Comparative Analysis of File Transfer Protocols in Low-Bandwidth Radionetworks

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Abstract: The use of modern digital ultra and very high frequency (UHF/VHF) radio stations in the construction of digital governmental automated control systems (ACS) of the low echelon management level has led to the creation of protocols and standards that allow data transmission in low-bandwidth communication networks. However, none of these standards provide recommendations for file transfer in communication networks facing low speed, long delay and high probability of data loss. This work investigates QoS parameters and performs comparative analysis of FTP, TFTP, SCP, SFTP, ETFTP protocols for file transfer in low-bandwidth communication networks based on UHF/VHF radio stations. A model of two Harris RF-7850M-HH radio stations connected by an attenuator and coaxial cables was used to measure the QoS parameters. The characteristics including the bandwidth, jitter and average time of data transmission depending on the operating modes of radio stations and the level of attenuation in the radio communication channel have been obtained. The time of file transfer and the actual size of the transmitted data when using these protocols was measured. The recommendations for use of file transfer protocols in radio communication channels depending on the operating mode of the radio station are given. The obtained results allow to rationally choosing the mechanism and algorithm of file transfer when building governmental ACS of the low echelon management level based on low-bandwidth communication networks to increase the efficiency of bandwidth use in radio networks.

1 INTRODUCTION

Modern governmental automated control systems (ACS) of the low echelon management level as base of command and control process are built on the basis of low-bandwidth radio networks by means of ultra and very high frequency (UHF/VHF) radio stations [1-5]. The results obtained in [6] show that the use of standard protocols for data transmission in UHF/VHF radio networks is complicated by low speed and high data delay, high jitter data delay, high probability of data loss in the channel. A number of protocols have been developed for such telecommunication channels, according to the standards STANAG 4677 [7], AdatP-36 [8], STANAG 5525 [9], etc. These standards are used to transfer information in the governmental ACS of the low echelon management level [1, 4, 5]. Modern file transfer protocols have been created for data transmission in high-speed cable networks. However, there are no recommendations or standards for transferring files in ACS built on low-bandwidth telecommunication networks. In 1996, the experimental protocol Enhanced Trivial File Transfer Protocol (ETFTP) [10] was created specifically for communication networks based on UHF/VHF radio stations with a data rate of 16 Kbps. However, today a new generation of radio stations is available with the support of data transmission of up to 1 Mbps [6]. Therefore, there is a need for a comparative analysis of existing file transfer protocols to determine the possibility of their use in low-bandwidth communication networks.

The purpose of the work is to perform a comparative analysis of file transfer protocols in low-bandwidth communication networks in terms of bandwidth efficiency of a radio communication channel. The relevance of the work is driven by the

lack of recommendations for the use of such protocols in low-bandwidth communication networks, which complicates the construction of governmental ACS of the low echelon management level on the basis of UHF/VHF radio stations.

For comparative analysis, let us consider the following file transfer protocols: File Transfer Protocol (FTP) [11], Trivial File Transfer Protocol (TFTP) [12], Secure Copy Protocol (SCP) [13], SSH File Transfer Protocol (SFTP) [14] and ETFTP [10]. FTP is one of the most common file transfer protocols. Its operation is based on the Transmission Control Protocol (TCP) [15], a client-server architecture and the ability to authenticate users to ensure secure access to data. TFTP is a simple file transfer protocol based on the User Datagram Protocol (UDP) [16] and is used mainly for the network boot of computers. It doesn`t have any authentication or encryption mechanisms. SCP and SFTP are similar in functionality to FTP, but run on Secure Shell (SSH) [17] and transmit files in the encrypted form. ETFTP is an experimental file transfer protocol designed specifically for low-bandwidth radio networks. ETFTP is configured according to the QoS parameters of the radio channel and considers the maximum possible speed and delay of data transmission. This protocol works on the basis of UDP and is focused on ensuring reliable file transfer with maximum speed and the smallest amount of service information.

Section 2 presents the results of experiments, that research and analyze the QoS parameters of file transfer and gives recommendations about their usage.

Section 3 provides the conclusions about usage of different file transmission protocols over UHF/VHF radio networks based on experiment results.

