Sharing Systems for Future HiFi Systems

Jürgen Nützel
Technische Universität Ilmenau
D-98684 Ilmenau, Germany
Juergen.Nuetzel@TU-Ilmenau.de

Matthias Kaufmann
Fraunhofer IDMT
D-98693 Ilmenau, Germany
kfn@idmt.fraunhofer.de

Abstract

Thanks to modern audio compression techniques and increased bandwidth in the Internet the music industry has changed dramatically. Music in the 19th century was a service. In the 20th century music became an industrial product. In the 21st century music will be a service again. Illegal sharing services like KaZaA are widely spread. Legal online music services like iTunes from Apple or Napster 2 from Roxio already have been started successfully. Using these systems PC users have access to a huge music database. In contrast to this users of home HiFi systems still miss such online services. The authors will give an impression of the future HiFi system they dream of. Like a modern PC the dreamed system which is currently under development has Internet access and operates with a hard disk. Unlike a PC the HiFi system has a simple user interface. Thanks to its connection to a special peer-to-peer network the HiFi system provides easy browsing through numerous music titles. The introduced automatic mode allows the user to listen to his favorite music with a one button interaction. Technologies like audio fingerprinting and melody transcription will be necessary for future HiFi systems. Some other technologies like recommendation engines and light weighted digital rights management systems are currently under development. The core component of the HiFi system is the content manager. It tries to match the user profile with other existing profiles to send song requests to the connected peer-to-peer network automatically.

The described system is closely related to a European research project called Semantic HiFi which is lead by the famous music/acoustic research institute IRCAM. The sharing system is the main contribution of Fraunhofer IDMT and 4FriendsOnly.com AG.

1. Motivation and Introduction

150 years ago music was a service. Making business with music was only possible by giving a live performance in a music theatre. Music consumption was not possible without music performers. Separating music production from music consumption was not possible until the late 19th century when Thomas Edison invented the phonograph and Berliner the gramophone. Since then music became a product. In the next 100 years the music business grew from a little seed to a very giant tree and began to do global business when it enabled everybody to buy recorded music and music playing devices. In the late eighties this industry reached its zenith. The invention of the CD brought maximum quality and high comfort into every home. The industry made a rather easy business because every music enthusiast replaced his analog records by digital audio CDs. The world seemed to be perfect.

But only 10 years later a few more inventions revolutionized the music business again. Internet and MP3 came up. Napster 1 is well known within this context. The Internet in combination with modern audio compression techniques made instant access to almost every music on earth possible. And it was even possible without the traditional music industry. What was needed instead? Computer manufactures and Internet providers became the winners. It took a few years for some to understand how the new business might work. The people from Apple made an excellent job. Some others will need a few more years to understand. In any case music business will become that it was 150 years ago - a service for the consumer.

But what happened to the device manufactures? They still produce machines in which you put on the one side the music recordings and on the other side you plug in the loudspeakers. MP3 in combination with cheap tiny hard disk drives allowed producing portable jukeboxes. The Apple iPod [1] is the must famous portable High Fidelity music playing device. With the iPod Apple is not only selling a device it is also providing full service to buy and manage music on the Mac and even on the PC. The iTunes software provides all the feature an ordinary user needs to buy, sort, burn and transfer music.

Keeping this in mind we and many other researchers ask the question: What will the future HiFi system in my living room look like.

2. The System We Dream Of

We dream of a HiFi system which allows the consumer to hear every song he likes with the easiest user interface. But before we explain internal features in detail, we describe how the system may look like.

2.1 How Does the System look like?

Figure 1 shows a possible system configuration which consists of a home HiFi system and an advanced portable device. The home HiFi system has multi-cannel-sound capabilities. It is connected to the Internet. For the existing music material a CD/DVD slot is integrated. An 8'' color display allows displaying additional metadata and control information. For the control of the system only a few dials and buttons are needed. Every modern home stereo has a remote control. Our remote control is much more advanced. It can be used as portable player like the iPod. The communication with the HiFi system is done bidirectional via Bluetooth. This allows downloading into the remote control. Couch potatoes control the HiFi system using this device. Microphone and camera allow fancy user interactions.

