# Biometric Templates Noise Immunity during Transmission by Mobile Networks

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**Abstract**

The work is devoted to the study of the immunity of biometric templates to interference and fading during transmission over the LTE network. The widespread use of remote biometric authentication systems, primarily in remote mobile payment systems, determines the relevance of the chosen topic, and the development of mobile networks, and first of all, the use of technologies that are more protected from attacks like LTE and NR increases its practical focus. However, when authentication information is transmitted, even over a secure channel, it can be subject to interference and fading. That is why it is important to study their influence on the integrity of the biometric template that will be used to authenticate the user in the system. We have analyzed the dependence of the quality of the authentication system on the parameters of the mobile communication channel (bit error rate, signal-to-noise ratio) and the parameters of the mobile device that transmits information (MIMO scheme, coding rate, modulation scheme), which improves the quality of the remote biometric authentication systems by reasonably choosing the transmission parameters and taking into account the parameters of the communication channel.

**Keywords**

biometric template, remote biometric authentication, noise immunity, finger-print recognition, modulation schemes, LTE, MIMO

## 1. Introduction

Remote biometric authentication is becoming more common in everyday life, and it has begun to be actively used in financial institutions and banks. Authentication is carried out remotely, on the side of the company, and allows companies to provide financial services to citizens remotely, for this, users confirm their identity using biometric personal data. This creates an equal opportunity to access financial services regardless of the user's location. It has also begun to be incorporated into Know Your Customer (e-KYC) procedures to make e-KYC faster and more customer-friendly.

Since users of these systems most often use mobile devices connected to the networks of mobile operators when conducting transactions and therefore the most interesting and relevant are the cases of remote authentication taking into account the influence of external factors arising in mobile communication channels. Based on the assumption that today the most common technology used in mobile communications in Ukraine and abroad is Long-Term Evolution (LTE) technology. Consequently, the mathematical model of the physical layer of the LTE network was chosen to conduct research on the quality of the remote biometric authentication system.

The aim of this work is to analyze the efficiency of the remote biometric authentication system, provided that it is used in mobile communication channels with interference. The practical significance lies in the selection and justification of the parameters of the mobile device transmitter during remote biometric authentication.

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A number of scientific papers [1–4] have been published in recent years devoted to the problem of information distortion during its transmission by wireless networks, due to the influence of various factors. These publications [1–3] mainly focus on the calculation of the Bit Error Rate (BER) as a function of the signal-to-noise ratio (SNR).

Unlike other publications, this work focuses on the specificities of processing distortion-sensitive data during authentication by calculating the remote biometric authentication system operation thresholds at different noise levels in the communication channel and optimizing the transmitter settings by choosing the elements that are optimal according to the efficiency/speed criterion, among which: a modulation algorithm, an antenna configuration technology (Multiple Input Multiple Output, MIMO, and Single In Single Out, SISO), an algorithm of error-correcting coding.

## 2. Description of the Biometric Template Forming Process

Fingerprint authentication is the most common biometric technology [5] due to its differences, permanence, acceptability, and universality [6]. Most of the available methods for comparing fingerprints can be roughly divided into three categories: a comparison based on correlation, minutiae-based comparison, and comparison based on papillary ridges [7]. The minutiae-based fingerprint matching algorithm is used in the modern Automatic Fingerprint Identification System (AFIS), therefore it was used in this work.

Fingerprints scanned by the Digitalpersona U.are.U 4000 scanner, with a resolution of 500 pixels per inch [8] were used as a database of fingerprint samples.

In order to obtain a biometric template, a minutiae template was first obtained from a fingerprint image using the MINDTCT utility included in the National Institute of Standards and Technology (NIST) Biometric Image Software (NBIS). MINDTCT is a minutiae detection system. The utility takes a fingerprint image as an input and finds all the minutiae on it, assigning to each of their coordinates, orientation, quality, and then writes the detected minutiae to a file.

