

# Context Management Framework and Context Representation for MNO

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## Abstract

Context Management technology is not novel itself, and ICT companies are already looking at this area and spending effort for a long time trying to find a technically feasible solution, appealing marketing usage and solve all the possible issues with its privacy and security concerns. However, after many years of technology scouting and academic scrutiny within this still innovating area, there is no unique best practice or reference standardization solving all the technological difficulties within this field. The context information available in the real world from many potential sources should be handled in a near real-time way, efficiently processed by many devices and be interoperable among different actors dealing with the context. Therefore not only a comprehensive context management framework shall be in the place but also efficient context representation formalism should be employed in order to represent the context data suitably for an autonomous Machine-to-Machine processing, with all the data maintained within that representation and with all the mechanisms or artifacts needed for a secure and privacy safeguarding sensitive data handling. This all compose a set of requirements to be respected in the context information data representation, which are listed and solved by the solution described within with paper.

## Introduction

The context information acquisition and handling requires efficient and simple interoperable representation formalism, especially for Machine-to-Machine (M2M) processing. A selection of a representation reference within a heterogeneous environment such as telecommunication networks consisting of the mobile network equipment and mobile devices shall be pondered by consideration of many peculiarities including resource- and energy-constrained mobile devices context sensors, limited and “expensive” connectivity bandwidth and data transmitting capacity of the mobile network operator within interested geographic areas, where the context information shall be not only

acquired but also used. Moreover, the reference choice of a representation formalism should be preferably standard or de-facto adopted solution allowing a wide employment on many devices and equipment and large usage among reference market. Telecom Italia, working in context awareness for many years, has performed a careful selection of the context representation based on the above mentioned principles and this work describes it as well as its evolution and usage in the telecommunication field.

This work, once started as based solely on the mobile network operator’s requirements, then has been proven and extended to various European research projects aimed to creation of systems and platforms using or handling the context information acquired from the operator’s customers, physical environment sensors, Internet and network equipment. Therefore, this work presents not a “vertical” “narrow” solution respecting only preferences of Telecom Italia, rather a careful academic research work that permitted to create a comprehensive formalism, very simple and interoperable on many energy and resource-constrained devices and at the same time sufficiently flexible format allowing its extension for additional functionalities and easy embedding comprehensive security features. Finally, this created formalism is based on a world recognized and widely adopted standard.

First section describes the requirements selected for creation of the context representation formalism, then the selected form is described with its usage model and usage examples (demo and trials) and finally its evolution is presented as add-ons to initially selected formalism, such as a simple query language based on the same reference representation. The paper wraps up with conclusions and mentioning of current work in progress within the context management and context-awareness representation fields.

## Context Management Framework

Telecom operators are always handled a lot of customers with their personal devices connected to the fixed line phone or mobile phone networks. Initially, the only services provided to the customers by the telecommunication networks were the voice-calls and the text messaging on a mobile, later evolved into reach communication services not limited anymore exclusively to the voice and the video calls or the multimedia messaging. Currently many services are offered or supported by a Mobile Network Operator (MNO) leveraging on a better communication quality control, a wider available bandwidth per customer pondering the Internet navigation and the content distribution, and on a better knowledge about the customers available from the network itself and customers' devices. This last aspect related to the customers' habits, their location, preferences, etc. is brought under the umbrella of the context-awareness. Although the context knowledge and exposure is a very strong driver opening new dimensions within the operator's ecosystem, at the same time this is also a great amount of data to be treated in a real-time or near real-time mode, and it opens plenty of privacy related issues along huge business opportunities. Telecom Italia has started research and development in this field many years ago and is continuing to learn its knowledge and experience evolving the context-awareness and the context management framework within a number of research projects involving many industrial and academic research partners under a severe academic scrutiny. The project list is including but is not limited to C-CAST [8], PERSIST [9], MobiLife, self-adapting applications for Mobile Users in ubiquitous Computing environment (MUSIC) FP6 IST Integrated Project, Open Platform for User-centric service Creation (OPUCE) FP6 IST Research Project, SPICE [10] and 4CaaS [11] projects. All these projects are contributed to the current results with academic research to select a solution satisfactory for context management and feasible and applicable to telecommunication network operator environment. Moreover, most even if not all, of the mentioned projects have benefitted from the chosen solution in terms of innovation services prototyping and trialing.

