Planning, Apps, and the High-End Smartphone: Exploring the Landscape of Modern Cross-Device Reaccess

Elizabeth Bales[1], Timothy Sohn[2], and Vidya Setlur[2]

[1] University of California San Diego, 9500 Gilman Dr., La Jolla, CA 92093, USA
[2] Nokia Research Center, 955 Page Mill Road, Palo Alto, CA 94304, USA
ebales@cs.ucsd.edu,{tim.sohn,vidya.setlur}@nokia.com

Abstract. The rapid growth of mobile devices has made it challenging for users to maintain a consistent digital history among all their personal devices. Even with a variety of cloud computing solutions, users continue to redo web searches and reaccess web content that they already interacted with on another device. This paper presents insights into the cross-device reaccess habits of 15 smartphone users. We studied how they reaccessed content between their computer and smartphone through a combination of data logging, a screenshot-based diary study, and user interviews. From 1276 cross-device reaccess events we found that users reaccess content between their phone and computer with comparable frequency, and that users rarely planned ahead for their reaccess needs. Based on our findings, we present opportunities for building future mobile systems to support the unplanned activities and content reaccess needs of mobile users.

1 Introduction

In the past several years the number of personal devices a user owns and interacts with has increased. Mobile phones, laptops, desktops, slates, and in-car navigation systems are becoming increasingly popular in the daily life of a user. In a previous study of multiple device usage, Dearman and Pierce found that users interact with as many as 5 personal devices a day [13]. With multiple devices, a user's data often becomes fragmented based on the usage pattern and affordances of each device. A mobile phone will have history of phone calls, applications opened, and websites visited that are different than activity on another device. The fragmentation of digital activity creates a challenge for the user to transfer and reaccess content across their devices.

Cloud computing has offered promise to enable consistent data access on any device. Services such as Evernote [4], synchronized bookmarks, Dropbox [3], and Chrome-to-phone [2] all offer tools for users to transfer content from one device to another. These tools are designed to support planning practices, where a user recognizes information he will need later and saves it for easy reaccess. Users can sometimes forget the information they will need later, or choose not to plan ahead to preserve flexibility. These unplanned situations are often addressed by attempting to access web content by performing web query searches [24].

Web content is one of the primary sources of information today, especially as web applications that support productivity tasks are becoming increasingly popular. Both the

K. Lyons, J. Hightower, and E.M. Huang (Eds.): Pervasive 2011, LNCS 6696, pp. 1–18, 2011.

computer and mobile phone are important devices in a user's ecosystem that provide access to web content. There have been a number of studies analyzing the types of web content and searches that users perform both on their desktop and mobile devices [17,18], but few have studied reaccess patterns across these devices. The explosion of mobile applications has also added a new dimension of content reaccess because the same web content can be accessed through a web browser or a dedicated mobile application.

In this paper we explore both the methods and content of web information reaccess among ones personal devices. We conducted a two week study with 15 users of high-end smartphones: iPhone, Android, N900. We used a combination of interviews, url logging, and a screenshot diary study to gather insights into cross-device reaccess patterns regardless of the method they used to access the content (e.g., web browser or mobile app). We measured cross-device reaccess by matching URLs and comparing timestamps to determine which access occurred first. This process required matching many of the URLs manually because mobile websites have different URLs than their desktop counterparts. We only considered two URLs a match if the content they referenced was the same. Our logging software captured over 123,497 web accesses on the computer and 3,574 web accesses on the mobile phone. Over the course of the study participants submitted 128 screenshots from *in situ* moments when participants noticed they were reaccessing content they had seen before. We captured over 1,200 cases where content was reaccessed on a device different from the original access device, with over 500 reaccesses originating on desktop and over 700 originating on the mobile device.

The results of our study show that:

- Cross-device reaccess, moving from computer to phone and from phone to computer, occurs with comparable frequency.
- Reaccess is often unplanned.
- Native applications are an important part of how users reaccess content.

Informed by these results, we discuss several opportunities to support content reaccess among a user's personal devices.

2 Related Work

There are three areas that researchers have explored the types of content mobile users access. These can roughly be divided into information needs, search patterns, and cross-device explorations.

2.1 Mobile Information Needs

Studies on mobile information needs have used diary study methods to gather ecologically valid data about the types of content mobile users look for. Sohn *et al*. found that mobile users attempt to address many of their information needs through web access or other online resources that may have been previously seen [24]. In a similar study, Dearman *et al*. found that mobile users would often look to online resources to address their mobile information needs, but the process could sometimes be difficult and cumbersome [12]. Church and Smyth looked at the intent behind mobile information needs

and found many information needs were related to finding PIM data, hinting that the data is related to content already seen by the user [10]. These diary studies hint at mobile users relying more upon connected resources through the cloud and understanding their re-access patterns would provider further insights into assisting mobile users in limited attention environments.

2.2 Search Behavior and Revisitation Patterns

There have been a number of studies investigating web search behavior on both desktop and mobile devices. Many desktop studies have conducted query analysis on search logs reporting on query length and categorization [16,7]. Spink *et al*. conducted a longitudinal study of query behavior between 1997 and 2001 [25]. As smartphones have evolved over the years, users are accessing content through desktop and mobile web browsers. To investigate this trend, Kamvar and Baluja conducted a large-scale analysis of mobile search queries and found that mobile users with less featureful phones submitted shorter queries [17]. In a follow up study they found that iPhone users in particular behave differently than other smart phone users [18]. Their research revealed that iPhone users create search queries more like desktop computer users. We believe that this trend towards higher end smartphones being used more like computers alters how mobile users reaccess content across their devices and the type of content they reaccess.

