Chapter 3

CONTEXT-AWARE AND WEB SERVICES TECHNOLOGY

3.1 Introduction

This chapter reviews the important topics of context-aware and Web Services technology and their applications in various industries. This review is a platform to understanding how integrated systems that consist of context-aware application, Web Services and wireless technology play their role in supporting human activities. It also focuses on a number of context-aware system frameworks that have been established by previous researchers which can be used as a ground work for developing a future application in the construction supply chain.

3.2 Context-Aware

The ability of devices through smart applications to identify user context and adapt their behaviour into the situation of the context can be translated as context-awareness. Context-aware computing enables a mobile application to leverage knowledge about various context parameters, such as who the user is, what the user is doing, where the user is and what terminal the user is using (CISCO, 2010). Context-aware services adds an additional layer on top of a real-time wireless connectivity, by providing the ability to intelligently interpret the user context and delivering data and services to a project team member based on the user’s context. A number of significant context-aware computing researches have been extensively conducted to support the services in various industrial sectors including health services (Ekahau, 2010), airport and train services (Appear, 2010), manufacturing services (Chen et al., 2008) and tourism industry (Cano et al., 2006). On the contrary, research related to the application of context-aware in the construction industry is still at an early stage with a lot of challenging tasks that need to be tackled especially in the
methodological and organisational aspects (Aziz et al., 2009). Consequently, no agreement on the definition and modelling of context has yet been reached (Benerecetti et al., 2001).

### 3.2.1 Context-Aware Definition

Before defining context-aware, it is best to define the term ‘context’ first. To date, several research papers have discussed the meaning of context in mobile computing perspectives including Chen and Kotz (2000), Dey et al. (2001), Kaenampornpan and O'Neil (2004), Truong and Dusdar (2009) and Huang and Gartner (2009), but the classic definition by Dey (2000) has always been referred to and critiqued in most literatures. According to Dey (2000), 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 application themselves”.

Correspondingly, for context-aware computing, Dey (2000) provided the following definition: “A system that uses context to provide relevant information and/or services to the user, where relevancy depends on the user’s task”. Also, according to Dey (2000), “the ability of application to interpret context and adapt their behaviour into the situation of the context can be described as context awareness”. In conjunction to this, Broens (2004) also stated that a system that provides tailored information or services which exhibit context and require context as an input is classified as context-aware. Schilit (1995) had stressed that the role of a context-aware application is to ensure that the mobile user receives highly specific data and services which are relevant to their context changes. Basically, it can be said that context-aware application leverages knowledge about various contexts such as who the user is, what the user is doing, where the user is and what terminal the user is using, which are relevant to the user’s interest.

### 3.2.2 Context-Aware Services

Conceptually, context-aware services delivery can be managed or supported by three parties as illustrated in Fig. 3-1. Service requestor plays a role by requesting services based on contextual criteria (e.g. nearest project team), service provider plays a role in supplying context (inputs) by matching processes whenever service requestor is unable to
support to the service and context provider plays a role in supplying contextual inputs to the service (e.g. GPS location data).

Referring to Dey and Abowd (1999), a context-aware application system is classified as a delivery system which can support a user in three different ways as follows:

- *The presentation of information and services* – The system uses implicit information such as user location to provide service that is relevant to the user’s current context. In this case, the application uses user’s current context to propose appropriate actions to the user. For example, based on the current location context, a system application sends a message to a user (e.g. Logistics Manager) asking him/her to browse the Project Management Software that matches with his/her current context.

- *The automatic execution of a service* – A service is automatically activated or triggered based on context change. A context can be the user context or any information that is relevant to the user. For example, the user’s (e.g. project manager) smartphone vibrates when new information (e.g. project current status) has been updated for him/her. In this case, a wireless sensor with specific context-aware application imbedded in his/her smartphone detects other mobile devices that are in close proximity to him/her and interprets that the user is in a meeting or discussion, therefore only vibrates the smartphone without sound so as not to disturb the meeting.
The tagging of context to information for later retrieval – In this service, specific information that is relevant to user contexts, either location, profile or time, is delivered or displayed when it matches with one of the contexts. For example, the system application tags (notes) information during a site visit taken by the Project Manager with the location and time of the event that occurs.

3.2.3 Intelligent Web Services

Web Services are self-contained, self-describing, modular applications that can be published, located and invoked across the Web. Once a Web Service is deployed, other applications (and other Web Services) can discover and invoke the deployed service regardless of operating system or programming language (Kreger, 2001). The key to Web Services is on-the-fly software creation through the use of loosely coupled, reusable software components (Fensel and Bussler, 2002). Typical Web Services architecture consists of three entities as illustrated in Fig. 3-2: service providers, service requestors (or clients) and service registries. Service providers publish their services through brokers who maintain registries that clients can look up. The API (Application Programming Interface) for registering services is called Universal Description, Discovery and Integration (UDDI). This API enables an enterprise to describe their businesses and services and how they wish to undertake transactions, search for other businesses that provide the desired services and integrate with these businesses to undertake a transaction, if desired. Service requestors (Human users or agents) search services in registries and invoke these services using Web Service Description Language (WSDL). With the help of information taken from the registries, users invoke the required service through web interface. Simple Object Access Protocol (SOAP) is used to pass object information between applications. Web Services loosely coupled approach suits the construction industry because of the temporary, multi-organisation structure of many construction projects where companies work together for a short period of time.
The introduction of an integrated computing system and wireless technologies concept has opened up new possibilities for leveraging the capabilities of mobile computing in construction. Referring to Aziz et al. (2006), the key building blocks of such integrated system technologies, as shown in Fig. 3-3, can best be summarised as follows:

- **High Bandwidth Wireless Technologies** provide the fundamental communication link between the wired back-end and the wireless front-end.
- The **Semantic Intelligence** layer enables knowledge description (using ontologies) and knowledge access (by supporting information retrieval, extraction and processing).
- The **Web Services** layer ensures dynamic discovery of resources and resource integration. Adherence to Web Services standards allows users or their agent software an ability to share data and dynamically invoke capabilities from other applications in a multi-domain, multi-technology, heterogeneous environment.
- The **Agents** layer plays the key role in addressing issues such as security, negotiation, personalisation and web service procurement.
- **Context Aware Technologies** play a key role by intelligently interpreting the user context based on various parameters such as location, time, profile and user task.
The Semantic Web is an extension of the current Web where information is given well-defined meaning through better enabling computers and people’s support. It is based on the idea of having data on the Web defined and linked such that it can be used for more effective discovery, automation, integration and reuse across various applications (Hendler et al., 2002). Conceptually, the Semantic Web architecture, as illustrated in Fig. 3-4, is based on a number of layers which include:

![Fig. 3-4: The Semantic Web architecture (W3C, 2008)]
• **URI/IRI (Uniform Resource Identifier/Internationalised Resource Identifier)** layer for identifying or naming a resource.

