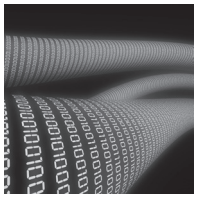

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Research on Quality Requirements of Data Transmission Services in RSMAD

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ABSTRACT

The paper presents results and analysis of research of the quality of service requirements (defined by the QoS attributes) for imaging data transmission services using Radio System for Monitoring and Acquisition of Data from Traffic Enforcement Cameras (in short RSMAD). The paper also presents and discusses results of test on the impact of the size of photos from traffic enforcement cameras on the average transmission time. These tests were conducted under conditions of actual operation of the RSMAD system. Basing on the obtained results, an analysis of the capacity, to provide in the RSMAD system required quality of service by different wireless data transmission systems, was performed.

KEYWORDS: RSMAD, QoS, UMTS, GSM, GPRS, TETRA

1. Introduction

Radio System for Monitoring and Acquisition of Data from Traffic Enforcement Cameras (in short RSMAD) is innovative, integrated system, designed to assist the work of the police and other services.

In general the RSMAD system for automated radio transmission of image data from traffic enforcement cameras (in short TEC) to the appropriate, distributed database is used [1]. This transmission is carried out using various cellular communication systems, depending on their availability in the area and instantaneous operating conditions [2].

In view of the fact that ensuring efficiency and reliability of the proposed system is an important feature of the proposed system, it is necessary to perform the analysis of the quality requirements for image data transmission services by the RSMAD system and define a corresponding set of QoS *(Quality of Service)* attributes for it [3].

Additionally, it is necessary to perform a research enabling reliable assessment of the suitability of different radio systems (such as: HSPA *(High Speed Packet Data)*, UMTS *(Universal Mobile Telecommunications System)*, EDGE *(Enhanced Data rates for GSM Evolution)*, GPRS *(General Packet Radio System)*, TETRA *(TErrestrial Trunked Radio)* to implement data transmission services with the required image quality [4]. During tests, images derived from the actual TECs were being sent.

2. Parameters and Quality of Services (QoS) in RSMAD

The documentation of the 3GPP standards organization (3rd Generation Partnership Project) for the UMTS [5] the radio communication service is defined as a set of functions offered to users over a network to meet their needs in telecommunications. The quality of services offered by the telecommunication system is directly related to a defined set of QoS's attributes. This set includes i. e. the following parameters:

- allowable transmission delay for the service, calculated from the source to the destination,

Table 1. Simplified set of attributes for the quality of the image data transmission services of the RSMAD system.

Parameter	Value
Time of access to the services	5 s
Time of calling the service	2 s
Time of changing the service's profile	5 s
Time of obtaining the information on services' quality	2 s
Bit Error Rate (BER)	10^{-7}
Probability of message loss	10^{-7}
Probability of delivering information to incorrect destination	10^{-7}
Maximum bit rate	depending on operator's network
Guaranteed bit rate	as above
Maximum size of SDU (*Service Data Unit*) – maximum size of a single message transmitted by the given system,	constant size, 2 MB, JPEG format
Error rate of SDU (messages lost or sent with errors)	10^{-6}

- time of access to the service (the time which must elapse between the performing of the action by the user to gain access to the network and receiving a positive confirmation by the user),
- time of calling the service and making any change in the service profile,
- delay and its fluctuations,
- the duration of data transmission,
- offered bandwidth capacity,
- transmission errors expressed as a percentage,
- Bit Error Rate (BER),
- Frame Error Rate (FER),
- probability of providing information to the wrong destination.

