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SYSTEM FOR DETECTING THE TRANSMISSION ERROR RATE DURING WI-FI COMMUNICATION WITH CC3220SF LAUNCHPAD

BY

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Abstract. The present paper proposes and evaluates a method to detect the ratio of the total number of data units in error to the total number of data units transmitted during Wi-Fi transmission under different environmental conditions, using the CC3220SF LaunchPad development board. The goal is to find the best applicability of this system for future IoT research. The proposed solution evaluates data provided by CC3220SF to the Windows application and CC3200 system through a Wi-Fi connection in different real conditions. For each data request, generated by the Windows application or the CC3200 development board, the CC3220SF will encapsulate data with a unique index. For this paper, using the proposed method for evaluation, the obtained result was the fact that the development board CC3220SF is working very well, with losses below 10% in the frequency range of 65 Hz to 200 Hz. This result leads to the fact that this development board can be used with high accuracy in a domain such as healthcare, IoT, automotive, or Home automation.

Keywords: Wi-Fi; Smart system; Development Board; CC3220SF LaunchPad; Error Rate.

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1. Introduction

During the last years, the growth of portable devices has led to the development of new solutions in the field of Telecommunication without a physical connection. Wi-Fi is one of the most used communication protocols, with many applications in different fields such as Telecommunication (Kadil and Adane, 2013), Power management (Rattagan, 2016), Home automation (Tan *et al*., 2016), Security (Yoon *et al*., 2012), Healthcare (Manzoor *et al*., 2019), etc. This communication protocol is used to create a connection between different devices, transfer data between them and controlling communication way in complex systems. The possibility of having a stable, secure and fast system that can exchange data with a global network leads to developing a new concept which is called “Internet of Things”. The IoT concept was created to provide a communication architecture for assuring interconnection between many devices with various complexity and communication protocols, with the main scope to create a complex system using the modular devices connected in the network. At this moment, more than 5 billion devices are connected to the Internet network and it is estimated that this number will grow to 50 billion until the end of 2020 (IoT, 2020). One of the most important domains for researchers is the medical area. This domain includes all solutions for providing and increasing the quality of life and to prevent and support the lifestyle. For acquisition data from the human body and taking diagnostic information, many portable solutions were developed for the moment that operate at different data acquisition rates (Chatterjee *et al*., 2017; Zois, 2016; Elkhail and Baroudi, 2018). Because many applications have different job tasks and operating frequencies, the most important aspect, in this case, is to exchange and adapt the data acquisition without error by means of Wi-Fi communication protocol. In this paper it is proposed and evaluated a method to detect the ratio of total number of data units in error to the total number of data units transmitted during Wi-Fi transmission under different environmental conditions (*e.g*., line-of-sight *vs*. various obstructions such as walls, high or low interferences, low or crowded AP access, etc.), using the CC3220SF LaunchPad development board. The focus will be to obtain a method for evaluating the CC3220SF LaunchPad performances and, which is the principal frequency work domain with a low error rate. For establishing the connection between CC3220SF development board and the local Wi-Fi station, in this paper was used the provisioning technique. This technique provides the possibility for the user to add a new device to the local wi-fi network using the template profile that includes information about AP name and password when the type of security is enabled (WEP/WPA/WPA2). The development boards CC3220SF created by Texas Instruments provide 4 operation mode options:

- Wi-Fi Protected Setup (WPS)

- Access Point (AP) Mode
- Smart Config Technology
- Wireless Accessory Configuration (WAC)

For this experiment the development boards CC3220 SF will be configured to be used in Access Point (AP) Mode. In this paper for performance evaluation many situations were taken into consideration such as: different distance between Wi-Fi router and AP, different numbers of users connected to the Wi-Fi network, different crowded communication channel and different technology used for data request. This experiment has as the main scope to highlight a method that can provide an evaluation of the work frequency domain with the lowest data transmission error for development boards CC3220SF. For the proposed solution, it was used information from an accelerometer sensor placed on CC3220SF board. The information from the accelerometer will be encapsulated in a data frame, with a unique identification data number. The encapsulation of data with a unique identification number has as the main scope to identify the correct receiving data at the end-user device and estimate the number of data errors. Estimation of data errors during Wi-Fi communication will be evaluated using a Windows application developed in Lab Windows CVI and using other development boards (CC3200). The proposed solution for this paper is easier to implement on the embedded system than the solution provided by (Khalili and Salamatian, 2004) or (Chrisikos and Clark, 1998), where the analysis of bit error value was done from the theoretical point of view. Another existent solution is represented by (Hsiao *et al*., 2012), which evaluate the number of bit error using a complex system composed of 3 parts. The first step is represented by power calibration in a specific bandwidth, the second one is represented by the error ratio method and the last one is represented by modulation of the synchronization signal. In this paper, the focus will be put to get the Wi-Fi error ratio provided by the new family of Wi-Fi development boards created by Texas Instruments using the proposed technique. One of the most important aspects that was taken into consideration during this experiment is that the evaluation of the performance was performed under different test condition to simulate the real transmission situation, this thing provided the realistic information about the limitation or range of bandwidth to the CC3220SF development board.

