

# Linked Internet UI: A Mobile User Interface Optimized for Social Networking

Yanqing Cui<sup>1</sup>, Mikko Honkala<sup>1</sup>, Kari Pihkala<sup>2</sup>, Kimmo Kinnunen<sup>1</sup>, Guido Grassel<sup>1</sup>

<sup>1</sup> Nokia Research Center, Helsinki

Itämerenkatu 11- 13, 00180 Helsinki, Finland

{yanqing.cui, mikko.honkala,  
kimmo.t.kinnunen, guido.grassel}@nokia.com

<sup>2</sup> Entry Point Oy

Vuorimiehenkatu 31 C 59, 00140 Helsinki, Finland

kari.pihkala@entrypoint.fi

## ABSTRACT

This paper presents the Linked Internet UI Concept, or LinkedUI for short, as a holistic user interface concept to facilitate social interaction on mobile devices. It aggregates social events from social networking services and communication channels and uses hypertext navigation for presentation and interaction. We describe the concept design principles, highlights of the design, and the prototype implementation. We conducted a user study to compare LinkedUI with the benchmark of web applications running in a web browser to follow their friends' activities in Twitter and Flickr and two other optional services on mobile devices. The study results reveal that the users performed tasks faster in LinkedUI and also liked it more than the benchmark. These findings support the design principles of LinkedUI in facilitating social interaction via mobile devices.

## Categories and Subject Descriptors

H.5.2 [User Interfaces]: Interaction styles (e.g., commands, menus, forms, direct manipulation)

## General Terms

Design, Experimentation, Human Factors, Verification

## Keywords

LinkedUI, Mobile, Web, Browser, Social networking services, Service aggregation, Hypertext navigation

## 1. INTRODUCTION

Nowadays, a variety of services are available for people to keep in touch while on the go. In addition to Short Message Service (SMS), voice call, and other conventional communication channels, more and more people also use social networking services (SNSs) on their mobile devices [6]. As of this writing, the popular examples include Twitter, Flickr, Facebook, and a long list of other web-based SNSs. With so many different communication channels and services in active use, keeping in touch with friends, family, celebrities, or bloggers is hardly an easy a task to perform on mobile devices.

Current mobile devices support communication and social services through three major user interface (UI) tools: mobile web

browser, mobile application, and mobile widget [12]. A *mobile web browser* is the web browser on a mobile device that supports access to all web sites through a conventional browser UI. A *mobile application* is the basic building block of native mobile functions; some recent ones are also mashed-up with web content. A *mobile widget* delivers a small piece of web information to mobile devices without user intervention. It is typically placed inside a not closely related view, supports restricted user interaction, and serves as a launch pad for the related mobile application or web site. For example, a home view widget may retrieve and show up-to-date news or weather information on the device's home screen. While effectively delivering the services, the current tools have some major problems.

Firstly, all the content is confined to separate applications. When users try to check their contacts and content from multiple services, they have to follow distinctive UI structures. Navigating in these structures is time-consuming and prone to errors [5, 17]. The proliferation of mobile functions inevitably leads to broad and deep hierarchical menus, which makes it difficult for users to reach target functions. This also means that users often miss new features buried in the UI structures [17, 21].

Secondly, the current tools support different interaction styles in one device. Mobile applications organize information through hierarchical structures; users need to navigate from high to low levels when performing a task. Web sites used with a web browser, however, organize information through hypertext connections. These different interaction styles may lead to confusion [10, 16]. For example, they are confused by the different behaviors of "Back" in web browser and in other mobile functions [10]. This problem will become more significant when people start using more web applications from mobile devices.

In this paper, we introduce the Linked Internet UI Concept, or LinkedUI for short, as a new mobile UI to deliver social services and to support communication channels. In essence, it fetches and links content from existing services, and uses hypertext navigation for presentation and interaction. LinkedUI removes unnecessary boundaries of individual applications and services. As a result, users can concentrate on the content that interests them instead of accessing separate web sites, applications, or widgets. LinkedUI also applies hypertext navigation system-wide and enables a consistent interaction style on a mobile device. The users can navigate the entire device through the mechanisms they are familiar with on the web.

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The key value of LinkedUI is to facilitate using multiple services, web-based SNSs in particular. To verify this hypothesis, we conducted a user study to compare LinkedUI with using web applications through a mobile web browser. We recruited users to use both LinkedUI and its benchmark to follow up on their contacts via services, and measured whether LinkedUI facilitates such tasks, and whether the users like our design principles. The result of this user study is reported after we review the related work, and explain our design and implementation of the LinkedUI concept. In the final part of the paper, we also discuss the findings and our future plans.

## 2. RELATED WORK

The key element of LinkedUI is to aggregate content of multiple services, and to follow hypertext principles for UI navigation. In this section, we review the work in these two fields.

### 2.1 Service Aggregation

Service aggregation means combining multiple services or communication channels in one system or user interface. We are especially focusing on SNSs. For example, a web site called FriendFeed<sup>1</sup> is a service aggregator, which allows users to have multiple SNS identities (e.g., Twitter<sup>2</sup>, Facebook<sup>3</sup>, Flickr<sup>4</sup>, and Delicious<sup>5</sup>) and to follow activities in each of these [9].

Some service aggregation systems have been designed for mobile devices. For example, Friendlee [1] is a prototype of a system, which integrates some social information to the mobile phone phonebook. The main limitation in that work is that it does not currently integrate to existing SNSs and the aggregation is mainly done in the phonebook but not system wide. FriendFeed can also be accessed through a mobile web browser or a third-party application. However, it does not fully integrate with local phone functions, such as phone calls or messages. As the latest development, Vodafone 360<sup>6</sup> aggregates contacts from multiple services, and presents late updates in timeline view. Its design follows application centric logic, and does not connect updates system wide. As a result, the user can only access these updates from the selected applications.

