SBPG: A Secure Better Portable Graphics Compression Architecture for High Speed Trusted Image Communication in the IoT

U. Albalawi[1], S. P. Mohanty[2], and E. Kougianos[3]

NanoSystem Design Laboratory (NSDL, http://nsdl.cse.unt.edu)
University of North Texas, Denton, TX 76203, USA.[1,2,3]

Email: UmarAlbalawi@my.unt.edu[1], saraju.mohanty@unt.edu[2] and elias.kougianos@unt.edu[3]

April 19, 2015

Outline of the talk

- Novel Contributions
- Introduction and Motivation
- SDC Integrated with SBPG for the IoT
- Proposed SBPG Encoder Integrated SDC
- Experimental Results
- Conclusions and Future Works

Novel Contributions of This Paper

- **The novel contributions of this paper include the following:**

1. The first-ever architecture for hardware SBPG compression integrated with SDC.
2. The concept of SBPG that is integrated with SDC, which is suitable for real time intelligent traffic surveillance (ITS).
3. A Simulink®–based prototype of the algorithm implementation.
4. Experimental analysis and comparison of the proposed architecture versus other studies and research.

Better Portable Graphics (BPG)

❑ **What is Better Portable Graphics (BPG) compression?**

BPG is a new image format offering several advantages over the JPEG format. It achieves a higher compression ratio with smaller size than JPEG for similar quality.

❑ Since its introduction in 1987, the Joint Photographic Experts Group (JPEG) graphics format has been the *de facto* choice for image compression. However, the new compression technique BPG outperforms JPEG in terms of compression quality and size of the compressed file.

❑ **The reference BPG image library and utilities (libbpg) can be divided into four functions: [1]**

1) BPG encoder
2) BPG decoder,
3) Javascript decoder,
4) BPG decoding.

[1] F. Bellard, "The BPG Image Format," http://bellard.org/bpg/, last Accessed on 09/20/2015.

Why BPG ?

❑ Why BPG compression instead of JPEG?

Attributes that differentiate BPG from JPEG and make it an excellent choice include the following:

1) Meeting modern display requirements: high quality and lower size.
2) BPG compression is based on the High Efficiency Video Coding (HEVC) standard, which is considered a major advance in compression techniques.
3) Supported by most web browsers with a small Javascript decoder.

Why BPG ?

