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White Paper

Are You Getting a True Picture?

The Facts About KVM over IP, Bandwidth and Video

WHAT'S INSIDE

How to get high-resolution video without the need for increased bandwidth

EXECUTIVE SUMMARY

For many years, keyboard, video and mouse (KVM) switching has been used to simplify the administration of multiple computers. With the introduction of KVM over IP by Avocent in 2000, there is no longer a restriction for the administrator to be in the same physical location as the computer.

One of the most frequently asked questions about the requirements of a KVM over IP system is how much bandwidth does the system use? Unfortunately, there is no single answer to this question as there are many variables that affect the bandwidth used. This document will discuss some of these variables and provide measured results from a representative set of conditions for illustrative purposes.

With the Avocent DS Series KVM over IP system, an administrator uses DSView® software[1] on his local machine to connect to a remote target computer. The target computer is connected to a DS Series appliance. That appliance takes the analog video output of the target computer, digitizes and compresses it and sends the data across the IP network to the DSView session on the local computer. As the administrator types on the keyboard or moves the mouse, the DSView software will transmit that information across the IP network to the DS Series appliance.

[1] DSView software is a Win32 application or can be run in a standard browser with the DSWebview component. For this document, the Win32 DSView application was used for all testing.

The DS Series appliance then passes the keyboard and mouse information to the target device. The target device acts on that information and the result is a change on the video screen of mouse movements, new windows, characters, etc. Thus, the IP network must move the video and keyboard and mouse data between the administrator's DSView software session and the DS Series appliance connected to the target device.

Overview of KVM over IP network traffic

The communication between the DS Series KVM over IP appliance and the DSView software consists of three basic types of data. These are:

- Management data
- Keyboard and mouse data
- Video data

Management data **-** Management data is used to start and maintain the KVM session. Typically, these messages account for a very small part of the overall network bandwidth of a digital KVM session. This data includes verifying user authentication and access control as well as the reservation of the digital channel within the DS Series appliance.

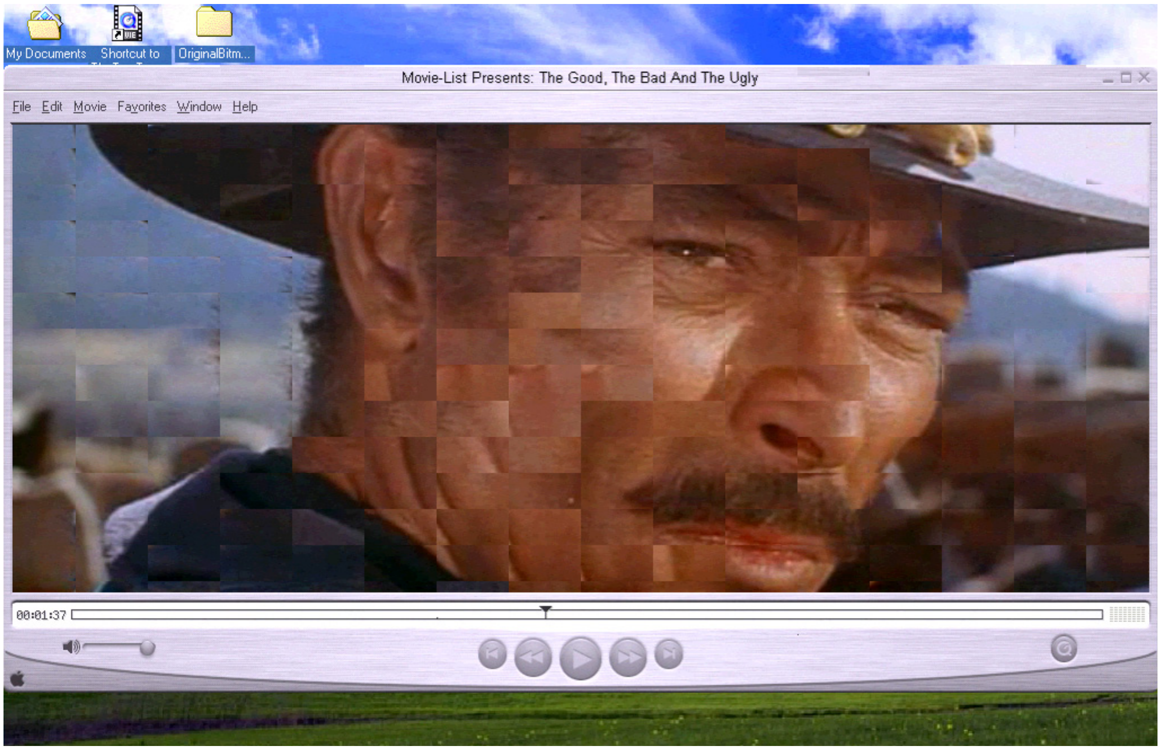
Keyboard and mouse data **-** When a keyboard key or a mouse button is pressed, two messages (a "make" and a "break") are generated. A series of messages is also generated when the mouse is moved. Depending on the timing of keyboard and mouse events, each of these messages may be sent as a separate TCP/IP packet, or multiple messages may be aggregated into a single packet. In most cases, the keyboard and mouse messages represent no more than a few percent of the total KVM traffic.

