

Aspect-Oriented Space Containers for Efficient Publish/Subscribe Scenarios in Intelligent Transportation Systems

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Abstract. The publish/subscribe paradigm is a common concept for delivering events from information producers to consumers in a decoupled manner. Some approaches allow the transportation of events even to mobile subscribers in a dynamic network infrastructure. Additionally, durable subscriptions are guaranteed exactly-once message delivery, despite periods of disconnection from the system.

However, in some application areas, like in the safety-critical telematics, durable delivery of events is not sufficient enough. Short network connectivity time and small bandwidth limit the number and size of events to be transmitted hence relevant information needed for safety-critical decision making may not be timely delivered.

In this paper we propose the integration of publish/subscribe systems and Aspect-oriented Space Containers (ASC) distributed via Distributed Hash Tables (DHT) in the network. The approach allows storage, manipulation, pre-processing, and prioritization of messages sent to mobile peers during bursts of connectivity.

The benefits of the proposed approach are a) less complex application logic due to the processing capabilities of Space Containers, and b) increased efficiency due to delivery of essential messages only aggregated and processed while mobile peers are not connected.

We describe the architecture of the proposed approach, explain its benefits by means of an industry use case, and show preliminary evaluation results.

1 Introduction

The publish/subscribe (pub/sub) paradigm [1] is a common and largely recognized concept for delivering messages (events) in an anonymous decoupled fashion from publishers to peers subscribed for a topic or for the content of a message.

Current implementations of and research in notification systems are mostly focusing on an effective and large-scale dissemination [2], [3], [4] of huge quantity of information from publishers to subscribers in a fault-tolerant manner, how to improve the semantical quality or the expressiveness of subscriptions [5], [6], how to ensure durability or the correct order of messages [7], [8]. Other pub/sub approaches deal with these issues as well but assume additionally that peers are mobile [9] or the entire network is completely dynamic [10], [11].

In some application areas the durable delivery (in other words the guaranteed delivery with "exactly once" semantics) of subscribed messages is essential. However, there are application domains, like safety-critical telematics, in which this kind of reliability for subscribed events may be considered a precondition for operation, due to jurisdictional reasons, but is not adequate at all. Among others, a durable notification service has to store any events a peer has subscribed for while the subscriber is off-line. Once the peer is reachable again, the saved events have to be delivered to the associated subscriber. This means that the peer would receive a large amount of data that it has to process locally in order to extract relevant information. However, in scenarios from Intelligent Transportation Systems (ITS), mobile peers (vehicles) have only a few seconds of connectivity and very limited bandwidth [12], [13]. This may cause several problems: the reconnecting peer should receive all stored events which may have very different importance for the user or be even stale, but due to the limited bandwidth and connectivity window only a very few messages can be forwarded to the peer creating a kind of back-pressure in the system. Furthermore, due to the small connectivity window, there is a possibility that essential information, such as safety-critical ghost driver warnings, cannot be transmitted to the peer. If such messages are not forwarded to the peer on time humans lives may be jeopardized. Therefore, the safety risk grows with the amount of irrelevant or even incorrect information delivered instead of important life-saving information.

In [14] we described a customizable storage component, called Space Container, for efficient storage and retrieval of structured data. In [15], [16], [17], [18] we presented the SABRON approach on how to distribute and replicate such Space Containers by means of Distributed Hash Tables (DHT) [19] to efficiently store and retrieve structured, spatial-temporal data in a fault-tolerant manner. In this paper we propose the concept of Aspect-oriented Space Container (ASC), an extension for event processing of the original capabilities of Space Containers, for linking pub/sub systems and mobile peers with short connectivity time. Extending the ideas in [20], this paper reviews existing related work, describes the concept in more detail, and presents first performance evaluation results of the implemented system.

A Space Container allows to store entries in a customizable structured way by means of so called Coordinators. DHTs are used to place such Space Containers in the network in a fault-tolerant and scalable manner. Aspects are components that are triggered whenever a Space Container is accessed. It is a customizable application logic executed either before or after the operation on the Space Container for events processing. An Aspect can be used to check security policies,