Service aggregation systems can rely on the initiation of publishers or readers. In the *publisher-initiated* aggregation systems such as FriendFeed, the publishers merge their own identities, which make their readers see all aggregated content once subscribing to; in the *reader-initiated* systems such as Vodafone 360, Flock browser<sup>7</sup>, and LinkedUI, the readers merge the identities of others, which has no impact to the publishers or other readers. Consequently, such systems allow publishers to keep separate identities for different readers.

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<sup>1</sup> <http://friendfeed.com/>

<sup>2</sup> <http://www.twitter.com/>

<sup>3</sup> <http://www.facebook.com/>

<sup>4</sup> <http://www.flickr.com/>

<sup>5</sup> <http://www.delicious.com/>

<sup>6</sup> <http://www.vodafone360.com/>

<sup>7</sup> <http://www.flock.com/>

From a technical perspective, service aggregation systems can occur at server side such as FriendFeed, at client side only, such as the Flock browser. The client-side approach has better support for offline operations and introduces fewer privacy risks; and it is chosen for the LinkedUI prototype. LinkedUI differs from the Flock browser in terms of the integration depth. It integrates services deeply as part of native functions, while Flock has a shallow integration and relies on the actual web applications for many of the functions. In addition, the Flock browser does not fully integrate contacts across services.

### 2.2 Hypertext Navigation

Hypertext is the structure of using nodes and links as a medium of thinking and communication for users [4]. It is likely to be the most familiar UI navigation method for users due to the popularity of the World Wide Web, so far the largest hypertext system. Chen concludes that hypertext users tend to be more effective than non-hypertext users, particularly when the users do not aim for specific goals [3]. The same conclusion is also supported by recent researches on mobile devices [21]. Hypertext, however, can cause disorientation. This manifests itself as difficulties to memorize the route taken to arrive at the present node, difficulties to understand the relation to the other nodes, difficulties in deciding which link to follow and not knowing which nodes have already been visited [4, 18].

Hypertext promotes some common navigation mechanisms. For example, in the web, searching is a dominant mechanism to locate new information through keywords; other hypertext navigation mechanisms include back-stepping, bookmarking, and a history list. As shown in previous studies, the users rely on these mechanisms to navigate in the web. Meanwhile, they also become experienced in using these tools [15, 20].

On mobile devices, many researches address hypertext navigation in web applications (such as, [2, 13, 21]); however, not many systems implement the hypertext navigation system wide. Marsden and Jones aim to organize the entire mobile UI in hypertext style to support a consistent UI between WAP and local application functions [17]. They introduce the system-wide hypertext navigation, but did not fully implement and verify the new UI system. In a recent research, Diehl creates an Associative PDA to unify personal information in ubiquitous devices [7]. Associative PDA stores the information through a network of associations and connects all related items. This is to solve the information that personal information is fragmented in separate applications, or different devices [14]. These researchers aim to enable hypertext navigation, but they do not focus on how to present it in a mobile user interface.

## 3. CONCEPT DESIGN

LinkedUI presents a holistic mobile UI design aiming to facilitate using multiple services on mobile devices. In this section, we present the design principles followed by key example views.

### 3.1 Design Principles

LinkedUI aggregates content across services and contacts. It fetches content from multiple networking services, interlinks the content items across service boundaries, and integrates them with native functions on mobile devices. Instead of confining content items in application silos, LinkedUI builds alternative views to

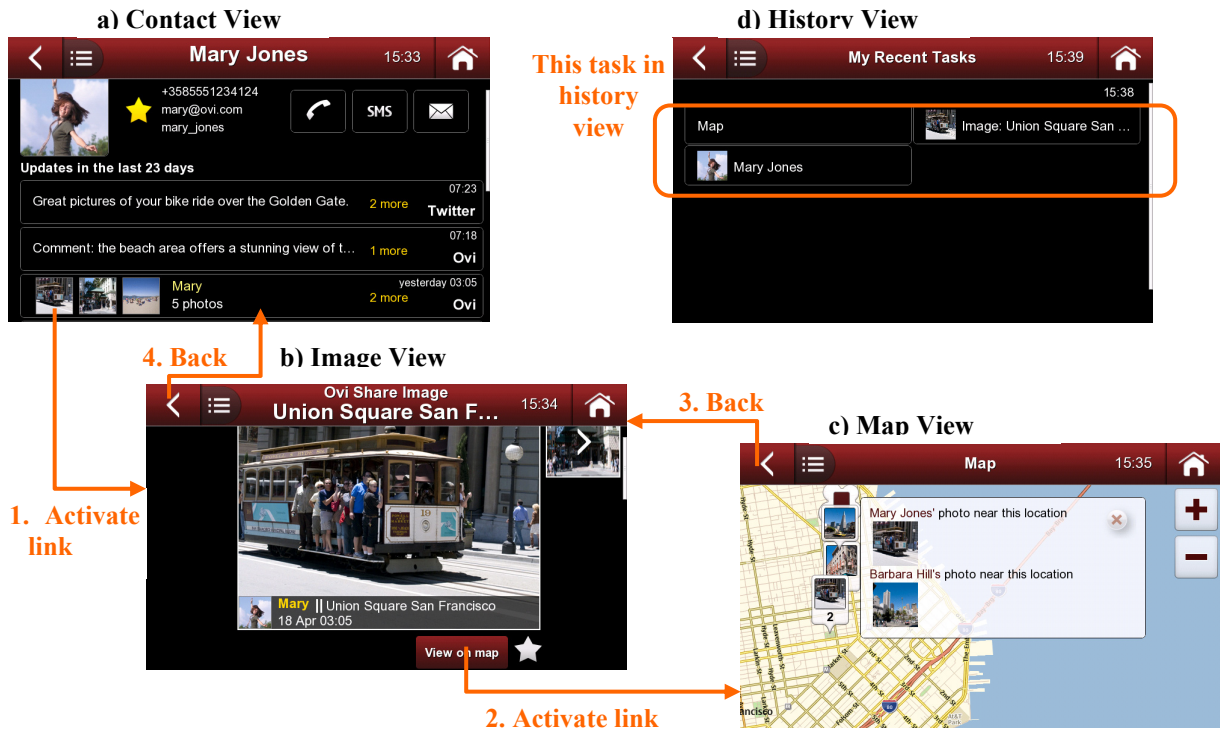


Figure 1. Hypertext navigation between views.

