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Interchangeability and Interconnectivity of Current Home Media Streaming Technologies

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Abstract
The way how people buy and consume media content has drastically changed over the last decade. The internet has replaced physical media as the primary distribution channel for media content, leading to large digital libraries on most people's computers. With that shift came the desire to stream media content to speakers and displays within the local network. Unfortunately, most streaming technologies are not mutually compatible. This report has evaluated solutions to achieve interoperability between the two most popular streaming technologies, Apple AirPlay and DLNA. It has revealed that although both technologies remain incompatible at the core, inexpensive workarounds for end-users exist to connect devices with support for either technology.

Keywords
Media Streaming; AirPlay; DLNA; Smart Appliances; Smart Homes; Home Networks; Ubiquitous Computing

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1. Introduction

In the field of distributed systems, one of the most important developments in recent years was the paradigm shift from mobile computing to ubiquitous computing in research. Nowadays, almost any electronic device is technically a computer, and electronic devices are everywhere, from cars to living rooms to your pocket. However, in a ubiquitous computing environment, the hassle of traditional computers should be hidden from the users, who should not even have the perception of using a computer, although they actually do [1]. Key technologies to enable ubiquitous systems are network protocols that allow autodiscovery and interconnectivity of heterogeneous devices. These technologies are also the base for smart appliances [2]; the next section will outline why home streaming can be seen as a subfield of smart appliances, and thus, ubiquitous computing.

1.1 Background Information

In early papers on smart appliances, like the one published by Schmidt et al. in 2001 [3], all use cases of smart appliances focus on energy efficiency. The prime example of smart appliances were, and still are, household and kitchen appliances that turn on and off with respect to the current electricity rate. It usually means doing as much work as possible during the night, while saving energy during peaks at daytime, based on real-time price information from the internet.

Later works became more open as to the use cases and components of smart appliance environments. Kango et al. [2] explicitly mention media devices, such as TV set-top boxes, in the context of smart appliances. They also point out clearly that computer networks are essential to any smart appliance environment. Recent product announcements by LG and Samsung [4, 5] show that smart appliances and smart media environments are about to merge – this is usually referred to as “smart homes.”

This project will focus on one piece of the puzzle, namely home streaming. Technologies such as Apple’s AirPlay streaming service [6] and the open DLNA standard [7] allow end-users to share media content, such as music, videos, and photos, wirelessly between different devices within their home network. These devices can be grouped into two categories: Sources, which carry or download the media content, and receivers, which play or display the media content. However, the most popular streaming technologies are not mutually compatible out of the box. If you have an AirPlay-enabled source, you cannot stream your content to DLNA-certified speakers, and vice-versa. The reasons for this incompatibility are of political rather than technological nature, but have to be dealt with anyway.

1.2 Purpose

The goal of this project is to find out whether there are non-programmatic solutions to achieve interconnectivity, and thus, interchangeability, of streaming technologies. If solutions are found, they will be evaluated, whereas the most important criterion is complexity. The primary users of home streaming are end-users without an IT background, so setting up and using a streaming system should be as easy as possible. Especially for the sources, which are usually portable or mobile devices, wireless solutions should be preferred in order not to limit the devices’ portability and convenience.

Behind this project is a strong belief that customers should have a free choice when buying a device. Without interconnectivity between devices from different vendors, however, customers might be tied to one vendor or its technology once they have bought their first device, if they want to utilize the streaming technology it offers. The results section should be seen as a guideline, revealing which sources and receivers can be combined at what price and effort. While this report is written for an audience with a technical background, the application of the results is supposed to help customers in the first place. Moreover, retailers can use the same information to recommend products that go well together. Lastly, the problems that have occurred during the research may

help third party suppliers to bridge a market gap by creating new products that solve current issues.

1.3 Scope

This project focusses entirely on home streaming. Although an introduction into smart appliances and smart homes has been given to outline the bigger picture, the integration of home streaming into smart homes in general will not be considered.

