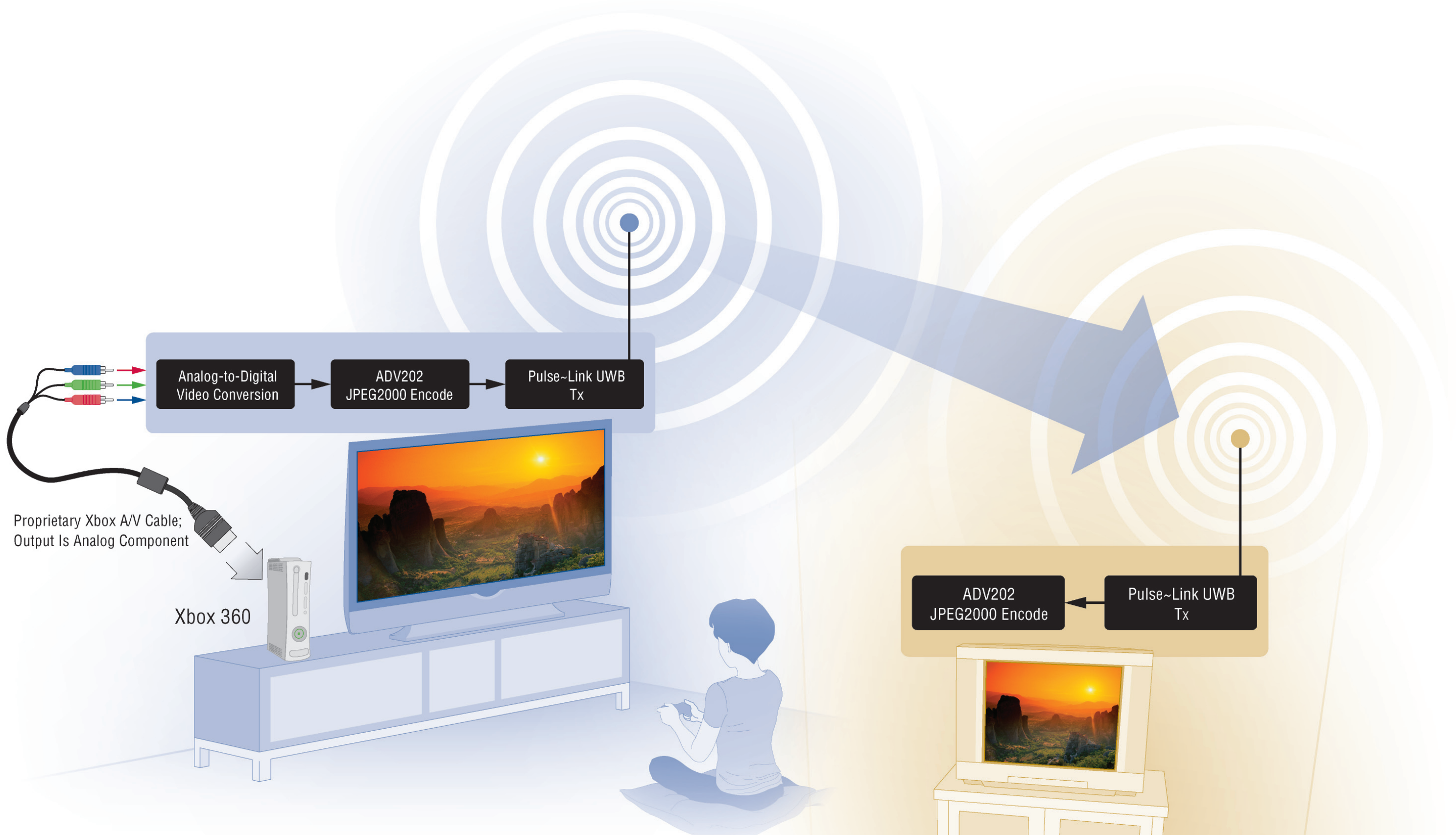
JPEG2000 Enables Wireless HD Video Distribution in the Home



JPEG2000 Is Ideal for Wireless Video

- Low latency—less than one frame
- More robust to errors than MPEG-X
- Error resiliency increases range
- Fixed bit rate simplifies design

JPEG2000 Is Ideal for Consumer Applications

- Capable of real-time HD compression
- Symmetric encode and decode
- Low cost, low complexity
- No external memory required

JPEG2000 Code Stream Is Scalable for Resolution and Quality

- Single encoded stream can supply different resolution displays
- Free thumbnail images available
- Dynamically adjustable bit rate: trade quality for bandwidth
- Reduce file size by reducing quality, without transcoding

Frequently Asked Questions

Q: Since most video reaches the home as MPEG-2, why not just send it wirelessly?

