www.itcon.org - Journal of Information Technology in Construction - ISSN 1874-4753

INTELLIGENT WIRELESS WEB SERVICES: CONTEXT-AWARE COMPUTING IN CONSTRUCTION-LOGISTICS SUPPLY CHAIN

PUBLISHED: June 2009 at http://www.itcon.org/2009/20

EDITORS: Kazi A S, Aouad G, Baldwin A

Balqis Omar, PhD Student,
School of Construction Management and Engineering, The University of Reading, UK.
b.omar@reading.ac.uk

Tabarak Ballal, Dr.,
School of Construction Management and Engineering, The University of Reading, UK.
t.ballal@reading.ac.uk

SUMMARY: *The construction industry has incurred a considerable amount of waste as a result of poor logistics supply chain network management. Therefore, managing logistics in the construction industry is critical. An effective logistic system ensures delivery of the right products and services to the right players at the right time while minimising costs and rewarding all sectors based on value added to the supply chain. This paper reports on an on-going research study on the concept of context-aware services delivery in the construction project supply chain logistics. As part of the emerging wireless technologies, an Intelligent Wireless Web (IWW) using context-aware computing capability represents the next generation ICT application to construction-logistics management. This intelligent system has the potential of serving and improving the construction logistics through access to context-specific data, information and services. Existing mobile communication deployments in the construction industry rely on static modes of information delivery and do not take into account the worker's changing context and dynamic project conditions. The major problems in these applications are lack of context-specificity in the distribution of information, services and other project resources, and lack of cohesion with the existing desktop based ICT infrastructure. The research works focus on identifying the context dimension such as user context, environmental context and project context, selection of technologies to capture context-parameters such wireless sensors and RFID, selection of supporting technologies such as wireless communication, Semantic Web, Web Services, agents, etc. The process of integration of Context-Aware Computing and Web-Services to facilitate the creation of intelligent collaboration environment for managing construction logistics will take into account all the necessary critical parameters such as storage, transportation, distribution, assembly, etc. within off and on-site project.*

KEYWORDS: *Context-Aware, Wireless Networking, Intelligent Wireless Web, Construction-Logistics*

REFERENCE: *Omar B, Ballal T (2009) Intelligent wireless web services: context-aware computing in construction-logistics supply chain, Journal of Information Technology in Construction (ITcon), Vol. 14, Special Issue Next Generation Construction IT: Technology Foresight, Future Studies, Roadmapping, and Scenario Planning, pg. 289-308, http://www.itcon.org/2009/20*

1. INTRODUCTION

The construction industry has incurred a considerable amount of waste as a result of poor logistics supply chain network management. The consequences of waste produced are losses in billion of pounds, poor image of the industry, poor quality, increased project time and increased risks to health and safety (Strategic Forum Logistics Task Force, 2005). Therefore, managing logistics in the construction industry is critical. An effective logistics system ensures delivery of the right products and services to the right players at the right time while minimising costs and rewarding all sectors based on value added to the supply chain.

With the advancement of information and communication technology (ICT) and wireless technologies, construction companies are driven to deploy supply chain management strategies to seek better outputs (Bassi and Parand, 2002). As part of the emerging wireless technologies, an Intelligent Wireless Web (IWW) using context-aware computing capability represents the next generation ICT application to construction-logistics management. This intelligent system has the potential of serving and improving the construction logistics through access to context-specific data, information and services. Existing mobile communication deployments in the construction industry rely on static modes of information delivery and do not take into account the worker's changing context and dynamic project conditions. The major problems in these applications are lack of context-specificity in the distribution of information, services and other project resources, and lack of cohesion with the existing desktop based ICT infrastructure.

This paper reports on an on-going research study on the concept of context-aware services delivery in the construction project supply chain logistics. The research works focus on identifying the context dimensions such as user, environmental and project contexts, selection of technologies to capture context-parameters such wireless sensors and RFID, selection of supporting technologies such as wireless communication, Semantic Web, Web Services and agents. The process of integration of Context-Aware Computing and Web-Services to facilitate the creation of intelligent collaboration environment for managing construction logistics will take into account all the necessary critical parameters such as storage, transportation, distribution and assembly within off and on-site project. The ultimate aim of this research is to investigate the potential of improving the supply chain interactions in the construction logistics delivery process through an effective integration of Context-Aware, Wireless Networking and Web Services technologies.

This paper discusses how Context-Aware computing and Intelligent Wireless Web (IWW) technology can support the management of construction-logistics critical services delivery in the supply chain network. It presents a conceptual framework of IWW used to facilitate the construction-logistics collaboration and integration. In conjunction to that, it is pertinent that the enabling technologies such as Web Services, Semantic Web, Agent and wireless technologies are highlighted. The problem background of construction-logistics is briefly described in Section 2, followed by the discussions of elements that form the IWW to support construction-logistics services in Section 3. Context-Aware technology in the tourism industry is briefly demonstrated in Section 4 to get an idea of the application in other industries. Finally, an example of a scenario development that illustrates the application of IWW in tracking material movement from the factory to the construction site is shown in Section 5.

2. CONSTRUCTION LOGISTICS: PROBLEM BACKGROUND

Fast development in information and communication technology (ICT) has emerged as a key driver and thus provided the opportunity for construction companies to be more sensitive towards their business strategy and productivity (Ahuja and Yang, 2005, Ribeiro and Lopes, 2001). The amount of project data and information generated during construction periods are enormous and uncontrolled due to the nature of fragility in the construction processes. The traditional paper-intensive method of processing and transferring data and information is still being practised due to high investment capital cost on ICT facilities, lack of supporting interoperability between hardware-software within organisations and culture of most construction organisations. However, the emergence of interconnectivity between different information and communication systems over the internet coupled with ICT-construction researches that have been actively and widely explored to overcome these critical unresolved problems has encouraged construction organisations to seek an alternative method of processing and transferring data (Leung et al, 2008, Zhou and Benton, 2007, Lu et al, 2006 and Aziz et al, 2006, 2005).

The construction supply chain network can be classified as a big and complex organisation that is difficult to manage. This is because the operations or activities involved in the construction network consist of multi-discipline groups and tasks. The concept of supply chain management is about managing information and material flows, plant operations, and logistics through a common set of principles, strategies, policies and performance metrics throughout its developmental life cycle. As part of the back bone for the supply chain processes, the logistics play a critical role in optimizing the flow of materials, equipment and people. Referring to the Council of Supply Chain Management Professionals (CSCMP)(2008), logistics is defined as *"the process of planning, implementing and controlling the efficient, effective flow and storage of goods, services and related information from point of origin to point of consumption for the purpose of conforming to customer* *requirements".* Communication technology, materials handling, transportation and warehousing are known as the critical services that serve the logistics operation processes. These include services in facilitating Just-In-Time (JIT) operation, optimising the movement of raw materials, work in-process and finished goods, optimising the transportation mode and locating and designing facilities to meet customer service levels respectively. According to Jang et al (2003), construction-logistics can be divided into two parts, namely; supply logistics and on-site logistics. The supply logistics focus mainly on the activities of production, transportation to a site and off-site, and storage control; while site logistics focus mainly on the physical flow such as controlling on-site activities or processes. In contrast to manufacturing industries, which profit from long-lasting partnership with suppliers and customers, construction-logistics supply chains are considerably more difficult to manage and optimize due to various factors such as diversification of projects (i.e. various materials, methods, project location) and technical complexity of a project.

A report 'Improving Construction Logistics' published by the Strategic Forum for Construction in August 2005 revealed that quite a considerable amount of waste produced in the construction is caused by poor management of materials delivery services (e.g. from supply logistics to site logistics), inventory, communications and human resources. The consequences of poor construction-logistics are the following setback; about 30% of losses in overall construction cost, contributing to the bad image of the industry, poor quality of product, increased project duration and added risks to workers' health and safety. The use of Information Technology (IT) and learning from other industries were part of the recommendation and action plans suggested by the Strategic Forum committee for better logistics processes. Jang et al (2003) and Rebolj et al (2008) also suggested that a great deal of improving the construction-logistics must be focused on the materials and information delivery in order to achieve better productivity, avoiding delays and reducing waste.