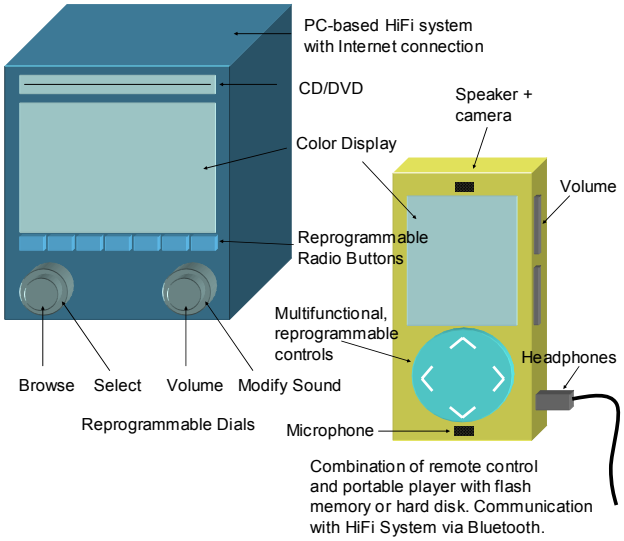

Figure 1 The HiFi system we dream of is a combination of Internet connected home device and portable player.

2.2 What are the Main Usage Scenarios?

The usage scenarios we propose are much more innovative than the technical parameters of the system. We want to list only the main scenarios with some remarks on their realization.

In the **CD mode** the user plays an audio CD or DVD. Different from an ordinary CD player the HiFi system rips automatically the CD to the local hard disc. The hard disc comes into play in the automatic mode.

In the **automatic mode** the user simply switches the HiFi system on and the system play the songs the user likes most. The music comes either from the local hard disk or from the hard discs of other HiFi systems which form together a protected peer-to-peer sharing network. The system uses different user inputs to "learn" the user's flavor. A simple button like the up/down auto seek button in a car stereo enables the system to "learn" from the listener. If the user does not like a song he will press the seek button. From the automatic mode several other modes are derived.

In the **browsing mode** the user can browse through genres, artists and songs. The user is also able to select a specific song by typing the title or simply by humming the melody. Browsing results extend the user profile which is used in automatic mode. In all modes specific metadata will be displayed. This metadata is not limited to official material like title and artist. Also recommendations or reviews from the fan community, i.e. users of other HiFi systems, or personalized advertisements can be displayed.

In the **community mode** the user is enabled to chat with users who like the same music. During the listening of a certain song messages from users who like similar songs may arrive. The user is allowed to make reviews or personal rankings. Community users are often different to coach potatoes. They want to hear their favorite music everywhere.

In the **portable mode** the user can transfer the music from the HiFi system's hard disc to the storage media of the "remote control" or any other device. The user profile learned from the user's inputs makes it very easy to find a favorite subset for the transfer to the portable. If the music content leaves the closed and protected environment of the home HiFi system we have to consider certain security technologies. These considerations have to be done if we discuss business models for the system we dream of.

2.3 What are the Business Models?

Beside the consumer's also the music producer's situation has to be considered. Hardware manufactures want to earn money as well as most of the artists. Music labels are interested to stay in business. Therefore they will need properly working business models that meet with the new world of instant access and easy transport of music files.

We understand the proposed system as a service. So a subscription model would fit most likely. Similar to the mobile phone business a customer subscribes for the service when he buys the hardware. A special music service company runs the backend system and sells the hardware. Different subscription models are possible: Buy the hardware for 1 Euro and pay the next two year every month 20 Euros. Or pay 200 Euros for the hardware and pay every month only 5 Euros. Or even pay 400 Euros to avoid any further monthly fees.

The music service company runs in the background an additional monitoring service which allows a fair splitting of the revenues to different artist, labels and collecting societies.

3. Some already Existing Technologies

In the previous chapter we made a lot of assumptions about a future HiFi system. Although the system is not in stores yet some of the needed components and technologies already exist or are going to be developed within the next years. The already existing technologies provide commercial solutions for:

- Transcription of sung melody for recognition and user performance (Karaoke)
- Identification of audio material for a better music look-up possibility
- Processing of audio similarity and genre for easier music browsing
- Sharing for instant metadata and content access building new forms of business models
- Digitally signing of content allowing a more user friendly digital rights management.

3.1 Browsing and Searching Functions

It is very important for a future home based HiFi system to provide easy access to large music databases. This is done by integrating comfortable search and browsing functions. Two searching technologies are already available. They are derived from research projects of Fraunhofer IDMT called Query by Humming (QbH) [2] and AudioID [3] [4].

