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## Contents

*Dear Readers,*

In the Journal JITA that is before you, there are five articles by choice of the editors. The papers deal with a wide range of information technologies, especially their applications.

In the first article of authors Yu.M. Inkov, A.S. Kosmodamianskiy, A.A. Pugachev and E.V. Sachkova, from the Russian University of Transport, the „Simulation of Electric Drive with Direct Torque Control of Induction Motor" is considered.

The main requirements for traction electric drives are listed and discussed. The direct torque control of an induction motor electric drive is established by a survey of operation modes of traction electric drives to thoroughly satisfy the requirements for traction electric drive. The topologies and operation principles of two- and three-level voltage source inverters are presented. The advantages and shortcomings of three-level voltage source inverters to be applied on locomotive traction drives are highlighted in relation to the two-level ones. The recommendations of choice between different voltage source inverter topologies are given. The topology and principles of operation of direct torque control of induction motors with two- and three-level voltage source inverters are described. The simulation peculiarities of electric drives with direct torque control and two- and three-level inverters in Matlab are considered. The simulation results are presented. The techniques to reduce the torque oscillations are shown and implemented in Matlab Simulink.

In the second paper, the author Petr Filimonovich Bestemyanov studies the evaluation of the period of sensors motion parameters of the train. The study of the spectral composition of the considered function classes is performed using Hartley's transformation.

The choice of polling period sensors for measuring the speed and acceleration of the train can be produced using the spectral representation of functions of velocity and acceleration from time to time. Using the spectral method of determining the period of the survey, you can choose different value depending on the category of the train and its dynamic characteristics. For high-speed trains, the period of sensors is less than for trucks, since the latter are tightened by the transients during acceleration and deceleration.

In the third article titled „Differentiation Loss in MANET Package Based on BP Neural Network", authors Dimitris Kanellopoulos and Pratik Gite show that an adaptive distributed routing algorithm is essential in MANETs, since there is no central routing system. Actually, there is no central point of coordination; each node is responsible for forwarding data packets to other nodes, thereby acting as router and host. A packet might travel through multiple intermediary ad hoc nodes in order to arrive to its destination, while the nature of wireless multi-hop channel is bringing in various types of packet losses.

This paper focuses on three main reasons of online packet losses in MANETs: (1) losses due to wireless link errors; (2) losses due to congestion; and (3) losses due to route alteration. It proposes a deep learning-based algorithm for packet loss discrimination. The algorithm uses the BPNN concept. We performed simulation experiments for evaluating the performance of the proposed loss discrimination algorithm under different network configurations. Through simulation results, we confirmed that the proposed algorithm improves packet loss discrimination and route alteration in the network. It also reduces congestion and increases network throughput.

In the fourth article entitled „Use of Mobile Benefits in the Communication System" by Klyachko Lev from the Krylov State Research Center, an adaptive radio communication system is considered.

Short wave and VHF wave data transfer systems are widely used in connection with the ability to transmit large amounts of information over relatively long distances at relatively low power transmitters. VHF radio stations are required to be installed on vessels of any tonnage. VHF radio communication is widely used in rail transport, in other industries.

The article discusses the use of multiparameter adaptation in communication VHF waves communication, provides specific schema that implements the proposed algorithm.

In the last paper, author Sinisa Macan presented the EU directives on services, digital identity and ID document in Bosnia and Herzegovina (BiH). The author states that in 2006 the European Union adopted the Services Directive, which establishes the obligation to establish unique points of contact through which citizens and businesses receive certain services from government bodies. The Services Directive unifies the services market throughout the European Union and creates an obligation for each Member State to improve its way of providing services to citizens. Citizens are accessing services through digital identities.

Having in mind that Bosnia and Herzegovina has more than 65% turnover with EU countries, there is a need and legal obligation for the introduction of the same standards in the field of digital services and digital identities in BiH as in the EU. Citizens and businesses in BiH need to have the same position with competitive and compatible markets in EU countries. To validate digital identities, it is possible to use ID documents in BiH.

This paper describes the way of validating the digital identity in BiH using ID card or passport. ID documents issued according to ICAO 9303 standards and EU regulations must have embedded chips. These documents can be used to access electronic services as well as for digital identity verification.

Editors, Gordana Radic, Editor-in-Chief, Zoran Avramović, Dušan Starcevic

# Simulation of Electric Drive With Direct Torque Control of Induction Motor

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**Contribution to the state of the art**

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**Abstract:** The main requirements for traction electric drives are listed and discussed. The direct torque control of an induction motor electric drive is established by a survey of operation modes of traction electric drives to thoroughly satisfy the requirements for traction electric drive. The topologies and operation principles of two-and three-level voltage source inverters are presented. The advantages and shortcomings of three-level voltage source inverters to be applied on locomotive traction drives are highlighted in relation to the two-level ones. The recommendations of choice between different voltage source inverter topologies are given. The topology and principles of operation of direct torque control of induction motors with two- and three-level voltage source inverters are described. The simulation peculiarities of electric drives with direct torque control and two- and three-level inverters in Matlab are considered. The simulation results are presented. The techniques to reduce the torque oscillations are shown and implemented in Matlab Simulink.

**Keywords:** induction motor, direct torque control, voltage source inverter, equivalent circuit, control system, Matlab.

## Introduction

The choice of the type of electric energy converter, electric motor and its control systems, which have to implement a desired traction forces and torques, is a key clue in a process of designing of up-to-date locomotives. Nowadays, electric drive with induction motors is employed as traction one in locomotives manufactured in Russian Federation [7]. An induction motor with the squirrel-cage rotor has a number of known advantages in front of DC-motor that allows to increase reliability and efficiency and decrease weight and dimensions of the electric drive [5]. A correctly chosen electric drive has to satisfy the next main requirements:

- It has to provide high value of the torque at low values of the speed and high value of the power at high values of the speed.
- It has to have a wide range of the speed including regions with the constant torque and the constant power.
- It has to deliver a fast torque response on the reference change.
- It has to be robust on variation of operation modes,parameters, faults and malfunctions of electrical and mechanical units.
- It has to have high value of the reliability and efficiency in the whole range of modes including braking and reversing.

The survey of electric drives lets us to conclude that the best option for it is a voltage-fed inverter induction motor that satisfies the above listed requirements almost thoroughly [3,4]. There are a numerous structures and techniques to solve the task of speed and/or torque control, the control systems can be divided into three main groups. Historically, the scalar control system is the first technique implicating the frequency converter to control the mo-

tor speed [5,6]. It utilizes the simultaneous variation of both magnitude and frequency of the stator voltage regardless to any phase value. The scalar control is easily provided by current sensors, sometimes the speed sensor is added to it for more accuracy delivering. The main applications employing such a type of speed control are a water and oil pumps, fans, conveyers and a range of traction drives of locomotives used in Russian railways. The second group is shaped of vector control systems which adjust continuously not only magnitude and frequency of the stator voltage but also phase between vectors of some currents and/or flux linkages [1]. Vector control needs a high precision current, voltage, flux and speed sensors. Some of sensors are substituted for identifiers and observers in state-of-art electric drives on a base of fast digital signal processors. The third group of control systems uses the discrete way of adjusting provided by using of relay controllers and predetermined states of induction motor and voltage source inverter. This technique of control is named direct torque control [9]. The second and third groups of control systems are implemented for applications requiring high accuracy and fast response. As a payback for its intrinsic structure and complicated network of sensors, these systems deliver higher values of efficiency than the scalar ones.

So, the system of direct torque control is an up-to-date and prospective control system of electric drive. This investigation aims to simulate electric drive with direct torque control and three-level inverter and compare its results to similar drive with the two-level inverter.

## Backgrounds of Two- and Three-Level Voltage Source Inverters

The historically traditional type of inverter for traction motor is the two-level voltage source inverter (Fig. 1) [11]. This inverter produces 8 voltage vectors, 2 of which have zero magnitude (Fig. 2). The main requirements for the correct switching of transistors are the following: the capacitor $C$ has not to be short-circuited; the next states of transistor legs have to differ only by state of a single transistor.
The first requirement is satisfied by applying the next switching functions:

$$S_i = 1, \Rightarrow (S_{i1}, S_{i2}) = (1,0) \quad (1)$$

$$S_i = 0, \Rightarrow (S_{i1}, S_{i2}) = (0,1) \quad (2)$$

where $i$ denotes phase of $a$, $b$, $c$.

These switching functions deliver vector of the stator voltage as follow:

$$v_s = (2/3)^{1/2} (v_{aN} + v_{bN} e^{-j2\pi/3} + v_{cN} e^{j2\pi/3}) \quad (3)$$

where $v_a$,$v_b$, $v_c$ denote the voltages of the respective phases.

The second requirement is satisfied by arrangement of switching functions as it shown in Fig. 2.

Since recently, the multi-level voltage source inverters have been employed in electric drive. A number of various inverter topologies has been developed. The main target of it is to enhance the harmonic spectrum of the stator voltage and current, to increase switching frequency of inverter transistors, to reduce the speed of output voltage changing that leads, in its turn, to fewer weight and dimensions of output filters and reactances.

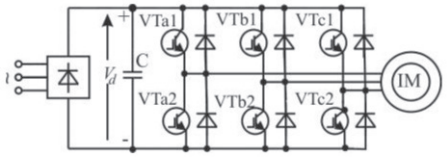



***Fig. 1.*** *Topology of the two-level inverter*

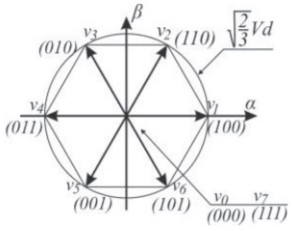



***Fig. 2.*** *Vectors of the output voltage of the inverter (Fig. 1)*

The topology of one of three-level inverters is shown in Fig. 3. This inverter is fed by voltage source with neutral point. The inverter consists of 12 transistors $VT_{a1}...VT_{c4}$ (4 series connected transistors $VT_{i1}...VT_{i4}$ in each leg). All transistors have the anti-parallel diode providing the back direction of current flowing. The scheme is augmented by 6 clamped diodes (2 diodes on each leg) allowing to connect each of phase of the stator winding to the

neutral point. All transistor legs have three states. The main requirements for the correct switching of transistors are the same as for the two-level inverter. The switching functions providing the requirement are written as follows:

$S_i = -1 = n, \Rightarrow (S_{i1}, S_{i2}, S_{i3}, S_{i4}) = (0,0,1,1)$ (4)

$S_i = 0 = o, \Rightarrow (S_{i1}, S_{i2}, S_{i3}, S_{i4}) = (0,1,1,0)$ (5)

$S_i = 1 = p, \Rightarrow (S_{i1}, S_{i2}, S_{i3}, S_{i4}) = (1,1,0,0)$ (6)

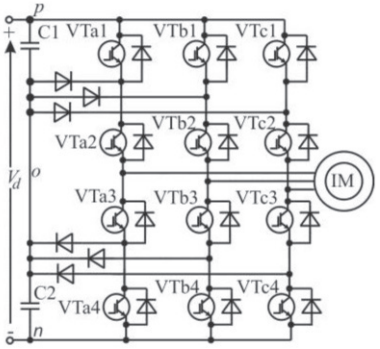



***Fig. 3.*** *Topology of the three-level inverter with clamped diodes*

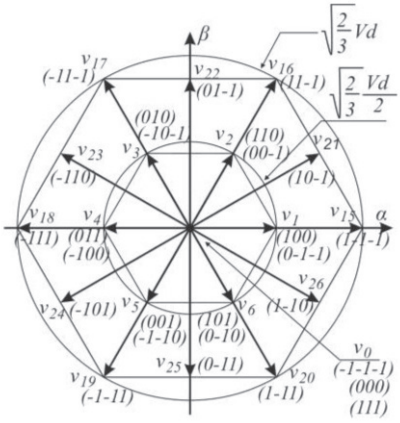



***Fig. 4.*** *Vectors of the output voltage of the inverter (Fig. 3)*

The three-level inverter has 27 vectors of the output voltages. If the values of capacitances *C1* and *C2* are equal then the voltages dropped on each capacitance are also equal. It leads to coincidences of some vectors and only 19 vectors of the voltage are left. All the vectors and its arrangement providing the correct operation of inverter are shown in Fig. 4. The voltage vectors can be divided into 4 groups in regard to its magnitude. The large vectors are created by connection all three phases of the stator winding to the positive *p* or negative *n* points of voltage source, except the state when the three legs connected to the same point. The mean voltage vectors are the vectors formed by connection of one phase of the stator winding to the neutral point *o* while the two others are connected to the positive *p* and negative *n* points of voltage source, respectively. The simultaneous connection of two legs to the same point while the third one connected to the point next to it creates the group of small vectors. The zero vector is produced by simultaneous connection of all three legs to the same point. The feature of the inverter with clamped diodes is that the groups of the small vectors could be formed by two different combinations of the switching functions (4) – (6).

The more complicated three-level inverters have the advantages before the two-level ones as it was stressed earlier. But, such a redundancy of a semiconductor devices could also mean a higher value of likelihood of any device fault or malfunction. The relevance of three-level inverters using in industrial and traction applications is mainly determined from the thermal behavior of power switches and the power losses. As some investigations show, the implementation of the three-level inverters is proved from the thermal conditions of semiconductor devices in the range of medium and high switching frequency since frequency of some kHz.

## Background sof direct torque control

The system of direct torque control of an induction motor (Fig. 5) wasfor the first time introducedin the middle of 1980's [10,11,12].The basic principle of its operation lays upon the keeping of permanent values of torque *T*and stator flux linkage $\psi_s$(regarding to the hysteresis band)which is implemented by choice of some output voltage vectors of voltage source inverter.The references on the output voltage vectors are the values of torque and flux linkage voltage references $\Delta_T$and$\Delta_\psi$taking discrete levels depending on sign and value of torque and flux linkage errors $T_{ref}$ – *T*and$\psi_{ref}$ –$\psi_s$, respectively, and sector of flux linkage. The main difficulty of such control is an accurate evaluation of the torque and flux linkage.The one of possible scheme of direct torque control is shown in Fig. 5. The transformation from three- to two-coordinated reference frame(A, B, C → α, β) is done on the basis of sensors data of the current $I_s$and voltage $V_s$of two phases of the stator. After

that, the respective stator flux linkages coordinates are evaluated:

$$\psi_{s\alpha} = \int (V_{s\alpha} - I_{s\alpha} R_s \psi_{s\alpha} = \int (V_{s\alpha} - I_{s\alpha} R_s) \mathrm{dt} \quad (7)$$

$$\psi_{s\beta} = \int (V_{s\beta} - I_{s\beta} R_s \psi_{s\beta} = \int (V_{s\beta} - I_{s\beta} R_s) \mathrm{dt} \quad (8)$$

where $R_s$ denotes the stator resistance.

It is obvious that direct torque control is very sensitive to the correctness of the used value of stator resistance due to the stator flux linkage calculation depends on the procedure of integration. As it shown in [8], the stator resistance calculation error of 1% causes significant drop in the quality indicators. The higher values of this error cause the lost of stability, so it could be recommended to employ the stator winding temperature correction [7].