• **XML (eXtensible Mark-up Language)** layer for defining contents and rules.

• **RDF (Resource Description Framework)** (RDF, 2008) is a conceptual data layer on top of XML. RDF is application and domain neutral and defines a metadata layer and domain specific vocabulary. RDF model can be used to describe resources with classes, properties and values or anything that has a URI.

• **RDFS (RDF Schema)** is an extension to RDF; it provides framework to describe application specific classes and properties.

• **OWL (Web Ontology Language)** is used as an ontology definition language.

• **SPARQL** is a query language for RDF.

• **RIF (Rule Interchange Format).**

• **Unifying Logic** layer defines rules for dynamic inference and definition of hierarchies and processing of schemas and instances.

• **Proof and trust** layers involve rating of sources and processes and monitoring of logical steps.

Semantic Web technologies offer considerable benefits in terms of project management, content and document management, knowledge management, supply chain management, integration of distributed applications and services and improved efficiency of construction project delivery (Anumba et al., 2003). Semantic description of project resources is envisaged to enhance construction supply chain in the following ways:

• Deeper understanding of the semantics of document content and project task structure will help the project team members in information retrieval, extraction and processing, thereby helping to accomplish elements of a project plan.

• Semantic Web techniques, through the introduction of ontological reasoning, are suitable for flexibly discovering abilities in using information that is not specifically designed or intended for a particular use case (Lassila and Adler, 2003). Thus, Semantic Web technologies will enable a project team member to use highly specific data and services on as-needed basis.

• Construction enterprises very often perform their processes in different ways. Difference in meanings of terms and modes of operation makes collaboration
difficult. The use of shared ontologies and semantic standards will ensure increased interoperability across devices, platforms and applications.

- Separation of presentation and data, as ensured by Semantic Web technologies, will ensure the use of the same middleware tier for serving both mobile and fixed network clients.

### 3.2.4 Context-Aware System Components

The context-aware system is principally designed to serve the user in the aspects of current situation or context and use them to interact in a more intelligent way with the combination of different technologies such as sensing devices (to capture physical context), intelligent software-application (agent to interpret social context) and wireless technologies (to create pervasive environment). According to an intensive review by (Malik et al., 2007), there are five generic components of a context-aware system. These are illustrated in Fig. 3-5 and described as follows:

![Context-Aware components](adapted from Malik et al.(2007))
- **Context Acquisition** – This component plays a role in sensing and gathering of contextual data. The contextual data are sensed by a sensor that is built in the environment or in mobile devices.

- **Context Representation** – This component provides efficient structuring and retrieval of gathered contextual data using representation scheme. Extensible Mark-up Language (XML), Resource Description Framework (RDF) and Web Ontology Language (OWL) are tag-based accepted standard formats for representing contextual data.

- **Context Storage** – The gathered and represented contextual data are stored in local storage. The storage process allows the system to maintain a history of context that is used to identify the preferences of entities.

- **Context Interpretation** – Interpreting raw, low-level gathered context information to meaningful and high-level interpreted context information is the first phase of the interpretation process. The interpreted context provides a high-level view of the context data and is used for adaptation process. In the second phase, implications are then reasoned from the interpreted context. These implications provide instructions for adaptation process and applications. The interpreted contexts are categorised as ‘What’, ‘Who’, ‘Where’ and ‘When’ contexts. These contexts are the subsets of the gathered contextual data and provide identification, activity, spatial and temporal information.

- **Context Adaptation** – The adaptation process starts as soon as the interpretation and reasoning of the contextual data is completed by employing decision making techniques. Context adaptation can be categorised into: (1) service discovery, (2) service delivery and (3) service adaptation.

### 3.3 Context-Aware System Architecture Framework

According to Hong et al. (2009), designing a context-aware architectural deployment framework is a challenging task. This is because the process involves multi-task systems such as architecture, resource discovery, context capture, context model, context processing historical data, security and privacy (Baldauf et al., 2007). The most common design approach for distributed context-aware framework is known as multilayer hierarchical type infrastructure. This type of infrastructure consists of one or many
centralised components integrated as one system in order to interact with each other. This classical type of architecture has been used by Aziz et al. (2006) in developing a context-aware application to enhance construction collaboration. Kaenampornpan (2009) used the same concept in developing context-aware for hospital application scenario. The motivation for using this kind of approach is due to the need to overcome memory and processor constraints in mobile computing devices. The generic multi-layered system architecture is best described by Henricksen and Indulska (2004) and Baldauf et al. (2007), as presented in Fig. 3-6. The description of the layered components is as follows (Baldauf et al., 2007):

- **Sensor Layer** – A sensing device or data source which can provide useful contextual data. Sensors are categorised into three: physical sensors (capturing physical data such as noise and object location), virtual sensors (use software applications or services in providing information such as by browsing an electronic calendar and email to translate into location information) and logical sensor (use a combination of physical and virtual sensors with other sources in order to produce intelligent tasks).

- **Raw Data Retrieval Layer** – This layer is responsible for retrieving raw context data from sensor source through sensor drivers and from Application Programming Interface (API) for both virtual and logical sensors system.

- **Pre-processing Layer** – This layer is responsible for providing reasoning and interpreting contextual information especially to increase the level of abstraction of low level data. This layer is also capable of aggregating data from multiple sources in order to produce more precise and accurate information.

- **Storage/Management Layer** – organises the gathered data and offers them via public interface to client. Clients may gain access in two different ways, i.e. synchronous and asynchronous. In synchronous access, the client polls the server for changes via remote method calls. This technique is more resource intensive as context data have to be frequently requested and the application has to verify changes using context history. Alternatively, asynchronous access is more suitable due to the rapid changes in underlying context.

- **Application Layer** – In this layer the actual reaction on different events and context-instances is implemented.
Dey (2000) had classified contexts into four dimensions: location, identity, time and activity. These four are known as primary contexts and can be linked to other secondary contexts. For example, location context can be linked to geographical expression (e.g. application, adaptation manager, situation repository, preference repository, trigger repository, query interface, context manager, context repository, model, model, model, context reception layer, context gathering layer, context management layer, adaptation layer, applications layer).
postal address, country and region.) in order to increase the level of abstraction. Alternatively, Pashtan (2005) had divided contexts into four key dimensions: user’s static context, user’s dynamic context, network connectivity context and environmental context as shown in Fig. 3-7. The network connectivity is represented as a context that directly refers to objects such as mobile devices. This is important since a device has different features which affect the user’s behaviour in very different ways (Kaenampornpan and O’Neil, 2004). Meanwhile, Aziz et al. (2005) also addressed five context dimensions in developing context-aware application for mobile construction workers which include location, user profile, user activity, user device and time.