2 RESEARCH AND ANALYSIS OF QoS PARAMETERS

The scheme shown in Figure 1 was organized to take the necessary measurements. RF-7850M-HH, manufactured by Harris, are used as UHF/VHF radio stations. The radio stations are connected to each other via a coaxial cable and an attenuator with a variable attenuation level. The attenuator has three possible attenuation levels of 40, 80 and 120 dB. The power of radio stations is set to 1 W. Different levels of attenuation will simulate external interference affecting the radio channel. Personal Computers (PC) are connected to radio stations via Ethernet cable with RJ-45 (12067-5220-01) from Harris radio station accessories.

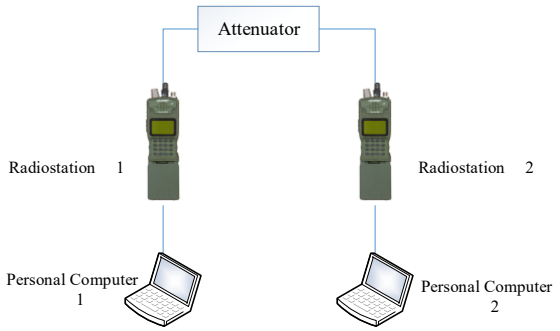

Figure 1: Scheme of the communication network for measurement.

The PC has the Ubuntu 20.04.1 LTS operating system [18]. The next utilities are used to transfer files via different protocols:

- vsftpd version 3.0.3 implements FTP, TFTP and SFTP protocols;
- OpenSSH version 1.0.2g implements SCP protocol;
- etftp and etftpd version 1.1.3 together implement ETFTP protocol.

For measurements, let us consider three modes of operation of the radio stations: FF - narrowband mode with a fixed carrier frequency, ANW2C (M-TNW) - broadband mode, QL1A - narrowband mode with frequency-hopping spread spectrum (FHSS). Let us consider 10KB, 100KB and 1MB files to be transmit via the UHF/VHF radio network. Larger files are not considered for the transmission because according to the bandwidth limits of the UHF/VHF radio network obtained in [6], such a transmission can take up to several hours, which can result in the loss of information relevance. According to [10], to estimate the effectiveness of the ETFTP protocol let us use the ratio of file size to the time of its actual transfer from one PC to another as the QoS parameter. The mentioned period includes the time to establish a connection, data transfer and disconnection. In this work, in addition, the actual size of the transmitted data is measured, which allows to evaluate the efficiency of using the bandwidth of the radio channel.

2.1 Research and Analysis of QoS Parameters in FF Mode

Three experiments were conducted to evaluate the QoS parameters and compare file transfer protocols in low-bandwidth communication networks in the

narrowband FF mode of UHF/VHF radio station. Let us consider three cases of measuring the QoS parameters at attenuation of 40, 80 and 120 dB, respectively.

The first experiment: set the attenuator to attenuation of 40 dB, and the radio station to the FF mode. Similarly to [1], the measurements of QoS parameters of the low-bandwidth radio network were performed and the following values were obtained:

- bandwidth - 102 kbit/s;
- jitter - 126 ms;
- the average ping – 1189 ms.

Files of different sizes from PC №2 to PC №1 were transferred, and measured the time of file transfer and the actual size of the transmitted data was measured. The results are shown in Table 1.

Table 1: The measurement result in the FF mode, 40 dB.

	10 KB file		100 KB file		1MB file	
	Time, s	Data size, KB	Time, s	Data size, KB	Time, s	Data size, KB
FTP	14	13	22	112	81	1149
TFTP	62	14	660	142	6840	1523
SFTP	10	12	27	113	115	1249
SCP	13	14	41	115	115	1154
ETFTP	23	11	45	109	298	1141

The second experiment: set the attenuator to attenuation of 80 dB. The research showed that QoS parameters have the following values:

- bandwidth - 100 kbit/s;
- jitter - 128 ms;
- the average ping – 1239 ms.

The results of file transfer measurements are shown in Table 2.

Table 2: The measurement result in the FF mode, 80 dB.

	10 KB file		100 KB file		1MB file	
	Time, s	Data size, KB	Time, s	Data size, KB	Time, s	Data size, KB
FTP	20	12	40	112	120	1145
TFTP	63	12	662	115	6933	1517
SFTP	22	12	41	113	120	1131
SCP	38	12	66	115	249	1156
ETFTP	28	11	42	111	256	1185

The third experiment: set the attenuator to attenuation of 120 dB. The research showed that QoS parameters have the following values:

- bandwidth – 58,8 kbit/s;
- jitter – 154 ms;
- the average ping – 1297 ms.