The Internet is bringing a major contribution to the evolving field of supply chain management. The primary benefits of e-commerce especially in logistics activities are reduced 'clerical' transaction costs, such as those involving contracting, ordering, confirming, invoicing and settlement. Information moved via the Internet has a number of characteristics that can change the way in which construction-logistics supply chains are configured and managed. It is therefore, a great challenge to identify which ICT package is capable of addressing such issues in order to deliver various jobs or tasks within the context (Egan, 1998). In addition, Aziz et al (2006) had revealed that the current state-of-the-art in mobile communications in the construction industry has some underlined limitations due to factors such as lack of cohesion with the existing ICT infrastructure, little work towards developing IWW technologies and poor selection of communication systems. Consequently, to support and improve the construction-logistics information and communication flow, the powerful wireless web technologies show a great challenge to be used to enable project team members (e.g. project manager) to access in real time different corporate back-end systems and multiple inter-enterprise data resources collaboration and integration. Also, the growth in number and sophistication of Web Services means that, increasingly, useful applications will be available on the Internet that can be invoked directly from the construction supply chain management systems. These invocations can be triggered by changes in the context of the users or the project, and can significantly enhance the effectiveness of construction supply chain interactions. This provides enhanced capabilities for interoperation between a variety of logistics services and applications that are essential for intelligent collaboration and information exchange within the supply chain management network. Context-Aware services delivery adds an additional layer on top of such 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.

2.1 Review of the Current Construction Logistics Practice

From a preliminary research survey, it is found that the current logistics practice in many construction projects is as illustrated in Fig. 1. Project manager appointed by the owner to manage a project acts either as a consultant or the main contractor to the project. The project manager plans the execution of the project and appoints contractors to carry out the works. In terms of site logistics, the project manager design for and provides facilities for storage and handling of materials or component. It is seldom for specialised personnel, e.g. logistics manager, to be in charge of the site logistics and everything else related to construction logistics, but some organisations do appoint consultants (third party) to deal with these. Nevertheless, 'managed' logistics are usually reserved for large projects. Contractors and sub-contractors order their own materials, components, equipment and machinery. For most construction sites, there is at least some sort of a booking system for the contractors to book the time for their suppliers to deliver construction materials. On some sites the security guard or gate keeper keeps a log book to record the material delivery schedule. Suppliers that are not pre-booked on the system or are late are turned away and asked to pre-book another delivery times as not to disrupt the delivery schedule for the day. Web-based booking systems are also becoming common on construction sites. Suppliers from all around the region can book themselves the delivery times without the contractors having had to do it for them provided that they are registered with the system and have access to it. However, as far as construction logistics are concerned, the material delivery is about the only thing that project managers design for. Other aspects of construction logistics are usually left to common sense and chance, resulting in double handling of materials, material damage and misplacement; creating waste.

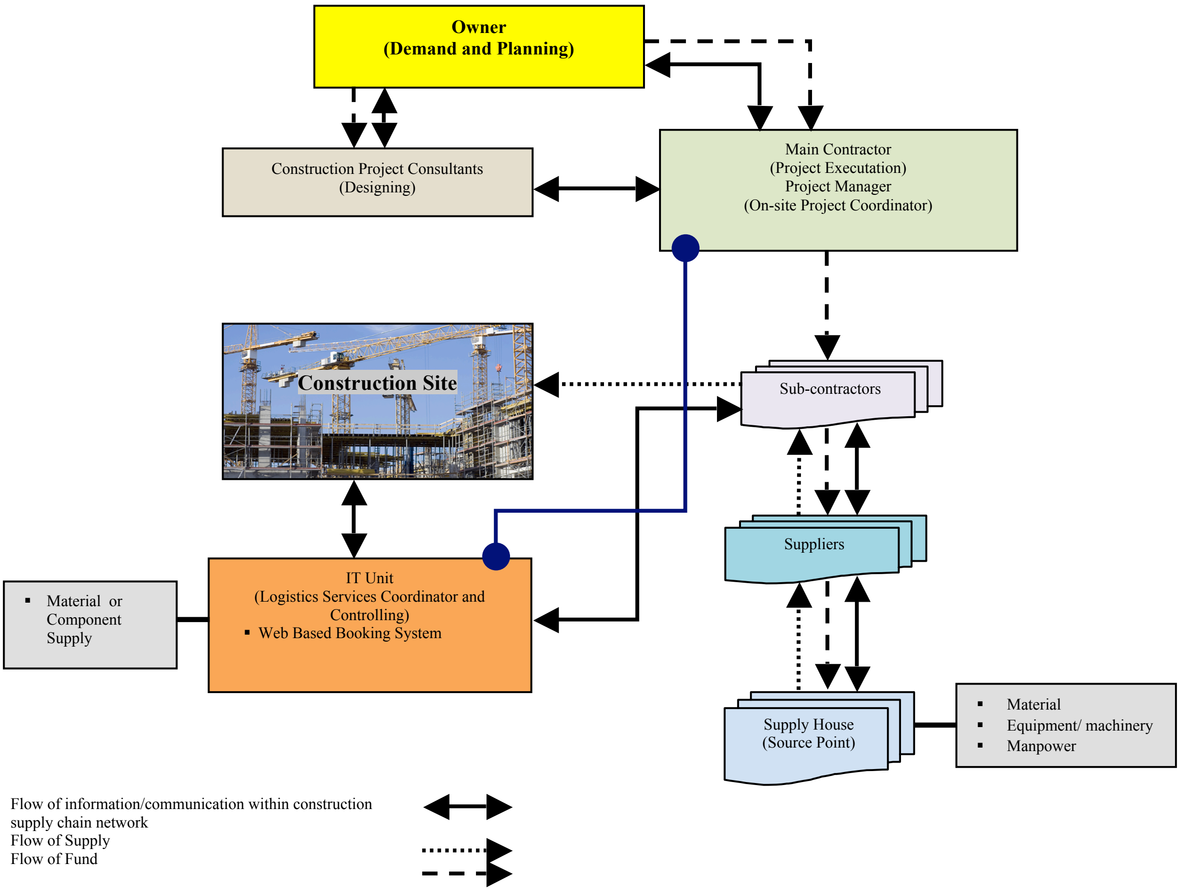

FIG. 1: Logistics supply chain model based on traditional construction contracting method

3. THE INTELLIGENT WIRELESS WEB (IWW) SERVICES

The integration of Context-Awareness and Web Services offers considerable potential for enhancing construction-logistics collaboration activities by providing access to context-specific data, information and services. The incorporated context parameters can be defined based on the project tasks requirements. These include user context parameters (e.g. role, discipline, interests, preferences, etc.) as well as project parameters (e.g. project stage, client requirements, project location, procurement/contract type, etc.). In capturing the context-parameters, sensor technologies (Wi-Fi tags) and radio frequency identification (RFID), for example, can be imbedded within the environment coupled with wireless communication technologies, Semantic Web, Web Services and software agents to form complete Intelligent Wireless Web (IWW) building blocks.

In this section, the concepts of IWW system architectural framework and implementation are introduced. The application of the system focuses specifically on the construction-logistics transportation and materials tracking service delivery operation. Collectively, the concepts open up new possibilities for leveraging the capabilities of mobile computing in construction-logistics. Referring to Aziz et al (2006), the key building blocks of the IWW are best described as follows (refer to Fig. 2):

- *High bandwidth wireless technologies* that 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 would allow users or their agents software an ability to share data and dynamically invoke capabilities from other applications in a multi-domain, multi-technology, heterogeneous environment;
- The *Agent 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 intelligent interpretation of the user context, based on various parameters such as location, time, profile, user task, etc.

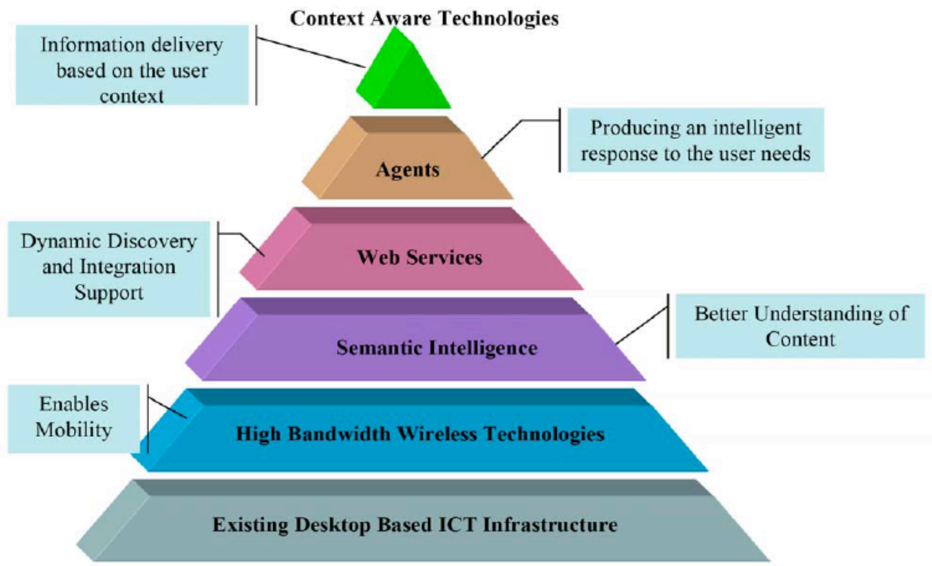

FIG. 2: The building blocks of IWW (source: Aziz et al, 2006)

Each of the above-mentioned building blocks is explained in Sections 3.1 to 3.5.

