Throughput Evaluation Approach for GSM Networks

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***Abstract* — Data Usage in GSM networks has increasingly become more important compared to voice calls. Smartphone usage grew rapidly in the last few years and Internet access via mobile devices is ever increasing. Experienced speed while using data, often called throughput, is a vital part of GSM service quality. Although throughput itself is a straightforward concept, evaluation of the values for throughput is complex. Experienced throughput value depends on many factors. Determining factors and their significance is central to measuring and improving perceived throughput. This papers deals with the evaluation problem and proposes a new approach to evaluate GSM network throughput experienced by subscribers.**

Keywords—Throughput evaluation; expected throughput; GSM network; data usage; evalution approach; smartphone; mobile network; mobile throughput evaluation.

I. INTRODUCTION

It is believed that communication between people far away started with smoke. Many years later telegraph was invented, which was a crucial invention. In the following decades, telephone, radio, computer, internet and cell phone were invented. Finally, smartphones have become widespread which was the sign of a different era. In this era, people increasingly tend to access Internet with their mobile devices predominantly using GSM network.

In the smartphone era, almost every person acquires a smartphone in order to increase life quality. Some people use it for its original purpose, which is connectivity, but now the phone became more than that; it can be used for social media, navigation, gaming, business, and even health. People also customized their smartphones according to their needs.

Intensive smartphone and mobile application usage led to intensive data download and upload volumes. So speed of data, which is called throughput, has become the most crucial service quality indicator in mobile communication business.

Since definition and measurement of throughput is performed easily, evaluation of measured values is not easy for GSM companies because there is not any globally accepted standard or reference point.

In this paper, the problem of throughput evaluation is discussed in detail. Previous market experience and measured values are combined in order to propose a modern approach to solve this problem. Finally, expected throughput approach is devised and success of this approach is tested, which lead to excellent results.

II. PROBLEM DEFINITION

Data experience of subscriber is one the hottest and most complex topics in GSM world. Since data experience has become more and more important for the smartphone era, companies tend to focus much on this topic.

Throughput, which is the measured data speed, is one of the most vital performance indicators of subscriber data experience and widely used by GSM companies while monitoring network health and data service quality. Although it is easy to define and calculate throughput, it is not so easy to evaluate measured throughput values. It is a complicated issue to make inferences from measured throughput values. As example, measured experience of 5 Mbps data download speed is acceptable and a good speed for many people. But for some people who are used to much higher speeds, 5 Mbps data speed is definitely not acceptable and means a poor quality of service.

In order to clarify the situation, we can look closer to a similar problem from daily life. Assume that one is driving a vehicle and it reached the speed of 110 km/h. Is it possible to accept that speed as good, or bad? Of course, that depends on some factors. If one is driving on a high-way, we can say that it is a slow speed. What about if one is driving a heavy-duty truck? Then the speed is fair enough. As we can see, the type of car is another factor used to evaluate the speed. Some other factors such as condition of the vehicle, top speed and engine type of vehicle, and driver's past experience can be added.

Similar to driving example, throughput in GSM network depends on many factors. Measuring the actual values and simple mathematical operation like average may not result in the correct evaluation.

Figure 1 shows the average throughput values measured in mobile network in the first quarter of 2015. Because of market competition and commercial limitations, exact throughput values cannot be revealed,

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instead values are multiplied by a private multiplier and general trend is depicted. The unit of multiplied throughput values is defined as "T" in the remaining part of this paper. Regarding Figure 1, throughput values vary daily and it is difficult to interpret this figure in terms of experience evaluation.

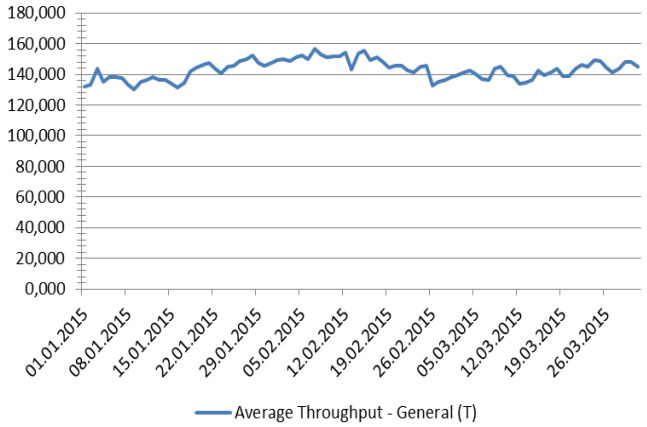

Fig. 1. Average Throughput values of whole GSM network

To better understand the variation, two cities of Turkey were selected for sampling. Because of the data security rules and market competition, we do not name the cities explicitly. Instead we call them as City A and City B.

