# A Compact Architecture for Wireless Video Surveillance over CDMA Network

Hang Zhou and David Suter
*Institute for Vision Systems Engineering,*
*Monash University, Clayton, VIC 3800, Australia*
*{hang.zhou, d.suter}@eng.monash.edu.au*

## Abstract

*Wireless video surveillance over CDMA network enables transfer of high quality live video via public wireless broadband, which is accessible anywhere with CDMA mobile phone network coverage. Real time video can be received on an internet connected PC, laptop or even mobile phone. This makes possible surveillance from moving vehicles, or quick deployment in almost unrestricted locations. While many general purpose solutions exist for sending video over CDMA, they have not taken into consideration certain specific features of the network nor the requirements of the related applications. This paper presents a new architecture for video transmission over CDMA with simple hardware complexity, high reliability and rich functions. The compact and flexible system has been under trial in China, Australia, Singapore, Italy, Egypt and Brazil, amongst others.*

## 1. Introduction

In this paper, we consider the problem of sending real time video over a mobile phone network, specifically on the Code Division Multiple Access (CDMA) channel. Our solution is designed to send real time video via the wide-coverage CDMA channel where the live video can be received on any internet connected computer or mobile phone, allowing the device to be placed in moving vehicles or deployed in almost any locations.

With increasing processor speed and reduced network cost it has become economically feasible to widely apply public network based wireless video surveillance within a variety of industries. However, even with these technological advances we still have to overcome the problem of how to manage and transmit the large volume video data over the wireless channel efficiently and reliably.

In [1] a framework is provided for optimizing the total power consumption of a mobile transmitter subject to a given end-to-end distortion by means of optimal parameters for the source encoder, channel encoder, and transmitter. Work has also been done in [2] and [3] to improve the reliability of video transmission over CDMA with effective video transmission scheme and methodology which can reduce packet loss, time delays as well as interference effects. In [4] a layered (scalable) video source codec is used to form resource optimization schemes. What has been done mainly focused on the source and channel codecs.

Besides the theoretical research, there also exist some practical solutions for CDMA video surveillance [11][15][16]. These systems are assembled with general purpose devices which result in high complexity, large volume as well as high power dissipation.

We put more consideration on issues like system architecture and hardware implementation and have put forward a compact system that is specially tailored to the wireless video transmission over CDMA.

The remainder of the paper has the following structure. In section 2, a description is given of the system architecture, the main processor, and related issues such as optimizing the H.264 video compression algorithm, as well as the communication mode. Section 3 summarizes the main conclusions of the work and discusses possible future extensions to the system. Results are presented throughout the sections whenever appropriate.

## 2. System description

### 2.1 Single processor architecture

There exists two alternative CDMA wireless video surveillance solutions as shown in Figure and Figure . One assembles together a video server with a

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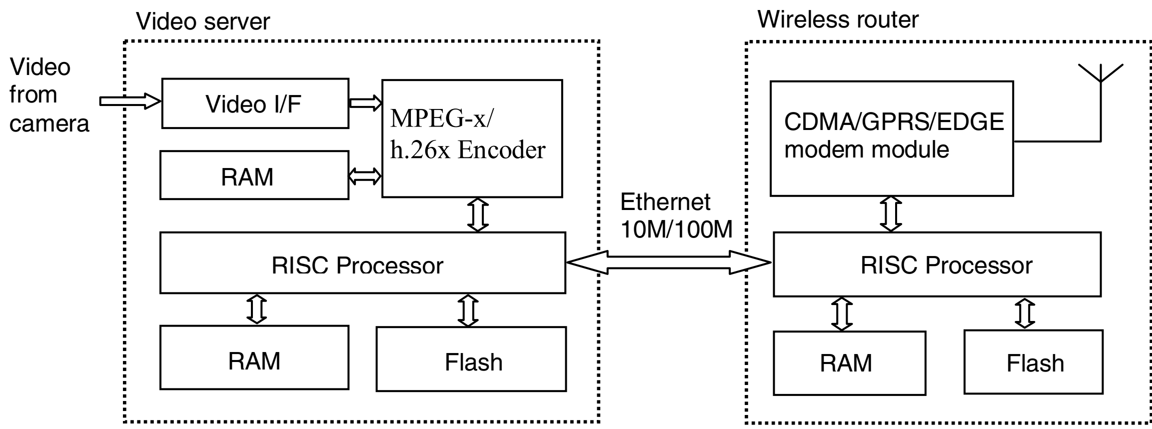