3.1 Semantic Web

The Semantic Web is an extension of the current Web in which information is given well-defined meaning, better enabling computers and people to work in cooperation. 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 (Fig. 3) is based on a number of layers, including:

- *URI/IRI (Uniform Resource Identifier/Internationalized Resource Identifier)* layer for identifying or naming a resource;
- *XML (Extensible Mark-up Language)* layer is for defining contents and rules;
- *RDF* **(***Resource Description Framework)* (RDF, 2003) 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 lay*er define 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.

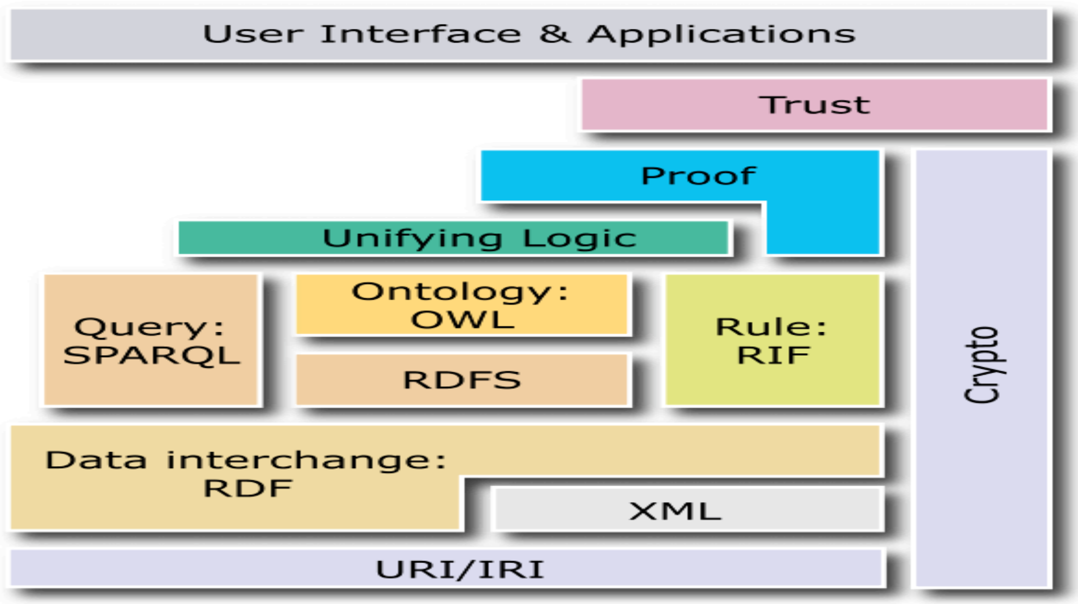

FIG. 3: The Semantic Web architecture (source: W3C, 2008)

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-logistics supply chain in the following ways:

- Deeper understanding of the semantics of document content and project task structure will help the project team member 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 was 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 mode of operation makes collaboration difficult. Use of shared ontologies and semantic standards will ensure increase interoperability across devices, platforms and applications;
- Separation of presentation and data, as ensured by Semantic Web technologies, will ensure use of same middleware tier for serving mobile and fixed network clients.

3.2 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 (Fig. 4): 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 Discovery and Description Interface (UDDI). This API enables an enterprise to describe its businesses, its services and how they wish to undertake transactions, search for other businesses that provide 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 a Web Interface (WSDL). With the help of information taken from the registries, users invoke the required service, through a 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.

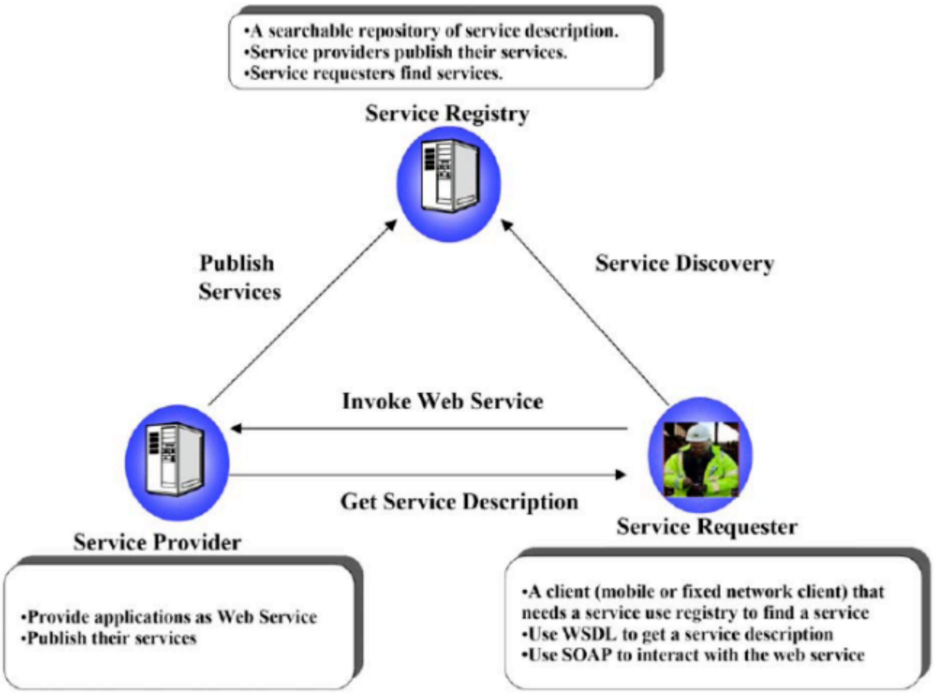

FIG. 4: Key components of Web Service architecture

3.3 Agent

An agent is an artificial agent 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 pro-actively in co-operation with other agents by order of personal (human) or non-personal principals*". Due to the nature of construction activities, the agent-based systems could offer some additional benefits in enhancing the supply chain management (Cutting-Decelle et al, 2007):

- *System Flexibility* - A supply chain is a domain which is frequently subjected to structural changes. This gives a robust system that can undergo continuous adoption to the changes in the environment without the degradation of performance often met in other types of systems. Automated procedures can be developed to deal with adding and removing agents to the system, and changes within an agent will not affect other agents;
- *Integration and Co-ordination* - A multi-agent system facilitates both multi-plant and general co-ordination. An example would be when an agent is planning production. The agent may be planning for one site in a supply chain, but information can be passed to and received from other sites, allowing a co-ordinated production planning;
- *Responsive and Speed* - A multi-agent system would also allow a high degree of reactivity to unforeseen events. The occurrence of an unexpected event, e.g. an order cancellation, can be communicated to every concerned entity in a matter of a few minutes. One important consequence of this is that customers could be informed of changes in delivery times caused by the unexpected events.

3.4 Context-Aware Computing

Context is defined by Dey (2000) as "*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*", 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*". 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. The application adapts services to the interpreted context, thereby ensuring that the busy user gets highly specific data and services (Schilit, 1995).

In principal, context dimensions can be classified into *resource context*, which is related to information resources such as image contents and the entity's context. The *entity's context* can be further divided into *entity static context*, which expresses the attributes of the entity's intentions, the intention of current behaviour, and the like, and *situational (environmental or dynamic) cont*ext, which concerns the situation of location, time, weather and so on. By referring to Fig. 5, using the two items of information showing the situational context and the entity context, the entity's situation can be interpreted as currently being on-delivery. For clarity, if the entity is a building material (e.g. pre-cast concrete beam) that needs to be delivered to a construction site, and it is now on its way to the site, therefore, its status is said to be currently being on-delivery.

