Report: Big Idea

Pervasive Video in the Enterprise

Understanding Desktop Video Solutions, How They Scale, Bandwidth Considerations and Their Total Cost of Ownership

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Purpose and Intent

This document examines the impact pervasive desktop video will have on the enterprise network and the subsequent total cost of ownership (TCO) an enterprise will experience when deploying desktop video across multiple sites. There are several major providers of desktop video solutions, and their solutions are not equivalent. Some offer desktop video as an element of their unified communications suites, while others focus on being video conferencing providers first but with some UC integration points. Consequently, it is critical to understand key implementation and deployment differences among them that affect the total cost of deployment and ownership.

The report provides management insights into three of Constellation's primary research themes: the Future of Work; Technology Optimization; and Consumerization of IT/The New C-Suite.

Executive Summary

This report begins with a fundamental question: if an enterprise already has a telephony system, what would it take to add multi-party desktop video to it and what would such a solution look like with respect to scalability, network impact, and total cost of ownership? To answer this question, solutions from five major desktop video providers have been assessed:

Figure 1. Desktop Video Providers and Their Solutions

Provider	Desktop/Tablet Client
Avaya	Avaya Flare Experience
Cisco	Cisco Jabber and Cisco WebEx
Polycom	Polycom RealPresence Desktop/Mobile
Microsoft	Microsoft Lync 2010/2013
Vidyo	Vidyo VidyoDesktop/VidyoMobile

We begin with a discussion of the research methodology used. We then review Scalable Video Coding (SVC) and point out how it differs from H.264 Advanced Video Coding (AVC) and H.263 video encoding with respect to capabilities and the impact on network bandwidth. For each vendor's offering, we then:

1. Provide an overview of the solution,
2. Discuss how it integrates with existing call control,
3. Show an architectural overview,

4. Describe the underlying encoding technology and how it scales,
5. Compute the impact on network bandwidth for several use cases, and
6. Show the total cost of ownership for those use cases including hardware, software licensing, maintenance, and network over a multi-year period.

We conclude with an analysis of these results and offer our conclusions.

Video Is Already Pervasive in the Enterprise

Any laptop, tablet, or mobile device with a built-in video camera can act as a video endpoint. Many PCs and Macs now come with cameras built into the bezel. Numerous consumer desktop videoconferencing options have worked their way into the enterprise, including Google Chat, Google+ Hangouts, Skype, AOL, Yahoo!, and Microsoft Messenger. Furthermore, many sellers of enterprise software suites have added video and are aggressively pushing video communications, including Avaya with both its Avaya Flare® Experience and its Avaya one-X® clients; Cisco with its Jabber client; Polycom through its RealPresence Desktop/Mobile clients; Microsoft through Microsoft Lync; IBM with its Sametime client; LifeSize with its ClearSea Connections client; and Vidyo with its VidyoDesktop and VidyoMobile clients.

Clearly, video is already pervasive in the enterprise.

However, for organizations that wish to scale video purposefully and roll out high quality desktop video to significant numbers of users, IT managers and CTOs/CIOs often inquire about the impact video will have on the network and what the total cost of ownership will be over a period of years. Indeed, if one considers the network impact of high definition (HD) video, which may have bit rates of over 1 megabit per second (Mbps) per endpoint, the amount of bandwidth consumed when video is pervasively used can become enormous in a hurry. Local area network (LAN) links may not be affected as much by HD video, but wide area network (WAN) links can be quickly compromised if they are not properly designed to handle the amount of voice, video and data traffic that an organization tries to flow over them.

Some video providers have responded to this challenge by developing codecs[1] that dynamically scale the video bit rates coming out of the video encoding process, based on the amount of available bandwidth. In addition, H.264[2] codecs have emerged that allow much more efficient video encoding, which when coupled with dynamic encoding bandwidth mechanisms, often leads to high quality, fluid video -- even when a network segment has a bandwidth limitation.

In the remainder of this report, we examine the effect of video bandwidth on LAN and WAN segments and look at the impact various video encoding and bandwidth management strategies have on the total cost of ownership for leading desktop video solutions from Avaya, Cisco, Microsoft, Polycom and Vidyo.

Approach and Methodology

In preparing this study, Constellation Research conducted interviews with the solution providers covered herein and/or developed information and data from publicly available sources. Sources for pricing information, when not provided directly by vendors, are cited in endnotes.

The TCO model in this report examines the three-year costs for any required upfront hardware, software licensing, hardware and software maintenance, installation and

bandwidth costs incurred as a result of deploying the video solution. The model examines several use cases as follows:

Figure 2. Use Cases Including Number of Users and Locations

Number of Users	Number of Locations
1000	4
2,000	6
5,000	10
10,000	20

Assumptions

In preparing the TCO model, we have made the following assumptions:

1. Organizations already have a telephony system installed. Consequently, we are adding video to an existing communications infrastructure. There is no replacement, upgrade or enhancement to the telephony infrastructure.

    a. For the Avaya video option, we have assumed that the organization will already have Avaya's Aura Session Manager, Avaya Aura Communication Manager and all other necessary voice components deployed.

    b. For the Cisco video option, we have assumed that the organization will already have Cisco Unified Communication Manager and all other voice components deployed.

    c. For the Microsoft video option, we have assumed that the organization will already have Microsoft Lync Server 2010/2013 for IM/presence deployed, but that it does not have multipoint videoconferencing deployed. Furthermore, it is not necessary that Microsoft Enterprise Voice is deployed.

2. A 10 to one ratio exists between total number of users and simultaneous conferencing users. Thus, an organization with 2,000 users, for example, will have a maximum of 200 simultaneous conferencing sessions. Looking toward a future of pervasive video, we assume for calculation purposes that half of these will be in audio conferences and half will be in video conferences.

3. At each location, the organization has sufficient bandwidth between endpoints and the network core so that LAN bandwidth is not an issue. It is only between WAN segments that bandwidth becomes an issue.

4. WAN bandwidth costs US $120 per Mbps/month.

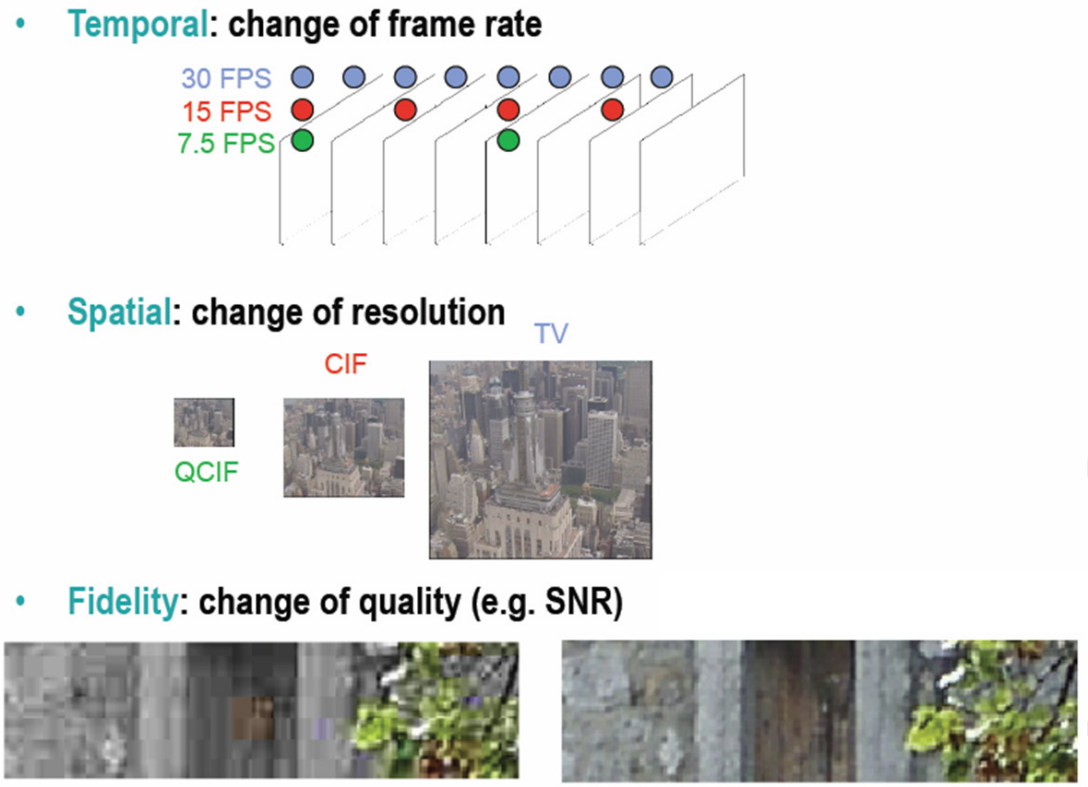
5. When additional licenses are required for video to traverse the firewall, we assume that 20 percent of the video participants are mobile users traversing the firewall.

A Short Discussion of Video Encoding

Digital video must be compressed, using a video codec, so that it can be transmitted efficiently over a network. Although many video codecs exist, the most prevalent in the enterprise video conferencing industry today are H.263 and the newer H.264.

The H.264 codecs allow video to be compressed into bit rates that are half or less of H.263 bit rates, for equivalent video quality. H.264 "AVC" or baseline profile codecs have been available since they were approved by the ITU in May 2003, and several clarifications or enhancements have been added since then. One of the most significant enhancements, approved in November 2007, was H.264 Scalable Video Coding (H.264 Annex G). It leverages the same encoding techniques but allows the encoding engine to split the video into a base layer, called AVC, and several enhancement layers or streams. These enhancement layers can represent spatial resolution (screen size), temporal resolution (frame rate) or video image quality.

Figure 3. H.264 SVC Introduces Temporal, Spatial and Quality Video Layers



Source: Ofer Shapiro in H.264/SVC (Scalable Video Coding) – New Video Compression Standard ISC West Conference, 2009

It is this additive capability of H.264 SVC layers that makes the encoding technique so compelling because it eliminates the need for video transcoding and bridging devices. Even if some layers of the full video stream are removed, the resulting sub-layers form a

valid video bit stream for some target endpoints supporting lower quality.[3] For example, a mobile phone, with a small screen, requires a much smaller amount of video information in order to show a high quality image on its small display, consequently, it does not need or use all of the SVC layers a telepresence system would require. Contrast this to a non-SVC call in which a transcoding video bridge would be required to connect systems with different resolutions to the same call.

It is the responsibility of the SVC-compliant endpoints to signal the capabilities they have to other endpoints and infrastructure participating in the call. Furthermore, H.264 SVC does not use less bandwidth than H.264 AVC, and it will actually increase bandwidth by 10 to 15 percent[4] compared with H.264 AVC. But the tradeoff is worth it because the video infrastructure should in principle be less expensive.

H.264 SVC also performs better over networks with significant packet loss or with less available bandwidth; that is because it sends only those video layers that can make it through the network and which are then used in the decoding process to reconstruct the video image at a lower frame rate or possibly a lower image size or even at a lower video quality.[5] Note, however, that H.264 AVC and H.264 SVC both require about half the bandwidth of the older H.263 codec.

Compressing H.264 SVC or AVC video requires more CPU processing than does compressing H.263. Consequently, care must be taken when deploying H.264 because one must assure that the devices on which this video is to be compressed have enough processing power. Typical personal computer CPU specifications would be an Intel Core 2 Duo 2.0 or higher. Note, however, that iPads are running H.264 codecs and have enough processing power to compress a 720p high definition video stream.

Not all H.264 and H.264 SVC encoders are created equally. The standard really defines how to decode video, not encode it. So, H.264 encoders from different vendors will support varying video quality and bandwidth efficiencies. In addition, all H.264 codecs should at least be able to decode the baseline profile layer. In reality, H.264 implementations from different vendors may not interoperate, even for the base layer, and H.264 SVC implementations certainly do not interoperate. Some of these incompatibilities may also be due to proprietary signaling a vendor may choose to use.

Other video compression scenarios are also available. Microsoft, for example, has created its own video compression codec, RTVideo, which is found in its Lync product. Another proprietary Microsoft codec is WMA video format. Both of these codecs have good bit rate characteristics and can perform well over lossy networks

Figure 4 below shows the video compression codecs used by major desktop video conferencing vendors at the time this report was written.

Figure 4. Video Compression Codecs Used in Several Desktop Video Solutions

Vendor	Product	Codec
Avaya	Avaya Flare Experience	H.264 SVC H.264 AVC H.263
Avaya	Avaya one-X Communicator	H.263+ H.263 H.261
Cisco	Cisco Jabber	H.264 AVC H.263+ H.263
IBM	IBM Sametime	H.264 AVC H.263
Logitech/LifeSize	LifeSize ClearSea	H.264 AVC H.263+ H.263
Microsoft	Microsoft Lync 2013	H.264 AVC/SVC Microsoft RTV[6]
Polycom	Polycom RealPresence Desktop/Mobile	H.264 AVC/SVC H.263+ H.263 H.261
Skype	Microsoft Skype	VP8 H.264 AVC
Vidyo	Vidyo VidyoDesktop/VidyoMobile	H.264 SVC H.263[7]

There is significant work being done on the next video compression standard, H.265. A recent Cisco demo showed equivalent video quality between H.264 and H.265 at half the bandwidth of H.264. Vidyo likewise has demoed H.265 versus H.264. There is often an

interval between when the next standard is ratified and when it appears in products. It is likely that Cisco and Vidyo will both adopt H.265 as soon as it is ratified.

Figure 5. Comparing H.265 SVC Image Quality and Bandwidth with H.264 SVC Video.

A Short Discussion of Multipoint Video

The first question many video users ask after experiencing a point-to-point video call is how to have a video meeting with three or more people. There are basically two

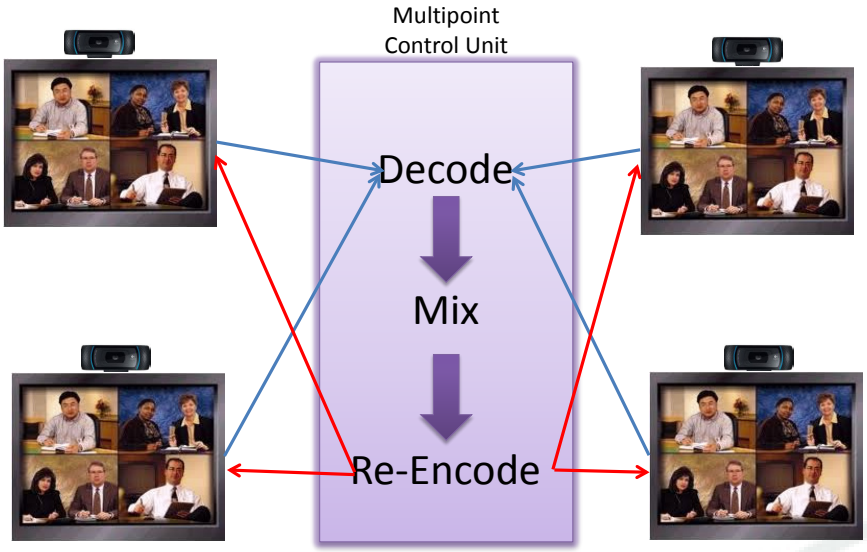
mechanisms for enabling multiparty video, depending upon which codecs and bridging hardware are being used: a Multipoint Control Unit (MCU) or a video media relay server.

Traditional MCUs

If multiple endpoints in a call are using single-layer codecs like H.264 AVC or H.263 (or earlier codecs), then an MCU is required for audio and/or video bridging (this assumes continuous presence[8]). Each video endpoint enters into a point-to-point call with the MCU. The MCU receives video feeds from all endpoints and mixes both the audio streams and the video streams and then sends a single audio and a single video stream back to each endpoint.

In order to do this mixing, the MCU must first decode the audio and video streams. It then combines or mixes the audio, often mixing only two or three of the audio inputs with the most amplitude. Simultaneously, the MCU takes those images corresponding to the loudest audio inputs and puts them together in a smaller single image. It then re-encodes the audio and video, and returns these streams to the individual endpoints[9].

Figure 6. How A Traditional MCU Mixes Video



MCUs exist as software running on a server or as dedicated hardware with Digital Signal Processing (DSP) chips. Large enterprises typically use hardware-based MCUs for performance reasons. By the nature of the processes involved, MCUs add some latency (typically less than 200 milliseconds[10]) to a multipoint video conference. Also, because there are multiple encode/decode cycles, the video quality will slightly degrade.

Media Relay Servers for H.264 SVC

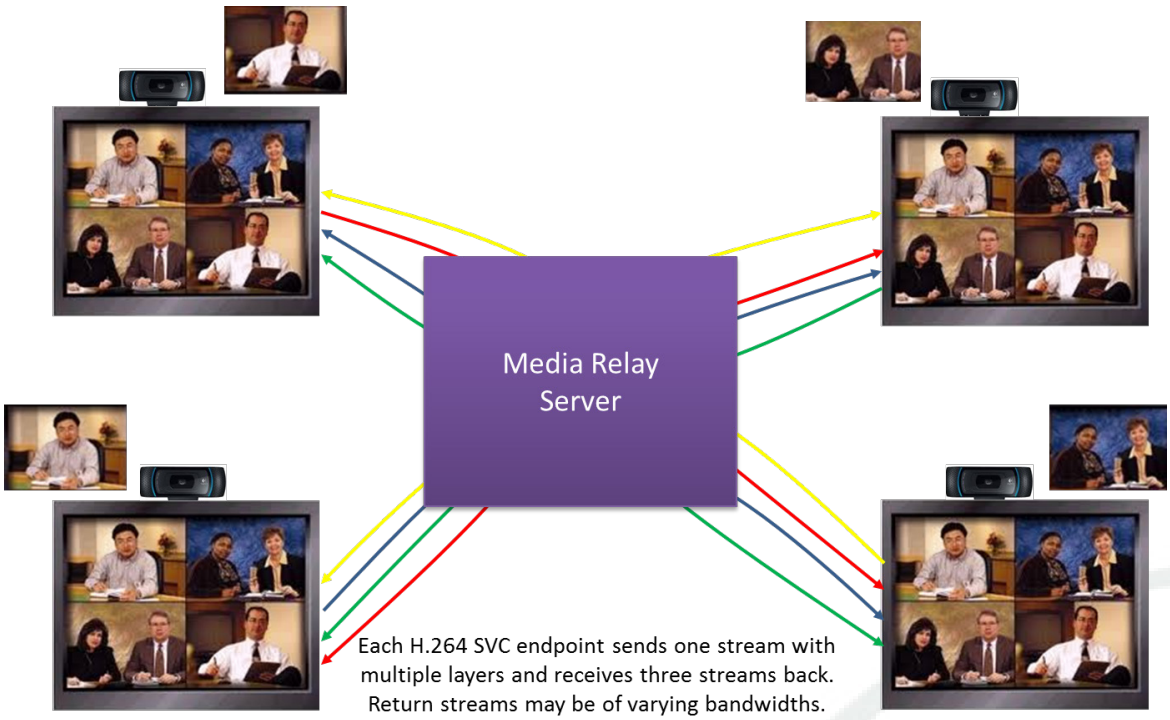
H.264 SVC codecs and the endpoints that support H.264 SVC have enabled a different way to provide multipoint video. These endpoints are able to encode and decode multiple streams simultaneously. An H.264 SVC multipoint video solution is controlled by a media

relay server that determines which layers are sent to each connected endpoint[11]. As discussed above, each endpoint receives only those SVC layers it can properly decode based on an endpoint's screen size, processing power and the dynamically computed available bandwidth connecting the endpoint to the video router.

In a H.264 SVC solution, no video is mixed or transcoded; video streams are routed between the participating endpoints[12]. The media relay server replicates and routes video streams for each participant to the other endpoints without mixing. The H.264 SVC-compliant endpoint simultaneously decodes these multiple video streams, each with their own layers, and displays a multipoint image properly on its corresponding screen.

Because H.264 SVC media relay servers do not encode or decode the video, the video quality will be higher than when a MCU is used. In addition, routing video packets adds less latency than does a MCU (typically less than 10 – 20 milliseconds).

Figure 7. H.264 SVC Call: Media Relay Server Replicates and Routes Video Packets, Mixing Only The Audio



Cascading MCUs and Video Routers

A concept first introduced by First Virtual Communications (later acquired by Radvision which in turn was acquired by Avaya) in 2003 is the cascading MCU. In a cascading MCU scenario, endpoints connect to the "closest" MCU. MCUs at different locations communicate with one another, and a single mixed stream of audio and video is sent between them. In such a scenario, only one audio and video stream is sent over a WAN connection versus multiple endpoints at the same location all sending audio and video streams traversing the WAN. Consequently, significant WAN bandwidth can be conserved.

Figure 8. Cascading Video MCUs or Video Routers

One of the artifacts in cascading multipoint continuous presence video is the "picture-in-picture" effect (shown below) that can affect the video experience. Some MCUs overcome this by keeping the main location in continuous presence mode and the remote locations sending only the video of the last person from that location that most recently spoke. By running the conference this way, the continuous presence images are displayed correctly and they are propagated out to the remote locations properly.

Figure 9. Picture-in-Picture Effect From Some Cascading MCUs

Setting up cascading calls for MCUs is not difficult conceptually, but it often requires the manual step of having the MCU dial out to other participating MCUs. It also adds another layer of latency to the call.

Media relay servers that cascade, on the other hand, do not exhibit the "picture-in-picture" effect because they route across the WAN only the video streams of those being observed by other endpoints. Thus, if three images were being viewed by participants on the remote side, three separate streams would be sent over the WAN between the video routers. When cascading, media relay servers can also be configured to limit the bandwidth consumed so that WAN bandwidth can be conserved[13].

One artifact of using cascading media relay servers is that multipoint capacity can be added without seriously increasing latency, which does happen when MCUs are cascaded.

Vendor Solutions for Scalable Enterprise Video

While there are numerous desktop video conferencing vendors that could be covered, we have chosen to cover the five with the most market impact with respect to how their desktop video solutions scale: Avaya, Cisco, Microsoft, Polycom and Vidyo. In the sections below, we describe each desktop video offering, show the scalable video architecture and describe the hardware and software components that enable the solution. In this discussion, we do not assume any telephony is being upgraded; the assumption is that for solutions that integrate with the telephony call control, the necessary elements are already in place.

Avaya

Avaya has had video offerings for many years and has worked with a number of third parties including Polycom and LifeSize to enable video to integrate with its Private Branch Exchange (PBX) solutions. The company also developed its own desktop video solution as part of its one-X Communicator; prior desktop video solutions were based on Polycom OEMed products. In 2010, Avaya introduced a new collaboration environment, branded the Avaya Flare Experience, which relied on Avaya's Aura® SIP Session Manager and the Avaya Aura Conferencing server. The Avaya Flare Experience first appeared on a custom-built Android tablet and sported a very intuitive interface that allowed easy multichannel communications including presence, IM, voice calling, multiparty audio conferencing, Web collaboration and video conferencing.

