The Problem of Traffic Utilization in GSM/UMTS/LTE Networks

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Abstract

The paper presents the main problems of mobile traffic growth and considers ways of solving the problem of increasing the capacity and speed of data transmission. Attention is also paid to the current state and development trends of cellular communication networks in Russia.

1 Analytics of current penetration rates and growth prospects

Mobile operators get the statistics of traffic consumption, both voice and packet, from their networks. However, there are also companies that collect this statistics and make forecasts for the next few years. Current trends in communication development, new communication standards, new technologies, manufactured devices and their software are also a reference data for the forecasts. The most famous companies that produce forecasts for mobile traffic utilization are Ericsson and Cisco.

Every year the number of mobile users is growing. According to the Ericsson Mobility Report released in June 2017, the number of mobile users in Russia in the first quarter of 2017 increased by 2 million [2]. According to the forecasts of Cisco in 2015, 85% of the population in Russia used mobile communications and by 2020 this index will be 87% [1].

The number of users whose mobile terminals support LTE technology is growing rapidly. Most 3G / 4G connections also have access to GSM / EDGE for using as a Fallback (switching to older generation technology for making voice calls). By the end of 2016, the share of LTE connections in Russia was 15% of the total number of connections. Ericsson predicts that LTE connections will be up to 70% in Russia by 2022 [2]. Cisco forecasts that for the period of 2015-2020 4G traffic will grow 33 times, and by 2020 its share will be 65% of all mobile data traffic (at the end of 2015 this index was 16.5%) [1].

According to Ericsson for the last year, from the first quarter of 2016 to the first quarter of 2017, mobile packet traffic has increased by 70% worldwide [2]. At the same time, a large percentage (about 50%) of the used traffic is watching the video online. Cisco predicts an 8-fold increase in mobile data traffic during the period of 2015-2020. At the same time, by 2020, watching video will be 75% of mobile data traffic in Russia (at the end of 2015 this index was 54%) [1].

Over the past few years, the number of connections of devices related to the Internet of Things (IoT) is also increasing. According to Cisco's forecasts for the period of 2015-2020, machine traffic (M2M - machine-to-machine) will grow 24 times and by 2020 it will be 4% of all mobile data traffic [1].

In connection with statistics mentioned above, mobile communication operators need to increase the network capacity and data rates.

2 Ways of solving the problem of increasing capacity and data rates

All mobile traffic can be divided into two parts - voice and packet traffic. With the development of 3^{th} and 4^{th} generations of mobile communications, there is a trend towards the development of packet data transmission, while voice traffic remains at the same level. By keeping voice traffic at a constant level, mobile operators can lay a larger resource on packet data transmission. In this regard, some of the technologies described below, largely, solve the problems associated with packet traffic.

Along with this, the actual problem in Russia is the allocation of the mobile operators' frequency spectrum for the implementation of new technologies. Since the spectrum is the most important resource, the frequency distribution between operators is quite dense. Therefore, it is necessary to develop technologies that can be implemented at already available frequencies.

2.1 Sectoring

One of the ways for increasing the subscriber capacity of a cellular network is splitting one sector of the base station into two sectors. In this way, the new sectors' directional pattern should be reduced by half compared with the primary sector. Using directional antennas significantly reduces interference between neighboring cells. This allows to use more dense frequency distribution.

Before sectoring, the selected sector should be checked that it is actually loaded. In city conditions traffic is used unevenly, therefore not all sectors have the same load.

2.2 Selecting the optimal location for base stations

If the sectoring does not lead to the desired result, determining the optimal location for the base station can be used. For these purposes, it is necessary to have statistical data of delays in the specified area and traffic consumption. Choosing the best location is not always possible, because a number of other factors are superimposed: density of building, provision with energy resources, etc.

To solve the problems of determining the optimal location for base stations, Big Data technologies based on the available mobile operators' statistics can be applied.

2.3 Carrier aggregation

Carrier Aggregation (CA) is used in LTE-Advanced to increase throughput and thereby increase the transmission rate. It is important to maintain backward compatibility with Release 8 and Release 9 UE (User Equipment), therefore the aggregation is based on Release 8 / Release 9 carriers. Carrier aggregation can be used for both FDD (Frequency-Division Duplexing) and TDD (Time-Division Duplexing).

Each aggregated carrier is referred to as a component carrier (CC). The component carrier can have a bandwidth of 1.4, 3, 5, 10, 15 or 20 MHz, and a maximum of five carrier components can be combined, so the maximum aggregate bandwidth is 100 MHz. In FDD, the number of aggregated carriers can be different in DL (Downlink) and UL (Uplink). However, the number of UL carrier components is always equal to or less than the number of DL carrier components. Individual carrier components may also have different bandwidths. For TDD, the number of CC, as well as the bandwidth of each CC, will usually be the same for DL and UL [3].

The easiest way to organize aggregation is to use continuous carrier components within one operating frequency band (as defined for LTE), the so-called in-band continuous aggregation. This may not always be possible due to the frequency distribution scenarios of the operator. For non-contiguous distribution, it can be either in-band, when the carrier components belong to the same working frequency band, but have one gap or gaps between them, or may be in different bands, when the carrier components refer to different operating frequency ranges.

When carrier aggregation is used, several serving cells are used, one for each carrier component. The coverage of the serving cells may differ, for example, because carrier components on different frequency bands will experience different propagation path losses. According to this, the set of carrier components will be different for different coverage areas.