Since all solutions have to be affordable, no custom software will be implemented. Either there is an existing piece of software or hardware that can be used to support interconnectivity, or not.

Only the most popular streaming technologies will be considered in the actual research, as space is limited and the project runs on a tight schedule. In Section 2.2, Materials and Methods, an overview of current technologies will be given, and the choice of the platforms and technologies for the research will be explained. Due to cost restrictions, no practical tests will be carried out.

2. Preparation

2.1 Theories, Models, and Hypotheses

It is not trivial to scientifically evaluate consumer products and their underlying, often proprietary, technologies. Academic sources may contribute to understanding common problems, but they rarely discuss implementation details of products you can buy. Therefore, sources such as blogs and product websites will be used in the absence of more academic texts.

Likewise, there are hardly any existing theories and models that research on this particular subject could be based on. One very basic model that will be used to categorize approaches and solutions is the OSI Basic Reference Model [8] that was standardized in 1984 and specifies the well-known seven abstract layers for software communication.

Virtually all modern operating systems for desktop, mobile, and even embedded systems share a standardized protocol stack that eliminates most compatibility issues on all layers but the top layer. If, for political reasons, incompatibilities are desired, they are usually introduced on the application layer. Security mechanisms on lower layers may also be used to hinder undesired devices to connect.

Given that most problems originate on the application layer, it is expected that most solutions must have an impact on the application layer in one way or another, too. Another prediction is a strong correlation between the openness of a system and the feasibility of solutions for it. This implies that it is likely to be a lot harder (which may translate to infeasible) to develop solutions for closed hardware, e.g., stereo speakers and traditional TVs, than it is for PCs and smartphones. To put it in a nutshell, it is expected that sources will be highly interchangeable, while there might be no way around the vendor-specific products on the other end, the receivers.

As will be shown in the next section, there is one major proprietary technology and one major open technology today. A product that supports a proprietary technology does not necessarily lock out an open one, but the inverse usually holds true. Integrating a proprietary product into an open environment is therefore expected to be easier than integrating an open product into a proprietary system.

2.2 Materials and Methods

2.2.1 Choice of Technologies

Today we have a handful of different media streaming technologies, but for various reasons that are about to be discussed, it is very likely that only two will persist in the long run. As mentioned earlier, none of the existing technologies are mutually compatible and only a very strong market position can justify a proprietary solution – everyone else will have to adapt to a standard.

The Digital Living Network Alliance (DLNA), founded by Sony in 2003 [9], has established such a standard – as a matter of fact, it is the only one of its kind. By now, the DLNA has more than 230 members and supporters [10] that include almost any consumer electronics company but Apple and Google. It should be noted that one does not have to be an active member to build DLNA-certified products, as, e.g., Google does. The DLNA streaming standard is completely open, but in order to advertise products with the “DLNA Certified” seal, a paid certification process is required.

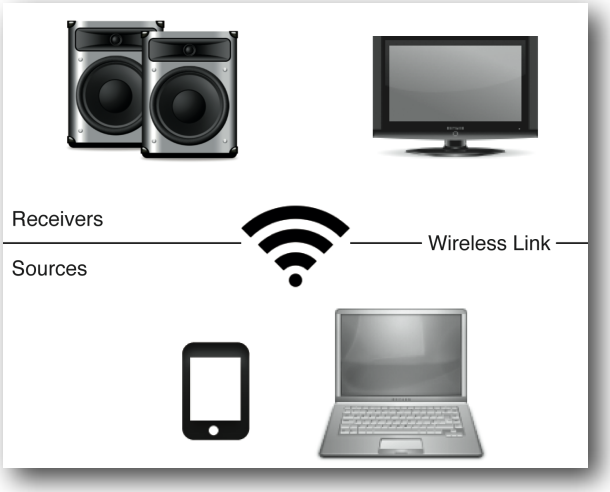
Although Apple has contributed to important open standards and frameworks, such as HTML5 and WebKit [11], it is also known to develop closed systems when standards are missing, ill-conceived, or involve the risk of a negative impact on the user experience. While the DLNA standard was still under development in 2004, Apple shipped the first products that supported AirTunes, AirPlay’s predecessor for music only [12]. Apple added video support with the introduction of Apple TV 2 and iOS 4.3 [13], and merged video and AirTunes into AirPlay. With more than 250 million iOS devices sold [14], Apple certainly has a strong market position to back up AirPlay – it would be surprising to see Apple opening up AirPlay or turning to DLNA any time soon. As with DLNA, third party suppliers can license AirPlay to make speakers, TVs, or even cars AirPlay compatible, but Apple’s selective policy and a $100 license fee per device sold [15] will keep the circle small.