The results of file transfer measurements are shown in Table 3.

Table 3: The measurement result in the FF mode, 120 dB.

	10 KB file		100 KB file		1MB file	
	Time, s	Data size, KB	Time, s	Data size, KB	Time, s	Data size, KB
FTP	10	13	30	112	88	1164
TFTP	44	13	720	113	7312	1589
SFTP	24	12	39	113	145	1131
SCP	60	14	103	111	240	1154
ETFTP	21	12	48	110	360	1185

After analyzing the results shown in Table 1, Table 2 and Table 3, it is not difficult to see that in the FF mode, the transfer of 10 KB files using FTP was from 10 to 20 s, 100 KB files - from 22 to 40 s, and 1 MB files - from 81 to 120 seconds. TFTP transmitted 10 KB files from 44 to 66 s, 100 KB files from 660 to 720 s, and 1 MB files from 6840 to 7312 s. ETFTP, SFTP, SCP in this case show worse data transfer rates than FTP, but better in contrast to TFTP. The ratio between the file size and the actual amount of transferred data files of 10 KB, 100KB, 1MB for FTP, SFTP, SCP, ETFTP protocols ranges from 10% to 40%. However, for the TFTP protocol, this ratio is from 20% to 59%. Thus, in the narrowband FF mode it is rational to use the FTP protocol.

2.2 Research and Analysis of QoS Parameters in QL1A Mode

Three experiments were conducted to evaluate QoS parameters and compare file transfer protocols in low-bandwidth communication networks in the narrowband QL1A mode of the UHF/VHF radio station. Let us consider the three cases of measuring QoS parameters at attenuation of 40, 80 and 120 dB, respectively.

The first experiment: set the attenuator to attenuation of 40 dB, and the radio station in the QL1A mode. The research showed that QoS parameters are significantly different from the FF mode and have the following values:

- bandwidth – 17,4 kbit/s;
- jitter – 453 ms;
- the average ping – 3969 ms.

Files of different sizes from PC 2 to PC 1 were transferred according to previous measurements. The results of measurements are shown in the Table 4.

Table 4: The measurement result in the QL1A mode, 40 dB.

	10 KB file		100 KB file		1MB file	
	Time, s	Data size, KB	Time, s	Data size, KB	Time, s	Data size, KB
FTP	57	13	372	112	3757	1621
TFTP	267	16	2321	169	26743	1723
SFTP	56	11	195	113	2242	1649
SCP	53	15	240	120	2755	1654
ETFTP	51	11	165	110	1891	1579

The second experiment: set the attenuator to attenuation of 80 dB. The research showed that QoS parameters have the following values:

- bandwidth – 15,7 kbit/s;
- jitter – 476 ms;
- the average ping – 4137 ms.

The results of file transfer measurements are shown in the Table 5.

Table 5: The measurement result in the QL1A mode, 80 dB.

	10 KB file		100 KB file		1MB file	
	Time, s	Data size, KB	Time, s	Data size, KB	Time, s	Data size, KB
FTP	65	13	363	113	3832	1626
TFTP	308	12	2417	169	27631	1763
SFTP	72	11	256	113	2312	1659
SCP	78	12	480	121	2933	1674
ETFTP	65	12	240	114	1911	1583

The third experiment: set the attenuator to attenuation of 120 dB. The research showed that QoS parameters have the following values:

- bandwidth – 12,5 kbit/s;
- jitter – 489 ms;
- the average ping – 4279 ms.

The results of file transfer measurements are shown in Table 6.

After analyzing the results shown in the Table 4, Table 5 and Table 6, it is not difficult to see that in QL1A mode ETFTP transmits 10 KB files for 51 – 66 s, 100 KB for 160 - 253 s, and 1 MB for 1891 – 1974 s. The ratio between the file size and the actual amount of data transmitted 10 KB, 100 KB, 1 MB files for ETFTP ranges from 10% to 61%. Other protocols have worse time and actual data rates. Thus, the ETFTP protocol provides the fastest transfer of files and minimal data overhead in the QL1A mode.

