CPaaS: Context Processing as a Service

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***Abstract*—The increasing number of sensing devices present in our everyday environments has led to an unprecedented amount of data about users and their situational context. To use this data in context-aware systems (e.g., in smart environments), the large volume of collected raw data must be appropriately processed to extract information of higher value. In this work, we introduce the notion of *Context Processing as a Service* (CPaaS), where this event stream processing is carried out in a service-oriented fashion. Instead of distributing the required external knowledge to all devices that process sensor data in order to extract context information, CPaaS borrows from the paradigm of service orientation and offers the transformation of sensor data streams into high-level information in the form of on-demand services. By combining a local event bus with remote CPaaS services, both high performance and a high quality of the processing results can be achieved.**

I. Introduction

Intelligent environments realize *smartness* by collecting information about the status of entities (e.g., users or buildings) and transforming this information into knowledge to infer actuation decisions. Possible practical realizations of smartness include the improvement of a building's energy efficiency by deactivating idle appliances, the support for ambient assisted living, or enhancing a building's security or the user's comfort. In any of these cases, the processing of the underlying sensor data (i.e., *context processing*) is resource-intensive and needs complex algorithms, e.g., the classification of appliances based on their power consumption characteristics [1]. Other examples include the localization of users or the prediction of expected next events within a building, or the classification of a user's activity [2].

II. Innovation

In order to achieve results of high accuracy, external knowledge is often required, e.g., the availability of a heatmap with pre-determined signal strength readings in case of indoor localization. Instead of distributing the required external knowledge to all devices that process data of a given type, our novel concept is based on the provision of context processing tasks in the form of services. Tasks that require significant amounts of both storage and processing power can thus be provided on hardware that fulfills their resource requirements (e.g., in the cloud of an external service provider), and can be used on demand. This does not imply that context processing cannot take place locally, but instead adds the possibility to enrich the capabilities of the locally installed context processors by means of external services. Like in traditional service-oriented architectures (SOA), our approach is based on registering the context processing services to a marketplace, enabling them to be found and remotely invoked by the locally installed sensor event bus.

In contrast to traditional service calls where calls to web services require all parameters to be encapsulated as arguments, our CPaaS approach follows an inverse scheme of operation; once a processing service has been identified, its provider is requested (via a regular service call) to connect to the local event bus in order to retrieve all sensor events that match its processing capabilities. Higher-level context information are subsequently generated from the incoming stream of sensor data, and continually returned to the service consumer while the service is in use.

A. Comparison to Related Work

In most current pervasive computing systems, context processing is performed locally on the data collecting device (e.g., a smartphone or gateway) [3], [4]. Only a few approaches to encapsulate context processing functionality into remotely invocable services are known, e.g., the SkyHookWireless XPS positioning system[1] or the disaggregation of electric load curves into their contributing appliances[2]. These services are, however, often statically linked in applications, and not dynamically selected based on a context processing service marketplace. In general, the idea of service marketplaces is prevalent in the domain of SOA, but has not been applied to context processing services. Our approach, which also builds upon our prior work on virtual context based services [5], can thus be seen as a novel and innovative combination of existing technology. Despite the similar name, it is also different from the notion of Context as a Service (CaaS), as defined by Wagner in [6], which refers to the provision of raw sensor data between neighboring devices.

III. Practical Relevance

The increasing number of sensors deployed in our physical everyday environments necessitates a scalable system that can provide context processing on demand. By shifting context processing tasks to specialized processing services, which can be located in remote data centers, the local event processing instance can be downsized (and thus also reduced in terms of its cost). Its sole purpose is then the forwarding of event streams to the distributed CPaaS services and the (significantly less demanding) processing of the returned results. A second benefit of collecting context data at remote CPaaS services with virtually unlimited physical storage is the fact that a large amount of historical data, which has been collected, can serve

[1] http://www.skyhookwireless.com/howitworks/xps.php
[2] http://www.plotwatt.com

