Enriching Context-aware Solution: Challenges and Issues

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Abstract

One of the visions for the future of telecommunication is for conventional services such as voice call to be integrated with data services. New markets for services and devices will be created. Services become personalised when they are tailored to the context and adapted to changing situation. Nevertheless, end users have always been constrained with the need to understand how the devices interact with the environment. The devices which end users access today are merely dumb terminals. Even though they facilitate productivity in the things they do, it forces the individuals using these terminals to learn how to utilise them. As the number of devices and services increase, the complexity of using them increases as well. This paper responds to the challenges by reviewing more flexible, adaptive and context-aware forms of collaborative work which shape part of the future of the communications landscape.

1. Introduction

It is believed that in the future, services will likely be customised to an individual's requirement. With the constant increase in diversity of devices, technology embedded within the very fabric of the common lifestyle can be seen. Devices will communicate with each other in their presence sphere. Figure 1 shows that as mobility-support becomes a crucial aspect for our everyday communication needs, services are required to be highly personalised to the end users' temporal needs (suitable for the situational context which they are in at any moment in time).

To support this, Figure 2 shows the forecast of the global distribution of mobile communication and broadband wireless access. Fixed-line subscriber growth is projected to lag behind cellular growth for the next few years.

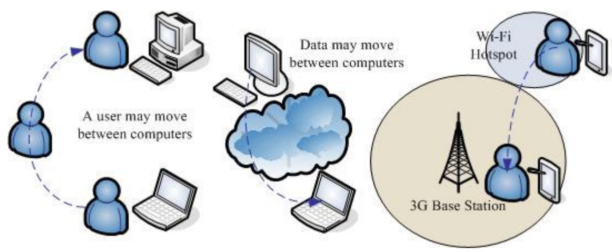

Figure 1: Mobility

This means that subscribers increasingly require access to mobile services on the move. As a result, adaptation and content tailoring to specific individual and current environment is one of the key enablers driving the diffusion.

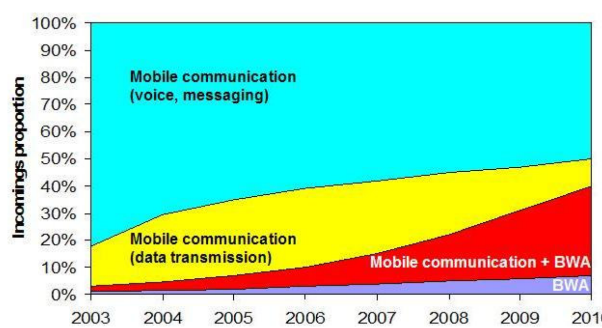

Figure 2: Forecast of worldwide distribution of mobile communication and broadband wireless access [1]

2. Current issues

Application solutions today are not sensitive to the user's environments and the user's needs. It constantly requires user's input in order to react. Even with the user's input, it does not always react in the appropriate manner that is required by the user. With the introduction of device heterogeneity in our daily lives, humans will be surrounded by intelligent interfaces supported by computing and networking technologies. Intelligence will be incorporated in everyday objects like clothes, vehicles, picture frames, even the cup of which we drink from. In order to support the level of complexities that will be introduced, information will need to be filtered adequately to provide only specific information relevant to an individual at any point in time.

These intelligence built-in in the environment focuses on performing its specific task well. Nevertheless, this task may not be necessarily attuned to the user at a specific moment in time. Future applications and services needs to synchronously customise to the users needs at any moment in time, putting the user as a focal point of its operation requirements. This behaviour is referred to as user-centric behaviour. Research in context awareness is a very important area for user-centric communications. This is because context awareness provides the ability for solutions to be aware to the situation a user is in, thus providing the ability for such solutions to react around the users every need. In order to achieve such goals, many issues that surrounds how context information can be gathered, represented, processed and consumed appropriately by the solution needs to be looked at.

Context aware applications rely on sensors to observe aspects of the context (see Figure 3 and 4) [2]. The basis of all adaptive solutions comes from inputs that form the data sets for analysis and design of the corresponding prediction model. This input information vary widely as it could be information based on a physical entity, e.g. person, device, place, or a non-physical entity, e.g. activity, mood, time of day. A ubiquitous environment contain a diverse range of sensors, each using its native access mechanisms and output formats, potentially leading to problems and complexity in system design and implementation [3]. The complexities of this diverse set of input types make it extremely difficult for solutions to use this information. Most context aware applications embed the interpretation logic of context inside of the applications itself. Delegating the data acquisition and context processing task to the application itself makes them almost impossible for reuse [3, 4]. In order for solutions to use this information consistently, there needs to be a standardised manner to represent these data, validate them against recognisable entities, with a standardised manner of which they could be obtained.