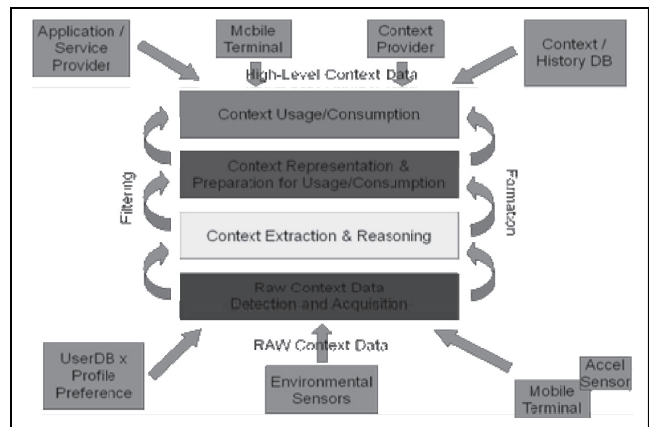
The main requirements for the context management from the beginning have been the following ones:

- To involve and use the context information available from the owned operated network and its subscribed customers, from the customers themselves (in both modes "opt-in" and "opt-out") and from the 3<sup>rd</sup> parties in Internet;
- Run on wide range of heterogeneous mobile devices with acceptable performance, interworking and

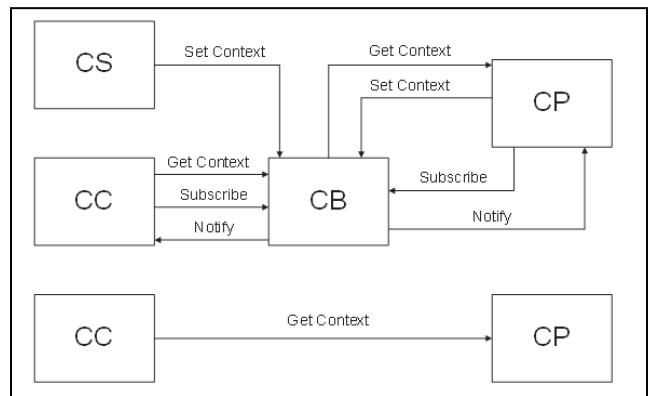
impacting as little as possible on the battery life of the customer devices and on customer's User Experience;

- Be real- or near real-time for a dynamic service configuration and execution;
- Be distributed and flexible in order to perform context related operations within dedicated context information domains (source, transport, distribution, consumer, etc.);
- Be extendable and scalable in order to extend the system by enriching the context information and to scale for acceptable overall performance;
- Be interoperable and interworking over the large operator's ecosystem including the networks, supporting Information Technology (IT) nodes, storages and myriad of customers' devices;
- Be secure and compliant with privacy regulations.

A generalized Context Management Model adopted by Telecom Italia is shown in the following figure:

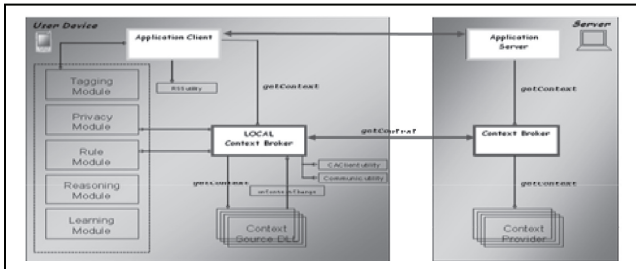


While a simplified context management framework [1] filled with the context represented within transmitted packets is shown in the below figure:



Proposed context processing model is very simple in this centralized scheme [4] based on a single context broker

and including roles of context providers or sources and context consumers. Nevertheless this scheme [2] shown above is under current work of its extension to a federated context brokerage concept based on well-know and standardized (also “*de-facto*”) Internet protocols, as one shown in the below picture. The current evolution is also consisting of integration of the context data and of the context-awareness, as a dedicated Service Enabler, into the Cloud Services technologies, i.e. Context as a Service (CaaS).



