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Design Of Digital Cellular Communication Networks

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Abstract:

This paper is devoted to designing for digital cellular networks of the GSM standard. The main goal of the research - to ensure the given value of the probability of blocking a call. This meaning is the fundamental criterion of an estimation of quality in modern cellular systems witha preset probability of a mistake, fixed frequency band, and information rate. We will calculate the basic parameters of a network from this value, such as the quantity of the subscribers, the dimension of a service area, etc.

Keywords: Call, frequency, the dimension, probability, subscribers, network, estimation of quality

Introduction:

The evolution of cellular systems includes several generations of 1G, 2G, 3G and 4G. Work is underway to create new fifth generation (5G) mobile networks. Standards of different generations, in turn, are divided into analog (1G) and digital communication systems (the rest). Let's consider them in more detail.

Communication has always been of great importance to humanity. When two people meet, the sound is enough for them to communicate, but as the distance between them increases, the need for special tools arises. When Alexander Graham Bell invented the telephone in 1876, an important step was taken to allow two people to communicate, but to do so, they had to be near afixed telephone! For more than a hundred years, wired lines were the only way for most peopleto organize telephone communications. Radio communication systems that did not rely on wires to access the network were developed for special purposes (for example, military, police, navy, closed car radio networks), and eventually systems that allowed people to communicate by Telephone using wireless communications appeared. These systems were primarily intended for people who traveled in cars and became known as mobile phone systems.

The first generation of mobile communications (1G):

The official Christmas of cellular communications is April 3, 1973, when Martin Cooper, president of Motorola's mobile communications, called Joel Engel, head of research at AT&T Bell Labs, while on a busy New York street. These two companies were at the forefront ofmobile phones. This technology was commercialized 11 years later, in 1984, in the form of first generation (1G) mobile networks, which were based on an analog method of information transmission.

The main standards for analog mobile communications are AMPS (Advance Mobile Service) (USA, Canada, Central and South America, Australia), TACS (Full Access Communications System) (England, Italy, Spain, Austria, Ireland, Japan) and NMT (Nordic mobile - Nordic mobile phone) (Scandinavia and several other countries). There were other standards for analog mobile communications - C-450 in Germany and Portugal, RTMS (Radio Mobile Phone System) in Italy, Radiocom 2000 in France. In general, first-generation mobile communications were a mixture of incompatible standards.

In the days of 1G, no one thought about data services - these were analog systems, designed and developed exclusively for voice calls and some other modest possibilities. Modems were present, due to the fact that wireless communication is more susceptible to noise and distortion than traditional wired connections, the data transfer rate was incredibly slow. In addition, the cost of aminute of conversation in the 1980s was so high that a mobile phone could be considered a luxury.

All analog standards use frequency modulation (FM) or phase (PM) for audio transmission and afrequency shift switch to transmit control information. This method has a number of significant drawbacks: the ability to listen to conversations by other subscribers, the lack of effective ways to combat signal fading under the influence of surrounding landscapes and buildings or due tothe movement of subscribers. To transmit information from different channels, different parts of the frequency spectrum are used - the method of frequency division multiple access (FDMA) is used. This is directly related to the main drawback of analog systems - the relatively low amplitude, which is caused by the insufficient rational use of the distributed frequency range in the frequency division of channels.

Each country has developed its own system, which is incompatible with others in terms of equipment and operation. This led to the need for a common European mobile communication system with high capacity and coverage of the entire European territory. The latter means thatthe same mobile phones can be used in all European countries and that incoming calls must be automatically routed to the mobile regardless of the user's location (auto-roaming). In addition, a single European market with common standards was expected to result in cheaper user equipment and network elements, regardless of the manufacturer.

The second generation of mobile communications (2G):

In 1982, CEPT (European Federation of Posts and Telecommunications Administrations) formeda working group called Groupe Spécial Mobile (GSM) to study and develop a pan-European terrestrial system for general purpose mobile communications - second generation cellular (2G) systems. The name GSM Working Group has also been used as the name for the MobileCommunications System. In 1989, CEPT's responsibilities were transferred to the European Telecommunications Standards Institute (ETSI). GSM was originally intended only for member countries of the European Telecommunications Standards Institute (ETSI). However, many othercountries also have GSM in place, such as Eastern Europe, the Middle East, Asia, Africa and the Pacific, and North America (with a GSM derivative called PCS1900). The name GSM has come to mean "Global System for Mobile Communications", which corresponds to its essence.

The first mobile networks of the second generation (2G) appeared in 1991. The main difference between them from the first generation networks was the digital method of transmitting information, thanks to which the SMS (Short Message Service) service loved by many appeared. During the creation of 2G networks, Europe went through the creation of a single standard - GSM, in the United States, most 2G networks are built on the basis of the D-AMPS (Digital AMPS - Digital AMPS) standard, which is a modification of analog amps. By the way, it was this circumstance that caused the emergence of the American version of the GSM standard - GSM1900. With the development and spread of the Internet, for mobile devices of second generation networks, WAP (Wireless Application Protocol) was developed - a protocol for wireless access to global Internet resources directly from mobile phones. The main advantages of 2G networks over their predecessors was that telephone conversations were encrypted using digital encryption. The 2G system provided data transmission services, starting with SMS.

