Avrupa Bilim ve Teknoloji Dergisi
Sayı 17, S. 445-453, Aralık 2019

Araştırma Makalesi

www.ejosat.com ISSN:2148-2683

European Journal of Science and Technology
No. 17, pp. 445-453, December 2019

Research Article

Hizmet kalitesi değerlendirmesi: Türkiye'de bir mobil ağ operatörü için optimizasyon performansı üzerine bir çalışma

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(İlk Geliş Tarihi 24 Eylül 2019 ve Kabul Tarihi 27 Ekim 2019)

(**DOI:** 10.31590/ejosat.624099)

ATIF/REFERENCE: Başyiğit, İ. B., Doğan, H. & Genç, A. (2019). Hizmet kalitesi değerlendirmesi: Türkiye'de bir mobil ağ operatörü için optimizasyon performansı üzerine bir çalışma. *Avrupa Bilim ve Teknoloji Dergisi*, (17), 445-453.

Özet

Her mobil ağın performansını korumak ve iyileştirmek için kontrol altında olması önemlidir. Optimizasyon, temel olarak istatistik verilerini ayrıntılı olarak inceleyerek ve sürüş testi sonuçlarını elde ederek/analiz ederek ağı izlemenin en etkili yoludur. Bu durum, ağın büyümesini ve ağın kapasitesinin gelişmesini mümkün kılar, mobil ağın işletme ve bakım ünitesindeki sorunlar hızla çözülür. Optimizasyonun başarılı olması için aşağıdakiler gereklidir: Çağrı başarısızlığının ana nedenlerini belirlemek ve analiz etmek, bir aramadan önce dijital ve RF verilerini anlamak. Optimizasyon, ağdaki spektrumu etkili bir şekilde kullanarak en iyi ağ kalitesini elde etmeyi amaçlar. Sahe kurulduktan ve yayına alındıktan sonra, sorunları mobil ağ kalitesi ölçütlerini karşılamak üzere bulup düzeltir. Dolayısıyla, optimizasyon işlemi, hücresel ağın kalitesini artırmak için sürekli ve tekrarlayan bir işlemdir. Ancak, bir sahada optimizasyon yaparken, diğer sitelerin parametrelerinin bozulmamasına özen gösterilmelidir. Bu makalede, bir mobil operatör için Rxlevel, RxQual, Konuşma Kalitesi Endeksi (SQI) gibi bazı parametreleri arttırmak ve servis kalitesini doğrudan etkileyen bazı sorunları çözmek için bir mobil operatör için Türkiye Diyarbakır'da bir optimizasyon çalışması yapılmıştır. Pek çok hücrede sinyal seviyesinin neredeyse aynı olması, görüş hattının kaybedimesi durumu, komşu hücrelerine ait sinyalllerinin ani görünümü ve kaybolması ve sinyal seviyesinde ani düşüşlerin gerçekleşmesidir. Sonuç olarak, bu problemler bazı durumlarda çözülmektedir: Komşu hücrelerin kapsama alanları, anten güçlerini ve antenlerin BTS'lerde aşağıya eğilme açıları azaltılarak giderilir. Servis hücrelerinin ikisini seçerek yeni bir frekans planlaması yapılır. Baz istasyonundaki problemli bölgeye hizmet veren sektörün anteni, 3 dB kazançla daha yüksek anten tipiyle değiştirilir. Ayrıca, bir tünele tekrarlayıcı adı verilen bir sinyal yükselticisi yerleştirilerek ve bu istenmeyen durumlar giderilir.

Anahtar Kelimeler: Servis kalitesi, mobil ağ, ana performans göstergeleri, radyo erişim ağı, hücresel haberleşme.

Quality of service evaluation: A study on the optimization performance for a mobile network operator in Turkey

Abstract

It is significant that each mobile network is under control to maintain and improve its performance. Optimization is basically the most effective way to monitor the network by examining statistics data in detail and obtaining/analyzing drive test results. This enables network growth and capacity development, problems in the operation and maintenance unit of the mobile network are resolved quickly. In order for the optimization to be successful, the following are required: Identify and analyze the main causes of call failure,

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Understanding digital and RF data before a dropped call. Optimization aims to achieve the best network quality by effectively using the spectrum in the network. Once the site is implemented and on-air, its problems are found and corrected to meet the criteria of mobile network quality. So, the optimization process is a continuous and repetitive process to improve the quality of the cellular network. However, while making optimizing in a site, care should be taken not to disrupt the parameters of other sites. In this paper, an optimization study is carried out in Diyarbakir of Turkey for a mobile operator to increase some parameters as Rxlevel, RxQual, Speech Quality Index (SQI) and to solve some problems directly affecting the quality of service (SQI) as cases of being nearly identical of the signal level in many cells, lost of line of sight, sudden appearance and disappearance of neighbor cells, and instantaneous decrease in signal level. As a result, these problems are solved by some cases: Coverage areas of the neighbor cells are decreased by reducing the antenna powers and antenna down tilt angles on the BTSs. A new frequency planning is made by selecting two of the serving cells. The antenna of the sector serving the distressed area at this station is replaced with a higher antenna type with a gain of 3 dB. Also, a signal amplifier called repeater is placed in the tunnel and this unwanted situation is removed.