The information that are captured via the sensors then needs to be modelled in the computing system, where there are issues concerning sharing of these context information. The five issues identified by Nihei [5] are:

- Interconnectivity
- Operability
- Pre-processing of context information
- Largeness of scale and real time sharing
- Rights management, privacy protection and authentication

The goal of context aware application is to have the ability to act in response to the situation, when certain context is met. To this end, a standard manner of addressing actions that can be carried out is required. Similar to sensors, the diversification of the meanings these actions carry implies that there are potential issues on how the actions can be understood and triggered.

3. Principles of adaptability

Context awareness, in short, means the capability to utilise environmental information including user's information to provide a truly user centric environment. Some of the companies in the telecommunication industry are already using presence information such as user location to improve user experience. Nevertheless more can be expected from the free flow of context information around us. With the continuous advances in sensor technology and the emergence of wireless sensors network, context aware systems will become reality in the near future with powerful capabilities.

Many of the research studies done in context awareness space are focusing only on single perspective such as event-trigger context service. However, the power of context aware systems is not bounded by one perspective. Each context aware system is expected to be interconnected with one another to exchange context information for context information integration. By having all context information (user status information, environment information, user historical information, user preference information, security information and etc.) integrated and available to the context aware service, the context aware service could "understand" the user better, whereby be able to provide a more dedicated service.

To provide a better illustration of how context-aware solution operates, Figure 3 shows a simplistic representation of how sensor abstractions that are created in the real world would report sensory data back to the platform which, in turn, translate to a virtual world representation.

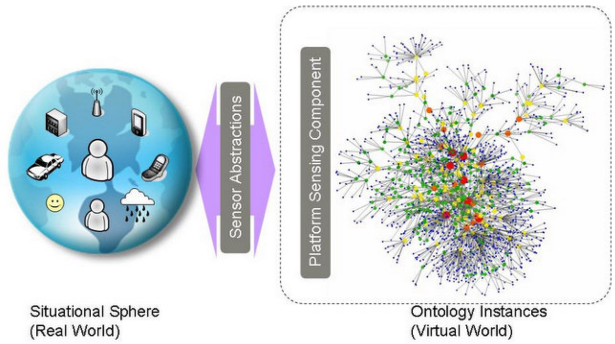

Figure 3: Simplistic view of sensor-ontology interaction

Figure 4 then shows how services that subscribes to context defined by certain conditions would receive triggers when the subscribed context is met in order to take the necessary action.

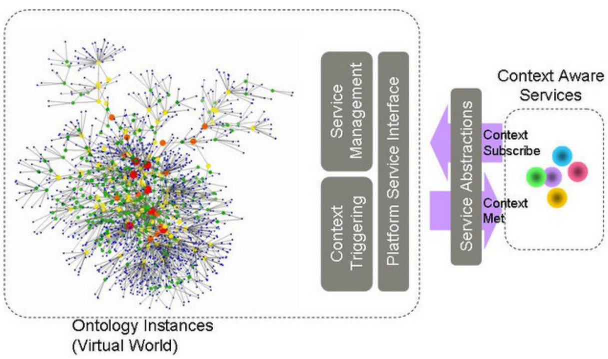

Figure 4: simplistic view of ontology-services interaction

The sensors abstracted are from the following categories:

- User-related category, typically consisting of user preferences, user history, user interest, user role, user priorities
- Mobility and location-related category, typically embedding physical coordinates, velocity, direction of movement, ambient conditions (indoor, outdoors, temperature, humidity, etc.)
- Network and terminal characteristics, such as bandwidth, graphic capabilities, screen size, etc.
- Non-user-related information, e.g. which contains content-related preferences (such as presentation format, encoding, etc.)
- Service-related information, e.g. describing what the service delivers, pricing information, service requirements on network and terminal, etc.

The basic principle of adaptability is simple: when the environment changes, the application changes to suit the requirements of a user. Services should adapt dynamically by using automated learning capability.

4. Where context-aware systems are today

Context-aware systems have mainly stayed in the academic world due to its dependencies on a large amount of information, building an information base, to support its logical constructs. Nevertheless, changes should be seen with the proposal of more Open Systems based approach for representation of entities around us. The following sub-sections describe some of the more relevant activities that were carried out.