By default, MINDTCT writes the minutiae points according to the American national standards institute/National Institute of Standards and Technology (ANSI/NIST), which means that minutiae points computed based on the pixel origin being at the bottom left of the image and directions are pointing out and away from the ridge ending or bifurcation valley. A detailed description of how MINDTCT works can be found in the official guide from NIST «User's guide to NIST biometric image software (NBIS)» [9]. It should be noted that different AFISs represent the location of minutiae in different ways, therefore MINDTCT can store their values according to the ANSI INCITS 378-2004 standard, which was used in this study. According to this standard, this format has the pixel origin at the top left of the image and directions are pointing up the ridge ending or bifurcation valley.

Subsequently, obtained minutiae values are converted into minutiae template using .Net DLL library, namely, Minutia Cylinder Codes software development kit (MCC SDK), which builds for each of the minutiae a local three-dimensional data structure (called cylinder), built from invariant distances and angles in a neighborhood of each minutia [10].

This library uses only coordinates and direction of minutiae in the range $[0, 2\pi)$ and does not take into account their type and quality. Standard values were taken as enroll parameters to create a template. The result was the biometric template in binary format.

## 3. Description of the Simulation Model

The biometric template is transmitted through the simulation models of the physical layer of the LTE standard. In order to find out under which network parameters the biometric template will be transmitted so that the receiver can correctly authenticate the user by comparing two biometric templates, a previously registered biometric template that is stored in the system database and a biometric template that was transmitted through the communication channel.

LTE technology is based on three main components: Orthogonal Frequency-Division Multiplexing (OFDM), MIMO multi-antenna configurations, and the architecture of the network core, namely System Architecture Evolution (SAE). Duplex channel division can be either Frequency Division

Duplex (FDD) or Time-Division Duplex (TDD), it allows operators to use the frequency resource very flexibly.

In order to simulate the physical layer of the LTE network, a model with FDD data transmission mode was built in MATLAB and Simulink, this model is presented in the book "Understanding LTE with MATLAB: From Mathematical Modeling to Simulation and Prototyping" [11]. This simulation model includes a transmitter, a channel model, and a receiver.

Transmitter processing includes both Downlink Shared Channel (DLSCH) and Physical Downlink Shared Channel (PDSCH) operations. The processing stack is fully defined in documents developed by the 3rd Generation Partnership Project (3GPP), which describe multiplexing and channel coding [12] as well as physical channels and modulation [13]. The channel model includes a fading channel and Additive White Gaussian Noise (AWGN) channel. The receiver performs data processing on the channels (DLSCH and PDSCH).

Processing in the DLSCH logical channel includes attaching a Cyclic Redundancy Check (CRC) code to detect errors, segmenting data into smaller fragments (subblocks), performing channel coding operations based on turbo coding, performing a rate matching operation that selects the number of output bits in accordance with the desired coding rate and conversion of code blocks into code words.

In the PDSCH processing step, the codewords are first scrambled and then undergo a modulation mapping, resulting in a stream of modulated symbols. The model supports the following modulation algorithms: QPSK, 16QAM, 64QAM.

The next step involves the use of MIMO technology, in which one modulated symbol stream is subdivided into multiple substreams for transmission over multiple antennas. The final step in the processing chain involves multi-carrier transmission. In downlink transmission, the multicarrier operations are based on the OFDM transmission scheme.

In Fig. 1 is a block diagram of the simulation model that represents the signal processing chain that is applied to transport blocks coming from the MAC layer to the PHY layer.