3G mobile phone communications:

The further development of mobile networks was the transition to the third generation (3G). 3Gis a standard for digital mobile communications, which under the abbreviation IMT-2000 (International Mobile Telecommunications - International Mobile Telecommunications 2000) unites five standards - W-CDMA, CDMA2000, TD-CDMA / TD-SCDMA, DECT (Digital Enhanced Wireless Communication - Communication Technology advanced digital wireless). Among the listed 3G components, only the first three represent 3G cellular standards. DECT is a standard for wireless telephony for home or office use, which, within the framework of 3G mobile technologies, can only be used to organize hotspots (hotspots) of these networks.

The IMT-2000 standard gives a clear definition of 3G networks - 3G mobile networks are understood as an integrated mobile network, which provides: for fixed subscribers, an information exchange rate of at least 2048 kbit / s, for subscribers moving at a speed of no more than 3 km / h - 384 kbps, for subscribers moving at a speed not exceeding 120 km / h - 144 kbps. With global satellite coverage, 3G networks must provide an exchange rate of at least 64 kbps.

The basis of all 3G standards are code splitting multiple access protocols. This type of network access technology is fundamentally nothing new. The first work on this topic was published in the USSR in 1935 by D. Agave.

Technically, code split networks work as follows - each user is assigned a specific numeric code that spreads over the entire frequency band assigned to the network. In this case, there is no time division of signals, and subscribers use the entire width of the channel. In this case, of course, thesubscriber's signals are superimposed on each other, but thanks to the digital code, they can be easily distinguished. As already mentioned, this technology has been known for a long time, but until the mid-80s it was classified and used exclusively by the military and special services. Afterthe labels of secrecy were removed, it began to be actively used in civilian communications systems.

The fourth generation of mobile communications (4G):

In March 2008, the International Telecommunication Union (ITU-R) Radiocommunication defined a number of requirements for the 4G standard for international mobile wireless broadband, called the International Mobile Telecommunications Advanced (IMT-Advanced) specification, in particular the data rate determination of subscriber service requirements: Provide a speed of 100 Mbit / s to mobile subscribers (for example, trains and cars), and users with limited mobility (for example, pedestrians and fixed subscribers) should be provided with a speed of 1 Gbit / s.

Since the early versions of Mobile WiMAX (Universal Interoperability for Microwave Access) and LTE (Long Term Evolution) supported speeds well below 1 Gbps, they could not be called IMT-compatible technologies. 4G technology. On December 6, 2010, the Radiocommunication Sector recognized that the most advanced technology is 4G.

The main and core technology of the fourth generation is OFDM (Orthogonal Frequency Division Multiplexing) technology. In addition, for the maximum transmission speed, the technology of transmitting data using N antennas and receiving it with antennas M - MIMO (Multiple Inputs / Multiple Outputs - Multiple Inputs / Multiple Outputs) is used. With this technique, the transmitting and receiving antennas are spaced apart to achieve a weak correlation between adjacent antennas.

The fifth generation of mobile communications (5G):

The letter G in the name of the next mobile communications standard is an acronym for Generation. That is, 5G is really the fifth generation of mobile networks. Let us briefly consider the features of the previous four features.

1G networks appeared in the 1980s. The main difference between them was that they are analog, not digital. This imposed severe limitations on data transfer rates and communication capabilities. In 1991, a network using the 2G standard was launched in Finland for the first time. It was a revolutionary event, because communication became digital, and this entailed a number of fundamental changes:

The data is now encrypted;

Besides conversations, SMS and MMS are now available to subscribers.

Modifications 2.5G (GPRS) and 2.75G (EDGE) slightly increased the data transfer speed and made it possible to connect to the Internet. The new generation of 3G became a broad telecommunications standard in the 2000s and worked on the basis of packet data transmission. Internet access has already become the norm.

The 4G generation has been around since 2010. The speed of data transmission has increased: subscribers no longer have problems with Internet games, watching online videos, as well as video connections.

And now - 5G. In what way does it outperform its predecessors?

Why increase your data transfer rate? Are modern speed indicators insufficient?

It all depends on the task to be solved. For the average user, the increase in speed is, for example, the ability to download a movie in Full HD in just a few seconds or play it in virtual reality without interference.

The 5G standard is essential for the large-scale operation of the Internet of Things. Thanks to this technology, tens of millions of devices can be connected to the Internet - from self-driving cars to smart electric boilers.

The fifth generation opens opportunities for the introduction of new technologies in various sectors of the economy. We are talking about increasing the productivity of robots in enterprises and remote control of agricultural machinery. Telemedicine with 5G will enable remote operations in real time.

