Reaching devices around an HbbTV television

Mikel Zorrilla, Angel Martin, Iñigo Tamayo, Sean O'Halpin and Dominique Hazael-Massieux

***Abstract*— HbbTV takes advantage of the opportunity to expand the broadcast experience exploiting the common media content. However, the time to reach the audience in a different way has come. Aware of the privileged position of the TV in the living room, manufacturers and marketplace app developers have fostered their own bunch of solutions to integrate the big TV display with the mobile ones, to consume broadband media but ignoring the broadcast traction potential. One major challenge of all these approaches is the resource discovery and association step, where different strategies have been employed. A TV content-centric approach opens new possibilities. First, the possibility to enhance the offer services scheduled on a time basis according to the broadcast signalling. Second, the awareness of a common media been played at the same temporal and spatial environment can support the discovery and association of surrounding handheld devices. This paper analyses the capacity of common visual and acoustic environmental patterns to build enhanced discovery and association protocols, concluding a multi-step combined solution as a suitable approach for broadcast-related second screen services.**

***Index Terms*—Multimedia systems, Digital multimedia broadcasting, Pervasive computing, Ubiquitous computing, Context-aware services.**

I. Introduction

THE new audience habits when enjoying the TV are changing its prominence introducing new entertainment displays in the living room, such as smartphones and tablets, all being connected to the Internet. This means users watching the TV at the same time as interacting with their handhelds. Thus, the TV is not always the foreground device but one more, combined with others. However, in this new multi-screen paradigm the TV has still the best position at the home area to attract all the surrounding devices providing enhanced experiences through all the displays. Moreover, it is often the only device that gathers connectivity to the broadcast signal and to the Internet at the same time.

Users are ready to new ways of enjoying TV linear media content with seamless multi-screen media services. This includes the migration of visual components from one device to another, creation of multiple views through different devices simultaneously and sharing social experiences with a friend or a community.

However, these services bring distributed computing and pervasive computing scientific challenges such as the service and device discovery, adaptation and self-organisation to dynamic scenarios, communication and synchronisation between devices, etc. These challenges remain on a particular way on this new home environment around a TV.

Connected TVs and Smart TVs are the bet from TV manufacturers and OS-based vertical approaches to face usage shifting and extend interaction possibilities. Nevertheless the full proprietary based ecosystems of multimedia services have created fragmented markets introducing interoperability problems that hurdle multi-screen experiences. Moreover, the broadcasted linear content is often not included in the media services of these proprietary solutions, reducing the TV capabilities only to the Internet connection.

Other stakeholders in the TV, producers and broadcasters, need their own standard technological solution. The enabling technology that opens a wide spectrum of possibilities for the broadcasters to reach audience is HbbTV [1]. It enhances the linear TV programming through non linear Internet-based content, providing enriched services over the mainstream TV content.

Current HbbTV 1.5 specification enables access to media services through the TV and its remote control but it does not cover the multi-screen environments. Thus, the research activity around this standard focuses in including mechanisms to communicate the TV with other devices around. To overcome this limitation there are a wide range of market solutions and different research approaches for the discovery and association of devices. However, there are still open issues that must be covered to apply these solutions to an HbbTV such as building multi-domain network connectivity of surrounding devices and delivering broadcast content centric services.

This paper focuses on the resource discovery and association procedures in order to be able to provide multi-screen media services around an HbbTV television

Manuscript received January 6, 2014. This work was supported in part by the European Commission under the FP7-ICT-2013-10 MediaScape project (Gran Agreement 610404, www.mediascapeproject.eu).

Mikel Zorrilla is with the Department of Digital TV & Multimedia Services, Vicomtech-IK4 GraphicsMedia.net. San Sebastian 2009, Spain (e-mail: mzorrilla@vicomtech.org; Phone: +34 943 309230; Fax: +34 943 309393).

