DATA TRANSFER RATES AND DATA TRAFFIC TRENDS ON MOBILE NETWORKS

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ABSTRACT

This article intends to demonstrate – through the monitoring of traffic data – the importance of data transfer rate on mobile networks and prevalent user trends. Current paper examines both already operating mobile networks and ones presently in the state of standardization in order to shed light on the data transfer rate maximizing strategy, and to find out how a wide frequency spectrum should be necessary for handling growing user demands. Furthermore, recognizing the demand for the continuous expansion of data traffic, current article – relying on previous Cisco research and the analysis of broadband mobile networks – aims to estimate the necessary data transfer rate and the amount of increase in data usage regarding the next few years to serve the developing mobile technologies. In the world of IoT, M2M and Smart Cities, the available mobile networks most likely will not be able to sufficiently deal with the high traffic, the article seeks to answer whether the development of new mobile technologies (like the 5G) are in line with the growing needs of users and machines and to propose a solution for handling the expected data traffic.

KEY WORDS

data traffic, data transfer rate, trends, growing needs

CLASSIFICATION

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INTRODUCTION

Demand for technological progress regarding the mobile networks is ever increasing. Thanks to the advancement of mobile technologies, user needs can be properly served. The position of frequency spectrum defines the possibilities of wireless technologies regarding the ensured coverage and quality, including the maximum available data transfer rate. The service providers have made huge efforts in the last few years to maximize data transfer rate and make the 4G (LTE) network available – including suburban and rural areas as well – since they already have the necessary frequencies to build a nationwide coverage. The LTE-Advanced and the upcoming 5G (that is still under standardization) is capable of a very high speed. But, is that rapid innovation, high data rate and huge capacity really necessary? This article is about to answer this question by presenting the LTE-Advanced and the 5G networks, and by analysing forecasts and showing trends of mass events and cities from a live mobile network point of view. The processed sampling data came from a mobile network of a service provider that has millions of users.

FREQUENCY BANDS FOR 4G (LTE) IN HUNGARY

The frequency is the basis of mobile services, having the appropriate frequency bands is fundamental to radiate mobile technologies, thus it has a key role in radio communication. It should be also taken into account that the frequency bands are exclusively allocated to specific services, which is a limitation of frequency resources. Cutting-edge technologies or creating new services increase the demand for wider frequency spectrum [1].

Mobile operators usually lease the frequencies on a long-term basis through a frequency tender issued by the Government. The last frequency auctions of Hungary took place in 2014, when 280 MHz frequency spectrum was announced for HUF 104,15 billion to be undertaken for 20 years. The purchasable frequencies were made public in packets, blocks “A”, “B” and “C” had the 800 MHz, the 900 MHz and the 2 600 MHz band, blocks “D”, “E” and “F” contained the 1800 MHz frequency band, block “G” offered the 2 600 MHz FDD band, while in block “H” the 2 600 MHz TDD could be purchased [2, 3]. The 800 MHz band became disengaged due to the disconnection of analogue TV broadcast [4]. This band is the most significant in respect of coverage, since the propagation of radio signals is more favourable in this band than in higher ranges.

During the auction, service providers entered successful bids in a total value of HUF 130,6 billion and acquired lease rights for the frequency bands for 20 years, and accepted other criteria as well: for instance the 4G service must be available for 96 % of the population and cover at least 90 % of Hungary’s territory within 60 months. All operators (which provide mobile services) got frequency band on 800 MHz, 900 MHz and 2 600 MHz. The 800 MHz and 2 600 MHz bands play a role in extending the 4G service, the 800 MHz band is essential to achieve nation-wide coverage. The successful frequency auction was a milestone of Hungarian mobile telecommunication and defined the long-term strategy of wireless service providing companies. The sold bands are shown in Fig. 1.

Hungary’s next frequency auction will take place in the coming years. The most important band that could be purchased through this tender is the 700 MHz spectrum. This band will likely be used for the LTE-Advance (and possibly in the future for the 5G), in conjunction with the neighbouring 800 MHz and later on the 900 MHz bands [5].