2. System Layout

This experiment contains 3 steps: the first step is represented by establishing Wi-Fi connection with the local network, the second step is represented by acquisition and encapsulated data from the accelerometer sensor on development boards CC3220SF and the third step is represented by receiving data and evaluating the number of data frame errors. The evaluation of data error will be performed in many different real conditions, such as: different distance between Wi-Fi router and AP, different number of users on a Wi-Fi network, different crowd level of communication channel and different technology used for requested data. In the current experiment, the focus will be put on the determination of the performance provided by CC3220 development boards and on the proposed evaluation techniques. Also, in this experiment, different end-user such as Windows applications or other Wi-Fi development boards were used for having the possibility to simulate real work conditions. The block diagram of the proposed experimental setup is shown in Fig. 1:

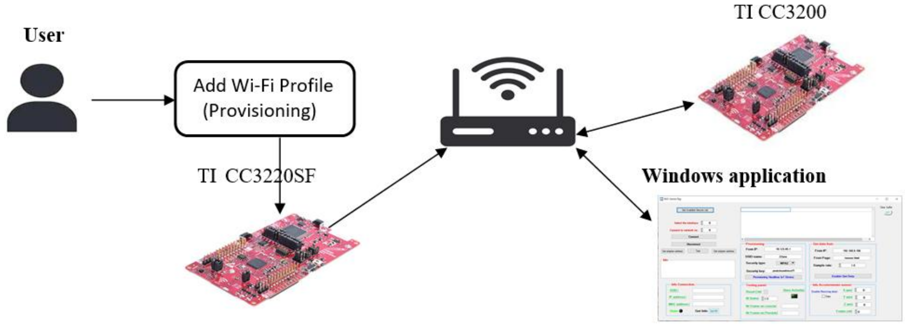

Fig. 1 – Block diagram of the system.

Figure 1 put in evidence the experimental setup and way to establish the connection through the Wi-Fi network.

3. Wi-Fi Communication

The Wi-Fi protocol is the most used communication protocol in the last period, with applicability in many various domains. For this paper, it was desired to obtain a quick and easy method for evaluating the performance provided by any Wi-Fi development boards. The actual Wi-Fi projects have high requirements such as high transmission speed, low data losses, and high portability. At this moment a lot of methods exist for establishing the connection with the global network using the Wi-Fi protocol. One of these methods is provisioning technique. For this experiment, the development board CC3220 was configured in the beginning as a "Station" for having the possibility to get any Wi-Fi profile provided by the user and save it inside of ROM memory. For this experiment, a new development board provided by Texas Instruments was used, the SimpleLink Wi-Fi CC3220 SF, which is a dual-band wireless device and can work with the 2.4 GHz and 5 GHz band frequency domains (CC3x20, CC3x35 SimpleLink, 2020). To have the possibility to operate at frequencies of 2.4 GHz and 5 GHz, this development board provides a chance to be used in a project that used a Wi-Fi protocol for the next generation of it. As was described in the previous chapter, in this experiment it was used the provisioning method. This technique is structured in two-stages: the first stage is represented by configuration of Wi-Fi profile and the second one is represented by confirmation of profile adding.

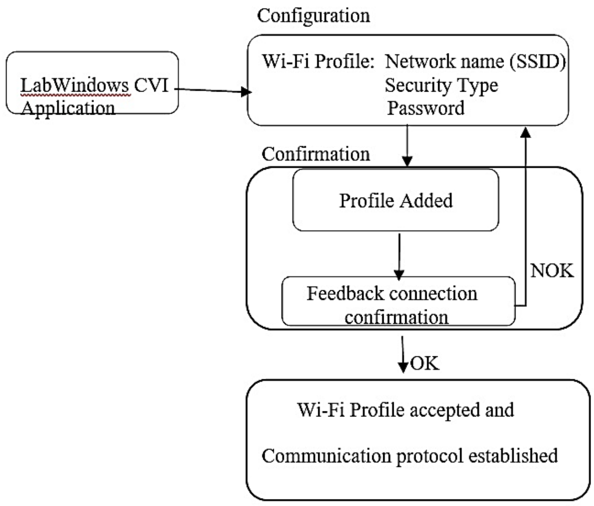

Fig. 2 – Block diagram for provisioning technique.

In this paper, the provisioning technique is implemented in Windows application, developed in Lab Windows CVI. The actual developed Windows application will consider the situation when the Wi-Fi profile is not well configured. In that situation the application will remain in the "Station" mode. If the Wi-Fi profile corresponds to a valid one, at that moment the development board will switch to AP and data can be transferred through Wi-Fi protocol. The graphic chart which describes the actual working state of the proposed experimental setup can be seen in Fig. 2.

At this time, the telecommunication domain was growing rapidly with many devices connected to the global network. Because of this aspect the main issue that appeared was regarding the loss of the data frame. This issue appears because for transmitting data by means of Wi-Fi protocol a limited number of channels is used and for this reason, at the same time multiple devices can send data and this thing leads to data frame loss. The ideal condition for the Wi-Fi protocol is to use a single communication channel with a transmission without data perturbation. For having small data loss, in the technical literature it is recommended to have under 10% usability for each transmission channel (Performance of Wireless Networks, 2020). The most used channels are that 1, 6, and 11, this one is representative for Europe region, for another region it is possible to be used more than 11 channels for transmitting data. For the moment many techniques exist that avoid the loss of data transmitted by means of the Wi-Fi protocol. The most known technique used for assuring the well-receiving data is represented by adaptive bandwidth (Das *et al*., 2017) or adaptive bitrate (Ruether, 2020). If we consider the fact that at this moment many Wi-Fi networks around us exist, the transmission error data is essential to be lower and as an expectation for this paper, data transmission will be affected by external factors. In this case, the focus will be put to check differently the transmission data using the development board CC3220SF. This topic is critical during the Wi-Fi connection because if the value of the error ratio is high, the performance of the system can be directly affected. Depending on the number of AP that can transmit data on a single Wi-Fi channel, the error rate value is directly affected. For this evaluation it was taken into consideration the alternative to check the performance of the CC3220SF in 2 stages. The first stage is represented by CC3220SF work frequency, while the second stage is represented by the request frequency that can have value in the range of 10 Hz to 200 Hz. To obtain the frequency work domain for development board CC3220SF, in this paper different situations for testing the CC3220SF performance were used such as different distances between the development board and Wi-Fi station, different loaded of a local network with the case when on single AP or multiple AP transmits data and transmit data when multiple Wi-Fi stations work on a single channel. After finishing this experiment, it was obtained an overview of the Wi-Fi performances provided by the development board CC3220SF. With the help of the obtained results, it can be easy to determine which is the best fit for the board CC3220SF for the next research ideas.

