and output helps to maximize the through-put. DVB-T2 used LDPC coder, as inner codes with word length up to 64,800 bits, enabling significant proximity to Shannon limit. This encoder supports all code rates and both normal and short frames. Output of LDPC encoder is interleaved with bit interleaver.

This project was fully optimized for speed and memory area, fully synchronized by using a single clock. The design was coded in VHDL, synthesized by using Xilinx ISE Design Suite 14.7. The design has been tested on development Kit NetFPGA-1G-CML of Digilent Corporation and the bit map was downloaded into Xilinx Kintex-7 XC7K325T-1FFG676, which is integrated on experimental transmitter system DVB-T2. This research product belong to program "Research of experimental testing of second generation digital terrestrial television broadcasting system DVB-T2" of Vietnamese Communications Television Development JSC.

KEYWORDS: *cardiovascular diseases, random forest, k-neares*

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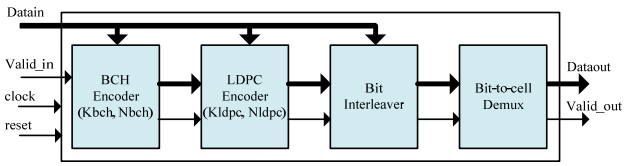
DVB-T2 (Digital Video Broadcasting - Terrestrial for Second generation) is a transceiver system of modern digital television nowadays, which have strong resistance to interference due to concatenated channel coding and bit interleaving combination. The forward error-correcting (FEC) includes Bose-Chaudhuri-Hocquenghem multiple error correction binary block code (BCH), Low Density Parity Check coder (LDPC) and bit interleaver. This coding combination has been developed by Xilins into IP Core based on the standard that used for DVB-S2 system and can be used compatibly for system DVB-T2.

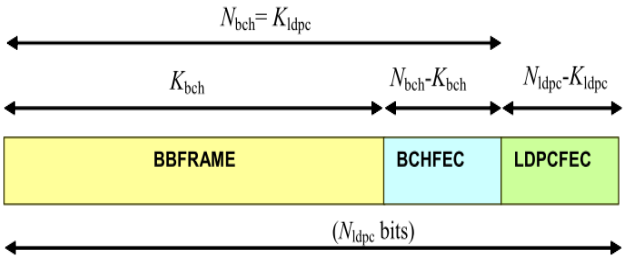
However, as well as other commercial companies in the world, product IP Core is copyrighted, users have to purchase the license and that license is used only one time for one computer. Morever, the final version LogiCORE IP DVB-S.2 FEC Encoder v2.0 of the Xilinx from 02/12/2009 has not developed further and integrated into programming Xillinx tools of FPGA. Therefore, the article named "Efficient implementation of FPGA-based forward error correcting combination and Bit to cell word de-multiplexer for a second generation digital terrestrial television broadcasting system" presents the design of a single FPGA intellectual property (IP) core for channel coding combination and Bit to cell word de-multiplexer. This design will be an open source for products of digital television systems.

This report focus on the implementation of FEC part. The motivation of the design is that FEC is an effective tool to mitigate problems associated with OFDM which stem from multipath fading channel, high speed data rate. One of the key features of BCH codes is that during code design, there is a precise control over the number of symbol errors that are correctable by the code. BCH coder proccesses parralelly with high-speed operation. 8-bit parallel data input and output helps to maximize the throughput. DVB-T2 used LDPC coder, as inner codes with word length up to 64,800 bits, enabling significant proximity to Shannon limit. This encoder supports all code rates and both normal and short frames. Output of LDPC encoder is interleaved with bit interleaver.

According to the literature [1, 8-10], the MPEG data stream after the input processing module is protected by a combination of BCH and LDPC. Then the bits are interleaved and modulated. The structural design diagram is presented below:



In general, this scheme is based on the Xilinx IP core, as shown in Fig. 1 [2]. The difference with Xilinx IP Core is that our design does not use a FIFO, but rather takes memory to store and process data. Therefore, the memory size is small. The data frame format is depicted in the following figure.



Where, K_{bch} - the length of the BBFRAME of the frame supplied to the BCH code, Nbch is the length of the data block, including the BBFRAME frame and the BCH data behind it.$K_{ldpc} = N_{bch}$ - this is the length of the data block that is received in the LDPC code. N_{ldpc} - data length at the LDPC code output.

As in [3], a specific implementation of BCH on FPGA with optimization of resources and processing speed is presented. The parameters of the BCH and LDPC codes Nbch, Kbch are selected in table 6a for the data stream, and for signaling in table 6b [1]. BCH correcting coding (Nbch, Kbch) must be applied to every BBFRAME frame to form an error-proof packet. The BCH generator polynomial of the encoder to correct t errors is obtained by multiplying the first t polynomials in Table 7a / 7b [1].

$$g_1(x) \quad 1 + x^2 + x^3 + x^5 + x^{16} \tag{1}$$

$$g_2(x) \quad 1 + x + x^4 + x^5 + x^6 + x^8 + x^{16} \tag{2}$$

$$g_3(x) \quad 1 + x^2 + x^3 + x^4 + x^5 + x^7 + x^8 + x^9 + x^{10} + x^{11} + x^{16} \tag{3}$$

$$g_4(x) \quad 1 + x^2 + x^4 + x^6 + x^9 + x^{11} + x^{12} + x^{14} + x^{16} \tag{4}$$

$$g_5(x) \quad 1 + x + x^2 + x^3 + x^5 + x^8 + x^9 + x^{10} + x^{11} + x^{12} + x^{16} \tag{5}$$

$$g_6(x) \quad 1 + x^2 + x^4 + x^5 + x^7 + x^8 + x^9 + x^{10} + x^{12} + x^{13} + x^{14} + x^{15} + x^{16} \tag{6}$$

$$g_7(x) \quad 1 + x^2 + x^5 + x^6 + x^8 + x^9 + x1^0 + x^{11} + x^{13} + x^{15} + x^{16} \tag{7}$$

$$g_8(x) \quad 1 + x + x^2 + x^5 + x^6 + x^8 + x^9 + x^{12} + x^{13} + x^{14} + x^{16} \tag{8}$$

$$g_9(x) \quad 1 + x^5 + x^7 + x^9 + x^{10} + x^{11} + x^{16} \tag{9}$$

$$g_{10}(x) \quad 1 + x + x^2 + x^5 + x^7 + x^8 + x^{10} + x^{12} + x^{13} + x^{14} + x^{16} \tag{10}$$

$$g_{11}(x) \quad 1 + x^2 + x^3 + x^5 + x^9 + x^{11} + x^{12} + x^{13} + x^{16} \tag{11}$$

$$g_{12}(x) \quad 1 + x + x^5 + x^6 + x^7 + x^9 + x^{11} + x^{12} + x^{16} \tag{12}$$

Insert Kbch bits of the message arriving in the BCH code, M = (mKbch-1, mKbch-2, ..., m1, m0). First, we multiply the information word by xNbch-Kbch. We get:

$$(m_{Kbch-1}x^{Kbch-1} + m_{Kbch-2}x^{Kbch-2} + \ldots + m_1x + m_0).x^{Nbch-Kbch} \quad (13)$$

где:

$$m(x) = (m_{Kbch-1}x^{Kbch-1} + m_{Kbch-2}x^{Kbch-2} + \ldots + m_1x + m_0) \quad (14)$$

is called the message polynomial.

This multiplication is done in the FPGA chip by left-shifting (Nbch - Kbch) bits.

Then the resulting polynomial is divided by the generator polynomial g (x). The remainder will be:

$$d(x) = d_{Nbch-Kbch-1}\, x^{Nbch-Kbch-1} + \ldots + d_1x + d_0 \quad (15)$$

Compilation of the output codeword I, which forms an information word for LDPC coding, namely:

$$I = (i_0, i_1, \ldots, i_{Nbch-1}) = (m_{Kbch-1}, m_{Kbch-2}, \ldots, m_1, m_0, d_{Nbch-Kbch-1}, \ldots d_1, d_0) \quad (16)$$

The equivalent polynomial of the codeword is

$$c(x) = m(x).\, x^{Nbch-Kbch} + d(x) \quad (17)$$

This is an *I* encoding word with length $K_{ldpc} = N_{bch}$ protected by LDPC code. He will calculate (N_{ldpc} - K_{ldpc}) parity bit ($p_0, p_1, \ldots, p_{Nldpc - Kldpc-1}$) for each information block k_{ldpc} bit ($i_0, i_1, \ldots, i_{Kldpc-1}$). As a result, we get the coding word Λ with length N_{ldpc}:

$$\Lambda = (\lambda_0, \lambda_1, \ldots, \lambda_{Nldpc-1}) = (i_0, i_1, \ldots, i_{Kldpc-1}, p_0, p_1, \ldots, p_{Nldpc-1}) \quad (18)$$

LDPC is a binary line parity code. A special feature is the low density of significant elements of the check matrix, due to which the relative ease of implementation of the coding tools is achieved. LDPC codes are described by a low density parity check matrix containing mostly zeros and a relatively small number of ones. The positions of the units are given in Appendix A and B [1].

The output data Λ of the LDPC encoder shall be bit interleaved, which consists of parity bit interleaving followed by a spin-column interleaving procedure. The output of the parity interleaver is U and the output of the spinning interleaver is V.

In the parity bit interleaver, the parity bits are interleaved according to the formulas:

$$u_i = \lambda_i \text{ , для } 0 \le i < K_{ldpc} \quad (19)$$

$$u_{Kldpc + 360t + s} = \lambda_{Kldpc + s.Qldpc + t} \text{ , для } 0 \le s < 360,\ 0 \le t < Q_{ldpc} \quad (20)$$

where Q_{ldpc} specified in tables 8a and 8b [1].

In a spin-column interleaver, the data bits ui from the parity bit interleaver are alternately written column-by-column to the column-spin interleaver and are alternately read line-by-line therefrom. Input bit u_i with index *i*, where $0 \le i < N_{ldpc}$, written to a column c_i, string r_i interleaver, where:

$$c_i = i \text{ div } N_r \quad (21)$$

$$r_i = (i + t_{ci}) \bmod N_r \quad (22)$$

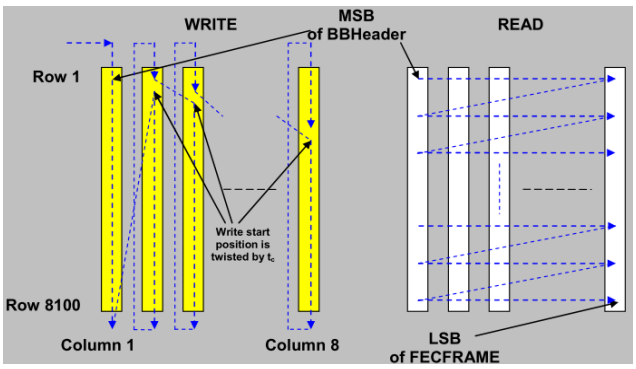
Input bit v_j with index $0 \le j < N_{ldpc}$ read from string r_j, column c_j, where

$$c_j = j \text{ div } N_c \quad (23)$$

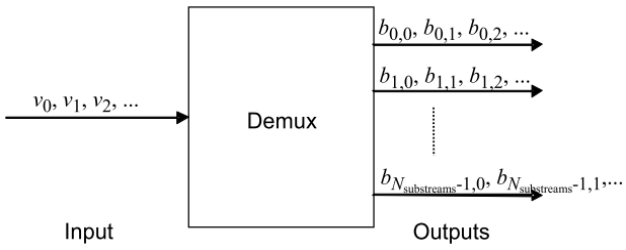
$$r_j = j \bmod N_c \quad (24)$$

where, N_r и N_c – the number of row and column of the bit interleaver, which depends on the type of modulation; the starting position of the record in each column is shifted by t_c according to the table.