In 2012, Avaya purchased Radvision, a manufacturer of videoconferencing infrastructure as well as room, desktop and mobile endpoints. Avaya now has two complementary video solutions in the Radvision suite of products and its own Avaya Flare Experience and Avaya Aura-based offering. The company's video strategy is that the Radvision suite of products will be primarily sold in the standalone video world, which is still most of the enterprise group and telepresence video market, while the Avaya Aura/Avaya Flare products will be sold to enterprises seeking tight integration with Avaya's unified communications offering. Radvision's Scopia® products will provide any desired integration between these two worlds.

Figure 10. Avaya Flare Experience Interface Running on a Windows PC.

The Scalable Solution

For this report, we will assume use of Avaya's scalable desktop video solution based around the Avaya Flare Experience and Avaya Aura Conferencing 7.x; this is clearly Avaya's strategy for wide scale deployment of video collaboration integrated into a UC experience. At the time this report was completed, the full Avaya Flare Experience was available on Avaya's Desktop Video Device (the Android-based tablet), and it is scheduled for availability in Q4 2012 on the iPad and on computers running the Microsoft Windows operating system[14]. A Mac version of the Avaya Flare Experience is slated for completion in 2013.

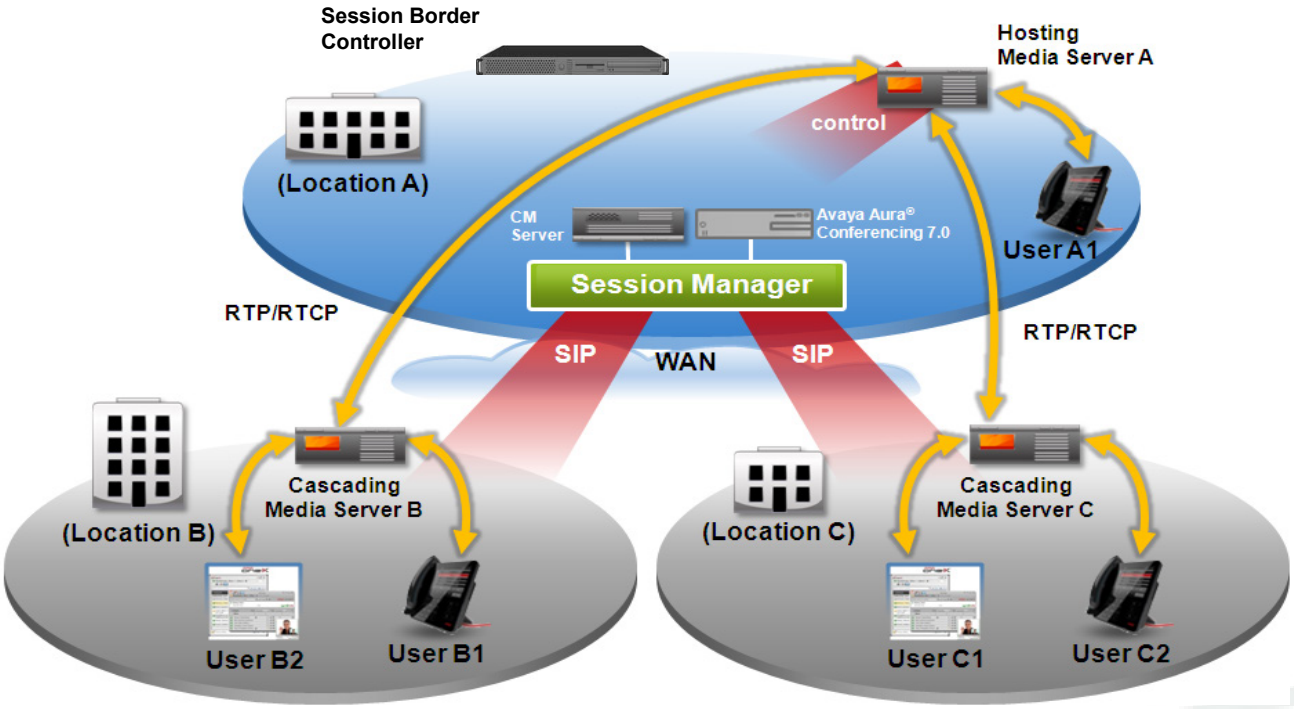
An individual license is required for each person wishing to take advantage of the Avaya Flare Experience. Licenses run $190/user (list price) and are in addition to any telephony licenses the user may already have. Users wishing to use Avaya Aura Conferencing without the Avaya Flare Experience can purchase a license for $140/user (list price)

Concurrently with announcing the availability of Avaya Aura Conferencing 7.0 in August 2012, Avaya announced that both the conferencing server and its Avaya Flare Experience now support H.264 SVC encoding. Thus, the Avaya Aura Conferencing Server acts as a video router, routing video packets whereas prior to this release, it functioned as an MCU. We note also that the Avaya Aura Conferencing servers presently support only voice-activated video switching; continuous presence video (with multiple video images being displayed simultaneously, is slated for a future release).

The Avaya Aura Conferencing server also supports server cascading, which can significantly reduce WAN bandwidth requirements for meetings involving multiple parties from several locations simultaneously.

The Avaya Aura Conferencing solution is composed of five logical components: the application server, one or more media servers, a Web conferencing server, a document server[15], and an optional session border controller. Video and audio conferences are controlled by the application server, and each application server can support up to 7,500 simultaneous sessions. The media servers can support up to 250 simultaneous 720p high definition video streams. Avaya Aura System Manager is used to administer Avaya Aura Conferencing and the rest of the Avaya Aura components and applications

Figure 11. Avaya Aura Conferencing Cascading Media Architecture



Because Avaya's scalable video solution integrates tightly with Avaya Aura, telephony-only users can be added to any video conference seamlessly. The telephony stream is treated by the media server just like the video stream, with the only exception being that the telephony audio stream does not have video. Media servers can support up to 3,000 G.711; 2,500 G.722; or 2,000 G.729 audio connections simultaneously.

Remote video and audio users traverse the enterprise firewall securely through the Avaya Aura Session Border Controller (SBC). Avaya's SBC is the same for voice and video; consequently, an organization would likely have already deployed the component.

Integration with Legacy Systems and Third-Party H.264 Solutions

Avaya Aura Conferencing will interoperate with third-party H.264 AVC video endpoints natively (including the Radvision endpoints running H.264 AVC). Integration with legacy H.263 and older systems requires a gateway, and the Radvision Scopia infrastructure will be used for these legacy integrations.

Figure 12. The Avaya Solution Summary

Avaya Solution Summary	
Desktop Solution	Avaya Flare Experience
Tablet Solution	Avaya Flare Experience
Devices	Windows iPad 2/3 Avaya Android Device (ADVD) Mac – 2013 Other Android Devices (2013)
Infrastructure	Avaya Aura® Conferencing Application Server Avaya Aura Conferencing Media Servers Avaya Aura Conferencing Web Server Avaya Aura Conferencing Document Server Avaya Aura Session Border Controller (optional)
Audio Codecs	G.729 (Narrow band) G.711 G.722 (Wide band)
Video Codecs	H.264 AVC/SVC H.263
Screen Sizes and bandwidth	720p 360p 180p
Continuous Presence	Avaya Aura Conferencing offers Voice Activated Switching only; Avaya flare can receive Continuous Presence images when connected to a Radvision bridge.
MCU/Video Router Latency	Audio < 45 ms (when mixed locally first) Video < 2ms Supports Cascading
Capacity	Application Server: 7,500 simultaneous sessions Media Servers: 3,000 G.711 2,500 G.722 2,000 G.729 250 HD video streams (720p) Use 8 to 1 port ratio for audio to video

Call Admission Control	Yes. Controlled by Avaya Aura Session Manager
Licenses Required	Every user needs a license and the license goes with the user.
Interoperability	• Will interoperate with third-party H.264 AVC solutions. Requires gateway for legacy video solutions (Avaya Radvision gateway).
Plug Ins	Outlook, Microsoft Lync (via Avaya Client Applications)
Misc.	• Individuals connect to the "closest" media server. • In multiparty meetings that span multiple media servers, traffic between media servers is consolidated into a single stream between media servers. • Local audio is mixed on the closest media server before traversing the WAN, where it is mixed again at the host media server. • During a video conference, Avaya's core technology continuously monitors the performance of the underlying network and the capabilities of each endpoint device, and adapts video streams in real-time to optimize video communication. Video communications are dynamically layered into multiple resolutions, quality levels and bit rates.

Cisco

Cisco is a major player in the video market, and not just in video conferencing and telepresence. The company has video entertainment solutions for IPTV and cable companies, video surveillance offerings, digital signage and content creation, as well as its high-end telepresence and video conferencing solutions.

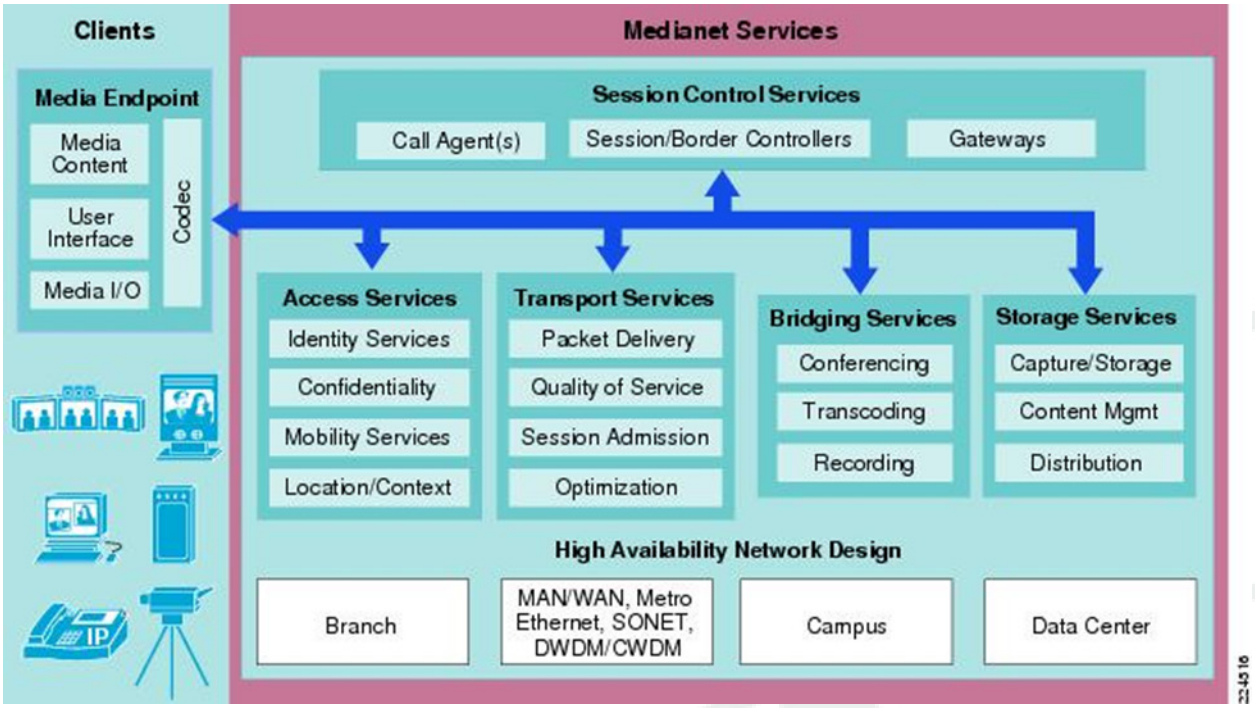
In the video conferencing space, Cisco had a relationship with Polycom wherein Polycom endpoints and MCUs were qualified for the Cisco AVVID network architecture. This relationship waned as Cisco began OEMing MCUs from Radvision in 2004.

The company introduced high-definition telepresence solutions in 2006, a move that effectively boosted the fortunes of every company in the videoconferencing industry. Cisco's marketing muscle caused executives in many companies to look at the benefits of telepresence in general, and it accelerated the move to high definition video across the entire gamut of video communications solutions.

Recognizing that much of the market still needed group videoconferencing endpoints and infrastructure, Cisco purchased Tandberg in 2009, causing no small stir in the market. At the time, Tandberg was battling with Polycom to be market leader in the video conferencing market. Cisco has since integrated the Tandberg standards-based technology throughout Cisco's entire portfolio, including its telepresence offerings.

Cisco has developed an entire network architecture branded Medianet along with a series of network-based video applications and products designed to make it easier to roll out pervasive video and to troubleshoot video quality issues. Medianet is an end-to-end architecture where network and applications are aware of each other. Elements of Medianet include auto configuration capabilities, video endpoint location awareness, performance monitoring, media tracing and synthetic traffic generation for pre- and post-deployment assessment. It also includes the Media Experience Engine which provides network-based video transcoding designed primarily for streaming applications in order to support any device and any display. The Medianet architecture can play a fundamental role in all of Cisco's video solutions.

Figure 13. Cisco Medianet Services Architecture



The Scalable Solution

Cisco has two scalable desktop video solutions, both of which use the Jabber software client as the video interface. The first is a premises-based offering and the second is a cloud-based service which uses the WebEx infrastructure.

Cisco's premises-based scalable video offering is centered on a Cisco Unified Communication Manager, which provides call control to all phones and video endpoints. Call signaling goes through the Communication Manager, while media flows between endpoints or between an endpoint and an MCU.

Several other components are necessary, including:

1. TelePresence Video Communication Server (VCS) Control Cluster: This is an appliance or a virtual application that provides SIP session management capabilities as well as transcoding between H.323 and SIP endpoints. It also allows integration of SIP video with Cisco Unified Communication Manager. The VCS is often used as a demarcation point between group and telepresence video units (including as legacy video endpoints) and the PBX world.

   In a scenario with pervasive video, the Jabber clients would most likely register with the Cisco Unified Communication Manager, and VCS servers would be required (in conjunction with VCS Expressway servers) in order to allow video to securely traverse the firewall.

2. TelePresence Management Suite server: This is server that runs the Cisco Telepresence Management Suite software, which provides control and management for infrastructure and endpoints. The server can support up to 100,000 users. It integrates with existing phone books and directories and allows users to schedule video conferences and the corresponding MCU ports. It can also facilitate software upgrades for group endpoints.

3. TelePresence Conductor: It is an appliance or a virtualized application that allows administrators to define specific classes of service for particular attendees, how many users can connect to a multipoint call, which multipoint unit users should use, and allows multipoint calls to cascade between MCUs.

Figure 14. Cisco TelePresence Conductor and VCS Infrastructure Capacities

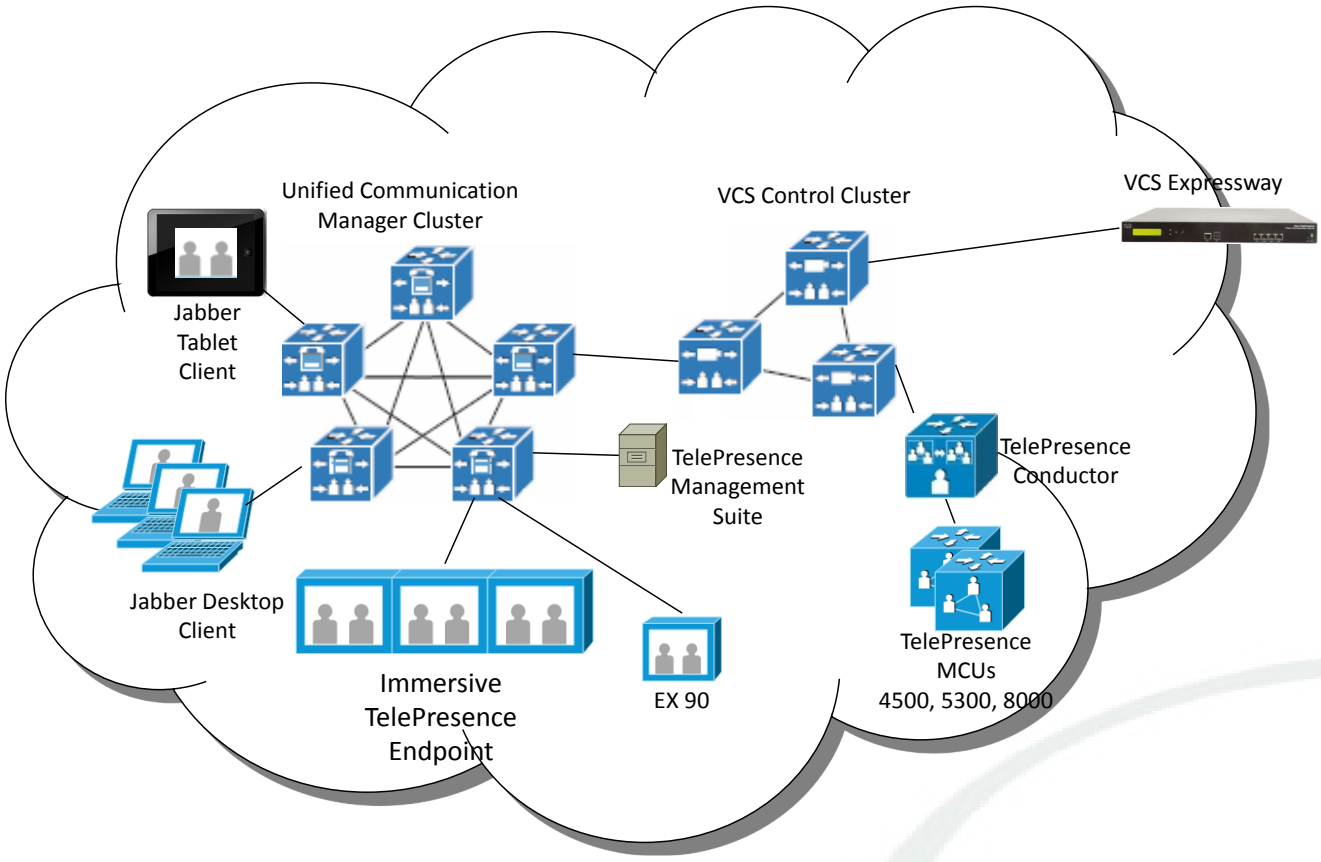
Model	Endpoint Registration Capacity
TelePresence Conductor	30 MCUs or 2400 MCU Ports
TelePresence VCS	2500 Registrations 500 SIP Calls 100 SIP-H.323 Calls

Cisco provides a number of multipoint control options. The 4500 and 5300 series are appliances (the 5300 series is stackable), and the MSE 8000 series MCU consists of a chassis and a number of blades that add capacity.

Figure 15. Cisco Video Bridge Capacities

Model	Continuous Presence Capacity at 720p
TelePresence 4500	40
TelePresence 5300	40
Telepresence MSE 8000	180

Figure 16. Cisco's Premises-based Scalable Video Architecture



Remote video and audio users traverse the enterprise firewall securely through the Cisco VCS Expressway option.

Cisco's Cloud-Based Desktop Solution

Cisco WebEx Telepresence, which uses the Jabber client for video, is available as part of a Cisco TelePresence for Small and Medium Business subscription available from WebEx. The subscription costs $29/user/month and can support up to six simultaneous 720p

video participants. Bridge subscriptions are also available starting at $249/month for six ports; a subscription allows unlimited port use and users from outside the organization to dial in with any standards-compatible SIP or H.323 endpoint.

Integration with Legacy Systems and Third-Party H.264 Solutions

Cisco's video solutions now integrate with all major videoconferencing solution providers. The only exception would be Vidyo's H.264 SVC implementation, which does not integrate with any other parties without a Vidyo Gateway. Other third party H.264 AVC products will integrate with Cisco. Legacy video systems can be accessed through a Cisco video gateway or MCU.

Figure 17. The Cisco Solution Summary

Cisco's Solution Summary	
Desktop Solution	Cisco Jabber (Premises-based) Jabber Video (Cloud-based) (US/Canada only)
Tablet Solution	Cisco Jabber for iPad
Devices	Windows Mac iPad iPhone
Infrastructure	Cisco Telepresence Video Communication Server Cisco VCS Expressway Cisco Telepresence Conductor Cisco TelePresence Management Suite Cisco Telepresence MCU 5300 Series Cisco Telepresence MSE 8000
Audio Codecs	MPEG4 AAC-LD; 48 kHz, 64 kbps G.722.1; 24 kbps G.722.1; 32 kbps G.711 a-law G.711 mu-law
Video Codecs	H.264 AVC H.263+ H.263
Screen Sizes and bandwidth	1080p 720p 360p
Continuous Presence	Yes
MCU/Video Router Latency	~60 ms
Capacity	Varies by Model MCU 4500 Series: 40 MCU 5300 Series: 40

	MSE 8000 Series: 360
Call Admission Control	Yes, with Cisco Unified Communication Manager
Licenses Required	• Cisco TelePresence Management Suite • Cisco TelePresence Management Suite Device Licenses • Cisco Unified Workplace Licensing Professional Upgrade • Cisco Telepresence VCS Traversal Licenses • Windows Server 2008 (for TMS)
Interoperability	• Interoperates natively with H.264 AVC, H.263+ and H.263 solutions.
Plug Ins	Outlook Microsoft Lync (CUCILync)
Misc	N/A

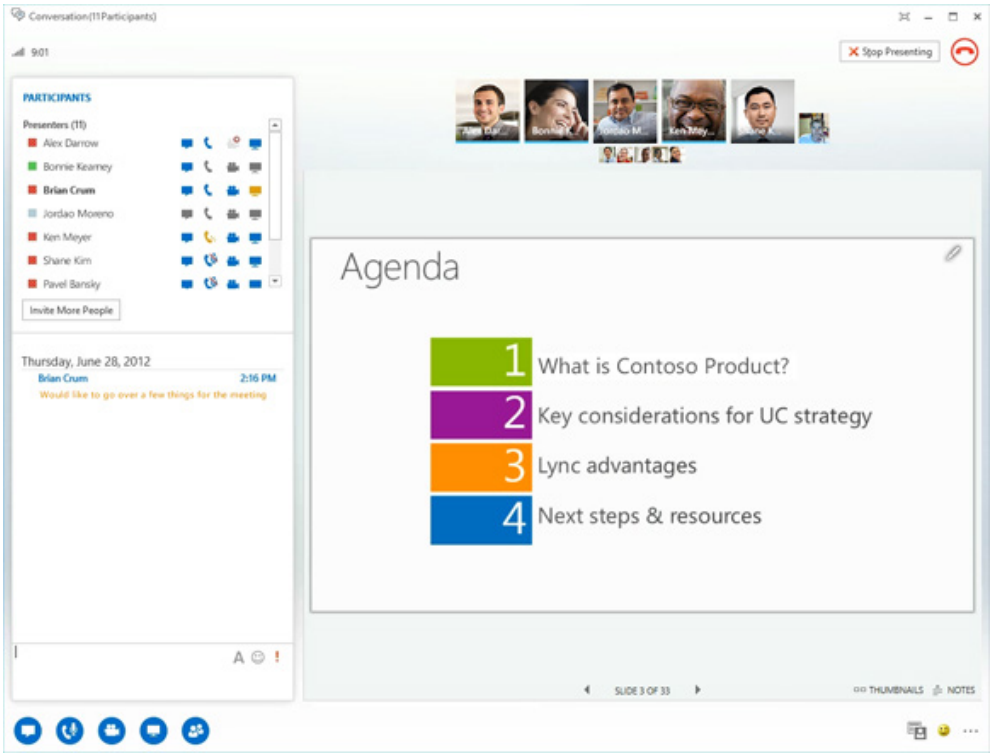
Microsoft

Microsoft has two widely deployed desktop video conferencing solutions: Skype for the consumer space and Microsoft Lync for the enterprise space. These widely varying solutions will be interoperable for presence, instant messaging, and VoIP when Lync 2013 becomes generally available in early 2013. Video interoperability between Skype and Lync is planned for a later date. In this report, we focus on Lync because it is the solution Microsoft heavily promotes to its enterprise business customers.

