Multi-Screen Video Routing for Active Learning Spaces

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INTRODUCTION

Team-focused, peer-to-peer, collaborative learning is a successful teaching and learning model that has garnered significant attention from the academic community. This model emphasizes the importance of peer-groups and self-directed learning rather than traditional lecture-style knowledge transfer. These approaches are known by several names including Team Enabled Active Learning (TEAL) or simply Active Learning and have been shown to increase student success rates and year-over-year retention.

Successful Active Learning models require a thoughtful combination of pedagogy, educational content, space design, and supportive technology. This paper focuses on the technical needs of an Active Learning model. In particular, we focus on a video routing system to enable team-to-team communication on-demand.

Given the focus on team-based collaboration, active learning spaces all have the following in common:

1. Team tables that each have a *group display* for team members to share content from their laptops and mobile devices. In this paper, we focus on team table displays that are enabled with Mersive's wireless sharing solution – the Solstice Pod.
2. The ability to route video from a group display to one or more displays in the space on-demand. Typically, a moderator/instructor will use this capability to compare results between teams or display one team to all groups as part of a team-based presentation.
3. One or more *control applications* that allow moderators to dynamically control how and when video from group displays is routed to team tables.

These three core technical components enable teaching models that enhance the learning experience. For example, to start class the moderator may broadcast a front-of-room display to all tables during a brief introductory session to introduce a new problem set or exercise for each team. During class, the moderator may then highlight a particular team's progress by routing their video to the front-of-the room. Later in the session, the moderator may show all freshman displays to senior teams so they can guide/direct their colleagues. Each of these examples require a simple, direct, and performant video routing capability.

Traditionally, these needs have been met through the use of specialized hardware, custom programming, and dedicated video switching. This paper covers an alternative approach using Solstice Active Learning. This solution leverages existing TCP/IP-based networking, a flexible software control platform, and the Solstice Pod connected to each team table. The remainder of this paper focuses on the technical details of Solstice Active Learning.

CONFIGURATION REQUIREMENTS

Physical setup and configuration of a Solstice Active Learning room is straightforward. The system only requires a few components:

Solstice Pods. The Solstice Pod is a network attached wireless sharing device that supports collaboration at each of the team tables. It supports HDMI output at up to 4K to connect to the display and attaches to the network via standard Ethernet.

Student Devices. These devices are brought to the environment by the students participating in the space. The system supports Windows, OSX, iOS, Android, Linux, and Chromebook-based devices.

Control Device. This device is used by the facilitator, moderator, or faculty member to control multi-screen routing, send messages to team table displays, and generally interact with the displays. The system supports mobile devices (Android, iOS) as well as laptops (Windows, OSX).

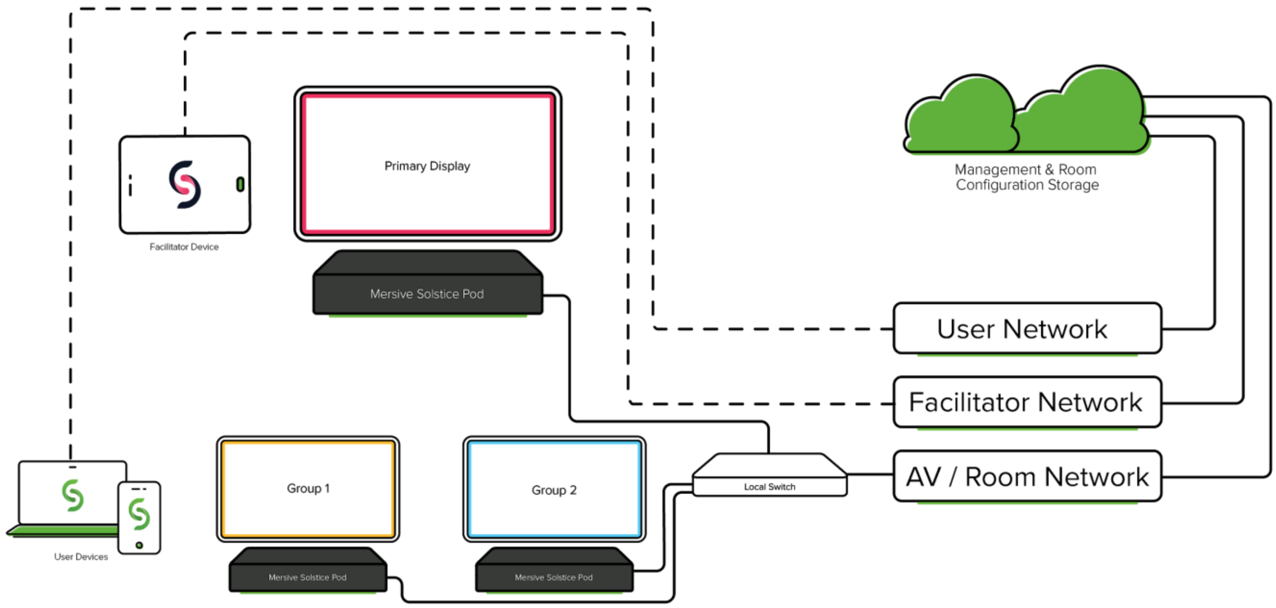

Figure 1: An example network configuration for an active learning space with several group displays and a primary display. Each Pod is routed to a local switch that is attached to the campus network. Different network segments can be configured to carry different device traffic as long as they are routable between one another. Finally, the control device must be able to reach the cloud for management and configuration.

First, each group display is directly connected to a Solstice Pod through a video cable. Each of the Pods must also be directly connected to the same Gigabit switch with a Pod-to-Pod latency of less than 3-4ms. While there are network topologies that can effectively maintain this performance by segmenting Pod traffic to a dedicated VLAN, for simplicity, we recommend wiring Ethernet to a local switch.

