4G LTE Network Data Collection and Analysis along Public Transportation Routes

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Abstract— **With the advancements in wireless network technologies over the past few decades and the deployment of 4G LTE networks, the capabilities and services provided to end-users have become seemingly endless. Users of smartphones utilize high-speed network services while commuting on public transit and hope to have a consistent, high-quality connection for the duration of their trip. Due to the massive load demand on cellular networks and frequent changes in the underlying radio channel, users often experience sudden unexpected variations in the connection quality. To overcome such variations and maintain a consistent connection, these variations need to be predicted before they occur. This can be accomplished by the spatio-temporal analysis of the different network quality parameters and the investigation of the main factors that affect the network's performance and QoS. To this end, we conducted a network survey via Kingston Transit in Kingston, Ontario, Canada. We used the Android network monitoring application G-NetTrack Pro to build a dataset of various client-side wireless network quality parameters. The dataset consists of 30 repeated public transit bus trips at three different times of the day, each lasting around one hour. In this paper, we describe the data collection process, present an analysis of the collected data, and investigate the effects of time and location on the network's measured throughput and signal strength. We made the collected data, including more than 190 thousand unique records, publicly available to researchers in a domain where open data is rare.**

Keywords—Cellular Networks, 4G, LTE, Data Collection, Throughput, Signal Strength.

I. INTRODUCTION

Over the years, there has been a dramatic increase in mobile network traffic. The technological advancements in the 4G LTE networks have brought broadband speeds directly to smartphones. Such speeds allow mobile users to access high-speed internet services such as online gaming and video streaming while on a public transit bus. This has significantly increased the load on cellular networks causing fluctuating loads on the network traffic. To cope with this increasing demand, cellular network operators are constantly looking ways to fulfill the clients' expectations. However, this task has many challenges; it requires effective scheduling, network load balancing, and efficient resource allocation. The achieved network quality depends on various factors such as cell tower locations, user's location and time of day. In the past few years, these factors have been studied extensively in the literature. Researchers have taken different approaches to analyze these factors and predict the network quality. However, most approaches were limited by the scarcity of cellular network data available [1]. Consequently, the usage of modern prediction techniques was limited, as most mechanisms require large amounts of data. To solve this problem, researchers directed their efforts towards collecting their own data. However, most of the data collection and analysis performed in the related work focused on 3G networks [2, 3, 4]. In addition to the scarcity of 4G LTE networks analysis, most of the research conducted did not investigate connectivity issues on public transportation [5].

Public transit passengers generate massive amounts of mobile traffic, due to using data-consuming applications such as HD on-demand video streaming. The routes and the bus stops are known in advance, which makes it possible to observe the status of the traffic during the bus trips and note any correlation with network quality of service (QoS). For the previously mentioned reasons, public transit buses are considered attractive candidates for cellular network analysis. In order to perform a precise analysis of 4G LTE networks performance within public transit buses, accurate and reliable data is a necessity. As there is no publicly available dataset of 4G LTE network parameters in Kingston, Ontario, conducting a network survey of 4G LTE network data was required for this research. Therefore, we conducted a user equipment (UE)-based network survey along a 23.4 km public transit bus route covering both urban and suburban areas in Kingston. To consider the effect of time and road traffic conditions, we conducted the measurements at three different times of the weekdays.

The following points are the key contributions of this paper:

- The collection and construction of an exhaustive and large 4G LTE dataset of UE-related wireless network parameters are carried out. This includes signal strength measurements, downlink and uplink throughput measurements, and GPS locations. The data was collected along a public bus route in Kingston, Ontario for over 30 hours, covering a total of 700 km. We noted the effects of varying time and road traffic by performing our measurements three times a day, for a period of ten days.
- We made the collected dataset, that includes more than 190 thousand unique records, available on the publicly accessible data repository, Scholars Portal Dataverse.

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We believe that this will make the dataset accessible by many researchers increasing the number of relevant studies. This will also enhance the process of reproducibility and validation needed by the research community. To the best of our knowledge, this is the most comprehensive 4G LTE measurements open dataset focusing on the public transit bus scenario.

- We performed a thorough analysis on the collected measurements, and investigated the effects of time, location, and hence traffic conditions and number of passengers on the signal strength and throughput measurements. Moreover, we studied the variations of the signal strength and throughput values at different times of the day and analyzed the relationship between the different wireless network parameters and the throughput. To the best of our knowledge, this is the first extensive analysis to be carried out over 4G LTE networks along public transportation in a midsize city like Kingston reflecting the various dynamics of the route.