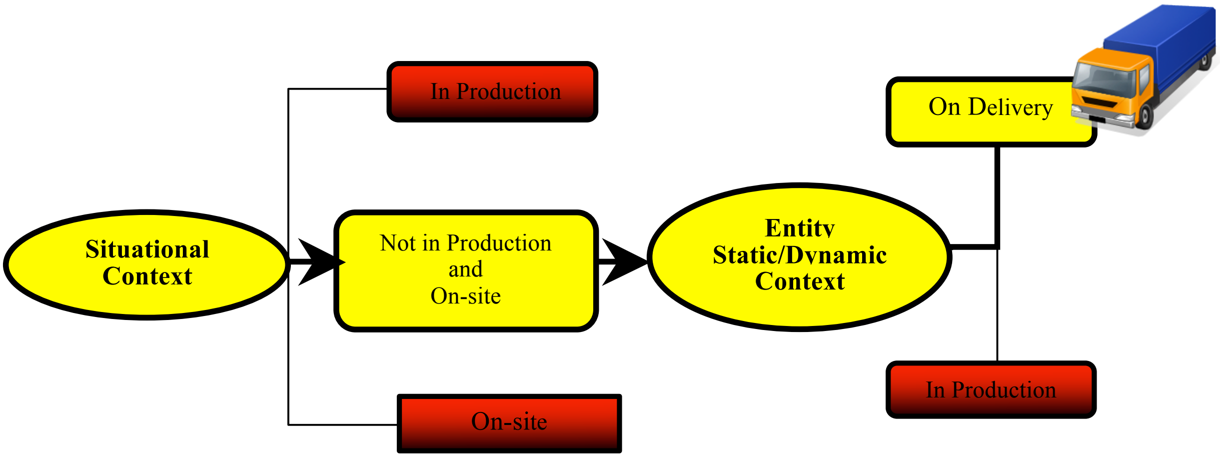

FIG. 5: Classification and entity's context

Pashtan (2005) had classified the context dimensions (Fig. 6) into four key partitions, namely; user static context, user dynamic context, network connectivity and environmental context. Each context dimension is described by its respective context parameters, for example, a user's static context parameters are his profile, information display preferences, interests, and etc.

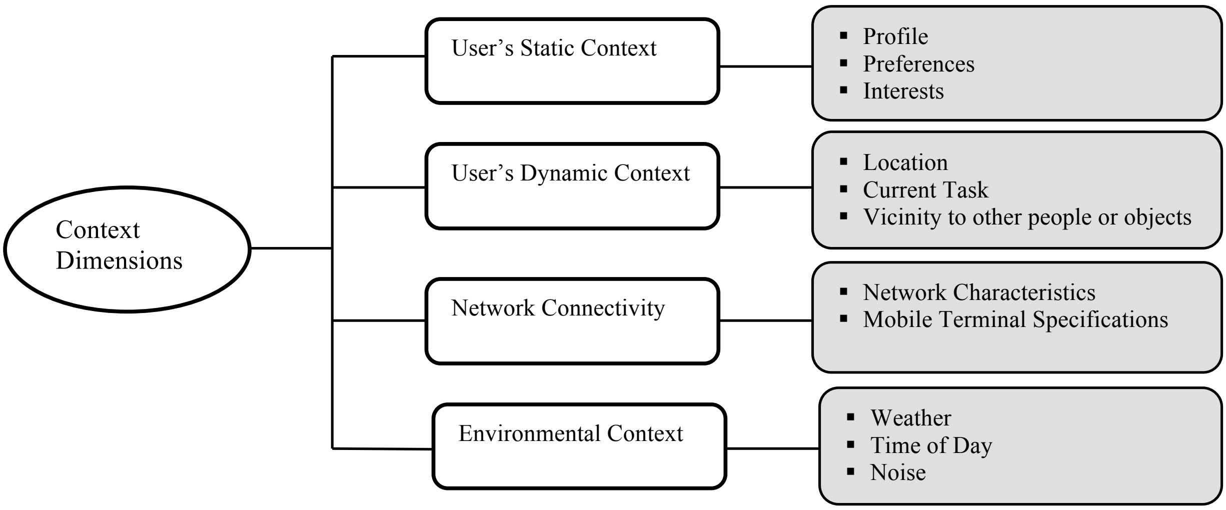

FIG. 6: Four partitions of context dimensions

The design stage of Context-Aware computing technology for such applications is a challenging process. The Context-Aware services must be able to understand various aspects of current situation or context and use them to interact with the user in a more intelligent way by combination of different technologies such as sensing devices, intelligent software, wireless technologies, etc. Fig. 7 is a conceptual diagram that shows the functional concept of sub-systems in the Context-Aware computing technologies in providing information services and delivery based on entity's behaviour. In general, the system consists of the following sub-systems;

- Hardware operation;
- Context information processing;
- Display devices/Operating devices;
- Context information distribution infrastructure.

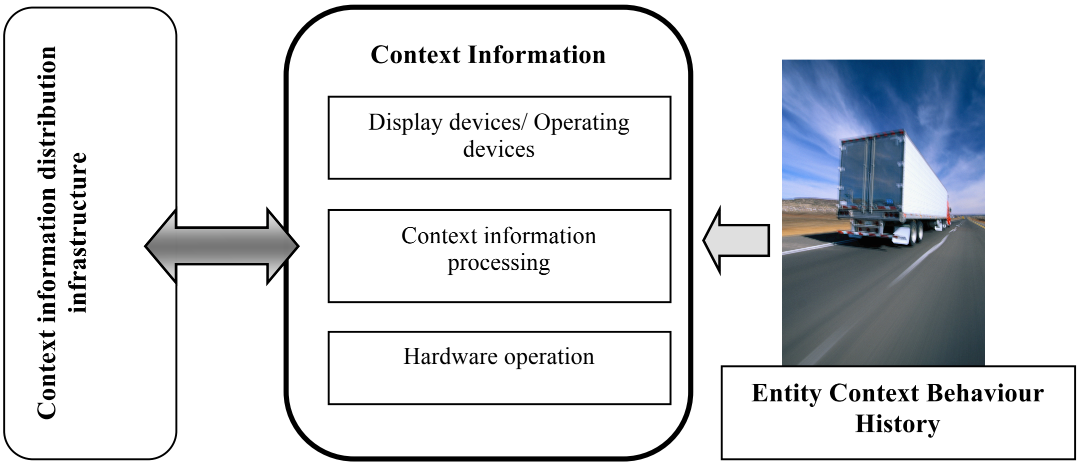

FIG. 7: General Context-Aware computing system

Hardware Operation System

The hardware operation is the lowest part of the Context-Aware hierarchical structure. At this level, the operation controlling the sensing devices or sensors is imbedded within the context environment, together with data acquisition system technologies. The sensing devices act as a detecting, analysing and interpreting of the captured data before transferring to intelligent software (middleware) for distribution, storage and query purposes.

Context Information Processing

In Context-Aware services the capability of a computer to interpret the entity's behaviour and the context is the basis of a new generation of services, whereby the interaction between the entities and the computer can be physically intangible. The task will have to be performed by an information distribution infrastructure that captures and processes the context data in an intelligent way by which could be imagined as a scenario where human-machine interfaces exist without the entity's awareness within the environment.

Display Devices/Operating Devices

In this level, the devices actually provide information services and other functions. These include mobile device, tags, monitors, information display devices and others.

Context Information Distribution Infrastructure

The interoperation of context information with the external 'context information distribution infrastructure' can be performed through Wide Area Network (WAN), Local Area Network (LAN), or other communications network. In general, the concept of the model of a technical infrastructure that enables the distribution of context information can be divided into three levels as shown in Fig. 8. The first level known as User Interface Technology (UIT) has a role to configure the applications that need to be provided to the user. In order to configure these applications, it is necessary to combine all those context dimensions that are specialised to designated users, and are configured in each application, and used to call the designated functions. The second level known as Middleware Technology (MT) provides functions creating various kinds of contexts. The functions of MT are to restore those contexts and retrieve them when necessary. The international standards for methods of configuring contexts are used. They are Web Services and Semantic Web which play a major role in the provision of services using Context-Awareness technologies.