The electromagnetic torque is evaluated as follow:

$$T = \frac{3}{2} \mathrm{p}_n \left( I_{s\beta} \psi_{s\alpha} - I_{s\alpha} \psi_{s\beta} \right) \quad (9)$$

Where $p_n$ denotes the number of pole pairs.

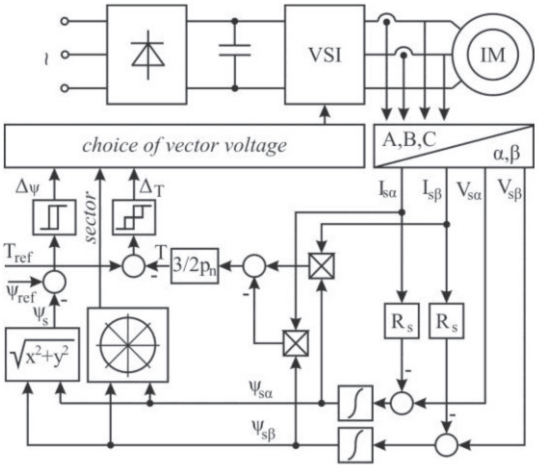



***Fig. 5.*** *Direct torque control topology*

Based on the scientific researches and proceedings survey[3,4,7,8,10], the main advantages of direct torque control relating to the classic version ofrotor field-oriented vector control systemare summarized asfollows:

- small response time of the torque and flux linkage loops;
- absence of the coordinate transformer (Fortran's formation from/to the frame synchronously rotated with the rotor shaft);
- absence of the speed sensor.

Alongside the advantages, there are some drawbacks:

- severe distortion of the stator current, the difficulties of stator current control;
- significant oscillation of torque;
- alternating switching frequency.

It should be noted that the magnitude of the torque oscillations and shape of the stator current depend directly on the type voltage source inverter applied to feed an induction motor.

With the two-level inverter applied in the scheme, the three and two position relay controllers are employed as a torque and flux linkage controllers, respectively.The choice of proper vector voltage of the inverter is corresponded to the data of the Table 1 [9].

***Table 1.*** *The state of inverter (Fig. 1)*

| $\Delta_\psi$ | $\Delta_T$ | sector | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 |
| +1 | +1 | $V_2$ | $V_3$ | $V_4$ | $V_5$ | $V_6$ | $V_1$ |
| | 0 | $V_7$ | $V_0$ | $V_7$ | $V_0$ | $V_7$ | $V_0$ |
| | -1 | $V_6$ | $V_1$ | $V_2$ | $V_3$ | $V_4$ | $V_5$ |
| -1 | +1 | $V_3$ | $V_4$ | $V_5$ | $V_6$ | $V_1$ | $V_2$ |
| | 0 | $V_0$ | $V_7$ | $V_0$ | $V_7$ | $V_0$ | $V_7$ |
| | -1 | $V_5$ | $V_6$ | $V_1$ | $V_2$ | $V_3$ | $V_4$ |

***Table 2.*** *The state of inverter (Fig. 3)*

| $\Delta_\psi$ | $\Delta_T$ | $\omega < \omega_{\rho\alpha\tau}/2$ | | | | | | $\omega > \omega_{\rho\alpha\tau}/2$ | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | sector | | | | | | sector | | | | | |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| +1 | +2 | $V_{21}$ | $V_{22}$ | $V_{23}$ | $V_{24}$ | $V_{25}$ | $V_{26}$ | $V_{16}$ | $V_{17}$ | $V_{18}$ | $V_{19}$ | $V_{20}$ | $V_{15}$ |
| | +1 | $V_2$ | $V_3$ | $V_4$ | $V_5$ | $V_6$ | $V_1$ | $V_{21}$ | $V_{22}$ | $V_{23}$ | $V_{24}$ | $V_{25}$ | $V_{26}$ |
| | 0 | zero vector | | | | | | zero vector | | | | | |
| | -1 | $V_6$ | $V_1$ | $V_2$ | $V_3$ | $V_4$ | $V_5$ | $V_{26}$ | $V_{21}$ | $V_{22}$ | $V_{23}$ | $V_{24}$ | $V_{25}$ |
| | -2 | $V_{26}$ | $V_{21}$ | $V_{22}$ | $V_{23}$ | $V_{24}$ | $V_{25}$ | $V_{20}$ | $V_{15}$ | $V_{16}$ | $V_{17}$ | $V_{18}$ | $V_{19}$ |
| 0 | +2 | $V_{22}$ | $V_{23}$ | $V_{24}$ | $V_{25}$ | $V_{26}$ | $V_{21}$ | $V_{22}$ | $V_{23}$ | $V_{24}$ | $V_{25}$ | $V_{26}$ | $V_{21}$ |
| | +1 | $V_3$ | $V_4$ | $V_5$ | $V_6$ | $V_1$ | $V_2$ | $V_{17}$ | $V_{18}$ | $V_{19}$ | $V_{20}$ | $V_{15}$ | $V_{16}$ |
| | 0 | zero vector | | | | | | zero vector | | | | | |
| | -1 | $V_5$ | $V_6$ | $V_1$ | $V_2$ | $V_3$ | $V_4$ | $V_{19}$ | $V_{20}$ | $V_{15}$ | $V_{16}$ | $V_{17}$ | $V_{18}$ |
| | -2 | $V_{25}$ | $V_{26}$ | $V_{21}$ | $V_{22}$ | $V_{23}$ | $V_{24}$ | $V_{25}$ | $V_{26}$ | $V_{21}$ | $V_{22}$ | $V_{23}$ | $V_{24}$ |
| -1 | +2 | $V_{23}$ | $V_{24}$ | $V_{25}$ | $V_{26}$ | $V_{21}$ | $V_{22}$ | $V_{23}$ | $V_{24}$ | $V_{25}$ | $V_{26}$ | $V_{21}$ | $V_{22}$ |
| | +1 | $V_3$ | $V_4$ | $V_5$ | $V_6$ | $V_1$ | $V_2$ | $V_{17}$ | $V_{18}$ | $V_{19}$ | $V_{20}$ | $V_{15}$ | $V_{16}$ |
| | 0 | zero vector | | | | | | zero vector | | | | | |
| | -1 | $V_5$ | $V_6$ | $V_1$ | $V_2$ | $V_3$ | $V_4$ | $V_{19}$ | $V_{20}$ | $V_{15}$ | $V_{16}$ | $V_{17}$ | $V_{18}$ |
| | -2 | $V_{24}$ | $V_{25}$ | $V_{26}$ | $V_{21}$ | $V_{22}$ | $V_{23}$ | $V_{24}$ | $V_{25}$ | $V_{26}$ | $V_{21}$ | $V_{22}$ | $V_{23}$ |

With the three-level inverter applied in the scheme, the five and three position relay controllers are employed as a torque and flux linkage controller, respectively. The choice of proper vector voltage in this case is corresponded to the data of the Table 2 [12]. In the Table 2 and after, $\omega$ denotes the rotor speed, the index *rat* denotes the rated value.

## Description of Simulation Technique

The equivalent circuit of an induction motor in the reference frame used for simulation is shown in Fig. 6. Here, $L_{\sigma s}$, $L_{\sigma r}$ denote the stator and rotor leakage inductances; $L_{\mu}$ denotes the magnetizing inductance; $\omega_k$ denotes the speed of the reference frame; $i_s$, $i_r$ denote the currents flowing through the stator and rotor windings; $i_{\mu}$ denotes the current flowing through the inductance of $L_{\mu}$; $\psi_s$, $\psi_r$, $\psi_{\mu}$ denote the stator, rotor and magnetizing flux linkages, respectively. The equivalent circuit does not account for the stator and rotor iron losses.

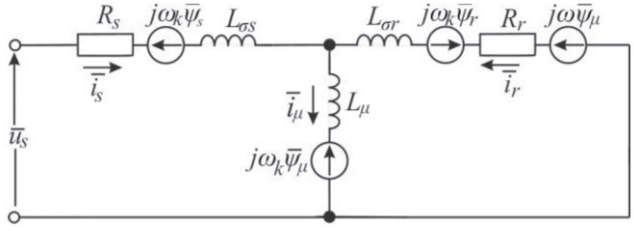



***Fig. 6.*** *Equivalent circuit of induction motor*

To simulate an induction motor, the following equations describing the equivalent circuit (Fig. 6) are used:

$$v_{s\alpha} = R_s i_{s\alpha} + \frac{d\psi_{s\alpha}}{dt} - \omega_k \psi_{s\beta}, v_{s\beta} = R_s i_{s\beta} + \frac{d\psi_{s\beta}}{dt} + \omega_k \psi_{s\alpha}, \quad (10)$$

$$0 = R_r i_{r\alpha} + \frac{d\psi_{r\alpha}}{dt} - (\omega_k - \omega)\psi_{r\beta}, 0 = R_r i_{r\beta} + \frac{d\psi_{r\beta}}{dt} + (\omega_k - \omega)\psi_{r\alpha}, \quad (11)$$

$$\psi_{s\alpha} = L_s i_{s\alpha} + L_{\mu} i_{r\alpha}, \psi_{s\alpha} = L_s i_{s\beta} + L_{\mu} i_{r\beta}, \quad (12)$$

$$\psi_{r\alpha} = L_r i_{r\alpha} + L_{\mu} i_{s\alpha}, \psi_{r\alpha} = L_r i_{r\beta} + L_{\mu} i_{s\beta}, \quad (13)$$

where $\alpha$,$\beta$ denote the coordinate axes.

The mechanical moving is described as follow:

$$T - T_L = J\frac{d\omega}{dt}, \quad (14)$$

where $T_L$ denotes the load torque, $J$ denotes the moment of inertia.

For reaching the correct results of simulation of electromechanical and energy processes it is necessary to take into account the effect of current replacement that influences on operation under low frequency condition. The active and inductive resistance are given by:

$$R_r = K_r R_{r,sl} + R_{r,end}, \quad (15)$$

$$X_r = K_x X_{r,sl} + X_{r,end}, \quad (16)$$

where $R_{r,sl}$ and $X_{r,sl}$ are resistances of slot winding, $R_{r,end}$ and $X_{r,end}$ are resistances of pieces of end rings between neighbor rotor bars, $K_r$ and $K_x$ are coefficients taking resistance change under the effect of

$$K_r = \xi\frac{sh2\xi + sin2\xi}{ch2\xi - cos2\xi}, \quad (17)$$

$$K_x = \xi\frac{sh2\xi - sin2\xi}{ch2\xi - cos2\xi}, \quad (18)$$

where ξ denotes the specified bar height:

$$\xi = 2\pi 10^{-3} h\sqrt{\frac{sf_s b}{10\rho b_{sl}}}, \quad (19)$$

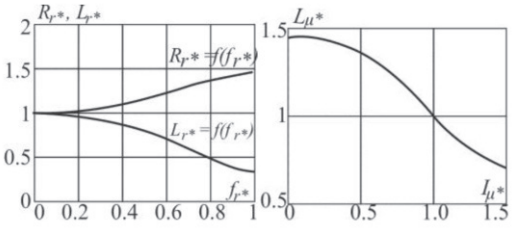
$h$ is the bar height, $\rho$ is specific resistance of the bar material, $b$ is the bar width, $b_n$ is the slot width.

The dependance of the $L_{\mu}$ from the magnitude of magnetising current $I_m$ is as follows

$$L_{\mu*} = -0{,}002I_{\mu*}^6 + 0{,}037I_{\mu*}^5 - 0{,}261I_{\mu*}^4 + 0{,}87I_{\mu*}^3 - 1{,}278I_{\mu*}^2 + 0{,}214I_{\mu*} + 1{,}413. \quad (20)$$

where $L_{m*} = L_m / L_{m,rat}$ and $I_{m*} = I_m / I_{m,rat}$, index *rat* denotes the rated value of some parameter.

The nonlinearity described by (15), (16)and (20) are shown in Fig. 7.




***a)*** ***b)***

***Fig. 7.*** *The rotor resistance and inductance depend on frequency of the rotor current (a), andthe magnetizing inductance depends on the magnetizing current (c)*

The blocks *Real Image to Complex* and *Complex to Magnitude Angle* from library of *Simulink* are implicated to evaluate of magnitude and phase of flux linkage. Generally, if the flux linkage phase was determined, the sector of flux linkage could be found by implying the next expressions (phase θ of the flux linkage is written in grades; simultaneously, it is taken into account that the phase θ varies -180° to 180°):

if -30°<θ≤ 30°, then $\vec{\psi}_S$ belongs to sector *1*;

if 30° <θ≤ 90°, then $\vec{\psi}_S$ belongs to sector *2*;

if 90°<θ≤ 150°, then $\vec{\psi}_S$ belongs to sector *3*;

if θ> 150° or θ≤ -150° then, то $\vec{\psi}_S$ belongs to sector *4*;

if -150°<θ≤ - 90°, then $\vec{\psi}_S$ belongs to sector *5*;

if -9 0 <θ≤ -30°, then $\vec{\psi}_S$ belongs to sector *6*.

To calculate the phase sector number, the block *Flux sector seeker* included in the subsystem of *DTC Induction motor drive* (*Sym Power Systems* → *Application Libraries* → *Electric Drives library* → *AC drives*) is used.

The relay controllers of flux linkage and torque implicated for simulation have the static characteristics shown in Fig.8. The implementation of relay controllers by means of Matlab is shown in Fig. 9 (the main units are *Relay*, *Logical operator*, *Gain*, *Data type conversion*, *Sum*).

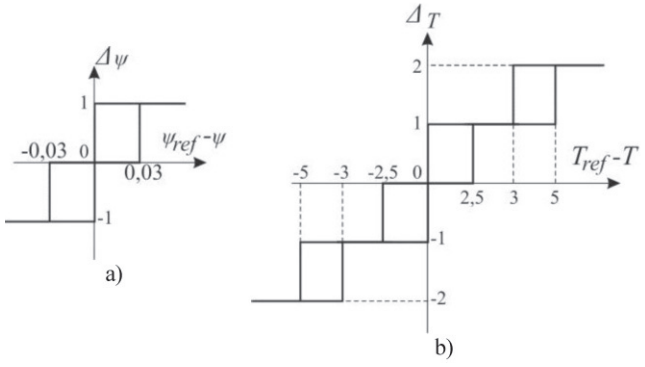



***Fig. 8.*** *Relay controllers of flux linkage (a) and torque (b)*

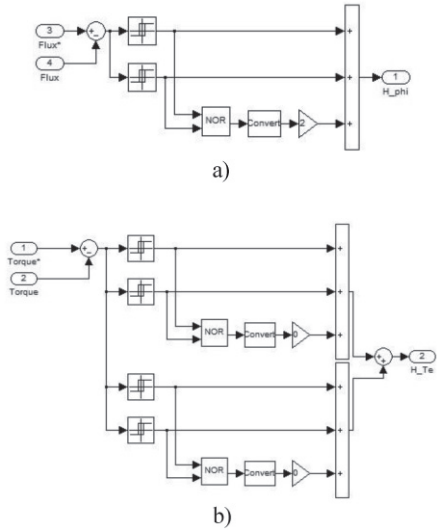



***Fig. 9.*** *Implementation of relay controllers of flux linkage (a) and torque (b)by Matlab Simulink*

The table of voltage source inverter switching is developed in Matlab by blocks *Relay*, *Logical operator*, *Gain*, *Look-Up Table*, *Data type conversion*, *Sum* (some part of the scheme is shown in Fig. 10).