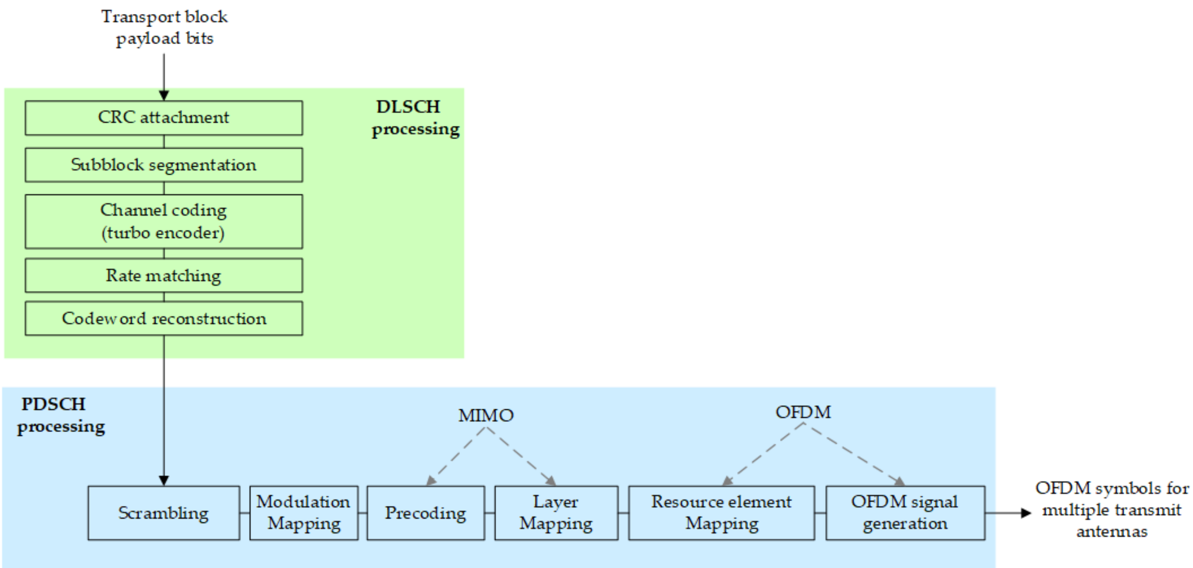


**Figure 1:** Signal processing chain of DLSCH and PDSCH channels

Channel modeling is performed by combining a fading MIMO multipath channel and an AWGN channel. Typical parameters for MIMO channels include antenna configurations, multipath fading profiles, maximum Doppler shifts (MDS), and spatial correlation levels at antennas, both at the transmitter and receiver sides. An AWGN channel is typically characterized by signal-to-noise ratio or noise variance values.

On the receiver, the signal processing chain is applied to the received symbols that have passed through the channel model and the reverse operations of the transmitter are performed.

After transmitting the biometric template through the LTE physical layer model, it was compared with the original one. The MCC SDK library was used to compare two biometric templates. This library proposes several scoring methods which calculate a global score that indicates overall similarity of two fingerprints. For comparison of biometric templates, standard values provided by the library were taken, except for the global assessment method. The Local Similarity Assignment (LSA) method was chosen. A global score can range from 0 (biometric templates do not match at all) to 1 (biometric templates match perfectly).

## 4. Research Results

In this work, multifaceted analysis of the impact of the transmitter parameters on the operability of the remote biometric authentication system was carried out, provided that there are Doppler shifts and interference in the communication channel. In order to do that, the system operation threshold was estimated, provided that 16QAM and MIMO 2×2 modulation were applied for a 1/2-rate code (Table 1). The research results (Table 1) showed that the quality of the system deteriorated with increasing the maximum Doppler shift.

**Table 1.**
Analysis of the threshold of the remote biometric authentication system depending on the value of the maximum Doppler shift and the signal-to-noise ratio (SNR)

| Maximum Doppler shift, Hz | 0 | 10 | 40 | 80 |
|---|---|---|---|---|
| Threshold SNR values, dB | 6.4 | 6.5 | 6.5 | 7.8 |

As shown in Table 1, in the absence of the Doppler shift, the operation threshold of the system is an SNR value of 6.4 dB, but if the MDS appears and increases, the operation threshold increases to 7.8 dB, that is, the presence of the Doppler shift in the channel will require an increase in the transmitter power or using more robust codes and modulation algorithms.

The first factor whose influence on the quality of the model was analyzed is the coding rate, which characterizes the ratio of the number of symbols at the input of an error-correcting encoder to the number of symbols at the output. Decreasing the coding rate usually makes it possible to improve noise immunity but decreases the efficiency of the data transfer rate. Research has shown that decreasing the coding rate (Fig. 2) to improve noise immunity makes it possible to almost double the operation thresholds for a remote biometric authentication system.