- **Why BPG compression Not JPEG?**

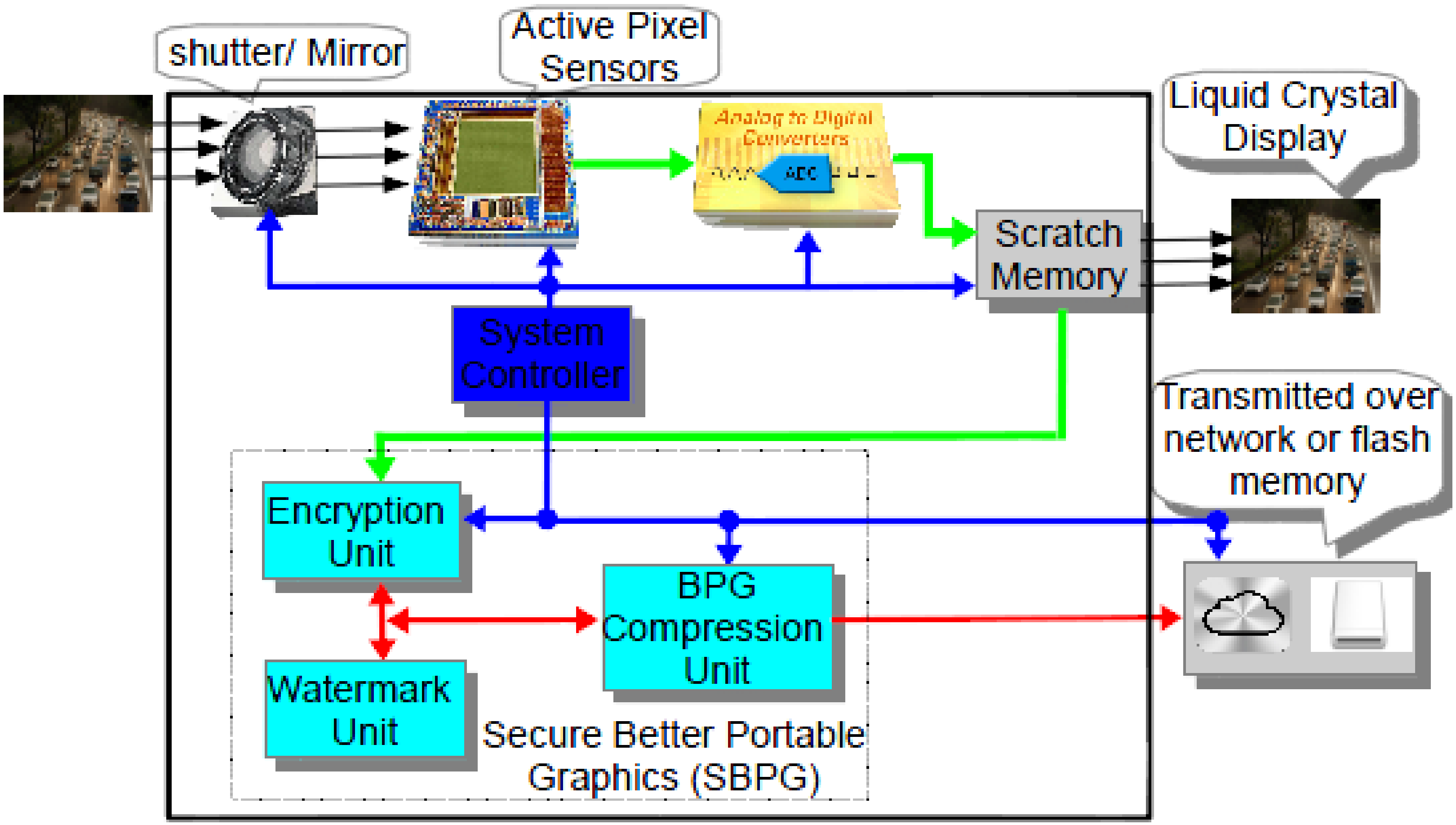
4) It is open source.
5) BPG is close in spirit to JPEG and can offer lossless compression in the digital domain.
6) Different chroma formats supported include grayscale, RGB, YCgCo, YCbCr, Non-premultiplied alpha, and Premultiplied alpha.
7) BPG uses a range of metadata for efficient conversion including EXIF, ICC profile, and XMP.

BPG Hardware ?

❑ **Advantages of hardware versus software implementation:**

1. Real-time image encoding with minimal hardware.
2. Significant reduction in power usage.
3. Dedicated circuity that does not slow down the host.
4. Hardware is less susceptible to malicious software such as viruses, and Trojans.
5. Performance is better since the hardware can be custom-built.
6. Hardware-based BPG can be integrated with multimedia creating or processing components e.g. GPU

