Share it! – The architecture of a rights-managed network of peer-to-peer set-top-boxes

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***Abstract*— The *Share it!* project is developing a system of rights managed content sharing between homes connected by the broadband Internet in a peer-to-peer network of set-top boxes with storage. Demonstrators of the system have been developed. This paper looks at the system requirements, the design choices and the overall system architecture that has been developed with an emphasis on the issue of rights management.**

***Index Terms*—broadcast content sharing, P2P, TV-Anytime, Share it!, DRM**

INTRODUCTION

Share it![1] is an EU-funded collaborative project [1]. Its aim is to develop an end-to-end system for easy access and transfer of content between homes using the broadband network. It enables innovative services through a seamless combination of on-line, broadcast, and stored content, in a rights-managed world. It contributes actively to international standards enabling interoperability between content, service providers, and equipment manufacturers.

This paper outlines the context of the project, describes the architecture of the system that has been developed, and discusses some of the issues raised during the project.

PROJECT GOALS

The goal of Share it! is to develop an end-to-end system enabling easy access and transfer of personal, stored and broadcast content. In particular it:

- Has developed scenarios and models for discovery and delivery of content and applications
- Enables seamless integration of broadcast, broadband and stored content
- Applies and extends home-to-home, peer-to-peer (P2P) technologies and applications
- Develops an end-to-end suite of P2P protocols
- Pays close attention to Digital Rights Management (DRM)
- Has built a demonstrator of the system to verify the design
- Contributes to DVB [2] and TV Anytime standards [3].

SYSTEM REQUIREMENTS

To derive the system requirements, we adopted a user-centric top-down approach. Initially the partners in the project developed more than 50 usage scenarios. Examples of such usage scenarios include:

- Showing your home video to other named devices
- Sharing content amongst user groups
- Viewing and passing content rights

The scenarios were analyzed for common properties, from these we derived user and system/content provider requirements, and then the technical requirements. These requirements were then prioritized according to whether we intended to support them in the demonstrator system or study the issues.

The system requirements fell into the following categories:

- The Share it Set-Top Box
- Types of Content
- Content Distribution
- Security
- Content Creation
- Rights Management
- Discovery of content and User Groups
- Personalization

Rather than give a detailed list of the system requirements in this paper, a set of example applications is given in the following section which illustrates the kinds of applications and scenarios that the Share it! platform supports [4].

EXAMPLE APPLICATIONS

Three broad categories of user scenarios were identified in the project: basic content sharing and exchange; network services and opportunities for adding value to broadcast services; and publishing home produced content.

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Content sharing and exchange

In this scenario users search the Share it! network to find content of interest. The Share it box user interface has to facilitate easy entry of search criteria in a TV-centric 'lean-back' manner. The box will issue the query to the network, peer boxes with matching content will return relevant results. These results include rights data so that the querying peer can establish whether it has the rights to acquire and access the content, and if not how it might acquire those rights. These results are presented to the user who can select and acquire the content they desire, and if necessary, the rights. The content published and searched for could include both originally broadcast, and consumer-created content.

Users are also able to publish content, which may be of interest to other users, to specific Share it! User groups if the content rights allow them to do so.

Network services

By placing a server supporting Share it! protocols in the network, service providers can offer a number of services:

- Premium content
- Broadcasters can manage user groups, tied in to a particular programme concept or theme, supplying additional content, chat and services to encourage return visits.
- Better quality of service (for example enabling real-time streaming of content, faster downloads, or enhanced / richer metadata).
- Rights brokering, enabling users to access a wider range of content, and content providers to find a wider audience.
- Sophisticated audience measurement functions, including tracking super-distributed content.

An important aim in providing these services is to encourage viewer loyalty and to extend their interest in the broadcaster's programming.

Creating, editing and publishing by consumers

The Share it! platform enables users to distribute content that they have created easily. For example, users could:

- Send images or videos to a friend – images from a digital camera, or video from a camcorder can be easily loaded onto the Share it! box and sent to friends.
- Creating a complex content bundle – users can bundle related items of content and publish this bundle of content.
- Annotating content – users can add text or image annotations to an existing piece of A/V content (rights permitting) and make this available for friends or family.

END-TO-END ARCHITECTURE

Having developed the system requirements the project designed the end-to-end system architecture. To do this we started from a layered model. We conducted a survey of existing candidate technologies, and mapped these to the previously identified layers. We then progressively detailed the choices, driven by need for early choices on issues that impact hardware, and identifying gaps in existing solutions where we needed to invent new technologies or customize existing technologies.