The competition came up with more closed streaming ecosystems, but most companies have switched to DLNA already. Google announced its media streaming service “Fling” in 2010 [16], but has never released any device or software to support it. Instead, Google TV’s only streaming option is DLNA [17]. Logitech, one of the most well-known manufacturers of desktop speaker systems, has developed a streaming technology called Squeezebox, but it only works in conjunction with other Logitech hardware and software, and it is audio only [18]. Another limiting factor is that Squeezebox relies on Bluetooth on the physical layer, while DLNA and AirPlay use WiFi, which is far less error-prone, has a far higher bandwidth (allowing compressed HD video streaming), and a wider range. Logitech still sells Squeezebox products, but has added products with AirPlay and DLNA support to its product line.

In this project, only DLNA and AirPlay will be considered further. The main reason for DLNA is its openness and the reasonable license fees. AirPlay’s strong market position and ease of use justify its consideration.

2.2.2 Setup and Scenarios

The general setup is straightforward: It consists of two types of sources and two types of receivers. For the sources, one portable device (e.g., a laptop computer) and one mobile device (a smartphone or tablet computer) will be considered. The receiver side includes a television set and a stereo speaker system. The generic setup is shown in Graphic 1.



Graphic 1: Project Setup

Note that this setup is completely independent of any streaming technology. When specific devices and technologies are included, the term scenario will be used to describe the instantiated setup. Two initial scenarios are the starting point for further examination: One scenario with AirPlay-enabled devices only, and on the other hand, one scenario with DLNA technology only. These will be referred to as Scenario A and Scenario B, respectively.

For Scenario A, the Apple iPhone has been chosen as the mobile device, since AirPlay is built into the operating system (since iOS 4.3). The laptop computer will be an Apple MacBook Pro with Mac OS X 10.7 Lion installed. Apple's music and video player application iTunes has integrated support for AirPlay, and iTunes is distributed with Mac OS X. At the time of this writing, there are no Apple speakers on the market, but numerous manufacturers have licensed the AirPlay technology. The Philips Fidelio SoundAvia is one of the more affordable solutions here, but in this project, the choice of the speakers is irrelevant, as long as they have AirPlay support. Although Apple sells a product named Apple TV, there is no Apple television set on the market, and no other vendor has licensed AirPlay for video so far. The easy solution is the aforementioned Apple TV, which is a set-top box that adds AirPlay support to any TV with HDMI input [19]. Here is an overview of specific products for Scenario A:

- Sources:
  - Mobile device: Apple iPhone 4S (iOS 5.1)
  - Portable device: MacBook Pro (Mac OS X 10.7 Lion)
- Receivers:
  - Speakers: Philips Fidelio SoundAvia
  - Display: Apple TV 3 + Medion Life P12085 TV

