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Reliability of the BTS-BSC System with Different Types of Communication Lines Between Them

Davronbekov Dilmurod Abdujalilovich[1], Matyokubov Utkir Karimovich[2]
[1]Tashkent university of Information technologies named after Muhammad al-Khwarizmi, Uzbekistan,
d.davronbekov@gmail.com
[2]Tashkent university of Information technologies named after Muhammad al-Khwarizmi, Uzbekistan,
otkir_matyokubov89@mail.ru

ABSTRACT

This work is devoted to the issue of calculating the reliability of a section of a mobile communication network "base station - BTS" - "base station controller - BSC" and the communication line between them for a mobile communication network of GSM-900 standard. The BTS-BSC system with communication lines based on copper wire, optical fiber, radio relay equipment with and without repeaters is considered. Analytical expressions for calculating the failure rate of the BTS-BSC system for these special cases are given.

Key words: base station, base station controller, communication link, failure rate, system, survivability reliability.

1. INTRODUCTION

Currently, mobile (cellular) communication systems have received great development in the world. One of the requirements for mobile communication systems is reliability [1 - 3].

The reliability of the communication system is its property to provide communication, keeping in time the values of the established quality indicators under the specified operating conditions [16, 36, 37].

The modern development of mobile networks also exacerbates the problem of survivability. This, in turn, makes ever-growing demands on the stability of their functioning. The relevance of this area of research is associated with an ever-growing need to improve methods for reliable assessment of the survivability of communication networks, due to the various negative factors affecting them [4 - 7, 17, 18].

The survivability of the cellular communication system is the stable operation of the communication system even under the influence of factors not related to the system. The impact on the system can occur independently or intentionally.

Of course, the survivability of communication systems can also be distinguished by quality indicators such as their reliability. Examples of such indicators are: the number of communication lines in use and a high level of protection from natural influences.

One of the most effective ways to ensure survival in mobile networks is to improve the reliability of data lines.

The main indicators characterizing the quality of data transmission in networks (reliability, data transmission speed and quality of transmitted messages) depend on the efficiency of the communication lines used.

The GSM-900 (Global System for Mobile Communications) mobile communication system is the most widely used mobile communication system in the republic and abroad. Figure 1 shows the block diagram and structure of the equipment of the communication network of the GSM-900 standard [9, 8, 23, 24, 32, 29].

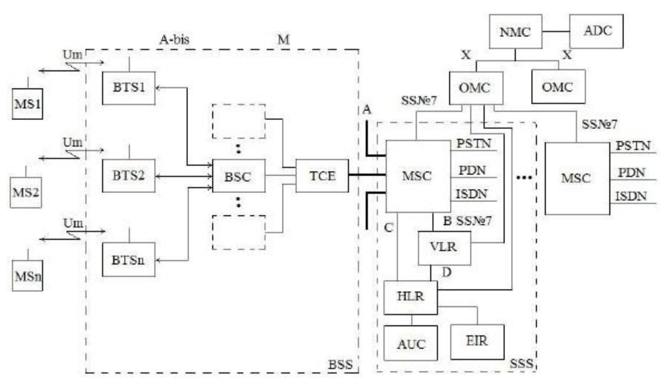

Figure 1: Block diagram and structure of GSM-900 communication network equipment

Typically, the components of a mobile communication system (BTS - base station; BSC - base station controller; TCE - transcoder; MSC - network central switch) are interconnected based on three transport media. Based on the analysis of the statistics of the use of these transport media in global mobile networks, it was found that copper cables are used by 90%, microwave radio lines by 6% and optical fibers by about 4% [28].

2. CONNECTING MOBILE COMMUNICATION COMPONENTS VIA COPPER CABLES

High-quality transmission of voice traffic for 2G networks with transmission rates of 1544 Mbps for T1 and 2048 Mbps for E1 is possible using communication lines installed over copper cables. However, multiple concurrent connections are required to transfer data traffic of 3G and higher networks. As a result, this relatively cheap line loses this feature. The disadvantage of such communication lines is that these types of lines do not provide high data transfer rates. However, some studies show that using copper cables over very short distances is more economical than optical cables, both in terms of overall data rate and quality [34]. Table 1 lists the common causes of cable line damage in percentages.

Table 1: Causes of damage to cable lines of the primary network [35].

Damage type	The number of damages from their total number,%
Construction and installation defects	9
Mechanical stress	36-45
Incorrect operation	4
Corrosion	8
High voltage breakdown, including from lightning currents	12
Soil shear and pressure	6
Rodent damage	4
Aging	3
Other	3

3. CONNECTING MOBILE COMMUNICATION COMPONENTS VIA FIBER OPTIC CABLES

Fiber optic links provide the highest speeds over long distances, for example 155.52 Mbps for STM-1, 622 Mbps for STM-4, 2.4 Gbps for STM-16, 9.9 Gbps for STM-64.

