Application Benchmark for Cellular Backhaul Network

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Abstract— **Recent studies have shown that global mobile data traffic has risen dramatically over the past five years. New network technologies and devices are introduced to handle the ever increasing traffic demand. An accurate application benchmark is required to evaluate the performance of these new cellular network infrastructures and devices. In this study, we measure and characterize the behaviour of popular cellular network applications such as video streaming, web browsing, file sharing, Voice over IP and Instant Messaging. The characterization includes both laptop and smartphone traffic and is expressed in the form of packet size and packet inter arrival time histograms. These histograms are required for the configuration of many synthetic traffic generation tools.**

Keywords- Application characterization, cellular backhaul network benchmark, traffic generation.

I. INTRODUCTION

Recent traffic reports have shown that global mobile data traffic has grown 69-percent in 2014, it is expected to surpass 24.3 exabytes by 2019 and mobile video traffic is accountable for 55 percent of all traffic [1]. The increasing use of smartphones, tablets and laptops connected to mobile networks, in addition to fourth generation (4G) deployment and the acceleration of network connection speeds only partially account for this growth. New network technologies, protocols and devices have been introduced to handle the ever - increasing mobile demand. In order to reliably evaluate the performance of such emerging technologies, protocols and network devices, we need a realistic evaluation framework reflecting the current and forecasted traffic patterns. Characterizing application behaviour in terms of packet size distribution and packet inter-arrival time distribution is especially important for evaluating quality-of-service and user experience of new traffic policies, anomaly detections, active queue algorithms, application classifications, and scheduling algorithms (see, some examples in [2]-[4]). Furthermore, most traffic generation tools (see a comprehensive list of traffic generators in [5]) require either a learning trace to fit their synthetic generated traffic to accurate real traffic distributions or a manual configuration of the traffic distributions. As a result, an additional time consuming measuring phase is needed for proper operation of such tools.

For this purpose, we actively measured and analysed the traffic distributions of the top most popular applications in cellular networks: video streaming, file sharing, web browsing, and Voice over IP (VoIP). According to Allot Mobile Trends [6], the traffic share of these applications represents more than 95% of the mobile broadband traffic. The traffic in this study was generated by both laptops and smartphones, and the characterization is expressed in terms of packet size and packet inter-arrival time histograms. Our results can be used for fast and accurate configuration of traffic generation tools, applications traffic modelling, analysis of new traffic policies, active queue algorithms, scheduling algorithms, or for statistical application classifications. Previous internet traffic studies have analysed the packet size distribution of IP packets on the Internet [7]-[10]. We differ from these studies in several ways. First, our measurements were performed over a cellular network and on mobile devices and not over the Internet. Second, we analysed distributions per-application and not the overall packet size distribution. This is essential for the evaluation of devices and algorithms that support more than one class of service. Third, in addition to the packet size distribution, we analysed the packet inter-arrival time distribution. This distribution is important, for example, for queue size tuning. Finally, to improve our understanding of application behaviour, we characterized uplink traffic and downlink traffic separately. Bonfiglio et al [11], provide detailed analysis of Skype traffic, but the measurements are from the campus Local Area Network (LAN). In [12], smartphones traffic is analysed but the analysis did not include packet size and packets inter-arrival time histograms.

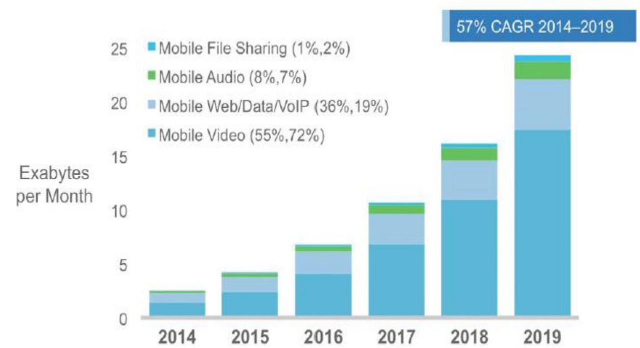

Figure 1. Traffic Share, by CISCO VNI Mobile 2015 [1]

This article is organized as follows. In Section 2, we present the data collection. Section 3 provides the application characterization results. Finally, Section 4 reports our conclusions.

