SPATIAL STRUCTURE OF INTERNET-TRAFIC CONSUMPTION IN THE MTS NETWORK IN A LARGE CITY (BASED ON KRASNODAR DATA)

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Abstract. For the first time based on the developed technique the authors studied the spatial structure of consumption of the Internet traffic in the MTS network in the territory of a large city - Krasnodar. Depth of analysis characterizes the distribution within the cell. Built maps allow linking a traffic distribution with functional areas in the city, as well as localized areas of high volume of daily Internet traffic on different days of the week.
Keywords: cellular network, Internet traffic, spatial structure, city.

Introduction. Problem statement. Although mobile communications are actively developing playing an increasing role in the Russian economy, investigations of a cellular network territorial structure are episodic in nature. They are mainly concentrated on federal or regional levels [2], while the case of a large city, which typically generates and consumes the most of mobile traffic, is under investigated.

The current research concentrates on the evaluation of the geographical distribution of a cellular network traffic in Krasnodar city for one of the main mobile providers. The solution of such a problem allows, at least, estimating the spatial distribution of active subscribers. This data may be further used for various applications, e.g., for optimal base station (BS) [4, 5], service center or, even, advertisement location, for the development of new tariffs, etc.

Statistics on the amount of the voice traffic are collected within a cell, which is a basic element of a cellular network. Being rather convenient such an approach provides only a superficial knowledge about the traffic geographical distribution due to the following reasons:

1. Cell boundaries (area covered by a single base station) is determined with a low precision.
2. The relatively large size of the cell (length from hundreds of meters to tens of kilometers to the city beyond) resulting in low spatial resolution for traffic density estimation.

Therefore, the main objective of the current research is the development and implementation of a methodology for high detail assessing the traffic territorial distribution, i.e. displaying traffic patterns within the cell.

Initial data and methodology. The initial data utilizes statistics of the JSC "MTS" operator for three months – April, June, October, 2014, which accepted being representative. There are no extreme values of the test indicator within these months. Moreover, they are characterized by the absence of long holidays, which, as it turned out [6], have an important influence on the volume of the Internet traffic consumption. It has been previously estimated that in the context of an "average" week maximum amounts of Internet traffic are observed on Sunday, while the minimum ones – on Wednesday [6]. That is why Wednesday and Sunday are further selected for the calculations being the most representative.

The analysis is based on the following statistical characteristics:

1. Total amount of traffic (Gb).
2. Propagation delay (PD), which is determined as a time interval required for the signal to propagate from a mobile phone to a BS; this indicator allows calculating the distance from a user to the current BS.

The traffic mapping has been realized with an algorithm described in [1] and briefly listed below. Since the speed of radio wave propagation is equal to the speed of light, the knowledge of the PD allows calculating the distance traveled by a signal from the BS to the subscriber. A script written in the Python programming language determines this distance numerically. The traffic is depicted by points on the arc, which is located from the BS at the evaluated distance (radius) according to the azimuth (direction) of the antenna. The coordinates of each "traffic point" are defined by the formula:

$$x_1 = x + \sin\big((A + rnd)\pi \div 180\big)\,(PD \times 234),$$
$$y_1 = y + \cos\big((A + rnd)\pi \div 180\big)\,(PD \times 234),$$

where x_1, y_1 are the Cartesian coordinates of the «traffic point»; x,y stand for the BS coordinates, A is the BS antenna azimuth, rnd denotes a random number between -60° to 60°.

The values taken by a variable rnd are rather provisional and relate to the 120° antenna opening angle. In reality, the signal propagation direction is not restricted and may exceed 120°. However, in a city with a high density of cells such cases may be ignored by their low probability.

The results obtained with the Python script, realizing the formulas above, are written to the file in ASCII format and are further visualized with ArcMap (Esri, USA) software (Fig. 1).