Bit interleaving scheme for standard FECFRAME frame length and 16-QAM.



After FEC encoding, the data is bit-demultiplexed into Nsubstreams of cell substreams to convert them to constellations. The number of Nsubstreams depends on the type of modulation and is indicated in table 12 [1], as shown in the following figure:



A set of design parameters is selected in [4]. The results obtained from control points 5, 6, 7a, 7 [5] are compared with the reference dataset [6].

The design is implemented on the Xilinx Kintex-7 XC7K325T-1FFG676 chip of the Digilent NetFPGA-1G-CML Development Kit [7]. The generated FPGA chip resource report for coding ratio 3/4 and modulation 64-QAM is shown in the following table.

Table

Slice Logic Utilization	Used	Available	Utilization
Number of Registers	34,203	407,600	8%
Number of Slice LUTs	29,943	203,800	14%
Number of occupied Slices	12,604	50,950	24%
Number of RAMB36E1/FIFO36E1s	0	445	0%
Number of RAMB18E1/FIFO18E1s	11	890	1%
Number of DSP48E1s	0	840	0%

This design was part of the project "Publishing the transmitter of the DVB-T2 system of the Vietnamese Television Development Company". The system is precisely functioning. Especially, the design is implemented in an open manner and has the ability to match with other television systems.

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TRAVEL ROUTE PLANNING AND TRACKING APPS

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ABSTRACT

The quality of a tourist trip depends on many factors, and one of the essential is route consistency route. This geographical factor influences the popularity, usefulness, efficiency and tourist travel safety. Drawing up logical routes requires not only a maximum of regional information, but also the developer experience. The creation of clear and convenient routes will allow for more organized tourism activities and reduce the chaotic load on the natural environment. Based on the analysis of applications for planning and tracking routes, this article focuses on the methodology for calculating the time of passage of multi-day cycling routes in main categories and solve the problem of symbiosis between geography and tourism practice. Article will talk about programs that will help you create a route and stick to it along the way.

KEYWORDS: *3D mapping, outdoor navigation, cycling routes, adaptive planning*

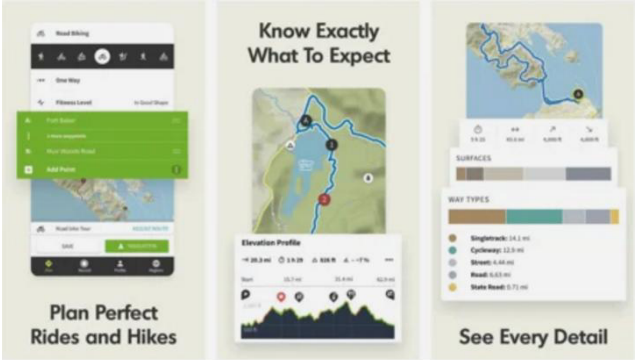
There are many useful apps and gadgets for travelers. In this section, author will talk about programs that will help you create a route and stick to it along the way [3, 4].

AllTrails provides detailed and hand-picked hiking maps. All maps have reviews, photos from the huge community of the application. The database contains more than 100,000 routes filtered by the required parameters. Use this app for hiking, cycling and running around the world. Download the route of your hike, walk, run or mountain bike ride to your GPS device. Looking for a good place for camping or hiking? The AllTrails community is a great place for inspiration. Download offline maps and start your outdoor adventure.

- AllTrails has the largest collection of GPS trail maps, topographic maps, and downloadable offline maps for trails in national parks and your area.
- Discover the street with new mountain bike, jogging or hiking trails, with reviews and ratings from the hikers, cyclists and trail runners community.
- Find a hike, mountain bike ride, or trail that's perfect for your fitness level and experience.
- Record your outdoor adventures with the AllTrails GPS activity tracker.
- Turn your phone into a GPS activity tracker and follow your trail so you don't get lost while walking outdoors.
- View stats for walking, running and cycling at a glance.
- Share your latest hiking, running and mountain biking with your friends on Facebook, Instagram and WhatsApp.

With this application, you can record your movements during hikes in automatic mode, as well as create your own routes and maps. Upon completion, the statistics can be viewed.

Komoot will help you plan your mountain bike route. Offline voice navigation is supported. There is a large database of ready-made routes.



The Komoot app allows you to motivate yourself and makes you run, walk, ride a bike. This application provides all the necessary indicators, and cycling becomes more interesting and brighter. If you want to receive statistics and a lot of other information about your sports activities, then I recommend using this program.

Statistics allows you to get information about what has been done, how much passed, and so on. It is worth stopping here in more detail and talking about what the application gives out as information. Let's start with the distance - the application counts how many meters, or kilometers, you drove. This is important, because just skating thoughtlessly quickly gets boring and you want some kind of records - to drive 20, 40 or 50 kilometers. The program counts all this and then shows it at the end of the trip, it is very convenient and helps to take care of yourself. There you can also see the duration of the trip, average speed and calories that you burned during the trip. A very useful thing, you can always look at the results at the end of the trip and draw conclusions - how did you ride in comparison with other days.

The application provides a rather interesting function of choosing a route along which you will go later. This is a very cool function, in fact, you just sit on the sofa and choose where and where you want to go, immediately see the distance and figure out if you can overcome it or not, then get on your bike and leave. The application not only shows on the map where you are driving, but can also act as a navigator.

For cycling routes, the type of road is displayed. Points of interest and elevations have been mapped by the community. Trips can be automatically tracked in the app and shared with friends.

Of course, there were some drawbacks. To begin with, the battery lasts for a very short time and if you want to use its navigator during a trip, it is better to immediately charge the gadget to 100% and even a portable battery will not be superfluous. There are also problems with navigation on the ground - you are driving, but the application shows that you are standing, and then abruptly throws you to the desired point without adding the distance traveled. This happens very rarely, but it does happen and it is not entirely pleasant.

You can use the application not only for cycling - you can run, ride in the mountains, and so on. There is nothing special here, the functions are, in principle, quite standard, but the ability to plot a route and then follow it with

navigation is very interesting, because if you travel long distances in an unfamiliar area, it will be very useful.

The Hiking Project offers deep map detail comparable to the printed version. Navigation, hills, photos of places and more. The app suggests places to visit along the route.

The community can supplement the maps with their information or create their own routes.

The Hiking Project is revising maps and travel guides. Like a printed route map, the app shows you all known routes. Complete with elevation profiles, full GPS routes, photos and more. As a guide, the program shows you the best recommended hikes that use these routes. Highlights, challenges, special features to look for, local contacts, and even a Virtual Hike so you can experience everything before you hit the road.

If you love exploring outdoors, having a hiking app is equally important as having survival gear to tackle the obstacles that befall your adventure. Besides browsing for interesting trails, a good hiking app helps you navigate safely, alerts your loved ones about your whereabouts, and traces your route accurately.

When it comes to best apps for hiking, you have many options. We have reviewed some famous hiking apps like Komoot, Outdooractive, and AllTrails in our previous articles. Today, we detail the features, pros, and cons of Hiking Project, another leading name in the market.

Hiking Project is famed for its large collection of hiking trails from around the world. Given the similarity of features, it's mostly compared with AllTrails and renowned for its global coverage of hiking trail information.

Hiking Project, as you might have gathered already, is an app solely dedicated to hikers. It was created by REI, a brand renowned for outdoor gear. The app is equipped with details on hiking trails worldwide and provides some handy features to help you figure out the most suitable trail for you.

Users can contribute to the database by providing details on local hiking trails for others to benefit from it. Hiking Project boasts of providing guide-book quality trail information and navigation tips by reviewing all user submissions to ensure they are accurate and reliable.

Hiking Project is available for free of charge. It is available in both website and mobile versions (Android and iOS compatibility). It's free, it doesn't contain advertisements either.

The app opens to a map, and you have to click on the arrow to specify your location and move the map around to find trails located nearby. Hiking Project has over 65,000 trails from around the world in its database, similar to AllTrails.

If you click on a trail, you can read the description of the trail, elevation characters, difficulty level, ratings, additional information, reviews left by previous hikers, and other trails found nearby. There's not a ton of information, but enough to give you the overall picture.

The app offers four main types of apps, namely terrain, satellite, OSM, and NeoTreks. You can download the maps beforehand and use them for navigation even when there's no cell service in the trail. All you have to do is download the GPX file and upload it to a GPS supporting device. You can also trace your route in the airplane mode and check your progress, ensuring you don't go off track.

You can submit information on new trails with a review and pictures. It will be published after being reviewed for authenticity. Additionally, you can also leave comments, ratings, and updated information on existing trails.

Although Hiking Project is not loaded with extra features, it offers a simple, clean, and organized user interface that's easy to navigate. So, if what you are looking for is a basic app with no-frills to support your hiking adventures, this is it.

Free outdoor apps are often blamed for sloppy features, but Hiking Project really stands out in this case. It offers some great and reliable features for an app that's free of charge. Best of all, it doesn't spam your interface with advertisements and diminish your experience.

If you are someone in the U.S, rest assured that you will have a lot of trail options for hiking. There is a lot of options for users from other countries, and it keeps increasing with time!

Cell reception is often unreliable when you are out in the wild, and you need a reliable app to help you complete the hike safely. Hiking Project has in-built GPS to trace your route and keep you updated about your location.

Use of the app can drain your battery faster even when using it on airplane mode, and it's one of the common complaints we found out about the app. If you are using Hiking Project for tracking, we recommend you take a power bank or satellite charger with you.

Compared to other leading outdoor apps like AllTrails, the features offered by Hiking Project are pretty limited. You don't have access to additional features like real-time overlays and off-route notifications – all of which are offered by AllTrails premium.

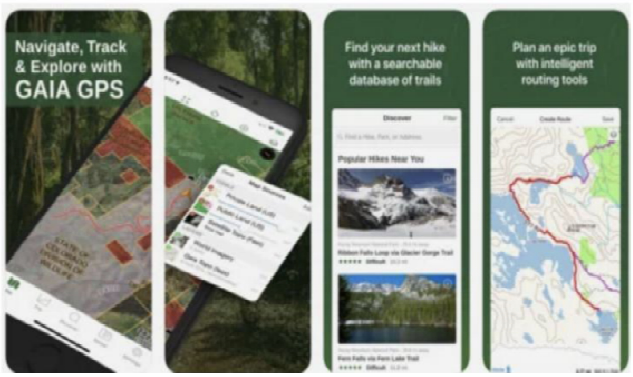
Hiking Project also doesn't offer the option of searching for trail options using filters, difficulty levels, and activity types.

Many Hiking Project reviews said it's a great app for beginners looking for day hikes. So, it may not be the ideal choice for serious hikers looking for advanced features like route building. That being said, you can use it to browse for trails located close to you and review their background information. Its offline functionality is

another major benefit to consider. Overall, it's best to review the above pros and cons before making a decision – ut since it's free of charge, you can always try it first hand and decide as well.

If you need a handy app to plan your nature-bound adventures or trips to anywhere on earth, we recommend you try Pilot. It's a social travel planner that lets you plan trips together with friends, family, and even work colleagues. Say goodbye to clutter, as this is the only app you need to keep all your travel details organized to the dot!

Gaia GPS is a mapping service that offers topographic, road and aeronautical maps of the entire world. They can be downloaded to your device for offline use.



