

Wireless image applications and next-generation imaging

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Ericsson constantly conducts worldwide consumer research to find out what kinds of application consumers want and how they want to use them. Besides making phone calls, imaging and messaging are on the tops of consumers' wish lists for future mobile applications.

Until now, imaging has mostly consisted of images and graphics that are displayed on Web pages. But because imaging will become a natural part of mobile services, image flow and digital-imaging requirements will change.

This article briefly discusses third-generation-imaging services, including multimedia messaging services, which is perhaps one of the most important services. It also discusses some requirements being put on new imaging applications and formats, and describes JPEG2000—the newly finalized ISO/IEC standard.

Imaging in third-generation messaging systems

Imaging is not an application, but it will be an integrated part of Ericsson's product offerings and solutions. Messaging is one of the most important applications that use images. For example—using a terminal, such as the one in Figure 1—envision taking photos of a hotel room when you are on a business trip, and sending them to your family, along with messages that say "miss you." Or how about taking photos of family members as they lie on a sunny beach, attaching a message, such as "don't want to come home," and sending the text and photos to your neighbors?

From consumers' perspectives, these applications will symbolize the third-generation regardless of underlying technology. The roadmap toward imaging in the third-generation starts with MMS in generation 2.5.

When we talk about imaging as a very important part of future mobile applications, we have to acknowledge that mobile phone users must somehow capture images. A natural way of doing this is to integrate a digital still-image camera into mobile phones, which would enable them to capture and send images and messages from the same phone. But not all mobile phones will have integrated cameras. To accommodate many different consumers and provide them with the most flexible solution, mobile phones must be able to transfer images from external cameras. In most cases, image transfer will occur via Bluetooth, which has the still-imaging profile—a dedicated profile that is standardized for this purpose.

Ericsson is actively participating in standards initiatives and thus ensuring that its phones will be compatible with external cameras. Ericsson also works with Canon Inc., to ensure that complete imaging systems will be available for mobile consumers. The Ericsson-Canon cooperation basically deals with

- Internet-based imaging services;
- image transfer from the camera to the mobile phone; and
- the development and promotion of world-

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Figure 1
This future, pocket-sized, mobile multimedia concept device features voice, imaging, and video. A wireless, hands-free ear-phone connects via a Bluetooth connection.



wide standards for imaging and image communication.

Multimedia messaging service—the next generation of SMS

Short message service (SMS) is one of the most-used services in second-generation mobile telecommunications systems—more than 15 billion messages are sent monthly. Multimedia messaging service (MMS) is currently being defined and specified for generation 2.5 and third-generation implementation. MMS takes the mobile messaging evolution (which began with SMS) a giant step forward by giving users the power to become content developers and content consumers. It will be the first mobile application that can handle several different kinds of media (text, images, animation, video, audio, or any combination thereof) in the same message. The message content will solely be limited by content developers' imaginations.

Regular mobile phone users will create MMS messages nearly the same way as they currently create SMS messages. The big difference will be opportunities to include different kinds of media—besides text. As mentioned above, mobile phones will be able to import digital images from digital still-image cameras. Some phones might even have built-in cameras, or cameras as accessories, that facilitate image capture. If video cameras are used, then video clips can be recorded and inserted into messages. Users then add text and send messages using recipients' phone numbers as addresses. Simple and straightforward! This type of messaging will probably be the most common use for MMS.

Another interesting use occurs when content providers send teasers to consumers, for example, excerpts from new music CDs. The messages can contain images of a new CD and a short video clip or sound sample that enables users to listen to parts of the CD and then buy the complete album via their mobile phones.

MMS will be launched on the market at the end of 2001 and will spread widely in 2002. This service, which has been standardized within the Third-generation Partnership Project (3GPP), has strong, broad industry support. Among the companies participating in the standardization, we find the biggest operators and terminal manufacturers in the world. We all recognize the importance of MMS, and we are jointly developing and enhancing MMS specifications.



Figure 2
A typical MMS message might consist of text, an image, and a 20-second music excerpt.

