Investigation Radio Resource Control Failure in LTE Networks*

Ashaev Ivan
Kazan National Research Technical University
named after A. N. Tupolev - KAI
Kazan, Russia
AshaevIP@stud.kai.ru

Vladimir Fadeev
Kazan National Research Technical University
named after A. N. Tupolev - KAI
Kazan, Russia
vladimir_fadeev1993@mail.ru

Artur Gaysin
Kazan National Research Technical University
named after A. N. Tupolev - KAI
Kazan, Russia
AKGaysin@kai.ru

Abstract

In this paper the analyze of changing probability Radio Resource Control connection failure was conducted for short-term and longterm period. The result of Time Series Decomposition and correlation between probability of failure and active users is presented.

1 Introduction

Guarantee of quality of working network is very important for providers to offer the best service for users. Failure of connection can happen on any level of LTE, and it is necessary to detect a failure, classify it and on base of this information improve the stability. Failure on the level of Connection Setup is one of the main parameters of Key Performance Identifiers to understanding of quality of network. In this paper analysis of KPI is conducted for failure connection for mobile users. Data was provided by local operator with total amount of users about 300 thousands.

Radio Resource Control is a protocol which is used for transmission of a common Non Access Stratum (NAS) (for all users) and dedicated NAS information (for certain user). The main function of Radio Resource Control (RRC):

- The sending of common broadcast information for UEs.
- RRC Connection Control which include paging, establishment, release or change RRC connection, integrity protection and ciphering.
- Establishment, release or change Resource Blocks carrying user information.
- Management of handover procedure. Measurement and reporting.

The failure of RRC Connection Setup can occurs on different steps of RRC Connection Setup[1]. The possible failure is shown on the Figure 1.

The errors of RRC protocol can be divided in several types:

- Type 1. ENodeB does not send RAR or RAR is lost. It could be connected with RAR is not transferred if BS's CPU is overloaded. Another reason is message was sent, but user did not get signal because it is too low on the receivers side due path loss or not enough coverage of the cell [2].
- Type 2. UE receive Connection Reject after sending Connection Request. This type of message is transmitted when eNodeB does not have necessary resources to serve UE or cell is overloaded.
- Type 3. Reestablishment procedure failure. RRC Connection Reestablishment Reject is used when eNodeB decide to start reconnection with UE with new configuration, but UE doesn't accept the new configuration. In the standard ETSI TS 136 331 V15.3.0 (2018-10) is specified only 3 case of reestablishment: handover failure, reconfiguration failure.
- Type 4. Failure due errors on RLC level. The failure of RRC Connection can be caused of bit or bytes error on lower level.

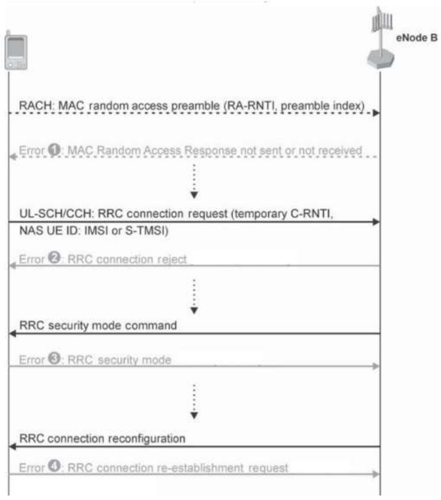

Figure 1: The cases of RRC failure [1]

These parameters affect on one cumulative KPI parameters - RRC setup access rate.

2 Analysis of Networks KPI

RRC Failure this is a percent unsuccessful RRC connection establishment. It is equated like ratio between unsuccessful and total attempts connection establishment is multiplied on 100:

$$RRC\_FAILURE = \left(1 - \frac{\sum RRC\_SUCC}{\sum RRC\_ATT}\right) \times 100 \quad (1)$$

The statistic is provided by local operator during 3 years for each hour. Provider's network is constructed on base of hardware of vendor Huawei. On the Figure 2 the graphs of changing KPI during all time observation. In addition, there is histogram of distribution the rate of RRC failure and approximation of Gaussian distribution is presented. The mean and variance of distributions is shown in Table 1.