The process of choosing products for Scenario B is slightly different, as DLNA is not controlled by one vendor. A reasonable choice for the mobile platform is Android because of the large app market that allows end-users to choose from a variety of DLNA-enabling apps. For it has by far the biggest market share [20], Microsoft Windows is the obvious platform choice for the laptop computer in Scenario B. Again, a large developer community provides DLNA support on the application layer. Currently, no operating system, desktop or mobile, has integrated DLNA support. However, on the receiver side, DLNA integration is very common in products in all price ranges. To approximately match the selected AirPlay speakers in price and size, the Sony SA-NS300 has been chosen to represent the DLNA speaker in Scenario B. As with the AirPlay speakers, the product is more or less a placeholder for any pair of DLNA-certified speakers. In contrast to AirPlay, there are many DLNA TVs on the market – the Medion Life MD 30465 is one of them. The overview of specific products for Scenario B is as follows:

- Sources:
  - Mobile device: Samsung Galaxy S III (Android 4.0)
  - Portable device: HP Pavilion (Windows 7)
- Receivers:
  - Speakers: Sony SA-NS300
  - Display: Medion Life MD 30465

In both initial scenarios, any source should be able to connect to any receiver of the same scenario. Subsequent scenarios are created by exchanging the original devices with a device from the opposing initial scenario, one device at a time. This leads to eight different scenarios in total:

- Initial scenario: Scenario A (AirPlay)
  - A.1 ...with an Android mobile device
  - A.2 ...with a Windows portable device
  - A.3 ...with DLNA-certified speakers
  - A.4 ...with a DLNA-certified display

- Initial scenario: Scenario B (DLNA)
  - B.1 ...with an iOS mobile device
  - B.2 ...with a Mac OS X portable device
  - B.3 ...with AirPlay-enabled speakers
  - B.4 ...with Apple TV

As explained in Section 1.3, no practical tests are carried out in this project. The research is solely based on product specifications and other publications, and it requires a fair bit of creative thinking in order to come up with solutions. Feasible solutions will be explained and evaluated by three main criteria: Complexity, stability, and approximate costs. Complexity refers to the number of steps necessary to implement a solution and the inconvenience it may cause. Stability indicates the likelihood of connection errors and incompatibility issues. In general, one can say that native solutions are most-certainly more stable than third party applications or solutions that require additional hardware. Actual runtime stability can only be evaluated by extensive testing though. Costs, on the other hand, are rather easy to evaluate. All prices are gained from Amazon.com, since it offers the biggest product range of any online shop. As prices are subject to regular change, it has been decided not to include specific prices, but a rounded value instead. After all, it is supposed to be a rough estimate only. Due to the fact that no practical testing is done, the evaluation will be rather coarse-grainded, ranging from one to three stars for every evaluation criterion.

There is one more technical prerequisite for all scenarios discussed: Both DLNA and AirPlay rely on DNS multicast in their autodiscovery mechanisms, namely Universal Plug and Play (UPnP) and Bonjour, on the network layer. DNS multicast is only available in local networks and therefore, all network devices need to be connected to the same local network. For home streaming, this is usually not a problem.

3. Results

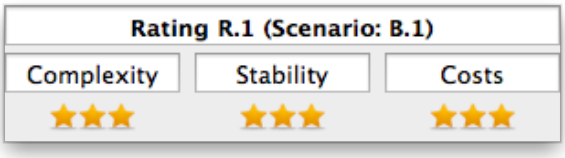
The following section presents and discusses the research results. It has shown that similar scenarios, such as Scenario A.1 and Scenario B.1, demand similar solutions. Therefore, the results section is not grouped by the initial scenarios but by the supposedly incompatible component.

3.1 Mobile Device

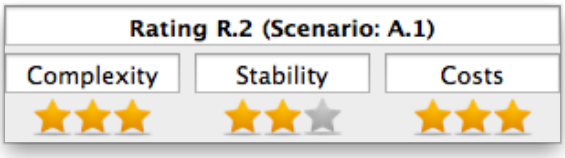
In Scenarios A.1 and B.1, the mobile device is not compatible with the environment out of the box. For Scenario A, this means that we try to connect the Android-powered Samsung Galaxy S III to AirPlay-enabled speakers and Apple TV. In Scenario B, it is attempted to stream to DLNA speakers and displays from an iPhone 4S.