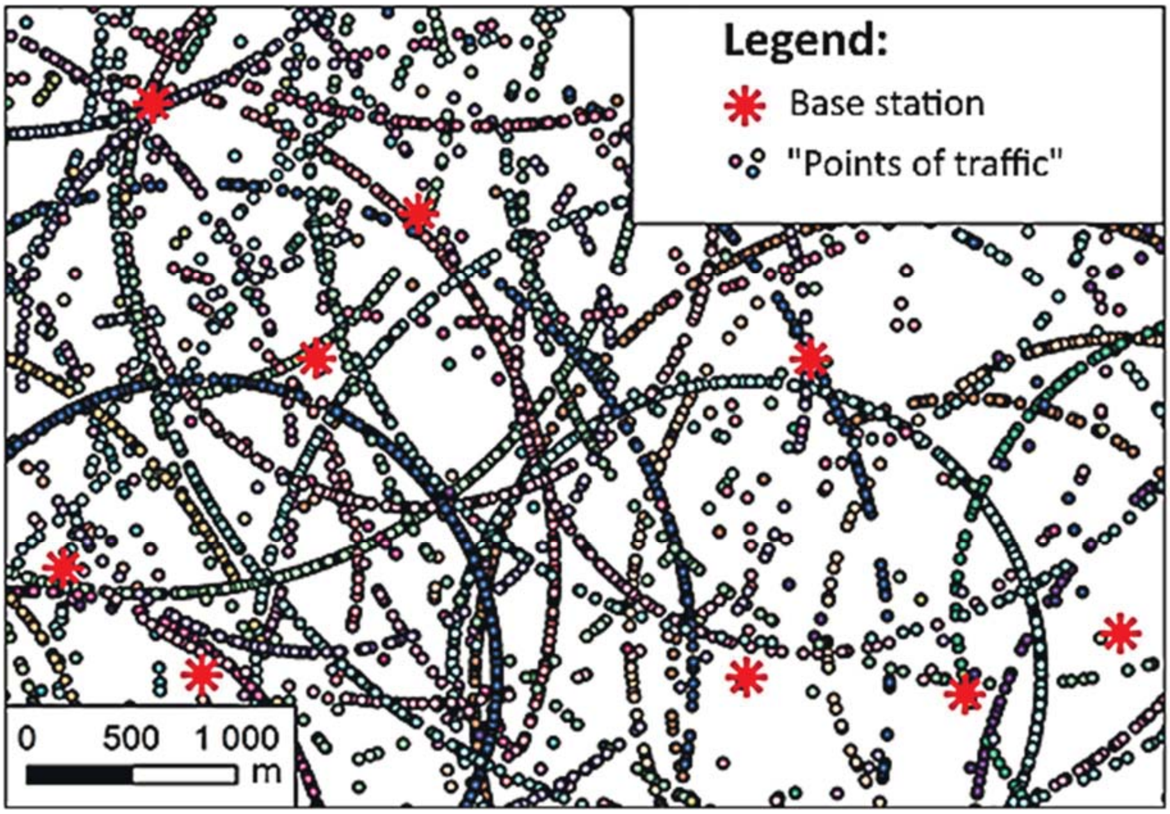

Fig. 1. Spatial distribution of the obtained Internet "traffic points"

Thus, the density of the evaluated «traffic points» allows estimating the spatial distribution of daily volumes of Internet traffic in Krasnodar. Because the information about Internet traffic in MTS network measured in specified units (GB) is a corporate one, some relative indicators have been used, which, however, allow reliably solving the problem. A discrete model (Fig. 1) is transformed to the continuum one using the module «Spatial Analyst Tools», – namely, the tool «Kernel Density», by constructing a map of the point object density. At the final stage of data processing a raster-to-vector conversion is performed. The images are exported to Google Earth environment indicating the areas with different traffic density, in other words, with a different daily activity of network users on Wednesday and Sunday.

Analysis of the results. The obtained density maps reflect a rather high heterogeneity of the daily Internet traffic volume distribution within the city area. The hypothesis of the Internet traffic volume dependency from the city spatial organization has been checked by comparison with the existing zoning of Krasnodar city using the zonal statistics tools. Functional zones of the city are used as such areas (in geostatistical sense).