the content items using the associated metadata and links between the items. These views present data in a way, which is logical to the users in their use cases. For instance, by aggregating content of many services, the users can see the updates of a contact in one view rather than needing to visit multiple web sites or applications.

The system aims to have high internal consistency [10] by handling logically similar items uniformly. For instance, messages directed to the user are treated similarly regardless of the delivering service (e-mail, SMS, or directed message in SNSs). It also optimizes the presentation of the content and interaction to fit the user's mobile device with limited input and output capabilities.

One design principle in LinkedUI is to allow good interplay of local views and web applications used in the browser. The key functions of a web application are integrated deeply into the system views, while the rest of the functions can be provided by links to the web application. It is up to the integrating application to decide the depth of integration.

LinkedUI follows the hypertext navigation, the UI convention used on the web. For example, users can access content through hyperlinks, and access the previously visited views through pressing the Back button or using other history mechanisms. Back is a system-wide function in LinkedUI. It always performs the same function: goes back to the previous view. This closely resembles the behavior of the Back button in web browsers, and makes the behavior familiar, consistent, and trustworthy to the users. The reasoning for this design principle is to increase the UI consistency in the entire device, which is crucial for usability [10, 16]. This will be particularly relevant when people are using more and more web-based services for their computing needs [12].

Figure 1 depicts a typical navigation sequence and is shown here as an example how a user can freely navigate between

applications using hyperlinks, Back, and history. First, the user opens the a) Contact View for her contact Mary Jones. Then, she selects one of the image updates and goes to the b) Image View. After that, she taps on "View on map" to show the image in the c) Map View. Finally, she navigates twice back (steps 3 and 4) and comes back to the Contact View. On the top of the image, this task is shown in d) the History View. More examples of the design can be seen in a video we have released<sup>8</sup>.

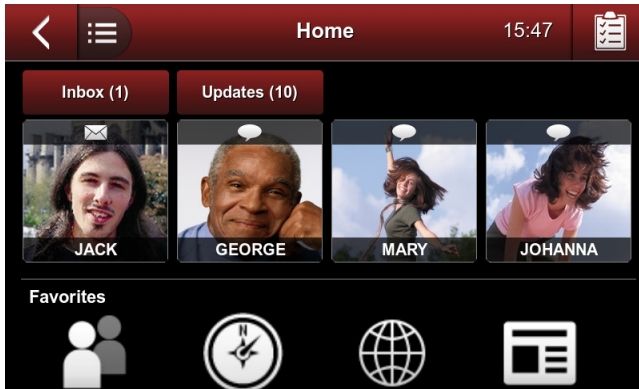
### 3.2 Example Views

In this section, we present a few key views in our current design, and explain how the design principles of service aggregation and hypertext navigation work. The UI design was performed according to Nokia N900 hardware specifications; including a 3.5" touch screen and a slide-out QWERTY keypad. All the views were created for landscape mode, because of limited designer resources. While these designs could be utilized for devices with other characteristics, an expert should always do a design for each targeted device separately.

The LinkedUI Home View is the starting point for use of the system. As depicted in Figure 2, the Home View provides a notification area, a task launcher, and links to user favorites. LinkedUI constantly checks for updates of services integrated to it and notifies the user when new content is received. The notification area presents thumbnail images of the originating contacts together with an indication of the categories that the updates belong to: an SNS, a text message, e-mail, or a missed call. This design resembles normal mobile phone design, where new text, media content, and e-mail messages are automatically

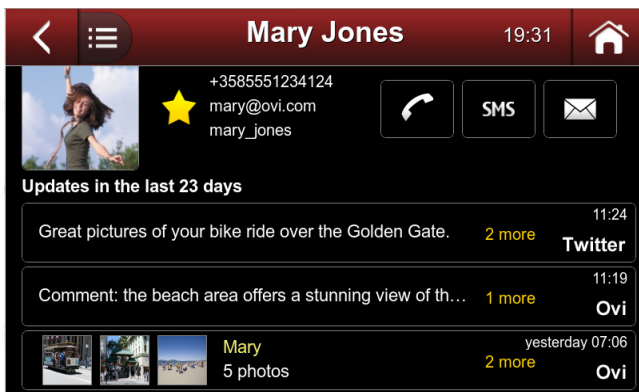
<sup>8</sup> LinkedUI homepage:  
<http://research.nokia.com/research/linkedu/>

fetched and reported. The user favorites can be views that aggregate information or actual content items.