At the time this report was written, Microsoft supported scalable desktop video to the enterprise through Lync 2010; however, since Lync 2013 availability was just around the corner, we also cover Lync 2013. Lync 2010 supports two video codecs: Microsoft's proprietary RTVideo and H.263. RTVideo is a variable bit rate codec based on the VC-1 codec. Lync 2013 adds support for H.264 SVC[16] but removes support for H.263.

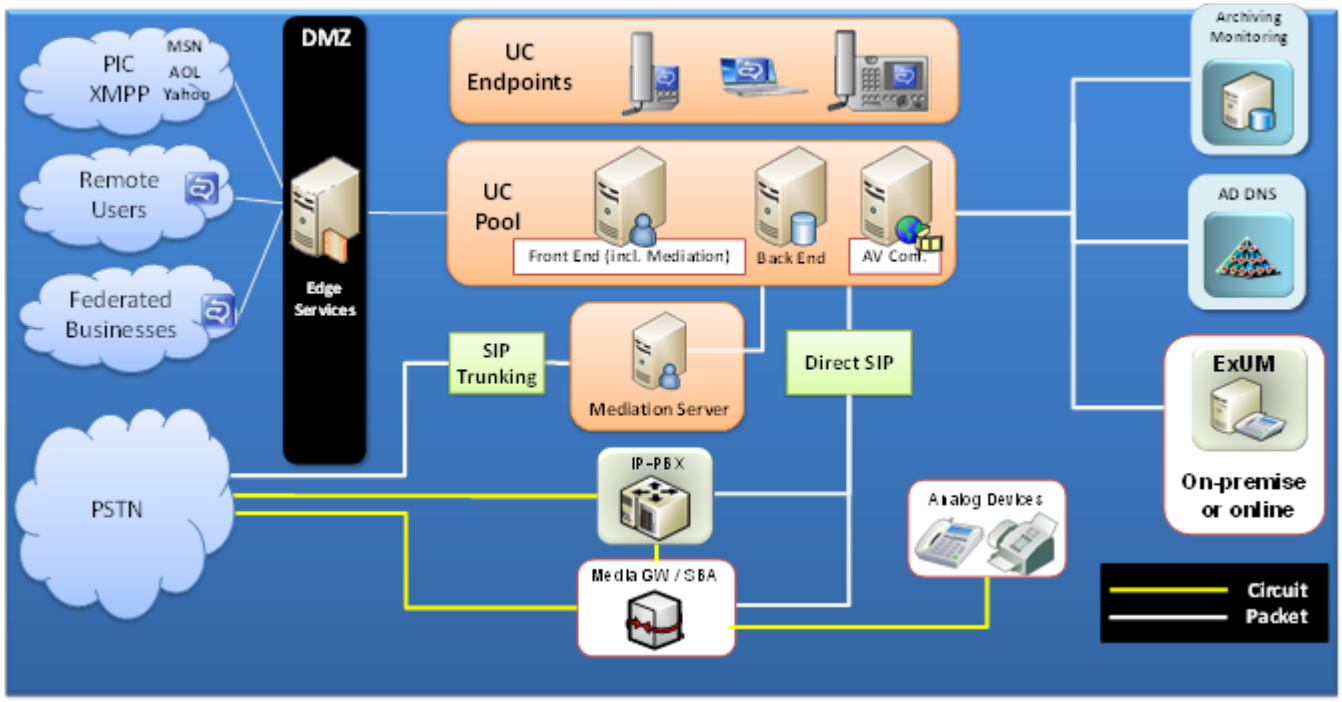
Microsoft is working with chip makers Intel and AMD to provide hardware-based video compression acceleration. The company has stated that any new dual core laptop will be able to compress 720p HD video and receive 1080p video.

Figure 15. Microsoft Lync 2013 Desktop Client



The key elements in the Microsoft architecture that influence video communications are the front-end servers and optional separate A/V Conferencing servers. Each front-end server has audio and video bridging capabilities; consequently, Microsoft recommends that the A/V server role be separated only if there are large numbers of multipoint video users. The recommendation changes based on which version of Lync is deployed: for Lync 2013, the company suggests that 160 simultaneous video users (70 percent at 288p and 30 percent at 480p) can be using a single front-end server with eight cores, each running with a CPU clock speed of 2.33 megahertz[17]. For Lync 2013, Microsoft recommends an additional A/V server for each 1,000 video users[18].

Figure 18. Microsoft Lync 2010 Reference Architecture[19]



In Microsoft Lync 2010, continuous presence videoconferencing is not supported, and in a voice-activated switching multipoint conference, the maximum resolution per endpoint is 480p. This is true even if a Lync 2013 client is used in a Lync deployment based on Lync Server 2010.

In a Lync Server 2013 deployment, Lync 2013 will enable 1080p video for multipoint conference participants. Lync Server 2013 also allows each user to see up to five other 1080p parties simultaneously[20] plus a panoramic video delivered by a RoundTable endpoint. Microsoft's technical documentation states that Lync 2013 clients may send up to five different streams with total bandwidth up to 8 Mbps (depending upon CPU and memory capacity) to allow different endpoints to see different image sizes or qualities[21]; normally, endpoints will use much less bandwidth, particularly in conferencing situations where smaller images are often displayed. In a scenario where Lync 2013 Server is deployed and a meeting has a mix of Lync 2013 and Lync 2010 desktop clients, the endpoints will try to send at least two video streams: one or more H.264 SVC streams for the connected Lync 2013 clients and one RTVideo stream for the Lync 2010 client. Microsoft has stated that the entire conference may revert back to RTVideo at 720p, but the conditions in which this will occur are not clearly specified in the available documentation.

Remote video and audio users will join a video conference by traversing the enterprise firewall securely through a Lync 2013 Edge Server.

Integration with Legacy Systems and Third-Party H.264 Solutions

Microsoft Lync 2010 and Lync 2013 have very limited third-party interoperability. Third-party H.263 systems can connect to Microsoft Lync 2010 if the packet headers are modified to support Microsoft's custom modifications to the SIP headers and packets are TCP/IP rather than UDP/IP. Support for H.263 has been eliminated in Lync 2013.

Polycom, LifeSize and Avaya/Radvision have integrations with Microsoft Lync either through their respective gateways or MCUs wherein they have licensed Microsoft's RTVideo codec. Polycom also has extensive Lync integration in all of its newer video endpoints that can register directly with Lync Server 2010 and can interoperate with the Lync client as well as with the Lync A/V multipoint server. These third-party solutions will also integrate with Lync 2013.

Figure 19. The Microsoft Solution Summary

Microsoft Solution Summary	
Desktop Solution	Microsoft Lync 2010 Microsoft Lync 2013
Tablet Solution	N/A (No Lync client with video for tablets)
Devices	Windows Mac
Infrastructure	Microsoft Lync 2010/2013 A/V Server Role Microsoft Lync 2010/2013 Edge Server Role
Audio Codecs	Microsoft RTAudio Wideband Microsoft RTAudio Narrowband G.722 G.711 Polycom Siren
Video Codecs	H.264 SVC/AVC (Lync 2013 only) RTVideo H.263 (Lync 2010 only)
Screen Sizes and bandwidth	1080p 720p 480p 288p Plus others[22]
Continuous Presence	Lync 2013 – Yes – up to five video images plus a panoramic view in a Gallery arrangement Lync 2010 - No – Voice Activated Switching only and No HD Multipoint (480p or lower)
MCU/Video Router Latency	~60 ms
Capacity	1,000 H.264 SVC clients in Lync 2013 0 – in Lync Server 2010 (no HD and no Continuous Presence video)

Call Admission Control	Yes, through Lync Server 2010/2013
Licenses Required	• Microsoft Lync Enterprise CAL
Interoperability	• Lync 2010 Interoperates with standard H.263 solutions. • Interoperates with third-parties who have licensed Microsoft Video technology
Plug Ins	N/A
Misc	N/A

Polycom

Polycom has long been a market leader in the video industry in both revenues and units shipped. The company has a full suite of video solutions, ranging from telepresence suites at the top end to HD group/room video systems to a variety of personal and desktop offerings. The latter include phones with integrated video cameras and displays, self-contained personal video units and software for personal computer and tablet users.

In 2011, Polycom introduced its RealPresence® Platform, which is the brand under which Polycom's current video solutions are marketed. Furthermore, the RealPresence Platform is really the standards-based software that is pervasive throughout Polycom's video endpoints and infrastructure solutions. This software has five core functional modules:

1. Standards-based multipoint HD voice and video software and content collaboration software.

2. Management software to centrally provision and manage all video endpoints and infrastructure elements.

3. Call routing software providing call admission control and distribution for video meetings spanning up to 64 video MCUs.

4. Security software that provides for secure traversal of network address translation (NAT) devices and firewalls, which opens up secure video conferencing to the world beyond an organization's firewall.

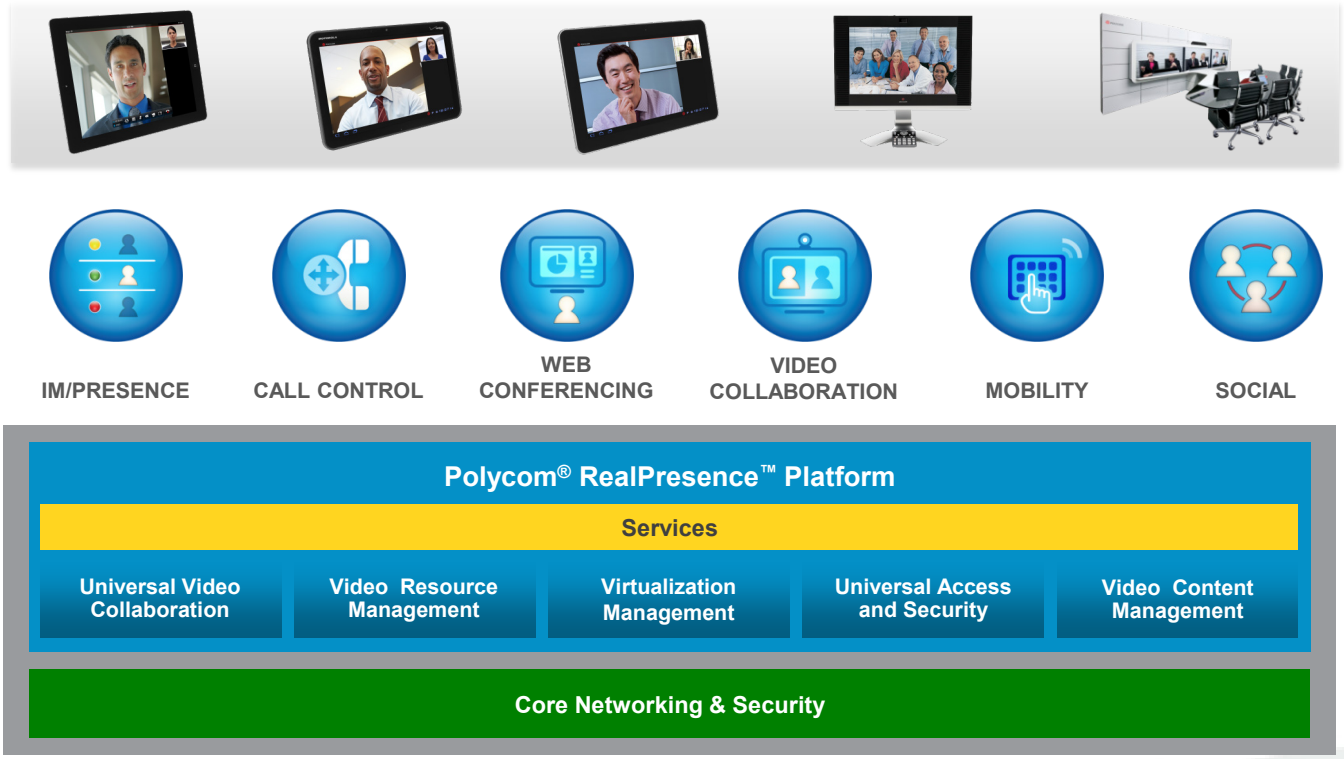
5. Video capture (recording and playback) software that also offers content management, administration and distribution of recorded meetings.

The Scalable Solution

Polycom's RealPresence strategy has numerous individually branded components, including endpoints, MCUs, servers and capabilities. At the core of a Polycom scalable desktop solution is the RealPresence Resource Manager (formerly called the Converged Management Application or CMA – we will use CMA herein because this is what is in the current price list). The CMA server provides centralized directory services, call admission control and routing (it contains an H.323 gatekeeper) and endpoint management

capabilities. Two versions exist, CMA 4000 and CMA 5000, which scale to up to 400 and 5,000 registered endpoints, respectively. The CMA operates in two modes -- direct and routed. In direct mode, the CMA provides call admission control and directory lookup for a call, but then all media and signaling are handled by the endpoints involved in the call. In routed mode, the call signaling remains anchored in the CMA – that is the call signaling still traverses the CMA even though the media flows directly between endpoints. Routed mode allows mid-call controls to be available such as rerouting a call to an MCU without tearing down the call. CMA capacities vary depending upon whether a call is in direct or routed mode.

Figure 20. Polycom's RealPresence Platform



Multipoint capabilities in a Polycom solution are provided by Polycom's RMX series of multipoint control units and its new 800s virtual software-based MCU[23]. Three RMX model numbers exist: 1500, 2000 and 4,000. These models have varying capacities, depending upon the video image size and whether the call is in continuous presence or uses voice-activated switching. When the endpoints support H.264 SVC, the 800s and RMX servers support three times as many H.264 SVC calls (which are routed) as H.264 AVC calls (which are both routed and direct). RMX servers also support bridge cascading so that multipoint calls over the WAN can be done at reduced bandwidth.

Figure 21. Polycom Converged Management Application Capacities

Model	Endpoint Registration Capacity	Direct Mode Simultaneous Call Capacity	Routed Mode Simultaneous Call Capacity
CMA 4000	400	240	120
CMA 5000	5,000	1,500	3,000

Mixed-mode calls can be made between conferences in which endpoints supporting H.264 SVC and non-SVC endpoints are used. In mixed codec calls, the video bridging or routing occurs as follows:

1. Video streams from SVC-based endpoints are routed directly to other SVC-capable endpoints.

2. Video from SVC-based endpoints is mixed with non-SVC-based video by the MCU and is sent to the non-SVC endpoints.

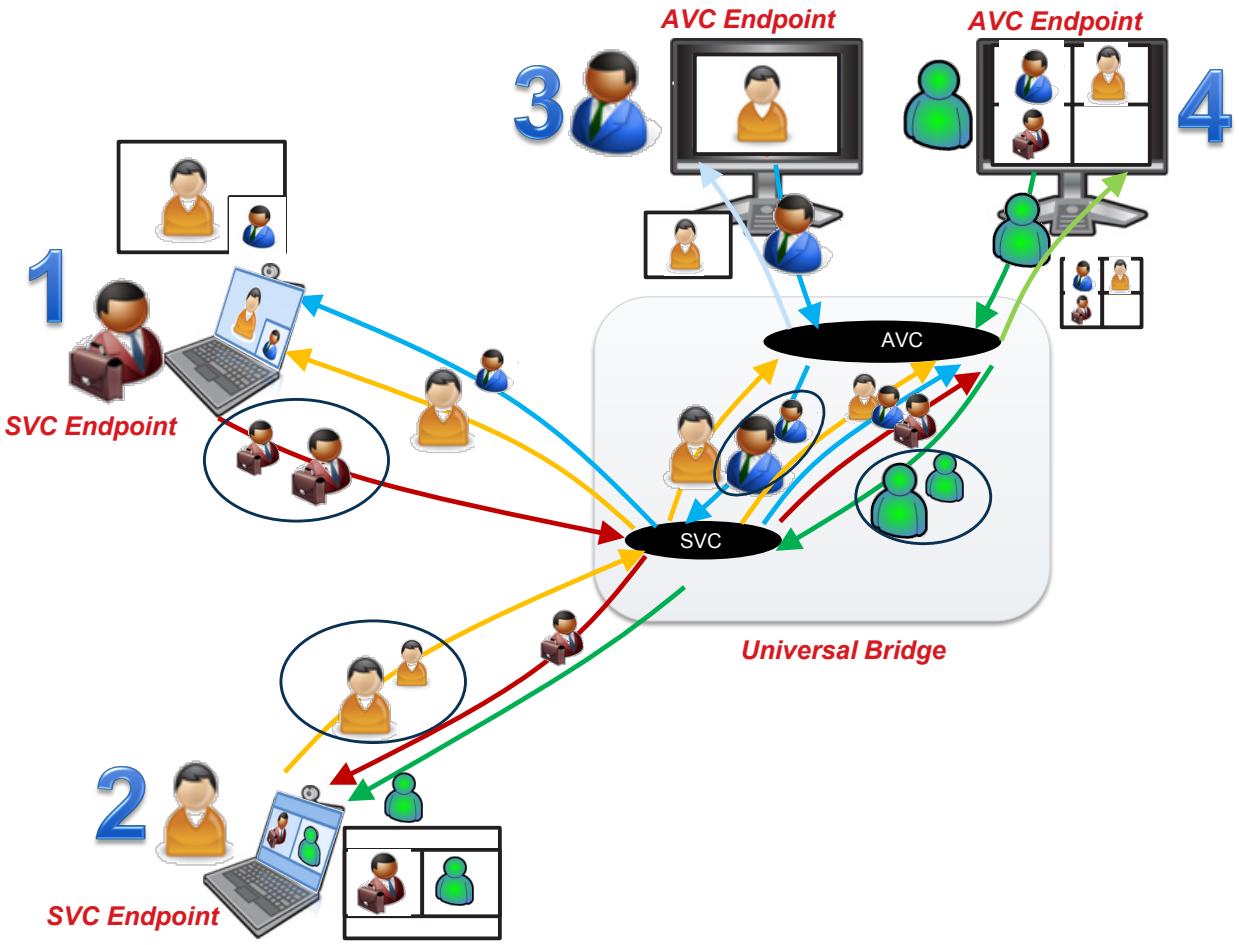
3. Non-SVC video is mixed and sent as an SVC video stream to the SVC endpoints.

Figure 22. Polycom RMX and 800s Video Bridging Capacities

Model	H264 SVC Capacity at 720p
800s	60
RMX 1500	90
RMX 2000	120
RMX 4000	360

Polycom's bridges use a capability called Dynamic Resource Allocation to enable mixed-codec bridging. During the capability exchange between the bridge and the endpoint, DSP resources are dynamically allocated as needed for a particular conference.

Figure 23. Mixed H.264 AVC/SVC Conferences Using Polycom Infrastructure

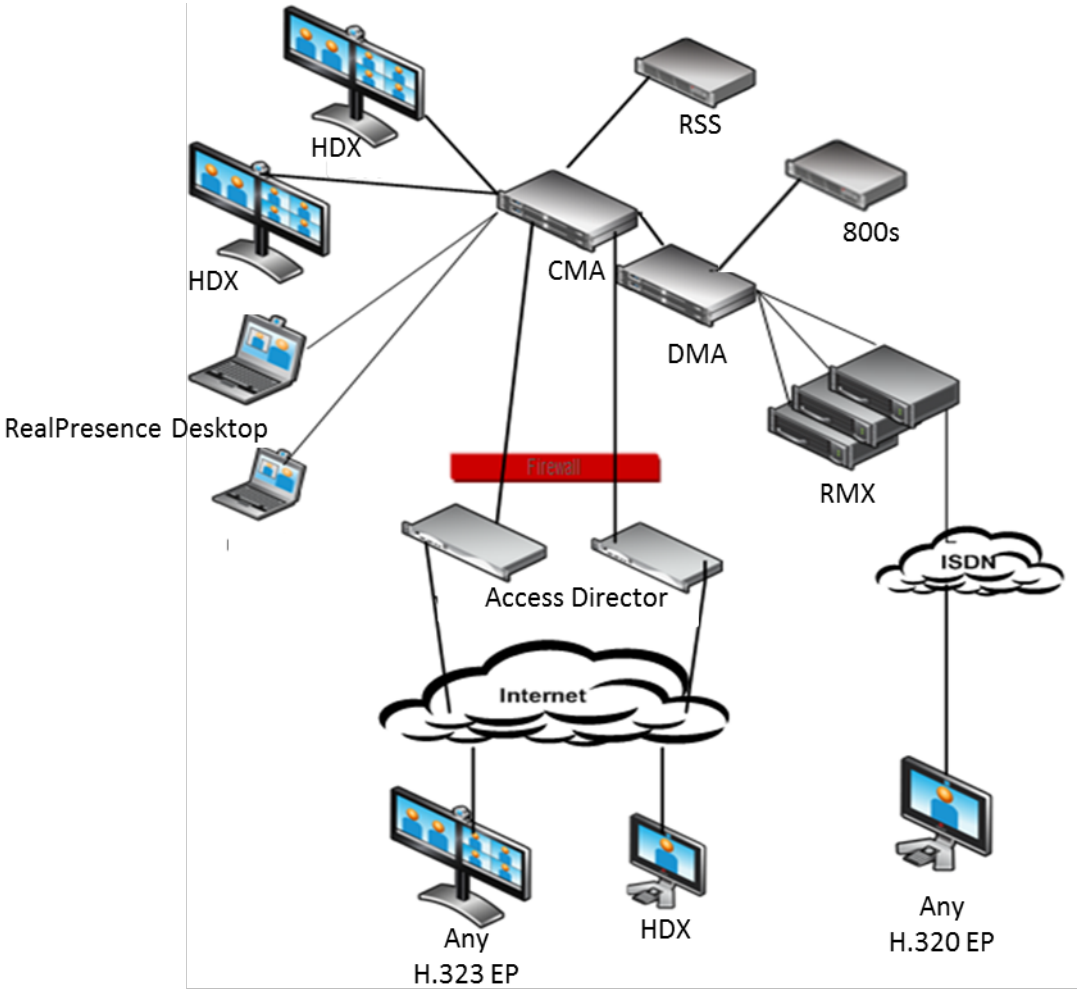


Polycom has a number of personal video conferencing products, including the HDX 4000 Series of executive endpoints, the VVX 1500 Media Phone, the RealPresence Desktop[24] for personal computers (Mac and PC) and the Real Presence Mobile for tablets. The RealPresence Desktop and Mobile applications support far-end camera control. In addition, the iPad version of RealPresence Mobile provides a capability known as "smart paring", which allows the video conference to be easily transferred from the iPad to a group conferencing video endpoint.