The rest of the paper is organized as follows. Section II explores the related work. Section III provides an overview of the measurement setup and the collected dataset. An analysis of the data and a discussion of the signal strength and throughput variations are presented in Section IV. In Section V, the limitations of our approach are explained. Lastly, our work is concluded and some future directions are presented in Section VI.

II. RELATED WORK

To analyze the problem of changing wireless network connectivity levels in mobile settings, several data collection campaigns have been reported in the literature. In [2], Xu et al. proposed a system interface called PROTEUS that measures various network performance metrics, such as throughput, loss rate, and one-way delay of the network. They used such collected information to forecast network performance to be exploited by high bandwidth mobile applications. However, their approach was proposed for 3G networks and was not tested on 4G LTE networks. Abou-zeid et al. [3] also investigated wireless connectivity levels in 3G networks by conducting a network survey along the same bus route that is used in our study. They performed 33 repeated bus routes, but they only measured the signal strength along with the GPS coordinates. They analyzed how the geographical, spatial and environmental conditions such as traffic congestion affected the signal strength variations. Nonetheless, they did not collect or analyze throughput data.

Another network survey was conducted on 3G networks by Margolies et al. in [4]. They used Samsung Galaxy S II Skyrocket phones along with the Qualcomm's QXDM tool [6] to measure signal quality to each sector. They did so during different car trips, along highways and suburban roads, and also performed stationary measurements in a more controlled fashion. Furthermore, they investigated the influence of slow fading on the observed channel quality of 3G networks, which is experienced by vehicles moving between different cell towers. In [7], Lu et al. conducted measurements in HSPA+ networks using the QXDM tool. The measurements were conducted by connecting a mobile phone to a host laptop that runs the QXDM software and sending UDP packets to a mobile phone. Nexus 5 phones were the measuring probes, and they performed 24 experiments with different mobility patterns including stationary, walking and driving. It is useful to note that, unlike our approach, QXDM software requires to be installed on a dedicated machine and a phone is then queried to capture physical-layer attributes.

Yao et al. [8] conducted a network survey for eight months, performing 71 repeated car trips to measure mobile bandwidth along a 23 km route in Sydney, Australia. The authors considered different radio conditions, such as terrestrial and underwater tunnels and relied on two different network operators for their measurements using HSDPA technology. In [9], Han et al. carried out a measurement study with 38 repeated car trips along a 5 km route in the campus of Seoul National University, Seoul, South Korea. They measured the downlink throughput of video streaming from 3G and 4G LTE networks. They considered the variations in location, time, humidity, and speed. Aside from time and location, they concluded that predicting the available bandwidth is affected by humidity in 3G networks, while it is affected by speed in 4G LTE networks. It is worth mentioning that both [8] and [9] have complex measurement architectures that require dedicated hardware and software and both studies incorporate relatively few data points. Chaoqun et al. investigated 4G LTE in [10] by conducting a measurement study in the US with seven different mobile phones under various mobility patterns at different times of the day and different locations. The authors collected a wide set of network parameters again using the QXDM tool and a proprietary Android application to investigate link bandwidth predictability. Although the collected dataset looks promising, the authors do not mention whether it is publicly available.

In [11] Samba et al. used a crowdsourcing approach to collect network parameter measurements. Their network survey was conducted by 60 different users in France, who collected a total of 5700 measurements which is still a relatively small number. Their measurements included the RSRP, RSRQ, throughput, distance to cell and speed. However, they did not include the GPS locations of the users and other UE-side network parameters. To analyze the throughput predictability, the users were asked to download a 32 MB file. Furthermore, Jomrich et al. conducted a network survey over three weeks in [5], collecting over 74,000 records of throughput and other network quality parameters, such as RSRP, RSRQ, CQI, and SNR. For performing the measurements, they had to develop their own android application, and used multiple mobile phones. To measure the throughput, they sent and received a packet train of 750 KB of data to a dedicated server. Their collected dataset is publicly available on GitHub, however, it is not obvious how the data points are organized, and the

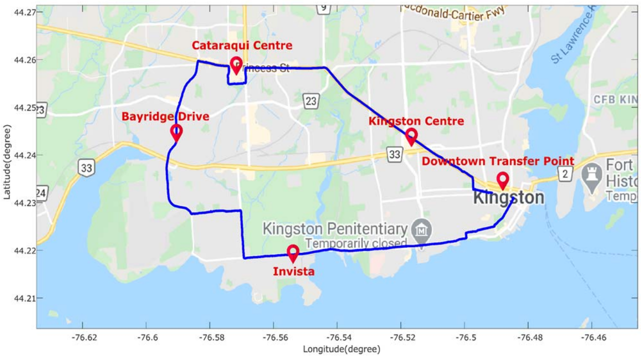


Fig. 1: The 23.64 km trajectory of the Kingston Transit Express Bus 502.