Imaging using Bluetooth

Bluetooth connectivity will also be an important part of the mobile future. The ability to transmit images, video, and audio wirelessly between cameras, MP3 players, phones and smartphones will allow users to extend their communications with friends and family members. Within the Bluetooth special interest group (SIG), a working party was established to create the Bluetooth still-imaging profile.

Bluetooth connectivity will enable friends to exchange images and graphics, which can then be sent to other friends—using MMS. Mobile phones can also be used for other tasks, such as browsing images stored in digital cameras. For example, after a day of sightseeing, users can browse their digital cameras, select the images they like, and send them to their private, online photo albums. They can also use their mobile phones as remote controls for camera shutters. At the press of a phone key, an image is captured and sent to the phone's display. When the user arrives at home, the image can automatically be transferred from the camera to a PC—as soon as the camera is within range of the PC.

BOX A, TERMS AND ABBREVIATIONS

| | | | |
|---------------|--|------|--|
| 3GPP | Third-generation Partnership Project | JPEG | Joint Photographic Experts Group |
| Bluetooth SIG | Bluetooth special interest group | JTC1 | Joint Technical Committee 1 |
| DCT | Discrete cosine transform | MMS | Multimedia messaging service |
| GIF | Graphics interchange format | MP3 | MPEG, 1 and 2, layer 3 |
| GSM | Global system for mobile communication | PNG | "Ping", portable network graphics |
| IEC | International Electrotechnical Commission | SC29 | Subcommittee 29 |
| ISO | International Standardization Organization | SMS | Short message service |
| ITU-T | International Telecommunication Union – Telecommunica- | UMTS | Universal mobile telecommunications system |
| | | WAP | Wireless application protocol |
| | | WG1 | Working Group 1 of ISO/IEC JTC1/SC29 |

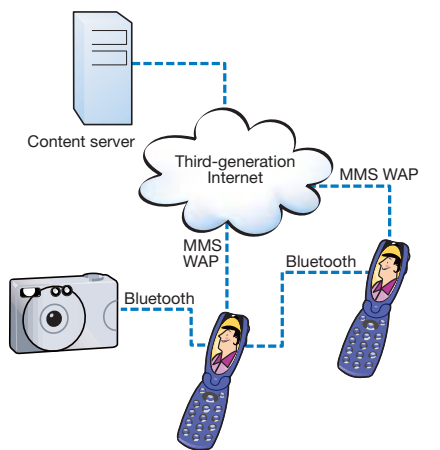


Figure 3
The new image flow.

New requirements

As image flow (Figure 3) changes, and the scope of mobile communication begins to embrace multimedia functions, new requirements will appear. Images will be exchanged between digital still-image cameras, phones and printers. As discussed above, images will also be uploaded to private photo servers or to online photo albums on the Internet, using Bluetooth, MMS, or WAP. Images and graphics will also be sent to and exchanged between family members and friends.

As new multiservice networks evolve, many different clients (phones and smart-phones, high-power home PCs, game consoles and TVs) will access content on the Internet and mobile Internet (Figure 4). The convergence of services and networks has changed requirements for forthcoming imaging formats.

To enable image communication, the imaging formats must be widely used—that is, most applications and users must accept them. New requirements will be put on multimedia services and applications, because many different clients with different capabilities will access the same content. This creates a need to adapt content to the client. Traditionally, the adaptation of images to