The final element of a Polycom solution is the Distributed Media Application™ (DMA™). The DMA can manage and distribute calls across video networks. It can also integrate with telephony solutions to provide a consistent dialing plan and calling paradigm. The DMA also has the capability to load balance multipoint video meetings among multipoint control units and can support up to 64 RMX MCUs.

For enterprises wishing to allow remote video users to traverse the enterprise firewall securely, Polycom offers its RealPresence Access Director as an option.

Figure 24. Polycom's RealPresence® Architecture Showing Endpoints, Bridges and Management Elements



Polycom is rebranding most of its components in the November/December 2012 time frame. A translation between old and new branding is shown below.

Figure 25. Polycom Infrastructure New Branding

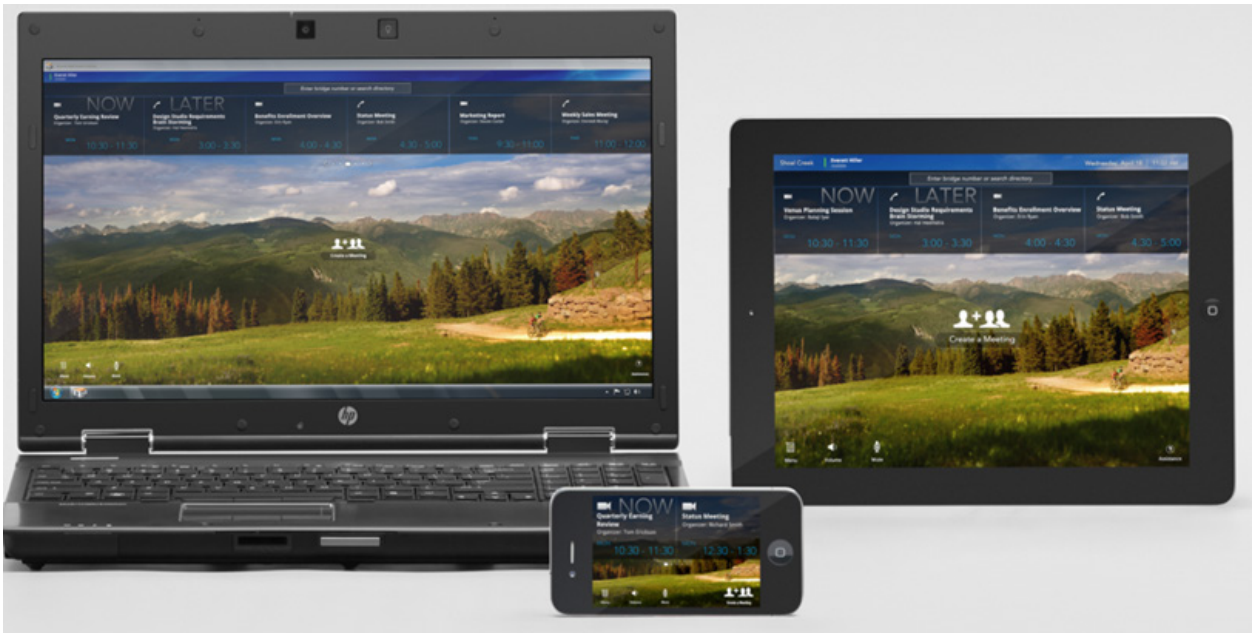
Old Branding	New Branding
RMX	RealPresence Collaboration Server
Converged Management Application (CMA)	RealPresence Resource Manager
Distributed Media Application (DMA)	RealPresence Virtualization Manager
Video Border Proxy (VBP)	RealPresence Access Director

Integration with Legacy Systems and Third-Party H.264 Solutions

Polycom's video solutions integrate with all major videoconferencing solution providers natively. The only exception would be Vidyo's H.264 SVC implementation. Even Vidyo's H.264 AVC base layer will not work with Polycom systems, although other third-party H.264 AVC solutions do interoperate with Polycom bridges and endpoints.

Polycom also interoperates with many telephony solutions, including those from Avaya, Cisco, Siemens and BroadSoft. Polycom endpoints can register with the communication manager in each of these solutions and receive call control from them.

Figure 26. Polycom RealPresence Desktop and Mobile Solution Interface



Microsoft and Polycom have a very strong relationship, and all of Polycom's newer endpoints integrate natively with Microsoft Lync 2010 (Polycom licensed Microsoft's RTA and RTV audio and video codecs), and we have been assured that these same endpoints will integrate natively with the new Lync Server 2013.

Finally, Polycom infrastructure, including the RMX/800s bridges and the DMA, integrate with IBM Sametime to provide video interoperability.

Figure 27. The Polycom Solution Summary

Polycom Solution Summary	
Desktop Solution	Polycom RealPresence Desktop
Tablet Solution	Polycom RealPresence Mobile
Devices	Windows Mac iPad iPhone Android
Infrastructure	Polycom Resource Manager/CMA 5000 Polycom 800s Polycom RMX 1500 Polycom RMX 2000 Polycom RMX 4000 Polycom DMA 7000 Polycom RealPresence Access Director Polycom Virtualization Manager
Audio Codecs	G.719 Siren 14 G.722.1 and G.722 Annex C G.722 G.729
Video Codecs	H.264 SVC and AVC H.263+ H.263 H.261
Screen Sizes and bandwidth	1080p 720p 480p 240p
Continuous Presence	Yes
MCU/Video Router Latency	80 – 100 ms; less with SVC
Capacity	CMA 4000 – 400 endpoints CMA 5000 – 5000 endpoints
Call Admission Control	Yes, with CMA/DMA
Licenses Required	• RealPresence Desktop/Mobile • CMA Server • DMA Licenses
Interoperability	• Native interoperability with call managers from Avaya, BroadSoft, Cisco and Siemens • Native interoperability with Microsoft Lync 2010/2013 • IBM Sametime through RMX/800s bridge

	• Native interoperability with many third-party video H.264 AVC, H.263, H.261solutions
Plug Ins	N/A
Misc	N/A

Vidyo

Vidyo was founded in 2005 around the belief that large numbers of personal video endpoints would be in demand and that these endpoints needed to work over the available network, regardless of whether it was in the home or office, at a hotel or coffee shop hotspot, or on a mobile carrier data network. The founders, one of whom was a principal architect of Radvision's early video infrastructure, also believed that scalable video would of necessity be software-based so that it would be affordable enough to roll out to the masses.

Vidyo's founding came at a fortuitous time -- shortly after the H.264 standard was ratified -- and its first products appeared two months after final approval of the SVC annex to the H.264 standard was approved. From the outset, Vidyo created products that used H.264 SVC exclusively. These included the VidyoRouter (the H.264 SVC video routing server), VidyoRoom (a group videoconferencing solution supporting up to 1080p video encoding) and VidyoDesktop (a software-based endpoint running on Windows and Mac OS).

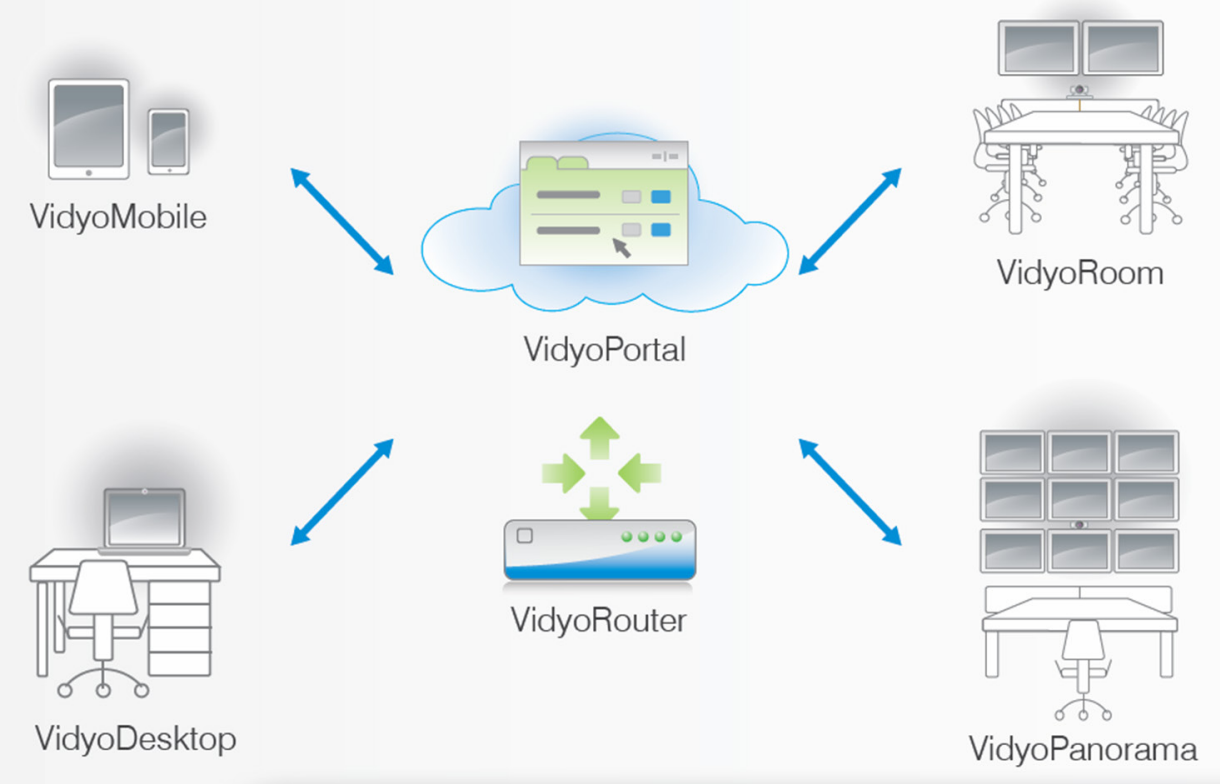
The Scalable Solution

Vidyo's scalable desktop solution is centered around the VidyoRouter, which contains most of Vidyo's intellectual property. The VidyoRouter is the heart of Vidyo's solution, along with the VidyoPortal, which provides a management interface into the solution. All video traverses the VidyoRouter, even point-to-point video between two endpoints.

Vidyo has coined the term "Adaptive Video Layering Architecture" for the intelligence in the VidyoRouter. The architecture lets the router interact with individual endpoints to dynamically determine which H.264 SVC layers should be encoded by the endpoint and which layers the endpoints can adequately receive, based on available bandwidth, screen resolution, CPU processing power and so forth.

Each endpoint encodes at the best quality possible. The VidyoRouter evaluates the capabilities of all devices receiving the video stream and determines which packets they can use based upon the resolution of that device and the bandwidth it has available. VidyoRouters will dynamically adjust what they send based upon what is required and what is available at the moment – many times per second. Other media relay servers may not take this same approach because some of this capability is intellectual property patent protected by Vidyo.

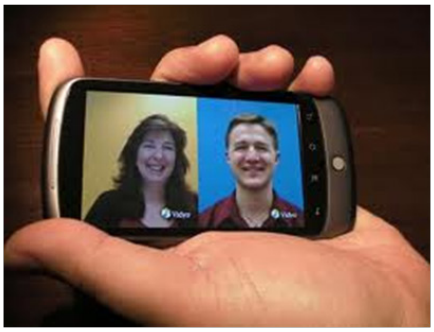
Figure 28. Vidyo's Scalable Multipoint Video Architecture

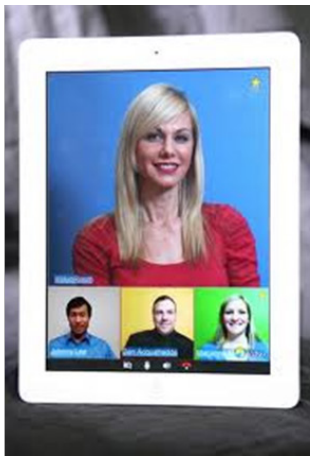


A key to Vidyo's endpoints is that they can simultaneously decode the multiple layers in an H.264 SVC bit stream, and they can simultaneously decode multiple bit streams. Thus, the VidyoRouter coordinates with each endpoint to have the endpoint encode the highest video quality possible and send this video to the VidyoRouter. The VidyoRouter determines which video streams are to be routed to a given endpoint and at what image size, frame rate and quality. Even though one endpoint may be on a bandwidth-limited connection, it will not affect the video quality for other endpoints. A further upside to requiring all video, even in point-to-point calls, to traverse the VidyoRouter is that if there is a requirement to resend a packet, it can be resent from the VidyoRouter, thereby potentially shortening delay and jitter.

In the personal videoconferencing space, Vidyo has two endpoints: VidyoDesktop for PCs, Macs and Linux devices, and VidyoMobile for iPads, Android tablets and iOS and Android-based smartphones. On the desktop computers, up to eight other parties can be viewed simultaneously while on the tablets and smartphones, up to four other parties may be viewed. Tablets and smartphones are also limited to 480p video resolution at 30 frames per second while the personal computers support full 1080p at 60 frames per second (note that the 27-inch iMac supports up to 1440p video).

Figure 29. Vidyo's Multipoint Video on a PC, Smartphone and iPad





A single VidyoRouter can scale up to 100 simultaneous 1080p video connections. After an organization has more than approximately 50 connections, the VidyoPortal management software should be installed on a separate server. Vidyo licenses its solution around "VidyoLines", which are concurrent connections to VidyoRouters.

Any number of users can have VidyoDesktop or VidyoMobile installed; it is only when they are actually using video and connected to the VidyoRouter that a "line" is consumed. For global organizations, VidyoLines can be used on any VidyoRouter, so a convenient follow-the-sun capability is possible with a minimum of licenses. VidyoLine licenses carry a list price of $950/line; in addition, Vidyo has a $5/user fee for downloading VidyoDesktop on Windows, Mac or Linux.

VidyoRouters can also operate in a cascaded arrangement, which can reduce bandwidth needs over WAN connections. The VidyoRouters communicate with each other, letting other VidyoRouters know which video streams are being viewed. There is no limit to the number of video streams that may be transmitted between routers for a single conference.

When remote users need to traverse the firewall with video, two options are available. One option is to open up ports in the firewall, but this is not a preferred option for most enterprises. The second, and more secure option, is to place one or more VidyoRouters in the network's DMZ and allow remote video endpoints to connect through it into the network. The external VidyoRouter then connects through the firewall with an internal VidyoRouter. This option would require an additional VidyoRouter for every 100 remote users and would be feasible as the latency in the VidyoRouters is very low (<20 ms).

Should individuals seek to join a conference using only audio, such as from a mobile or fixed-line telephone, the VidyoGateway may be used. There is no VidyoLine charge for audio calls traversing the VidyoGateway.

Integration with Legacy Systems and Third-Party H.264 Solutions

Vidyo's solutions do not natively integrate with other video offerings, even if a third-party endpoint is running H.264 AVC. To connect with third parties' H.264 AVC solutions and legacy H.263 and older offerings, Vidyo offers its VidyoGateway, which transcodes the video streams between Vidyo H.264 SVC streams and H.264 AVC or legacy video streams. A VidyoLine license is not required for any endpoint entering a Vidyo environment through the VidyoGateway. In addition, Vidyo group video endpoints do not consume a VidyoLine license.

Vidyo recently announced a cloud-based service branded VidyoWay that allows free multipoint bridging, using the VidyoGateway, with most third-party standards-based H.264 AVC or legacy IP endpoints[25].

Figure 30. The Vidyo Solution Summary

Vidyo Solution Summary	
Desktop Solution	VidyoDesktop
Tablet Solution	VidyoMobile
Devices	Windows Mac Android iPad iPhone
Infrastructure	Vidyo Router – Dedicated or Virtual Vidyo Portal Video Gateway (integrates with legacy and MCUs) Off the shelf servers
Audio Codecs	SPEEX Wideband Audio
Video Codecs	H.264 AVC H.264 SVC
Screen Sizes and bandwidth (SVC Only)	1440p 1080p 720p 360p 180p
Continuous Presence	Yes, up to 8 participants 720p at 30 fps (desktop) 480p (mobile) up to 4 participants
MCU/Video Router Latency	< 20 ms Supports Cascading
Conferencing Server Capacity	• VidyoRouter: 100 concurrent connections/router (50 when a single system hosts VidyoPortal and Vidyo Router)

Call Admission Control	No
Licenses Required	• VidyoLines™: A floating, perpetual license for a single logical connection through VidyoRouter. VidyoLines are shared among users and only consumed while a soft client is connected through the VidyoRouter. • For multiple VidyoRouters, the licenses are fluid between routers
Interoperability	• Requires a gateway for any third party or legacy solutions
Plug Ins	• Microsoft Lync • IBM Sametime • Adobe Connect • Microsoft Outlook
Misc.	• Individuals connect to the "closest" video router • In multiparty meetings that span multiple VidyoRouters, inter VidyoRouter traffic is consolidated to only those streams being viewed remotely. • During a video conference, Vidyo's core technology continuously monitors the performance of the underlying network and the capabilities of each endpoint device and adapts video streams in real-time to optimize video communication. Video communications are dynamically layered into multiple resolutions, quality levels and bit rates. • Content sharing origination is available on desktops, but not on tablets. Tablets can view content, however.

Bandwidth Requirements for Video Solutions

Estimating the bandwidth necessary for video solutions can be tricky because there are so many variables including frame rate, picture size and video quality. In addition, when video is part of a unified communications solution, Web conferences may also be occurring as part of the video meeting. Consequently, one must consider bandwidth from both video and Web conferencing when doing bandwidth estimation computations. In addition, if a solution has cascading video, this will decrease the video bandwidth required. Finally,

variable bit rate codecs, such as H.264 AVC/SVC and H.263, allow the video bandwidth to fluctuate widely during a call, based on the compression requirements for each video stream.

It would not be realistic to forget audio conferencing bandwidth, even though we are focusing primarily on video in this report. Today, there are many more audio conferences than there are video conferences; however, as video becomes more pervasive, more video conferences will occur. Consequently, we will include audio conferencing bandwidth in the analysis along with video and Web conferencing bandwidth.

To ensure enough bandwidth is available, bandwidth provisioning should be estimated based on how the enterprise intends to use the solution and on worse case scenarios. Based on specifications for the five scalable desktop video solutions covered, we have developed bandwidth requirements for each provider assuming a video conference with 720p video. We use 720p because not every solution can support 1080p in a multipoint conference.

Figure 31. Maximum Endpoint Bandwidth As Specified By Each Vendor[26]

Vendor	Product	Bandwidth (kbps)		
		Video 720p[27]	Audio[28] (G.711)	Web[29]
Avaya	Avaya Flare Experience	1536[30]	64	30[31]
Cisco	Jabber	1300[32]	64	30
Microsoft	Lync 2013	2500[33]	64	30
Polycom	RealPresence Desktop	1920[34]	64	30
Vidyo	VidyoDesktop	2000[35]	64	30

Web conferencing bandwidth will vary widely depending upon what is being shared and how it is being shared. For example, screen sharing will consume more bandwidth than sharing slides. For calculation purposes, we will assume an average of 30 kbps for Web conferencing in each connection.

In addition, there is IP packet header overhead that must be accounted for. We will assume a 20 percent increase in the required bandwidth to account for this overhead[36].

The Centralized Infrastructure Scenario

To set up the calculations, we need to consider two scenarios. The first is when all multipoint infrastructure is located at a centralized headquarters location. In this scenario, all participants except those at the location where the infrastructure is housed require WAN bandwidth. Thus the WAN bandwidth required will be

$$Required\ Video\ WAN\ Bandwidth = RP * (V_b + W_b + A_b) * 1.20$$

where

$RP = the\ total\ number\ of\ remote\ participants,$

$V_b = the\ video\ bandwidth\ per\ connection,$

$W_b = the\ web\ conferencing\ bandwidth\ per\ connection,$

$A_b = the\ audio\ (voice)\ bandwidth\ per\ connection,$

$1.20 = 20\%\ packet\ overhead$

The Video Cascading Scenario

The second scenario is one where the organization will use cascading multipoint video infrastructure: MCUs or video routers. In this scenario, multipoint infrastructure or video routers may be placed at some or all remote locations. The total amount of WAN bandwidth will depend on the number of meetings held simultaneously and how many of them include participants from remote locations. There are an infinite number of permutations for this scenario.

For the scenario we will consider, we will assume that the remote MCUs or video routers will send only a single video and audio stream between each remote location and the main MCU or video router at the headquarters location. For Web conferencing, we will assume that each participant receives an individual Web conferencing bit stream.

Under these conditions, the WAN bandwidth calculation becomes

$$Required\ Video\ WAN\ Bandwidth = \big(((L-1) * (V_b + A_b) * N) + (RP * W_b)\big) * 1.20$$

where

$L = number\ of\ locations\ in\ the\ meeting\ (the\ minus\ 1\ removes\ the\ headquarters\ location\ on\ the\ LAN)$

$N = total\ number\ of\ simultaneous\ remote\ meetings$

$RP = the\ total\ number\ of\ remote\ participants,$

$V_b = the\ video\ bandwidth\ per\ connection,$

$W_b = the\ web\ conferencing\ bandwidth\ per\ connection,$

$A_b = the\ audio\ (voice)\ bandwidth\ per\ connection.$

$1.20 = 20\%\ packet\ overhead$

It is important to point out that not all solutions work in the same fashion. For example, the Avaya and Vidyo media relay servers can be configured to cascade automatically as can Cisco and Polycom MCUs. Microsoft Lync does not support cascading.