Table 6: The measurement result in the QL1A mode, 120 dB.

	10 KB file		100 KB file		1MB file	
	Time, s	Data size, KB	Time, s	Data size, KB	Time, s	Data size, KB
FTP	120	13	346	113	3951	1723
TFTP	335	40	720	113	29767	1871
SFTP	68	12	340	113	2432	1789
SCP	70	15	293	111	3123	1811
ETFTP	66	12	253	116	1974	1613

2.3 Research and Analysis of QoS Parameters in ANW2C Mode

Three experiments were conducted to evaluate QoS parameters and compare file transfer protocols in low-bandwidth communication networks in the narrowband ANW2C mode of the UHF/VHF radio station. Let us consider the three cases of measuring QoS parameters at attenuation of 40, 80 and 120 dB, respectively.

The first experiment: set the attenuator to attenuation of 40 dB, and the radio station in the ANW2C mode. The study showed that this mode of operation has the best QoS parameters compared to other modes:

- bandwidth – 259 kbit/s;
- jitter – 14 ms;
- the average ping – 273 ms.

Files of different sizes from PC №2 to PC №1 were transferred according to the previous measurements. The results are shown in the Table 7.

Table 7: The measurement result in the ANW2C mode, 40 dB.

	10 KB file		100 KB file		1MB file	
	Time, s	Data size, KB	Time, s	Data size, KB	Time, s	Data size, KB
FTP	1	12	3	112	34	1143
TFTP	5	12	62	123	571	1265
SFTP	1	12	4	113	33	1151
SCP	1	14	3	119	34	1157
ETFTP	7	11	11	109	51	1124

The second experiment: set the attenuator to attenuation of 80 dB. The research showed that QoS parameters have the following values:

- bandwidth – 201 kbit/s;
- jitter – 15 ms;
- the average ping – 319 ms.

The results of file transfer measurements are shown in Table 8.

Table 8: The measurement result in the ANW2C mode, 80 dB.

	10 KB file		100 KB file		1MB file	
	Time, s	Data size, KB	Time, s	Data size, KB	Time, s	Data size, KB
FTP	1	12	4	112	33	1178
TFTP	7	12	60	118	555	1102
SFTP	1	12	4	113	33	1150
SCP	1	14	5	114	60	1156
ETFTP	3	12	21	116	83	1185

The third experiment: set the attenuator to attenuation of 120 dB. The research showed that QoS parameters have the following values:

- bandwidth – 150,8 kbit/s;
- jitter – 34 ms;
- the average ping – 327 ms.

The results of file transfer measurements are shown in Table 9.

Table 9: The measurement result in the ANW2C mode, 120 dB.

.	10 KB file		100 KB file		1MB file	
	Time, s	Data size, KB	Time, s	Data size, KB	Time, s	Data size, KB
FTP	1	12	7	112	68	1143
TFTP	6	12	55	111	555	1142
SFTP	1	12	4	113	35	1150
SCP	1	12	5	112	67	1102
ETFTP	5	11	22	116	240	1185

It is not difficult to see that according to the results shown in Table 7, Table 8 and Table 9, in the ANW2C mode, the FTP, SFTP and SCP protocols transmit 10 KB files in 1 s, 100 KB in 3 - 7 s, and 1 MB for 33 - 68 s. TFTP with ETFTP transferred 10 KB files in 3 - 7 s, 100 KB in 11 - 62 s, 1 MB in 51 - 571 s. The ratio between file size and the actual amount of data transferred was 10% to 27% for all protocols. Thus, in this mode it is rational to use protocols FTP, SCP, SFTP.

2.4 Recommendations for Use of File Transfer Protocols in Low-Bandwidths Networks

Based on the experiments, the following recommendations can be proposed:

1) It is advisable to use ETFTP in narrowband, low latency and low bandwidth radio networks.

2) In broadband radio channels with low latency and high bandwidth, compared to narrowband radio modes, it is advisable to use FTP protocol.

3) TFTP has the worst QoS parameters when transferring files, but it should be used when you need to occupy only part of the maximum bandwidth.

4) In the narrowband mode of UHF/VHF radio stations, it is rational to compress files before sending them to reduce data transmission time.

