UbiOpticon: Participatory Sousveillance with Urban Screens and Mobile Phone Cameras

Marcus Foth[1], Tommi Heikkinen[2], Johanna Ylipulli[2],
Anna Luusua[2], Christine Satchell[1], Timo Ojala[2]
1. Urban Informatics Research Lab, Queensland University of Technology, Brisbane, Australia
2. Urban Computing and Cultures Research Group, University of Oulu, Finland
{m.foth, christine.satchell}@qut.edu.au
{tommi.heikkinen, johanna.ylipulli, anna.luusua, timo.ojala}@oulu.fi

ABSTRACT
In many cities around the world, surveillance by a pervasive net of CCTV cameras is a common phenomenon in an attempt to uphold safety and security across the urban environment. Video footage is being recorded and stored, sometimes live feeds are being watched in control rooms hidden from public access and view. In this study, we were inspired by Steve Mann's original work on *sousveillance* (surveillance from below) to examine how a network of camera equipped urban screens could allow the residents of Oulu in Finland to collaborate on the safekeeping of their city. An agile, rapid prototyping process led to the design, implementation and 'in the wild' deployment of the UbiOpticon screen application. Live video streams captured by web cams integrated at the top of 12 distributed urban screens were broadcast and displayed in a matrix arrangement on all screens. The matrix also included live video streams of two roaming mobile phone cameras. In our field study we explored the reactions of passers-by and users of this screen application that seeks to inverse Bentham's original *panopticon* by allowing the watched to be watchers at the same time. In addition to the original goal of participatory sousveillance, the system's live video feature sparked fun and novel user-led apprlopriations.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – *Prototyping*; K.4.1 [**Computers and Society**]: Public Policy Issues – *Human safety, privacy*.

General Terms
Design, Experimentation, Human Factors

Keywords
Urban screens, public displays, ubiquitous computing, safety, security, CCTV, sousveillance, touch screens, urban informatics.

1. INTRODUCTION
Since the Wikileaks website was founded by Julian Assange, secret and confidential information gathered by Manning, Snowden and others has been publicly available online. Causing a worldwide uproar, this brought questions about privacy and surveillance back onto the front pages of news and current affairs and onto the agenda of public debate. Citizens question what information about them is being recorded and stored by governments and other public and private organisations and for what purpose. More recently, media coverage and discussion have centred around leaked documents about the mass electronic surveillance data mining program launched in 2007 by the National Security Agency (NSA) in the U.S. These mirror some of the questions and concerns raised about the ubiquity of CCTV surveillance camera systems installed across the urban environment. Surveillance has become ubiquitous in the sense of both omnipresent as well as bridging digital (e.g., online data) and physical realms (e.g., video footage of people in public space).

The capture and recording of information is only one side of the coin. Secrecy opponents argue that the publication and revelation of kept information can potentially increase transparency and strengthen accountability of organisations and governments. Mass media such as newspapers, radio and TV, have been portrayed as the 'fourth estate.' It contributes to the balance of power in a nation state based on the traditional divide between the three estates of legislative, executive, and jurisdiction. The internet is now considered an additional force in its own right, as Dutton [4] calls particular parts of it, such as Wikileaks, the 'fifth estate.'

Figure 1. Operations Centre for the City of Rio de Janeiro installed by IBM. Source: http://goo.gl/ET5Wnz.

As researchers and interaction designers interested in ubiquitous computing and urban informatics at the intersection of social, spatial, and technical domains (people, place, technology) [8], we are particularly interested in the fifth estate. Our concern is how it can translate into novel designs of situated technology applications for participatory urbanism, civic innovation, and community engagement [7]. In the urban context, both Townsend

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[24] and Greenfield [12] call for a shift away from a top-down 'smart city' approach (Fig. 1) and towards a more bottom-up 'smart citizen' view. We are profoundly inspired by this debate and take Foucault's treatment of Bentham's *panopticon* [6, 16] as the point of departure for our study. We question the information asymmetry of common surveillance approaches and whether safety and security can only be achieved through top-down surveillance and CCTV cameras, or whether (and what) alternatives are possible. In her seminal book, Jacobs [15] argued for more 'eyes on the streets:' *"This is something everyone knows: A well-used city street is apt to be a safe street. A deserted city street is apt to be unsafe."* Following Jacobs' call, we examine how a network of urban screens deployed outdoors across an inner-city area together with roaming personal mobile phone cameras can be put towards more collective and collaborative use for increasing safety and security.