4. Transmission Data Format

For this paper, the evaluation of Wi-Fi performance provided by Texas Instruments development board CC3220SF was performed using an accelerometer sensor. The information from the accelerometer is acquired using the I2C communication protocol. After that information was acquired, each data from the accelerometer will be encapsulated in a data frame with a unique number for data identification. The data frame structure after the encapsulation process has the format which can be seen in Fig. 3.

Fig. 3 – Data frame format.

The proposed idea for this paper is based on evaluation data frame error using a unique number identification as is exemplified in Fig. 3. For this experiment, each data was transmitted from an accelerometer by means of a Wi-Fi communication protocol with a unique data identifier. The proposed idea for evaluation of data frame error contains two parts. First part is represented by encapsulation of data from an accelerometer sensor, while the second part is represented by requesting data from diverse applications such as Windows application or Texas Instruments CC3200 development board application. To have the possibility to get the frequency work domain for the development board CC3220SF, it was proposed as an evaluation solution, to perform a data request in the range of 10 Hz to 200 Hz from Windows application or the embedded application. Because the acquisition of data from the accelerometer is performed with constant time sample, the main expectation is to obtain a low error data frame when the request of data from Windows application or the embedded application is performed with the same sample. When requesting of data is performed with low sample time or larger sample time than acquisition sample time configured on development board CC3220SF, the expectation is that to obtain a lot of data loss. The representation of the main idea of the above affirmation can be seen in Fig. 4.

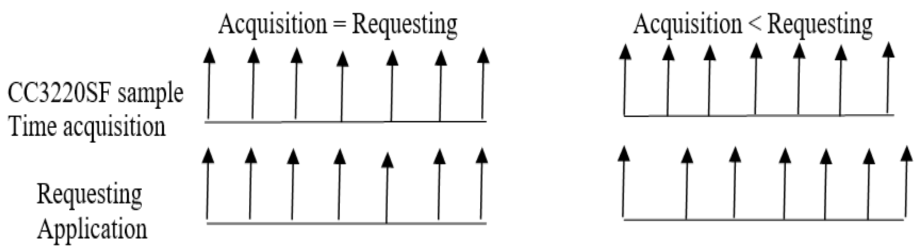

Fig. 4 – Sample time of acquired data and request data.

The proposed idea for performance evaluation is very simple and provides us information about which is the range domain when the data frame is received well without an error. The main idea was started from the necessity to know how much data can be received by an application by means of Wi-Fi communication protocol using the development board CC3220SF. In this experiment for each test of data transmission, the data acquisition on the development board was configured at a constant value in the range of 10 Hz to 65 Hz. For simulating a diversity of the requesting types, during this experiment paper was used a Windows application developed in Lab Windows CVI and a CC3200 development board. The data frame encapsulated on CC3220SF was requested from the application using the GET HTML method.

5. Experiment Setup

For this paper, the current experiment is composed of 2 parts: the first part is represented by the CC3220SF development board, while the second part is represented by the Windows application developed in the Lab Windows CVI and the application developed for the CC3200 board. The Windows application developed in the Lab Windows CVI has the main role to check the number of frames lost as a result of data transmission by means of the Wi-Fi protocol. For this experiment, the execution of each test session to verify the number of data received correctly, the following aspects were considered:

- The data acquisition from the accelerometric sensor was configured at a fixed value in the range of 10 Hz to 65 Hz.
- The request for data acquisition was made from the Windows application and the application developed for the CC3200 at a fixed frequency in the range of 10 Hz to 200 Hz.
- To verify the data transmission performance by means of the Wi-Fi protocol. it was tried to transmit the data in different transmission conditions.

The test conditions used to verify the data transmission performance for this paper are:

- Use of a Wi-Fi station at a maximum distance of 3 meters on an unused transmission channel.
- Use of a Wi-Fi station at a maximum distance of 3 meters on a transmission channel occupied by at least 3 Wi-Fi stations.
- Use of a Wi-Fi station with a distance greater than 10 meters on an unused transmission channel provided with several transmission obstacles (walls).
- Use of a Wi-Fi station with a distance of more than 10 meters on a transmission channel used by at least 3 Wi-Fi stations provided with several transmission obstacles (walls).
- Using a Wi-Fi station with at least 3 devices connected at a different distance.

For this experiment, the CC3220SF development board will be considered a web server, from which through the use of getting instances, the packets of data encapsulated were requested by the end-users (Windows application or CC3200 application). The proposed solution for evaluating the data transmission performance using the Wi-Fi protocol consists of evaluating the data packets transmitted by the CC3220 development board with a unique identification id, with the value of the packets received at the Windows application or CC3200 development board in a ratio of 1 to 1. To evaluate the quality of the data transmission, the information received will be compared with the information transmitted, and when certain disturbances appear on the channel, the data packets will be received with a unique ID, which will lead to the determination of the numbers of errors that have occurred since the last correct reception. The proposed solution is a simple one and is based on the evaluation of the unique data packets that are transmitted by means of Wi-Fi networks. For this work, the part of the evaluation and determination of the quality of data transmission was done by means of the Windows application and the embedded application for the CC3200 development board. With the help of the Windows application developed in the Lab Windows CVI environment, it was possible to query the data for several 500, 1000 and 2000 packets of data acquired at a frequency of acquisition between 10 Hz and 200 Hz. Because running an application under the Windows operating system is not very accurate, this one depends on the priority of internal execution processes within the Windows operating system, in this experiment the priority of application running was set on Real-time option. For Windows application was used an asynchronous timer with 1ms resolution. The representation of developed Windows GUI application can be seen in Fig. 5:

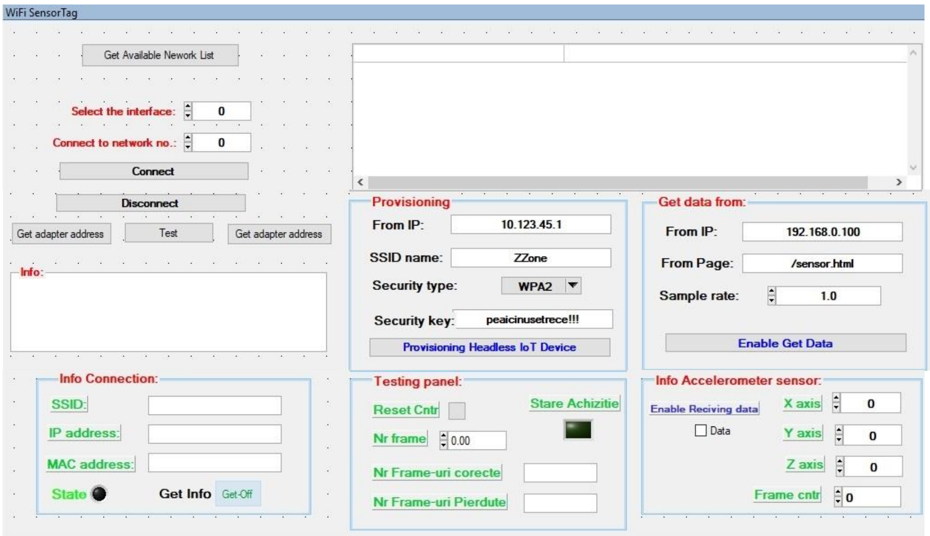

Fig. 5 – Windows application for evaluation Wi-Fi transmitting performance.

For this experiment, the performance evaluation of the CC3220 development board was performed offline on a series of 10 repetitions for each test condition. The conclusion regarding the performances offered by the CC3220SF development board was obtained by performing arithmetic mean applied to the results obtained after the 10 repetitions. The technique of mediating the information regarding the data reception rate correctly is used in this paper because the information transmitted through the Wi-Fi protocol cannot be reproduced in an ideal way every time, being directly dependent on external transmission conditions. The current experiment has the main focus to validate the proposed solution for evaluating the data transmission performance for a development board using the Wi-Fi transmission protocol. Also, in this paper, another focus is to get the frequency range in which the CC3220 development board works optimally without getting errors when receiving data by means of Wi-Fi communication protocol. To simulate a real data transmission environment and to validate the proposed solution, a CC3200 development board was used in this paper. This development board will require several 500, 1000 and 2000 packets of data from the CC3220SF development board via Wi-Fi connection with a frequency data acquisition between 10 Hz and 200 Hz. The method for evaluating the number of packets received correctly following the transmission process via the Wi-Fi protocol, using the CC3200 development board, is similar to the one implemented in the Windows application, the difference being that an evaluation system using the CC3200 development board, was used the single-threaded task with the highest priority in RTOS operating system. This leads to the fact that the execution of the data request task will be done with high precision and it is not affected by other execution threads as it is in the case of the Windows application where the execution thread of the application will execute according to the priorities established by the Windows operating system. The results obtained in this experiment proposed for this paper will be used as a theoretical basis for the future research ideas. The complete experimental setup used for this work can be seen in Fig. 6:

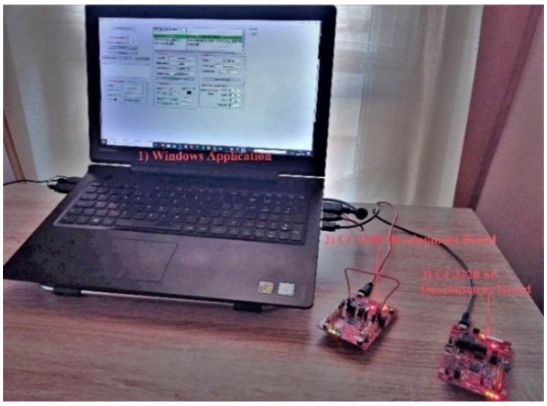

Fig. 6 – Wi-Fi evaluation frame ratio error setup.

6. Experiment Results

For this paper, the experiment was performed in real condition with many perturbations on the communication channel, this one comes from other Wi-Fi stations, other communication devices or other wireless portable devices placed inside of the room. For the first experiment, it was used a local Wi-Fi router placed inside of the room at a maximum of 3 meters to the CC3220SF development board. For data evaluation, it was used the developed Windows application and the embedded application developed for the CC3200 development board. For the aforementioned case, it was conducted 2 verification sessions with the help of the proposed solution. The first verification session consisted of measurements for the case where the local network uses an unused channel and several 3 devices connected to it. The second verification session consisted of measuring data transmission performance if the local Wi-Fi station was configured to use a transmission channel already used by another network. For each session of verification of the performances given by the CC3220SF development board, there were performed 10 measurements, that were processed offline using the arithmetic mean, this step giving the real result about the number of errors encountered when transmitting data using the Wi-Fi protocol. The results obtained after performing the first verification session mentioned before can be seen in Table 1.

