Accelerating WebGIS (ArcIMS® et al) with Image Web Server

Technical Overview & Performance Analysis

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Note: Whilst every care has been taken to ensure the accuracy of details in this document such as (but not limited to) Product Specifications, Features, Pricing and Performance Analysis, **ABSOLUTELY NO GUARANTEE IS GIVEN AS TO THEIR ACCURACY**. We strongly recommend anyone using this information to perform their own research and analysis to verify any required details prior to making any decision based on this document.

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Overview

ECW, ECWP and Image Web Server provide a practically unique imaging solution in the spatial imagery market today. As a family of products combined with ER Mapper along with the numerous free application plugins, they provide an end-to-end imaging solution ranging from data preparation, distribution and use of high-resolution spatial imagery in today's GIS solutions.

This document is an analysis of ECW, ECWP and Image Web Server with other technologies available and demonstrates - based on available evidence - the compelling advantages of using ECW-based technologies as an integral part of a **WebGIS** solution. WebGIS is a term used to refer to any web-based GIS solution such as ArcGIS®, MapXtreme® and MapGuide®, which provide client access to GIS services on a server across the Internet.

All pricing in this document is in US$, and is based on available pricing data.

WebGIS (ArcIMS et al) Performance Characteristics

Serving large amounts of imagery quickly to users across an intranet or the Internet is challenging. The Image Web Server is the perfect solution to enhance GIS servers such as ArcIMS®, MapXtreme®, MapGuide® and many other products. By adding the Image Web Server to a GIS web server site, fast imagery access and lower CPU and network bandwidth can be achieved in a very cost-effective manner.

It is important to note that the Image Web Server is used along side your GIS server, such as ArcIMS®, to enhance access to imagery whilst reducing server resource requirements. In other words, the Image Web Server acts as an enabling and accelerating agent to significantly improve performance. This provides the strong benefits of using Image Web Server and the WebGIS in a combined solution, at a reduced total cost.

This document benchmarks integration of ArcIMS® with Image Web Server as a specific example of enhanced imagery access in a current state-of-the-art WebGIS solution. The concepts and improvements detailed in this document also apply to other GIS servers, and their performance typically represents what is shown by ArcIMS®.

Image Web Server is a product of Earth Resource Mapping, who also offers the ER Mapper product for preparing imagery and a wide range of free Enhanced Compressed Wavelet (ECW) plugins for accessing imagery within desktop applications. Earth Resource Mapping's products include Image Web Server, ER Mapper and ECW. These products are not associated in any way with ESRI® (producers of ArcIMS®), MapInfo® (producers of MapXtreme®) and Autodesk®(producers of MapGuide®).

Earth Resource Mapping has made every effort to provide accurate information in this document. Please notify us should you require clarification or detect any errors.

Test Configuration

To compare the different technologies on an equal footing, the following test configuration was used:

Server: Dual P3 450MHz Dell server, 512MB PC100, Windows 2000 Server with SP2

Network: 100MB LAN

Test Harness

- Custom test client pages utilizing 1.7 ActiveX client.
- Customized script enabling exact replay of test
- GIS Overlay functionality to ensure identical client requests (same view size & extents)
- Sequence of ~46 views were employed (see appendix)
- Test employed a “click-zoom” ArcIMS type interface.
- Test harness runs in a continual loop
- Test imagery consisted of an ~250MB TIFF file (ArcIMS) compressed to a 9MB ECW file of the same dimensions (Image Web Server).

Note: The test involved blocking the client until 100% of the imagery was available. This was to ensure parity of the test between the different technologies. However, in real-world applications an Active Zoom interface would be used, thus improving the figures for the Image Web Server accelerated solution.

Raw Results

As the test was run, the average actual Response Time (time between view-change and image-display), IO Bandwidth (Network and Disk) used and %CPU used were recorded after several minutes of continuous activity seen in figure 1