The RSMAD system require high reliability and transmission of large amounts of data, without having to carry out its basic functions in real time. RSMAD have to meet the requirements defined in general by the ITU-T [6]. For the RSMAD system have been specified services' quality parameters, which are as follows:

- **equitable access to resources**, which does not require additional action is possible through the existing UMTS and GSM network infrastructure,
- **control and reduction of capacity**, the application have a built-in control algorithm to reject images not suitable for further processing, i.e. out of focus, underexposed, overexposed, etc., in order to reduce unnecessary use of available data transmission bandwidth,
- **control of transmission delays**, which are not crucial for the RSMAD system due to: lack of necessity of transmission of data in real time and the presumed use of transmission channels of UMTS and GSM systems outside the hours of greatest congestion,
- **buffering redundant messages,** the RSMAD system have a mechanism checking whether the picture has not already been uploaded to the database [1] in order to avoid a situation in which the same traffic offense can be penalized twice; it is necessary to create a buffer to which each incoming message is sent, then after reading the header, the decision is required to continue processing the file or delete it, if it is found that the same file has already reached the base,
- **identifying the characteristics of packet loss**, the system send to TEC a feedback about the receiving each message to make sure that the image files are not "lost" on the way. Keeping statistics on the number of common errors, sent files which did not make it to the database and files that were sent two or more times, as a result of problems in the communication link between camera and the database, should also be considered,
- **control of resources use**, to avoid overload in the system, there should be implemented a mechanism for control of quantity of processed images and statistics on the use of resources allocated by the GSM/UMTS operator should be maintained.

As one can see, defining a new system requires a fairly detailed analysis of the qualitative parameters of QoS. As a result of the analysis a set of basic quality requirements for RSMAD was defined, as shown in Table 1.

Assessment of QoS in the RSMAD system should be based on measuring and controlling the fulfillment of the parameters presented in Table 1. Each parameter requires the implementation of an appropriate mechanism for measurements and the transmission of statistics.

Another, separate problem is the quality of images captured by TECs. Statistics on number of failed images for each TEC allow quick reaction, i.e. move the camera properly, check its technical condition, take care of better lighting conditions.

3. Simulation Tests

For the preliminary test of the suitability of different radio systems to transmit image data in the RSMAD system, a laboratory environment was used [4], shown in Figure 1, supplied with appropriate equipment and its own simulation software. Mentioned position generally consists of two PCs and a router. The computer marked in Figure 1 as a PC (1), with an installed, dedicated application, is designed to browse the certain folder

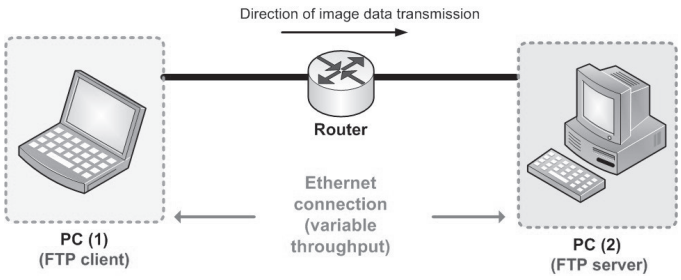

Fig. 1. Schematic illustration of laboratory for testing the suitability of radio systems for use in RSMAD.

and transfer all of its contents to the server via the FTP (File Transfer Protocol). For the purpose of that transmission data is placed in special transport blocks. Computer marked as PC (2), with an installed set of dedicated applications, is used to receive the transport blocks (sent by the PC (1)) and measuring the time of their transmission. However, the router (Linksys WRT54GL) with software Tomato ver. 1.27, combines the test PC (1) and PC (2) and limits the rate between them, with the router's software functionality allows to adjust the link rate between the computers. Functionally, it can be concluded that PC (1) and PC (2) perform the roles of FTP's client and server.

The study was designed to assess the suitability of selected, wireless data transmission systems such as HSPA, UMTS, EDGE, GPRS and TETRA for use in RSMAD [7]. During the measurements, it was assumed that errors of transmission and retransmission of files occur in the simulation environment.

In Table 2, there are assumed data rates, in the uplink in the simulated, selected systems of data transmission, theoretical rates and the forced (by the router) rate in a simulation environment.