You can plan trips and record GPS tracks for free, view hiking trail maps, hunting parties, and off-road hikes. There is also the option to buy a membership to download maps including topos, aerial imagery, public / private land ownership, and National Geographic. The program also allows you to find your favorite walking route, get directions or find a hunting object. The Gaia GPS app can be used for hiking or even downloading hunting maps, off-road maps and special data such as public and private land ownership. It is possible to sync GPS data and maps seamlessly between all phones, tablets and computers. The program exists not only as a mobile application, but also on the gaiagps.com website. The function of recording trips has been implemented. You can share your travel plans before you hit the road and keep track of them after you return. Gaia GPS works great as a hiking app, hunting app or off-road app.

OpenStreetMap maps are used as a source. There is an online view of topographic maps. For example, to search for the required maps within the United States and Canada, the application offers to use the MyTopo service. Unfortunately, MyTopo cards are only available in the US and Canada. In addition to trips, you can record travel checkpoints and create photos with geo-tags for the convenience of subsequent systematization and search for the desired images and locations. Navigation on the terrain is convenient, the determination of your location is accurate. The search for the desired point or route on the map is fast, you can also view reviews about a particular location. Also, the program implements individual user settings, implying changes in the interface, units of measurement, coordinates and sound effects. The latest version of the application has accelerated the process of loading and showing the display of the necessary routes on the maps, and also eliminated all the bugs that interfered with the normal operation of the application. Overall, objectively speaking, Gaia GPS is one of the most feature-rich navigation apps around.

Once installed, the application provides several functions:

• Route can be created by specifying when to start, when to pause capture, and when to continue.

• In the background, you can view OpenStreetMap or topographic maps with global coverage.

• More than 10 million famous points can be displayed, such as mountains, river crossings, settlements and other points of interest.

• GPS does not depend on internet connection, it still captures, although displaying images only shows what is in the cache.

• T prevent this, it is possible to save the area as a mosaic of images to display its tileada even offline.

• Stores graphical and statistical counts of each capture point along the route, which can be seen in real time; with data such as geographic coordinates or UTM, current speed, average travel speed, altitude, distance traveled, etc.

The iPad performs much better than the phone because of the size of the display and the ease of using your fingers to interact. The route can then be saved and redeployed for analysis at any time.

At its best, it can run in the background so you can work on other features from iPad or hibernation. At any time, it is activated, and the tour stops or starts a new one without increasing memory or battery consumption.

To display the route on Google Maps, you must register with alltrail.com, including logging in with a Facebook user. Then the route is downloaded from the iPad and the export option is selected. Stored as a new file in My Trips, which can be public or private.

It is possible to view routes using Google Maps layers in the background, be it satellite view, elevation, map or hybrid.

The red line shows the recorded route. On the graph, the traversed profile is displayed in blue, and the speed in kilometers per hour is displayed in orange.

This graph can even be run as a video, although it looks more online.

Decent location accuracy like any browser. It is enough to walk from 3 to 6 meters, although it would be necessary to try to make a static capture, because if you drive a vehicle at a speed of about 50 kilometers per hour, then in some cases you have to check the difference by changing the capture time by distance or seconds.

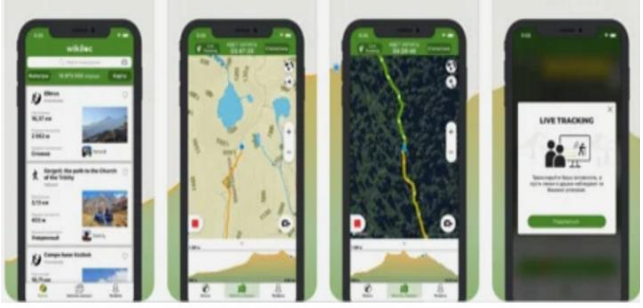
Of course, the route does not line up so well with the Google Earth photo, not because the device loses accuracy, but because the Google image represents movements between 10 and 20 meters in rural areas away from large cities or with rather irregular topographies

where the simplicity of the earth model used influenced its georeferencing.

In online mode, the program allows you to add new routes, including clicking on the map and editing by dragging vertices. Another very nice feature is that you can create a new route containing multiple routes. Not bad as it can be sent to GPX to be installed on other devices like Garmin, Magellan, SPOT Satellite Messenger, Blackberry, etc. The program also supports downloading GPX files captured by any GPS navigator. In addition, the route can be exported in kml so that it can be viewed in 3D in Google Earth.

Wikiloc Outdoor Navigation GPS has over a million routes available worldwide. The routes are categorized by type: hiking, running, cycling, MTB, kayak, skiing and more. You can plan your routes and add photos.

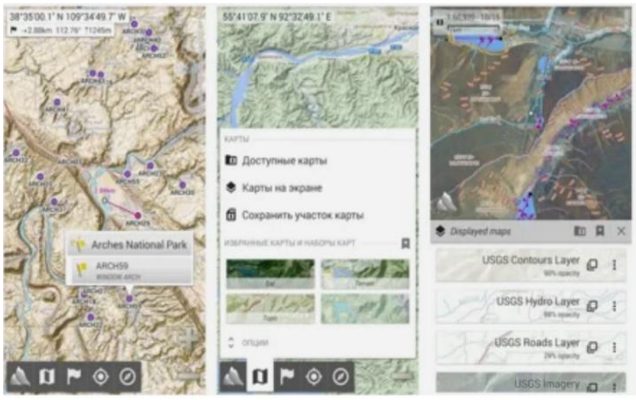
There is the possibility of activating GPS navigation inside the application, tracking the position in real time, the ability to share GPS coordinates.



Find the perfect route for your next hike by filtering by distance traveled, altitude gain, or by narrowing down the area of interest using the map.

To find routes and save data in the application, you need the Internet. Record your hikes in nature on a map and get real-time statistics: graphs of speed, distance and altitude; take photos and set directions along the way and upload it all directly to Wikiloc. Offline recording and saving in the app. You need the Internet to send.

Wikiloc Premium allows you to explore and discover the best routes near your location, and follow them with course pointers, compass and audio prompts to alert you if you go astray. No internet needed!



Wikiloc Premium is available as an internal purchase in the free app. Internet is required for searching and saving in the application, as well as for downloading maps for offline use. Once saved, you can track routes offline.

So, you decide who can see your location on the route. Walking the route alone? Activate real-time tracking for your friends or loved ones and they will always know where you are.

Are you racing? Activate real-time tracking so they know where you are or that you are almost at the finish line.

Wikiloc Premium subscription and internet connection required. Subject to the Terms of Use.

Developers have created offline maps so that you can enjoy nature travel around the world, with information about altitude and with features that you need away from the beaten track – on mountain peaks, lakes, streams, springs or in mountain huts.

Once downloaded, the maps are saved on your smartphone and will work even without Internet access. Convenient for areas with poor mobile coverage or when traveling abroad.

Developers strive to provide free offline maps of every corner of the world. If maps of your location are not found, you can inform the developers, and they will try to create maps for your area.

Tell your real friends about your hikes. After finishing the recording of your trip, you can tell about it to your fellow travelers who were with you on the route. Thus, the route will also be displayed in the list of routes they have traveled in their personal profiles.

You can also share your adventures not only with close friends, but also on your social networks by sharing your hikes on Facebook and Twitter.

Download routes from Wikiloc directly to your Garmin, Apple Watch or Suunto. The feature is available on Wikiloc Premium for compatible devices.

AlpineQuest – solution for all types of outdoor activities and sports: hiking, running, hunting, geocaching, off-road and water navigation and much more.

Maps can be saved to the device for offline use. AlpineQuest also supports various map files such as QCT

and OZFx2. There is support for GPS navigation. You can save and load your waypoints, plan and track routes.

The advantages of this program:

• support for several types of maps (which she knows how to download), between which you can switch in the process;

• fast wor of the interface (smooth scaling, fast rendering);

• support for tracks in GPX format (format of Garmin navigators), KML (format Google Earth);

• recording tracks;

• convenient "estimation" of the distance on the map;

• there is a search for objects (us d by OpenStreetMap, Google, Google Maps).

Minuses:

• no download by region, country, only by the selected area on the map;

• no routing.

Let's consider the main settings of the program:

1) Select the location for saving downloaded maps (phone memory / memory card). It also shows the amount of already downloaded maps and the amount of free space.

2) Disable GPS, if the program is "minimized" (inactive). This checkbox "disable in the background" is already set by default in the program.

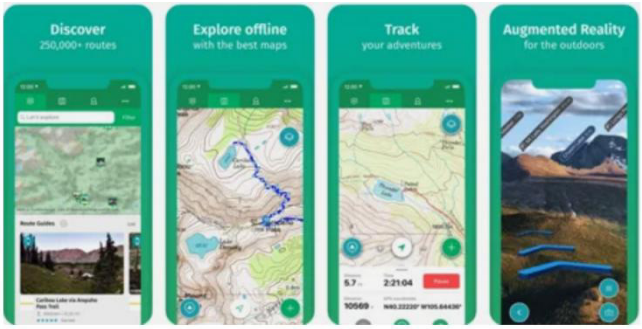
3) If GPS is active (trac ng the current position), you can choose to automatically return the screen to the GPS position. That. when scrolling through the map (for example, viewing the road ahead), it itself returns to the place of its current location (and there is no need to "scroll" back). When GPS is off, this setting has no effect - you can flip through the maps as you like.

4) Also the default setting is "Full Screen Mode". Those. when the program is running, the standard Android status bars at the top and buttons at the bottom are not visible. The lack of panels allows you to allocate more space for displaying maps. To make the panels appear in "full screen mode", you need to make a "zoom out" gesture from the edges of the screen (top and bottom).

To select an active map, you need to click "Available maps", then open one of the tabs and select a specific map (its name is in bold). The size of each downloaded map will also be shown (well, the total amount of free space in the memory where the maps are saved).

When downloading, the map type that is currently active will be downloaded. It is necessary to select a rectangular area on the map, with the blue slider at the bottom ("zoom in"), select the desired level of detail, monitor the size of the maps, because at the maximum (13th) detail, their size can be very large, and click the flash drive icon at the bottom right. During the download process, the current download speed, how long to download and the estimated time will be displayed. At the end of the download, an inscription will appear: "completed successfully".

Topo Maps+ provides topographic maps from USGS, MapBox, NRCAN/GEOBC and Thunderforest for offline download and use



Easily download maps so you can use the maps offline while deep in the backcountry.

Use your iPhone's GPS to view your current location, even when you don't have a cell signal.

GPS and downloaded maps work even without an internet connection so you can use Topo Maps+ deep in the backcountry.

Add waypoints at important locations, like where you parked, so you can navigate to those locations.

Topo Maps+ was designed for serious hikers who love to go deep into backcountry and get as far away from a cell signal as possible. Whether you enjoy pounding out the miles day after day or relaxing at high alpine lakes, Topo Maps+ can help you get there and back again.

Trails Illustrated maps are the most trusted and popular recreation maps available. The USGS 7.5 minute topographic maps are the gold standard for backcountry maps in the USA.

Topo Maps+ has maps for any adventure you want to go on:

- NRCAN Topo Maps cover all of Canada.
- Glacier Topo is a beautiful world wide topographic map with hiking and biking trails.
- Thunderforest is a world wide topographic map with hiking, biking, and skiing trails.
- LINZ Topo Map is the the ultimate backcountry map for New Zealand.
- Satellite Map lets you see satellite imagery for the entire world.

