Lea Kutvonen
Nancy Alonistioti (Eds.)

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5th IFIP WG 6.1 International Conference, DAIS 2005
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Preface

This volume contains the proceedings of the IFIP WG 6.1 International Working Conference on Distributed Applications and Interoperable Systems V held in Athens, Greece, on June 15–17, 2005.

The conference program presented the state of the art in research concerning distributed and interoperable systems. The emergence of 4th-generation communication systems, the evolution of Internet technologies, the convergence of telecom and datacom, wireless and fixed communication systems and applications pave the path for ubiquitous service and application provision. Innovative solutions are required for the development, implementation and operation of distributed applications in complex IT environments full of diversity and heterogeneity. Today, the emerging wide spectrum of distributed systems – ranging from ambient intelligence to global computing scenarios – lacks systematic application development support. Following the evolution of the field, DAIS 2005 focuses on models, technologies and platforms for interoperable, scalable and adaptable distributed applications within all kinds of computing environments.

The papers presented at DAIS 2005 cover methodological aspects of building and architecting distributed and interoperable services, interoperability technologies, context- and location-based applications, configurability of communication services, performance issues, data-integration issues, and Web services. In comparison to earlier events, the submissions showed increased interest towards methodological aspects and large-scale system interoperability.

These proceedings contain 16 regular and 5 short papers, which were selected in a careful, international reviewing process. The DAIS 2005 conference was sponsored by IFIP (International Federation for Information Processing) and it was the fifth conference in the DAIS series of events organized by IFIP Working Group 6.1. The previous conferences in this series took place in Cottbus, Germany (1997), Helsinki, Finland (1999), Krakow, Poland (2001), and Paris, France (2003). In Paris, DAIS was organized for the first time in conjunction with the FMOODS conference (Formal Methods and Open Object-Based Distributed Systems), and that practice was followed in Athens as well.

The conference program was complemented with joint invited talks with the FMOODS audience. Prof. Gordon Blair (Lancaster University) discussed *Middleware and the Divergent Grid*, while Prof. Rocco de Nicola (University of Florence) addressed *Programming and Reasoning on Global Computers with Evolving Topologies.* Prof. Andreas Reuter (European Media Laboratory GmbH) shed light on the area of *Application Integration with Emphasis on Orchestration and Consistency.*

Finally, we would like to take this opportunity to thank the numerous people whose work made this conference possible. We wish to thank the University of Athens for hosting the event, and Prof. Lazaros Merakos for acting as a general

chair of the joint DAIS and FMOODS event. Costas Polychronopoulos provided the Web services for us. Prof. Hartmut König took care of the publicity for the event. The Steering Committee with Profs. Guy Leduc, Hartmut König, Kurt Geihs, and Elie Najm extended their helping hand on many essential occasions.

It is the good technical papers that make a conference. Especially we thank the submitters and reviewers for their contributions towards an interesting conference.

June 2005 Nancy Alonistioti and Lea Kutvonen

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Towards Real-Time Middleware for Applications of Vehicular Ad Hoc Networks

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Abstract. Applications of inter-vehicle and vehicle-to-roadside communication that make use of vehicular ad hoc networks (VANETs) will often require reliable communication that provides guaranteed real-time message propagation. This paper describes an event-based middleware, called RT-STEAM, designed to meet these requirements. Unlike other event systems, RT-STEAM does not rely on a centralized event broker or look-up service while still supporting event channels providing hard real-time event delivery. RT-STEAM event filtering can be based on subject, content and/or proximity. Proximity filters define geographical areas within which events are delivered. To guarantee real-time communication, we exploit proximity-based event propagation to guarantee real-time constraints within the defined proximities only. The proximity within which real-time guarantees are available is adapted to maintain time bounds while allowing changes to membership and topology as is typical of VANETs. This Space-Elastic Model of real-time communication is the first to directly address adaptation in the space domain to guarantee real-time constraints.

1 Introduction

Many Ad hoc wireless networks comprise sets of mobile nodes connected by wireless links that form arbitrary wireless network topologies without the use of any centralized access point or infrastructure. Ad hoc wireless networks are inherently self-creating, self-organizing and self-administering [1].