Video data **-** The majority of network traffic in digital KVM systems is related to video. In DS Series appliances, the initial video screen is drawn in its entirety. Subsequently, only video changes are encoded and sent across the network.

The video encoding system is an important component of digital KVM systems. Unlike movies, television, and video conferencing systems, KVM systems use "lossless" video compression techniques to exactly reproduce the target machine's video display.[2] This is necessary because computer screens typically contain icons, text, and other high-definition images that must be exactly reproduced by the KVM system. In 1024x768 mode, a single frame of video contains 786,432 pixels, which, at 16 color bits/pixel, corresponds to 12,589,912 bits (by reducing the color depth, the bits per frame is reduced as well). At 60 frames per second, the lowest typical screen refresh rate, a data stream of 754,974,720 bits/sec would be required to send full-resolution uncompressed video across the network. This is both undesirable and unnecessary.

In digital KVM systems, video is compressed by removing redundancy from the video signal. In general, the video data is compressed as much as possible while keeping the frame rate as high as possible. In 2003, Avocent introduced the Dambrackas Video Compression™ (DVC) algorithm. DVC, the industry-leading video compression technology, applies compression in three dimensions to dramatically reduce bandwidth. Unlike some competitors' video compression algorithms, DVC always provides full-screen updates to assure faithful reproduction of the target computer's video display by sending the changes from the previous whole video frame, not just certain blocks of the frame. The following screen shots from Test Case 5 clearly show the difference between the compression algorithms.

[2] "Lossless" video compression systems do, in fact, lose some video information. In particular, color depth is adjusted on a selectable basis and noise filtering can cause some subtle coloration changes to be lost between video frames. The term "lossless" refers to no loss of resolution in the video stream.



Screen Shot 1: Competitive Product Compression Algorithum

Screen Shot 2: Avocent Dambrackas Video Compression

The compression efficiency of DVC allows Avocent DS Series appliances to display a larger number of frames per second with a smaller amount of network traffic than competitive systems. In comparing systems, the number of frames per second transmitted affects both the speed of video update to the administrator as well as the amount of data transmitted.

KVM over IP bandwidth usage factors

A number of factors affect the amount of network traffic that KVM over IP systems use. These include usage type, color depth, screen size, available network bandwidth, and the KVM system's processing capacity. Each of these factors works in conjunction with the others to determine the actual network bandwidth utilization.

Usage scenario **-** The single most important factor affecting network bandwidth is the type of task being performed on the target computer. Today, the most typical task for the DS Series systems is server management by network administrators. This type of usage frequently involves installing and configuring software, moving between multiple applications, and editing text files. Server management tasks usually generate relatively few large-scale changes to the screen and rarely display continuous motion. In these applications, the DS Series appliances send bursts of network packets at high speed associated with the occasional large changes on the screen and use very little network bandwidth at other times. As is the case for many other network-based applications, KVM over IP traffic tends to be extremely bursty in nature with a high peak-to-average ratio. User-class applications such as web browsing may involve more high-resolution images and more large-scale screen movement. As a result, the bursts of high-speed KVM over IP data may be longer and more frequent. The worst case usage scenario for KVM over IP is full-screen, full-motion video, where there are large and frequent frame-to-frame changes and many video frames that must be redrawn in their entirety. This type of video source can cause a digital KVM appliance to produce a nearly continuous stream of high-speed network data.

Screen size **-** Encryption of data transmissions eliminates the possibility of critical systems being compromised by the interception of legitimate KVM sessions. The level of encryption that can be used is contingent on the ability of the OS, device and/or browser involved. Best KVM security practices should include 128bit SSL encryption and 3DES encryption – which encrypts, decrypts and re-encrypts data with three separate keys. In some cases, however, only 56bit DES encryption will be possible. Ideally, the KVM system will automatically implement the highest level of encryption that the environment can support in order to optimize security.

