# Measurement Analysis of Mobile Traffic in Enterprise Networks

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*Abstract*— **The number of mobile devices and the amount of mobile traffic are increasing rapidly. The users of mobile device use various services such as web surfing, email, video and audio streaming, etc. Analyzing mobile traffic is necessary to provide high quality mobile network services such as QoS management, traffic engineering, etc. In fact, several multi-flow applications consume a lot of mobile network resources. In this paper, we performed measurement analysis to observe not only application-level traffic characteristics, but also device-level traffic characteristics in terms of traffic volume and flow characteristics. We present the relationship between application traffic and its origin device to understand the application traffic generation from the different types of devices.**

***Keywords-Network Monitoring and Measurement; Mobile Traffic Measurement***

## I. INTRODUCTION

The number of mobile devices and the amount of mobile traffic are increasing rapidly. The users of mobile devices use various services such as web surfing, email, video and audio streaming, etc. Network traffic generated by mobile devices is increasing at this very moment along with the number of smartphone users and mobile services (or applications). Statistics about increase of wireless traffic supports this phenomenon [9]. The statistics showed that wireless traffic in the United States increased 73% from 2007 to 2009. Consequentially, need for understanding mobile traffic and its characteristics is essential to provide high quality mobile network services and becomes one of major issues in network management research area.

One of difficulties to understand mobile traffic is the diversity of applications and mobile devices. On App Store and Android market there are about six hundred thousands of mobile applications even though it is only around 4 years since application-installable smart handheld devices are introduced. In fact, network operators sometimes block or limit certain application traffic, such as P2P traffic, to allocate network resource fairly. For example, BitTorrent consumes most bandwidth on the network by generating hundreds of traffic flows at the same time, which is also observed in the mobile network. Today's mobile file sharing and multimedia applications have required high quality network services. Thus, understanding their traffic characteristics is necessary for network operators to provide high quality service of mobile networks in terms of QoS and traffic management.

Another challenge in mobile traffic analysis is to identify the origin of flows. Wi-Fi access points (APs) are widely used and most APs utilize Network Address Translation (NAT) functionality to support multiple devices with a single IP address. In the other words, source addresses and ports do not guarantee identifying the origin of flows. For this reason, network operators cannot distinguish whether the flows generated by a single device or two more different devices if the source address and port are the same.

In this paper, we performed measurement analysis to observe not only application-level traffic characteristics, but also relationship between the applications and devices in terms of traffic volume and flow characteristics.

## II. RELATED WORK

In previous studies, mobile traffic measurement and analysis aimed to show traffic usage information for mobile networks.

*Won et al.* analyzed the mobile data traffic trace of a CDMA network [1]. The authors observed several unique traffic characteristics. These days, however, new types of mobile devices, such as smartphones, are popular and new mobile applications appear all the time.

*Maier et al.* studied the characteristics of hand-held mobile device traffic monitored on DSL lines [2]. They observed that iPhones and iPods generated most mobile traffic and HTTP is the most used protocol in TCP. However, the results are not able to explain the characteristics of mobile traffic because of the limited number of analysis categories.

*Falaki et al.* collected traffic logs from 43 users by deploying a smartphone application [3]. They deployed the smartphone application on each device and analyzed the port distribution, application-level traffic usage, and mobile traffic flow characteristics. Even though the authors obtained mobile traffic data and measured the traffic usage precisely, the analysis result could be biased because of the small dataset.

*Gember et al.* compared handheld and non-handheld device traffic in campus Wi-Fi networks in terms of the content-types and flow characteristics [4]. However, the study's device identification method, which is based on the HTTP user-agent and MAC address, cannot be applied to non-HTTP traffic and backbone traffic monitoring environments.

In this paper, we define mobile devices as wireless network accessible devices including laptop, and smartphone [8]. Mobile traffic is generated by such mobile devices when users access Internet through Wi-Fi APs. Our measurement study is performed on Wi-Fi traffic monitored at Internet junction. Our classifier to categorize the types of devices is based on OS fingerprint approach [6] that detects operating system of traffic flow using TCP option fields. We can collect sufficient mobile traffic trace easily without any extra equipment and applications.