In addition to search behavior, studies have shown that web revisitation accounts for 58% [26] to 81% [11] of all desktop web site visits. Obendorf *et al*. found that 50% of desktop web revisits occurred within 3 minutes, while the other half took place much later [22]. Adar, Teevan, and Dumais looked deeper into the intent behind revisits [6] and found a variety of revisitation patterns. When studying how users reaccess content across devices, the analysis becomes multifaceted. A single piece of content can be accessed through a desktop URL, mobile URL, or a mobile application. As far as we are aware, few researchers have studied reaccess patterns across multiple devices, specifically when the content can be accessed through a web browser or mobile application on a high end smartphone [19].

2.3 Cross-Device Interaction

Researchers have explored how users manage their life with multiple devices. Dearman and Pierce conducted a study into how users interact with all their computing devices [13]. In a study of 14 Windows Mobile phone users, Kane *et al*. found that users frequently visit websites on both their phone and laptop/desktop machine, suggesting that sharing web history among these devices could be beneficial [19]. In a later study, Karlson *et al*. looked at situational constraints that mobile users face while using their device [20]. Participants were asked to take screenshots whenever they encountered a barrier on their mobile phone. They suggest the idea of decomposing tasks into subtasks so users can complete them across their devices based on their situational context. Neither of these studies looked at the effect of web reaccess on high-end smartphones and content that can be accessed through a mobile application.

Several systems have created ways for users to plan ahead and share data between their mobile device and their desktop machine. The Context Clipboard uses a clipboard

metaphor where users can place notes on the clipboard from their desktop and it is synchronized with their mobile device [15]. Gurungo uses the concept of mobile data types to identify key data that a user may want to access later on and sends the content to the device through Bluetooth [14]. There are also a number of commercial tools available today to support re-accessing content. These tools tend to support planned activities, where users knows ahead of time the content they will need later. Evernote [4] and Dropbox [3] both enable file sharing through the cloud. Googles bookmarks for maps and websites as well as the Chrome-to-phone extension let users synchronize data with their mobile device [2]. Firefox Home synchronizes bookmarks, tabs, and web history between desktop and mobile Firefox clients [5] supporting unplanned activites, where a user does not plan ahead for the content they need. The PIE system also supports unplanned activities by allowing users to search for files and documents on their devices [23].

We build upon this work by specifically exploring re-access patterns among high-end smartphone users. The high quality of smartphone interfaces and always-on connectivity have changed how phones are used today, with many phones being used more like desktops. We focus specifically on the frequency of cross-device reaccess by device type, the amount of preplanning users performed for content they reaccessed, and the role of mobile applications in content reaccess. The following sections describe our study design and results from our exploration of content re-access patterns.

3 User Study

Gathering ecologically valid data from mobile users is challenging. We wanted to gather data from the moments of reaccess on a mobile device or on a computer, but placing an observer in the field to shadow a user can be time intensive. Logging methods are useful, but as mobile applications have become much more prevalent to access web information, the content remains siloed from the data-logging processes. As a result we used a hybrid approach of logging and a diary study to capture data *in situ*. Websites represent a majority of content users may want to access on their device, so we focused mainly on studying web content reaccess through a web browser or mobile application. The following sections describe our methods for obtaining ecologically valid data about the web content that user's reaccess.

3.1 Participants

We recruited 15 smartphone participants (7 iPhone, 4 Android, and 4 N900) through an advertisement on Craigslist from a city in the United States[1]. Due to the sensitive nature of the data collected we experienced a relatively high attrition rate during our recruiting process. We also found it more difficult to recruit Android and N900 users compared to iPhone users which affected our overall recruitment numbers. Our Android users used a variety of phone models that run the Android software platform including the Nexus One, T-Mobile Cliq, and Motorola Droid. All iPhone participants used either the 3G or 3Gs models. Participants ranged in age from 22 to 50 years (μ: 35) and had

[1] City is anonymized for submission.

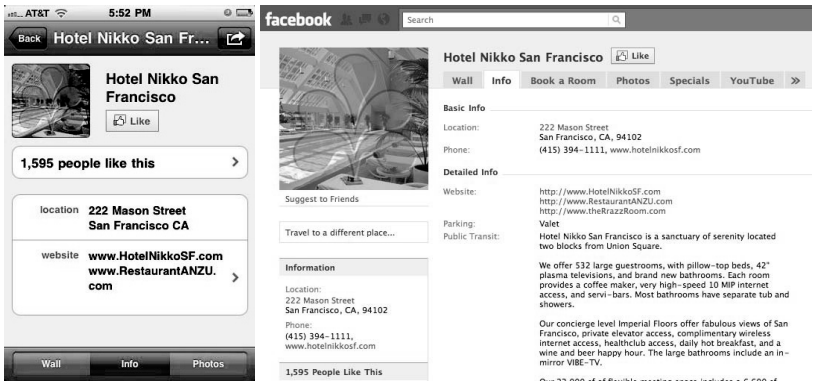

Fig. 1. Example of the same content accessed on through a native mobile application(left) and through the traditional web interface(right)

a wide variety of occupations including students, nanny, financial analyst, engineer, and freelance writer. We focused our recruiting on high-end smartphone users to understand how users of computer-like mobile phones manage content reaccess between their personal devices. Previous research found that users of high-end smartphones with computer-like capabilities behave differently than other smartphone users [18]. As a result, we chose three high-end smartphones with a modern web browser and an available set of mobile applications. All references to participants in this paper are anonymized with *i1-i7* representing iPhone owners, *a1-a4* representing Android owners, and *n1-n4* representing n900 owners.

