Combined Management of Power- and Quality of Service in Distributed Embedded Video Surveillance Systems

Arnold Maier, Bernhard Rinner, Thomas Trathnigg
Institute for Technical Informatics
Graz University of Technology, AUSTRIA
{maier, rinner, trathnigg}@iti.tugraz.at

Helmut Schwabach
Video & Safety Technology
ARC Seibersdorf Research, AUSTRIA
helmut.schwabach@arcs.ac.at

Abstract

In this paper we present PoQoS, a novel approach for combined management of power- and quality of service (QoS) in distributed embedded video surveillance systems. PoQoS allows the implementation of hardware-tailored dynamic power management schemes for different individual QoS-levels. The proposed approach also offers an extensible model for implementing PoQoS in an overall distributed video surveillance system.

We demonstrate the feasibility of PoQoS in a simple experimental setup for video surveillance. Experimental results show that the approach leads to power savings of up to about 25%.

Keywords: *Video Surveillance; Distributed Embedded System; Dynamic Power Management; QoS; DSP; Real-Time MPEG-4 Streaming;*

1. Introduction

3rd generation video surveillance has become an important research area over the last years due to its various different applications. Recent embedded video surveillance systems combine video sensing, data-compression and analysis as well as short- or long-term storage.

Beside high demands in computing performance, power efficiency is also of major importance in embedded surveillance systems. For instance, recent applications need to deliver compressed video data in high-level quality of service (QoS) while using devices that are solar- or battery-powered. Furthermore, safety critical applications like, e.g., traffic surveillance, typically have strict requirements in reliability that get affected if a device for instance suffers from thermal problems. Fig. 1 summarizes the main reasons that indicate the use of power aware video surveillance.

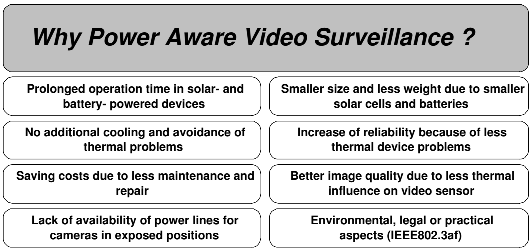

Figure 1. Power Aware Video Surveillance

In order to allow power aware implementation of a distributed video surveillance system, we present a novel and generic approach for combined management of power- and quality of service (*'PoQoS'*). PoQoS takes use of individual and device specific local dynamic power management strategies that respect the actual executed QoS-level. Furthermore, we present a generic implementation of PoQoS for DSP-based hardware platforms that demonstrates the feasibility of the proposed approach. Experimental results show that PoQoS leads to power savings of up to about 25%.

2. Related Work

2.1. 3rd Generation Video Surveillance

Video surveillance is an area with widely spread different applications. In this work, we focus on 3rd generation video surveillance as described in [1]. It is based on the recent employment of embedded intelligent video sensors [2], [3]. These sensors combine video sensing with image processing and data communication. The design of the processing unit allows to yield various parameters of a captured scene and to compress a live video-stream simultaneously.

In safety critical applications such as traffic surveillance, it allows the recognition of dangerous situations and the generation of alarm signals to avoid consecutive endangerment of the situation. For instance, stationary vehicle detection is used to detect accidents or traffic jams that cause dangerous situations. Further applications [4] include the surveillance of buildings, persons or container shipping.

2.2. Power Reduction Approaches

Minimizing the power consumption of electronic systems is an area of intense research. A lot of different power reduction approaches have been described in the literature [5].

A commonly used online method is *Dynamic Power Management (DPM)* [6]. DPM is based on the observation that a lot of power is wasted because of system components that are fully powered up even if they are not in use. Thus, the basic idea behind DPM is that individual components can be switched to different operating states (like 'working', 'idle', 'sleeping' etc.) during runtime. Each operating state is characterized by a different set of power- and performance- parameters.

The commands to change a component's operational state are typically issued by a central power manager. The commands are issued due to a corresponding power management policy. In order to decide which command to issue the power manager must have individual knowledge about the system's workload behavior. It also must take into account that changing a components operational state takes a specific time leading to latency of the device.