Differentiation of urban areas into zones, which are characterized by different typological peculiarities of the phenomenon, is typical for all cities in the world. The basis of the functional organization of the city territory is the principle of allocation of sites, fulfilling the same life functions such as working, living and recreation. This fact is used in the method of functional zoning of territories, which in accordance with Russian normative documents [10] involves dividing the city into three main zones: residential, industrial, landscape and recreation. These zones are linked by the city transport system. A map of Krasnodar functional zones, developed on the basis of the master plan (2012), is shown in Fig. 2.

Within the boundaries of each of the 7 zones (residential, recreational purpose, business, special purpose, industrial, agricultural, transport infrastructure) the daily Internet traffic volume is defined by the amount of "traffic points" (Table 1). In addition to the obtained estimates of the traffic distribution, the main data consumers have been detected and traffic variability in the characteristic days of the week have been investigated.

It is clear from Table. 1 that the maximum amount of traffic (66–70%) is consumed by subscribers in the residential zone covering only 22% of the city are. Previous studies shown [6] that the daily peak traffic consumption falls on the evening hours, i.e. when the majority of subscribers are located in a residential area. About 10–12% of the consumed Internet traffic is generated in recreational and downtown zones. The remaining four functional zones covering a total area of 34.5% of the city territory altogether account for 9-10% of the traffic. While in the agricultural zones only 0.2% of its volume is generated, their area is comparable, for example, with the size of the downtown zone.