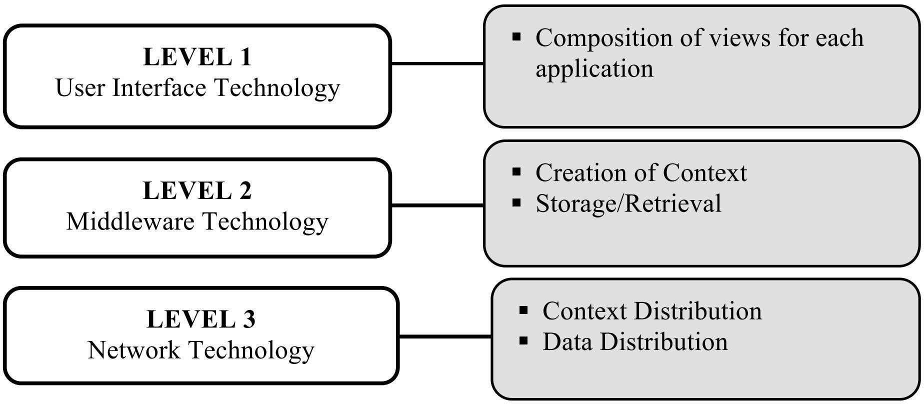

FIG. 8: Context information distribution infrastructure configuration

3.5 Wireless Technologies

The concept of *anywhere, anyplace and anytime* that people or organisation can have access to information is becoming a reality by rapid advancement in wireless communication technologies (DELL white paper, 2005). Various portable devices, such as PDAs, mobile phones and other wearable equipment are emerging, supporting W-WAN (Wireless Wide Area Network), W-LAN (Wireless Local Area Network) and PAN (Personal Area Network) capabilities. Technologies such as Radio Frequency Identification (RFID) have been predicted to supersede conventional technologies such as barcodes. RFID tags an individual physical object with a memory chip that identifies and, by wireless, communicates data about the product for example, the date, location and name of manufacturer and retailer to information systems. The RFID technology is able to improve data accuracy by tracking products through supply chains and by identifying products at specific points through Automatic Identification (Auto-ID). Wang et al (2006) had demonstrated that the application of RFID enabled PDA technology managed to enhance the information flow between offices and sites in tracking materials from supply logistics to site logistics environment. However, the tracking system for construction industry needs to be more robust and dynamic due to many things moving all the time in various directions, and in this case, RFID is not an appropriate tool to support context-aware applications compared to Wi-Fi network communication technology. Apart from that, RFID also lacks much in computing power which is a necessary element to perform in dynamic tracking.

On the other hand, Bluetooth, another short-range wireless technology (PAN), enables communications between in-vehicle devices and fixed location information systems, for example in warehouses. Wireless networks and handheld personal computers are already widely used for real-time inventory control. Moreover, wireless and mobile technologies will allow multiple companies to track individual products across the supply chain in real-time, improve asset utilisation and increase the accuracy of demand forecasts. In real-time materials tracking technology, the capability of GPS system alone cannot be fully utilised due to multipath satellite signal being blocked in certain dense areas. To overcome the problems, Lu et al (2006) had proposed the integrated system of GPS-DR-BB (Global Positioning System-Dead Reckoning-Bluetooth Beacon) which had proven in increasing the accuracy of positioning to about 82-93% in highly dense areas in their six months trials in monitoring ready-mixed concrete delivery truck movement. Therefore, to fully support the IWW, wireless sensor networking (WSN) has to be imbedded in the designated environment to suit the need of user. Sensor networks can be used to monitor a wide range of construction environments and in a variety of applications, including on-site progress monitoring, environmental monitoring, on-site security, tracking of parts or materials delivery on-site and many others. WSNs are intelligent compared with traditional sensors, and some WSNs are designed to be used in-network processing, where sensed data can be gathered in-situ and transformed to a more abstract and aggregated high-level data before transmission.

4. CONTEXT-AWARE TECHNOLOGY IN OTHER INDUSTRIES

Although a variety of mobile and Context-Aware applications already exist, there are still major shortcomings. Most of the developed systems are research prototype demonstrator based that have only been evaluated in small field trials with a limited scope of usage. The limitation for a bigger usage is impossible for the two following reasons. First, mobile guides might have restrictive hardware requirements like a specific type of PDA (Personal Digital Assistant), the availability of GPS (Global Positioning System) functionality or client-side software installations. However, new generations of mobile phones having larger display sizes, more standardised browsing capabilities and higher speed broadband data transfer will ease these hardware requirements. Second, the availability of extensive and accurate resource data is another limitation.

The application of Context-Aware for mobile users has been demonstrated in a large number of applications, including Physical Service Environment (Cortese et al, 2005), UbiqMuseum System for museum (Cano et al, 2006), Business/Enterprises (Ali et al, 2006), Construction (Aziz et al, 2004, 2006) and, CATIS (Pashtan et al, 2003) and GUIDE (Cheverst et al, 2000) for tourism. Due to rapid deployment of Wireless Local Area Network (WavLan) connectivity in the public sectors (i.e. hospital, government offices) and in the private sector (i.e. airport, supermarket), opportunities for businesses to offer services to users moving within their physical location or area with portable wireless devices (i.e. PDA, smart phones and notebook computer) are increasing. At the same time, the emergence of sensing devices and semantic interpretation technologies enables the implementation of user context services that are key enablers for the Context-Aware services to be delivered.

In Section 4.1, examples of Context-Aware application in the tourism industry, which is highly distributed activities based, are briefly described in order to get an idea on how their architectural system and performance are deployed. The reasons for selecting the tourism industry are based on the following factors;

- The researches in the application of Context-Aware computing in the tourism industry are among the most intensive to date. A number of well established related works were successfully developed such as GUIDE (Cheverst et al, 2000) and CATIS (Pashtan et al, 2003);
- The development of works in tourism is quite similar to construction, as both is based on the same factors, i.e. taking into account the aspects of engineering, information and communication management, human activities and business strategy.

4.1 Context-Aware Application in the 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-dimensions are location, time of day, speed, direction of travel, personal preferences, and device types are leveraged to adapt Web-based information that is delivered to mobile tourists. The CATIS system architecture scenario (Fig. 9) is Web Services based and includes a context manager element that manages both dynamic and static context. For example, when a tourist needs information about restaurants in his vicinity, he connects to the application server to request the information (step 1 as in Fig. 8). The application server queries the context manager for user context information such as location and restaurant preferences (step 2). It then sends an inquiry to the Universal Description, Discovery and Integration (UDDI) Server to get the addresses of the available restaurant Web Services (step 3). The application server then sends a request to all the Web Services along with the user's location and desired distance from the user (step 4). 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 (step 5).

However, the CATIS prototype system is still lacking in context mobility, hence the concept of *anywhere, anyplace and anytime* that tourists can access to information has not been achieved.

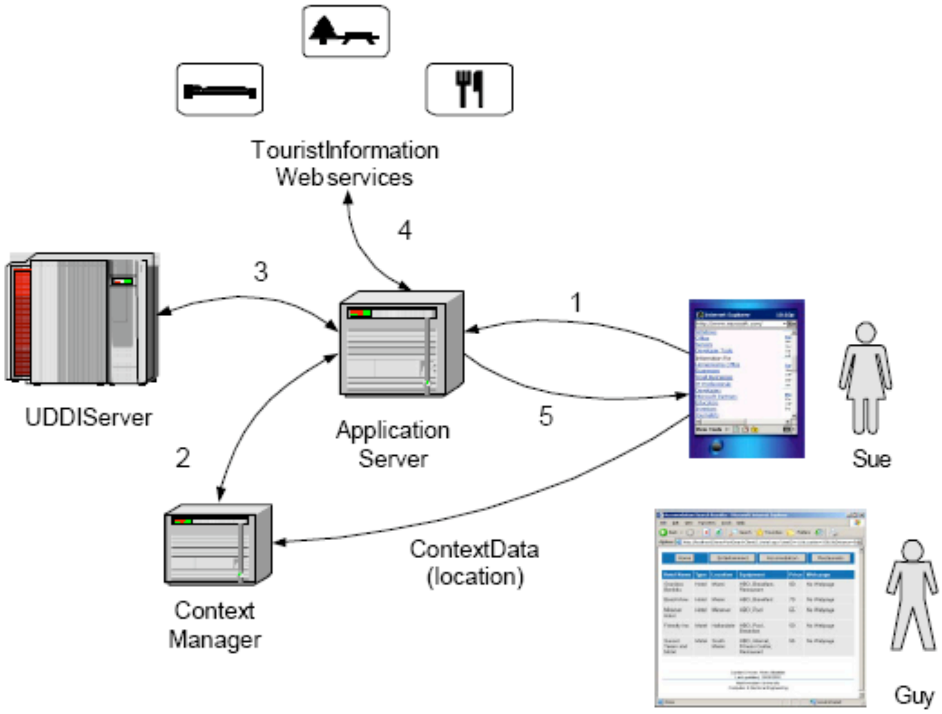

FIG. 9: CATIS System Architecture

Cheverst et al (2000) developed Context-Aware Tourist Guide (GUIDE) to provide city visitors with a hand-held Context-Aware tourist guide. The system has been successfully deployed in a major tourist destination and is currently at the stage where it is publicly available to visitors who wish to explore the city of Lancaster. 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 same network infrastructure provides location information to the end-systems, thus obviating the need for a separate location 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 has been evaluated as useful and reassuring through field trial. The test objective was to measure the quality of the visitors experience as opposed to absolute performance times for accessing specific pieces of information. It was found that even visitors without previous web experience felt comfortable using the system, and willing to trust the information presented by the system. This is not surprising as the GUIDE system has been designed to meet a set of real end-user requirements.

