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A Framework for NFC-based Context-aware Applications

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Abstract

Near Field Communication (NFC) is an emerging technology that facilitates data exchange between two devices wirelessly within close proximity. As integrated into more and more mobile phones, the NFC technology enables the users to interact with the intelligent environments in a natural and intuitive manner and thus changes the way people perform many routine daily activities like mobile payment, business card exchange, etc. Although NFC has bridged the physical and virtual worlds, context-aware technology is needed to sense and use NFC context actively in order to provide users with more intelligent and personalized services. In this paper, we propose an ontology-based framework for developing NFC-based context-aware applications, which can perceive user context and offer appropriate context-aware services to the user by combining the NFC technology with context-aware technology. With the proposed framework, application providers are enabled to develop NFC-based context-aware applications in a simple way. Meanwhile, the framework provides security service for protecting data integrity of the NFC context. This paper presents the framework's design, implementation and a real use case scenario that shows the validation of the approach.

Keywords: *Near Field Communication, Context-aware Applications, Ontology, Mobile Phone*

1. Introduction

Ambient Intelligence (AmI) is an emerging discipline that brings intelligence to our everyday environments and makes those environments sensitive to us [1], which builds upon technologies including ubiquitous computing, ubiquitous communication as well as intelligent human-computer interaction [2]. In AmI environments, people are surrounded by intelligent resources that are embedded in all kinds of objects, while intelligent devices work together to support people in performing their routine daily activities in an easy and natural way.

Near Field Communication (NFC) [3, 4] is an emerging technology that facilitates data exchange between two devices wirelessly within close proximity. As integrated into more and more mobile phones, the NFC technology enables the users to interact with the AmI environments in a natural and intuitive manner. Since NFC has multiple operating modes including reader/writer mode, peer-to-peer (P2P) mode and card emulation mode, it can be used in multiple scenarios such as ticketing [5], tour guide [6], health care [7], access control [8],etc. Because of its ease of use that is guaranteed by the touch paradigm, NFC can be used for the development of AmI systems.

Although NFC has bridged the physical and virtual worlds, context-aware technology is needed to sense and use NFC context actively in order to provide users with more intelligent and personalized services. As a matter of fact, the AmI

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systems are inherently context-aware, since they should be able to react to, adapt to and even anticipate user actions or events occurring in the environment in a manner consistent with the current context [9].

The widely adopted definition of context is provided by Dey: Context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves [10]. Context can be classified into two types: static context and dynamic context. Static context does not often change and is usually obtained directly from the user, which may include user's sex, age, profession, etc., while dynamic context changes frequently, like location, NFC tag information, time, etc. The context can be collected and processed by the context-aware systems to adapt the system's behavior to it without explicit user intervention. Context-aware technology has already been exploited in applications such as smart home [11],tourist guide [12], social networks [13], education [14], etc.

However, the development of NFC-based context-aware applications is not a trivial task for developers since it involves the emerging NFC technology as well as complicated semantic web technology that relates to context modeling, context reasoning, etc. Meanwhile, as users are often on the move, the context-aware applications have to acquire user context promptly in order to identify their situation at a given time and place and provide personalized information for that situation. In addition, the resource-limited environment of mobile devices should also be taken into account.

In this paper, we propose an ontology-based framework for developing NFC-based context-aware applications, which can perceive user context and offer appropriate context-aware services to the user by combining the NFC technology with context-aware technology. Since mobile phones are resource-scarce compared to desktop computers, we relieve them of computationally intensive tasks that derives from context management. With the proposed framework, application providers are enabled to develop NFC-based context-aware applications in a simple and fast way. Moreover, the framework provides security service for ensuring data integrity of the NFC context.

The remainder of this paper is organized as follows. The related work is presented in Section 2. In Section 3, the description of the proposed system is given. We propose the system's architecture and describe its main components in detail in Section 4. Section 5 presents the sample application built using the proposed framework, which shows the feasibility of the approach. Finally we conclude the paper in Section 6.

2. Related Work

In the recent years, many architectures and frameworks have been proposed in order to support the development of context-aware systems.