Angel Martin is with the Department of Digital TV & Multimedia Services, Vicomtech-IK4 GraphicsMedia.net. San Sebastian 2009, Spain. (e-mail: amartin@vicomtech.org).

Iñigo Tamayo is with the Department of Digital TV & Multimedia Services, Vicomtech-IK4 GraphicsMedia.net. San Sebastian 2009, Spain. (e-mail: itamayo@vicomtech.org).

Sean O'Halpin is with the BBC R&D. London, UK. (e-mail: sean.o'halpin@bbc.co.uk).

Dominique Hazael-Massieux is with the W3C/ERCIM. Sophia Antipolis, France. (e-mail: dom@w3.org).

II. State of the Art

This section overviews the state of the art from three different point of views; a) the market solutions for device and service discovery and association, b) the discovery and association challenges in distributed and pervasive computing, and c) the translation of the general scientific challenges to a TV centric home environment.

A. Market approaches

The industry solutions for resource discovery and association are several such as UPnP, Bluetooth, Wi-Fi Direct or Zigbee. However, some of them are based over hardware connectivity interfaces not present on all the devices (including TVs), while others require a common network interface that could not be enabled through all the devices at the same time (e.g. handheld devices are often in a home environment connected through 3G, out of the home gateway).

Concerning zero-configuration networking standards, the most widespread protocols are: DNS-based service discovery (DNS-SD), multicast DNS (mDNS), UPnP Simple Service Discovery Protocol (SSDP), Service Location Protocol (SLP), W3C Web Intents [2], Bluetooth Service Discovery Protocol (SDP), Web Services Dynamic Discovery (WS-Discovery) [3], Discovery and Launch Protocol Specification (DIAL).

This research field has a lot of activity and we can find different software frameworks that face these topics such as: XMPP Serverless Messaging, WS-Discovery Implementation (Apache Foundation) and Google Cast, exploiting the previous mDNS, WS-Discovery and DIAL protocols respectively; Webinos Discovery API[1], considering additional application areas such as in-car displays; AllJoyn, exploiting the SoC potential for specific architectures; etc. Other working groups like IETF Homenet aims to simply deploy home networks based on device density explosion linked to the IPv6 technology.

This well-stocked protocol landscape provides a set of solutions tailored for multi-screen applications and broadband services. They open new browsing and interaction possibilities for marketplace apps developers and enhance the broadband and local media sharing integrating TV and handhelds. Nevertheless, not only none of them brings a significant and direct added value for the broadcaster, but also they do not take benefit of the broadcast signalling and media nature.

B. Discovery and association challenges in distributed and pervasive computing

In the field of pervasive computing environments, arisen challenges in terms of resource discovery and association have been studied for long time [4] and defined solutions are still open to new approaches tracking new paradigms and embracing incoming technologies.

Once the most representative solutions have been depicted, it is necessary to understand the different protocol features to match the proper discovery and association technology with the HbbTV multi-screen scenario needs. To this end, it is required to take into account the communication overhead and to consider the performance degradation trade-off. A service discovery protocol must be designed to minimise administrative overhead and increase usability.

In this line, but going deeper, the classification of the resource discovery and association protocols will support later decisions to build a suitable mechanism:

Presence Discovery. Its objective is to find the specific address though the active network interfaces of each surrounding device. In this case, the options are: unicast, requires factor preset or manual set up to obtain environment awareness; multicast, try to provide a fully automatic solution reaching any device by flooding the network with UDP messages; broadcast, with the same principle but constrained to a single hop.

Naming Service. Its aim is to provide the available service description. In this case, there are two possibilities depending on the preliminar mutual knowledge: preset, including service names, parameters and structure; template, providing a common format. The preset option involves a minimum overhead and transparent discovery but reduces significantly the expressiveness and expandability for new services, while the template one will require often human intervention.

Service Availability. Its target is to report the list of services in a device. The alternatives are: notification, only listening devices get awareness; querying, a device ask for features and capabilities to a specific one when it wants to interact. The periodic notification introduces traffic overhead so the continuous polling is not the best option.

