User Evaluation of Dynamic User-Centric Networking*

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Abstract. In user-centric networking users become the endpoint of their communication sessions. This approach intrinsically accounts for mobility management, as terminal handovers and session migrations are expected when the user moves. However, effectiveness of session migration procedure is not trivial to assess, because it mainly concerns the subjective impressions that human users have about their interaction with the system, thus a common approach is to carry out user-evaluation at live demos.

In this paper we describe the user evaluation of our dynamic user-centric networking framework, done at a national science exhibition through a Voice-over-IP application running on top of it.

Keywords: User-centric networking, Mobility management, User-evaluation.

1 Introduction

Recently, the user-centric paradigm was applied to networking [1], by making users the endpoints of their multimedia sessions, whereas devices in their surrounding only are instruments to access networks and to interface with multimedia tools. In this approach, users are assigned a personal network identifier (i.e., the *Personal Address*, PA) for each of their communication sessions. Technically, that address is indeed bound to the device currently used, which performs network operations on behalf of the user.

Mobility management becomes integral part of the whole framework, in order to let users using any device and accessing any network in a seamless, transparent and automatic way. The current implementation of this framework exploits the Mobile IP (MIP) [2] infrastructure, which allows to deal with terminal handover and session migration in a uniform way (see [1] for details). Indeed, MIP only

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deals with terminal mobility, but the powerful of the PA approach resides in realizing session migration as well on the same infrastructure.

Terminal handover with MIP has been thoroughly investigated in the past; however, session migration is a more recent application and its performance is not so much clear [1], [3], [4]. Preliminary measurements have already been carried out for the Personal Address framework, both in local environment and in Internet testbeds [1]; however, these results usually are difficult to interpret as effectiveness of session migration mainly concerns the subjective impressions humans have about their interaction with the system: just consider that the terminals often are not side by side, and the person may need several seconds to move to the new device.

This paper extends our previous work [1] with qualitative user evaluation of session migration in the PA framework: a live demo with a sample multimedia application was shown at an Italian national exhibition named "Festival of Science", where a large number of visitors got their feedback through compilation of questionnaires and direct interviews. The demo planning, the questionnaires and their analysis were organized with the support of a psychologist, who was already skilled in user evaluation for multimedia applications.

The paper is organized as follows: Section 2 describes the live demo and the application, Section 3 explains the procedure for evaluation and Section 4 analyzes the feedback and answers from visitors. Finally, we give our conclusions in Section 5, together with our plans for next developing.

2 The Live Demo

The networking framework was evaluated at the live demo through a very simple and minimal Voice-over-IP (VoIP) application based on the SIP protocol [5] for communication. Figure 1 shows the architectural elements for automatic session migration.

Mobility relies on the user-centric Personal Address framework described in [1]; the user identification (Chloe's PA in the picture) remains the same independently of the current device. The framework integrates with the SIP infrastructure; SIP extensions to handle session migration were already described in [1].

Sensor networks are in charge of locating the user. Sensors are MicaZ[1] motes, which operate at the 2.4 GHz ISM frequency band and adopt the IEEE 802.15.4 communication protocol [6]. Fixed sensors (anchors) are scattered in the environment, while one mote is worn by the user; the Context Server accumulates RSSI measurements from motes, estimates the user position and decides the most suitable device (that one closest to the user). Moreover, the Context Server is in charge of tracking the user position; the SIP proxy subscribes a localization service at the Context Server which notifies the current (closest) device every time the user moves.