Figure 2 shows the throughput trend of City A versus whole network in the first quarter of 2015. 2015 Q1 time period is used in the whole study. Throughput average values of City A are fluctuating more than the whole network and have different characteristics compared to the whole network. For some of the days, throughput average value of City A is higher than the whole network's throughput average. But for some of the days, throughput average value of City A is lower than the whole network's throughput average.

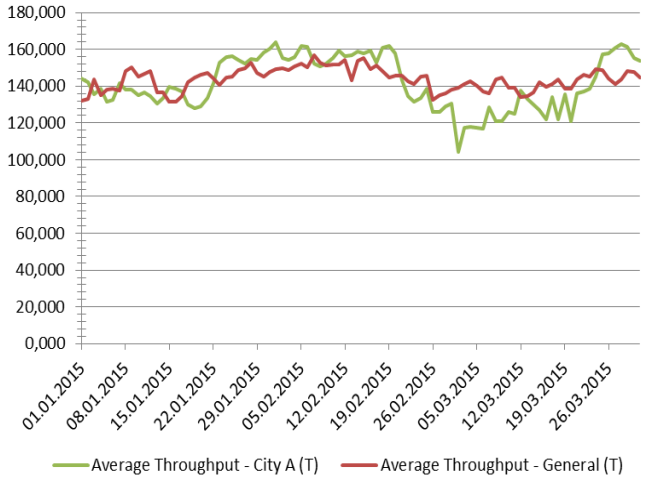

Fig. 2. Average Throughput values of City A vs whole GSM network

Figure 3 shows the throughput trend of City B in the first quarter of 2015. For most of the days, throughput average of City B is lower than the whole network's average values.

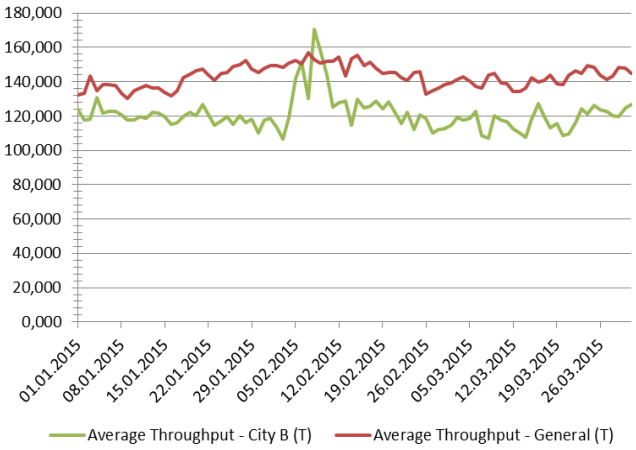

Fig. 3. Average Throughput values of City B vs whole GSM network

Only two cities are given as example for this article, but during the study nearly 30 cities were analyzed. Increasing number of city analysis, even smaller regions called districts, did not change the fact that there is no correlation between average throughput trends of cities and whole network.

If we come back to throughput evaluation problem for data experience, one common methodology is comparing individual subscriber's throughput figures with the whole network's throughput average. Another common methodology is location based throughput comparison. Individual subscriber's throughput figures are compared to his/her city or district's throughput average. As we mentioned previously, these methodologies may result in wrong interpretations. Data experience should be evaluated session by session and generalizations will lead to incorrect results.

In the remaining part of the study, factors affecting experienced throughput by GSM subscribers are analyzed in detail and a modern approach is devised.

III. Investigation of Factors

In this section of the article, investigations of various factors that are assumed to affect experienced throughput of subscriber are performed.