Service Publication. Its purpose is to keep the list of the available services. In this case, the options involves: a centralised publication board, which must be hosted in a stable device in terms of availability; peer publication, where each device share just their services. Obviously, the first one enables a wider integration for applications where all the devices participate, not just peers.

Discovery Scope. Its goal is to define service discovery sessions gathering the appropriate data including: network topology, this information is based on domain belonging; user role, needing of user authentication; high-level context, including temporal, spatial and user activity. The network information is a key factor in environments with heterogeneous connection interfaces. Anyway, when trying to launch a seamless experience just in time, it is important to avoid explicit user authentication because it usually brings additional user interaction that restrains the usage willingness.

C. Translation of discovery and association challenges to the home environment around the TV

This section tackles the adoption of the distributed and pervasive computing discovery solutions to multi-screen scenarios with the TV as the main device on the home environment.

Regarding *presence discovery*, there are two relevant issues to keep in mind. First, while the TV is mostly connected to

[1] http://dev.webinos.org/deliverables/wp3/Deliverable34/servicediscovery.html

Internet through a home gateway (WiFi or Ethernet), mobile devices are usually shifting from the home gateway (WiFi) to 3G. In this case, a broadcast mechanism will be constrained to a specific network area or domain, not reaching every device.

Second, only HTTP services are supported in HbbTV devices and most of the multicast discovery protocols are over UDP (UPnP, etc.). Web Intents could be a solution to exploit in the browser other resources of the TV. The W3C is also addressing this challenge with The Network Information API working draft[2] and Network Service Discovery working draft[3].

Discarding unicast option in order to foster transparent solutions, it is necessary to create new strategies that exploit media broadcasting nature combined with the surrounding presence awareness step of the discovery protocol.

Concerning *naming service*, it is mandatory to avoid human setup. This point would enhance the HbbTV technology potential but requires processes for specification expansion through releases, while meeting its business model.

In terms of *service availability* and *service publication*, the notification option fits better with the centralised publication board, achieving a major inclusive scope embracing all living room devices participation. Moreover, notification mechanisms enable event-based services that fits perfect in the broadcast business model.

Regarding the *discovery scope,* some considerations apply; From a network topology point of view, there are different discovery protocol stacks over a LAN, but they need all the devices to be connected to the same gateway and are mostly based on UDP. However, these technologies cannot be deployed on top of pure HTML devices like HbbTVs. From a user role perspective, the authentication is a key element which is a big challenge by itself in multi-user multi-device environments. Webinos creates trustworthy zones where the user can share devices with a community. From a context point of view, there are temporal and spatial approaches for the discovery scope. The main spatial scope is the physical location: using sound or light patterns, QR code scanning, bumping devices synchronously, etc.

III. Proposed Solutions

This section provides different solutions to overcome the open issues introduced in the previous section, designing multiple approaches that have been landed by the implementation of spatial discovery scope solutions regarding the physical location, where the different devices are all around the TV.

All these solutions are designed to be implemented over current TVs or Set-top boxes with HbbTV v1.1 or v1.5. The TV will receive a related service from the broadcast carrousel and the HbbTV application must discover the devices around the TV. An association will be done between the second screen device applications and the HbbTV application.

Event-driven server based approaches enable the communication between the associated devices for the visual component migration, multi-screen views and social experiences between users. On [5] an event-driven solution to synchronise HbbTV applications and second screen devices is proposed. [6] presents a standards-based framework that enables bi-directional communication between HbbTV applications and second screen devices. These event-driven solutions need a previous association step. Often these association mechanisms are based on a common server session established by means of a common HTTP URL accessed by a set of devices. This is done discovering an HbbTV application in the TV, and sharing the URL with the second screen device and a unique ID created by the HbbTV application that allows the server to associate a unique HbbTV applications with a unique HTML-based mobile application. The following solutions address how to exchange this URL and the unique ID amongst the devices in a friendly way for the user.