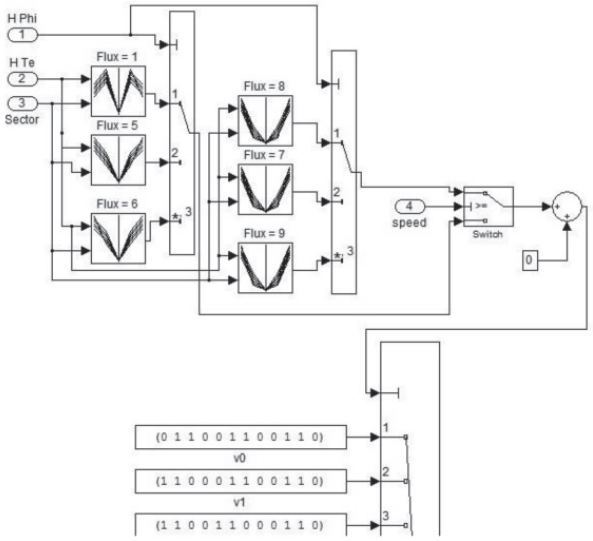
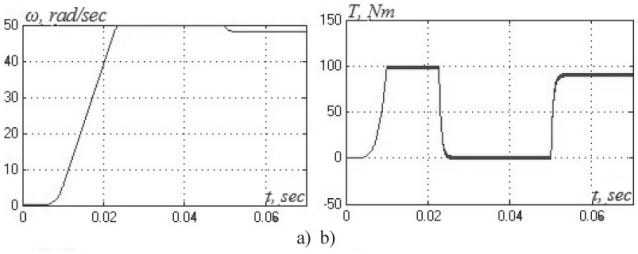



***Fig. 10.*** *Implementation of switching table (Table 2) by means of Matlab Simulink (fragment)*

## RESULTS OF SIMULATION

The simulation was carried out in Matlab. The three-level inverter (Fig. 3) was used, the switching functions (4) – (6) were applied to control inverter states.The induction motor was presented in accordance to (9) – (14), the nonlinearity were implemented by (15) – (20) and Fig. 7. Table 2 was employed as the table of inverter optimal switching (Fig. 10). The topology of simulated scheme coincided to the scheme (Fig. 5).

The simulation results of electric drive with the direct torque control of an induction motor are shown in Fig. 11. The parameters of induction motor to be simulated are follows: $V_{s,rat}$ = 380 V; $I_{s,rat}$ = 27 A; $P_{rat}$ = 11 kW; 2p = 4; $n_{rat}$ = 1460 rev/min; $f_{s,rat}$= 50 Hz; $X_{ls}$ = 0,73 Ω; $R_s$ = 0,34 Ω; $X_{m,rat}$= 31 Ω; $X_{lr,start}$= 0,73 Ω; $X_{lr,rat}$= 1,68 Ω; $R_{r,start}$ = 0,41 Ω, $R_{r,rat}$ = 0,29 Ω, where $P_{rat}$ denotes the rated mechanical power.



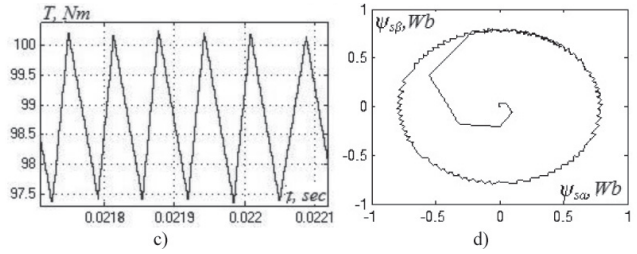



***Fig. 11.*** *Resultsofsimulation:a)–rotorspeedvstime, b) – torquevstime, c) – torque graph (zoom in), d) – plot of stator flux linkage*

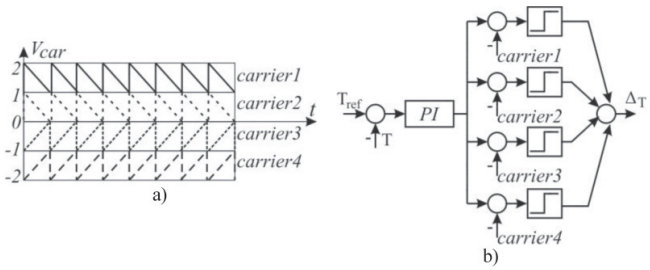



***Fig. 12.*** *Carrier voltages graph (a) and topology of torque controller fixing the switching frequency (b)*

Analyses of the results let us conclude that the electric drive has the small response time and high accuracy of torque and flux linkages loops at the change of reference on the rotor speed and step-like change of the load torque. Relatively to the classic direct torque control with the two-level inverter (results of this system simulation is given in [8]), the investigated scheme of control system allows to reduce the torque oscillation on 25 – 40 % at the same switching frequency.

## Fixing the Switching Frequency

As it was stressed earlier in the section 4, one of the main drawbacks of classic direct torque control is a variable switching frequency that imposes some extra requirements for inverter and induction motor control systems. The simple and effective way to mitigate such a drawback is to employ PI-controller of torque and pulse-width modulation [6] instead of relay controllers.To achieve this aim, the four carrier references are needed to be employed (Fig. 12). As it follows from the Fig. 12a, the limits of carrier voltages are justified by the following expressions:

$$1 \le carrier1 \le 2,\ 0 \le carrier2 \le 1,\ -1 \le carrier3 \le 0,\ -2 \le carrier4 \le -1.$$

It should be noted that the phases of two positive and two negative carriers shift on period of switching frequency.

The principle of producing the reference voltage $\Delta_T$ follows the next rules:

If $T_{ref} - T > carrier1$, then $\Delta_T = 2$;
If $carrier2 \le T_{ref} - T < carrier1$, then $\Delta_T = 1$;
If $carrier3 \le T_{ref} - T < carrier2$, then $\Delta_T = 0$;
If $carrier4 \le T_{ref} - T < carrier3$, then $\Delta_T = -1$;
If $T_{ref} - T > carrier4$, then $\Delta_T = -2$.

The implementation of these rules in Matlab Simulink is shown in Fig. 13. The used blocks are *Gain*, *Integral*, *Saturation*, *Repeating Table*, *Relay* and *Sum*. The parameters *Switch on point* and *Switch off point* of block *Relay* are set out in the value *eps*.

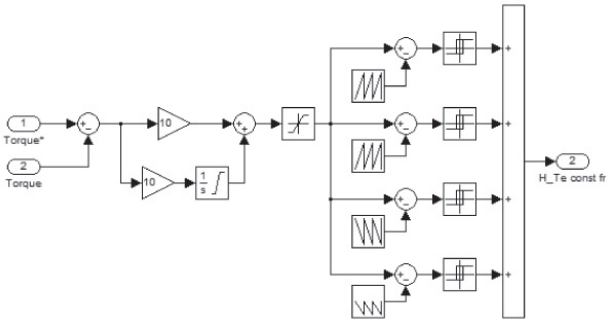



***Fig. 13.*** *Implementation of torque controller (Fig. 12b) by Matlab Simulink*

The results of simulation of direct torque control with the application of torque controller (Fig 12b) instead of torque relay controller in the scheme (Fig. 5) show that this substitution allows to fix swirching frequency accordingly tothe period choosen (Fig. 12a). The magnnitude of torque ripple becomes a variable and non-controlling by control system. It strictly depends on the switching frequency and could be reduced by frequency increasing.

## Conclusion

The simulation carried out in the present investigation by means of tools and algorithms of Matlab Simulink shows that the implementation of the three-level voltage source inverter with the three-positioned flux linkage relay controller and five-positioned torque relay controller enhances the quality of direct torque control operation. Relatively to the classic direct torque control with the two-level inverter, the investigated scheme of control system allows

to reduce the torque oscillation on 25 – 40 % at the same switching frequency. Also, it leads to reducing the total harmonic distortion of the stator current. The employment of PI-controller and algorithms of pulse-width modulation instead of torque relay controller leads to the fixing of switching frequency.

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# EVALUATION OF THE PERIOD OF SENSORS MOTION PARAMETERS OF THE TRAIN

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**Contribution to the state of the art**

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**Abstract:** The choice of polling period sensors for measuring the speed and acceleration of the train can be produced using the spectral representation of functions of velocity and acceleration from time to time. Using the spectral method of determining the period of the survey, you can choose different value depending on the category of the train and its dynamic characteristics. For high-speed trains, the period of sensors is less than for trucks, since the latter are tightened by the transients during acceleration and deceleration.

**Keywords:** Hartley transform, parameters of the train, period of sensors, spectral method.

## INTRODUCTION

The study of the spectral composition of the considered classes of functions will be made using the Hartley transform. R. Hartley introduced a couple of integral transforms in an article published in the journal *Proceedings of the Institute of Radio Engineers* in 1942. If you use frequency $f$ instead of angular frequency $\omega$, it is as follows:

$$H(f) = \int_{-\infty}^{+\infty} V(t) cas 2\pi f t dt,$$
$$V(t) = \int_{-\infty}^{+\infty} H(f) cas 2\pi f t dt. \quad (1)$$

Then $H(f)$ is regarded as the Hartley transform of the function $V(t)$, which in turn is the inverse Hartley transform of the function $H(f)$. Function $cast \equiv \cos t + \sin t$. Any function can be represented uniquely as a sum of even and odd component. For instance, $H(f) = E(f) + O(f)$, where $E(f)$ and $O(f)$ are respectively the even and odd components of the function $H(f)$.

Then:

$$E(f) = \int_{-\infty}^{+\infty} V(t) \cos 2\pi f t dt,$$
$$O(f) = \int_{-\infty}^{+\infty} V(t) \sin 2\pi f t dt. \quad (2)$$

These two integrals are known as, respectively, the cosine - and sine-Fourier transform, which have tabulated values [1].

## REPRESENTATION OF REAL FLUCTUATIONS

Energy and phase spectra can be obtained directly from the Hartley transform.Thus we have the energy spectrum:

$$P(f) = E^2(f) + O^2(f) = \frac{[H(f)]^2 + [H(-f)]^2}{2}, \quad (3)$$

and the phase spectrum:

$$\arg F(f) = arctg \frac{-O(f)}{E(f)} = \frac{H(-f) - H(f)}{H(f) + H(-f)}. \quad (4)$$

In a sense, the Hartley transform can be considered as a smooth form of representation of real

fluctuations. Being purely physical, the Hartley transform does not require other ways of representing [2]. We will use the following hypothesis on the speed of the train:

$$V(t)=\begin{cases}V_0+at, 0\le t<T\\ V, T\le t<T_1\\ V-at, T_1\le t<T_2\\ 0, t<0, t\ge T_2\end{cases}. \quad (5)$$

Then the even part of the Hartley transform is defined determined as follows:

$$E_v(f)=\int_0^T (V_0+at)\cos 2\pi ftdt+\int_T^{T_1} V\cos 2\pi ftdt+\int_{T_1}^{T_2}(V-at)\cos 2\pi ftdt. \quad (6)$$

Using tabulated values of the integrals [3]:

$$\begin{aligned}&\int\cos(a+bx)dx=\frac{1}{b}\sin(a+bx)\\ &\int x\cos x dx=\cos x+x\sin x\end{aligned}, \quad (7)$$

we get:

$$\begin{aligned}E_v(f)=&\frac{1}{2\pi f}[V_0\sin 2\pi fT+V\sin 2\pi fT_2-V\sin 2\pi fT]+\\ &+\frac{a}{4\pi^2 f^2}[\cos 2\pi fT+2\pi fT\sin 2\pi fT-1-\cos 2\pi fT_2-\\ &-2\pi fT_2\sin 2\pi fT_2+\cos 2\pi fT_1+2\pi fT_1\sin 2\pi fT_1].\end{aligned} \quad (8)$$

The odd part of the Hartley transform is defined by the following expression:

$$O_v(f)=\int_0^T (V_0+at)\sin 2\pi ftdt+\int_T^{T_1} V\sin 2\pi ftdt+\int_{T_1}^{T_2}(V-at)\sin 2\pi ftdt. \quad (9)$$

Using tabulated values of the integrals [3]:

$$\begin{aligned}&\int\sin(a+bx)dx=-\frac{1}{b}\cos(a+bx),\\ &\int x\sin x=\sin x-x\cos x,\end{aligned} \quad (10)$$

we get:

$$\begin{aligned}O_v(f)=&-\frac{V_0}{2\pi f}(\cos 2\pi fT-1)+\frac{V}{2\pi f}(\cos 2\pi fT-\cos 2\pi fT_2)+\\ &+\frac{a}{4\pi^2 f^2}(\sin 2\pi fT-2\pi fT\cos 2\pi fT-2\pi fT-\sin 2\pi fT_2+\\ &+2\pi fT_2\cos 2\pi fT_2+\sin 2\pi fT_1-2\pi fT_1\cos 2\pi fT_1).\end{aligned} \quad (11)$$

The model of acceleration change in train movement will be considered in the following form:

$$A(t)=\begin{cases}0, t<0\\ a(1-e^{-\frac{t}{\tau}}), 0\le t<T\\ ae^{-\frac{(t-T)}{\tau}}, T\le t<T_1\\ -a(1-e^{-\frac{(t-T_1)}{\tau}}), T_1\le t<T_2\\ -ae^{-\frac{(t-T_2)}{\tau}}, t\ge T_2\end{cases} \quad (12)$$

Even part of the Hartley transform for this case is described by the expression:

$$\begin{aligned}E_a(t)=&\int_0^T a(1-e^{-\frac{t}{\tau}})\cos 2\pi ftdt+\int_T^{T_1} ae^{-\frac{(t-T)}{\tau}}\cos 2\pi ftdt+\\ &+\int_{T_1}^{T_2}-a(1-e^{-\frac{(t-T_1)}{\tau}})\cos 2\pi ftdt+\int_{T_2}^{\infty}-ae^{-\frac{(t-T_2)}{\tau}}\cos 2\pi ftdt.\end{aligned} \quad (13)$$

Using tabular values of the integral [3]:

$$\int e^{bx}\cos nxdx=\frac{e^{bx}}{b^2+n^2}(b\cos nx+n\sin nx), \quad (14)$$

given that if $T>4{,}6\tau$ can be considered a $e^{-\frac{T}{\tau}}\approx 0$:

$$\begin{aligned}E_a(t)=&\frac{a}{\tau(\frac{1}{\tau^2}+4\pi^2 f^2)}+\frac{a}{2\pi f}(\sin 2\pi fT+\sin 2\pi fT_1+\sin 2\pi fT_2)+\\ &+\frac{a}{(\frac{1}{\tau^2}+4\pi^2 f^2)}[(\frac{1}{\tau}\cos 2\pi fT-2\pi f\sin 2\pi fT)+\\ &+(\frac{1}{\tau}\cos 2\pi fT_1-2\pi f\sin 2\pi fT_1)-(\frac{1}{\tau}\cos 2\pi fT_2-2\pi f\sin 2\pi fT_2)].\end{aligned} \quad (15)$$