In the last years the transcription of a melody excerpt from a sung user input has been developed [5] [6]. The melody recognition system Query by Humming (QbH) is useful for easy and direct access of music and for browsing in similar music. The recognition of a sung or hummed query is divided into three steps. 1st the short singing is recorded. Adaptive pre-processing reduces the influence of background noise on the succeeding steps. 2nd the fundamental frequencies are analyzed and transformed into a pitch contour which is subsequently divided into several scores. Each score is characterized by its temporal duration and tone height. 3rd a complex database lookup algorithm results a list of music titles from songs that are very close to the users singing. It compares and tries to adapt the resulted melody query phrase with all melodies stored in the database (see figure 2). Each adaptation of scores within the query phrase is noticed by a penalty value. The resulted music titles are sorted by the penalty value. The song with the lowest value i.e. the most similar one is placed at top of the list.

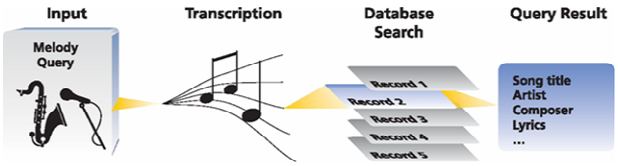

Figure 2 Functionality scheme of Fraunhofer's [2] "Query by Humming"

With the help of the melody transcription function of QbH the user is able to sing an excerpt of the music he has in mind. The melody transcription function computes the scores on the user's HiFi system and sends them to a server which compares these with a large melody database by using the error-robust search algorithm described above. As a result the server sends back a list of the ten most similar pieces of music to the user. It allows the user to look shortly for the correct song or just to listen to similar music.

Another already existing technology from Fraunhofer IDMT for audio identification is called AudioID [3] [4]. It aims to identify any recorded audio material. Unlike to QbH the input for the identification process is neither hummed nor sung by the user. The input comes from any desired audio source. The recorded signal is analyzed in the frequency domain and some few particular features are combined to an audio fingerprint – the AudioID fingerprint. This very small file (compared to a compressed audio file) represents the recorded signal and is needed as input for the fingerprint search procedure.

AudioID is able to identify pieces of music by their spectral fingerprint. The user takes a short (10s) record of the music he wants to know more about like title, artist and album. This recording can be done by any input device, if it is digitally transferable to the HiFi system. The HiFi system itself computes the AudioID fingerprint and sends it to a server. A version with locally stored database is also possible. Within a few seconds the one fingerprint is identified out of more than one million other fingerprints. The associated metadata for the found fingerprint is transferred back to the user. In figure 3 the database structure is shown. The advantage for the user is that he can enjoy the music without asking some other for title and artist. When he happens to miss the record then he gets a second chance by singing the song and using the melody search.

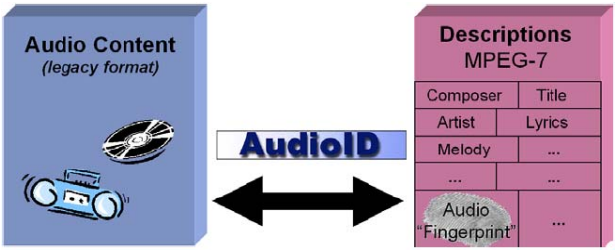

Figure 3 AudioID allows to look-up associated metadata

The possible applications of audio identification extend the search and browsing capabilities for the users. Audio identification also makes simultaneous broadcast monitoring of a high number of broadcast stations possible. In our future HiFi system audio identification can be used as filter within the peer-to-peer sharing network. AudioID fingerprints of songs that are allowed to be shared are stored on a central white list server (the AudioID fingerprint database server). Each time a HiFi system user wants to share a ripped song from a CD the system sends the extracted fingerprint to the white list server. If a white list entry exists sharing will be enabled.

Figure 4 Results of an AudioID database query

Within the fingerprint comparison step on the HiFi system audio similarities (sounds-like information) could be calculated additionally. The audio fingerprint technology also allows the assignment of a genre to a cluster of fingerprints. Very often a song is assigned to multiple genres. Further research on this topic has started recently. The goal of these research efforts is a musical advisory service which knows user's taste and offers new pieces of music relating to the same genre or simply being similar to songs the user often listens. The personalization of content is the key feature to comfortable music consumption.