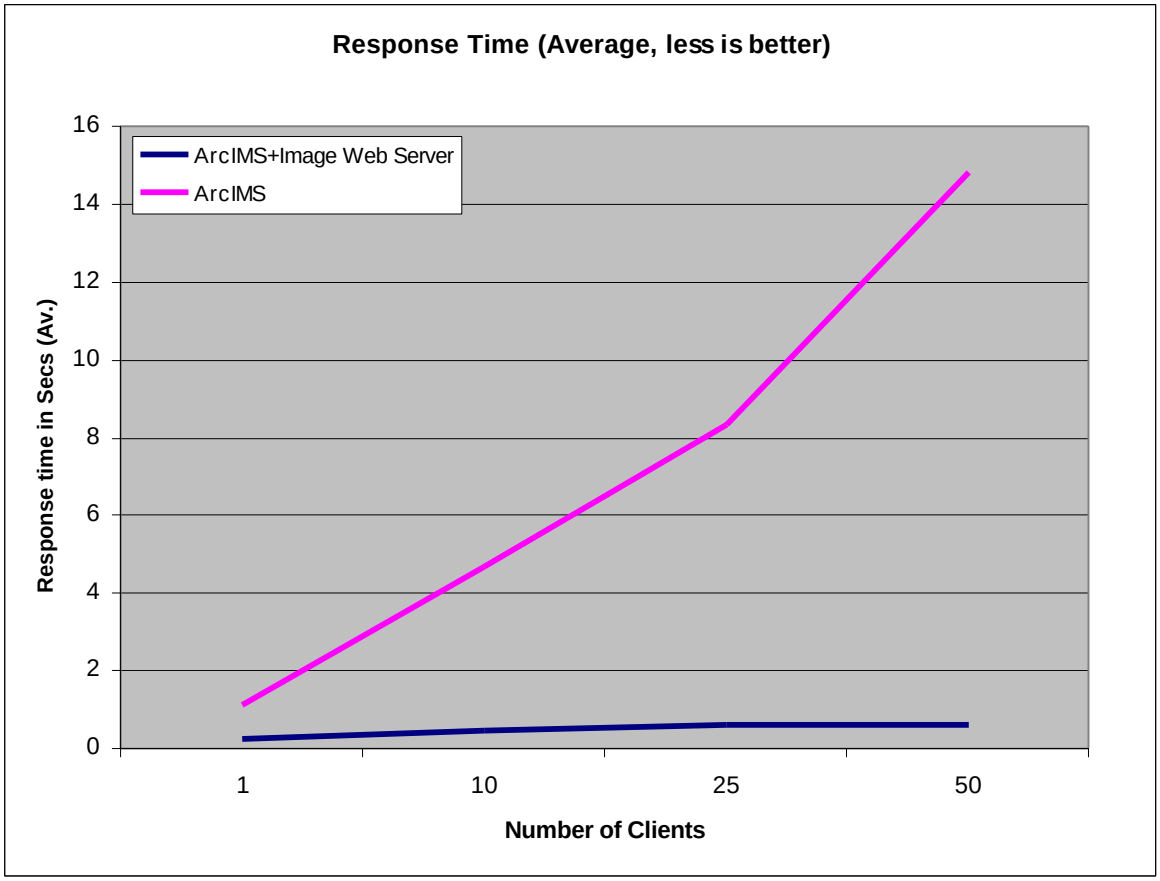

Fig 1

As can be seen in the Response-Time test, the responsiveness of the server is directly proportional to the load on the server. As the server is heavily loaded with a sub-setting server, with only a handful of clients connected the response times rapidly become unusable. The load on the server can be seen in the CPU Load Performance graph below.