The odd component is the sum of the following integrals:

$$\begin{aligned}O_a(t)=&\int_0^T a(1-e^{-\frac{t}{\tau}})\sin 2\pi ftdt+\int_T^{T_1} ae^{-\frac{(t-T)}{\tau}}\sin 2\pi ftdt+\\ &+\int_{T_1}^{T_2}-a(1-e^{-\frac{(t-T_1)}{\tau}})\sin 2\pi ftdt+\int_{T_2}^{\infty}-ae^{-\frac{(t-T_2)}{\tau}}\sin 2\pi ftdt.\end{aligned} \quad (16)$$

Using tabular values of the integral [3]:

$$\int e^{bx}\sin nxdx=\frac{e^{bx}}{b^2+n^2}(b\sin nx-n\cos nx), \quad (17)$$

we get:

$$O_a(t)=\frac{a}{2\pi f}(1-\cos 2\pi fT+\cos 2\pi fT_2-\cos 2\pi fT_1)+$$
$$+\frac{a}{(\frac{1}{\tau^2}+4\pi^2 f^2)}[(\frac{1}{\tau}\sin 2\pi fT+2\pi f\cos 2\pi fT)+ \quad (18)$$
$$+(\frac{1}{\tau}\sin 2\pi fT_1+2\pi f\cos 2\pi fT_1)-(\frac{1}{\tau}\sin 2\pi fT_2+2\pi f\cos 2\pi fT_2)].$$

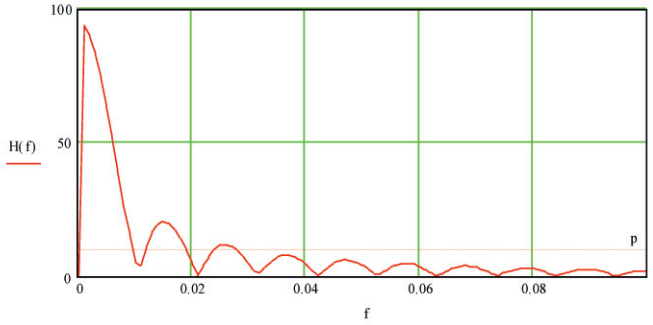


***Fig. 1.*** *The energy spectrum function of velocity (trapezoidal model, T1=5 s, T2=95 s, T=100 sec)*

In microprocessor system of interval traffic control, rating speed of the train and its acceleration is produced digitally through certain discrete intervals.

Discretization of measurement signals leads to a methodological error, which can be determined from the conditions that limit the spectrum of the signal of interest [1] in accordance with the theorem by Rayleigh

$$s_{ou}=\sqrt{\frac{1}{\pi}(\int_{\omega_B}^{\infty}P(\omega)d\omega)}. \quad (19)$$

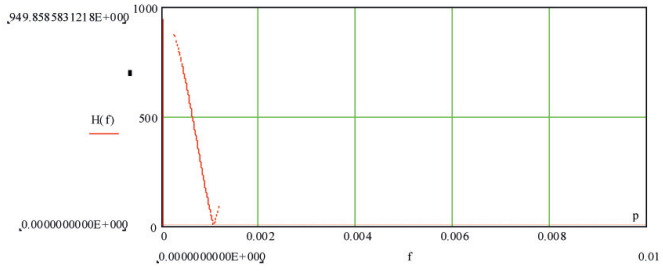


***Fig. 2.*** *The energy spectrum function of velocity (trapezoidal model T1=50 sec, T2=950 h, T=1000 sec)*

However, this formula is not convenient for numerical integration, so given that $s_{ou}{}^2=s^2-s_{oc}{}^2$, we have the expression for the relative error of discretization:

$$\frac{s_{ou}}{s}=\sqrt{(1-\frac{s_{oc}{}^2}{s^2})}=\sqrt{1-\frac{\int_0^{\omega_B}P(f)df}{\int_0^{\infty}P(f)df}}, \quad (20)$$

where $\omega_B=\frac{2\pi}{t_B}$ is the maximum value of the angular frequency determined by the sampling time reports for discretization of $t_B$, $P(f)$ represents the energy spectrum, calculated according to the expression (3).

## CONCLUSION

Method of evaluation period of sensors measuring the acceleration and speed of the train is as follows. A relative sampling error is specified and, according to expression (20), the upper limit of the angular frequency is determined, at which a predetermined error is provided. It is uniquely determined by the polling period of $t_B$ sensors. Using the spectral method of determining the period of the survey, you can choose different $t_B$ value depending on the category of the train and its dynamic characteristics. For high-speed trains, the period of sensors is less than for trucks, since the latter are tightened by the transients during acceleration and deceleration (parameters $T_1$ and $T_2$ in the expression (5)).

A graph of the relative error from the sampling period of sensors is shown in Fig. 3 and Fig. 4.

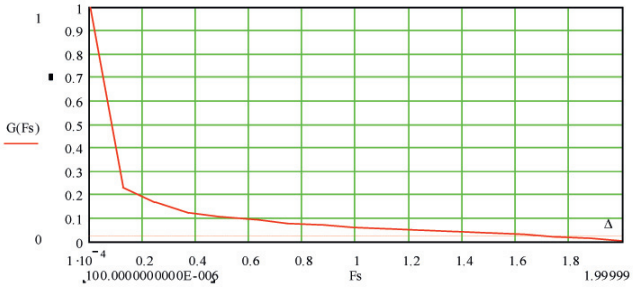


***Fig. 3.*** *The dependence of relative sampling error from the sampling frequency of the speed sensor (trapezoidal model of motion, T1=5 s, T2= 95 s, T=100 sec)*

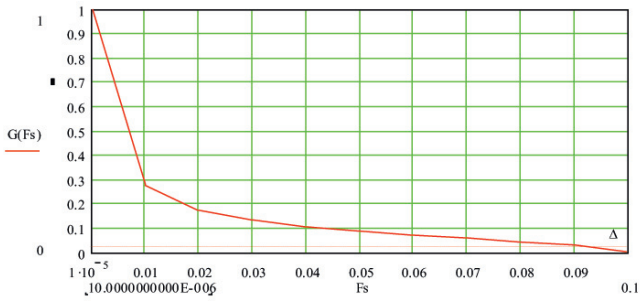


***Fig. 4.*** *The dependence of relative sampling error from the sampling frequency of the speed sensor (trapezoidal model of motion T1=50 sec, T2=950 h, T=1000 sec)*

In this case the sampling time is determined with an error which is less than 2.5%.

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# PACKET LOSS DIFFERENTIATION OVER MANET BASED ON A BP NEURAL NETWORK

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**Contribution to the state of the art**

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**Abstract:** An adaptive distributed routing algorithm is essential in MANETs, since there is no central routing system. Actually, there is no central point of coordination; each node is responsible for forwarding data packets to other nodes, thereby acting as router and host. A packet might travel through multiple intermediary ad hoc nodes in order to arrive to its destination, while the nature of wireless multi-hop channel is bringing in various types of packet losses. This paper focuses on three main reasons of online packet losses in MANETs: (1) losses due to wireless link errors; (2) losses due to congestion; and (3) losses due to route alteration. It proposes a deep learning-based algorithm for packet loss discrimination. The algorithm uses the backpropagation neural network (BPNN) concept. We performed simulation experiments for evaluating the performance of the proposed loss discrimination algorithm under different network configurations. Through simulation results, we confirmed that the proposed algorithm improves packet loss discrimination and route alteration in the network. It also reduces congestion and increases network throughput.

**Keywords:** MANET, packet loss discrimination, multicast congestion detection, backpropagation neural network, deep learning.

## INTRODUCTION

Mobile ad-hoc networks (MANETs) can be deployed in many applications such as disaster recovery, search and rescue operations, military service, and vehicular networks. A MANET is a group of autonomous nodes that form a dynamic, multi-hop radio network in a decentralized way [3]. MANET nodes can be a variety of mobile devices such as mobile phones, laptops or handheld devices, which present various computational and bandwidth capabilities. Nodes themselves implement the network management in a cooperative fashion. They operate on a multi-hop basis, while they are detecting routes and forwarding data packets. Since the channel is broadcast in nature, multiple nodes contend for the channel simultaneously. The wireless channel is also error-prone, and this situation becomes even worst because packet losses occur due to route alteration and congestion [8]. MANETs have peculiar characteristics including dynamic network topology, asymmetry, multi-hop communication, and limited bandwidth and energy resources. These characteristics complicate quality of service (QoS) provision, and impose various challenges in the design of congestion control [11]. Wired transport layer protocols tend to achieve congestion control, flow control, and end-to-end delivery of data packets.

TCP ensures reliability by using acknowledgments (ACK); for every transmitted TCP packet it waits for an ACK. *Additive-Increase/Multiplicative-Decrease* (AIMD) is the feedback control algorithm used in TCP congestion control. AIMD combines linear growth of the *congestion window* with an exponential reduction when a congestion occurs. The window size is increased by one segment in every round-trip-time (RTT), when no packet losses occur. In case of the re-

ception of a duplicate acknowledgment, a TCP sender will first assume that some packet reordering has occurred in the network. But upon reception of the fourth copy of an ACK (Triple Duplicate ACK, TDACK) a congestion loss is assumed. In this case, the missing segment is repeated and the window size is cut in half. Additionally, TCP uses a timeout that depends on the measured RTT of the connection. If this retransmission timeout (RTO) elapses without an acknowledgment, TCP concludes severe congestion. Then, the window size is reduced to one and the unacknowledged segment is sent again. The timeout until the next retransmission attempt is doubled, if still no acknowledgment arrives. Thus, this timeout grows exponentially. During the first phase of a connection and after a timeout, the "*slow start*" mechanism is employed that allows for a faster convergence to the correct window size [2]. While "*slow start*" is active, the window size is not increased by one segment size for every RTT, but instead for every received acknowledgment. This means that during this phase, the window size grows exponentially.

TCP-friendly congestion control schemes for the wired channels provide smooth sending rates [17]. These schemes include the window-based schemes and the rate-based schemes, which can be further classified into probe-based and equation-based schemes. Such schemes cannot be applied to wireless scenarios [19]. Rate-based congestion control schemes control the transmission rate and generate a smoothed flow by spreading the data transmission across a time interval. Thus, the burstiness induced by the window-based mechanisms is avoided. Equation-based congestion control enables bandwidth estimation, based on statistics of RTT and packet loss probability. In response to the bandwidth estimates, the source adjusts the transmission rate to prevent congestion. A typical equation-based protocol is the *TCP-friendly rate control* (TFRC) designed for wired link, and thus it accounts wireless losses also as congestion losses. TFRC adjusts its transmission rate in response to the level of congestion, as estimated based on the calculated loss rate. Multiple packet drops in the same RTT are considered as a single loss event by TFRC leading to a more slow congestion control strategy.

Wired transport protocols cannot be migrated directly to MANETs, due to some of the issues associated with it [10]. The TCP congestion control mechanism cannot handle the special properties of a shared wireless multi-hop channel well. Various situations may lead to packet loss like path break due to mobility, hidden terminal problem, high error-prone wireless links, node failure due to low battery etc. [6]. Route changes and the error-prone wireless channel result in unsteady packet delivery delays and packet losses. Thus, packet losses must not be misinterpreted as congestion losses. Other mechanisms are required to identify network congestion instead of packet loss and retransmission timeout. The transport protocol needs to decrease the sending rate only when there is congestion in the network. Also, the transport layer in the wireless network must periodically interact with lower layers to adapt the changing network conditions often and the frequent changes in network topology.

An enhanced transport protocol should reliably handle loss, minimize errors, manage network congestion and transmit efficiently. An enhanced transport protocol for MANETs should support *packet loss differentiation and estimation*. Traditional transport protocols assume that a packet loss is encountered due to congestion in the network. This assumption may lead to performance degradation in MANETs where the packet losses due to transmission errors are more probable in error-prone links. Actually, packets might be missing due to multipath fading, link-layer contention and channel errors Doppler shift, node's buffer excess. Conclusively, the transport layer mechanism must distinguish between the packet losses experienced due to network congestion and packet losses due to wireless link errors.

## Deep Learning for Packet Loss Discrimination in MANETs

In MANET, an accurate packet loss discrimination system in the transport layer is often cooperated with the flow-control protocol in order to improve the overall network performance. Deep learning can be applied in MANET for discriminating packet losses due to wireless errors, congestion, and route alteration. Many studies have shown that deep learning entirely surpasses other machine learning approaches for solving similar problems. When a loss discrimination algorithm is utilized with a deep learning neural network (NN), then it can be more accurate and ef-

fective than other discrimination algorithms utilized with other machine learning algorithms. Deep learning is a branch of machine learning methods based on learning data representations [14]. Learning can be supervised, partially supervised or unsupervised. Deep learning architectures such as deep neural networks, deep belief networks and recurrent neural networks have been applied to various fields including signal processing, communication systems, and adaptive control systems etc. The hardware implementations of deep learning algorithms are often exploiting the advantage of deep learning characteristic, called '*parallelism'*. A deep learning method stores knowledge inside inter-neuron connection through the support of the neuron weights. Deep learning contains a huge amount of processing elements, which are used to yield inputs and then processing takes place and after that it provides response to the inputs. A huge Network contains a huge number of processing elements. Deep learning is complete up of an amount of layers. Layers are organized by a quantity of consistent nodes, which contain an *activation* function. Patterns are characterised in the network as the *input layer*, which takes links to one or additional hidden layers. Then, the input layer is connected with the middle layer, which is identified as *hidden layer*. In the hidden layer, processing is completed by a number of weighted influences. The hidden layer straight connected to an *output layer*, which has the ability to provide response to completely the inputs. Deep learning works similar an input since the user and previously processing is taking place. Then, the processing takes place. Deep learning has the capability to originate the meaning after the difficult data and is used to extract patterns and detect leanings that are further multifaceted to announcement. A trained deep learning (based on backpropagation neural network - BPNN) can be supposed as an expert that analyse specified information. *Hyperbolic tangent sigmoid* is the activation function used in deep learning. It processes the input (which might have some value among plus and minus immensity). It is used in multi-layer neural networks and performs the training by using the BP algorithm, and thus this function is differentiable.

## KEY-CONTRIBUTIONS

In this paper, we assume congestion control as a transport layer issue and propose a Loss Discrimination Algorithm (LDA) that distinguishes the packet losses due to congestion, route alteration, and wireless link errors in MANETs. The proposed deep learning algorithm for packet loss discrimination is based on a backpropagation neural network (BPNN) architecture, while semi-supervised learning is applied. So, we exploited the feature reduction capability of the deep learning for pre-training. A deep learning algorithm is very powerful, when it is used with semi-supervised learning that reduces the training time. The key contributions of our work can be summarized as follows:

1. Experimental simulation results demonstrated that the proposed packet loss discrimination algorithm improves the accuracy under different network configurations and high-level network congestion conditions. This is achieved as an introduced congestion control process is invoked, when packet losses/failures (due to congestion) are detected.
2. The proposed packet loss discrimination algorithm can be implemented by a similarity circuit, which is fast and insignificant in size. Thus, the algorithm is appropriate to MANETs, where time and space are critical and near-optimal resolution is suitable.
3. In our framework, deep learning is executed on MANET for observing the regularity of '*hello*' messages of the AODV routing protocol in MANET. The Ad hoc On-Demand Distance Vector (AODV) is a well-established reactive routing protocol that is used for MANETs [7]. The term "*reactive*" implies that routing does not depend on periodic exchange of routing information or route calculation. When a route is required, the node must start a route discovery process. AODV uses classification numbers, where sequence statistics regulate the 'freshness' of routing information and to avoid routing loops. When an active link is broken, AODV initiates a finding process for a new route.

