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# Image Manipulation Specifications on Social Networking Services for Encryption-then-Compression Systems

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**SUMMARY** Encryption-then-Compression (EtC) systems have been proposed to securely transmit images through an untrusted channel provider. In this study, EtC systems were applied to social media like Twitter that carry out image manipulations. The block scrambling-based encryption schemes used in EtC systems were evaluated in terms of their robustness against image manipulation on social media. The aim was to investigate how five social networking service (SNS) providers, Facebook, Twitter, Google+, Tumblr and Flickr, manipulate images and to determine whether the encrypted images uploaded to SNS providers can avoid being distorted by such manipulations. In an experiment, encrypted and non-encrypted JPEG images were uploaded to various SNS providers. The results show that EtC systems are applicable to the five SNS providers.

***key words:*** *JPEG, image encryption, EtC system, social media*

## 1. Introduction

The use of images and video sequences has greatly increased because of rapid growth of the Internet and multimedia systems. A lot of studies on secure, efficient and flexible communications have been reported [1]–[3]. For securing multimedia data, full encryption with provable security (as with RSA and AES) is the most secure option. However, many multimedia applications have been seeking a trade-off in security to enable other requirements, e.g., a small amount of processing, bitstream compliance, or signal processing in the encrypted domain. Here, perceptual encryption schemes have been studied as ways of achieving this trade-off [4]–[8].

Image encryption sometimes must be performed prior to image compression in certain practical scenarios such as secure image transmission through an untrusted channel provider. This framework is carried out by Encryption-then-Compression (EtC) systems [3], [9], [10]. In this paper, we focus on EtC systems, although the traditional way of securely transmitting images is to use a Compression-then-Encryption (CtE) system. However, most studies on EtC systems assume the use of their own compression schemes that have no compatibility with international standards such as JPEG [3], [11]–[14]. In this paper, we focus on block scrambling-based image encryption schemes which have compatibility with international compression standards [15]–[19].

On the other hand, almost all social networking service (SNS) providers support JPEG, one of the most widely used image compression standards [20]. However, JPEG images are uploaded to SNS providers by users on the assumption that the uploaded images in SNS servers are trustable, so the privacy of uploaded images is not under the control of the users. Nevertheless, there is no way to protect the uploaded images, because SNS providers generally manipulate them. Although some papers have studied image manipulation on social media [21]–[23], e.g., alternation of image filenames or headers of JPEG images, the recompression parameters and the conditions of image manipulation remain unclear. Therefore, we investigated how SNS providers manipulate images and whether EtC systems are applicable to their methods.

We uploaded a lot of images to five SNS providers, Facebook, Twitter, Google+, Tumblr and Flickr, to examine the robustness of EtC systems. We found that encrypted images including some block distortion due to image manipulations on some SNS providers greatly reduce the quality of the decrypted images. Otherwise, we confirmed that the EtC systems are applicable to five SNS providers.

## 2. Preparation

### 2.1 Necessity of EtC Systems

The importance of this work is to point out that most encryption schemes, such as RSA and AES, are not applicable to images uploaded to SNS providers and cloud photo storage services like google photos, due to manipulation on providers, and to show that EtC systems are useful for such applications under some conditions. If we send encrypted images directly to receivers, this difficulty will not be generated, but some advantages obtained by using the providers, e.g. data storage services, will be lost. As a result, uploaded images to such providers have currently no guarantee on privacy.

### 2.2 Block Scrambling-Based Image Encryption

Block scrambling-based image encryption schemes have been proposed for EtC systems [16]–[19]. In these

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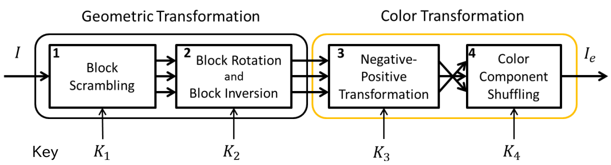
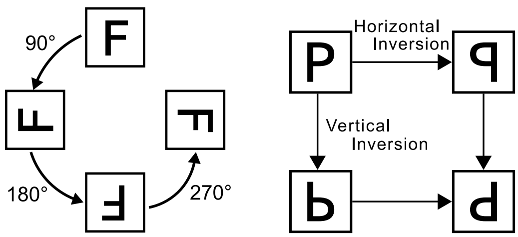