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II. DATA COLLECTION

We recorded single user scenarios of the most popular applications: video, file sharing (downloading), browsing and VoIP to obtain an active dataset. The traffic was recorded from three iPhone devices and two laptops connected via a wireless modem to a cellular network. The measurements were done over two different cellular networks. For each device, we capture single user scenarios over *live* network during peak and non peak hours. As a result, any impact of other devices/users on our measured devices is incorporated in the traffic statistic behavior. Each scenario was repeated ten times. In each time, the device cache and cookies were cleared. According to Allot Mobile Trends [6] and to CISCO Mobile Trend report [1], these applications represent the mobile broadband application share as presented in Figure 1 above. They describe the subscriber behaviour that is likely to shape the future of the mobile internet. Their share of overall bandwidth has risen in 2014. In the second half of 2014, video streaming continued to dominate the mobile broadband with more than 55 percent of the global mobile data traffic, reflecting the demand for real-time experience. On the other hand, file sharing, which offers a delayed experience, consists of only 2 percent of overall bandwidth. In the following subsections, we describe the trace collection process per application type.

A. Video data collection

The trace collection for video streaming application included both cellular operator portal videos and Internet videos.

1) *Video Content:* Three of the most frequent video content types were included in this trace collection: football, news and music clips. The major characteristics of football are the prevailing green field and the fast moving ball. Therefore, the transmissions of this video type leads to intensive traffic. A news video is characterized by a small number of slow changes which naturally result in different transmission patterns. A music clip is a mixture of different characteristics. Scenes do not move quickly, but they change often and rapidly.

2) *Data Collection of Videos from Cellular Operators Portal:* The trace collection involved a single user connected to the video directory in a operator portal server. The videos from the operator portal consisted of the three video clip types as described above. This traffic generation operation repeated ten times. Each time, the cache and cookies were cleared.

3) *Data Collection of Video from the Internet:* The trace collection involved a single user connected to the Internet via the cellular operator network browsing to video sites. The video sites were YouTube [13] and Ynet [14] and the specific videos consisted of the three video clip types as described above. This traffic generation operation was repeated ten times using the same videos every time. Each time, the cache and cookies were cleared.

B. File sharing data collection: file download/upload data collection and Peer to Peer data collection

The applications in this data set were File Transfer Protocol (FTP) and Hypertext Transfer Protocol (HTTP)-download. The FTP scenarios included both PUT and GET sessions. A single user downloaded/uploaded data using FTP GET and PUT/HTTP download data to a FTP/web server located in our demilitarized zone (DMZ). The objects were files of 1MB, 10MB, 20MB, and 50MB in size. The traffic generation operation was repeated ten times. The file sharing, Peer to Peer (P2P) application types included both BitTorrent and eDonkey sessions. The file was large (more than 500MB). This traffic generation operation was repeated ten times for each P2P application.

C. Browsing data collection

The trace collection for browsing included captures of browsing the top 5 popular Israeli sites according to Alexa rating [15]: Google [16], Facebook [17], Walla [18], Wikipedia [19], and Mako [20]. This traffic generation operation was repeated ten times. Each time, the cache and cookies were cleared.

D. VoIP, IM, Signalling, and SMS data collection

The trace collection for VoIP included talks of approximately five minutes each with pre-defined lines between two users. The VoIP application used was Skype. The first user's laptop ran Skype and was connected via a wireless connection with a data card connected to a cellular operator network. The second user was connected via our network to the Internet and also ran Skype. The following trace collection was used for signalling and Short Message Service (SMS) traffic. The user was on a moving train and connected to a cellular operator network. At certain intervals, the user sent a pre-defined SMS to a specific destination. This traffic generation operation was repeated ten times.

