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TIKI: A TRIGGER-BASED INFRASTRUCTURE FOR KNOWLEDGE AND INFORMATION SHARING

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This paper describes TIKI (Trigger-based Infrastructure for Knowledge and Information sharing) and scenarios for its use as a knowledge management support system in an international peacekeeping coalition. TIKI is a lightweight infrastructure to support knowledge management across loosely connected virtual enterprises using mobile computing devices. TIKI allows users to mark-up physical space with triggered task, location and time information. Relevant information can be downloaded onto the user's mobile device, where it remains persistent until purged. This allows operation in a disconnected environment or where poor connectivity exists. As a user moves through time and space, the mobile device evaluates information triggers and displays the associated information if trigger conditions are met.

1. INTRODUCTION

Within the defence domain, virtual organisations frequently exist in the form of short term, international coalitions formed for specific purposes such as peacekeeping operations. Within these types of virtual organisations knowledge management is often problematic. This typically results from complex relationships between coalition partners, the one-off nature of the operation and the instability of communication infrastructures.

In this paper we will describe a knowledge management support system called TIKI (Trigger-based Infrastructure for Knowledge and Information sharing). This system is targeted principally at supporting users with handheld computers and wireless communications. TIKI allows users to distribute information that is to be displayed only when triggered by appropriate contextual parameters. These parameters may be spatial locations, points in time or user tasks. The ability to mark-up space and time with messages is particularly useful in a peacekeeping context where messages can relay the location of past events or provide warnings about otherwise unmarked aspects of the environment. For example, when engineers approach the wharf of a particular port a trigger left by their predecessors may activate to tell them that a vessel sunk during a previous militia raid lies concealed beneath the water line.

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Some information may be specific to particular user tasks, for example a team of engineers assessing a port for offloading of supplies may have different interests to peacekeepers responsible for securing the port facilities against attack. This is where context acts to help overcome information overload.

TIKI has several innovative aspects, firstly it allows the possibility of creation and evaluation of triggers containing selected information by users, devices, intelligent agents and enterprise software applications and workflows. As a result, a wide array of activities are possible through the same shared communications infrastructure. TIKI allows smart push of information using personal intelligent agents. These agents seek information relevant to the user they support from back-end data sources and push this information out to the user in the form of triggers. The use of JavaSpaces™[1] technology to store trigger objects opens the possibility that software objects may also be distributed to end users to allow access to certain types of information.

The next section will discuss the background to this work by defining the motivation for the work and providing a brief summary of related work. Section Three will describe the TIKI system in detail. Then in Section Four the use of TIKI in an international peacekeeping coalition will be described. We will provide a summary of this work and directions for future work in Section Five.

2. BACKGROUND

2.1 The Motivating Problem

In the modern defence context, peacekeeping, disaster relief and humanitarian operations are becoming increasingly commonplace. These types of operations typically involve the creation of a virtual organisation from an international coalition of participating countries and non-government organisations. Several key characteristics are typical of this type of virtual organisation:

i. *Churn of personnel.* New personnel are rotated in and out of the organisation on a regular basis. This entails a significant loss of knowledge.

ii. *Limited information infrastructure.* Peacekeeping operations typically take place in environments where information infrastructure has been damaged, destroyed or may never have been in place. This includes both electronic infrastructure and physical infrastructure such as road signs. Defence organisations often bring in their own infrastructure and must be able to operate with limited connectivity.

iii. *Geographic significance.* Geographic boundaries and positions become particularly important as they hold political and military significance. In the context of war-torn areas, these locations may not necessarily be stable, agreed upon or well known.

iv. *Heterogeneity.* The need to communicate and harmonise efforts between diverse sets of coalition partners poses difficult challenges. Barriers include language, culture, training levels, sensitivity of information and

[1] URL http://java.sun.com/products/javaspaces/

equipment compatibility. Typically, the lowest common denominator may be chosen to allow communications with everyone.

v. *Unpredictability.* There is typically a high degree of unpredictability and danger within a modern humanitarian operation. Therefore, the ability to respond rapidly to challenges becomes important. Rigid processes may need to be abandoned quickly for reasons of practicality.