3.2 Matching and Data-mining

The data mining of usage statistics open a different approach for personalized music recommendation services. The basic algorithm sounds quite simple. Many users of a music service like several different songs. This statistical information is stored on central server. For privacy reasons all information which allow tracking back to a certain user have been removed before. Let us suppose a new user has purchased or wants to purchase the song A. The server of the download shop scans its database for other users who also like i.e. purchased the song A. If several users who like song A also like the song B the system recommends song B to the first user. The server has learned that song A is some how related to song B. The online book shop Amazon [7] does such recommendations for books. But Amazon's algorithm implemented in their live system is much more complex.

In the PotatoSystem [8] [9] a simple user matching algorithm was developed [10]. Different from the basic idea it does not recommend songs it recommends users. The PotatoSystem has an affiliated business model where users become re-sellers. Therefore it is useful to recommend a reseller which offers the most interesting content.

For a future HiFi system which offers an automatic mode a modified approach is needed. The primary feed-back of automatic mode user's is pressing the seek button if they dislike a song. Research on recommendations based on dislike statistics have recently started.

3.3 A New Less Restrictive DRM Approach

Publishers of digital music aim to control the usage of their products. They normally do not trust their customers. They use strong Digital Rights Management (DRM) systems to restrict the usage of their files on the user's playback devices [11]. This is totally in contrast to the user's wish to hear the music everywhere and on every device. In all DRM systems the music file is delivered encrypted [12]. The license record including machine readable usages rules and the track key are handled separately. On the user's device usage rule handler has to be installed. This software component decrypts the music file using the track key only if a valid license record was found. To make such a system secure against hacks the usage rule handler and the license records have to be kept obscure. When such a system wants to allow transfers to portables the DRM technology becomes rather complicated and proprietary.

Fraunhofer's lighted weighted DRM (LWDRM) goes a different way [13]. If the user wants to transfer the music file to its portable or car stereo no complex license record transfer or check-out process is needed. The user simply signs the content digitally using its LWDRM certificate. This signature process frees the file from the hard DRM usage limitations. From this time on it is up to the user to behave legally.

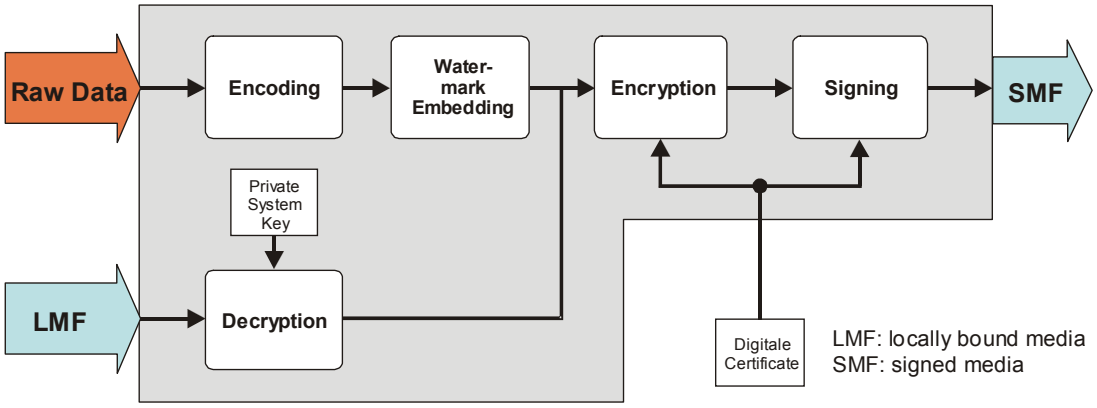

Figure 5 The signing profile of the LWDRM [13] system

As consequence the user's files can be traced when spread over illegal peer-to-peer sharing networks. The signed files can be traced back to the original user. Therefore to user will be careful making copies (what is tolerated by law in Germany) or giving the music files to unreliable friends. For privacy reasons LWDRM uses pseudonymous certificates which include no personal data. This limits the ability for backtracking to the certification authority (CA) which created the certificate. The CA is not responsible for the selling of the songs (separation of duty).

Figure 5 shows the signing process of raw data (from CD) and encrypted data (LMF). As second line of defense a watermark will be embedded.