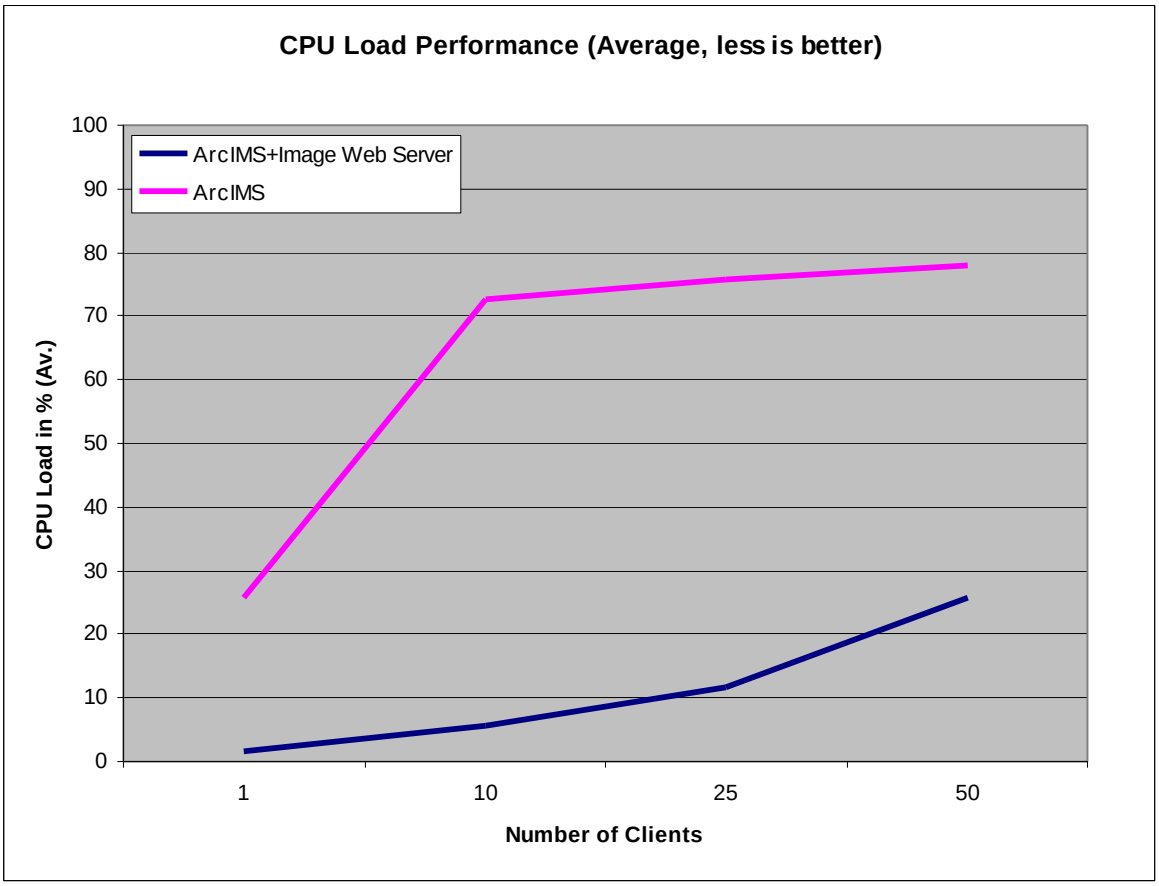

Fig 2

The result for the CPU Load Performance measurement shows the sub-setting server rapidly saturates the CPU resources of the system – see figure2. With approximately 25% usage for a single client, it actually saturates the CPU with only 3-4 concurrent clients. The rapid increase in response-time is a direct result of the CPU saturation. On the other hand with the integrated solution only 25% CPU is used with 50 concurrent clients. It was easily able to maintain a sub-second response time versus the previous result over 14 seconds.

I/O Performance of the server also falls off considerably when the CPU becomes saturated and the response times become excessive. This can be seen in the I/O Performance Graph.

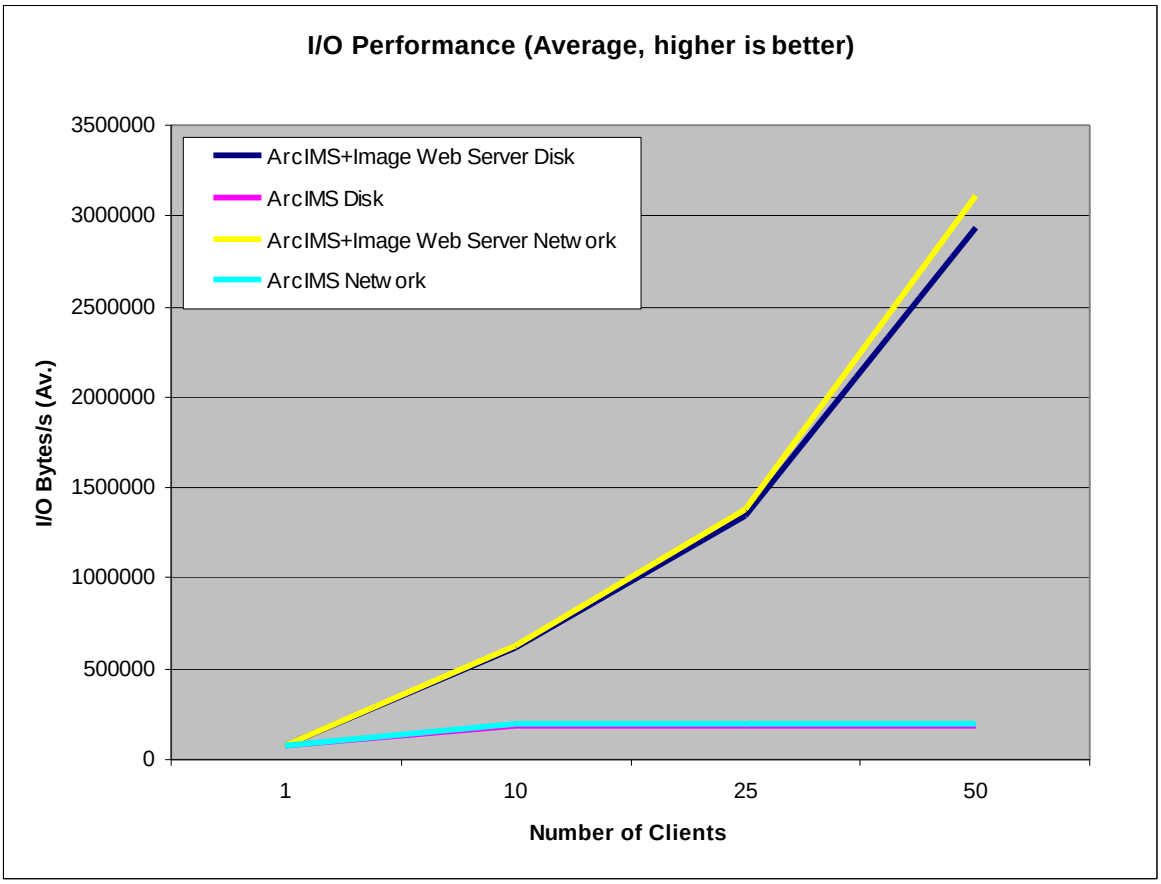

Fig 3

This result shows Image Web Server accelerating the I/O performance to over 3MB/sec with 50 clients, whereas due to the extreme response times, the sub-setting server's I/O rates flat-line at approximately 200KB/sec – refer figure 3.

Normalised Results

Due to the extreme response times affecting the results for the sub-setting server, the results were normalised to a 1-second response time, i.e. to achieve a 1-second response time (the time between changing the view and the updated image being served and displayed), what hypothetical I/O bandwidth and CPU Performance is required?