A: (Note that although MPEG-2 is used in this FAQ, the same principles apply to answers for any temporal scheme.) Most MPEG-2 video streams are already decoded before being sent to the TV for various reasons: to add menu overlays, program guides, etc. This is true for most set-top boxes, DVD players, and digital broadcast receivers. The video is then either sent to the TV in an uncompressed format or is recompressed using an inexpensive encoder (for SD resolution).

Some video sources aren't encoded in MPEG-2, or there is no access to the MPEG-2 signal. Outputs from PCs and many DVD players feature uncompressed analog or digital video formats, such as DVI and HDMI. These will have to be compressed in real time before being wirelessly transmitted from a PC or DVD player to a display. The cost of a real-time HD MPEG-2 encoder is roughly $20,000; clearly this is not a solution intended for the consumer market.

JPEG2000 permits low cost, real-time compression of HD video, enabling interactive applications and the transmission of menu overlays.

Q: If I do have access to the MPEG-2 stream, why not send it wirelessly?

A: The video community has identified two major problems with video in wireless environments: error resiliency and latency. Unless the application is interactive, latency is less of an issue than error resiliency.

An error in an I-frame is visible through the entire group of pictures (GOP), so a single transmission error can result in several frames containing errors, creating disturbing artifacts. JPEG2000 compresses each frame individually, so errors do not propagate across frames. Also, JPEG2000 is a wavelet-based scheme, and errors in the codestream tend to “soften” the picture, not create blocky artifacts. Although JPEG2000 is a digital compression scheme, it offers an analog-like graceful degradation of image quality.

Q: Why not use MPEG-2 I-frame-only transmission? That way errors wouldn't propagate across multiple frames.

A: This requires real-time compression, and while real-time MPEG-2 encoders do exist, real-time HD MPEG-2 encoders are very expensive and complex. Like most compression schemes, MPEG-2 was designed to be more complex on the encode side than the decode; MPEG-2 simply wasn't intended for use in high volume encode applications.

Let's suppose, though, that real-time HD I-frame-only MPEG-2 encoding is feasible. I-frame-only MPEG-2 streams are much higher bandwidth than typical streams and require substantially more resources to decode. Most MPEG-2 decoders aren't built to handle these bandwidths. New decoders would have to be deployed, and they would be substantially more complex and expensive than existing decoders.

Q: Doesn't JPEG2000 consume a lot more bandwidth than MPEG-2?

A: Actual efficiency is different depending on whether the transmission channel is error-free (wired) or noisy (wireless or powerline). In a wired channel with no errors, JPEG2000 consumes about twice the bandwidth as MPEG-2 for SD and HD video, at similar quality levels. For cable TV broadcast or DVD compression, JPEG2000 is not competitive with MPEG-2. However, as image resolution increases to 1080p and beyond, MPEG-2 becomes less and less efficient. MPEG-2 encode complexity increases exponentially as the image size increases, but JPEG2000 complexity is roughly linear. At some point, JPEG2000 becomes more efficient, which is one reason it was chosen by the Digital Cinema Initiative. It's also worth noting that JPEG2000 can perform lossless compression, which may be attractive in high end wired and wireless HD transmissions. For similar quality in an error-free transmission environment, an SD MPEG-2 stream requires about 3 Mbps; the equivalent JPEG2000 stream would be about 6 Mbps. Similarly, 720p HD MPEG-2 stream requires about 16 Mbps; the equivalent JPEG2000 stream of the same video would consume about 30 Mbps.