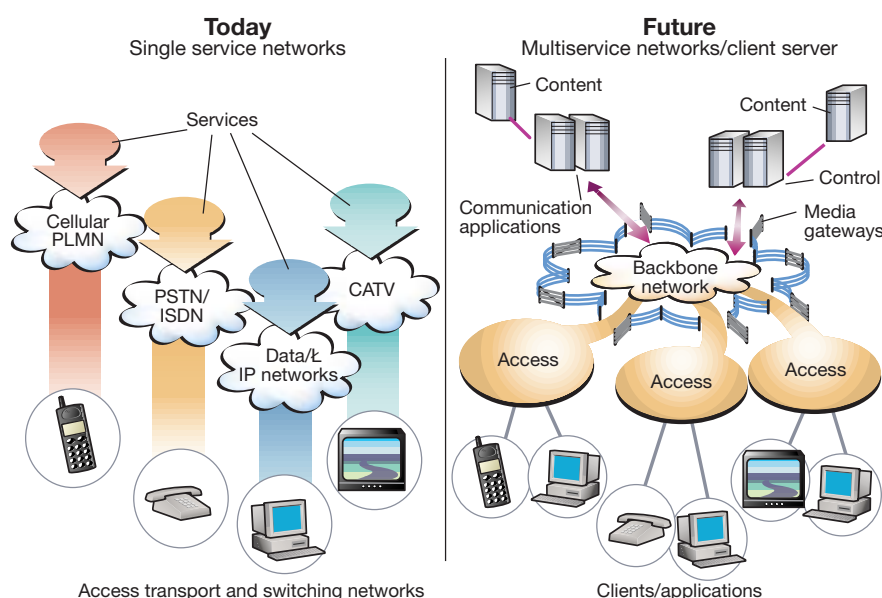
clients' capabilities has not been an important issue, because most clients that access content on the Internet have similar capabilities. The trend among new imaging formats is that they are designed to ease transcoding and adaptation to client capabilities.

To illustrate the need for adaptation, let us consider an online photo album service. Imagine that you take a photo of your favorite car with your digital camera and then upload the photo to your online photo album. At the website for the online service, the image can be accessed in the following formats:

- low resolution (thumbnail images, typically 160-by-120 pixels)—to be viewed, say, on your mobile device;
- medium resolution—for display on a PC or TV screen; and
- high resolution—to be used for high-quality printouts. Many of today's photo album services allow you to order high-quality printouts from the nearest print shop (so far, mainly in the US).

This scenario requires that content providers can deliver three different versions of the same image. A simple solution is to store three separate images with different resolution, but this increases the need for storage space. Another solution is to store one, high-quality version and then adapt the image to the client's requirements using media gateways in the network. However, operations at the gateways could be computationally complex if the imaging format is not properly designed for this type of application.

Figure 4
Evolution of network architecture.



Imaging formats

The adoption of digital imaging on the Internet depends on factors such as bandwidth, processing capacity and the number of users connected to the Internet. In the context of the mobile Internet, imaging is still in its infancy. As the number of services and users increases, the adoption rates and demand for imaging applications will grow—compared to the evolution of imaging applications on the fixed Internet. Several different imaging formats currently exist:

- GIF87a and GIF89a are among the most widely used formats for graphics compression and computer-generated images.
- JPEG (ITU-T Rec. T.81 | ISO/IEC 10918-1) is used for the compression of photographic images.

Some new formats (such as PNG, mainly for graphics) are becoming increasingly popular. Traditionally, imaging formats were de-

signed for specific types of image, such as graphic or photographic images. So far, no format has been able to cover different types of image using the same compression engine. However, a new standard, JPEG2000 (ITU-T Rec. T.800|ISO/IEC 15444-1) leads the way in the new, imaging-formats area. The standard

- enables a unified system solution for as many imaging applications and image types as possible;
- introduces a way of compressing graphic and photographic images with the same compression engine;
- provides functions, such as random access, for the image code-stream and thus enables client-server applications to take advantage of the fact that users have limited viewing areas but want access to the full resolution of the stored image via commands such as image zoom and pan. This way, information that is solely required on the client side can be sent directly from the server; and
- provides different progression modes, superior compression efficiency, and region-of-interest capabilities. It will also offer easy transcoding with low computational complexity, which makes adaptation to client capabilities simple compared to other existing formats.

JPEG2000

Since 1997, Ericsson has been actively involved in JPEG2000 standardization (Table 1, see also Box B). As part of this initiative, Ericsson Research personnel held several positions, such as co-editors of JPEG2000—parts I, II, and V; editor of the JPEG2000 verification model, and chairman of the region-of-interest subgroup.