description of the logged attributes is not clear. Lastly, Raca et al. [12] constructed a 4G LTE dataset consisting of various client-side network performance metrics. The data was collected from two Irish mobile operators, using different mobility patterns: stationary, walking, driving, riding a bus and riding a train. They used the G-NetTrack Pro application [13] on an Android phone to conduct the measurements. To analyze transmission medium oscillation, throughput was measured by continuously downloading and uploading a 50 MB file. The dataset is publicly available, but the traces are of relatively short durations and are divided into a spectrum of scenarios leading to fewer data points per each scenario or use case.

III. THE DATASET

To make our collected data comparable to other researchers' works, we chose to use Android phones as our measuring tool. This also makes the whole process easily reproducible. We used the G-NetTrack Pro Android application for obtaining UE measurements, since it is capable of measuring different network quality parameters, downlink, and uplink throughput, as well as some context-related information. Further advantages of using this application are its simple design and low cost with no need of extra dedicated hardware or complex measurement architecture. The G-NetTrack Pro application has a one-second granularity. Granularity in network data collection refers to the time interval between different recorded measurements. A high granularity means a small interval between data records, and vice versa. Two different Android phones with the same Canadian operator were used; a Samsung Galaxy S9 (LTE Category 18) and a Samsung Galaxy S10e (LTE category 20). This is to ensure accuracy and robustness of the collected data and to allow comparing different LTE categories where both of the phones obtain the same set of measurements.

As shown in Table I, the logged measurements include, but not limited to, the reference signal received power (RSRP), reference signal received quality (RSRQ), along with the downlink and uplink throughput. We also collected context information such as the GPS coordinates and speed of the bus, operator information, and neighboring cell information such as the neighboring cell ID, neighboring cell RSRP and neighboring cell RSRQ [14]. Appendix A provides the details of each of these measurements. For downlink and uplink throughput measurement, we continuously downloaded and uploaded a 10 MB file (connection-oriented, TCP) every two seconds, and recorded the achieved throughput using the G-NetTrack Pro application. The measurements were conducted along the Kingston Transit Express Bus 502 route (shown in Fig. 1). The route has a length of 23.64 km, with two major transfer points at Cataraqui Centre and Downtown Transfer Point. The route from the Downtown Transfer Point to Cataraqui Centre is urban, while the route along Bayridge Drive is suburban. To cover scenarios of different context, the measurements were recorded by taking three bus trips every weekday (Monday to Friday) at 9:00 am, 12:00 pm and 6:00 pm for 10 days. Each trip has the same exact route, the same starting and ending points, takes around one hour to complete, and starts and ends at almost the same time every day.

TABLE I. LOGGED PARAMETERS

Parameter Type	Parameter Name
Contextual	Timestamp, Longitude, Latitude, Altitude, Speed, Operator
Cell-related	CellID, LAC, NCell,
Signal Quality-related	RSRP, RSSI, RSRQ, SNR, NRxLev, NQual
QoS-related	Uplink bitrate, Downlink bitrate, PING

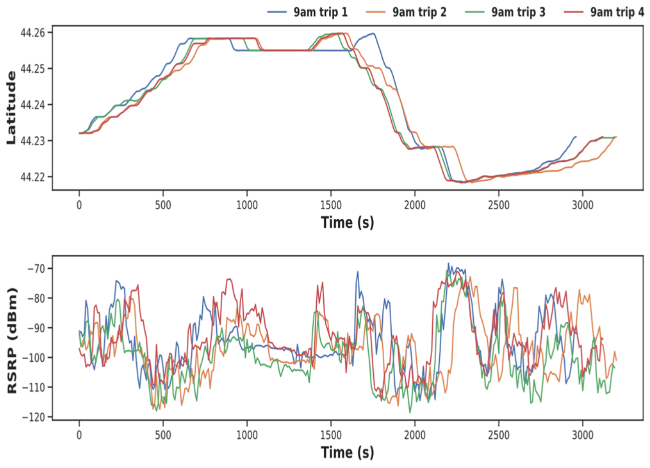


Fig. 2: A Sample of the 9-am-trips latitude and signal strength variation per second.

We managed to collect more than 190 thousand unique data points representing 30 trips covering a total of 700 km in over 30 hours. Our dataset is publicly available on the Scholars Portal Dataverse in an effort to help other researchers in the field conduct cellular network analysis. We took the following aspects into consideration while choosing a platform to deposit our data: long-term availability, accessible data formats, discoverability, ease of use, access, versioning and citing. The size of the dataset is 259 MB, and its files and full description can be accessed at [15].

