ContextNet: Context Reasoning and Sharing Middleware for Large-scale Pervasive Collaboration and Social Networking

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ABSTRACT
In this paper, we describe ContextNet, a middleware architecture with context services for wide- and large-scale pervasive collaborative applications. It also provides context-based reasoning over data and events generated by autonomously moving users or their vehicles.

Categories and Subject Descriptors
C.2.4 [Distributed Systems]: Distributed applications

General Terms
Algorithms, Management, Performance

Keywords
Middleware, Context-awareness, Scalability, Reasoning, Social Networks

1. INTRODUCTION
Context-awareness is widely recognized as the core element of modern pervasive systems, but so far has been handled mainly from the perspective of individual users, and for medium-scale applications. On the other hand, wide-scale collaboration, coordination and social interactions can be strongly enhanced by real-time distribution of context data and by performing context-based reasoning over context data and events generated by sets of autonomously moving users or vehicles. For example, in team or task force applications, on-line monitoring of the movement pattern of the group may determine success or failure of a collaborative work.

2. OBJECTIVE
Project **ContextNet** aims at provisioning context services for wide- and large-scale pervasive collaborative applications such as on-line monitoring or coordination of mobile entities' activities, and information sharing through social networks. These entities may be users of portable devices (e.g. smart phones), vehicles, or even autonomic mobile robots.

ContextNet is primarily focused on developing middleware technology addressing three major challenges:

- Enable scalable distribution of context information among hundreds of thousands of context-producing and context-consuming entities;
- Devise automated reasoning techniques that are inherently distributed and capable of detecting application-relevant patterns of global context situations;
- Use semantic Web to combine several types of context (computing, physical, time, user context) and integrate it with social networks so as to leverage the communication and coordination capabilities of mobile users and/or vehicles.

In this project we are primarily interested in enhancing mobile collaboration and coordination (among groups of users and/or vehicles) by information about the group movement pattern and place-specific services.

3. APPLICATIONS
One possible application is the coordination of police vehicles, e.g. cars and/or helicopters: The goal is to inform/notify in real time police vehicles in certain region that one specific vehicle needs special mission assistance. Moreover, the vehicle requiring assistance is able to inform the required firepower or how many police officers/vehicles are desirable. Another feature is allowing citizens to easily inform the police that something wrong has happened at a specific location. Thus, the police could arrive faster at the place where the event has occurred. In this scenario, a location-aware collaborative service that is capable to coordinate a police task force may be more appropriate than conventional radio channel communication because: (i) radio communication could be tampered, (ii) radio would not directly and precisely inform where the vehicle are, (iii) the service could notify only the vehicles that are actually able to give assistance, considering all its context information and (iv) for normal citizens, it would be faster and easier to use the service via a smart phone, than call 911.

4. TIERS AND REQUIREMENTS
The ContextNet middleware requires an infra-structured wireless network (e.g. 3G, Wi-Fi, BigZee), and will run on five types of inter-networked systems (Fig.1): Mobile Clients, e.g. Smart phones, with limited resources and energy capacity; Vehicle Clients, with more computing and storage resources and unlimited energy capacity; Ambient Mediators, place-specific computing devices that are responsible for local communications and context reasoning; Nodes of an Overlay Data Distribution Network, used for on-line distribution of information over long distances, and Web Services executing on Cloud platforms, which will implement all sorts of application and context processing functions.

The key requirements of the devised middleware system are scalability (in number of users/device, context types, and applications), light-weight client components (low energy consumption and bandwidth-saving interactions), modularity, extensibility, reuse, adoption of well-established standards, context-awareness, support for dynamic adaptivity, asynchronous communication, distributed control, interoperability with external cloud services and support for social networks and inter-network domain applications.