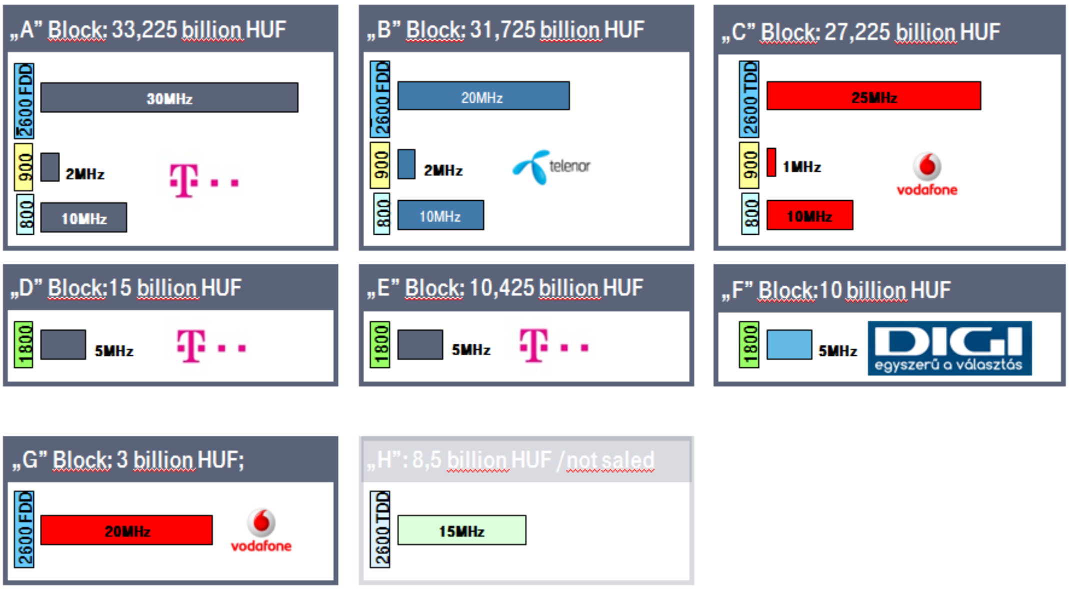

Figure 1. The sold bands of Frequency Auction Hungary 2014.

BROADBAND MOBILE NETWORKS

4G (LTE) PLANNING STRATEGY TO MAXIMIZE DATA TRANSFER RATE

The 4G is a single-frequency wideband network, which means that each mobile cell of a base station interferes with each other and with the surrounding base stations (and with their cells) as well. This considered, the dominance of mobile cells should be increased in their respected service area as much as possible, in order to achieve the theoretically available maximum speed. Increasing dominance and reducing interference will result in an improvement of SNR (signal-to-noise-ratio), which directly affects the data transfer rate. Therefore the mobile operators design their networks in the line with this strategy [6, 7]. The following diagrams indicate the importance of SNR and the reduction of available data transfer rate due to SNR degradation close to the boundary of cells (sectors).

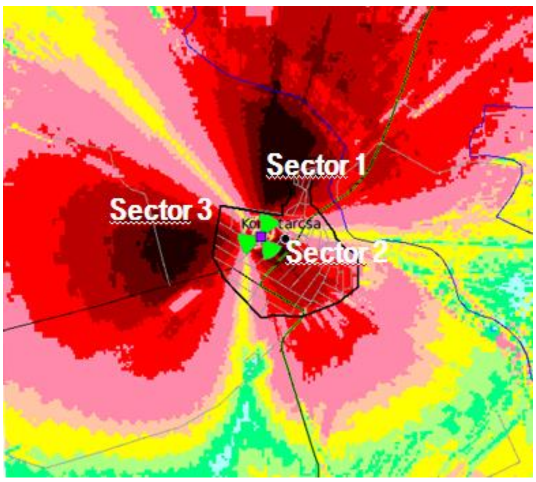

Figure 2. The available data transfer rate within the three cells of a base station (the darker the area, the higher the available speed – the data transfer rate is the minimum at the boundary of the cell's range).

In Fig. 2, mobile sector 2 is rotated to the direction of sector 3. The two cells operate on the same frequency, which increases the interference and damages SNR in both cells (in sector 2 and 3), thus the available data transfer rate is also getting lower [7].

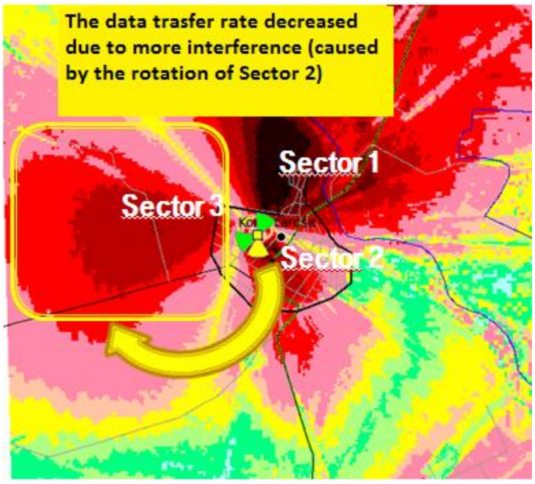

Figure 3. The available data transfer rate within the three cells of a base station (the darker the area, the higher the available speed) – after the rotation of sector 2 to the direction of sector 3.

THEORETICAL DATA TRANSFER RATES ON LTE-ADVANCED IN HUNGARY

The 4G service has been available in Hungary since 2012 and operated on the 1800 MHz band with 10 MHz bandwidth, which was capable of reaching ~75 Mbps [8] theoretical maximum data transfer rate by using MIMO (Multiple Input Multiple Output – multiple antenna is in use on the transmitter and receiver side) [7]. Following the successful frequency auction, the Hungarian operators could multiply the available speed on their 4G network since the end of 2014 due to the new frequency bands (800 MHz and 2 600 MHz) and the fact that the bandwidth was increased on 1800 MHz.

The LTE-Advanced refers to the data transfer rate of over 150 Mbps, which was switched on in Hungary in 2014 and has been available nation-wide since 2015. LTE-Advanced could be described as a combination of available frequency bands, which means that separated bands can be aggregated using the so-called „carrier aggregation" feature. For example if a 20 MHz wide frequency band provides 150 Mbps theoretical maximum download speed and there is an additional 20 MHz bandwidth aggregated to our bandwidth, the maximum download speed will be doubled, reaching 300 Mbps and the capacity will increase as well [9].