[1] Crossbow Technologies, MicaZ Specification, `http://www.xbow.com`

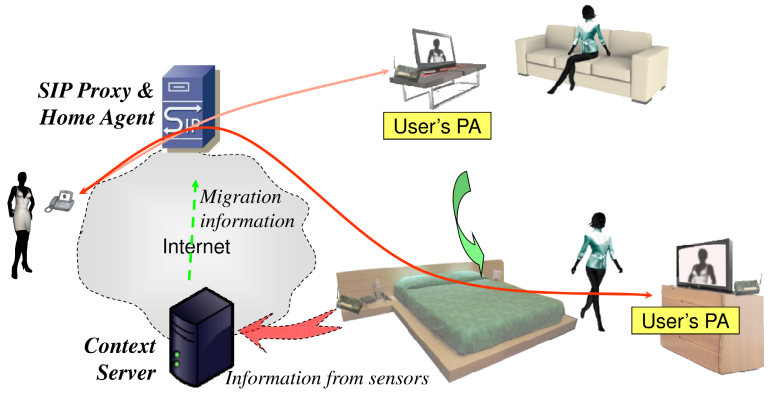


Fig. 1. Automatic session migration for interactive multimedia sessions

The VoIP client has a very minimal interface; it mainly provides buttons to start/stop the call, a few options (codecs, address book) and two rendering boxes: the largest displays the video of the remote user, and the smallest plays the video of the local user.

3 User Evaluation

We showed the live demo at the 2009 edition of the Festival of Science[2], Future Internet session. The Festival is held in Genoa and last year it was attended by 200,000 visitors from October 23rd to November 1st: 160,000 people visited exhibitions and laboratories whilst 40,000 people attended conferences, shows and free-access events. They were professionals and skilled people, young students, science fans and mere curious people. We stayed at the Festival two days (October 23rd – 24th) and got feedback from 101 users.

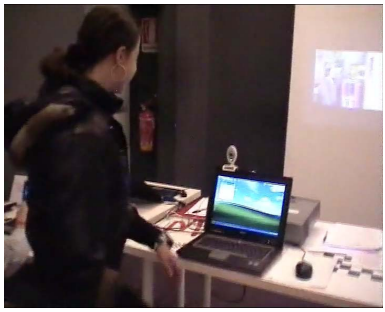
Visitors tried the demo themselves after a short introduction about the Intermedia project[3] and the meaning of automatic session migration.

Three laptops were deployed as user terminals; two of them were assigned to the mobile user, whilst the third was used by the correspondent user. Two sensors were lying near each terminal and one anchor sensor was tied to the wrist of the mobile user by a strip of velcro (see Fig. 2(a)).

One user started the VoIP call and the other answered. Then, the "mobile" was asked to move to and fro between his terminals (see Fig. 2(b)), so he could evaluate the responsiveness of the automatic session migration (there was no way to separate localization and session migration); the corresponding user saw a freezing image during the migration and could assess the nuisance value of this interruption.

[2] Festival della Scienza, `http://www.festivalscienza.it` In Italian.
[3] The InterMedia project, `URL: http://intermedia.miralab.ch/`

(a) The sensor tied to the user's wrist.



(b) The user moves during the demo.

Fig. 2. Screenshots from the live demo

After they had tried the demo, users were asked to compile the questionnaire. The assessment phase was not limited to that issue; indeed, it was also extended to the previous two phases by observing commonly asked questions from users, their difficulties while using the migration service, their comments and suggestions for improvement.

The questionnaire was organized in three parts concerning user profiles (age, gender, education, work, familiarity with and use of technologies in daily life), assessment of the live demo (usability and responsiveness), suggestions and improvements.

4 Analysis of Results

4.1 Users Profile

The questionnaire was filled in by 101 people (48 females, 53 males), aged between 10–69. In the analysis of results we divided the subjects based on their age, as shown in Table 1.

Most people who completed the questionnaire are schools, high schools and university students (69 people). The other part of the sample is rather heterogeneous in terms of education and employment; they are teachers, employees, professional men, housewives, unemployed people and pensioners with a school-leaving certificate or a university degree.

Most of the sample feels skilled with technology and uses several devices every day (see Table 2) . They usually use 7 devices on average out of 12 we suggested them, mainly televisions (98%), mobile phones (97%) and PCs (86%).

4.2 Evaluation of the Test Session

The first question was the effort in understanding the migration feature (immediateness of use), which only means the level of difficulty in learning how to

Table 1. Number of questionnaires for different age groups

Age	<14	15-19	20-29	30-50	>50
# users	25	36	15	13	12

Table 2. Number of used devices proposed in the questionnaire and familiarity with technology. Evaluation of familiarity with technology is placed on a Likert scale from 1 up to 5, where 5 indicates a great familiarity and 1 no familiarity.