- **Context Toolkit**
  Salber et al. [6] have defined Context Toolkits in 1999 to create a framework for the context-aware application development. In the architecture, the context toolkits have three primary components which are widgets, aggregators and interpreters. These three components provide the abstraction to the context-aware application on contextual information. The widgets are the source of contextual information. It extracts contextual information and translates raw data from sensors that are monitoring the environment. The interpreters will then further derive the information to more meaningful higher level contextual information. Lastly the aggregators help to aggregate the contextual information to minimise the complexity of context-aware applications. Although the paper of Dey and Abowd [7] define the framework for context-aware application development, they do not define the contextual data modelling.

- **Context Shadows**
  Another infrastructure that has been developed by Martin Jonsson [8] of Stockholm University in Sweden for a user-centred communication system that employs context-awareness is called Context Shadows.

This architecture allows the use of context information from sensors in a communication system, just like the Context Toolkit does. However, the Context Shadow surpasses the Context Toolkit in that it allows other applications to be used as context information. The Context Shadow also incorporates service discovery, as opposed to the Context Toolkit where this feature was not available. Hence, when new services are created, the Context Shadow architecture allows the user to discover these services and be able to use them at run-time.

- **GAIA (University of Illinois)**
  The Gaia, created by Roman et al [9], is a distributed middleware infrastructure that coordinates software entities and network devices. It exports services to query and utilise existing resources. The objective of Gaia is to provide a framework for development of user-centric and context sensitive mobile application. The team focuses providing a framework to allow users to interact with physical space, making these spaces termed by the team as Active Spaces.

- **Context Broker Architecture (CoBrA)**
  Chen et al [10, 11] has introduced Context Broker Architecture (CoBrA) for supporting the context-aware systems. The CoBrA is an intelligent contextual information broker that could share all contextual data. The intelligence of this broker came from the use of Semantic Web Language to model the contextual information and the use of Web Ontology Language to perform intelligent reasoning. Computer system that could understand Semantic Web Language will be able to trace through the ontology. This capability allows such computer system to perform automatic reasoning. On top of the intelligent reasoning, CoBra governs the contextual information sharing model through the implementation of policy language to control sharing level of user information.

- **Java Context-aware Framework (JCAF)**
  Java Context-awareness Framework (JCAF) is another framework that serves the purpose to assist in context-aware application development [12]. JCAF has the objective to create a general-purpose, event-based and distributed service oriented Java Framework. The core design principles of JCAF are based on the following beliefs:
  - Contextual information is scattered everywhere in the environment and some of the contextual information is stored at remote location.
  - Each contextual service may require services from each other.
  - Contextual information is the changes that happen in the environment including the changes of user activities.

  JCAF introduced Context Monitor to handle sensors that are monitoring the environment and Context Actuators to handle deployed actuators as the response on changes. In the interpretation of JCAF, context is considered as a container that is storing context item where the entity in the context is one of the context items. Each context item within the context container is related to each other.

- **Service Oriented Context-aware Middleware (SOCAM)**
  Service-Oriented Context-aware Middleware (SOCAM) [13] is a middleware architecture that targets to enable rapid prototyping of context-aware services. SOCAM models the contextual information based on the ontology using OWL to resolve the issues of semantic representation, context reasoning, context classification and dependency. SOCAM define ontology in OWL to enable it to describe context semantically which is independent from any programming language and enabling computer system to understand the semantic value. This combination of technology enables the formal analysis on domain knowledge that could be done automatically by the computer system. A set of independent services is provided within SOCAM to facilitate the context-aware applications and enabling contextual information exchange with other context providers. These services provide the fundamental functionalities such as context acquisition, context discovery, context interpretation and context dissemination.

- **BerlinTainment**
  The Berlintainment project [14] focuses on realising a scalable Serviceware Framework

based on Multi-Agent System (MAS) technology. It uses agents encapsulating specific functionality that exchanges information with other agents, where the interactions between them are ontology based providing a common vocabulary.

5. Closing remarks

Some of the challenges in the past decade including convergent services suffering from lack of definition, unclear market demand, technology integration challenges, incompatible organisational structures, regulatory constraints and inadequate supply of devices. Players seeking to capitalise on opportunities with converged solutions need to focus on addressing the market segment which is likely to be the most receptive to converged solutions, such as business users on the move as well as the youth.

This paper serves as a foundation to understand current status of context-aware studies which facilitate the ease of developing, deploying, and maintaining context-aware services and applications through the use of a structured framework and dynamic definition of domain ontologies to promote growth of the knowledge plane. Future services and applications would be more aware of variables which could affect how an individual would communicate. With such a platform in place, boundaries for creation of adaptable services and applications are limitless.

6. Acknowledgment

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