As mentioned above the double carrier aggregation is already in operation in many parts of Hungary. The triple carrier aggregation was introduced in November 2016 in Hungary, when the 800 MHz (20 MHz wide band), the 1800 MHz (20 MHz wide band) and the 2 600 MHz (20 MHz wide band) frequencies were merged in order to reach the theoretical maximum download speed of 450 Mbps (with 60 MHz wide spectrum). The maximum download data transfer rate of LTE-Advanced technology are summarized on the following diagram.

Later on the so-called Massive MIMO will be released, which provides much more than 2×2 antennas on the transmitter and receiver side [11], the theoretical maximum downlink data transfer rates could be also seen in Fig. 4.

5G EXPECTATIONS FROM A DATA RATES POINT OF VIEW

Standardization of the fifth-generation mobile network (5G) is currently under way. All the relevant mobile base station manufacturing companies and the major players on telecommunications market are involved in this collaborative effort. The first release is expected in 2020 [12].

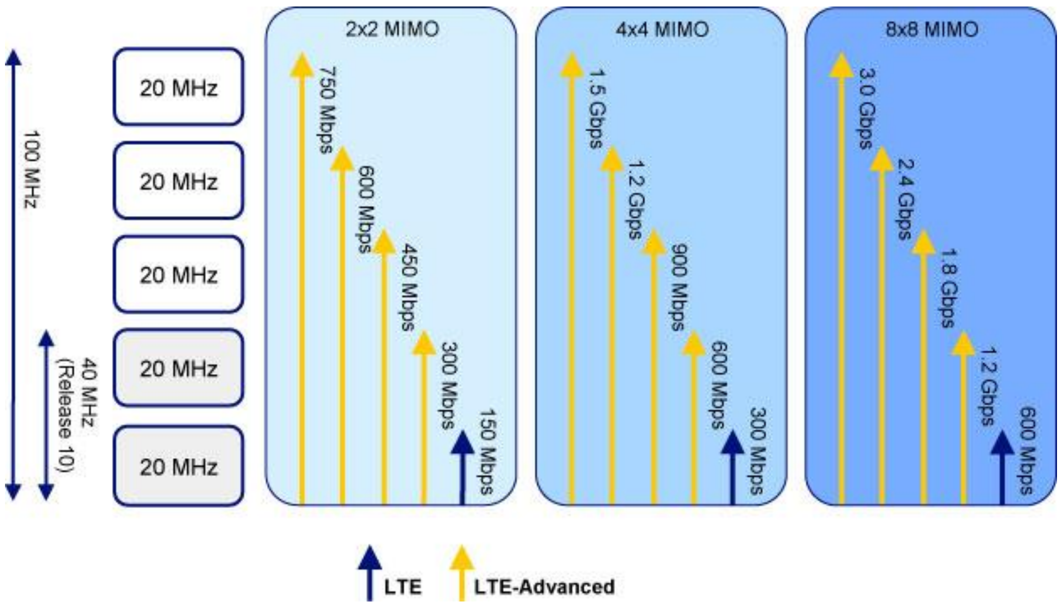

Figure 4. The available theoretical data transfer rates on LTE-Advanced [10].

As noted above the frequency spectrum is the pillar of wireless technologies. As expected, a much higher range will be allotted for the 5G than for existing mobile technologies. Currently the highest frequency band that used for mobile service in Hungary is the 2 600 MHz. The primary frequency band of 5G is currently set at around 6 GHz, which means an unusual high band in terms of radio service, but it is assumed that (after the disconnection of terrestrial broadcasting) the 700 MHz band could also be used in order to enable the nationwide and indoor 5G coverage [13].

The spread of radio signals weakens with increasing frequency and radio signals penetrates with more attenuation through materials and objects in the higher frequency range [14]. In the 6 GHz range the radio signal propagates with a level of degradation that it might require a denser network (an increase in the number of base stations) in order to supply nation-wide coverage. This could mean the largest investment that mobile operators have ever made regarding the access, the transmission and the core networks. The transmission network will most likely be a system of optical networks or possibly in the future of high-performance microwave devices [15]. The expected frequency bands for the 5G are shown in Fig. 5.

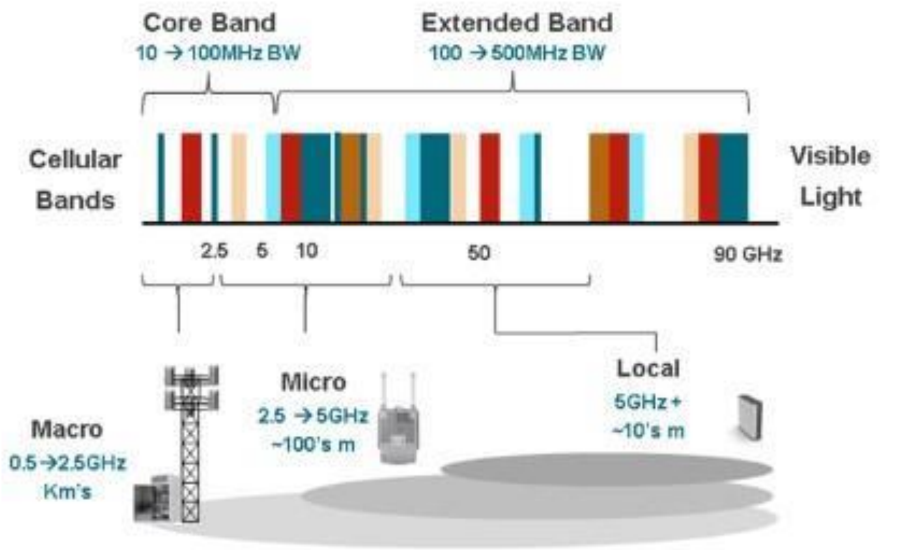

Figure 5. The planned band and the use of frequency ranges of the 5G [16].