A. Visual solutions

A visual approach is a main basic solution to take advantage of the visual information that the user is watching in the TV. HbbTV can show in the application a URL with the related service and a unique ID for that TV app session. The user introduces manually the URL in his mobile device. The ID could be included in a second step, inside the mobile application as a PIN or code it in a REST URL.

A usability improvement for the user is to use QR codes. The HbbTV application generates a unique QR code where the URL and the ID are coded inside. The user scans the QR code with the mobile device and the second screen HTML application starts already associated with the TV session. This is the current association approach for [5] and [6].

In this case, the mobile device must have a camera and a native application to scan the QR code and open a web browser with the URL and the ID information on the TV. These requirements are very reasonable for current smartphones and tablets but require a tedious process for the user, where first has to navigate inside the HbbTV application with the remote control until the QR code is shown, and then open a QR scanning application on the mobile device. Depending the distance between the user and the TV, the size of the QR code, the data amount in the QR code and the camera of the mobile device, the experience of the user changes a lot. Next section provides the experiments carried out to characterise these parameters.

B. Sound patterns

The use of sound patterns is a more transparent approach to exchange information between two devices that are physically close. The broadcaster is able to overlay out of band sound patterns over the TV programme. A URL could be coded inside that sound pattern, but if it is done in the broadcast signal, it is not possible to generate a unique ID for each TV.

The HbbTV applications are also able to generate a sound

[2] W3C Working Draft 29 November 2012 http://www.w3.org/TR/netinfo-api/
[3] W3C Working Draft 20 February 2014 http://www.w3.org/TR/discovery-api/

pattern, unique for each application but there are limitations to overlay an extra audio to the broadcast signal in HbbTV. HbbTV v1.1 and v1.5 have a *video* object and the specification[4] says that "Attempting to present broadband delivered video using the AV Control object may result in suspension of access to broadcast resources, including (…) Broadcast video presentation being stopped". This clause applies to terminals which do not have the HW capability to present broadband delivered video at the same time as de-multiplexing MPEG-2 sections from the broadcast. Indeed, most of the HbbTV devices.

This interruption of the broadcasted content to play the application generated audio is unpleasant to the user. Next section presents experiments with different TVs and STBes to assess the QoE related to measures of the interruption time when switching and managing the *video* object in HbbTV.

C. Bump based solutions

Bumping two devices is a solution that has been used to pair mobile devices. Bump[5] was an application for Android and iOS to exchange images and videos from one device to another with a simple bump between devices. It was also possible to send content from a mobile device to a PC pressing the space bar of the computer and at the same time the mobile phone is bumped. In September of 2013 Bump Company announced that Bump was joining Google to continue exploring the user interaction with mobile devices[6].

This association paradigm can be transferred to a TV centric home environment. When the HbbTV applications are loaded, instead of showing the typical "press red button" message, shows a "bump based message available". The user shakes the mobile phone while pressing a button in the remote control and from this moment on the association is done.

The presented bump based solution is based on an event-driven server that receives requests from different devices and associates them according to the *timestamp* of the request and some additional information of the request (such as the location). The accuracy on the *timestamp* measure on both devices, and a precise location of each device is critical in order to avoid false positives. The next section shows experiments in order to evaluate the latency of the request from different networks and the accuracy to associate them in a TV centric home environment.

Due to the bump-based solutions needs the user to press a button on the remote control, to develop a more robust approach the server can operate a button-hopping mechanism to spread the interaction spectrum. Thus, exploiting all the standard buttons available on the remote control. The mobile device will indicate the user which button to press while shaking the mobile so the event-driven server can conclude unambiguously between different request coming in the same moment and from a similar location.

The bump based approach is much more user friendly since the user directly starts the experience associating the devices, and could be used with multiple second screen devices with a single TV at the same time.