**Figure 1. Video server/IP camera + wireless router solution**

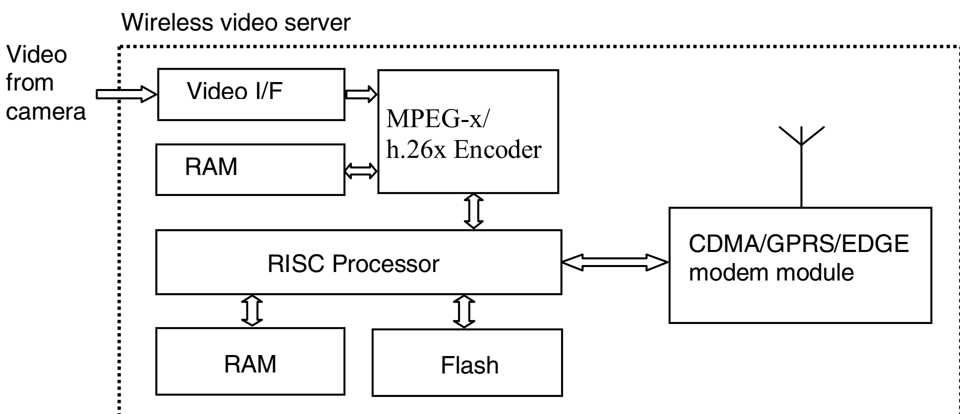


**Figure 2. All in one dual processor wireless video server solution**

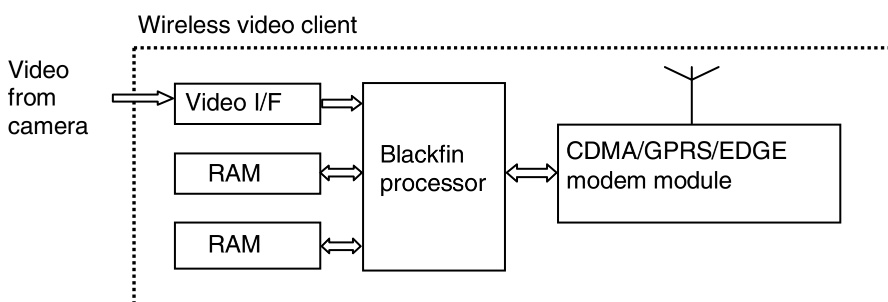


**Figure 3. Single processor wireless video client solution**

wireless router [11][15]. Another is a dual processor architecture integrating a DSP/media processor together with a RISC processor [14][17]. Both solutions employ two processors, one for the video codec, the other for general purpose processing, e.g. running operating system, networking protocol layers and system control, etc.

We present here a third alternative - an innovative wireless video surveillance system. It possesses a single processor architecture using a Blackfin [7][8] processor - a product of Analog Device Inc. (ADI). The system features a distinctive low hardware complexity, which provides a sound base for achieving a small size, low power consumption and reliable solution. A schematic diagram of the architecture is shown in Figure 3.

ADI Blackfin is a DSP processor based on the Micro Signal Architecture (MSA) developed by ADI and Intel. It combines the 32 bit RISC instruction set [9] and dual 16 bit Multiplication Accumulator (MAC) digital signal processing capability together with the easy to use characteristic of the general purpose micro-controller. This combination enables Blackfin to fulfill the task normally carried out by DSP multimedia processor + general purpose RISC processor.