III. RESULTS

The benchmark analysed each of the following applications in terms of packet size and the packet inter-arrival time in both the uplink (to the network) and downlink (to the user) directions. The information was represented in the form of a histogram – where the packet size histogram was divided into 40 byte bins, and the packet inter-arrival time was divided into 200 millisecond bins.

A. Video Streaming

As mentioned in Section 2, recordings of the video streaming application included both a cellular portal and an internet video. The content of the videos were football, news and music video clips, which characterize intensive traffic (football), variable traffic patterns (music clip) and slow transmission patterns (news).

1) *Video Streaming Packet Size Analysis:* The video streaming packet size histogram is presented in Figure 2. The uplink stream was characterized by more than 95 percent of small packets (40-80 bytes). The downlink stream was

characterized by large packets; between 77 percent (iPhone) and 85 percent (laptop) of the packets were 1440-1560 bytes.

2) Video Streaming Packet Inter-arrival Time Analysis: The video streaming packet inter-arrival time histogram is presented in Figure 3. In both directions, the packet inter-arrival time was very low, and more than 95 percent of the packets had an inter-arrival time of less than 200 milliseconds. More than 10 percent of the packets in the uplink flows had a zero inter-arrival time and more than 85 percent of the packets were less than 200 milliseconds. The downlink flows had more zero inter-arrival packets (25 percents); thus, only 60 percent of the packets had an inter-arrival time of less than 200 milliseconds. Note that “zero” is not really a zero inter-arrival time but appears as such because it is lower than the time resolution of the application (Wireshark [21]) used to captures these recordings.

B. File sharing

As mentioned in Section 2, recordings of file download and upload included FTP, HTTP download on both Bitorrent and eDonkey sessions. The sizes of the files downloaded were 1 MB, 10 MB, 20 MB and 50 MB. The P2P sessions were used to download a large file (more than 500 MB).

1) File Sharing Packet Size Analysis: The file sharing packet size histogram is presented in Figure 4. Almost 100 percent of the packets in the iPhone’s upload recordings were small packets: 40-80 bytes in size. In the laptops recordings, 72 percent of the packets were small and only around 23 percent were large packets of 1400-1480 bytes. The downlink stream was characterized by large packet size; 44 percent of the packets were 1440-1480 bytes and more than a one third of the packets were 1520-1580 bytes. The mid-size packets (1040-1120 bytes) accounted for 21 percent of the packets on the iPhone, and only 6 percent of the laptop captures. Small packets (40-80 bytes) also accounted for 10% for the laptops.

2) File Sharing Packet Inter-arrival Analysis: The file sharing inter-arrival time histogram is presented in Figure 5. Both in the uplink and the downlink traffic the packet inter-arrival time was extremely low. More than 95 percent of the packets had an inter-arrival time below 200 milliseconds. The uplink captures consisted of approximately 50 percent of the packets with a zero inter-arrival time (that is, smaller than 0.1 milisecond), and the remainder with an inter-arrival time of less than 200 milliseconds. The downlink captures were composed of more than 65 percent of packets with a zero inter-arrival time, and around 30 percent of the packets with an inter-arrival time of less than 200 milliseconds.