The rest of this paper is organized as follows. In the next Section, we discuss related work. Then, we present the proposed LDA algorithm. After that, we analyze the performance of our LDA algorithm. In the last Section, we provide our conclusions and further work.

## Related Work

The main causes for packet loss in MANET are mobility, channel error, and congestion. Reducing packet loss involves congestion control functioning on top of an adaptive routing protocol at the OSI-RM Network layer that supports errors due to mobility and failures. In the current designs, routing is not congestion-adaptive. Routing may let a congestion happen which is detected by congestion control, but dealing with congestion in this reactive manner results in longer delay and unnecessary packet loss and requires significant overhead, if a new route is required. This problem becomes more visible especially in large-scale transmission of heavy traffic such as multimedia data, where congestion is more probable and the negative impact of packet loss on the service quality is of more significance. Habbal and Hassan [5] introduced a model that analyses the factors that impact on TCP congestion control. Furthermore, their model points to those critical factors that must be addressed by researchers in order to improve TCP performance over MANETs.

Tran and Raghavendra [16] argued that routing should not only be aware of, but also be adaptive to, network congestion. They proposed a routing protocol (CRP) with such properties. CRP improves the packet loss rate and end-to-end delay, while enjoying significantly smaller protocol overhead and higher energy efficiency as compared to AODV and DSR. Designing an efficient routing protocol for MANET is a challenging task because of the dynamic environment of the network topology and resource limitations. Multipath routing can offer consistent communication in MANETs. Mallapur et al. [12] introduced an efficient routing technique called the *Multipath Load Balancing technique for Congestion Control* (MLBCC) for MANETs to efficiently balance the load among multiple paths by reducing congestion. MLBCC introduces a congestion control mechanism and a load balancing mechanism during the data transmission process. The congestion control mechanism detects the congestion by using an arrival rate and an outgoing rate at a particular time interval $T$. The load balancing mechanism is the selection of a gateway node by using the link cost and the path cost to efficiently distribute the load by selecting the most desirable paths. For an efficient flow of distribution, a node availability degree standard deviation parameter is introduced. Simulation results, under the network simulator-2 (NS-2), show that MLBCC improves the performance of FLMB and AOMDV in terms of the control overhead, packet delivery ratio (PDR), average delay and packet drop ratio. The results also show that MLBCC efficiently balances the load of the nodes in the network.

De Oliveira and Braun [4] investigated the use of fuzzy logic theory for assisting the TCP error detection mechanism in MANETs. They presented an elementary fuzzy logic engine as an intelligent technique for discriminating packet loss due to congestion from packet loss by wireless induced errors. They also introduced the architecture of the proposed fuzzy-based error detection mechanism. Their full approach, for inferring the internal state of the network, relies on Round Trip Time (RTT) measurements only. Hence, their end-to-end scheme requires only end nodes cooperation. Preliminary simulation evaluations showed how viable their approach is.

Yang et al. [18] proposed an explicit loss discrimination scheme (F-ECN) to discriminate, if a packet loss is due to congestion or to a wireless link fault. F-ECN is based on a fuzzy logic controller that uses queue length and packet arrival rate in order to measure congestion and achieves a tradeoff between queue stability and responsiveness. The performance of F-ECN takes a tradeoff between the throughput and the delay time. Papanastasiou and Ould-Khaoua [13] developed a TCP variant that adjusts the sending rate increase to achieve competitive throughput for TCP connections. Extensive simulation experiments indicate that a slower sending rate increase, during the congestion avoidance phase of TCP, leads to improved performance for TCP Reno, while eliminating the negative effects inherent in restricting the maximum sending window size. Their work discusses the applicability of their TCP oriented solution to the hidden terminal effect.

For effective load balancing and congestion control, routing metrics need to accurately capture the load in various locations of the network. Ali et al. [1] presented a congestion adaptive multipath routing protocol to increase the throughput and avoid congestion in MANETs. In their approach, when the average load of an existing link increases beyond a

defined threshold and the available bandwidth and residual battery energy decreases below a defined threshold, traffic is distributed over fail-safe multiple routes to reduce the traffic load on a congested link. Through simulation results, they showed that their approach achieves better throughput and PDR with reduced delay for constant bit rate (CBR) traffic, when compared with QMRB (viz., a protocol using mobile routing backbones).

Sliwa et al. [15] presented a simple passive decentralized load balancing scheme for MANET routing protocols. In contrast to existing load balancing schemes, the nodes consider only local knowledge and no additional communication or coordination is required. The proposed scheme can easily be applied to increase the reliability of existing routing protocols. Their simulative evaluation showed that three examined routine protocols (B.A.T.M.A.N, B.A.T.Mobile, G-OLSR) were able to achieve significant PDR gains through integration of the proposed load balancing approach. By distributing the packets over multiple suitable links, packet collisions are less probable and the reliability is increased. The probability for losses of routing packets is lowered, which leads to a higher consistency of the routing tables and avoids occurrences of drastic PDR drops. Additionally, the transmission queues of the forwarding nodes are relieved and queuing-related packet drops occur less often.

Khan et al. [9] designed a new routing algorithm using the combination of AODV and cross layer design approach. It is referred as *Congestion Control AODV* (CCAODV) *approach*. It is used to avoid link break in MANET. Received signal strength is used as cross layer design parameter. The CCAODV protocol creates strong and stable route by using signal strength of node. The signal strength mainly depends on the parameters like transmission power of node and distance between two nodes. The Cross layer design approach is tested by using Ns 2.35 simulator and compared with the AODV routing protocol.

## The Packet Loss Differentiation Algorithm (LDA)

In the proposed LDA, a BPNN is employed to classify the causes of packet losses. The proposed technique is based on a deep learning algorithm that adopts the BPNN method into MANETs. Backpropagation (BP) is a method used in neural networks to calculate the error contribution of each neuron after a batch of data is processed. The proposed technique achieves multi-metric cooperative decision at the receivers (nodes) to distinguish the three main reasons of packet losses.

## The BPNN architecture

The ratios of the evaluation indicators are used as input features of the deep learning-based BPNN packet loss Classifier, located in the transport layer. These end-to-end evaluation indicators are the following ones:

- *X1*: *The comparative one-way expedition time,*
- *X2: The inter-arrival time of packets fore-and-after the losses, and*
- *X3: The amount of out-of-order packets.*

These input variables *X1, X2, X3* are used as measures to predict congestion. In our BPNN architecture (Figure 1), we have three continuous variables as output variables (*Yl, Y2,* and *Y3*). These outputs vary at range [0, 1].

- *Y1*: It represents that network is at normal conditions. If the output were *Y1*, the MANET would be at normal conditions.
- *Y2*: It represents that network is at congestion conditions (packet loss due to congestion).
- *Y3*: It represents that in the network, this TCP connection is experienced link bit error just now (packet loss due to link error).

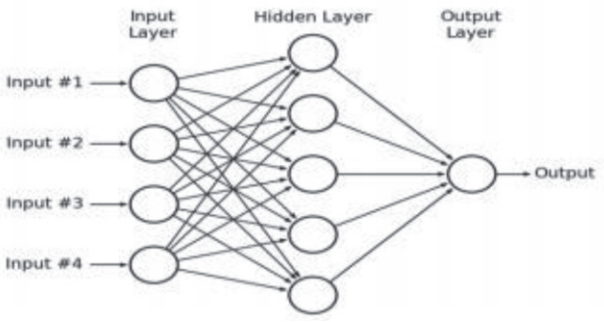


***Figure 1.*** *The BPNN architecture*

Hereafter, the proposed packet loss discrimination algorithm follows:

***Algorithm 1:*** *The LDA algorithm for MANETs*
***ALGORITHM 1****: Load dissemination using the multiple paths in deep leaning adopting the BPNN method.*
***Step 1:*** *a) Process for load distribution and choose the INPUT parameters for deep learning.*

*b) Choose the OUTPUT parameter after the deep learning.*
***Step 2:*** *Compute the training pairs of INPUT and OUTPUT using deep learning.*
***Step 3:*** *Train the Deep learning using the training pair's congestion detected. After training, acquire the trained Deep learning.*
***Step 4:*** *IF (congestion is identified OR accumulation contextual traffic exists)*
*THEN*
***Step 5:*** *Acquire the weights and biases after the trained Deep learning and input it to the BPNN program of deep learning.*
***Step 6:*** *Implement the BPNN program for the definite input, weights, and biases for deep learning.*
***PACKET LOSS DISCRIMINATION ALGORITHM:***
***Step 7:*** *Evaluate node accessibility of path using Step 2*
***Step 8:*** *Estimate entire node accessibility of path using Step 3.*
***Step 9:*** *Estimate entire average node accessibility of path.*
***Step 10:*** *Evaluate the normal node accessibility degree consuming the normal deviation using Step 5.*
***Step 11:*** *ENDIF*
***Step 12:*** *Based on the value found of opening node, it selects implementation of deep learning- based reactive routing protocol.*
***Step 13:*** *Observe the outcomes using NS2.*
***Step 14:*** *Repeat Steps 2 to 6 for dissimilar INPUTs and confirm the OUTPUTs.*
***Step 15:*** *Link the outcomes with NS2-based deep learning.*
***Step 16:*** *IF (outcomes are acceptable) THEN Load BPNN program of deep learning. The default path and the additional normal path to distribute the traffic complete the multiple paths using Step 12.*

### Congestion control

The lost packets in MANET often trigger retransmissions. In particular, control packets are retransmitted in order new routes to the destination node to be found. That means that even more packets are sent into the network. Therefore, network congestion can severely deteriorate network throughput. If no congestion control is performed, this can lead to a network collapse, where almost no data is successfully delivered. In traditional route discovery approaches, nodes use control packets (e.g., RREQ, RREP) to find out a new route to the destination. For designing a congestion control mechanism, we must use a hybrid approach for applying the different state of data preprocessing with received signal asset parameter.

In the proposed routing algorithm, routing is done on demand, and BPNN is used to save information about the link status and observing the route state. Each node in MANET can share its information with its neighboring nodes. A query processing for particular routing information is originated to complete the search between ad hoc nodes. All nodes are linked through one additional forwarding a request message from one node to the next ad hoc node until a search for the particular information processing is completed. The information is processed on ad hoc basis from the source node to that node that can satisfy the particular requirements. The information passes through numerous ad hoc nodes until the suitable node is resolute. The proposed BPNN uses this information as input information to find the decision for repeating the information into the nodes. The decision is made by assembling the input parameters of respectively node and by yielding these input parameters into the deep learning algorithm.

### The routing algorithm for discovering the best route path

The proposed routing algorithm is based on the deep learning algorithm discussed. It finds the most reliable route path set. A flooding technique is used for route discovery. In the proposed algorithm, routing is done on demand and BP is used to save link status information and route state observing. We propose a congestion control technique that detects the congestion through candidate nodes by using the influx rate and the leaving rate. For load balancing reasons, our deep-learning learning technique allocates the existing traffic over numerous route paths by using gateway nodes. Algorithm 2 follows.

***Algorithm 2:*** *The proposed routing algorithm for discovering the best route path*
***Step 1:*** *Initialize the input parameters*
***Step 2:*** *Select the data for processing*
***Step 3:*** *Define the information by setting the input parameters (required delay, required PDR, and re-*

*quired energy)*
***Step 4:*** *Select the nodes for replication this information for processing.*
***Step 5:*** *Find the node's position using the BPNN classifier*
***Step 6:*** *IF (Output=0) THEN STOP: Information processing is completed.*
*ELSE Output=1: stay on the network: more node information processing is required.*
*ENDIF*
***Step 7:*** *Form the group of nodes (viz. the route path) by selecting the next ad hoc node to be examined.*
***Step 8:*** *Try to succeed until a suitable node is reached in the random replication.*

This routing algorithm achieves objective one route finding to compute the separate path set. Thus, it creates less number of control packets compared with the conventional AODV routing algorithm that achieves numerous route findings. For every pair of the network parameters (required delay and required PDR), the total number of the generated control packets differs. The number of nodes for information processing is 100 with the intention of specifying the number of control packets (*m*) generated by the new routing algorithm process. The routing algorithm of AODV was simulated in this work for comparison reasons.

## PERFORMANCE EVALUATION

### Simulation Setup

We created and configured a small size MANET that contains 20, 40, 60, 80 and 100 nodes. This MANET uses AODV as a routing protocol. We defined the locations of nodes manually in TCL script. Also, we used the Omni antenna model: a wireless transmitting or receiving antenna that radiates or interrupt radio-frequency (RF) electromagnetic fields equally well in all horizontal directions in a flat, two-dimensional (2D) geometric plane. The parameter of "*Topography area*" indicates the area where the nodes can be moved in all directions. Finally, we used the "*Two Ray ground*" propagation model to predict the received signal power for each packet. The "*random mobility model*" was used to simulate the mobility of nodes. Table 1 shows the simulation parameters for our experiment.

***Table 1.*** *Simulation parameters*

| Parameter | Value |
|---|---|
| Simulator | Ns-2.34 |
| Simulation time | 100 seconds |
| Channel type | Wireless |
| Number of nodes | 100 |
| Topography area: | 500 x 500 (sq.m.) |
| Pause time | 20 sec |
| Packet size | 512 byte |
| Bandwidth | 40 MHz |

The simulation results were gained using NS-allinone-2.35.tar.gz simulator. NS2 is discrete event simulator. System language is C++ and scripting language is OTcl. Authors deliberate performance indices as stated in equation. For the experiments performed, a variable-size network of size 500*500 (sq.m.) was randomly generated with number of nodes afterward accomplishment its destination, the node silences for a definite time period, and then it chooses a different random location and continues the method again.

In our experiments, every node pauses at the current position for 10 sec, while movement speed of separate nodes ranges from 0 to 20 m/s. Simulations for networks have been path with 100 mobile hosts, effective at transmission ranges changing from 150 to 500 m. The Max_hop property is set to 5 as an initial value. The behaviour of the replicated network Relationships of reliability, lifetime, amaount of paths and above is compared to existing algorithms. Similarly, the computational complexity of the proposed algorithm is assessed and evaluated to separate AODV routing protocol. Control packets (as overhead) are generated in order to compute separate path sets. In this segment, the above performance of the proposed algorithm, in relationships of produced control messages, is linked to the AODV routing algorithm.

## RESULTS ANALYSIS AND DISCUSSION

In order to analyse the performance of an intermediary/gateway node, we calculated for each node, the *average Throughput* and PDR for the following two cases:

- **Case 1:** TCP *Multiplicative Decrease*-MD is applied (without LDA) over AODV.

- **Case 2:** TCP MD cooperates with the new LDA algorithm over the new introduced routing scheme. In this case, the new routing scheme (Algorithm 2) is used.