We embedded in the Blackfin several modules: a specifically designed compact operation system kernel [10] with watchdog (supporting long term operation without any maintenance), a simplified and optimized H.264 video compression algorithm, as well as an adjusted TCP/IP protocol to fit the needs of wireless communication.

A photo of the main processing board of our system is given in Figure 4, which shows that there are only 4 main chips on board, giving a compact mechanical size.

We have compared our system with the existing two kinds of solutions with the results shown in Table 1. It can be seen that our solution has significantly fewer chips, smaller PCB size, lower power dissipation and consequent longer lasting operating time.

## 2.2 Main processor

Our main processor, the ADI Blackfin, has a speed of 400MHZ, with external memory being of size 8M/16M. It was first released in 2003 and put into production in 2004. With high integration and flexibility, it is especially suitable for multimedia

**Table 1. Parameter comparison of different wireless video surveillance solutions**

| | Video server + wireless router | Dual processor wireless video server | Single processor wireless video client |
|---|---|---|---|
| Main chips (approximate) | Video server:<br>Risc processor x1<br>SDRAMx1<br>Flashx1<br>Ethernet controllerx1<br>MPEG-x/h.26x encoderx1<br>DRAMx1<br>Video decoderx1<br><br>Wireless router:<br>Risc processorx1<br>SDRAMx1<br>Flashx1<br>Ethernet Controllerx1<br><br>Minimum chip count: 11 | Main processor:<br>General purpose processorx1<br>DRAMx1<br>Flashx1<br><br>Encoder:<br>MPEG-x/h.26x encoderx1<br>(or DSPx1)<br>DRAMx1<br>Flashx1(or none)<br>Video decoderx1<br><br>Minimum chip count: 6-7 | Blackfin:<br>processorx1<br>DRAMx1<br>Flashx1<br>Video decoderx1<br><br>Chip count : 4 |
| PCB size ( aprox. size with wireless modem on board) | Video server:<br>150 x 75mm<br><br>Wireless router:<br>130 x 75mm | 150mm<br>x<br>120mm | 100mm<br>x<br>65mm |
| Power consumption | 8W | 5W | 1.5W |
| Battery life (7200mAh/7.2V battery pack) | 6 hours | 10 hours | 32 hours |

application.

Our design has mostly benefited from the advantages of Blackfin listed down below:

1. Extraordinary high integration [7]. Integrated with most of the system parts, the Bill of Material (BOM) is significantly reduced.
2. Equipped with enhanced dynamic power management capability [8], the power consumption is very low. i.e. it can dynamically change the frequency and core power supply of the processor, so that high frequency and high power supply voltage are employed when processing large volume of data. In sleeping mode, it runs at low frequency and low power supply voltage.

Despite the high performance of Blackfin, it has some limitations. In particular, Blackfin has only one serial port, with no Inter-Integrated Circuit (I2C) interface [8]. In our system, this has been overcome. Our system realises 2 serial ports by means of software (for simultaneous external data communication). Indeed, since Blackfin has a fast processing speed, we have simulated many hardware functions by software.

In this way, sophisticated hardware functions are implemented with software, which reduces the parts used on board; resulting in effective increasing of Mean Time Between Failure (MTBF). For two systems with the same component reliability, and under the same manufacturing process, the one with less number of components is more reliable.

On the other hand, software simulation itself is also a key factor in enhancing the system stability as a software exception can be handled by exception processing code, avoided by strict testing program, or can simply be addressed by rebooting by the on board watchdog hardware (Blackfin has on chip watchdog hardware). While a hardware failure is normally not renewable which is fatal for a wireless video surveillance system working at a 24x7 non-stop mode.

### 2.3 Optimizing H.264 algorithm on Blackfin

The codec algorithm of our system is H.264 [5][6]. H.264 is a video compression scheme that is perhaps becoming the de facto worldwide digital video standard for consumer electronics and personal computers.

In order to lower the power consumption, work has been done on optimization and simplification of H.264 coding so as to lower the complexity and enhance the hardware data access speed. The optimization covers C coding and assembler. C coding optimization includes linearizing the compiler code, decorrelation of continuous data dependence, conversion of division to multiplication or look up table, minimize accessing times on external memories, etc. Assembler optimization mainly focuses on saving register resources, using reserved instructions and parallel instructions and mode selection optimization, etc..