![Context Dimensions](Pashtan, 2005)

In classifying contexts, Kaenampornpan and O’Neil (2004) had revealed that previous computing researchers had classified context elements into many different systems as shown in Table 3-1. Lack of agreement in the context classification occurs because different interpretations have been given to certain context meaning according to what is considered to be important to enable a particular context-aware system to adapt to user’s needs (Chen and Kotz, 2000). According to Chen and Kotz (2000), contexts consist of two types: active and passive. Active context is a context that influences the behaviours of a context-aware application and its user; for example, a list of tasks during quality inspection might be the main interest of a user. On the other hand, passive context is a context that is relevant but not critical to an application and its user; for example, a message regarding the
current location of material delivery transport being displayed on the project manager’s device based on his profile.

Table 3-1: Classification of context elements by previous researchers
(Kaenampornpan and O’Neill, 2004)

<table>
<thead>
<tr>
<th>Researchers/Context Elements</th>
<th>Location</th>
<th>Conditions</th>
<th>Infrastructure (Computing Environment)</th>
<th>Information on User</th>
<th>Social</th>
<th>User Activity</th>
<th>Time</th>
<th>Device Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benerecetti et al. (2001)</td>
<td>Physical Environment</td>
<td>Cultural Context</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schmidt et al. (1999)</td>
<td>Physical Environment</td>
<td>Human Factor</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hull et al. (1997)</td>
<td>Physical Environment</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chaimers and Sloman (1999)</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lucas (2001)</td>
<td>Physical Environment</td>
<td>Information Context</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schult et al. (1994)</td>
<td>Physical Environment</td>
<td>x</td>
<td>User Environment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abowd and Dey (1999)</td>
<td>x</td>
<td>Identity</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chen and Kotz (2000)</td>
<td>x</td>
<td>Active/Passive</td>
<td></td>
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</tbody>
</table>

3.4.1 Construction Services Context Dimension

The classification of context dimension elements to develop context model is a very challenging task due to the dynamic contexts in activities within the construction domain. Construction domain is rich with human–human and human–machine related activities that are difficult to manage especially in a big and complex organisation and in the current wireless mobile computing environment. Activities such as daily inspection, ordering, reporting and collaborating involve multi-disciplined groups and tasks. For example, in managing logistics, activities such as managing the flow of materials, equipment, people and information from the point of source to the point of consumption are categorised as purely dynamic. In this situation, a mobile worker is likely to become distracted when performing his tasks due to information overload (Aziz et al., 2006).

Construction supply chain (CSC) activities are associated with the operations of managing and controlling of information, materials and fund flows involving multi-disciplined groups and tasks. Therefore, to identify context elements relationships between different entities along the CSC processes and to model them is a critical task. According to Fathi et
al. (2006), context-aware applications must be able to support such context elements in an intelligent manner especially in updating construction activity status that is relevant to user context (e.g. project identification and location).

As previously mentioned, Aziz et al. (2005) had addressed five context dimensions towards developing the context-aware application to support mobile construction workers, i.e. location, user profile, user activity, user device and time. As shown in Fig. 3-8, relevant construction tasks, such as the inspection of reinforced concrete beam after demoulding, that are relevant to a mobile worker (site supervisor) can be delivered to him/her based on his/her profile context which is drawn from his/her mobile device’s unique IP address.

![Fig. 3-8: Context dimensions to support mobile worker in construction information delivery](image)

According to previous works by Sheng et al. (2010), contexts for supply chain enterprises are drawn by supplier selection criteria and have been categorised as in Table 3-2. As a summary to their research, they had classified six parameters to represent the common business supply chain contexts together with their context attributes. In addition, their B2B contexts are presented in a bigger scope which in practicality means that developing the context-aware application is critical.
Table 3-2: Business to Business (B2B) context and attributes selection criteria
(Sheng et al., 2010)

<table>
<thead>
<tr>
<th>B2B Context</th>
<th>Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Organisational</strong></td>
<td>Company demographics</td>
</tr>
<tr>
<td><strong>Capability</strong></td>
<td>Technical</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>Price</td>
</tr>
<tr>
<td><strong>Ability to deliver</strong></td>
<td>On-time delivery</td>
</tr>
<tr>
<td>(Speed and capacity)</td>
<td></td>
</tr>
<tr>
<td><strong>Environmental</strong></td>
<td>Programs/policies</td>
</tr>
<tr>
<td><strong>Quality</strong></td>
<td>Site evaluation</td>
</tr>
<tr>
<td><strong>Continue ...</strong></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B2B Context</th>
<th>Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Organisational</strong></td>
<td>Level of trust</td>
</tr>
<tr>
<td><strong>Capability</strong></td>
<td>Service</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>Payment terms</td>
</tr>
<tr>
<td><strong>Ability to deliver</strong></td>
<td>Delivery lead time</td>
</tr>
<tr>
<td>(Speed and capacity)</td>
<td></td>
</tr>
</tbody>
</table>

For further enhancement towards defining context dimensions for supply chain services, it is critical to consider the following factors which could promote the context-aware dimensions into a more standardised manner.

- **Human factor** – Information about user’s physical behaviour, activity and beliefs (Kaenampornpan, 2009).
- **Physical factor** – Information about user’s surrounding situation that influences his activity, actions or operations (Kaenampornpan, 2009).
- **Technology factor** – The rapid development of current technology in wireless communication, wireless sensor, mobile devices, computing science (e.g. semantics web language and agent technology) and internet capability to support a context-aware application to the highest level of intelligence (Podobnik et al., 2007; Aziz et al., 2009).
- **Social factor** – the relationship between a user and other users within a specific domain must be taken into account because they will influence each other in every angle of human behaviour (Dey et al., 2000).
- **Environmental factor** – the physical surroundings, such as location, time, weather,
noise, route, place, type of services and information which are accessible by the user (Dey et al., 2000; Kaenampornpan, 2009).