Table 2: Level of provision of telecommunication networks of the Khorezm region with optical cables.

№	City (district) names	Optical link availability (km)
1	Urgench city	527,484
2	Khiva city	155,539
3	Bagat district	185,646
4	Gurlen district	156,805
5	Kushkopir district	274,357
6	Urgench district	162,53
7	Khazorasp district	130,923
8	Khonkiy district	189,416
9	Shovot district	204,953
10	Yangiarik district	178,023
11	Yangibazar district	165,604
12	Tuprokkalli district	95,361
	Total amount:	**2426,641**

The advantage of transmitting information over optical fiber is that the fiber introduces very little attenuation into the transmitted signal. Also, optical fiber has other advantages: low susceptibility to external electrical interference, fire resistance, electrical safety [10, 11, 19] However, their placement is relatively expensive and requires a large initial investment.

Table 2 shows the level of provision of telecommunication networks of the Khorezm region with optical cables (as of July 2020).

4. CONNECTION OF COMPONENTS OF MOBILE COMMUNICATION SYSTEMS VIA RADIO RELAY DEVICES

In traditional radio frequency technologies, data transmission rates are relatively limited, and resistance to problems such as noise, information security is lower. In the millimeter wave range, distance and even weather conditions impede RF transmission [30] In addition, the licensed part of the spectrum incurs additional costs [31] However, it should be noted that in areas where wired or fiber optic communication lines cannot be installed, this connection is the most efficient option.

Let us consider the situations for research using the example of the Khorezm regional branch of the Uzmobile national communications operator. As of January 2020, there were 193 base stations in the Khorezm region operating in the GSM standard and 49 in the CDMA standard, of which 52 are BTS nodes (Table 3).

Table 3: Information about BTS owned by the Uzmobile operator in the Khorezm region

№	Number	Technology type	Number of connected base stations
1	HRZ5900	GSM, UMTS, LTE	13
2	HRZ5903	GSM, UMTS, LTE	5
3	HRZ5907	GSM, UMTS, LTE	2
4	HRZ5912	GSM, UMTS	1
5	HRZ5913	GSM, UMTS	1
6	HRZ5915	GSM, UMTS, LTE	3
7	HRZ5917	GSM, UMTS, LTE	5
8	HRZ5919	GSM, UMTS	1
9	HRZ5920	GSM, UMTS	1
10	HRZ5921	GSM, UMTS, LTE	5
11	HRZ5924	GSM, UMTS, LTE	2
12	HRZ5925	GSM, UMTS, LTE	7
13	HRZ5927	GSM, UMTS	1
14	HRZ5929	GSM, UMTS, LTE	3
15	HRZ5930	GSM, UMTS	9
16	HRZ5931	GSM, UMTS, LTE	15
17	HRZ5932	GSM, UMTS, LTE	9
18	HRZ5933	GSM, UMTS, LTE	6

19	HRZ5937	GSM, UMTS	1
20	HRZ5942	GSM, UMTS	4
21	HRZ5943	GSM, UMTS	4
22	HRZ5949	GSM, UMTS	6
23	HRZ5951	GSM, UMTS	1
24	HRZ5952	GSM, UMTS	1
25	HRZ5956	GSM, UMTS	2
26	HRZ5966	GSM, UMTS	3
27	HRZ5967	GSM, UMTS	2
28	HRZ5979	GSM, UMTS	1
29	HRZ5989	GSM, UMTS	1
30	HRZ5990	GSM, UMTS, LTE	2
31	HRZ6000	GSM, UMTS, LTE	1
32	HRZ6006	GSM, UMTS, LTE	3
33	HRZ6007	GSM, UMTS	2
34	HRZ6011	GSM, UMTS, LTE	4
35	HRZ6018	GSM, UMTS	2
36	HRZ6019	GSM, UMTS	3
37	HRZ6027	GSM, UMTS	2
38	HRZ6039	GSM, UMTS	1
39	HRZ6041	GSM, UMTS	1
40	HRZ6045	GSM	2
41	HRZ6051	GSM, UMTS	2
42	HRZ6052	GSM, UMTS	2
43	HRZ6059	GSM, UMTS	1
44	HRZ6066	GSM	1
45	HRZ6068	GSM, UMTS	1
46	HRZ6069	GSM, UMTS	1
47	HRZ6070	GSM, UMTS	5
48	HRZ6072	GSM, UMTS	1
49	HRZ6075	GSM, UMTS	1
50	HRZ6080	GSM, UMTS	5
51	HRZ6087	GSM, UMTS, LTE	3
52	HRZ6098	GSM, UMTS	1

5. IT SHOULD BE NOTED THAT IN ORDER TO PROVIDE HIGH-QUALITY AND UNINTERRUPTED MOBILE SERVICES IN THE REGION, BTS NEEDS HIGHLY RELIABLE COMMUNICATION LINES

Consider the following, the most commonly used options for organizing a communication line between components of a mobile system, in particular, BTS and BSC:

1) communication line between BTS and BSC based on copper wires;

2) communication line between BTS and BSC based on fiber optic cables;

3) communication link between BTS and BSC based on radio relay systems.