5. IWW CONSTRUCTION-LOGISTICS SERVICES DELIVERY ARCHITECTURE

In brief, the synergy between the application of Semantic Web, Web Services, agent technologies, Context-Aware Computing and wireless technology used to facilitate construction-logistics services (Fig. 10) collaboration support infrastructure is conceptually discussed in this section. Fig. 10 shows some of the construction-logistics services, which include material supply, material and equipment storage, manpower supply, schedule control, infrastructure and equipment locations, etc. These services or activities will be monitored by the integrated IWW-ERP (Enterprise Resource Planning).

A multi-tier architecture system will be presented which includes Semantic Web (i.e. to provide a framework for shared definitions of terms, resources and relationships), Web Services (i.e. to provide dynamic discovery and integration) and multi-agent technologies (i.e. to help a project team member accomplish a particular task such as checking materials delivery) to support intelligent mobile collaboration. The architecture framework and its implementation will be designed such that information could be delivered to support construction project team members based on their context parameters. The framework which facilitates context capture, context brokerage and integration with back-end systems using a Web-Services model will be presented. The system will be implemented based on a Pocket PC (e.g. PDA, Tablet PC, etc.) platform and made use of wireless local area networking (WLAN) to capture the context parameters such as project team member's location, preference, etc.

In this project, a Semantic Web, i.e. based on Resource Description Framework Schema (RDF Schema or RDFS), will be used for context interpretation and to define construction documents and project task structure. Fig. 10 shows a delivery framework that combines Context-Aware, Semantics Web, Web Services and agent technologies to create a pervasive, user-centred mobile work environment, which has the ability to deliver relevant information to the workers by intelligent interpretation of their context so that they can make more informed decisions. Fig. 11 show the deployment architecture where the context parameters will be drawn from Wi-Fi link (context location), user device (e.g. Pocket PC) via W3C CC/PP standards to allow description of capabilities and preferences with mobile devices, user identity (e.g. logistics engineer) via the unique IP address of the mobile device and user's current activity (e.g. tracking materials location) via integration with project management application.

The concept of IWW as discussed in this paper centres on the need to provide the project team members with specific information and services as need in a real-time basis within the construction-logistics environment. The system architectural concept will demonstrate how the project team members could intelligently be supported by specific information through IWW infrastructure which could finally enhance both materials and information flow within the construction-logistics environment. In conjunction to that, the multi-tiers system architectural infrastructure for Context-Aware Services Delivery developed by Aziz et al (2006, 2004) is being referred to and further enhanced for this application (Fig. 11). The detail descriptions for each tier can best be referred to Aziz et al (2006).

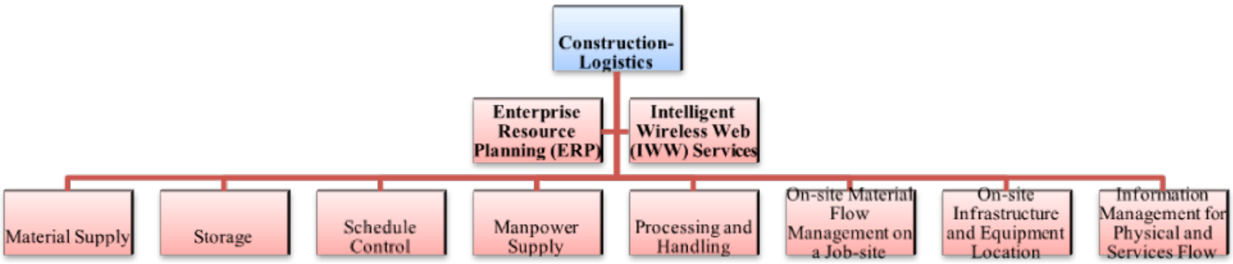

FIG. 10: Integrated IWW-ERP Construction-Logistics Services

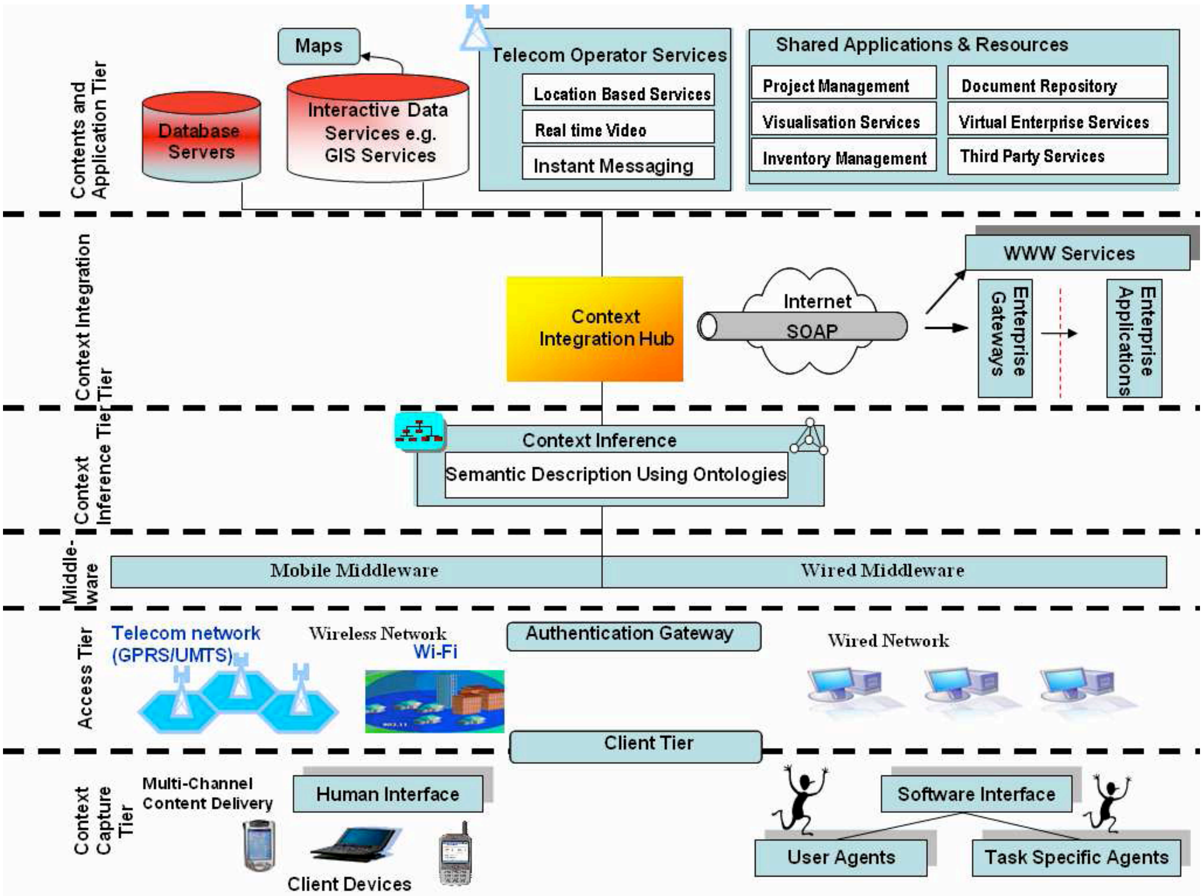

FIG. 11: The concept of IWW services delivery architecture developed by Aziz et al (2006)

5.1 Context Brokerage and Mapping

Aziz et al (2005) addressed five context parameters, i.e. Location, Time, User Device, User Profile and User Activity in their related work for supporting mobile workers activities. In order to support the construction-logistics activities, the following context parameters are established, namely:

- User profile;
- Components profile;
- Location;
- Time;
- User device;
- Component device.

