Driving Innovation in Urban Computing With a Community Testbed

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Abstract. This position paper argues that establishing a community testbed where researchers can quickly test their ideas hands-on in an authentic urban setting can accelerate innovation in urban computing. To support the thesis we first give an overview of our open urban computing testbed and then present two case studies on utilizing the testbed in researcher training and in international R&D collaboration. The paper concludes with some thoughts on the challenges and benefits of this type of testbed driven research.

Keywords: urban computing, open testbed, summer school, challenge

1 Introduction

This position paper argues that the urban computing research community is in need of a community testbed where ideas can be developed hands-on and tested in a realistic urban setting. Such testbeds have been particularly successful in other domains and disciplines. For instance, the network and distributed systems community has been particularly successful in establishing a number of such testbeds, e.g. PlanetLab (http://www.planet-lab.org) and Emulab (http://www.emulab.net). Similarly, the wireless sensor networking community has developed testbeds such as the Wisebed (http://www.wisebed.eu), while the security community has developed testbeds such as Deter (http://www.isi.edu/deter) for research and development on next-generation cyber security technologies.

The testbed approach is not unique to computer science, since other disciplines have a long tradition of establishing such testbeds. For instance, the physics community has long relied on huge and expensive testbeds in the form of particle accelerators or telescopes. Similarly, meteorology has developed a testbed for easy and accurate testing of weather forecasts (http://www.ral.ucar.edu/jnt), while atmospheric scientists rely on the AMT testbed to systematically and objectively evaluate new aerosol process modules over a wide range of spatial and temporal scales (http://www.pnl.gov/atmospheric/research/aci/amt).

We argue that a community testbed would be beneficial for the broader urban computing community. To support this thesis, we first give a brief overview of the urban computing testbed we have deployed in Oulu, Finland. Then we present two case studies illustrating the benefits of the testbed in researcher training and in international R&D collaboration. We then discuss the lessons learned so far, and argue that community testbeds could be an important force in driving innovation in urban computing.

2 Open urban computing testbed in Oulu, Finland

We have invested lots of resources to establish a testbed which allows us to deploy a wide range of applications and services in authentic urban setting for use by real people. Our goal is to enable urban computing research in authentic urban setting with real users and with sufficient scale and time span. Such studies are important because real world systems are culturally situated, and cannot be reliably assessed with lab studies detached from the real world context. By deploying a system for a sufficiently long time we can establish the technical and cultural readiness and the critical mass of users needed for determining whether the system can be deemed ‘(un)successful’ [1].

The testbed comprises of a wide variety of computing resources deployed across the City of Oulu, including UBI-hotspots, panOULU WLAN/BT/WSN networks and assorted middleware resources. We provide just here a brief overview of these resources, while a more detailed description is given in [4].

(a) (b) (c)

Figure 1. (a) UBI-hotspot; (b) panOULU WLAN AP and WSN ER; (c) panOULU BT AP.

UBI-hotspots (Fig. 1(a)) are effectively interactive public displays embedded with other computing resources such as two cameras, NFC/RFID reader, panOULU AP’s and high-speed Internet access. Currently, 12 hotspots are deployed, six double-sided outdoors at the walking street area at the heart of the city and six single-sided indoors in key public buildings. A hotspot alternates between two states. In passive broadcast state the whole screen is allocated for the UBI-channel, a digital signage service. In interactive state the screen is split between the UBI-channel and the UBI-portal, which can embed effectively any web service found in the public Internet. The UBI-portal provides access to a wide range of interactive services such as service directories, games, a street gallery of new media art exhibitions, sending of an UBI-postcard, and uploading of personal photos and videos. All interaction events such as face detections and launches of services are logged for reporting and research purposes. Since June 2010 the 12 hotspots collectively have had 350 daily service launches on average and exactly 532 yesterday (Feb 10, 2011).

panOULU WLAN is a city-wide WiFi network comprising of ~1270 IEEE 802.11 AP's, of which ~500 reside within 1 km of the city center [3]. While the city center is blanketed with 60 mesh AP's (Fig. 1(b)), coverage is provided in hotspot manner elsewhere. The AP's provide open (no authentication) and free (no payment) wireless Internet access to general public without any limitations. Comprehensive real-time traces of the network are archived for reporting and research purposes. For example, in January 2011 the network was used by 24686 devices, which totaled 621732 sessions and 19.2 million online minutes. 26.5% of the devices were multi-mode WiFi phones manufactured by Nokia, 23.9% Apple devices and 18.2% Intel-based laptops. 80.3% of the devices had "home AP" (where most of the usage took place) and 8.7% of the sessions were mobile (spanning 3+ AP's at least 50 m apart).