First, type network or GSM technology must be the dominant factor affecting experienced throughput. By nature, detail specifications and methods are different for each network type. By the mid of 2015 2G and 3G network technologies were in use in Turkey. Figure 4 shows the average throughput trend for 2G and 3G network technologies for the first quarter of 2015. As expected, average throughput of 3G network type is obviously higher than 2G network type. So, it is proved that network type is a major factor affecting experienced throughput.

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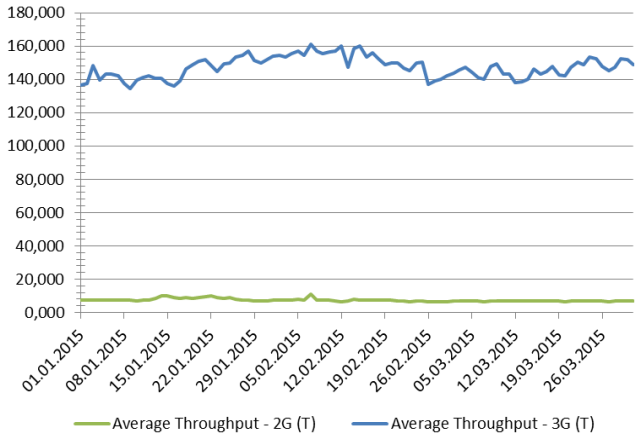

Fig. 4. Effect of network type

Second, data traffic direction may be another important factor affecting experienced throughput. Figure 5 shows the average throughput trend of downlink and uplink data traffic directions in the first quarter of 2015. Not surprisingly, average throughput of downlink direction is clearly higher than uplink direction. Therefore, data traffic direction is another factor affecting experienced throughput.

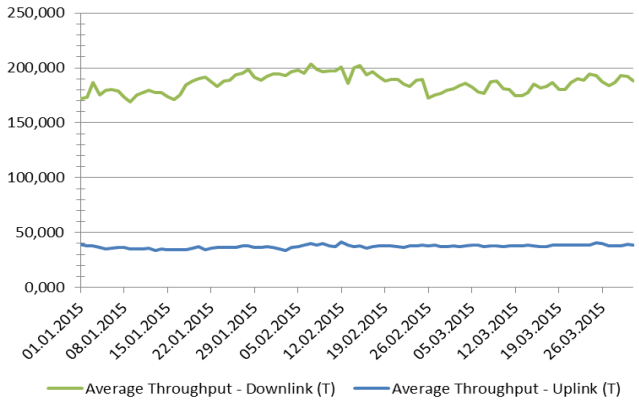

Fig. 5. Effect of traffic direction

Another factor may be the subscriber and mobile application behavior. Figure 6 shows the average throughput trend of selected popular applications in the first quarter of 2015. In this figure, the first finding is that video based applications, such as Youtube and Vine, have higher average throughputs. Messaging applications like Whatsapp and Turkcell Bip have comparably lower average throughputs. Facebook, which can be assumed having a mixed character (combination of text, image &video), has the lowest average throughput. Also, significant decrease in Vine's average throughput is detected towards the end of the quarter.

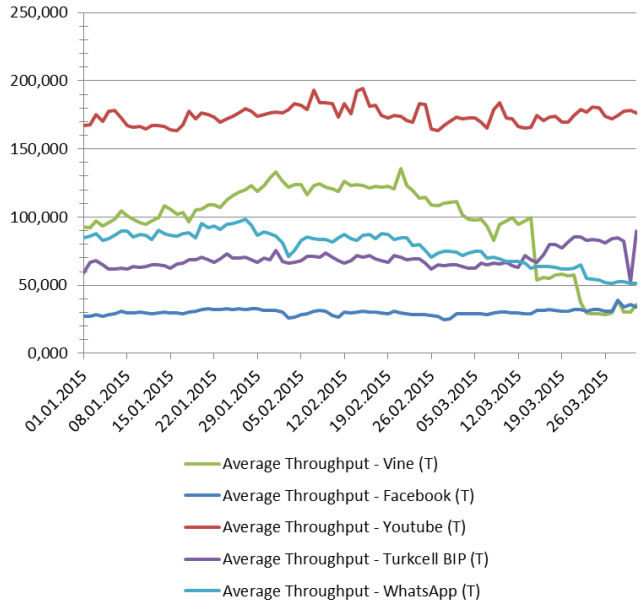

Fig. 6. Effect of mobile applications

Application based analysis gave us better understanding, but it is not sufficient to come to a result. It can be said that content type of data traffic that is called mime type (video, image, text, audio, web browsing) should be considered while analyzing application effect. Figure 7 shows the average throughput trend of mime types in the first quarter of 2015. As we see in the figure, mime type directly affects experienced throughput values.