Topo Maps+ has trail data for over 500,000 trails. Just tap on a trail to see distances and elevation profiles. Don't want to exactly follow the trail, no problem. The trails interact with your own traced routes so you can easily explore custom routes. In the wild, trails are not isolated segments between two points, they are a network of interconnected paths with numerous possible routes. Topo Maps+ lets you explore any possible route through a trail network.

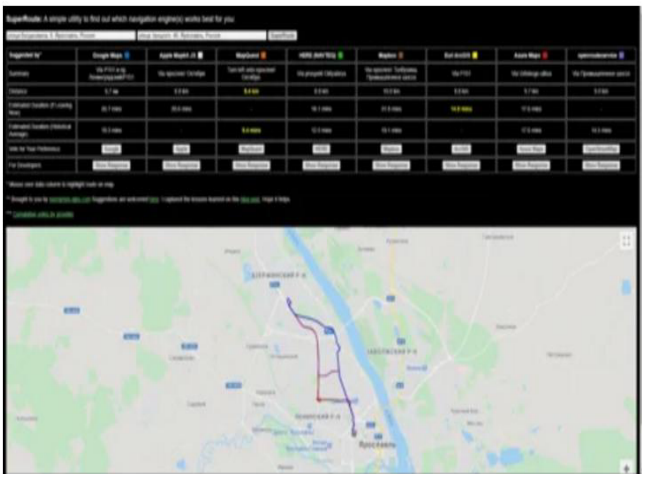
Easily trace new routes right on the map and see the routes distance and elevation profile. Create custom routes from trail networks. The trace will snap to the trails. Create waypoints for your trip before you head out. Check out the distance and elevation profile along a trail between any two points. Keep everything for you trip

organized by simply tagging it. Share all of the routes and waypoints for your trip with your friends. Bring peace of mind, maps & GPS work offline. Topo Maps+ for iPhone has a deep feature set to help you plan, prepare, and go deeper into the backcountry. Topo Maps+ gives you the tools you need to plan and be prepared for you next backcountry adventure.

Use all of the same features on your iPad and iPhone. Plan your trip on your iPad and then use your data on your iPhone. Topo Maps+ can sync your data between your iPhone and iPad.

View your offline maps and current location just by glancing down at your wrist. You no longer need to pull your iPhone out of your bag to check your position.

ViewRanger is a collection of route guides and topographic maps for travel planning.



If in cities it is possible to use online maps without any problems, then outside the city, where there may not be a stable reception of mobile networks, the situation is changing. When looking for an app with maps that could show not just something like "you are here in the middle of the forest", but trails and dirt roads can be found on the Android version of ViewRanger. In 90% (or even more) of cases, all the necessary information is displayed (trails, swampy / wet areas on them, etc.)

Of course, online maps do not offer specialized travel products, but in this case they are mentioned among the most common applications for navigation on mobile devices.

Moving on. Trails are, of course, good. Well, what if there is no stable mobile Internet? With the help of ViewRanger, you can download maps to a device without a 3G module, but with GPS support, the required area of the map and follow it. Distances and crossroads of trails are reflected quite correctly, it is quite possible to walk on such a "map". But, on the ViewRanger maps, far from all the trails available on the terrain are shown. That is, sometimes you can "cut" rather well, but ViewRanger does not show it.

There are also paid cards. In total, 7-8 free maps are available in the application. There are also additional useful functions. This application can be used according to the scheme "looked at the landmarks on the maps before leaving - opened the application several times so as not to miss a turn - calculated the approximate mileage traveled."

There is a quite stable, low-key application with a good free map + the ability to save fragments of it for offline orientation.

The ViewRanger GPS software, unlike most existing navigators, is a full-fledged tracker and navigation service for building routes, which is focused more on users who love outdoor activities, tourism and travel. Plan your trips quickly and easily, build challenging tourist routes and explore the world with the program. Moreover, the maps are absolutely free, and the main feature is that all streets and sections displayed on the map are displayed in the language of the country where they are located. The ViewRanger GPS interface itself, unfortunately, is presented in English, but it will not be difficult to figure it out.

The advantages of this navigator include fully autonomous operation, even if your gadget has lost the mobile signal. Searching for satellites and displaying your location is almost instantaneous. Any selected area can be saved as a separate offline map and used at any time. It is possible to quickly build and record a route.

Also, while driving, statistics on speed, distance traveled and other useful data are kept and recorded.

You can use the camera to locate peaks, places, and other points using augmented reality. There are three-dimensional air tours 3D Flyover. BuddyBeacon helps you share your location with family and friends in real time.

Google Maps app will start directing drivers along routes estimated to generate the lowest carbon emissions based on traffic, slopes, and other factors, the company announced on Tuesday. Google, an Alphabet Inc unit, said the feature would launch later this year in the US and eventually reach other countries as part of its commitment to help combat climate change through its services. Unless users opt-out, the default route will be the "eco-friendly" one if comparable options take about the same time, Google said. When alternatives are significantly faster, Google will offer choices and let users compare estimated emissions.

Google said it derives emissions relative estimates by testing across different types of vehicles and road types, drawing on insights from the U.S. government's National Renewable Energy Lab (NREL). Road grade data comes from its Street View cars as well as aerial and satellite imagery. The potential effect on emissions from the feature is unclear. But in a study of 20 people at California State University, Long Beach, university researchers last year found participants were more inclined to consider carbon emissions in route selection after testing an app that showed estimates.

Google's announcement included additional climate-focused changes. From June, it will start warning drivers about travel through low emissions zones where some vehicles are restricted in Germany, France, the

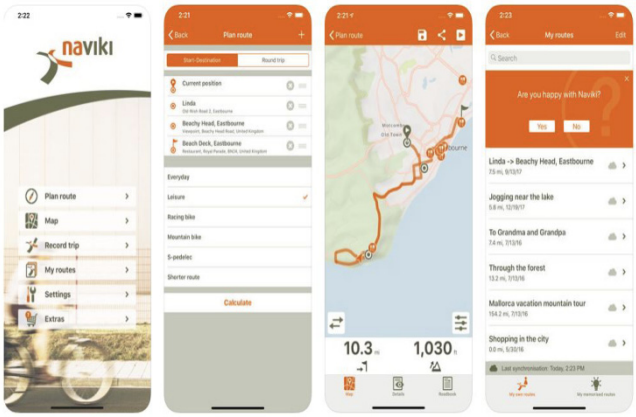
Netherlands, Spain, and the UK. In the coming months, Maps app users will be able to compare car, biking, public transit, and other travel options in one place instead of toggling between different sections.

We often use various navigation services. But how can you be sure that Google Maps really does route better than Apple? Or vice versa.

SuperRoute will help you compare the quality of building a route between Google, Apple, MapQuest, Mapbox, HERE, Esri, AzureMaps, OpenRouteService.

To compare routes, you just need to go to service website and enter addresses of origin and destination. Then a map with routes and information about their quality will be displayed. The comparison includes length of journey, duration when departing now, and historical average duration.

Naviki – удобная и практичная программа для велосипедистов



The application will allow you to comfortably plan your cycling trips, raise routes on the map, use navigation.

The Naviki app will record your rides and sync them to www.naviki.org. You will collect all your routes in one place.

Mark the beginning of the route and its end - and get a laid route with the necessary information.

You will see all the necessary information on the display. Audio instructions are not distracting during the ride. If you accidentally (or not accidentally) deviated from the planned route, the program will automatically create a new route.

The program itself will choose the best route, taking into account the road surface, the straightness of the route, the shortest distance and the safety of movement.

Программа The program will lay out individual mountain routes, in which it will take into account the isolation of the track, designated MTB routes, routes in the bosom of picturesque nature, it will choose tracks with the appropriate surface suitable for racing, secondary, unloaded roads - the trips will be as fast, comfortable and safe as possible.

Also, the program will provide you with special safe routes for e-bikes at speeds up to 30 miles per hour and will build various alternative circular routes.

The program has a collection of attractions that will decorate your trip along a particular route.

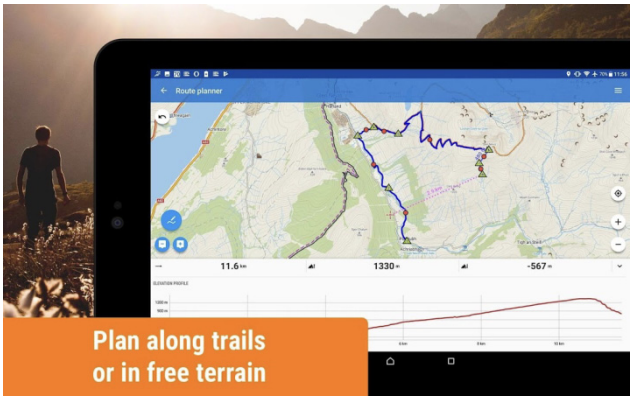
Download Naviki maps to your device and use them without going online. The program displays the profile of the route height: high, low points and total height.

Maximum speed, average, distance covered, distance to the end of the route are always at your disposal.

The program via Bluetooth will show the distance to the next turn and navigation arrows on the display screen. It is easy to record routes - press the button and the route will be recorded and saved in your personal cloud of the program. All statistics of your trips will be posted on www.naviki.org

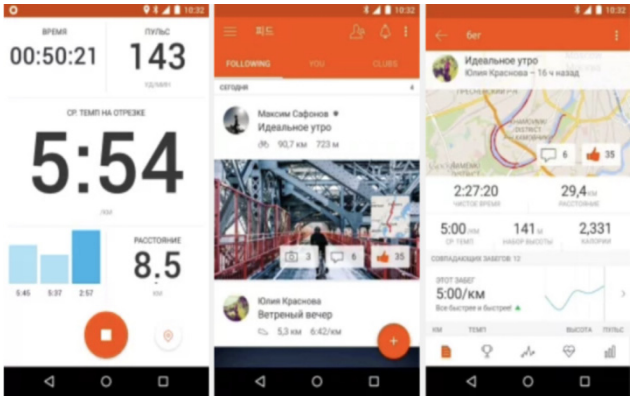
The program makes step-by-step instructions on the routes of all randomly chosen ones.

Another very popular application among cyclists is *Locus Map Free – Outdoor GPS*. Here you can also download maps to your device and then use them without an Internet connection. The first three offline maps will be absolutely free.



The app is available for free download. But if you want to use additional functions, such as statistics recording or full Bluetooth support, you can buy the Pro version.

Every selection of the best cycling apps will feature this familiar name – *Strava*.

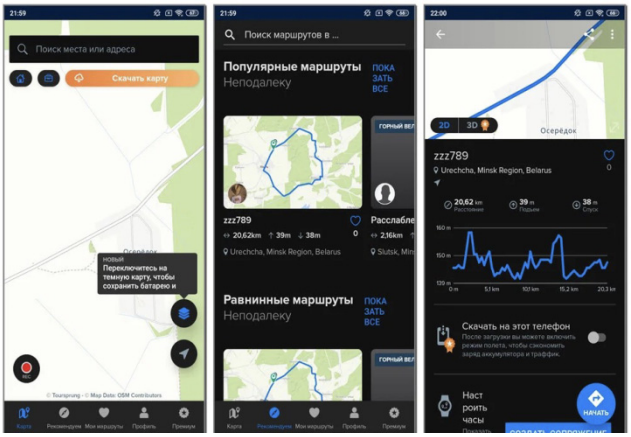


At first glance, this is an unremarkable tracker of routes, speed and other data that athletes love to track. However, as it turns out, Strava is a whole social network

that allows you to follow the results of your friends and compete with them. In addition, the application has the ability to sync with a variety of wearable equipment. Among them are the budget Amazfit from Xiaomi, sports models from Garmin, Suunto, as well as smart watches based on the Wear OS platform from Google. For iPhone users, there is support for the Apple Watch.