Color depth **-** Color depth (the number of colors that can be represented) is another factor that affects the network bandwidth used by the DS Series appliances. Video encoding algorithms rely on both spatial and temporal redundancy for compression. The more color changes there are in any given video frame, the less redundancy there is, and more data will be required to represent it. For solid colored backgrounds and text files, the choice of color depth makes relatively little difference, since there are a limited number of colors on the screen. For pictures and more complex (and colorful) patterns, the selection of color depth can make a much more significant difference.

Noise **-** The noise characteristics of the video source can also have a significant impact on the video bandwidth that the DS Series appliances use. If a video card or the environment in which it operates is particularly noisy, the DS Series appliance will be unable to correctly distinguish changes due to noise from intentional changes in the video signal. As a result, it will unnecessarily send indications of video changes. If this situation occurs, adjustments to the video source or the noise filter settings of the DS Series appliance may be necessary to improve performance.

Other considerations **-** Other considerations that may affect the network traffic produced by digital KVM appliances include the capacity of the KVM over IP system itself and the available bandwidth of the network. The design of the KVM over IP system, the network architecture, and the processing speed of the administrator's computer determine which part of the system is the "bottleneck" in a particular implementation. In any case, the DS Series KVM over IP system is designed to degrade gracefully when the system performance limit is reached by reducing the number of video frames per second as necessary to avoid overrunning the system.

Bandwidth measurement test results

In analyzing the network bandwidth usage data, it is important to remember that there are at least four important dimensions of performance measurement in KVM systems: (1) network bandwidth, (2) frames per second, (3) video quality, and (4) cursor responsiveness. It is easy to optimize any one of the measures at the expense of the others. The best designs are those that effectively balance all of these aspects of performance.

The following tables contain results for five test cases that are intended to represent typical and worst-case usage of KVM over IP systems. These cases are: (1) continuous mouse movement, (2) navigating text files, (3) Windows reboot, (4) Web browsing, and (5) a QuickTime movie trailer. Each test case was run using a typical target and client computers and network configurations.[3] The test cases were run with 1024x768 and 640x480 DSView software screen sizes[4] and with color settings of Best Color, Med Color/Med Compression, Low Color/High Compression, and Gray Scale/Best Compression. These color settings correspond to 15-, 12-, and 9-bit color and 3-bit grayscale, respectively. All tests were executed on an unconstrained network with the DSR® switch and client computer connected to the same 100M Ethernet switch.

For each test case, a table is included that gives measured network bandwidth data for an Avocent DSR1021 switch. In addition, Average Frames per Second is reported for Test Cases 1 and 5. For the other cases, Average Frames per Second is not meaningful, since all of the other test cases contain sections where video doesn't change for several consecutive frames. Video quality is largely subjective and is not specifically addressed here. Cursor responsiveness is directly related to the mouse latency.[5]

3 Target computer: Dell Dimension L566cx running Windows 2000 (for all except Test Case 3). Video set to 1024x768 @ 60 Hz.
Client computer: Dell Optiplex GX260 running Windows XP Professional.
Avocent Appliance: DSR1021 switch, version 2.0.1.6, with DSView software version 2.2.2.61
Network: Switched Full-Duplex 100Mbit/s

4 In the Avocent DS System, the DS appliance scales the video before sending it to the client computer. For all of the test cases shown, the target computer resolution remained at 1024x768.

5 Mouse latency consists of the time between a mouse movement on the client computer and the video updating to show the new mouse location.

Test Case 1: Continuous Mouse Movement

Video Mode	Color Mode	Average Bandwidth (Mbit/s)	Peak Bandwidth (Mbit/s)	Peak-to-Average Ratio	Average Frames per Second
1024 x 768	15-bit	0.30	0.47	1.4	19
	12-bit	0.29	0.41	1.6	19
	9-bit	0.27	0.35	1.3	19
	3-bit grayscale	0.25	0.29	1.2	18
640 x 480	15-bit	0.25	0.33	1.3	19
	12-bit	0.25	0.27	1.1	19
	9-bit	0.21	0.25	1.2	19
	3-bit grayscale	0.22	0.24	1.1	19

***Test Case 1* -** The first test case was continuous mouse movement, where a user manually moved the mouse in a continuous circular motion for 1 minute. This case was selected because mouse movement is one of the most typical user activities.

As can be seen from the data, continuous mouse movement generated about 19 frames/sec of video at 200 to 300 Kbit/sec. The low peak-to-average ratio indicated a relatively constant data stream, as would be expected from a continuous repetitive activity. The measured data includes all KVM related network traffic.