3.2 Procedure

In order to gather in situ data from our participants, we used both a logging and screenshot capture method. The logging part of the study allowed us to observe the URLs that a participant visited on their desktop and some mobile devices. We developed a Chrome browser extension to log URL accesses on participants' laptops/desktops. The extension logged the URL, timestamp, and page title each time a participant navigated to a webpage. We did not save any content from the web page due to privacy reasons. The data collected by the extension was automatically sent to a server in our research facility. We also used device specific methods, discussed later in this section, for extracting the URL history from each user's mobile device so that it could be compared with the Chrome browser log data.

With the explosion of applications available on a mobile device, users have multiple ways to access web-based content. Many applications act as native clients to web-based content and keep content in silos from other applications. It is difficult to observe content that may be accessed on a laptop through a web browser (e.g., Facebook website) and then on a mobile device through a specialized application (e.g., Facebook application). These types of reaccesses are also important, so we asked users to take screenshots when reaccessing content on their mobile device. Participants annotated these

screenshots with additional comments about their reaccess event later through a nightly journal. Our study design is similar to the idea of snippets [9,8] , where users capture screenshots in the moment and annotate them in depth later on a PC. Figure 1 illustrates an example of the same content viewed through a dedicated mobile application and on the standard web interface.

Participants attended a 1 hour in-office visit, filled out nightly online journals about their reaccess activity for the day, and participated in a semi-structured final interview two weeks after their start date. During the first in-office visit, we installed the Chrome browser and extension on the user's laptop. N900 and iPhone users were instructed to take screen shots on their mobile devices and all users were instructed to take screenshots on their computer. Android phones do not have a screen capture function, so android users were asked to use a note application to document reaccesses on their mobile devices. We sent participants daily reminders with a link to an online journal where they could elaborate on their screenshots and reaccess stories they collected throughout the day. During the initial visit we performed a detailed walkthrough of the process of creating and annotating screenshots with the participants.

We installed URL-logging software on the Android and N900 devices that uploaded the same information as the Chrome extension. This data was automatically sent to the server in our research facility. Because of device limitations on the iPhone (i.e., Mobile Safari does not allow browser extensions), we used an alternative method for collecting URL access events. iPhone participants sent us weekly phone data backups that would contain their URL history information.

At the end of the two week study we conducted an exit-interview with the participants. The interview followed a semi-structured format and asked participants about their screenshots and reaccess patterns. Participation were compensated $80 USD at the end of the study.

4 Results and Observations

We collected a total of 123,497 (μ: 6370 min: 775 max: 33892) web page visits on the computer and 3,574 (μ: 215 min: 28 max: 745) web accesses on the mobile phone. Of those webpage visits 14,642 were unique URLs on the computer and 260 unique URLs on the mobile phone. Table 1 shows a breakdown of average number of URLs accessed per user by device type. Android participants tended to browse more pages on the computer, while iPhone participants browsed more web pages on their mobile phone.

Within-device reaccess of data, defined as reaccessing data on the device of original access was observed on all device types with iPhone users averaging 98.4, Android users averaging 9.8, and N900 users averaging 79 within-device reaccesses. Within-device reaccess on the user's personal computer averaged 6683.73 over all users.

To study cross-device reaccess we matched the URL history from both devices to find access patterns. We considered two URLs a match when they accessed the same content, even if one was a mobile page and one was the full page (ex. `m.cnn.com` and `www.cnn.com` would be considered the same content even though one is the mobile URL and one is the standard URL). For password protected pages such as social

Table 1. Total number of URLs access per user by device type

Device	computer	mobile
iPhone	μ: 6370 min: 1482 max: 11667	μ: 327 min: 31 max: 745
Android	μ: 14854 min: 775 max: 33892	μ: 182 min: 28 max: 449
N900	μ: 2169 min: 2527 max: 7344	μ: 142 min: 34 max: 309

networks and email we had to rely solely on the URL to determine if the content was the same. In total there were 1276 cross-device reaccesses (μ: 35, min: 4 max: 378), with 754 starting on the phone with reaccesses on the computer, and 522 starting on the computer with reaccesses on the phone. Table 4 shows the frequency and direction of reaccess for each of the smartphone participant classes, as well as the most common content reaccessed by direction. To gain a better understanding of what type of content users reaccessed we manually analyzed all the cross-device reaccessed URLS to identify the top categories. We categorized the reaccess events from the logs into website categories based on a scheme proposed by BBC [1] . The most frequent reaccesses were related to social network (e.g., Facebook) and news websites (e.g., New York Times). Information articles were also a common category of reaccess (e.g., Wikipedia).

We also gathered temporal data about each logged reaccess event. In most cases the time to reaccess information varied between several minutes and several days (Table2). Most reaccesses were short term reaccesses, with the second access occurring on the same day as the initial access event. It is likely that the clustering of reaccesses in the short range time frame is influenced by memory, with reaccess that take place over a longer period of time being easy to forget to complete. This is especially likely when we take into account the methods participants used to remind themselves to reaccess data. WIth most participants using systems that depended on temporally affected interface,

Table 2. Temporal Information of Cross-Device Reaccesses. Percentage represents percentile error. Time is displayed in hours:minutes:seconds.

Device	Direction	25%	50%	75%	90%
iPhone	Phone to Computer	02:38:19	05:47:13	06:21:05	08:28:41
	Computer to Phone	00:45:19	07:22:27	08:18:41	10:31:17
Android	Phone to Computer	00:14:52	02:19:45	05:25:26	05:52:16
	Computer to Phone	02:33:12	04:08:23	05:31:46	06:29:27
n900	Phone to Computer	01:38:16	03:17:58	04:03:17	04:48:28
	Computer to Phone	01:12:17	03:46:24	04:29:13	05:17:57

such as email inboxes, it is likely that if they waited too long to reaccess, the email would be pushed down off the main screen and forgotten.