Another important aspect is the routing function in the application. While its support is implemented only through a computer, in the future the developers promise to implement it on mobile devices, however, it is much more convenient to plan a trip route from a computer. During the trip, there are voice prompts and voice navigation. So, we can say that Strava is a whole platform with many different features that will be useful not only for cyclists, but also for runners. The app is free and available on Google Play. No advertisements, however, there are optional transactions for additional features. And without them, you can fully use the application.

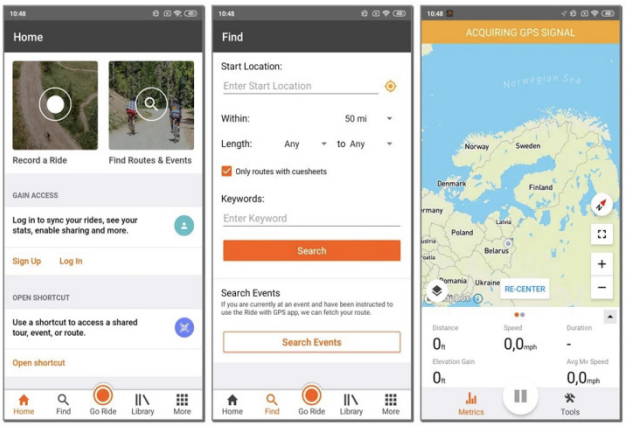
Any cyclist at least once thought about how interesting it would be to ride a route created by another user. And this idea is brought to life by the *BikeMap* application. Here you will find a built-in map, the ability to use the program without the Internet, a convenient speedometer and a personal account. To gain access to all functions, you need to go through a simple registration. It's even good, because when you change your phone, you can restore your progress and statistics.



The start screen contains a map of your area. If it is not displayed, then check if GPS is activated. And the most interesting tab is “Recommended”. There are other people's routes for your area, and they are even divided into categories. Do you like to ride on a bad road? Take a look at the Plain Routes menu. Do you prefer evening bike rides around the city? Go to the "Popular Routes" section.

The map will show the total duration of the route, the ratings of other users and the name of the author. Just save the card to your phone and use it even without an internet connection. And if you have a smartwatch, then you can easily link it to the application.

For anyone, even a novice cyclist, the most important thing is the accuracy of measurements and, of course, the availability of a convenient map with a route. All of these features can be found in the Strava app, but not every user likes it. A relatively new program was discovered on Google Play, which received a simple name *Ride with GPS*.



It is a handy utility with a built-in map, ready-made routes and data synchronization. But the main drawback for the Russian-speaking population is a completely English-language interface. However, after a few days of using the program, you will not even read the names of the tabs, because everything will become intuitive.

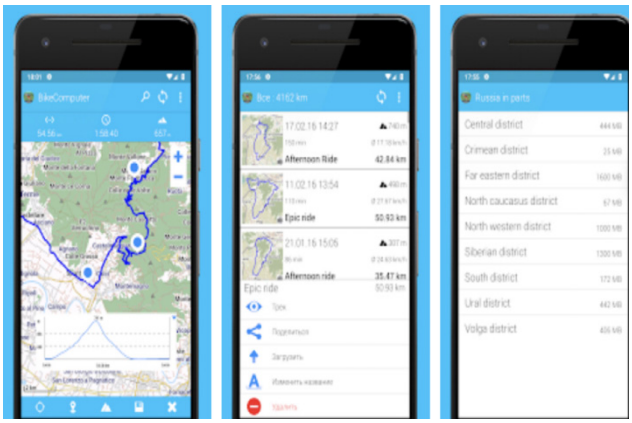
To work with the application, you need to perform a simple registration by entering your email address and password. And after that you can start the virtual computer and start your trip. A map will be displayed on the screen, and just below a block with all the data. Information about the current speed, distance traveled and travel time is indicated here. Optionally, you can collapse the map and turn the program into a full-fledged bike computer.

Each of us at least once in our life found ourselves at a crossroads and did not know how to return to civilization. Next time, before driving on an unknown route, do not forget to download *TrailForks* before leaving your home: it will save you a couple of hours of wandering through the woods or along the slopes of the mountains.

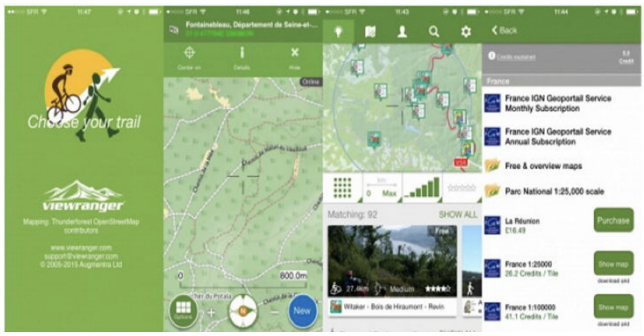
Drawing on information from other cyclists, the program boasts detailed maps of more than 161,000 routes around the world, real-time geolocation +

information on attractions. In case something goes wrong, there is an alarm function that transmits your exact GPS coordinates and the name of the nearest settlement. It is extremely important if you like to drive alone.

BikeComputer – another version of the cycling computer, which, unlike its analogues, does not require any registration. It also allows you to track physical activity and get detailed statistics for each race. The ability to get directions is available both online and for maps downloaded through the application.



Viewranger is useful for those who prefer to ride a bike away from noisy cities and busy highways. Recommended for all bike travelers and cyclists who value adventure and nature. The Viewranger app relies on the free OpenCycle map that covers the entire world, so you can get directions for cycling where other apps fail. Viewranger offers 20 detailed country maps for an additional fee. The application stores maps on the phone, and uses the built-in GPS for navigation, so there is no need for a constant Internet connection – excellent functionality for cyclists who prefer wild forest or mountain trails.



The app allows you to create routes and share them with other cyclists, as well as download tracks from other cycling enthusiasts. The Viewranger has a real-time location tracking function called Buddy Beacon, which allows you to show your current coordinates on the map for friends or generally for all users of the application. The Buddy Beacon bike app is available for free on both iOS and Android. There are in-app purchases.

Conclusion

In this article analysis applications for planning and tracking routes, which allows to develop clear and well-constructed tourist routes and solve specific problems, including taking into account weather conditions and terrain. Modern sports tourism is being transformed under the influence of global tourism trends. Meanwhile, creation of clear and convenient routes will allow for more organized tourism activities, improve control over "wild" tourism and reduce the chaotic pressure on natural environment. It is important to understand, evaluate and preserve those of its strengths that allowed this area to develop successfully and solve problem of symbiosis between geography and tourism practice.

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The International Telecommunication Union (ITU) is the United Nations specialized agency for information and communication technologies (ICTs), driving innovation in ICTs together with 193 Member States and a membership of over 900 companies, universities, and international and regional organizations. Established over 150 years ago in 1865, ITU is the intergovernmental body responsible for coordinating the shared global use of the radio spectrum, promoting international cooperation in assigning satellite orbits, improving communication infrastructure in the developing world, and establishing the worldwide standards that foster seamless interconnection of a vast range of communications systems. From broadband networks to cutting-edge wireless technologies, aeronautical and maritime navigation, radio astronomy, oceanographic and satellite-based earth monitoring as well as converging fixed-mobile phone, Internet and broadcasting technologies, ITU is committed to connecting the world. For more information, visit www.itu.int.

RADIO INTERFERENCE

OVERVIEW

• Radio interference is defined by provision No. 1.166 of the ITU Radio Regulations as "the effect of unwanted energy due to one or a combination of emissions, radiations, or inductions upon reception in a radiocommunication system, manifested by any performance degradation, misinterpretation or loss of information which could be extracted in the absence of such unwanted energy".

• Radio interference and its subsequent potential for blocking, jamming, altering the information or degrading the quality of a service can occur for a wide range of reasons, accidental or intentional.

• The consequences can be either short-term (degradation, obstruction or interruptions of a service) or long-term (jeopardizing dependent services or incentives for future investments).

• Radio interference may impact and disrupt broadcasting signals, mobile and fixed communications systems, as well as scientific services which are vital to measure the health of our planet and combat climate change and radionavigation systems used by airplanes, maritime vessels, autonomous cars and any other personal device or telecommunication network relying on time-geolocation information.

• The application of the ITU Radio Regulations is the best instrument to keep interference levels under control and to prevent harmful interference, and the Regulations also contain other corrective measures to be applied, when harmful interference occurs.

• Moreover, these regulatory measures can be complemented with technological solutions for interference mitigation and cancellation.

The following three levels of interference are defined in Article 1 of the RR:

• permissible interference (see No. 1.167);
• acceptable interference (see No. 1.168);
• harmful interference (see No. 1.169).

When interference is harmful

Harmful interference is defined in both No. 1.169 of the RR and in No. 1003 of the ITU Constitution, as"interference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with Radio Regulations". Harmful interference, the blocking, jamming or degradation of service can take place for a wide range of reasons, which can be either accidental or intentional. Both commercial services as well as critical safety-of-life applications may be degraded and affected.

In general, according to the preamble of the RR (which reproduces No. 197 of Article 45 of the ITU Constitution),"all stations, whatever their purpose, must be established and operated in such a manner as not to cause harmful interference to the radio services or communications of other Members, recognized operating agencies, or other authorized operating agencies which carry on a radio service, and which operate in accordance with the Radio Regulations".

Along these lines, jamming is prohibited by No. 15.1 of the RR, which states that "all stations are forbidden to carry out unnecessary transmissions, or the transmission of superfluous signals, or the transmission of false or misleading signals (...)". Special attention needs to be paid to safety services (aeronautical, maritime and radionavigation), that require absolute international protection. The elimination of harmful interference for these services is imperative, according to No. 15.28 of the RR. Harmful interference can have both short-term consequences (in degradation of service etc.) or long-term effects (jeopardizing dependent services or incentives for future investments).

What can be done

One of ITU-R's main objectives is to ensure interference-free operations of radiocommunication systems by implementing the RR and regional agreements, as well as updating these instruments in an efficient and timely manner through the processes of World and Regional Radiocommunication Conferences.

"It is essential that ITU Member States exercise the utmost goodwill and mutual assistance in the application of

the provisions of Article 45 of the Constitution to the settlement of problems of harmful interference". Section VI of Article 15 of the RR sets out the procedure in case of harmful interference, as well as the conditions for the resolution of a problem of harmful interference. The initial procedure is based mainly on a direct approach between the administrations concerned. However, a case of harmful interference may also be communicated to the ITU either for information or with a specific request for assistance, where action on a bilateral basis may have been unsuccessful.

Reporting a case of harmful interference through the national telecommunication regulatory agency to the ITU Radiocommunication Bureau is key to be able to assess the actual situation and to resolve that case but also to prevent its recurrence.

ITU has made efforts to modernize and facilitate the reporting of harmful interference and undertakes capacity-building initiatives to educate and raise awareness about the impact of and possible solutions to harmful interference.

Furthermore, under Article 18 of the RR, any station must be duly licensed by the governments having jurisdiction over the territory where it is intended to operate. The prohibition of jamming equipment lies under the responsibility of ITU Member States and their regulators/enforcement agencies. A growing number of countries have already made it illegal to purchase, sell and/or use GNSS jamming equipment. The Bureau reported this issue to WRC-19 and encouraged Member States to strengthen their control mechanisms at a domestic level.