Keywords: Quality of oservice, mobile network, key performance indicators, radio access network, cellular communication.

1. Introduction

High data rates and mobility is increased the demand for wireless service. Accordingly, the cellular mobile communication system is undergone an effective development process over the last decade. From first generation (1G) technology to today's LTE, the mobile communication system is made significant changes in the field of communication system. For example, multiple access methods are evolved from frequency-division multiple access (FDMA), time-division multiple access (TDMA) and code-division multiple access (CDMA) to orthogonal frequency-division multiple access (OFDMA) employed by the 4.5G network. Due to these different multiple accesses, the network structure in LTE and future 5G technologies is, however well planned, in no way similar to previous communication networks. There is some low transmission power access points located within the coverage of macros in 5G technologies and beyond. Relays, femtoceles and picoceles are examples of these access points. These structures, also known as a heterogeneous network (HetNet), not only increase system efficiency, but also improve service quality (QoS) [1]. Figure 1 illustrates an overview of the development of mobile and cellular networks. Accordingly, in the future, it is expected to use new frequency, novel network architectures, and antennas running in different methods as well as areas with smaller and more cells.

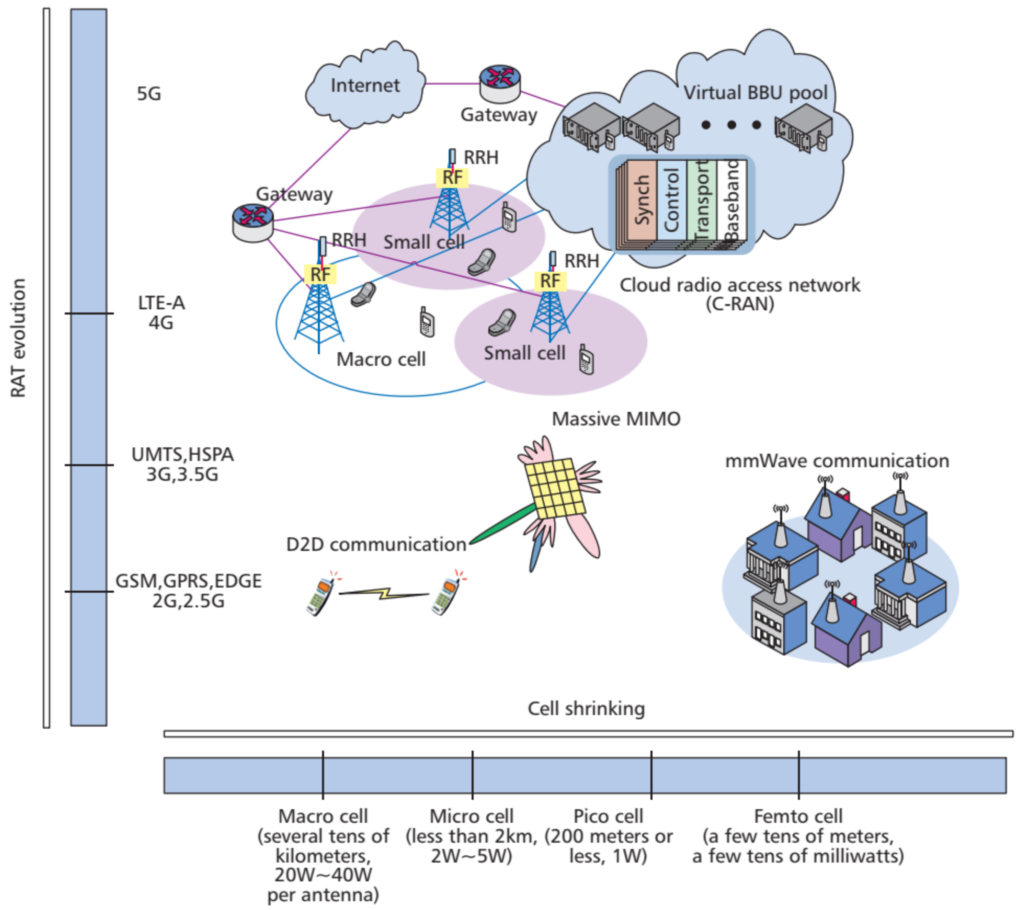

Figure 1. The evolution process of the mobile communication network

The concept of cells emerged in the 1940s. Since then, the main aim of a cellular and mobile system is to increase the coverage area to ensure that the network is high capacity. For this aim, it is important to locate cells in the most appropriate areas during the planning process. On the other hand, in the optimization process, attention should be paid to determining RF optimization parameters such as antenna height, maximum transmission power, number of sectors and orientation [2]. When selecting cells for RF planning, infrastructure cost calculation is also taken into consideration in addition to network coverage and service capacity [3]. Figure 2 gives the RF cell planning stages in general. In these stages, there are three elements for the analytical approach which are radio network analysis, cell coverage/capacity analysis, and also radio network definition. In the process of radio network definition, RF planning engineers take care to select the most appropriate cell areas to generate optimization parameters. The next step is coverage/capacity analysis that collects factors such as RF interference to achieve optimal resource allocation.