In order to create a system to provide contextually grounded information to all members of the virtual enterprise we need to map the above organisational characteristics onto technical requirements for such a system. Whilst there are many desirable properties for such a system, we have defined the following characteristics as guidelines for our candidate information system:

i. *Lightweight.* The system should be able to be "handed out" to coalition partners and be physically lightweight enough to be taken on foot patrols.

ii. *Robust.* The system should be able to operate with limited connectivity communicating when connections are available. Devices should be ruggedized against physical damage.

iii. *Intuitive.* The system should be able to be used by personnel with only minimal training required.

iv. *Projected.* The main functions of the system should have the capacity to reside in a non-deployed position and feed only the required information out to deployed personnel via wireless communications.

v. *Spatio-temporal aware.* The system should have the capacity to capture information in it's spatio-temporal context.

vi. *Self-sufficient.* The system should not rely heavily upon the agreement of standards by users, or presume that users have access to certain equipment.

vii. *Transparent.* The system should not require significant input from the users in order to receive information and benefit from it. This implies a need for information push where the information becomes an ambient aspect of the users environment while avoiding information overload.

2.2 Related Work

An important aspect of the TIKI system is the use of triggering conditions that allow information to be provided in a specific user context. Context can be simply defined as *that which surrounds, and gives meaning to something else* (Schmidt *et al.* 1999). The provision of information specific to a user's context helps avoid information overload and research in this area has grown with the advent of mobile computing (Brown *et al.* 1997). Modelling user context is a complex issue that is bounded significantly by the ability to capture the dimensionality. Several approaches to modelling context have been proposed e.g. (Burnett *et al.* 2001). Of particular interest is the mark-up of physical space and research in this area is ongoing e.g.(Pradhan *et al.* 2001).

A survey of context-aware mobile computing research is provided by Chen and Kotz (2000). Of the systems described, TIKI is most similar in its design to the Rome system (Huang, *et al.* 1999). Rome is based around the distribution of context triggers that are evaluated on the client devices. We have adopted this distributed trigger-based approach for TIKI because it suits an environment where connectivity

is likely to be poor. Rome proposes a "semantic translator" component to create triggers within the system, however no implementation is described. By comparison, we advocate triggers being entered into the system from a wide variety of sources such as devices, intelligent agents, enterprise workflows and end-users themselves. We have enabled this by creating a generic software interface that allows triggers to be entered into the system. The use of JavaSpaces™ technology as the central clearing-house of triggers allows us to consider the possibility of sending software components to encapsulate and allow access to special communications or information types.

3. THE TIKI SYSTEM

The TIKI system supports the management and distribution of triggered objects as a fundamental form of communication. These objects are distributed to clients and triggered upon client context. There are three fundamental activities that underlie the TIKI system: trigger creation, trigger distribution and trigger evaluation and each of these operations will be discussed later in this section. The TIKI system architecture is displayed in Figure 1.

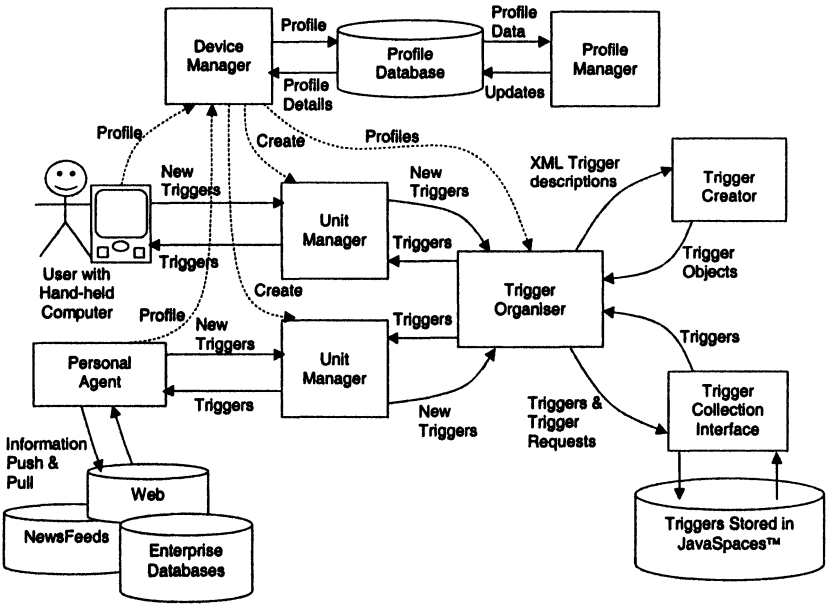

Figure 1 – The TIKI System Architecture

The TIKI system is composed of the following main components:

- *Trigger Organiser.* This component performs the high level operation of adding, removing and subscribing to triggers within the system. Triggers are also created here via calls to the Trigger Creator component.
- *Trigger Creator.* This component is responsible for creating triggers from an XML string using a software factory design pattern.