IV. DATA ANALYSIS

A. Signal Strength Variation

Fig. 2, Fig. 3 and Fig. 4 show the latitude and signal strength (RSRP) vs. time for the three bus rides of the day. In each figure, sample trips from four different days of the campaign are used as an example. We display the latitude graphs on top of the signal strength graphs to show the signal strength with respect to both time and location, and to show

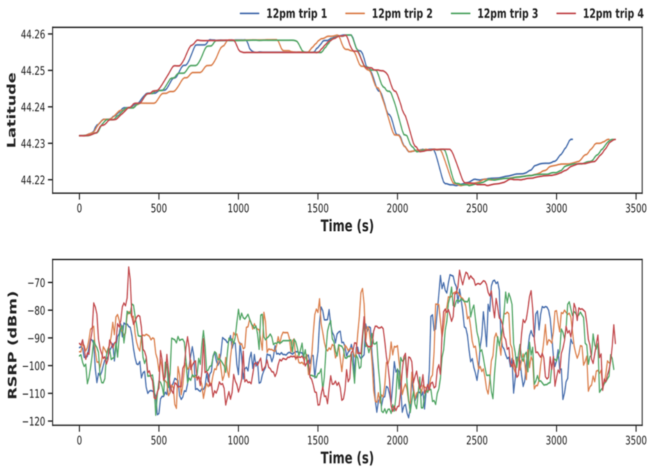


Fig. 3: A Sample of the 12-pm-trips latitude and signal strength variation per second.

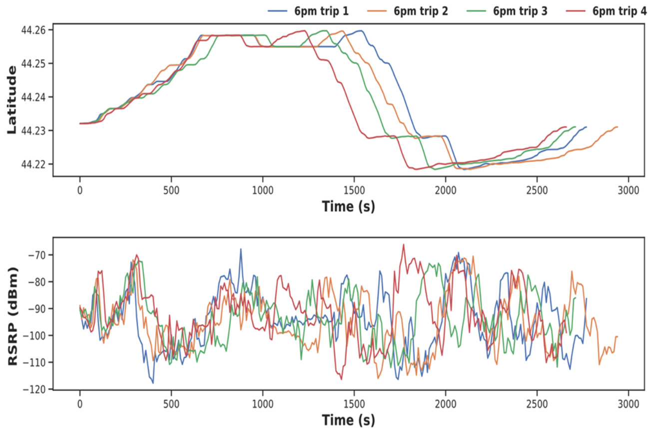


Fig. 4: A Sample of the 6-pm-trips latitude and signal strength variation per second.

the effect of bus delays. The variations between the trips could be caused by various factors, such as traffic lights, bus stops, road traffic levels, and the behavior of different drivers. In the three figures, one can notice that the 6-pm-trip exhibits more time variations than the other two trips; the variance in the latitude is higher than in the 9-am-trip and the 12-pm-trip. This could be due to heavier traffic or a higher level of passenger activity on the bus that we noticed at 6 pm, as this is a typical rush hour. It is important to note that these observations differ from those made by Abou-zeid et. al in [3], which indicated that the measurements were more consistent in the 6-pm-trip than in the 12-pm-trip, as at 6 pm there was less traffic. We believe that this change in conditions is due to the city's development in the last five years and the evolution of cellular networks from 3G to 4G. It is also good to note that the range of values of 4G networks signal strength slightly differs from those of 3G networks, thus the quality ranges are also different. Moreover, one can observe two main consistent dips in the signal strength graphs at 500s and 2000s. These roughly correspond to GPS coordinates (44.24485680, -76.51957566) and (44.22804575, -76.58746690), which are located at Princess Street near Kingston Center and Bayridge Drive, respectively. We can see that the suburban area along Bayridge Drive suffers from a relatively long period of low signal. From Fig. 2 and Fig. 3, one observes that there is not much variation in the latitudes as in Fig. 4. The 9-am-trips and 12-pm-trips are much more consistent with respect to the location variance. However, some minor variations due to context changes, i.e., traffic conditions and number of passengers on the bus are normal.

