MobiCom 2010 Poster: Mobile TCP Usage Characteristics and the Feasibility of Network Migration without Infrastructure Support

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In this poster we describe initial findings regarding Internet usage characteristics, in particular TCP flows from a field study with 27 iPhone 3GS users. We present details regarding their usage characteristics, and provide a solution for migrating flows between different networks and/or network interfaces without requiring infrastructure support or changes to current applications and protocols, with minimal impact to the user.

I. Introduction

Numerous research efforts have analyzed network usage characteristics, without distinguishing between mobile phone and PC users. Others have analyzed usage at the router or backbone, and remain agnostic to different types of users.

We have developed and installed software, called LiveLab [1], on 27 iPhone 3GS phones, and collected real-life network traces from their mobile users over a three month period. We have provided the phones along with service plans to participants. We have found that in our traces, TCP packets outnumber UDP packets by more than 13 to 1; therefore we focus on TCP sessions. From our traces, we present characteristics of TCP flows on phones in real-life usage. We have found that most often, there are few flows and they are short lived.

Furthermore, we present two mechanisms for switching and/or aggregating multiple networks on consumer mobile devices, without requiring backend or application support. Switching between networks can occur either on one interface (e.g., between 3G and 2G only modes on a cellular interface, between two Wi-Fi networks), or on two interfaces (e.g., between cellular and Wi-Fi), in order to improve efficiency, performance, and/or to offload data from congested 3G networks [2, 3]. Furthermore, switching between multiple Wi-Fi networks, or between Wi-Fi and cellular networks can provide a solution to Wi-Fi's lack of support for mobility [4], with minimal disruptions to the user.

Aggregating is enabled by utilizing multiple network interfaces for allocating different TCP flows, where each TCP flow resides on a specific interface. It has been shown allocating different TCP flows to different interfaces can indeed improve overall performance [5, 6]. While we found that, based on our traces, multihoming can help in at most 20% of times; we expect this number to increase with more applications and services on phones.

We note that there exists a body of research on providing session continuity [7] between different networks, i.e. maintaining a permanent IP address while moving between networks. Pahlavan et al. compare several methods for vertical handoff [8], but they all require infrastructure support, e.g. in the form of a gateway (proxy), or changes to the TCP protocol. In sharp contrast, we present a novel switching mechanism that can be fully implemented on the client side, and requires no proxy/gateway support or support from applications.

II. TCP Flow Characteristics

TCP does not provide for migrating flows. Therefore, it is impartial to look deeper into TCP flow lifetime characteristics in real-life usage. We measure the flow lengths during the time they are connected, without including the disconnection (teardown) phase (e.g., wait_fin). We present the statistics separately based on the display status (on/off) as an indicator of whether the user is using the phone interactively.

II.A. TCP Flow Types

Based on the port number of the server, we categorize TCP connections into three categories based on application type. We will ignore local (loopback) flows, i.e. flows internal to the phone. The three types are shown in Figure 1:

1. Web (HTTP: 80, HTTPS: 443): These are used by the browser and native applications that utilize web services or a built-in browser.
2. Email (IMAP: 143, 993, POP3: 110, 995, SMTP: 25, 465): These are used by the native email client, and will not include email accessed through the browser.
3. Other: All other applications and services.

II.B. Applications

Using the data from our field study, we identify the eight most common applications that require Internet

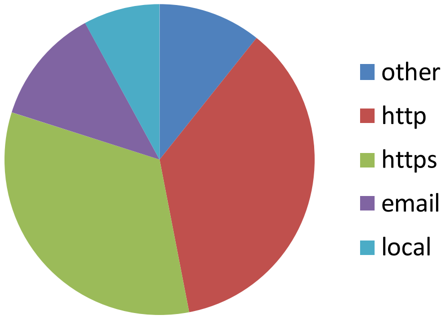

Figure 1: Fraction of TCP flows for each flow type

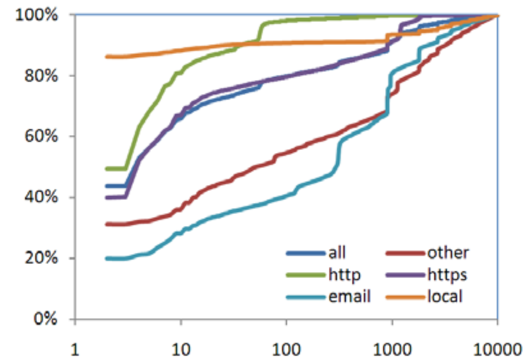

Figure 2: CDF of TCP flow lifetimes in seconds, average among all users

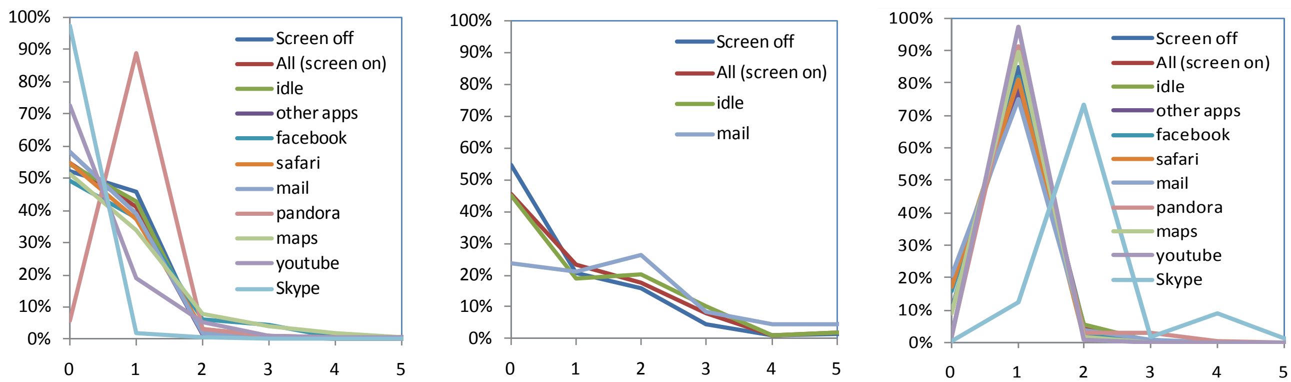

Figure 3: Distribution of number of TCP flows when running different Internet enabled applications. Left: Web. Middle: Email. Right: other ports.