The main high-level areas of interest in the system architecture are shown in figure 1.

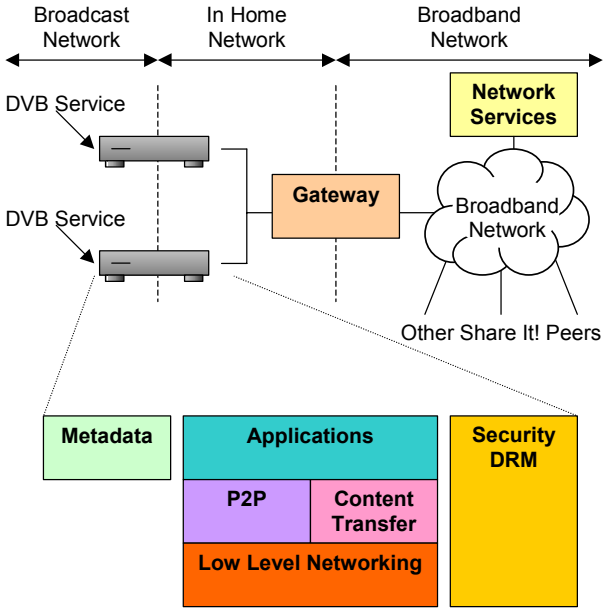

Figure 1 – System architecture

System concepts and identifiers

A central concept of many peer-to-peer networks is that of bringing together groups or communities of peers that are interested in similar things. Within Share it! this concept remains valid, however we developed it into the idea of user groups. User groups have three attributes which define how users can interact with that user group. These attributes are:

- Membership – restricted or unrestricted
- Publishing – moderated or unmoderated
- Visibility – hidden or visible

Various combinations of these attributes give different types of group, for example:

- The unrestricted unmoderated visible group, e.g. a group of users interested in Ferrari. This is a self-managing group of people interested in a given topic. All members are able to indicate content of interest to the group
- The unrestricted moderated visible group, e.g. BBC EastEnders group. This is a simple group whereby a single entity (e.g. the BBC) is able to indicate public content that is of interest to the group

- The restricted unmoderated hidden group, e.g. family group. The group itself is invisible to non-members. Any member can publish content to the group.

Within Share it! we chose to support a range of content sharing models, for example broadcast originated content and home produced content. These have different visibility requirements, for example, home produced content may require privacy, which is not required for broadcast content. To this end we have defined public content and private content – public content can be freely discovered by users, whilst private content cannot (note that even if you can discover public or private content, you may not have the rights to acquire, consume or share it).

Public content is available from any type of user group, whereas private content is only available from restricted membership user groups. Typically broadcast originated content would be public whilst home originated content could be private or public.

Several identifiers are needed within the system to identify various entities such as users, devices, pieces of content. In particular the identification of content has proven to be a problem area. Within the demonstration system we have adopted the TV-Anytime Content Reference Identifier (CRID) [5], however this is to some degree stretching the CRID beyond its original intended application. The CRID has shortcomings when applied to peer-to-peer content; primarily as it has been designed as a managed entity for use in broadcast networks rather than as an unmanaged entity to be released into a distributed network.

Peer-to-peer protocols, discovery and search for content

Candidate peer-to-peer protocols identified in the survey phase of the project included JXTA [6, 7, 8, 9], UPnP, and Gnutella. Whilst UPnP is a popular protocol for in-home networks, its difficulties with scalability made it unsuitable for a potentially global, home-to-home network architecture. The Gnutella protocol is basic compared to JXTA and so we essentially had the choice of extending Gnutella to include the functionality we needed, or using JXTA (a more complete but 'heavier' solution). We chose JXTA, which is an open-source peer-to-peer protocol initiated by Sun Microsystems. JXTA provides much of the required Share it! peer-to-peer functionality. A companion paper [12] provides a more detailed description of how we have used and adapted JXTA.

Content transfer

Of the several well-known IP content transfer protocols, we decided to use HTTP for content download and RTP/RTSP for real-time streaming. Given typical current in-home and broadband between-home connection bandwidths it is likely that streaming would only be feasible for in-home and network-server to home connections (as most broadband connections have lower rate uplink than downlink connection bandwidths).

In principle multiple video codecs can be supported within the Share it! System e.g. MPEG2, MPEG4 part 2, MPEG4 part 10. Transcoding to lower bit-rates potentially enables faster content transfers over rate-constrained links. However, for the project demonstrator we have focussed on MPEG2 video as this is currently the only codec supported by DVB.