The introduction of carrier aggregation affects mainly the channel and physical layers, and new RRC (Radio Resource Control) messages appear [3].

It is also possible to use bands in the unlicensed spectrum of 5 GHz, but there are difficulties in allocating frequency bands outside the network of one operator.

For mobile operators in Russia, the aggregation of carrier frequencies is problematic for the introduction of technology, because the frequencies are distributed fairly tightly, and it is not always possible to select several bands in the same band for optimal use. In addition, interference is amplified because of using frequencies in different bands, which affects the quality of voice transmission.

2.4 Increasing the order of modulation

As known, the higher the order of modulation, the more information can be transferred. However, the requirements for the signal-to-noise ratio in the signal propagation path increase.

Currently, the LTE standard already uses QPSK, 16QAM, 64QAM modulation. Huawei successfully tested 256QAM modulation. The speed is increased by 30% with using of 256QAM modulation (in comparison to 64QAM modulation). However, the possibilities of this gain have limitations on the signal-to-noise ratio. The signal-to-noise ratio should be high for using high-performance modulation methods. In particular, if the ratio is 25-29 dB, then the speed increases by an average of 25%. If the signal / noise drops to a level of 24 dB, then using the 256QAM modulation will only increase the speed by 8-9% compared to 64QAM. In this case, it can be concluded that this modulation is effective only in the presence of subscribers near the base stations, which requires a dense placement of base stations and is relevant for pico- and femtocell structures [4].

2.5 Frequency reframing

Frequency reframing is a procedure for replacing the radio technology used on radio frequencies allocated to the mobile communication operator. In particular, this refers to GSM in the 900/1800 MHz bands. These ranges can be re-used for 3G to provide voice traffic, and for LTE. 900 MHz band is reused the most widely in LTE (band 8), because it is the most common band for operators, which significantly increases the speed of LTE implementation. Also, 900/1800 MHz bands can be used for carrier aggregation in LTE-Advanced.

Frequency reframing is primarily used to free the spectrum, thereby it is speeding the introduction of new technologies on the already available spectrum. At the same time, interference in the released bands is increasing, which inevitably leads to a deterioration in the quality of voice transmission. For example, the 900 MHz band is gradually engaged in LTE networks, operators are starting to gradually drop GSM.

2.6 MIMO technology

MIMO (Multiple Input Multiple Output) is used to increase the overall transmission rate by transmitting two (or more) different data streams to two (or more) different antennas - using the same resources, both in frequency and in time, separated only using different reference signals for reception by two or more antennas.

In order to be able to configure the type of transmission scheme with several antennas, according to, for example, the propagation medium, a number of different transmission modes (TM) are defined. The UE will be informed through the RRC signaling about the transmission mode for using one of the TMs [5]. To implement the technology, support from the base stations is also required.

Nowadays, there are user devices that support MIMO 2x2 and MIMO 4x4 technology, they are used in LTE. In the standard LTE-Advanced MIMO 8x8 is presented in the direction of Downlink and MIMO 4x4 – in the direction of Uplink.

2.7 VAMOS technology

The VAMOS technology (Voice Services over Adaptive Multi-User Channels on One Slot) is added to 3GPP GERAN Release 9 specification. It allows to double the bandwidth of the transceiver, because one radio resource can be used by two voice subscribers. The solution introduces the Adaptive QPSK (AQPSK) modulation scheme, new orthogonal training sequences and the VAMOS subchannel power control function, which is completely backward compatible, so it can be introduced without affecting on existing end-user devices.

VAMOS allows to multiplex two users simultaneously on the same physical resource in the channel switching mode both for downlink and uplink, using the same time interval, the same frequency and the same TDMA frame number.

Support from BSS (Base Station System) and from the user terminal is necessary for implementing the technology. Subscriber devices are divided into groups according to the level of technology support - VAMOS I and VAMOS II. It is assumed that VAMOS I devices have less stringent requirements than VAMOS II. The VAMOS I terminals must meet the Downlink Advanced Receiver Performance (DARP) Phase 1 [6] requirements described in the specification [7].

VAMOS technology primarily helps operators to increase the network capacity for voice traffic on existing frequencies Applying this technology is possible when operators implement frequency refarming and rejection of GSM networks.

3 Prerequisites for 5G. Projections for implementation

Based on current trends in the development of mobile communications, it can be concluded that the requirements for communication standards will increase. Ericsson already predicts the emergence of 5th generation devices by 2020. Mobile Internet users will be online constantly by 2020, creating a load on the network around the clock. There are also applications that require a maximum transfer rate with minimum delays. For example, watching online video in high quality. There is growing interest in the M2M sphere and the Internet of Things (IoT), where many applications require a minimum delay [8].

At the same time, the requirements for network equipment are increasing. New base stations with support for next-generation networks are needed. It is necessary to seal the location of the base stations, because a much higher frequency will be required for networks of new standards. The user terminals need to support new technologies, because the combinations of technologies described above will be applied. Operators also need a spectrum to implement new communication standards.

Deploying 5G networks requires detailed analysis, because it entails major changes on the network.

4 Conclusion

Utilization of mobile traffic is a quite complex problem. On the one hand, this problem is influenced by developers and mobile operators, on the other hand - by the end users. Rational use of the available frequency spectrum, the gradual introduction of new technologies and standards allows users to build various information systems and develop new applications. The active traffic usage and the update of devices in accordance with the introduced standards allows developers to move to the new stages of mobile communication development.

This paper describes the most applicable technologies that can be used by operators to build and update networks.

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