Test Case 2: Navigating Text Files

Video Mode	Color Mode	Average Bandwidth (Mbit/s)	Peak Bandwidth (Mbit/s)	Peak-to-Average Ratio
1024 x 768	15-bit	1.11	5.0	4.5
	12-bit	0.82	4.7	5.8
	9-bit	0.77	4.0	5.2
	3-bit grayscale	0.59	3.3	5.5
640 x 480	15-bit	0.59	2.5	4.2
	12-bit	0.45	2.8	6.3
	9-bit	0.43	2.7	6.3
	3-bit grayscale	0.32	1.7	5.2

***Test Case 2* -** The second test case was playback of a captured video sequence on the target computer. A 1 minute, 49 second video sequence was captured using netu2's mediaCam Version 2.8[6] software package. The sequence included (1) opening Windows Explorer, (2) opening two separate text files and scrolling through their contents, and (3) closing everything. The sequence is typical of the types of administrative tasks performed using KVM over IP systems. The video capture was a 20 Hz full-screen capture at 1024x768. Use of the video playback approach allowed the identical sequence of video frames to be analyzed in various modes.[7]

In reviewing the measurements, the peak-to-average ratio was relatively constant for all video cases and, at about 5, indicated that the test case generated a few peaks when large changes occurred and much less traffic at other times. It is also noteworthy that scaling down from 1024x768 to 640x480

6 Information on mediaCam can be found on the netu2 website at www.netu2.co.uk.
7 The network usage data did not include mouse movement information from the client computer to the target computer, since no movements were required during playback of the video sequence. As previously described, mouse traffic generally represents a small percentage of the total traffic, so the measured data should be representative even without the mouse movements.

(a factor of 2.5 in the number of pixels) accounted for about a 2-to-1 decrease in network traffic. Average Frames per Second was not meaningful for this test case, since there were several times in the video session where the screen was still momentarily and thus no frames of video were sent.

Test Case 3: Windows 2000 Reboot

Video Mode	Color Mode	Average Bandwidth (Mbit/s)	Peak Bandwidth (Mbit/s)	Peak-to-Average Ratio
1024 x 768	15-bit	0.83	12.2	14.7
	12-bit	0.73	16.5	22.6
	9-bit	0.72	12.5	17.4
	3-bit grayscale	0.44	14.0	32.2
640 x 480	15-bit	0.44	4.5	10.2
	12-bit	0.37	4.8	13.0
	9-bit	0.33	3.5	10.6
	3-bit grayscale	0.19	3.0	15.6

***Test Case 3* -** The third test case was the reboot of the target computer. Here, network traffic was captured and analyzed, beginning with clicking on the Shut Down button in the Windows menu and ending when the Windows desktop was completely redrawn after the restart.[8]

As with the previous test case, no Average Frames per Second measurement is given, since there were several segments of the boot sequence where no video changes occurred for a period of time. The peak utilization was based on a single frame spike related to the shutdown screen, and the measured peak utilization results varied substantially based on the alignment of that usage spike with the measurement window. In any case, the high peak-to-average ratio values are indicative of the bursty nature of traffic during the startup process.

Test Case 4: Web Browsing

Video Mode	Color Mode	Average Bandwidth (Mbit/s)	Peak Bandwidth (Mbit/s)	Peak-to-Average Ratio
1024 x 768	15-bit	1.65	8	4.8
	12-bit	1.54	6.5	4.2
	9-bit	1.15	5	4.4
	3-bit grayscale	0.80	3.7	4.6
640 x 480	15-bit	0.85	4	4.7
	12-bit	0.68	3.4	5.0
	9-bit	0.60	3	5.0
	3-bit grayscale	0.44	2.3	5.3

***Test Case 4* -** The fourth test case was the playback of another video capture using the methodology described above for Test Case 2. A 2 minute, 46 second Web browsing session was recorded. Internet Explorer was used to open and scroll through several Web pages, including www.msn.com,

[8] A different target computer (an Acer Emerge 2000 running Windows 2000) was used for this test case. The Dell L566cx computer was unusually slow at rebooting. As such, it would have skewed the results and given inappropriately low network bandwidth numbers.

www.foxnews.com, and www.weather.com. This case was intended to be representative of typical user-class applications. Note that, while the total bandwidth was somewhat greater due to the larger amount of graphical content, the patterns in the usage data were strikingly similar to Test Case 2.