The decision to cascade MCUs will ultimately be based on the economic tradeoff between whether it is less expensive to pay for WAN bandwidth or pay for the remote MCUs or video routers. Other factors may also play into this decision, including whether you want multiple video images (continuous presence) from the remote location[37].

The Meeting Scenario for Comparative TCO Computation

There are nearly an infinite number of scenarios one could use to configure a pervasive desktop video solution in an attempt to develop a cost model which includes the hardware/software, maintenance and impact on network bandwidth. We note that the majority of group video conferences are done between three or four locations at a time. The number of participants in each location will certainly vary.

For the sake of creating a concrete scenario for which we can perform TCO calculations, we will assume four locations involved in the meeting and four participants per location. For a pervasive desktop video solution, this will result in 16 participants in total: four at a central or headquarters location and 12 at remote locations. We will also assume that for design purposes, there will be a maximum 10:1 ratio of total employees to participants involved at one time in either a video or audio conference. Furthermore, with an eye toward the future of pervasive video, we will assume that half of these individuals are involved in video conferences and the other half are participating in audio conferences[38].

According to this scenario, a company with 1,000 employees would have a maximum of 100 people participating in an audio or video conference at any time, and the design would have a maximum of 50 simultaneous video conferencing participants and 50 simultaneous audio conferencing participants. Similarly, a company with 5,000 employees would have a maximum conferencing capacity of 500 simultaneous users, 250 in multipoint video conferences and 250 in multipoint audio conferences.

Comparing Scalable Video Solution Total Cost of Ownership

Each vendor is very passionate about its own pervasive video vision and solution. We have tried to be as impartial as possible, using specifications and product descriptions supplied by the vendor. Each vendor has had an opportunity to review the product descriptions, architectures and costs, and to provide feedback. Most, but not all, did provide very helpful guidance, and if needed, corrections and clarifications in pricing.

For each of the five solutions described in this report, we have calculated the total cost of ownership over a three-year period for both desktop video and audio conferencing capabilities for organizations with 1,000, 2,000, 5,000, and 10,000 employees. Given the assumptions above, this would then require video infrastructure for 50, 100, 250, and 500 simultaneous users respectively. The number of audio conferencing users would be the same.

TCO Model Assumptions

In preparing the TCO model, we have made the following assumptions:

1. Organizations already have a telephony system installed. Consequently, we are adding video to an existing communications infrastructure. There is no replacement, upgrade or enhancement to the telephony infrastructure.

    a. For the Avaya video option, we have assumed that the organization will already have Avaya's Aura Session Manager, Avaya Aura Communication Manager and all other necessary voice components deployed.

    b. For the Cisco video option, we have assumed that the organization will already have Cisco Unified Communication Manager and all other voice components deployed.

    c. For the Microsoft video option, we have assumed that the organization will already have Microsoft Lync Server 2010/2013 for IM/presence deployed but that it does not have multipoint video conferencing deployed. Furthermore, it is not necessary that Microsoft Enterprise Voice is deployed.

    d. For Polycom, we assume a DMA will be used to integrate with the call control.

    e. Vidyo's solution does not integrate with call control engines at the present time.

2. A 10 to one ratio exists between total number of users and simultaneous conferencing users. Thus, an organization with 2,000 users will have a maximum of 200 simultaneous conferencing sessions. Looking toward a future of pervasive video, we assume for calculation purposes that half of these will be in audio conferences and half will be in video conferences.

3. At each location, the organization has sufficient bandwidth between endpoints and the network core so that LAN bandwidth is not an issue. It is only between WAN segments that bandwidth becomes an issue.

4. We have assumed multiple locations will be involved in multipoint conferences; consequently, WAN bandwidth will be required and it will have a cost associated with it. We have assumed $120/Mbps/month for managed WAN bandwidth[39]. Bandwidth costs fluctuate widely, depending upon location and the type of circuit (T1, T3, etc.). Readers should modify the findings in this report based on their own

experience with what QoS-enabled WAN bandwidth costs are within their organization.

5. When additional licenses are required for video to traverse the firewall, we assume that 20 percent of the video participants are mobile, traversing the firewall[40].

6. Video bandwidth has been estimated based on the vendor specifications for each solution, and we have designed the system to support 720p resolution; this resolution was chosen because not all systems support 1080p in multipoint configurations.

7. Along with the video codec bandwidth, we also include the audio codec bandwidth (G.711 in all cases) and make an allocation for Web conferencing bandwidth, assuming that many of these will need to support Web conferencing.

8. Finally, we multiply the total bandwidth by a 20 percent packet overhead factor.

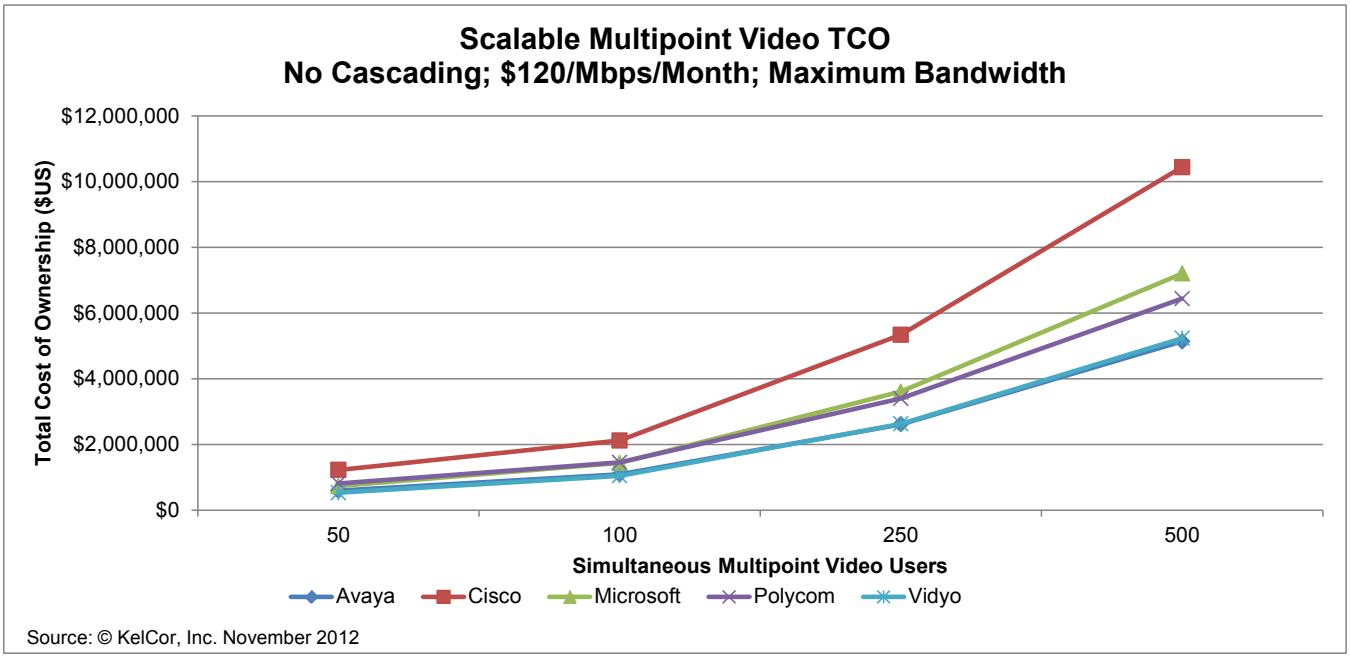
9. For software licensing and hardware components we have list prices[41]; we have also assumed or found reasonable street discounts, where applicable. Reader discretion is advised to assess whether these discounts adequately reflect the reader's actual experience when working with the vendors covered.

Multipoint Video, No Cascading

As we examine the TCO results, we see in Figure 32 below that the scalable solution from Cisco appears to be significantly more expensive than those of Microsoft, Polycom, Vidyo or Avaya. The lines for Avaya and Vidyo are nearly on top of one another exactly: Vidyo is lower by nearly $60,000 at the 50 user level while Avaya is lower by $100,000 at the 500 user level.

In working through the analysis, Cisco and Polycom have significantly more complicated licensing structures because the multipoint infrastructure for these solutions is hardware-based, and it has numerous configuration options (the new Polycom 800s MCU is software-based, but at higher numbers of users the Polycom RMX hardware bridges were used for capacity reasons). We configured reasonable solutions based on pricing and capacity. Infrastructure for the Avaya, Microsoft, and Vidyo options rely on software-based platforms; a portion of Polycom's infrastructure is software-based. Audio is still mixed on each platform[42], even those that route the video.

Figure 32. Scalable Multipoint Video TCO – Discounted Pricing, No Cascading

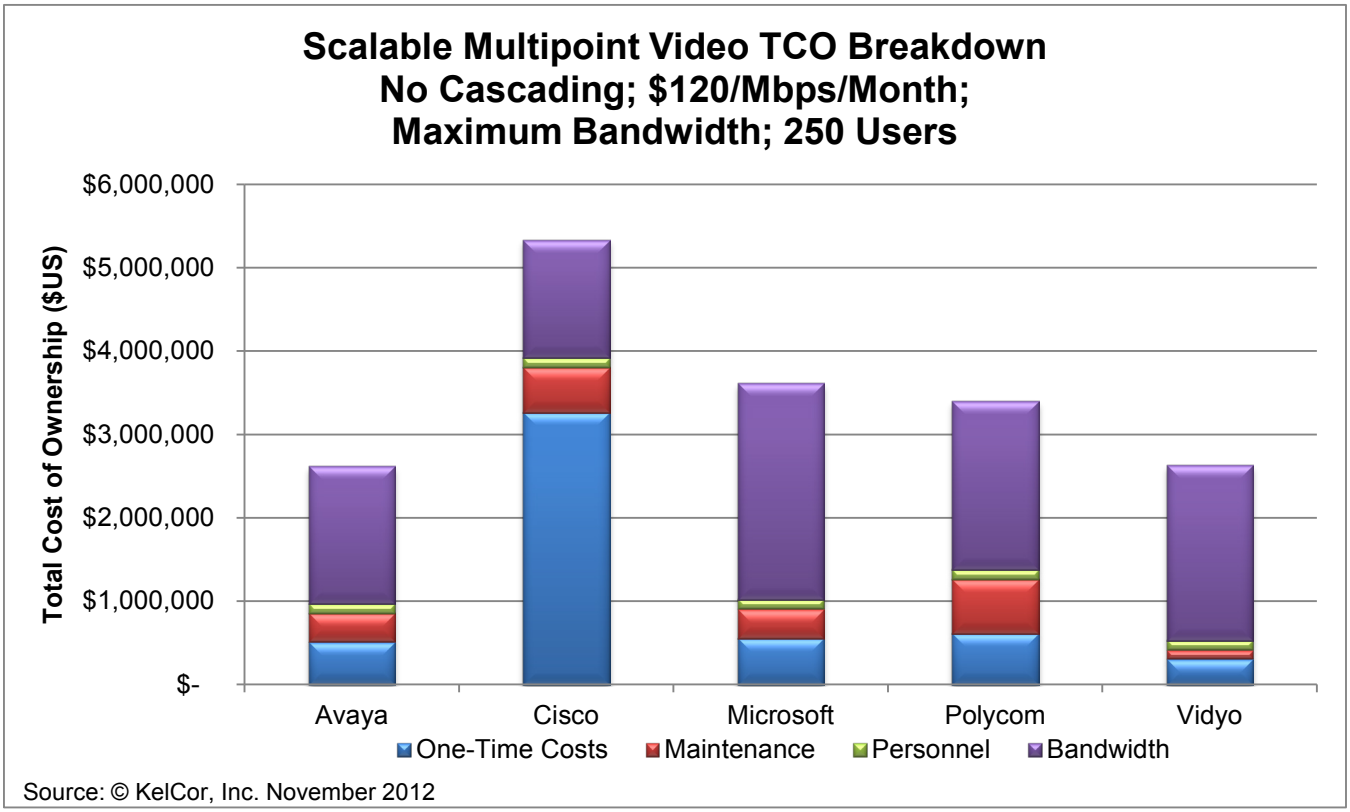


There are arguments both for and against hardware-based multipoint options, but given the price differential, organizations considering pervasive desktop video should consider software infrastructure options. Avaya's, Microsoft's, Polycom's, and Vidyo's software solutions are based on H.264 SVC[43]. Cisco really has an eye on H.265 and seems to waiting on that new codec before it will release software-based video routing capability[44,45].

We should also point out that the results shown in Figure 32 highlight some of the differences in WAN bandwidth costs based on the bandwidth specification for each endpoint. Avaya's H.264 SVC video bandwidth, per the specification from Avaya (1536 kbps), is lower than that for Microsoft (2500 kbps[46]), Polycom (1920), and Vidyo (2000). In the TCO model, these bandwidth differences can cause significant differences in the price for WAN bandwidth. Interestingly, Cisco's Jabber client has the lowest WAN cost, based on specified bandwidth, but the other solution components are significantly more expensive. In fairness to each vendor, a scenario in which the same bandwidth is used across vendors is examined later in this section.

One of the surprising findings Figure 32 illustrates is the impact of WAN bandwidth costs for Microsoft Lync. Microsoft documentation mentions a "typical bandwidth" of 260 kbps for conferences but also states that the maximum stream bandwidth without forward error correction can be as high as 8015 kbps. We used a bandwidth of 2500 kbps in the calculations for the WAN bandwidth cost based on additional material in the specifications. It appears that Lync 2013 clients may send up to five video streams to other endpoints in the meeting[47].

Figure 33. Scalable Multipoint Video TCO Breakdown by Cost Category – 250 Simultaneous Multipoint Users

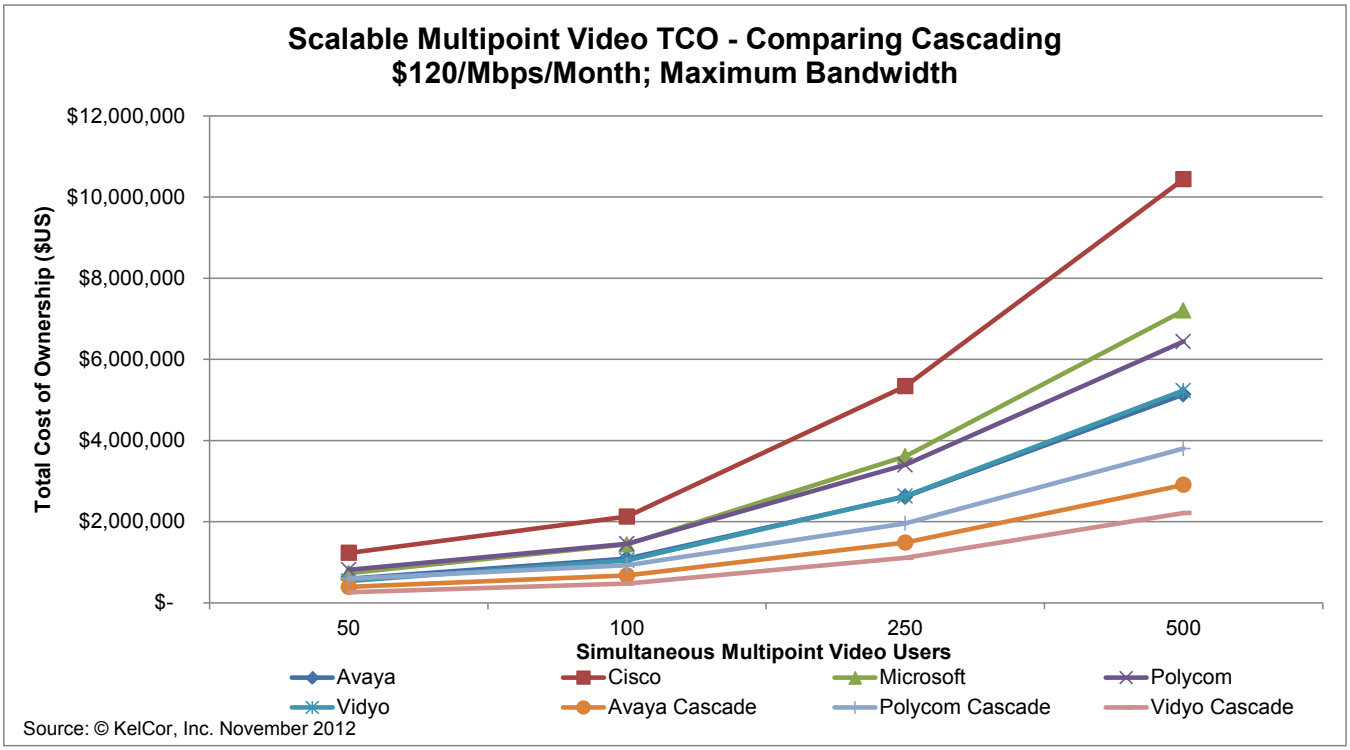


The chart above provides insight into the differences in total costs based on expenses in several categories: one-time costs, maintenance, personnel (which is the same for each vendor) and bandwidth costs. The biggest differences are in the initial one-time hardware/software costs; other significant differences are in the maintenance costs, and there is some cost differential in the total bandwidth costs. The bandwidth cost for all vendors is based on 720p multipoint video. The figures used in the calculations were those suggested in vendor design guides or other reputable sources.

Multipoint Video, With Cascading

When we cascade multipoint video solutions, we see another dynamic that shows up primarily in the cost of bandwidth, but somewhat as well in the one-time costs. In Figure 34 below, we show TCO costs for the same five solutions, but this time, we have added cascaded multipoint meetings for the Avaya, Polycom and Vidyo solutions. We have also assumed voice-activated switched video (single image) rather than multi-stream H.264 SVC video, which implies a single video stream from remote media relay servers to a host media relay server. (Vidyo supports an unlimited number of streams even in a cascaded mode, while Avaya uses voice-activated switching. Polycom will also typically be a single stream although it could be a mixed image from a local RMX or 800s video bridge. We assumed a single stream across the board to try to get a cost comparison.)

Figure 34. Scalable Multipoint Video TCO – Discounted Pricing, With Cascading



We could have cascaded the Cisco solution as well, but the hardware costs for Cisco's solution were already expensive, and adding multipoint bridges at multiple locations is cost prohibitive for the scenario we are operating under[48].

In the cascading scenario, the costs for the cascaded solutions decreased significantly. The implication is that there can be a significant economic benefit, in some instances, between lower bandwidth costs and cascading server costs by using more media relay servers with H.264 SVC. Clearly, each case must be analyzed carefully.

We also note that the Avaya solution did not see as much decrease as did the Vidyo solution when implementing cascading. This is because the server and maintenance costs for the Avaya solution are higher than for Vidyo, and adding media relay servers at the remote locations for Avaya's solution increased these costs enough that it offset some of the decreasing cost of bandwidth in the cascaded configuration. In addition, for the Polycom solution, we used 800s bridges throughout rather than RMX bridges because they would support the lower cascaded bridging demand. Given that the 800s pricing has not been definitively announced, it is possible that the Polycom solution could be priced higher or lower than that shown here[49].

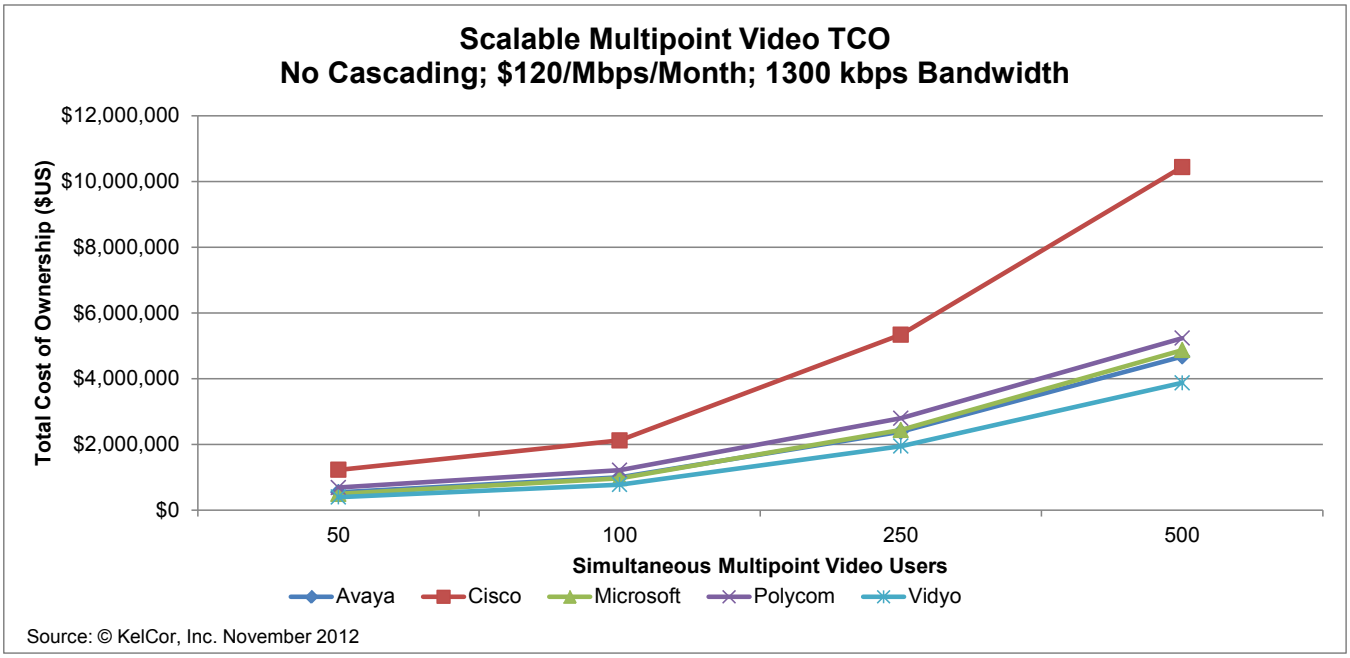
In fairness, we must also state that the Avaya media servers are also full-fledged audio bridging servers as well, so this added utility will also need to be considered when deciding about deployment options.

Multipoint Video – Same Bandwidth For Each Solution

The vendors will all justifiably argue that the bandwidth for their particular solution can be significantly reduced, without too much impact on video quality, given that they are all using variable bitrate codecs that adjust automatically to network conditions. In the calculations above, we used the specifications recommended by the vendors.