We are interested in exploring such screens at night as part of our research team's ongoing focus on HCI After Dark [23], as well as screens that are used in a post-cinematic mode, rather than display only [9]. The significance of the study as an experimental and exploratory field study is further corroborated by the advent of wearable interaction devices supporting forms of augmented reality such as Google Glass. The seamless integration of personal recording and display technology into these devices may add further momentum to Mann's notion of *sousveillance* [19]. Not only mobile phones, but now a diverse range of other personal devices can be carried everywhere, allowing everyone to record (covertly?) and be a reporter (in disguise?). Previous examples include citizen journalism on ushahidi.com [14] as well as people using their cameras to record traffic situations such as Russians in their cars [e.g., 26] or Australians on their bikes [e.g., 29].

Figure 2. UbiOpticon shows the matrix of live video feeds captured by the overhead cameras of six UBI-hotspots around downtown Oulu.

Our research is inspired by previous debates in HCI on participation and surveillance [e.g., 16]. More specifically, we set out to implement a locally tailored variation of the design idea dubbed *Chat-Stop* [3] that was never deployed. The Chat-Stop concept proposed a live video link between people waiting at remote bus stops to increase a sense of safety by feeling virtually connected. UbiOpticon collects the video feeds from the overhead cameras of the outdoor UBI-hotspots installed at pivotal locations across downtown Oulu, Finland [21]. It combines them together with the video feeds of up to three mobile phone cameras roaming around the city, and renders all the video feeds as a screen matrix on the screens of the UBI-hotspots (Fig. 2). We evaluated UbiOpticon via two field studies, deploying the system on the UBI-hotspots and collecting data via in situ participant observations, interviews, and video recordings.

The overarching research program asks: (1) how can urban screens be used to increase "digital eyes on the street" in a sousveillance manner, and (2) what impact does this have on a user's perceived sense of safety and security in the city at night? Our study is a first step towards exploring these questions further.

The remainder of the paper is structured as follows. We first outline the design and implementation of UbiOpticon. Section 3 reports on the data we collected during our field studies. We summarise our findings in Section 4 and conclude by discussing ideas for further research in Section 5.

2. DESIGN AND IMPLEMENTATION

UbiOpticon was developed with an agile, rapid prototyping process that commenced on Monday afternoon and culminated in the execution of the first field study four days later on Friday afternoon. The UbiOpticon system has two incarnations, fixed UBI-hotspots and mobile phone cameras. Our goal was to achieve visibility and/or interaction between the places and people in the city through our system, i.e., the main user interface of the system is the interconnected web camera streams. Therefore, we wanted to limit the interactivity on the individual devices' user interfaces to minimal and focused on making the video feeds as large and visible as possible. Users would thus simply use their eyes to view the different areas in the city and use 'bodylanguage' to interact with the people they potentially see. The mobile phone cameras would in addition provide interactivity through mobility.

2.1 Interconnected UBI-hotspots

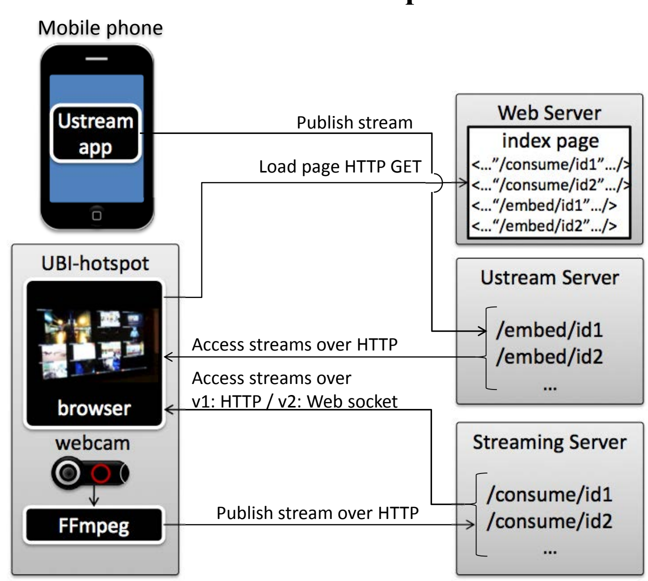

Figure 3. UbiOpticon software architecture.