Key performance indicators are one of the measures used to evaluate the services provided by mobile networks. This is accomplished by monitoring the effectiveness of some network impairments. QoS is defined as a set of specific requirements provided by a network necessary to achieve the required functionality of service.

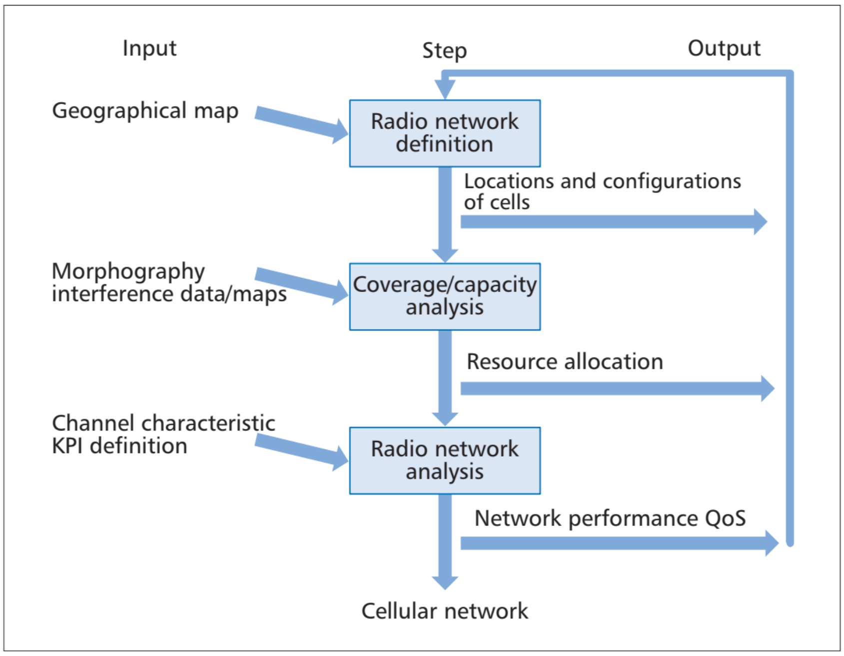

Figure 2. RF cell planning stages

2. Wave Propagation in Cellular Communication

The Cellular communication system consists of overlapping cells. The cell is the region covered by a single base station (BTS) antenna system. The BTS antenna may be directional or omni-directional. The coverage using a single BTS with the omni-directional antenna constitutes the omni-directional cell. Coverage using directional antennas creates sector cells and BTS serves each cell [8]. It also controls the A-bis interface. The MS is linked to the BTS by the A-bis interface. MS hinges on one BTS within the cell. It also distinguishes BTSs transmitting at the same frequency with the base station identification code (BSIC). The Base Station Controller (BSS) manages one or more BTSs. The BSC collects measurement reports from MS and BTS [9]. It also performs HO [10], power control and channel assignment in the service area [11].

2.1. Attenuation of Signal

A signal radiated from the transmitter undergoes free space loss if it reaches the receiver directly without any obstacles. However, as mentioned before, in real life the receiver and the transmitter are not able to communicate with each other directly. Reflection and diffusion in mobile communication systems are the main mechanisms that cause multipath propagation. Due to the rapid change of the signal transmitted from the transmitter to the receiver, the signal changes both in amplitude and phase to reach the receiver. Such attenuation is called Rayleigh fading [12]. Rayleigh fading is divided into two as multi-path fading and frequency selective fading. Due to the fact that the transmitter signal follows different paths, the time and amplitude difference between the signals reaching the receiver is multipath fading [13]. Frequency selective fading [14] occurs with atmospheric factors. The selective fading of the frequency occurs when the specific frequency of the signal attenuates due to atmospheric factors. In addition, the Doppler shift [15] of the signal at the receiver due to the reflection of the objects in motion is also one of the factors causing the fading of the signal. The signal interference occurs as a result of the interference of the signals of different network elements using the same frequency band. If the cell planning is not done correctly, the signals of the BTSs operating in the same frequency band may interfere and create interference.

2.2. Fundamental Values for Power Loss in Cellular Systems

In planning cellular systems, the power requirements of the components of the GSM network are taken into consideration. In this respect, the power threshold values of the components present in the network are of great importance. The power threshold values for

MS vary from mobile vendor to vendor. However, the values used as standard are determined by calculating the signal to noise ratio (Eb/No). The threshold value for MS is -102 dBm and -100 dBm. The same rules apply to BTS as the threshold power value for MS. The threshold power value for BTS is standardized to -106 dBm. The average signal attenuation value must be calculated to determine the power threshold levels for MS and BTS. This value is close to 2 dB. Such losses should include the losses of connectors and cables. Such losses are also considered to be 0.1 dB. The following calculations are made for the uplink and downlink between MS and BTS, and the minimum power levels required for both MS and BTS are determined.