**Fig. 1** Block scrambling-based image encryption




(a) Block rotation (b) Block inversion

**Fig. 2** Block rotation and inversion

schemes [15]–[19], an image with $X \times Y$ pixels is first divided into non-overlapping blocks with $B_x \times B_y$ pixels, with the number of blocks $n$ given by

$$n = \lfloor \frac{X}{B_x} \rfloor \times \lfloor \frac{Y}{B_y} \rfloor \quad (1)$$

where $\lfloor \cdot \rfloor$ is the floor function that rounds down to the nearest integer. Next, four block scrambling-based processing steps, as illustrated in Fig. 1, are applied to the divided image. The procedure of performing image encryption to generate an encrypted image $I_e$ is as follows:

Step 1: Divide an image with $X \times Y$ pixels into blocks with $B_x \times B_y$ pixels, and randomly permute the divided blocks using a random integer generated by a secret key $K_1$, where $K_1$ is commonly used for all color components. In this study, $B_x = B_y = 16$. This is the same choice that was used in [17].

Step 2: Rotate and invert randomly each block (see Fig. 2) by using a random integer generated by a key $K_2$, where $K_2$ is commonly used for all color components as well.

Step 3: Apply the negative-positive transformation to each block by using a random binary integer generated by a key $K_3$, where $K_3$ is commonly used for all color components. In this step, the transformed pixel value in the $i$th block $B_i$, $p'$, is computed as

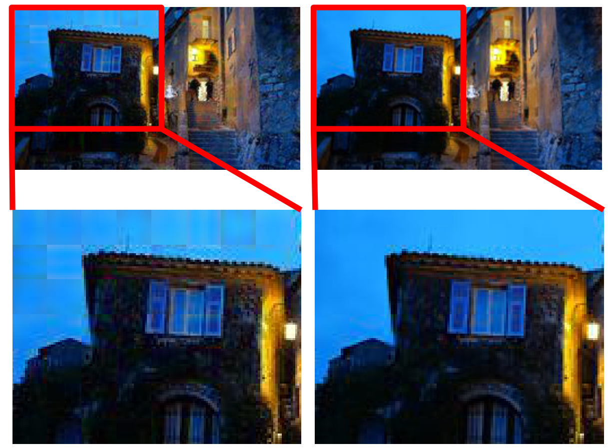
$$p' = \begin{cases} p & (r(i) = 0) \\ p \oplus (2^L - 1) & (r(i) = 1) \end{cases} \quad (2)$$

where $r(i)$ is a random binary integer generated by $K_3$ and $p \in B_i$ is the pixel value of the original image with $L$ bpp.

Step 4: Shuffle three color components in each block (color component shuffling) by using a random senary integer generated by a key $K_4$.

An example of an encrypted image is illustrated in Fig. 3 (b); Fig. 3 (a) is the original one. The key space of the block scrambling-based image encryption is generally large enough to resist brute-force attacks [17]. On the other hand, jigsaw puzzle solver attacks, which utilize correlations among pixels in each block, have been considered [25]–[27]. It is confirmed that appropriate selection of the block size and combination of encryption steps can improve the strength of EtC systems.

(a) Original image [24] ($X \times Y = 256 \times 144$)
(b) Encrypted image ($B_x = B_y = 16, n = 144$)



(c) Decrypted image with block artifact (PSNR=26.57dB, sub-sampling ratio=4:2:0, downloaded from Facebook)
(d) Decrypted image (PSNR=29.37dB, sub-sampling ratio=4:2:0, downloaded from Twitter)