In exchange the 5G will provide the highest data transfer rate that has ever been experienced on mobile networks: it will offer near real time communication sans delay and also increased capacity. The data transfer rate is expected to be 10 to 20 Gbps for one subscriber, the delay of the network might be less than 1 ms and the capacity could be ~1000 times more than that of existing technologies. As mentioned above, a denser network will be required, which means the number of users (that are in one cell) will decrease and this will also increase the capacity compared to previous technologies [17].

In Fig. 6 one can see the comparison of data transfer rate regarding the existing mobile technologies and the 5G.

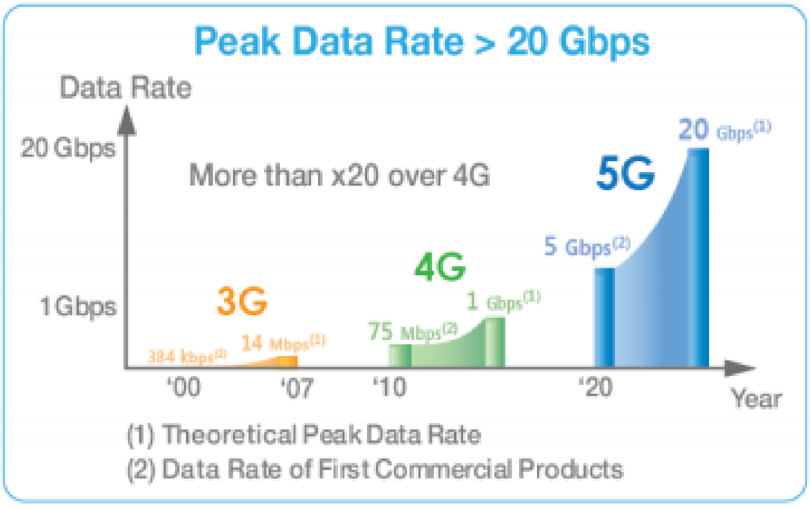

Figure 6. Representation of “Peak data rate” for 3G, 4G and 5G [18].

The real time latency can be a milestone in several sectors, such as healthcare or self-driving cars. Regarding medical surgeries the vision of 5G can be illustrated with the following examples. As the 5G will offer high data transfer rate and almost zero network latency, the surgical interventions could be made remotely – even from a continental distance – without a personal presence. With the help of high performance sensors (on the doctor’s side) and robotic arms (on the patient’s side), the surgery can be performed in real time (due to approximately zero latency). After the release of self-driving automatic cars 5G could provide innovative solutions like avoiding traffic jams and accidents by connecting and synchronizing vehicles to each other. Each necessary manoeuvre (that will handled by automatic cars) could be realized immediately in real time [19].

In addition to the above the engineers, who are currently working on the 5G standard, are trying to reduce the complexity of the network compared to the 4G. The focus is on the environmental sustainability as well: the battery of a 5G device can be expected to use a hundredth of the energy required in case of a 4G terminal [18].

The 5G is also expected to serve machines rather than people directly, like IoT (Internet of Things), which means the connection between devices and the internet that will communicate in real time with each other. The number of these devices is expected to rise in the tens of billions by 2020 [19].

TRAFFIC FORECASTS

The swift evolution of mobile technology brings up the question, whether LTE-Advanced and 5G will be able to provide the high data transfer rate and capacity foreshadowed by the increasing number of users and data traffic trends. In order to find the answer, forecasts –

published by the Cisco – have been analysed, which might provide an insight for the growth of mobile data traffic and trends that are to be experienced in the coming years. In order to have an accurate result, a live network of a mobile operator has also been examined in this regard and will be discussed in the following section.

DATA TRAFFIC FORECASTS BY CISCO

There are some important milestones we might start with, which are also anticipated by Cisco's study. Over the past 5 years the global mobile data traffic has grown 18-fold.

- In the next 5 years the global mobile data traffic will reach a new milestone: The 4G networks will handle more than three-quarters of the global total mobile traffic by 2021;
- 4G connection will generate double traffic on average as a 3G connection;
- By 2021 the 5G will be 0,2 % of connections and 1,5 % of total traffic but a 5G connection will generate 4,7 times more traffic than the average 4G connection due to the high speed that the 5G is expected to provide [20].

The global mobile data traffic grew 63 % in 2016, which was a huge increase. The following figure shows how the data traffic in each region increased in 2016. Central and Eastern Europe saw a 64 % increase, while data traffic in Western Europe grew by 52 %.