We have defined a 'content-bundle' which allows multiple media elements to be distributed as a single file. Such elements might include an MHP Xlet, still images etc. The use of a TV Anytime CRID allows us to reference a collection of content that includes the 'bundle' file and several pieces of related content.

Metadata and metadata management

As far as possible we have adopted the TV-Anytime standards for metadata [10] within the Share it! Project. TV Anytime metadata forms the basis of the JXTA content advertisements used to publish and search for content on the peer-to-peer network. We have also implemented TV Anytime SP006 compliant [11] metadata servers to enable Share it! Boxes to query and retrieve metadata for broadcast schedule.

Rights management and security

Digital Rights Management (DRM) is a very complex area, as perhaps indicated by the number of standards groups tackling this topic! Our approach with Share it! has not been to try to design a complex general purpose DRM system that can address all of the world's DRM applications; rather we have focussed on appropriate models to enable home-to-home sharing, extending current broadcast rights models.

We have therefore defined two models; so-called light touch and heavy touch approaches.

In the light touch model, rights negotiations and verification are performed directly between trusted peers. In this scenario the requesting peer would typically already have rights to consume the desired content, it has to satisfy the serving peer that it has appropriate rights before it can acquire the content.

In the heavy touch model, rights negotiations include a trusted third party in a rights-brokering role. Typically the requesting peer does not have rights to consume the desired content, and has to obtain these from the third party broker before then satisfying the serving peer that it has appropriate rights and then acquiring the content.

Within the project demonstrator we are implementing the DRM protocols using simple XML and JXTA services however, in principle the DRM data could be encapsulated in various rights expression languages.

Within the system, we have defined both usage and sharing rules. Usage rules govern the peers' entitlement to consume content, whilst sharing rule restrict a peers entitlement to share content with other peers. We have also defined user credentials, which comprise information that represents the user and Share-It! peer (such as might be used when negotiating to acquire rights from a rights broker), and access tickets, which represent the right to access content.

Content providers or Rights Brokers can issue access tickets to a specific peer with respect to one or more pieces of content (for example they may reflect rights to access all of the content broadcast by a particular TV channel). Usage rules (and if appropriate, sharing rules) are issued to a specific peer, for a specific piece of content, and operate if that peer is in possession of valid access ticket(s). Note that the content needs to have its individual content or set ID (as referred to by an access ticket) securely bound to it.

The way that access tickets and usage / sharing rules are used in the various DRM processes is shown in the Figure 2 below.

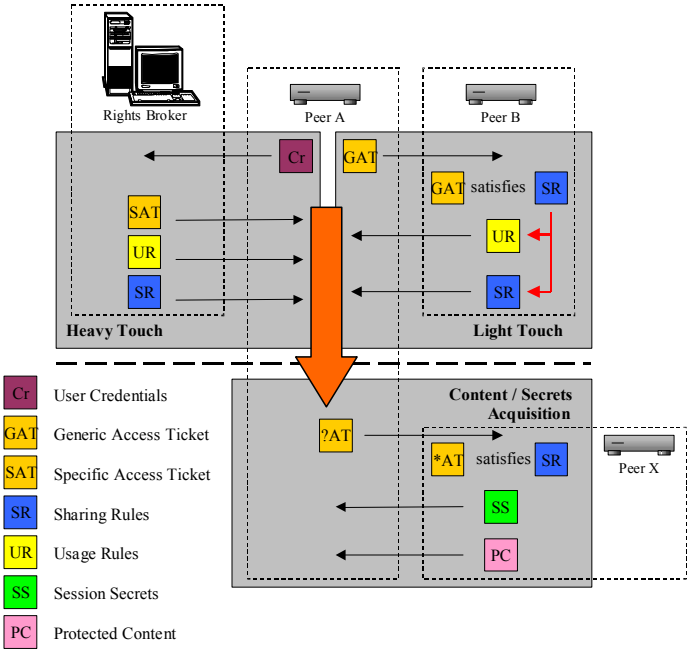

Figure 2 – Usage and sharing rules

This mechanism is used for controlling the sharing of both home produced and broadcast content. For private content, the publishing box may need to generate it's own access tickets. Each of the entities (tickets and rules) described above is signed when it is created, so a box that can issue rules and tickets needs to be able to sign them.

Current (non-Share it!) set-top boxes typically use a Conditional Access (CA) system to manage content acquisition from a DVB service, and subsequent local consumption. A Share it! box could use a suitably extended CA system to derive usage rules (and possibly sharing rules) to enable content acquired from a DVB service to propagate into the Share it! network. Alternatively, a server in the network could make these rules available. Figure 3 shows how usage rules and sharing rules propagate through the network. Note that the sharing rules can 'create' a new set of usage rules, so in effect the sharing rules contain a full set of usage rules.