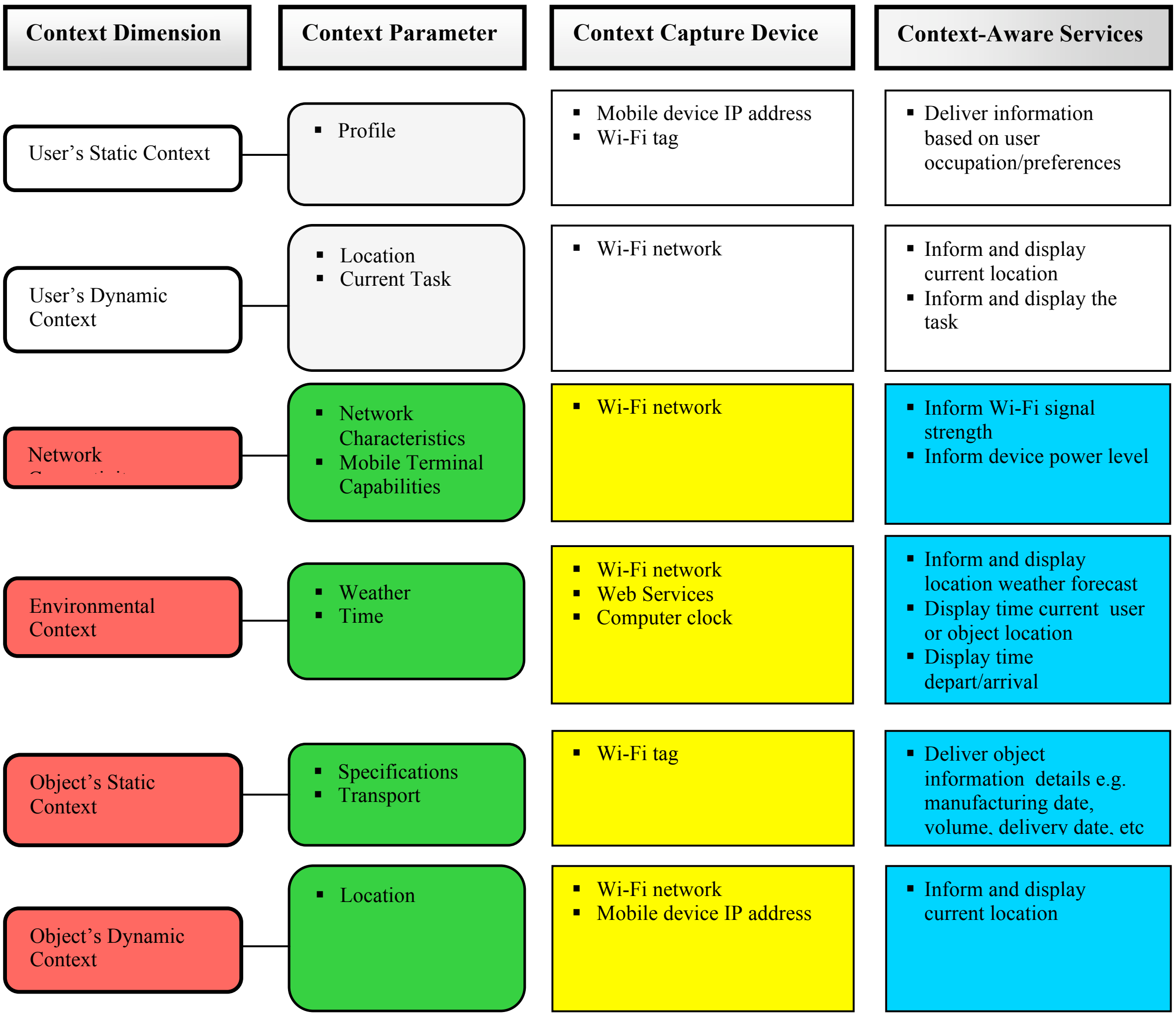

FIG. 12: Context dimensions

Context is captured from the following sources:

- Current location (project team members) – via WLAN positioning system. A client application running on a user's mobile device or WLAN tag sends constant position updates to the position engine over a wireless link;
- Current location (material components) – via GPS for outdoor tracking and WLAN for indoor tracking system. A client application running on a user's mobile device or WLAN tag sends constant position updates to the position engine over wireless link;
- User Device – via Microsoft.NET framework application;
- Component Device – RFID tag passive type;
- User Profile – associated with mobile device's unique IP address;
- Component Profile – associated with RFID ID code;
- Time via computer clock.

Changes in the context prompt the context broker to trigger the pre-programmed events. Events may include delivery of push-based messages to the user or an exchange of information with other applications, to make them aware of the events on the site. As the user context changes (e.g. change of location, tasks), the context broker recalculates the available services to user in real-time. In the prototype implementation, RDFS (RDF, 2004) will be used to provide vocabulary and structure to express the gathered contextual information. Previously, many researchers had also used RDFS for representing and delivering the context information (Ferscha et al, 2002; Chen et al, 2004; Toivonen et al, 2003). Being XML-based, RDF also ensures provision of context information in an application and platform-independent way. Using RDFS, the context broker maps captures and delivers contextual information to available data and services.

5.2 IWW Services Delivery Implementation Scenario

This implementation describes the processes by which the Logistics Manager based on his/her profile will be contextually aware of the tracking and report of the flow of materials from supply logistics to on-site logistics progress. For specific discussion purpose, the monitoring of the delivery activities of pre-cast concrete beams from production area to on-site area will be established as a project scenario. The importance of monitoring the delivery processes is due to the project location which is based at the inner city centre and has limited storage space on-site. The pre-cast concrete beam delivery process has been defined in the early project planning stage as one of the critical activities that needs to be monitored in a day to day logistics operation. Therefore, to facilitate the JIT operation, the supplier for the pre-cast concrete beam has been assigned from the very beginning. The information and the material delivery flow from production site (factory) to the on-site can be monitored instantly at any time, any place and anywhere by the logistics manager. The project scenario is illustrated in Fig. 13.

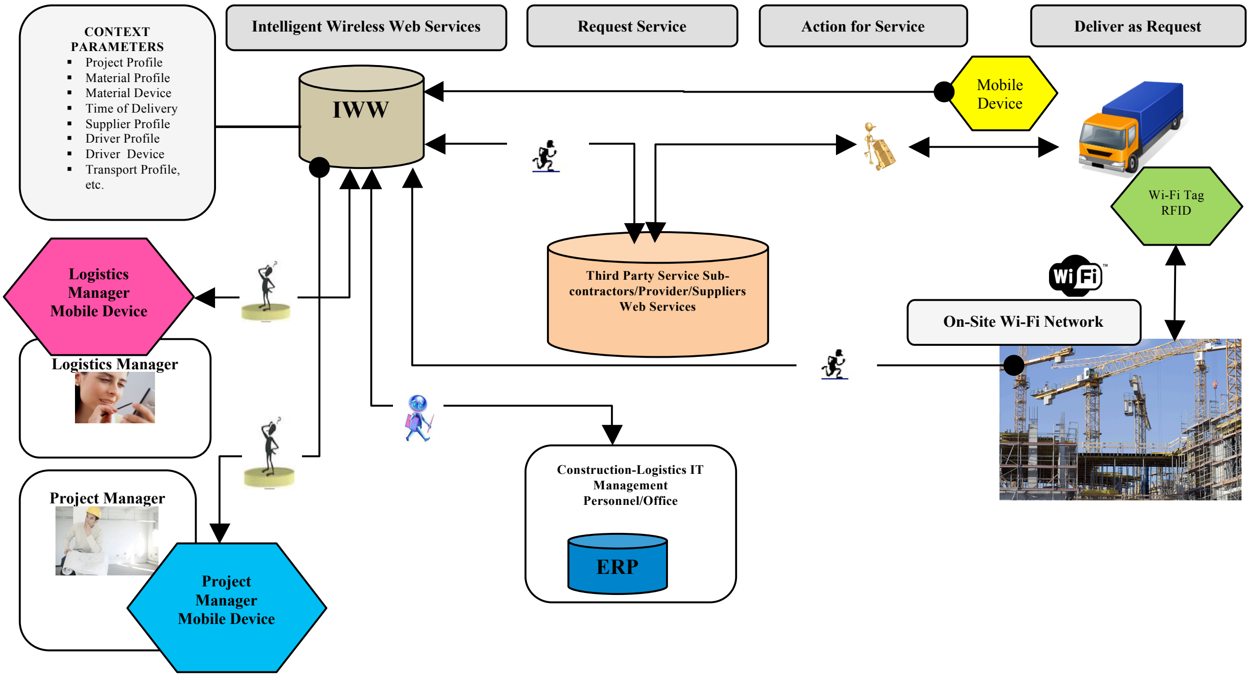

FIG. 13: Project Scenario – Material Delivery

The following illustrates the chronology of material delivery scenario in Fig. 13.

1. As pre-programmed, ERP agent delivers information to IWW logistics agent regarding scheduled material delivery to site.
2. Logistics agent makes request to supplier via supplier web services. Supplier agent informs logistics agent about the acceptance of request.
3. Supplier agent checks the stock availability and confirms delivery to logistics agent.
4. Supplier agent informs the preparation for delivery (context parameters - material description, quantity, delivery time, transport profile, driver profile, transport device, material device, etc.) to logistics agent. All context parameters are stored in Wi-Fi tags.
5. Delivery progress is tracked through the transport driver's mobile device IP via mobile telecommunication network (e.g. PDA).
6. Upon arrival at site gate, the on-site Wi-Fi network (IWW) detects all the devices (driver device and Wi-Fi tags), and updates the delivery information into ERP system for inventory control. At the same time, logistics agent will alert the logistics management/personnel and project manager.
7. The driver will then be directed to deliver the material to a specific storage location via his mobile device.