The double sided outdoor UBI-hotspots feature on both sides a web camera in the upper edge of the enclosure. UbiOpticon collects the video feeds from the web cameras of all the participating UBI-hotspots into a single screen page that is shown on each UBI-hotspot – interconnecting them together. There are six double sided outdoor UBI-hotspots resulting in 12 surfaces and 12 feeds all together. All UBI-hotspots are connected to the same network which would allow point-to-point streaming.

However, to limit network traffic we introduced a streaming server to collect the feeds from the hotspots and serve them forward (Fig. 3). The feeds are captured from the local web cam using the FFmpeg software and simultaneously streamed to the streaming server over HTTP. A completely browser based solution like WebRTC was also briefly evaluated, but despite being a promising approach, at the time its browser support and documentation was too limited and did not fit our rapid prototyping cycle.

The web server hosts an index page that collects all the feeds into a single web page shown on the hotspots. In the first version of UbiOpticon, the feeds were embedded using HTML5 *video* tags and the streams were accessed over HTTP from the streaming server – a Java based stream-m server with the video format being WebM at a resolution of 640 x 480 pixels. This first version suffered from crucial real time problems as the automatic buffering done on the *video* tags caused a considerable lag of up to several minutes to the streaming of the feeds. The buffering appeared to be hardcoded into the *video* tags' behaviour in the browser (Firefox), and we could not find a way to prevent this issue. The lag of this magnitude rendered our anticipated usage model, the interaction through displays in real time, impossible.

In the second version of UbiOpticon, we managed to cut out the lag at the expense of slightly reducing the picture quality. To achieve real time streaming all the way from the web cam to the browser, we chose to re-implement the streaming server according to the solution published in Phoboslab [22]. In this solution, the streaming server is based on a Node.js server written in JavaScript and uses web sockets to serve the streams. On the browser side, a JavaScript based custom player was used to play the videos on a HTML *canvas* element. With these changes, the second version achieved the real time requirement making the lag between video capture and playback unnoticeable. However, it forced us to use an outdated MPEG1 video format, and together with the custom JavaScript-based player, it required us to decrease the resolution per feed down to 320 x 240 pixels in order to enable the browser to play all parallel video streams simultaneously.

2.2 Roaming mobile phone cameras

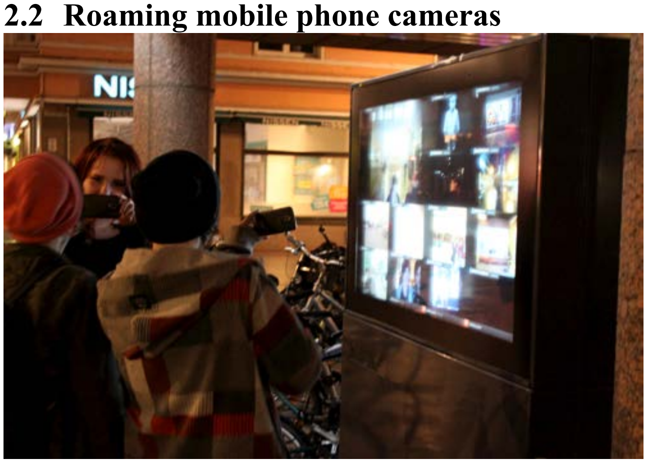

Figure 4. Mobile broadcasting.

The roaming mobile phone cameras (Fig. 4) were implemented with the Ustream service [25]. The Ustream app publishes the camera stream to the Ustream server, which can be embedded on a web page using an *iframe* tag. We noticed a small lag also on the Ustream service varying from 10 to 30 seconds. This variation was likely caused by the quality of the mobile phone's wireless connection (mobile data or WLAN) at a specific location in the city.

2.3 User interface

The hotspots require the UbiOpticon's user interface to be web based [18]. The interface design mimics the screen matrices found on typical CCTV surveillance operating rooms (Fig. 1). We chose a mixture of 2 x 2 and 4 x 4 grids with a quarter screen placed in the top left corner and 12 x 1/16 screens filling the rest of the screen real estate (Fig. 5). The quarter screen initially shows the stream of the hotspot's own web cam, but in the second version of the UbiOpticon it can be replaced by any of the 12 smaller screens by tapping them, in which case the contents swaps. For easier orientation, the streams from the cameras of the double sided hotspots were placed side by side on the layout. A small label was also shown on the top left corner of each stream which showed a well-known name of the particular location, e.g., the "Market Square."