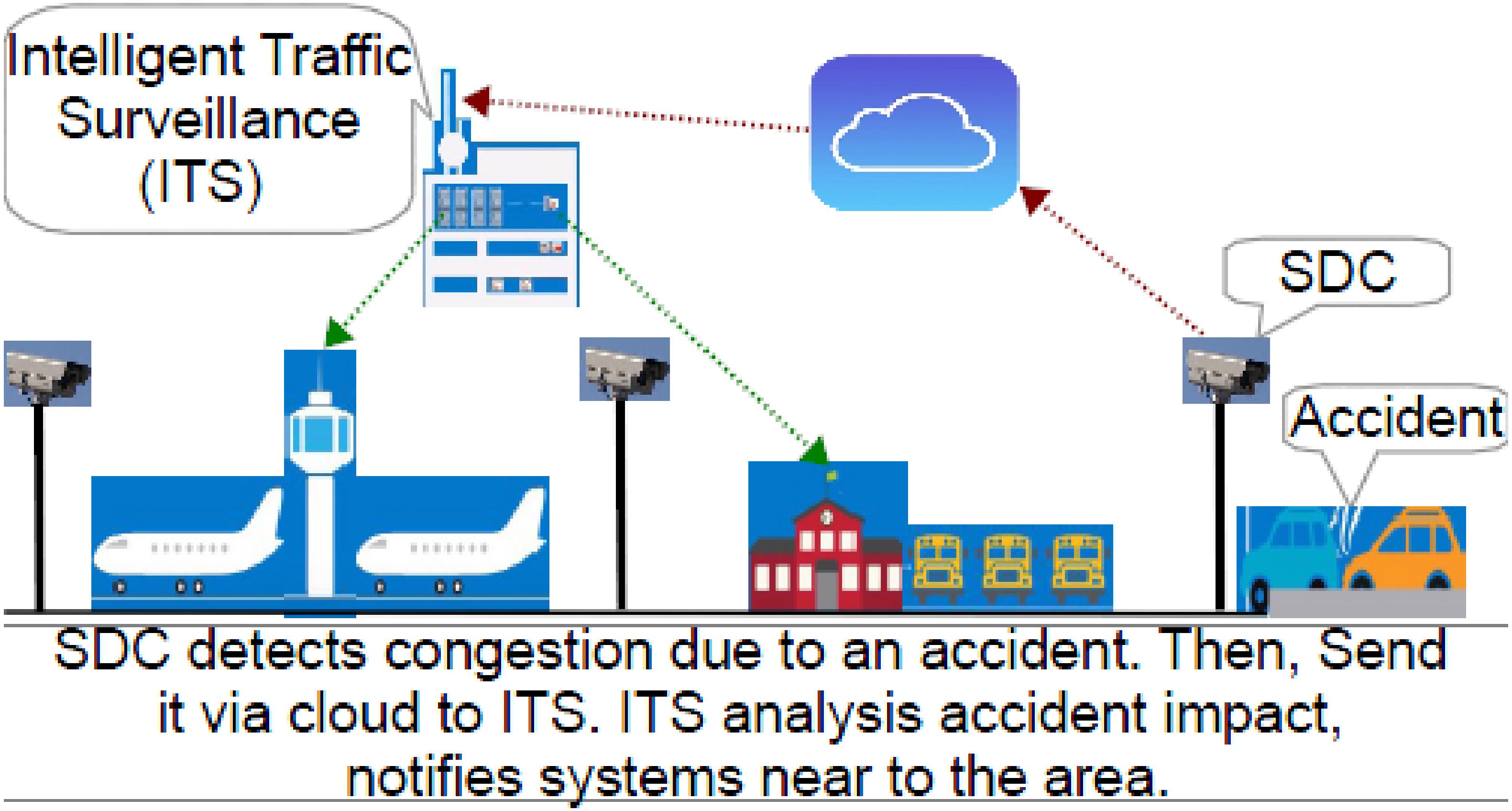
Architectural Overview of SBPG integrated SDC



System-level block diagram of SBPG integrated with SDC

SDC Integrated with SBPG for IoT

❑ A Broad Application Perspective:



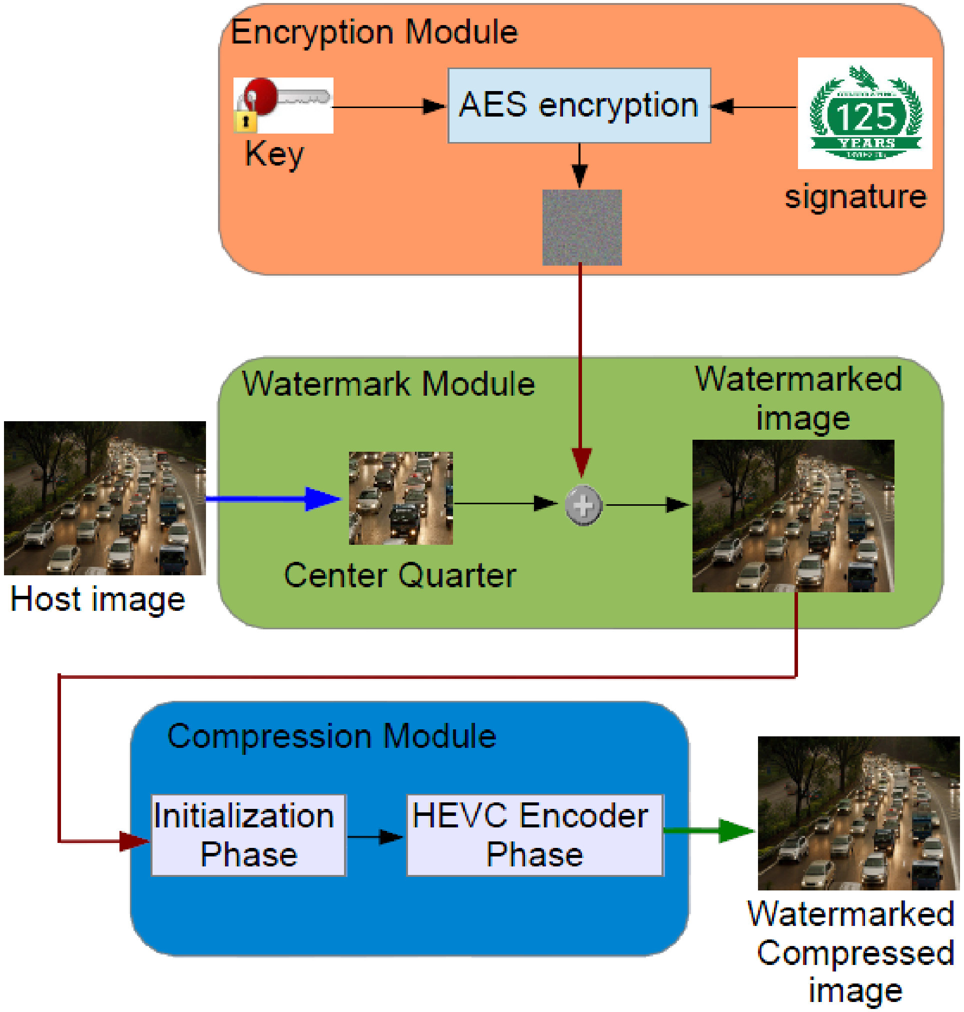
Potential benefits of introducing the IoT in ITS system.