Logistics manager or project manager or any other authorised personnel could browse through the delivery content and record any discrepancies.

5.3 IWW Business Model

It is not the intention of the IWW services delivery system to change the way the whole of the construction industry operates. The practice and processes will mainly remain the same, but the introduction of IWW to the construction business model means that all the parties involved in the construction project communicate their information through the IWW system. However, this does not mean that they do not communicate with each other as previous. The proposed IWW system is updated on real-time basis where any information required can be pushed or pulled to the relevant user as appropriate. Fig. 14 shows the proposed IWW business model specifically focused on activities or services within the logistics supply chain network. Through this model, all the logistics services will be controlled by IT manager/unit under the main contractor's responsibility. The IT unit could either be appointed through third party logistics (3PL) or under the full responsibility of main contractor.

Comparing this new proposed model to the traditional one (through one case study) shown in Fig.1, it is seen that the existing model only use low level IT capability which does not cover all of the logistics services within off-site and on-site. The unit is fully under the project manager's responsibility where all the material supply to the on-site is arranged by the contractors or sub-contractors through their nominated suppliers. The logistics IT activity is limited to controlling the material supply to on-site through the limited capability booking system. From the case study, it is observed that the system fails to respond to any delay/inconvenience that could occur during material delivery by the suppliers. The consequences from this will indirectly affect the activities on-site.

By proposing the new logistics supply chain network information/communication model, the activities/services within the supply chain could be improved through the concept of pull-push that is fully controlled by context-aware and wireless technology capability. This model provides the facility for information to be accessed by all parties at anytime, anywhere and anyplace with most updated information services.

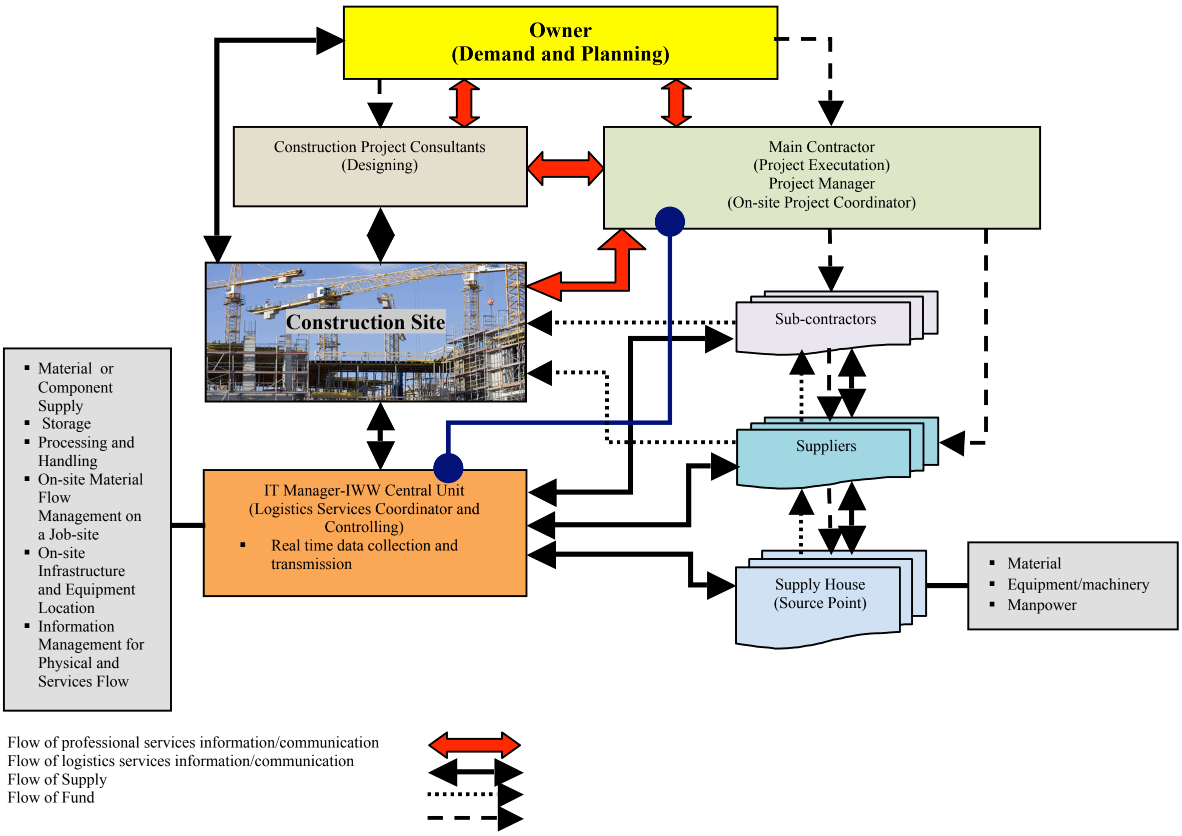

FIG. 14: IWW logistics supply chain proposed model based on traditional construction contracting method

6. KEY BARRIERS AND ENABLERS

A survey conducted recently for this research revealed that one of the key barriers to the implementation of the proposed IWW framework is culture. This is supported by Green et al (2005), who found that the work culture that has developed for decades within the construction industry is among the hardest barrier to overcome even if a catalyst is brought into their organisation. Workers are reluctant to change their way of doing things without any promise of personal gains. Also, most construction organisations are technologically conservative organisations. They are unwilling to invest in new, costly technology, due to the lack of belief of its potential benefits. They are not easily persuaded to try something that has not been proven its cost-effectiveness and demonstrated its practical application benefits. The full finding of this survey will be reported in the authors' next paper.

Basically, to introduce a new technology involves cost, time, manpower and training. First of all, an organisation needs to develop and implement the new system. Then, workers are required to work the system, and they need training to become knowledge workers. To implement the system and train the workers all involve time and fund, which most organisations would rather spend trying to complete a construction project. Due to this, client and top management are important enablers in the adoption of the proposed IWW system. Without motivation and client enforcement to adopt the technology, organisations would not bother testing the IWW system. Therefore, top management awareness and commitment in this matter are crucial for the system to be successful. Government also needs to play an important role in persuading and supporting construction organisations by providing IT technical training centre specifically for construction based skill workers. By doing this, one of the main barriers can be overcome and the application of full IT in construction industry can be implemented. This is also parallel with the government's plan to provide free wireless broadband (Digital Britain) through the UK by 2012 as broadcasted recently (BBC, 2009). Wireless network coverage is, of course, another important enabler.

7. FUTURE WORKS

The ultimate aim of the research is to design and evaluate a prototype system that demonstrates the effectiveness of context-aware services delivery in the construction-logistics supply chain. After the identification of the most suitable context parameters, the range of services required for the identified contexts and the social and technical requirements for context-aware service provision, the next step is to develop a process model for the construction-logistics supply chain interactions within the new context-aware environment. Then, the integrated context-aware services delivery framework with provisions for context capture, context brokerage, context inference and integration with other applications and services using a Web-Services-based architecture will be developed.

Validation of the framework will be carried out through a workshop involving both technology experts and industry practitioners. Next is the development of functional specifications for the prototype demonstrator based on the framework developed.

The designated concept and role of IWW will be adopted to improve the communication within the construction -logistics and construction networks supply chains. The prototype system architecture framework of IWW will be developed and demonstrated for evaluation and validation through a workshop involving both technology experts and industry practitioners.

8. CONCLUSION

In this paper, the application of Context-Aware has been demonstrated through the material supply delivery process as part of the construction-logistics activities. The project scenario has illustrated that conceptually Context-Awareness could be integrated with Web Services in order to ensure the delivery of pertinent information and enhance construction-logistics supply chain collaboration. It postulates that parallel developments in Web Services, which provide the ability to dynamically discover and invoke services regardless of operating system or programming language, can be leveraged to enable construction project team members to access, in real-time, different corporate back-end systems and multiple inter-enterprise project resources. The integration of Context-Awareness and Web Services with construction-logistics supply chain management offers considerable potential for enhancing logistics services and ensuring that each service is provided with access to context-specific data, information and services. The implementation of IWW in construction-logistics could enhance the JIT operation, reduce waste and increase cross-functional activities. Furthermore, the proposed new business model is capable of being used as a reference for future construction logistics where the logistics services can be classified as one of the important units in the overall construction supply chain network.

9. ACKNOWLEDGEMENT

This research has been funded by Universiti Teknologi Malaysia and the Ministry of Higher Education of Malaysia.

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