panOULU BT is a network of 30 Bluetooth AP's (each equipped with three BT radios) scattered across the city center. 18 AP's are installed in traffic lights (Fig. 1(c)) and they use the panOULU WLAN for Internet access. Additional 12 AP's are placed inside the UBI-hotspots. All AP's sniff bypassing BT radios and the real-time traces are used for modeling pedestrian and vehicular flows and networks. In January 2011 the AP's sniffed 26754 unique devices of which 6774 had never been seen before. Further, the 12 AP's inside the UBI-hotspots are used for distributing multimedia content to mobile devices over BT connectivity [2].

panOULU WSN is an IP-based wireless sensor network comprising of 13 ER (edge routers) across the city. The ER's are equipped with an IEEE 802.15.4 radio on the 868 MHz band and the 6LoWPAN protocol stack. 12 ER's are installed inside the WLAN mesh AP's (Fig. 1(b)), so that the mesh AP provides enclosure, power and IPv6 connectivity. It should be noted that a mesh AP having sufficient free space for housing a small ER was not planned but just a lucky coincidence. One ER is placed inside an UBI-hotspot. An ER has about 500 m line-of-sight range with 1 mW transmission power. The first two use cases for the panOULU WSN are automated metering and environmental monitoring using low-power sensors.

3 Case study #1: 1st International UBI Summer School 2010

The summer school was organized in Oulu, Finland, on May 31 - June 4, 2010 (http://www.ubioulu.fi/en/UBI-summer-school-2010). It comprised of six parallel workshops that enrolled 72 students from 20 countries via an open international call. All students attended a number of joint events, including a poster session where students presented their background and ongoing research, the opening plenary where each workshop was introduced and the closing plenary where each workshop presented their results. Each workshop had its own curriculum and activities, which included theoretical presentations by the instructor and practical projects conducted in groups of 3-5 students. Each workshop was assigned a liaison researcher who was intimately familiar with local arrangements including the testbed resources and could offer assistance when necessary. Several ‘development’ UBI-hotspots were available at the summer school site to support application development and testing. The opportunity to deploy an application on the public ‘production’ UBI-hotspots in the city center was also offered, in case any project would get that far.

The six workshops utilized the testbed in varying degree. For example, Prof. Anind Dey’s (CMU, USA) “Real World Context Aware Systems” workshop produced both functional prototypes and conceptual designs of new services. Prof. Vassilis Kostakos’ (University of Madeira, Portugal) “Urban Social Networks Analysis” workshop collected BT traces to model and visualize pedestrian, vehicular and social networks in the city. While describing all notable projects presented at the closing session of the summer school is beyond the scope of this paper, we briefly show few representative examples. None of the projects has been deployed for ‘production’ use after the summer school, which was not the objective in the first place, to be fair.

Project 1 developed the “Message Wall” service to allow users quickly and easily sketch and post notes on UBI-hotspots (Fig. 2(a)). Project 2 developed the “Group Detector” application for real-time identification of groups of people moving together across the city from the BT traces (Fig. 2(b)).

(a) (b)

Figure 2. (a) Message Wall; (b) Group Detector.

Project 3 analyzed pedestrian activity in the city from the BT traces, and correlated it with the average daily temperature, patterns of rain, and the effect of weekends/weekdays (Fig. 3). Project 4 developed real-time visualizations of traffic flows in the city center from the BT traces using different tools (Fig. 4).

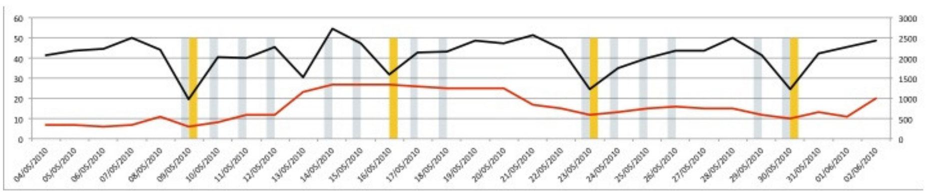
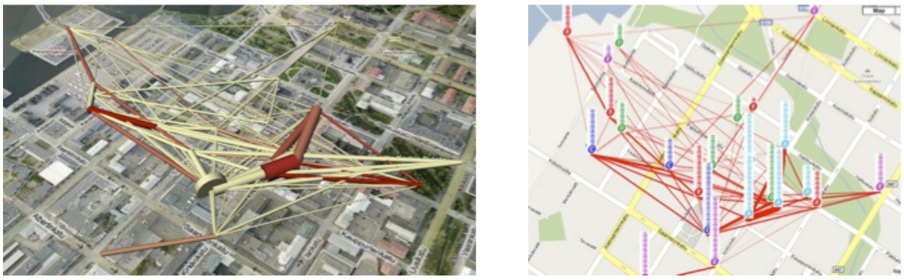