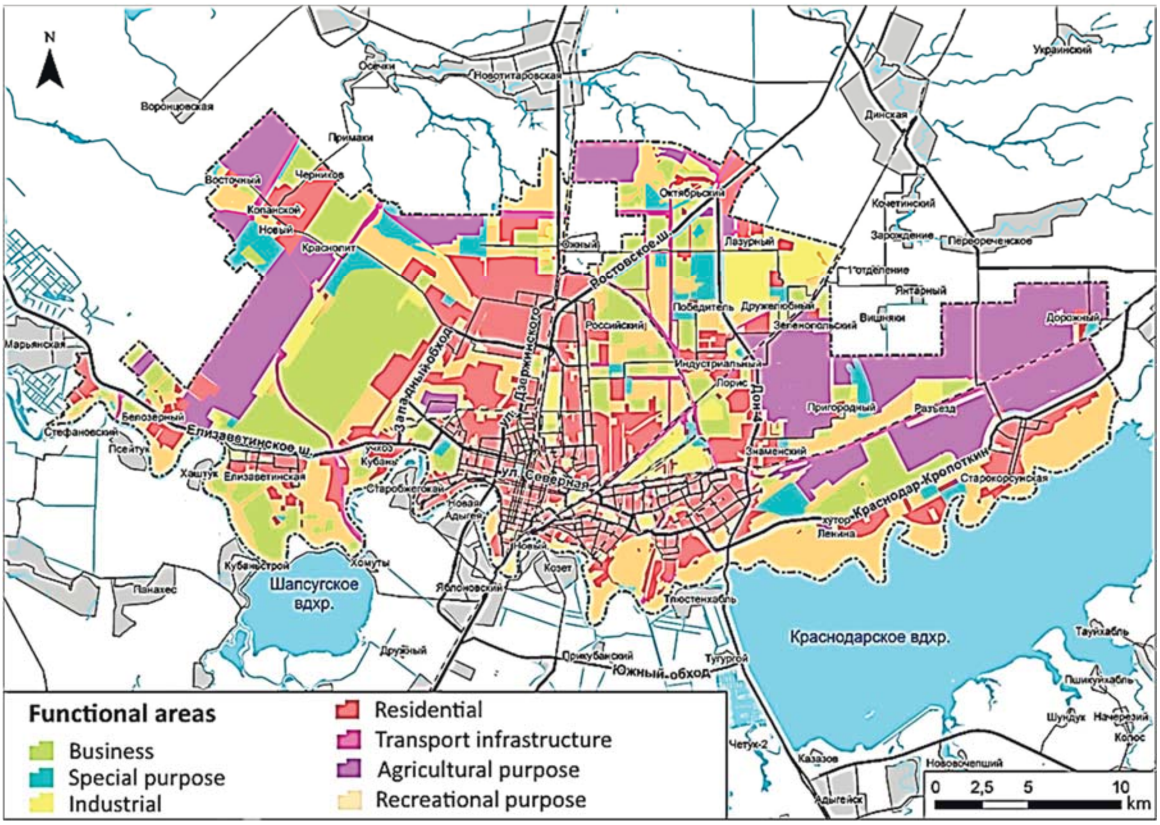

Fig. 2. Functional areas in Krasnodar

Table 1

The distribution of Internet traffic in the functional areas of Krasnodar

Functional areas	Area		The distribution of Internet traffic			
			Wednesday		Sunday	
	km^2	%	%	*N**	%	*N**
Recreational purpose	194,4	23,1	10,9	0,056	10,3	0,053
Residential	186,2	22,1	66,3	0,356	70,1	0,376
Business	170,9	20,3	12,9	0,075	10,9	0,064
For agricultural purposes	150,6	17,9	0,2	0,001	0,2	0,001
Industrial	58,7	7,0	5,5	0,094	3,8	0,065
Special purpose	40,9	4,9	1,7	0,042	2,0	0,049
Transport infrastructure	39,5	4,7	2,5	0,063	2,7	0,068

**N* – the value is normed by the corresponding area

It turned out that the factor of the specific day of the week (Wednesday and Sunday) has low influence on the territorial pattern of the traffic consumption and does not result in radical changes of the ratios described above (Table 1). As expected, the greatest differences in consumption for these two days is observed for a residential area. In all other zones, these changes are minor.

In addition to the "zonal" aspect, it is of great interest to evaluate the local features of the traffic density distribution. Since the developed technique operates with the relative indicators of daily Internet traffic, a rank scale is used for the construction of the corresponding maps. The classification values are produced by the method of natural breaks (Jenks). In this case, the same class get similar values with a maximum difference between classes. Classes correspond to the following values of consumed traffic (GB), Wednesday: moderate – 0,41-22,1, heightened – 22.02-46,56, high – 46,57-87,91; Sunday: moderate – 0,64-24,56, heightened – 24.57-56,35, high – 56,36-113,77.

The spatial structure of daily Internet traffic in the city, amid its apparent heterogeneity, is characterized by the presence of foci (Fig. 3). Borders of the foci do not coincide with the particular streets, and have typical sizes of 0.4 to 2.4 km^2 with a compact form.