2.3. QoS in Video Surveillance

Typical QoS-parameters in video surveillance are video data quality and its distortions in network transmission. It also includes user perceived quality metrics such as the number of frames per second (fps), the image size, data rate or blockiness. However, further quality parameters like the availability of the service are also taken into account.

QoS is also linked with power parameters. For instance, in case of low energy in parts of the system, the QoS can also get seriously affected and degraded. If video data is processed, the time of computing activity of the processing unit and therefore its consumed power typically depends on the quality of the video data. QoS-adaptation focuses on a trade-off between the loss of quality and the reduction of power consumption. The degree of freedom in adapting QoS-parameters strictly depends on its designated application.

In a safety critical application like video surveillance of traffic control, a degradation of the QoS-level may be unacceptable when it appears during the capturing of an accident. Therefore, this may only be carried out with respect to the QoS-specification of the target's application.

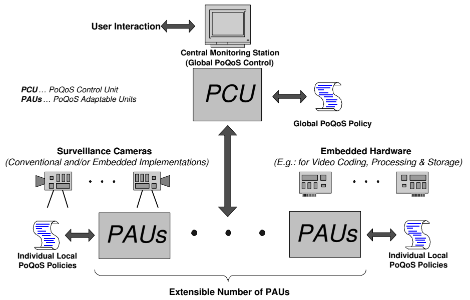

Figure 2. Architectural Concept of PoQoS

3. Combined Management of Power- and QoS

As mentioned before, the sole adaptation of QoS does not inevitably result in power savings due to remaining idle processing activity. Furthermore, optimal power reduction is only achieved if target-specific power reduction policies are used to allow hardware tailored DPM. Thus, we focus on applying hardware tailored DPM policies for all individual QoS-levels.

Our proposed scheme of combined dynamic power- and QoS-management ('*PoQoS*') [7] also offers an extensible model for its implementation in distributed embedded video surveillance systems. The approach is based on some ideas presented in [8] and is described more detailed in [9].

3.1. Architectural Concept

The infrastructure of an video surveillance system typically consists of a central monitoring station that is connected to a various number of system devices whose power- and QoS-level is adaptable dynamically. In PoQoS, all these units get abstracted due to their use for dynamic power- and QoS-management.

Fig. 2 illustrates the architectural concept of PoQoS that mainly consists of a single *PoQoS Controller Unit (PCU)* and a variable number of *PoQoS Adaptable Units (PAUs)*.

PoQoS Controller Unit (PCU): The PCU implements the interface in between the user and the *PoQoS Adaptable Units (PAUs)*. There exist several global PoQoS policies for different operation modes of the system. For instance, in alarm situations (e.g., due to an accident in traffic surveillance) the global policy of the PCU forces corresponding PAUs to deliver video data at best possible QoS. However, if the amount of energy gets critical, the PAUs get forced to alter its local policies in order to maximize power savings.

PoQoS Adaptable Units (PAUs): A PAU is any device in the system whose PoQoS parameters are dynamically configurable. Examples of PAUs include video sensors, processing units or network devices. Since a PAU's opera-

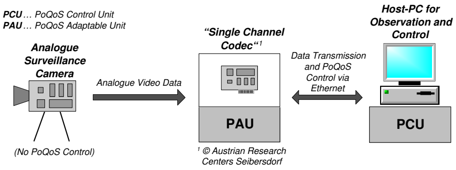

Figure 3. Experimental Setup of PoQoS

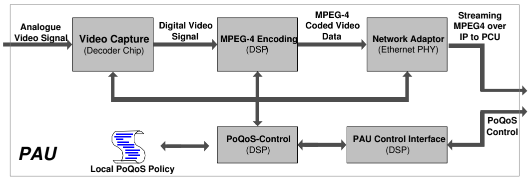

Figure 4. Functional Overview of the PAU

tion in a lower QoS-level usually leads to longer idle periods of its components, it makes sense to apply DPM as well. In PoQoS, each PAU employs its individual device specific implementation of DPM. Thus, a PAU contains its locally stored individual DPM policies for corresponding QoS-levels, i.e., it has its individual local PoQoS policies.

A PAU also contains a local lookup table with a set of its predefined PoQoS levels. It lists the PAU's QoS-levels and their corresponding power consumption. Its purpose is to provide on demand information for the PCU. Obviously, the more PoQoS levels a PAU has, the better it is adaptable to actual requirements. The PAU also delivers on demand status information to the PCU and to execute the PoQoS control commands issued by the PCU.