The application of the research results allows to rationally use the existing file transfer protocols in the construction of governmental ACS of the low echelon management level depending on the type and conditions of use of modern UHF/VHF radio stations.

3 CONCLUSIONS

1) The QoS parameters of FTP, TFTP, SCP, SFTP and ETFTP file transfer protocols in low-bandwidth radio networks based on UHF/VHF radio stations were measured.

2) The analysis of expediency for various file transfer protocols is carried out. Recommendations for their use depending on the operating modes of UHF/VHF radio stations are given.

3) It is not advisable to transfer files larger than 1 MB in narrowband modes of radio stations because a significant delay in data transmission can result in losses of information relevance.

4) Approbation of the research results allows building governmental ACS of the low echelon management level with the ability to transfer files in low-bandwidth networks with the rational use of bandwidth of the radio channels.

5) The research results of this article and publications [1, 6] represent the part of work concerning development of telecommunication system model with QoS parameters in UHF/VHF radio networks.

REFERENCES

[1] I. V. Strelkovskaya, R. V. Zolotukhin, and A. O. Makoganiuk, "Modeling of telecommunication components of automated control systems in low-bandwidth radio networks" / Springer Science & Business Media, 2021.

[2] J. S. Bayne, "A Theory of Enterprise Command and Control", MILCOM 2006 - 2006 IEEE Military Communications conference, 23-25 Oct. 2006, Washington, DC, USA, doi: https://doi.org/10.1109/MILCOM.2006.302294.

[3] J. Lawson, "Command control as a process", IEEE Control Systems Magazine, pp. 5-11, March 1981, doi: https://doi.org/10.1109/MCS.1981.1100748.

[4] R. Masnica and J. Štulrajter, "Development of Interoperability C4IS", 7th International Scientific Conference Communication and Information Technologies, 9 – 11 Oct. 2013, Starý Smokovec, Slovakia, ISBN 978-80-8040-464-2.

[5] J. Rhea, "Seamless communications: the challenge of tactical command and control", Military&AeroSpace Electronics, Jan 1st, 1997, [Online]. Available: https://www.militaryaerospace.com/communications/article/16710327/seamless-communications-the-challenge-of-tactical-command-and-control, accessed March 2021.

[6] I. Strelkovskaya and R. Zolotukhin, "Research of low-bandwidth radionetworks QoS parameters" //Information and Telecommunication Sciences, International Research Journal, Volume 11, Number 1(20), January-June 2020, doi: https://doi.org/10.20535/2411-2976.12020.77-81.

[7] STANAG 4677: 2014 Dismounted soldier systems standards and protocols for command, control, communications and computers (C4) interoperability./ NATO 2014.

[8] NATO - ADATP-36: Friendly force tracking systems (FFTS) interoperability / NATO 2017.

[9] STANAG 5525: 2007 Joint C3 Information Exchange Data Model - JC3IEDM/ NATO 2007.

[10] Experiments with a Simple File Transfer Protocol for Radio Links using Enhanced Trivial File Transfer Protocol (ETFTP) [Online]. Available: https://tools.ietf.org/html/rfc1986, December 2020.

[11] File transfer protocol (FTP), RFC 768 [Online]. Available: https://tools.ietf.org/html/rfc768, December 2020.

[12] The TFTP protocol (revision 2), RFC 1350 [Online]. Available: https://tools.ietf.org/html/rfc768, December 2020.

[13] "Linux and Unix scp command". Computer Hope [Online]. Available: https://www.computerhope.com/unix/scp.htm, December 2020.

[14] SFTP - SSH Secure File Transfer Protocol [Online]. Available: https://www.ssh.com/ssh/sftp/, December 2020.

[15] Transmission Control Protocol, RFC 793 [Online]. Available: https://tools.ietf.org/html/rfc793, December 2020.

[16] User Datagram Protocol, RFC 768 [Online]. Available: https://tools.ietf.org/html/rfc768, December 2020.

[17] The Secure Shell (SSH) Transport Layer Protocol, RFC 4253 [Online]. Available: https://tools.ietf.org/html/rfc4253, December 2020.

[18] Ubuntu 20.04.1 LTS (Focal Fossa) [Online]. Available: https://releases.ubuntu.com/20.04/, December 2020.