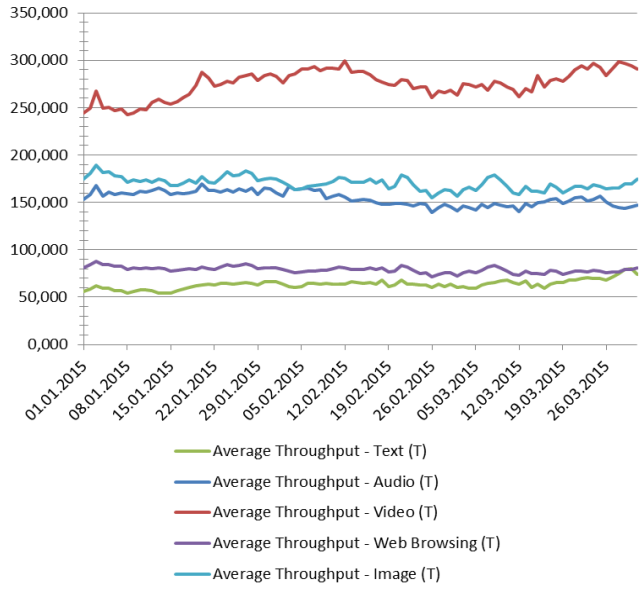

Fig. 7. Effect of mime type

Applications also vary in communication protocols used behind. Hypertext Transfer Protocol (HTTP) and Secure Hypertext Transfer Protocol (HTTPS) are two major protocols used by applications. Figure 8 shows the average throughput trend of communication protocols in the first quarter of 2015. As it is known, HTTPS is a secured version of HTTP protocol. Relevantly, HTTPS average throughput values are lower than HTTP protocol's

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average throughput values. It is clear that, impact of communication protocol on experienced throughput is significant.

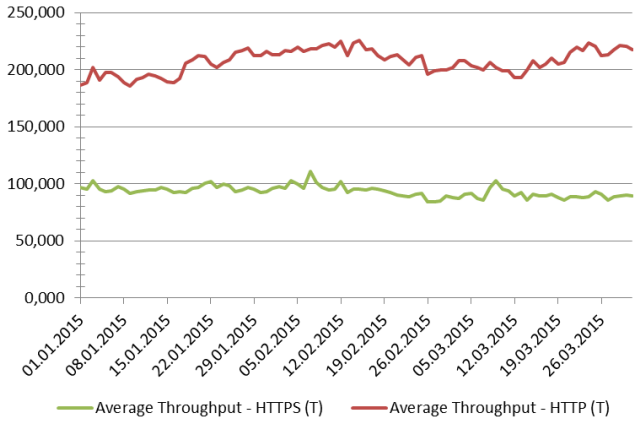

Fig. 8. Effect of application communication protocol

When we come back to driving example, the vehicle itself is a key factor for speed evaluation. In our case, the device used by the subscriber called terminal is another factor that may affect experienced throughput. Figure 9 shows the average throughput trend of terminal types in the first quarter of 2015. It is clear that, type and HDSPA support of terminal is another factor affecting experienced throughput.