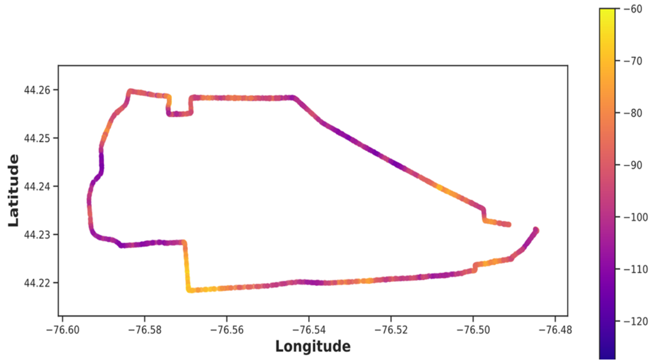
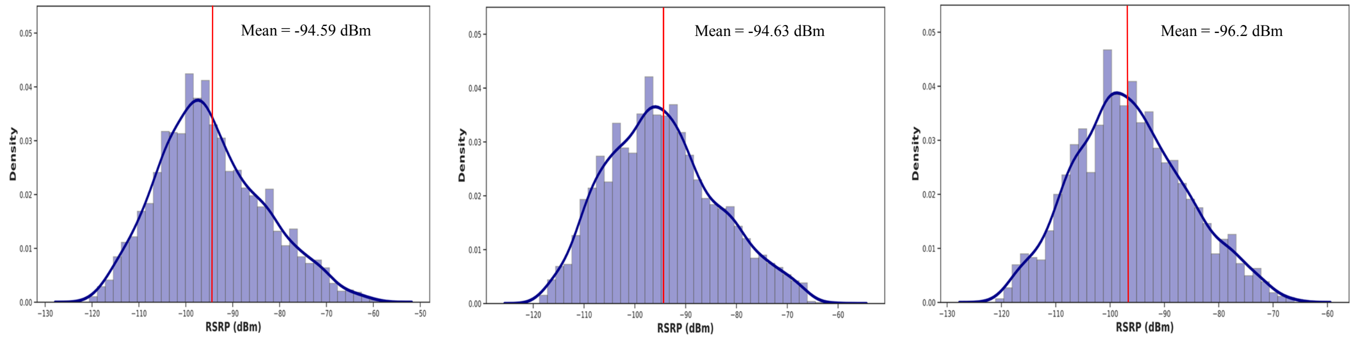


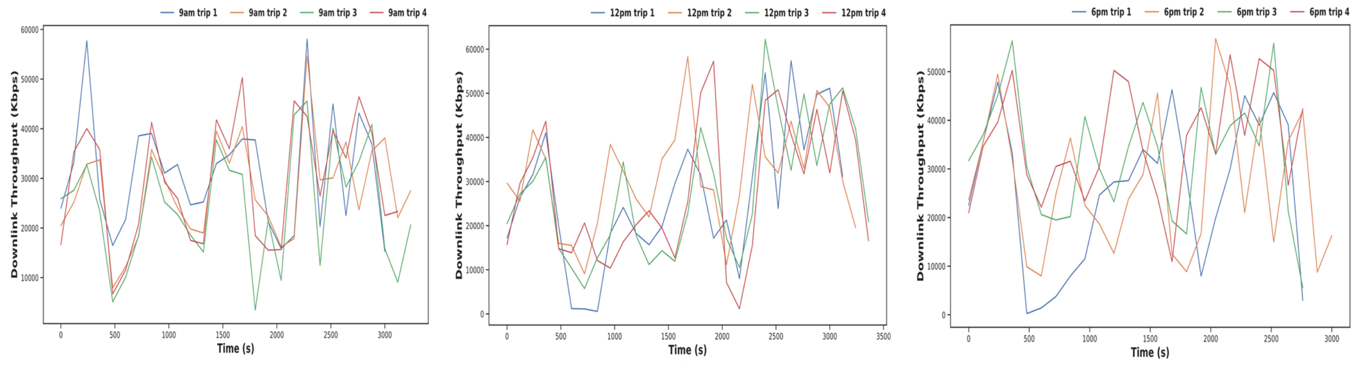
Fig. 6: Average RSRP map of the bus route.

The density plots in Fig. 5 represent the signal strength distributions at each of the three different times. We can infer from these plots that the 6-pm-trips have a slightly lower average signal strength value (-96.20 dBm). This is possibly caused by the increased vehicular traffic at that time; which can influence propagation and can contribute to signal strength variation. Conversely, the distributions for the 9-am-trips and 12-pm-trips have relatively higher signal strength values. Fig. 6 shows a heat map of the average signal strength variation at different locations along the bus route. We can see there are areas of poor signal strength, such as on the road to Cataraqui Centre on Princess Street and on Bayridge Drive.