access. These account for over 95% of phone use, and include Pandora (music streaming) and Skype. Other applications, including those without specifically requiring Internet connectivity, are clustered together as other. Finally, applications that are ongoing while the display is off (i.e., non-interactive applications) are grouped together.

Figure 1 shows the fraction of TCP flows utilized for each application. The most common flows were web (HTTP, HTTPS). This shows the importance of properly handling such flows when switching between different networks.

II.C. Flow Length

Our logs show a wide variation in the lifetime of TCP flows on the experimental phones. Figure 2 shows the CDF (cumulative distribution function) distribution of TCP session lengths, average among our participants. Our second finding is that most flows are short lived. In particular, 50% and 44% of flows for non-interactive and interactive sessions were ~2 seconds or less, respectively. In turn, this limits the effectiveness of power saving schemes that rely on long-lived downloads, e.g. Catnap [9].

Our third finding is that the distribution of flow lifetimes varies significantly based on application. As shown in Figure 1, the fraction of short lived local sessions (i.e. localhost to localhost) is significantly higher at 86%, and the fraction of short lived email connections (i.e. imap, smtp, pop3) is much lower, 30% and 20% for non-interactive and interactive sessions.

II.D. Flow Concurrency

We were surprised to see there is almost always one or more TCP sessions in progress whenever the phone's processor is running; 96% and 97% of times for non-interactive and interactive sessions respectively. The median number of connections was 2 for both interactive and non-interactive sessions. As expected, different applications have different patterns of TCP flow utilizations. Figure 3 shows the distribution of number of concurrent TCP connections for different applications, for the flow types presented in Section II.A (Web, Email, other). We can see that even when running Internet enabled applications, the phone is typically not engaged with one (or multiple) TCP connections continuously. The exceptions in our data are Pandora and Skype.

The small numbers of TCP connections utilized also show that for HTTP sessions on mobile phones, multihoming mechanisms (i.e. non-striping) are effective for at most 20% of flows, as the other 80% of times where there exist an HTTP connection, it is a single flow. Yet, we expect this number to increase with more applications and services on phones.

III. Migrating TCP Flows

We present three methods to migrate TCP flows with minimum disruption to the user.

III.A. Wait-n-Migrate

For Wait-n-Migrate, we take advantage of the fact that most TCP connections are short lived, as seen in Section II.C and, in particular, Figure 3. Wait-n-Migrate requires that a device be able to connect to multiple networks simultaneously. This may be through multiple interfaces (e.g., 3G and Wi-Fi) or through one interface (e.g., multiple Wi-Fi networks through Virtual Wi-Fi).

In order to migrate one or more flows from the old interface to the new interface, Wait-n-Migrate works as follows. First, it enables both networks, so the system is connected to both. Second, it modifies the routing tables such that all new connections are created on the new interface. Then, it waits for the old connections on the old interface to end, up to a specific timeout, or until there are no more connections left on the old interface. The timeout, for each connection can be set according to application, bandwidth and power considerations. The timeout may also be imposed by environmental or device characteristics, e.g. losing signal coverage. Finally, if there are no remaining flows on the old interface, the system can disable or power it off altogether.

When the system cannot be connected to both networks simultaneously, a special case of Wait-n-Migrate, called Wait-n-Switch can be used. It takes advantage of the fact that that most TCP flows are short lived. Wait-n-Switch monitors TCP connections and attempts to choose the best moment to switch, within a specific allowed range, in order to minimize disruptions. Since our focus is on interactive applications, we assume the Wait-n-Switch waits for the moment when there are no web connections to switch between networks.

III.B. Resumption Agent

For Resumption Agent, we take advantage of the fact that most interactive applications use HTTP/HTTPS connections, and that most servers support resumes. Resuming implies the ability to resume a disconnected download from where the disconnection occurred vs. restarting the download from the beginning. Therefore, when a flow is required to be migrated to a new network, it can be simply terminated, and the remainder of the download can be resumed on the new network. The same resume functionality may also be used to stripe a download through multiple TCP flows, by downloading different parts of the download through different networks. The HTTP standard, from version 1.1 onwards (1996), supports specifying a *range* when requesting a web page. The FTP standard also supports resuming via the *rest* command. While many download managers or download accelerators (e.g. Wget, Getright) support automatically resuming disconnected downloads and/or parallel downloading through multiple TCP connections, browsers and other applications lack such capability.

Resumption Agent requires a background service running only on the device itself, which acts as an HTTP/HTTPS/FTP proxy, and modifying the phone settings accordingly to use a proxy to connect to the Internet. Since Resumption Agent handles requests from applications (e.g. the browser), it can not only handle network migration by simply killing the old flow, creating a new connection, and resuming the download, but can also support striping for larger downloads by downloading them in parallel over multiple networks. We must note that Resumption Agent becomes aware of the download size at the beginning of the transfer, since the size is part of the standard HTTP response header.

Finally, we must note that it is further possible to extend Resumption Agent to support other application types as long as they support resuming form a specified location. This includes email protocols and file streaming formats.

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