Ericsson Research also developed one of two official reference software applications for JPEG2000 together with Canon Research Centre France S.A and École Polytechnique Fédérale de Lausanne.¹ Ericsson will also host the JPEG meeting in July 2001, in Stockholm.

Requirements

When work on JPEG2000 first began, the goals for the new standard were high. Working Group 1 (WG1) wanted to design and create a flexible image-coding system that would last for many years. One important issue was that JPEG2000 was intended as a complement to the JPEG standard, not as a replacement. The aim of the new standard

TABLE 1, THE SEVEN PARTS OF JPEG2000

| Part | Description |
|------|---|
| I | JPEG2000 image-coding system. The core coding system was finalized in December 2000. JPEG2000 part I was designed to contain a limited set of technologies, covering as wide a range as possible for the targeted applications of the standard. |
| II | JPEG2000 image coding system. Extensions to the coding system will be finalized in July 2001. Part II contains additional tools that are tailored to specific imaging applications. |
| III | Motion-JPEG2000 (to be finalized in November 2001). This part will be a standard for creating compressed video sequences, each video frame of which is compressed as a still image. |
| IV | Conformance testing (to be finalized in November 2001). This part describes what is required by a compliant implementation of a JPEG2000 decoder. |
| V | Reference software (to be finalized in July 2001). There are two reference implementations of JPEG2000 part I: the first implementation is written in C; the other is written in Java. |
| VI | Compound image file format (to be finalized in March 2002). In compound imagery, different parts of the image can be encoded separately using different encoding algorithms. |
| VII | Technical report (to be finalized in October 2001). Guideline of minimum functionality support of part I. |

BOX B, BRIEF HISTORY OF THE JPEG2000 STANDARDIZATION INITIATIVE

| | |
|-----------|--|
| Mid-1980s | The lack of an international standard for compression of continuous-tone still images becomes an issue. |
| 1986 | A working group is formed; the current name of this group (2001) is ISO/IEC JTC1/SC29/WG1, or the Joint Photographic Experts Group (JPEG). |
| 1992 | Work with the continuous-tone still-image standard results in the publication of ITU-T Rec. T.81 ISO/IEC 10918-1—the JPEG standard. |
| 1996 | Extensions to JPEG ITU-T Rec. T.84 ISO/IEC 10918-3 are published. During this work, it becomes evident that a new standard is needed that offers greater flexibility and functionality than JPEG. |
| 1996 | The original proposal for the new standard is submitted to ISO. |
| 1997 | WG1 issues a call for proposals for JPEG2000; Ericsson submits two proposals (the second is refined and subsequently included in parts I and II of the JPEG2000 standard): 1. An embedded DCT-based still-image-coding algorithm, which is based on the discrete cosine transform (DCT) algorithm, is used in the JPEG standard (called embedded DCT). 2. Efficient methods of encoding regions of interest in the upcoming JPEG2000 still-image standard, for a wavelet-based encoding of regions of interests. |
| 1997 | During an evaluation of the proposed algorithms, WG1 selects a scheme that is based on the Wavelet Transform—as a starting point for the development of JPEG2000. Ericsson's embedded DCT proposal is judged to be the best DCT-based proposal. |

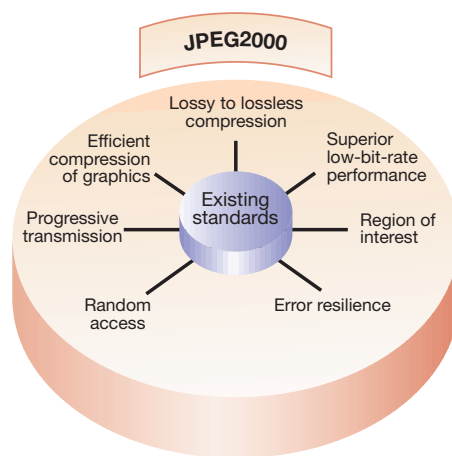


Figure 5
Requirements for JPEG2000 compared to existing standards.

was thus to provide (preferably within one unified system) an image-coding scheme for different image types (for example, bi-level, gray scale, color) with different characteristics, such as natural, medical, remote sensing, and rendered graphics.