**Fig. 3** Examples of encrypted image and decrypted images, downloaded from Facebook and Twitter

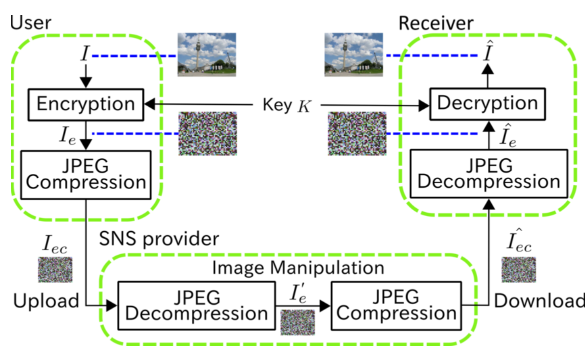



**Fig. 4** EtC system

## 2.3 Application to Social Media

Figure 4 illustrates the scenario of this paper, where a user wants to securely transmit an image $I$ to a receiver via an

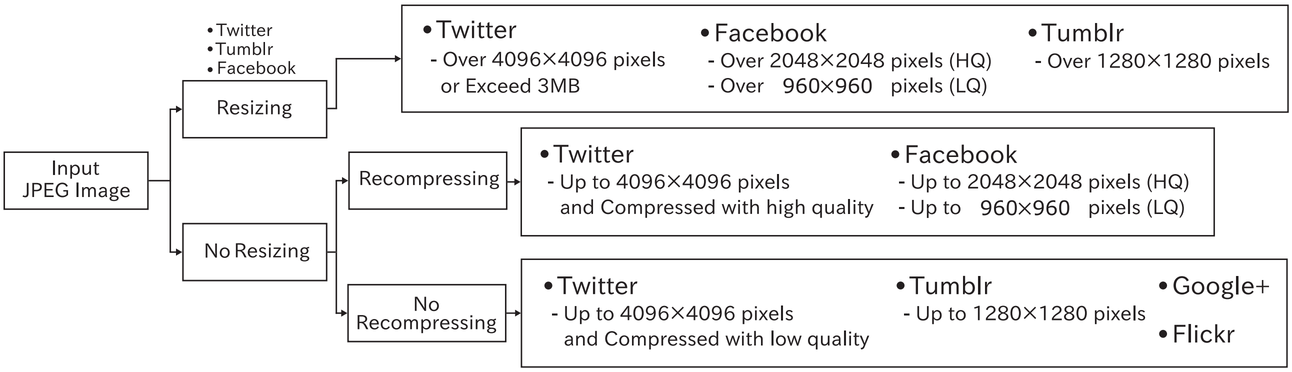



**Fig. 5** Image manipulation on social media

SNS provider. Since the user does not give the secret key $K$ to the provider, the privacy of the image to be shared is under the control of the user, even when the provider decompresses it. Therefore, the user can ensure privacy by him/herself. Even if the encrypted images saved on the SNS servers are leaked by malicious users, third parties are not able to see them unless they have the key.

Meanwhile, it is known that almost all SNS providers manipulate images uploaded by their users, e.g., by rescaling the image resolution and recompressing with different parameters, for decreasing their data size. Manipulation of encrypted images by SNS providers might distort the decrypted ones like in Fig. 3 (c). Although numerous studies have examined the conditions for resizing images [22], [23], the actual recompression parameters and conditions remain unpublished by SNS providers and researchers. Therefore, we investigated how each SNS provider manipulates images uploaded by users.

## 3. Image Manipulation and Robustness

In this section, we examine how each SNS provider manipulates images uploaded by users. Then, the conditions to avoid block distortion are discussed with regard to applying EtC systems to social media.

### 3.1 Image Manipulation on Social Media

We focus on two key aspects regarding image manipulation. The first aspect is the maximum resolution of the uploaded images. The second is the parameters of recompression.

(1) Maximum Resolution

A number of SNS providers automatically resize images uploaded by users when the size of the images exceeds the maximum set by them [22], [23]. When the resolution is changed in the encrypted domain, decrypting the images downloaded from providers becomes difficult.

Figure 5 shows the classification of SNS providers in terms of recompression and resizing. Twitter, Facebook, and Tumblr apply resizing algorithms to uploaded images, if the images satisfy the following conditions. Twitter resizes uploaded images that are over $4096 \times 4096$ pixels or exceed 3MB. Facebook has two modes to control the maximum resolution, i.e., Low Quality (LQ) and High Quality (HQ). The selection of LQ enables users to upload up to images having $960 \times 960$ pixels without any resizing. Meanwhile, HQ allows them to upload images up to $2048 \times 2048$ pixels. Tumblr changes the resolution of uploaded images that are over $1280 \times 1280$ pixels. Unlike these three providers, Google+ and Flickr do not carry out any resizing operations, even when the resolution of the uploaded images is large.