The Context Toolkit [15] is the first proposed context-aware architecture that aims at facilitating the development and deployment of context-aware applications. It consists of functional components to acquire, aggregate and interpret context information and provides applications with access to context information while hiding the details of context sensing. JCAF [16] is a Java-based context-awareness infrastructure for creating context-aware applications. It uses an object-oriented model to represent context and suggest a compact Java API for context-awareness, which can be implemented and extended in special-purpose context-awareness systems. However, these approaches do not include powerful inference mechanisms to deal with complex context transformations. To achieve context reasoning and

context knowledge sharing, some architectures, like CoBrA [17] and SOCAM [18], use the Web Ontology Language (OWL) for modeling ontologies of context.

As mobile phones are equipped with more and more intelligent sensors, context-aware frameworks for mobile environment [19, 20] are proposed for supporting the development of context-aware mobile applications. However, these frameworks differ from ours in that they delegate many computationally expensive context management tasks to mobile devices, which are in fact not the practical solutions for resource-limited mobile phones.

Tracking and identifying users is one of the key requirements of many location-based context-aware systems [21, 22]. The emergence of NFC technology bridges the physical environments and cyberspace, which can help to track the users who carry NFC phones and are surrounded by NFC devices. Borrego-Jaraba et al. [23] propose an NFC-based pervasive solution for city touristic surfing oriented to help the user to find the location of interest points within the city and navigate through them. However, context-aware technology is not integrated into the solution. In [24], an NFC-based context-aware solution is proposed for access to bibliographic sources in university environments. Although the system is context-aware, it is application-specific and does not provide security measures for NFC context.

This paper presents a framework aimed to simplify the development of NFC-based context-aware applications. By combining NFC technology with context-aware technology, it enables the NFC-based context-aware applications to sense environmental context via the NFC phones and provide users with personalized content and services related to current context in an easy manner.

3. System Description

The proposed system is applied in AmI environments where users are enabled to interact with the surrounding intelligent objects in a natural and intuitive way and receive appropriate context-aware services. It acquires raw data of the user's context (NFC touch context, location, profile, device information, etc.), converts them into abstract context representation that the system can understand, then infers high-level context by using reasoning mechanism, and finally delivers personalized services according to current context.

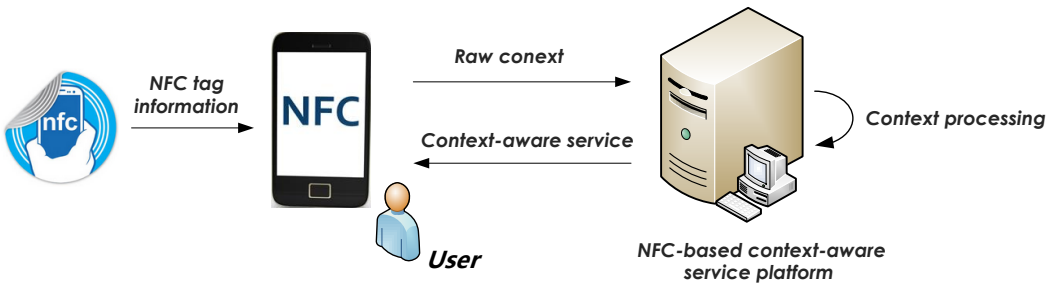


Figure 1. The Service Scenario of an NFC-based Context-aware System

Figure 1 shows the service scenario of an NFC-based context-aware system built using the proposed framework, which includes three phases: context collection phase, context processing phase and context-aware service delivery phase.

In the context collection phase, users perceive NFC context by using NFC phones that have installed the mobile application of the system. The service providers write context information to the NFC tags, which usually includes the brief description of the physical object, embed them into the physical objects like smart posters and place them at locations like restaurants in advance. Once the user touches the NFC tag, the NFC phone that works in NFC read/write mode will launch the mobile application automatically to read the context information stored in the tag. After

receiving the raw NFC context data from the AmI environment, the NFC phone will send it as well as other context of the user to the server for further processing.

In the context processing phase, the NFC-based context-aware service platform converts the raw context data such as NFC context, user profile, device information, etc. to unified context representation model that is recognizable to all entities of the system. Based on the abstract context representation, the system infers the high-level context from the raw context data by using the built-in inferring engine.

In the context-aware service delivery phase, the NFC-based context-aware mobile application is enabled to receive context-aware content or services when given conditions are satisfied by the current context. The system is responsible for managing the context and ensures that the context-aware services are delivered in a proper and timely way according to the service delivery rules that the application developers define.