Table 1
Wi-Fi Performance of Development Board CC3220 SF when the Strength of the Signal is High and the Request is Performed from Windows Application

Freq Request	**µC Acquisition 10 Hz**			**µC Acquisition 25 Hz**		
Number of Frame request	500	1000	2000	500	1000	2000
No Errors 10Hz [%]	46.4	57.1	55.8	100	100	100
No Errors 25Hz [%]	10.8	2	2	14	13.2	5.35
No Errors 45Hz [%]	5	1.2	0.7	3	6	2.2
No Errors 65Hz [%]	0	1	0,5	2	2	0
No Errors 85Hz [%]	0	0,4	0.45	1.2	0.5	0
No Errors 120Hz [%]	0	0.8	0	0	0.2	0
No Errors 150Hz [%]	1	0.2	0.2	3.2	1.4	2.15
No Errors 200Hz [%]	2	0,5	1.25	4.2	3.7	4.7
Freq Request	**µC Acquisition 45 Hz**			**µC Acquisition 65 Hz**		
Number of Frame request	500	1000	2000	500	1000	2000
No Errors 10Hz [%]	100	100	100	82.4	85.6	96.1
No Errors 25Hz [%]	100	100	100	75	71.1	85.55
No Errors 45Hz [%]	29.8	10.5	18.1	62.2	65	83.85
No Errors 65Hz [%]	22.8	11.4	17.35	49	62.3	75
No Errors 85Hz [%]	18.8	12.8	17.5	46.6	67	80
No Errors 120Hz [%]	11.4	18.6	16.15	69.2	79.5	84.35
No Errors 150Hz [%]	9.8	12	18.7	77.6	95.5	90
No Errors 200Hz [%]	14	15.5	17.1	84.2	100	97.6

To evaluate the results presented in Table 1, where the data were requested from the developed Windows application, in this paper the same measurement was performed, in the case when a data request is made using the application developed for the CC3200 development board. With this test step, was tried to use and simulate a real case where several devices with different characteristics may request data from the CC3220 SF development board using the Wi-Fi communication protocol. The results obtained in the case where the data request is made using the CC3200 development board and the Wi-Fi station to which it is connected working on an unused communication channel can be seen in Table 2.

Table 2

Wi-Fi Performance of Development Board CC3220 SF when the Strength of the Signal is High and the Request is Performed from the SW Application Running on CC3200 Dev Board

Freq Request	**µC Acquisition 10 Hz**			**µC Acquisition 25 Hz**		
Number of Frame request	500	1000	2000	500	1000	2000
No Errors 10Hz [%]	7	2.2	2.45	70	45	75
No Errors 25Hz [%]	3	1.4	0.4	64	38	45
No Errors 45Hz [%]	1	0.2	0.25	32.4	32.6	37.9
No Errors 65Hz [%]	0.4	0.2	0.1	4	2.4	5.1
No Errors 85Hz [%]	0	0	0	0	0	0
No Errors 120Hz [%]	0	0	0	0	0	0
No Errors 150Hz [%]	0.4	0.2	0.05	0.2	0.2	0
No Errors 200Hz [%]	1	0.4	0.1	0.4	0.3	0.25
Freq Request	**µC Acquisition 45 Hz**			**µC Acquisition 65 Hz**		
Number of Frame request	500	1000	2000	500	1000	2000
No Errors 10Hz [%]	100	100	100	77.4	83.1	92.5
No Errors 25Hz [%]	88.8	86.2	60	47.4	30	80
No Errors 45Hz [%]	53.8	45	12.3	37.8	29.5	40
No Errors 65Hz [%]	25.4	28.5	3.65	26	17.2	20
No Errors 85Hz [%]	1	0.2	0.15	1	0.2	0.15
No Errors 120Hz [%]	0	0	0	0	0	0
No Errors 150Hz [%]	0	0	0	0	0	0
No Errors 200Hz [%]	0.4	0.5	0.15	0.4	0.4	0.1

From the results presented above, it was noticed the fact that the best results were obtained in case when CC3200 was used. The better results obtained with development board CC3200 than with developed Windows applications were provided by the timer used for acquisition requests. This statement is plausible because the accuracy of the timer used in the developed Windows application is directly dependent on the processes that are executed at a given time in the Windows operating system. Based on the results presented in Table 1 and Table 2, the following preliminary conclusion were obtained:

- The frequency range domain obtained is 65 Hz to 200 Hz.
- The best results were obtained when the CC3220SF development board acquires and transmits the data with a frequency of 10 Hz.
- At high frequencies of data acquisition and transmission using the CC3220SF development board, this one is no longer manages to receive all the data, reaching their total loss.

In Fig. 7 and Fig. 8 are presented the above results presented in Table 1 and Table 2 under graphical representation. In the given pictures, the microcontroller acquisition frequency used in the current experiment has the following value: 10 Hz (blue signal), 25 Hz (orange signal), 45 Hz (grey signal) and 65 Hz (yellow signal). That pictures highlight the preliminary conclusions which were presented in the previous section, in Fig. 7 the ratio of the total number of data units in error to the total number of data units transmitted during Wi-Fi transmission is under 10 % when the transmitted rate on the CC3220SF development board is below or equal to ~ 30 Hz. Also, from Fig. 7 and Fig. 8 we can see the fact that several transmission errors depend on the type of devices that take the request from the development board CC3220SF. In the case of the developed Windows application, the high work frequency on the development board obtained a high number of errors up to 50 %. The next part of this paper, will present the results in case when the local Wi-Fi station was configured to use a transmission channel that is already used by another network and up to 3 devices are connected to it. In this test situation, we wanted to simulate the real case when a lot of devices use at the same time a local Wi-Fi station for transmitting data.