D. Three step solution

The previously mentioned solutions could be used combined providing a new solution to discover and associate an HbbTV television and a second screen device. This proposed combined solution follows a three step cloud-based distributed approach.

In a first step, the server collects all the bump based requests received from different devices, analyses the data related with the request, and finds the correct associations between requests.

As explained before, the main feature to associate two devices is the timestamp of the requests together with the additional information (location of the devices and the button-hopping mechanism). If the first step is enough to associate the devices exceeding a predetermined threshold of success, the process ends here.

However, with millions of user discovering and associating devices at the same time, the bumped-based solution could be complemented with other two steps as a scalable verification method to minimise the uncertainty.

In the second step, the server will activate a verification protocol based on sound patterns. The HbbTV application will play an audio pattern and will expect that the presumably associated second screen device will listen to that pattern. This verification protocols are executed seamlessly to the user.

Finally, as a last and secure solution, a second verification task could be done as a third step if the first two steps are not enough. The server can send a visual information (such as a PIN number or a QR code) to the HbbTV application to display it in the TV and wait until the user introduces the information in the mobile device (writing a PIN of scanning a QR code). This third step is the most explicit for the user but provides security and certainty.

IV. Experiments and Validation

This section presents the experiments outlined in the previous section to define technological thresholds for suitable environments. On the one hand, some experiments have been performed to assess QR code scanning accuracy between a TV and a mobile device. On the other hand, some tests about experience interruption to play an application generated audio pattern in an HbbTV device have been done. Finally, other experiments have been done to evaluate the timestamp based accuracy of an HTTP event-driven approach.

A. QR code scanning

Four parameters have been identified as the main factors

[4] ETSI TS 102 796 v1.2.1 (2012-11), known as HbbTV 1.5
[5] Bump: https://bu.mp
[6] http://blog.bu.mp/post/61411611006/bump-google

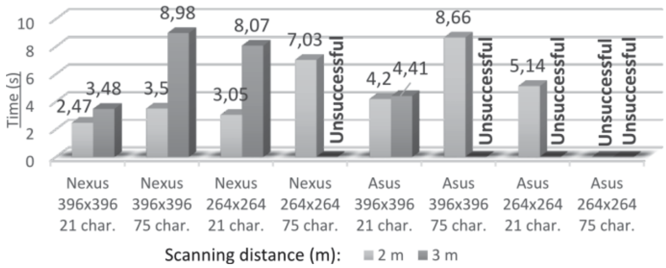

Fig. 1. The QR code scanning time (s) for the successful processes depending the scanning distance, the device, the length of the QR code and its size.

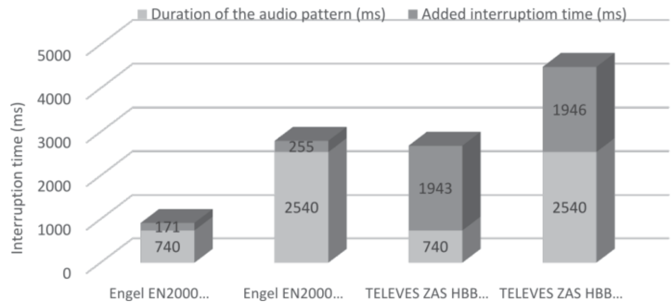

Fig. 2. Interruption time in EN2000 and zAs Hbb Set-top Boxes measured for a 21 and 75 characters long URL coded in an audio.

involved in the QR code scanning process:

a) QR code size: The size of the QR code rendered in the HbbTV application in the TV. Two different sizes have been used in the experiments: a 264x264 px and a 396x396 px in a 1280x720 px HbbTV application and a 40 inches TV.

b) Character length: The number of characters coded in the QR code. We used a QR code with a 75 characters URL and a shorten URL of 21 characters using bit.ly[7].

c) Scanning distance: Distance from the mobile device to the TV. Different distances have been tested in the experiments: 2 m, 3 m and 4 m.

d) Capabilities of the camera of the mobile: Two different tablets have been used. A Nexus 10 and an Asus Eee Pad Transformer TF101 Tablet. Both have 5 MP cameras but different optics and features.