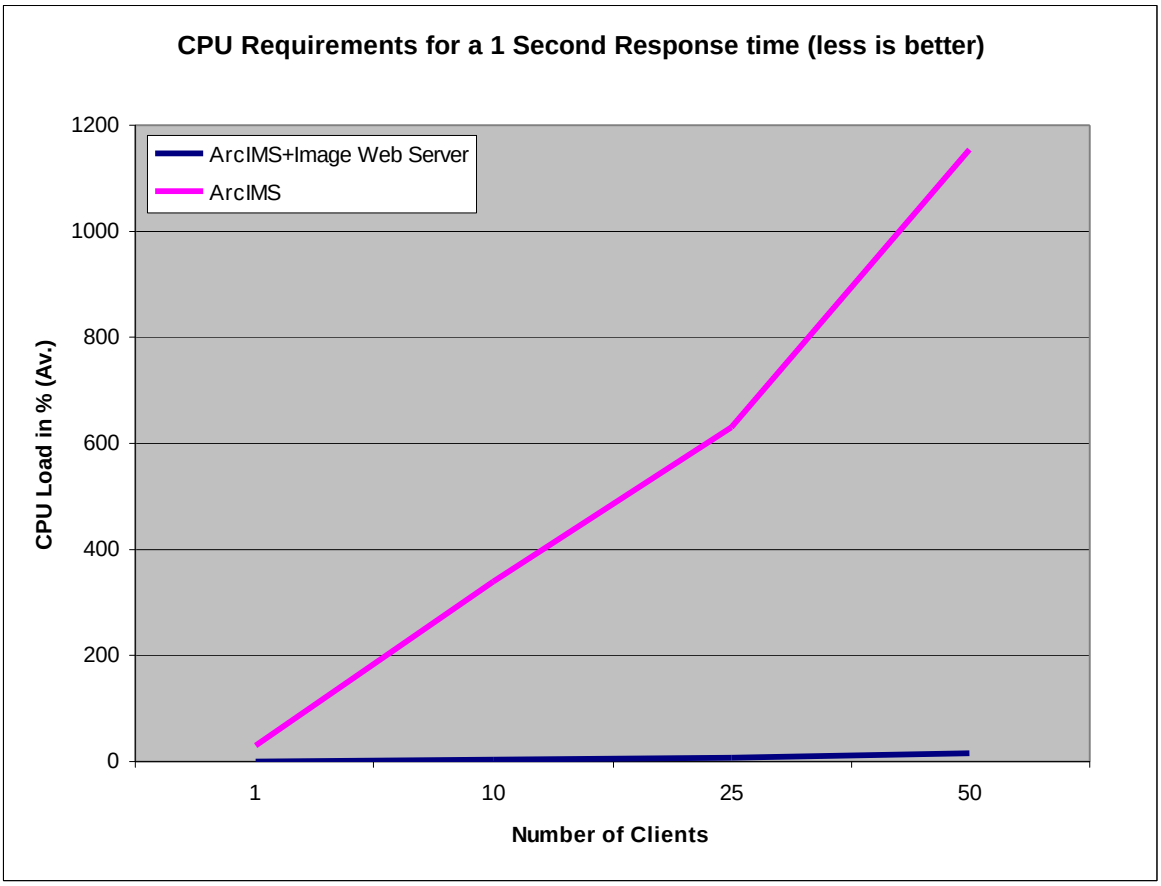

Figure 4

To achieve a 1-second Response Time with 50 clients, the integrated solution using Image Web Server requires only 16% of the available CPU on the server used for these tests refer figure 4. Without the Image Web Server accelerating the sub-setting server it requires approximately 1150% - 11.5x the CPU power available!