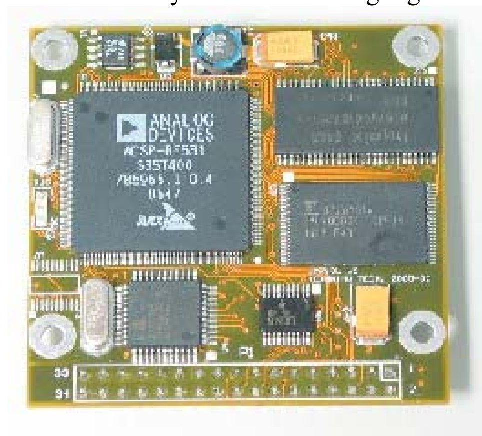


**Figure 4. Main processing board**

Following the above optimization principles, what has been done is briefly summarized as follow:

1. Estimation optimization. Intra-frame mode selection and inter-frame mode selection are new features introduced in the H.264 standard. Intra-frame mode selection dramatically reduces spatial redundancy in I-frames, while inter-frame mode selection significantly affects the output quality of P-/B-frames by selecting an optimal block size with motion vector(s) or a mode for each macroblock. Unfortunately, this feature requires a huge amount of encoding time where the computational complexity is mainly concentrated on a SAD (Sum of Absolute Difference) function. Assembler optimization on SAD can significantly enhance the mode selection speed. Taking the 16x16 macroblock prediction as an example, before and after optimization, the clock cycles consumed are 1385 vs 66.
2. VLC (Variable Length Coding) optimization. VLC involves large amount of bit operations. By employing the Blackfin reserved instruction, the bit operations can be finished in single clock cycle rather than multiple clock cycles if executed with conventional instructions.
3. Lower the computational complexity method (1). When calculating on motion estimation, selectively using 1/2 or 1/4 pixel interpolation based on SAD value. This can significantly lower the computational complexity at the expense of slight SNR (Signal Noise Ratio) decrease.
4. Lower the computational complexity method (2). Before conventional mode selection on inter macroblock, copy and test on the original block by

means of SSD (Sum of Squared Difference) instead of SAD, which results in higher compression ratio and efficiency.

### 2.4 Communication mode

A network usually places a higher demand on the resources of a server, such as public IP, appropriate processing capability, bandwidth and firewall, etc. For a client, the demand is lower, both public IP address and private IP address are acceptable. A client is more flexible, and can be better adapted to the network.

Many CDMA service provider around the world assign limited authority to mobile terminals, such as assigning with private IP only, isolating from internet with firewall and rejecting requests from outside the CDMA network, etc. Therefore, it is quite difficult to make the device in the CDMA network to act as a server in most situations.

The conventional video server works in server mode [13][15], which makes it easier for it to be managed on a LAN, eg. it can be browsed by internet explorer. However it is not suitable for wireless communication, as wireless network conditions may vary significantly in different parts of the world.

Taking all these into consideration, we chose our device to be the client (and the receiving PC terminal being the server). Transmission is done on demand. This demand may either come from the receiving terminal or the transmitting terminal (being triggered). Trials in different parts of the world shows that in contrast to the performance when being a server, our wireless video client is well adapted to the different networks.

## 3. Conclusion and Future Work

We have presented a novel solution for wireless video surveillance over a mobile phone network. The system is a fully customizable application that can be used to address the requirements for this application domain. We have discussed the key features of the system and demonstrated how this system can have high efficiency.

The key novelty of our Blackfin DSP based system is integrating all the CDMA tailored functions in a single processor instead of two or more processors in contrast to conventional solutions. This is achieved by means of careful design and a series of optimizations.

However, the solution is still far from being perfect. In the future, a higher speed processor will be employed to further improve the performance and to enable us to embed video analysis algorithms in the system.

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