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Network aware dynamic context subscription management

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ABSTRACT

Context-awareness is a key requirement in many of today's networks, services and applications. Context management systems are used to provide access to distributed, dynamic context information. The reliability of remotely accessed dynamic context information is impacted by network delay, packet drop probability, its information dynamics and the access strategy used. Due to the characteristics of the different access strategies, different levels of reliability of context information can be ensured, but at the same time, these strategies lead to different access traffic which impacts also the network performance, and hence feeds back to the reliability of the information. Furthermore, different levels of QoS may be available and used in order to mitigate the impact of network performance degradation on the reliability of the dynamic context information. In this paper we describe a system and algorithms that are capable of configuring effectively context access strategies in order to maximize reliability of all accessed dynamic context information. The framework utilizes and extends existing information reliability models, and it can utilize different network performance models. Simulation results of scenarios in which the framework uses finite-buffer bottleneck performance models demonstrate the effectiveness of our algorithm to increase reliability. Furthermore, the framework is applied to a scenario with QoS classes that allows to trade off delay and loss via different buffer-size configurations.

1. Introduction

The ability of applications to adapt to the users' environment is often referred to as context awareness, [1], and is becoming a key factor in today's mobile networks, since users need to be able to efficiently interact with applications and platforms in a highly dynamic world. Context awareness is achieved by accessing dynamic context information provided by context agents in a context management system and is a highly desirable feature for future mobile applications. However, the access to dynamic context information distributed in the environment has to be carefully designed to achieve scalability and context reliability. European projects like MAGNET Beyond [10], SPICE, [11] or E-SENSE, [12], and others outside Europe, have been researching and developing concepts for context management for some time, whereas reliability and accuracy indicators for context information just recently caught the attention e.g. in the project SENSEI, [13].

In those projects as well as within the research field, see e.g. [3,4], reliability of context information has been acknowledged as an important meta data to context information as the end user's satisfaction obtained from context-aware systems is directly depending on the reliability of the context information. In the respect of reliability, some work focuses on information reliability in terms of the uncertainty of the information source, e.g. using fuzzy logic approaches, [5] or [6], in which reliability is related to inexactness and uncertainty of obtained information and not the timely aspects of the information. Other work focuses on reliability of the information either by considering the age of the information, see e.g. [8,14] or [7]. However, the information age needs to be related to the

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temporal dynamics of the information in order to provide a useful notion of reliability.

The reliability of context information is challenged by network delay, information dynamics, the context access strategy used and its parameter settings. The choice of the context access strategy on the other hand also influences network performance through the context access traffic. This paper provides a framework for automatic configuration of access to remote dynamic context information which accounts for the interplay between the network, the access strategies and their configurations, while maximizing the overall reliability of the information access.

The quality of context information plays an important role in adapting a system to continuously changing situations. In order for these systems to function optimally, they are required to implement measures that can resolve context conflicts in order to limit making of faulty context-aware adaptation decisions. Today there are several means to measure context quality and there is a large amount of literature on context modeling and representation, yet more needs to be done to insure context information exchange with guaranteed quality levels [23] [24]. There are several methods and techniques that are able to measure Quality of Context, amongst them are sensor training i.e (precision and correctness calculation), algorithms to calculate QoC value of aggregated context and conflict resolution algorithms. However most of the research done on context quality aims to develop a control scheme where context information is gathered, then classified and then is checked for quality by using one of the previous methods. Most of these methods seem to neglect the fact that there are networking issues that need to be addressed such as delay, overhead, jitter which directly context quality for dynamic context sources. While there is work [25] that provides networking QoS to context information, targeting higher-level context quality metrics with a model-based approach is the main novel contribution of this paper.

2. Context management framework

For applications to be able to adapt to their environment, access to dynamic context information [1], which describes the current situation, is required. Context Management systems offer flexible access often via dedicated query languages, e.g. [9,2], which allow applications easy access to distributed information.

A generic context management framework is illustrated in Fig. 1, which contains a set of entities called Context Agents (CA). Each CA is responsible for collecting data from its own local environment, as shown to the right in the figure: one CA exists on each device collecting information on, for instance, location, noise and temperature, respectively. A server in the network will act as context manager, which is responsible for maintaining the overlay network of context agents, i.e. it performs agent discovery, maintenance of agent information, information (de)registration and later on also access optimization for access to context information. In our considered architecture, context sensitive applications access context information through the context manager. The node that operates the context manager, is called the Context Management Node (CMN).

As seen to the right of Fig. 1, context information at the source changes according to external events, while the context-sensitive application would like to perform actions matching the true state of the context values at the source. When that information is dynamically changing, communication and processing delays can lead to deviations of the known context value at the application from the true value at the source. In our earlier work, we introduced the notion of mismatch probability (mmPr), [17] that is defined as *the probability that at the time instant of using a certain information for processing in the context-sensitive application, this information does not match the value at the (physical) source*. The reliability of context information has previously been acknowledged and considered an important part of the quality of context, [3,4,14] or [8], but not used in any effective way. In this paper we use this quantitative context reliability metric for intelligent choices of access strategies to improve reliability for all context sensitive applications requiring access to various dynamic distributed information elements.

The mismatch probability depends not only on the two stochastic processes (a) network delay and (b) information change process, but also on the strategy by which the information is accessed. The following three strategies will be used as principle mechanisms to access remote dynamic context information:

- *Reactive strategy*: whenever the application intends to process a certain context value, the context manager sends a request to the context providing agent, and gets a response with the information value in return. Fig. 2 illustrates this access strategy.
- *Proactive, event driven*: the context manager has setup a subscription to the context providing agent, and each time information changes value, the context agent sends an update to the context manager. For continuous information types, such change events can be defined via discretization intervals. The proactive event-driven strategy is illustrated in Fig. 3.
- *Proactive, periodic update*: the context manager has setup a subscription to the context providing agent, which after recurring time interval sends the current value to the context manager. Fig. 4 illustrates this periodic strategy.

The goal of the developed framework and algorithms is that the context manager is able to select and configure the access strategy by which it interacts with the various context agents to provide the information in such way that the reliability of the information is effectively increased.

The decision on which strategy to take is not trivial as it involves several stochastic processes and parameters that may be adjusted, and as each different strategy puts different loads to the network, and any decision effectively feeds back via an increased network delay to the mismatch probability and hereby may render decisions not optimal.

The objective of the algorithm is therefore to decide upon one of the three access mechanisms that should be used, as well as parameter settings, while considering that the context access traffic also affects the network; so impact on network delay and loss caused by the higher load is taken into account.