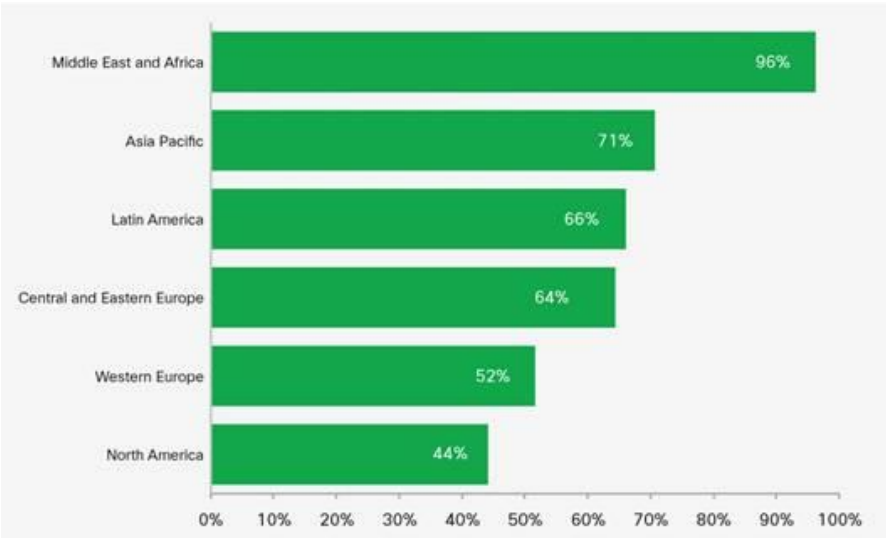

Figure 7. Mobile Data Traffic Growth in 2016 [20].

By 2021 the overall global mobile data traffic is expected to grow to 49 Exabytes per month, which means a seven-fold increase from 2016 to 2021. During this period the mobile data traffic will grow at CAGR (Compound Annual Growth Rate) of 47 %. Expectations of the coming years are shown on the next figure [20].

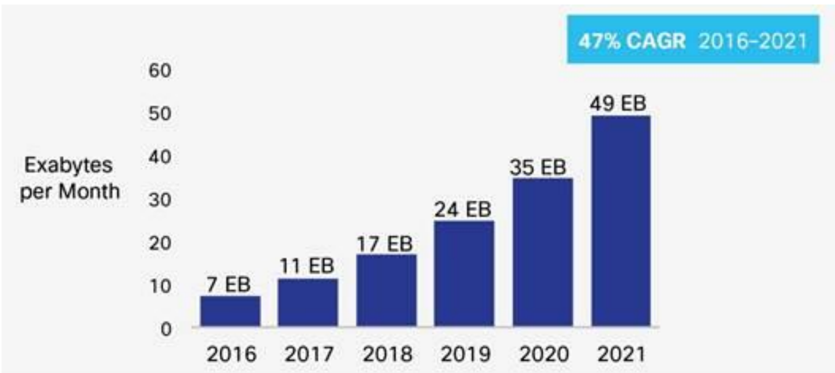

Figure 8. Cisco Forecasts 49 Exabytes per Month of Mobile Data Traffic by 2021 [20].

Cisco also predicts that 4G networks will become increasingly dominant by 2021, 56 % of the terminals will already be driven on 4G networks, but 3G networks will also have a minimal 2 % increase. However the proportion of 2G (GSM) usage will decrease from 42 % to 11 % between 2016 and 2021. The reason for this is that the ratio of devices capable only of 2G will decrease, therefore the 2G is not expected to follow an increasing trend. The newest technology, the 5G will produce more than 1000 % rise regarding the number of connections (2,2 million in 2020 to over 24,5 million in 2021), which ratio includes M2M (Machine to Machine) connections as well, as illustrated in Figure 9 [20].

Figure 9. Global Mobile Devices (Excluding M2M) by 2G, 3G, and 4G+ [20].

4G carried 69 % of total global mobile traffic in 2016 by representing the largest share of mobile data traffic by network type. It will grow exponentially faster than other technologies to represent 79 % of all global mobile data traffic by 2021. 5G will support 4G with 1,5 % of mobile traffic by 2021 and provide high bandwidth (1000 Mbps) and ultra low latency (1 ms) [19, 20].

A 4G connection currently generates nearly four times more traffic than a 3G connection. 4G networks provides significantly more data traffic rates and drive users with greater bandwidth usage, thus the terminals on 4G are expected to generate much more traffic than on 3G. The following figure summarizes the mentioned prognosis and shows the ratio of overall data traffic in exabytes per month [20].

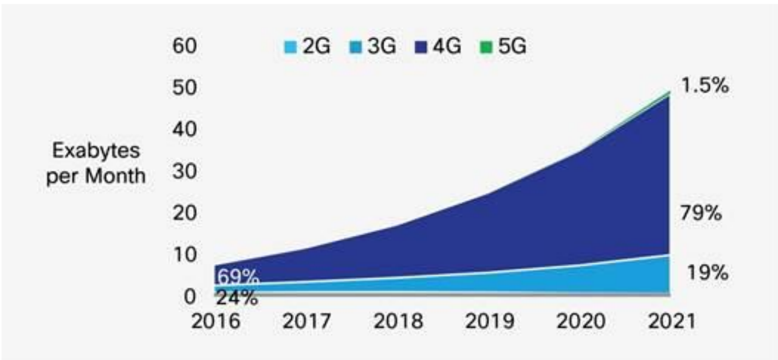

Figure 10. Global Mobile Traffic by Connection Type [20].