- *Device Manager.* The job of the Device Manager is to manage connections into the TIKI system. This involves invoking an appropriate Unit Manager to interface to the target device. In addition, it passes the user profiles to the Trigger Organiser and instantiates Personal Agents when required.
- *Unit Manager.* Each entity connected to the TIKI system connects via its own Unit Manger. The Unit Manager acts a mediator capable of communicating with the specific type of entity connected.
- *Trigger Collection.* This is a store of all triggers currently active within the TIKI system and is implemented using JavaSpaces™.
- *Profile Manager.* Profiles can be created and entered into the profile database via the Profile Manager. Profiles describe the relevant subscriptions for given profile characteristics.
- *Personal Agents.* Personal Agents are instantiated for individuals connected to the TIKI system. They determine and maintain a knowledge of that user's context and push information relevant to that context onto the system in the form of triggers. They receive triggers notifying them of changes in their subjects context. We have been investigating the development of these agents using JADE[2] (Java Agent Development Environment).

Users connect to the system by making contact with the Device Manager. The Device Manager uses the users profile to create an appropriate Unit Manager via which they may interact with the Trigger Organiser. It also passes their profile on to the Trigger Organiser. Once the Unit Manager is in place the client will receive all appropriate triggers stored within the system. The client will also have the capacity to create triggers and place them into the system for others. If the user profile deems it appropriate, a Personal Agent will be created by the Device Manager to push information to the user based upon their context. The agent will be given their profile as a starting point and will receive updates of their context in the form of triggers pushed back through the system from the client on an event-driven basis.

Triggers can be created by the human users of the system, physical devices attached to the system, workflow processes flowing within the enterprise, or intelligent agents seeks to push useful information. For example, a user with a GPS card will have the capacity to mark a given spatial location and attach a trigger to it. They may also wish to target the trigger to a more specific context by defining trigger conditions based upon parameters such as time or task. Triggers can be sent into the TIKI system in the form of XML strings that are converted into trigger objects via the Trigger Creator component. Alternatively, trigger objects can be added directly into the system.

Trigger distribution is based upon the client profile that can be thought of as a high level description of the client context. The profile contains details of the users device type, location, current task as well as other characteristics that may be used by personal agents such as language or user preferences. Triggers appropriate for the target user are fetched by the Trigger Organiser and placed on the client device. These triggers will remain until they are purged via a trigger retirement process.

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[2] URL http://sharon.cselt.it/projects/jade

Trigger evaluation is performed on the client device. This implies that the client has the capacity to evaluate the trigger by knowing the user's context. For example, the device will need a GPS capability in order to evaluate spatial triggers. Other cues such as user task may need to be input directly by users before they start or while they undertake their operations. Once the conditions of the trigger are met, it is activated and the textual message that is contains will be displayed to the user. We are investigating ways in which this simple textual message can be augmented with further complexity, for example by allowing images and software to display them to be distributed inside trigger objects.

Our experimentation with TIKI to date has been based around a testbed constructed with iPaq handheld computers equipped with GPS cards. These form the principle client devices. They connect to the TIKI system via a wireless network. We have used Java technologies to implement the TIKI system and Visual Basic on the iPaq handheld clients.

4. PEACEKEEPING SCENARIO

4.1 Contextually Relevant Information

The simplest use of TIKI within the defence domain is to make contextual relevant information available to users. One of the simplest, and potentially most useful, contexts is the user's location. In this case, the TIKI triggers are simple location coordinates (obtained from GPS, or other navigation systems) with TIKI providing summary descriptions relevant to the user's current location. This may include the location of a country, the depth of a river, or the destination of a road, and so on.

As well as using location as a trigger, TIKI can also make use of a task condition to improve the relevance of information provided. Within the defence domain it is possible to describe the various functions performed by military organisations using a set of well defined Task Descriptors; for example, Patrol, Survey, Defend, Secure, and so on (Prekop and Kingston 2001). These can be combined with location coordinates to improve the relevance of information provided.