The QR code has been rendered by an Engel EN2000 set-top box, inside an HbbTV application. The Barcode Scanner[8] application has been used in both mobile devices (Nexus 10 and Asus). The illuminance in the room was 84 lux. As the outcome of the experiment, the process has been evaluated as successful or unsuccessful and the time for the scanning process has been measured.

Fig. 1 presents the QR code scanning time in seconds for the successful processes depending the scanning distance, the device, the length of the QR code and its size. As a conclusion, the longer distance, the higher the probabilities of an unsuccessful process it is, and the higher the scanning time for the successful processes. While almost in all the conditions the processes have been successful with a distance of 2 m, there were not successful processes with a distance of 4 m.

The scanning time was faster and with more success index with a QR code of 21 characters than with 75 characters, and for a size of 396x396 px instead of 264x264 px. The experiments conclude that a larger distance of scanning can be address while the QR code size is bigger and the URL coded in the QR is shorter. On the other hand, the quality of the camera of the mobile device has a big impact in the scanning process. In this case the Nexus 10 has a better camera than the Asus under the same conditions in all the cases.

B. Playing a broadband audio in HbbTV

Due to the limitation of HbbTV specification to overlap a broadband audio to the broadcast signal, these experiments measure the interruption time since the broadcast signal is cut in the TV, until the broadcasted content is back after played the sound pattern, recognisable by the second screen device.

We used Minimodem[9] to generate the audio AFSK modulated patterns for both coded URLs presented in the previous section (21 and 75 characters long). For the long URL, we obtained a WAV file of 2540 ms, and for the short URL, a WAV with a duration of 740 ms. After some AFSK tests, the best configuration is 300 baud rate, 1700Hz for mark frequency and 1060Hz for space frequency guaranteeing successful data transmission on a noisy environment (58dB of background sound).

We created an HbbTV application[10] to interrupt the broadcasted video as less as possible to play the sound pattern, and measured the interruption time. We have confirmed with a Minimodem capture console that the URL was well transmitted on that acoustic environment.

Fig. 2 presents the obtained interruption time for 21 and 75 characters long URLs coded in an audio pattern with two different HbbTV Set-top Boxes: ENGEL EN2000, and Televes zAs Hbb.

The results show that the interruption time goes from 911 to 4486 ms. While the Engel introduces only an added interruption of around 200 ms, the Televes STB adds almost 2 seconds. In all the cases, the experience for the user is acceptable, above all as verification process as proposed in the *three step solution*.

C. Timestamp accuracy in a TV centric home environment

We have done four different experiments to measure the timestamp accuracy for a *bump-based* solution of discovery and association of a second screen device around a TV.

For these experiments we have created an HbbTV application for the TV and a HTML5 application for the mobile device. Both applications send a message when the user interacts.

From a user perspective, the user interacts with both devices at the same time (e.g. pressing a button on the remote control

[7] https://bitly.com/
[8] https://play.google.com/store/apps/details?id=com.google.zxing.client.android&hl=en
[9] http://www.whence.com/minimodem/
[10] https://github.com/itamayo/Fsk_test_4_hbbtv

while shakes the mobile device). For each of the four experiments we have done 50 measures and got the average to compensate the random precision of users pressing two buttons at the same time. The event-driven server has been published in an Amazon Web Services server.

In the first experiment, we measured the time difference comparing the server reception timestamps. Both devices were in the same local network area. The average of the difference of the events received in the server has been 150 ms.

In the second experiment, we also compared the server side reception timestamp for both events. In this case the Set-top Box was connected to a home gateway while the mobile device was using an HSDPA phone network. In this case, the average of the difference between both events has been 1584 ms. It increases due the heterogeneous networks and the different trace to reach a same server.