The screen resolution of the hotspots is 1920 x 1080 pixels, which meant that the 320 x 240 pixel video streams needed to be enlarged by a factor of 1.5 for the smaller screens and by a factor of 3 for the larger screen. As a result, mainly the quarter screen was pixelated when observed from close distance, but it still allowed recognising the faces of familiar people for instance.

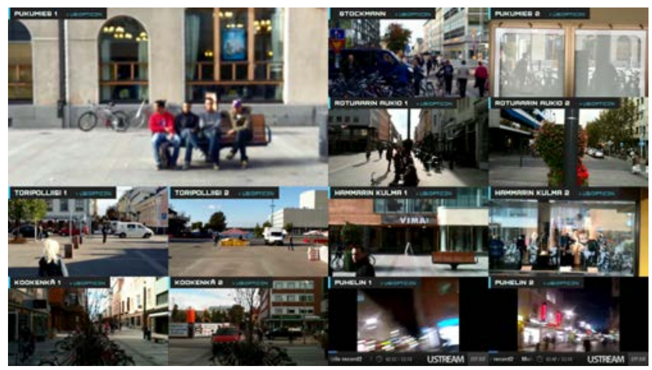

Figure 5. User interface of UbiOpticon.

3. FIELD STUDIES

The two versions of UbiOpticon were evaluated via two field studies conducted on two separate Fridays, version 1 in late September 2013 and version 2 in early November 2013. The weather conditions on these two days were quite different: while version 1 was deployed at a mild temperature of +12°C with dry and overcast conditions, version 2 was deployed at 0°C temperature with sleet. UbiOpticon was deployed on the six outdoor hotspots, of which five are installed around the pedestrian area at the heart of the city, while the sixth hotspot is located at the market square approximately 200m away. The hotspots have been in operation since 2009, thus they are a familiar sight to the residents of the city [27]. Two smart phones equipped with both 3.5G (HSPA) mobile data connection and WLAN were used as the roaming mobile cameras.

On both Fridays, UbiOpticon was deployed on the hotspots from 2pm till late at night around 1am. We collected qualitative research material by observing how people interacted with the hotspots when UbiOpticon was running, and by conducting interviews with 38 study participants in total. 13 of the interviewees were under 20 years old, 16 were 20–30 years old, six were 30–40 years old, and three were 50–65 years old. Researchers made written notes and recorded interviews with a video camera upon participants' consent. The interviews were conducted *in situ* using an open ended, unstructured approach and focused on understanding the interviewees' responses to the design. What they saw on the display, or what they are doing with it; how they would use such an application; what kinds of pros and cons it might have in their opinion; and could it increase their sense of safety and security in Oulu? The interviewees were also given a demonstration of the mobile video streaming concept, and some of them were asked to briefly try it out for themselves.

Care was taken to understand the responses of a cross section of people to the screen. This meant including participants beyond those who exhibited an interest in the technology and had been interacting with it. Passers-by that did not pay any attention to the display at first, were asked by our researchers to try the application, as well. The majority of the interviewees interacting with the display were under 30 years old, which reflects that technologies such as public interactive displays are favoured by the younger generation as noted in [28]. Passers-by who did engage with UbiOpticon often did so from a distance; some of them were waving at people who were visible in the displayed live stream channels. However, some also tried to tap the feeds to view them larger, which we addressed in the second version of the implementation. When interviewed later, they stated that either novel content or moving images had captured their attention [20].

Table 1: Statistics of 60-minute observations at one hotspot.