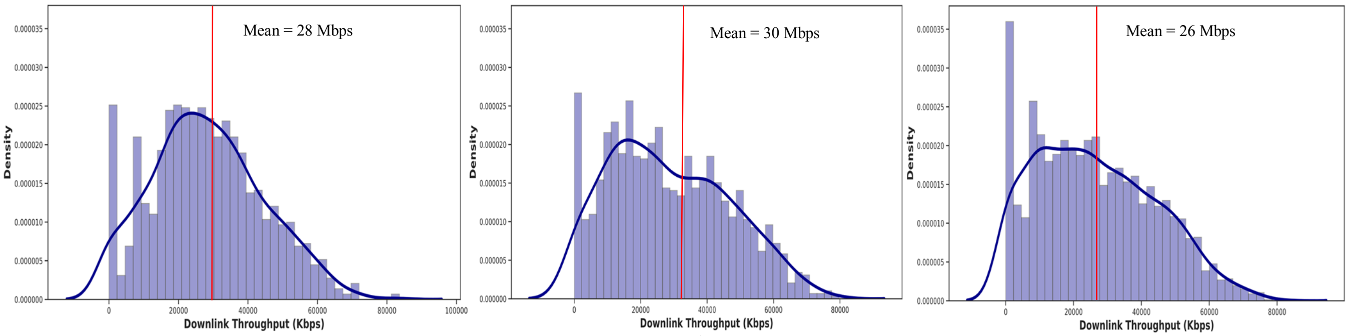
(a) (b) (c)

Fig. 5: RSRP density distribution at (a) 9 am, (b) 12 pm, and (c) 6 pm.



(a) (b) (c)

Fig. 7: Downlink Throughput variation per second for sample trips at (a) 9 am, (b) 12 pm, and (c) 6 pm.



(a) (b) (c)

Fig. 8: Downlink Throughput density distribution at (a) 9 am, (b) 12 pm, and (c) 6 pm.

On the other hand, areas with more demand such as Downtown, Cataraqui Centre, Invista Centre, St. Lawrence College, are shown to have a higher signal strength.

B. *Throughput Variation*

Fig. 7 displays sample downlink throughput values at the 9-am-trips, 12-pm-trips and 6-pm-trips, respectively. In a similar manner to the signal strength, the throughput variation at the 6-pm-trips is much higher than at the other times of the day. In the three figures, we can observe some major dips in the throughput at 500s, 2000s, and in almost all trips at 2900s, which roughly correspond to GPS coordinates of (44.24909641, -76.52827461), (44.22807929, -76.58608385), and (44.22177393, -76.50510436). These coordinates are located at Princess Street near Kingston Center, Bayridge Drive and King Street near Kingston General Hospital, respectively. This is consistent with the low signal strength measurements recorded in these areas, which are caused by the lack of cell towers in these locations.

Fig. 8 shows the density plots of the throughput, which indicates the throughput distributions at each of the three different trip times. It is noted that the throughput measurements in the 9-am-trips are close to a Gaussian distribution, while those in the 12-pm trips have a bimodal-like distribution and the 6-pm trips are right-skewed. Consistently with the signal strength, the throughput in the 6-pm-trips demonstrate lower values possibly due to more users being connected to the same cell, leaving each user with a lower throughput. On the other hand, the distributions for the 9-am-trips and 12-pm-trips exhibit higher throughput values. The mean throughput in the 6-pm-trips is 26 Mbps, while it is 28 Mbps and 30 Mbps in the 9-am-trips and 12-pm-trips, respectively. The heatmap in Fig. 9 shows the variation of the average downlink throughput along the bus route. In consistence with the signal strength values in Fig. 5, the achieved throughput is low on the way to Cataraqui Centre and on Bayridge Drive. This is also in agreement with the fact that there are less cell towers located in each of these areas, as shown in the map in Fig. 10. The uplink throughput also follows a pattern similar to what is shown in Fig. 7 and Fig. 9 while naturally having lower values. The figures were omitted to conserve space. It is worth noting that the figures included in this section were generated using the data collected by the Samsung Galaxy S9 phone. The data logged by the Samsung Galaxy S10e phone exhibits a slightly different pattern especially when it comes to downlink and uplink throughput. The average throughput values achieved by the S10e phone is lower than those achieved by the S9 phone. Additionally, the S10e's throughput data is less consistent and more skewed.

