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# NEXT GENERATION CELLULAR NETWORKS SERVICES FOR TRANSPORT NEEDS

***Abstract***

*Transport infrastructure is vital to the well-functioning of economic activities and a key to ensuring social well-being and cohesion of populations. Adequate infrastructure is a fundamental precondition for transport systems. So, the main aim is to provide innovative services relating to different modes of transport and traffic management and enable various users to be better informed and make safer, more coordinated, and 'smarter' use of transport networks. In this case modern and next generation wireless technologies can be used. In the nearest future, up to 2020, 5G cellular networks have to be deployed in Europe and they will bring lots of benefits for transport systems. That's why it is necessary to investigate new opportunities of next generation cellular networks and to implement them to the concept of intelligent transport systems of the future.*

## INTRODUCTION

Worldwide transport system includes: network routes (land, water, air etc.), rolling stock of all transport modes, transport corporations that organize trade and investment in this area, people who work in transport. Transportation provides links between production and consumption, meets the needs of the population in traffic, has great defensive value. The volume and structure of transport determine the level of development and the particular structure of the country or region, and the configuration of the transport network determine the characteristics and patterns of economic activity distribution.

The highest density of transport network was formed in North America (USA, Mexico, Canada), Europe, including the regions of Central and Eastern Europe, Asia (especially Japan and the East China), the Indian subcontinent (India, Pakistan) and the South East and South America.

In these conditions the vehicles are constantly being improved. The railways reached speed of 250-300 km / h (somewhere up to 600 km/h). In road transport more comfortable and environmentally friendly car models with a relatively low cost of fuel per kilometer are implemented.

Today, however, the state of the transport system is not everywhere can be considered as satisfactory. For example, in Eastern Europe (eg Ukraine and especially Kyiv) most of the objects of transport infrastructure must be recognized as those that do not meet modern requirements to fulfill their basic functions. This primarily refers to road and rail transport.

The level of safety, passengers transportation quality and efficiency, energy efficiency, environmental impact does not meet modern requirements.

Therefore, in these circumstances, implementation of elements or of whole Intelligent Transport Systems (ITS) is an actual scientific and practical problem. It's solution will reduce the workload of the existing transport network and ensure the safety and comfort of participants movement.

That's why the main aim of this paper is to explore modern transport infrastructure, the benefits and problems of ITS, explore capabilities that provide current and future generations cellular networks for it.

## 1. ANALYSIS OF THE MAIN PROBLEMS OF MODERN ITS

After substantial analysis, we can identify the main problems of the large cities transport systems [1-3]:

- Discrepancy of road network capacity and real demand for transport services;
- Potential faults or mood lights that could create significant congestion at the intersections;
- "Stop-start" move mode, that prevents comfortable movement for drivers and passengers in the city;
- Slow response to congestion and technical services failure;
- Lack of real control over the speed limit of road transport movement, which leads to accidents cases;
- Unequipped parking;
- Lack of awareness and widespread source drivers on the state of traffic and roads. control and penalties for parking in unassigned areas, reducing the capacity of roads and leads to slower traffic, impedes movement of pedestrians;
- Lack of global road traffic management.

All these problems create more complex effects. For example, the analysis of Yandex congestion software open data [4] shows that for the period January - August in 2015 traffic load of the roads in Kyiv was as shown in (Fig. 1) and (Fig. 2).

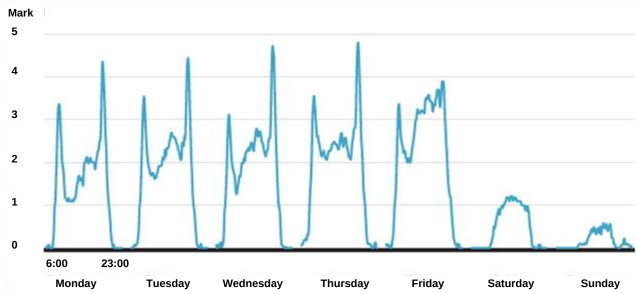



***Fig. 1.*** *Traffic load in Kyiv during the week*

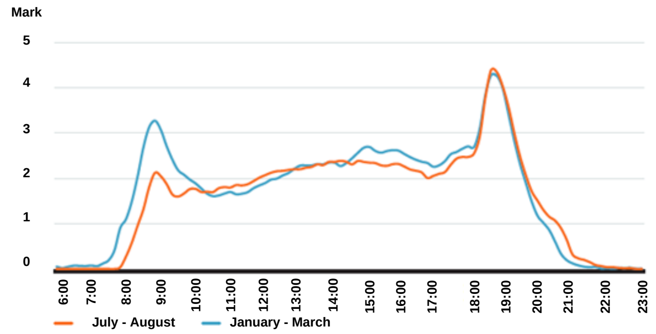



***Fig. 2** Traffic load in Kyiv during the workday*

The greatest congestion occurs Monday through Friday from 8 am to 10 am and from 6 pm to 8 pm. With that in winter time schedule shifts for about an hour to the left.