4. System Architecture

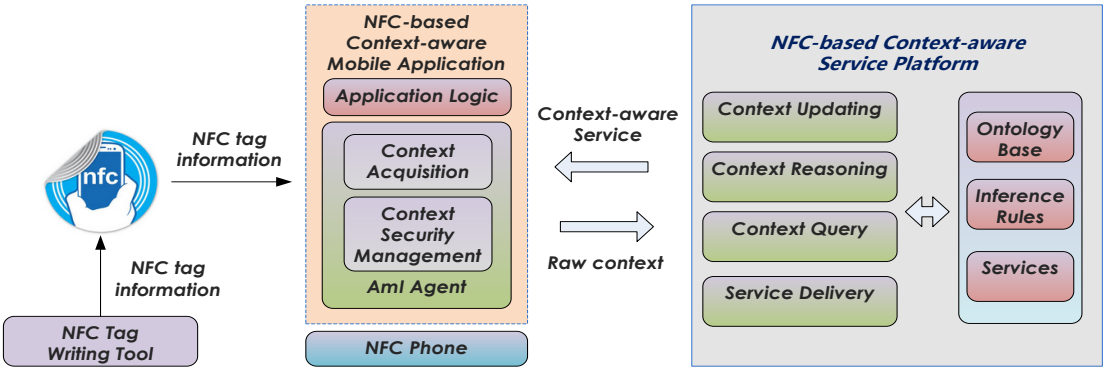


Figure 2. Architecture of the Proposed System

The system consists of three parts: AmI Agent, NFC Tag Writing Tool and NFC-based Context-aware Service Platform (See Figure 2), which provides necessary, reusable and extensible context management functionalities for application developers and thus greatly reduces the overhead of developing an NFC-based context-aware application. Furthermore, as the NFC phones are resource-scarce, computationally intensive tasks of the proposed system, like context reasoning, are carried out by the server instead.

4.1 AmI Agent

The AmI Agent is the mobile agent of the proposed system that should be integrated by the NFC-based context-aware mobile application and installed on the NFC-enabled Android phone in advance. It is lightweight enough since it is only responsible for collecting raw context data from the AmI environment and providing context security management service. Using the AmI agent, the developers do not have to know much about NFC data exchange technology.

As depicted in Figure 2, the AmI Agent is composed of two modules: the Context Acquisition module and the Context Security Management module.

- **Context Acquisition Module**

  The module collects the context information of the physical objects for the context-aware system. In order to facilitate the context modeling, we organize the raw context data in XML format, which has good readability

and can be easily converted to ontology-based context representation model. Since it takes much time to frequently convert the raw context data to XML format data, we directly write the XML format context data into the NFC tag. We do not write ontology-based context representation to the NFC tag because ontology-based context contains much more information than XML format context and the NFC tag has very limited storage space. Table 1 shows the template of the raw context information stored in the NFC tag.

Table 1. Template of the Raw Context Information Stored in the NFC Tag

```
<NFCContexts>
  <context name="Context1">
    <content type="type1">content1</content>
    <content type="type2">content2</content>
  </context>
  <context name="Context2">
    <content type="type1">content1</content>
    <content type="type2">content2</content>
  </context>
</NFCContexts>
```

As shown in Table 1, the XML format context has good extensibility, hence it can be applied to a wide variety of service scenarios.

In the proposed system, the Context Acquisition Module is mainly in charge of collecting the raw context data from the NFC tag since it is a general requirement for NFC-based context-aware applications. In contrast, other context, like user profile, device information, etc., should be acquired by the application itself according to its business logic.

- **Context Security Management Module**

  Currently many NFC applications store the context information in plain text into the NFC tag, which is not safe since malicious persons can modify the tag information and provide fake URLs that lead to phishing sites that attempt to steal user's private information and even provide illegal services. Because of this, the Context Security Management Module provides data integrity authentication service for the NFC tag information. The module does not provide data confidentiality protection service because the NFC tag information is usually published in public and should be accessed by any person. When application providers want to write context information to the NFC tag, the raw context data as well as its digital signature will be encapsulated into the NDEF (NFC Data Exchange Format) message and then written into the tag. Once the Context Security Management Module confirms the validity of the signature by using the associated public key, the context information can then be used by the context-aware system for further processing.