3.1.1 Solution: Applications

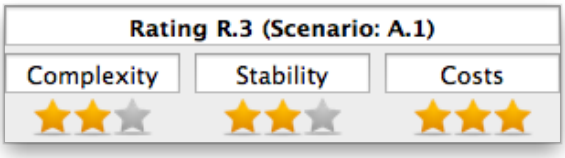
As predicted in the hypotheses paragraph of Section 2.1, using a closed device and operating system (iPhone and iOS) with an open technology (DLNA) is rather easy. Since DLNA is not built into the Android operating system, there is no disadvantage of the iPhone after all. In order to connect the iPhone to DLNA receivers, music and video streaming applications are necessary, as would be for an Android device. Fortunately, there is a variety of apps available that support streaming of media content to arbitrary DLNA receivers, including speakers and displays; one example is the free MediaConnect app [21]. There is no reason why DLNA apps for iOS were less stable or more complicated to install than the equivalent apps for Android, which results in Rating R.1.



For Scenario A.1, the initial situation is slightly different, as AirPlay is deeply integrated into the iOS operating system, plus it is a proprietary technology. Interestingly, developers have found ways to write Android apps that do support streaming to AirPlay speakers and displays. It comes as a surprise because although the proprietary AirPlay protocol stack has been published on the web [22], it still relies on secret AES keys managed by Apple. A selection of AirPlay-enabled Android apps, including free ones, can be found in [23]. However, there is a pending danger of Apple changing an implementation detail, disabling these apps all at once – therefore, only two stars have been given for stability in Rating R.2.



There is one more interesting approach for Scenario A.1. Given that a portable device running iTunes is available, the Remote for iTunes application [24] gives you full control of the streamed media from your Android mobile device, while the actual streaming is delegated to iTunes. As this adds another component to the system, two stars have been given for complexity and stability, as shown in Rating R.3.



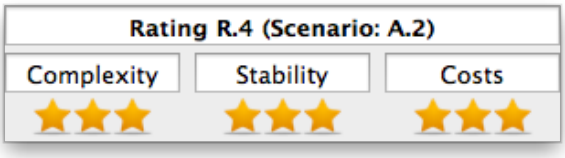
3.2 Portable Device

The situation for Scenarios A.2 and B.2 is quite similar to the situation described in Section 3.1, Mobile Device, only the operating systems have changed from iOS and Android to Mac OS X and Windows, respectively. As smartphones have become very powerful, the difference in hardware is negligible for local streaming.

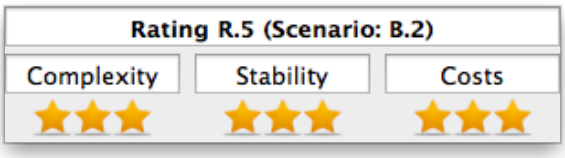
3.2.1 Solution: Applications

In this case, integrating the non-Apple device into the AirPlay environment (Scenario A) is trivial because Apple itself provides the solution. Currently, all AirPlay streaming from laptop computers is done by iTunes, which is available for Mac OS X and Windows. It supports audio and video streaming on both platforms – however, if streaming to Apple TV, the sound cannot be sent to AirPlay speakers separately. Also, if media cannot be imported into iTunes, it is not available for AirPlay streaming. Both limitations will be removed with the release of Mac OS X 10.8 Mountain Lion, where AirPlay is integrated into the operating system, but for now, Mac OS X and Windows with iTunes installed[1] are equally compatible with AirPlay, which results in the obvious Rating R.4.

[1] If you refuse to use iTunes as your primary music and video library, applications such as AirFoil [25] can help your Windows (or Mac) computer connect to AirPlay as well.



Using DLNA on a Mac computer requires a dedicated application, so does DLNA streaming on any other operating system, e.g., Windows. A free solution is the TV Mobili application that runs on Mac OS X, Windows, and Linux [26]. Therefore, using a Mac within a DLNA environment is equally complex, stable, and costly as a Windows computer. This is reflected in Rating R.5.