Results of the performed tests are shown in Figure 2 and Figure 3. Figure 2 shows how for specific, tested systems, the time needed to send two files with a total volume of 1.52 [MB] (which corresponds to the two images registered by a TEC) changes.

Table 2. Summary of rates for the tested radio communication systems.

System name	Theoretical rate in uplink [kbps]	Rate established in the simulation environment [kbps]	
		min.	max.
HSPA	2700.00	2500.00	2700.00
UMTS	384.00	344.00	384.00
EDGE	236.00	206.00	236.00
GPRS	115.00	100.00	116.00
GPRS	55.00	50.00	60.00
TETRA 7.2	7.20	7.00	8.00
TETRA 2.4	2.40	2.00	3.00

Figure 3 presents the results of tests showing the average speed of data transmission during the transmission of image data in 20 files (with a total size of 13.62 [MB]) for the selected radio systems. As expected, the highest average speed of transmission the files was achieved using HSPA and UMTS systems, which means that using these systems we are potentially able to transmit data from TEC to database in the shortest time [4].

As one can see, we are able to upload these files in the fastest way using the capabilities of HSPA and UMTS (basic version) - for those systems the time needed to send two photos from the TEC amounted accordingly to 5 seconds and 35 seconds. Time of file transmission with the use of EDGE (about 1 min) and GPRS (approx. 2 min) is also acceptable. In case of attempt to use trunked system TETRA for data transmission, this time is at least several times longer (in the variant of the rate of 28.8 [kbps]), or even several dozen (a variant of the rate of 2.4 [kbps]), than in the case of mentioned earlier cellular systems. Even assuming that the pictures will be sent out of hours of largest traffic, the time needed to send image data using the TETRA system is long.

Summing up, cellular systems (HSPA, UMTS, EDGE, GPRS), are potentially more suitable for use in the RSMAD system than the trunking systems of TETRA family. It is important that the RSMAD system will be used to handle very heavy traffic, measured in

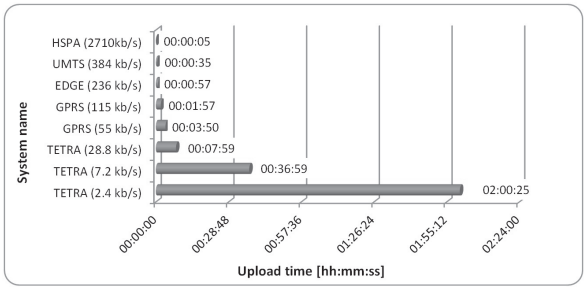

Fig. 2. Characteristic of changes in the time required to send two files for the selected systems.

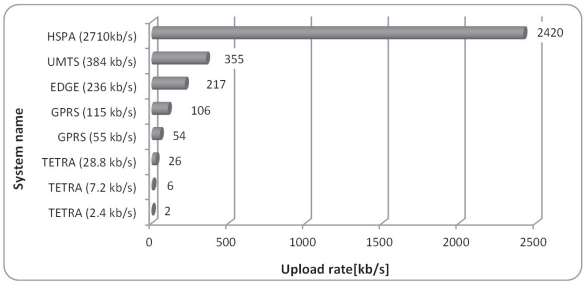

Fig. 3. Average speed of transmitting 20 files (13.62 [MB]) for selected systems.