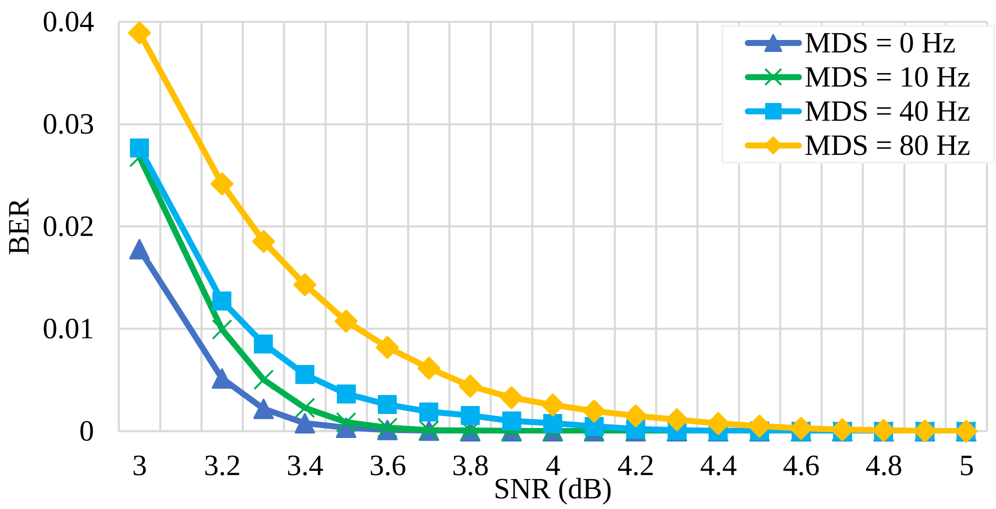


**Figure 2:** Bit error rate (BER) as a function of the signal-to-noise ratio (SNR) values with 1/2 coding rates, 16QAM modulation, and different values of Doppler shifts

Based on Fig. 2, provided that there is no influence of Doppler shifts, the system operation threshold improves from an SNR value of 6.4 dB with a 1/2 coding rate, to an SNR value of 3.4 dB with a 1/3 coding rate, and the influence of even the maximum values of Doppler shifts insignificantly deteriorates the operation thresholds (from an SNR value of 6.4 dB with an MDS value of 0 Hz, to an SNR value of 7.8 dB with an MDS values of 80 Hz) compared to the effect of the coding rate. As a consequence of this, it is advisable to use exactly the 1/3-rate code for any values of the Channel Quality Indicator (CQI).

The next factor that can be changed at the transmitter is the modulation algorithm. In LTE technology, depending on the CQI, three main modulation algorithms can be used (Table 2). CQI can range from 1 to 15, where 1 corresponds to the worst network conditions and 15 corresponds to the best one.

**Table 2.**
Dependence of the modulation algorithm on the channel quality indicator

| CQI | 1 | 4 | 6 | 7 | 9 | 10 | 12 | 15 |
|---|---|---|---|---|---|---|---|---|
| Modulation scheme | QPSK | QPSK | QPSK | 16QAM | 16QAM | 64QAM | 64QAM | 64QAM |
| Bit/Symbol | 2 | 2 | 2 | 4 | 4 | 6 | 6 | 6 |
| Code rate x1024 | 78 | 308 | 602 | 378 | 616 | 466 | 666 | 948 |

The results of the study showed (Fig. 3) that the QPSK algorithm, even with the worst channel parameters, provides a BER value of $3.5e^{-6}$, while the 16QAM and 64QAM algorithms can only provide SNR values of $1e^{-5}$ and $1.5e^{-3}$ respectively. As a result, it is not recommended to use 64QAM in a remote biometric authentication system.