Figure 3. Contextual analysis of pedestrian activity: black line ~ pedestrians detected; red line ~ temperature; blue bars ~ rain; yellow bars ~ Sunday.



(a) (b)

Figure 4. Real-time visualizations of traffic in the city center: (a) 3-D; (b) web.

4 Case study #2: UBI Challenges

We have organized two UBI Challenges to make our testbed available to the greater R&D community and to stimulate the innovation of new services. The national UBI Challenge 2010 (http://www.ubioulu.fi/UBI-haaste) was opened in Feb 2010, challenging both individuals and organizations to innovate and implement new services to UBI-hotspots. 4000 EUR grant was awarded to each proposal selected for implementation by a local expert jury. The grant was payable in two allotments, the first half upon selection for implementation and the second half upon the deployment of the service in UBI-hotspots. Further, the service deemed most successful of those deployed on the UBI-hotspots would receive an additional grant of 2000 EUR and a high end smart phone. Participation was stimulated by a raffle, so that a high end smart phone was raffled between all entries.

By the submission deadline in May 2010 we received just nine valid proposals, of which the jury selected three for implementation: Battleship (game proposed by two local exchange students), Diversus Oulu (interactive multimedia art piece proposed by a local freelancer artist couple) and UBI Mixer (interactive music mixing application proposed by an SME in Helsinki). During implementation the participants had access to a development UBI-hotspot to test their service, technical support provided by us, and to appropriate server resources upon deployment. Eventually, Battleship and Diversus Oulu were successfully deployed on the UBI-hotspots, UBI Mixer not. Incidentally, Battleship is the first service on the UBI-hotspots, which allows two users on the opposite sides of a double-sided outdoor hotspot to explicitly interact (i.e. to play against each other).

The summer school discussed in the previous section kicked off the 1st International Open Ubiquitous City Challenge (http://www.ubioulu.fi/en/UBI-challenge, "UBI Challenge" for short) prepared together with a number of leading international experts on urban computing. It challenges the global R&D community to design, implement, deploy end evaluate novel applications and services in real-world setting in the City of Oulu, Finland. Thus, the scope is broader than in the national challenge limited to just UBI-hotspots. The motivation of the international challenge is to stimulate global research collaboration on urban informatics in a very concrete manner, provide the international R&D community with an opportunity to transfer ideas from labs into real-world urban environment, make our testbed available to the international R&D community, and support developing metrics for evaluating urban computing infrastructure and applications in real-world setting. Preparing the final call and proposal submission template included producing proper API documentation for the testbed computing resources. Participation was encouraged by advertising that up to five proposals would be invited as finalists for deployment in Oulu, receiving up to 10000 EUR grant and a full paper in the MUM 2011 proceedings (subject to regular peer review by selected members of the challenge jury). The program of the MUM 2011 conference to be held in Beijing, China, in Dec 2011, will have a special session dedicated to the challenge, including presentations by the finalists and the presentation of the awards to the winner(s).

11 written proposals were submitted by the Nov 2010 deadline, three from Finland, six from Europe and two outside Europe. The international jury invited four proposals into the final. All four proposals were submitted by European university teams, who will arrive in Oulu at the beginning of June 2011 to finalize the implementation and deployment of the service by the beginning of July. Empirical evidence will be collected in July-August for reporting in September. Further, the jury's Oulu-based members will meet and assess the finalists in-situ. Each finalist has been assigned a dedicated liaison researcher to serve as the primary technical contact point. As the first task the liaison researchers provided the finalists with detailed technical, content related and cultural assessments of the proposals in the light of our own knowledge and experiences of the open ubiquitous Oulu.