Statistic	**Ver. 1**	**Ver. 2**
People walking past the hotspot	990	718
People stopping in front of the hotspot	30 (3.0%)	22 (3.1%)
People touching the screen	21 (2.1%)	2 (0.3%)
People making gestures at the screen	9 (0.9%)	15 (2.1%)
Median duration of interaction (seconds)	n/a	13.5

We also collected quantitative data via covert observations at the hotspot located at the northern entry point of the pedestrian area. The hotspot is placed at the 10 m wide entrance to the local square – created by a building and a large stage opposite the building. A researcher sat at the edge of the stage, facing the hotspot and logging each person entering the square, regardless of their mode of transportation (walking, cycling, child carried or in baby buggy). In version 1, logging was done manually for 60 minutes between 3 and 4pm. In version 2, logging was done by recording a video with a GoPro video camera hidden in the pocket of the researcher for 60 minutes between 7 and 8pm. People's interactions with the hotspot and the UbiOpticon system, if any, were coded as an activity sequence, e.g. (L)ook at the hotspot → (S)top in front of the hotspot → (T)ouch the screen → G(esture) at the hotspot (waving, jumping, etc.). Table 1 shows selected statistics from the logs. We see that in both field studies only about 3% of the people passing the hotspot stopped in front of the hotspot to take a look at the UbiOpticon user interface. The video log of version 2 allows us to look at the durations of interaction sequences in more detail. The median duration of interactions that included stopping in front of the hotspot was 13.5 seconds, while the longest interaction lasted 64 seconds. These results are not uncommon compared with other interactive public display installations we have conducted [17, 21].

Fig. 5 shows a snapshot of the video log. A woman entered the square with two children. About 7 meters before the hotspot one of the children noticed their own image in the UbiOpticon video matrix and shouted excitedly "*Hey, look!*" The children hurried to the hotspot, and the smaller of them started jumping up and down to see the effect in the interface. The woman then lifted the smaller kid up so that he could see himself better in the interface. The interaction lasted 43 seconds.

Figure 5. A snapshot of the video log.

4. DISCUSSION OF FINDINGS

Overall, teenagers and young adults were enthusiastic about UbiOpticon and came up with additional, creative ways to use or improve it. On the other hand, many of the older citizens were more skeptical and worried about privacy. Some of them questioned the idea behind the project, or felt that it was not designed for them: for example, one interviewee, a 52-year-old female, commented that "*I'm old-fashioned, this is not my thing*." We regard these concerns beyond generational bias as valuable insights into how to improve the next design iteration.

The data from the interviews can be grouped around two themes:

1) Security and privacy;
2) Creative use and appropriations.

4.1 Security and privacy

Security and privacy are certainly two distinct themes, however, for reasons of scope we will look at both of them in correlation with each other. Most of the interviewees thought that showing a live stream of different locations on public displays could increase the feeling of security in the city. They also had relatively good awareness of, and positive attitudes towards, the surveillance cameras located in the city center. However, some of them felt embarrassed when actually seeing themselves on a public display, as the system acted like a digital mirror.

When we demonstrated the possibility of mobile live video streaming, and especially discussed the option of making this feature available to everyone, the opinions between different age groups differed remarkably. Young people liked the idea and found it interesting, but older adults were worried about privacy issues; they raised questions such as: who is going to moderate the videos, does mobile video streaming violate privacy, and what about misuse – e.g. drunken teenagers filming each other – and how it could be prevented. Care should be taken to avoid seeing these concerns as being purely generational, instead attention should be put into how these insights might improve the next design iteration.

Most of the interviewees felt that this feature would not increase the feeling of security in the city; they reflected on practical issues, such as how could anybody rush to help on time if they saw someone being attacked on a display; how would the potential helper know where the attack is happening; and what if the attacker actually locates a potential victim through this application. In general, the video surveillance practiced by authorities was accepted, but giving the ability to monitor individuals was seen as problematic. The local Nordic culture, in which authorities are usually trusted and crime is generally not a daily problem in people's lives, is probably reflected in many of our interviewees' attitudes and responses.

4.2 Creative use and appropriations

On the other hand, within the second theme, that is, creative use and appropriations, participants were mostly focused on mobile video streaming. Interviewees came up with many creative ideas, such as private individuals using mobile video streaming during different festivals or happenings taking place in the city. Some interviewees also wished they could see what is happening in other cities – and not necessarily during e.g. festivals; they just found the idea of peeking into other cities intriguing [1].

A couple of participants mentioned how they would like to see and share "beautiful scenery" on the displays, and compared this aspect to the habit of sharing "nice little things" on Facebook and Twitter. Furthermore, the possibility to spot and find friends in the live streams was discussed, which reflects the overall importance of "social navigation" [17, 2]. Some interviewees also thought it would be great if the live video streams could be accessed on the internet.