Uplink budget calculations: Path loss for uplink is PLu, EIRPm is the maximum isotropic radiating power of MS, the power received in BTS is Prb, the transmitted power from MS is Ptm, the antenna gain of MS is Gm, the cable losses in MS is Lcm, all other losses is Lom, the antenna gain of BTS is Gb, the cable losses in BTS is Lcb, all the other losses in the BTS is Lob, the sensitivity of BTS is Bs [2]. Uplink budget calculations can be seen in Eq. [5-9] in dB.

$$PLu = EIRPm - Prb \tag{5}$$

$$EIRPm = Ptm + Gm - Losses \tag{6}$$

$$Losses = Lcm + Lom \tag{7}$$

$$Prb = -Gb - Losses + Bs \tag{8}$$

$$Plu = (Ptm - Lcm - Lom + Gm) - (-Gb + Lcb + Lob + Bs) \tag{9}$$

Downlink budget calculations: the path loss of the downlink is PLd, the maximum isotropic radiated power of BTS is EIRPb, the recieved power of MS is Prm, the transmitted power of BTS is Ptb, the antenna gain of BTS is Gtb, the cable loss of BTS is Lcb, the connector loss of BTS (connector is a device that allows different transmitters operating at different frequencies to radiate from the same antenna) is Lccb [2]. Downlink budget calculations can be sen in Eq. [10-14] in dB.

$$PLd = EIRPb - Prm \tag{10}$$

$$EIRPb = Ptb + Gtb - Losses \tag{11}$$

$$Losses\ in\ BTS = Lcb + Lccb \tag{12}$$

$$Losses\ in\ MS = Lcm + Lom \tag{13}$$

$$PLd = EIRPb - Prm = (Ptb + Gtb - Lcb - Lccb) - (Ms - Lcm + Lom + Lob - Gm) \tag{14}$$

3. Results

It is important to explain the radio parameters [16] related to this study which can be seen in figures in this section in order to make the determination and analysis in the field measurement more efficiently before the solution to quality problems. RxLev shows the power level of the signal received from the BTS and received by the MS and is between -30 dBm and -110 dBm. A voice quality measured on the basis of a Bit Error Rate (BER). Uplink and downlink radio quality (RxQual) is divided into eight levels. RxQual-0 shows the best quality while RxQual-7 shows the worst quality. When RxQual-4 is exceeded, there is a noticeable decrease in voice quality. The Frame Error Rate (FER) shows the percentage of falling frames due to a large number of uncorrected bit errors in the frame. It is an indication of the voice quality in the network. BER is the ratio of the number of bit errors to the total number of bits transmitted over a given time period and is a parameter for the voice quality in the network. The SQI, which is calculated on the basis of BER, FER and speech code is more complex than other quality parameters that take into account the reflection of the signal, and therefore is the most important parameter in the network quality parameters. C/I is the ratio of signal strength in the serving cell (carrier) to the power of unwanted disturbing signals (interference) and should have a minimum value of 9 dBm as a criterion. Finally, the MS power control level displays the power control range from 0 to 8 depending on the network design.

3.1. Signal levels very close to each other

The signal levels (Rx_level) of the cells are very close to each other as shown in Figure 3. This situation is one of the problems that need to be solved urgently. Coverage areas of the neighbor cells are decreased by reducing the antenna powers and antenna down tilt angles on the BTSs. Thus, the presence of overlapping cells is blocked, and more dominant service delivery is occurred.

3.2. The signal level of many cells is nearly identical

From Figure 4, it is found that there are many overlapping cells during the test. In that, the signal strength of all of the neighbor cells is almost identical. It is important to study on other options first as much as it is possible to build a new BTS here. First, a new frequency planning is made by selecting two of the serving cells. A serving cell with better signal quality between cells whose signal levels are close is obtained. In this way, due to the close signal level, the call drop and the formation of parasites are prevented. In the tests performed later, it is determined that this problem is decreased occasionally compared to the pre-treatment level. Second, this problem is completely solved by adding a third sector to the BTS had two sectors before.