The following sections describe our observations around user's current methods to synchronize content among their devices, the role of planning in reaccess behaviors, and the role of native applications in content reaccess.

4.1 Current Tools Do Not Adequately Support Cross-Device Reaccess

We observed a variety of methods for sharing content among one's personal devices. Through the nightly journals and interviews, we learned that our participants use many creative, sometimes cumbersome, methods to make their devices interact with each other. Participants expressed pride when sharing their clever syncing solutions. However, even those who were proud of their solutions noted that the methods were time intensive and often reserved for tasks where they could foresee an obvious return on their invested effort.

Table 3 shows a list of the different practices employed by our participants as evidenced from their nightly journals, screenshots and interviews. The common theme among these practices was storing the information in a place for easy access later. Tools that synchronize easily across devices were used more heavily than others, but these methods were not particularly created for save and retrieval purposes (e.g., browser tabs). Email was a common place for our participants to put content they would need later. Many of our participants used a web-based email system that allowed them to access their data anywhere. In addition to emailing oneself links or files for later, users would also repurpose features to save content for reaccess. Marking an email as unread was a common example of repurposing a feature that was not necessarily meant for that purpose. One user also reported using the Facebook 'like' button to populate her 'news feed' with items she wanted to reaccess later. She knew that Facebook was easy to access from any device, and her news feed would be readily available to find the item she was looking for.

The methods shared by our participants required some amount of planning to save the needed data in a place for later access. If user's did not plan ahead, they would attempt to recreate web search queries in order to find the content they needed. Search can work effectively, but can also present additional hurdles when the technology does not behave the way the user expects. For example, *Participant a3* encountered search results on his phone that were "completely different" than the results he got on his computer, making it hard for him to find the information that he wanted to reaccess. He expected the same results he had seen before, but the search engine he used displayed different results on the computer and mobile versions.

Even if the user plans ahead, there is a high recovery cost when restarting a task or trying to find content previously seen. Bookmarks were one way to tag content to access later. However, as the number of bookmarks increases, users need to sift through large amounts of data to find their information. For some participants this lead to frustration. *"I feel like bookmarks are buried, like I have thousands of bookmarks. I have bookmarks for car stuff, I have bookmarks for vegan stuff, I have bookmarks..." (Participant a2)*

Some of these methods (e.g., browser tabs) act as a reminder tool to reaccess information later, which can be useful reinforcement. However, participants still need to

Table 3. Methods for content reaccess shared by users. Many methods require the user to plan ahead for content reaccess.

Method	Description
Email	Email applications automatically sync messages across devices. Users often depended on this feature to find content they had seen before.
Repurposing Features	Features built for other purposes were overloaded by users to identify items for reaccess later. Common examples included emailing content to themselves and using the "mark unread" feature in email to mark a read email that the user wished to return to.
Browser Tabs	Leaving browser tabs open on the mobile device as a reminder to reaccess them on another device was a common user strategy for remembering to reaccess content.
Paper	Paper for reaccess was used by several participants to help sync their devices. Informations was handwritten or printed, carried between the devices, and inputted on the second device to reaccess content.
Bookmarks	Shared bookmark systems were utilized by several users to share data between devices. Using these systems users could save a bookmark on one device and have it be available on their other device automatically.
Search	Unplanned reaccesses were frequently executed by entering search queries into another device.

manually enter the information into each device. Our participants expressed a need to overcome these challenges and have an easy method to reaccess their data.

4.2 Cross-Device Reaccess Happens in Both Directions

We found that content reaccess occurs frequently in both directions between the mobile phone and computer (Table 4). Phones and computers have different strengths that influence reaccess patterns. Computers have large screen real estate, fast processing, and a high-speed network connection. Phones are locationally aware, always on, and ubiquitously connected. Phone to computer reaccess was often driven by technical barriers and participants decomposing their tasks among their devices. Computer to phone reaccess occurred due to contextual factors including location, time, and social context. We also found that the most convenient and accessible device was a factor in deciding which device to use for reaccessing content. In the remainder of this section we analyze the different reasons for each reaccess direction.

Computer to phone: Need it at another location. Location was a prime contextual factor for motivating reaccess. Location affects the range of tasks the user can engage in, influences the external stimulus experienced by the user (which can act as a catalyst for reaccess), and often places constraints on which devices the user can interact with.

Reaccess behaviors influenced by location often began on the computer and shifted to the smartphone as users realized they needed the information while mobile. This

Table 4. Top three categories of cross-device reaccessed URLs, broken down by device and reaccess direction

Device	Top 3 Categories	Categories by direction	Phone to Comp	Comp to Phone	Total Reaccess
iPhone	News 27.6% Search/Portal 25.19% Social Networks 20.06%	Phone to comp: News 73.74% Comp to phone: Social Networks 67.34%	μ: 31 min: 3 max: 193	μ: 32 min: 1 max: 74	μ: 72 min: 4 max: 267
Android	Social Networks 49.89% Media/News 38.7% Information Articles 11.41%	Phone to comp: Social Networks 84.23% Comp to phone: Media/News 72.18%	μ: 20.5 min: 5 max: 166	μ: 10 min: 3 max: 212	μ: 28 min: 13 max: 378
N900	Social Networks 56.02% Mail 13.86% News 19.28%	Phone to comp: Social Networks 80.36% Comp to phone: Social Networks 71.93%	μ: 11.5 min: 4 max: 53	μ: 17.5 min: 7 max: 44	μ: 29 min: 11 max: 97

frequently happened with maps and directions, where turn-by-turn directions are more useful due to the mobile nature of the device. *Participant a1* shared this story of reaccess inspired by location.