### 3.5 Context Modelling

One of the most important aspects of context-aware computing application is the ability to translate events in a user’s surrounding or environments through context. When dealing with dynamic situations, context is the key element used to infer possible information and services. Contexts continually change; therefore they are very difficult to model. The challenging task of modelling contexts has been attempted by many researchers for pervasive computing environment using Activity Theory tool. Activity Theory (AT) is a framework of human activities which has been expanded by Engeström et al. (1999) from the first generation of triangular structure developed by Vygotsky. It is considered as an appropriate framework to be considered in developing a comprehensive context model because AT framework has proven its capability in identifying relationships between each element in the model for context-aware system development (Afridi and Gul, 2008; Kaenampornpan, 2009). The framework of AT is based on psychological aspects which is developed to understand the unity of consciousness and activity. The extended Engeström’s AT framework presented in Fig. 3-9 shows all the important context elements involved in an activity. The elements in the AT activity diagram are listed as follows:

- **Subject** – information about an individual or subgroup involved as the point of view in the analysis.
- **Tools** – information about any technological devices or system used to support the *community* (internet, web services, wireless communication network, computing devices and mobile devices).
- **Community** – information about individuals or subgroups that share or use the same *object* (e.g. project manager, logistics supervisor and material supplier involved in material delivery to site).
- **Roles** – the division of tasks between members of the *community* (e.g. material supplier delivers materials to construction site).
- **Rules** – explicit or implicit regulations, norms and conventions that constrain action or interaction.
- **Object** – a target of the activity within the system, i.e. subject’s intention or objective (e.g. information on material delivery and supply services).

- **Outcome** – the result when the object is achieved (e.g. context server delivers information based on occupation of user).

According to Kaenampornpan (2009), the AT elements such as tools and tasks are not static but rather dynamic as conditions continually change. This can be seen in construction activities for example, a construction worker’s daily activities such as performing site inspection, attending project progress meeting, preparing daily report and receiving messages. From the AT framework hierarchical structure, it can be seen that there are three important levels of human activity as follows:

- **Activity** – a goal-directed action to be performed to meet the subject’s objective (e.g. supply building materials)

- **Actions** – an activity consists of a collection of actions (e.g. itemising the materials specification, loading onto transport, delivering to site and unloading to point of use).

- **Operations** – an action consists of a collection of non-conscious operations (e.g. reading message displayed on a smartphone or PDA and watching route map on satellite navigator).

Fig. 3-9: The extended framework of Engeström’s Activity Theory
In developing a context model, it is crucial to fully understand the user’s activities, state and intentions in order to better understand the above three elements to support the context-aware system. This is because these elements might change over time due to the nature of human behaviour where actions can automatically change to operations when they are done many times. Kaenampornpan (2009) gave justification for adopting AT for context classification and modelling as follows:

- **It provides a standard form for describing human activity** – can be described as a simple standard form of theory that covers the most important aspect of a human activity which involves community, user objective and the tools that they use. Through this, the applications designer can decide which elements have an influence on each task.

- **It provides a representation of the user** – this is very important because information about a user gives a big impact on the context-aware system reasoning.

- **It relates individual human activity to society/organisation** – this is also very important because a user’s behaviour will also influence the behaviour of the surrounding people especially in pervasive computing environment.

- **It provides a concept of tool mediation** – able to demonstrate how tools (devices) or services influence a user’s behaviour in accomplishing a task objective.

- **It maps the relationship amongst the elements of human activity model** – the model is able to provide the right method in classifying and relating context elements and mapping them to the exact key context element. This is very important to support the process of inference in context-aware applications design process (Huang and Gartner, 2009).

Kaenampornpan (2009) had extended the existing AT framework by adding environmental and timeline (i.e. can be related to the past, present and future) context dimensions that are considered to have great influences on human actions (Fig. 3-10). In relation to this, Huang and Gartner (2009) also mapped the existing activity elements of AT into five dimensions: environmental context, user context, social context, task context and artefact context. They included time context (history) in user and artefact contexts. The context elements provided by both Kaenampornpan (2009) and Huang and Gartner (2009) are listed and briefly described in Table 3-3.
Table 3-3: Comparison of Context classification and description used in Activity Theory Framework

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Subject</strong></td>
<td>user</td>
<td>Information about a user including identity, preferences, schedule, devices.</td>
<td>user</td>
<td>Describes the mental and physical information about a user, such as mood, expertise, preference and information.</td>
</tr>
<tr>
<td><strong>Object</strong></td>
<td>objective</td>
<td>User’s intention and objective of the activity that a user wants to perform.</td>
<td>task</td>
<td>Describes what a user is engaged in; it can be the user’s goals, tasks and activities.</td>
</tr>
<tr>
<td><strong>Outcome</strong></td>
<td>outcome</td>
<td>This is the result of user’s activities, which may or may not be the objective.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Tools</strong></td>
<td>tools</td>
<td>Information about tools that are available to a user and their availability, including device characteristics, public services – applications, and computing environment.</td>
<td>artefact</td>
<td>Describes the profile or characteristics of tools such as system capabilities and information about devices.</td>
</tr>
<tr>
<td><strong>Community</strong></td>
<td>community</td>
<td>Information about people around a user (in both physical and virtual environments) that may have an influence on user’s activity.</td>
<td>social</td>
<td>Describes the social aspects of a user, such as information about the people in an organisation that have influence on the user’s action.</td>
</tr>
<tr>
<td><strong>Division of Labour</strong></td>
<td>roles</td>
<td>Roles of user in completing the activity in a particular situation including who can perform which tasks on the object.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Rules</strong></td>
<td>rules</td>
<td>Norms, social rules, activity rules and legislation within which a user relates to others in the community.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>environmental</td>
<td>Information about the physical and virtual environments that have influence on a user’s activity in the situation.</td>
<td>environmental</td>
<td>Describes a user’s surroundings, such as location, things, services, people and information accessed by the user.</td>
</tr>
<tr>
<td></td>
<td>time</td>
<td>Point of time that a situation is occurring.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.6 Context-Aware System Classification

A context-aware system framework must be designed such that it is able to demonstrate its flexibility characteristic in order to meet the system’s dynamics features such as location changes with respect to time and the network changes over time with respect to location. Context-aware system architecture can be classified as three common systems (Neelima, 2009):

- Server Based System
- Agent Based System
- Service Oriented Based System

Referring to Truong and Dustdar (2009), both server and agent based approaches are classified as non-web service-based system while service oriented-based system can be classified as entirely or partially web-based. There has yet to be a standard definition for a system that employs both agent and web services.
3.6.1 Server Based System

In general, a server based system is designed with a centralised component which is responsible for context acquisition, context management, context reasoning and maintaining privacy. Salber et al. (1999), Dey (2000) and Dey et al. (2000, 2001) used Context Toolkit, as shown in Fig. 3-11, as a context management tool in a number of their context-aware application system projects. The Context Toolkit framework architecture system consists of the following components:

- **Context Widget** – the component (software) that provides applications with access to context information from their operating environment (i.e. responsible for retrieving state information about the environment from sensor).

- **Context Interpreter** – the component that is responsible for interpreting abstraction of context, i.e. by increasing the level of abstraction by gathering from one or more context sources and finally producing new context information.

- **Aggregator** – the component that is responsible for gathering multiple pieces of context information from distributed sensors that are logically related into a common repository that the application needs.