**Figure 2. The LinkedUI Home View showing the contacts with recent updates.**

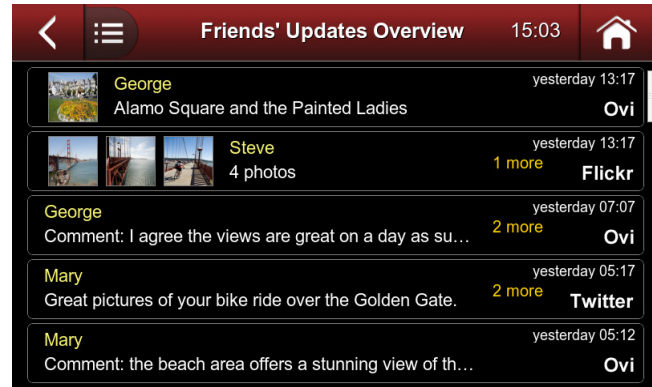
Studies have underlined the importance of the contact viewer for a mobile communication device [11]. In addition to allowing the user to call or send a message to a contact, the LinkedUI Contact View organizes and presents an update stream for an individual contact, as shown in Figure 3. The view aggregates updates from all the services that the contact uses. Thereby, it enables the user to glance at summaries of all her friends' updates in one place. The Contact View is also linked to from any content related to a contact – e.g., a message or a Flickr comment. We envision that joining the various online identities and contacts information of a person should be a semi-automatic process: The system retrieves the device user's contacts from all services, matches identities automatically using unique identifiers such as email address or phone number. It assists the user in manually linking remaining disjoined identities by making suggestions. These suggestions could be based on similarities in identities or by learning from the user frequently accessing two identities in combination.



**Figure 3. The LinkedUI Contact View showing the recent updates of a contact.**

In Contacts View, the user can tap on an update to open it in a separate detail view. These detail views are designed for each service, to allow service-specific functionality. For instance, LinkedUI provides a detail view for reading and responding to a Twitter message; a view for a Flickr photo allows commenting the photo.

The LinkedUI Update Stream View provides a summary of recent updates from all contacts in a time-line order, as depicted in Figure 4. Therefore, it allows the user to keep up to date on recent updates from all of her contacts without needing to go to each contact or each service separately. This view gives more information about the updates than the highly summarized Home View. Further filtering of updates is also possible for advanced users. This allows displaying updates from one selected service as the Service View.



**Figure 4. The LinkedUI Updates Stream View, which shows recent updates of all contacts in any service.**

Some contacts may generate a large volume of updates that pose a great challenge to be accommodated in the Update Stream View. For instance, it is typical for people to post a large number of related images in Flickr within a short span of time. Our design meets this challenge by grouping related updates in clusters by time and service, as shown in Figure 4. Activating a group of updates expands the group in place for selecting an individual update for viewing. LinkedUI also moves old updates in the Update Stream View to an archive view of older updates.

The LinkedUI Inbox View combines all messaging directed to the user into a single user interface. This includes, e.g., SMS, e-mail, and Twitter direct messages. The reason for showing direct messages in a separate view (instead of including them in the Friend Updates View) is that they are typically considered more important and urgent than normal SNS status updates that are targeted to a larger number of contacts. The inbox groups messages by thread and sorts them by time, similarly to many current messaging UIs such as N900, iPhone, and Gmail. It is also possible to reply to messages in Inbox.

LinkedUI Search provides a full text search function into all cached content of the users and that shared by their contacts. It can be initiated from any view by either pressing a key on the keyboard or selecting it from the menu. The search is scoped to the items related to the current view. It is always possible to remove the scoping and thus search through all content. Search is interactive so that each key press runs a new search. This allows the user to keep refining the search until the item that she is looking for appears in the results. The search results can be of different types and are ordered by a personalized ranking algorithm.

LinkedUI History presents the user's recently visited UI states. It allows the user to select any state from the list and thus return to

it. The history contains all states, also those that cannot be reached by the Back function that only retains the linear list, and no branches, and groups UI states logically.

#### 4. IMPLEMENTATION

We have developed a functional prototype of our research UI concept. It supports online and offline operations and is able to synchronize the user's own content and content shared by his contacts with services. It also synchronizes metadata describing the content, such as tags, comments, and geographical data. Our current prototype supports Flickr, Ovi, and Twitter, among others, for demonstration and user evaluation purposes; and it can be extended to cover new views, content types, and services. Because of the limited development resources, the prototype has most of the functional requirements derived from the UI concept (including the ones described above in this paper) but does not yet meet all stability-, deployment-, and security-related requirements as would be expected from a product.

As described in Figure 5 below, the UI and logic layers (middle of Figure 5) were implemented using web technologies (HTML5, CSS, JavaScript). The main benefit of using CSS and other web technologies in the UI layer is to increase abstraction level compared to native programming, thus improving agility for UI changes and helping cross-platform development. The runtime part is written in C++ and C (at the bottom in Figure 5) and is based on open source components WebKit<sup>9</sup> and SQLite<sup>10</sup>.

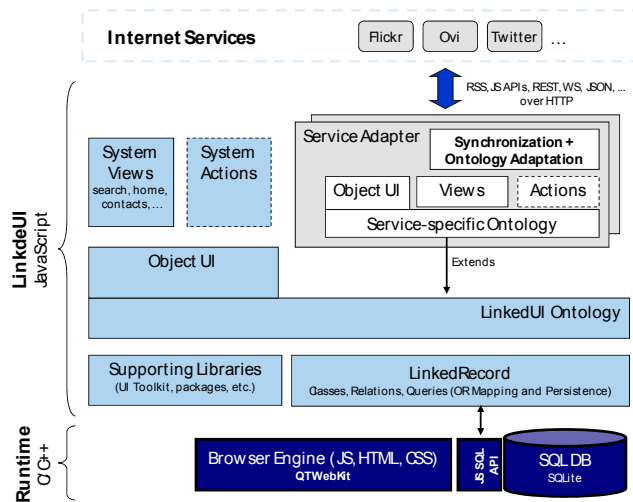


Figure 5. High-level architecture of the functional prototype.