In a wireless environment, JPEG2000 becomes much, much more attractive. Because MPEG-2 manifests errors as very obvious artifacts, much more forward error correction (FEC) is required, and many more packets may have to be retransmitted. FEC and retransmission both consume bandwidth, requiring a large frame buffer with complex memory and timing considerations. Once FEC is taken into account, the bandwidth requirements of JPEG2000 may be less than or equal to that of an MPEG-2 stream. Also, because the decode is straightforward, the JPEG2000 solution will be less expensive. Further, retransmission requires significant amounts of buffer on the receiver, which can be costly and which increases latency.

Using JPEG2000 has additional benefits that are discussed below. Many of the benefits are related to the scalability of the code stream, which, among other things, allows displays of different resolutions to decode only the portions of the code streams they need.

UWB provides ample bandwidth for JPEG2000, and allows the other benefits of JPEG2000 to be realized.

Q: Why don't we just wait for H.264? It's going to address all of these problems, right?

A: H.264 promises better compression efficiency, but there are no advantages over MPEG-2 for wireless applications. Like any motion estimation scheme, any errors will be propagated throughout several frames.

Further, for recompression in the home (cases where the stream didn't originate in H.264) the encoder would require too much space and cost too much for any consumer product. Today, H.264 HD encoders are prohibitively expensive for consumer electronics applications.

Q: Why not just make the wireless environment more robust?

A: Even in a robust environment errors will occur. Forward error correction is a critical part of quality of service (QoS), but it consumes bandwidth. Using less bandwidth on FEC means it can be used elsewhere.

Q: What about security? Is there content protection for JPEG2000?

A: The same questions apply to JPEG2000 as they do to MPEG-2 or H.264, or any other compressed video. It is very possible to apply a content protection scheme, such as HDCP or AES128, to a compressed stream. Since the input to all video compression codecs is uncompressed video, the content protection must be applied after compression, not before. At the present time, many wireless chip vendors use AES128. Recently, Sandia National Labs used 256-bit AES encryption to secure real-time live-streaming video images over a wireless UWB link for military applications.

Some features of JPEG2000 may make it easier to apply existing encryption methods. The fixed output bit rate of JPEG2000 should make it easier to implement handshaking and other timing-critical elements of content protection. The intraframe-only compression may also ease system design requirements.

Q: How do UWB and JPEG2000 enable wireless HD gaming? Why can't MPEG-2 be used?

A: The video from a gaming console must be compressed in real time before being wirelessly transmitted. JPEG2000 provides better image quality than MPEG-2 for real-time compression of either SD or HD at the price points of interest.

Real-time compression is not the same thing as low latency. Because it must wait for several compressed frames to display a single decompressed frame, MPEG-2 has high latency. Latency and bandwidth can be traded by going to I-frame only, but, as discussed earlier, this is an expensive, complex proposition even for SD; recall that real-time HD MPEG-2 encoders are thousands of dollars.

The latency of a JPEG2000 stream is about one frame for encode and one frame for decode. The total latency of the HD game shown at CES 2006, using Analog Devices' ADV202 and Pulse~LINK's CWave™ UWB technology, is less than 200 ms—the user can't tell that it's a wireless video link.