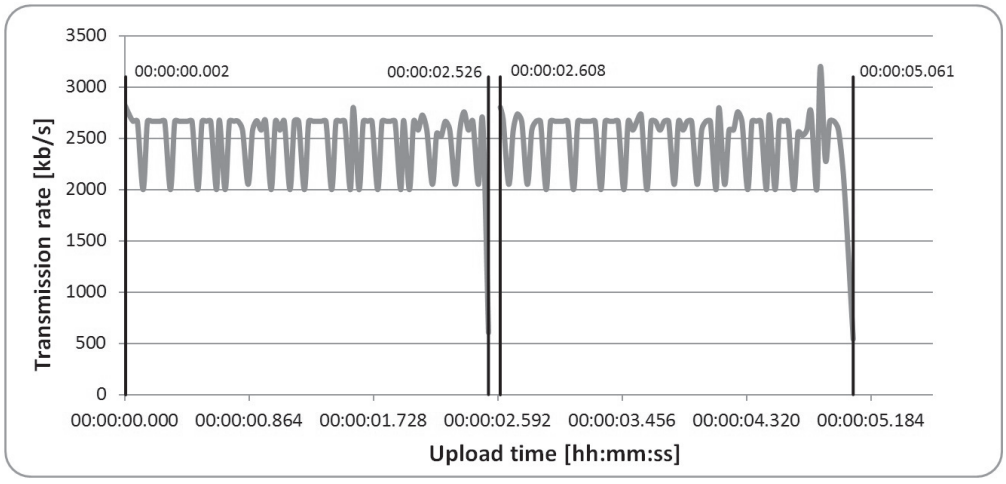

Fig. 4. Changes in the instantaneous speed of data transmission over time for HSPA.

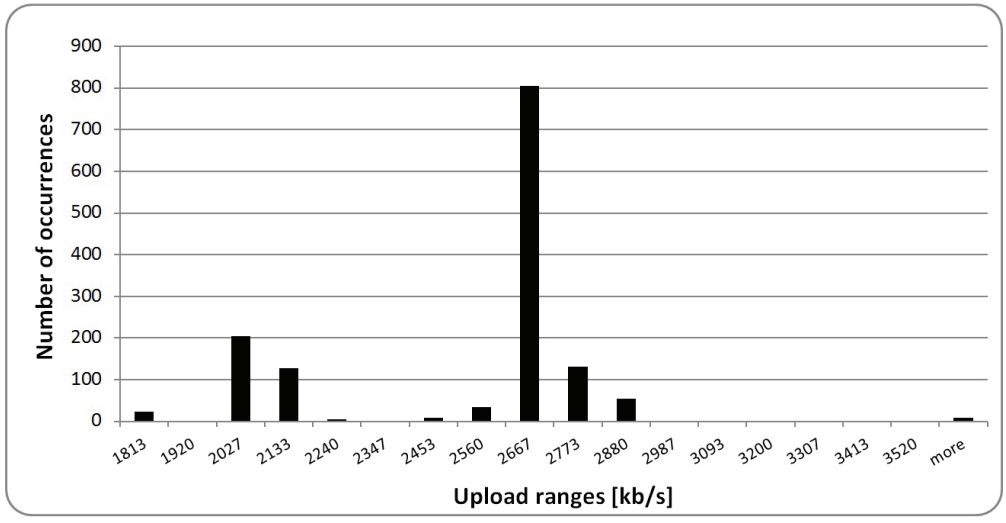

Fig. 5. Histogram of instantaneous frequency of the available rate for HSPA.

hundreds of GB/year/region, and therefore the performance capabilities of the TETRA system seem to be woefully inadequate unless a subsystem is used, for example TEDS (TETRA Enhanced Data Service). In order to confirm the observed dependencies individual systems were examined in more detail - by specifying the physical data rate change over time and the instantaneous frequency histogram, the available rate. Figure 4 and 5 shows an example of the characteristics obtained for a system offering the greatest potential rate, which means the shortest time needed to send images, so HSPA.

As shown in Fig. 4 and 5, in case of using the HSPA system offered rate of transmitted image data is stable on acceptable level and generally varies in the range around 2600 to 2700 [kbps] which is enough for the use of the RSMAD system.