## III. MOBILE TRAFFIC MEASUREMENT ANALYSIS

We collected mobile traffic traces from the Internet junctions at the residential area of POSTECH, a university with a user population of about 4,000 people and 1,000 deployed Wi-Fi APs. To avoid packet loss, a monitoring probe equipped with an optical tap and Endace DAG 4.3 GE card [5] was used to monitor 500 Mbps Ethernet link. The traffic generated from the APs consists of both handheld and non-handheld traffic. The collected trace covers 7 days (April 16-22, 2011). The trace from one day (April 16th), *trace1*, was captured with the entire packet payloads while the traces from the other days, *trace2*, were captured with a 96-byte packet snapshot. The collected traces consist of 825 GB TCP traffic and 567 GB UDP traffic (Table I).

TABLE I. SUMMARY OF MOBILE TRAFFIC TRACE OVER 7 DAYS (GIGABYTES PER HOUR)

| Protocol | Trace | Mean | s.d | Max | min | Total |
|---|---|---|---|---|---|---|
| TCP | Trace 1 | 5.578 | 4.113 | 18.046 | 0.652 | 133.881 |
| | Trace 2 | 4.803 | 3.232 | 15.211 | 0.210 | 691.569 |
| | **TCP Total** | 4.983 | 3.370 | 18.046 | 0.210 | 825.449 |
| UDP | Trace 1 | 4.268 | 3.623 | 12.098 | 0.226 | 102.443 |
| | Trace 2 | 3.226 | 3.692 | 24.660 | 0.011 | 464.497 |
| | **UDP Total** | 3.375 | 3.690 | 24.660 | 0.011 | 566.941 |

### A. *Mobile Application Traffic Measurement*

We performed application-level traffic classification, which is the first step to analyze the relationship between the usage of application traffic on mobile network and its devices. We observed most mobile applications are based on the client-server architecture with HTTP protocol. We extracted *host* fields of HTTP as classification signatures of mobile application traffic and several signatures are extracted manually for non-HTTP traffic (Table II). This measurement was performed on *trace1* to use entire payload information. The File Transmission category, including P2P and web hard traffic, shows over 25% traffic occupation, while Web Search and Portal traffic (popular web sites) shows about 7% volume occupation. Multimedia streaming made up about 2.5% of the traffic. These results show that users also try to share files using wireless networks, which is the same as wired network usage. Messaging and SNS service traffic, which is usually considered the heavy hitter in mobile networks, is relatively lower than others.

TABLE II. MOBILE APPLICATION TRAFFIC VOLUMES AND PROPORTION

| Category | Volume [GB] | Proportion [%] | Signatures |
|---|---|---|---|
| **File Transmission** | 34.535 | 25.607 | BitTorrent protocol; COFILE; |
| **Web Search & Portal** | 9.327 | 6.916 | google.com; naver.com; daum.net; |
| **Multimedia** | 3.265 | 2.421 | tvpot.daum.net; afreeca.com; gomtv.com; |
| **News & weather** | 0.432 | 0.320 | mk.co.kr; kma.co.kr; |
| **Market** | 0.301 | 0.223 | tstore.co.kr; itunes.com; |
| **Messaging & SNS** | 0.146 | 0.108 | kakao.com; fbcdn.net; |
| **Advertisement** | 0.009 | 0.007 | admob.com; |
| **Unknown** | 86.850 | 64.398 | - |
| **Total** | 134.864 | 100.000 | |

Figure 1 shows the relative volume of mobile application traffic over 24 hours. File Transmission traffic increases rapidly in the evening. Web Portal and Multimedia traffic is generally spread evenly over the full day. In addition, users read daily news and check the weather using their mobile devices in the morning.

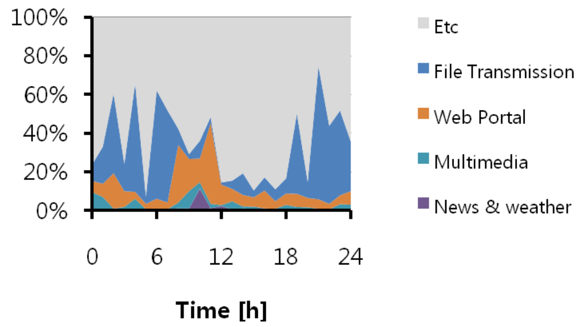
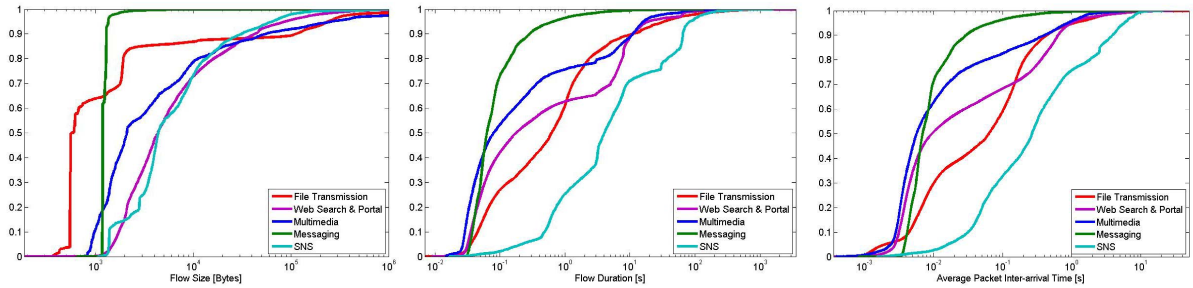