In the third experiment, we captured in each client application the interaction timestamp and send it to the server. The server compares the difference between the two timestamps received. In this case, both devices were in the same LAN. The devices were configured to automatically synchronise their clocks and the LAN provides a common clock for both devices. The average difference between the received events is 528 ms.

In the last experiment, we also captured the timestamp in the client side and send it to the server, but in this case the STB was connected to the home gateway, while the mobile device was using an HSDPA phone network. Both devices were also configured to automatically synchronise their clocks through the network but they were in different networks. The average difference between the timestamps has been 3315 ms.

Using client-side timestamps we obtain worst results comparing to the server-side timestamps. This is due the inaccurate clock synchronisation of the different devices, more evident when they are in different networks. We could force user to set up a common NTP server on all his devices to synchronise the clocks of all the devices involved in the process, but this does not seem realistic.

The first and the second experiments seem to provide accurate scenarios, where we have a server on the Internet and in the worst case two devices at home connected through different networks. The latency jitter ranges from 150 to 1584 ms. The *bumped-based* approach can be strengthen with additional information in the request messages to overcome the association uncertainty for requests closer than 1584 ms. Moreover, the *three step solution* improves the timestamp mechanism with additional information and provides extra verification steps.

V. Conclusion

This paper proposes different solutions to discover and associate a second screen device around an HbbTV television. Three different discovery and association solutions are presented landed by the implementation of spatial discovery scope approaches regarding the physical co-location.

On the one hand, *visual solutions* are proposed to deliver a URL and a unique ID generated from an HbbTV application from the television to a mobile device, represented by widespread QR code technique. It requires a second screen device with a camera and a native application for the QR code scanning. Some experiments are presented to evaluate the main factors involved in the QR code scanning process from a mobile device to a TV.

On the other hand, *sound patters* are proposed for the delivery of the association information from the TV to the second screen device seamlessly. Due to the necessity to generate a unique ID for each TV, the sound pattern should be generated in the TV application itself and the paper analyses the current problems to overlap an HTML-based audio to the broadcasted signal in HbbTV. Experiments are presented to measure the interruption time of the mainstream media since the broadcast signal goes to background, until it is back to foreground after played a sound pattern recognisable by the mobile device.

As the third approach, a *bumped-based solution* is presented in the paper to discover and associate the second screen devices around an HbbTV television. It is based on a synchronous event-driven server that receives the different requests and associates them depending on the reception timestamp and some additional information (the location of the devices and a button-hopping mechanism). The paper presents some experiments measuring the delay between the different requests received by the server through various networks.

Finally, a *three step solution* based on the combination of the previous approaches is presented as the most user friendly and robust. All the experiments confirm the viability of the discovery and association approach as a suitable solution for the discovery and association of a mobile device around an HbbTV television in broadcast-related second screen services.

References

[1] Merkel, K. (2011, March). Hybrid broadcast broadband TV, the new way to a comprehensive TV experience. In Electronic Media Technology (CEMT), 2011 14th ITG Conference on (pp. 1-4). IEEE.

[2] Lyle, J., Nilsson, C., Isberg, A., & Faily, S. (2013, March). Extending the web to support personal network services. In Proceedings of the 28th Annual ACM Symposium on Applied Computing (pp. 711-716). ACM.

[3] Jammes, F., Mensch, A., & Smit, H. (2005, November). Service-oriented device communications using the devices profile for web services. In Proceedings of the 3rd international workshop on Middleware for pervasive and ad-hoc computing (pp. 1-8). ACM.

[4] Zhu, F., Mutka, M. W., & Ni, L. M. (2005). Service discovery in pervasive computing environments. IEEE Pervasive computing, 4(4), 81-90.

[5] Zorrilla, M., Tamayo, I., Martin, A., & Olaizola, I. G. (2013, June). Cloud session maintenance to synchronise HbbTV applications and home network devices. In Broadband Multimedia Systems and Broadcasting (BMSB), 2013 IEEE International Symposium on (pp. 1-6). IEEE.