Test Case 5: Movie Trailer

Video Mode	Color Mode	Average Bandwidth (Mbit/s)	Peak Bandwidth (Mbit/s)	Peak-to-Average Ratio	Average Frames per Second
1024 x 768	15-bit	12.0	27	2.3	17
	12-bit	9.9	23	2.3	18
	9-bit	8.6	17	2.0	19
	3-bit grayscale	4.5	11	2.4	20
640 x 480	15-bit	8.0	18	2.3	20
	12-bit	6.4	15	2.3	20
	9-bit	4.5	10	2.2	20
	3-bit grayscale	2.2	5	2.2	20

Test Case 5 - The fifth and final test case was a full-motion QuickTime movie trailer. The selected trailer was for the movie *The Good, The Bad and The Ugly* (good-the-bad-and-the-ugly.mov[9]). The QuickTime viewer was set to show the trailer at its native size of 640x264 on the standard 1024x728 screen. This particular trailer was chosen because it is especially difficult for KVM over IP systems due to its frequent use of panning and full-screen changes, along with its noisy, grainy backgrounds.

While this test case was certainly not typical of KVM over IP usage, it was instructive in that it represented a worst-case scenario in several ways. The noisy, specked backgrounds stressed the video encoding algorithm's ability to distinguish changes from video noise. In addition, several scenes contained subtle color variations that showed the capabilities (and limitations) of the video encoding algorithm. Finally, the large number of color variations rendered some parts of the video sequence nearly incompressible, requiring very high instantaneous transfer rates to faithfully reproduce the video clip.

In this test case, the DSR switching system maintained an average of 17 to 20 frames per second with an average of 2.2 to 12 Mbits/sec, depending on screen size and color depth. The peak-to-average ratio of about 2.3 was indicative of the continuous nature of large-scale changes in the video clip.

9 The movie trailer is available from http://www.rottentomatoes.com/m/TheGoodtheBadandtheUgly-1008619/trailers.php?rtp=1

CONCLUSIONS

The above test cases indicate the network bandwidth utilization of Avocent DSR series switches should typically be in the range from a few hundred Kbits/sec to about 1.5 Mbits/sec for administrative and user-class tasks. Usage spikes can push momentary usage above 20 Mbits/sec, but, from a network planning perspective, there is little reason to allocate bandwidth for that type of usage on a sustained basis. The system is capable of producing good video quality for more demanding tasks such as full-motion video, and occasional use of this type shouldn't significantly affect network planning.

The test data demonstrates that users can affect the network bandwidth by minimizing variation and changes in colors. This can be done by using solid colored backgrounds and disabling screen savers. The Avocent scaling feature in the DSView software reduces screen size and can reduce bandwidth usage by as much as 2-to-1. If high color video is not required, bandwidth can be minimized by using a lower color setting. There are several other bandwidth saving features in the Avocent DSView client software. When a viewing session is minimized to the toolbar, the video stream is turned off until the window is reopened. When multiple viewing windows are open, any window that is not in "focus" is updated periodically.

The tests cases were run on an unconstrained 100Mbps network. When the DS Series system is used on a slower network or other connection, the system will slow the video stream to match the capabilities of the communication channel. Communications between the DSR switch and the DSView client software allow the DSR switch to monitor the transmission of the video data stream. The DSR switch will adjust the frequency of frames transmitted from the appliance to the client software to match the capacity of the LAN or WAN connection. The DS Series system does not require user interaction to maximize performance of the video connection as this adjustment is made automatically by the DSR appliance. This maximization is performed on each connection between a DSR appliance and the DSView client software. Thus, if a user switches between a local DSR connection on a high speed LAN and a remote DSR connection the system will adjust the video stream without intervention from the user.

The DS Series system has been tested on connections ranging from 28.8kbps modem connections through 100Mbps Ethernet connections. The visible difference between these connections is in the frames per second the DSR switch can transmit to the DSView client software. To provide the best performance on slower channels, minimum screen sizes and minimum color settings should be used. Screen sizes can be changed easily by scaling the DSView client image rather than adjusting the resolution of the target device.

ABOUT AVOCENT CORPORATION

Avocent (NASDAQ:AVCT) is the leading worldwide supplier of KVM (keyboard, video and mouse) switching, remote access, and serial connectivity solutions that provide IT managers with access and control of multiple servers and network data center devices. Branded products include switching, extension, intelligent platform management interface (IPMI), remote access, and video display solutions. Avocent KVM solutions are distributed by the world's largest server manufacturers and installed in Fortune 100 companies around the world. Visit www.avocent.com for more details.

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