Executive Summary

Wireless content streaming is a way for students and instructors to share the content of their devices and laptops with the entire class by streaming them to the main classroom display. Testing conducted by Iowa State University Information Technology Services found that by combining the AirServer software, which can turn a PC or Apple computer into an Apple AirPlay receiver, with a Google Chromecast instructors can enable simple and easily manageable wireless content sharing for users of both Apple iOS and Android platforms in the classroom. This provides obvious instructional potential with a minimum of training and investment in equipment. Other solutions from vendors of institutional AV equipment promise the ability to do controlled sharing of multiple devices from multiple platforms. However, these devices were either not available for sale in time to be included in this review or had received such mixed user reviews that we decided they are not yet a viable option. However, as the field changes rapidly we will continue to keep an eye on new and existing options and update this paper accordingly. Note that this paper is an updated version of the March 2014 paper. Notable changes include the added testing of a Nexus 5 Android phone and added Chromecast features that now allow for Android screen mirroring. This added functionality caused us to recommend its inclusion with the AirServer software as a hybrid classroom solution. In addition, instructor impressions from a classroom test are included.

Introduction

Since the introduction of Apple AirPlay in 2010 and Google Chromecast in 2013, both of which allow users to stream content from their laptops and mobile devices to their TVs, users are starting to ask for the same kind of wireless streaming capabilities at school or work (Grimes, 2013, para. 2). Iowa State University (ISU) Information Technology Services (ITS) has also seen an increase in faculty requests for this capability. The requests, so far, have centered on installing Apple TV devices to ease faculty streaming of content and enable students to connect and display their work in the classroom via Apple AirPlay. Because the use of wireless presentation systems to support single or multiple presenters could provide interesting pedagogical possibilities for instructors ITS decided to conduct its own research into different wireless streaming solutions with a view to identifying the best one(s). This white paper contains the results of this testing together with an overview of the concept of wireless content streaming. The review also touches upon the various network, security, and usability issues associated with offering this capability in classrooms. Lastly, recommendations are provided for the best solutions together with an overview of potential issues that instructors may face when trying to use wireless streaming.
Wireless Content Streaming
While wireless content streaming appears to be a relatively simple concept that works well in a home environment different factors affect its deployment and use on a large-scale network for educational purposes. Below, some of these concepts and issues are discussed.

User Platforms
Home users who invest in wireless content streaming devices will often favor one technology or platform over another. The two primary contenders on the home front are Apple TV, which supports the proprietary Apple AirPlay, and Google Chromecast, which is platform-independent. Those who own mostly Apple devices such as iPhones, iPods and iPads are thus free to buy an Apple TV, because it will support streaming from their different Apple devices. On the other hand, those who use Android phones or tablets and PC laptops may need to get a Google Chromecast. Android devices and PCs do not reliably stream to Apple TVs because they do not have the needed AirPlay software built in and must rely on third-party solutions which often have unreliable performance. Similarly, iOS devices can stream some types of media to a Chromecast, but cannot do screen mirroring. However, in an educational setting both platforms should be served while taking into consideration the limitations of each type of device. Different software programs also exist that enable Apple and PC computers to receive Apple AirPlay signals and display the screens and media of the connected devices. Both types of devices and software were tested in this report.

Media Sharing vs. Screen Sharing
When talking about wireless content streaming it is important to distinguish between the ability of a technology or solution to share the screen of the transmitting device versus its ability to share digital media such as audio, video, and photos. The reason is that students and faculty are likely to want to share presentation materials that include Power Point presentations or media such as websites that do not fall into the category of audio, video, or photos. Not all available solutions can do screen sharing.

Network Capabilities and Limitations
One of the key issues of wireless content streaming has to do with the fact that it relies on the existing wireless network setup. Consequently, the user experience depends heavily upon various network factors such as bandwidth, signal strength, and the number of concurrent users of the network as a whole and the particular wireless access point serving the classroom where the solution is deployed. Likewise it may make a difference whether a device is connected via Ethernet cable to the network (Apple TV has this feature available), as do most PC and Apple laptops, or relying on a wireless connection (Google Chromecast).