Cisco's research showed that the data traffic on mobile networks will nearly increase 1,5-fold per year [20]. Cisco has also made a study about the data transfer rates that will expected to be available on average by 2021, as shown in Fig.11.

The 4G data transfer rate will nearly double by 2021 according to Cisco, which can be realized for instance through carrier aggregation.

In order to handle the forecasted significant increase of data traffic in the next few years, it seems to be necessary to re-allocate new frequency bands (which were explained in the first chapter) in order to launch new 4G layers (use of the 4G on several frequency bands) and use LTE-Advanced.

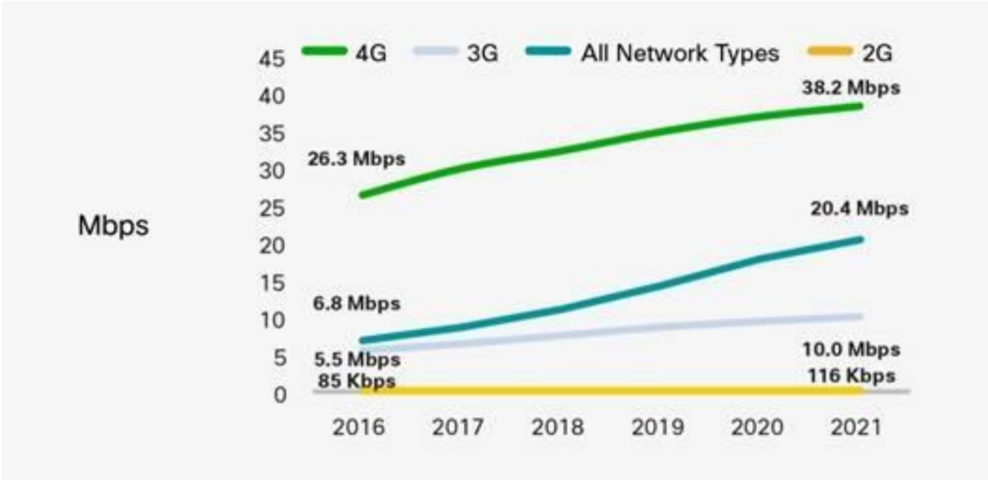

Figure 11. Mobile Speeds by Technology: 2G Versus 3G Versus 4G (Source: Cisco VNI Mobile, 2017; Ookla Speedtest.net) [20].

DATA TRAFFIC FORECAST REGARDING LIVE MOBILE NETWORK USAGE

As it has already been mentioned above, the operations of a mobile service provider have also been examined in respect of data traffic change. The operator has more than 5 million subscribers. Trends of data traffic were analysed using data collected from three mass events and three large cities.

Changes in Data Traffic of Mass Events

For major events, the mobile operators install temporary base stations to ensure high data transfer rate, capacity and quality in order to provide great customer experience and uninterrupted service. Regarding temporarily installed mobile networks of mass events (like a festival attracting tens of thousands of users) it can be said that they have the required capacity as it could be able to meet the demands of a whole town or a large city. Thus the annual data traffic of these events might provide a good prognosis for the annual increase of live mobile network on average, and also could provide a feedback to Cisco’s forecast.

The events that were analysed had 45k-100k visitors, who were present at the same time. As there are a plenty of user located in a small area, this means a challenge from mobile operator point of view to deal with the demand in proper quality and without any interruption of service. For the analysis broadband mobile networks (3G, 4G) are in the focus. The 2G network was not analysed, because the data traffic – driven by the 2G network – is negligible compared to broadband networks.

Event 1 lasted 5 days on a territory of about 0,12 km^2 and had 45 000 visitors (who were present at the same time). Fig. 12 shows the increase in data traffic. The diagram starts in 2015 and the comparison expands to the following two years, the growth is presented in percentage. The table contains upload and download data aggregated and show the change of 3G and 4G network traffic separately and cumulatively as well.

Event 2 was bigger than Event 1 regarding its geographical size (~0,17 km^2), the number of users and the mobile network. ~50 000 people stayed at the same time on the 4 days long event. Fig. 13 shows the result of the last three years.

Event 3 was located on a ~1 km^2 territory and counts 100 000 people at the same time, lasted for 7 days and proved to be the most demanding from a mobile network capacity point of view. Its data traffic change is presented in Fig. 14.

The total data traffic – on 3G and 4G overall – grew to 1,9-fold at Event 1 from 2015 to 2016 and doubled from 2016 to 2017. This load mostly affected the 4G network. The data traffic of 3G network had a downturn in 2016 compared to 2015 and increased a bit in 2017 compared to 2016 (the load of 2017 exceeded the amount of data traffic – experienced in 2015). The 4G network usage grew more than 2.8-fold from 2015 to 2016 and it doubled from 2016 to 2017.

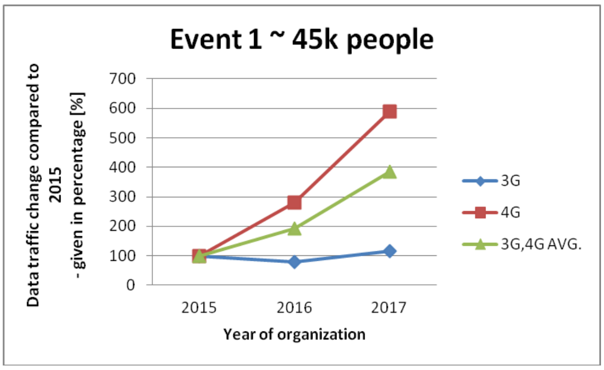

Figure 12. Data traffic change of Event 1.