"it [restaurant] had good reviews and a lot of people were talking about it, so we actually went back friday the next week. and I looked it up (on phone) to see exactly what street it was."

Location-based reaccess also occurred when users recognized that information would be more useful at another place besides the point of original access.

"Today, my girlfriend was interested in getting a new phone from sprint. I had heard about them having a few android phones, so I went online to read up on HTCs. I read a lot of information on my laptop before we left. While at the sprint store, she was curious also about HTC, but wanted different information. I went back to the same wiki and let her read, since she didn't want me basically reading 2/3 of the wiki out loud as she perused cell phones." (Participant i6)

Participant i6 knew he would need the information he looked up on his laptop, but his ability to reaccess the content a particular location is what really made it valuable.

Computer to Phone: Need it at a later time. Time was another contextual factor that motivated how users reaccessed content on their phones and computers. Participants would typically carry their phone while mobile and could rely on it being available at other times. In these types of reaccesses, users either did not have all the information they needed at the time when they started the task, the task was too long to complete at the initial access, or external events controlled the time at which they could finish the task.

"In the morning, I felt like going to Chili's for lunch so I went to the Chili's website to find locations near me. I then repeated this on my phone when it was time for lunch so that I would have the address/map with me." (Participant i4)

The participant actually had to wait until the right time, here lunchtime, before he could act on the content he accessed. He wasn't interested in knowing how to get to

Chilli's until lunchtime arrived, and waited until then to conduct his reaccess on his phone.

Time constraints were another common reason to postpone a task and reaccess it later. *Participant n3* shared an example of receiving a long email from a friend that contained a riddle. *"A friend gave me a puzzle, like a really long thing, it was going to require a really long answer and it was going to require rereading and thinking about [...] I had glanced at [it] earlier on my computer when I was at work and couldn't read it." (Participant n3)* When she first read the email she didn't have time to think about what the answer might be. Later when she was at the airport waiting for a plane, and consequently had a lot of time, she revisited and answered the email on her phone.

Computer to Phone: Show my Friends. Social factors was a third type of context that influenced mobile reaccess. Mobile reaccess influenced by social situations was reported 7 out of 15 participants. We define socially motivated reaccesses as any reaccess which prompted social interactions with a friend or colleague. In each of these instances, participants accessed a link, video, or picture they had seen on a device at an earlier time to share with another person. Spontaneous reaccess was common in this category, with many of the reaccesses inspired by conversations with friends. Inspired by his social context, *Participant n4* related this situation where his reaccess of a recently watched video.

"We were at a bachelor party and started playing foosball, so it kind of came up in conversation, and I was like, oh you gotta see this crazy foosball video! and I pulled it up. I googled 'Nokia foosball I had remembered that they had spelled it funny, and so I was able to recreate that funny spelling on the google search and it came right up. (Participant n4)

This reaccess was impossible for him to predict and he had to rely on his memory for the video's name and search for it on the spot. Participants noted it was especially important that the content be found quickly, otherwise the conversation flow could be negatively impacted.

Computer to Phone: Mobility Barrier. Although laptops are portable and travel frequently with their owners they are ergonomically difficult to use in settings where the user must stand or move frequently. They also have long boot up times, and are often difficult to access quickly. Participants would reach for their phone for convenience and speed depending on their current situation. Nylander *et al*. observed similar behavior in understanding the motivation for users to perform tasks on their mobile phone [21]. Participants experienced these mobility barriers, which influenced their choice of device when both were available.

"I want to access something really quickly, don't want to wait for computer to boot up [or there is] no surface to put it on OR not a safe location to reveal I have a computer that someone might want to steal OR I'm actually walking/moving somewhere [or] I'm in a situation where using a computer would be ergonomically difficult (eg. remembering something I needed to do online, but already in bed) (this sounds like a weird use case, but it happens surprisingly often..." (Participant n3)

Phone to Computer: Technical Barrier. When reaccessing content on the computer that was originally seen on the phone, technical barriers were the main influencing

factors in a reaccess event. Although mobile phone technologies are fast approaching the capabilities of personal computers there are still some things that are impossible to do on today's mobile smart phone. For example the iPhone is incapable of rendering Flash websites, thus users were forced to view it on their desktop or laptop computer. When users came to a website that looked *"wrong"* on their phone they often would revisit it later on another device to check and see it their phone was the problem.

"I received a link to play a game and knew it would start immediately when I clicked it so I read that I got the msg but waited to get home to click the link." (Participant a2)

Although *a2* was able to receive an invitation to play an online game through his email, his phone was not capable of running the game due to technical barriers. Motivated by a desire to beat his friend's score, *a2* delayed playing the game until he knew he was on a capable device.

Phone to Computer: Decomposing Tasks. Participants would decompose tasks doing as much as they could on their mobile device and then following up later on their computer. Decomposition can occur because of barriers or mobile limitations, but can also happen when resources are more readily available at another location. *Participant i2* shared that at the grocery store she accessed a recipe on her phone so that she could buy the correct ingredients. Later at home she accessed the recipe again from her laptop to assemble the ingredients into a meal. Both of the locations in this example have a specific function, the grocery store for selling food, and the kitchen for preparing it. Accessing the same content at both locations the user was able to complete her full task.

Tasks can also be decomposed because they are ongoing over time. *Participant i7* had an ongoing task of looking for a new apartment. When she saw an apartment complex that looked reasonable while she was commuting (as a passenger on public transit) she would conduct a brief search to find the price range and amenities to see if the place peaked her interest. Later when she had more time she would use her computer to look up more in depth information on the apartments such as reviews and neighborhood information. In this example i7's physical location inspired a spontaneous access of data, however her location also imposed time and device constraints which limited her gathering of information. The cost benefits analysis of looking up basic information about the apartments on her phone was worth it, but doing more in-depth research on her phone was not. Once she determined, using her phone, to consider an apartment complex, she would wait until she was in the locational context of 'home' to peruse more details about the apartments at her leisure.