Figure 3 Shows the Process of Acquiring Context Information by the AmI Agent

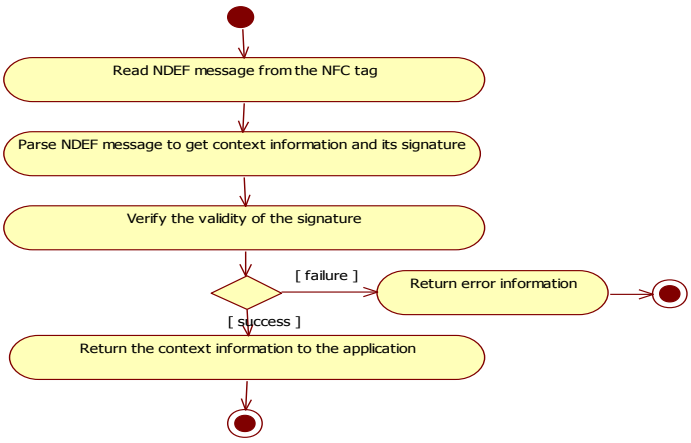


Figure 3. The process of Acquiring Context Information

4.2 NFC Tag Writing Tool

To reduce NFC service deployment efforts, the proposed framework provides NFC tag writing tool for application providers to write associate context information to the NFC tags that need to deploy at different locations. To simplify its implementation, the tool is developed as a mobile application that can run on NFC-enabled Android device.

As described in Sect. 4.1, the XML format context information and its signature should be written to the NFC tag to ensure integrity protection of NFC context. Figure 4 shows the tool's working process of writing context information to an NFC tag.

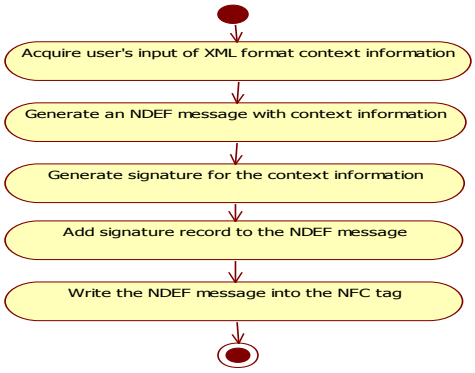


Figure 4. The Process of Writing Context Information to an NFC Tag

4.3 NFC-based Context-aware Service Platform

After collecting the raw context information, the system should deliver context-aware services to the user. The NFC-based Context-aware Service Platform is mainly in charge of building abstract context representation model, inferring high-level context, and delivering personalized services to the user according to his/her current context. The platform consists of four modules as shown in Figure 2:

- **Context Updating Module**

The Context Updating module is used for converting sensed data to abstract context representation model. As the proposed system is a general framework for a wide variety of context-aware applications and different application scenarios contain different forms of context, the context model to be built should be domain-independent and easy to extend. In addition, the context model should be easy to perform context reasoning over for obtaining high-level context.

Although many context models have been proposed [25], ontology-based context model is widely considered the best approach for modeling context, since it supports representing context data coming from different sources and context reasoning based on semantic web technology. Therefore, the Context Updating module provides ontology-based context updating service, which exposes the following methods:

- Add context information
  This method enables applications to add a new context ontology instance to the ontology base by providing XML format context information.
- Update context information
  This method enables applications to update a context ontology instance stored in the ontology base.
- Remove context information
  This method enables applications to delete a context ontology instance from the ontology base.

By using the above methods, application providers can update the context in a simple and efficient manner, as the complicated ontology modeling work is kept hidden from them.

- **Context Reasoning Module**

The Context Reasoning module is the key module of the service platform, since it can deduce high-level context, i.e. user's implication, that is much more useful for context-aware applications to provide users with personalized services than low-level context collected by the Context Acquisition module. As the proposed system adopts ontology-based context model, the module makes ontology-based context reasoning by using Jena [26], which is an open source semantic web framework that supports OWL and rule-based reasoning. Because different NFC-based context-aware applications have different business logic, their inference rules are also different. The application developers should provide the module with inference rules for inferring the high-level context (See Figure 5). The inferring process is performed whenever context changes.

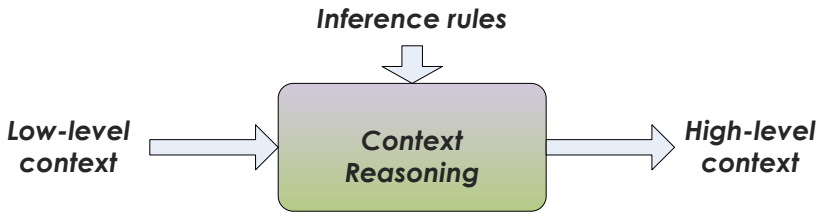


Figure 5. The Process of Rule-based Context Reasoning

- **Context Query Module**

  The Context Query module enables applications to synchronously access the ontology base using SPARQL [27] queries. As a result, the user can request context information in an explicit way.