Formulation of the problem

In the last decade, mobile cellular networks (MCN) are being intensively developed in countries around the world, providing its subscribers with numerous telephone services and data transfer. Currently, work is underway to developed design methodology MCN when choosing different quality criteria for such systems.

The most common criteria for the quality of land system, a mobile public radio is considered the probability of failure and maintenance $P_{\mathbf{fail}}$ (probability of blocking calls on the network P_a) given the error probability fixed bands information transfer rates.

The proposed solution:

In the method of private MCN planning, allowable phone load of Erlang in one sector, each cell is determined by the relationship

$$A = \begin{cases} \text{no}\left[1 - \sqrt{1 - \left(P_a\sqrt{\frac{1}{2}}\pi_{no}\right)}\right] \text{ Where } P_a \leq \sqrt{\frac{2}{\pi_{no}}} \\ \text{no} + \sqrt{\frac{\pi}{2} + 2_{no}\ln\left(P_a\sqrt{\frac{1}{2}}\pi_{no} - \sqrt{\frac{\pi}{2}}\right)} \quad \text{Where } P_a > \sqrt{\frac{2}{\pi_{no}}} \end{cases} \tag{1}$$

Where no – total allowable number of subscribers, who can work in one sector of each cell.
Based on the load, the number of subscribers is calculated, serviced by one base station

$$N_{bc} = M_{int}(\frac{A}{\beta}) , \qquad (2)$$

Where M- number of sectors in cell,
β – Activity of one subscriber at the hour of the great load, in Erlang.
Within further calculation of networks taking into account the number of subscribers, serviced by one base station, the number of base station is calculated, cell radius, and so on. Quality of cellular network and communication design is estimated by the definition of probability call blocking P_a , and compare the obtained value with the original. For calculating the probability and blocking of cells, using expression (2)

$$P_{fail} = P_a = P_o[1 + \frac{(1-P_0)(1-P'_k)}{1-(1-P_0)(1-P_k)} \qquad (3)$$

Where P_o = probability of call blocking on one cell;
P_k – probability of ending the conversation with one cell (except for the first);
P_k' - probability of the end of the conversation in the first cell.
The probability of blocking a call one cell can be determined by Sevastynevs formula:

$$P_o = \frac{P^n}{n!\sum_{m=0}^{n}\frac{P^n}{m!}} \qquad (4)$$

Where n – number of channels fixed for each base station;
P – Allowable telephone load is one cell

$$\rho = \beta \cdot N_{bc} = M \cdot A$$

The probability of ending the conversation P_k is determined by expression

$$P_k \approx \left(1 - e^{-\frac{2VR}{V}}\right) - \frac{D_I V^2}{2} e^{-2VR/V} \qquad (5)$$

Where V- constant speed of moving a mobile object;
R – radius of cell;
t = I/V – average duration of a communication session;
$D_I = (R/4V)^2$ – dispersion of the penetration time of mobile object in one cell (without first one).
The probability P'_k Can be determined by using expression :

$$P'_k \approx \left(1 - e^{-\frac{-VR/V}{V}}\right) - \frac{D'_I V^2}{2} e^{-VR/V} \qquad (6)$$

Where $D'_I \approx (R/16V)^2$ – dispersion the residence time of the mobile object in the first zone.
The network was calculated according to the following initial data:

- The radius of the serviced
- Territory R_o = 15Km;
- Number of subscribers N_{ac}= 60000;
- The activity of one subscriber at one o'clock the greatest load β= 0.05 Erlang;
- Allowable call blocking P_a =0.1;
- Frequency band for transmission for the base station F=7.2 MHZ;
- Necessary protective ratio for the receiver in standard GSM p_c / P_{db} ;

- Percentage of time, during which it is allowed , to the relationship p_c /p_{nom} at the receivers input in the network was less protective ratio p_t =10%;
- The speed of moving a mobile object v=40 km / hr;
- Average duration of telecommunication session t = I/V =0.1 hr.

The following results were obtained in the calculation:
P_o=0.862; p_k =0.6621; p'_k=0.3446.
It follows that the calculated network does not provide what was assumed in the calculation of p_o=0.1.
The author propose to further test the possibility of using the methods of assessing the probability and blocking the call standard GSM.
Assumed presenter with a value p_a and calculated p_k, p'_k, find the value p_o, which using to calculated the load and another network parameters.

In the method of private MCN planning, allowable phone load of Erlang in one sector, each cell is determined by the relationship.

Results:
In this paper, a model for digital cellular networks is designed for the GSM standard. And the main objective of the research was done - to ensure the given value of the probability of blocking the call. The results of the calculation were also compared with the results obtained in the calculation by the method.

Conclusion:
As we know Communication has always been of great importance to humanity. When two people meet, the sound is enough for them to communicate, but as the distance between them increases, the need for special tools arises. When Alexander Graham Bell invented the telephone in 1876, animportant step was taken to allow two people to communicate, but to do so, they had to be near afixed telephone! For more than a hundred years, wired lines were the only way for most people to organize telephone communications.
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