4. Tests Results

The test environment, which consisted of TEC marked as Fotorapid CM, to generate source files in the TEC manufacturer encrypted format, called ZUR, of average size of medium size of 1153 [kB]. Studies conducted within the RSMAD project showed that the image data on traffic offenses are easy to compress. This is because of the fact that most of these photos have only a smooth tonal gradations. Figure 6 shows the average size of files stored in ZUR and JPEG formats for different compression parameters, set by the target resolution and image quality (marked in the rest of the work as Q). On Figure 6 a quality scale, from 0 to 100 proposed by the IJG (Independent JPEG Group) was adopted. In further part of the paper, the quality Q of 90, is called the standard picture quality. The use of JPEG compression can significantly reduce the size of a single file, with no loss of quality (Fig. 6).

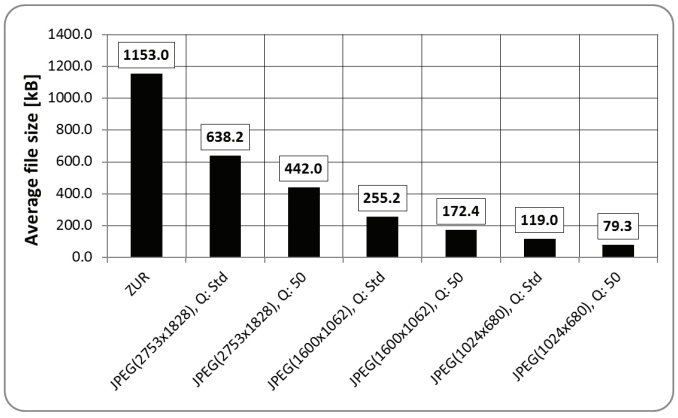

Fig. 6. Average size of the file for different compression parameters.

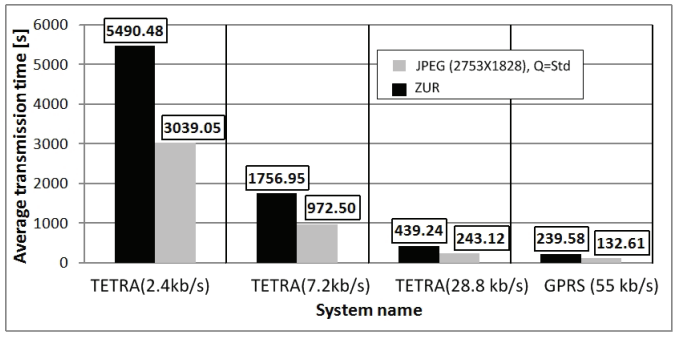

Fig. 7. Average transmission time of a single file for TETRA and GPRS systems.

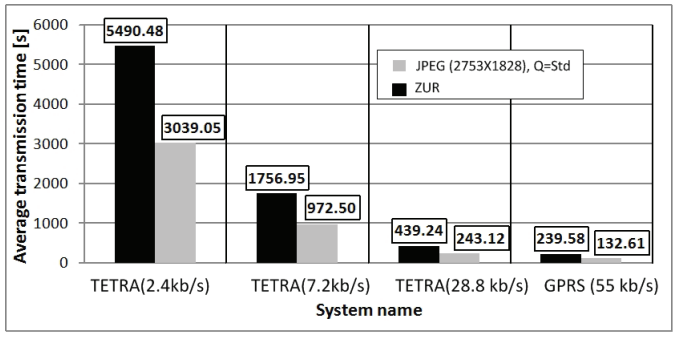

Fig. 8. Average transmission time of a single file for GPRS, EDGE, UMTS i HSPA systems

The average file size for the different formats can be expressed as follows:

$$R_A = \frac{\sum_{i=1}^{n} R_i}{n} \qquad (1)$$

where:

R_A – size of a single file from the sample,

i=1, 2, 3, …, n,

n – number of files;

n = 634.