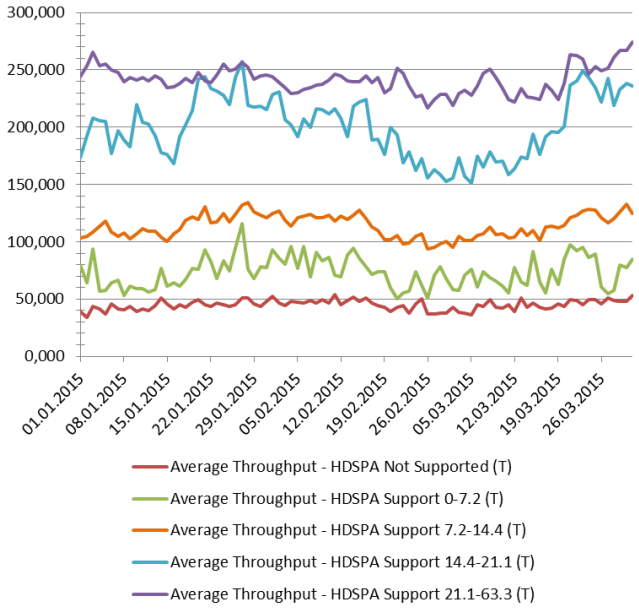

Fig. 9. Effect of terminal type

IV. PROPOSAL OF NEW APPROACH

In the previous section we have proved that experienced throughput depends on various factors which are:

- Network type (2G, 3G)
- Data traffic direction (downlink, uplink)
- Mime type (video, text, audio, web browsing, image)
- Communication protocol (HTTP, HTTPS)
- Terminal HDSPA Support (Not Supported, 0-7.2, 7.2-14.4, 14.4-21.1, 21.1-63.3)

When data traffic is simplified down to session level, each session has unique characteristics of 5 major factors mentioned above. In other words, a session is either 2G session or 3G session (4G was not launched in Turkey yet by mid of 2015). Similarly, a session is either established by HTTP or HTTPS.

TABLE I. SAMPLE SESSION CHARACTERISTICS

Sessions	Major Factors				
	Network Type	*Data Traffic Direction*	*Mime Type*	*Communication Protocol*	*Terminal HDSPA Support*
Session 1	2G	Uplink	Video	HTTP	21.1-63.3
Session 2	2G	Downlink	Video	HTTPS	14.4-21.1
Session 3	2G	Downlink	Image	HTTP	Not Supported
Session 4	2G	Uplink	Image	HTTPS	0-7.2
Session 5	2G	Downlink	Audio	HTTPS	7.2-14.4
Session 6	3G	Downlink	Text	HTTP	7.2-14.4
Session 7	3G	Uplink	Text	HTTPS	21.1-63.3
Session 8	3G	Downlink	Web Browsing	HTTPS	Not Supported
Session 9	3G	Uplink	Image	HTTPS	0-7.2

Table I shows 9 different session characteristics as an example. Since characteristic of a session is formed by 5 major factors, we reach 200 (2x2x5x2x5) possible combinations, therefore 200 distinct session characteristics.

Each of the 200 distinct session characteristics has its own requirements and story. We have come up with the concept of **Expected Throughput** that is ideal throughput value of a session. Formula for expected throughput is devised as follows:

*Expected Throughput = C * Square Root (Net Data Volume)*

where C is a constant value for related session characteristic. Net Data Volume is measured total data volume; the packet header and footer are not included. For each session characteristic, detailed statistical analysis are performed and constant C values are calculated. So 200 different C values are formed.

For any subscriber session, Expected Throughput is calculated by measuring net data volume, square rooting and then multiplying by related constant C value.

In order to test the success of proposed Throughput Evaluation Approach, which is Expected Throughput concept, subscriber complaints are correlated with expected throughput values. All sessions of subscribers who made a complaint about data speed are taken into account. In order to make a correct matching, only sessions

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before actual complaint time are included in the analysis set. During the analysis, it is found that 97.7% of individual subscribers who complained about bad data experience or low data speed fall below expected throughput values within complaint period. As a result, it can be said that the proposed Expected Throughput Approach is successful in evaluating subscriber data experience.

V. Conclusion and Future Work

This paper presented a detailed analysis on experienced throughput values and the problem of evaluation. Depending on analysis results, a new concept of expected throughput was formed and a formula was created.

The solution was easy to use and very applicable in subscriber data experience evaluation. Success rate of the expected throughput concept and formula to reflect real subscriber data experience was very high.

Currently, the solution is in use in Turkcell and feedbacks from our colleagues are very positive.

Acknowledgment

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