[6] Ziegler, C. (2013, September). Second screen for HbbTV—Automatic application launch and app-to-app communication enabling novel TV programme related second-screen scenarios. In Consumer Electronics?? Berlin (ICCE-Berlin), 2013. ICCEBerlin 2013. IEEE Third International Conference on (pp. 1-5). IEEE.

M. Zorrilla is with the Department of Digital Tv & Multimedia Services, Vicomtech-IK4 GraphicsMedia.net. He received his Telecommunication Engineering degree in 2007 from Mondragon Unibertsitatea (Spain) and an advanced degree in Computer Science from UPV-EHU University of the Basque Country (2011-2013, Spain).

He focuses on the research lines related to multimedia services and interactive media technologies. During his studies he worked in the area of communications of IK4 Ikerlan Research Centre (www.ikerlan.es) (2002-2006). Since 2007 he is working at Vicomtech-IK4 (www.vicomtech.org), where he designs, develops and leads projects of the Digital Television and Multimedia Services area. He is also a professor in the University of Deusto (www.deusto.es) in multimedia technologies in Computer Science.

A. Martin is with the Department of Digital Tv & Multimedia Services, Vicomtech-IK4 GraphicsMedia.net. He received his engineering degree in 2003 from University Carlos III, Spain.

He starts his Phd in the Communications and Signal Processing Department of the University Carlos III in the video coding research area in 2003. At the same time he collaborates with Prodys developing a standard MPEG-4 AVC/H.264 codec for DSP. In 2005 he starts to work on Telefonica I+D in projects related to multimodal interactive services for Home Networks. Also in Telefonica I+D, he goes deeper into image processing area in terms of 3D video and multiview coding. From 2008 to 2010 he worked in Innovalia as R&D Project consultant related with smart environments and ubiquitous and pervasive computing. Currently he is on Vicomtech-IK4 managing and developing R&D projects around multimedia content services.

I. Tamayo is with the Department of Digital Tv & Multimedia Services, Vicomtech-IK4 GraphicsMedia.net. He received his Computer Science Engineering degree in 2007 from Mondragon Unibertsitatea (Spain).

He focuses on the research lines related to multimedia services and interactive media technologies. He developed there the End of Degree Project developing a Quality Management System on Fundación Legarra Etxebeste. In 2007-2008 he collaborated with Geoaim in the development of a Geographical System Information. Since 2008 he is working at Vicomtech-IK4, where he designs and develops projects of the Digital Television and Multimedia Services area.

S. O'Halpin is with the BBC R&D Internet Research and Future Services section.

He is a Lead Engineer. He has over 20 years experience in programming, specialising in coordinating data processing systems, realtime communications and messaging systems. At the BBC, he designed how iPlayer for Radio is scheduled, the data feeds and control systems for Visualising Radio and helped build the XMPP pubsub infrastructure. He has also worked on the DAB LiveText and Slideshow systems. Since joining BBC R&D, he has worked on various projects including media bookmarking, ingesting the Twitter Firehose, designing the RadioTAG protocol and a prototype of a programmable TV. His main research interests are in information flow and control over realtime messaging systems from editorial and production to the home.

D. Hazael-Massieux is with the W3C/ERCIM. He is the Activity Lead of the Mobile Web Initiative, and is responsible for the W3C Web Real-Time Communications Working Group and the W3C Device APIs Working Group. He also develops tools and applications as part of the W3C Systems. Dominique holds an engineering degree from the "Grande Ecole" École Centrale Paris. He joined initially W3C's Communication and Systems Team as a member of the Webmaster Team in October 2000; after having joined then lead the QA Activity until September 2005, Dom took part to the Mobile Web Initiative as Staff Contact for the Best Practices Working Group and later as co-Chair of the Mobile Web Test Suites Working Group.