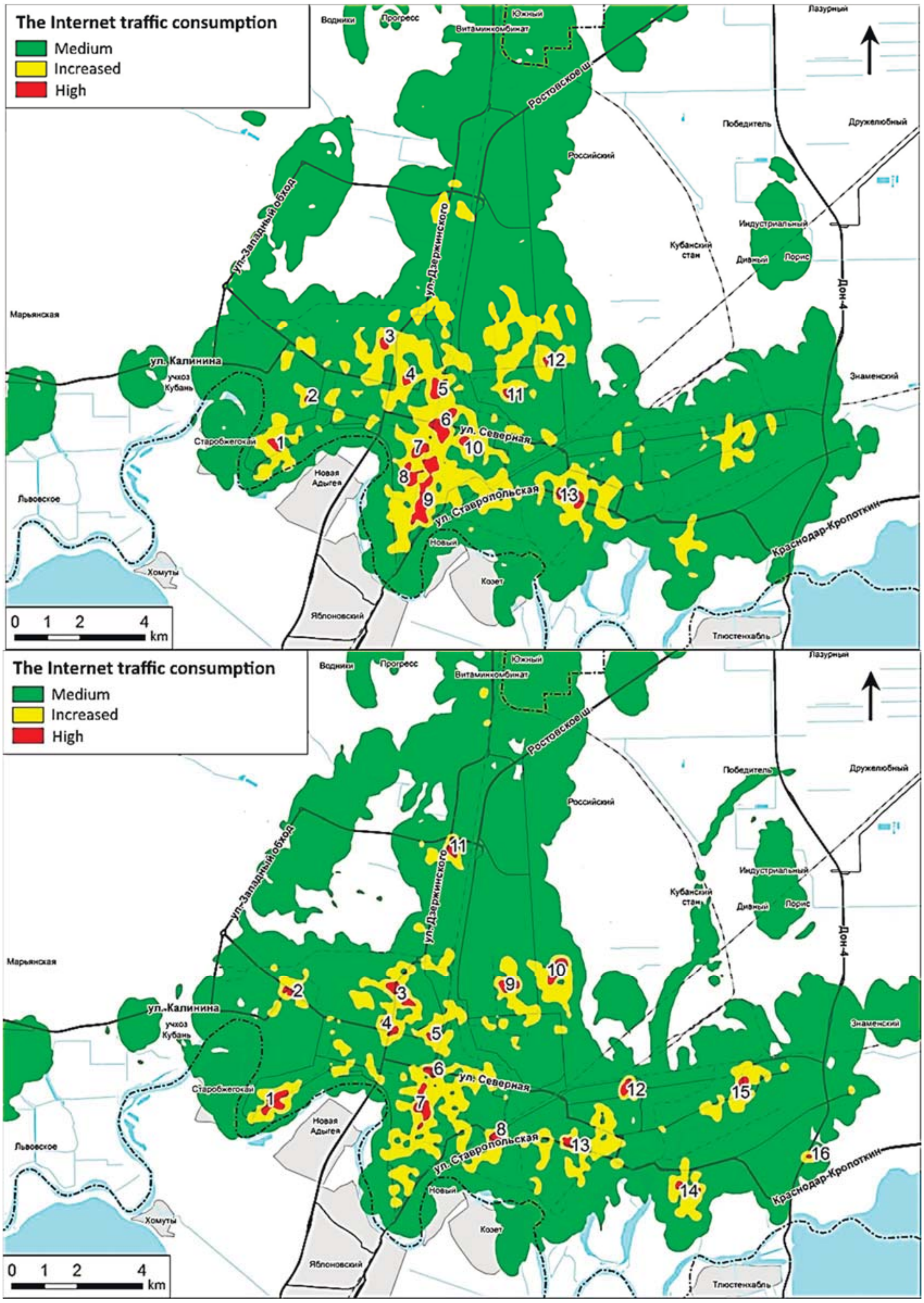

Fig. 3. The Internet traffic consumption in Krasnodar on Wednesday (top) and Sunday (bottom)

According to the Wednesday data 13 areas of high Internet traffic consumption may be obtained (Fig. 3). The territorial structure of the analyzed indicator in this day of the week seems to be close to the concentric one, in which the focuses are mainly concentrated around the city centre. Five major foci are located along the Krasnaya street. Such areas of the high traffic consumption are usually conditioned by 8 to 44 high-rise residential buildings, 1-3 kindergartens, 1-3 schools, a hospital, a market, shops, garages. Such foci are typical for the residential micro-districts (centers №1, 3, 4, 5, 12). In addition, areas of high traffic consumption are formed around major universities (centers No. 2, 11, 13).

On Sunday, the structure of the indicator is close to the polycentric one (Fig. 3) with at least 16 centers of high consumption of Internet traffic. While the city center is relatively unloaded, the new foci are detected in the suburbs – in the Northern and Eastern parts of the city. Nine from 16 foci are localized in the residential micro-districts (№ 1, 3, 4, 5, 6, 9, 10, 14, 15). It is estimated that MTS subscribers are actively using the Internet in major shopping and entertainment centres (foci № 2, 8, 11, 12, 16).

It can be stated that the most of the identified foci are localized in a residential area, being additionally spread in half of the cases throughout the social, business and recreational functional zones. On Wednesday, four from 13 centers of high traffic consumption are solely to residential zone, while on Sunday – 6 foci from 16.

The maps allowed us to link the traffic distribution of functional zones in the city, as well as to localize foci of increased volume of consumed Internet traffic.

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