- **Context Service** – the component that is responsible for controlling or changing the state of information in the environment using an actuator. The service can be in the form of synchronous or asynchronous.

- **Discoverer** – the component that is responsible for maintaining a registry of what capabilities exist in the framework. This includes knowing what widgets, interpreters, aggregators and services are currently available for use by the applications.
The application of Context Toolkit framework can be referred to in the building of Mobile Tour Guide context-aware applications shown in Fig. 3-12. The system is based on peer-to-peer framework that consists of a combination of features to capture and access context, storage, distribution and independent execution from applications. The space location system is managed under a centralised location server. The context widget is responsible for gathering context data, storing and supplying data to interested applications. Meanwhile, room aggregator notifies the location widget when a user enters or leaves the room. It also subscribes to the exhibit widgets of each room in order to be aware about exhibits that are available at any given time. Exhibit widget contains information about exhibitions on a tour. The mobile tour guide application subscribes to the location widget for current user location in order to update tour map and polls the room aggregator to list all available information based on user’s current context.

**Fig. 3-11: Context Toolkit context management components**

(Salber et al., 1999; Dey et al., 2001)
UbiqMuseum (Cano et al., 2006) is another piece of context-aware framework categorised as a server-based system that is used to support museum visitors. The system architecture is based on object-oriented framework that consists of three main software entities developed to support the context-aware application (Fig. 3-13). The system communication network is supported by the cooperation of Bluetooth and the integration of WLAN and Ethernet LAN (ELAN) technologies. Bluetooth network is used to support mobile devices such as PDAs and laptops. Meanwhile, WLAN and ELAN is used to connect mobile clients (residing in user’s mobile devices) with central server. The three main software entities developed to support the overall system are briefly described as follows:

- **Clients Applications** – reside in user’s mobile device (PDA) enabled by Bluetooth technology for communication purposes.
- **Museum Information Points (MIPs)** – support one or more information of art or objects and connect mobile clients to Central Data Server (CDS) via integration of WLAN and ELAN.
- **Central Data Server (CDS)** – logs, processes and relays back requests made by a user via MIP. It is also responsible for managing the Structured Query Language (SQL) database (i.e. information related to museum entities).

**Fig. 3-12: Mobile Tour Guide context-aware applications** (Dey et al., 2001)
3.6.2 Agent Based System

A number of researchers have built complex agent based systems to support e-business applications, supply chain management and contract administration (Obonyo and Anumba, 2011). Agent based approach consists of agents encapsulating specific functionality and offering services to exchange information with other agents. Multi-agents enhance the modularity, flexibility, scalability and ease of use of a system. They make the system reactive and proactive in nature. An agent is an artificial agent or also known as intelligent agent (IA) which operates in a software environment (i.e. operating systems, computer applications, databases, networks and virtual domains). Referring to Alda et al. (2006), agent is defined as “encapsulated software unit that is situated in a dynamic, heterogeneous environment, capable of solving well defined tasks autonomously and proactively in cooperation with other agents by order of personal (human) or non-personal principals”.

A Context Broker Architecture (CoBrA) as shown in Fig. 3-14 is an agent-based framework that dispatches broker agents to gather context information from sensors in a pervasive intelligent environment (Chen, 2004). The broker is an autonomous agent that manages and controls the context model of a specific domain. The agent has a layered architecture containing the following components: context knowledge, context reasoning...
engine, context acquisition module and privacy management module. It gathers contexts from devices, other agents and sensors of its surrounding environment and makes their fusion in a coherent model which is shared among devices and their corresponding agents. CoBrA uses ontology for context description which allows a good reasoning and a better sharing of contextual information. It uses a centralised model for the storage and processing of context in order to save the limited resources of mobile devices and uses a confidentiality policy for the user. The architecture requires a dedicated server for the broker which increases its cost and limits its usability in addition to the problem of a centralised architecture.

Fig. 3-14: CoBrA framework (Chen, 2004)

### 3.6.3 Service Oriented Based System

This design approach provides a loose-coupling nature to the system and on-the-fly services to the user which are very much needed in today’s mobile world (Aziz et al., 2006). Web Services are an alternative for providing dynamic services to a context-aware system (Truong and Dustdar, 2009). Web service-based oriented either fully or partially-based also enhances the scalability, modifiability, modularity and remote accessibility to a context-aware system. Pashtan et al. (2003) developed CATIS (Context-Aware Tourist Information System) by leveraging Web Services and XML technologies for its
implementation. The elements of context parameters such as location, time of day, speed, direction of travel, personal preferences and device types are leveraged to adapt Web-based information that is delivered to tourists. The CATIS framework is another peer-to-peer architecture (Fig. 3-15) that consists of three main sub-components:

- **Application Server** – processes a user’s query, filters information from Web Services and presents to it the user according to his/her context (preference).
- **Context Manager** – provides contextual information based on user location and preference.
- **Universal Discovery and Integration (UDDI) Server** – searches for information that is relevant to a user’s context query via Web Services.

![CATIS system architecture](image)

**Fig. 3-15: CATIS system architecture** (Pashtan et al., 2003)

COMPASS (COntext-aware Mobile Personal ASSistant) is another context-aware system that had been developed to support tourists with map services through proprietary interfaces such as Microsoft’s Mappoint. In principal, the COMPASS system architecture framework shown in Fig. 3-16 consists of the following important sub-systems:

- **Web Architectures for Services Platform (WASP)** – supports context-aware applications based on Web Services which operate under 3G networks. This platform needs a permanent network connection (e.g. GPRS).
- **Third Party Services** - use a registry that contains information about third party services providing contents such as objects of attraction like museums and restaurants information (Fig. 3-17). Semantic Web technology such as OWL is used to describe the description service.

In COMPASS, the user context is manually provided which is described as using an extended Platform for Privacy Preferences (P3P) specification indicating the user’s interests that is automatically updated by the system based on the user’s feedback for specific Point of Interests (POIs). Meanwhile, context parameters such as weather or traffic information can be incorporated into the system via Web Services. A subscription mechanism is offered so that components of the system can be notified as soon as a context changes. The location information is obtained automatically through GPS or from mobile network (e.g. GPRS, UMTS). In COMPASS, the changing of context for both physical and logical is considered dynamically.