  The process of context query is depicted in Figure 6.

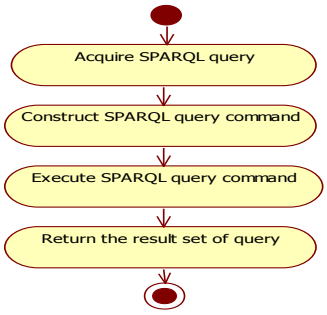


Figure 6. The Process of Context Query

- **Service Delivery Module**

  The Service Delivery module enables the context-aware application to deliver context-aware services in order to meet users' needs by making use of obtained context information.

  While the Context Query module provides synchronous method to access high-level context information, the application can receive context-aware services in an asynchronous way using the subscription method provided by the Service Delivery module. In this way, context-aware services can automatically respond to the user once predefined conditions are satisfied by the current context.

5. Sample Application

In order to evaluate the feasibility of the proposed approach, Smart Bookstore, an NFC-based context-aware application is developed using the proposed framework. The application enables the user to acquire book information and intelligent book recommendation by interacting with the smart book posters augmented with NFC tags in the AmI environment.

Before publishing book posters, we write context information to the NFC tags to be embedded in the posters by using the NFC tag writing tool. The raw context data template, as described in Table 1, is used to construct the context information of the NFC tags. The code snippet that defines the context information of a smart book poster is shown in Table 2.

Table 2. Context Information of a Smart Book Poster

```
<NFCContexts>
  <context name="book">
    <content type="Name">Semantic Web Programming</content>
    <content type="Author">John Hebeler</content>
    <content type="bookType">Computer Science</content>
    <content type="bookId">BN10000001</content>
  </context>
</NFCContexts>
```

Since the proposed framework adopts ontology-based context model, domain ontology of the Smart Bookstore application should be created. To accelerate the ontology creation, we use Protege [28], a user-friendly open source ontology editor.

Figure 7 shows the context ontology of Smart Bookstore.

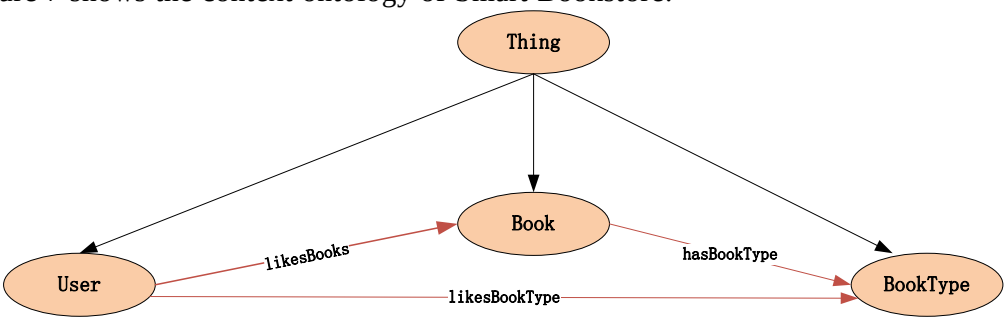


Figure 7. The Context Ontology of Smart Bookstore

The ontology classes include User, Book as well as BookType that the user likes. User context is added to the ontology base by creating individuals from the ontology classes. The aim of this application is to provide the user with more detailed information about the book that he is currently interested in and book recommendation information. As all of the detailed information of books are stored in the ontology base, the application accesses them using SPARQL query as shown in Listing 1.

Listing 1. SPARQL Query for Retrieving Context Information of the Book that the User is Currently Interested in

```
PREFIX smartBookstore: <http://www.semanticweb.org/administrator/ontologies/smartBookstore.owl#>
SELECT ?name ?author ?picUrl ?description ?pages ?price ?rating
WHERE {
   ?book smartBookstore:hasName ?name .
   ?book smartBookstore:hasAuthor ?author .
   ?book smartBookstore:hasCoverPictureUrl ?picUrl .
   ?book smartBookstore:hasDescription ?description .
   ?book smartBookstore:hasPages ?pages .
   ?book smartBookstore:hasPrice ?price .
   ?book smartBookstore:hasRating ?rating .
   ?book smartBookstore:hasBookId "BN10000001"
}
```

After receiving the returned result set of the query, the application can display detail information of the book to the user.