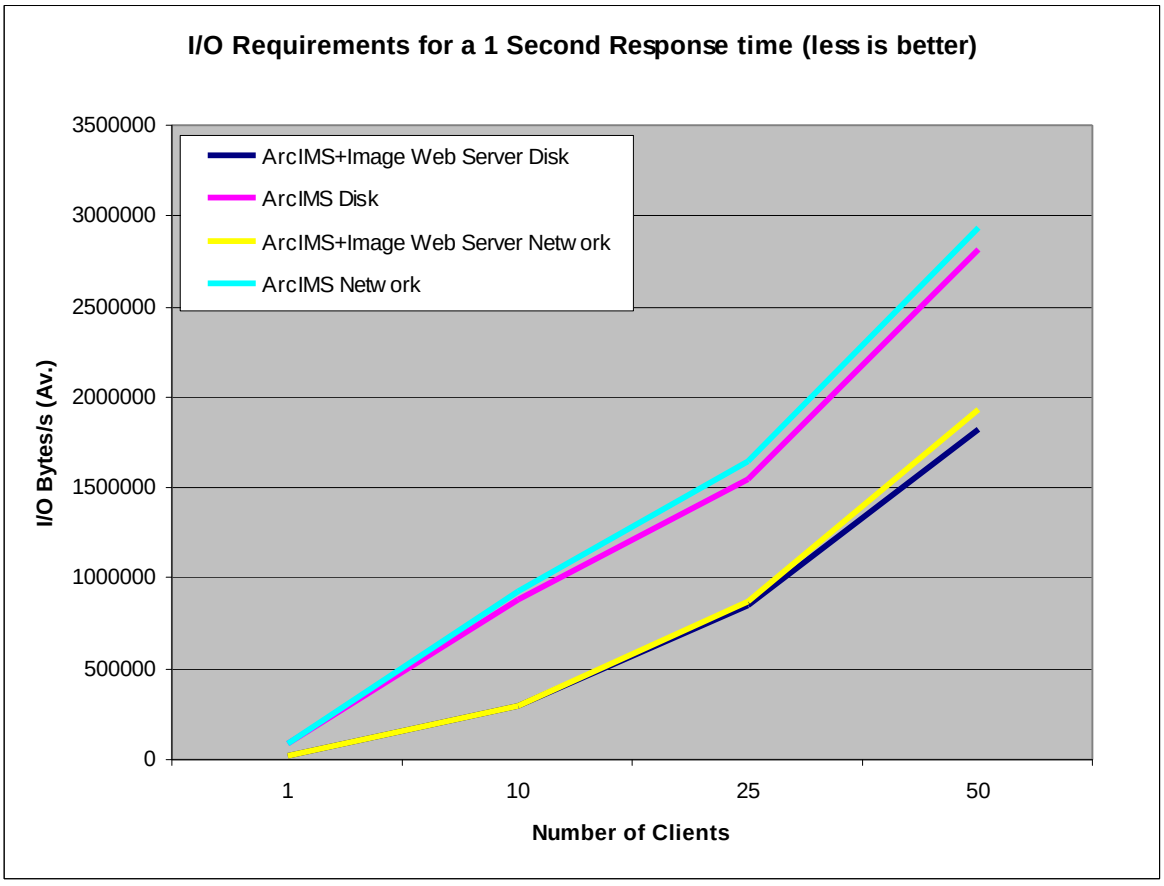

Fig 5.

To achieve a 1-second Response Time with 50 clients, the integrated solution using the Image Web Server requires approximately 2MB/sec I/O bandwidth, refer to figure 5. Without the Image Web Server, the accelerating of the sub-setting server requires approximately 3MB/sec I/O bandwidth.

Conclusions

The conclusion drawn from these results are as follows:

1. A sub-setting server typically requires ~60x the CPU power to achieve the same level of performance as a combined solution using Image Web Server.
2. A sub-setting server typically requires ~1.5x the I/O bandwidth (disk and network) to achieve the same level of performance as a combined solution using Image Web Server.

To calculate a Hardware + Software capital cost for the 1-second response normalised results, 2 Dell Servers were priced:

1. Dell PowerEdge 500SC Server, 1xP3@1150Mhz with 512KB Cache, 512MB RAM, 20GB HD, **US$1,852.00**. (Note, this is the cheapest Dell server currently available of equivalent performance to the test system)
2. Dell PowerEdge 6400 Server, 4xP3 Xeon@900MHz with 2MB cache, 512MB RAM, 20GB HD, **US$28,319** (Estimated to have ~12x the CPU performance of the test system)

Pricing available on ArcIMS indicates the initial license is US$10,000, + US$9,000 per additional CPU. Using these figures, the total cost for either raster serving solution is:

	Hardware	**Base Software**	**+Additional CPU licenses**	**Total**
ArcIMS + Image Web Server	$1,852	$20,000	$0	$21,852
ArcIMS	$28,319	$10,000	$27,000	$65,319

However, even powered with high-end hardware, a sub-setting solution will still not match a combined solution with Image Web Server, as it requires approximately 50% more network bandwidth between each client and the server. As client bandwidth is almost always fixed and outside the control of the implementation, this will limit the ultimate performance of such a solution to approximately two-thirds that of the significantly cheaper combined Image Web Server option.

Accelerating WebGIS with Image Web Server

The patented ECW and patent-pending ECWP technology enables Image Web Server to make terabytes of imagery available in real-time over a broad range of connectivity speeds such as dialup-modems and broadband connections through to high-speed fibre links. Due to it's decoupled architecture, even modest performance servers hardware can satisfy several hundred or even thousands of simultaneous users.

Image Web Server Technical Overview

Referring to the ECW Technical Overview in later sections, the ECWP Protocol enables the decoupling of the ECW Block data reading from the image decompression phase. With ECWP the requesting and the reading of the block data is asynchronously decoupled from the decompression. This allows the client application to continue using whatever data is available in the cache whilst the server is performing the read operation and sending the ECW block data to the client. This even allows the client to cancel reading of a block asynchronously if the application has changed the view, for example in response to user input.