We propose such a light weighted DRM system for future HiFi system having a portable mode. The needed digital certificate is embedded in a small USB device. The certificate device works similar to the SIM of mobile phones. If a user buys a HiFi system a certificate devices will be included. The certificate device has several added values. It allows customizing the setup of the HiFi system and transferring the user settings to another HiFi system.

4. The Sharing System

Future HiFi system will be connected to the Internet. The standard Internet connection allows accessing many central services. The HiFi systems we propose form additionally a protected peer-to-peer (P2P) sharing network. This P2P network allows direct message, music and metadata transfer between two HiFi systems (the peers). The network has to provide transport functions concerning:

- Music
- Metadata
- User made metadata
- User messages

For a legal service the P2P system components have to control carefully what content is allowed to be shared. Content will be classified as public (in the system), restricted (to a specified group) and private (local) content. The sharing system will use the audio identification (AudioID) technology and signed license files to detect private (purchased) content and prevent it from being shared with other HiFi systems.

4.1 Basic Principles of P2P Networks

A good understanding of the basic technological principles helps us a lot to find the best (and even legal) business cases for P2P systems.

The P2P principle is the traditional communication pattern of the Internet. Every computer (peer) in a P2P network is able to communicate with each other computer. The Arpanet of the late sixties in the last century allowed the exchange of resources between equal computers across the USA. The early Internet provided P2P services like USENET and DNS. In these days every Internet computer had a fixed IP (Internet protocol) address.

After the invention of the web protocol and the success of Internet access via modem, the communication structure of the Internet changed. In the nineties the client-server pattern became more and more popular. Personal home-based computers connect temporally via the telephone line to central web or email servers. Every time they connect they receive a different IP address from the Internet provider. This is the reason why these home-based machines are not able to provide reliable resources to other computers. They can not act as a server. Firewalls and intranet computers which are hidden behind gateways result similar problems.

In the late nineties powerful PCs appeared. DSL in combination with flat-rates transformed the Internet back

to what it was before: A P2P network. Special software came up which allowed to work around the problem of dynamic IP addresses. These P2P clients combine the functionality of a server and a client. Sometimes they are called "servants". They provide their own addressing and search service on the top of the Internet protocol.

Without a few machines (at least one) with a fixed IP address a modern P2P network will not work. These machines are called super-peers. If a new peer wants to enter a P2P network for the first time it has to contact such a super-peer. It drops its dynamic IP address there and receives a logic address. The super-peer knows also addresses of other peers and further super-peers.

If a peer searches for certain resource (e.g. a music file) in the P2P network it will contact all the peers its address it knows from. If a peer can not provide the searched resource it will propagate the request to the peers its addresses it knows. After a few steps the request reaches thousands of machines.

After two peers have found each other, they will communicate directly to exchange the requested data.

4.2 Use-cases for the Sharing System

Why became such P2P systems so popular? The first answer is that these systems made it as simple as possible for ordinary users to make files from the local hard disc public. The second answer is that searching thru these thousands of publishing machines is much easier than using Google. But what is about the business case?

From the user's perspective there is no need for such a decentralized system. If one dedicated huge server would provide all the content the service would be much more reliable. But nobody is neither interested nor allowed to run such a service for free.

BMG tried to transform the old Napster into a legal subscription service. But they did not manage it as we already know. Why should a user pay for the right to work for the profit of BMG? In 2003 Roxio started Napster 2. This new Napster is now a centralized music download subscription service. This legal service generates revenues without P2P technology.

But in the case of our future HiFi system we see a business case for a legal P2P system. Like Napster 2 we believe in a subscription based service. For a single company it might become very expensive to provide such a centralized service. With the help of the users the service could be done much cheaper. But the company has to encourage the user to do two things: to rip as many CDs as possible and to be online as often as possible. This could be achieved by rewarding the users for doing this. The reward is the access to more interesting content. Each time a file will be requested the providing HiFi system receives special "sharing credits". Each time the HiFi system requests a music file from the P2P network it has to transfers one of its sharing credits to the HiFi system the file was providing. With an empty credit store the system stops downloading music files.

