RTDB’96
First International Workshop on Real-Time Database Systems
Workshop Report

Azer Bestavros†
(best@bu.edu)
Kwei-Jay Lin†
(klin@uci.edu)
Sang Son‡
(son@cs.virginia.edu)

1 Introduction
On March 7 and 8, 1996, the First International Workshop on Real-Time Databases (RTDB’96) was held in Newport Beach, California. There were about 50 workshop participants from many countries, including Germany, Netherlands, Norway, Sweden, Finland, Korea, Japan, Hong Kong, Taiwan, and USA. Twenty two papers were presented and actively discussed in the 2-day 6-sessional technical program. There were also two panel sessions to review and to suggest the technology needed for real-time database applications.

One of the goals of RTDB’96 was to create a forum for recent advances in real-time databases—an area that is becoming more important as real-time computing is needed in our systems and environment. We hoped to, and indeed we did, bring together researchers and engineers from academia and industry to explore the best ideas in real-time database systems research, and to evaluate the maturity and directions of real-time database systems technology. The interaction among all participants in the workshop (such as discussing the advanced functionalities and timely management of data, arguing about the real-time requirements in practical systems, suggesting new issues to be investigated in future projects, etc.) provided a very precious and fruitful experience for everyone.

In RTDB’96, single track sessions were scheduled to give all participants the opportunity to have full interactions with all speakers and panelists, and to exchange opinions with other participants. The technical program covered a range of issues, such as temporal consistency, scheduling, models and benchmarks, concurrency control, and applications. In this report, we provide highlights of the workshop.

2 Temporal Constraints and Issues
The first session, chaired by Kwei-Jay Lin of the University of California at Irvine, aimed at solidifying the notions of temporal constraints so that workshop participants may achieve a common understanding/agreement on the temporal constraint aspects of RTDB. Three papers were presented by research groups at the University of Massachusetts at Amherst, the University of Arizona, and the University of Michigan at Ann Arbor. Each one of these papers considered the origins and implications of temporal constraints in a specific environment or for a specific platform, including feedback control process control systems, Active Rapidly Changing data Systems (ARCS), and real-time databases in which transaction deadlines are implied from temporal constraints on data.

Several approaches to maintain data temporal consistency were mentioned during the presentations and during the discussions that ensued, including determining the periods for sensor transactions, data version selection, forcing user transactions to delay for a more up-to-date version, etc. One of the messages that came out of this session is that using traditional concurrency control techniques may not be appropriate for active RTDB because the effect of transaction “chaining” is not adequately addressed. Another open problem is the issue of how updates from the environment (through sensors) should be scheduled against user transactions and other updates. Finally, the merits of relating transaction scheduling decisions to transaction completion probabilities were discussed.

3 Real-Time Database Applications
The second session of the workshop was chaired by John Stankovic of the University of Massachusetts at Amherst, who opened the session with a “challenge” to the RTDB community—to make the case for RTDB technology by showing the “value-added” it brings to as many applications as possible. In a later panel, he presented a list of application domains that came up during the various sessions and added his belief that there are many more.

Four papers were presented in this session by research groups from Telenor R&D and SINTAF Telecom and Informatics in Norway, from VTT Information Technology in Finland, from Linkoping University in Sweden, and from Technische Hochschule Darmstadt in Germany. Each one of these presentations overviewed the constraints imposed by a particular application domain and how these constraints were accomodated in a RTDB design targeted at that domain. The RTDB applications considered represented telecommunication systems, process-control systems, real-time simulation systems, and Web-based systems.

One of the points made during the presentations was that as any engineering practice, RTDB systems must provide the “best compromises” as opposed to the “most elegant solutions”. One of the messages that came out of the
discussion that followed was that sometimes deadlines are
set based on what the system can do (in other words, if
the system is built to be twice as fast, then laxities will be
halved). Another point made during the presentations was
that researchers must look at the notion of cost in a more
pragmatic way (e.g. the learning curve of new techniques
and the man/machine interaction issues are important for
systems that involve a “person in the loop”).

4 Scheduling Techniques for RTDB

This session of the workshop was chaired by Al Mok of
the University of Texas at Austin. Four papers were presented
in this session by research groups from Linkoping University
in Sweden, Boston University, Eindhoven University in the
Netherlands, and the University of Michigan at Ann Arbor.

One of the promising research techniques discussed in the
first paper of the session is performance polymorphism for
RTDB systems, whereby ideas from imprecise computation
research (e.g. FLEX language) are applied to declarative
query languages and to query optimization techniques.

Another interesting dimension of scheduling for RTDB
systems is that of overload management. The second pa-
per of the session showed evidence that admission control is
much more important than other RTDB resource manage-
ment techniques (e.g. concurrency control and scheduling).
In particular, admission control makes simple concurrency
control protocols (e.g. 2PL-HP protocols) perform as well
as sophisticated ones (e.g. Wait-50 and SCC protocols).