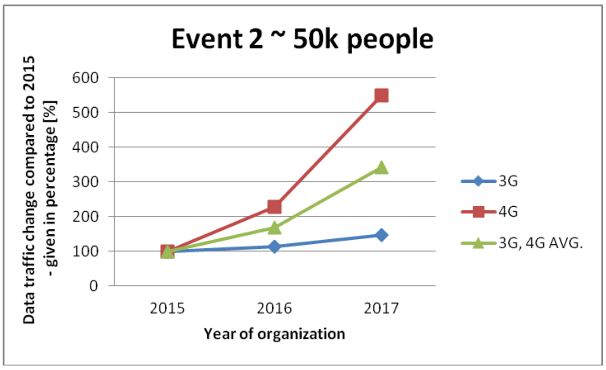

Figure 13. Data traffic change of Event 2.

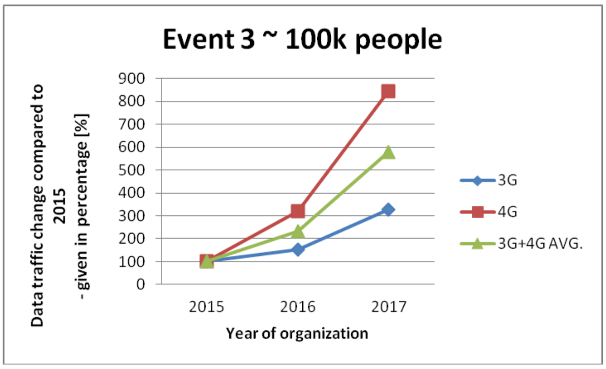

Figure 14. Data traffic change of Event 3.

The data traffic of Event 2 – similar to Event 1 – grew to about 1,7-fold from 2015 to 2016 and doubled from 2016 to 2017. 3G traffic saw a minor increase, while 4G traffic increased considerably.

The traffic of Event 3 doubled from 2015 to 2016 and it nearly grew to 2,5-fold by 2017 including 3G and 4G data. 2,3-times more data was driven through the 4G network in 2016 than in 2015 and from 2016 to 2017 the traffic grew 2,6-fold.

According to Fig. 15, one can conclude that the more users were attending the events, the larger annual traffic growth was experienced. The data of analysed events shows an annual doubling in the volume of data at least.

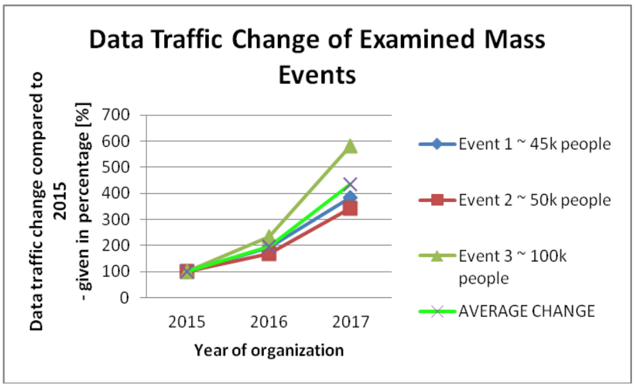

Figure 15. Data traffic change of analysed mass events – 2016, 2017 compared to 2015 (growth is given in percentage).

As stated previously – an intense increase could be discerned on the 4G network and minimal increase or lower decrease on the 3G network in 2016 and 2017 compared to 2015. The penetration of 4G terminals is rising year by year, the number of only 3G capable phones is decreasing, that is why there is more data going through 4G network broadband mobile networks.

Changes in Data Traffic of Large Cities

Three large cities – City 1, City 2 and City 3 were also examined in terms of data distribution. The sampling took place in September and was also analysed in 2016 and 2017.

City 1's geographical size is 280,8 km^2, the population is around 164 000. Fig. 16 shows the data traffic in September of City 1 regarding the last two years (growth is given in percentage). City 2 is located on 461,2 km^2 territory with a population of 204 000. Fig. 17 shows the result of the sampling months. City 3 (territory: 525,2 km^2), with a population of 1732 000 people, was also examined, and the data obtained is shown in Fig. 18.

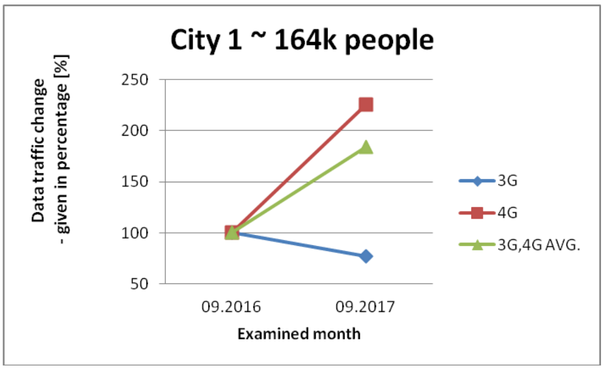

Figure 16. Data traffic change of City 1.