While most research in ad hoc networks has assumed a random waypoint mobility model in a network of a particular shape, e.g., rectangular, [2], the specific patterns of vehicle movement make inter-vehicle and vehicle-to-roadside networks distinctive. In particular, the potential for high speeds and the limited dimensionality afforded by a confined roadway, differentiates vehicular ad hoc networks (VANETs) from other ad hoc networks.

By enabling inter-vehicle and vehicle-to-roadside communication a broad range of applications in the areas of cooperative driver assistance and mobile information systems are being developed. One of the more sophisticated applications for inter-vehicle communication is the platooning of vehicles [3]. For example, the lead

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vehicle in such an application may broadcast sensor information to coordinate movement and potentially reduce the consumption of fuel.

A possible application of vehicle-to-roadside communication is in next generation urban traffic control (UTC) systems. A vehicle (or set of vehicles) approaching a junction could inform a traffic light controller at the junction of its pending arrival. The traffic light controller could then change the traffic light sequence to allow the approaching vehicle to pass through the junction without stopping. When a number of vehicles are approaching the junction, and if the traffic light controller is informed of the presence of the approaching vehicles, then the controller could optimize the traffic flow across the junction. This time constrained communication between vehicles and traffic light controllers should continue reliably during peak times when a large number of vehicles approach the junction from a number of different directions. The potential for contention increases as the number of vehicles communicating with the controller increases.

Both the vehicle platooning and UTC applications require a communication paradigm that supports dynamic changes to the topology of the underlying wireless network, for example to accommodate vehicles joining and leaving a platoon, as well as delivery guarantees for time-critical messages. In the UTC application scenario described above, the traffic light controller needs to be informed of the presence of the approaching vehicle in sufficient time to allow it to change the flow of traffic across the junction.

This paper describes an event-based middleware, called RT-STEAM, designed for ad hoc networks. Unlike other event systems, RT-STEAM does not rely on centralized services while still supporting event channels providing hard real-time event delivery.

RT-STEAM is based on an implicit event model [4] and has been designed for mobile applications and wireless ad hoc networks. RT-STEAM differs from other event services in that it does not rely on the presence of any centralized components, such as event brokers or look-up services, and supports distributed techniques for identifying and delivering events of interest based on location. RT-STEAM supports decentralised approaches for discovering peers, for routing events using a distributed naming scheme, and for event filtering based on combining multiple filters. Filters may be applied to the subject and the content of events, and may be used to define geographical areas within which events are valid. Such proximity-based filtering represents a natural way to filter events of interest in mobile applications.

RT-STEAM provides a programming model based on the concept of event channels. A number of event channel classes with different temporal and reliability attributes are available to integrate real-time support into the event channel model. Depending on the guarantees available from the underlying network, the proximity characteristically associated with an event channel may require adaptation to maintain the required real-time guarantees while allowing changes to membership and topology as is typical of VANETs. This Space-Elastic model is the first to directly address adaptation in the space domain to maintain real-time guarantees.

An underlying assumption of the Space-Elastic model is that a real-time application in a VANET can specify and interpret specified bounds in space (the proximity) where real-time guarantees are critical. This assumption relates to the observations in [3], that the relevance of data to a specific geographical area is one of the key features of an inter-vehicle network and that mission-critical (e.g., emergency braking notification), and non-critical (e.g., weather reports), communication competes for the limited available resources. Thus, Space-Elastic applications must be space-aware, i.e., operate correctly in a dynamic proximity, and information-sensitive, i.e., aware of the criticality of different sources of information (event channels). In the vehicle platooning scenario, the proximity where real-time communication is critical may bound the platoon and, for example, vehicles within the vicinity of the platoon, moving in the same direction. In the UTC scenario described, the critical proximity may be the minimum area within which the controller has sufficient time to change the flow of traffic following communication with an approaching vehicle.

The reminder of this paper is structured as follows: Section 2 introduces RT-STEAM's programming model and architecture. Section 3 presents our Space-Elastic Model of real-time communication and describes its approach to exploiting proximity-based event propagation for maintaining time bounds. Section 4 outlines RT-STEAM's communication architecture. Finally, section 5 concludes this paper and outlines our future work.