4.3 Implementation using the JXTA 2 Framework

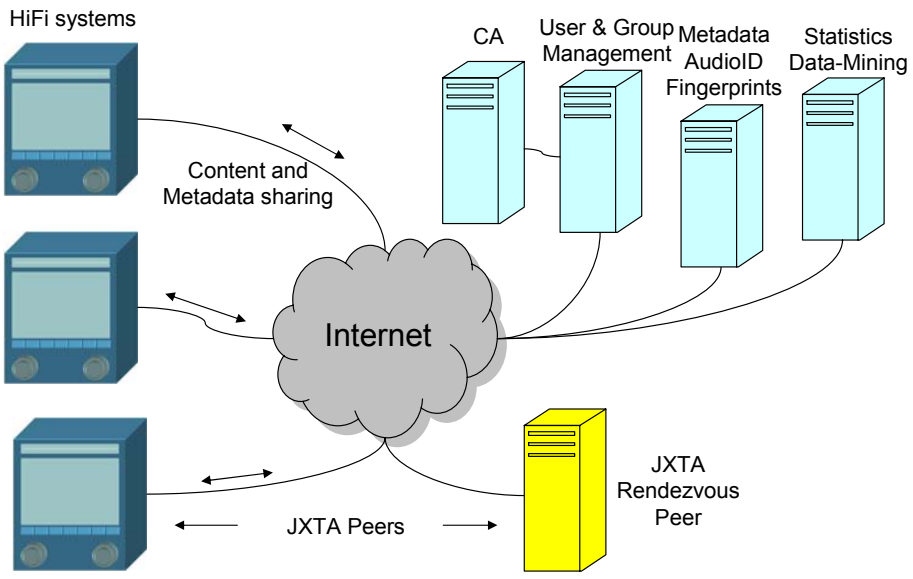

Figure 6 Architecture behind the HiFi systems

Figure 6 shows the simplified network architecture behind the scenes. The root CA (certification authority) creates certificates (PKCS#12 files with public und private RSA keys). The user and group management server stores login names and the certificates (public key only) which belong to a login. This server verifies user's

login name which was signed using the certificate which is stored on the certificate device. The central metadata server stores the AudioID fingerprints and the associated metadata. This server also stores the sharing white list and creates signed licenses files. These license files allow a decentralized white-list check. The central statistics server stores the requests to this metadata database server. The usage logs (statistics) are needed for a fair compensation of the rights holders and for further content recommendations. One rendezvous server (a super-peer) is needed for the setup of the P2P system. For the implementation of the P2P system we use the JXTA 2 open source framework [14].

Bill Joy and Mike Clary setup a small team at SUN Microsystems to develop a P2P language which specifies the communication in a P2P network. The research project was named JXTA. The word JXTA was derived from the word "juxtapose". The target of the project was to simplify the realization of P2P applications. The developer can concentrate on the application.

The core of JXTA is a set of protocol specifications, which manage the communication in a P2P network. In the JXTA protocols only XML messages will be exchanged. This makes the JXTA platform language independent. The reference implementation is available in Java.

In 2001 the project was transferred to an open developer community. JXTA is under the "SUN Project JXTA Software License" which is based upon "Apache Software License Version 1.1". In 2003 the JXTA protocols in version 2.0 have been published.

Figure 7 shows the internal structure of the sharing components in the HiFi system. The core component is the content manager block. This block generates automatically search requests for new content. The requests will be passed to the JXTA sharing component. The sharing component also decides (using AudioID and signed licenses) if content on the local hard disc is allowed to be visible for other HiFi systems.