(2) Recompression

Next, we investigated how each SNS provider recompresses images uploaded by users. As illustrated in Fig. 3, the quality of downloaded images depends on the provider. Block artifacts in the decrypted images might be generated by recompression, as shown in Fig. 3 (c).

In terms of recompression, SNS providers are divided into two groups, as shown in Fig. 5. Some providers, such as Google+, Tumblr, and Flickr, manipulate only meta-data embedded in image files. Meanwhile, Facebook recompresses all images regardless of the data size and resolution. Twitter recompresses images only when the data size of images uploaded by users is larger than a threshold.

Most SNS providers support JPEG [20], one of the most widely used image compression standards. Therefore, we decided to focus on JPEG. JPEG encoding of color images consists of six steps:

1) Perform the color transformation from RGB space to YCbCr space.
2) Sub-sample the Cb and Cr components to reduce the spatial resolution.
3) Divide the image into 8-by-8 blocks.
4) Apply the 2-D discrete cosine transform (DCT) to each block.
5) Carry out block-based quantizing with a quantization matrix $\boldsymbol{Q}$.
6) Carry out entropy coding using Huffman coding.

SNS providers reduce the data size of uploaded images by

**Table 1** Relationship between uploaded JPEG files and downloaded ones in terms of sub-sampling ratios

| SNS provider | Uploaded JPEG file | | Downloaded JPEG file | |
|---|---|---|---|---|
| | Sub-sampling ratio | $Q_f$ | Sub-sampling ratio | $Q_f$ |
| Twitter (Up to 4096 × 4096 pixels) | 4:4:4 | low | No recompression | |
| | | high | 4:2:0 | 85 |
| | 4:2:0 | 1,2,... 84 | No recompression | |
| | | 85,86,... 100 | 4:2:0 | 85 |
| Facebook (HQ, Up to 2048 × 2048 pixels) | 4:4:4 | 1,2,... 100 | 4:2:0 | 71,72,... 85 |
| Facebook (LQ, Up to 960 × 960 pixels) | 4:2:0 | | | |
| Tumblr (Up to 1280 × 1280 pixels)<br>Google+<br>Flickr | 4:4:4 | | No recompression | |
| | 4:2:0 | | | |

changing the quality factor $Q_f$ ($1 \leq Q_f \leq 100$), which is a parameter to control the matrix $\boldsymbol{Q}$ in step 5). $Q_f = 100$ gives the best quality, and $Q_f = 1$ provides the worst quality.

There are three sub-sampling ratios in the JPEG standard, referred to as 4:2:0 (reduction by a factor of 2 in both the horizontal and vertical directions), 4:2:2 (reduction by a factor of 2 in the horizontal direction), and 4:4:4 (no sub-sampling). The sub-sampling conditions are also important when considering the effect of image manipulation by social media. The JPEG bitstream of a color image is generated by performing steps 3) to 6) on the brightness component Y and sub-sampled chroma components Cb and Cr independently.

### 3.2 Recompression Parameters

Although some image manipulation specifications on SNS providers have been previously reported [21]–[23], the recompression conditions and recompression parameters are still unclear. In the previous works [21]–[23], the maximum resolution condition to avoid resizing uploaded images, alternation of image filenames and manipulation of JPEG headers have been investigated. This paper investigates how the uploaded images are manipulated by the SNS providers in terms of the color sub-sampling ratio and quality factor.