During the discussion that followed these presentations,
there were questions about the “cost” of elaborate RTDB
protocols versus the cost of admission control. The motiva-
tion of the question was that RTDB must be light weight and
that unless solutions we provide are easily portable, they will
never be implemented in real-systems. Krithi Ramananritham
from the University of Massachusetts at Amherst intervened
to give evidence of this from concurrency control research,
where hundreds of algorithms are proposed, but only few
(mainly 2PL) are implemented in real systems. In reference
to admission control and overload management techniques in
general, Azer Bestavros from Boston University suggested
that these techniques in effect reduce the overall overhead,
because they make the use of other complicated real-time
protocols unnecessary! Another point brought up was that
the techniques must be possible to add as a layer on top
of existing off-the-shelf DB systems. Admission control and
overload management is a good candidate layer.

To conclude, Al Mok challenged the participants to iden-
tify a set of properties that are worth proposing as stan-
ards for RTDB (akin to the ACID properties of traditional
DBMS). The discussion that ensued questioned whether a
single model will ever be possible, given the richness of
RTDB systems—a richness that comes from the disparity of
application requirements as pointed out by John Stankovic.
Another thread in this discussion had to do with the quan-
tification of predictability and perhaps the use of a proba-
bilistic model (akin to the ideas from the third paper of the
session) or the use of values and various QOS guarantees
(akin to the ideas from the second paper of the session).

5 RTDB Models and Benchmarks

This session was chaired by J.Y. Chung of IBM and con-
sisted of three paper presentations by research groups from
HP Labs in Paolo Alto, the University Skovde in Sweden,
and Hughes Aircraft Corporation.

The first paper in this session addressed an important
(and often neglected) aspect of RTDB systems—that of query
optimization. It proposed an elegant paradigm for cost mod-
eling based on the relative “cost” of various operations—a
modeling that abstracts away many of the details of the un-
derlying machinery and algorithms. The discussions that en-
sued focused on two possible extensions to the cost modeling
approach to better support RTDB systems, namely adding
absolute timing analysis, and allow for load parametrization
(i.e. to allow the estimation of cost to be parametrized based
on the system load).

The third paper in this session offered a number of bench-
marks that could be used to define the structure of an avion-
ics database and test the various aspects of RTDB systems
performance. The benchmarks were abstracted out from
actual avionic systems. Seven test scenarios were defined
ranging from periodic-readers-only to periodic-readers plus
sporadic-readers plus periodic-updates. The paper fills in
a void that was identified throughout the workshop—that
of quantifying RTDB properties. The discussion that en-
sued reaffirmed the need for similar benchmarks for other
applications.

6 RTDB Design Issues

The last two sessions of the workshop were chaired by Kane
Kim of the University of California at Irvine and by Kang
Shin of the University of Michigan at Ann Arbor. These two
sessions were dedicated to the presentation of a potpourri of
new design and implementation techniques for RTDB and
consisted of six paper presentations by research groups from
the City University of Hong Kong, the University of North
Carolina, Case Western Reserve University, MITRE Corpora-
tion, the University of Oklahoma, and the University of
Florida.

Among the issues that were highlighted as worthy of fur-
ther investigation was the problem of priority assignment
for sub-transactions in distributed real-time databases. The
presentation of K.Y. Lam of the City University of Hong
Kong suggested two such approaches: one is based on the
real-time constraint of the base transaction, and the other
based on the data contention with other transactions.

Another implementation optimization that stirred quite
a bit of discussions was the use of lock-free objects to syn-
cronize transactions in main-memory RTDB systems. This
technique was suggested by James Anderson of the Univer-
sity of North Carolina as an implementation technique that
gets rid of priority inversion by substituting blocking with ef-
cient busy-waiting. The hidden overhead cost and reduced
predictability were some of the concerns voiced regarding
this technique.

Two new concurrency control protocols were also pre-
seated as candidates for improving the timeliness of trans-
action execution in RTDB systems. The first concurrency
control protocol extends the read/write priority ceiling pro-
tocol by defining a compatibility table for all the methods
defined for an object in an OO RTDB system, and then
using this table to come up with an affected set priority
ceilings (ASPC) that could be used to regulate the access
to the object to ensure consistency. During the discussion,
there were questions about the scalability and practicality of
such an approach (and similar semantic-based techniques),
because they depend on the ability of designers to identify the conflict modes. The second protocol attempts to reduce the hazards of blocking-based algorithms and restart-based algorithms by suggesting an algorithm that combines them (using alternative *shadows*). The work is similar to the Speculative Concurrency Control (SCC) work by Bestavros and Braoudakis in RTSS'94 and VLDB'95.