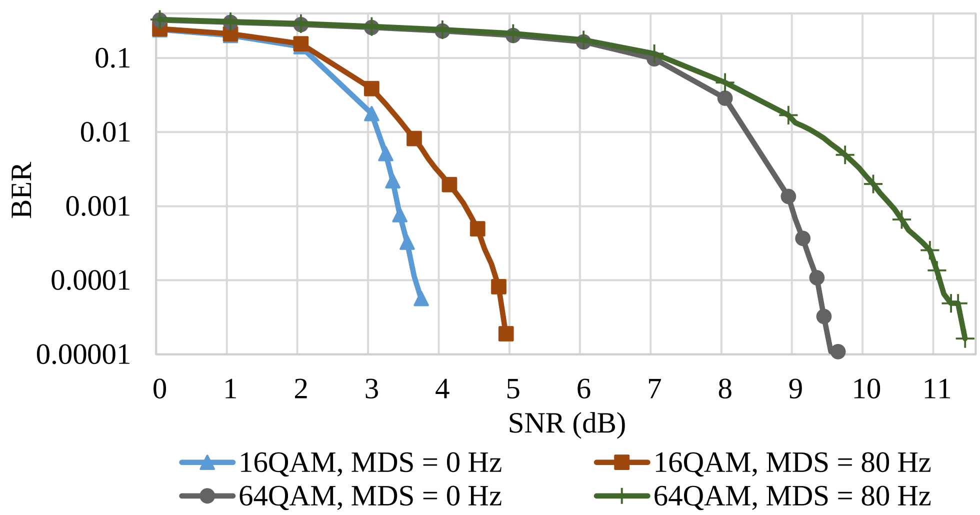


**Figure 3:** The bit error rate (BER) as a function of the signal-to-noise ratio (SNR) when using 16QAM and 64QAM modulation schemes, with a 1/3 coding rate and different values of Doppler shifts (0 and 80 Hz)

Another factor that can affect the quality of the system and can be adjusted at the transmitter is the MIMO antenna configuration. In this work, the effect of the use of 2×2 and 4×4 MIMO antenna configuration on noise immunity was evaluated, in comparison with the absence of the use of MIMO (1×1 antenna configuration). The research results show in Fig. 4 that the use of MIMO also makes it possible to almost double the noise immunity and thus improve the operation thresholds.

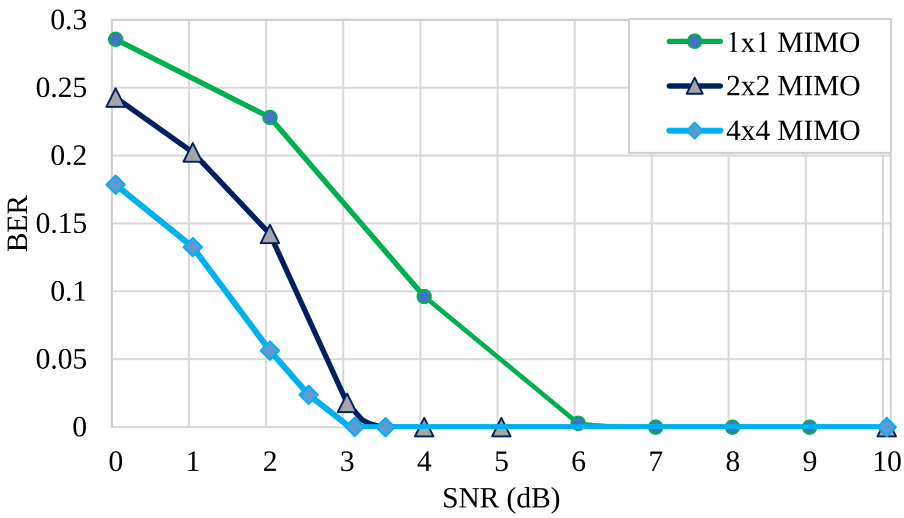


**Figure 4:** The bit error rate (BER) as a function of the signal-to-noise ratio (SNR) using the MIMO multiple antenna technology with a coding rate of 1/3 and a value MDS of 0

## 5. Conclusion

The results of the work show that the quality of the remote biometric authentication system can be significantly improved by using additional means of noise immunity and using adaptive settings on the transmitter side.

Based on the obtained research results, it can be concluded that the best compromise between noise immunity and speed when conducting remote biometric authentication in the LTE network is provided by 16QAM modulation, whereas 64QAM quadrature modulation is not desirable to use when conducting transactions. The conclusions are based on the fact that in the absence of the influence of Doppler shifts, the operation threshold of the system using QPSK modulation is an SNR value of 0 dB, with 16QAM modulation is an SNR value of 3.4 dB, and with 64QAM is the SNR value is 9 dB.

The use of multiple antennas for signal transmission and reception (2×2 and 4×4 MIMO) has improved the quality of the channel. Because to ensure the same bit error rate as when using 1×1 MIMO, a lower BER is needed, that is, a worse state of the data link.