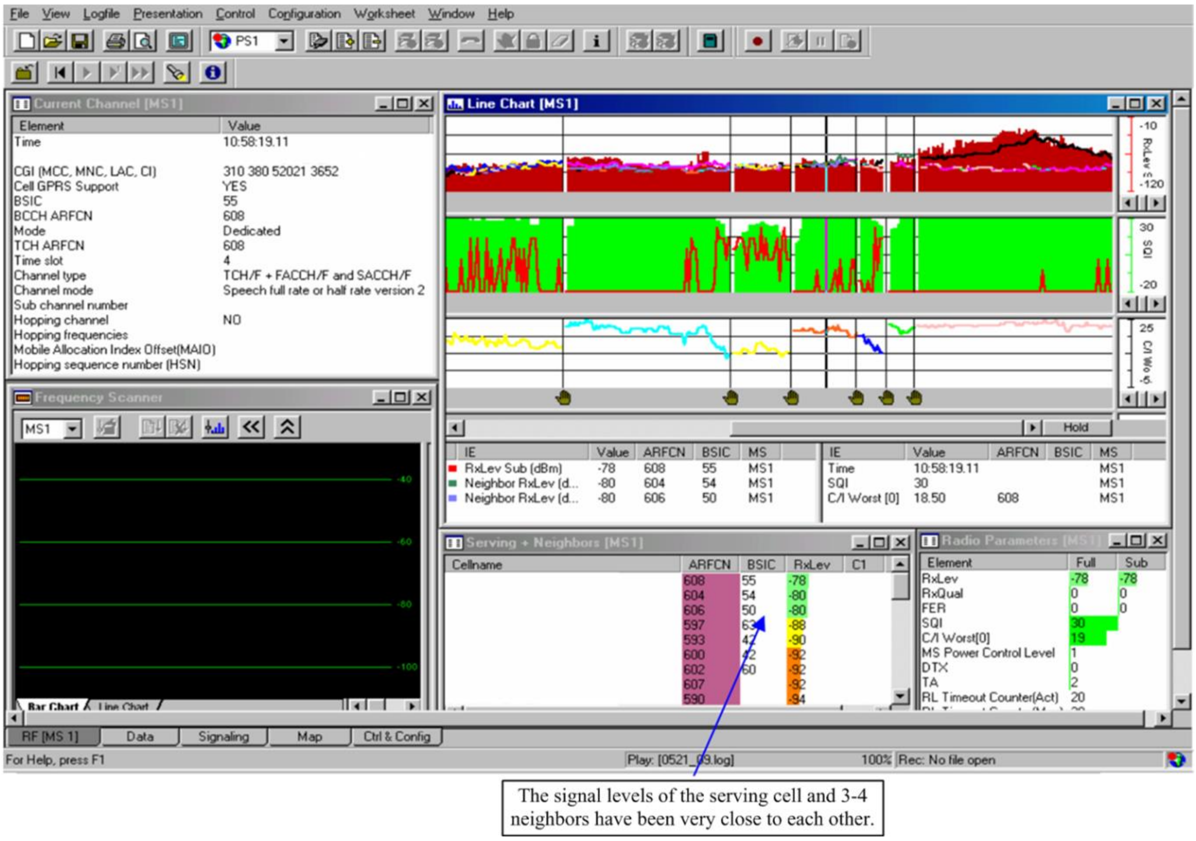

Figure 3. The signal strengths of the cells are very close together

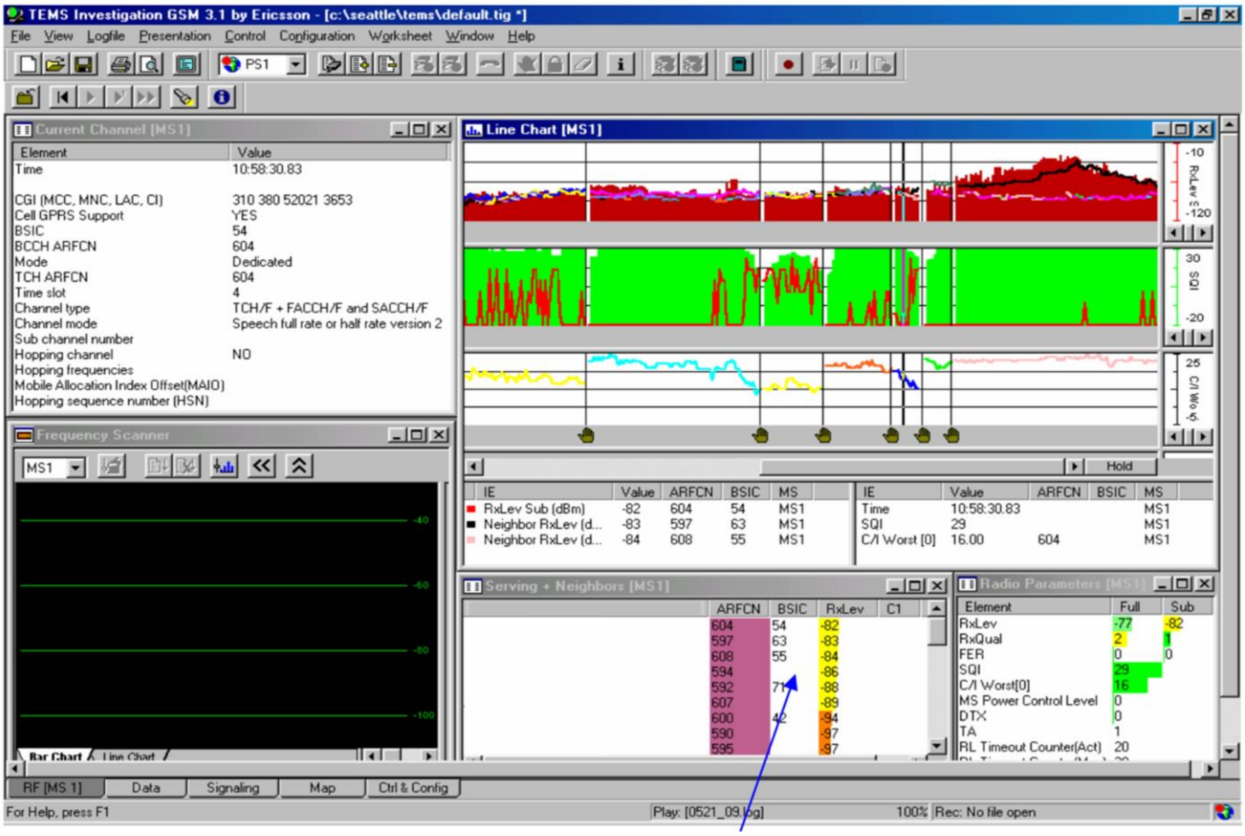

Figure 4. Too many overlapping cell

3.3. Lost of line of sight

The signal strength of the serving cell is determined by rapid fall and rise due to the loss of line of sight in Figure 5. When this situation is examined, the signal level is suddenly fallen because the line of sight is been lost due to a high hill at the test point. In this case, the signal quality is got worse due to the decrease of the signal level. Because the location is not a very important and touristic place and the cost of opening a new BTS is high, it is more correct to ignore the problems experienced in such places.

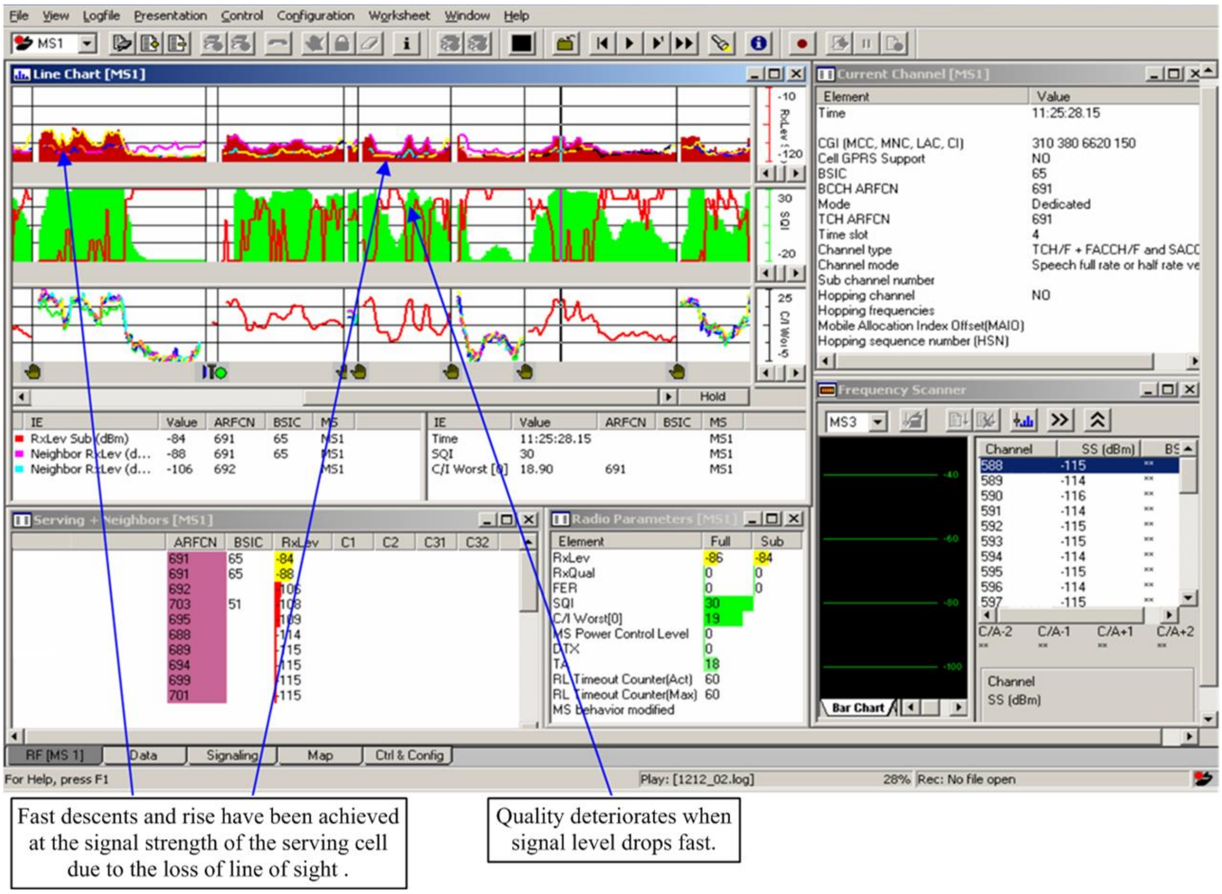

Figure 5. Lost of line of sight

3.4. Sudden appearance and disappearance of neighbor cells

It is seen that there are many HO due to the sudden increase and decrease in the signal level of neighbor cells as indicated in Figure 6. Sudden changes in the signal level of neighboring cells due to terrain or obstructions lead BSC to make incorrect HO decisions. In this case, the call undergoes HO to the neighbor cells for a very short time because there is no stable service provider. In order to minimize the effect of this problem, BTS with the best signal level is selected for optimization. The antenna of the sector serving the distressed area at this station is replaced with a higher antenna type with a gain of 3 dB. However, it is important to note that a more careful frequency planning (to reduce interference) is made for the sector facing the region as a higher antenna is used.