4.3 Reconciling the contradictory themes of privacy and creativity

The findings of the two field studies will inform the design and system improvement of future UbiOpticon versions. However, attempting to integrate the two emerging themes of *privacy* and *creative use and appropriation* is problematic as the way they are embraced by the participants in our study is inherently contradictory.

The people who embrace the system from the perspective of creative use and appropriation desire enhanced digital interactions with others. These include live feeds into their homes, and the potential to find friends at a festival. However, facilitating these types of interactions has implications for people who object to their image being digitised and circulated in real time and seen across the city. Concerns ranged from minor embarrassment to serious threats generated by the technology being used to track and follow individuals. This has implications for rolling out a platform that favours the need for creativity and sociability. Although this type of design is compelling, it should not come at the price of compromising on privacy.

From a future design point of view, this indicates the potential to integrate a mechanism that protects the people's identity by providing a degree of anonymity. A pre-existing example of this is Google's automatic technology that blurs faces and license plates in Street View. "*If one of our images contains an identifiable face (for example, that of a passer-by on the pavement) or an identifiable license plate, our technology will blur it automatically, meaning that the individual or the vehicle cannot be identified.*" [10].

Ultimately, we need innovative approaches that are able to reconcile the contradictory themes and needs of privacy and creative use and appropriation.

4.4 Reflection on the field studies

In future design iterations of UbiOpticon, the collection of more in-depth qualitative research material by using methods derived from, e.g. participatory design (PD), would be useful. After all, we consider it crucial to take citizens' experiences and attitudes into account when designing applications that can significantly change power relations in a public space [11, 13].

Although we gained many valuable design ideas and were able to reveal surprising attitudes by conducting rapid in-situ interviews, we also learnt two key lessons: First of all, many participants had difficulties in understanding all the implications of our relatively multi-faceted application that had highly nuanced philosophical roots in Foucault's complex theories; and, many participants would have simply needed more time to comprehend how the application actually works, and what it would mean to have such an apparatus available to them in the city space. However, due to the study set-up, they did not have time to discuss and reflect with us for long.

A second – and a more prosaic – lesson was that the weather affected our study participants' attitudes greatly. In the second field study, which was carried out in unpleasant weather conditions, people were clearly less willing to talk to the researchers on the street and, interestingly, they also had more negative opinions about the application. This indicates how vital it is to take the real world context into account when conducting 'research in the wild.'

In order to decrease the negative impact of external factors, such as weather and a hurried feeling, we could use a mixed methods approach and combine in-situ interviews with, for instance, additional workshops with recruited participants, arranged in the spirit of PD [5]. In these workshops, participants would get a chance to better reflect on the topics of safety, security and surveillance, and it would perhaps be possible to find solutions for how to sensitively solve the problems posed by contradicting themes of privacy and creativity.

5. CONCLUSIONS

Our study set out to examine how situated urban screens could be used to increase "digital eyes on the street" in a sousveillance manner. UbiOpticon sought to fulfil this premise in an exploratory and experimental way. However, the *digital* aspect of "digital eyes" also brought with it well-known limitations, such as telepresence reducing the richness of human-to-human communication and interaction.

Our design intervention begged follow-up questions that require further investigation and reflection. For example, some study participants reported that they are concerned about a live image of them being displayed on the other hotspot screens. Would this issue make them wonder about where the video feeds of the existing CCTV surveillance infrastructure is being displayed? In other words, does the visibility of the UbiOpticon video streams trigger concerns about the current invisibility of CCTV video streams? In this sense, our installation acts at the same time as a type of provocation to make people think about aspects of the surveillance infrastructure that is usually taken for granted.

The current UbiOpticon prototype has several limitations which decreases its potential impact on the perceived sense of safety and security in the city at night. However, the main design elements that have been integrated into the application are clear and might inspire further variations and adaptations that could lead to more advanced and sophisticated solutions towards participatory sousveillance.

Furthermore, we were pleased to hear many study participants suggest improvements and spin-off ideas, such as a mobile version of UbiOpticon, so the screen matrix is accessible on a smart phone or tablet whilst on the move, as well as “OuluTV” – an easy way to become your own community TV broadcaster utilising the existing network of UBI-hotspots as a content display platform for on the spot live reporting by residents and citizens.

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