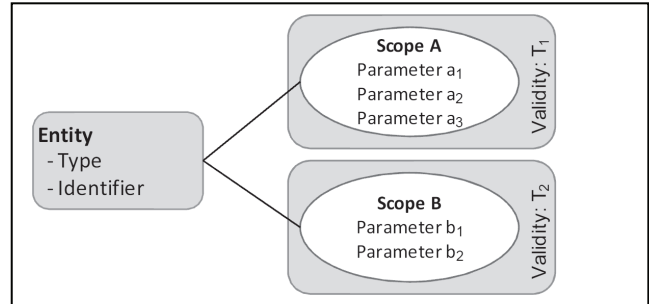
### ContextML

The ContextML [3] is a context data representation scheme or language chosen mainly with respect to the above listed initial requirements and focused especially onto the portability among the devices within the MNO’s ecosystem. This formalism is extendible, able to represent any available within the ecosystem context information and contains a minimum necessary information to transport within its payload using its tag-value schema. Therefore it is simple with minimum overheads and overloads, easy to extend and process and based on the open standards. Indeed, the ContextML is based on the XML technology adapted to the context-awareness needs.

ContextML includes the following elements:

- *Entity* – a source or owner of the context information available within the context management system. This element must be always present within a ContextML document;
- *Scope* – a context data consisting of a tag name and a value published within the ContextML document, which may contain more than one context scopes regarding the same entity;
- *Time-stamp* – a date and time of the context creation or acquisition that is very important for a real- or near real-time context peculiarity;
- *Validity* or *expiration time* – a context expiration date and time or a validity time till which the context information may be considered valid, that is very important especially for a near real-time concept.

The entity/scope association is shown in the below figure:



A very small snippet of the ContextML is given in the following example:

```

<contextML>
  <ctxEls>
    <ctxEl>
      <contextProvider id="LP" v="1.1.0" />
      <entity type="username" id="Max" />
      <scope>civilAddress</scope>
      <timestamp>2007-02-27T12:20:11+01:00</timestamp>
      <expires>2009-02-27T13:20:11+01:00</expires>
      <dataPart>
        <parS n="civilAddress">
          <par n="room">1037</par>
          <par n="corridor">North</par>
          <par n="floor">2</par>
          <par n="building">B</par>
          <par n="street">Via G. Reiss Romoli
            274</par>
          <par n="postalCode">10148</par>
          <par n="city">Torino</par>
          <par n="subdivision">TO</par>
          <par n="country">Italy</par>
        </parS>
      </dataPart>
    </ctxEl>
  </ctxEls>
</contextML>

```

The ContextML [12] is easy to integrate within a Web Service or any other SOA technologies like the REST used by Telecom Italia, is simple to include security elements and is ready to embed into a security suite. The REST communication, very similar to the HTTP, consist of two only communication request-respoce (GET and response) to retrieve any information or to acknowledge (ACK/NACK) a malfunctioning within the response. Therefore no additional overheads provided neither to the communication network nor to its components, such as network equipment, switches and nodes, nor to the communicating parts such as server and client. Moreover, chosen ContextML over REST communication protocol interoperates over a vast range of server platforms and mobile devices due to its XML legacy with a durable and

successfully proven best-practice employment and vastest usage experience. One very important ContextML property is its ability to be automatically processed in M2M operations during the context distribution and its readiness for secondary context acquisition mechanisms such as context aggregation, extraction, reasoning and prediction. Additionally, ContextML has its intrinsic semantic characteristics inherited from the XML including the hierarchically nested information nodes and the parameter/value data structures. Nevertheless, a more sophisticated context semantic and an application or service domain specific ontology are missing and required to be integrated into a system benefitting from a better intelligence and an autonomous automatic context processing. Therefore the context management model and the employed context representation are continuously evolving towards a higher intelligence, a social artifacts embedding, a better security and privacy management and an autonomous computing and self-QoS provisioning accordingly to the service configurations and SLAs, while always remaining respecting the initially assigned requirements.