Table 1: Parameters of Approximation

Year	Mean	Variance
2016	0.2390	0.0478
2017	0.1475	0.027
1'st part of 2018	0.1056	0.000709
2'nd part of 2018	0.19106	0.000739

According to result we can see that the highest rate of RRC failure was in 2016, the lowest in 2017. Also, there are several picks of high failure which, probably, connected with accidents in network. The frequency of high load became lower, but the values is increasing. In 2018 we have two components because of some anomaly during 05.2018-11.2018. To understand the reason of the growing we have to analyze not integer parameters like KPI, but amount of internal counts inside hardware.

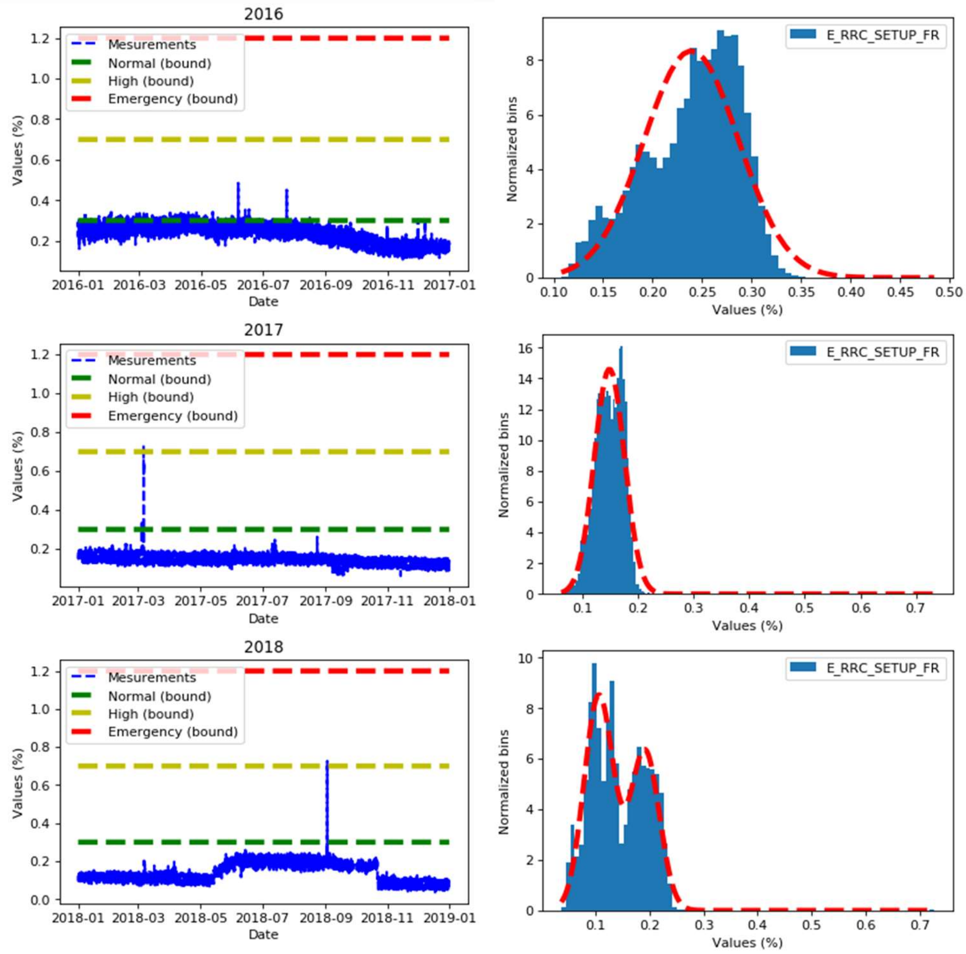

Figure 2: Measurements and histogram of distribution value with approximation

For analyze the trend and short term changing of failure the Time Series Decomposition was used. Time Series Decomposition represents time series like a combination of 4 components [4]:

- Level — the mean value.
- Trend — changing of value in data set.
- Seasonality is a component characterized the short-term changing.
- Noise — random variation.