Student devices and even the device carrying the control application must be able to route TCP traffic to each of the Pods in the room, but do not need to share a switch. For example, a faculty device may be deployed on an internal faculty network and student devices may be connected to a student network. However, both of these networks must support peer-to-peer routing between the device and the Solstice Pods. This allows students at each of the team tables to collaboratively share content from their devices to the group display.

Finally, the control device must have access to the internet so that management, configuration changes, and state of the application can be stored.

PERFORMANCE STUDIES

When configured as described, the Solstice Active Learning app, running on the control device, provides capabilities that are important to the Active Learning model. These include the ability to display text messages to each of the team tables, transmit video from one table to another, or broadcast video from one table to all other displays in the environment. In the case of routing video from one display to another, this action can be performed between multiple screens simultaneously, allowing more than one video route to be created at the same time.

Bandwidth Utilization

Because the system leverages commodity network infrastructure, it is important that both the bandwidth and expected performance characteristics are known. Bandwidth utilization, of course, is dependent on both the number of simultaneous video sends as well as the compressibility of the content on the source display. To study bandwidth usage for Solstice Active Learning, we report usage for two scenarios. First, student devices shared two PowerPoint presentations, two documents, and a PDF for a total of five content sources live on a single display. This represents a *business* use case where the content only changes periodically – for example by advancing a slide. In this scenario, video compression will result in a reduction of bandwidth needed to send to other destinations. In a second scenario, a live streaming 4K YouTube video playing on an iPad is posted to a display. This *video* use case will require additional bandwidth.

For both business and video use cases, we measured bandwidth rates when the display content was routed to an increasing number of team table displays. For testing, an average total bandwidth being utilized was computed over a 3-minute window for each use case.

Active learning sources encode the local display once before sending it to multiple destinations. Each destination receives video via an individual network connection, and sending is multi-threaded to minimize delay. In the business use case, such as PowerPoint slides, each connection generally uses less than 8 Mbps. The bandwidth required for additional connections scales linearly because the encoded content is identical for all connections. For example, with 10 different receivers the bandwidth needed is at most 80 Mbps. This represents less than 8% of the theoretical bandwidth on a Gigabit network switch. It is important to note that this bandwidth does not leave the local switch. Control signaling and state management that needs a route to the Active Learning Cloud server only requires a very small amount of bandwidth.

The video use case has similar performance. If a 10 Mbps video is streamed alongside a live YouTube window, then bandwidth usage is approximately 18 Mbps. If the source is then broadcast to eight other screens the total bandwidth for all the connections would be around 144 Mbps. This is less than 15% of the bandwidth of a Gigabit switch. Based only on bandwidth, this use case would therefore not saturate the switch until 50 receivers or so are connected. Before this limit is reached, it is important to note that frame rate may degrade as new receivers are connected. Frame rate performance is covered in the next section.

Frame Rate Performance at Scale

We studied the frame rate at each display by first sharing a 10 Mbps video to a single source display. That display was then transmitted to an increasing number of destination team table displays in a Solstice Active Learning space. The table below reports the frame rate we measured at each increment of 5 additional receivers.

Number of Receivers	Average Frame Rate at Receiver
1	30
5	30
10	30
15	30
20	30
25	30
>25	degrades gracefully

These results demonstrate that a Solstice Active Learning room with as many as 25 displays will maintain a 30 fps frame rate. A higher number of connections has not been tested, but we expect graceful degradation of the video frame rate above 25 connections. This scenario assumes a video-focused use case where frame rates are critical as video is shared between displays at scale. This should be sufficient for almost all use cases that occur in an active learning space. A larger number of team table displays is certainly feasible, especially if most of the content can be delivered at less than 30 fps without affecting the viewer experience. For example, a PowerPoint slide presentation broadcast to all displays in an active learning environment would be viewable at 10 fps or less.

The graph below depicts the measured results as the number of tables (and receivers) increases, and also includes the estimated performance line for rooms that want to move past 25 displays.

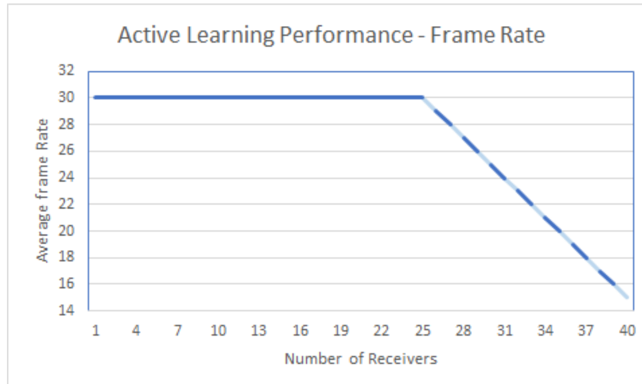

Figure 2: Frame rate versus number of displays simultaneously receiving video from a display source. At 25 receivers, the frame rate remains at 30fps. Above that number, we expect graceful degradation up to 50 receivers, which is the maximum currently allowed.

CONCLUSION

Enabling successful active learning spaces requires thoughtful consideration of the technology within the room. When selecting technology to enhance the experience, it is also important to be cognisant of any possible constraints that could distract from the teaching and learning environment. For example, long-term unnecessary costs due to leveraging commodity network infrastructure. To avoid future hidden costs - network usage, additional hardware, IT support, etc. - the proper assessment of bandwidth and performance are essential.

Solstice Active Learning represents an alternative solution that looks to solve historical challenges within traditional technology enabled learning spaces. This study shows that bandwidth and frame rate remain adequate with Solstice Active Learning while scaling the number of displays for both business (PowerPoint) and video (YouTube) use cases.