A new scheme for estimating H.264/AVC-based video sensor network power consumption

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Abstract. Video sensor networks (VSNs) require extensive computation for encoding and transmitting the captured video data. The encoder settings used by the VSN nodes determine the encoding complexity and bitrate of the video streams. There is a tradeoff between encoding complexity and compression performance. In order to exploit that trade-off, we have modeled the complexity and bitrate of H.264/AVC, based on encoder setting parameters. We also propose a method to reduce the bitrate and complexity estimation error of the model. To verify the performance of our scheme a large database of real scene videos captured by video sensor network cameras is used. Experiment results confirm our model successfully estimates the VSN power consumption for a given network topology.

Keywords: H.264/AVC; complexity and bitrate modeling; energy consumption model; and video sensor network

1 Introduction

Video sensor networks (VSNs) offer an alternative to existing monitoring technologies [1], [2]. There are several studies on energy consumption of VSNs in the literature [1], [3], [4]. J.J. Ahmad et al. [4] have studied the required energy for encoding and transmission of video content in a H.264/AVC-based VSN. The H.264/AVC is latest video compression standard that is currently being widely used in the consumer market [5], [6], [7]. Authors in [8] have proposed a model to estimate the coding complexity and bitrate for a H.264/AVC based VSN. In this paper, we improve the model proposed in [8] by providing a method to reduce the estimation error in the case that the motion activity captured by the video changes with time.

2 H.264/AVC Complexity and Bitrate Modeling

In order to mimic realistic VSN applications, we have captured 20 videos using four cameras in a public building. All videos are downsampled to 416x240 pixels resolution and 15 frames per second (fps). Four of these videos are used as the training set for the model, while the remaining videos are used as the test set. The proposed model in [8] is used in our study. The training set is used to obtain the parameters of the model. In addition, we also encode the first two frames of each video sequence of the test set. However, in some video sequences, content may change during a 10s video shot. In order to tackle this problem, we divide the 10s video into a number of sub-shots and encode the first two frames of each shot. The

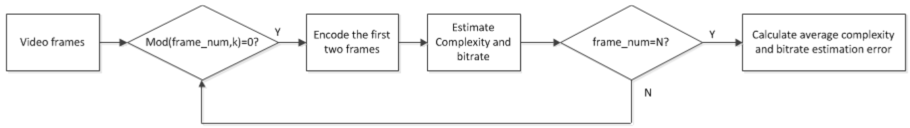

Fig. 1 Flow chart for complexity and bitrate estimation error calculation

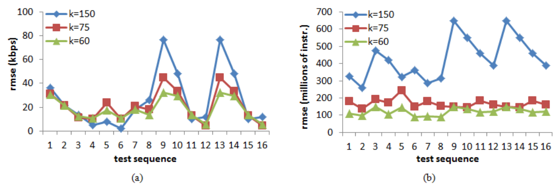

Fig. 2 RMSE of the video test sequences (a) bitrate (b) encoding complexity

overall bitrate estimation error is calculated as the average bitrate estimation error from all the sub-shots. Fig.1 illustrates the diagram of the proposed scheme.

In order to estimate the modeling error, the root mean square error (RMSE) of encoding complexity and bitrate error for GOP={1, 2, 4, 8, 16, 32}, M_L={1, 2, 3, 4, 5, 6, 7} and the length of sub-shot k={150, 75, 60} is calculated. Note that the complexity level of ME process (called M_L) is classified based on the used block-size candidates in the encoding process as proposed in [8]. The test set consists of 16 videos. Fig. 2 shows the RMSE of the estimated bitrate and encoding complexity for the test sequences. It can be seen from the figure that the proposed approach manage to reduce the estimation error for test sequences used. In particular, the average RMSE for bitrate and encoding complexity estimation using k=150 is 26.47 kbps and 428.28 millions of instruction respectively. However, when we use k=60, the RMSE for bitrate and encoding complexity estimation is reduced to 18.57 kbps and 120.55 millions of instruction respectively.

3 Power consumption estimation

We assumed that there are four video nodes that are located at the same distance d from the sink. The power consumption for encoding (P_e) of a VSN node can be estimated as:

$$P_e = \frac{fr}{N}\sum_{i=1}^{\lceil N/k \rceil} C_f{}^i \cdot CPI \cdot E_c \tag{1}$$

where $C_f{}^i$ denotes the estimated encoding complexity for the i-th sub-shot, CPI is the number of CPU cycles to perform one basic instruction, E_c is the energy depletion per cycle, fr is the frame rate of the video, N is the number of frames in a video sequence, and k is the number of frames in a sub-shot. The transmission power consumption is modeled as:

$$P_t = \frac{fr}{N}\sum_{i=1}^{\lceil N/k \rceil} \left(\alpha + \beta \cdot d^{\eta}\right) \cdot L_f{}^i \tag{2}$$

where $L_f{}^i$ is the estimated size (in bit) of the encoded i^{th} sub-shot, α is a constant coefficient related to coding and modulation, β is the amplifier energy coefficient, and η is path loss exponent. In order to estimate the nodes' power consumption, the following parameters are used: α=1e-9 J/b/m^2, β=5e-8 J/b, η=3.5, d=3m, fr=15 fps,

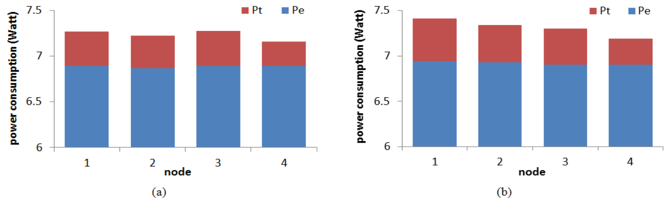

Fig. 3 Node's power consumption for (a) case 1, using test sequence 1 until 4) and (b) case 2, using test sequence 5 until 8. For both cases, the GOP size is eight and k=60.

N=150 frames, k=60 frames, CPI=1.78, and E_c=1.215e-9 J/cycle. Fig. 3 shows the nodes' power consumption for two different scenarios. In the first scenario, the nodes are assumed to have the video test sequences 1 to 4. On the other hand, in the second scenario the nodes are using the video test sequences 5 to 8. The GOP size is set equal to eight, while the M_L is set equal to four. The figure shows that by using the proposed model and approach we can estimate the VSN node's power consumption.

4 Conclusion

In this paper, we have proposed a new scheme to estimate the VSN node's power consumption. The scheme is based on using a model that incorporates some important encoding parameters. Through some adaptive scheme and training, we showed that the model estimation error can be reduced. Using the model, we have analyzed the VSN node power consumption. We showed that the VSN node's power consumption depends on both the encoding parameters and the video content captured by the node.

Acknowledgement

This work was supported by the NPRP grant # NPRP 4-463-2-172 from the Qatar National Research Fund (a member of the Qatar Foundation). The statements made herein are solely the responsibility of the authors.

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