SBPG: Algorithm and Architecture

❑Encryption and watermark module:

The invisible-robust-blind watermarking algorithm is summarized as follows:

1. Optimization for robustness, quality, and computational load because of use of the center portion of the image.
2. Watermarking is done in the frequency domain using the Discrete Cosine Transform (DCT) that will increase watermarking insertion speed.
3. The insertion of the watermark is done in the midfrequency of the image block so that will increase the robustness since any removal of high or low frequency components of the watermarked image does not significantly affect the watermark.



Schematic overview of the proposed SBPG Module

Algorithm of BPG Image Compression unit

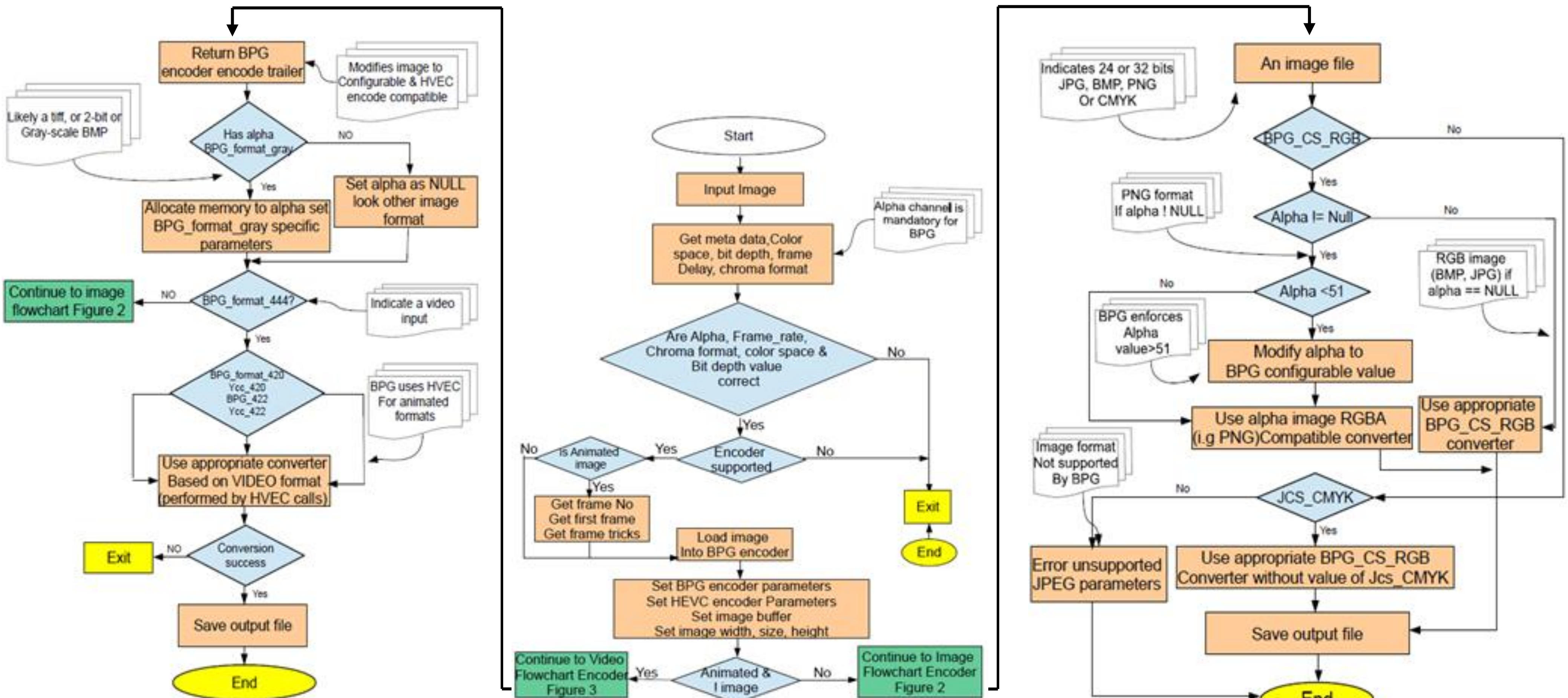
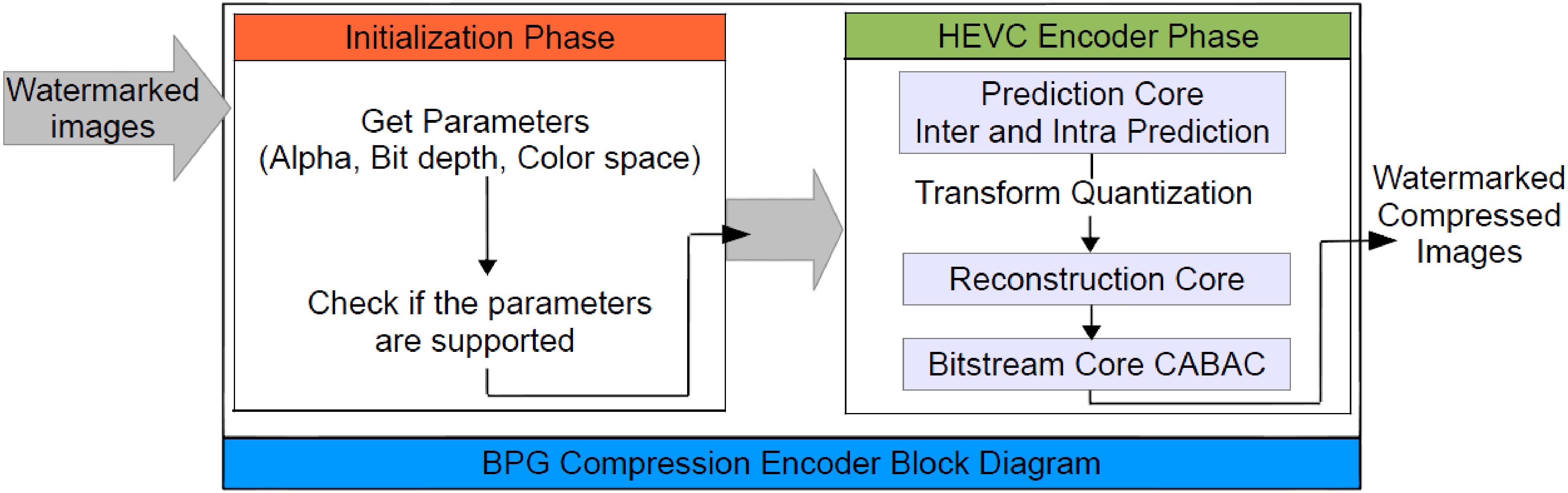


Fig. : BPG Video Encoder Algorithm.

Fig. : BPG Encoder Algorithm.

Fig. : BPG Image Encoder Algorithm.

Architecture of BPG Image Compression unit



BPG Compression encoder block diagram

Simulink® Based Modeling

❖ The proposed algorithm is prototyped in Simulink ®

❖ The methodology that is used to represent the high level system modeling is bottom-up.

❖ The first step is focused on building functional units; the next step is to integrate these units into subsystems.

❖ Finally, verifying and testing overall system functionality.

Experimental Results

❑ Insertion of watermark and image compression using SBPG encoder:

❖ Five standard images are selected randomly from a large set of images of the Joint Picture Expert Graphics (.jpg) with different spatial and frequency characteristics.

❖ The cover image, watermarked image, and corresponding BPG image are shown for a sample image.