Another issue that was identified by workshop participants as worthy of further investigation is the issue of recovery for RTDB systems. In a real-time system, the recovery of a database may be subject to timing constraints, which imply that during normal operation, activities such as logging and checkpointing must be performed in fashion that would guarantee that in the event of a failure, the database will be able to recover in a timely manner. The paper by Le Grunewald of the University of Oklahoma presented a first step in studying this issue for main-memory RTDB. The main argument in the paper is to have the rate of data checkpointing related to the time-constraints associated with the data.

7 Panel: “Are we looking at the right problems?”

The first panel of the workshop was entitled “Are we looking at the right issues of RTDB?”. The panel was moderated by Kwee-Jay Lim. The panelists were Doug Locke of Loral Federal Systems, Lui Sha of SEI/CMU, Brad Adelberg of Stanford University, and Krithi Ramamritham.

Doug Locke first spoke of the application requirements for Aerospace RTDB systems. He emphasized that transactions that miss their deadlines must finish and argued for value-cognizant RTDB systems as opposed to the hard/firm deadline paradigm. Several workload requirements in the Air Traffic Control, Spacecraft Control, Training Simulation, etc., were presented and discussed.

Lui Sha then talked about the need for an equivalent to the ACID properties for RTDB systems. He suggested that the notion of stream data is fundamental for RTDB. In other words, one may think of stream-data RTDB as different enough from traditional RTDB that deal with closed systems where changes to data are only carried by transactions from within the system.

Brad Adelberg described the STRIP project at Stanford, which is aimed at financial applications (*e.g.*, financial market monitoring). Much emphasis have been placed on the data update streams received by the database and how they can be effectively handled to provide a real-time view in the database.

Krithi Ramamritham finally discussed the impact of RTDB technology in commercial products. He pointed out that while temporal and active database ideas have found their way into commercial products as well as into SQL, real-time database ideas have not. One plausible reason is that developing time-cognizant extensions to database protocols requires a fairly substantial overhaul. The second reason is that a large proportion of the techniques developed thus far apply only to soft real-time constraints with the percentage of missed deadlines being the metric. This implies that the use of the protocols is intended more to improve performance and not for increasing functionality, unlike in temporal and active databases. He emphasized that RTDB researchers must aim at achieving greater predictability in real-time databases so that we get improved performance as well as predictability that is quantifiable, the latter is a property that is not achievable simply by “faster hardware”.

8 Panel: “Lessons learned and places to go”

The second panel of the workshop was entitled “What have we learned and where to go from here?” The panel was intended as a concluding session for the workshop. It was moderated by Program Co-Chair Sang Son from the University of Virginia. The panelists were Jane Liu from the University of Illinois at Urbana Champaign, Al Mok from the University of Texas at Austin, Kang Shin, and John Stankovic. Janet Prior of Eastern Carolina University was also invited to give a review of the current real-time SQL effort.

Sang Son pointed out that the RTDB'96 workshop was timely; since demand for advanced functionalities and timely management of data in new applications require practical solutions. He then asked each panelist whether the current research is on the right track and what are the remaining critical issues to be addressed.

John Stankovic first identified the key issues for RTDB systems, including predictability, fault-tolerance, and QoS for multimedia management. He argued that the technologies developed by the RTDB research community should show that RTDB systems can do significantly better than traditional approaches vis-a-vis properties such as cost, performance, functionality, and availability. It was generally agreed that we should focus on a few driving applications in which traditional DBMS cannot serve or are very inefficient to serve. He also pointed out that integrated solutions for distributed RTDB systems architecture are needed.

Jane Liu talked about the lessons we learned: how to schedule transactions using the timing constraints and how to maintain temporal consistency of data. She emphasized that we need to utilize semantic information and different query processing methods for QOS management. She also felt that deciding on a small set of effective concurrency control algorithms is important. Before this can be accomplished, however, some benchmarks for RTDB systems must be developed.

Kang Shin argued that we need to develop real systems, demonstrating usefulness using benchmarks and real applications. The first step is to form a consensus on terminology and concepts being used within the RTDB research community. He also discussed some technical issues that are yet to be addressed, including OS interface, ACID-equivalent properties for RT transactions, and fault-tolerance issues.

Finally, Al Mok pointed out that there are strong motivations behind the ACID properties: granularity, consistency, non-interference, and failure semantics. He argued that we need to consider what should be the right characterization of the requirements for real-time transactions.

9 Conclusion

At the conclusion of the workshop, most participants showed strong support to have the workshop continued in the future. Plans for a second workshop to be held in the fall of 1997 are underway. For more details, please check RTDB'97 Home Page on the WWW at [http://cs-www.bu.edu/pub/rtdb97/](http://cs-www.bu.edu/pub/rtdb97/).

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3Since then a WWW Real-time SQL Home Page has been created and is accessible from [http://www.math.ecu.edu/rtsql](http://www.math.ecu.edu/rtsql).