4.3 Unplanned Reaccess Behavior

Planning ahead can be one of the easiest ways to expedite reaccessing content later. Easy access to directions for an event, phone numbers in an email, printing out a map, or bookmarking a page for later are all methods and practices our participants used to access their content. Despite these methods for planning ahead, participants communicated a general preference not to plan and would rather rely on internet connectivity to reaccess information they needed. Planning ahead was mainly reserved for important items, such as the map to an interview. *Participant i5* said that she *"wouldn't preplan unless it's a big date or a longer trip."* . The typical day to day activities did not involve much planning ahead.

Unforeseen reaccess. It is often hard for users to recognize what information they will need to access later. Content was only accessed a second time if something changed in the participant's original plan. The mobile convenience of the phone serves users well in these scenarios because they can often tweak their previous search queries to get the results they need.

"what you actually need, like, when when you're right in the situation, is not just information from earlier. It's information of, like, highly contextual information if something changes. So if you try to go somewhere according to a plan or map that you had ahead of time but you get lost... and so you're pretty close to where you were supposed to be, and so you need to change it a little bit." (Participant n3)

"I had to go to a wedding and so I just said great! I had to type it the thing[phone] from the paper invite, but then it was nice, I really did like it on my phone vs. paper because when I made wrong turns I could just restart it [...] I'd get to a light and just hit recalculate." (Participant i3)

In another example of unforeseen reaccess, *Participant i6* was trying to walk his dog at a new location. *"I used a website to locate a walking trail in San Mateo country. After I chose the destination, we headed with the dogs only to discover that the place was under construction. I quickly revisited the website with my iPhone, and decided on an alternate place to roam." (Participant i6)* The participant was not planning on using his phone once he arrived at the planned location but unforeseen circumstances forced him to change his plans. Since his web history was not shared between his devices, he had to redo a search query in order to find the website.

Mobile connectivity was a crutch used by our participants to support their unforeseen reaccesses. Even if the participants had pre-planned their activities, the highly contextual nature of their circumstances and changes in plans made it difficult to anticipate the information needed later. Although it is difficult to predict what a user will need ahead of time, since user's are reaccessing web content seen before, there may be opportunity to explore shortcuts to this content.

Plan a little, find it later. Connectivity was an expectation for most of our users given their capable mobile devices. These expectations offer users the freedom to access content they might need on demand without having to completely plan ahead of time. When users would plan ahead, some would prime themselves with a small bit of information and rely on mobile connectivity to access more information while mobile. A common method for doing this was to do a search on the computer, such as visiting a website for initial ideas, but allowing final decisions to be made in a more fluid fashion as the day progressed.

I went online to yahoo movies to look for a film that I'd like to see. I chose one, but didn't select a specific time, since I was meeting someone for dinner first. When we went to the movie theater, I looked up times on my iPhone at the same website. The second search was for a different theater, so I was glad that I hadn't settled on a time - life's great when your schedule is flexible ;)". (Participant i6)

Participant i5 shared her all too familiar story of how limited preplanning and on-the-fly mobile research came together for her on a recent weekend. Although she had performed minimal pre-planning to get an idea of restaurants and clubs, she and her friends left the final decisions to the last minute, often changing their minds at the last second.

"We had done some emailing, like mostly he[boyfriend] had emailed with them, so then it was like let's meet up for dinner, and then they wanted to eat dinner while we wanted to be at the beach, so then it was like let's have drinks later. We were going to meet them at a dance club and they were like 'oh we're not really in the mood for that... maybe something more low key,' and then I was like 'ok let me look up some other bars on my phone like through yelp', and then they met us at the place." (Participant i5)

In another example, *Participant a4* shopped initially online of shoes, but visited the brick and mortar store to browse and have the in-store experience.

"She[wife] had to have these shoes and you could get them online but she wanted them today so I went out and got them for her.... I went to the store and I said 'hey I need this shoe,' and I read the description. They still asked me another question, and I said 'well I don't know, here it is, that's what I need.' "[showed clerk webpage]. (Participant a4)

Although *a4* had looked at the shoe online on his computer at home, he accessed the mobile version of the page because he was not familiar with the product details. He relied on the content he was able to access on his phone in the store, to show the store clerk what he wanted, so that he would go home with the correct item.

Plan for the long term. Proper planning was reserved for longer term activities, such as finding a job, applying for schools, finding a new apartment, or planning a big event. These longer term reaccess can be particularly difficult for users to handle because the time between the original access and the final reaccess can make it hard for the user to remember the details they need to locate the content.

Planning for travel was a common longer term reaccess behavior. Purchasing flights and accommodation usually required many visits to the same websites to check prices before a final purchase. Once tickets were purchased the confirmation emails would be reference multiple times by the user as they made their final decisions about other elements of their trip. Finally, when on the trip, webpages and previously received confirmation emails would commonly be reference to help users navigate, check-in, and remember their schedule.