(a) Cover Image. (b) Watermarked Image (c) Watermarked Compressed Image

Fig. Secure BPG Compression of PepperImage (512×512).

Experimental Results

❑ **Metrics to describe the type and amount of degradation in reconstructed compressed images:**

1. Root Mean Squared Error (RMSE).

2. Peak Signal to Noise Ratio (PSNR).

$$RMSE = \frac{1}{\sqrt{mn}} \sum_{j=1}^{m-1} \sum_{n=1}^{N} ||(O(i,j) - O'(i,j)||^2 \quad (1)$$

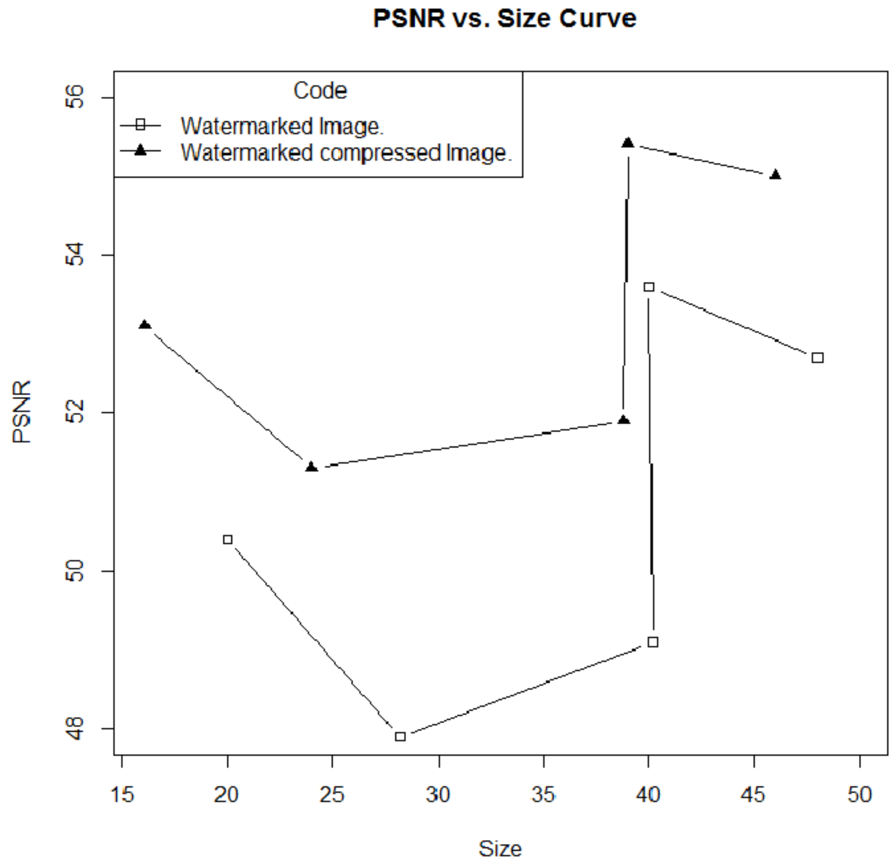
$$PSNR = 10\log\left(\frac{(2^n-1)^2}{MSE}\right) = 10\log\left(\frac{255^2}{MSE}\right) \quad (2)$$