There is a long-standing practice within ITU-R Study Groups preparing ITU-R Recommendations or standards to ensure compatibility between radiocommunication systems. Reserving a portion of the link budget as a margin (additional energy in the wanted signal being transmitted) to compensate for any interference has worked well for decades to protect against unintentional interference.

ITU'S CONTRIBUTION

ITU assists administrations for resolving cases of harmful interference. When contacted, ITU investigates the causes of the potential harmful interference and forwards to the administrations involved its findings and recommendations for resolving the problem. If this approach proves unsuccessful, the BR then prepares a report for the ITU Radio Regulations Board. Finally, ITU transmits the conclusions of the Board to the administrations concerned, inviting them to take steps and apply ITU's recommendations for eliminating any harmful interference.

ITU also organizes international monitoring programs to identify sources where signal emissions are not in compliance with the RR and to take necessary actions for eliminating unauthorised emissions. The procedure to be followed in cases of harmful interference is regularly highlighted and described in seminars/workshops organised by the ITU, regional organisations, industry and other entities.

ITU organizes regular ITU international satellite symposia to raise awareness of the impact of interference in different domains, presenting solutions from industry as well as regulators. The latest event took place virtually as a webinar in September 2020 and featured experts from NASA, ESA, EUTELSAT, EuroControl and ITU (https://www.itu.int/en/ITU-R/space/workshops/sat-webinars/Pages/default.aspx).

ITU offers an online application, "Satellite Interference Reporting and Resolution System (SIRRS)" (https://www.itu.int/ITU-R/space/sirrs), which assists Member States by facilitating the reporting of harmful interference cases affecting space services. The Radiocommunications Bureau of ITU then investigates the matter and, if requested, provides the necessary assistance to concerned administrations or specially designated stations of the international monitoring system that may be able to help in identifying the source of harmful interference.

Once a source is located, ITU then contacts the administration believed to be responsible for the source of harmful interference to request prompt action to eliminate it. The Bureau can also provide a report to the Radio Regulations Board to help in investigations and options for resolution. In addition, Article 56 of the ITU Constitution sets out a Dispute Resolution Mechanism based on diplomatic channels, and Article 41 of the ITU Convention provides another legal instrument, the Optional Protocol for Compulsory Arbitration.

ITU also uses an International Monitoring System and several Cooperation Agreements signed with Member States, allowing these monitoring facilities to be used to geolocate interference sources.

IN SUMMARY

The ITU Radio Regulations enable the reporting of cases of harmful interference to ITU, technological solutions to mitigate and eliminate interference, and cooperation among Member States, industry and other stakeholders as the vital elements to resolve cases of harmful interference under their control.

Only by doing so, governments and industry can guarantee the required quality and availability of radiocommunications and safety services, to ensure the return of investments and successful space missions so that every citizen of the world can benefit of so many applications in daily life relying on interconnected radiocommunications networks in a transparent manner to end-users.

GEOSPATIAL

OVERVIEW

• Geospatial data describes any data related to or containing information about specific location(s) on the Earth's

surface, including 3D information. A geographic information system (GIS) is a framework that provides the ability to capture and analyze spatial and geographic data. Geospatial analysis describes the gathering, display, manipulation and analysis of imagery, Global Positioning System (GPS), satellite imagery and historical data.

• Applications of geospatial analysis include: climate change modelling, weather monitoring and tracking of human and animal population distributions, and planning radiocommunication systems. GIS applications are used to predict, manage and learn about many different phenomena affecting the Earth, its systems and inhabitants.

• The evolution of information and communication technologies (ICTs) and data processing techniques and the availability of higher resolution data have resulted in an explosion in geospatial information and processing.

• There is a growing need for common standards or taxonomies to maximize the use, sharing and analysis of geospatial data. However, changing user requirements, industry changes, and an evolving regulatory and policy environment are all creating new challenges for international cooperation. Who has the right to access such data, and how can we prevent misuse?

OPPORTUNITIES

Geospatial analysis involves the gathering, display, and manipulation of imagery, Global Positioning System (GPS) coordinates, satellite photography and data (real-time or historical), making use of explicit geographic coordinates or identifiers used in geographic models.

Geospatial analysis has advanced considerably in terms of:

1. Greater precision, accuracy and granularity;
2. Easier and faster transmission, analysis and manipulation (e.g. the connectivity of mega-constellations of satellites);
3. The number and type of devices equipped with geospatial and location identification (e.g. different types of devices include the Internet of Things, mobile phones, sensor networks, connected cars, etc.).

For example, fifth-generation mobile technology, IMT-2020 (or 5G), when implemented in the millimetre wave bands, would require very accurate geospatial data and denser telecom networks with significantly higher numbers of base stations than traditional mobile networks. Both accurate geographical data and advanced spatial analytics would be crucial to ensure that these radio networks are cost-effective and efficient. 5G base stations would need to be synchronized to within nanoseconds to improve the positioning accuracy for smart transportation and intelligent traffic management systems [8]/

Geospatial data and information are very valuable, from the global level right down to the local level and can be used for many different use cases, including to monitor, verify and/or confirm:

• Climate modelling and weather prediction; monitoring local weather, seasonal or climatic systems (e.g. the El Ni?o effect);

• Tracking urbanization and the gas emissions and/or pollution from cities and industry;

• Urban use cases, including intelligent transport systems, autonomous vehicles and monitoring traffic congestion in real-time;

• Natural disasters (e.g. extent of landslides or flooding) and relief efforts;

• Identifying and mapping facilities, e.g. schools, clinics, refugee camp size and facilities;

• Monitoring abuse of human rights (e.g. treatment of refugee populations);

• Identifying archaeological sites of interest;

• Mapping deforestation and land use, and estimating crop yields for predicting trends in food and commodity markets;

• Estimating poverty and income levels (e.g. from type of cars or the quality of roof materials);

• Population and animal migrations.

National governments and local authorities need information about a country, the environment, assets, people, and its physical and social infrastructure to inform robust evidence-based decision-making and to encourage economic development, entrepreneurial activity, transparency, or national security.

CHALLENGES

Different concepts, software and taxonomies can give different meanings or interpretations to the same data in creation or storage, creating a need for common standards or taxonomies to maximize the use, sharing and analysis of geospatial data in smart cities, and help scale smart city projects.

However, changing user requirements, industry changes, and an evolving regulatory and policy environment are all creating new challenges for international cooperation. Who has right to access geospatial data, and how can misuse be prevented?

Enabling effective collaboration between the stakeholders responsible for different aspects of geospatial analysis, global or local, is a challenge. Stakeholders may have different interests and incentives. In different domains with different stakeholders, even small differences can make data sharing or exchange difficult or even impossible or result in loss of information or changes to the structure or meaning of the data.

ITU'S CONTRIBUTION

ITU has worked with geospatial information for decades, since it first established the international numbering system for telephony and assigned international codes to countries and territories.

• ITU published the original "International public telecommunication numbering plan", assigning the number structure and functionality for different geographic areas, networks, global services and groups of countries.

• ITU-T Technical Report TR.CLE (06/2020), "Identify call location for emergency services", identifies the call location of fixed and mobile devices for emergency services, helping save time and lives in emergencies.

ITU is working on the regulatory and privacy-related aspects of geospatial information, in relation to mobility of mobile phones or the security aspects of connected cars, for example.

ITU allocates orbital slots, harmonizes and coordinates spectrum management at the international level for global satellite systems using geospatial and radio-meteorological data from ITU membership.

• ITU uses geospatial data and services to:

• Perform accurate technical examinations to ensure operations of radiocommunication systems free of harmful interference;

• Provide software tools (including GIS display) to assist ITU membersin their radio frequency planning activities to comply with the ITU Radio Regulations and Regional Agreements. The ITU Digitized World Map (IDWM[1]) and Subroutine Library represent a database of international geographical data and technical data related to the Radio Regulations and Regional Agreements.

• ITU is currently developing a Geoportal (using the open source technology GeoServer) to store relevant geospatial data and make it accessible to internal and external stakeholders.

ITU has brokered various ICT standards that include the use or transport of geospatial data:

• Recommendation ITU-T Q.3615 (2015), "Protocol for GeoSMS", defines the protocol for 'GeoSMS' which can be used to encode location information.

• Recommendation ITU-T H.460.25 (2010) defines the parameters and method for exchange of geographic information between ITU-T H.323 entities. Geographic information may be either coordinates (i.e., longitude, latitude and altitude) or addresses (e.g., city and street address).

• Recommendation ITU-T L.262/L.94 (2015), "Use of global navigation satellite systems to create a referenced network map", elaborates the guidelines on creation, operation and maintenance of the telecommunication network map by using the Global Navigation Satellite System (GNSS) and geo-referenced systems.

• Recommendation ITU-T F.747.7 (2014), "Requirements for network-based location information conversion for location-based applications and services", enables location information to be accessed and understood by multiple applications and services.

• Recommendation ITU-T F.747.5 (2014), "Requirements and functional architecture of an automatic location identification system for ubiquitous sensor network (USN) applications and services", describes automatic location identification in sensor networks. The automatic location identification (ALI) capability enables a device to discover its own location in various networks such as a mobile network, the Internet, or a low-power wireless network.

ITU also provides information to its Member States using various maps:

• SMS4DC, the Spectrum Management System for Developing Countries, uses maps for displaying terrain data.

• Digital Terrestrial Television transition (DSO database).

• The Interactive Transmission Maps display the transmission lines, nodes and satellite earth stations and also the broadband map.

• Project implementation (ICTs for sustainable development) at the regional and national levels, e.g. GIGA,PRIDA, and FIGI.

• ITU's Transmission Maps display transmission lines, nodes and satellite earth stations, as well as access to digital financial services[2].

• ITU has developed an ArcGIS StoryMap for the Global E-waste Monitor 2020, which includes interactive maps with spatial data [3].

ITU also collaborates with external stakeholders on various issues to do with geospatial data, including with the UN Geospatial Network, WGIC and OGC.

SMART SUSTAINABLE CITIES

OVERVIEW

• More than half of the world's people live in cities today. By 2050, nearly seven in ten people will be living in cities. Cities account for more than 70 per cent of global carbon emissions and 60 to 80 per cent of energy consumption. Rapid urbanization has created additional challenges such as social inequality, traffic congestion and water contamination and its associated health issues.

• Governments and municipalities can use information and communication technologies (ICTs) and other technologies to build smarter and more sustainable cities for their citizens. A smart sustainable city is an innovative city that uses ICTs to improve quality of life, the efficiency of urban operations and services and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental and cultural aspects [1]

• Although cities where all urban systems and services are connected do not exist as of yet, many cities are already on the path to becoming smart sustainable cities. They rely on ICTs, for example, to enhance energy efficiency and waste management, improve housing and health care, optimize traffic flow and safety, detect air quality, alert police of crimes occurring on the streets and improve water and sanitation systems.

• ICTs have the potential to accelerate the achievement of all 17 United Nations Sustainable Development Goals (SDGs), including SDG 11, which aims to achieve sustainable cities and communities.

CHALLENGES AND SOLUTIONS

Smart sustainable cities need a telecommunication infrastructure that is stable [2] , secure [3], reliable [4] and interoperable [5] to support an enormous volume of ICT-based applications and services.

Recent developments in the Internet of Things (IoT), Artificial Intelligence (AI) and smart grids and meters are driving and supporting the development of smart sustainable cities throughout the world.

IoT-referring to the network of rapidly growing computing devices with built-in sensors and software to connect with each other and share data-enables billions of devices and objects equipped with smart sensors to connect with each other, collect real-time information and send this data, via wireless communication, to centralized control systems. These, in turn, manage traffic, reduce energy usage and improve a wide range of urban operations and services.