Solution Evaluation
In order to try to decide which wireless content streaming solutions might work best in a variety of ISU classrooms ITS researched popular home-user devices online. Based on this research, two devices were acquired for testing: An Apple TV (Gen. 3) and a Google Chromecast (Model H2G2-42). Also included in this testing were software-based solutions for allowing PC and Apple computers to act as AirPlay receivers. These software programs are called Reflector and AirServer. It is important to note that some industrial solutions also exist which were not included in this testing, such as the Crestron AirMedia and Extron ShareLink 200 devices. However, other universities who have tested Crestron device have found various problems with connectivity and reliability. The Extron device has only just been offered for sale and was not
available for testing in time to be included in this paper. While both were excluded from our testing we will keep an eye on their performance at other institutions and test one or both if we start to hear favorable reviews of them. Two other options that were not included are the Black Box Wireless HDMI Presentation System, and Barco’s ClickShare. The reason is that the latter requires the presenter to plug a USB dongle into their computer in order to connect to the screen, which will not work with mobile devices, while the former only works with laptops.

The testing itself centered on the devices and software listed in Table 1. Since Android devices are not normally compatible with the Apple AirPlay protocol several free apps with high user ratings which promised to enable connections to AirPlay receivers were downloaded from the Google Play Store and tested. The AirParrot software, which claims to enable PCs to connect to AirPlay receivers, was also installed on the PC test laptop.

The devices and software solutions were evaluated according to the following criteria:

- Ease of setup and classroom integration
- Ease of use
- Features
- Performance and Reliability

**Wireless Content Streaming Recommendations**

The results of the testing are listed in tables 1, 2 and 3. Our findings make it clear that Apple devices are the most reliable and flexible transmitters of streaming content. In the same vein, the Apple TV is the most reliable AirPlay receiver when content is streamed from other Apple devices as well as from the few Android AirPlay apps that showed partial functionality. Following closely, the iMac, Macbook Pro and Windows 7 laptop computers running AirServer were reliable receivers with a few limitations in terms of copy-protected video playback. However, using AirServer allows more users to connect to the receiver at one time and provides more teacher control over who may stream content to the screen.

**Table 1. Apple AirPlay Receiver and Transmitter Compatibility**

<table>
<thead>
<tr>
<th>Transmitters</th>
<th>iMac w. Reflector</th>
<th>iMac w. AirServer</th>
<th>Receivers</th>
<th>Win 7 with Reflector</th>
<th>Win 7 with AirServer</th>
<th>Apple TV</th>
</tr>
</thead>
<tbody>
<tr>
<td>AllCast</td>
<td>✓ ~ ✓ X</td>
<td></td>
<td>X X ✓ X</td>
<td>✓ ~ ✓ X</td>
<td>✓ ~ ✓ X</td>
<td>✓ ~ ✓ X</td>
</tr>
<tr>
<td>Twonky Beam</td>
<td>✓ ~ ✓ X</td>
<td>X ✓ ✓ X</td>
<td>X X X X</td>
<td>X X X X</td>
<td>X ✓ X X</td>
<td>X ✓ X X</td>
</tr>
<tr>
<td>iMediaShare</td>
<td>✓ ✓ X X</td>
<td>✓ ✓ ✓ X</td>
<td>X X X X</td>
<td>✓ ✓ ✓ X</td>
<td>✓ ✓ ✓ X</td>
<td>✓ ✓ ✓ X</td>
</tr>
<tr>
<td>Apple Devices</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>iPod Touch 5th Gen</td>
<td>✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓</td>
<td>✓ ~ ✓ ✓</td>
<td>✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓</td>
</tr>
</tbody>
</table>
Based on the results of our lab and classroom testing we recommend that people use the AirServer software on a Mac or PC computer if most users will have an Apple device. If wireless content streaming capabilities for Android users is also important, as it may be for many instructors, then a hybrid AirServer and Chromecast solution is the best way to go. Given the relatively low cost of a Chromecast, this solution should be feasible.