This method is contained two main models of representation of series — Additive and Multiplicative models. Additive model is a linear because components are presented like a sum. Seasonality in this case has the same frequency.

$$y(t) = Level + Trend + Seasonality + Noise \quad (2)$$

Multiplicative model suggest that the components are multiplied and has nonlinear behavior. Frequency of seasonality can change.

$$y(t) = Level \cdot TrendSeasonality \cdot Noise \quad (3)$$

The time series was decomposed according to the Additive model, because it has a clear behavior of the seasonality in 24 bins (1 day).

Seasonality part shows how probability of failure change during the average day (fig.3). The highest chance of error of RRC connection is about 10-12 p.m. According to trend we can see that the highest failure probability during a week in the Wednesday and Thursday. The time series was decomposed according to the Additive model, because it has a clear behavior of the seasonality in 24 bins (1 day).

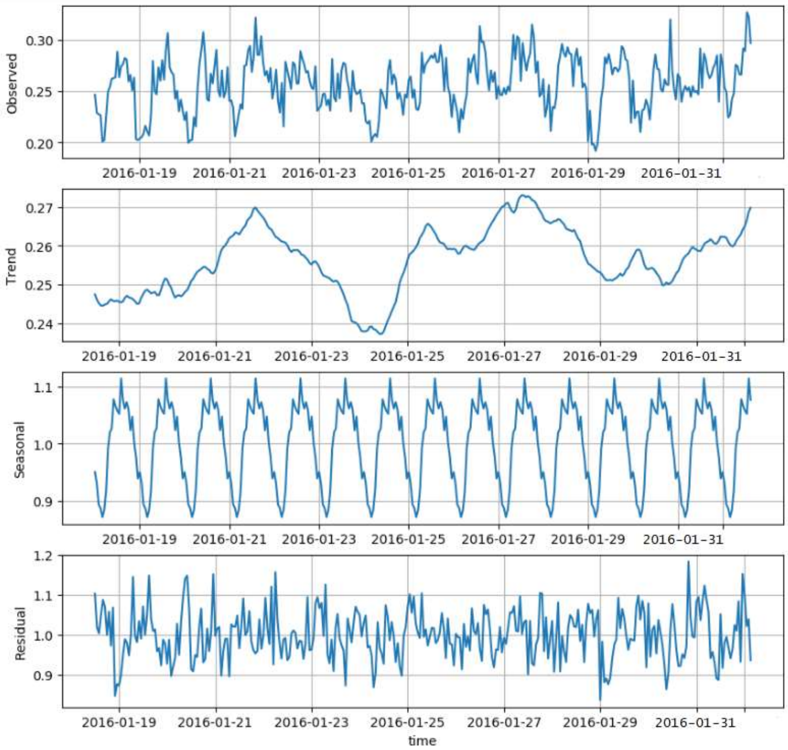

Figure 3: Result of Time Series Decomposition during one month

The Scattering is presented on Figure 4. The approximation was got by using linear regression. According to the result we can see that in short-term perspective we can see the dependence between number of users and probability of RRC connection failure.

For the long-term analyze the average values during a day was founded for each quarter of the year. After it Time Series Decomposition was conducted for resulted data set. According to the result, the trend for 3 year period is decreasing the mean amount of RRC Connection failure except the period from May 2018 to November 2018, after this the probability is also falling (Figure 5).