During the simulation process, we compared PDR and average Throughput for both cases. We evaluated our algorithm under numerous network configurations and we observed that it provides high accuracy under most types of packet losses. Moreover, in order to evaluate the accuracy of our BPNN classifier, we defined two types of errors:

- EC (*Error in discriminating packet loses due to Congestion*): The probability that the BP Network classifier misclassifies a congestion error as a link error.
- EL (*Error in discriminating packet loses due to Link errors*): The probability that the BP Network classifier misclassify a link error as a congestion error.

During the evaluation of the proposed algorithm, the network size and speed were changing. The simulation results (Figures 2, 3) showed that Case 2 outperforms Case 1. In a MANET having 100 nodes, we found the generated and received packets, when no LDA algorithm is used over AODV (the TCP MD is used without LDA over AODV). This is **Case 1**. Then, we found the generated and received packets, when the new routing scheme (Algorithm 2) cooperates with our packet loss discrimination algorithm (**Case 2**). Afterward, for both cases, we specified *average Throughput* and *PDR* and compared them.

NS-2 was used to generate the learning sample set. In order to evaluate our packet loss Classifier we divided the learning sample set database into two parts: (1) a learning sample that was used to learn the model, and (2) a test sample on which the resulting classifier was tested. In particular, we collected 1000 positive and 1000 negative samples correspondingly to make the training set. For the testing set, we used 200 positive and 200 negative samples to assess the accurateness. As depicted in Figure 2, the average Throughput in Case 2 is increasing, especially when the number of nodes is greater than 70.

The receiver uses the training deep learning model to automatically identify the reason of the current packet loss. This technique is an endwise solution and does not require support. The proposed packet loss Classifier cooperates with the TCP MD algorithm. The TCP MD algorithm is executed upon detecting a packet loss. Thus, we can say that we have a new TCP variant for MANETs, after using the proposed Loss Differentiation Algorithm (LDA).

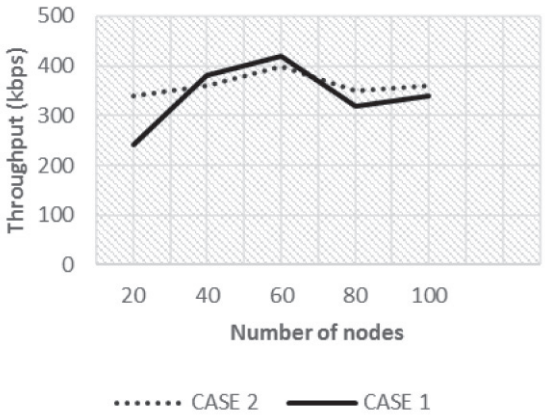


***Figure 2:*** *Comparison of average Throughput (Case 1 vs. Case 2)*

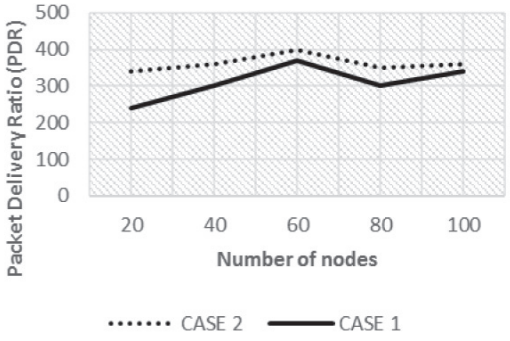


***Figure 3.*** *PDR comparison (Case 1 vs. Case 2)*

## Conclusion

In this paper, we proposed a deep learning–based algorithm for packet loss discrimination in MANETs. The proposed algorithm uses the back propagation neural network (BPNN) concept. Based on this loss discrimination algorithm (LDA), we also introduced a new route maintenance scheme that reduces the overall routing overhead of control packets in the network. Such reduction is obtained as the new routing scheme is changing the problematic, "weak" associations inside a link with more robust associations. Obviously, in "weak" associations, a lot of packet failures are observed. We performed simulation experiments for evaluating the performance of the proposed LDA under different network configurations. Through simulation results, we confirmed that the proposed LDA algorithm improves packet

loss discrimination and route alteration in the network. It also reduces congestion and increases network throughput. By using simulation, in the near months, we will compare our case/TCP variant (Case 2) with other TCP variants (e.g., TCP New Reno, TCP Vegas, TCP Westwood) over AODV.

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# Use of Multiparameter Adaptation in Communication Systems

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**Contribution to the state of the art**

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**Abstract:** The article discusses the use of multiparameter adaptation in communication VHF waves communication, provides specific schema that implements the proposed algorithm.

**Keywords:** adaptation, multiparameter system VHF waves communications, the transmission of information.

## Introduction

Short wave and VHF wave data transfer systems are widely used in connection with the ability to transmit large amounts of information over relatively long distances at relatively low power transmitters. VHF radio stations are required to be installed on vessels of any tonnage. VHF radio communication is widely used in rail transport, in other industries.

However, the reliability of wireless radio depends largely on the level of interference, deliberate and natural, i.e. generated by other sources of radio emission, interference current radio propagation conditions. These features have the greatest apparent for a range of HF and VHF frequencies.

The most significant type of interference in radio signals close in frequency spectrum radios which are commensurate with the wide spectrum of useful signal. These disturbances are called "lumped". Statistics show that 85% of radio sessions exposed to concentrated disturbances. The data about the properties of these disturbances (except fixed isolated radio systems) are missing.

## Adaptive Radio Communication System

To ensure reliable transfer of large amounts of information at high speed and the required accuracy of multiparameter methods adaptation to specified dynamically changing signal-jamming conditions.

The main characteristic is to reduce the level of the ratio signal/noise. On this ratio except for the above-mentioned reasons affect mismatched transmission line of the signal, thermal noise and shot noise in components of the system, resonance phenomena, parasitic coupling, the self-excitation of system, the nonlinearity of the transfer characteristics, etc.

Adaptive radio communication system is a system that has the property to adapt to changes in the external environment operation and properties of incoming radio in it and set the value of qualitative indicators by the radio settings and modifying its structure. Under the adaptability of the system should understand such a level of organization that is characterized by the presence not only of backward linkages, but also devices of observation, measurement and analysis, identification and control, providing the ability to make decisions based on analytical builds.

Feature build adaptive radio communication systems is the lack of a priori information about the characteristics of interference and signal, the signal level is continuously changing and there are power-

ful Nonstationary interference. Should therefore be provided with observability and identification.

A parametric task adaptation in general case boils down to optimize a function Q (U) in an atmosphere of random noise, i.e. on its observations, noisy polyaddition hindrance [2]:

$$Q`(U) = Q(U) + \varepsilon(\sigma)$$

where U is the vector of optimized parameters, and $\varepsilon(\sigma)$ is an independent random noise (in most cases it is assumed - with zero mathematical expectation) and variance σ, which can be unknown.

To solve function optimization problem

$$Q(U) \to \min_{U \in S}$$

given only their observations, developed many adaptive methods.

Distinctive features of the build adaptive systems for VHF radio is that they, in conjunction with dynamically changing external environment must run in real time.

In addition, these circumstances make it necessary to undertake, to improve reliability, adaptation by several parameters, i.e. use multiparameter adaptation.

Thus, there is a certain contradiction: on the one hand the algorithms should be implemented to operate in real time, i.e. are fairly simple, on the other hand, to improve reliability, and requires their constant complication.

In this regard, in many practical ways to build the algorithms adaptation, despite widespread use of microprocessor technology in these systems, heuristic methods are used.

Among the existing approaches it is possible to identify some solutions used in practice.

In particular, usually taken when building automatic control systems and communication HF (VHF) allocate deterministic number of fixed frequencies to test HF (VHF) range. In so doing, to meet this challenge creates a standalone hardware from the channel communications system using microprocessor technology designed to manage HF (VHF) range. This allows to tailor the operation channel equipment to changing dynamics of the ionosphere and radio interference. Using the inertia of the ionosphere and controlling the dynamics of the transmitter on best radio frequency signals, predicted the time of permanent bounce and in advance, even before the emergence of refusal is done rebuilding communications both correspondents of the new optimum frequency.

The aviation data transfer systems consisting of on-board and ground parts to ensure greater reliability of information exchange in the aviation communications system established radio communications are complemented by control systems assessment units the quality of the communication channel, as well as control units and blocks that implement the adaptation task rate measurements in real time and select parameters and operation modes of the radio links under specific conditions of propagation of this range using multiparametric adaptation.

Also known transfer method of discrete messages with multiparameter adaptation based on the procedure of entering the link, initial messaging using codes from most corrective ability in each of the areas rate on the current underlying messages, sharing the main messages in each direction, radio links, with dedicated time intervals or away from the transfer are the main messages and passed special sequence parameters sensitive maximum channel of communication and its changes, analyze these sequences for admission, according to the results of their analysis and other data about the status of the message transmission channel choose the code and alternation options signals and transmit its correspondent along with software settings alternation signals.

The main disadvantages of the described techniques multiparameter adaptation use tend to channel sounding the same receiving and transmitting funds, and for reference. Accordingly, while sensing the channel an interruption in communication. In addition, no multi-channel radio receivers to reduce the time of the occurrence.

## Compensate Deficiencies

To compensate for these deficiencies can be offered parallel structure with the main line radio uses a separate radio link that enables you to carry out adaptation signal in accordance with changing conditions [1].

The adaptation is carried out both in frequency and the signal code design. Thus implements a multiparametric adaptation.

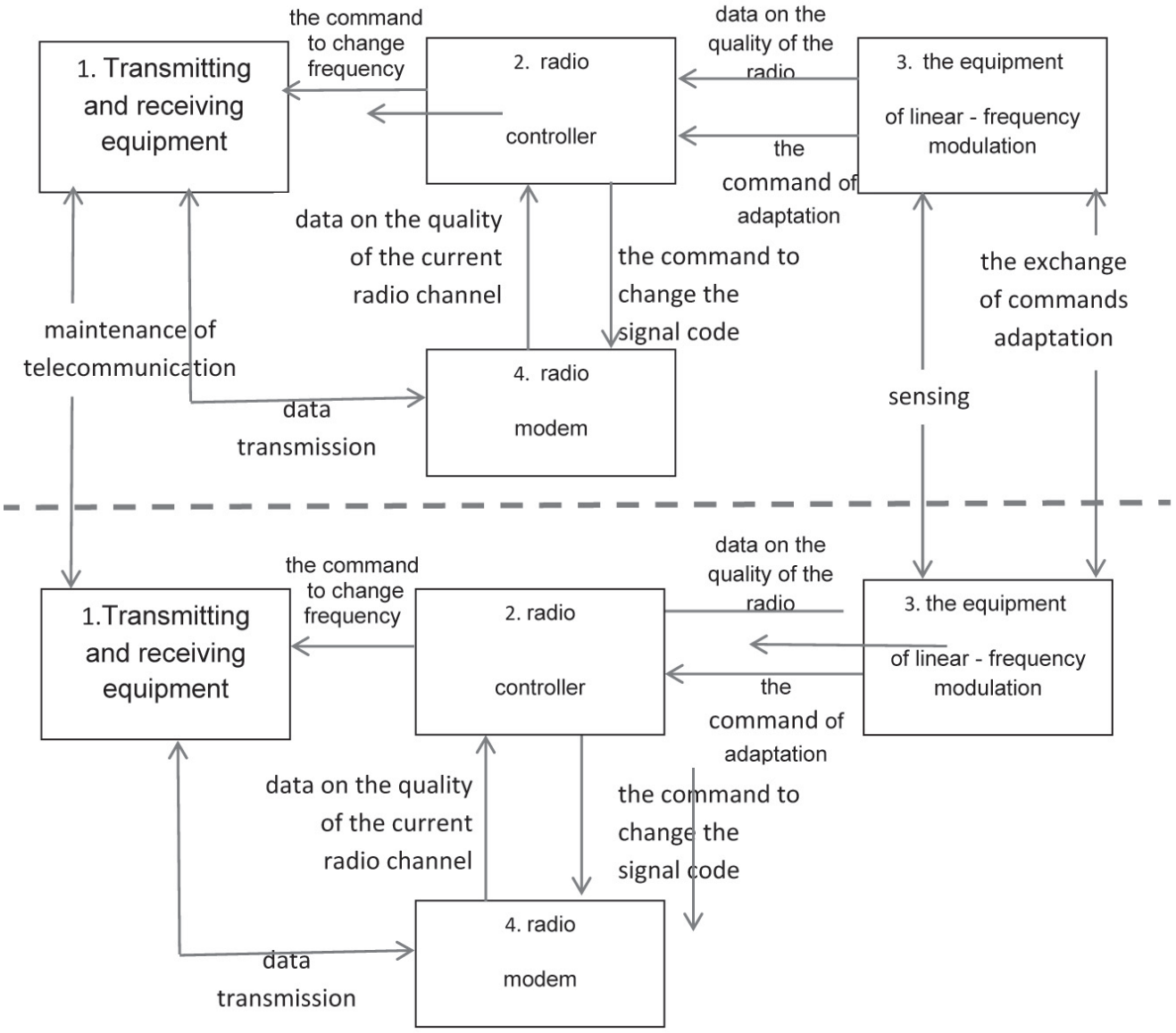


***Fig. 1.*** *The structure of the proposed radio system with multiparametric adaptation.*

This will significantly reduce the duration of the session, which will be achieved by reducing the amount of time entering the relationship, and by reducing the time of message transmission. The general structure of the proposed radio system is shown in Fig. 1.

To build the proposed structure of the radio, you must decide the following tasks.

In General, the build system is based on ensuring the process of transfer of discrete messages with multiparameter adaptation, based on:

- the procedure of entering the link,
- initial messaging in each of the areas of radio links,
- assessment of the status of message transmission in each direction radio links,
- selecting signal code constructs,
- the message about the selected signal code constructs to your correspondent,
- exchange main messages in each direction radio links.

When the assessment ratio signal/noise ratio (usually expressed in logarithmic units using the decibel $SNR_{dB}=10\log_{10}\left[\frac{P_{signal}}{P_{noise}}\right]$), on the current operating frequency during a data transfer form in radio modem, exercising demodulation and decoding the signal, and transmits the radio controller, managing hardware mode linear frequency modulation, get-

ting from her information on assessments of the current signal-to-noise ratio on all selected to conduct the session, except for frequencies used by radio.

Further commands to the adaptation of the ability to send and receive using transmission and reception equipment tools linear frequency modulation probing to each of the correspondents.

Also in the proposed structure of discrete information transmission with multiparameter adaptation via the availability of operational data on the state of the ionosphere, derived from the linear frequency modulation equipment sensing, rank assigned in order of decreasing frequency ringing their ease and begin to call with the most favourable reception by using frequency call multi-channel radio receiver, listening all the ringing frequency.

Evaluation of signal/noise ratio and frequency fading correlation on the current operating frequency of exercise and transmit radio radio controller. The controller evaluates the current signal code constructs and data packet size of the actual condition of the communication channel. In case of inconsistency calculated the optimal values for the above parameters and simulate the situation of application of these settings. When this commands to adapt the send and receive using transmission and reception equipment tools linear frequency modulation probing each of the correspondents.