In a spirit of fairness, it is informative to examine the TCO curves when all solutions are used at the same bandwidth. Given that Cisco's specified bandwidth was the lowest, at 1300 kbps, we have calculated the TCO curves again using 1300 kbps for each solution.

Figure 35. TCO Comparison When All Solutions Operate at 1280 Kbps

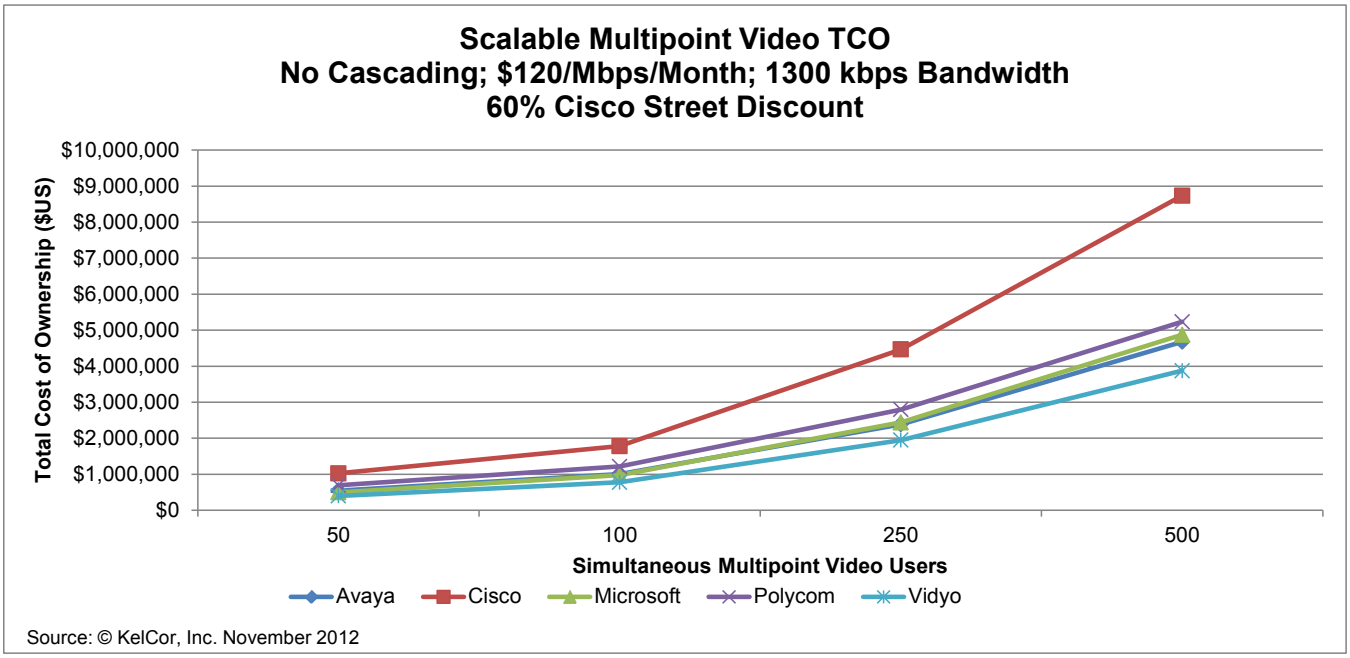


When we limit the bandwidth to 1300 kbps, we see that the Microsoft and Polycom solutions decrease significantly in cost, and that Avaya and Microsoft are approximately equivalent in cost. Vidyo comes in at a somewhat lower cost at this bandwidth.

Multipoint Video – Lower Cisco Discount

In doing the research, we are able to justify the discount used for Cisco's solution based on public data available at a Cisco reseller; however, we have spoken to vendors who have implied that the Cisco street discount used in the calculation above was not steep enough. Consequently, the chart below changes the discount on hardware and software licensing from an average of 42percent to 60 percent of list prices.

Figure 36. TCO with 1300 Kbps and 60 Percent Cisco Street Discount



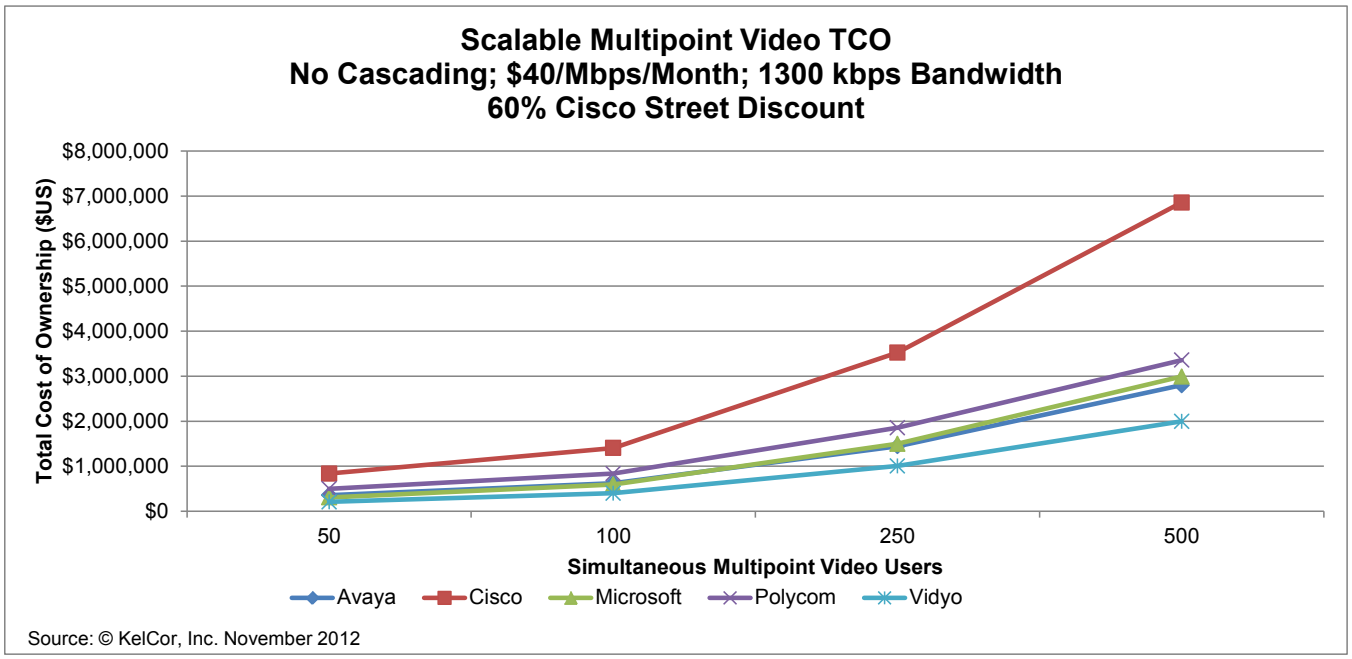
In the figure above, bandwidth is constant at 1300 kbps for each solution while varying only the Cisco street discount to 60%. While the total for the Cisco solution decreases significantly, it still remains the highest cost option.

Running Video over Unmanaged Networks

One of the advantages proponents of H.264 SVC articulate is that solutions encoding with H.264 SVC can operate over unmanaged networks –those without Quality of Service (QoS) – and still have excellent video quality. This is because H.264 SVC can adapt dynamically to bandwidth availability, adjusting the amount of information sent in the various SVC layers or discontinuing one or more layers altogether. In the calculations below, we show the results of running each of the five solutions over unmanaged networks that cost only $40/Mbps/month.

All solutions see a marked decrease in the TCO when the WAN does not require QoS. That is, when the assumed cost of bandwidth decreases from $120/Mbps/month to $40/Mbps/month.

Figure 37. Comparing TCO with No QoS-Enabled Network



As illustrated in the figure below, the Vidyo solution comes in at just under $2 million when there are 500 users. Avaya and Microsoft are at $2.8 and $3 million, respectively. Polycom is somewhat more expensive at $3.4 million and Cisco is significantly more expensive, even with the 60 percent Cisco discount.

Figure 38. Comparing TCO with No QoS-Enabled Network – 500 Users

Users	Avaya	Cisco	Microsoft	Polycom	Vidyo
500	$2,800,762	$6,855,923	$2,992,663	$3,356,003	$1,995,792

Analysis and Conclusions

As desktop video solutions become more pervasive, business executives and decision makers will closely examine the total cost of ownership a pervasive video solution will have. It is important to note that the costs for pervasive video are not in the software endpoints; many of these endpoints are either free or very inexpensive. Rather, the significant money for pervasive desktop video is in the multipoint infrastructure and the network required to support ubiquitous HD video.

As the results in this document illustrate, hardware solutions for providing multipoint capabilities are significantly more expensive than software solutions in which video is routed through, rather than mixed in an MCU. The future of pervasive video is clearly in software-based multipoint infrastructure.

Furthermore, significant savings can occur if video can be run over non-QoS enabled networks; however, in a business setting, where the quality may vary from day to day,

based on network traffic, QoS may be necessary. This is particularly true when considerations for audio are added. Audio is much more sensitive to non-QoS-enabled networks. Marginal video quality, while annoying, may not disrupt a meeting too much; poor audio quality will cause the meeting to be canceled. Hence, even though the promise made by some vendors is that their solution works well over non-managed networks, there may be times that it will not work well[50]. Microsoft learned this when it said that its RTVideo codec would work on networks with up to 20% packet loss; the company has since backed off making such statements because while the video was ok, it was not business quality.

The Group and Telepresence Factor

We must also point out that any organization promoting pervasive desktop video will probably also have some group or high-end telepresence endpoints. While group and telepresence video will ensure a market for hardware-based MCUs for the foreseeable future, even these endpoints will likely migrate to media relay servers over time as the codecs within them change to SVC-based encoding. In the near to mid-term, organizations will need to consider how they will integrate group and telepresence endpoints with the desktop endpoints so that there can be continuity and ease of use as people go from group to telepresence to desktop to tablet video solutions. Considerations for integrating group and telepresence video with desktop solutions is beyond the scope of this report, but it is an important factor to consider moving forward.

Another issue organizations will face is the standards their endpoints support. The vendors covered in this report all say their endpoints are standards-based, yet they may not interoperate. While one can always buy a gateway to transcode between differing endpoint standards, this should be kept to a minimum. Consequently, when evaluating solutions, it will be important to consider how often non-standard endpoints will need to interface with standards-based endpoints. If this needs to happen frequently, or if there are a sizeable number of legacy video units that are still function and which will still be used, then the issue of standards and gateways looms larger. This type of situation may put Vidyo and Microsoft at a possible disadvantage: for Vidyo, gateways must be purchased from Vidyo while for Microsoft, third-party gateways or MCUs will need to be procured unless the endpoints are from Polycom and they integrate natively with Lync.

Integrated Call Control

A small, but growing trend in the enterprise is to have a single source of call control. This means that both video endpoints and telephones rely on the same device for call signaling and routing. For many organizations this will be either their PBX or call manager.

As a company considers a pervasive desktop video strategy, it will be important to have a consistent calling pattern, whether a person is on a phone or a video unit. For organizations seeking to rationalize voice and video call control, the ease with which an endpoint can integrate with the voice infrastructure will be an important consideration. This report does not address this integration directly, but several of the solutions provide this capability natively, including Avaya, Microsoft (with Microsoft Lync Enterprise Voice), and Cisco.

Clearly Avaya, Cisco, and Microsoft have an advantage in providing integrated calling environments because they also manufacture call control software. Of these three, our cost analysis shows that Avaya has the lower TCO when adding pervasive video to the existing call control infrastructure.

Polycom's endpoints can integrate with Avaya and Cisco PBXs (and others), and they have tight integration with Microsoft Lync. Polycom also provides its DMA product to provide a "call control bridge" between the video world and the voice world.

Vidyo presently does not integrate with any third-party call control engines, which may not be an issue for those organizations that have no desire or need to integrate video with the call control.

Integrated Audio and Video Conferencing

As we look at the costs, we note that we have included audio conferencing with video conferencing. Mixing audio on a video bridge is possible, but relatively expensive compared to an audio conferencing bridge. Consequently, companies most likely would not buy video bridge ports in order to provide capacity for audio bridging. In the Cisco, Polycom, and Vidyo options above, we did add extra video bridge ports or licenses, which can be used for mixing audio. But for very large deployments, organizations would likely consider separate audio bridges or third-party audio conferencing service providers. Here again, the importance of integrating with a consistent call control engine will make both audio and video conferencing easier.

Furthermore, for the Vidyo solution, we added additional VidyoRouter capabilities to handle audio bridging even though the Vidyo solution was not really designed as an audio bridging solution. We did this to try to provide solution parity.

An interesting side note is that the Avaya Aura Conferencing server and the Microsoft Lync A/V Server 2010/2013 were both specifically designed to handle audio and web conferencing and video bridging on the same platform. So these can be effectively scaled for either or both, making them quite flexible for both large audio, video and mixed deployments.

Point-to-Point Bandwidth and Redundancy

An element of cost that this analysis does not consider is the effect that point-to-point video communications will have on the network, particularly the WAN. In this analysis, we have only considered the case of multipoint video conferences. Organizations will need to add some reasonable estimate to the additional bandwidth required to account for these point-to-point video calls which will surely arise as video becomes pervasive in the enterprise. One way to account for this in the pervasive video world of the future is to look at today's point-to-point audio calls, estimate a percentage of these calls that will be video-based in the future, and add the WAN costs for the necessary bandwidth.

In addition, the analysis did not take into account any costs associated with building a redundancy and failover to provide greater reliability and availability. As desktop video

conferencing becomes more pervasive, reliability and availability will become a critical consideration; individuals will expect these systems to provide the same level of video reliability that we experience with audio communications today. Vendors should be consulted as to how they provide redundancy capabilities, and what the user experience will be in various failover conditions.

Caveats about Specific Solutions

The video communications world is complex, and there are always caveats in any solution. We list some of these below.

Avaya

Avaya's Aura Conferencing server presently supports 720p video in voice-activated switching mode. It does not presently support continuous presence video (Hollywood Squares) or a video gallery. Continuous presence can be obtained on Avaya Flare if a Radvision bridge is used, but this was not included in the cost calculations.

As mentioned above, the Avaya media servers were designed for large volumes of audio and video calls on a single platform; consequently, an organization does not need to buy a separate audio bridge for large scale audio conferencing with Avaya's solution. This could ultimately lead to lower TCO when redundancy and scaling are considered.

When multiple Avaya conferencing servers are part of a solution, they automatically cascade every call. In locations with limited WAN bandwidth, this automatic cascading can prove very useful.

Avaya also has developed into its media servers (not just the endpoints) a capability called "silence suppression". Silence suppression conserves audio bandwidth by not sending the audio stream between media servers if all the participants at a particular location are listening and not talking. This presently works only with audio conferencing, but is slated to work in video conferences in a future release. The value of building this capability into the media server is that it works for any endpoint, even endpoints that do not by themselves support silence suppression.

Finally, Avaya's Aura Conferencing solution tightly integrates with the Avaya Aura Session Manager, which makes desktop and tablet endpoints extension off of the PBX, giving the video endpoints full mid-call control capability (hold, transfer, forward, and so forth).

Third-party video integration with Avaya's Aura Session Manager and Communication Manager is native for Polycom and LifeSize endpoints. For other endpoints, Avaya would suggest the enterprise use one of its Radvision gateways.

Cisco

With the acquisition of Tandberg several years ago, Cisco now has a full suite of video communications solutions, from tablet and desktop up through the largest telepresence

suites. All of these solutions are integrated with the Cisco Unified Communication Manager so that dialing is like making a phone call. Full mid-call controls are available as well.

Cisco's solutions support full 1080p in continuous presence mode. The company seems to be bypassing H.264 SVC in favor of H.265, and although no H.265 release date has been mentioned, we anticipate that it will be in 2013. Cisco's video solutions are standards-based, and they can integrate with most third-party H.263 and H.264 AVC endpoints.

Cisco recently has stepped up its focus on HTML5 and on promoting browser-based video through WebRTC. The company has provided its SIP stack to Mozilla as well as its H.264 codec for Firefox 18.

Cisco is looking forward to H.265, and it recently demonstrated H.264 AVC next to H.265 AVC, along with a bandwidth meter showing that an H.265 image with equal quality was transmitted at half of the bandwidth of H.264.

Microsoft

Microsoft Lync 2010 does not support HD conferences, but Lync 2013 does. In a Lync 2010 deployment, voice-activated switching multipoint conferences are possible at 480p. Lync 2013 clients in a Lync Server 2010 environment can do point-to-point HD, but multipoint will default back to 480p with no continuous presence.

In a Lync 2013 server pool, 1080p multipoint conferencing is supported. Lync 2013 clients may see up to five different participants plus one panoramic view in what Microsoft calls a video gallery. Unlike traditional continuous presence calls, Lync 2013 clients allow users to pick and choose who they see, with up to five people on display at the same time.

Lync 2010 clients running in a Lync 2013 server pool will receive a single 720p RTVideo image (that of the current speaker) from a Lync 2013 A/V Server.

Microsoft's solution does not integrate natively with third-party video endpoints with the exception of Polycom, who has licensed the Microsoft audio and video codecs. Avaya/Radvision and Cisco/Tandberg have also licensed Microsoft's RTVideo codec for use in their gateways. Integration with Microsoft has been left to the other video vendors, most of whom will integrate with Microsoft Lync Server through an infrastructure component such as a gateway or an MCU. It is unclear whether Microsoft Lync 2013 will better integrate with third-party H.264 SVC solutions, and no announcements of greater interoperability have been made. Microsoft does have a Video Interop Program which lets third parties license Microsoft technology and test their integrations.

Microsoft has announced that Lync 2013 software was released to manufacturing in October 2012 and will be generally available in early 2013.

Polycom

Polycom endpoints and infrastructure all support 1080p video continuous presence. The company has a very strong video offering. Polycom's DMA product can act as a call router

and demarcation point between the world of video and the world of telephony. When DMA is integrated with a PBX, video endpoints can call regular telephones and vice versa.

Although we priced Polycom's solution to support both audio and video conferencing, large installations will generally not buy video MCU ports from Polycom to serve as audio conferencing ports. At low volume audio conferencing, using those ports is satisfactory, but at high volumes, they are not cost-effective versus a hosted solution or a premises-based offering.

Polycom's video solutions are standards-compliant and they integrate with many third-party H.263 and H.264 AVC video endpoints.

Vidyo

The Vidyo offering was built around scalable high definition desktop video communications, and the company has added group video endpoints as well. The solution is based on H.264 SVC, and it will integrate with other H.264 AVC and H.263 solutions only when a VidyoGateway device is used as an intermediary. The Vidyo software works very well on tablets such as the iPad and Android-based devices. We have also seen it work well on non-QoS-enabled networks.

Although we priced Vidyo's solution to support both the audio and the video conferencing, large installations will generally not buy VidyoRouters and VidyoGateways to serve as audio conferencing ports.

We are personally aware of some large, geographically diverse organizations that have deployed Vidyo's desktop solution specifically for use over non-QoS-enabled networks, like the Internet. The largest organization we are personally familiar has over 20,000 potential users (not simultaneously, but worldwide). These organizations generally report good satisfaction with Vidyo's technology.

Appendix 1: Detailed Calculations for Each Vendor

Figure 39. Avaya – No Cascading, Bandwidth Per Specification, $120/Mbps/Month

Avaya Aura Conferencing 7.0 Deployment															
	Number of Employees			1000			2000			5000			10000		
	Number of Locations			4			6			10			20		
	Number of Simultaneous Video Calls			50			100			250			500		
	Video Calls/Location			13			17			25			25		
	Video Bandwidth/Call (kbps)			1536			1536			1536			1536		
	Number of Simultaneous Audio Calls			50			100			250			500		
	Audio Calls/Location			13			17			25			25		
	Audio Bandwidth/Call (kbps)			64			64			64			64		
	Calls Traversing the Firewall			50			100			250			500		
Cost Category	Item Description	Unit List Price	Street Discount	Qty	List Price	Street Price	Qty	List Price	Street Price	Qty	List Price	Street Price	Qty	List Price	Street Price
Hardware	Aura Conferencing 7.0 Application Server	$10,000	50%	1	$10,000	$5,000	1	$10,000	$5,000	1	$10,000	$5,000	1	$10,000	$5,000
	Aura Conferencing 7.0 Media Server	$16,000	50%	1	$16,000	$8,000	1	$16,000	$8,000	2	$32,000	$16,000	3	$48,000	$24,000
	Aura Conferencing 7.0 Web Server	$16,000	50%	1	$16,000	$8,000	1	$16,000	$8,000	1	$16,000	$8,000	1	$16,000	$8,000
	Aura Conferencing 7.0 Document Server	$8,000	50%	1	$8,000	$4,000	1	$8,000	$4,000	1	$8,000	$4,000	1	$8,000	$4,000
Software Licensing	Aura Conferencing 7.0 Audio/Web/Video w/Flare	$190	55%	1000	$190,000	$85,500	2000	$380,000	$171,000	5000	$950,000	$427,500	10000	$1,900,000	$855,000
	Aura Session Border Controller	$145	60%	50	$7,250	$2,900.00	100	$14,500	$5,800.00	250	$36,250	$14,500.00	500	$72,500	$29,000.00
Installation	Installation Costs	N/A	0%	1	$35,000	$35,000	1	$35,000	$35,000	1	$37,000	$37,000	1	$39,000	$39,000
	Total One Time Costs				$282,250	$148,400		$479,500	$236,800		$1,089,250	$512,000		$2,093,500	$964,000
HW/SW Maintenance	Aura Conferencing 7.0 Application Server	$900	13%	1	$2,700	$2,349	1	$2,700	$2,349	1	$2,700	$2,349	1	$2,700	$2,349
	Aura Conferencing 7.0 Media Server	$900	13%	1	$2,700	$2,349	1	$2,700	$2,349	2	$5,400	$4,698	3	$8,100	$7,047
	Aura Conferencing 7.0 Web Server	$900	13%	1	$2,700	$2,349	1	$2,700	$2,349	1	$2,700	$2,349	1	$2,700	$2,349
	Aura Conferencing 7.0 Document Server	$900	13%	1	$2,700	$2,349	1	$2,700	$2,349	1	$2,700	$2,349	1	$2,700	$2,349
	Aura Conferencing 7.0 Audio/Web/Video w/Flare	$27	24%	1000	$27,000	$20,520	2000	$54,000	$41,040	5000	$135,000	$102,600	10000	$270,000	$205,200
	Total Annual Maintenance Costs				$37,800	$29,916		$64,800	$50,436		$148,500	$114,345		$286,200	$219,294
Bandwidth	Remote Video Conferencing Participants				38			75			188			375	
	Remote Audio Conferencing Participants				38			75			188			375	
	Total WAN Bandwidth Required (Mbps)				77			152			380			758	
	Bandwidth Cost/Mbps/Month	$120			$9,240	$9,240		$18,240	$18,240		$45,600	$45,600		$90,960	$90,960
Personnel Costs	Full Time Equivalents to Run Solution	$80,000		0.1	$8,000	$8,000	0.2	$16,000	$16,000	0.5	$40,000	$40,000	1	$80,000	$80,000
	Total Cost of Ownership (3 Years)				$752,290	$594,788		$1,378,540	$1,092,748		$3,296,350	$2,616,635		$6,466,660	$5,136,442
	TCO/User (3 Years)				$752	$595		$689	$546		$659	$523		$647	$514