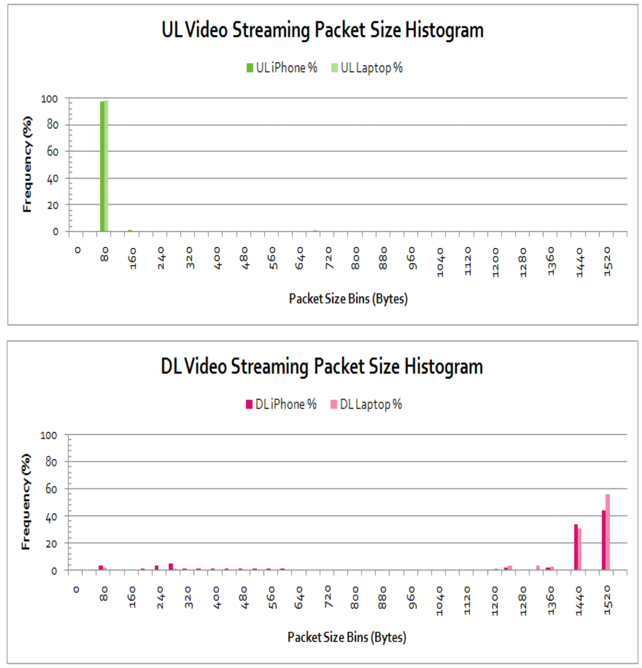

Figure 2. Video Streaming Packet Size Histogram

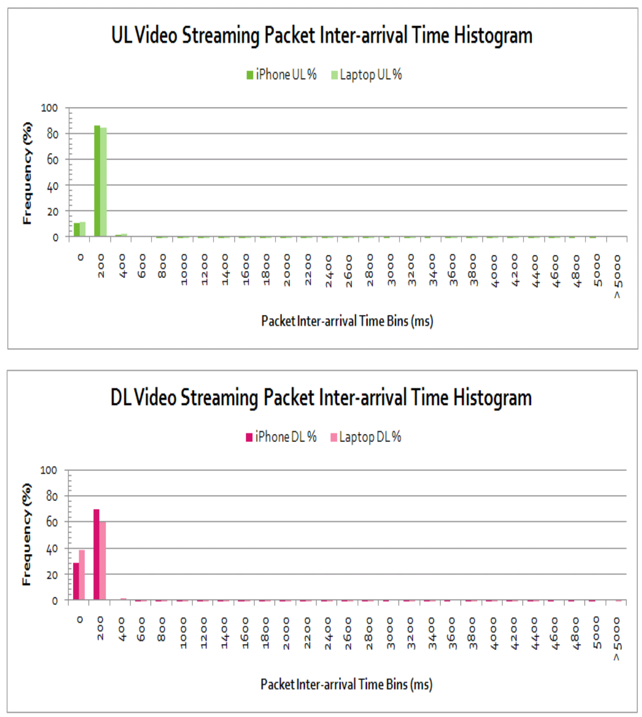

Figure 3. Video streaming Packet Inter-arrival Time Histogram

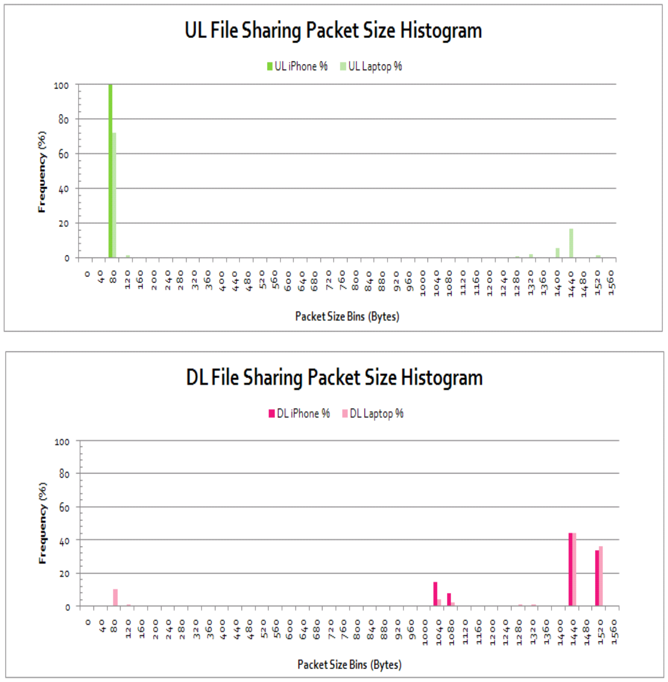

Figure 4 File Sharing Packet Size Histogram

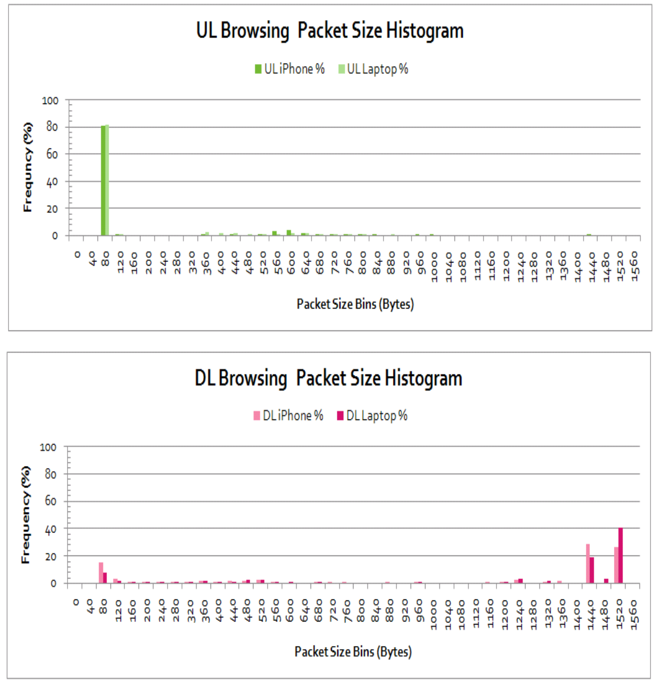

Figure 6. Browsing Packet Size Histogram

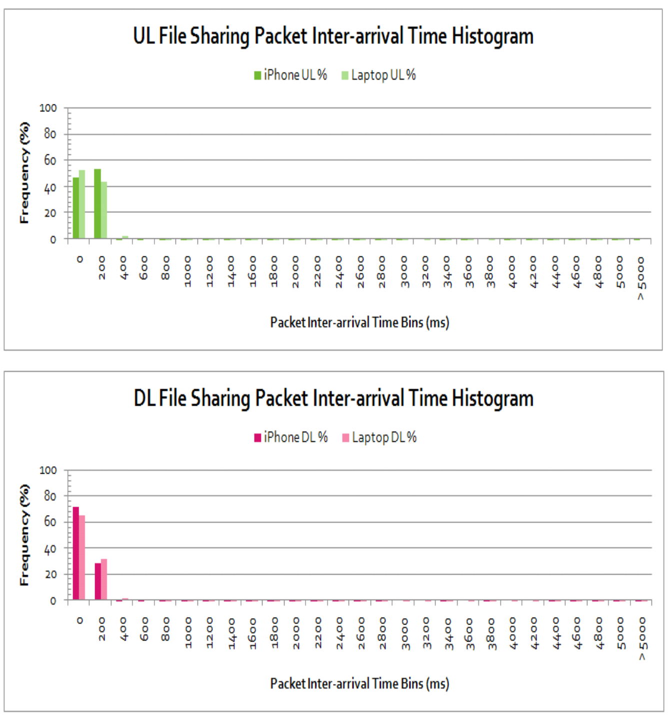

Figure 5. File Sharing Packet Inter-arrival Time Histogram

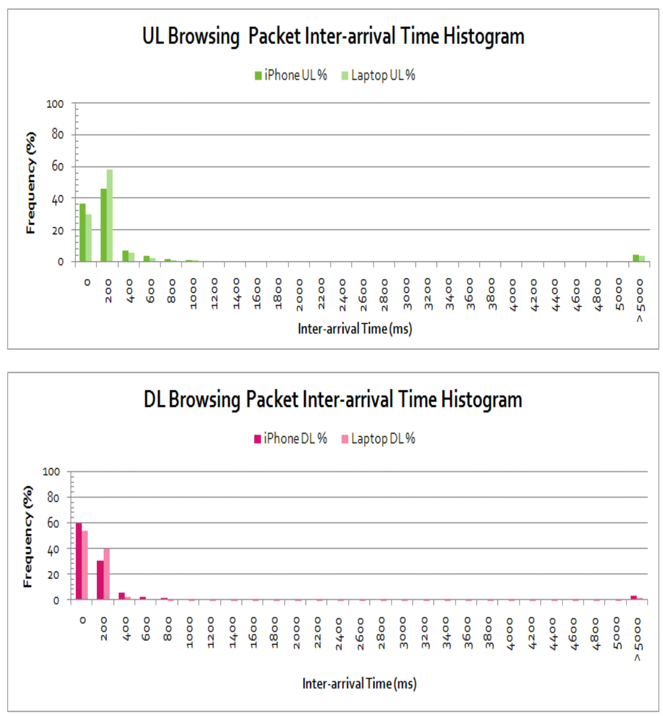

Figure 7. Browsing Packet Inter-arrival Time Histogram

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C. Web Browsing

As mentioned in Section 2, recordings of browsing were of the top five popular live websites in Israel according to [15].

1) Web Browsing Packet Length Analysis: The Web browsing packet size histogram is presented in Figure 6. Though exhibiting the same tendency, the iPhones downlink browsing traffic was somewhat different from the laptop downlink browsing traffic. All in all, the majority of the packets were large, in the range of 1440-1480 bytes and 1520-1560 bytes. Some small packets from 40 bytes to 80 bytes were observed