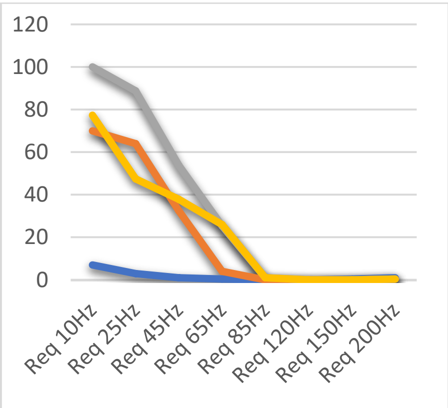

Fig. 7 – The Wi-Fi performance obtained with the request from the CC3200 development board.

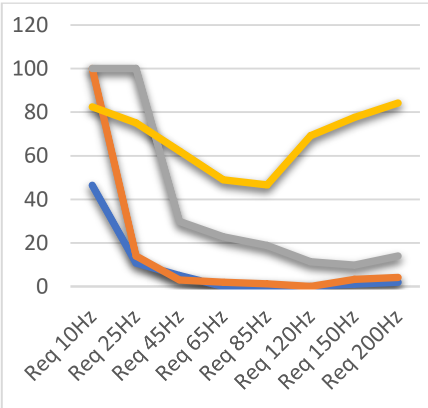

Fig. 8 – The Wi-Fi performance obtained with the request from the Windows application.

Because in the real world the Wi-Fi router can be used at the same time by a lot of devices and transmit data on the already used transmission channel, it was checked the case when the device under test (CC3220SF) is connected to the Wi-Fi station which transmits data on already used transmission channel and several than 3 devices are connected to it. In this test conditions, we checked if the transmission performances of development board CC3220SF, can be affected by external transmission condition. The test was done using the Windows application and embedded application running on CC3200. The results obtained in the previous test condition and using the proposed evaluation method described in this paper can be seen in Table 3 and Table 4. From that table results, it can be noticed the fact that the development board CC3220SF is affected by the external conditions and the best working domain is between 85 Hz to 200 Hz when the embedded device CC3200 is used. For the case when the Windows application was used, the best results were obtained when the development board CC3220SF is working in the range of 10 Hz to ~30 Hz, this fact leads to obtaining good error ratio value which is below than 10%, while the other situations obtain error up to 30%.

Table 3

Wi-Fi Performance of Development Board CC3220 SF when the Strength of the Signal is High and Local Wi-Fi Station Use an Already Used Transmission Channel with Request Performed from Windows Application

Freq Request	**µC Acquisition 10 Hz**			**µC Acquisition 25 Hz**		
Number of Frame request	500	1000	2000	500	1000	2000
No Errors 10Hz [%]	78.4	60	83.45	100	100	100
No Errors 25Hz [%]	4	0.5	0.25	8.6	0.4	49.85
No Errors 45Hz [%]	0.8	0.2	0.7	0.6	1.6	4.2
No Errors 65Hz [%]	0	0.5	0.25	0.4	2.1	1.55
No Errors 85Hz [%]	0	0	0.1	1.2	0.6	0.8
No Errors 120Hz [%]	0.8	1	0.3	0.8	0.4	1.35
No Errors 150Hz [%]	0.8	0.8	0.5	2.4	2	3.5
No Errors 200Hz [%]	0.8	0.8	0.3	2	0.9	1.75
Freq Request	**µC Acquisition 45 Hz**			**µC Acquisition 65 Hz**		
Number of Frame request	500	1000	2000	500	1000	2000
No Errors 10Hz [%]	100	100	100	100	100	100
No Errors 25Hz [%]	100	100	100	100	100	100
No Errors 45Hz [%]	42.2	47.7	23.45	100	100	100
No Errors 65Hz [%]	35	46.1	26.35	69	56.4	50
No Errors 85Hz [%]	34	36.9	25.05	64.2	61.1	80
No Errors 120Hz [%]	31.6	20.5	23.95	57.4	74.4	87.2
No Errors 150Hz [%]	28.6	17	24	72	71.5	87.75
No Errors 200Hz [%]	23.6	18.2	27.5	90.8	98.9	100

Table 4
Wi-Fi Performance of Development Board CC3220 SF when the Strength of the Signal is High and Local Wi-Fi Station Use an Already Used Transmission Channel with Request Performed from the Embedded Application CC3200

Freq Request	**µC Acquisition 10 Hz**			**µC Acquisition 25 Hz**		
Number of Frame request	500	1000	2000	500	1000	2000
No Errors 10Hz [%]	13	12.1	9.4	78.4	47.2	84.25
No Errors 25Hz [%]	7	7.5	7.35	71	41.2	47.25
No Errors 45Hz [%]	4.8	3.4	5	40	36.5	40
No Errors 65Hz [%]	2.8	2.1	3.7	8.8	3.3	6.75
No Errors 85Hz [%]	2.2	1.4	1.7	4.8	2.7	2.25
No Errors 120Hz [%]	1.2	1	1.25	2.6	1.5	1.65
No Errors 150Hz [%]	0.8	0.9	0.8	1.2	0.3	0.4
No Errors 200Hz [%]	1.4	1.6	1.65	1	0.3	0.2
Freq Request	**µC Acquisition 45 Hz**			**µC Acquisition 65 Hz**		
Number of Frame request	500	1000	2000	500	1000	2000
No Errors 10Hz [%]	100	100	99.6	84.2	90	96.65
No Errors 25Hz [%]	97.6	91.2	72.75	66.6	35.7	86.05
No Errors 45Hz [%]	64.4	51.3	17.75	52.8	36.6	43.05
No Errors 65Hz [%]	28	30	5	29	21.1	21.05
No Errors 85Hz [%]	3.2	1	0.65	5.2	3.2	0.9
No Errors 120Hz [%]	2.4	0.5	0.6	1.8	1.7	0.25
No Errors 150Hz [%]	1.8	0.7	1.25	1.6	1.2	0.6
No Errors 200Hz [%]	1	1.6	2.5	1	0.6	2.55