2 RT-STEAM

The design of the RT-STEAM architecture is motivated by the hypothesis that there are applications in which mobile components are more likely to interact once they are in close proximity. For example, a vehicle is interested in receiving emergency braking notifications from other vehicles only when these vehicles are within close proximity. Similarly, traffic light controllers are only interested in arrival notifications from vehicles that are located within a certain range of their own locations. This means that the closer event consumers are located to a producer the more likely they are to be interested in the events that it produces. Significantly, this implies that *events are relevant within a certain geographical area surrounding a producer.*

Event Types, Proximities, and Channels. RT-STEAM implements an implicit event model [4] that allows event producers to publish events of a specific *event type* and consumers to subscribe to events of particular event types. Producers may publish events of several event types and consumers may subscribe to one or more event types.

To facilitate the kind of location-aware application described above, RT-STEAM supports a programming model that allows producers to bound the area within which their events are relevant and to define Quality of Service (QoS) attributes describing the real-time constraints of these events. Such a combination of event type, geographical area and QoS is called an *event channel*. Producers *announce* event channels, i.e., they announce the type of event they intend to *raise* together with the geographical area, called the *proximity*, within which events of this type are to be disseminated with the required QoS constraints. Thus, an event channel announcement bounds event propagation to a defined proximity where required QoS constraints are guaranteed. Events are delivered to consumers only if they reside within a proximity where the QoS constraints for the event type are satisfied.

Producers may define proximities independently of their physical transmission range with an underlying group communication system routing event messages from producer to consumer using a multi-hop protocol. Proximities may be of arbitrary shape and may be defined as nested and overlapping areas. Nesting allows a large proximity to contain a smaller proximity subdividing the large area. Fig. 1 depicts two overlapping proximities of different shape and illustrates that multiple consuming and producing entities may reside inside a proximity. These proximities have been associated with events of *type A* and *type B* as well as *QoS A* and *QoS B* respectively. Consequently, consumers handling these event types receive events if they reside inside the appropriate proximity. An example of overlapping proximities might include a vehicle disseminating an emergency braking notification within the vicinity of a traffic light controller that is also receiving arrival notifications from approaching vehicles.

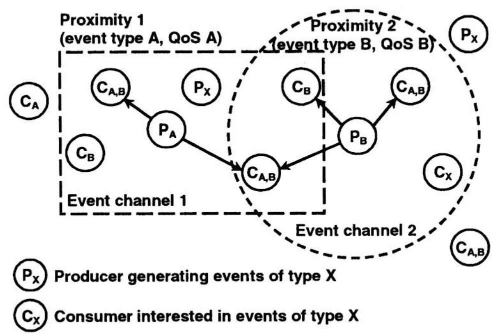

Fig. 1. Disseminating events using event types, proximities and event channels

Supporting Mobility. RT-STEAM has been designed to support applications in which application components can be either stationary or mobile and interact based on their geographical location. This implies that the RT-STEAM middleware as well as the entities hosted by a particular machine are aware of their geographical location at any given time. RT-STEAM includes a location service that uses sensor data to compute the current geographical location of its host machine and entities. To suit outdoor applications, for example, in the traffic management domain, RT-STEAM exploits a version of the location service that uses a GPS satellite receiver to provide latitude and longitude coordinates.

In addition to supporting stationary and mobile entities RT-STEAM allows proximities to be either stationary or mobile. A stationary proximity is attached to a fixed point in space whereas a mobile proximity is mapped to a moving position represented by the location of a specific mobile producer. Hence, a mobile proximity moves with the location of the producer to which it has been attached. This implies that mobile consumers and producers may be moving within a mobile proximity. For example, a group of platooning vehicles might interact using a proximity that has been defined by the leading vehicle. Such a proximity might be attached to the position of the leader moving with its location.

Subscribing to Event Types. Consumers must subscribe to event types in order to have the middleware deliver subsequent events to them when located inside any proximity where events of this type are raised, until they unsubscribe. A consumer may move from one proximity to another without re-issuing a subscription when entering the new proximity. Thus, subscriptions are persistent and will be applied transparently by the middleware every time a subscriber enters a new proximity. This implies that a subscription to a specific event type applies to all proximities handling