"It's usually in my email (flight confirmation numbers, hotel reservations, etc.), originally viewed via computer, and I then need to access it again while in transit (on my way to the airport to figure out which terminal to go to, at the counter of the hotel, etc.) [...] what I used to do was print or write this down and carry a piece of paper with all the information in one place. With the phone and a data plan, it was possible to look it up again in transit instead." (Participant n3)

She did note problems with this method saying *"This required logging in to my email and searching for the information, which may be spread out over several emails. I found it a bit of a frustrating experience because the internet access was always quite slow, and I needed to load many pages to get to the piece of information I needed"*. In light of the troubles she experienced while having to locate travel related documents on her phone, often months after her original access she shared her vision for a more accommodating mobile solution. *"what I really would prefer for that situation is to [...] have them all sent to my phone so that they ended up on one "page" accessible offline. Basically analogous to my printed consolidated piece of paper, only it's easier to find because it's on my phone, and the information can be collected as soon as I receive it, rather than right before the trip."*

4.4 The Role of Applications

Applications are at the center of how user's interact with and user their smartphones. These applications are typically native portals into content that could be accessed through a web browser. However, we found many of the heavily trafficked webpages from the desktop absent from the mobile phone logs when the users also had a related native application installed on their device (e.g., Bank of America application). Native applications provide numerous benefits over web pages including better performance, use of sensors and actuators, and easy access from the phone interface. In order to capture data in third party applications, we asked participants to take screenshots whenever they found themselves reaccessing content on their mobile devices. Participants sent 128 screenshots over the course of the two week study, accompanied by a story of the moment of reaccess on the phone. 30 (23.4%) of the 128 screenshots were from applications.

We expected more screenshots to be from applications given the plethora of applications that participants used. One possible reason is that frequently used applications are more conducive towards realtime content and not previously seen, static content. For example the BBC news application application for iPhone is designed towards consumption of new data, with the first screen the user is directed to presenting the most recent news stories. It may also be true that when users do engage in reaccess in these applications it is often as a subtask rather than a primary task making it harder for the user to recognize. For example, if a user goes to the Facebook application to see their friend updates and while browsing around decides to comment on a picture that she saw earlier, she may not consciously recognize this sub task as reaccess.

"I would go on Facebook and say I feel like I saw this stuff three times ... I go on physical Facebook [on the computer] a lot less than I check the phone app [...] it's probably 70-30 [iphone-computer]. (Participant i7)"

She was aware that she was revisiting content she had seen before, however she never took a screenshot on her phone of any of these encounters. It is possible that although she was reaccessing information, the fact that the content was being "pushed" to her, instead of her actively retrieving it, caused her to not recognize it as a reaccess. Self reporting is one of the difficulties with gathering data *in situ* from mobile users with a diary study method.

Participants indicated a general preference for interacting with native applications rather than mobile web pages.

"if theres an app of something I definitely will do that, like, Ill look up products on the amazon app rather than going to amazon through safari. (Participant i5)

There was also indication that the advantage native applications had over mobile web pages was slight with users others mentioning that, *"if I have Safari open, I'm not going to close it to go to an app, I'll get the mobile version anyway." (Participant i7).*

Mobile web browsers are improving with the adoption of HTML5 that gives web applications access to local storage and on-device sensors. Application-centric smartphones also allow users to save bookmarks in their application screen, letting them live side-by-side with native applications. As the debate over native versus web applications continues, our results around reaccess suggests that users want to enable data to interact among their devices regardless of how they access it.

5 Discussion

Our investigation into reaccess habits among mobile users revealed the cumbersome workarounds used to find and reaccess information. We found that users would often use features that were made for different purposes as methods to find information later. Many tools, such as Context Clipboard, Evernote, and Dropbox, have attempted to address this problem by enabling easy capture and reaccess, such as saving a link to find later [15] [4] [3]. Although these tools are seamless and easy to use, they still require planning on the part of the user. Through our interviews and discussions with participants, they communicated a general attitude of only planning ahead for big trips and not for the more common reaccess tasks that occur in their everyday life. Sometimes our participants did not know what information they needed later, thus were not able to plan ahead effectively, and other times they expressed dislike of the rigidity imposed by preplanning. Based on these observations, we offer several opportunities to support content reaccess.

First, several contextual factors were influential in computer to phone reaccess. Participants would often reaccess content previously seen on their desktop based on future location and time. This is an opportunity to identify content that a user may need later and use location and time context to present it at a relevant moment. Social context is also an opportunity to present previously seen information that can promote dialogue and help keep conversation flow moving.

Second, the general attitude among users not to plan ahead presents a large design space to create tools to assist these unplanned reaccesses. Existing tools, such as Firefox Sync, have started the process by using cloud computing to enable the sharing of bookmarks and web history across multiple devices [5] . The next opportunity is exploring how to enable just-in-time access to this data without the burden of searching for it in a mound of data. *Participant n4* said that when trying to search for information again while mobile he *"[doesn't] try very hard, if I don't find it in the first or second search then I just give up."*

Finally, breaking content free from mobile application silos can help assist with content reaccess. As applications have become the center of the mobile universe, we noticed signs that people prefer native applications. The content within the application is important, and having better reaccess tools to synchronize this content is essential. For example, after a user looks up directions on the computer, that content should automatically sync to their mobile phone. Many applications are locked in content silos that make it difficult to interact with other applications or devices. As applications continue to move forward, whether as native phone applications or web-based applications, synchronized content is the key to helping users effectively access their data and help support faster unplanned reaccess.

6 Conclusion

We presented a two-week study of high-end smartphone users exploring cross-device reaccess patterns. Our analysis of web and mobile application content through logging and screenshots revealed that reaccess occurs with comparable frequency in both directions between the phone and computer. Participants also communicated a general

attitude not to plan ahead for their reaccess needs, preferring to rely on the connectivity of their device. Based on these results, we suggested several areas of opportunity to support the unplanned activities of users. As more devices are introduced into the personal ecosystem, we believe there will be even greater opportunities to support quick, easy reaccess among these devices.