![The COMPASS System Architecture](image)

*Fig. 3-16: The COMPASS System Architecture (Setten et al., 2004)*
Fig. 3-17: Screenshots of the COMPASS Applications – Object Location Service (left), Application-User Interaction Service (middle) and Object Ranking Service (right)

3.7 Wireless Technology

The enormous number of wireless network solutions available (Fig. 3-18) and capable of supporting interoperability between services for mobile user are normally engaged with portable devices (e.g. PDA and smartphones). The concept of *anywhere, anyplace and anytime* for the user to access to information is becoming a reality with the rapid advancement in wireless technologies (DELL White Paper, 2005). A rapid growth in wireless mobile network technologies has also opened a wide range of support for context-aware application and this could revolutionise the business methodology of enterprises in the future. To date, there is still major shortcoming due to the heterogeneous of mobile network communication system operated by different service providers (Neumann, 2007).
To support context-aware technology, several wireless system networks can be deployed to allow multiple companies across the supply chain to track their project delivery status or processes in real-time (Fathi et al., 2006; Behzadan et al., 2008). The most widely adopted wireless technology to date is Wireless Local Area Network (WLAN), Wireless Metropolitan Area Network (WMAN) and Wireless Wide Area Network (WWAN) which is also known as cellular system network. The successful deployment of mobile wireless technology in supporting location-based context-aware system for assets mobility tracking, inventory management, condition monitoring and personalisation in numerous industries could motivate the future automation in the construction industry (Aziz et al., 2009). Wireless location-based context-aware technology has become an important tool in service-oriented businesses in providing information (knowledge) based on user’s surroundings context (Khoury and Kamat, 2007).

Driving forces such as mobility, ubiquity, integration and collaboration, better responsiveness, better access to information and enhancing the user access to information are the main reasons that motivate enterprises to adopt wireless technology (Aziz, 2005; CISCO White Paper, 2008; Fathi, 2009). Also, the advancement in computing hardware and software technology, high-speed wireless data transmission and increased in mobile devices features could support information sharing and accelerate the information flow effectively. Current construction on-site activities are already making positive move towards the application of wireless based technology as shown in Fig. 3-19 and Fig. 3-20. Wireless technology is capable of enhancing the visibility of movement of assets mobility,
improving the construction planning and enhancing security within the construction supply chain management.

Fig. 3-19: PDA in use to record on-site activities

Fig. 3-20: Tablet PC in use to discuss current activities on-site

3.7.1 WLAN

WLAN uses electromagnetic airwaves (radio and infrared) to transfer information from one point to another without relying on any physical connection. The typical range for WLAN systems varies from under 30 metres to more than 95 metres. The Institute of Electrical and Electronics Engineers (IEEE) 802.11 standard for wireless local area networks (WLAN) are as follows:

- 802.11a -5 GHz spectrum with a bandwidth of 54 Mbps
- 802.11b -2.4 GHz spectrum with a bandwidth of 11 Mbps
- 802.11g -2.4 GHz spectrum with a bandwidth of 54 Mbps

End users access the WLAN through wireless LAN adapters which are implemented as PC cards in laptop computers, PCI cards in desktop computers or integrated within handheld computers. WLAN adapters provide an interface between the client network operating system and the airwaves (via an antenna). Among the benefits offered by WLAN technology are as follows:

- Range and coverage – WLAN systems use Radio Frequency (RF) that can penetrate many indoor walls and surfaces
• Throughput – WLAN provides sufficient throughput for most common LAN-based office applications, including electronic mail exchange, access to shared peripherals and access to multi-user databases and applications.

• Interoperability with wired infrastructure.

In the following sections, the applications of WLAN in supporting Real-Time Location System (RTLS) are presented.

3.8 Location-Aware Technology in Manufacturing Industry and Other Sectors

The manufacturing industry has undergone profound changes in its supply chain activities over the past 20 years due to the adoption of ICT. The manufacturers no longer measure their business performances by their ability to produce high quality end products, but with the deployment of ICT (e.g. location-aware technology), they can now compete among themselves by producing value-added services along the supply chain operations. A location-based context-aware system uses location as the main context parameter and has become a popular tool for various industries in managing their assets mobility with great success. The application across these industries can be seen in four services as shown in Fig. 3-21.

1. Inventory management – defines zones and monitors mobile assets entering and exiting the area.
2. Asset tracking – locates mobile asset anywhere in the working zone.
3. Condition monitoring – monitors the environmental conditions that an asset is subjected to by measuring physical parameters such as temperature, humidity, pressure and many more.
4. Presence – uses mobile worker’s location information to automate presence status in unified communications applications.
Location-based context-aware has become an important tool in supporting highly dynamic environment service orientated businesses by providing information or knowledge relative to user’s surroundings context (Khoury and Kamat, 2007). Despite needing further enhancement in terms of interoperability capability to support dynamic and complex supply chain network, this technology has proven to be an effective tool to support service-based sectors such as healthcare, airport and railway (Appear, 2010; Ekahau, 2010).

3.8.1 Context-Aware Mobility Definition

A location-based context-aware mobility is defined as “a system that provides the ability to dynamically capture and use contextual information about mobile assets to optimise, change or create communications flow and business processes” (CISCO, 2010). Contextual information can be gathered or captured for any mobile asset involved along a business process and this includes information about workers, customers and manufacturing components via wireless devices and networks (CISCO White Paper, 2010). The system that is developed based on this principal is known as Location-based Context-Aware Mobility where the context information (i.e. based on location entity) for asset mobility can be tracked and captured within a business process that covers from devices, work-in-progress components and mobile workers.
In the following discussions, the term Location-based Context-Aware is used instead of Context-Aware to refer to any works that deal with the application of such technology in capturing, processing of context data and delivering services for business application.

### 3.8.2 Real-Time Location System (RTLS) Context-Aware Mobility Deployment

RTLS is a wireless location-based technology that offers services such as tracking and monitoring of mobile assets in real-time. Services are delivered to authorised users via the corporate network through application software or Application Programming Interfaces (API). As shown in Fig. 3-22, RTLS deployment components consist of Wi-Fi devices (e.g. active tags, smartphone and notebook), wireless network (Wi-Fi Infrastructure), server software (positioning engine) and end-user Application Software (i.e. can be linked via web services to third party applications). One of the well-known solution providers for RTLS is Ekahau. In Ekahau RTLS Controller (Positioning Engine), the component is responsible for providing the following functions to support the overall system network:

- To receive signal strength measurements from mobile devices, compare the measurements to an existing reference data and calculate location.
- To receive events such as tag-originated call button alarms or tamper switch alerts and routing them to designated applications.
- To automate management tasks and monitor the system through a web-based user interface.
- To integrate third party applications to the system by providing location inputs, queries and events to the application using industry-compliant standards.
- To record reference data during deployment phase.
3.8.3 RTLS Solution Providers