Figure 1. Proportion of application traffic volume over 24 hours

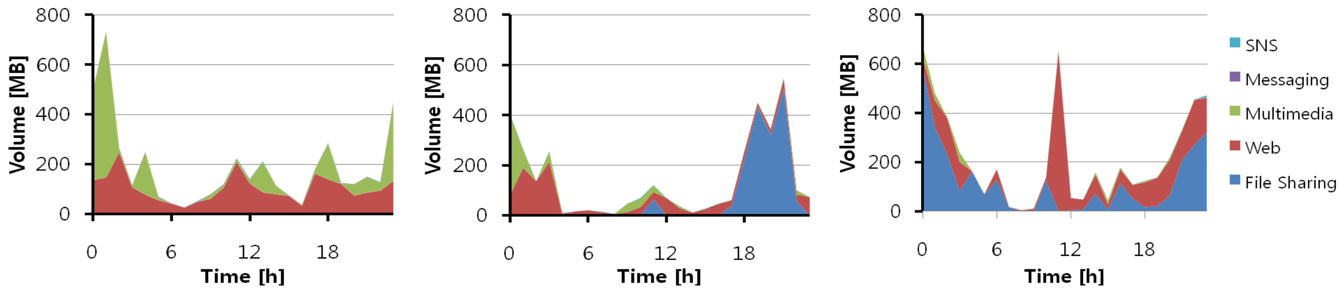
We compared flow characteristics according to the types of mobile applications. In this paper, a flow is defined as a 5-tuple (source address, source port, destination address, destination port, protocol) TCP bi-directional flow because of the obscurity of the start and end time of UDP. We use SYN packets as the flow start and FIN/RST as the flow end with a 64-second timeout [7].

Figure 2(a) shows the cumulative distribution of flow size according to application. More than 60% of the flows for file transmission are less than 1,000 bytes. In fact, today's P2P applications split a huge file into very small pieces and transfer them simultaneously to speed up file transmission. Usual web and SNS traffic show almost the same flow size distribution. Most SNS services are based on web traffic and their contents are images, text, and short videos, similar to typical web sites. We notice that about 80% of flow size for multimedia traffic is distributed to less than 10K bytes. Like file transmission, multimedia services also need to transfer video or audio files,




(a) Flow size (bytes)   (b) Flow duration (bytes)   (c) Average packet inter-arrival time

Figure 2. CDF of flow size/duration/average packet inter-arrival time according to applications




(a) Android   (b) iOS   (c) Windows

Figure 3. Cumulative application traffic from Android over 24 hours

which are relatively larger than other objects, so they use the same strategy (file splicing) with file transmission. Messaging applications show constant flow size. More than 97% of flows show about 1K bytes with 10 packets (including TCP handshake and FIN/RST).

Figure 2(b) illustrates the cumulative distribution of flow duration according to application. Roughly, flows in File Transmission are distributed from 0.03 sec to 10 sec. Compared with other applications, P2P client connects to many different servers simultaneously, so each connection shows different conditions. However, a client of multimedia applications, which use the same file transfer strategy, connects to fixed content servers. Thus, multimedia service connection shows consistent link conditions. About 70% flows are also less than 1 second. For web service, the flow duration seems to be a mixture of two Gaussian functions. In fact, different views of web pages for PCs and mobile devices affect the flow duration. The highest flow duration of messaging application traffic is less than 1 second. For SNS, the flow duration is longer than the others because we measured Facebook traffic and this site's servers are located in the United States.

Figure 2(c) shows the average packet inter-arrival time according for each application. The distributions of application traffic are almost the same as the distributions of flow duration. The reason for this similarity is that the number of packets of 90% flow ranges from 10 to 100. In all application groups, except for SNS, the packet inter-arrival time is shorter than 1 second for more than 90% flows.