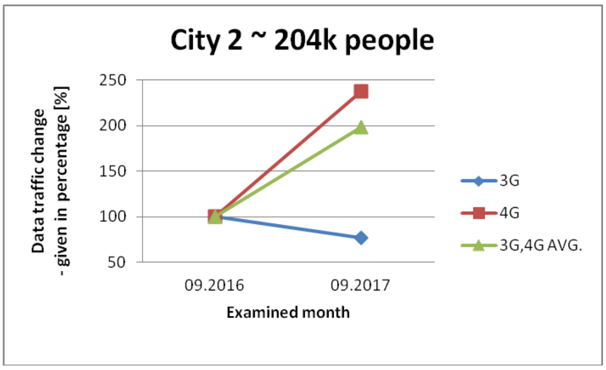

Figure 17. Data traffic change of City 2.

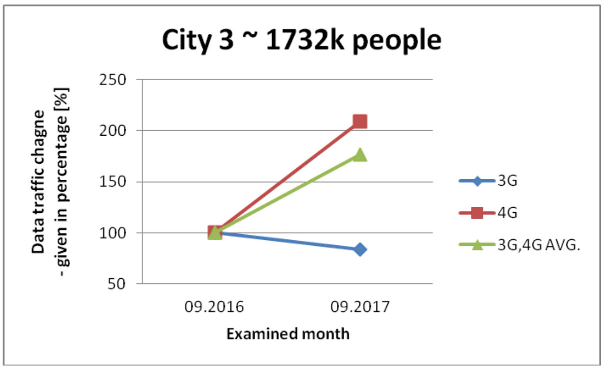

Figure 18. Data traffic change of City 3.

The data traffic usage of City 1 grew by 1,8-fold compared the data of September 2016 to the same month in 2017. The use of 3G data declined by 20 %, while the use of the 4G network significantly increased. The dataflow on 4G was more than 2,2 times higher in September 2017 than a year earlier.

Data traffic of City 2 also shows an increase in 2017, almost 2 times higher traffic was handled in 2017 than in 2016. This was achieved by the decline of 3G traffic by more than 23 %, while the 4G network generated nearly 2,5 times increase in September 2017.

The data volume of City 3 grew by nearly 80 % in September 2017 compared with the same month of 2016. The data usage decreased more than 16 % on 3G, so the 4G network had more than twice as much traffic in 2017. The increase in data traffic of large cities is summarized in Figure 19.

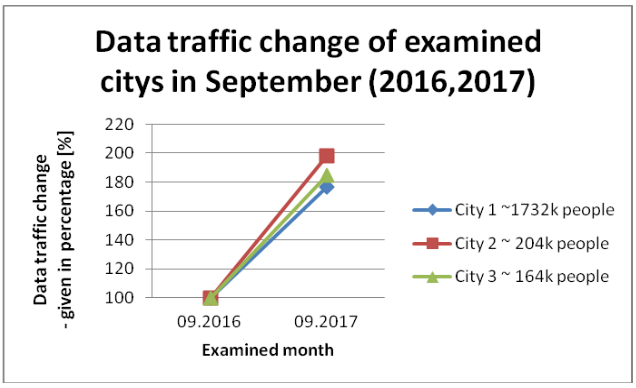

Figure 19. Data traffic change of the largest cities September 2016 compared to September 2017.

Based on live network results it can be noticed that concerning large cities the annual traffic was about 80 % more in September 2017 than in September 2016. The most densely populated city saw a more minor, but also significant increase in data traffic.

CONCLUSIONS

The results in the previous chapters show a major increase in data traffic both in the Cisco forecasts and in the live network analysis. According to Cisco and live mobile network data we can say that the data traffic on mobile networks is close to doubling each year. At the events that were under review, the utilization of 3G networks grew slightly and decreased only in one case in the examined years, while 3G traffic – in the cities that were surveyed – recorded a remarkable decline in the sampled month. On the 4G network there was a considerable and unstoppable increase experienced on mass events and in large cities as well. The results of live network analysis are in line with Cisco's forecast considering aggregated data traffic and shows disparity in the case 3G network usages. A possible explanation for this might be that the penetration of 4G capable terminals seemed greater in large cities, therefore the 3G took a back seat.

All this leads to the conclusion that mobile operators have a tough task due to the significant data traffic growth. Now we may answer the question posed in the abstract of this article: The LTE-Advanced and the upcoming 5G (that is still under standardization) is capable of a very high speed, but is this rapid innovation, high data rate and huge capacity really necessary? The answer is clear on the basis of the results: yes.

The new technologies (like the 5G) and features could provide a tool for the service providers to increase the available data transfer rate, which is important from a capacity point of view as well: the higher the available data rate, the faster the mobile user downloads the data and for the shorter time the network resources are utilized (the data transfer rate has an indirect effect on the capacity).

Based on the results of live mobile networks and Cisco, the service operators might have to invest into cutting-edge technologies and features in order to keep up with the trends of growing traffic, thus there is a need for launching new 4G layers and using LTE-Advance until the arrival of the 5G. It is already apparent that in the upcoming years the implementation of new technologies (such as the 5G) will be essential in order to handle the forecasted traffic increase in sufficient quality and without congestion and interruption. 5G is the key technology for smart cities [21].

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