The process of reading an ECW file *via* ECWP is as follows:

1. When an image is first opened by an application such as *ER Viewer*, the file header is read into memory *by the server and transmitted to the client*, which then determines the physical dimensions of the file and the correct decoding structure is built in memory. Normally the offset table is read into memory *by the server*. The physical dimensions of the file (width, height, #bands etc) and metadata such as the registration details are made available to the application (at the SDK level, this correlates to the Open() call).
2. When the application decides to read a "view" from the file (that is, a subset or complete set of the data), the view structure is built in memory. The client checks to see what blocks are already cached at the client side. If any additional blocks are required, a *list of required blocks is then sent to the server which determines the* locations of the appropriate blocks of data from the offset table, the data is read into memory *by the server, then transmitted back to the client* as compressed blocks (the client will later decompress the blocks as required). The application can read any number of views from the file without needing to close and re-open the file, and much of the data will be cached between views (at the SDK level, this correlates to the SetView() and Read() calls). *If blocks are have been requested from the server and haven't arrived yet, they can be cancelled by the client if no longer required for the current view.*
3. Once the application has finished with the file, the view and file structures in memory are released (at the SDK level, this correlates to the Close() call). *The Server will close the file after a predetermined amount of time has elapsed.*

The highlights in *italics* are the differences when reading a file via ECWP. As can be seen the process is similar to reading the file locally, except there is a transmission layer. The work done by the server is very simple, it primarily just received lists of block numbers from the client to either read or transmit or cancel if still outstanding. This requires very little system resources to perform, especially compared to traditional approaches.

The Traditional Approach to Image Serving.

The traditional approach to an image server is for the client to request a specific image from the server, either a complete image or a specific subset. What happens then depends on which approach is taken:

- If it's a complete image, it acts the same as an FTP server and transmits the entire file to the client. This file may be many MB's in size and can take many minutes to transmit.
- If a subset image is requested, the server will read the source image into memory, which may take many MB and require a decompression phase if the source image is compressed. The subset is then extracted, and will typically be re-compressed into a format such as JPEG, GIF or PNG. The subset image, which may be several 100KB in size, is then transmitted back to the client. This approach consumes vast amounts of CPU and memory resources on the server for even a small number of requests at a time. Also typically during this the client is blocked waiting on the subset to be sent, which may take several seconds to many minutes.

Now compare it to Image Web Server & ECWP:

- Server receives a small list (<1KB) of block numbers from the client
- Server reads the blocks into memory (typically only a few KB each).
- Server sends the blocks back to the client.

Obviously the Image Web Server approach requires significantly less resources than a sub-setting server.

Image Web Server and WebGIS Integration Techniques

Image Web Server can be integrated into an existing WebGIS solution in a number of ways. This may consist of simply installing the software and running a wizard, or may require custom website development work depending on the requirements of the individual site. The typical approach for an existing ArcIMS site:

1. Image Web Server is installed onto the server and configured.
2. ECW imagery is prepared and placed on the server.
3. **I-Wizard** is used to integrate Image Web Server into the existing ArcIMS site built with ArcIMS Designer. I-Wizard is free and no custom HTML/JavaScript coding required – only a couple of mouse clicks.
4. Integration is complete, you may now utilise the integrated site.

Solution Comparison

To demonstrate the competitive advantages of an integrated WebGIS solution using Image Web Server we will compare it to a typical current image sub-setting solution.

ArcIMS+Image Web Server Acceleration		
	ArcIMS+Image Web Server 1.7 Office/Corporate/Enterprise	**ArcIMS 3.1**
Price	$20,000/$30,000/$60,000	$10,000 + $9,500 per CPU
Maximum File Size	10GB/100GB/Unlimited	2GB
Maximum # Users	100/1000/Unlimited	Low*
Technology	Streaming ECWP	Sub-setting
Connectivity/Protocol	ECWP, ArcXML, GML	ArcXML, GML
Browser Clients	HTML, ActiveX (Windows), Netscape (Windows, Macintosh), Java	HTML, Java
Desktop GIS Clients	MapInfo, ArcView 3.x, ArcGIS 8.1, SmallWorld, AutoCAD MAP, MapObjects, MapX, ArcPAD, GML clients + more	ArcView 3.x, ArcGIS 8.x, MapObjects, ArcPAD
Other Desktop Clients	ER Mapper, ER Viewer, MS Office, AutoCAD, PhotoShop, PaintShop Pro, +dozens more.	None
Installation & Configuration	InstallShield®, Automatic configuration	InstallShield®, Manual install of Java server, Manual configuration
Site Development	ArcIMS Author, Designer, I-Wizard	ArcIMS Author, Designer

ECW Analysis

The Patented (US Patent #6,201,897) ECW technology enables a wide range of applications to utilise high-resolution spatial imagery on commodity, low-cost hardware. The technology covered by the patent enables the efficient wavelet-based compression and decompression of very large amounts of imagery (multiple terabytes) with the relatively small system resources found in current desktop PC's and X86 based workstations. It is also ideal for delivering large images on PocketPC type PDA's and mobile devices due to the ECW processes low memory requirements.

Due to the large amount of free products available (Currently Free ECW Compressor, 5 SDK's, ER Viewer and dozens of plugins), ECW has rapidly become the de-facto standard for highly compressed spatial imagery. This in turn has lead to widespread support of ECW across the spatial information market. To date there are over 10,000 installations of the free ECW SDK's worldwide being used to add ECW support to an incredibly diverse range of application from MapInfo Professional to IrfanView, a freeware desktop image viewer with over 1 million users.