The goals for JPEG2000 were to create a standard that was comparable to existing standards and that included all functions in one coding system (Figure 5). Moreover, the standard would

- allow for different imaging models, so the standard could work, for example, in client-server applications, real-time transmission, image archiving, and in situations with limited buffer and bandwidth resources;
- offer numerous functions—to suit it to a wide range of applications and markets;

- provide capabilities to markets that currently do not use compression;
- enable superior, low-bit-rate performance, because no existing imaging format provided good visual quality at high compression ratios;
- create a system that allows lossy and lossless compression. JPEG provides lossy and lossless compression, but uses different technology. It is impossible to decompress a lossy image with JPEG's lossless mode. Image formats (such as GIF and PNG) support only lossless compression;
- enable good compression of photographic and computer-generated images and other types of image, such as medical and remote sensing;
- create a flexible, image-coding system for the wireless environment that is robust against noisy channels; and
- enable random access to the image file and different types of progressive transmission (important requirements and tools)—this enables an image format to be used in as many applications as possible.

Important markets and imaging applications identified during the requirements work were the Internet, mobile communication, digital photography, e-commerce, digital library, printing, scanning (consumer and prepress), medical, and facsimile.

Features and functions

After drafting the requirements, the standardization group has worked to include as many features and functions as possible,

Figure 6
Comparison of JPEG and JPEG2000, at a compression ratio of 1:96.



without sacrificing too much in compression performance and without increasing the complexity of the algorithm.

The resultant compression algorithm offers very competitive compression performance for a wide range of image types, while still offering a large set of features and functions. The standard only addresses decoders, which means that all JPEG2000 decoders will be able to use those features and functions, whereas encoders can choose to implement only those features and functions that are necessary for a particular application. The main JPEG2000 features and functions of the JPEG2000 standard are

- compression efficiency;
- lossy to lossless;
- progressive transmission;
- error resilience;
- region-of-interest coding; and
- random access.

Compression efficiency

Arguably the most important feature of a still-image compression system is its compression efficiency. The more an image can be compressed while retaining acceptable image quality, the faster it can be transmitted and the easier it can be stored. One of the goals of JPEG 2000 was that it should perform better than JPEG at high compression rates. The comparison in Figure 6 illustrates that this goal has been achieved to a very large degree. Although it would

probably be possible to design a compression system that is superior to JPEG2000 for some types of image, JPEG2000 currently performs well on more image types than any other standard.

Lossy to lossless

JPEG2000 can be used to compress images with and without loss of information. The lossless capability is very important for the compression of, say, medical and satellite images. But when a digital camera is used to take vacation photos, it might be sufficient to store them with acceptable quality—greater compression permits users to store more images in their cameras.

Progressive transmission

Another important feature of JPEG 2000 is the embedded nature of the compressed file. The most important information pertaining to the image is placed first in the compressed file. Thus, when the image is being transmitted, the recipient receives this information first.

The degree of importance of information in the image is determined when the image is encoded. Three progression modes are available:

- Progressive by resolution (Figure 7)—the image is encoded so that the recipient first receives a low-resolution version of the image followed by the information needed to increase the resolution (step by step).



Figure 7
Progressive by resolution. The image is encoded so that the recipient first receives a low-resolution version of the image followed by the information needed to increase the resolution.



Figure 8
Progressive by quality. The image is encoded so that the recipient first gets a low-quality version of the image at full resolution and then receives information needed to improve the image quality.

- Progressive by quality (Figure 8)—the image is encoded so that the recipient first gets a low-quality version of the image at full resolution and then receives information needed to improve the image quality (step by step).
- Progressive by position (Figure 9)—the image is encoded in scan-line order so that

the recipient first gets the top-left region of the image at full quality and resolution; the recipient then receives the remaining parts of the image from left to right and from top to bottom.

At any point, the recipient can choose to stop receiving the image and to decompress the information received thus far. For example, a device with a small display that receives an image that has been compressed according to the progressive-by-resolution mode can choose to stop receiving information when the desired resolution has been received.