3.2. Surveillance-Specific Communication Scheme

PoQoS uses a video surveillance-specific, event-driven interaction scheme. It works independent of the underlying network topology and communication protocol and is specified to be applied upon a heterogenous network environment. Thus, it assumes as little as possible about the underlying network. In PoQoS, both global and local policies are triggered by several predefined events.

For instance, if a PAU (e.g., an intelligent camera) recognizes an accident, an accordant event message to the PCU is generated. The PCU then triggers the corresponding PAUs to alter its local policies due to the global policy for handling alarm situations (that means, e.g., maximum possible QoS delivery and minimum power savings).

Furthermore, the PCU uses a time-driven observation scheme for the PAUs in order to recognize malfunction or breakdown of a single unit.

4. Feasibility Study of PoQoS

We evaluate the feasibility of PoQoS with a simple experimental setup that implements video sensing, encoding and transmission. As depicted in fig. 3, the experimental configuration only consists of a single PAU. However, it adequately demonstrates the effect of PoQoS.

The setup contains a camera that delivers an analogue video signal in full PAL resolution at 25fps. It is directly connected to a DSP-based hardware MPEG-4 compliant. Fig. 4 gives a functional overview on the *"Single Channel Codec"* (SCC, designed by the *Austrian Research Centers Seibersdorf*) that is used as PAU. However, the camera cannot change its PoQoS parameters and therefore it is not used as PAU in this setup. The SCC captures the analogue video signal, performs MPEG-4 encoding (simple profile) and real-time IP-streaming. The MPEG-4 encoding is performed by the DSP in software (ATEME). The network connectivity is given by a TCP/IP stack from Texas Instruments, whereas real-time protocol (RTP) and multicast transmission is used. In our setup, the network bandwidth is reduced to a maximum of about 1.5MB/s (in PAL resolution with 25fps).

The SCC contains a video decoder chip and is capable of using composite video as input. Its main part is a TMS320DM642 DSP from Texas Instruments (TI), that also provides an internal ethernet media access controller (EMAC). Thus, the PHY-transceiver gets directly connected to the DSP.

The DSP powers-down its processor core by register control and gets woken up by predefined interrupt sources. Measurements showed that changing the DSP-core's power mode usually takes less than 15ns. Thus, the effect of latency is negligible for the DSP. The video decoder chip also offers a power down mode that is controlled via I^2C (hosted by the DSP). In contrast to the DSP, altering its power mode takes up to about 120ms which cannot be neglected. Thus, it is defined in the local policy of the PAU that it gets only powered down in frame rates below 10fps when long enough idle periods of the device are guaranteed. In addition, measurements showed that the PHY-device cannot be used for PoQoS due to setup problems with the TCP/IP stack that is used.

We applied a generic implementation of PoQoS for DSP-based embedded PAUs in order to allow easy porting to other DSP-based hardware platforms whose onboard components can be abstracted as PMCs. The RTOS ('DSP/BIOS') of the C6000 series from TI provides so called 'hooks' that are called upon specific events such as task switches. In the given application, the local power manager is called upon every task switch by the hook. The power manager maintains a data structure for each individual task, containing data about all corresponding PMCs that are used by the task.

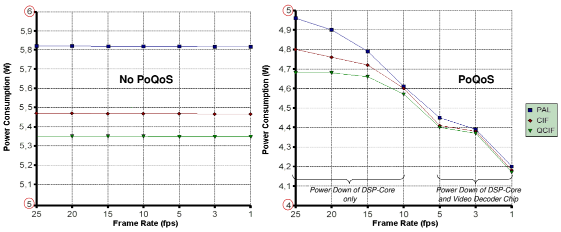

Figure 5. Power Consumption of the SCC

Each PMC also has several associated additional elements, including its DPM policy, its actual power state and a mechanism for changing the power state. The implementation has no limitations in terms of the use of static or adaptive DPM-policies or the number of power states of each power manageable components (PMCs).