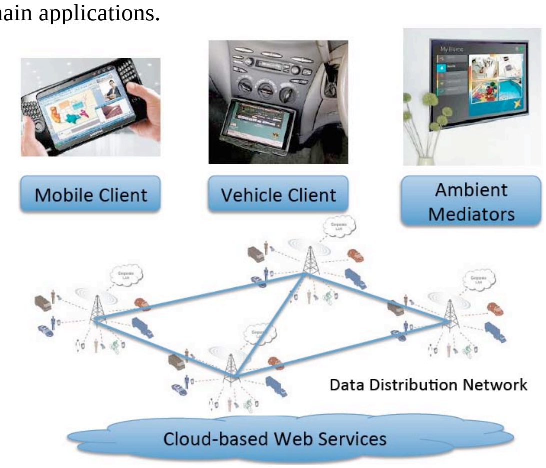

Fig.1: Typical Tiers of a ContextNet Application

5. LAYERED ARCHITECTURE

As an approach to meet the above requirements, we are designing the ContextNet system's architecture considering following software layers. Fig. 2 shows the layers of the proposed ContextNet architecture, to be deployed on the different tiers as explained in Section 4.

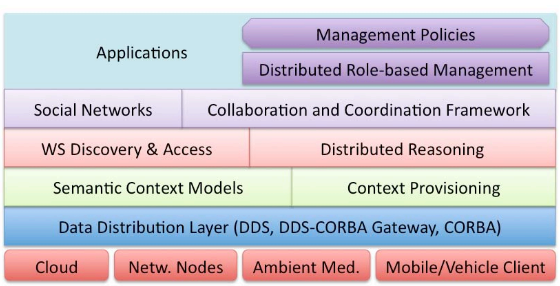

Fig 2: Middleware general architecture

The Data Distribution Layer uses a set of different communication technologies, depending on the device capabilities and the type of connectivity, to allow efficient, scalable and high performance communication. For example, it will use DDS (in Section 6) on static network nodes and in the Cloud, and CORBA on resource constrained devices. In between, specific gateway nodes will be responsible for translating between CORBA's IOP and DDS. The Semantic Context Models serve as a global and uniform semantic description of all entities in the system, the relevant local and global context information types and their dependencies, as well as the reasoning rules, entities, and events. Also, it will have meta-information about the middleware and applications necessary for autonomic deployment, adaptation, and management. The Context Provisioning layer contains modules for the acquisition and device-specific inference of more abstract context data related to devices' resources, networks and users. These modules will also combine and aggregate context information of different sources so as to provide higher-level and system-wide information about global situations. The Distributed Reasoning contains a set of global inference engines, deployed on fixed nodes on the network (or the Cloud), which aggregate and process information that comes from local inference engines deployed on mobile devices. The local inference engines gather local atomic events on the devices, generating complex events, which are abstractions of local situations, and forward them to the global inference engines. This approach brings scalability and power of reasoning, because the higher the abstraction, more powerful is the reasoning about global situations. The collaborative applications are to be built within Social Networks or by using our Mobile Collaboration and Coordination Framework Mobilis [1]. Finally, we plan also to develop a distributed Role-based Management infrastructure capable of enforcing application-specific management policies.

6. ENABLING TECHNOLOGIES

The ContextNet middleware will be built around the following technologies and standards:

OMG Data Distribution Service For Real-Time Systems [2]: Specifies a high performance, robust and scalable data-centric publish-subscribe peer-to-peer architecture for real time data distribution, allowing the definition of a wide set of Quality of Service (QoS) parameters for contracts between producers and consumers of data. It provides many benefits which include decoupling, provided by the publish/subscribe model, high availability due to its fully distributed model, interoperability between implementations, due to its standard wire network protocol [3] and automatic application discovery.

Complex Event Processing (CEP) [3]: Is an emerging technology for the real time processing of information flows on event-based systems. With CEP, one can express interest over relationship patterns between events, such as temporality, causality, dependency and composition. CEP allows the so-called complex events to be composed by other more basic events, and also the tracking of causality between many different events in different abstraction levels.

Semantic Web Standards: The Semantic Web provides a common framework that allows data to be shared and reused across applications, enterprises, and community boundaries [4]. The adoption of the Semantic Web standards for representing context data is fundamental to guarantee a common understanding among devices and services, enabling interoperability. Particularly, we intend to use the Linked Data standard [5], which is based on the representation of data in the form of RDF triples, using standard vocabularies – such as DBPedia, FOAF, Geo, GeoNames, etc – to represent context data types and instances.

7. REFERENCES

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