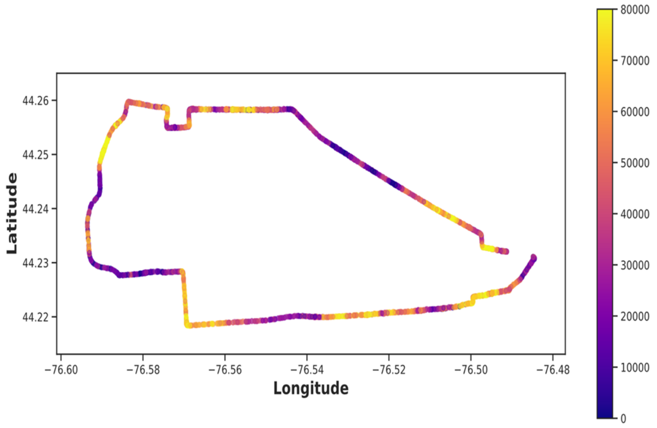


Fig. 9: Average downlink throughput map of the bus route.

V. LIMITATIONS

A key limitation to our approach is the measurement granularity. The maximum possible granularity for the Android API is only one second. The measurement granularity is crucial for determining the accuracy of the throughput prediction algorithms; the higher the granularity, the more accurate the instantaneous throughput prediction could be. In addition, network operators often refuse to make their data public for privacy concerns. For this reason, we only had access to the operator's client-side data. Network operators can offer information about the cellular network performance, such as the average throughput of each cell, the average number of users, the connection success rate and the Block Error Rate. Another limitation is that the G-NetTrack Pro application uses transmission control protocol (TCP) for throughput measurement. As a result, the measured throughput is impacted by external factors such as congestion window, retransmission, and packet loss. Furthermore, it is not an open tool, which poses minor concerns about wide adoption. However, it is still affordable and has been used in academic context as highlighted in section II.

VI. CONCLUSION AND FUTURE WORK

In this paper, we presented a new data collection survey, and performed an in-depth analysis of the collected data to investigate the effects of the geographical area, time and

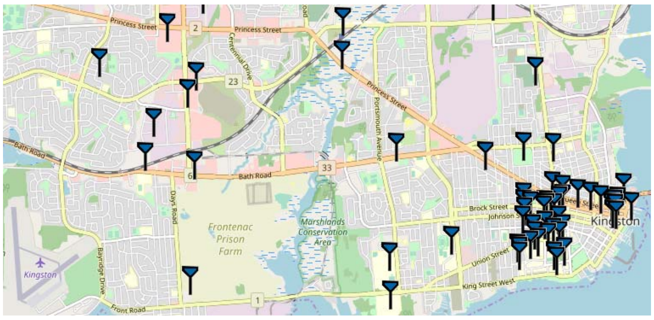


Fig. 10: Operator's cell tower locations in Kingston.

Reprinted from Canadian Cellular Towers Map, by Steven Nikkel, retrieved from https://www.ertyu.org/steven_nikkel/cancellsites.html/ by Steven Nikkel.

contextual factors such as bus stops and number of passengers on the network performance and quality.

Our analysis shows that there are significant fluctuations in the network connectivity at different times of the day. At 6:00 pm, the mean signal strength and throughput measurements are notably less than at 9:00 am and 12:00 pm. Furthermore, the location variations at 6:00 pm were much higher than at the other two times of the day. We believe this occurs because there is more traffic on the road and more active passengers on the bus at 6:00 pm, which in turn causes an increased network traffic at this time. From these observations, one can conclude that the time of the day and the road traffic condition play an important role in controlling the network QoS. Moreover, we showed that some locations along the bus route exhibit remarkably lower signal strength and throughput values. This is mainly due to the lack of cell towers located in these areas, compared to other areas along the bus route. We feel that network operators could greatly enhance the network connectivity and the overall user Quality of Experience (QoE) by deploying more towers at these locations.

The collected data is publicly available on the Scholars Portal Dataverse. The following points indicate some future directions for studies that can be conducted on the data:

- The collected dataset can be used for throughput prediction, based on other network quality parameters present in the dataset which could be used to enhance user QoE in many ways.
- User mobility prediction could be performed by investigating the correlation between mobility and the various cellular network parameters.
- Since the dataset contains information about the GPS locations of the device and serving cells and their IDs, as well as channel parameters of the serving cell and neighboring cells, handover analysis could be applied on the data.
- The data could be used for predictive resource allocation mechanisms, such as content prefetching, which relies on the awareness of user location and the experienced data rate.

REFERENCES

[1] G. Barlacchi, et al., "A multi-sourcedataset of urban life in the city of milan and the province of trentino," *Scientific data*, vol. 2, p. 150055, 2015.

[2] Q. Xu, S. Mehrotra, Z. Mao, and J. Li, "Proteus: network performance forecast for real-time, interactive mobile applications," in *Proceeding of the 11th annual international conference on Mobile systems*, applications, and services, 2013, pp. 347–360.