	Mean	**SD**	**Min**	**Max**
# devices	7.35	2.07	1	11
Familiarity	3.92	0.74	2	5

use the migration service. The second question concerned how quick the migration had happened (speed). The following questions were about the usefulness of session migration among multimedia devices: how much users liked this feature (pleasant), their assessment about its usefulness in everyday life (utility) and how much they would spend to use it (value). The assessment of the economic value of the feature was proposed in Euros according to the following arbitrary scale: above 20 (5); 5 up to 20 (4); less than 5 (3); nothing, I would only use it whether it were free (2); nothing, I would not use it (1). Mean values for each age class are shown in Table 3.

Table 3. User feeling about the migration feature for each age range. Users answered these questions on a Likert scale from 1 to 5, where 5 is the more positive and 1 is the more negative opinion.

	Immediateness	**Speed**	**Pleasant**	**Utility**	**Value**
<14	4.16	4.24	4.76	4.48	4.12
15-19	3.94	4.14	4.22	3.89	3.97
20-29	4.13	4.21	4.50	4.00	3.31
30-50	3.92	4.08	4.46	4.00	3.42
> 50	3.92	4.08	4.75	4.08	4.08

As the results show, the effort to understand the user interface and the migration feature was acceptable; further, we may note younger generations required less effort, as probably they are friendlier and more used to modern technologies than eldest people. The rapidity of migration mainly depends on the Personal Address and the mobility framework, as the delay introduced by media codec in video acquisition and rendering is almost negligible; we got a good score here, thus we can take the quantitative analysis for the local testbed given in [1] as a good benchmark for assessing the effectiveness of session migration.

The second part of the evaluation shows a substantial interest by users towards the demo scenario and their willingness to accept the migration feature in the

next future; this feedback motivates our work and future research in this field. Users like the feature to migrate an interactive video session among devices, they consider the service useful and they would spend some money for it. A MANOVA [7] analysis has been conducted to check if there were differences in the answers by different age groups; no relevant variation has arisen among those groups in assessing usability and suitability of the migration service to the needs and interests of potential users. Finally, innovation has been evaluated by asking users whether they had ever found session migration in any application. Most people (86% of interviewed) considered the migration service innovative, as they had never seen before this functionality. A small percentage (9%) said they had already seen similar application, but oral interviews following the compilation of the questionnaires pointed out that most of them refer to side aspects of the demo, which are not related with session migration, as the use of webcam and VoIP calls. Finally, few users (about 3%) found the migration service similar to other kinds of functionality: the GPS localization available in the iPhone, the automatic re-tuning to a different frequency providing the same station when the first signal becomes too weak (e.g., when moving out of range) usually found in car stereo systems (AF function of the RDS[4] system), the handover mechanism of cellular networks.

4.3 Indication from Users

The last part of the questionnaire investigates how users perceive our technology and their feeling with related ethical issues; in particular, we are interested in understanding whether they found the migration framework intrusive, whether they are afraid of their privacy to be violated and which kind of devices they would be willing to interact with.

As an indication for future investigation, we asked users what applications they expect the feature to be available for. Indeed, our demo falls into the most rated application: phone calls (74%), watching TV (53%), listen to music (49%), Internet browsing (40%), videogames (38%), chat (34%), work (23%), and other (2%). Figure 3 shows the preferred user applications for each age group; in this case there are significant differences. For example, 80% of users aged under 14 would like to use the migration service to play videogames, whilst the corresponding percentage for the other groups is significantly lower (range 15-19 = 31%, range 20-29 = 33%, range 30-50 = 0%, > 50= 17%). Note that the youngest people always have higher percentage than other groups; this means they checked off a larger number of items for this question; the only exception is the work item, as users under 14 are students and are not involved with such activity.