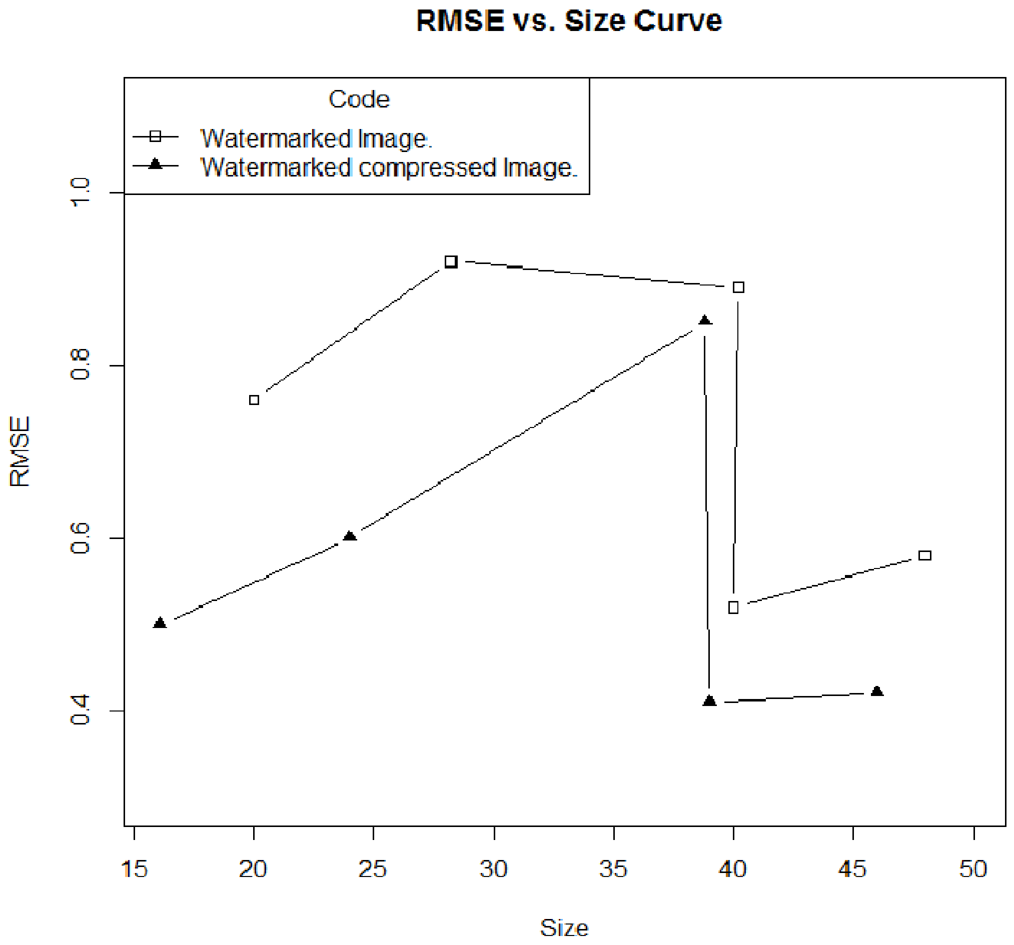
Experimental Results

- **TABLE1: Quality metrics for the watermarking and compression techniques and test images:**

Test Image	Code	Size (KB)	RMSE	PSNR
Cover Baboon Image (16.7KB)	Watermarked Image	20.0	0.76	50.4
	Watermarked Compressed Image	16.1	0.50	53.1
Cover Forset Image (25.1KB)	Watermarked Image	28.2	0.92	47.9
	Watermarked Compressed Image	24.0	0.60	51.3
Cover IceClimb Image (83.3KB)	Watermarked Image	48.0	0.58	52.7
	Watermarked Compressed Image	46.0	0.42	55.0
Cover Lena Image (32.0KB)	Watermarked Image	40.2	0.89	49.1
	Watermarked Compressed Image	38.8	0.85	51.9
Cover Pepper Image (39.3KB)	Watermarked Image	40.0	0.52	53.6
	Watermarked Compressed Image	39.0	0.41	55.4

Experimental Results





Experimental Results

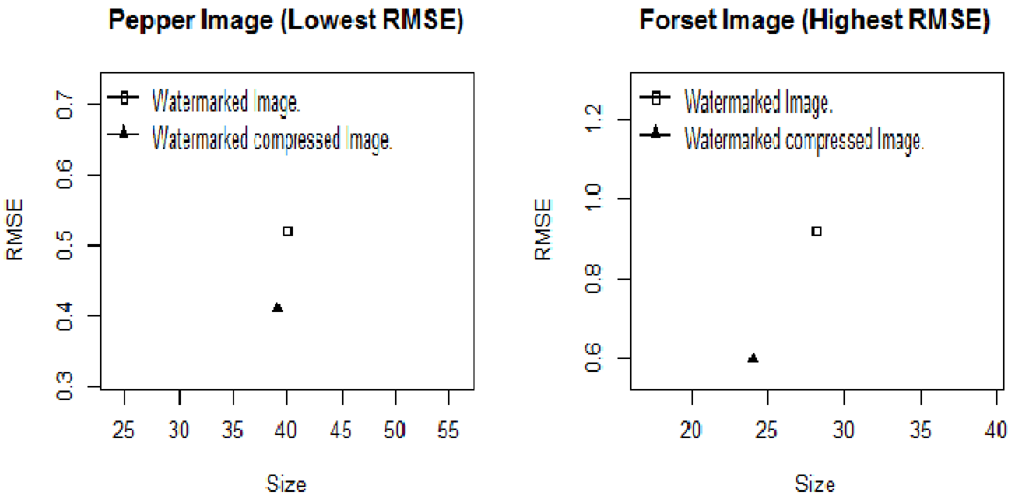


Fig. Highest and Lowest value of RMSE.