Long-term field tests, relating to examination of the impact of the size of images with varying degrees of compression on the average transmission time, conducted within the RSMAD project, showed that the resulting transmission speeds are on average about 30% lower than the maximum speeds provided in the specification of a system for data transmission. Figures 7 and Figure 8 show the average times of transmission of a single file obtained by analysis, after the assumptions of the test field (that is, assuming that the RUL,A=0.7·RUL,MAX). The value of the proportionality factor was chosen as a result of tests in actual operation of the RSMAD system. Data presented in graphs show that by using the JPEG compression (resolution: 2753x1828 pixels, the quality Q: 90) the transmission time of such files from test TEC to DAC is reduced by almost half, compared to the files stored in its original ZUR format [4].

The average speed of transmission was determined by measuring repeatedly the instantaneous speed and dividing the sum of values by the number of measurements:

$$PT_A = \frac{\sum_{i=1}^{n} \frac{\Delta D_i}{\Delta t_i}}{n} \qquad (2)$$

where:

ΔD – number of data (in kB), effectively sent in time Δt,

i = 1, 2, 3, …, n,

n – number of measurements,

n = 1408.

Using the measurement data it can be calculated how much time per day will be needed to send files from a single source to a proxy server using the test systems:

$$TD_i = TT_{Ai} \cdot LP \qquad (3)$$

where:

TD_i – total time of transmission of files during one day,

TT_{Ai} – average time of transmission of one file for this system,

LP – number of files transmitted during one day.

The test results clearly show that the majority of the surveyed systems, under normal system load should ensure a transmission of data from TEC at the satisfactory level. Test results show that the transmission of images from the cameras via the TETRA system, also provides quality service at an acceptable level, particularly in situations where transmission take place in multislot mode called MSPD (Multislot Packet Data). Calculations show that total, theoretical transmission time of 100 files should vary in the range from about 8 minutes (if using HSPA system) to about 9000 minutes (in the case of the TETRA system in modes that offer the lowest rate). The calculation results

Table 3. Total time taken to transfer 100 files (ZUR) for different radio systems.

Name of the system	Total time of transmission [min]
TETRA ($R_{UL,MAX}$=2.4kb/s)	9150.79
TETRA ($R_{UL,MAX}$=7.2kb/s)	3050.26
TETRA ($R_{UL,MAX}$=28.8kb/s)	762.57
GPRS ($R_{UL,MAX}$=55kb/s)	399,31
GPRS ($R_{UL,MAX}$=115kb/s)	190.97
EDGE ($R_{UL,MAX}$=236kb/s)	93.06
UMTS ($R_{UL,MAX}$=384kb/s)	57.19
HSPA ($R_{UL,MAX}$=2710kb/s)	8.10

presented in Tab. 3 show clearly that it is highly desirable to apply data compression techniques, which in a very tangible way shorten times of transmission of images from the traffic enforcement camera to the DAC (Fig. 6).

Both GPRS and EDGE subsystems [7] as well as the UMTS system, and its extension in the form of HSPA, can effectively implement service of data acquisition from TECs, especially that under the service transmission of images does not have to be implemented in real time or even close to real. Thus, defining the maximum transmission delay as an important parameter is not required, because in practice it is limited only by the formal and legal considerations related to the maximum time between registration of the offense and the notification of this fact to the offender.

5. Conclusion

The RSMAD system, due to its practical applications and carried out important functions, is characterized by the high requirements regarding quality of services, including the reliability and performance. As it was shown by the tests, not all of functioning radio systems is potentially eligible for use as a transmission medium for use in RSMAD, because of a long time of transmission of even a single image and minor offered rates. A particular example are the various options of use of the TETRA system. It should be noted, that there is no need to transfer the collected image data in real time. As a result transmission delays have no critical meaning to the operation of the entire system. It is important to implement an appropriate policies for dealing with loss of messages (re-sending them) and when receiving the same message more than 1 time (removing redundant information). It is also essential to plan adequate resources (transmission channels) obtained for the disposal from the GSM/UMTS operator - needed for the proper functioning of services in the first phase of the system as well as after it is fully operational and taking into consideration the planned expansion of the system.

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