ECW Technical Overview

The ECW format is conceptually a spatial quad-tree of encoded wavelet-space image data. In layman's' terms, this basically means it is highly compresses images at ratios of up to 100:1, and its very fast to extract any given part of the image. The highly compressed nature of an ECW file, it's structure, and the method by which views are read from the file poses some interesting possibilities. For example, the offset table, which is the largest individual part of the file, is only needed to locate the blocks in the file on disk to read them into memory, and not the actual decompression process. If the actual reading of the data and the decompression are decoupled, then they could be performed on separate CPU's on the system, or even separate systems. This decoupling is in fact the principle behind the patent-pending ECWP (ECW Protocol) technology and the Image Web Server, which is discussed elsewhere in this document.

Format Comparison

Although ECW is not the only compressed imagery format available, it has a number of compelling advantages over the competition as the following table shows:

Image Format Features Comparison					
	ECW v2	**MrSID®**	**JPEG2000**	**JPEG**	**GeoTIFF**
Codec Basis	Wavelet	Wavelet	Wavelet	DCT	JPEG, LZW, PACKBITS, DEFLATE
Typical Ratio[1]	25:1	25:1	25:1	6:1	2:1
Max File Size	Unlimited	2GB	2GB[2]	2GB	2GB
Max X/Y Dimensions	32bit	31bit	32bit[3]	31bit	31bit
Max Bands	2.1 Billion	4	255[4]	3	4
Precision	8bit, 12bit[8]	8bit, 11bit[9]	1bit – 23bit[6]	8bit, 12bit[5], 16bit[5]	1bit, 8bit, 16bit
Loss-less support	No	No	Yes	Yes[7]	Yes
Standard Geo-Reference MetaData	Yes	No[10]	No	No	Yes

Notes:

1. Manufacturer/recognised recommended ratio for minimal quality degradations
2. Support for >2GB is dependent on the specific JPEG2000 implementation.
3. Actual support dependent on the specific JPEG2000 implementation
4. Actual support for >3 bands dependent on the specific JPEG2000 implementation
5. Support for 12-bit lossy and loss-less 2-16bit compression is optional and not widely available
6. Actual support for >8bit components is dependent on the specific JPEG2000 implementation
7. Loss-less 2-12bit JPEG support is not widely available
8. Support for >8bit precision requires specific application support
9. 11bit stored in 16bit components
10. MrSID can store MetaData including Geo-Referencing information, but this is not widely supported with .sdw World files being significantly more common

Features:

- **Codec Basis and Typical Ratio** – Using Wavelet based image compression provides superior compression ratios over traditional approaches such as LZW and DCT. Wavelet codecs can generally compress an RGB Airphoto at 25:1 with little effect on the quality of the image
- **Max File Size, Dimensions and Bands** – ECW file for all intents are unlimited in size, dimensions and multi-spectral capabilities. Although JPEG2000 can theoretically also have 2^64 sized files, actual support for this is dependent on both the encoder and decoder implementation (resulting in compatibility issues), and JPEG2000 does not address how to encode or decode images that do not fit into system memory, effectively limiting it to 2GB maximum file sizes.
- **Precision** – ECW is primarily intended for high-resolution imagery such as aerial photography using 8bit precision component values (eg, 8 bits each for R, G, B). Support for up to 12-bit precision is available, but requires specific support in each application to recognise the additional precision.
- **Loss-less support** –ECW only support near-lossless compression at 1:1 Target Ratio (actual compression ration may be higher). As typical high-resolution imagery is rarely used for statistical analysis lossless support is not required.
- **Geo-Referenced** – As ECW was designed from the beginning as a spatial format, the ECW file itself stores geographic metadata such as Projection and Datum information, Units and Registration information. This means you can take an ECW file generated in one application and use it in another without having to re-register the image.

For further details on the ECW format and an in-depth comparison with MrSID®, see the ECW v2 White Paper and ECW vs. MrSID® White Paper available from www.ermapper.com.

Applications

A file format by itself is not particularly useful. Applications, their features, benefits and cost are all relevant when comparing formats. A wide range of both free and commercial software exists for ECW. Some examples include:

- For viewing ECW imagery, **ER Viewer** is available free for viewing, printing and converting ECW imagery along with a number of other formats such as GeoTIFF and JPEG.
- The **Free ECW Compressor** allows users to compress files up to 500MB to ECW imagery at no cost from a range of common formats.
- **ER Mapper**, rated #1 spatial image processing product, includes a very diverse range of Remote Sensing processing, classification and interpretation functionality in addition to being able to compress several thousand images at a time into a seamless, color-balanced ECW file of unlimited size.
- **ECW PhotoShop Plugin, MapImagery for MapInfo, AutoCAD 2000 plugins** etc. A wide range of free application plugins for practically every common desktop image processing and GIS product.
- **Native ECW support** – with the ever-increasing popularity of ECW, a long list of vendors have included native ECW support into their applications using the **Free** ECW Software Development Kits (SDK's).