For instance, for a BER value of 0.14, if the antenna configuration is 1×1 (with an MDS value of 80), the value of SNR is 4 dB, and for 4x4 MIMO (with an MDS value of 80 Hz) for the same BER value, the value of SNR is 1 dB. This indicates the advantage of using 4×4 MIMO antenna configuration. The operation thresholds for remote biometric authentication are (with an MDS value of 0 Hz):

- For 1×1 MIMO antenna configuration, the value SNR is 6.1 dB.
- For 2×2 MIMO antenna configuration, the value SNR is 3.4 dB.
- For 4×4 MIMO antenna configuration, the value SNR is 3.1 dB.

In addition to modulation and antenna configuration, it was determined that the coding rate also affects the BER value. The system response threshold has decreased by almost half from the SNR value of 6.4 dB for coding rate 1/2 to the SNR value of 3.4 dB for coding rate 1/3.

As a recommendation for the use of remote biometric authentication systems in mobile networks, it is necessary to utilize the transmitter parameters with 2x2 and 4x4 MIMO antenna configuration, 1/3 coding rate, and 16QAM modulation scheme. In this case, better results can be achieved with system operation. Under the worst network conditions, priority should be given to using 4×4 MIMO scheme, QPSK modulation scheme, and using 1/3 coding rate.

These results can be applied to the formation of a new class of service and the formation of requirements for its priority transmission and ensuring the necessary features, including noise immunity.

## 6. References


[1] H. Mousavi, I. Amiri, M. Mostafavi, C. Choon, LTE physical layer: Performance analysis and evaluation, Applied Computing and Informatics 15(1) (2019) 34-44. doi: 10.1016/j.aci.2017.09.008.

[2] V. Nandal, D. Nandal, Improving the BER in LTE System using various Modulation Techniques over Different Fading Channel, International Journal for Research in Technological Studies 4(8) (2017) 5-9.

[3] M. Lal, H. Arora, B. Gurdas, P. Ptu, BER performance of different modulation schemes for MIMO systems, International Journal of Computer Science and Network Security 11(3) (2011) 62-79.

[4] S. Ghosh, Performance Evaluation of Different Coding and Modulation Scheme in LTE Using Different Bandwidth and Correlation Levels, Wireless Personal Communications 86(2) (2015) 563-578. doi:10.1007/s11277-015-2945-6.

[5] N. Kanjan, K. Patil, S. Ranaware, P. Sarokte, A Comparative Study of Fingerprint Matching Algorithms, International Research Journal of Engineering and Technology 4(11) (2017) 1892-1896.

[6] A. Jain, A. Ross, S. Prabhakar, An Introduction to Biometric Recognition, IEEE Transactions on Circuits and Systems for Video Technology 14(1) (2004) 4-20. doi:10.1109/TCSVT.2003.818349.

[7] D. Maltoni, R. Cappelli, Fingerprint Recognition, in: A. Jain, P. Flynn, A. Ross (Eds.), Handbook of Biometrics, Springer, Boston, MA, 2008, pp. 23-42. doi: 10.1007/978-0-387-71041-9_2.

[8] Neurotechnology.com, Fingerprint samples were scanned with DigitalPersona U.are.U 4000 scanner at 500 ppi, 2007. URL: http://www.neurotechnology.com/download/UareU_sample_DB.zip.

[9] C. I. Watson, M. D. Garris, E. Tabassi, C. L. Wilson, R. M. McCabe, S. Janet, K. Ko, User's Guide To NIST Biometric Image Software (NBIS), NIST, Gaithersburg, MD, 2007.

[10] R. Cappelli, M. Ferrara, D. Maltoni, Minutia Cylinder-Code: A New Representation and Matching Technique for Fingerprint Recognition, IEEE Transactions on Pattern Analysis and Machine Intelligence 32(12) (2010) 2128-2141. doi: 10.1109/TPAMI.2010.52.

[11] H. Zarrinkoub, Understanding LTE with MATLAB: From Mathematical Modeling to Simulation and Prototyping, John Wiley & Sons, Chichester, UK, 2014.

[12] LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Multiplexing and channel coding (3GPP TS 36.212 version 10.6.0 Release 10), European Telecommunications Standards Institute, Sophia Antipolis, France, 2012.

[13] LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation (3GPP TS 36.211 version 10.0.0 Release 10), European Telecommunications Standards Institute, Sophia Antipolis, France, 2011.