We recommend AirServer for several reasons. First of all, the software turns your computer into an AirPlay receiver that is as reliable as the Apple TV. Secondly, it allows you several options for password protecting the connection including an ‘Ask Me’ function that requires the instructor to approve of incoming connections before they are displayed on the screen. Third, it supports several simultaneous connections from different AirPlay transmitters, which is not possible on an Apple TV. This allows instructors to project several student device screens as the same time and provides additional pedagogical tools and options. Fourth, AirServer allows you to record the screen and anything that is displayed on it and save it for future use, such as dissemination to students. Lastly, AirServer also supports the Miracast protocol when installed on a Windows 8.1 PC. Miracast is built into many newer Windows 8.1 tablets, laptops running Windows 8.1, Windows phones and most Android devices running version 4.2.1 and above.

We recommend Chromecast because it provides a relatively simple and stable way for Android users to share their screens. It also allows PC and Mac laptop users with the Chrome browser to share their screens, albeit with a small lag between the computer and the screen. That said, the Chromecast is still not as advanced as the Apple TV and lacks some functionality that instructors should consider. Most importantly, there is no way to password protect the access to a Chromecast, only one user can display to it at a time, and there is no way to prevent new users from bumping out existing users without warning.

For a simpler installation that can better be tucked away in a media cabinet, an Apple TV can be used instead of a computer with AirServer, as long as the added features of that software are not needed. Access control must also be defined carefully in order to prevent access to the Apple TV from users who are not currently in the room. If this setup is used users can take advantage of the fact that an Apple TV can be ‘discovered’ via Bluetooth which helps users establish a network connection if their device is on a different network from the Apple TV.

Lastly, people who are considering a hybrid solution involving both an AirServer or Apple TV setup together with a Chromecast need to ensure that there are enough video inputs available in the room for both to be
active at the same time – especially if an Apple TV and Chromecast are installed and the instructor wishes to also hook up a laptop. Currently, most classrooms support the simultaneous hookup of a laptop via VGA and a Chromecast or Apple TV via HDMI.

Table 2. Google Chromecast Functionality

<table>
<thead>
<tr>
<th>Transmitters</th>
<th>Receiver Google Chromecast</th>
<th>A</th>
<th>V</th>
<th>P</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asus Transformer Prime TF201 tablet (Android 4.1.1)</td>
<td>~ Only select apps² Only select apps¹ X X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Google Nexus 5 (Android 5.0.1)</td>
<td>✓ Works well with apps¹ Other sources: Depends on wireless bandwidth ✓ ✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>iPod Touch 5th Gen</td>
<td>X Only select apps¹ X X X X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Macbook Pro</td>
<td>✓ Via screen mirroring Some limitations³ ✓ ✓ ✓ ✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>PC Laptop</td>
<td>✓ Only from Chrome browser tab Some limitations³ Via screen mirroring Beta functionality, but very stable ✓ ✓ ✓ ✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

A = Audio, V = Video, P = Photos, M = Screen Mirroring
Worked = ✓
Worked Partially = ~ (see limitation noted in table).
Did not work = X
¹ = Currently 120+ video apps such as Netflix, HBO GO, YouTube, etc. See full list at www.chromecast.com.
² = Currently 100+ audio apps such as Google Play Music, Pandora, etc. See full list at www.chromecast.com.
³ = Local video only through Chrome tab, if Chrome plays that format. Performance depends on file resolution (higher resolution may see dropped frames and audio glitches) and wireless bandwidth. Sites such as YouTube, with an app built into the Chromecast usually work well.

Having made the above recommendations, the test results also make it obvious that users should not expect Android devices or PCs to be able to reliably connect to any AirPlay receivers. Considering that research shows that as of November 2014, 41.8% of U.S. smartphone subscribers age 13 or older used Apple while 52.6% used Android (Lella, 2015), instructors need to take this into account. This might be done by conducting only group work in which at least one member of each group owns a compatible iOS device (first-generation iPads and first-third generation iPods have limited AirPlay functionality and cannot mirror their screens) or by adding a Chromecast to the classroom setup.

