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Seongsoo Hong (Eds.)

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Preface

This volume contains the 37 papers presented at the 9th International Conference on Real-Time and Embedded Computing Systems and Applications (RTCSA 2003). RTCSA is an international conference organized for scientists and researchers from both academia and industry to hold intensive discussions on advancing technologies topics on real-time systems, embedded systems, ubiquitous/pervasive computing, and related topics. RTCSA 2003 was held at the Department of Electrical Engineering of National Cheng Kung University in Taiwan. Paper submissions were well distributed over the various aspects of real-time computing and embedded system technologies. There were more than 100 participants from all over the world.

The papers, including 28 regular papers and 9 short papers are grouped into the categories of scheduling, networking and communication, embedded systems, pervasive/ubiquitous computing, systems and architectures, resource management, file systems and databases, performance analysis, and tools and development. The grouping is basically in accordance with the conference program. Earlier versions of these papers were published in the conference proceedings. However, some papers in this volume have been modified or improved by the authors, in various aspects, based on comments and feedback received at the conference. It is our sincere hope that researchers and developers will benefit from these papers.

We would like to thank all the authors of the papers for their contribution. We thank the members of the program committee and the reviewers for their excellent work in evaluating the submissions. We are also very grateful to all the members of the organizing committees for their help, guidance and support. There are many other people who worked hard to make RTCSA 2003 a success. Without their efforts, the conference and this volume would not have been possible, and we would like to express our sincere gratitude to them. In addition, we would like to thank the National Science Council (NSC), the Ministry of Education (MOE), and the Institute of Information Science (IIS) of Academia Sinica of Taiwan, the Republic of China (ROC) for their generous financial support. We would also like to acknowledge the co-sponsorship by the Information Processing Society of Japan (IPSJ) and the Korea Information Science Society (KISS).

Last, but not least, we would like to thank Dr. Farn Wang who helped initiate contact with the editorial board of LNCS to publish this volume. We also appreciate the great work and the patience of the editors at Springer-Verlag. We are truly grateful.

Jing Chen and Seongsoo Hong

History and Future of RTCSA

The International Conference on Real-Time and Embedded Computing Systems and Applications (RTCSA) aims to be a forum on the trends as well as innovations in the growing areas of real-time and embedded systems, and to bring together researchers and developers from academia and industry for advancing the technology of real-time computing systems, embedded systems and their applications. The conference assumes the following goals:

- to investigate advances in real-time and embedded systems;
- to promote interactions among real-time systems, embedded systems and their applications;
- to evaluate the maturity and directions of real-time and embedded system technology;
- to bridge research and practising experience in the communities of real-time and embedded systems.

RTCSA started from 1994 with the International Workshop on Real-Time Computing Systems and Applications held in Korea. It evolved into the International Conference on Real-Time Computing Systems and Applications in 1998. As embedded systems is becoming one of the most vital areas of research and development in computer science and engineering, RTCSA changed into the International Conference on Real-Time and Embedded Computing Systems and Applications in 2003. In addition to embedded systems, RTCSA has expanded its scope to cover topics on pervasive and ubiquitous computing, home computing, and sensor networks. The proceedings of RTCSA from 1995 to 2000 are available from IEEE. A brief history of RTCSA is listed below. The next RTCSA is currently being organized and will take place in Sweden.

1994 to 1997:	**International Workshop on Real-Time Computing Systems and Applications**
RTCSA 1994	Seoul, Korea
RTCSA 1995	Tokyo, Japan
RTCSA 1996	Seoul, Korea
RTCSA 1997	Taipei, Taiwan
1998 to 2002:	**International Conference on Real-Time Computing Systems and Applications**
RTCSA 1998	Hiroshima, Japan
RTCSA 1999	Hong Kong, China
RTCSA 2000	Cheju Island, Korea
RTCSA 2002	Tokyo, Japan
From 2003:	**International Conference on Real-Time and Embedded Computing Systems and Applications**
RTCSA 2003	Tainan, Taiwan

Organization of RTCSA 2003

The 9th International Conference on Real-Time and Embedded Computing Systems and Applications (RTCSA 2003) was organized, in cooperation with the Information Processing Society of Japan (IPSJ) and the Korea Information Science Society (KISS), by the Department of Electrical Engineering, National Cheng Kung University in Taiwan, Republic of China (ROC).

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Scheduling-Aware Real-Time Garbage Collection Using Dual Aperiodic Servers

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Abstract. Garbage collection has not been widely used in embedded real-time applications since traditional real-time garbage collection algorithm can hardly bound its worst-case responsiveness. To overcome this limitation, we have proposed a scheduling-integrated real-time garbage collection algorithm based on the single aperiodic server in our previous work. This paper introduces a new scheduling-aware real-time garbage collection which employs two aperiodic servers for garbage collection work. Our study aims at achieving similar performance compared with the single server approach whilst relaxing the limitation of the single server approach. In our scheme, garbage collection requests are scheduled using the preset CPU bandwidth of aperiodic server such as the sporadic server and the deferrable server. In the dual server scheme, most garbage collection work is serviced by the secondary server at low priority level. The effectiveness of our approach is verified by analytic results and extensive simulation based on the trace-driven data. Performance analysis demonstrates that the dual server scheme shows similar performance compared with the single server approach while it allows flexible system design.

1 Introduction

As modern programs require more functionality and complex data structures, there is a growing need for dynamic memory management on heap to efficiently utilize the memory by recycling unused heap memory space. In doing so, dynamic memory may be managed explicitly by the programmer through the invocation of "malloc/free" procedures which is often error-prone and cumbersome.

For this reason, the system may be responsible for the dynamic memory reclamation to achieve better productivity, robustness, and program integrity. Central to this automatic memory reclamation is the garbage collection (GC) process. The garbage collector identifies the data items that will never be used again and then recycles their space for reuse at the system level.

In spite of its advantages, GC has not been widely used in embedded real-time applications. This is partly because GC may cause the response time of application to be unpredictable. To guarantee timely execution of a real-time application, all the

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