### B. *Relationship Between Application and Devices*

In this section, we present measurement results to understand the relationship between application traffic and type of devices by merging application-level and device-level analysis obtained in the previous sections. This relationship can be used for users and device profiling and show the impacts of device type and application category on mobile networks.

To classify the types of access devices, we use an operating system (OS) fingerprinting approach [6] which is based on the differences of an OS's default parameters in TCP SYN or SYN-ACK packet. Instead of identifying devices directly, we identify the OS on the devices and infer the types of end-user devices. We used *trace1* to extract OS fingerprints, and applied to identify the end-user devices over seven days monitored period.

Table III shows the traffic volume and the proportion of traffic type related to each application and operating system. The application with the highest traffic volume is file sharing. The identified operating systems only generate about 3.5% of file sharing traffic but most traffic (22.1%) is classified from unknown OSs (Etc.). It is reasonable to assume that the most devices in unknown OSs are non-handheld devices because there is no messaging application traffic in unknown OS traffic. In other words, most file sharing applications generate about 25% of traffic from non-handheld devices. Web traffic, second rank, is generated in equal measure by Android, Windows, and iOS. We also observed that users usually enjoy multimedia streaming service using their handheld device even though the screen size is much smaller than non-handheld devices. There are still un-classified applications and operating system traffic. We will improve the completeness of the traffic classification in the future.

TABLE III. TRAFFIC VOLUME (MB) AND PROPORTION ACCORDING TO OPRATING SYSTEMS AND APPLICATIONS

| | File Sharing | Web | Multimedia | Etc | Total |
|---|---|---|---|---|---|
| **Android** | 4.2 | 2459.2 | 1974.6 | 6128.0 | 10566.0 |
| | 0.003% | 1.837% | 1.475% | 4.577% | 7.892% |
| **iOS** | 1646.4 | 1161.4 | 564.4 | 8411.1 | 11783.3 |
| | 1.230% | 0.867% | 0.422% | 6.283% | 8.801% |
| **Windows** | 2924.9 | 2237.1 | 168.4 | 21944.2 | 27274.6 |
| | 2.185% | 1.671% | 0.126% | 16.391% | 20.372% |
| **Mac OS** | 314.9 | 61.4 | 4.3 | 444.7 | 825.4 |
| | 0.235% | 0.046% | 0.003% | 0.332% | 0.617% |
| **Etc** | 29643.8 | 3409.6 | 553.9 | 49824.0 | 83431.3 |
| | 22.142% | 2.547% | 0.414% | 37.215% | 62.318% |
| **Total** | 34534.2 | 9328.8 | 3265.6 | 86752.1 | 133880.7 |
| | 25.795% | 6.968% | 2.439% | 64.798% | 100.000% |

Figures 3 show the cumulative volume of application traffic over 24 hours according to operating system. It is difficult to observe messaging and SNS traffic in the figures because of their small volume. Android generates mainly web and multimedia traffic during the day. Android users use multimedia services around midnight when multimedia traffic is generated intensively. iOS generates huge file sharing traffic in the evening. The file sharing traffic from iOS is identified as cloud storage services. In the future, cloud services will become more popular and mobile traffic will then increase dramatically. Windows traffic consists overwhelmingly of file sharing traffic generated from BitTorrent and other domestic P2P file sharing services. File sharing traffic consumes network bandwidth rapidly whether or not it is P2P traffic, and it is also very intensive. Android generates most of its multimedia traffic around midnight. The volume of multimedia traffic is comparable with file sharing traffic and its intensity is also very concentrated on the service time. Android and Windows have almost the same web traffic, but Windows traffic is more concentrated between 8:00 a.m. to 12:00 p.m. The traffic is directed to domestic web portals.

## IV. CONCLUSION

In this paper, we have measured and analyzed mobile network traffic in our campus network. We monitored traffic from Wi-Fi APs at the Internet junction of POSTECH. We measured the volume of mobile traffic, application traffic characteristics and the relationship between applications traffic and its devices.

We suggest several mobile network management recommendations to enterprise networks based on our analysis:

- Device-level resource allocation should be considered to manage application traffic separately and avoid interference among different aimed devices.
- Call admission control [10] should be considered to guarantee QoS for multimedia traffic
- Mobile web pages and web proxies can reduce web traffic directed to popular web portals to 30% during the peak time.

For future work, we plan to focus on improving the completeness of our analysis results. We will also deploy the measurement system to our campus network management system.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