This traffic in Kiev have periodic significantly increase the time required for getting a job. This result creates obstacles to doing business, and therefore economic growth.

Therefore, in these circumstances, it is necessary to develop new advanced technologies that will make travel more comfortable and secure. For this purpose, the world is already quite widely used concept of Intelligent Transport Systems.

Intelligent Transport System (ITS) - is an intelligent system that uses innovation in modeling of transport systems and traffic regulation, giving end users higher level of informing, safe and qualitative transportation of road users compared to conventional transport systems [5].

Analyzing [1-3, 6], it can be argued that the problems that ITS solve are as follows:

– Time and space distribution of road traffic optimizing;
– Capacity of the existing transport network increasing;
– Giving priority to travel a certain type of transport;
– Management of transport in the events of accidents or events, that affecting traffic;
– Improving safety on the roads;
– Reducing the negative environmental impact of transport;
– Providing information on traffic conditions to all interested parties.

## 2. TECHNOLOGIES FOR ITS

For solving of these problems can be used different types of ITS. ITS vary in the use of technology (Tab. 1)

***Tab. 1**. Types of ITS*

| Simple | Complex |
|---|---|
| ✓ Car navigation systems;<br>✓ Traffic light control systems;<br>✓ Cargo control systems;<br>✓ Information characters systems (including placards);<br>✓ Systems of car numbers recognition;<br>✓ Vehicles speed recording systems. | ✓ CCTV;<br>✓ Systems that integrate information flows and the flow of feedback from many different sources:<br>- Parking management system (Parking guidance and information (PGI) systems),<br>- Meteorological services,<br>- Breeding system of bridges and others. |

Fig. 3 shows a fragment of ITS network. It was suggested to use complex following modern information technologies and systems: a system of global positioning GPS, advanced cellular networks (3G, 4G and 5G), sensor networks, Wi-Fi, wired infrastructure, RF tags, network surveillance etc.

In this architecture, intelligent traffic control center gathers information from smart devices on the road, among which are the vehicles and "smart" traffic lights and from the Internet. This information is about road congestion, the number of vehicles, the condition of the roadway etc. Data exchange between different nodes of the system can be provided via cellular networks of different generations, including future 5G.

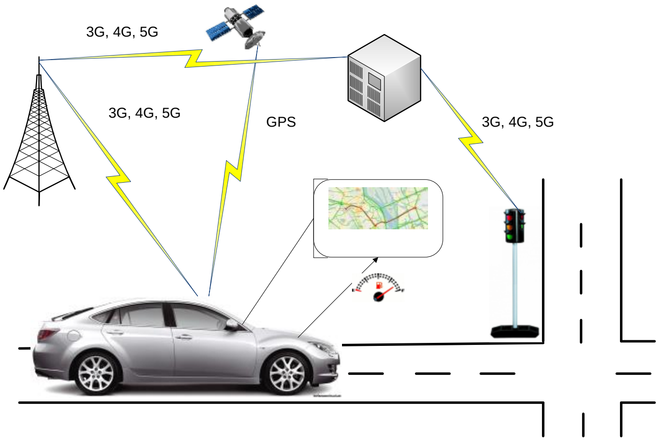



***Fig. 3** Fragment of ITS network*

Fig. 4 shows the capabilities that wireless fifth-generation technologies provide for ITS