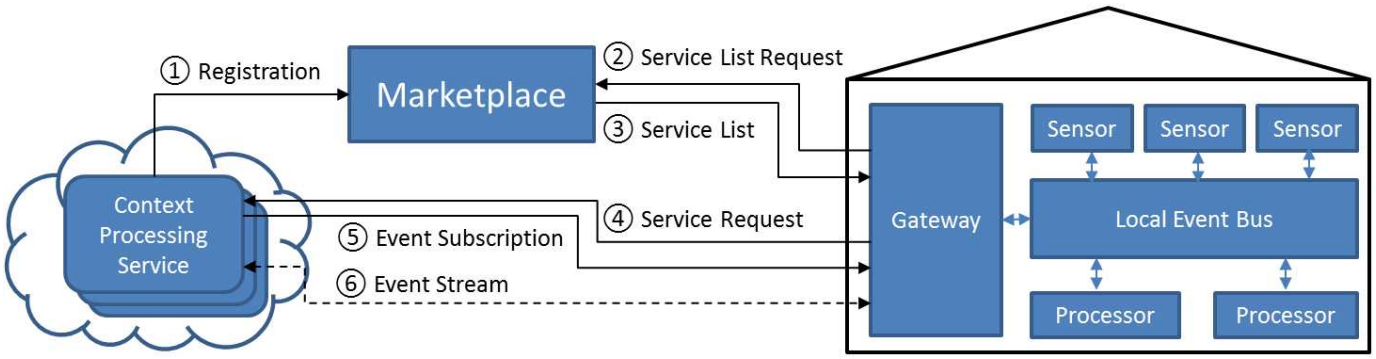

Fig. 1. System architecture of the Context Processing as a Service demonstrator

as training data for novel processing options. In other words, the CPaaS service can improve its own accuracy by learning from past behavior, and converges to a good model even faster when more training data, e.g., from different end users, is available. As a third benefit, the context processing services are maintained by professional service providers, which, e.g., leads to higher reliability, professionally administered evaluation models and the ability to incorporate community knowledge like common datasets for device behavior. Finally, the local gateway shown in Fig. 1 also protects the user privacy by only granting external providers access to the data granularity required to successfully execute the service.

IV. Demonstrator Description and Requirements

The architecture of our CPaaS system is shown in Fig. 1. The cloud on the left comprises the CPaaS services which can be consumed on demand and which can be located at any physical machine with network access. On the right, the local building's event bus with event processing capabilities and its gateway are shown. The marketplace, which is shown on top, establishes the link between both parties by matching the available data from event stream providers (i.e., sensorized buildings) against the input requirements of the registered CPaaS services, and offers the user a list of services that can be consumed.

The flow of operations, which will also be presented at NetSys, can be outlined as follows: In Step (1), CPaaS services register at the marketplace. The local event bus acquires knowledge about its available sensor types. When the user issues a query for possible event processing services to the marketplace (2), the marketplace performs a matching between service requirements and sensor descriptions and (3) returns a list of suitable services. The user can then choose matching CPaaS services of interest from this list. Upon selection, the service provider is contacted in Step (4). Finally, the remote processing host subscribes to the user's local event bus with a specific filter to allow the retrieval of all events that match the input requirements (5). Once the user has acknowledged the subscription, the CPaaS service provider consumes the forwarded event data and returns the processed higher-level context information to the event bus (6).

We will demonstrate our event bus and context processing framework, to which several sensors that contribute live data will be interfaced. The CPaaS service marketplace will be instantiated, which lists all CPaaS services that can be called given the local availability of sensor data. The demo visitors will be able to browse the context processing services and choose a CPaaS service. The locally collected sensor events will then be made available to the selected service, and higher level context information will be returned to the bus whenever the CPaaS service has generated a result. Novel opportunities based on the higher-level context will be highlighted.

V. Maturity

The CPaaS concept has been implemented in a prototypical fashion within the scope of an internal research project on smart building services. Documentation of the interfaces will be made available in the near future, allowing other context processing service providers to integrate their CPaaS services directly into the marketplace. In the long term, we are planning to operate the system as a research prototype, for which no licensing fees will apply, and we are currently working on services that can raise the awareness for energy consumption and can help users to save energy.

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