### Context Operation Messages

The ContextML [3] representation formalism described in the previous section is a format for the payloads in the communications between different components composing the Context Management Framework consisting of the context producers (Context Providers), context using or context aware applications and services (Context Consumers) and centralized context handlers (Context Brokers) mentioned in the first section. ContextML is employed as packets payload within the communication transport protocol between aforementioned components such as REST or XMPP. The messages in this communications are the following ones:

- Context Provider Advertisement is a type of message from a Context Provider to a Context Broker announcing the Internet address of the provider and the context information (context entities and context scopes) it could provide to the system. Thanks to this message a Context Broker knows how and where to retrieve the context information (scopes) regarding a certain entity. There is no alternative of this message for detaching a Context Provider, instead the Context Provider shall periodically send its advertisement repetitively as a keep-alive message, otherwise the Context Broker will clean its record regarding this Context Provider in 5 minutes of inactivity. This is implemented as a simple mechanism of cleaning the Context Brokers from unused or non working Context Providers;

- Context information retrieval and Context Provider lookup requests are the REST GET messages from a Context Consumer to a Context Broker requiring in a synchronous mode the information regarding a Context Provider (Internet address) being provided with required context scope or context information and with entity's ID and required context scopes. Context information retrieval message could be also used directly to a Context Provider from a Context Consumer being provided with the Context Provider's Internet address;
- Context publishing is a type of message sent from a Context Provider to a Context Broker or to a Context Consumer, or from a Context Broker to a Context Consumer. This message contains the context information (scopes) regarding an entity being before requested or subscribed by a Context Consumer or by a Context Broker;
- Acknowledgement is a type of message sent from a Context Provider or from a Context Broker to a Context Broker or to a Context Consumer respectively on a context information request or on a subscription request indicating a correct context subscription (when no yet context information is available) or a "malformed request" response to a Context Provider or to a Context Broker;
- Context subscription is a type of message sent from a Context Consumer to a Context Broker requiring certain context information (scopes) regarding an entity.

The messages examples are not given here for the sake of the text simplicity and its useless complexity due to the reason that they are solely HTTP-like REST GET and POST messages or their XMPP alternatives. However, in case of a necessity the communication examples could be demonstrated in a demo showing a real communication between existing components – part of the running in production or a test-bed set-ups, taking into account first the privacy measures of a non disclosure of real entities and of their sensitive context information handled by Telecom Italia.

### ContextQL (CQL)

Additionally to the unconditional context retrieval by the getting context queries the Context Management Platform integrates an event- or context-based publish/subscribe interface [6], [7]. It allows to formulate the event conditions in a specific schema, the Context Query Language (ContextQL or CQL), which is similar to the well known Structured Query Language (SQL). In addition, a callback URL is provided for required conditional context retrieval when the conditions would become true.



An example of a query condition is given below:

```

<contextQL>
<ctxQuery>
<action type="SUBSCRIBE"/>
<entity>username|boris</entity>
<scope>civilAddress</scope>
<validity>180</validity>
<conds>
<cond type="ONVALUE">
<constraint param="civilAddress.city" op="EQ" value="Turin"/>
</cond>
</conds>
</ctxQuery>

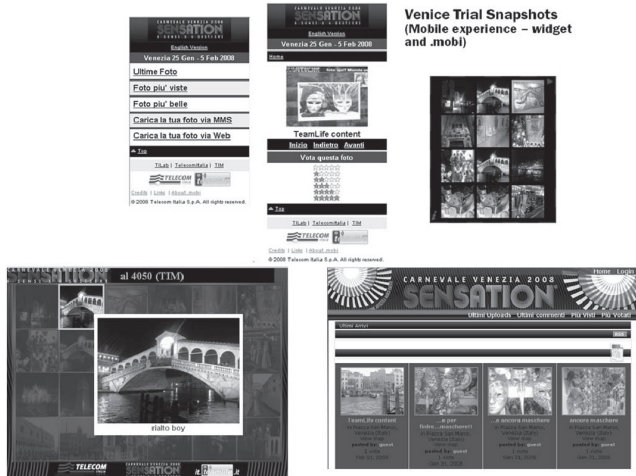
```

The operand of the context query messages could assume the following values: matching the context conditions (ON-VALUE), being more or less value (MORE or LESS), on arrival of the context information (ON-AVAILABILITY) and on a contest information update regarding certain entity (ON-UPDATE).