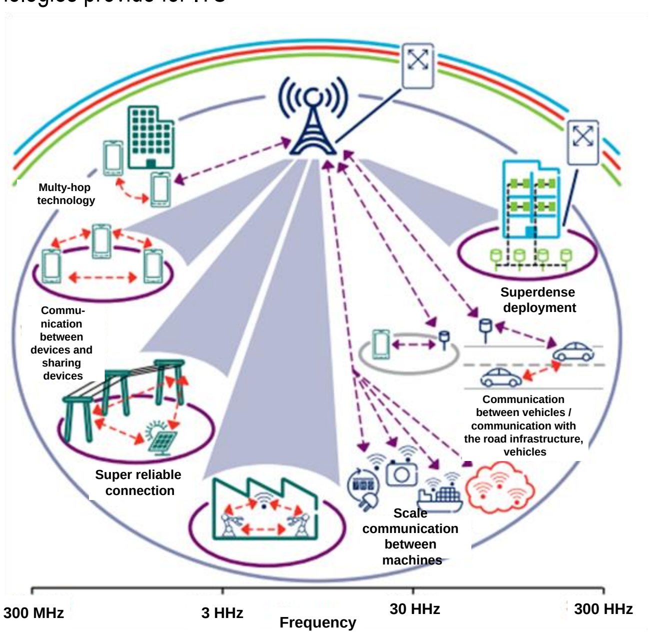



***Fig. 4.** Capabilities that wireless fifth-generation technologies provide for ITS*

Considering these opportunities we can say the following. The automotive sector is expected to be a very important new driver for 5G, with many use cases for mobile communications for vehicles [7]. For example, entertainment for passengers requires simultaneous high capacity and high mobility mobile broadband, because future users will expect to continue their good quality connection independent of their location and speed. Other use cases for the automotive sector are augmented reality dashboards. These display overlay information on top of what a driver is seeing through the front window, identifying objects in the dark and telling the driver about the distances and movements of the objects. The previous two use cases are related to content provisioning for the car users, but the cars themselves will also be connected. Device-to-device (D2D) communication is seen as a major technology to overcome the imminent wireless capacity crunch and to enable new application services [8], which will play a great role in machine-to-machine communication between cars. Many car manufacturers are already adding driver assistance systems based on 3D imaging and built-in sensors. In the future, wireless modules will enable communication between vehicles themselves, information exchange between vehicles and supporting infrastructure and between vehicles and other connected devices, for example, those carried by pedestrians. These include cars detecting safety critical situations, such as black ice, accidents within reach of the car and other hazardous road conditions. Safety systems will also guide drivers on alternative courses of action to allow them to drive more safely and lower the risks of accidents. The next phase will be remotely controlled or even self-driven vehicles, which will require ultra reliable and very fast. In this case 5G provides Reliable Communication (URC). URC refers to provision of certain level of communication service almost 100 % of the time. Example URC applications include reliable cloud connectivity, critical connections for industrial automation and reliable wireless coordination among vehicles [9].

## 3. MODEL FOR CELLULAR NETWORKS PLANNING

As noted above, in the ITS modelб shown in Fig. 3, wireless technology of different generations play the most important role for data exchange. So, the very important task is to determine communication range, capacity and the devices in the service area. For this we consider the following model.

The maximum allowable loss of the propagation in wireless channel is:

$$L = P_{TX} + G_{TX} - P_{RX} - B_{BODY} + \\ + G_{RX} - B_{fid} - IM - L_{slow} - L_{met}, \qquad (1)$$

where

$P_{TX}$ – transmitter power;

$G_{TX}$ – gain of transmitting antenna;

$P_{RX}$ – receiver sensitivity;

$B_{BODY}$ – loss in subscriber body;

$G_{RX}$ – gain of receiving antenna;

$B_{fid}$ – losses in the feeder;

$IM$ – interference margin;

$L_{slow}$ – reserve for slow fading, is set equal to 10.3 dB.

$L_{met}$ – losses caused by the absorption of atmospheric gases, hydro meteors, fog, etc., dB, which is determined by the following formula:

$$L_{met} = L_{fog} + L_{hidro} + L_{ag}, \qquad (2)$$

where $L_{fog}$ – loss of signal strength in the fog, dB;
$L_{hidro}$ – loss of signal strength during rain, dB;
$L_{ag}$ – loss of signal in atmospheric gases.

The mathematical apparatus for calculation $L_{fog}$ , $L_{hidro}$ та $L_{ag}$ is the next.