In the investigation, this paper focuses on 4:4:4 and 4:2:0 sub-sampling ratios, although there are other sub-sampling ratios used in JPEG compression, such as 4:4:0 and 4:2:2 sub-sampling ratios, because considering these two ratios can determine the requirements to avoid block artifacts. Moreover, 4:4:4 and 4:2:0 sub-sampling ratios are widely used by most JPEG applications, including SNS providers. Table 1 shows the relationship between uploaded images and downloaded ones in terms of sub-sampling rate and quality factor. This relationship, which has not been investigated before in any published study, was confirmed by uploading and downloading a lot of JPEG images to individual SNS providers through a personal computer. For instance, if a user uploads JPEG images compressed with 4:4:4 sampling to Facebook, a receiver will view JPEG files manipulated with 4:2:0 sampling and certain quality factors ($71 \leq Q_f \leq 85$). Note that $Q_f$ were estimated by using JPEGsnoop software [28], which utilizes the scaling method from Independent JPEG Group (IJG) [29] to obtain the scaling factor used for generating the quantization table. Let us consider image manipulation on Facebook and Twitter in more detail.

#### a) Image Manipulation on Facebook

Facebook recompresses uploaded JPEG files with the sizes of up to 2048×2048 (HQ) or up to 960×960 (LQ) as follows.

1) Decompress JPEG files as color images in the spatial domain.
2) Compress the images at 4:2:0 sub-sampling ratio and specific $Q_f$ ($71 \leq Q_f \leq 85$) in accordance with the Facebook compression algorithm.
3) Save the recompressed JPEG files on a server to publish them for a receiver.

In the above way, all uploaded images are converted to JPEG files with 4:2:0 sampling regardless of the data size of those images. As a result, the JPEG images with 4:2:0 color sub-sampling ratio are interpolated to increase the spatial resolution for chroma components in the decoding process. Since this interpolation process utilizes the relationship among blocks, encrypted images with 4:2:0 sub-sampling are affected by this interpolation. Hence, block artifacts are generated in the decrypted image, as shown in Fig. 3 (c).

#### b) Image Manipulation on Twitter

Twitter recompresses uploaded JPEG files in accordance with the sub-sampling ratio. When a user uploads JPEG files compressed at high quality and with 4:4:4 sampling to Twitter, the images are recompressed as follows.

1) Decompress JPEG files as color images in the spatial domain.
2) Compress the images at 4:2:0 sub-sampling ratio and $Q_f = 85$.
3) Save the recompressed JPEG files on a server to publish them for a receiver.

The image manipulation conditions of uploaded JPEG images with 4:4:4 sub-sampling depend on not only the uploaded quality factors, but also other properties of images, so it is difficult to provide the strict definition of the uploaded quality factor conditions. Thus, the condition of $Q_f$

is shown as low/high in Table 1. Twitter also recompresses uploaded JPEG files if they were compressed under 4:2:0 sampling and high quality ($Q_f \geq 85$) as follows.

1) Reconstruct the DCT coefficients by using entropy decoding.
2) Quantize the DCT coefficients by using a quantization matrix $\boldsymbol{Q}$ with $Q_f = 85$.
3) Carry out entropy coding using Huffman coding.
4) Save the recompressed JPEG files on a server to publish them for a receiver.

Note that Twitter manipulates only meta-data, including in the header of the uploaded JPEG images, if the images were compressed at a low quality such as $Q_f = 60$.

### 3.3 Requirements to Avoid Distortion

Decrypted images often have block distortion that depends on the relationship between the encryption and recompression conditions. Here, we examine how to avoid such distortion. In particular, we find that block distortion does not result from image manipulation on social media if the encrypted images satisfy the two conditions listed below.

a) The resolution of the encrypted images is left unchanged by the SNS providers.
b) The encrypted images uploaded by users are compressed with 4:4:4 sub-sampling ratio.

Requirement a) means that the resolution of the encrypted images needs to be smaller than the maximum resolution that each provider decides as a resizing condition. Resizing the resolution of encrypted images makes the block size of the encrypted images smaller, although the JPEG compression is still carried out based on the size of $8 \times 8$. As a result each $16 \times 16$-block in resized encrypted images includes pixels from originally different blocks, so the compression performance decreases and block distortion is generated in the decrypted image due to the discontinuity among pixels. Moreover, as shown in Fig. 5, users need not consider the maximum resolution of encrypted images when uploading to Google+ and Flickr.