Availability of radio receivers with the number of channels is not less than N, where N is the number of frequency of calling allows you to opt out on the receiving side of radio frequency scanning, implementing efforts to detect a call signal simultaneously on all N frequencies.

The availability of operational data on the state of the ionosphere, derived from equipment linear frequency modulation sensing allows for high confidence rank assigned frequency ringing in descending order of their joining. Call transfer must start with the most favorable rate. Availability on the receiving side of radio links multi-channel radio receivers allows you to receive calls at any order of calling frequencies.

As a result of the proposed solutions, in most cases, the connection will be provided at the first used a ringing frequency of N of allowed frequencies.

Reduction of time expenses in the data transfer phase is achieved by excluding time spent on multiparametric adaptation. Evaluation of propagation conditions and jamming on dedicated to holding the session frequencies in the process of the session is carried out equipment linear frequency modulation. Receiving funds from the whole apparatus of linear frequency modulation sensing are also used to transmit/receive service commands that control the operating mode of the complex communications, carrying out thereby multiparametric adaptation.

Provided in Figure 1. 1 diagram of the proposed radio system, which proposed a way to transfer discrete messages with multiparameter adaptation, showing the main components of the proposed system: transceiver apparatus 1, Radio 2 controller, Unit 3, linear frequency modulation 4.

The proposed method works as follows. For the transfer of discrete messages with multiparameter adaptation rate controller 2 through Repeater equipment 1 produces guaranteed entry into the relationship. Call transfer starts with the most favorable frequency from ranking dates of sensing equipment according to 4 of the list of frequencies. Receiving a call is carried out from the device to foster multi-channel repeater equipment 1 reception parties for any order of calling frequencies. Entering the link exchange messages through exchange of radio modems 3 assesses the state of channels of communication in each direction, radio links and the assessment rate controller on each side 2 shall decide on the need to conduct a multiparametric adaptation.

Adaptation takes place in frequency thus:

Signal/noise ratio on the current operating frequency in the transmission of data is generated on radio modem exercising demodulation and decoding the signal and transmitted to the radio controller. Radio controller controls the equipment of linear frequency modulation, receiving from her information on assessments of the current signal-to-noise ratio on all selected to conduct the session, except for frequencies used by radio modem. If the current operating frequency does not provide a maximum data transfer rate supported by radio modem, and according to the linear frequency modulation sensing a frequency capable of high speed data transmission, simulate the situation of transition to this frequency.

## Conclusion

If by the results of modeling time communicating the message is reduced when you navigate from the current operating frequency for the better according to the linear frequency modulation equipment sensing, is an appropriate transition. Commands to adaptation transmitted and accepted by using transmission and reception equipment tools linear frequency modulation probing each of the correspondents.

Adaptation to signal code design is as follows:

Signal/noise ratio and frequency fading correlation on the current operating frequency is carried out by radio and transmitted to the radio controller. Radio controller assess the appropriateness of the current signal code constructs and data packet size of the actual condition of the communication channel, in case of inconsistency calculates the optimal values for the above parameters and performs simulation of the situation of these parameters.

If by the results of modeling time communicating the message is reduced when moving to the optimal batch size values calculated data and signal code design, is an appropriate transition.

Commands to adaptation transmitted and accepted by using transmission and reception equipment tools linear frequency modulation probing each of the correspondents.

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# EU SERVICE DIRECTIVE, DIGITAL IDENTITY AND ID DOCUMENTS IN BOSNIA AND HERZEGOVINA

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**Case study**

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**Abstract:** In 2006, the European Union adopted the Services Directive, which establishes the obligation to establish unique points of contact through which citizens and businesses receive certain services from government bodies. The Services Directive unifies the services market throughout the European Union and creates an obligation for each Member State to improve its way of providing services to citizens. Citizens are accessing services through digital identities.

Having in mind that Bosnia and Herzegovina have for more than 65% turnover with EU countries, there is a need and legal obligation for the introduction of the same standards in the field of digital services and digital identities in BiH as in the EU. Citizens and businesses in Bosnia and Herzegovina need to have same position with competitive and compatible markets in EU countries. To validate digital identities, it is possible to use ID documents in BiH. This paper described the way of validating the digital identity in BiH using ID card or passport. ID documents issued according to ICAO 9303 standards and EU regulations must have embedded chips. These documents can be used to access electronic services as well as for digital identity verification.

**Keywords:** Digital identity, ID documents, BAC, EAC, SAC, interoperability, PSCs, Service Directive.

## INTRODUCTION

With the development of technologies, electronic procedures can be created in which persons with real identities appear through digital identity. Persons can be involved in the procedures accessing appropriate resources, while the Internet becomes the medium to which resources are connected and through which communication is made. Following technological development, public administrations have to adapt their business processes to make their activities more efficient and cost-effective, and open new channels of communication with citizens.

Electronic procedures contribute to the modernization of public administrations, making them more efficient. The use of electronic procedures is shown to be cost-effective, both in terms of cost and time. The European Union has defined the obligation to establish a single market and the same conditions in the EU Member States, and later on, in accordance with the "e-government" objectives, foresees the establishment of electronic procedures and services not provided for in the EU Services directive of the European Parliament and of the Council of 12 December 2006, (2006/123/EC) [5]. The principles defined in the Services Directive can therefore also be used when providing services to business entities. The European Commission has adopted two decisions to implement the Services Directive.

The first is the Decision of 2 October 2009 [1] on the establishment of practical programs for the exchange of information by electronic means between Member States in accordance with Chapter 6 of the Services Directive. In accordance with that decision, the Internal Market Information System (IMI) is used to exchange information for the purposes of

the Services Directive. The Internal Market Information System was established in accordance with Decision 2004/387/EC of the European Parliament and of the European Council of 21 April 2004 on the interoperable delivery of pan-European "e-Government" services to public administrations, businesses and citizens (IDABC) [3].

The second decision is the European Commission Decision of 16 October 2009 [7] on the establishment of measures enabling the use of electronic means by means of "points of single contact" (PSCs – Points of Single Contacts) in accordance with Directive 2006/123/EC on services in the internal market. This Decision concludes that the completion of procedures and formalities through PSCs must be possible across borders between Member States as defined in Article 8 of Directive 2006/123/EC. In order to comply with the obligation to simplify procedures and formalities and to enable cross-border use of SCPs, procedures by electronic means should rely on simple solutions, including the use of a digital signature and digital identity. It is for these purposes that they can use ID documents, which can store digital signatures. PSCs are online e-government portals that allow you to [7]:

- Find out about the rules, regulations and formalities that apply to service activities
- Complete the administrative procedures online (by submitting the necessary application forms and supporting documents etc. electronically)

All national PSCs are part of the European EUGO network.

After an appropriate risk assessment, specific procedures and documents may require an advanced digital signature, based on a qualified certificate, which is equivalent to a manual signature. Each Member State shall establish, maintain and publish, in accordance with certain technical specifications, a "confidential list" containing minimum information regarding accredited providers of certification services.

Implementation of the European Directive on Services by Member States requires the adoption of legislative and organizational measures. For the implementation of the EU Services Directive, the EU has adapted the legislation and implementing regulations in such a way that legal transactions that are conventionally made and legal transactions that are digitally made are placed at the same level. The EU Services Directive is related to the Treaty on the Functioning of the European Union [21], in particular in the part relating to the Internal Market of the European Union. Treaty relating to the establishment and functioning of the EU govern the freedom of movement and performance of the Union's entire territory. National legislation regulates service activities in accordance with Articles 49 and 56 of the Agreement on the Functioning of the EU [21]. It is imperative that public administrations must adapt their procedures so that they can provide electronic access to services through one or more access points within the country.

The purpose of the EU Services Directive is to create equal and competitive conditions throughout the Union. As Bosnia and Hercegovina has the largest turnover with the EU, it is necessary that there are similar business conditions and similar services in BiH as in the EU. Bosnia and Herzegovina has the largest share of its business exchanges with the European Union and CEFTA countries. According to the Chamber of Commerce of Bosnia and Herzegovina, from the total commodity exchange in 2016, 65.18% refers to European Union countries and 13.5% to CEFTA countries [28]. In addition, Bosnia and Herzegovina, by signing the Association Agreement (The Stabilization and Association Agreement between Bosnia and Herzegovina and the European Union was signed on 16 June 2008) [24], has undertaken to align its legislation with EU legislation. Chapter IV of the Stabilization and Association Agreement between Bosnia and Herzegovina and the European Union defines freedom of movement for goods between Bosnia and Herzegovina and the European Union and Chapter VI of this Agreement defines the obligation to harmonize legislation in Bosnia and Herzegovina with European Union (Article 70 paragraph (1) of the Stabilization and Association Agreement between Bosnia and Herzegovina and the European Union reads as follows: "1. The Parties acknowledge the importance of harmonizing existing legislation of Bosnia and Herzegovina with EU legislation and its efficient implementation. Bosnia and Herzegovina will seek to ensure the gradual alignment of its existing laws and future acquis with the acquis. Bosnia and Herzegovina will

ensure proper implementation and implementation of existing and future legislation.)[24]

In order to provide access to electronic services provided by a public administration, it is necessary to identify person who ask some service from public administration. The service can be accessed via the Internet, and the person must be efficiently authenticated and reliably validate his real identity through digital identity.

In this paper, the main issues of digital identity in Bosnia and Herzegovina are presented. The analogy between the real and digital identity is established, and the concept of identity management is described. Furthermore, an identity-based identification concept based on the ICAO 9303 document was presented through an electronic document. Finally, based on the ICAO 9303 document, a document ID system was established in Bosnia and Herzegovina and the content of the BiH electronic ID card was presented, which can be used as a means of validating the digital identity in Bosnia and Herzegovina.

## The Notion of Identity

Identity is a set of all known personally identifiable information. The number of this data can be extremely high. This is birth data, names and surnames, relatives, physical characteristics, preferences, profession and education, social status, health, and a complete set of characteristics that identifies a person. However, one part of a data set to a person can uniquely identify such a person, or make his authentication. A person appears, we know his identity by name and surname, and the competent state authority through the identification procedures confirms that this really is that person. Such a person has access to certain jobs or education or social protection system or other resources available in the real world [20].

People in real life access resources. For some more important resources, they must have special access permissions, which are obtained on the basis of appropriate certificates issued by other entities from the real world. Such entities can be organizations or individuals. For driving a car, it is necessary to identify the person and to know his identity that he knows how to operate the car in order to enable him to use such a resource. If he or she does not possess the knowledge to manage such a resource, it can cause a breach of security and a violation of the rights to the health and life of others. Confirmation that a person of a particular identity can manage the vehicle's resource is reissued by the state authority.

The real identity model consists of the following terms [22]:

1. A person with certain characteristics has a certain identity
2. Identity is a set of data about your face, such as its properties, preferences and features
3. Characteristics are information about the person who determines it, such as name, surname, date of birth, health data, and data acquired through education, skills and the like
4. Preferences are information about a person that characterizes the person's habits
5. Characteristics are data that the person inherits, such as hair color, eyes or biometric data
6. A resource in a real world is a property or a right or a public good for which a person may have an interest
7. A person confirms his information with specific evidence of his identity issued by an authorized body, such proof is in real life an identity card or identification document
8. Identification information is on the given identity certificate
9. The authentication procedure determines whether a person with a certain identity has the right to access the appropriate resources

The above text explains the notion of identity and the way of identifying a person in the real world. The Internet is a global information and communication system that contains many sets of digital data, that is, logical resources that can be accessed from the real world through access devices. As data, as logical resources, does not have a conventional physical reality, this digital world within the Internet is also called a virtual world. Data sets on the Internet are models of real or abstract objects in a computer-readable form. A special case of a model of a real world object is a model of a citizen. Each model, and so on, the citizen model, in order to be practically usable, it should be authentic to the original to the extent that it descriptively contains the user requirements.

In the real world, state authorities establish citizens' registers, and issue personal documents that

serve to authenticate citizens. In the case of a citizen register, user requests arise from the relevant national and accepted international normative solutions in the domain of law. If a set of citizen model data sets is sufficient to establish a mutually unambiguous correspondence between a citizen and an appropriate subgroup of citizen data in a computer readable form on a request, we will say that this subset of data represents the digital identity of citizens. For the real functioning of the real and virtual world, it is necessary to establish a system of trust between the entities from the real and the digital world, that is, to establish mechanisms for the confirmation of access to resources from the digital world.

The digital identity of a citizen can be used in many ways. For an example, it can be the basis for managing the right of access to physical or logical resources within a computer or communication system. Today, there are several global systems for this purpose and are known under the common name of identity management systems (the US National Institute of Standards and Technology - NIST working with the Department of Commerce has defined one of the systems for managing identities. Of particular security interest are identity management systems at border crossings, such as the Schengen Information System (SIS) [6].

## Digital Identity and Internet

The Internet, with all the computers connected to the Internet, contains a real-world model in which digital resources are stored and exchanged with resources, that is, information available under certain rules [23].

In the business world, especially in the banking sector, the concept of user identification has been established in order to conduct banking transactions. A large number of companies issue special cards for accessing resources and conducting business activities.

In accordance with the needs, Identity Management has been developed. In a digital environment that, via Internet technologies, is expanding to a global digital environment, a certain entity through communication channels provides a set of information about itself. The set of information available is changed depending on the context. Identity management allows a person to use an exact digital identity at a given time, for the purpose that he needs, the relationship is used in the right context at the right time. Identity management is viewed as a concept for [20]:

- defining the actual identity of the person represented,
- keeping relevant information about the entity, or a person in a safe and flexible manner,
- providing access to information in a well-defined manner in an adequate environment,
- the establishment of a flexible, distributed and high-quality identity management infrastructure.

In order to realize the concept of digital identity management, it is necessary, through appropriate steps, to authenticate the person, or to present it. A person or entity may be represented, for example, in the following ways:[8]

- something that the person knows (username and password)
- something that a person has (a corresponding token or card)
- something that the person possesses and knows (identification card)
- something that the face is (biometric data)
- something that a person is and what he knows (biometric data with a credit card with an identification code.

Once a person is presented or authenticated, then the authorization process, that is, confirming the allegations from the authentication process and approving access to resources, is initiated.

It is possible to introduce an access control mechanism when determining whether a person really has the right to access certain resources. The monitoring mechanism involves determining whether all identity management processes are adequate [15].

The concept of a digital identity is a real-world identity model. In the real world, each individual is identified by registering himself, giving his name, surname, and other attributes that make him unique. Institutions of trust, which perform the act of registering a person, are the authorities of the state. These authorities shall issue appropriate documents to persons, as a kind of evidence of the person's identity. On the basis of these documents the right of movement and freedom is allowed.

One person can have a larger number of digital identities. As a large number of social activities, including business, take place through the Internet, there is a need for standardizing the process of creating a digital identity, and modeling a digital identity with a real identity.

In the real world, personal identification documents are issued. Personal documents have evolved into electronic personal documents in the last ten years, that is, standards have been created that enable the issuance of personal documents with a built-in chip, which contains stored data that can be used for identification purposes in the digital world.

