



## Mobility in Databases and Distributed Systems: Summing up Achievements of the Past Decade

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This special issue represents the best papers presented at the “Mobility in Databases and Distributed Systems” (MDDS’99) workshop held in September of 1999 in Florence, Italy. The year 1999 was a milestone in a sense that it marked the end of an era in mobile database management research where focus was on human interaction and on extending classical concepts of distributed databases and systems to cater for mobility. These selected papers reflect the state of the art in the issues of mobility in mobile data management and can serve as a summary of the achievements of the past decade; they also look ahead at forthcoming research challenges and opportunities.

The MDDS workshop is an annual international workshop running in conjunction with DEXA ([www.dexa.org](http://www.dexa.org)) conference series. Its goals are expressed succinctly in the editors’ message for MDDS’99 (*DEXA W/S Proceedings* (CS Press, 1999) p. 72):

“MDDS workshops provide an important forum for the dissemination and exchange of new ideas and research related to mobility aspects in distributed systems, database systems and advanced applications on mobile computing platforms. The goal of the MDDS workshop is to bring together researchers and practitioners with mobile communications background, database research interests, advanced applications and distributed computing systems research and development skills to discuss all aspects of emerging mobile computing paradigm. Together with wireless communication technologies portable computers and personal digital assistants (PDA) provide a pervasive base for mobile computing. As the mobile computing technology matures, millions of people will become mobile users communicating with one another and accessing various information resources. In business environments, the ability to access critical data regardless of location and time is even more crucial because corporate data must be available to applications running on mobile workstations.

On the other end of the spectrum, database and distributed systems are instrumental in managing distributed information resources in fixed and wireless network environments. Interoperability and standardization have become the major features. However, existing DBMS and distributed systems lack the mechanisms for dynamically changing the environment where applications execute and the way they communicate over a heterogeneous network. Mobile computing therefore involves mobility of users, hardware, software and data.”

The workshop program included both theoretical papers and papers reporting implementation and practical results. The papers were organized in three sessions: “Mobile Transaction Processing” with 3 papers discussing theoretical issues of conflict resolution, consistency and migrating workflows; the invited talk “Achieving Temporal and Semantic Consistency of Broadcast Data in Mobile Environments” by Prof. Krithi Ramamritham followed by two presentations discussing implementation issues of mobile file systems and atomicity; the session “Mobile Data Access” with three papers discussing causality, dynamic data delivery and mobile agents.

The workshop closed with an open discussion session on the trends and future of mobile computing. All participants were invited to express their own views with a short position statement. The discussion which went well beyond the initially allocated time, focused primarily on the challenges and opportunities in managing location dependent data. A clear conclusion of the discussion is that location-dependent data and location-dependent queries as well as mobility of small, possibly autonomous and intelligent devices and users will form the core of the data management research agenda, in general, in the first five years of the new century. Indeed this prediction can be confirmed by the emerging technology of sensor networks.

Mobile computing can be traced back to file systems and the need for disconnected operations in the end of the 1980s. In the early 1990s, the goal of mobile computing was to support of AAA (*anytime, anywhere* and *any-form*) access to data by

users from their portable computers and mobile phones, devices with small displays and limited resources. This led to research in mobile transaction processing, query processing, data dissemination, and mobile web browsing. A key characteristic of all these research efforts was the great emphasis on energy-efficiency and power-saving. At the turn of the century the focus of mobile data management research has shifted from human interaction and distributed activities in mobile computing environments towards context-aware data management, sensor networks, continuous queries and web-based services. The papers in this special issue which are summarized below offer an opportunity to look back at mobile data management challenges and examine the ways in which the research community addressed those in the 1990s.

Transaction management, replication and caching played a prominent role in mobile data management research since the early days of mobile computing. The paper “Transaction-Centric Reconciliation in Disconnected Client–Server Databases” by Shirish Hemant Phatak and Badri Nath from Rutgers University addresses the challenges of optimistic replication of data in the presence of client disconnections. The authors discuss the problem of serialization of conflicting updates from disconnected clients on all replicas of the database, or in other words, the problem of reconciliation of conflicting updates in a mobile environment. They propose some solutions to this problem, and in particular, present an algorithm that combines server-based multiversion concurrency control techniques with reconciliation of updates from disconnected clients. The paper offers a sample application to demonstrate feasibility of the approach.