For book recommendation, the application needs to know what kind of books the user may like, which is inferred from the user preference and books' ratings. The user preference is acquired from the context of the NFC tag that the user touches, which is the type of the book shown on the smart poster. The recommended books are deduced if their type matches the user's preference and they receive high ratings as well. The inferring rule for finding highly recommended books is described in Listing 2.

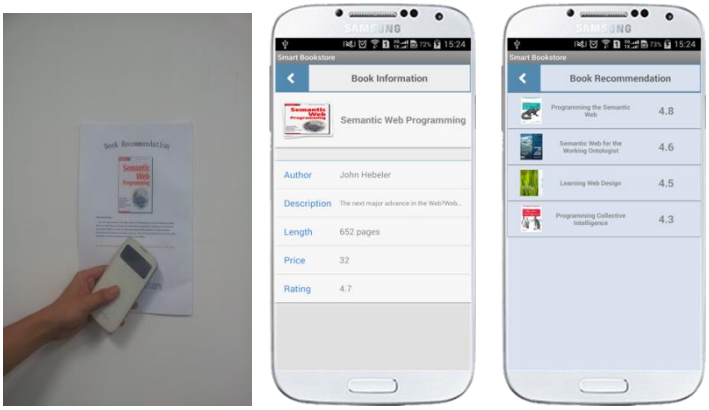
Listing 2. Inferring Rule for Finding Highly Recommended Books

```
 (?book smartBookstore:hasRating ?rating)
greaterThan(?rating,4)
(?user smartBookstore:likesBookType ?bookType)
(?book smartBookstore:hasBookType ?bookType)
->
(?user smartBookstore:likesBooks ?book)
```

As the application registers context subscription in the proposed system, information of the highly recommended books will be sent to the user automatically

after being sorted by rating.

The NFC-enabled mobile phone that we use for running the application is a Samsung Galaxy S4 smartphone. During the service usage phase, the user uses the NFC phone to touch the NFC tag embedded in the smart book poster and then the Smart Bookstore application previously installed is started. Operating in reader/writer mode, the NFC phone reads the context information stored in the tag and sends it to the application server for retrieving its detailed information and obtaining context-aware book recommendation. Figure 8 shows the service scenario of the application.



(a) (b) (c)

Figure 8. Service Scenario of the Smart Bookstore Application (a) The User Touches the NFC Tag Embedded in the Smart Book Poster (b) The Book's Detail Information is Displayed (c) Information of the Highly Recommended books is Sent to the User Automatically

6. Conclusions

Nowadays, more and more intelligent objects are distributed in our living environments, which supports people to carry out everyday tasks in an intelligent way. As NFC technology simplifies the way people interact with the AmI environments, it can be a good choice for developing AmI system.

In this paper, we propose an NFC-based context-aware framework that is able to perceive and make use of NFC context for providing users with context-aware services in a natural and effective way by combining the NFC technology with context-aware technology.

With the proposed framework, development overheads of acquiring, aggregating, inferring and storing context information are greatly reduced. Moreover, application providers even do not have to know much about NFC data exchange technology for adding semantic information to physical objects, since the framework provides easy-to-use NFC tag writing tool for developing smart posters.

In order to achieve knowledge sharing and knowledge reuse, the framework models the context with the context ontology using OWL. And rule-based context reasoning is performed over the context ontology model. Since the inference rules and domain ontology are decoupled from the system, application developers can add new business logic in a flexible and extensible way.

As NFC phones are resource-limited in terms of processing and storage capabilities, it is not suitable for them to carry out computationally intensive tasks. The proposed framework is designed specially for mobile devices. It enables the server to take most of the computational burden deriving from context processing, while the mobile device is mainly responsible for collecting raw context information.

In addition, the proposed framework provides security service for ensuring data integrity of the NFC context. The context information of the physical object and its digital signature are written to the NFC tag by using the provided NFC tag writing tool. During the context collection phase, the data integrity authentication of the NFC tag context is performed by validating its signature, and only the authenticated NFC context information can be used by the system for further processing. In this way, the NFC context is distributed and managed in a secure manner, which prevents it from being illegally tampered with.

We think the framework proposed in this paper can effectively simplify the development of NFC-based context-aware applications and accelerate the adoption of NFC technology in AmI systems. Currently we are working on implementing the NFC tag writing tool running on desktop computers, which can facilitate editing and management of NFC tag context information for application providers.

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