Apart from Ekahau, there are numerous other known solution providers such as Airetrak, Aeroscout, Awarepoint, CISCO and Ubisense that are involved in developing the RTLS technology. The summary of RTLS characteristics and performances for selected solution providers are presented in Table 3-4. It shows that RTLS can be deployed under standard networks of Institute of Electrical and Electronics Engineers (IEEE) 802.11a/b/g/n (better known as Wi-Fi) and 802.15.4 (known as Zig-Bee). Wi-Fi based network is most preferred by users due to its competitive investment cost, easy to deploy and supported by wireless broadband. On the other hand, Zig-Bee RTLS shows a weakness in overcoming the issue of interference (noise) if the system operates within the same zone with other wireless network system. Zig-Bee RTLS also needs a dedicated system tailored to its network specification which limits the usage of the system in global enterprises that prefer Wi-Fi based network. Some of the RTLSs are only capable of covering or operating within indoor environment instead of both indoor and outdoor. This limitation is due to the lack of software design interface capability with numerous Wi-Fi vendors and hardware providers such as Alcatel, Aruba, CISCO, Linksys, Motorola, Nortel, Siemens and Xirrus (Ekahau, 2010).
Table 3-4: System characteristics comparison between RTLS solution providers

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>EKAHAU</th>
<th>AIRETRAK</th>
<th>AEROSCOUT</th>
<th>AWAREPOINT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coverage</td>
<td>Outdoor and indoor</td>
<td>Closed Loop/ Indoor</td>
<td>Outdoor and indoor</td>
<td>Closed Loop/ Indoor</td>
</tr>
<tr>
<td>Tracking Method</td>
<td>Client software and Wi-Fi tags</td>
<td>Client software and Wi-Fi tags</td>
<td>Wi-Fi client software, Wi-Fi tags, GPS and Sensors</td>
<td>Wireless sensor network and Awarepoint software</td>
</tr>
<tr>
<td>Wireless Network Deployment (RF Signal)</td>
<td>IEEE 802.11a/b/g/n</td>
<td>IEEE 802.11a/b/g/n</td>
<td>IEEE 802.11a/b/g/n</td>
<td>IEEE 802.15.4 (Zig-Bee)</td>
</tr>
<tr>
<td>Operating System</td>
<td>Windows XP and Windows 2000, Pocket PC 2002 and 2003</td>
<td>n/a</td>
<td>Microsoft Windows Server 2003</td>
<td>n/a</td>
</tr>
<tr>
<td>System Integration</td>
<td>Support 3rd party applications via Web Services (HTTP/XML)</td>
<td>Support 3rd party applications via Enterprise Service Bus (ESB) architecture</td>
<td>Support 3rd party applications via Mobile View Gateway</td>
<td>Support 3rd party applications via Web Services</td>
</tr>
<tr>
<td>Positioning Accuracy (m) under Wi-Fi</td>
<td>&lt; 3m with 99% at 1 second</td>
<td>n/a</td>
<td>1-5m (3.3-16ft)</td>
<td>n/a</td>
</tr>
</tbody>
</table>
| System Components Architecture         | ● Ekahau Positioning Engine  
● Ekahau Client  
● Ekahau Tracker  
● Ekahau Finder  
● Ekahau Site Survey  
● Ekahau Vision | Airetrak Resource View | Aeroscout Mobile View | ● Awarepoint Search Engine (Searchpoint)  
● Securepoint  
● Infopoint |
| Mobile and Network Visibility Source   | PDA, Smartphone, Wi-Fi tags, Tablet PC and PC | PDA, laptop, Wi-Fi phone and active RFID | Wi-Fi laptop, Smartphone, PDA, telemetry, Wi-Fi tags, UWB, GPS | Active RFID (Tags) and Wireless sensor |

3.8.4 Summary of RTLS Case Studies

The case studies presented in Table 3-5 have shown that the RTLS technology deployed across the respective industries has benefitted the end users. In inventory management services, the technology is able to define zones, track and monitor the movement of mobile assets and up-date inventory database in real-time. By using wireless sensor technology, the physical parameters of an asset can be monitored regularly from anywhere and anyplace without physically interfering with the asset condition. In the service-based sector, for example in airport or railway management, context-aware personalisation services allow a user to retrieve or receive information automatically with respect to the
user’s context which reduces the amount of time the user spends to access to the right and accurate information.

Table 3-5: The Summary of RTLS Case Studies

<table>
<thead>
<tr>
<th>Project List</th>
<th>UBISENSE</th>
<th>APPEAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Name/Location</td>
<td>Posco Steel Mill, South Korea</td>
<td>BMW Plant, Regensburg, Germany</td>
</tr>
<tr>
<td>Year</td>
<td>2009</td>
<td>2009</td>
</tr>
<tr>
<td>Objective</td>
<td>To reduce potential accidents of personnel, improving employee and visitor safety and lowering energy consumption under u-management program.</td>
<td>To identify cars and to control the tools under BMW Tool Assistance System (TAS).</td>
</tr>
<tr>
<td>Application</td>
<td>● Locate personnel in an event of accident through helmet fitted with active RFID tag-RTLS  ● Generate safety alert  ● Adjust lighting level  ● Accidental fall  ● Worker presence or absence</td>
<td>● Automating customised car assembly with the correct tools  ● Track the location of each car and tool within 15 cm throughout 2 km assembly line.</td>
</tr>
<tr>
<td>Benefit</td>
<td>● Improved safety  ● Energy saving</td>
<td>● Tools data can be used for additional purposes such as tracking the location of a vehicle sent for servicing and adjustments after assembly</td>
</tr>
<tr>
<td>Link to 3rd party application</td>
<td>n/a</td>
<td>Collaborate with IBS (tools management software)</td>
</tr>
<tr>
<td>Source</td>
<td>RFID Journal</td>
<td>RFID Journal</td>
</tr>
</tbody>
</table>

Continue...
### Objective

| To increase quality of information and rail services, personal security, transport capacity, train punctuality and a clean environment. | To provide a medical tracking solution (devices) | To provide visibility into the location of specific tools used in maintaining the fleet of F 16 and C-130 aircraft. | To improve workflow and increase staff/patient safety |

### Application

| Enables the push and synchronisation of personalised real-time information | Tracks and locates portable medical assets | Track 3000 mechanical equipment such as hydraulics, tools, compressors, winches, specialty equipment. | Supports two-way messaging |
| Dynamic synchronisation workflows between devices and office back end. | Alerts and notifications | | Provides room level and sub-room location accurately |
| | Bed management | | Tracking clinical assets |
| | Call button for emergency | | |

### Benefit

| Productivity gain of 25 minutes per employee, per shift, per day. | Less time spent on searching | Reduced turnaround time for maintenance operations to ensure fleet readiness at all times. | Improved safety |
| Improved staff decision making | Increased productivity | | Lowering overall operational cost |
| Improved customer service and satisfaction | Improved equipment utilisation | | |
| | Reduced risk of faulty devices | | |