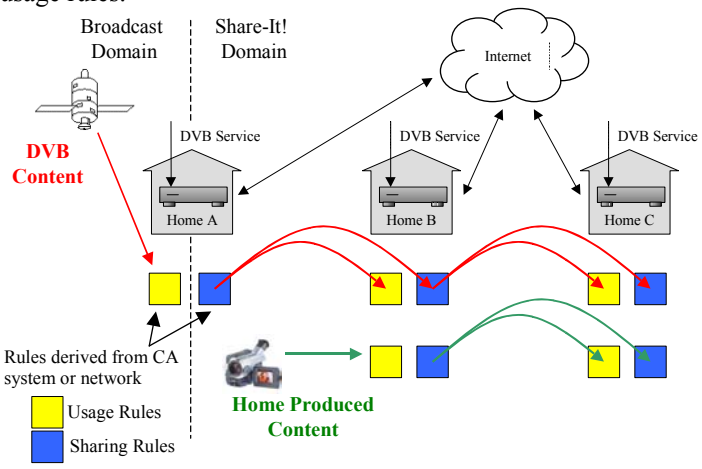

Figure 3 – Propagation of rights information

Although our focus has been more on DRM than on security, we are mindful of security and privacy issues (particularly content protection and robustness of the DRM solution to attack), and are conducting threat analyses on the platform. Note that the DRM data used for negotiations is always signed, and that the content itself is protected by a cipher with a session key that is specific to each transfer.

Within our system architecture we have presumed that each in-home network's Internet connection is protected by a gateway, and as such our peer-to-peer and content transfer protocols are able to cope with gateways and Network Address translation (NAT).

One of the key issues of building a rights managed secure platform is that of trust. Managing and maintain a network of trusted devices is a prerequisite to enabling rights managed content sharing. Within a typical vertical TV platform the platform operator and their security technology provider could clearly perform a trust management role. Within a horizontal market, it is less clear who might perform this role, however there could be opportunities for providing such services.

APIs

Within the Share it! box implementation, a number of Java API's have been defined to allow interactive application writers to take advantage of Share it! system functionality. These extend the DVB MHP and include support for:

- TVAnytime location resolution
- Content access, control and acquisition
- Metadata queries (local database, peer-to-peer and TVA SP006 servers)
- Share it! user group access (note that rather than expose the full JXTA implementation, a simplified abstraction is available to applications)

- Address book and user to user messaging

AN EXAMPLE OF RETRIEVING CONTENT AND RIGHTS

This section gives an example of searching and acquiring content and rights to illustrate how the aspects of the system work together. It shows the high level steps that are taken in order to search for and acquire content and rights from another peer. In this example, the user of Box A is searching for content, which is available on Box B.

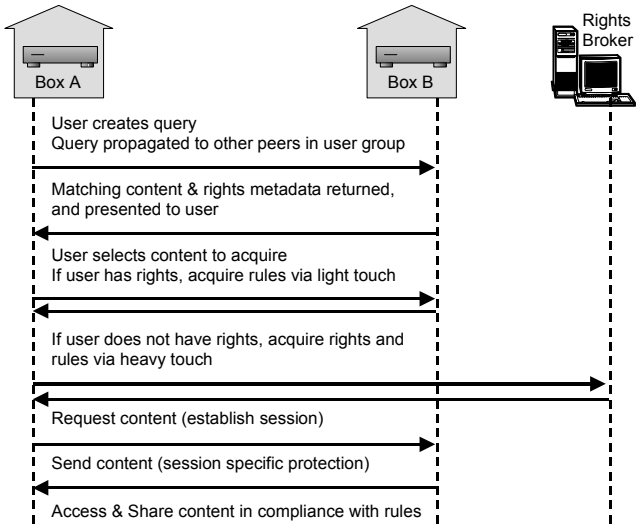

Figure 4 – Rights negotiation

CONCLUSIONS

The project has explored many issues involved in the design and deployment of a wide spread, consumer, TV-centric, peer-to-peer network of connected homes. Starting from a set of scenarios of potential use we have proceeded to refine the usage models, to design and adapt protocols for P2P content sharing, for DRM, and APIs to access this new functionality. We are developing a number of trial applications based on the usage scenarios to evaluate the value of the new service ideas and the underlying technology.

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