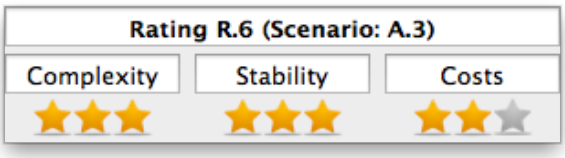
3.3 Speakers

Exchanging the speaker system has been predicted to be harder than exchanging source devices, because it is assumed that speakers do not run software, or at least you cannot modify it. This scenario is particularly interesting as hi-fi systems can easily cost a couple of thousand dollars and many people own systems that were produced when neither DLNA nor AirPlay were on the horizon.

3.3.1 Solution: Hardware Proxy

A very generic and convenient solution is to put a piece of hardware between the source and the receiver. The source communicates with the proxy wirelessly, while the stereo system (receiver) is plugged into the proxy with a standardized cable, such as 3.5 mm audio minijack or TOSLINK.

For Scenario A.3, the Apple Airport Express [27] can be used. It is an 802.11n Wi-Fi base station acting as an AirPlay endpoint, and any audio signal it receives is forwarded to the digital or analog audio out, in case a cable is plugged in. Note that this solution works with any speaker system, regardless of DLNA or AirPlay support. With respect to the high price of most stereo systems, it seems reasonably priced at around $100, which leads to Rating R.6.



Given the simplicity of this solution, it is highly surprising that no equivalent device could be found for a DLNA environment. Products such as the Cisco-Linksys WMB54G Wireless-G Music Bridge or the Logitech Wireless Speaker Adapter do allow wireless streaming to any stereo system, but rely on Bluetooth or proprietary wireless communication, which means the end-user has to install a separate application on his source device in order to connect and stream to the proxy. For this reason, these products have not been considered further. The bottom line is: If your speaker system does not have built-in DLNA support, you will have to use a cable.

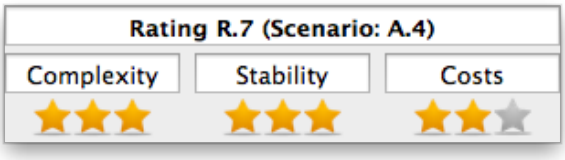
3.4 Display

Although modern TVs allow the installation of third party applications, which could be used as application-layer adapters between different streaming technologies, these so-called smart TVs are not widely used yet. Therefore, solutions that do not rely on specific television sets (or displays in general, such as projectors) have been preferred.

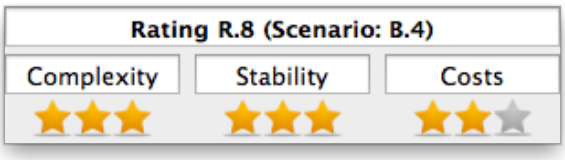
3.4.1 Solution: Set-Top Boxes

Similar to the proposed solution for audio streaming, intermediary devices can add streaming support to almost any television set. The DLNA or AirPlay source will stream the media content to the proxy device, which forwards the video signal to the television set via cable. This is beneficial because cables, such as HDMI or DVI, are well-standardized and vendor-independent.

Scenario A.4 is a special case – Apple's set-top box Apple TV works perfectly fine as a solution, but it is part of the initial Scenario A, as there is no AirPlay-enabled display on the market. However, it does not limit the choice of the actual display in any way, the only requirement for the display is an HDMI input port. The fair price of $100 leads to Rating R.7.



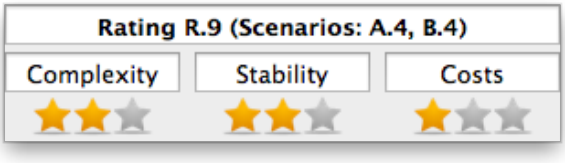
Google TV can be seen as a DLNA-equivalent to Apple TV, although Google TV is a set-top box blueprint rather than an actual device. One implementation at the lower end of the price range is the Logitech Revue Companion Box at just above $100. With regard to its streaming capabilities, it is equal to Apple TV, which is reflected in Rating R.8.