Classroom Testing
Our classroom testing included a variety of devices owned by ITS staff as well as in-class testing with an instructor and 30+ students. The results listed in Table 3 show that a MacBook Pro is very capable of acting as an AirPlay receiver when running AirServer. During our testing we had up to 4 different iOS devices connected via AirPlay with good results. We were able to simultaneously stream a live feed from one device camera while another showed a YouTube video clip with sound, while yet another was displaying photos
and the last was navigating the main iPad menu. The YouTube video did see a bit of stutter in this scenario, but it was watchable. However, this represents an unlikely worst-case scenario. Instructors are unlikely to need to show more than one audio or video feed at a time. Consequently, several devices showing more static images, such as slides with text, should work well, as indeed they did during our testing sessions with students.

Table 3. AirServer and Reflector Classroom Testing

<table>
<thead>
<tr>
<th>Transmitters</th>
<th>Receivers</th>
<th>Macbook Pro (Late 2013 model) w. Reflector</th>
<th>Macbook Pro (Late 2013 model) w. AirServer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Android Tablet (Asus Transformer Prime TF201)</td>
<td>A V P M</td>
<td>✓ ✓ ✓ X</td>
<td></td>
</tr>
<tr>
<td>iMediaShare</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Google Nexus 7 tablet</td>
<td></td>
<td>X X X X</td>
<td></td>
</tr>
<tr>
<td>AllCast</td>
<td></td>
<td>✓ ✓ ✓ ✓</td>
<td></td>
</tr>
<tr>
<td>Google Nexus 5 phone</td>
<td></td>
<td>X X X X</td>
<td></td>
</tr>
<tr>
<td>iMediaShare</td>
<td></td>
<td>X X X X</td>
<td></td>
</tr>
<tr>
<td>AllCast</td>
<td></td>
<td>X X X X</td>
<td></td>
</tr>
<tr>
<td>Twonky Beam</td>
<td></td>
<td>X X X X</td>
<td></td>
</tr>
<tr>
<td>Samsung Galaxy S3</td>
<td></td>
<td>X X X X</td>
<td></td>
</tr>
<tr>
<td>Apple Devices</td>
<td></td>
<td>X X X X</td>
<td></td>
</tr>
<tr>
<td>iPod Touch 5th Gen</td>
<td>✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓</td>
</tr>
<tr>
<td>iPhone 5S</td>
<td>✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓</td>
</tr>
<tr>
<td>iPhone 4S</td>
<td>✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓</td>
</tr>
<tr>
<td>iPad 2</td>
<td>✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓</td>
</tr>
<tr>
<td>iPad 3</td>
<td>✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓</td>
</tr>
</tbody>
</table>

A = Audio, V = Video, P = Photos, M = Screen Mirroring
Worked = ✓
Worked Partially = ~ (e.g. video with no audio, low-quality image, problems starting and stopping media on receiver).
Did not work = X
1 = sometimes, shared media does not terminate on target device, freezing screen.
2 = Clips protected by Digital Rights Management (DRM) copy protection will not play.
Gray shaded area = Combination not tested.

Our testing with an instructor and about 30 undergraduate students revealed that students were very receptive to the implementation of this technology and enthusiastic about its use. Once students understood the need to be connected to the same ISU wireless network as the instructor’s computer running AirServer, students found it easy to use. The instructor used the technology for an activity where students had to work in groups and answer different questions based on their homework readings. Each group was seated by one of five flat screen monitors in the room which were showing the AirServer feed from the instructor’s computer. One device for each group was used to connect to the instructor machine and display the group notes as they were discussed and typed up. In each group, students could look at the
screen and follow the notes typed in their own group as well as those in the other groups. The students appeared to appreciate this and find it interesting and everyone seemed to be on task and participating actively. When asked to comment on the main advantages of using mobile device content sharing in the classroom the course instructor stated that engagement is improved because “students are more participative when using their device for course content rather than passive listening” (C. Stephens, personal communication, January 26, 2015). In addition, it allows for multiple voices “during a five minute period of class, educators might be able to call on 4-5 students to orally share their views. But using mobile devices during class, in that same time period we can be more thoughtful viewpoints from every student. Classmates can then read and consider many more perspectives than we ever could orally. This also scales from working with 20 students to 200 students” (C. Stephens, personal communication, January 26, 2015).