as well. The uplink browsing traffic for both the iPhone and laptop was characterized by small packets with more than 80 percent of the packet lengths between 40 bytes and 80 bytes. The rest of packets were evenly distributed throughout the range with 10 percent divided between mid-size packets (360 bytes to 680 bytes).

2) Web Browsing Packet Inter-arrival Time Analysis: The Web browsing inter-arrival time histogram is presented in Figure 7. The iPhone and the laptop recordings on both uplink and downlink streams presented the same trend but with different percentages. The downlink and the uplink traffic were characterized by a very low packet inter-arrival time; more than 90 percent of the packets had an inter-arrival time of less than one second. One third of the packets had a zero inter-arrival time for the uplink traffic. Around half of the packets had an inter-arrival time of less than 200 milliseconds. Four percent of the packets had an inter-arrival time of more than 5 seconds. More than 53 percent of the packets had a zero inter-arrival time for the downlink traffic, and more than a third of the packets had an inter-arrival time of less than 200 milliseconds. Only 3 percent of the packets had an inter-arrival time of more than 5 second.

D. VoIP, IM, Signalling, and SMS

As mentioned in Section 2, recordings included conversations on Skype of approximately five minutes between two users with predefined talk content.

1) VoIP and IM Packet Length Analysis: The VoIP and IM packet size histogram is presented in Figure 8. Uplink streams consisted of mostly small packets at 40-80 bytes whereas the downlink streams also had 12 percent of large packets of 1440-1560 bytes.

2) VoIP and IM Packet inter-arrival Time Analysis: The VoIP and IM inter-arrival time histogram is presented in Figure 9. In both directions, more than 87 percent of the packets had an inter-arrival time of less than a second. Whereas in the uplink stream more than 40 percent of the packets had a zero inter-arrival time and 20 percent were less than 200 milliseconds, the downlink exhibited the reverse pattern: only 20 percent of the packets had a zero inter-arrival time and 40 percent had less than a 200 millisecond inter-arrival time. In both directions 4 percent of the packets had an inter-arrival time exceeding 5 seconds.