From a technological point of view, users expect the migration feature on most of their daily equipment: televisions (83%), cell phones (71%), PCs (67%), laptops (51%), MP3 players (33%), stereos (26%), fixed phone (24%), DVD players (23%), PDAs (20%), smart phones (19%), car stereos (17%) and others

[4] Radio Data System, `http://www.rds.org.uk/`

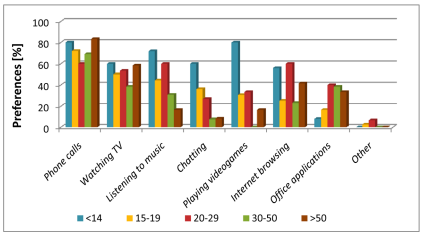


Fig. 3. Preferred applications for session migration

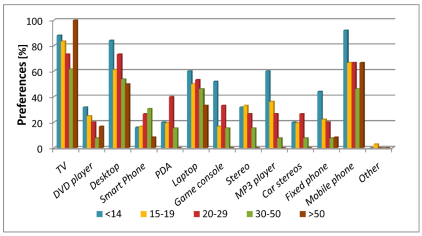


Fig. 4. Preferred devices for session migration

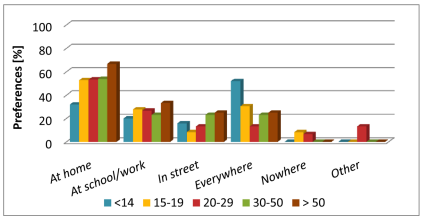


Fig. 5. Where users wish the migration function be available

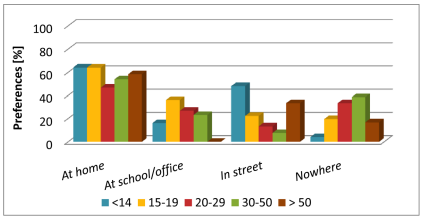


Fig. 6. Where users are willing to be located

(1%). This implies the algorithm must be kept simple enough to be ported on a wide range of different devices. The preferred devices vary with age (see Figure 4): 100% of the oldest users (> 50) checked off television, while 92% of youngest people (under 14) selected the cell phone. Other devices voted by a large number of people are desktops and laptops.

Session migration is a component of pervasive communication; however, users may not need pervasive communication everywhere. Indeed, user feedback has been quite surprising for us: they mainly expect session migration at home (which is the preferred answer of eldest people), and only in lower percentage everywhere (which is the preferred answer of youngest users). Figure 5 shows the detailed answers for each age group.

As a side effect of automatic session migration, users movements have to be tracked and this may concern privacy issue for many people. Taking into account the behavior according to age, all groups agree that home is a perfect place to locate sensors, while disagree in the other responses (see Figure 6): perhaps people believe a tracking system working in home environment keeps all data on private equipment and does not allow anybody to access such information. People who did not like to be located anywhere knew cellular systems indeed maintain information about the cell of their phone; we have argued people are willing to postpone their qualms about privacy whether they are really interested in the service.

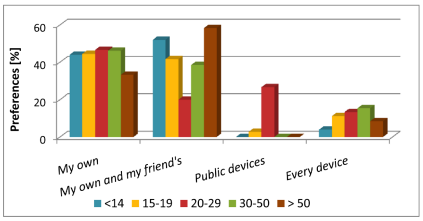


Fig. 7. Which devices people would migrate their sessions to

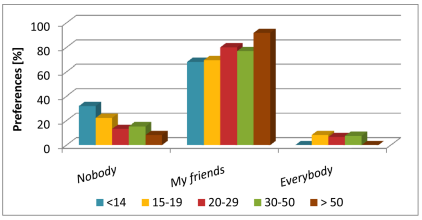


Fig. 8. Willingness of users to share their personal devices with other people

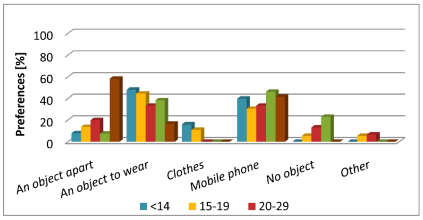


Fig. 9. Users preference about the placement of the sensor they have to bring with them