Furthermore, a data structure containing the following elements is kept: *(1)* a task-enter callback function (its return value determines the next power state of the PMC); *(2)* a task-leave callback function (its return value determines the next power state of the PMC); *(3)* a pointer to an arbitrary policy data structure. Upon each task switch, the power manager determines the set of PMCs that have been used by the last task and those that will be used by the next task. Furthermore, the power manager collects data about busy and idle periods and to decide upon the appropriate power state of the PMC for the next idle/busy period.

5. Experimental Results

The total power consumption of the SCC is measured by a digital oscilloscope using a current probe. In the 'standard' implementation (i.e., without PoQoS), the power consumption of the SCC varies from about 5.82W*(PAL)* and *5.47W(CIF)* to 5.36W*(QCIF)*. Measurements showed that these values are independent of the frame rate due to idle clocking activity of the DSP core and the video decoder. The power consumption is also measured under different PoQoS-levels (i.e., with different DPM policies for each QoS-level) leading to power savings of up to about 25% (as depicted in fig. 5).

Fig. 6 shows the effect of PoQoS on the profile of the total power consumption of the SCC. At less than 10 fps, another policy gets used that also also powers down the video decoder chip for a longer period of time without risking latency effects due to its previously described behavior.

6. Conclusion

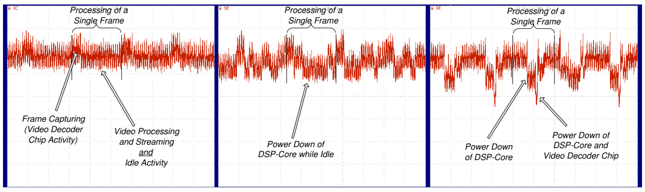

Figure 6. Profile of Total Power Consumption

In this paper we have presented PoQoS, a novel hierarchical approach for combined power- and QoS-management in distributed video surveillance systems. We have demonstrated the feasibility of our approach on a simple experimental setup containing an embedded DSP-platform. Experimental results indicated power savings of up to about 25%.

Future work includes the experimental evaluation of PoQoS in a distributed heterogenous video surveillance setup that includes several different embedded platforms as PAUs. Furthermore, we plan to extend PoQoS by implementing an user interface for dynamic configuration and modification of both global and local policies.

References

[1] G. L. Foresti, V. Ramesh, and C. S. Regazzoni, "Special Issue on Video Communications, Processing and Understanding for Third Generation Surveillance Systems," *Proceedings of the IEEE*, vol. 89, no. 10, pp. 1355–1367, Oct 2001.

[2] M. Bramberger, R. P. Pflugfelder, B. Rinner, H. Schwabach, and B. Strobl, "Intelligent Traffic Video Sensor: Architecture and Applications," in *Proceedings of the Telecommunications and Mobile Computing Workshop*, 2003.

[3] W. Wolf, B. Ozer, and T. Lv, "Smart Cameras as Embedded Systems," *IEEE Computer*, pp. 48–53, 2002.

[4] G. L. Foresti, P. Mähönen, and C. S. Regazzoni, Eds., *Multimedia Video-Based Surveillance Systems*, Kluwer Academic Publishers, Boston, 2000.

[5] M. Pedram and J. Rabaey, Eds., *Power Aware Design Methodologies*, Kluwer Academic Publishers, 2002.

[6] A. Bogliolo, L. Benini, and G. De Micheli, "A Survey of Design Techniques for System-Level Dynamic Power Management," *IEEE Transactions on Very Large Scale Integration (VLSI) Systems*, vol. 8, no. 3, Jun 2000.

[7] A. Maier, B. Rinner, H. Schwabach, and T.Trathnigg, "Combined Dynamic Power- and QoS-Management in Embedded Video Surveillance Systems," in *Proceedings of the Second Workshop on Intelligent Solutions in Embedded Systems, Graz, Austria*, 2004.

[8] L. Abeni and G. Buttazzo, "Hierarchical QoS-Management for Time-Sensitive Applications," in *Proceedings of the Seventh IEEE Real-Time Technology and Applications Symposium*, 2001, pp. 63–72.

[9] T. Trathnigg, "Combined Management of Power and Quality of Service in Video Surveillance Systems," M.S. thesis, Institute for Technical Informatics, Graz University of Technology, Graz, Austria, 2004.