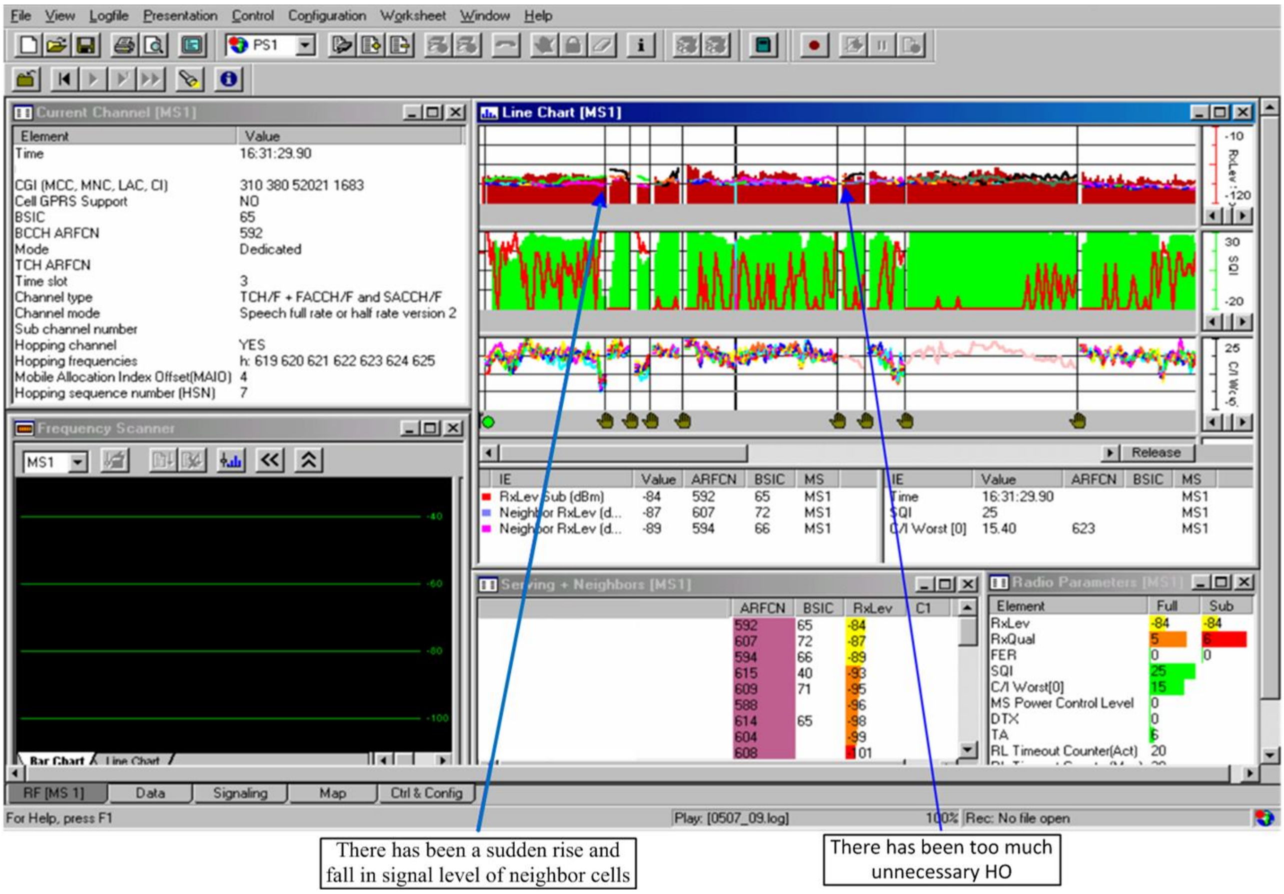

Figure 6. Sudden appearance of neighbors due to land impact

3.5. Instantaneous decrease in signal level

It is determined that the signal level of the serving cell decreased and caused many Ping Pong HOs as shown in Figure 7. Before suspecting anything else, it is obtained that there is a tunnel where the problem occurred and where the field test is performed. The signal level in the Figure 7 creates a curve rather than an unbalanced change due to the tunnel effect. In order to eliminate this unwanted situation even though the cost of it is high, a signal amplifier called repeater is placed in the tunnel and this unwanted situation is removed. Repeaters should always be taken into consideration when adding to the network, as repeaters may bring additional interference to the network. As the signal emitted from the repeater is delayed, the repeater may interfere the signal emitted from the BTS antenna. Therefore, there is a danger of getting both original and repeating signals in the same area of the MS. A repeater should not increase the signal levels of frequencies outside the desired frequency band. It should also be noted that the signal level received at the repeater is above -80 dBm (or the desired limits) to be increased and re-transmitted.