The service adapters (the upper right of Figure 5) connect to the various internet services using HTTP and synchronize service data using public service APIs. The main benefit of this approach is the stability of the APIs and resulting adapters compared e.g., to screen scraping. In order to handle and aggregate somewhat heterogeneous data from different services, a common data repository and a common ontology is required. In LinkdUI the data repository is called LinkedRecord, a metadata persistence layer. LinkdUI Ontology provides the system-wide ontology,

which describes the concepts that the system supports and understands. As a result, all the data in the system is stored in this typed metadata graph provided by the LinkedRecord system. LinkedRecord was implemented as an object-relational mapping and it uses a SQL database backend. RDF storage could be used for this purpose as well.

Object UI allows pluggable UI implementations for different object classes. The System Views provide the main views, such as Search and Home. Service Adapters are used to integrate 3rd party Internet services to the system. They synchronize and adapt the data between the LinkdUI Ontology and service-specific data representation. They can also extend the system with service specific ontology extensions, views, object UI, and actions. This way, the resulting UIs provide varying levels of service-specific content and functions rather than the least common denominator of all the services only.

The runtime mainly consists of an open-source web engine WebKit's QT port, which was optimized to run well on a Nokia N900 smart phone running a Linux-based Maemo5 OS.

#### 5. USER STUDY

To test if LinkdUI facilitates using multiple services from mobile devices, we conducted a user study to compare it with the existing approach to use services through a mobile web browser. The study was similar to a conventional laboratory test; but we used users' own real content in test tasks and conducted the study in a quasi real-life context. As suggested by a recent study, using users' real content makes users more involved in the test and therefore reveals more potential problems [8].

Table 1. Basic information on all test participants

ID	Sex	Age	#Contact	Phone	Mobile Web	Test Order
U1	M	26	93	N95	several/day	Bm/linkdUI
U2	F	21	66	E71	don't use	Bm/linkdUI
U3	M	23	118	N97	occasionally	Bm/linkdUI
U4	F	25	86	7510a	don't use	Bm/linkdUI
U5	M	31	151	N95 8G	several/day	Bm/linkdUI
U6	F	29	205	N95	several/day	Bm/linkdUI
U7	M	25	63	N900	several/week	LinkdUI/Bm
U8	M	32	102	N82	occasionally	LinkdUI/Bm
U9	M	27	146	iPhone	several/week	LinkdUI/Bm
U10	M	34	54	E72	several/day	LinkdUI/Bm
U11	F	27	59	N900	several/day	LinkdUI/Bm
U12	M	29	42	X6	several/day	LinkdUI/Bm

##### 5.1 Participants

12 users (8 male, 4 female) participated in the study. All were living in the Helsinki, Finland capital area, except one in Tampere, Finland, 21 to 34 years old ( $M = 27.42$ ,  $SD = 3.78$ ). They were recruited through a mailing list, an online forum, and a corporate blog web site. As of enrollment, all participants had to use Twitter and Flickr services several times a week, and follow at least 20 contacts on each service. 10 participants had already used the services on their mobile phones. Table 1 presents the

<sup>9</sup> <http://webkit.org/>

<sup>10</sup> <http://sqlite.org/>

basic information of individual participants. “#Contact” is the number of contacts that each participant follows on SNSs in total ( $M = 98.75$ ,  $SD = 48.60$ ). “Bm” is the abbreviation for benchmark. Each participant spent 90 minutes in the study and was rewarded a 20-euro or 30-euro gift card, depending on travel expense involved.

## 5.2 Devices, Materials, and Test Environment

The benchmark in the study was to use web applications through a web browser on the N900. Users had to use regular web sites of tested services. All the services were accessible from their bookmarks on the device’s home screen, as shown in Figure 6.



Figure 6. Home screen of the benchmark device.

Because LinkedUI was implemented on top of the Nokia N900, the same device was selected for the benchmark, to minimize the parameters in the comparison test. We chose the web browser because it is the main tool to access the web from mobile devices [12]. The N900 ships with a state-of-art web browser; but as of the study, widgets or applications serving the purposes of this study could not be found.

LinkedUI and its benchmark were set up on two identical N900 devices in the study. 3G connections were used on both devices. The test primarily focused on Twitter and Flickr as they are typical services for messaging and photo-sharing. It also included Delicious and Last.fm<sup>11</sup> as examples of social bookmarking and music-sharing services. However, only three participants had contacts in the latter services. Therefore, for the rest of the paper, we concentrate on Twitter and Flickr.

All test sessions were done in a public cafe area in an office building. This setup is close to the contexts where the participants may use SNSs on their mobile devices [5, 12]. We audio recorded all sessions after gaining permission from each participant. Video recording was avoided for privacy concerns. All participants’ data on the test devices was permanently removed at the end of each session.

## 5.3 Test Tasks

Three tasks and one orientation task were used. The test tasks used real content from each participant’s own accounts in SNSs. The orientation task used test accounts that were created for this test, and not known to the participants before the study.

The orientation task was to freely explore LinkedUI or the benchmark (T0). The participants had to check all services for about eight minutes in order to get familiar with the designs.

The first test task was to openly browse what was going on (T1) in the relevant services within three minutes. The participants were asked to check all services, and to “think aloud.”

The second test task was to follow one contact (T2). The participants had to check the recent activities of the given contact on multiple services and attempt to make a call. The contact that they needed to check in LinkedUI was different but comparable to the one in the benchmark.

The third test task was to locate a Flickr photo and a Twitter post (T3). The search targets were the same in LinkedUI and in the benchmark system. But the participants were encouraged to alternate searching and browsing strategies to locate the search targets. All the search targets were published recently confirmed having been seen by the participants before the study.

We designed these three tasks after consulting one of our unpublished background diary studies. Out of 84 sessions noted down by six Finnish users over two weeks time, the common activities were open check-up (53%), locating special targets (15%), publishing content (11%), and others (21%) on Facebook. Our test tasks cover all major activities except publishing content. We excluded it because participants could have felt intimidated if they had been forced to publish something in the test.