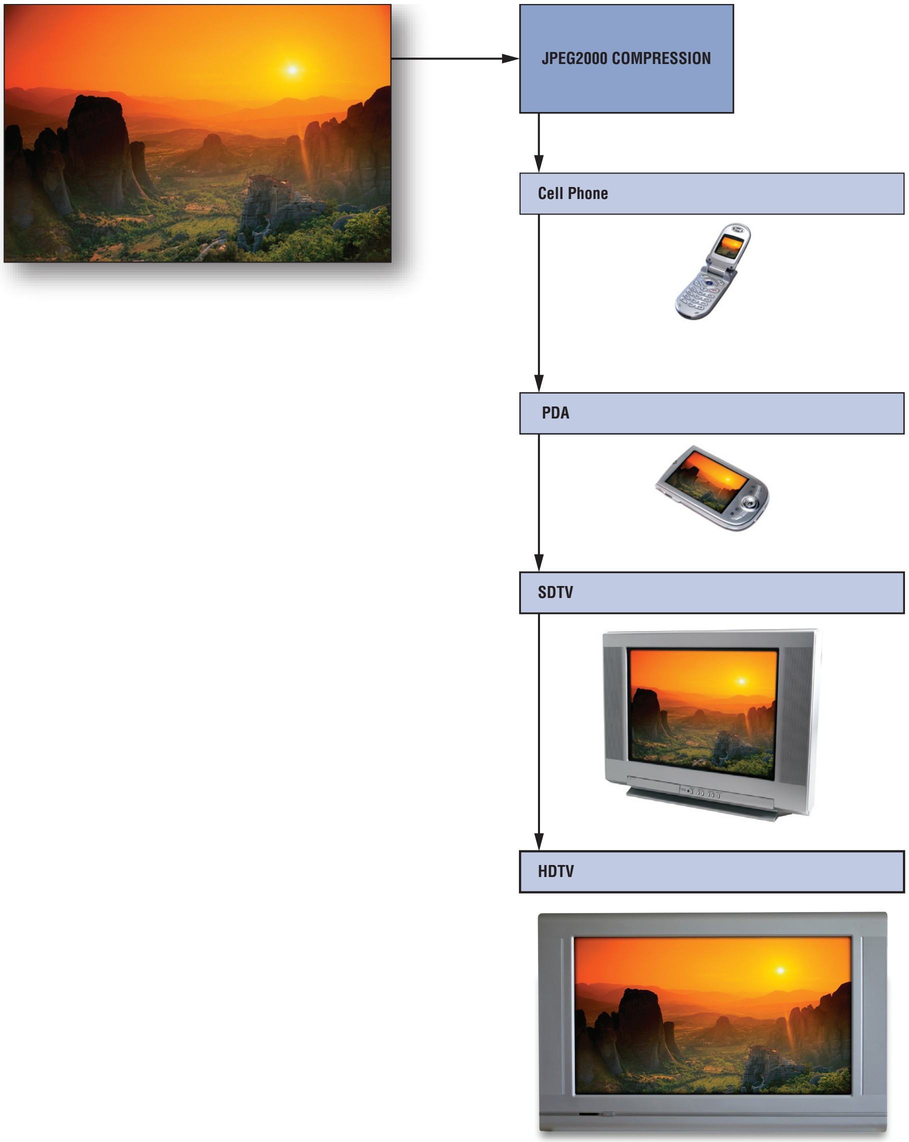
Q: What is meant by "scalable" quality and resolution?

A: For quality, scalability means that the compressed code stream is organized so that different quality levels can be extracted without decompression. JPEG2000 will produce the best possible image for the available bandwidth. If the channel is 50 Mbps, JPEG2000 produces the best possible image quality for 50 Mbps. If the bandwidth drops to 25 Mbps, JPEG2000 will automatically produce the best possible image quality for 25 Mbps. Because it's intraframe-only compression, the output bit rate can be instantaneously adjusted to match channel conditions.

Quality scalability also means that portions of the code stream can be selectively protected. Like MPEG-2, the header of the JPEG2000 code stream is the most important section and errors to this section can be mitigated using FEC. Unlike MPEG-2 though, some sections of the JPEG2000 stream are more important than others and FEC can be applied only to those sections. If the section of the packet containing very high detail is lost or damaged, the image will not suffer as much as if the low frequency portion is disrupted. Because of this, JPEG2000 makes more efficient use of FEC bandwidth than does MPEG-2.

For resolution, scalability means that the compressed code stream is organized so that different resolution levels (image sizes) can be extracted without decompression. Any receiver can decode just the portion of the code stream it requires, allowing it to display its native resolution. The same JPEG2000 code stream could be broadcast to an HDTV, an SDTV, a display in a remote control, or a PDA with ideal results. For temporal schemes this is not possible; the highest resolution must be decoded by each device before, which could be very expensive for HD temporal decoders.

Resolution Scalability



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Analog Devices currently offers the ADV202, a JPEG2000-compliant codec. More information on the ADV202 is available at: *ftp.analog.com/pub/Digital_Imaging/ADV202_FTP_site_contents_3.html*.

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