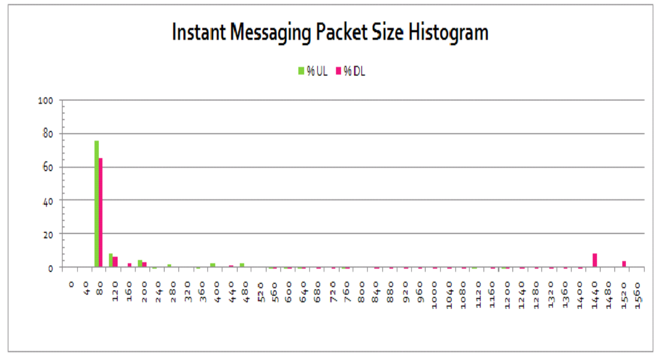

Figure 8. VoIP and IM Packet Size Histogram

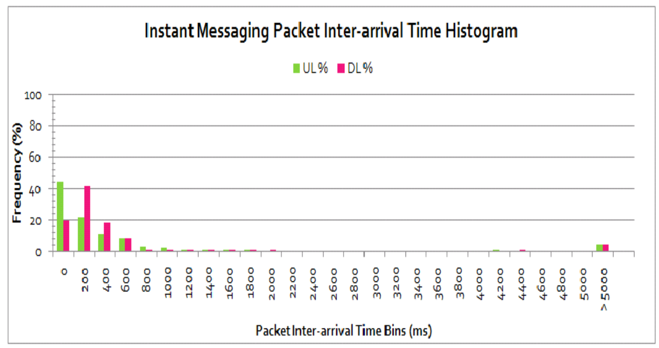

Figure 9. VoIP and IM Packet Inter-arrival Time Histogram

IV. CONCLUSIONS

This study aimed at:

- The measurement and dataset collection of traffic in cellular networks from laptops and smartphones of the most popular applications in cellular networks: video streaming, file sharing, web browsing, and VoIP.
- Per application characterization in terms of packet size and packet inter-arrival time histograms that can be used for traffic generation tool configurations, or for applications traffic modelling and analysis or for statistical application classification.

In terms of characterizing these applications, the analysis shows that:

- Video streaming, web browsing and file sharing have very short packet inter-arrival times (less than 200 ms) and have similar distributions. VoIP and IM have longer packet inter-arrival times. We believe that this is a result of the relatively slow human interaction integrated in these applications.

- The packet sizes of smartphones are slightly smaller than the packet sizes of laptops.
- Video streaming, web browsing and file sharing have asymmetric packet size distributions in the downlink and uplink directions. The packet sizes in the downlink direction are usually large (> 1440 Bytes) whereas the packet sizes in the uplink direction are usually small (< 100 Bytes). That is, current packet sizes seem mostly bimodal at 80B for uplink traffic and 1440-1560B for downlink traffic. This observation supports a previous recent Internet measurement study [8] but with slightly different values (40B and 1500B were reported in [8]). This observation represents a shift away from the common wisdom such as the pre-2000 data that reported tri-modal packet sizes around 40, 576, and 1500B [9].
- VoIP and IM have symmetric packet size distributions in the downlink and uplink directions. The packet sizes in both directions are small (< 100 Bytes). This observation supports a previous recent LAN measurement study [11]. However, the observed inter-arrival times were significantly larger in our measurements. A possible explanation is the difference between LAN and cellular backhaul network behavior.
- In the downlink direction of file sharing applications, we observed an additional common value range around 1040-1080B.

For fast traffic generation tools configuration, Table I summarizes the packet size average and standard deviation per application and Table II summarizes the packet inter-arrival time average and standard deviation per application.

TABLE I. PACKET SIZE STATISTIC (BYTE)

Application	**Uplink**		**Downlink**	
	Mean	Std.	Mean	Std.
Browsing	201	247	1147	535
File Sharing	389	550	1321	409
Video	114	94	1329	411
IM	153	1	328	470

TABLE II. PACKET INTER ARRIVAL STATISTIC (MSEC)

Application	**Uplink**		**Downlink**	
	Mean	Std.	Mean	Std.
Browsing	470	983	311	726
File Sharing	235	378	188	290
Video	345	527	265	355
IM	647	1188	717	1218

ACKNOWLEDGMENT

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