## ICAO System of Documents

Freedom of movement, and the right to personal safety and security and the right to nationality and the choice of a home where a person is to live are guaranteed by international documents. Documents adopted by the United Nations are incorporated into the constitutions of the UN member states. Also, the documents adopted by the Council of Europe and the European Union guarantee the rights to freedom of movement, and the right to citizenship, security and personal freedom [6].

Through the evolution of legal regulations guaranteeing fundamental freedom and human rights, control mechanisms have been developed, as well as mechanisms for implementing certain guaranteed rights. With the development of technologies and the development of traffic in the twentieth century, the need for a man to travel and change the place of residence and work has been increasingly expressed. Globalization completely changes the needs of man, and the jobs that a person performs. Also, the needs of man change, and the need for travel between countries and continents is extremely evident. A modern man travels for work, for learning, for curiosity and for tourism. There is an extremely intensive traffic between countries and continents.

The most common way of transport is by plane. At the beginning of the second decade of the twenty-first century, approximately 2.8 billion passengers were transported on airplanes [25], which is about 7.5 million passengers per day.

At airports it is necessary to provide a complete infrastructure that ensures fast flow of passengers, but also a safe border crossing. The United Nations legal framework, which is translated into regional and national legislation, guarantees the right to freedom of movement, but also the right to a safe environment and personal freedom. The data indicate that the largest number of passengers between countries, but also between continents, uses air traffic. Border crossings have been established at airports. Crossing the border should be quick in terms of a guarantee of the right to freedom of movement, but at the same time it should guarantee the right to a safe environment, or to reduce the risk of passing passengers that could endanger the safety of others.

The United Nations International Civilian Aviation Organization (ICAO) creates standards for identification documents that are implemented in Member States and which should facilitate border crossings, and improve controls and reduce the risk of unwanted border crossings. Thus, ICAO defines standards for ID documents (ICAO - International Civil Aviation Organization) in ICAO 9303 document [26]. Members of the ICAO are 191 countries.

The intensive development of technical possibilities related to the system of documents created the need for continuous improvement of recommendations and standards. The current valid ICAO document 9303 includes the following group of documents [26]:

1. Part 1: Introductory document, seventh edition from 2015 - introductory part containing general data, links to other standards, descriptions of concepts and structure of document 9303.
2. Part 2: Safety Specifications for Design, Production and Issue of Machine-Readable Documents, Seventh Edition of 2015 - defines mandatory and optional specifications and prerequisites that must be met by the competent ICAO Member States issuing documents to ensure the process of issuing and personalizing personal documents, the protection of the rights of the document holders, and the measures taken to reduce the risk of forgeries of documents. Mandatory and optional specifications for the physical protection of the document itself, and the premises where the documents are produced and personalized, and recommendations for officers working on

procedures related to document identification documents.

3. Part 3: Common specifications for all machine readable documents, seventh edition of 2015 - define common specifications for travel documents of different dimensions. Namely, according to the ICAO specification or ISO (International Organization for Standardization) international standardization standards, travel documents are divided into four basic sizes: Travel Document 1 (TD1) (ID card), TD2 (standard size for visas that are admired in passports), TD3 (passport size).
4. Part 4: Specifications for machine readable passports and other machine-readable travel documents of size 3 type, seventh edition of 2015 - describes the technical specifications for passports or TD3 documents, according to the International Organization for Standards (ISO). The focus is on physical and optical elements of protection.
5. Part 5: Specifications for other type 1 travel documents, seventh edition of 2015 - describes the technical specifications for TD1 size documents, according to the ISO size of the ID card.
6. Part 6: Specifications for other type-2 travel documents, seventh edition of 2015 - technical specifications of the size of TD2, according to ISO.
7. Part 7: Machine-readable visas, the seventh edition of 2015 - describes the technical characteristics for visas.
8. Part 8: Reserved for emergency travel documents, which should be described in the following period.
9. Part 9: The development of biometric identifiers and data warehouses in electronic machine readable documents, seventh edition of 2015 - describes the electronic memory elements contained in the documents and allow Member States to put data into electronic parts of a document, and that such data is read by other countries, which guarantees global interoperability, or the ability to keep the documents legible at every place with equipment that meets the standards adopted.
10. Part 10: Logical data structure for the storage of biometric and other data in contactless chips, the seventh edition of 2015 - provides a data structure that is written in documents such that it is possible to read data according to standard devices.
11. Part 11: Mechanical protection for machine readable documents, seventh edition of 2015 - describes cryptographic mechanisms for the protection of electronic machine readable documents
12. Part 12: PKI for machine readable documents, seventh edition of 2015 - standards for data protection that are entered into electronic documents, issuing digital certificates and reading certificates in order to access data on documents.

The ICAO document system created recommendations for Member States in the domain of citizen identity management. Citizens' identity management has a legal basis in international conventions, which are incorporated in the legislation of member states of international organizations. Through the document standardization process, efficient and fast flow of people at border crossings is ensured, guaranteeing data exchange that reduces the risk that persons who have or need to have restricted movement for safety reasons cross the border[13].

With an electronic identity, the ICAO document recognizes the media in which data models on the identity of the actual data carrier are stored [12]. The data stored in this way is used when crossing the border and a complete system is developed which allows control mechanisms in cases of identity abuse. Biometric data can be used for authentication.

The concept used by ICAO has been extended to other types of identification documents. The development of a system of documents in the world, especially in the European Union, opened projects for the establishment of a European ID card. The European ID card model was developed by the German Institute for Standardization [4], and some countries have begun to build a similar identification model, such as Hungary, and Bosnia and Herzegovina.

The concept of establishing an Electronic ID card is based on the expansion of the ICAO identity model used on passports for several new applications installed on chips [4]. On the ID card, the ICAO applet

is installed, as well as the digital presentation appliance and the digital signature applet.

On this concept it is possible to establish mechanisms that guarantee that a person in the digital world identifies the same way and the same means through which the identification in the real world takes place.

## DIGITAL IDENTITY IN BOSNIA AND HERZEGOVINA

In the real world, an identity card is used to authenticate an individual. Given the existence of global standards that prescribe elements of an electronic ID, the ID card appears as an optimum option for the storage of digital identity data.

In the personal documents of Bosnia and Herzegovina, according to the law, contactless memory elements, or chips, are integrated. In Article 6, paragraphs (5) and (6) of the Law on Identity Card of Citizens of Bosnia and Herzegovina reads [17]: "The ID card form contains an electronic memory element, in which all visible data on the ID card is entered, as well as other data provided by this Law, which the Agency issues a special instruction. A citizen of Bosnia and Herzegovina may be issued an ID card containing a qualified certificate from the Agency as a competent authority. The qualified certificate contains the data prescribed by the Law on Electronic Signature of Bosnia and Herzegovina [18] and the regulations adopted on the basis of that Law. The Law on the Agency for Identification Documents, Records and the Data Exchange of Bosnia and Herzegovina [19] defines that this Agency is a certification body for issuing digital certificates through personal documents.

A contactless chip is integrated into the body of the ID card form in Bosnia and Herzegovina. The chip manufacturer is NXP [9]. The chip design is Smart MX P5CDO81A6 J3A081GA6 / T1AG2331 (mifare) for ID cards (Instructions on the contents of the electronic memory element of the identity card of citizens of Bosnia and Herzegovina [11]). A similar chip is also used for travel documents by citizens of Bosnia and Herzegovina. The chip, built into the body of the ID card, supports cryptographic algorithms (cryptography of elliptic curves) and enables a number of advanced features of the ID card.

The contactless chip communicates with the appropriate reader (terminal), which is simultaneously a read and write device. The communication of these two components is in accordance with ISO 144443 and is based on ISO 7816.

Applications on the ID card were made in accordance with the profile defined by the "European Citizen Card" standard (Part IV) [4]. The documents adopted by Bosnia and Herzegovina defining the use of this model are the Instructions on the Contents of the Electronic Memory Element of the Identity Card of the Citizens of Bosnia and Herzegovina [10].

In order for communication between the chip and the reader to be secure, cryptographic authentication methods are used (defined in the Instruction on the contents of the electronic memory element of the identity card of citizens of Bosnia and Herzegovina) [9] and [2]:

- BAC – "Basic Access Control"
- PACE - "Password Authenticated Connection Establishment"
- TA - "Terminal Authentication"
- PA - "Passive Authentication"
- CA - "Chip Authentication"

Access to the data written in the applications is possible after a successful presentation of the reader using the Basic Access Control (BAC), the authentication chip (CA), and the authentication terminal (TA) or the password protected secure connection (PACE), terminal authentication (TA) or authentication chip (CA) .

The data on the chip are organized through three applications [2]:

- biometric application
- digital representation application
- a digital signature application with a qualified certificate

The biometric application has been developed according to ICAO recommendations for travel documents so that the ID card can be used as a travel document. Based on the data from the machine readable zone, this application is accessed and identification of the identity card holder is enabled.

The digital representation application enables the holder of an identification document to present itself to a third party. When downloading an ID card, the citizen will receive a special form on which the activation code is located. Personal identification code can be for digital representation. Digital representation can be used when sending requests

for electronic services. Personal identification cod confirms the identity of the person requesting the service. Digital representation does not have the legal power of digital signing and is analogous to the physical signature given in certain cases (filing a request for a service)

The digital signature application is used to generate a qualified digital signature in accordance with the regulations used in Bosnia and Herzegovina. In order to use this application, it is necessary to implement the legal procedure and to conclude a contract between the signer and the citizen. Before using this application, it is necessary for the card owner to create a pair of keys for digital signing.

## Data Access Passwords

For the needs of the BAC / PACE protocol, different passwords are used depending on the type of data access application:

- 6 characters from the first row of the machine-readable zone (16-24 characters) starting behind the "CAN" mark,
- the value of the serial number of the document, the date of birth and expiration date from the machine readable zone,
- The eID PIN is either the 5th digit transport key delivered to the owner at the time of the submission of the request or the operational 6th digit number known only to the cardholder and
- The 10-digit PUK is delivered to the owner at the time of submitting the request

### „CAN" – Card Access Number

CAN is a six-digit number entered in the first line of the machine-readable zone in positions after the "CAN" mark. These are signs 19 to 24. This is a space in the MRZ for the purpose of registering arbitrary data. The password is used for BAC / PACE. This password can not be calculated based on the visible data from the ID card. It is used to establish a secure channel between the card and the terminal in cases when no entry is required from the cardholder:

- checks within the Agency for Identification Documents, Records and Data Exchange for the implementation of the Law on the Identity Card
- administrative operations at the competent authority issuing the card
- establishing a connection with a digital signature application

This password does not have an unsuccessful attempt counter. It is also used when entering EID Pina after two failed attempts.

### Password from Machine Readable Zone - MRZ

Inspection systems can use a password from the MRZ instead of the CAN password for the BAC / PACE protocol. The MRZ password is in fact the SHA-1 hash value of the document number, date of birth and expiration date of the document. In this way, the existing inspection systems may use an electronic ID card instead of a passport to control the crossing of the state border. It should be noted that a certain adjustment of the software for reading the passport is needed since the MRZ's personal ID card is on the back of the document and consists of three lines (as opposed to a passport where the MRZ consists of two lines).

### eID PIN

The six-digit eID PIN is a decimal number known only to the cardholder. It is used to unlock the card or access permission. Knowing this number connects the cardholder to the card. In the terminology of two-phase authentication, a personal card (card) is something "a citizen has" and an eID PIN number is something "a citizen knows."

During the submission of the request for the issuance of an eID, a transport key is generated. The transport key is used only to change that start key and generate a new permanent and only the card holder of the known eID PIN number. The use of applications installed on eID is not possible until the transport key is changed.

The chip contains an attempt counter that increases after every unsuccessful eID PIN entry. In order to avoid card locking by denial of service (DoS) during the third PIN entry, it is necessary to first enter the PUK. If the third PIN is incorrect, the card is blocked.

The eID PIN can be changed only in the way that a citizen uses the application (middleware) to enter the first existing PIN and then the new PIN.

### PIN for digital signing

The chip also contains the PIN number used for digital signing. The chip provides a PIN check service that the user has entered so that the PIN never leaves the card. The chip counts unsuccessful PIN code entries and blocks the application after a third unsuccessful attempt.

The signing PIN can be changed only in the way that a citizen uses the application (MW) to enter the first existing PIN and then the new PIN.

At the moment of personalization, this PIN is not known and the user determines it at the time of generating a pair of keys used for digital signing.

### PUK - Pin Unblocking Key

Once the card is blocked, unblocking it is possible using the 10-digit PUK number. The chip takes into account the number of cards unblocking. Maximum 10 unblocking is allowed. PUK is a randomly generated number that is delivered to a citizen at the time of submitting a request for issuing an ID card.

Applications that are placed on personal documents of citizens of Bosnia and Herzegovina enable digital representation of citizens, that is, the full affirmation of digital identity.

In order to access data on the chip, it is necessary to go through the steps in Table 1[27].

***Table 1.*** *Access to data on the chip*

| Chip | Terminal |
|---|---|
| | Reading EF.CardAcces |
| | Reading PACE passwords |
| | PACE |
| | Send chain certificate for TA<br>TA |
| | Reading EF.CardSecurity |
| | PA (Passive Authentication) |
| | CA (Chip Authenitcation) |
| | Optional validation of the document<br>Optional reading token for recall |
| | Check in tokens list (possible only for valid documents) |
| | Reading ED.SOD (only for the inspection terminal) |
| | Checking the signature EF.SOD (Passive Authentication, only for the inspection terminal) |
| | Select the desired application<br>Optional read data for which terminal has access rights<br>Calling Special Functions |
| | Comparison of the value of the groups of data with the values recorded in the EF.SOD file (for the inspection system only) |

Electronic ID cards in Bosnia and Herzegovina are issued as of 1 March 2012, while passports are issued as of October 15, 2009 [14]. Over seventy percent of citizens of Bosnia and Herzegovina have electronic personal documents.

## CONCLUSION

The paper describes the notion of identity and digital identity, with a special emphasis on the protection of identity on the Internet. The ID of the document created according to ICAO recommendations can be used for digital representation. In Bosnia and Herzegovina, a document ID is issued according to ICAO recommendations that can be used to confirm the digital identity[16]. Methods of data protection in the documents of Bosnia and Herzegovina have been presented.

In Bosnia and Herzegovina there is a developed legal and technical framework that enables the issuance of electronic identification documents. ID cards and passports of Bosnia and Herzegovina citizens own chips in which data on holders of these documents is stored. These are contactless chips that allow data to be read at a distance with the possession of adequate devices. The specificity of the BiH ID documents system is that electronic data is processed through a single technical system. Passports and ID cards have similar chips, and both documents can be used to confirm the digital identity.

On the chips in the documents there are applications for digital representation and for digital signing. Since most citizens have such documents, there is a huge potential for providing electronic services. The use of such IDs is possible in Bosnia and Herzegovina for the implementation of the EU Services Directive. In this way, it is possible to create services for citizens and business, and authentication of users by ID card. Also, it is possible to install qualified digital signatures on chip in ID cards or passports.

However, there are no software products based on electronic personal documents on the market. Also, there is no developed reader market that would allow the provision of such services. In the future, the possibility of using ID documents in Bosnia and Herzegovina for the needs of business via the Internet and confirmation of digital identity should be explored. The possibility of developing software products based on ID documents can be explored in future.

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