## 5.4 Procedure

Prior to the start of the user test, we synchronized the data from the services into LinkedUI. This process involved automatically downloading the recent updates from all the contacts in the test services and manually merging some contact entries that belong to the same person. Up to seven such persons were manually merged after we consulted the participants in the study. For the benchmark, the participants had to log into services and temporarily save user credentials to the web browser. All relevant services were open in the background to mimic the scenario that an active user may keep these Web pages open in separate windows of the browser all the time.

In a test session, each participant performed all tasks both in LinkedUI and the benchmark before they compared the two in the end. Six participants (U1–U6) started from the benchmark device, the other six (U7–U12) started from the LinkedUI.

For each design, the participants firstly had to do an orientation task (T0), and then complete all test tasks in using real data from their own accounts (T1, T2, and T3). After that, they had to rate their subjective impressions about that design using a list of statements with a 7-point scale, as reported in Results section. The “Don’t know” option was also allowed. We also interviewed the participants to understand their choices.

After repeating the above steps for both LinkedUI and the benchmark, the participants had to choose which design better supports social interaction with their contacts, and give reasons to support their decision. They were also asked what should be improved or developed further in LinkedUI.

<sup>11</sup> <http://last.fm/>

## 6. RESULTS

### 6.1 Overall Preference

After using LinkedUI and the benchmark devices, the participants were asked which design supported social interaction with their contacts better. Out of 12 participants, 11 preferred LinkedUI and only one preferred the benchmark device.

The positive user comments focused on the LinkedUI principles. For example, U6 liked LinkedUI in providing an overview of live events from multiple services, “*I really enjoy the fact that everything I can have a look at with, like, one application. I suppose [LinkedUI] might actually be faster. I usually tend to have Facebook, Jaiku, and Twitter opening all the time in my browser, and my e-mail program. So if I could incorporate them all into one, I could have just one program on, instead of having zillions of web pages*” (U6).

The other positive comments included organizing content through contacts, integrating web applications with local content, and optimizing content presentation for small screens. They also pointed out specific LinkedUI elements such as Search, Back, History, and Favorites. On the other hand, in the benchmark, the participants complained that it was not easy to follow multiple services, because of delays in loading web pages, tedious process to switching services, and difficulties to navigate within a web page or between windows.

Whilst preferring LinkedUI, three participants also commented that LinkedUI and the web browser should complement each other. LinkedUI “*is best when I am away from my home, where I only want an overview of my friend things. But the browser is the device for home where I want a full experience, since everything is possible there*” (U10). “*Sometimes, I may still want to visit the web site, because you can have more personalization features there, such as people may create different background on their page*” (U11).

The only participant who did not prefer LinkedUI complained that she was overwhelmed by the “*ambitious*” changes in LinkedUI. She liked content from multiple services to be put into one view, but would have liked the content from each service to be separated in order to make it feel more “*organized*.” She had tried a service aggregator on the web before the study but was not impressed by its design.

### 6.2 Observations in Tasks

Not only being preferred by most participants, LinkedUI was also better than the benchmark in supporting the tasks to browse openly and to locate some target item.

#### 6.2.1 Open Browsing

When freely browsing services in T1, the participants were able to access significantly more contacts in LinkedUI than the benchmark, based on the analysis of vocal protocols ( $X. t(10) = 2.63, p = .01$ ). Figure 7 presents the average number of contacts accessed within the 3 minute limit. The data are from 11 participants because one participant (U2) had difficulty in performing thinking aloud.

When probed about their experience, the participants thought LinkedUI supported their browsing strategies well. In particular, nine participants commented that Update Stream put the updates from all services into one place, which helped them to scan all

updates quickly. Three participants praised Back for making it smooth to switch back when checking many interesting items (U11, U6, U12). Three other participants (U1, U10, U5) liked the Favorite feature to mark some items for future access.

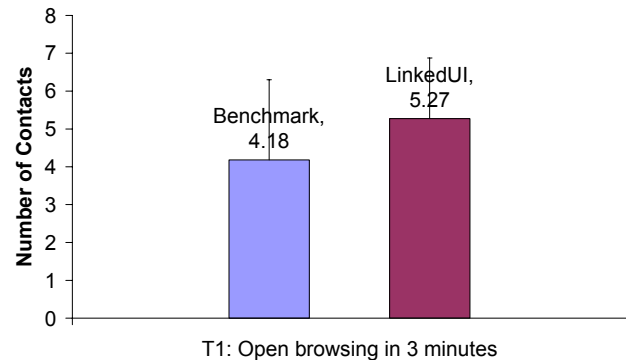


Figure 7. The average number of contacts checked in T1.

LinkedUI also enabled two browsing strategies not possible with the benchmark. Six participants used notification area in the Home View for this task. They appreciated the contact centric logic in this view and asked for a way to skip contacts that were active but less relevant. To our surprise, two participants also used Search to follow trends within their contacts. U3 queried “football” to check a soccer match result his friends were playing. U9 queried “N900” to see what his contacts think about the device. These unexpected findings show that LinkedUI may well enable new ways for people to follow their contacts.

#### 6.2.2 Finding Contacts or Updates

When trying to locate contacts or updates in T2 and T3, all participants succeeded in both tasks in LinkedUI. But one participant failed in T2 and other one failed in T3 within the 5 minute limit in the benchmark. Figure 8 presents the average task completion time for the successful cases. It was faster to track contacts or updates in LinkedUI than in the web browser. (T2:  $t(10) = 4.92, p = .00$ ; T3:  $t(10) = 3.60, p = .00$ )

Task Completion Time (Seconds)

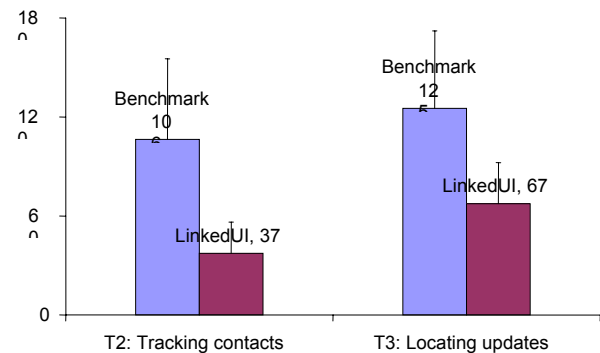


Figure 8. The average task completion time in T2 and T3.