The operating experience of radio engineering systems, including mobile communication systems, showed that the change in the rate of system failures occurs as follows (Figure 2) [12 - 15, 20, 32, 25].

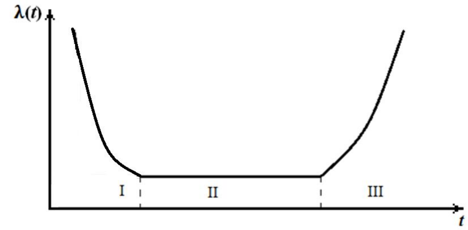

Figure 2: Change in failure rate λ (t) of the system

The graph (Figure 2) clearly shows three areas of changes in the failure rate λ (t) of the system [12 - 14, 20, 32].

I - initial running-in period. In this period, there is an increased failure rate associated with defects that may arise during the production, installation and commissioning process.

II - the period of normal operation. Here, the failure rate remains almost constant and is random. Failures in this period appear suddenly, as a rule, due to non-observance of operating conditions, exposure to external factors, etc.

III - a period of mass wear and tear. During this period, an increase in the number of sudden failures is associated with wear, aging, and other factors associated with long-term operation of equipment.

When developing analytical expressions for calculating the reliability of the BTS-BSC mobile communication system, we will take the following [16, 21, 22, 32, 25, 33]:

- The mobile communication system is operating during normal operation;
- Failures and failures in the mobile communication system are subject to an exponential distribution law;
- Failure of any component of the BTS-BSC mobile communication system results in failure of the entire system.

A view of the BTS-BSC system with a copper-based communication line is shown in Figure 3.

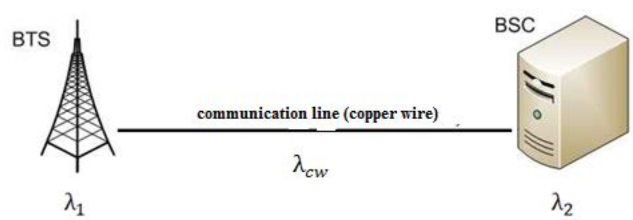

Figure 3: BTS-BSC system with copper wire communication line

λ_1 - BTS failure rate;

λ_2 - BSC failure rate;

λ_{cw} - copper wire failure rate:

$$\lambda_{cw} = l * \lambda_3 \qquad (1)$$

where, l is the length of the BTS-BSC communication line;

λ_3 - failure rate of 1 km of copper wire.

Then drawing up a structural-logical diagram of connecting elements in terms of reliability, we believe that the failure of any element of the BTS-BSC section will lead to a failure of the entire system. In this case, the connection of system elements in terms of reliability is as follows (Figure 4).

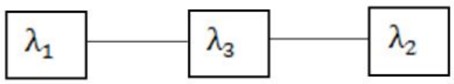

Figure 4: Connection of elements in terms of reliability for the case of a BTS-BSC communication line with a copper wire

Total failure rate of BTS-BSC line with copper wire:

$$\Lambda_1 = \lambda_1 + \lambda_2 + \lambda_{CW} = \lambda_1 + \lambda_2 + l * \lambda_3. \quad (2)$$

A view of the BTS-BSC with an optical fiber link is shown in Figure 5.

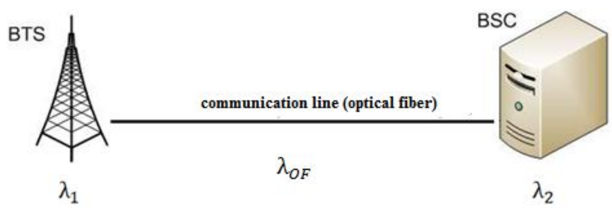

Figure 5: BTS-BSC system with optical fiber communication line

λ_{OF} - optical fiber failure rate.

$$\lambda_{OF} = l * \lambda_4 \quad (3)$$

Where, l is the length of the BTS-BSC communication line with optical fiber;

λ_4- failure rate of 1 km of optical fiber.

The connection of the elements of the BTS-BSC communication line with optical fiber in terms of reliability looks the same as in Figure 4.