AI allows extremely large data sets to be analysed computationally to reveal patterns, which are used to inform and enhance municipal decision-making.

Smart grids-referring to electricity supply networks that use digital communication technology to detect and react to local changes in usage-help to optimize energy use in cities. Smart meters and sensors, equipped with Internet Protocol addresses, can communicate information about the end-users? energy use to the energy supplier, giving end-users more control over their consumption.

While 3G and 4G networks used by mobile phones today pose a number of problems in supporting the range of services required for smart sustainable cities applications, the development of 5G, referring to the fifth generation of mobile technologies, has the potential to reliably connect devices to the Internet and other devices, transport data much more quickly and process a high volume of data with minimal delay.

ITU'S CONTRIBUTION TO SMART SUSTAINABLE CITIES

ITU is working to improve the reliability, security and interoperability of ICT infrastructure needed for smart sustainable cities, while at the same time advocating for the use of ICTs to reduce the consumption of energy and enhance services and quality of life for city dwellers.

Setting standards

ITU and members within the ITU-T Study Group 20, which is dedicated to IoTs, smart cities and communities, have been developing international standards that establish technical criteria, processes and practices to enable a coordinated development of IoT technologies for smart sustainable cities. Most recently, the study group has been working on topics including AI, blockchain, machine-to-machine communication and Big Data aspects of IoT.

ITU and members within the ITU Focus Group on Data Processing and Management are working on the development of international standards that allow the IoT ecosystem to be fully inclusive, interoperable and capable of making full use of the data generated by the devices feeding into the system. This is to mitigate the risk of data ?silos? emerging in different industry sectors.

ITU has also recently developed standards ensuring the security of networks in urban areas.

ITU's work on standards for 5G systems, which will help make smart sustainable cities a reality, is also underway.

ITU standards outline how smart grids can help build more controllable and efficient energy systems.

The ITU Focus Group on Smart Sustainable Cities has identified standardized frameworks needed to support the integration of ICT services in smart cities and key trends in urban smart water management.

Global collaboration and advocacy

In 2016, ITU and the United Nations Economic Commission for Europe (UNECE) launched the global platform "United for Smart Sustainable Cities " (U4SSC) to advocate for public policy and to encourage the use of ICTs to facilitate and ease the transition to smart sustainable cities. The platform is now supported by 14 other United Nations bodies. The U4SSC has developed a set of key performance indicators (KPIs) for s mart sustainable cities, allowing cities to set goals, collect data and measure progress in five major areas: the use of ICTs; physical infrastructure; social inclusion and equity of access to services; quality of life; and environmental sustainability. More than 50 cities worldwide, including Bizerte, Dubai, Kairouan, Maldonado, Manizales, Montevideo, Moscow, Pully, Rimini, Singapore, Valencia and Wuxi, are already implementing these KPIs.

Below are just a few examples showing how ICTs are helping to build smart sustainable cities:

• In Singapore , sensors and cameras build on the city state?s existing digital system and enable the government to assess the performance and efficiency of traffic flow and identify problems such as potholes and bumpy bus rides as well as lawbreakers. For example, to strengthen security in public spaces, the city has installed more than 62,000 police cameras in public housing blocks and carparks.

• Copenhagen, Denmark, has upgraded its street lights with efficient lamps connected by a wireless network. Smart street lights save costs because they can be programmed to dim or brighten automatically, optimizing the use of energy while lowering the risk of crime and traffic accidents.

• So Paulo, Brazil, has developed a solution to estimate and predict air quality using AI and Big Data analytics. Aggregated, anonymized data is leveraged from the mobile network and layered with data from weather, traffic and pollution sensors. This helps calculate pollution levels 24 to 48 hours in advance, helping policy-makers, municipalities and governments to take action to prevent death and disease-for example, by redirecting traffic before air pollution hotspots strike.

• In Holon municipality in Israel, the sewage system was plagued with problems such as frequent blockages and overflows. The municipality installed devices equipped with sensors to better manage its sewer systems and send alerts via short message service (SMS) when the level reaches low or high limits.

• Dubai introduced an eComplaints system for citizens to regularly provide feedback on public services.

SATELLITE ISSUES: EARTH STATIONS IN MOTION (ESIM)

OVERVIEW

• Earth stations in motion (ESIM) address a complex challenge - how to provide reliable and high-bandwidth Internet services to what are - literally - moving targets. They provide broadband communications, including Internet connectivity, on platforms in motion. There are currently three types of ESIMs: ESIM on board aircraft (aeronautical ESIM), ESIM on board ships (maritime ESIM) and ESIM on board land vehicles (land ESIM).

• Advances in satellite manufacturing and earth station technology have made ESIM more widespread and more practical. When ships are at sea or aircrafts cross the oceans, they are out of reach of terrestrial networks. ESIM systems can provide continuous and consistent service with very wide, or literally global, geographic coverage as ships and aircraft operate at or over almost any location.

• The demand for spectrum for ESIM is increasing. For example, in 2014, over 20 000 vessels were connected via satellite. This number is expected to increase to around 50 000 vessels over the next few years.

• The typical data rates currently provided by terminals operating in networks serving ESIM are around 100 Mbit/s - much higher, or faster, than those provided historically by satellite networks and systems in the mobile-satellite service (MSS), which use lower frequency bands (e.g. the 1.5 GHz, 1.6 GHz, 2.1 GHz, and 2.4 GHz bands).

• To address the increasing need of ESIM for radio-frequency spectrum, while protecting other and existing services, the ITU World Radiocommunication Conference (WRC-19), which took place in Sharm el-Sheikh, Egypt, from 28 October to 22 November 2019, decided on the regulatory and technical conditions under which the frequency bands 17.7 19.7 GHz (space-to-Earth) and 27.5-29.5 GHz (Earth-to-space) can be used by the three types of ESIMs communicating with geostationary (GSO) space stations in the fixed-satellite service (FSS).

• ESIM contribute, to Sustainable Development Goal 9 (industry, innovation and infrastructure) by connecting ships, aircraft and land vehicles and ensuring their safety and security and and that of their passengers, cargo and systems. When information and communication infrastructure is down in natural disasters, land ESIM can be vital.

CHALLENGES AND SOLUTIONS

Earth stations in motion (ESIM) are earth stations that communicate with geostationary-satellite orbit (GSO) systems operating in the fixed-satellite service (FSS) and operate on platforms in motion in the frequency ranges 17.7-20.2 GHz (space-to-Earth) and 27.5-30 GHz (Earth-to-space).

Historically, communication services to mobile platforms were usually provided by satellite systems in the mobile-satellite service (MSS) using relatively low frequency bands (e.g.- the 1.5 GHz, 1.6 GHz, 2.1 GHz, and 2.4 GHz bands). The frequency bandwidths available to individual users in these ranges are relatively low - typically a few kHz to a few hundred kHz. The narrow frequency bandwidths available limit the data rates that can be achieved, which range from a few kbit/s to around 700 kbit/s in a single channel.

The typical data rates currently provided by terminals operating in networks serving ESIM are around 100 Mbit/s. Data rates may increase to support higher broadband demand or be reduced for applications using smaller earth station antennas while still supporting much higher data rates than are available over existing MSS systems. ITU studies examine how to deliver higher data rates, without impacting other and existing services adversely.

When ships are at sea or aircraft cross the oceans, they are out of reach of terrestrial networks. For such crafts on or over vast oceans, an ESIM system can resolve this challenge by providing continuous broadband connectivity for crew and passengers.

ESIM provide broadband communications on cruise ships, the largest of which can accommodate several thousands of passengers. In addition, ESIM stations can provide broadband communications for managing ship operations, such as for transmission of engine diagnostics, as well as for access to the corporate network and for crew communications. The number of maritime vessels with a broadband connection by satellite grew by almost 25% between 2012 and 2013. In 2014, over 20 000 vessels were satellite connected and this number is expected to increase to around 50 000 vessels over the next few years. This strong growth has created greater demand for spectrum for ESIM.

In addition, ESIM meet the broadband connectivity requirements of land vehicles, including trains, coaches, vans, trucks and motorhomes. Land ESIM can provide connectivity throughout countries and are particularly useful in areas without coverage by terrestrial networks.

ESIM applications also exist for government users and aid organizations that have broadband communication needs for land vehicles, ships and aircraft. For example, when information and communication infrastructure is down in natural disasters, land ESIM can be vital.

ITU'S CONTRIBUTION

ITU Member States agreed at the WRC-19 in Sharm el-Sheikh, Egypt to a new Resolution that will boost the deployment of ESIM.

To address the increasing need for radio-frequency spectrum for ESIM, while protecting other services, WRC-19 agreed decided on the regulatory and technical conditions under which the frequency bands 17.7 19.7 GHz (space-to-Earth) and 27.5-29.5 GHz (Earth-to-space) can be used by the three types of ESIM communicating with geostationary (GSO) space stations in the fixed-satellite service (FSS).

The new Resolution starts by stating that "there is a need for global broadband mobile-satellite communications, and that some of this need could be met by allowing earth stations in motion (ESIMs) to communicate with space stations of the geostationary-satellite orbit (GSO) fixed-satellite service (FSS) operating in the frequency bands 17.7-19.7 GHz (space-to-Earth) and 27.5-29.5 GHz (Earth-to-space)."

However, the Resolution also cautions that the frequency bands 17.7-19.7 GHz (space-to-Earth) and 27.5-29.5 GHz (Earth-to-space) "are also allocated to terrestrial and space services used by a variety of different systems, and these existing services and their future development need to be protected, without the imposition of undue constraints, from the operation of ESIMs."

Considering the above, the Resolution lays out technical, operational and regulatory conditions for any ESIM communicating with a GSO FSS space station in the frequency bands 17.7-19.7 GHz and 27.5-29.5 GHz, or parts thereof.

WRC-19 also decided to continue studies on this issue for the next WRC scheduled in 2023, where the use of the frequency bands 17.7-18.6 GHz, 18.8-19.3 GHz and 19.7-20.2 GHz (space-to-Earth) and 27.5-29.1 GHz and 29.5-30 GHz (Earth-to-space) by ESIM communicating with non-geostationary satellites in the fixed-satellite service will be addressed together with a potential additional 500 MHz of new spectrum being identified for ESIM communicating with geostationary satellites in the fixed-satellite service in the frequency band 12.75-13.25 GHz (Earth-to-space).

NON-GEOSTATIONARY SATELLITE SYSTEMS

OVERVIEW

• National governments, companies and international institutions have all acknowledged the importance of bridging the digital divide to foster economic growth, drive social inclusion and meet consumer demand. However, billions of people still do not have access to broadband internet, particularly those living in rural or remote areas.

• Satellite systems offer significant advantages for expanding broadband coverage: they provide instant-on coverage across wide geographies without regard to challenging topography; they are reliable and largely immune to many risks that other networks face, including accidental damage, theft, conflict areas and natural disasters.

• The rapidly increasing use of non-geostationary satellite orbits (non-GSO), such as medium Earth orbits (MEO) and low Earth orbits (LEO), represents an important innovation in satellite technology - and a potential breakthrough in connecting the unconnected so that they, too, can reap the benefits of today's digital economy. Satellite connectivity is also important for the aviation and maritime sectors that operate aircraft and vessels that can be out of reach of terrestrial networks during their journeys.

• The ITU Radio Regulations (RR) enable the introduction of new applications of radiocommunication technology while ensuring the efficient use of radio-frequency spectrum, i.e. the operation of as many systems as possible, without interference.