Loss of signal in atmospheric gases $L_{ag}$, dB, is

$$L_{ag} = (\gamma_{O_2} + \gamma_{H_20}) \cdot l \qquad (3)$$

where $\gamma_{O2}$ , $\gamma_{H20}$ – linear loss (dB / km) for oxygen and water vapor in atmosphere at a temperature of 15 0 C and a relative humidity of 100% (absolute humidity is 13.4 g / m³):

However, as shown in [10], the received power can be represented as follows:

$$P_{RX} = 10 \cdot \lg((E_b / N_0) \cdot k \cdot T \cdot R) \qquad (4)$$

where $(E_b / N_0)$ – signal to noise ratio in digital communication systems;
$R$ – data rate;
$k$ = 1,23×10$^{-23}$ J/K – Boltzmann constant,
$T$ – absolute temperature.

Thus the expression (1) can be represented as:

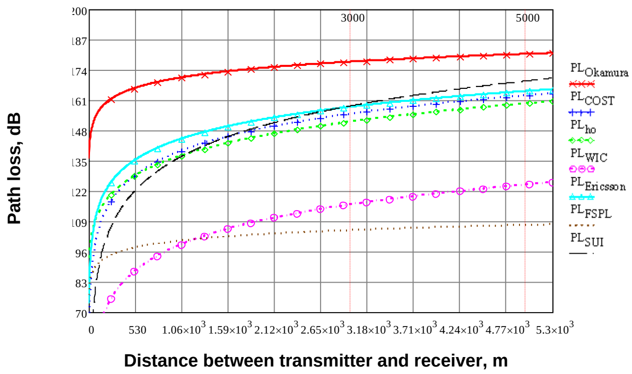
$$L = P_{TX} + G_{TX} - 10 \cdot \lg((E_b / N_0) \cdot k \cdot T \cdot R) - \\ - B_{BODY} + G_{RX} - B_{fid} - \\ - IM - L_{slow} - L_{met}, \qquad (5)$$

To assess the value of $L$ on the propagation, following the results of the studies were designed following recommendations on the use of radio wave propagation models for different frequency bands (Table. 2).

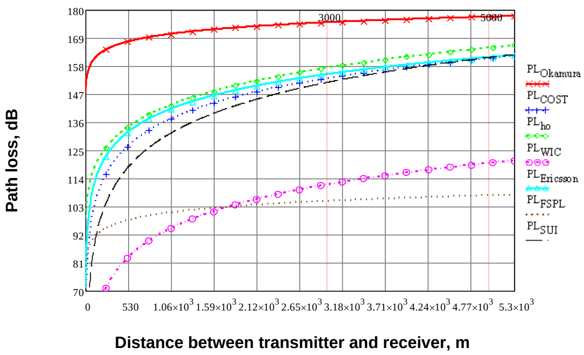
***Tab. 2.*** *Recommendations on the use of radio wave propagation models for different frequency bands*

| Frequency range | Technology | Recommended propagation model |
|---|---|---|
| Up to 2 HHz | LTE, WiMAX, GSM, UMTS etc. | Hata model |
| 2,3 HHz; 2,5 HHz; 2,6 HHz | LTE, WiMAX | Hata Cost 231 model |
| 3,5 HHz | LTE, WiMAX | SUI (for LOS conditions) and Ericsson (for NLOS conditions) |
| 5 HHz; 5,8 HHz | WiMAX | SUI (for LOS conditions) and Ericsson (for NLOS conditions) |

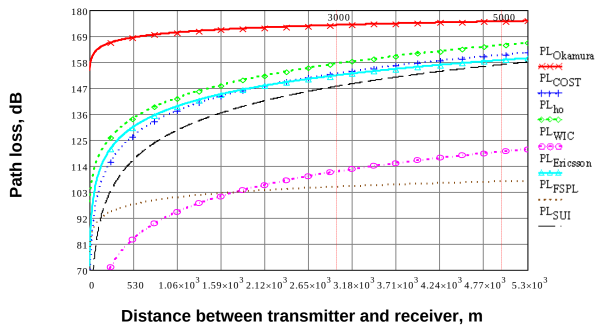
For these models the dependence of signal loss from communication range modeling were conducted (Fig. 4-5).