Requirement b) means that we have to consider the sub-sampling ratios of the encrypted images. Compression of JPEG images with 4:2:0 sub-sampling ratio is performed to increase the spatial resolution for chroma components in the decoding process. This interpolation processing is carried out by using the relationship among blocks. Therefore, the encrypted images compressed with 4:2:0 sub-sampling ratio are affected by this interpolation, while JPEG images compressed with 4:4:4 sampling do not need any interpolation.

However, JPEG files compressed with 4:2:0 sub-sampling ratio can sometimes avoid block distortion even if interpolation is carried out. Table 2 indicates the conditions under which JPEG files uploaded by users will avoid block artifacts. As discussed in Sect. 3.2, Facebook performs interpolation in the spatial domain when JPEG images compressed with 4:2:0 sampling ratio are uploaded by users. Consequently, images with artifacts such as in Fig. 3 (c) are generated. Meanwhile, Twitter manipulates JPEG images in the DCT domain for some operations such as quantization. Therefore, JPEG images that are compressed with 4:2:0 sampling can avoid to block distortion due to recompression when they are uploaded to Twitter. Thus, users do not need to consider the sampling ratios of encrypted images when uploading to Twitter.

**Table 2** Condition of JPEG images to prevent block artifacts from being generated by Facebook and Twitter (∘: Block artifact is generated, ×: No block artifact)

| SNS provider | Twitter | | Facebook | |
|---|---|---|---|---|
| Sub-sampling ratio (Uploaded JPEG file) | 4:4:4 | 4:2:0 | 4:4:4 | 4:2:0 |
| Block artifact | × | × | × | ∘ |

## 4. Experimental Results

We evaluated the effectiveness of EtC systems for social media by conducting a number of simulations. In the simulations, encrypted and compressed JPEG files were uploaded to SNS providers.

### 4.1 Simulation Conditions

The following procedure was carried out to evaluate the robustness of EtC systems based on Fig. 4.

1) Generate an encrypted image $I_e$ from an original image $I$ in accordance with Fig. 1.
2) Compress the encrypted image $I_e$.
3) Upload the encrypted JPEG image $I_{ec}$ to SNS providers.
4) Download the recompressed JPEG image $\hat{I_{ec}}$ from the providers.
5) Decompress the encrypted JPEG image $\hat{I_{ec}}$.
6) Decrypt the manipulated image $\hat{I_e}$.
7) Compute the PSNR value between the original image $I$ and $\hat{I}$.

We made use of the JPEG implementation from IJG [29] in steps 2) and 5). Then, we compressed each image with 4:2:0 or 4:4:4 sampling ratio and $Q_f = 80, 81 \ldots 100$. To compare the PSNR values in step 7), the original image $I$ was compressed without any encryption and then uploaded.

To reduce dispersion, we used 20 FHD images from Ultra-Eye dataset ($1920 \times 1080$) [24]. We focused on Facebook and Twitter, because these SNS providers recompress all images uploaded by users that meet the conditions (see Fig. 5). The encrypted and non-encrypted JPEG files compressed with 4:2:0 and 4:4:4 sampling were uploaded to the providers.