• Space-based connectivity is helping make smart societies a reality across all 17 Sustainable Development Goals (including intelligent transport systems, e-government, tele-education, e-health, e-logistics, smart energy, smart agriculture), in both developed and developing countries, and particularly in rural and remote areas.

CHALLENGES AND SOLUTIONS

• Providing terrestrial connectivity is difficult in rural or remote areas, not only due to terrain and their isolation, but also because the cost of providing service via terrestrial mobile networks yields a poor return on investment for sparsely populated areas as compared to urban areas.

• New advances in satellite technologies could help bridge the digital divide more rapidly - and at lower cost - than ever before.

• Geostationary (GSO) satellites are at 36 000 kilometres above the Earth, a place where they appear fixed in the sky when observed from the ground. Non-GSO satellites at medium Earth orbits (MEO) altitudes are between 8 000 and 20 000 kilometres above the Earth and low Earth orbits (LEO) altitudes are between 400 to 2 000 kilometres above the Earth. Since non-GSO satellites move across the sky during their orbit around the Earth, non-GSO operators must deploy a fleet of satellites, generally called "constellations", to provide continuous service from these altitudes.

• Advances in satellite design, manufacturing and launch service capabilities have enabled the design and deployment of non-GSO fixed-satellite service (FSS) constellations. Additionally, the advances in antenna and terminal technology have enabled the usage of the 50/40 GHz frequency bands for both GSO FSS networks and non-GSO FSS systems.

• Constellations intend to cover the globe providing high-bandwidth connectivity, processing very high volumes of data with minimal delay. This could enable the fifth generation of mobile technologies (IMT-2020/5G) and theInternet of Things - a network of things to connect with each other and share data - which in turn help build smart societies.

• There is a need to encourage the development and implementation of new technologies in the FSS at frequencies above 30 GHz. The FSS systems based on the use of new technologies above 30 GHz and associated with both GSO and non-GSO satellite constellations can provide high-capacity and low-cost means of communication even to the most isolated regions of the world.

• The ITU Radio Regulations (RR) should enable the introduction of new applications of radiocommunication technology while ensuring the efficient use of radio-frequency spectrum, i.e. the operation of as many systems as possible, without interference. The RR include provisions

that allow GSO networks and non-GSO systems to operate without creating harmful radio interference to each other.

ITU'S CONTRIBUTION

ITU Member States at the World Radiocommunication Conference (WRC-19) in Sharm el-Sheikh, Egypt, adopted an innovative new milestone-based approach for the deployment of non-geostationary satellite (non-GSO) systems in specific radio-frequency bands and services.

The agreement reached at WRC-19 established regulatory procedures for the deployment of non-GSO systems, including mega-constellations in low-Earth orbit.

Under the newly adopted regulatory regime, these systems will have to deploy 10% of their constellation within 2 years after the end of the current regulatory period for bringing into use, 50% within 5 years and complete the deployment within 7 years.

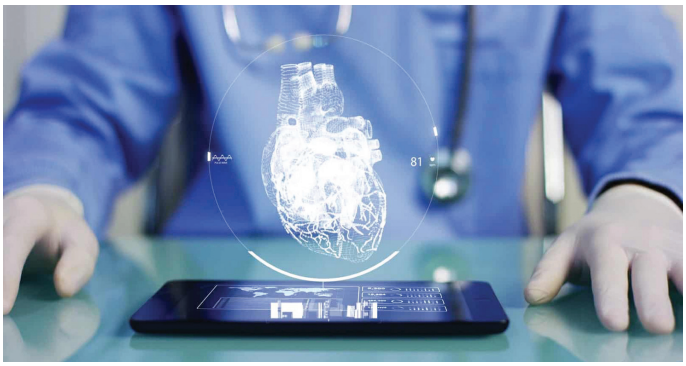
The milestone-based approach will provide a regulatory mechanism to help ensure that the Master International Frequency Register (MIFR) reasonably reflects the actual deployment of such non-GSO satellite systems in specific radio-frequency bands and services.

This agreement strikes a balance between the prevention of radio-frequency spectrum warehousing, the proper functioning of coordination, notification and registration of frequency assignments in the MIFR and the operational requirements related to the deployment of non-GSO systems.

Filings for frequency assignments to non-GSO satellite systems composed of hundreds to thousands of satellites have been received by ITU since 2011, in frequency bands allocated to the fixed-satellite service (FSS) or the mobile-satellite service (MSS).

The Conference also specifically called for further studies by ITU-R on tolerances for certain orbital characteristics of non-GSO space stations of the fixed-satellite, mobile-satellite, and broadcasting-satellite services to account for potential differences between the notified and deployed orbital characteristics, as well as for the possible development of non-GSO post-milestone procedures.

5G, HUMAN EXPOSURE TO ELECTROMAGNETIC FIELDS (EMF) AND HEALTH



OVERVIEW

• 5G – the 5th generation of mobile technologies - is an evolution from the previous generations of mobile technology: 2G, 3G and 4G.

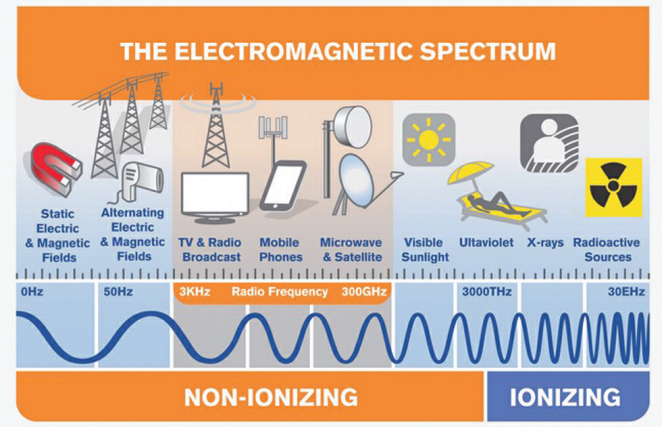
• 3G, 4G and 5G networks produce radio-frequency electromagnetic fields which are used to transmit information.

• Despite extensive studies into the health effects of mobile phones and base stations over the last two or three decades, there is no indication of an increased health risk when exposed to electromagnetic fields below the levels specified by international bodies.

• For all radio frequencies (0 to 300 GHz), international maximum levels are designed to avoid any adverse health effects.

• ITU does not set maximum levels of exposure of the public to electromagnetic fields. These levels are set by competent bodies and ITU in turn references their standards and recommendations in its relevant ITU Recommendations.

• Countries (ITU Member States) are sovereign and set their own national standards for exposure to electromagnetic fields. Most countries draw on the ITU Recommendations.



Mobile, or wireless, technologies – mobile phones, tablets and other wireless devices – have become basic communication tools of everyday life. They enable billions of people around the world to listen to the radio in their cars, watch free-to-air television programmes at home, travel safely in cities and around the globe and stay connected. For many on this planet, mobile is the primary - sometimes only - channel for accessing the Internet and the benefits it brings.

5G - the 5th generation of mobile technologies - is an evolution from the previous generations of mobile technology: 2G, 3G and 4G. 4G systems, for example, have opened a new era for mobile Internet, enabling many apps-based businesses used for such services as m-Learning, m-Health and mobile money.

5G, referred to by ITU as IMT-2020, is seen as opening yet another new era, supporting applications such as smart homes and buildings, smarter and cleaner cities, self-driving cars and road safety, other intelligent transport systems, 3D video, work and play in the cloud, remote medical services, virtual and augmented reality, and massive machine-to-machine communications for industry automation and manufacturing. 3G and 4G networks currently face challenges in supporting these services.

Mobile technologies and human health

Together with the introduction of mobile communication technologies, there has been some public concern about the potential health risks associated with the use of mobile phones and living near base stations.

3G, 4G and 5G networks produce radio-frequency electromagnetic fields which are used to transmit information. Electromagnetic fields have been around in different forms since the birth of the universe. They differ from each other by frequency and visible light is its most familiar form.

For all radio frequencies (0 to 300 GHz), international maximum levels are designed to avoid any adverse health effects.

Despite extensive studies into the health effects of mobile phones over the last two or three decades, there is no indication of an increased health risk when exposed to electromagnetic fields below the levels specified by international bodies.

There is no evidence that electromagnetic fields from existing (2G, 3G and 4G) mobile networks pose any health risks, provided that administrations enforce the exposure limits established by international bodies.

There is no scientific basis of any relation between the transmission of the coronavirus and 4G or 5G or any other electromagnetic waves.

Who regulates the exposure to EMF?

ITU does not set maximum levels of exposure of the public to electromagnetic fields. These levels are set by competent bodies and ITU in turn references their standards and recommendations in its relevant ITU Recommendations.

Countries (ITU Member States) are sovereign and set their own national standards for exposure to electromagnetic fields. Most countries draw on the ITU Recommendations.

Two main bodies have issued radio frequency exposure guidelines:

• The International Commission on Non-Ionizing Radiation Protection (ICNIRP): see https://www.icnirp.org, and

• The Institute of Electrical and Electronics Engineers (IEEE): see https://standards.ieee.org/standard/C95_1-2019.html

ITU'S CONTRIBUTION

ITU's mandate is to allocate the global radio spectrum and satellite orbit resources, to develop the technical standards that ensure networks and technologies seamlessly interconnect, are secure and improve access to ICTs to underserved communities worldwide.

ITU maintains the international treaty on the use of the radio-frequency spectrum (bands of radio frequencies) and satellite orbits that provides for a wide variety of wireless services on a harmonized basis. This avoids the possibility of harmful interference, ensures interoperability and reduces the cost of services and devices through the resulting economies of scale. The treaty provides for all generations of mobile technologies, from 2G to 5G and beyond.

ITU Recommendations refer to the standards, guidelines and recommendations on the maximum levels for exposure to EMF, which are established by competent international bodies [1] [2].

ITU publishes an EMF Guide and app in ITU's 6 official languages.

ITU provides recommendations on the means for measuring and monitoring electromagnetic fields and mitigating exposure [3] [4] [5] [6] [7].

REFERENCES

[1] Recommendation ITU-T K.91 "Guidance for assessment, evaluation and monitoring of human exposure to radio frequency electromagnetic fields"

[2] Recommendation ITU-T K.91 Supplement 1 "Guide on electromagnetic fields and health"

[3] Recommendation ITU-T K.61, "Guidance on measurement and numerical prediction of electromagnetic fields for compliance with human exposure limits for telecommunication installations"

[4] Recommendation ITU-T K.52, "Recommendation ITU-T K.52 (2018), Guidance on complying with limits for human exposure to electromagnetic fields"

[5] Recommendation ITU-T K.70, "Recommendation ITU-T K.70 (2018), Mitigation techniques to limit human exposure to EMFs in the vicinity of radiocommunication stations"

[6] Recommendation ITU-T K.100, "Recommendation ITU-T K.100 (2018), Measurement of radio frequency electromagnetic fields to determine compliance with human exposure limits when a base station is put into service"

[7] Recommendation ITU-R BS.1698, "Recommendation ITU-R BS.1698 (2005), Evaluating fields from terrestrial broadcasting transmitting systems operating in any frequency band for assessing exposure to non-ionizing radiation";

[8] https://www.itu.int/en/publications/ITU-R/Pages/publications.aspx?parent=R-SOFT-IDWM-2010&media=electronic

[9] ICT infrastructure for Financial inclusion is available at https://www.itu.int/en/myitu/News/2020/10/06/07/37/Mapping-financial-inclusion-Mexico-FIGI

[10] https://www.itu.int/en/ITU-D/Environment/Pages/Toolbox/Country-Story-Maps.aspx