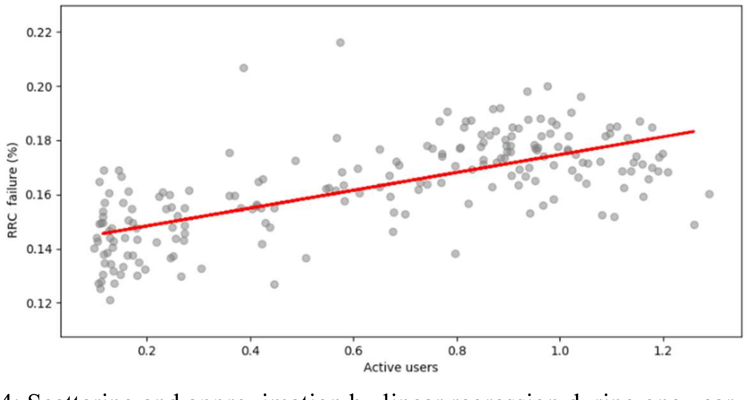

Figure 4: Scattering and approximation by linear regression during one year

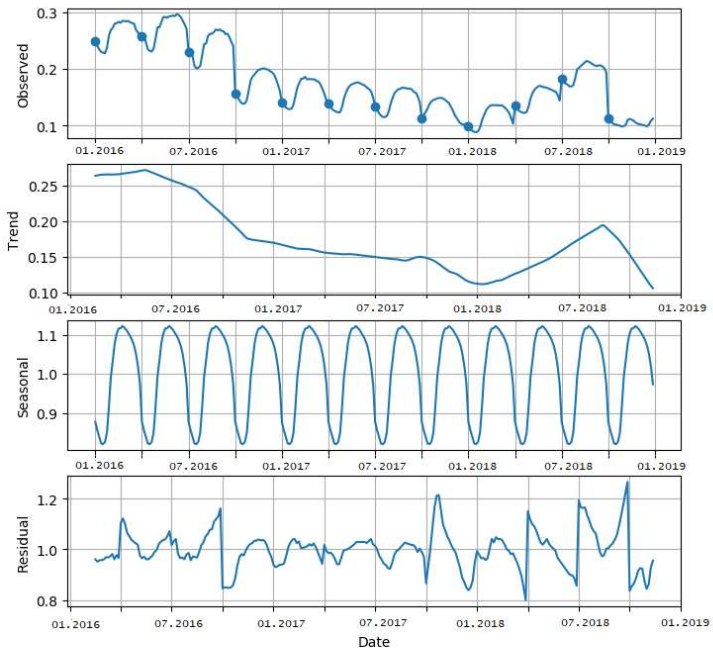

Figure 5: Result of Time Series Decomposition for average day for each quarter of the year

On the Scatter plot Figure 6 we can see that in long-term perspective the correlation between active users and frequency of RRC Connection failure becomes less. Moreover, the highest amounts of failure is about average the number of users.

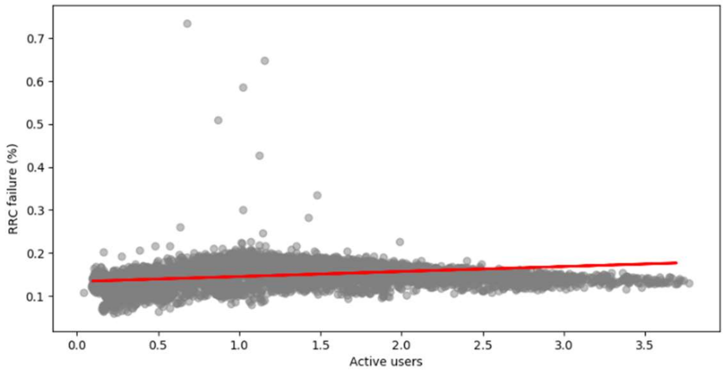

Figure 6: Scattering between active users and RRC failure during one year

According to the correlation between numbers of active users and probability of RRC Connection failure, we can suppose that the overloaded is not the main reason of RRC Connection failure. On the scatter plot for long-term the highest rate of RRC failure on the average number of active users. It means that the probability of RRC failure is more affected of coverage and signal strength, not overloaded. The interference between users in high loaded cell also can increase the percent of unsuccessful RRC connection, but influence of this much lower than propagation loss.

Further analysis on a long-term sample of three years showed that there is a strong correlation between the number of active users and RRC Connection failure with coefficient of 0.77. This may indicate the development of the network following an increase in the number of subscribers. For more accurate and deep analyze of causes RRC Connection failure the information of internal signalization and other radio channel parameters is necessary.

References

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4. Rob J Hyndman and George Athanasopoulos, "Forecasting: Principles and Practice", Monash University, Australia.