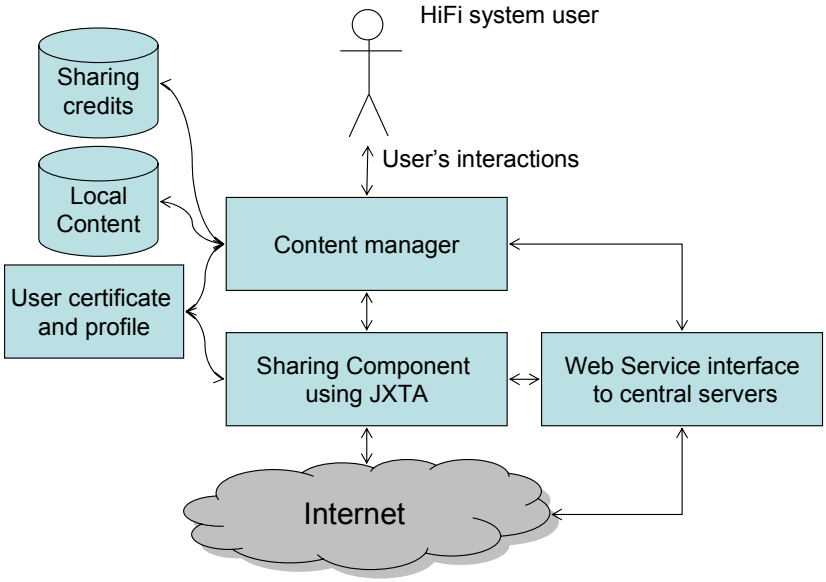

Figure 7 Internal structure of the HiFi system

4.4 The Automatic Mode

In the automatic mode the HiFi system plays user's favorite music automatically. The content manager generates automatically content requests for the sharing component. The requests will be calculated from the simple feedbacks of the users. Pressing the seek button if the playing music does not fit a user's taste is the most likely feedback. Not pressing the seek button while hearing a song is the second type of feedback. These feedbacks will be stored in the local profile. The daytime of a specific feedback may also become important. Via the sharing component the local profile will be made visible for all other HiFi systems.

To find new songs the HiFi system does not search for songs directly, it searches for profile entries which match entries of its own local profile. As a result of this search the content manager receives a list of HiFi systems which have similarities in their profiles. Using the profiles of these matching HiFi systems the content manager derives a list of songs it will directly request for. If the user likes the new songs the matched HiFi system will added to the local profile for later search requests. If the user dislikes the songs the "matched" HiFi system will be deleted from the watch list.

At the beginning the results will be more or less randomly because no specific entries in the profile are available. The more feedbacks are stored the more specific entries are available.

In [10] a P2P variant of the user matching was described. But much more research has to be done on this field.

5. Relations to the Semantic HiFi EU Project

The described approach of the authors is closely related to the Semantic HiFi research project. Semantic HiFi which started in December 2003 is a multinational research project funded by the 6th Framework of the European Commission. The project is lead by IRCAM the French research institute for music and acoustics [15]

It aims towards research in semantic audio processing combined with the development of a consumer HiFi system. The HiFi system will be able to support all the functionality of today's home HiFi devices like playback from radio, audio CD, MP3 or other codecs and streaming contents.

Usability is also an important research topic. The device will be controllable via a small TFT display, soft keys and wheels. The user will be able to browse through its own music very comfortably.

When unknown music is played its metadata like beat, instruments or the name of the artist and album will be extracted automatically or gathered from metadata server. Further the user will be able to feed the system with metadata himself and share these with other HiFi systems.

Users know HiFi systems only from their consumer functions like music playback and optional sound equalizer. Some users love more bass sound and thus change the musical spectrum to their wishes. The HiFi system in the Semantic HiFi project will be able to provide further manipulation functions. The user will be able to:

- vary the tempo
- alter the tone height
- strengthen or weakening single voices or instruments
- perform a number of filter functions
- combine all possibilities and create remixes

As known from DJ tools like Native Instruments' DJ Traktor the user will be able to crossfade between two songs through adapting their tempos to each other. This will be done automatically but also manual tempo correction will be possible.

The user may also alter the tone height of a song he listens. It allows the user to adapt the tone height to his voice in the case he likes to join by singing. On the other hand it is needed for automatic crossfading. A very complex field is the manipulation of single voices or instruments. It has been shown by Universitat Pompeu Fabra that single voices can be strengthened or weakened compared to the rest of the complex signals. Further research work and developments will lead to an error-free algorithm that allows the user to change the loudness of single voices. These functions are completed by a number of digital filter functions to add reverberation, and other manipulations to the music.

The user will be able to combine all operations on music and so create new musical content. Remixes from given music can be made by the help of scripting. A user who found a good sound doing some filter processing on music will be able to send a processing script to a friend via a sharing network. The friend will then be able to reconstruct the remix, if he owns the same original pieces of music.

Unlike other HiFi systems the Semantic HiFi system will allow user input for entertainment. Beginning with a Japanese tradition – karaoke – the system will provide additional performing possibilities.

By the help of the above mentioned semantic processing functions the HiFi system will be able to use normal pieces of music for karaoke. The music will be prepared through single voice loudness reduction. This reduces the singer's voice very strong so that the user can sing nearly to the remained music or melody. It will be possible to show the lyrics and link them to their onset data.