Figure 40. Avaya – Cascading, Bandwidth Per Specification, $120/Mbps/Month

Avaya Aura Conferencing 7.0 Deployment															
	Number of Employees			1000			2000			5000			10000		
	Number of Locations			4			6			10			20		
	Number of Simultaneous Video Calls			50			100			250			500		
	Video Calls/Location			13			17			25			25		
	Video Bandwidth/Call (kbps)			1536			1536			1536			1536		
	Number of Simultaneous Audio Calls			50			100			250			500		
	Audio Calls/Location			13			17			25			25		
	Audio Bandwidth/Call (kbps)			64			64			64			64		
	Calls Traversing the Firewall			50			100			250			500		
Cost Category	Item Description	Unit List Price	Street Discount	Qty	List Price	Street Price	Qty	List Price	Street Price	Qty	List Price	Street Price	Qty	List Price	Street Price
Hardware	Aura Conferencing 7.0 Application Server	$10,000	50%	1	$10,000	$5,000	1	$10,000	$5,000	1	$10,000	$5,000	1	$10,000	$5,000
	Aura Conferencing 7.0 Media Server	$16,000	50%	4	$64,000	$32,000	6	$96,000	$48,000	10	$160,000	$80,000	20	$320,000	$160,000
	Aura Conferencing 7.0 Web Server	$16,000	50%	1	$16,000	$8,000	1	$16,000	$8,000	1	$16,000	$8,000	1	$16,000	$8,000
	Aura Conferencing 7.0 Document Server	$8,000	50%	1	$8,000	$4,000	1	$8,000	$4,000	1	$8,000	$4,000	1	$8,000	$4,000
	Aura Session Border Controller	$8,000	50%	1	$8,000	$4,000	1	$8,000	$4,000	1	$8,000	$4,000	1	$8,000	$4,000
Software Licensing	Aura Conferencing 7.0 Audio/Web/Video w/Flare	$190	55%	1000	$190,000	$85,500	2000	$380,000	$171,000	5000	$950,000	$427,500	10000	$1,900,000	$855,000
Installation	Installation Costs	N/A	0%	1	$42,000	$42,000	1	$48,000	$48,000	1	$66,000	$66,000	1	$97,000	$97,000
	Total One Time Costs				$338,000	$180,500		$566,000	$288,000		$1,218,000	$594,500		$2,359,000	$1,133,000
HW/SW Maintenance	Aura Conferencing 7.0 Application Server	$900	0%	1	$900	$900	1	$900	$900	1	$900	$900	1	$900	$900
	Aura Conferencing 7.0 Media Server	$900	0%	4	$3,600	$3,600	6	$5,400	$5,400	10	$9,000	$9,000	20	$18,000	$18,000
	Aura Conferencing 7.0 Web Server	$900	0%	1	$900	$900	1	$900	$900	1	$900	$900	1	$900	$900
	Aura Conferencing 7.0 Document Server	$900	0%	1	$900	$900	1	$900	$900	1	$900	$900	1	$900	$900
	Aura Conferencing 7.0 Audio/Web/Video w/Flare	$27	24%	1000	$27,000	$20,520	2000	$54,000	$41,040	5000	$135,000	$102,600	10000	$270,000	$205,200
	Total Annual Maintenance Costs				$33,300	$26,820		$62,100	$49,140		$146,700	$114,300		$290,700	$225,900
Bandwidth	Remote Video Conferencing Participants				38			75			188			375	
	Number of Video Meetings/Remote Site				3			4			5			5	
	Remote Audio Conferencing Participants				38			75			188			375	
	Number of Audio Meetings/Remote Site				3			4			5			5	
	Total WAN Bandwidth Required (Mbps)				25			44			99			198	
	Bandwidth Cost/Mbps/Month	$120			$3,000	$3,000		$5,280	$5,280		$11,880	$11,880		$23,760	$23,760
Personnel Costs	Full Time Equivalents to Run Solution	$80,000		0.1	$8,000	$8,000	0.2	$16,000	$16,000	0.5	$40,000	$40,000	1	$80,000	$80,000
	Total Cost of Ownership (3 Years)				$569,900	$392,960		$990,380	$673,500		$2,205,780	$1,485,080		$4,326,460	$2,906,060
	TCO/User (3 Years)				$570	$393		$495	$337		$441	$297		$433	$291

Figure 41. Cisco – Non-Cascading, Bandwidth Per Specification, $120/Mbps/Month

Cisco TelePresence Deployment																
	Number of Employees			1000			2000			5000			10000		
	Number of Locations			4			6			10			20		
	Number of Simultaneous Video Calls			50			100			250			500		
	Video Calls/Location			13			17			25			25		
	Video Bandwidth/Call (kbps)			1300			1300			1300			1300		
	Number of Simultaneous Audio Calls			50			100			250			500		
	Audio Calls/Location			13			17			25			25		
	Audio Bandwidth/Call (kbps)			64			64			64			64		
	Calls Traversing the Firewall			50			100			250			500		
Cost Category	Item Description	Unit List Price	Street Discount	Qty	List Price	Street Price	Qty	List Price	Street Price	Qty	List Price	Street Price	Qty	List Price	Street Price
Hardware	Cisco TelePresence VCS	$12,360	42%	1	$12,360	$7,206	1	$12,360	$7,206	1	$12,360	$7,206	1	$12,360	$7,206
	Cisco TelePresence Conductor	$40,560	42%	1	$40,560	$23,646	1	$40,560	$23,646	1	$40,560	$23,646	1	$40,560	$23,646
	Cisco TelePresence MSE 8000	$60,960	42%	1	$60,960	$35,540	1	$60,960	$35,540	2	$121,920	$71,079	4	$243,840	$142,159
	Cisco TelePresence MSE 8510	$124,680	42%	3	$374,040	$218,065	5	$623,400	$363,442	13	$1,620,840	$944,950	25	$3,117,000	$1,817,211
	Cisco TelePresence TMS Suite Server	$1,742	42%	1	$1,742	$1,016	1	$1,742	$1,016	1	$1,742	$1,016	1	$1,742	$1,016
	Cisco TelePresence VCS Expressway	$12,360	42%	1	$12,360	$7,206	1	$12,360	$7,206	1	$12,360	$7,206	1	$12,360	$7,206
Software Licensing	Cisco TelePresence Management Suite	$3,648	42%	1	$3,648	$2,127	1	$3,648	$2,127	1	$3,648	$2,127	1	$3,648	$2,127
	Cisco TelePresence Management Suite Device Licenses - 10 pk	$3,648	42%	1	$3,648	$2,126.65	1	$3,648	$2,126.65	3	$10,944	$6,379.96	5	$18,240	$10,633.26
	Cisco Unified Workplace Licensing Professional Upgrade	$0	0%	1000	$0	$0	2000	$0	$0	5000	$0	$0	10000	$0	$0
	Cisco TelePresence VCS Traversal Licenses	Varies	42%	50	$63,840	$37,219	100	$67,162	$39,155	250	$270,000	$157,410	500	$528,240	$307,964
	Cisco Telepresence VCS Expressway	Varies	42%	50	$31,920	$18,609	100	$63,840	$37,219	250	$147,120	$85,771	500	$270,000	$157,410
	MSE 8510 Screen Licenses	$8,316	42%	50	$415,800	$241,164	100	$831,600	$482,328	250	$2,079,000	$1,205,820	500	$4,158,000	$2,411,640
	Windows Server 2008 (for TMS)	$999	0%	1	$999	$999	1	$999	$999	1	$999	$999	1	$999	$999
Installation	Installation Costs	30%	0%	1	$306,563	$178,477	1	$516,684	$300,603	1	$1,296,448	$754,083	1	$2,522,097	$1,466,765
	Total One Time Costs				$1,328,440	$773,400		$2,238,962	$1,302,613		$5,617,941	$3,267,692		$10,929,086	$6,355,981
HW/SW Maintenance	Cisco TelePresence VCS	$1,545	$990	1	$1,545	$989.59	1	$1,545	$989.59	1	$1,545	$989.59	1	$1,545	$989.59
	Cisco TelePresence Conductor	$5,070	$3,247	1	$5,070	$3,247.40	1	$5,070	$3,247.40	1	$5,070	$3,247.40	1	$5,070	$3,247.40
	Cisco TelePresence MSE 8000	$7,620	$6,828	1	$7,620	$6,827.95	1	$7,620	$6,827.95	2	$15,240	$13,655.90	4	$30,480	$27,311.80
	Cisco TelePresence MSE 8510	$15,585	$9,982	3	$46,755	$29,947.14	5	$77,925	$49,911.90	13	$202,605	$129,770.93	25	$389,625	$249,559.49
	Cisco TelePresence TMS Suite Server	$0	$0	1	$0	$0	1	$0	$0	1	$0	$0	1	$0	$0
	Cisto TelePresence Management Suite	$456	$292	1	$456	$292.07	1	$456	$292.07	1	$456	$292.07	1	$456	$292.07
	Cisco TelePresence Management Suite Device Licenses	Varies	19%	1	$456	$408	1	$456	$408	3	$1,368	$1,225	5	$2,280	$2,042
	Cisco Unified Workplace Licensing Professional Upgrade	$0	0%	1000	$0	$0	2000	$0	$0	5000	$0	$0	10000	$0	$0
	Cisco TelePresence VCS Traversal Licenses	Varies	19%	50	$7,980	$7,146	100	$8,395	$7,518	250	$33,750	$30,223	500	$66,030	$59,129
	Windows Server 2008 (for TMS)	$0	$0	1	$0	$0	1	$0	$0	1	$0	$0	1	$0	$0
	Total Annual Maintenance Costs				$69,882	$48,858		$101,467	$69,195		$260,034	$179,404		$495,486	$342,571
Bandwidth	Remote Video Conferencing Participants				38			75			188			375	
	Remote Audio Conferencing Participants				38			75			188			375	
	Total WAN Bandwidth Required (Mbps)				66			131			327			652	
	Bandwidth Cost/Mbps/Month	$120			$7,920	$7,920		$15,720	$15,720		$39,240	$39,240		$78,240	$78,240
Personnel Costs	Full Time Equivalents to Run Solution	$80,000		0.1	$8,000	$8,000	0.2	$16,000	$16,000	0.5	$40,000	$40,000	1	$80,000	$80,000
	Total Cost of Ownership (3 Years)				$1,847,206	$1,229,096		$3,157,284	$2,124,118		$7,930,683	$5,338,543		$15,472,184	$10,440,334
	TCO/User (3 Years)				$1,847	$1,229		$1,579	$1,062		$1,586	$1,068		$1,547	$1,044

Figure 42. Microsoft – Non-Cascading, Bandwidth Per Specification, $120/Mbps/Month

Microsoft Lync Video Deployment															
	Number of Employees			1000			2000			5000			10000		
	Number of Locations			4			6			10			20		
	Number of Simultaneous Video Calls			50			100			250			500		
	Video Calls/Location			13			17			25			25		
	Video Bandwidth/Call (kbps)			2500			2500			2500			2500		
	Number of Simultaneous Audio Calls			50			100			250			500		
	Audio Calls/Location			13			17			25			25		
	Audio Bandwidth/Call (kbps)			64			64			64			64		
	Calls Traversing the Firewall			50			100			250			500		
Cost Category	Item Description	Unit List Price	Street Discount	Qty	List Price	Street Price	Qty	List Price	Street Price	Qty	List Price	Street Price	Qty	List Price	Street Price
Hardware	Additional Front End Servers	$6,374	0%	0	$0	$0	0	$0	$0	2	$12,748	$12,748	5	$31,870	$31,870
	Edge Servers/Directory Servers	$6,374	0%	1	$6,374	$6,374	1	$6,374	$6,374	1	$6,374	$6,374	1	$6,374	$6,374
Software Licensing	Microsoft Lync Enterprise CAL	$107	25%	1000	$107,000	$80,250	2000	$214,000	$160,500	5000	$535,000	$401,250	10000	$1,070,000	$802,500
	Microsoft Lync Server 2010 Enterprise	$3,999	25%	1	$3,999	$2,999	1	$3,999	$2,999	3	$11,997	$8,998	6	$23,994	$17,996
Installation	Installation Costs	30%	0%	1	$35,212	$26,887	1	$67,312	$50,962	1	$169,836	$128,811	1	$339,671	$257,622
	Total One Time Costs				$152,585	$116,510		$291,685	$220,835		$735,955	$558,181		$1,471,909	$1,116,361
HW/SW Maintenance	Microsoft Lync Enterprise CAL	$27	15%	1000	$26,750	$22,738	2000	$53,500	$45,475	5000	$133,750	$113,688	10000	$267,500	$227,375
	Microsoft Lync Server 2010 Enterprise	$1,000	15%	1	$1,000	$850	1	$1,000	$850	3	$2,999	$2,549	6	$5,999	$5,099
	Total Annual Maintenance Costs				$27,750	$23,587		$54,500	$46,325		$136,749	$116,237		$273,499	$232,474
Bandwidth	Remote Video Conferencing Participants				38			75			188			375	
	Remote Audio Conferencing Participants				38			75			188			375	
	Total WAN Bandwidth Required (Mbps)				121			239			598			1192	
	Bandwidth Cost/Mbps/Month	$120			$14,520	$14,520		$28,680	$28,680		$71,760	$71,760		$143,040	$143,040
Personnel Costs	Full Time Equivalents to Run Solution	$80,000		0.1	$8,000	$8,000	0.2	$16,000	$16,000	0.5	$40,000	$40,000	1	$80,000	$80,000
	Total Cost of Ownership (3 Years)				$782,554	$733,992		$1,535,664	$1,440,290		$3,849,562	$3,610,251		$7,681,845	$7,203,223
	TCO/User (3 Years)				$783	$734		$768	$720		$770	$722		$768	$720

Figure 43. Polycom – Non-Cascading, Bandwidth Per Specification, $120/Mbps/Month

Polycom RealPresence™ Deployment																
	Number of Employees			1000			2000			5000			10000		
	Number of Locations			4			6			10			20		
	Number of Simultaneous Video Calls			50			100			250			500		
	Video Calls/Location			13			17			25			25		
	Video Bandwidth/Call (kbps)			1920			1920			1920			1920		
	Number of Simultaneous Audio Calls			50			100			250			500		
	Audio Calls/Location			13			17			25			25		
	Audio Bandwidth/Call (kbps)			64			64			64			64		
	Calls Traversing the Firewall			50			100			250			500		
Cost Category	Item Description	Unit List Price	Street Discount	Qty	List Price	Street Price	Qty	List Price	Street Price	Qty	List Price	Street Price	Qty	List Price	Street Price
Hardware	Polycom Resource Manager/CMA 5000	N/A	35%	1	$55,528	$36,093	1	$97,805	$63,573	2	$277,009	$180,056	4	$554,018	$360,112
	Polycom 800s	N/A	35%	1	$24,854	$16,155	0	$0	$0	1	$24,854	$16,155	0	$0	$0
	Polycom RMX 1500	N/A	35%	1	$118,779	$77,206	0	$0	$0	0	$0	$0	0	$0	$0
	Polycom RMX 2000	N/A	35%	0	$0	$0	1	$234,090	$152,159	0	$0	$0	0	$0	$0
	Polycom RMX 4000	N/A	35%	0	$0	$0	0	$0	$0	1	$408,068	$265,244	2	$816,136	$530,488
	Polycom DMA 7000	N/A	35%	1	$11,560	$7,514	1	$19,450	$12,643	1	$46,992	$30,545	1	$116,330	$75,615
	Polycom RealPresence Access Director	$27,922	35%	1	$27,922	$18,149	1	$27,922	$18,149	2	$55,844	$36,299	2	$55,844	$36,299
Software Licensing	Polycom RealPresence Desktop/Mobile	$0	0%	1000	$0	$0	2000	$0	$0	5000	$0	$0	10000	$0	$0
	Polycom Video Border Proxy Upgrade	$14,991	35%	0	$0	$0	0	$0	$0	1	$14,991	$9,744	2	$29,982	$19,488
Installation	Installation Costs	N/A	0%	1	$35,545	$35,545	1	$41,149	$41,149	1	$74,165	$74,165	1	$91,707	$91,707
	Total One Time Costs				$274,188	$190,663		$420,416	$287,673		$901,923	$612,208		$1,664,017	$1,113,709
HW/SW Maintenance	Polycom CMA 5000	N/A	35%	0	$23,815	$15,480	1	$47,630	$30,960	1	$76,877	$49,970	1	$153,754	$99,940
	Polycom 800s	N/A	35%	1	$10,180	$6,617	0	$0	$0	1	$10,180	$0	0	$0	$0
	Polycom RMX 1500	N/A	35%	1	$49,928	$32,453	0	$0	$0	0	$0	$0	0	$0	$0
	Polycom RMX 2000	N/A	35%	0	$0	$0	1	$96,558	$62,763	0	$0	$0	0		$0
	Polycom RMX 4000	N/A	35%	0	$0	$0	0	$0	$0	1	$228,840	$148,746	1	$351,597	$228,538
	Polycom DMA 7000	N/A	35%	1	$2,492	$1,620	1	$4,984	$3,240	1	$11,831	$7,690	4	$23,662	$15,380
	Polycom RealPresence Desktop	N/A	35%	0	$0	$0	0	$0	$0	0	$0	$0	0	$0	$0
	Polycom Video Border Proxy	N/A	35%	1	$11,454	$7,445	1	$11,454	$7,445	2	$16,328	$10,613	2	$16,328	$10,613
	Total Annual Maintenance Costs				$97,869	$63,615		$160,626	$104,407		$344,056	$217,019		$545,341	$354,472
Bandwidth	Remote Video Conferencing Participants				38			75			188			375	
	Remote Audio Conferencing Participants				38			75			188			375	
	Total WAN Bandwidth Required (Mbps)				95			187			467			931	
	Bandwidth Cost/Mbps/Month	$120			$11,400	$11,400		$22,440	$22,440		$56,040	$56,040		$111,720	$111,720
Personnel Costs	Full Time Equivalents to Run Solution	$80,000		0.1	$8,000	$8,000	0.2	$16,000	$16,000	0.5	$40,000	$40,000	1	$80,000	$80,000
	Total Cost of Ownership (3 Years)				$1,002,195	$815,908		$1,758,134	$1,456,733		$4,071,531	$3,400,706		$7,561,960	$6,439,043
	TCO/User (3 Years)				$1,002	$816		$879	$728		$814	$680		$756	$644

Figure 44. Polycom – Cascading, Bandwidth Per Specification, $120/Mbps/Month

Polycom RealPresence™ Deployment															
	Number of Employees			1000			2000			5000			10000		
	Number of Locations			4			6			10			20		
	Number of Simultaneous Video Calls			50			100			250			500		
	Video Calls/Location			13			17			25			25		
	Video Bandwidth/Call (kbps)			1920			1920			1920			1920		
	Number of Simultaneous Audio Calls			50			100			250			500		
	Audio Calls/Location			13			17			25			25		
	Audio Bandwidth/Call (kbps)			64			64			64			64		
	Calls Traversing the Firewall			50			100			250			500		
Cost Category	Item Description	Unit List Price	Street Discount	Qty	List Price	Street Price	Qty	List Price	Street Price	Qty	List Price	Street Price	Qty	List Price	Street Price
Hardware	Polycom Resource Manager/CMA 5000	N/A	35%	1	$55,528	$36,093	1	$97,805	$63,573	2	$277,009	$180,056	4	$554,018	$360,112
	Polycom 800s	N/A	35%	4	$99,416	$64,620	6	$149,124	$96,931	12	$298,248	$193,861	24	$596,496	$387,722
	Polycom RMX 1500	N/A	35%	0	$0	$0	0	$0	$0	0	$0	$0	0	$0	$0
	Polycom RMX 2000	N/A	35%	0	$0	$0	0	$0	$0	0	$0	$0	0	$0	$0
	Polycom RMX 4000	N/A	35%	0	$0	$0	0	$0	$0	0	$0	$0	0	$0	$0
	Polycom DMA 7000	N/A	35%	1	$11,560	$7,514	1	$19,450	$12,643	1	$46,992	$30,545	1	$116,330	$75,615
	Polycom RealPresence Access Director	$27,922	35%	1	$27,922	$18,149	1	$27,922	$18,149	2	$55,844	$36,299	2	$55,844	$36,299
Software Licensing	Polycom RealPresence Desktop/Mobile	$0	0%	1000	$0	$0	2000	$0	$0	5000	$0	$0	10000	$0	$0
	Polycom Video Border Proxy Upgrade	$14,991	35%	0	$0	$0	0	$0	$0	1	$14,991	$9,744	2	$29,982	$19,488
Installation	Installation Costs	N/A	0%	1	$47,423	$47,423	1	$41,149	$41,149	1	$74,165	$74,165	1	$91,707	$91,707
	Total One Time Costs				$241,849	$173,800		$335,450	$232,445		$767,249	$524,670		$1,444,377	$970,943
HW/SW Maintenance	Polycom CMA 5000	N/A	35%	0	$23,815	$15,480	1	$47,630	$30,960	1	$76,877	$49,970	1	$153,754	$99,940
	Polycom 800s	N/A	35%	4	$99,416	$64,620	6	$149,124	$96,931	12	$298,248	$193,861	24	$596,496	$387,722
	Polycom RMX 1500	N/A	35%	0	$0	$0	0	$0	$0	0	$0	$0	0	$0	$0
	Polycom RMX 2000	N/A	35%	0	$0	$0	0	$0	$0	0	$0	$0	0		$0
	Polycom RMX 4000	N/A	35%	0	$0	$0	0	$0	$0	1	$0	$0	0	$0	$0
	Polycom DMA 7000	N/A	35%	1	$2,492	$1,620	1	$4,984	$3,240	1	$11,831	$7,690	4	$23,662	$15,380
	Polycom RealPresence Desktop	N/A	35%	0	$0	$0	0	$0	$0	0	$0	$0	0	$0	$0
	Polycom Video Border Proxy	N/A	35%	1	$11,454	$7,445	1	$11,454	$7,445	2	$16,328	$10,613	2	$16,328	$10,613
	Total Annual Maintenance Costs				$137,177	$89,165		$213,192	$138,575		$403,284	$262,135		$790,240	$513,656
Bandwidth	Remote Video Conferencing Participants				38			75			188			375	
	Number of Video Meetings/Remote Site				3			4			5			5	
	Remote Audio Conferencing Participants				38			75			188			375	
	Number of Audio Meetings/Remote Site				3			4			5			5	
	Total WAN Bandwidth Required (Mbps)				30			53			122			243	
	Bandwidth Cost/Mbps/Month	$120			$3,600	$3,600		$6,360	$6,360		$14,640	$14,640		$29,160	$29,160
Personnel Costs	Full Time Equivalents to Run Solution	$80,000		0.1	$8,000	$8,000	0.2	$16,000	$16,000	0.5	$40,000	$40,000	1	$80,000	$80,000
	Total Cost of Ownership (3 Years)				$806,980	$594,895		$1,251,986	$925,129		$2,624,141	$1,958,113		$5,104,857	$3,801,671
	TCO/User (3 Years)				$807	$595		$626	$463		$525	$392		$510	$380