The paper “Providing Transactional Properties for Migrating Workflows” by Andrzej Cichocki and Marek Rusinkiewicz from MCC discusses deficiencies of current workflows and argues that adding transactional properties would increase flexibility and usefulness of workflows. The authors propose the Migrating Workflow Model in which transactional properties are addressed by incorporating a Transactional Workflow Model. The workflow designer would have the ability to specify the task coordination requirements, the failure atomicity requirements and the execution atomicity requirements. The paper discusses the prototype implementation.

Enhancing mobile data management with localization of integrity constraints is demonstrated in the paper “Localization of Integrity Constraints in Mobile Databases and Specification in PRO-MOTION” by Subhasish Mazumdar and Panos K. Chrysanthis from New Mexico Tech and University of Pittsburgh, respectively. The authors focus on the challenge of maintaining database integrity constraints in the presence of possible disconnections and costly communications. The paper offers an approach to reformulating global constraints in order to enhance the ability of mobile hosts to function autonomously while participating in global transactions. The authors discuss how the proposed approach integrates with PRO-MOTION – the flexible infrastructure for transaction processing in a mobile computing environment.

The paper “Adaptive Dissemination of Data in Time-Critical Asymmetric Communication Environments” by Jesus Fernandez and Krithi Ramamirtham from University of Massachusetts at Amherst discusses the issues of broadcasting and disseminating data in mobile computing environments. The authors analyze push-based techniques as well as the broadcast disks model to reveal potential problems if applied in time-critical asymmetric communication environments. They propose an adaptive data dissemination model and the associated online scheduling algorithms. Consequently, functionality and performance of bi-directional broadcast models are improved. Performance evaluation is offered as a proof of feasibility and effectiveness of the proposed approach.

Theoretical insight into ordering and localization of events in mobile computing systems is offered in the paper “Causality and the Spatial–Temporal Ordering in Mobile Systems” by Ravi Prakash and Roberto Baldoni from University of Texas at Dallas and University of Rome “La Sapienza”, respectively. The authors address the problem of tracking the location of nodes and synchronizing their clocks through the global positioning system (GPS) technology and use of a simulated global virtual clock. The authors propose two distributed mutual exclusion algorithms that make use of space-time vector. The paper discusses accuracy and its impact on resource allocation policies.

Constantinos Spyrou, George Samaras, Paraskevas Evripidou, all from the University of Cyprus, and Evangelia Pitoura from the University of Ioannina in the paper “Mobile Agents for Wireless Computing: The Convergence of Wireless Computational Models with Mobile-Agent Technologies” discuss mobile agents as a new paradigm that can enable anytime-anywhere user access to information. The authors argue that mobile agent technology allows the overcoming of low bandwidth and potential disconnections’ drawbacks. This argument is supported by the prototype implementation. The second contribution of this paper deals with a proposed framework for web-based distributed access to databases.

The paper “Dynamic Information Dissemination to Mobile Users” by Ana Paula Afonso and Mário J. Silva from the University of Lisbon presents an information push model for disseminating data to mobile users. The authors discuss dynamic channels and their use for filtering and setting update order priorities for the user-monitored data. The monitored information depends on user location and roaming parameters. Implementation of the proposed model is presented and discussed.

David Ratner, Peter Reiher and Gerald J. Popek all from the University of California at Los Angeles in their paper “Roam: A Scalable Replication System for Mobility” discuss replication issues to support nomadic users who may experience periods of disconnection. The proposed system, called Roam, offers a scalable replication scheme for

mobile users. The authors present the motivation, design and implementation of Roam as well as study its performance.

In conclusion, it must be said that subsequent MDDS workshops have continued addressing the remaining open and often hardest questions from the 90s, have provided a fertile space for the new directions in data management on tiny and mobile devices and contributed into shaping up the modern state of mobile data management. This impact is evident in new and exciting research areas of location data management, sensor networks, continuous data streams, mobile information agents and extending transaction management concepts into many aspects of pervasive and ubiquitous computing.



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