### Link to 3rd party application

| n/a | n/a | Integrated with Maintenance Management System | Integrated with existing management system in the hospital |

### Source

| Appear.com | Airetrak.com | Ekahau.com |

*n/a* Information not available

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### 3.9 Context-Aware Technology in Tourism Industry

The main agenda towards the development of context-aware computing technology for the tourism industry is to support three important request statements: *where you are*, *who you are with* and *what resources are nearby*. Pashtan et al. (2003) developed CATIS (Context-Aware Tourist Information System) by leveraging Web Services and XML technologies for its implementation. The elements of context parameters which are location, time of day, speed, direction of travel, personal preferences and device types are leveraged to adapt the Web-based information that is delivered to mobile tourists. The operation of CATIS system architecture shown in Fig. 3-15 can be described as follows:

- Step 1: Triggers the application server to request information about a service (i.e. restaurant) within a user’s vicinity.
• Step 2: The application server queries the context manager for user context information.
• Step 3: Sends an inquiry to the Universal Description, Discovery and Integration (UDDI) Server to get the addresses of available restaurants from Web Services.
• Step 4: The application server then sends a request to the Web Services along with the user’s location and desired distance from the user.
• Step 5: The Web Services search their databases for the appropriate addresses and filter out those that are too far away. The Web Services return an XML list to the application server. The application server filters the XML documents according to the user’s preferences, prepares the presentation of the information and sends it to the client.

However, the CATIS prototype system still lacks context mobility to fully support the end user in terms of anywhere, anyplace and anytime concept. Cheverst et al. (2000) developed Context-Aware Tourist Guide (GUIDE) and provide city visitors who wish to explore the city of Lancaster with a portable device. The GUIDE system incorporates a high-bandwidth, cell-based, wireless infrastructure and this enables the support of interactive services and highly dynamic information (including access to the World Wide Web). In addition, this network infrastructure provides location information to the end-systems, thus obviating the need for a separate location tracking system such as GPS. The GUIDE system provides city visitors with a wide range of functionality: a visitor can use their GUIDE unit to access context-aware information, create a tailored tour of the city, access interactive services and send and receive textual messages. The GUIDE prototype location-aware navigation and system retrieval mechanism had been evaluated as useful and reassuring through a field trial with the objective of measuring the quality of visitors’ experience as opposed to absolute performance times for accessing specific pieces of information. Results from the survey had shown that even visitors without previous web experience felt comfortable using the system and willing to trust the information presented by it.
3.10 Context-Aware Technology for Construction Industry

The application of context-aware technology in the construction industry is still in the research stage. The useful and successful experiences of the manufacturing and other services sectors in managing their assets mobility using context-aware technology could be learned and strategically adopted by both system developers and construction industry practitioners. Context-aware application is an intelligent system that uses context parameters such as environmental (e.g. location and time) and network connectivity (e.g. signal strength) in order to ensure that the user gets highly specific data or services (Schilit, 1995). According to Aziz et al. (2006, 2009), this technology has the potential of overcoming the fragility in construction communication system by focusing on the delivery of information that are relevant to user’s needs. Recent advancement in virtual building prototyping has been coupled with context-aware technology in order to deliver relevant construction design and processes information in construction site (Aziz, 2012).

In supporting mobile construction workers and to enhance construction collaboration, Aziz et al. (2005) proposed a multilayered architecture framework system as shown in Fig. 3-23. Their architecture framework consists of five tiers and their roles are briefly described as follows:

- **Client Tier** – designated to capture contextual data (via mobile devices), provide context relevant information to the user (via human and software interface layer) and provide access to the system. For example, user profile context is captured through IP address of user’s device and log-in information, user device type through RDF-based Capability/Preference Profile (CC/PP) and user activity associated with the project management application.

- **Access Tier** – designated to provide the link that is vital to communication between wired back-end and wireless front-end. Link is very important in order to support both push and pull interaction modes.

- **Positioning Tier** – designated to detect and determine user’s mobile devices or tags (e.g. asset mobility) in a wireless zone.
- **Context Brokerage Inference Tier** – designated to support the user or the user’s agent in service discovery by reasoning about the captured context using a Semantic Web-based model.

- **Applications Tier** – designated for construction project database and their applications. This tier is also supported by third party service providers such as B2B (Business to Business) enterprises web-based company.

![Diagram of Context-Aware Framework Architecture](image)

**Fig. 3-23: Context-Aware Framework Architecture (Aziz et al., 2006)**

Another development towards the application of context-aware technology for construction information delivery services is from Fathi (2009). His research involved the development of context-aware for Construction Programme Manager (e.g. head of project consultant) known as C-aIS (Context-Aware Information System) and the system consists of four main components as shown in Fig. 3-24:

- Positioning System – GPS and WLAN are designated for tracking the current location of a user.

- Mobile Client – Client application that resides in a mobile device is designated to receive location coordinates from GPS and WLAN, transmit location coordinates to the application server and receive information or data from the server and the C-aIS application.
- Context Information Network System – The wireless network is designated for transmitting contextual information and data relevant to user.
- Server System – Designated to process location data received from GPS and WLAN and intelligently select the right information and services from the Database server, the GIS server and the Enterprise Project Management server.

C-aIS allows its context-aware application to present information and services that are relevant to the Construction Programme Manager’s current position. For outdoor and indoor environment respectively, GPS and WLAN have been alternately used to deliver services to user. Technically, in this system design scenario, the user location coordinates (latitude, longitude and altitude) are transmitted from a mobile client device (GPS and WLAN capabilities) to the C-aIS application server through a wireless network before information data are processed by C-aIS server engine and other server components.

3.11 Summary

The integration of context-awareness and Web Services offers considerable potential for enhancing services by providing access to context-specific data, information and services without distracting the user’s attention. In such integrated system, the incorporated context

Fig. 3-24: Deployment of Context-Aware Information System (C-aIS) Architecture
(Fathi, 2009)
parameters are defined based on the project tasks requirements ranging from design, planning, supplies and execution. These include user’s context parameters such as role, discipline, interests and preferences as well as project parameters such as project stage, client requirements and project location. In capturing the physical context parameters, sensor technologies such as Wi-Fi tags can relay positioning data to a context-aware system to determine the exact location of a user in real-time.

Context-aware computing is a useful tool in providing dynamic interaction and self-management services by translating the contextual information of a user’s physical surrounding or virtual environment into relevant information according to the user’s needs. The technology which is currently limited to control-space location-aware based application can now be explored for more dynamic conditions such as in construction supply chain activities. This chapter has also revealed that wireless technology is one of the most important technologies to back-up the application of context-aware technology in various service-based industries.
References


CISCO. (2010), from [www.cisco.com](http://www.cisco.com).