### 4.2 Compression Performance of EtC System

Figures 6 and 7 show the experimental results, where the

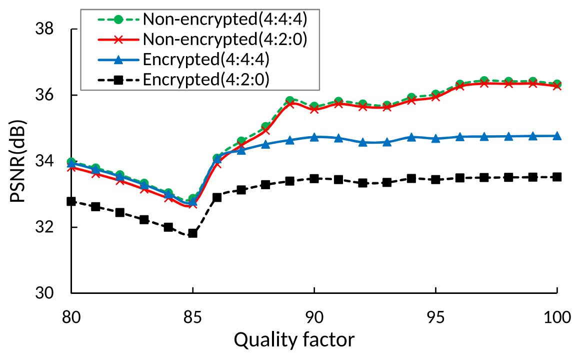



**Fig. 6** Experimental result using original images as ground truth ones (Facebook)

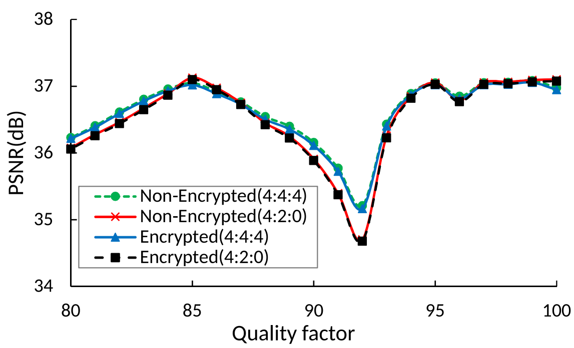



**Fig. 7** Experimental result using original images as ground truth ones (Twitter)

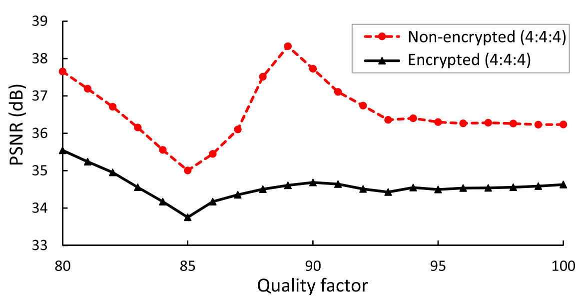
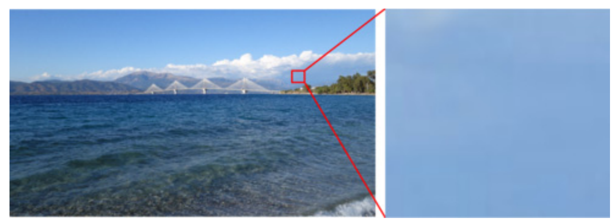



**Fig. 8** Experimental result using JPEG encoded images as ground truth ones (Facebook)

(a) Original image [24] ($X \times Y = 1920 \times 1080$)

(b) Decrypted image with block artifact (PSNR=29.89dB, downloaded from Facebook, uploaded image with 4:2:0 sub-sampling and $Q_f = 85$)



(c) Decrypted image (PSNR=35.99dB, downloaded from Twitter, uploaded image with 4:2:0 sub-sampling and $Q_f = 85$)

**Fig. 9** Examples of decrypted images, downloaded from Facebook and Twitter

average PSNR values of 20 images were calculated by using original images without any compression distortion as ground truth ones. The PSNRs of the decrypted images were low when images compressed with 4:2:0 sub-sampling ratio were uploaded to Facebook. This shows that block distortion due to recompression in the spatial domain greatly reduces the quality of decrypted images. Even though the decrypted images with 4:4:4 sub-sampling ratio did not include block distortion, their PSNRs were lower than those of the non-encrypted images compressed with 4:4:4 sub-sampling ratio, as indicated in Fig. 6. This is because Facebook recompresses uploaded JPEG images with a non-constant $Q_f(71, 72, \ldots 85)$, unlike Twitter.

On the other hand, Twitter recompresses images with 4:2:0 sub-sampling ratio in the DCT domain. Thus, the PSNRs of the decrypted images uploaded to Twitter were almost same as the non-encrypted ones even if the images were compressed with 4:2:0 sub-sampling ratio. Regarding the decrypted images with 4:4:4 sub-sampling ratio, the PSNRs were almost the same as the non-encrypted ones.

To clearly show the quality degradation caused by the providers, in Fig. 8, PSNR values were calculated by using JPEG encoded images as ground truth ones, which correspond to images taken by a smartphone. PSNRs of both non-encrypted and encrypted ones have almost the same tendency as the result in Fig. 6.

Moreover, the examples of an original image and the decrypted images downloaded from Facebook and Twitter are shown in Fig. 9. The result shows that the decrypted image downloaded from Twitter did not include any block artifacts. In contrast, block artifacts were generated in the decrypted image downloaded from Facebook.

## 5. Conclusion

This paper proposed an application of EtC systems to enable users to send images securely to receivers through SNS providers. Moreover, we investigated how SNS providers manipulate JPEG images uploaded by users in terms of their maximum resolution and recompression parameters. In addition to the conditions that encrypted images uploaded by users generate some block distortion, the quality of images downloaded from the SNS providers was confirmed. On the other hand, we determined that EtC systems are applicable to five SNS providers, Facebook, Twitter, Google+, Tumblr and Flickr, if the encrypted images meet certain conditions.

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