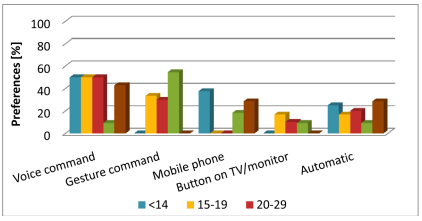


Fig. 10. Users preferences about control of session migration

People aged 15-19 have a higher percentage at school/office than other group. This last fact is quite curious as well, as teenagers often care about let their parents know they are (or are not) at school!

Another issue in pervasive communication is the presence of public, shared and private devices in the environment. Most people would use their own devices and those of their friends, but few users are interested in third parties' and public devices (Figure 7). Indeed, this group includes university students and young workers which are usually more used to share computers and other devices with their colleagues.

The other side of the problem concerns sharing of users devices. The result is congruent with the previous question: people are not inclined to share devices with third parties (Figure 8), yet older users are more willing to share their devices with people they know.

Coming back to more technical issue, sensors may be integrated in several objects users usually bring with them, and the main question here is what kind of object the users would like. Many differences arise among answers from the different groups (see Figure 9). Users who chose an object to wear or other specified that it could be a clock.

Finally, we cared about the control of session migration. The automatic feature was appreciated by many users, but they also like other forms of control (see Figure 10). Also in this case, there are many differences among the different age groups.

4.4 Final Remarks

The results coming from questionnaires, the observation of the user interaction with the service and the analysis of type and number of errors allow us to give a positive judgment about usability of the migration service (conclusions are drawn using the ISO 9241 standard [8]). This evaluation takes into account three parameters:

Effectiveness. The level of achievement of the objectives. The first and simplest effectiveness index is the achievement of the objective: a product is effective if it carries out its task. Otherwise, if the objective is not achieved, the effectiveness can be measured in terms of number of operations towards its completion state. The migration service has been evaluated as effective because all users achieved the goal in the live demo, i.e. they migrated a video call from one computer to another one, without they were required to take any control action.

Efficiency. The effort required by the user to achieve the goal. The migration service has been evaluated efficient because users easily learned how it works and they quickly began to use it.

User Satisfaction. The perceived usefulness of the service by users. The service was evaluated useful by users and they talked positively about the migration concept.

More feedbacks were collected by analyzing answers, comments and critics from the users during the demo. This information provides us useful indications about aspects that should be taken into account in following developments. For example:

- **Security:** Users were interested in security and privacy issues involved in using devices owned by other people.
- **Human-Machine Interface (HMI):** Many users, especially the youngest, underlined the importance of improving the service interface and physical aspect of sensors; obviously these are minor remarks for our purposes, as our framework works at the network layer and the VoIP application was only developed to set up a live demo, while at the current stage sensors are only prototypes and are far from a real product. About control of migration, a clear and unique trend does not appear from users; indeed, answers from users suggest that different solutions could be integrated, according to different user profiles and preferences.

Finally, the last remarkable aspect to be considered was the tendency of adult users to perceive the migration service as a futuristic technology, while younger users seemed more inclined to use this technology in daily life straightaway.

5 Conclusions

This paper reports our experience and user evaluation we did in a live demo. Users appreciated the performance of our user-centric framework and were interested in its implementation in daily applications and commonly used devices.

The Personal Address framework currently exploits the MIP framework, which is known leading to poor performance and resource wasting. Nevertheless, the feedback we got was very positive: users declared themselves satisfied in terms of migration speed; indeed, we must remark the drawbacks of MIP are less evident in local scenarios.

The live demo demonstrated the feasibility of bringing the user-centric paradigm to networking as well; our future work will progress towards two main directions. On the one hand, we will investigate more powerful and efficient overlay architectures to manage the Personal Address and mobility issues. On the other hand, we will study new architectural paradigms for the Future Internet, where both users and content are natively the session endpoints and can be addressed directly (without any overlay infrastructure) at the network layer.

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