Performance advantage of LinkedUI was largely attributed to its contact centric designs and Search functionality. For example, in T3, all participants tried using contact as a bridge when browsing toward the target updates. When using LinkedUI, only one participant had problems to locate the contact list, or to search or

browse in it. When using the benchmark, however, six participants had problems to use contact lists from individual services; three of them had to type in URLs to access the contacts as a workaround. In the same task, Search was used by nine participants to locate update items in LinkedUI, but it was only used by three participants in the benchmark. This difference was big given the participants were encouraged to use Search.

### 6.3 Subjective Ratings

The participants rated their experience with LinkedUI and the benchmark after performing all tasks on each of them. Figure 9 presents the statements we used and their average ratings. 7-point scales were used: 7 represents “strongly agree,” 4 represents “neither disagree nor agree,” and 1 represents “strongly disagree.” In general, LinkedUI was rated higher than the benchmark on the average of all questions (5.12 vs. 4.71). The trend was the same regardless of the test order (U1–U6 starting from the benchmark: 5.11 vs. 4.76; U7–U12 starting from the LinkedUI: 5.14 vs. 4.67).

LinkedUI was clearly preferred over the benchmark by the participants to follow their contacts as individuals across services (Q1) ( $t(11) = 3.34, p = .00$ ). One participant commented, “*It is easy for you to know a person. Click the person, and you will see everything. You have friends on different services, so you don’t have to log onto all services any more*” (U10).

This result is further supported by the ratings of Q2. The participants liked to keep content from multiple services mixed, or “*having everything in one place*,” more than keeping it separate as in the web browser ( $t(11) = 1.89, p = .04$ ).

LinkedUI was also perceived as helping people follow their contacts on various services all together (Q3), close to the benchmark ( $t(11) = 0.11, p = .46$ ). Some participants commented that they would have given higher ratings if LinkedUI “*remembered what you left last time*” (U9, U10) or “*did not show irrelevant tweets, so it could be easier to find what my favorites are doing*” (U5).

Most participants thought they would know their contacts better if they kept using LinkedUI (Q4), significantly higher than the benchmark ( $t(11) = 3.32, p = .00$ ). As U2 explained, “*If I follow someone on Twitter, I may not check their Flickr all the time. But here, Flickr photos will automatically come out as well*.” Another participant joked that using LinkedUI would make him “*a bit nerdy since I may end up using those social services so often*” (U8). A powerful mobile browser, however, would not change their behavior much. As one participant commented, “*I am not sure I will all the time open my browser to check my friends*” (U10).

LinkedUI got reasonable ratings for being easy to use and easy to learn (Q5), but lower than the benchmark ( $t(11) = 1.97, p = .04$ ). It was overall perceived “*standard, nothing too novel*” (U5) and “*self-explanatory*” (U3), but some of its features needed further improvement. For example, two participants criticized the design to combine tweeter posts into groups (U8, U12), or to mix favorites of different natures (U9).

As for the easiness to locate something (Q6), LinkedUI was rated reasonably high and similar to the benchmark ( $t(11) = 0.16, p = .44$ ). The participants liked LinkedUI because it supported Search and linking content through contacts. As U7 commented,

“*[LinkedUI] is easy because it connects things with the person behind it.*”

In LinkedUI, the participants were not certain about where they were and how they could proceed (Q7), worsen than in the benchmark ( $t(11) = 2.40, p = .02$ ). The constant availability of Back and Home function appeared to lessen the problem. As U6 commented, “*The Back button always goes to where I come from, and helps me orient myself in the system. It works more or less how I expect, just like going through graphics in my memory.*”

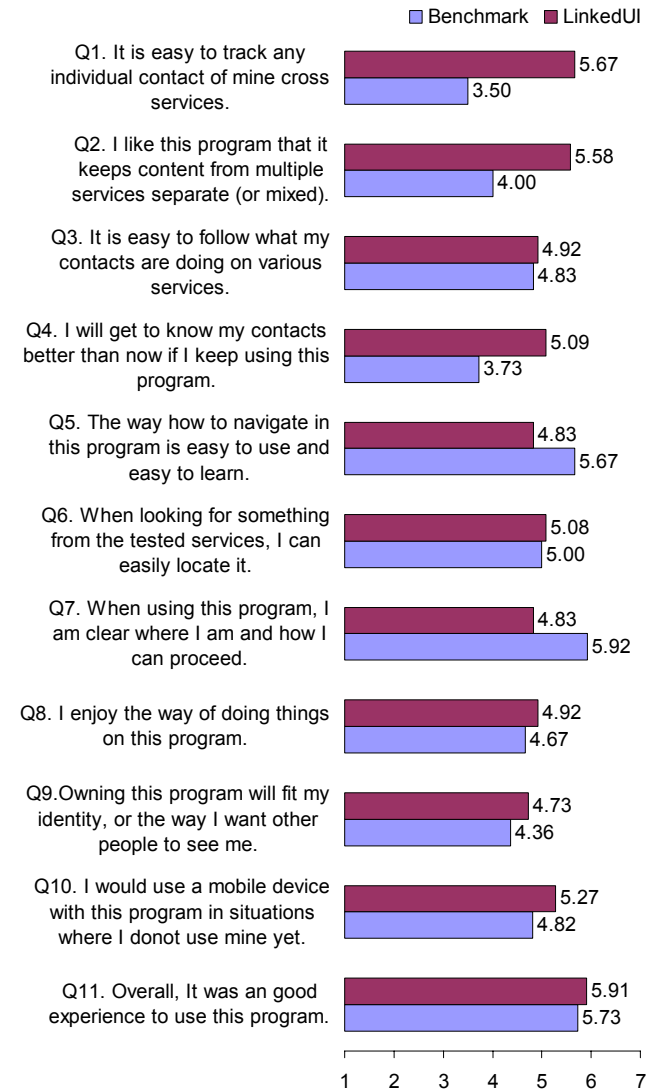


Figure 9. The average subjective ratings for LinkedUI and the benchmark.