Another performing function will be a Voice2MIDI interface provided by the Fraunhofer melody transcription function (also used for QbH). The Voice2MIDI interface allows the user to play instruments by voice input. He simply sings into the microphone connected to the HiFi system and sings for his own or additionally to already playing songs. The interface will analyze the scores and synthesize them as MIDI output via a MIDI instrument or a wavetable synthesizer.

Another idea that will be investigated is the sound manipulation by mouth. The user will wear a face camera. The face camera will look on their mouth. By opening, closing and different movements the music will be altered so that it will be funny to listen to.

6. Conclusion and Further Work

The music business is one of the most exiting ones. But the industry behind it regards the industrial product *music* as much more important than the art of it. Thanks to the Internet and modern audio coding technologies people broke with the industry that has hardly been able to follow developments that already last for 10 years now. This new concept about music consumption of the future will open the door for new music business models. By integrating existing technologies future HiFi systems will bring much more comfort to the user by offering him a series of new music browsing manipulation and processing tools. Through a sharing network users will get information about artists, tours and other related

events instantaneously. Semantic audio processing will be a major property of the future HiFi system. Users will change from pure consumers to music artists because they will be enabled to (re)create content. Together with a very user-friendly, light weighted digital rights management system the peer-to-peer sharing network will build a marketing and distribution platform for young and often unknown artists.

A way to realize our dream of the future HiFi system is the EU project SEMANTIC HIFI. It will be a playground for music and acoustic research and will help getting experience in new consumer behavior and new way to deal with music. The sharing network is one of the main components of this concept. Users will exchange their play lists or other information. They will get instant access through technologies like AudioID and QbH. Also the automatic mode is not part of the EU project it may become a new type of music consumption. A protected sharing system prevents users to distribute content illegally. The personalization of files by the LWDRM system allows exporting content legally to portable devices. Music will come back to its origin: Like 150 years ago it will become a service again.

References

[1] Home page of the Apple iPod, Apple Computer Inc., February 2004, http://www.apple.com/ipod/

[2] Homepage of Fraunhofer Institute for Digital Media Technologies IDMT, http://www.idmt.fraunfer.de

[3] Hellmuth, O.; Allamanche, E.; Cremer, M.; Grossmann, H.; Herre, J.; Kastner, T.: "Using MPEG-7 Audio Fingerprinting in Real-World Applications", 115th AES Convention, Oct. 2003, New York

[4] Herre, J.; Cremer, M.: "AudioID: MPEG-7 audio fingerprinting", from Roberto Raieli and Perla Innocenti (publishers): "MultiMedia Information Retrieval", ISBN 88-901144-9-5, AIDA, 2004

[5] Luís Gustavo; P. M. Martins; Aníbal J. S. Ferreira: PCM to MIDI Transposition, In 112th AES-Convention, Munich, May 10-13 2002. Paper 5524

[6] Wei Chai: Melody Retrieval on the Web, Proposal for master thesis at the Massachusetts Institute of Technology, Media Laboratories, 2000

[7] Homepage of the online book store Amazon: http://www.amazon.com

[8] Homepage of the PotatoSystem: http://www.potatosystem.com

[9] Grimm, R., Nützel, J.: Peer-to-Peer Music-Sharing with Profit but Without Copy Protection, Wedelmusic 2002, Darmstadt, 9th - 11th December 2002. IEEE Computer Society, ISBN 0-7695-1623-8, p. 17 ff. http://www.4friendsonly.org/eng/papers.htm

[10] Nützel, J.: Matching Algorithms in File-sharing Systems to find new Users having new Content. I2CS, Leipzig, June 2003, Springer, LNCS

[11] Grimm, R., Nützel, J.: A Friendly Peer-to-Peer File Sharing System with Profit but Without Copy Protection. Intelligent Internet Computing Systems I2CS, Kühlungsborn, June 2002, Springer, LNCS 2346.

[12] Neubauer, Ch.; Brandenburg, K.; Siebenhaar, F.: Technical Aspects of Digital Rights Management Systems, In 113th AES-Convention, LA, October 2002. Paper 5688

[13] Homepage of Light Weighted Digital Rights Management LWDRM, http://www.lwdrm.com

[14] Homepage of JXTA: http://www.jxta.org

[15] Homepage of the Ircam in Paris: http://www.ircam.fr