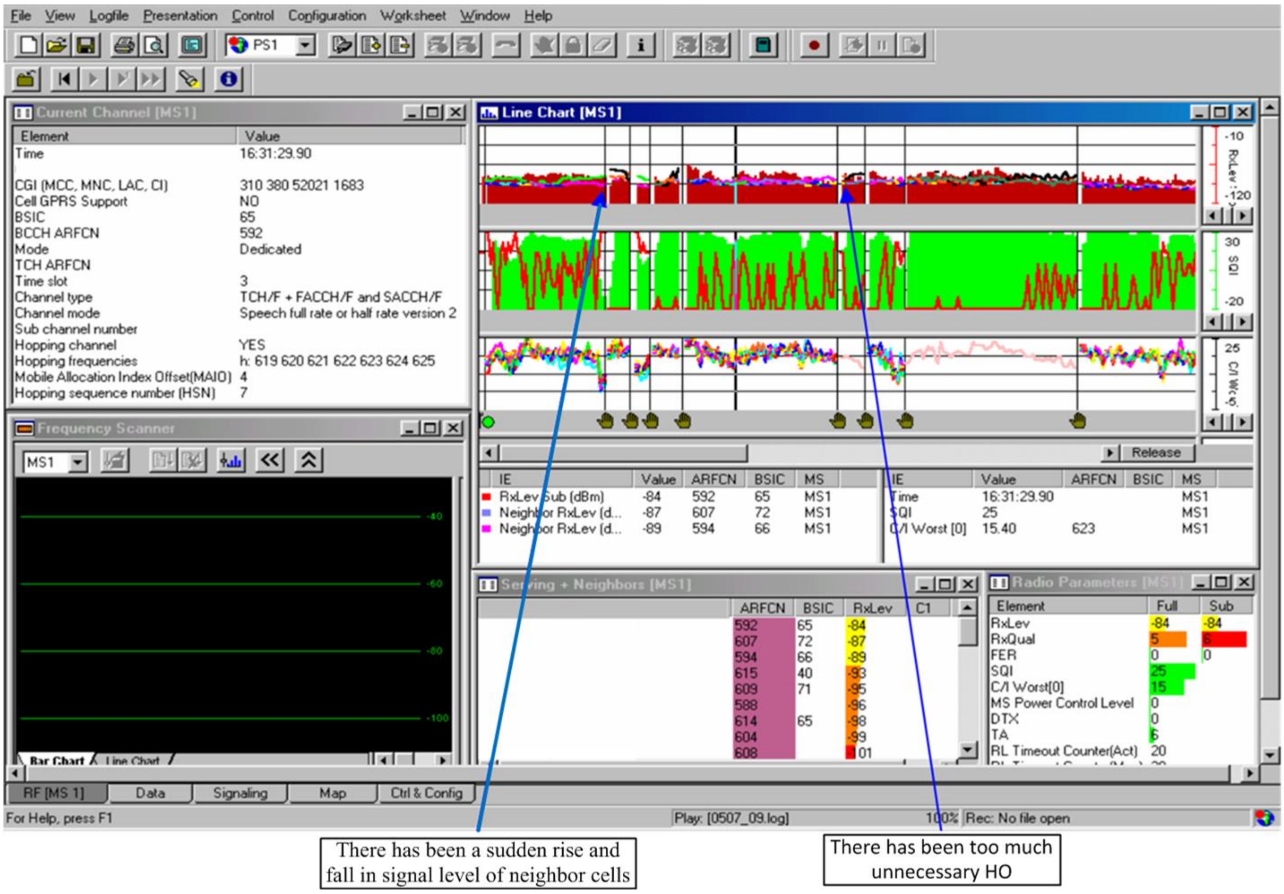

Figure 7. Sudden decrease in signal level due to tunnel effect

4. Conclusion

The QoS for a mobile operator/vendor is targeted in advance of certain criteria. Maximum attention should be paid to increase the quality of the network in terms of both the prestige of the operator and the increase in the number of mobile subscribers. RxQual, SQI, C/I, BER, and FER and MOS are the most important optimization parameters that directly affect network quality. Bad values of these parameters result in call drop, call block, RACH fail, SDCCH fail, and low MOS values.

It is necessary to eliminate negative situation due to the service quality problems by not only optimizing related parameters but also increasing of coverage area as opening new site, addition of sector, using repeater, site configuration change (antenna height, antenna down tilt, antenna diversity, antenna gain, turning antenna direction), frequency re-planning and BCCH change (for decreasing the co-channel and/or co-adjacent interference) and checking hardware configuration (jumpers, connectors, feeders and etc.)

In this paper, an optimization study is carried out in Diyarbakir, Turkey for a mobile operator to incresse some parameters as Rxlevel, RxQual, Speech Quality Index (SQI) and to solve some problwms directly effecting the quality of sevice (SQI) as cases of being nearly identical of the signal level in many cells, lost of line of sight, sudden appearance and disappearance of neighbor cells, and instantaneous decrease in signal level. As a result, these problems are solved by some cases: Coverage areas of the neighbor cells are decreased by reducing the antenna powers and antenna down tilt angles on the BTSs. A new frequency planning is made by selecting two of the serving cells. The antenna of the sector serving the distressed area at this station is replaced with a higher antenna type with a gain of 3 dB. Also, a signal amplifier called repeater is placed in the tunnel and this unwanted situation is removed.

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