Total BTS-BSC link failure rate with optical fiber:

$$\Lambda_2 = \lambda_1 + \lambda_2 + \lambda_{OF} = \lambda_1 + \lambda_2 + l * \lambda_4 \quad (4)$$

Consider the third case, the organization of a communication line based on radio relay communication systems (RRL). Two situations are possible when establishing a communication line between the BTS and the BSC using the RRL:

- without intermediate repeaters;
- with intermediate repeaters.

Figure 6 shows a block diagram of a radio relay communication line without an intermediate repeater. This scheme is implemented at distances up to 10 km.

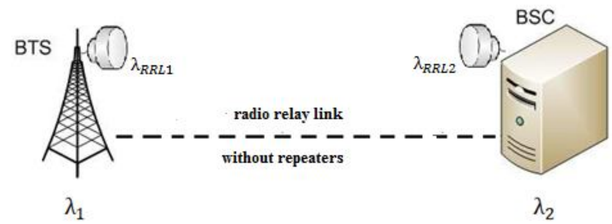

Figure 6: BTS-BSC communication line based on RRL without repeaters

The structural and logical diagram of the connection of elements according to the reliability of the BTS-BSC communication line based on RRL without repeaters is shown in Figure 7.

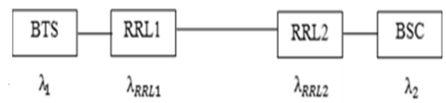

Figure 7: Connection diagram for reliability of BTS-BSC with radio relay link without repeaters

$\lambda_{RRL1}, \lambda_{RRL2}$- the failure rates of microwave communication equipment on the BTS and BSC side, respectively.

$$\Lambda_3 = \lambda_1 + \lambda_2 + \lambda_{RRL1} + \lambda_{RRL2} \quad (5)$$

If the same equipment is installed on the sides of the BTS and BSC and it is assumed that $\lambda_{RRL} = \lambda_{RRL1} = \lambda_{RRL2}$, then

$$\Lambda_3 = \lambda_1 + \lambda_2 + 2 * \lambda_{RRL} \quad (6)$$

Let us consider the situation when an intermediate repeater (IR) is used in a radio relay communication line, and there can be several of them (Figure 8).

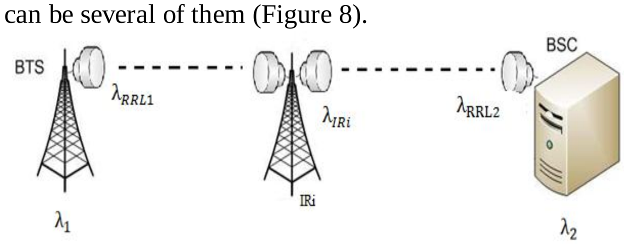

Figure 8: Communication line BTS-BSC on RRL with intermediate repeaters

The structural and logical diagram of the connection of system elements in terms of reliability will look as follows (Figure 9).

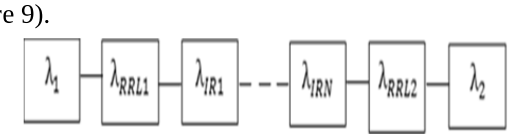

Figure 9: Connection diagram of elements for reliability of BTS-BSC on RRL with intermediate repeaters

Then the failure rate of the entire system is:

$$\Lambda_4 = \lambda_1 + \lambda_2 + \lambda_{RRL1} + \lambda_{RRL2} + \lambda_{IR1} + \cdots + \lambda_{IRN}, \qquad (7)$$

Or

$$\Lambda_4 = \lambda_1 + \lambda_2 + \lambda_{RRL1} + \lambda_{RRL2} + \sum_{i=1}^{N} \lambda_{IRi}, \qquad (8)$$

where, N - is the number of repeaters.
Assuming that
$\lambda_{RRL} = \lambda_{RRL1} = \lambda_{RRL2}$ *and* $\lambda_{IR} = \lambda_{IR1} = \lambda_{IR2} = \cdots = \lambda_{IRN}$ then

$$\Lambda_4 = \lambda_1 + \lambda_2 + 2\lambda_{RRL} + N\lambda_{IR}. \qquad (9)$$

CONCLUSION

When calculating the reliability of the BTS-BSC system with various types of communication lines, it is necessary to select the parameters that carry the maximum information on the reliability of the system. Based on the analysis, it was found that such parameters are [16, 21]: the probability of failure-free operation of the system; system failure rate; average uptime; recovery rate; availability factor; downtime ratio.

Substituting into (2), (4), (5) and (8) the failure rates of the elements of the mobile communication system from the technical documentation for the equipment, it is possible to calculate the total failure rate of the BTS-BSC system and then using the well-known expressions [26, 27] to determine all required indicators for reliability.

The obtained analytical expressions allow calculating the reliability of the BTS-BSC mobile communication system for the following types of communication lines between BTS and BSC: copper wire, optical fiber, radio relay communication line without repeaters and with repeaters.

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