(a)




(b)




(c)

*Fig. 4 Dependence of signal attenuation on the distance to 2.4 GHz (a - urban areas, b - a suburb, c - rural)*

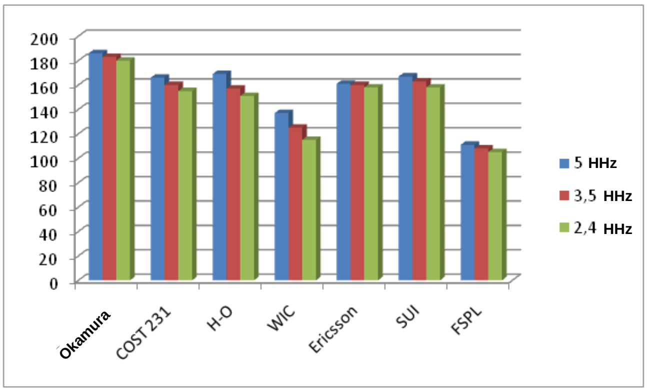



*Fig. 5 Level of signal loss for the 2.4 GHz, 3.5 GHz, 5 GHz radio during distribution within urban*

From the formula (3) can be expressed maximum communication range for different frequency bands used in LTE and will be used in 5G.

The simulation results show that for the urban environment:

1. The range of LTE base stations coverage in the 2300 - 2400 MHz band working at 10, 15 and 20 MHz is reduced and, accordingly,

- With QPSK 1/3 modulation – 3.3, 2.8 and 2.4 km.
- With 16QAM ½ modulation– 1.8, 1.6 and 1.45 km
- With 64QAM ¾ modulation– 1, 0.8 and 0.7 km.

The corresponding modulation-coding scheme selection based on the required quality of service.

By increasing the frequency band from 10 to 20 MHz LTE base stations coverage area decreases: with QPSK 1/3 modulation – from 28 to 15 square kilometers; with 16QAM ½ modulation – from 8 to 5 square kilometers; with 64QAM ¾ modulation – from 2.6 to 1.3 square kilometers. Communication range of frequency bands dependence shown in (Fig. 6).

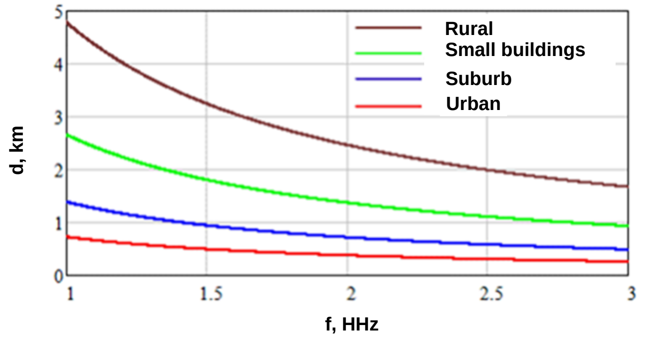



*Fig. 6 Communication range of frequency bands dependence for different types of buildings*

Based on the above model specialized software for assessing cellular radio networks and determination of the optimal location of base stations was developed. This allow to conduct simulation base station radio coverage in the center of Warsaw. These results can be used for planning of ITS network. The results of the simulation are shown in Fig. 7.


*Fig. 7 Results of the simulation of radio coverage in Warsaw*

## CONCLUSION

Thus, the proposed concept of ITS in future will provide the following objectives: lower operating costs and improve the economic efficiency of operation of the transport sector of the city, creating an integrated system of transport complex of the city, the coordination of different services, enterprises and organizations, improving the quality of transport services to the population, improve safety transport, a centralized information system safe operation of the vehicle with the use of GPS, additional income from the commercial exploitation of ITS for the benefit of private organizations and individuals.

## LITERATURE

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# KOLEJNA GENERACJA SIECI KOMÓRKOWYCH W USŁUGACH TRANSPORTOWYCH


**Streszczenie**

*Infrastruktura transportowa jest niezbędna do prawidłowego funkcjonowania działalności gospodarczej i kluczem do zapewnienia dobrobytu i spójności społeczeństwa. Odpowiednia infrastruktura jest podstawowym warunkiem dla systemów transportowych. Tak więc, głównym celem jest dostarczanie innowacyjnych usług związanych z różnymi środkami transportu i zarządzania ruchem oraz umożliwienie użytkownikom dostępu do "inteligentniejszego" korzystania z sieci transportowych. W tym przypadku można stosować nowoczesne technologie bezprzewodowe. W najbliższym czasie, aż do roku 2020, sieci komórkowe 5G mają być rozmieszczone w Europie i dostarczyć wiele korzyści dla systemów transportowych. Dlatego konieczne jest zbadanie nowych możliwości kolejnej generacji sieci komórkowych i wprowadzić je do koncepcji inteligentnych systemów transportowych w przyszłości.*



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