The graphical representation of the results based on the information presented in Table 3 and Table 4 can be seen in Fig. 9 and Fig. 10. From these graphical representations, it can be noticed that the transmission performance of the CC3220SF development board is directly dependent on the transmission conditions and the type of device from which the data transfer is requested. Another test situation which was checked in this paper when the Wi-Fi station to which is connected the developed board CC3220SF is placed at a distance higher than 10 m. In this test case, we wanted to check the error ratio in the case when a lot of obstacles (walls) between the Wi-Fi station and the CC3220SF and transmission distance between them is higher than 10 m. This case will highlight the performance of the CC3220SF development board under the real conditions when the data transmission will take place between different Wi-Fi stations or access points placed at great distances within the communication network. The results obtained for the case mentioned above can be seen in Table 5 and Table 6.

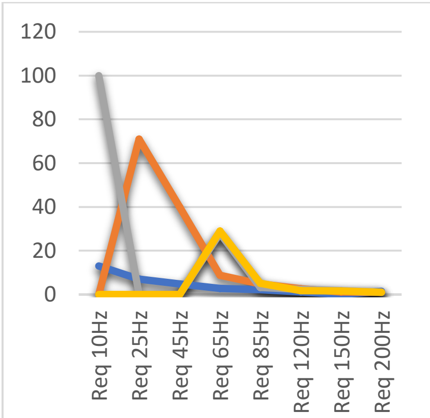

Fig. 9 – The Wi-Fi performance obtained with the request from a CC3200 development board and transmit data on an already used channel.

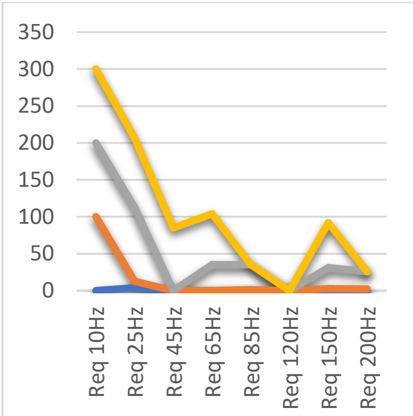

Fig. 10 – The Wi-Fi performance obtained with the request from Windows application and transmit data on an already used channel.

Table 5

Wi-Fi Performance of Development Board CC3220 SF when the Strength of the Signal is Low and Local Wi-Fi Station Use an Unused Transmission Channel with Request Performed from the Windows Application

Freq Request	**µC Acquisition 10 Hz**			**µC Acquisition 25 Hz**		
Number of Frame request	500	1000	2000	500	1000	2000
No Errors 10Hz [%]	62.6	77.2	73.65	100	100	100
No Errors 25Hz [%]	15.8	8.5	5.75	66	40.8	26.5
No Errors 45Hz [%]	11	4.1	3.45	57.4	13.6	7.85
No Errors 65Hz [%]	9.6	2.2	2.6	8.6	10.3	6.05
No Errors 85Hz [%]	2.2	0.8	0.4	4.6	2.1	0.4
No Errors 120Hz [%]	1	0.2	0.55	3.8	1.6	0.6
No Errors 150Hz [%]	5	0.4	6.2	6.4	8.7	1.5
No Errors 200Hz [%]	20	0.5	6.75	8.8	21.6	3.85
Freq Request	**µC Acquisition 45 Hz**			**µC Acquisition 65 Hz**		
Number of Frame request	500	1000	2000	500	1000	2000
No Errors 10Hz [%]	100	100	100	100	100	100
No Errors 25Hz [%]	100	100	100	100	100	100
No Errors 45Hz [%]	29	32.4	34.15	81.8	100	90
No Errors 65Hz [%]	20.8	28.8	17.25	67.6	84	85
No Errors 85Hz [%]	19.2	28.8	10.25	67.2	60	57.5
No Errors 120Hz [%]	26.4	6.3	8	65.4	45	55
No Errors 150Hz [%]	37.2	7.2	13.9	74.8	91.5	85
No Errors 200Hz [%]	22	22.4	28.4	70	97.2	90

Table 6
Wi-Fi Performance of Development Board CC3220 SF when the Strength of the Signal is Low and Local Wi-Fi Station Use an Unused Transmission Channel with Request Performed from the CC3200

Freq Request	**µC Acquisition 10 Hz**			**µC Acquisition 25 Hz**		
Number of Frame request	500	1000	2000	500	1000	2000
No Errors 10Hz [%]	62.6	65.7	75	90.5	89.2	91.6
No Errors 25Hz [%]	10	8.4	5	55	34	20
No Errors 45Hz [%]	5	4.1	3.45	48	14	7
No Errors 65Hz [%]	8	3	3	10	8	8
No Errors 85Hz [%]	5	3	2	4	4	3
No Errors 120Hz [%]	0.8	0.7	2	2	1.5	5
No Errors 150Hz [%]	4	1	5	4.2	7	3
No Errors 200Hz [%]	18	1	10	7	22	2
Freq Request	**µC Acquisition 45 Hz**			**µC Acquisition 65 Hz**		
Number of Frame request	500	1000	2000	500	1000	2000
No Errors 10Hz [%]	91.4	90.1	95	95.2	96.4	94
No Errors 25Hz [%]	94	98	93	96	96	95
No Errors 45Hz [%]	25	30	30	90	94	90
No Errors 65Hz [%]	14	25	15	80	90	82
No Errors 85Hz [%]	17	24	8	70	64	58
No Errors 120Hz [%]	24	6	4	64	54	60
No Errors 150Hz [%]	35	5	12	69	90	92
No Errors 200Hz [%]	20	20	17	72	95	90

Based on the results obtained, after verifying the transmission performance, mentioned in Table 5 and Table 6, it was concluded that the transmission performance of the CC3220SF board is not affected by the physical transmission obstacle. The results obtained in this case are similar to those obtained in the previous check case. This result confirms the validity of the verification method by obtaining results with a similar trend in several test situations, with the main focus to obtain information about data error ratio. The graphical representation of the results presented in Table 5 and Table 6 can be seen in Fig. 11 and 12. Fig. 11 and Fig. 12 show that the working frequency range for the CC3220SF development board, where the received number of errors on the communication channel is a very small one, is 65 Hz to 200 Hz.