References

1. BBC. The top 100 websites of the Internet, http://news.bbc.co.uk/2/hi/technology/8562801.stm
2. Chrome-to-phone, http://code.google.com/p/chrometophone/
3. Dropbox, http://dropbox.com
4. Evernote, http://evernote.com
5. Firefox Home, http://www.mozilla.com/en-US/mobile/home/
6. Adar, E., Teevan, J., Dumais, S.T.: Large scale analysis of web revisitation patterns. In: CHI 2008: Proceeding of the Twenty-Sixth Annual SIGCHI Conference on Human Factors in Computing Systems, pp. 1197–1206. ACM, New York (2008)
7. Beitzel, S.M., Jensen, E.C., Chowdhury, A., Grossman, D., Frieder, O.: Hourly analysis of a very large topically categorized web query log. In: SIGIR 2004: Proceedings of the 27th Annual International ACM SIGIR Conference on Research and Development in Information Retrieval, pp. 321–328. ACM, New York (2004)
8. Brandt, J., Weiss, N., Klemmer, S.R.: txt 4 l8r: lowering the burden for diary studies under mobile conditions. In: CHI 2007: Extended Abstracts on Human Factors in Computing Systems, pp. 2303–2308. ACM, New York (2007)
9. Carter, S., Mankoff, J.: When participants do the capturing: the role of media in diary studies. In: CHI 2005: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, pp. 899–908. ACM, New York (2005)
10. Church, K., Smyth, B.: Understanding mobile information needs. In: MobileHCI 2008: Proceedings of the 10th International Conference on Human Computer Interaction with Mobile Devices and Services, pp. 493–494. ACM, New York (2008)
11. Cockburn, A., Mckenzie, B.: What do web users do? an empirical analysis of web use. International Journal of Human-Computer Studies 54(6), 903–922 (2001)
12. Dearman, D., Kellar, M., Truong, K.N.: An examination of daily information needs and sharing opportunities. In: CSCW 2008: Proceedings of the 2008 ACM Conference on Computer Supported Cooperative Work, pp. 679–688. ACM, New York (2008)
13. Dearman, D., Pierce, J.S.: It's on my other computer!: computing with multiple devices. In: CHI 2008: Proceeding of the Twenty-Sixth Annual SIGCHI Conference on Human Factors in Computing Systems, pp. 767–776. ACM, New York (2008)
14. González, I.E., Hong, J.: Gurungo: coupling personal computers and mobile devices through mobile data types. In: HotMobile 2010: Proceedings of the Eleventh Workshop on Mobile Computing Systems & Applications, pp. 66–71. ACM, New York (2010)
15. Harding, M., Storz, O., Davies, N., Friday, A.: Planning ahead: techniques for simplifying mobile service use. In: HotMobile 2009: Proceedings of the 10th Workshop on Mobile Computing Systems and Applications, pp. 1–6. ACM, New York (2009)
16. Jansen, B.J., Spink, A., Bateman, J., Saracevic, T.: Real life information retrieval: a study of user queries on the web. SIGIR Forum 32(1), 5–17 (1998)
17. Kamvar, M., Baluja, S.: A large scale study of wireless search behavior: Google mobile search. In: CHI 2006: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, pp. 701–709. ACM, New York (2006)

18. Kamvar, M., Kellar, M., Patel, R., Xu, Y.: Computers and iphones and mobile phones, oh my!: a logs-based comparison of search users on different devices. In: WWW 2009: Proceedings of the 18th International Conference on World Wide Web, pp. 801–810. ACM, New York (2009)
19. Kane, S.K., Karlson, A.K., Meyers, B.R., Johns, P., Jacobs, A., Smith, G.: Exploring cross-device web use on pCs and mobile devices. In: Gross, T., Gulliksen, J., Kotzé, P., Oestreicher, L., Palanque, P., Prates, R.O., Winckler, M. (eds.) INTERACT 2009. LNCS, vol. 5726, pp. 722–735. Springer, Heidelberg (2009)
20. Karlson, A.K., Iqbal, S.T., Meyers, B., Ramos, G., Lee, K., Tang, J.C.: Mobile taskflow in context: a screenshot study of smartphone usage. In: CHI 2010: Proceedings of the 28th International Conference on Human Factors in Computing Systems, pp. 2009–2018. ACM, New York (2010)
21. Nylander, S., Lundquist, T., Brännström, A., Karlson, B.: "It's just easier with the phone" – A diary study of internet access from cell phones. In: Tokuda, H., Beigl, M., Friday, A., Brush, A.J.B., Tobe, Y. (eds.) Pervasive 2009. LNCS, vol. 5538, pp. 354–371. Springer, Heidelberg (2009)
22. Obendorf, H., Weinreich, H., Herder, E., Mayer, M.: Web page revisitation revisited: implications of a long-term click-stream study of browser usage. In: CHI 2007: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, pp. 597–606. ACM, New York (2007)
23. Pierce, J.S., Nichols, J.: An infrastructure for extending applications' user experiences across multiple personal devices. In: UIST 2008: Proceedings of the 21st Annual ACM Symposium on User Interface Software and Technology, pp. 101–110. ACM, New York (2008)
24. Sohn, T., Li, K.A., Griswold, W.G., Hollan, J.D.: A diary study of mobile information needs. In: CHI 2008: Proceeding of the Twenty-Sixth Annual SIGCHI Conference on Human Factors in Computing Systems, pp. 433–442. ACM, New York (2008)
25. Spink, A., Jansen, B.J., Wolfram, D., Saracevic, T.: From e-sex to e-commerce: Web search changes. Computer 35(3), 107–109 (2002)
26. Tauscher, L., Greenberg, S.: How people revisit web pages: empirical findings and implications for the design of history systems. International Journal of Human-Computer Studies 47(1), 97–137 (1997)