Q8–Q11 address the other general experience elements. LinkedUI was rated high and slightly better than the benchmark on these questions, although there was no significant difference.

## 7. DISCUSSION

The user testing shows that LinkedUI supports the test tasks better than the benchmark. The users achieved better performance with LinkedUI, and preferred it over the benchmark. This result supports the overall LinkedUI design principles.

On the one hand, LinkedUI puts all users content together and tries to unify the presentation of similar content from all services and communication channels. The users are able to check what their contacts are doing on multiple services via LinkedUI faster than via individual web applications. They also find it natural that LinkedUI uses contacts to structure and present their content. Though this design, the users are able to quickly locate their previously seen content and constantly follow up on the contacts they care about.

On the other hand, LinkedUI applies hypertext navigation to entire mobile device. For example, the user can jump between any linked content items, and return to the previous view by pressing the Back button. When performing test tasks, the users were able to use this navigation naturally, and some of them spontaneously praised that the design works in the same way as with the web. LinkedUI also provides a full-text search function covering all data on the device. This search function emerged as a major tool to locate content in our user study. Some users even used it to monitor the trend among their contacts. This reflects the user habit in using search to locate content on the web [19].

LinkedUI presents a holistic mobile user interface. All the functions on a mobile device, relevant to the web or not, are structured and presented in the same way (internal consistency) [10, 16]. But this goal is achieved at the expense of organizing and presenting content differently than in other platforms (external consistency). For example, updates from Twitter and Flickr are structured and presented differently from their conventional appearance in web browsers. This expense appears to be justified in the overall test results. In particular, nine users liked LinkedUI for optimizing content organization and presentation for small devices, three of them even demanding further optimization. Instead of showing all the posts in Twitter, they asked LinkedUI to filter out irrelevant ones.

The study also indicates that some users may feel disoriented in subjective ratings when using the system for the first time (e.g. in Q5 and Q7). We argue that the problem is attributed to the test setup itself rather than the design principles. The users got about eight minutes to familiarize the design in orientation period of the user study, which may be too short for a completely new system. In addition, some features in current tested version were “confusing” for some users, such as some buttons, UI layout, and icons. In the next step, we are going to improve the current design and execute a field study, which should provide a more conclusive answer to this question.

## 7.1 Design Implications

On the basis of the user study results, we have derived the following design implications for mobile UIs within a similar scope to the one proposed in this paper. Some of the implications stem from successful features of the LinkedUI system, while others are proposed fixes to features that were not received well in the tests.

Hypertext navigation seems to work well in the case where there are naturally a lot of links between content items. Because of the popularity of the web, people are already familiar with the concept.

The Back functionality should be implemented consistently, in contrast to what is done in many current commercial systems,

which often mix Back with hierarchy navigation functionality within an application.

Search should be provided in the mobile UI consistently. It seems that, especially in goal-oriented tasks, people find this feature very handy. As a detail, the key-press interactive search has worked well in LinkedUI.

Restructuring of aggregated content should be done in a way that is logical to users and supports their main tasks well. Breaking down application boundaries seems to work, but it requires new designs to organize and present information. An example from LinkedUI that worked well is the Contact View, which reorganized updates from all channels into one user interface.

Information overload is a problem in a system that aggregates and restructures content from multiple sources. We propose to use grouping, user customization, and automatic adaptation as means to solve this problem.

The web applications through a web browser is the main delivery channel for most services currently [12]. It is therefore important to provide consistent navigation and interaction between the native views and the web applications used through the browser. In practice, a system needs to make it easy to use links and navigation between native and web applications. Window and task management also needs to take this issue into consideration.

## 7.2 Methodological Notes

There are some key restrictions in interpretation of our user test findings. In this study, we tested LinkedUI with real user content. The participants were repeatedly exposed to the same data set in both LinkedUI and the benchmark devices. We tried to control the influence of this by balancing the order of the test sets, but that may not completely counterbalance the learning effects. Because of the novelty of LinkedUI, we believe that the participants may have found out in the middle of the study that it was a concept created by us, although we tried to make a “blind” comparison.

## 8. CONCLUSION

LinkedUI introduces a holistic mobile user interface. It aggregates content from several social networking services and communication channels so that they can be followed in one consistent user interface. It also follows the hypertext navigation conventions by using hyperlinks, Back, search, and other history mechanisms. The user test conducted reveals that the users preferred the new approach over the traditional web browser for accessing social networking services on mobile devices. LinkedUI eliminates some significant shortcomings of using services through a web browser. These shortcomings included problems in switching applications and web sites, delays loading web pages, difficulties with switching windows, and navigating in web pages that were not optimized for a small screen.

The test also revealed some problems, such as information overload due to service aggregation and disorientation potentially related to the hypertext navigation. In future work, we will address these problems by improving the navigation aids and by utilizing machine learning techniques for personalizing the presentation to prioritize content that appear most relevant to the user. We also plan to conduct a longer-term field test to study how these improvements affect the design. The field study will

also further reveal how much LinkedUI will facilitate using social networking services on mobile devices.

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