5 Discussion

The summer school and the UBI Challenges reported here are our first experiences in opening up the infrastructure available in the City of Oulu to the greater scientific community. This section presents the lessons learned from these experiences, as well as from an analysis of testbeds that have been successful in other disciplines.

5.1 Testbed requirements

There exists a set of testbed characteristics that are common to most successfully established testbeds across other disciplines. These include open access to the community, supporting documentation, flexibility and configurability. We found that it was crucial to provide adequate documentation to the various resources, APIs and tools that the participants needed access to. At the same time we found that liaison researchers, who are acquainted with the testbed, have played a crucial role in facilitating access to the testbed.

Beyond these generic requirements, there is a set of further requirements that are more concerned with the needs of the urban computing community. A crucial difference with traditional testbeds is that in addition to input technologies, output and feedback technologies are crucial to the development of urban computing applications. In our case, output is possible with the use of the public UBI-hotspots, as well as Bluetooth and WiFi which can push information to people's devices. Furthermore, realism is crucial, which is not always the case with traditional testbeds. In our case, realism is substantial, since the testbed is part of the fabric of the city. This, however, comes at the cost of access: we believe that currently it would be very difficult for researchers to remotely deploy and test an application without being physically present on the ground. This is due to high realism and dynamism of the city, which make it very hard to convey remotely. In our experience, visiting the site of deployment makes a big difference in developing the application as well as interpreting the obtained results.

It is also important to discuss the extent to which the testbed is representative, or whether results obtained within the testbed would be reproducible elsewhere. While our current testbed is highly realistic and situated within a city, it is still culturally and geographically biased. Specifically, the testbed is situated in Northern Europe, and it can be argued that the personalities and reactions of Finns would be different to, say, Portuguese or Chinese, and similarly Finnish weather is distinct from that in other countries. This, however, is a problem that any realistic Urban Computing testbed would face, since by definition it would be situated in a specific location with people of a specific culture.

5.2 Cost/benefit analysis

Deploying and testing an application using our testbed currently requires certain resources. It requires on-site visits and support from local researchers. These are resources required in addition to the "fixed costs" necessary for developing, testing, observing and evaluating a system. It is therefore interesting to consider whether such an approach offers an attractive cost/benefit ratio from the perspective of researchers.

We argue that any research lab conducting urban computing research is likely to carry out a number of studies and deployments on an annual basis. Each deployment may have varying requirements depending on its nature, but can include the selection of participants, the booking and management of space, as well as researchers' time for management and preparation. These are all costs beyond the "fixed costs" reported above in relation to pure development and evaluation. Arguably the most expensive of the resources required for deployment is researcher's time, which is typically used for managing and maintaining the deployment during a study. Our experience from the summer school shows that researchers' time was drastically reduced in deploying and testing an urban computing application, due to the fact that there was a rich set of tools and resources ready to be used. Even though there is a learning curve associated with becoming familiar with a testbed, our analysis shows that the substantial reduction in researcher time required for successfully deploying a system across the city provides a substantial benefit for researchers, as costs are overall reduced.

From the perspective of the testbed manager, there are fixed and variable costs associated with maintaining the testbed and supporting researchers using it. In our case, these costs have been covered by research funding and commercial sponsorship, much of which is obtained by using the UBI-hotspots for advertising. At the moment this is not a sustainable model, and there would need to be community contribution for maintaining the testbed. It is not clear to us to what extent researchers would be willing to contribute to the infrastructure (possibly with a part of the savings that can be achieved), and to the actual costs that a deployment incurs in terms of the testbed.

6 Conclusion

We reckon that very few researchers have equally unlimited access to equally versatile testbed in authentic urban setting. Therefore, we want to make our testbed openly available to as many researchers as possible. The summer school and the challenges are prime examples of the activities we have taken in that direction. We wish to develop the summer school into an annual tradition, thus the second summer school comprising of five parallel workshops and hoping to enroll 80 students will be organized in May 2011 (http://www.ubioulu.fi/en/UBI-summer-school-2011). We are also considering providing "researcher in residence" opportunities for visiting researchers. However, our current testbed is far from a perfect 'final' product. We need support and collaboration from the international urban computing community to improve the testbed and to utilize it to the fullest. In this regard we really look forward to the upcoming deployment by the four finalists of the international challenge which will be the first large-scale test on the readiness of our testbed. We hope that the international collaboration will also help us in guaranteeing the long-term future of our testbed in terms of financial and technical sustainability.

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