The table below compares different compressed imagery technology:

Compressed Image Technology Capabilities					
	ER Mapper v6.3	**Free ECW Compressor v2.3**	**MrSID GeoSpatial Workstation v1.5**	**MrSID Desktop v1.5**	**LuraWave© JPEG 2000 SmartCompress 3.0**
Price	$5,495	**$Free**	$4,990	$1,499	$19.95
Input file size limit	None	500MB	2GB (individual file), 40GB mosaic (@20:1 compression)	500MB	64MB (4096x4096 pixels)
Output File Size limit	None	None	2GB	500MB	64MB (4096x4096 pixels)
Multiprocessor support	Yes	Yes	No	No	No
Supported Input formats	ER Mapper Raster, ER Mapper Algorithm, ESRI BIL HDR, GeoSPOT HDR, BMP, RESTEC/ NASDA CEOS, USGS DOQ, ECW, TIFF/TFW/ GeoTIFF, JPEG, ERDAS Imagine, BIL/BIP/BSQ **+ 100's more spatial formats for ER Mapper**	ER Mapper Raster, ER Mapper Algorithm, ESRI BIL HDR, GeoSPOT HDR, BMP, RESTEC/ NASDA CEOS, USGS DOQ, ECW, TIFF/TFW/ BIL/BIP/BSQ, JPEG/JPW	TIFF/TFW/ GeoTIFF, ERDAS Imagine, BIL/BIP/BSQ, DOQ, LAN, Sun RASTER, JPEG/JPW	TIFF/TFW/ GeoTIFF, ERDAS Imagine, BIL/BIP/BSQ, DOQ, LAN, Sun RASTER, JPEG/JPW	BMP, PPM, PGM, TIFF, JPEG
Multi-spectral support	Yes	Yes	No	No	No
Mosaicing	Yes	Yes (via .alg files)	Yes (no resampling)	No	No
Mosaic feathering	Yes	Yes (via .alg files)	No	No	No

Mosaic Color Balancing	Yes	No	No	No	No
Full Image Processing & RS functionality	Yes	Limited (via .alg files)	No	No	No
Typical encoding speeds*	10GB/hour	10GB/hour	3GB/hour	3GB/hour	
Photoshop Plugin	$Free	$Free	$Free/$249	$Free/$249	$79.00
SDK	$Free	$Free	$Free*/$OEM	$Free*/$OEM	$2,500 + ***RUNTIME LICENSES***

As can be seen from the comparison, the **Free ECW Compressor** is a bargain compared to the other "low-cost" compression solutions. Not only does it have more features, it is also significantly faster, not to mention free instead of $19.95 or $1,499!

ER Mapper comes in at approximately the same price as the competitors' top-of-the-shelf compression product, yet has significantly more functionality and compresses imagery over 3x faster.

Custom Application Development and Native ECW Support

To date there are over 10,000 people using the free ECW SDK's. This has resulted in ECW being supported in 100's of applications, with many more announcements expected over the next 12 months. This places ECW in a ubiquitous position as the de-facto format for compressed spatial imagery.

Earth Resource Mapping provides several SDK's depending on developers needs, ranging from:

- The full ER Mapper SDK, which allows developers to harness the full power of the ER Mapper Algorithm Process Engine
- The ECW Java SDK for Java Developers
- The ECW ActiveX SDK for Windows component-based development using a range of languages such as Visual Basic and Delphi,
- The ECW Compression/Decompression SDK exposing the raw ECW compression and decompression technologies to applications developers using C and C++ on a range of platforms such as Windows, Macintosh and Solaris.

All these SDK's are provided free for use in desktop applications, allowing full use of ECW imagery at no cost to the developer or their end users. To compare the ECW and ER Mapper SDK's to the competitors:

Compressed Image Technology SDK's					
	ECW SDK's v2.5	**ER Mapper SDK v1.1**	**MrSID Decode SDK/Encode SDK v2.1.2**	**LuraTech JP2 C-SDK**	**Kakadu JPEG2000 SDK v3.1**
Price	$Free (Unlimited Decompression/ 500MB Compression)/ $3,000 (Unlimited Decompression, Unlimited Compression)	$Free*	$Free*/ $"available at a cost commensurate with the advanced capabilities they offer for OEM solutions"	$2,500 + Runtime licenses	$5,000
Platforms	Windows, Macintosh, Solaris	Windows	Windows, Solaris	Windows, Macintosh	Windows, Linux*, Solaris*
Interfaces Supported	C/C++, COM*, ActiveX*, Java*	C/C++	C++	C++	C++
Input file size limit	500MB/ Unlimited (Compress) None (Decompress)	None	2GB*	2GB*	2GB*
Output File Size limit	None	None	2GB	2GB	2GB*
Multiprocessor support	Yes	Yes	No	No	No
Additional formats supported	None	ER Mapper Raster, ER Mapper Algorithm, ESRI BIL HDR, GeoSPOT HDR, BMP, RESTEC/ NASDA CEOS, USGS DOQ,TIFF, TFW, GeoTIFF, JPEG	None	None	None

Multi-Spectral support	Yes	Yes	No	No	Yes
Mosaicing	No	Yes	No	No	No
Mosaic feathering	No	Yes	No	No	No
Fill Image Processing & RS functionality	No	Yes	No	No	No
Typical encoding speeds*	10GB/hour	10GB/hour	3GB/hour	3GB/hour	5GB/hour
Typical decoding speeds*	30GB/hour	30GB/hour	3GB/hour?	7GB/hour	30GB/hour
Integrated Client-Server Architecture	Yes, ECWP, seamless	Yes, ECWP, seamless	No	No	Yes, JPIK, non-standard JP2 extension

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