Figure 45. Vidyo – Non-Cascading, Bandwidth Per Specification, $120/Mbps/Month

Vidyo Deployment															
	Number of Employees			1000			2000			5000			10000		
	Number of Locations			4			6			10			20		
	Number of Simultaneous Video Calls			50			100			250			500		
	Video Calls/Location			13			17			25			25		
	Video Bandwidth/Call (kbps)			2000			2000			2000			2000		
	Number of Simultaneous Audio Calls			50			100			250			500		
	Audio Calls/Location			13			17			25			25		
	Audio Bandwidth/Call (kbps)			64			64			64			64		
	Calls Traversing the Firewall			50			100			250			500		
Cost Category	Item Description	Unit List Price	Street Discount	Qty	List Price	Street Price	Qty	List Price	Street Price	Qty	List Price	Street Price	Qty	List Price	Street Price
Hardware	VidyoRouter - Dedicated	$6,000	30%	2	$12,000	$8,400	2	$12,000	$8,400	6	$36,000	$25,200	10	$60,000	$42,000
	VidyoGateway	$6,510	30%	1	$6,510	$4,557	2	$13,020	$9,114	5	$32,550	$22,785	10	$65,100	$45,570
Software Licensing	VidyoDesktop (download from VidyoPortal)	$5	0%	1000	$5,000	$5,000	2000	$10,000	$10,000	5000	$25,000	$25,000	10000	$50,000	$50,000
	VidyoLine	$950	30%	50	$47,500	$33,250	100	$95,000	$66,500	250	$237,500	$166,250	500	$475,000	$332,500
Installation	Installation Costs	30%	0%	1	$21,303	$15,362	1	$39,006	$28,204	1	$99,315	$71,770	1	$195,030	$141,021
	Total One Time Costs				$92,313	$66,569		$169,026	$122,218		$430,365	$311,005		$845,130	$611,091
HW/SW Maintenance	VidyoLine	$171	30%	50	$8,550	$5,985	100	$17,100	$11,970	250	$42,750	$29,925	500	$85,500	$59,850
	VideoRouter	$600	30%	2	$1,200	$840	2	$1,200	$840	6	$3,600	$2,520	10	$6,000	$4,200
	VidyoGateway	$651	30%	1	$651	$456	2	$1,302	$911	5	$3,255	$2,278	10	$6,510	$4,557
	Total Annual Maintenance Costs				$10,401	$7,281		$19,602	$13,721		$49,605	$34,723		$98,010	$68,607
Bandwidth	Remote Video Conferencing Participants				38			75			188			375	
	Remote Audio Conferencing Participants				38			75			188			375	
	Total WAN Bandwidth Required (Mbps)				98			194			485			967	
	Bandwidth Cost/Mbps/Month	$120			$11,760	$11,760		$23,280	$23,280		$58,200	$58,200		$116,040	$116,040
Personnel Costs	Full Time Equivalents to Run Solution	$80,000		0.1	$8,000	$8,000	0.2	$16,000	$16,000	0.5	$40,000	$40,000	1	$80,000	$80,000
	Total Cost of Ownership (3 Years)				$570,876	$535,771		$1,113,912	$1,049,462		$2,794,380	$2,630,376		$5,556,600	$5,234,352
	TCO/User (3 Years)				$571	$536		$557	$525		$559	$526		$556	$523

Figure 46. Vidyo – Cascading, Bandwidth Per Specification, $120/Mbps/Month

Vidyo Deployment															
	Number of Employees			1000			2000			5000			10000		
	Number of Locations			4			6			10			20		
	Number of Simultaneous Video Calls			50			100			250			500		
	Video Calls/Location			13			17			25			25		
	Video Bandwidth/Call (kbps)			2000			2000			2000			2000		
	Number of Simultaneous Audio Calls			50			100			250			500		
	Audio Calls/Location			13			17			25			25		
	Audio Bandwidth/Call (kbps)			64			64			64			64		
	Calls Traversing the Firewall			50			100			250			500		
Cost Category	Item Description	Unit List Price	Street Discount	Qty	List Price	Street Price	Qty	List Price	Street Price	Qty	List Price	Street Price	Qty	List Price	Street Price
Hardware	VidyoRouter - Dedicated	$6,000	30%	4	$24,000	$16,800	6	$36,000	$25,200	10	$60,000	$42,000	20	$120,000	$84,000
	VidyoGateway	$6,510	30%	1	$6,510	$4,557	2	$13,020	$9,114	5	$32,550	$22,785	10	$65,100	$45,570
Software Licensing	VidyoDesktop (download from VidyoPortal)	$5	0%	1000	$5,000	$5,000	2000	$10,000	$10,000	5000	$25,000	$25,000	10000	$50,000	$50,000
	VidyoLine	$950	30%	50	$47,500	$33,250	100	$95,000	$66,500	250	$237,500	$166,250	500	$475,000	$332,500
Installation	Installation Costs	30%	0%	1	$24,903	$17,882	1	$46,206	$33,244	1	$106,515	$76,810	1	$213,030	$153,621
	Total One Time Costs				$107,913	$77,489		$200,226	$144,058		$461,565	$332,845		$923,130	$665,691
HW/SW Maintenance	VidyoLine	$171	30%	50	$8,550	$5,985	100	$17,100	$11,970	250	$42,750	$29,925	500	$85,500	$59,850
	VideoRouter	$600	30%	4	$2,400	$1,680	6	$3,600	$2,520	10	$6,000	$4,200	20	$12,000	$8,400
	VidyoGateway	$651	30%	1	$651	$456	2	$1,302	$911	5	$3,255	$2,278	10	$6,510	$4,557
	Total Annual Maintenance Costs				$11,601	$8,121		$22,002	$15,401		$52,005	$36,403		$104,010	$72,807
Bandwidth	Remote Video Conferencing Participants				38			75			188			375	
	Number of Video Meetings/Remote Site				3			4			5			5	
	Remote Audio Conferencing Participants				38			75			188			375	
	Number of Audio Meetings/Remote Site				3			4			5			5	
	Total WAN Bandwidth Required (Mbps)				32			55			126			252	
	Bandwidth Cost/Mbps/Month	$120			$3,840	$3,840		$6,600	$6,600		$15,120	$15,120		$30,240	$30,240
Personnel Costs	Full Time Equivalents to Run Solution	$80,000		0.1	$8,000	$8,000	0.2	$16,000	$16,000	0.5	$40,000	$40,000	1	$80,000	$80,000
	Total Cost of Ownership (3 Years)				$304,956	$264,091		$551,832	$475,862		$1,281,900	$1,106,376		$2,563,800	$2,212,752
	TCO/User (3 Years)				$305	$264		$276	$238		$256	$221		$256	$221

Disclosures

Your trust is important to us, and as such, we believe in being open and transparent about our financial relationships. With our clients' permission, we publish their names on our website.

The genesis for this report came from a conversation with Avaya. However, the entire report, including all research, content, editing, and modeling was under Constellation Research's full control. Furthermore, each vendor whose solution is covered in this report was given an opportunity to confirm the technical information and costs for their respective solution prior to publication. The analysis and conclusions are the author's alone. Avaya ultimately purchased exclusive worldwide rights to distribute this document.

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Dr. Brent Kelly is a Vice President and Principal Analyst at Constellation Research and President of KelCor, Inc. He focuses on the unique intersection of unified communications, social business, cloud services, video and mobility. Dr. Kelly provides strategy and counsel to key clients including Chief Information Officers, Chief Technology Officers, investment analysts, venture capitalists, technology policy executives, sell-side firms and technology buyers.

Prior to joining Constellation, Dr. Kelly served for 10 years as a partner at Wainhouse Research where he was the primary author of most of the firm's unified communications reports and forecasts. Dr. Kelly is a regular presenter at Enterprise Connect (formerly VoiceCon), the communications industry trade show where his well-respected, half-day tutorials have covered topics such as hosted and managed unified communications services, Microsoft Office Communications Server technical deep dives and IBM Lotus Sametime architectural reviews. He has also taught seminars in North America, Europe, Australia and South America.

Dr. Kelly has experience as the Vice President of Marketing for Sorenson Vision, an early innovator in the IP communications space, and he has served as the chief executive in a privately-held manufacturing company. Prior to this, Dr. Kelly was part of the team at Schlumberger that built the devices Intel used to test its Pentium microprocessors. He also led teams developing real-time data acquisition and control systems and adaptive intelligent design systems for use in several Schlumberger Oil Field services companies. His experience includes 4 1/2 years doing research and development in France.

He has worked as a research engineer for Conoco, implementing more efficient mathematical convergence methods for oil reservoir simulators, and as a process engineer for Monsanto. Dr. Kelly has a Ph.D. in engineering from Texas A&M University specializing in thermodynamics and a B.S. in engineering from Brigham Young University. He is serving in his second term as an elected official in his community.

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About Constellation Research

Constellation Research is a specialty research and advisory firm that serves business leaders who seek to unleash the power of emerging and disruptive technologies. Our research analysts start by understanding the business objective, applying real world experience and insights, and then incorporating disruptive technologies and innovative business models as appropriate.

We cater to board of directors, C-suite executives, and line-of-business leaders looking for an edge in business model and technology innovation. We help our clients combine the disruptive and traditional technologies in solving the tough business problems. Most importantly, our research outputs always provide an insightful buy-side point of view. We look forward to serving you with Insight, Inspiration, and Impact.

We're business leader and business value focused. Constellation differentiates itself by:

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2. Addressing the business problem first. Research starts by addressing business value and then applying where disruptive and emerging technologies may play a role.

Organizational Highlights

- Founded and headquartered in the San Francisco Bay Area, United States, in 2010.
- Named Institute of Industry Analyst Relations (IIAR) New Analyst Firm of the Year in 2011.
- Serving over 150 buy-side and sell-side clients around the globe.
- Growing firm with 35 members including 14 research analysts and futurists, 7 sales professionals, 4 professional staff, and a board of 10 industry-recognized advisors.
- Experienced research team with an average of 21 years of practitioner, management, and industry experience.
- Creators of the Constellation Supernova Awards - the industry's first and largest recognition of innovators, pioneers, and teams who apply emerging and disruptive technology to drive business value.
- Organizers of the Constellation Connected Enterprise - an innovation summit and best practices knowledge sharing retreat for business leaders.

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Endnotes

[1] Codec is an acronym for compression/decompression algorithms in a video conferencing endpoint.
[2] H.264 is an International Telecommunication Union (ITU) standard for recording, compressing, and distributing video. The ITU is a specialized agency which is part of the United Nations. It is responsible for international information and communication technologies.
[3] Quoted from http://www.excitingip.com/1063/h-264-svc-scalable-video-coding/, accessed on November 2, 2012.
[4] See http://blog.radvision.com/videooverenterprise/2011/02/15/ask-the-expert-svc-and-bandwidth-optimization/ accessed November 2, 2012.
[5] Friedel, Seymour A., Andrew W. Davis, and Ira M. Wienstein, "H.264 SVC: A Technical Assessment", 2009. Accessed November 2, 2012 at http://www.vidyo.com/documents/whitepapers/h.264%20svc-a%20technical%20assessment%20summary.pdf
[6] Note that Lync 2013 does not support H.263. Lync 2010 does support H.264. Also see http://social.technet.microsoft.com/Forums/en-US/ocscapacityplanning/thread/8bb71480-64d8-47f3-b639-0f4b7d3320ff for more details on the Microsoft codecs.
[7] The Vidyo clients do not support H.263 natively. A gateway is required to connect with H.263 endpoints. Vidyo asked that H.263 be placed in this list so that readers would not be misled into thinking that Vidyo does not support H.263 at all.
[8] Continuous presence is a video stream in which the video from multiple video endpoints can be seen simultaneously. In a continuous presence call, the MCU receives individual images from each endpoint and processes them into a single image. This single image is then returned to the video endpoints. Continuous presence is sometimes called "Hollywood Squares" video after the popular TV game show that showed a 3x3 vertical stack of open-faced cubes, each containing a celebrity.

Note that in a voice-activated switching call, no video is mixed. Only the audio is mixed. In such a video conference, the video image of the current or loudest is sent to other participants.
[9] There is more processing than is described here. The description in the body of the paper is somewhat simplistic. For example, there has to be some subtraction when mixing audio so that a speaker's own audio is not returned. There are many nuances with audio and video bridging, and other sources exist in which these can be explored.
[10] In addition to doing the processing necessary to create a composite video image, the MCU must have "jitter" buffers to reassemble packets that arrive out of order, a common occurrence on many networks.
[11] At least one H.264 SVC solution, that from Vidyo, also requires the media server even in point-to-point calls between Vidyo's H.264 SVC endpoints.
[12] Note that some solutions support conferences in which there is a mix of H.264 SVC and non-SVC endpoints. In this situation, some mixing will still occur for the video images returned to non-SVC endpoints.
[13] A cascading media relay server will mix the audio before sending it across the WAN. However, unless there are some controls placed on the video, cascading media relay servers could consume more bandwidth than a cascading MCU if multiple images are sent.

What would really happen in real life is that the administrator would cap the available WAN bandwidth available to the H.264 SVC endpoints so that the bit stream from each endpoint sending video through the cascading media relay server and onto the WAN would be reduced.

[14] Windows and iPad versions of the Avaya Flare Experience were announced in early 2012, but they did not include audio or video capability.

[15] The Web conferencing server provides users with Avaya's web conferencing solution while the document server is a repository or persistent library for files used during web conferences.

[16] Although not specifically announced, we believe Microsoft has licensed its H.264 SVC capability from Polycom. Polycom has repeatedly suggested that this is the case.

[17] See the Microsoft Lync Scenario-Based Capacity Planning guide at http://technet.microsoft.com/en-us/library/gg615029.aspx.

[18] See the Microsoft Lync 2013 planning guide at http://technet.microsoft.com/en-us/library/gg399060%28v=ocs.15%29.aspx for more details. Microsoft also recommends http://technet.microsoft.com/en-us/library/gg425833(v=ocs.15).aspx for reviewing Lync 2013 reference topologies.

[19] The Lync 2013 reference architecture will be similar to that of 2010. The author was unable to locate an adequate Lync 2013 reference architecture image. One change is that Microsoft has indicated that the A/V server role is built into the Front End Server. It is unclear what Microsoft means by this. In 2010, the A/V server role could be installed on its own server as well as co-resident with the Front End server role. Microsoft has not been clear as to whether the A/V server role can still be installed on a separate physical machine in Lync 2013.

[20] See http://technet.microsoft.com/en-us/library/jj688118(v=ocs.15).aspx for a list of the video resolutions and bandwidth Lync 2013 supports. See http://blog.schertz.name/2012/07/video-interoperability-in-lync-2013/ for more details on the video capabilities in Lync along with an excellent overview of video encoding and H.264 encoding particularly. Note that this reference incorrectly states the multipoint video conferencing in Lync 2013 is limited to 720p video.

[21] See http://technet.microsoft.com/en-us/library/jj688118%28v=ocs.15%29.aspx for more details on the multiple streams a single Lync 2013 client may send.

[22] See http://technet.microsoft.com/en-us/library/jj688118%28v=ocs.15%29.aspx for a full list of image sizes supported in Lync 2013.

[23] The 800s virtual video bridge has the same software as Polycom's RMX bridges. In its initial release, organizations must buy both the software and the server (Dell) from Polycom. Sometime in 2013, the company plans to release the 800s such that it can run as a virtual instance on a server blade that is not provided by Polycom.

[24] RealPresence Desktop combines and replaces the CMA Desktop software solution and the Telepresence m100 desktop software product.

[25] See http://www.vidyo.com/solutions/vidyoway/ for more details on Vidyo's VidyoWay cloud-based multipoint video conferencing service.

[26] The bandwidth in this table represents the worst case scenario for bandwidth usage. The average bandwidth during an actual call will clearly be much less than this. In addition, each vendor allows bandwidth to be throttled through administrator settings. We used these numbers, found in actual documentation or provided by the vendor, to

compare the worst case for the required bandwidth. Later in the document, we compare each solution using the same bandwidth.

[27] Although each solution is using H.264 AVC or SVC, the bandwidth varies widely. There a many reasons for this variation. Some of it is from the H.264 profile ID and levels used while some comes from "tuning" the encoding algorithms. Endpoint manufacturers can encode the video using proprietary encoding algorithms; the output, however, must be a bit stream that standards-based decoders can decode properly – if the vendor is truly standards based.

[28] A G.711 audio codec produces a bit stream of 64 kbps.

[29] Web conferencing bandwidth can fluctuate widely. If someone is doing desktop sharing, the bandwidth may go as high as 500 kbps. We use 30 kbps as an average because many times people are looking at a PowerPoint slide that is not building or transitioning.

[30] From discussions with Avaya. This number will ultimately be published.

[31] Web conferencing bandwidth can fluctuate widely. If someone is doing desktop sharing, the bandwidth may go as high as 500 kbps. We use 30 kbps as an average because many times people are looking at a PowerPoint slide that is not building or transitioning.

[32] See https://supportforums.cisco.com/docs/DOC-23366.

[33] Lync 2013 bandwidth characteristics may be found at http://technet.microsoft.com/en-us/library/jj688118%28v=ocs.15%29.aspx.

[34] From a Polycom support document that may be found at http://supportdocs.polycom.com/PolycomService/support/global/documents/support/user/products/video/m100_help_book.pdf

[35] From a Vidyo Technical Note titled, "Bandwidth Guidelines & Limitations, VidyoConferencing™ Best Practices".

[36] There are numerous references that discuss IP packet overhead. The following document accessed on September 21, 2012 describes 20 percent the packet overhead: http://www-10.lotus.com/ldd/stwiki.nsf/dx/Sametime_Audio_and_Video_Network_Bandwidth_Requirement.

[37] Vidyo's cascaded VidyoRouters will send up to three images from the remote location. If this is the desired situation, then the WAN bandwidth will need to be adjusted accordingly, or the tradeoff can be that the frame rate, image size or image quality can be diminished to fit in the same WAN bandwidth allocation.

[38] Today, the ratio of multipoint audio to video conferences is heavily skewed to audio conferencing. We use this scenario of 50% to reflect what pervasive availability and use of video could look like from a bandwidth scenario.

[39] In a recent RFP that included the option for the hosted UC vendor to provide WAN bandwidth, multiple vendors provided QoS-enabled WAN costs that were higher than $120/Mbps/month. So, $120/Mbps/month is not unreasonable.

[40] Some of the vendors have session border controllers that are different for audio and video. Cisco, for example, has voice gateways one would use with a telephony deployment. But when video is involved, a different video gateway is used, hence, this subtle distinction. The additional hardware and software costs for firewall traversal do not materially affect the calculation results.

[41] Prices came directly from the vendor or from vendor publications.

[42] In looking at the detailed calculations in the appendix, one may question why the Avaya SBC was not added to Avaya's costs when Cisco's Expressway SBC was. The logic is that

our baseline was an existing audio deployment. Avaya's SBC would have already been deployed in an Avaya Aura deployment and Avaya uses the same SBC for audio or video. In Cisco's case, the voice SBC is different from the video SBC - Cisco's Expressway video SBC. Hence, the Cisco VCS servers and VCS Expressway were added in to Cisco's costs. Including the SBC in Cisco's costs and not including the SBC in Avaya's costs does not affect the results materially in any case.

[43] The Polycom pricing is based on its 800s and RMX bridges and the specifications that were available at the time this report was completed. Exact pricing was not available, but Polycom suggested that we use pricing "similar" to the RMX 1500 bridge.

[44] An interesting side note is that Cisco is heavily promoting WebRTC. Furthermore, the company has supplied Mozilla with Cisco's own H.264 codec for the Mozilla Firefox browser version 18. At the time this report was completed, the Firefox browser was at version 16.

[45] At a recent analyst event, Cisco showed a video endpoint decoding H.264 AVC next to an endpoint decoding H.265 AVC along with a bandwidth meter for each endpoint. The H.265 AVC had equivalent quality to the H.264 AVC endpoint with approximately half of the bandwidth.

Vidyo has also demonstrated H.265 SVC at half of the bandwidth for equivalent video quality versus H.264 SVC.

[46] Microsoft actually states that its endpoints might send up to 8000 kbps if they are sending multiple streams, which can include RTVideo as well as up to five H.264 SVC video streams. For the calculations, we have kept with the specification for a single H.264 SVC video stream per Microsoft's documentation.

[47] See http://technet.microsoft.com/en-us/library/jj688118%28v=ocs.15%29.aspx for more details. This technical note is confusing as it does not really state how the Lync client and the Lync A/V server handle video. One may reasonably assume from the discussion of using Lync in a conferencing scenario that up to 8Mbps of bandwidth can be used and that the endpoints connect in a meshed fashion rather than video being routed through the Lync 2013 Front End Server.

[48] Putting Cisco hardware bridges would make sense in some other scenario where there is a large remote campus or many small offices that use a regional MCU.

[49] We say this because we do not have all of the ancillary pricing elements that will go into a Polycom 800s solution. We have made our best estimate on pricing based on guidance that Polycom gave us. Polycom did not fully check out the calculations in this document although it did provide comments on the textual description of Polycom's solution.

[50] Experience has shown that video conferencing in a business context is very different from using video in a family or close relationship setting. People will accept lower quality video where the relationships are very strong because, for example, they really want to see their mom or brother; however, in a business setting, video quality is much more important, hence, our caution about using non-QoS-enabled networks even for H.264 SVC and other variable bit rate video codecs.