Error resilience

In JPEG2000 files, there are several ways of increasing resilience against bit errors that occur in the file. Similarly, there are several ways of restarting the decoder at certain intervals, to prevent errors that occur in one part of the image from propagating into other parts of the image when the image is decoded. It is also possible to collect the most important information, such as header data, in one part of the file. This information can then be protected during transmission.

Region-of-interest coding

One requirement for JPEG2000 was the ability to encode different parts of the image at different qualities. Another requirement was earlier placement of information in the compressed file for regions of the image with

Figure 9
Progressive by position. The image is encoded in scan-line order so that the recipient first gets the top-left region of the image at full quality and resolution; the recipient then receives the remaining parts of the image from left to right and from top to bottom.



higher quality (regions of interest). Both of these functions have been implemented in the JPEG2000 algorithm. So when a JPEG2000 image is being received that contains region-of-interest information, the important parts of the image will be received before the background (Figure 10).

Random access

When a JPEG2000 image is compressed, it is divided into several levels of subdivisions. Each subdivision is encoded separately and can easily be found within the file. It is thus very easy to extract and decode only a desired region of the image.

A standard for the future

As described above, the JPEG2000 standard is intended to be a standard for the future. It will probably not replace existing standards, but it can serve to complement them with a wide range of features and functions. The flexibility and performance of JPEG2000 could make it a good candidate for future use in wireless image applications and next-generation imaging.

Conclusion

Imaging will be a regular part of future mobile services. MMS will probably be one of the most important services in third-generation systems. The use of digital imaging will change as multiservice networks evolve—thus putting new requirements on



Figure 10
Region of interest.

future imaging formats. Because many different clients will access images, the new format must be flexible, so that it can easily adapt to different clients' capabilities. One such format is JPEG2000, recently finalized by ISO/IEC. JPEG2000—which is one of the first formats that can deal with different types of image and imaging application—is a good candidate for future wireless image applications.

REFERENCES

- 1 JJ2000 Project, <http://jj2000.epfl.ch>
- 2 ITU-T Recommendation T.81 | ISO/IEC 10918-1:1992, Information Technology—Digital Compression and Coding of Continuous-Tone Still Images—Requirements and Guidelines.
- 3 ITU-T Recommendation T.84 | ISO/IEC 10918-3:1996, Information Technology—Digital Compression and Coding of Continuous-Tone Still Images: Extensions
- 4 Portable Network Graphics, PNG (Portable Network Graphics) Specification, Version 1.2, <http://www.libpng.org/pub/png/spec/>
- 5 ITU-T Recommendation T.800 | ISO/IEC 15444-1:2000, JPEG2000 Image Coding System: Core Coding System
- 6 ITU-T Recommendation T.801 | ISO/IEC CD 15444-2:2000, JPEG2000 Image Coding System: Extensions, ISO/IEC JTC1/SC29/WG1 N851
- 7 ITU-T Recommendation T.xxx | ISO/IEC CD 15444-5:2000, JPEG2000 Image Coding System: Reference Software, ISO/IEC JTC1/SC29/WG1 N1851
- 8 D. Nistér and C. Christopoulos, An Embedded DCT-based Still Image Coding Algorithm, *IEEE Signal Processing Lett.*, vol. 5, No. 6, pp.135-137, June 1998.
- 9 C. Christopoulos, J. Askelöf and M. Larsson, Efficient Methods for Encoding Regions of Interest in the Upcoming JPEG2000 Still Image Standard, *IEEE Signal Processing Lett.*, vol. 7, No. 9, pp.247-249, September 2000.
- 10 C. Christopoulos, A. Skodras and T. Ebrahimi, The JPEG2000 Still Image Coding System, *IEEE Trans. on Consumer Electronics*, Vol. 46, No. 4, pp. 1103-1127, November 2000.
- 11 WAP Forum, Wireless Application Environment Specification, March 29, 2000, <http://www.wapforum.org/>