In terms of what instructors should be aware of when using this technology, C. Stephens (personal communication, January 26, 2015) provided the following insights:

We need to be careful not to assume every student has access to the same technology and the same skill sets to use them. Educators must provide options to students without a modern digital device to obtain one for class periods where they will be used. This is often easily done by bringing two or three extra tablets to share, or referring students to campus services for checking out electronic equipment. As for skill sets, early on time should be allowed for students to learn how to use the software being used. Some students will be experienced, others will learn quickly, and a few will benefit from time to ask questions of peers and practice with the technology before beginning to work on the course content.

Caveats
While sharing streaming content and/or the screen from one’s computer or device is technically possible it depends on a number of factors that are difficult to control. The following list of caveats demonstrates that the technology still has severe limitations that may affect its usefulness and reliability in an educational setting.

- Not all Android devices can do screen mirroring and models from different manufacturers do it different ways in the operating system.
- Android AirPlay apps are generally not reliable and may show different functionality from one device to another.
- Any transmitter that starts casting a signal to a Google Chromecast will bump out the current transmitter.
- The Google Chromecast cannot be locked with a password.
- On the Apple TV, the instructor cannot accept or reject connections from student devices, though the remote control can be used to control it and end a transmission session.
- All wireless streaming connections rely on the speed and quality of the wireless network in the room. If the wireless network is overloaded with devices or bandwidth is stressed content streaming and screen mirroring may not work. These connected devices and their users do not need to be in the particular
classroom that is trying to use wireless streaming as many wireless access points cover several classrooms that may be in session at the same time.

- All devices that wish to connect to an AirPlay receiver or a Google Chromecast need to be on the same network subnet. Because the university network uses the Dynamic Host Configuration Protocol (DHCP) user device IP addresses may or may not be provided in the same subnet as the receiver. That said, classroom testing showed that as long as students connected their mobile devices to the same wireless network as the Apple TV or computer running AirServer, they were able to connect to it without issues.
- Consumer devices like the Apple TV and Google Chromecast are attractive to students and need to be installed in a way that guards against theft.

Limitations
The testing that was done on these wireless content streaming receivers and transmitters was comprehensive and tried to take into consideration different user needs, device types, platforms, and features. However, it is very difficult to predict all possible scenarios. In addition, technology changes fast and the devices and software tested may gain or lose features in future versions as demonstrated by the need to revise this paper less than a year from its initial publication. Consequently, users may wish to conduct some testing with their chosen device(s) in their actual teaching environment(s) before committing to a solution. ITS is happy to help with this and is available for questions.

Evaluation hardware
- Apple iMac, late 2009 model with 2.66 GHz Intel Core 2 Duo processor, 4GB memory, running OS X 10.9.1.
- Macbook Pro Retina, Late 2013 model with 2.3 GHz Intel Core i7 processor, 16 GB memory, running OS X 10.9.1.
- Macbook Pro Retina, Late 2013 model with 2.3 GHz Intel Core i7 processor, 16 GB memory, running Windows 7 (SP 1) via Bootcamp.
- Apple iPod Touch (5th Gen.), Model MD723LL/A, running iOS 7.0.6.
- iPhone 4S, Model MD276LL/A, running iOS 7.0.6.
- Apple TV Model A1469 (7.0.2 (6915))
- Google Nexus 7, running Android 4.4.2.
- Google Nexus 5, running Android 5.0.1
- Google Chromecast Model H2G2-42
- Samsung Galaxy S4
- Android Asus Transformer TF201 tablet, running Android 4.1.1.

Evaluation Software
References and Resources