[3] H. Abou-zeid, H. S. Hassanein, Z. Tanveer and N. AbuAli, "Evaluating mobile signal and location predictability along public transportation routes," in *2015 IEEE Wireless Communications and Networking Conference (WCNC)*. IEEE, 2015, pp. 1195–1200.

[4] R. Margolies, A. Sridharan, V. Aggarwal, R. Jana, N. K. Shankaranarayanan, V. A. Vaishampayan, and G. Zussman, "Exploiting mobility in proportional fair cellular scheduling: Measurements and algorithms," *IEEE/ACM Transactions on Networking*, vol. 24, no. 1, pp. 355–367, 2014.

[5] F. Jomrich, A. Herzberger, T. Meuser, B. Richerzhagen, R. Steinmetz, and C. Wille, "Cellular Bandwidth Prediction for Highly Automated Driving - Evaluation of Machine Learning Approaches based on Real-World Data," in *Proc. of the 4th International Conf. on Vehicle Technology and Intelligent Transport Systems,* vol.1, pp. 121-132, Funchal, Madeira, Portugal, 2018.

[6] Qualcomm eXtensible Diagnostic Monitor Professional. http://www.qualcomm.com/documents/qxdm-professional-qualcomm-extensible-diagnostic-monitor.

[7] F. Lu, H. Du, A. Jain, G. M. Voelker, A. C. Snoeren, and A. Terzis, "Cqic: Revisiting cross-layer congestion control for cellular networks," in *Proceedings of the 16th International Workshop on Mobile Computing Systems and Applications*, 2015, pp. 45–50.

[8] J. Yao, S. S. Kanhere, and M. Hassan, "An empirical study of bandwidth predictability in mobile computing," in *Proceedings of the third ACM international workshop on Wireless network testbeds, experimental evaluation and characterization*, 2008, pp. 11–18.

[9] D. Han, J. Han, Y. Im, M. Kwak, T. T. Kwon, and Y. Choi, "Maserati: Mobile adaptive streaming based on environmental and contextual information," in *Proceedings of the 8th ACM international workshop on Wireless network testbeds, experimental evaluation & characterization*, 2013, pp. 33–40.

[10] C. Yue, et al., "Linkforecast: Cellular link bandwidth prediction in lte networks," *IEEE Transactions on Mobile Computing*, vol. 17, no. 7, pp. 1582–1594, 2017.

[11] A. Samba, Y. Busnel, A. Blanc, P. Dooze, and G. Simon, "Instantaneous throughput prediction in cellular networks: Which informationis needed?" in *2017 IFIP/IEEE Symposium on Integrated Network and Service Management (IM)*. IEEE, 2017, pp. 624–627.

[12] D. Raca, J. J. Quinlan, A. H. Zahran, and C. J. Sreenan, "Beyond throughput: a 4g lte dataset with channel and context metrics," in *Proceedings of the 9th ACM Multimedia Systems Conference*, 2018, pp. 460–465.

[13] G-NetTrack Pro Application. https://www.gyokovsolutions.com/G-NetTrack%20Android.html.

[14] M. Sauter, *From GSM to LTE-advanced Pro and 5G: An introduction to mobile networks and mobile broadband*. John Wiley & Sons, 2017.

[15] H. Elsherbiny, A. M. Nagib, and H. S. Hassanein, "4G LTE User Equipment Measurements along Kingston Transit 502 Bus Route," 2020. [Online]. Available: https://doi.org/10.5683/SP2/EQWKO1

APPENDIX A

- Timestamp: precise time when the measurement is taken.
- Longitude, Latitude and Altitude: the GPS coordinates of the mobile device.
- Speed: speed of the bus at the time of measurement in km/h.
- Operator: combined codes which are used to identify a mobile network operator uniquely.
- CellID: cell ID of serving cell.
- LAC: location area code of serving cell, a unique identifier used by each public land mobile network (PLMN) to update the location of mobile subscribers.
- RSSI: received signal strength indicator, a measure of the power present in a received radio signal.
- RSRP: reference signal received power; this is the measure of power of the LTE reference signals spread over the full bandwidth and narrowband.
- RSRQ: reference signal received quality, indicates the quality of the received reference signal.
- SNR: signal-to-noise ratio, which is the ratio of signal power to the noise power, expressed in decibels.
- Downlink/Uplink bitrate: current downlink/uplink bitrate at the time of measurement expressed in kbps.
- NCell: ID of neighboring cell.
- NRxLev: RSRP of neighboring cell.

NQual: RSRQ of neighboring cell.