This frequency range has been obtained for all test cases mentioned in this paper, this result makes the determined values for the CC3220SF development board to be a realistic one. Also, as a conclusion to the used evaluation technique, which was proposed to be used in this paper, this one is valid and this affirmation is supported by the uniformity of received results for all test cases presented in this section. In this paper for each session of verification of the performance given by the CC3220SF development board, 10 measurements were performed, that were processed offline using the arithmetic mean, this step giving the real result about the number of errors encountered when transmitting data was done. This stage represents an essential step from the evaluation method proposed for this work. This step was needed because the Wi-Fi communication protocol depends on the external communication condition, this thing leads to the fact that the error ratio can lead to having a different value in similar test conditions.

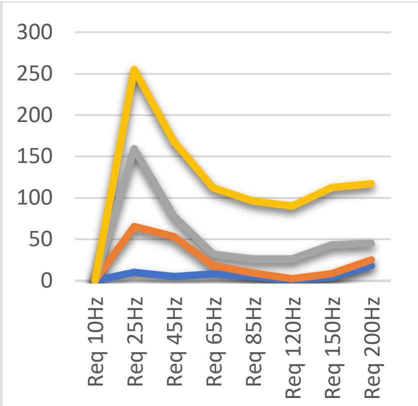

Fig. 11 – The performance with request from a CC3200 and obstacle on the channel.

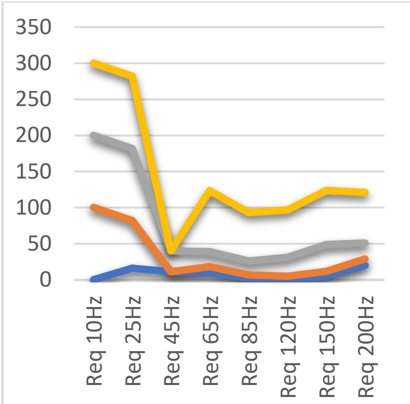

Fig. 12 – The performance with request from Windows application and obstacle.

7. Conclusion

In this paper, it was tried to show the performance of the Wi-Fi transmission provided by the development board CC3220SF. For providing some primary results, it was proposed an evaluation technique that consists following parts: the first part is represented by encapsulation of data method acquired by CC3220SF with a unique ID specific for each data frame. The second component of the proposed evaluation technique is represented by the evaluation error ratio part which is implemented in this case on Windows application and CC3200 embedded application. To evaluate the error ratio, for this paper the receiving data on Windows application or embedded application, will be compared with the last well-received data frame. Using the above technique for evaluation of the Wi-Fi transmission performance, we got some conclusions about the actual limitation provided by the development board CC3220SF. The first conclusion which we obtained is that after the performance evaluation the CC3220SF is working well without a high number of error when the working frequency is in the range of 65 Hz to 200 Hz. The second conclusion is represented by the fact that the number of received error during the Wi-Fi protocol can be affected by the external transmission condition such as overloaded network, the high number of devices connected to the network, the high number of Wi-Fi station which transmit data on the already used transmission channel. The advantage offered by the evaluation technique presented in this paper is provided by the fact that the solution is not a complicated one to implement and does not require additional resources to evaluate the transmission performances through the Wi-Fi protocol. The results obtained in this paper are very good and for the near future, this result will be used in my next research's ideas with applicability to IoT and the medical field. For the future research, I want to include the development board CC3220SF in an IoT project for transmitting data remotely between two medical devices placed at different distances one to another with the possibility to monitor the human body.

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SISTEM PENTRU DETECȚIA RATEI ERORILOR DE TRANSMISIE ÎN TIMPUL COMUNICAȚIEI WI-FI FOLOSIND PLACA DE DEZVOLTARE CC3220SF LAUNCHPAD

(Rezumat)

Lucrarea actuală propune și evaluează o metodă de detecție a raportului dintre numărul total de unități de date transmise eronat din numărul total de unități de date transmise în timpul comunicației Wi-Fi în diferite condiții de mediu, folosind placa de dezvoltare CC3220SF Launchpad. Scopul acestei cercetări este acela de a găsi cea mai bună aplicabilitate a acestui sistem pentru viitoarele cercetări în domeniul IoT. Soluția propusă evaluează datele furnizate de CC3220SF, folosind o aplicație Windows și o placă de dezvoltare CC3200 prin intermediul conexiunii Wi-Fi în condiții reale diferite. Pentru fiecare cerere de transmitere a datelor, generată de aplicația Windows sau de placa de dezvoltare CC3200, CC3220SF va încapsula datele cu un indice unic. Pentru această lucrare, folosind metoda propusă pentru evaluare s-a concluzionat că placa de dezvoltare CC3220SF funcționează foarte bine, cu pierderi sub 10% în intervalul de frecvență 65 Hz la 200Hz. Acest lucru, concluzionează faptul că această placă de dezvoltare poate fi utilizată cu o precizie ridicată în domenii ca: IoT, dispozitive medicale, automatizare locuinței, sisteme auto, etc.