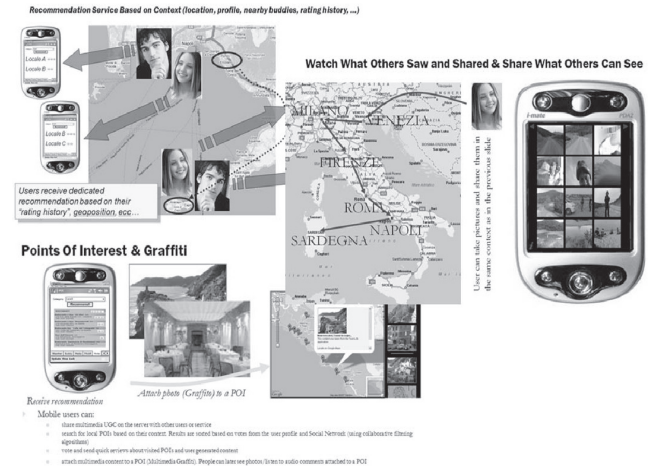
In order to allow to mix the abovementioned conditions thus creating more complex subscription requests and more comprehensive therefore precise entity selections or context retrieval, the CQL supports the following operators: equals (EQ), unequals (NEQ), starts with (STW), contains (CONT), ends with (ENW). Each subscription is bound to a specified validity time (in seconds) but can be easily renewed. All subscriptions are acknowledged by Context Brokers and all subscribed messages are acknowledged by Context Consumers.

### Usage and Application Examples

Research projects listed in the first section of this paper have provided number of prototypes and service demos, some of which still could be found in the projects' respective sites. Telecom Italia on its side, as an industrial partner, largely exploited the context-awareness developed during the last years and implemented in various services in production and services prototypes, beginning many years ago from simple context-aware content share services such as Mosaic shown below:



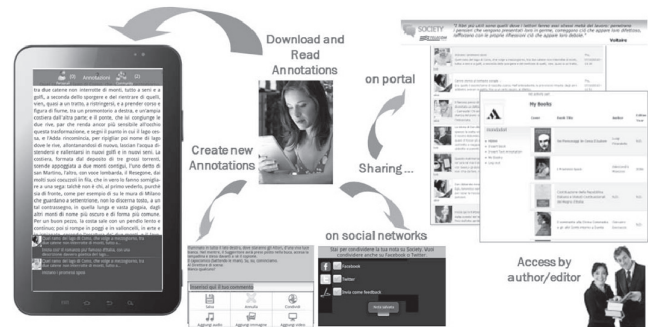
Or Graffiti, iTourism based on context-aware recommendation content and Point Of Interest demonstrated in the next picture:



Then many services created for local Public Administrations such as Bicistaffetta:



And currently is working on implementation and running services oriented to social-networks usage within its context management platform for ebooks writing, editing and opinion exchange as showed below:



Telecom Italia's check-in into places as Social Places concept demonstrated in the below picture:



And of course also Augmented Reality is of a paramount interest within exploitation plans and one snap shot of the service usage demo is shown below:



There are a lot of such services and systems based on or using the context-awareness within innovated telecommunication services of Telecom Italia and listing of all of them as well as giving examples of all the context-aware services is out-of-scope of this paper.

## Conclusions and Ongoing Work

The context model employed by Telecom Italia during many years initially involved mainly the entities under direct control of TIM (Telecom Italia Mobile) operator, therefore TIM customers, and aimed for usage as internal Telecom Italia provided services and applications. However, this solution has been disseminated and its functionality has been included within Open Mobile Alliance (OMA) standardization as Next Generation Service Interface (NGSI) Enabler [5]; and currently Telecom Italia is extending its context-awareness domain as context information acquisition from and usage to external entities, therefore a context federation concept involving many federated Context Brokers and a more precise and secure privacy control are required. These two areas of an

efficient context federation model and a security context information exchange and privacy control remaining at the same time as much interoperable as possible and totally compliant with regulation requirements through the standard and de-facto used solutions and law-regulations enforcements respectively are the two main topics, where Telecom Italia is intensively working within its internal innovation research and development and involving academy research as partners within European research projects and initiatives. One of the current technologies under study for further applications within the Telecom Italia's Context Management Framework are the open-source protocols OpenID and OAuth employed already for a long time by many world-wide ICT companies with large customer base and a number of available context-aware or context providing services.

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