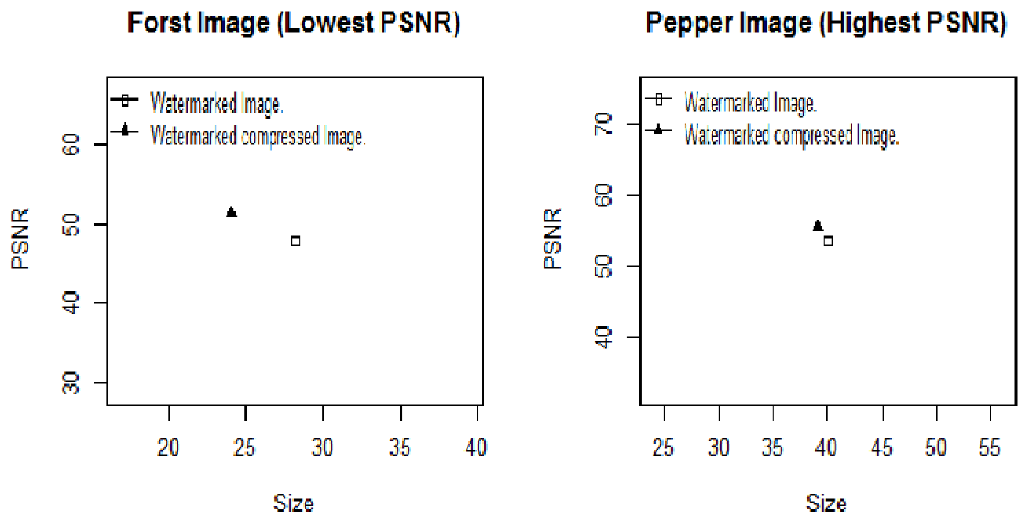


Fig. Highest and Lowest value of PSNR.

Experimental Results

❑Testing for High Performance:

* It is imperative to consider watermark and compression quality and performance trade-offs.
* The proposed SBPG architecture gives high quality since the value of PSNR is maintained above 47.9 dB for all cases.
*To achieve a high performance architecture the following are considered:

1) Optimization of robustness, quality, and computational load because of considering just the center portion of the image.
2) Watermarking is done in the frequency domain using block-wise Discrete Cosine Transform (DCT) of size 8x8 that will increase watermarking insertion speed.

3) In the BPG encoder, the proposed architecture uses inter and intra prediction to reduce the temporal and spatial redundancy, which improves the computational speed.

- To calculate the frame-rate, the Simulink model is fed with 30 random images as inputs. The time taken to obtain the outputs (30 watermarked compressed images) is 1.27 s.
- Thus, the maximum throughput of the proposed SBPG is 25 frames/sec at a clock speed of 2400 MHz.

Comparison with Existing Research

Prior Research	Built-in Security Function		Domain	Built-in Compression	object
	Watermarking	Encryption			
Mohanty *et al.* [1]	Invisible Robust	AES	DCT	None	Image
Anand *et al.* [15]	Invisible Feasible	None	DWT	None	Image
Mohanty *et al.* [16]	Visible	None	DCT	JPEG Encoder	Image
Lei *et al.* [17]	Semi-Fragile and Robust	None	DWT	None	Image
Mohanty *et al.* [12]	Visible	None	DCT	MPEG-4 Compression	Video
This paper	Invisible Robust Blind	AES	DCT	BPG Encoder	Image

Conclusions

- The first-ever architecture for hardware SBPG compression integrated with SDC is presented.
- The concept of SBPG that is integrated with SDC is suitable for real time intelligent traffic surveillance (ITS).
- The proposed architecture is prototyped in Simulink ®.
- Experimental results are compared with existing studies and research.
- The proposed SBPG architecture gives high quality PSNR above 47.9 dB for all cases, with performance 25 frames/sec.

Future Works

- Design and Optimization of SBPG integrated SDC though iVAMS (Intelligent Verilog-AMS).

- Designing energy-efficient architectures also ensures less overhead to manage thermal dissipation, and heat generation is controlled at the source by optimizing the power consumed.

- Integration of video compression in SDC.

Thank you !!!