It is noteworthy that both products are a lot more than simple streaming endpoints. In addition to the two products mentioned, many NAS devices support DLNA and can be used as streaming-enabled set-top boxes, too. TV set-top boxes are also a feasible solution for Scenario B.3 (missing DLNA speakers), which has been unsolved so far. As video and audio is streamed to the set-top box, the audio out of either the set-top box or the TV can be connected to the speaker system. This is not a completely wireless solution, but at least there is no cable to any source.

3.4.2 Solution: Computer Proxy

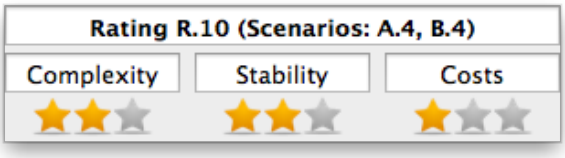
As this possible solution is very cost-intensive, it is only explained briefly. Instead of a set-top box between the source and the receiver, one could use a full-fledged computer as a proxy. The HDMI out of the computer would be connected to the HDMI input of the TV. Applications such as Reflection (AirPlay) [28] allow wireless transmission of video and audio to a computer, similar software is available for DLNA. However, using a set-top box is easier, more stable (as these boxes have no other purpose), more energy-efficient, and of course, less expensive. A rating (Rating R.9) is given for completeness.



3.4.3 Solution: WiHD

While all previous solutions utilize either AirPlay or DLNA, an alternative can be to use a completely different technology, as long as is does not limit the streaming technology in other parts

of the scenario. WirelessHD (WiHD) has been developed as a replacement for Wi-Fi on the physical layer, as the current Wi-Fi standard 802.11n is not fast enough for uncompressed 1080p video streaming. Since hardly any devices, neither sources nor receivers, support WiHD, adapters have been introduced to the market. A pair of adapters transmits data between each other over WiHD, each is plugged into either the source or the receiver via HDMI. The advantage is that no additional software is needed – the operating system, Windows or Mac, will transmit the audio and video signal to the HDMI port automatically. However, a pair of adapters, such as the VIZIO XWH200 Universal Wireless HD Video and Audio Kit, costs more than $200, and it requires HDMI, which dismisses most mobile devices. The evaluation is summarized in Rating R.10.



4. Conclusion

Despite the inherent incompatibility of AirPlay and DLNA, it has shown that there is a variety of solutions to achieve interchangeability of devices with support for either technology. Thanks to large developer communities on all platforms used on the source devices, application-layer solutions exist for virtually any scenario, and most applications are free. This supports the initial hypothesis that sources are highly interchangeable.

While there was skepticism whether the receivers of different technologies were equally easy to exchange, it has revealed that hardware plug-and-play solutions are available at relatively low cost. In fact, the only unsolved problem is the integration of traditional speakers into a DLNA streaming environment – all other legacy speakers and displays can be integrated in various ways.

The correlation between the openness of a system and the feasibility of solutions has not been confirmed in all cases. While it is not possible to integrate displays into an AirPlay environment without buying an Apple TV or interfering at the physical layer, it has revealed to be surprisingly easy to use Android mobile devices as AirPlay sources. However, with ongoing integration of AirPlay into Apple's operating systems, it will be increasingly convenient to use AirPlay with products from Apple and their official partners.

5. Recommendations

All conclusions drawn in this project are based on theoretical analysis only. To confirm the evaluations of all solutions, practical tests should be carried out.

The project has summarized the interchangeability of currently available products and technologies. All solutions are workarounds for end-users, while the technologies themselves remain incompatible. In order to implement the vision of smart homes in general, scientists and companies will have to cooperate and create standards to allow a much wider and more transparent interoperability between devices of all kinds, including media devices.

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