In addition to location and task information, TIKI, can also make use of other trigger conditions where appropriate, including time, type of platform (truck, aircraft, tracked vehicle, etc), environmental conditions, and so on. These can be combined to provide highly contextually relevant information. For example, the information needed about a road (a location), will differ depending on the task being performed, the type of platform, and the current environmental condition. When patrolling (task), during the wet season (environmental conditions), in a tracked APC (platform), the information needed may include, the destination of the road, and the suitability of the road for travel by tracked APC. When securing (task) a road (location) at night (time) the information needed may include, frequency and type of traffic, nearby geographic features, and so on. By using very simple trigger conditions, it becomes possible to provide highly contextual information to systems users.

4.2 Dynamic Mark-up of an Operational Area

One of the most difficult knowledge management problems facing an international peace keeping operation is dealing with the churn of personnel, and the transfer of historical information from generation to generation. This is further complicated by the different (and often incompatible) information management, and information sharing policies of the various individual organisations involved in the operation. For a military organisation, gaining an understanding of what actions have occurred in the past is vital to being able to operate in the present, and build an understanding of what might occur in the future.

Using TIKI, it becomes possible to mark-up the physical space of the operational area with information of past events, for example, the location of previous skirmishes, previous locations of hostile forces, and so on. This information can be encoded as a collection of spatially triggered tags. When patrolling an area, new generations of personnel are able to gain a contextually grounded description of actions and locations relevant to their area.

As well as marking up the physical space with historical information, using TIKI, it also becomes possible to augment existing information about the operational area with additional, more detailed information. For example, it would be possible to mark the location of a poisoned well, or record the location of unexploded ordinance, and so on. Since the information is recorded relevant to space, the information is only made available to personnel working in the relevant areas, helping to reduce information overload.

4.3 Dynamic Coordination

A problem often encountered during international peacekeeping operations, is the coordination between many different organisations, including various military organisations, host governments, and international aid organisations. Coordination and sharing an awareness of activities is often hampered by language and cultural difference, as well as different physical locations of decision makers, different decision cycles of key decision makers, multiple levels of management, and so on. Using simple, spatial, temporal, and task-based triggers, it becomes possible to coordinate complex activities, and to share awareness of activities through different organisations. Likewise, barriers such as language may be overcome via the use of personal agents within the TIKI system to automatically translate trigger messages.

Consider the coordinating of security for food distribution activities, an activity that is often difficult. Food shipments are often sporadic, and their distribution often depends on the availability of personnel and transport. Food distribution is coordinated by aid organisations, while security is coordinated by military organisations. Food distribution is also, time and location dependent, because the food distribution event only occurs for a limited time, in a small area. Using a simple spatial, temporal and task-based trigger, it becomes possible to dynamically coordinate between the various organisations. Using a simple trigger in the form of, *if Patrolling in Area X at Time Y, then perform secure food distribution in Area X*, it becomes possible to dynamically coordinate security for food distribution. This trigger will only fire if the patrol is near the food distribution activity, when it is occurring.

Awareness of activities performed by members of other organisations is also difficult to manage and coordinate within international peacekeeping operations. For example, consider interactions in a patrol area between Patrol-A and Patrol-B. Patrol-A needs to be aware of when Patrol-B starts their patrolling activity. Using a simple spatial and task trigger, in the form of *If Patrol-B enters Area-X* (patrol area) *and is Tasked to patrol then notify Patrol-A,* it becomes possible to for Patrol-A to be aware of patrolling activities being performed in their area.

5. SUMMARY AND FUTURE DIRECTIONS

This paper has presented TIKI, a lightweight trigger-based infrastructure for knowledge and information sharing targeted at mobile computer users within a virtual organisation. We have described the use of TIKI as a knowledge management support system within an international peacekeeping coalition.

An important characteristic of the TIKI system is the fact that it is generic enough to allow many different types of entities to share information, although to date we have only investigated human users and intelligent agents. Importantly, the information provided to users is displayed only in a specific context, and hence information overload is avoided.

To date we have only examined the passing of textual messages within the TIKI system. It is equally possible that we may send software objects that perform, encapsulate or allow access to useful behaviour and information. It may also be possible to send scripts that act as recipes for the remote construction of software from components within the enterprise *q.v.* (Rainsford *et al.* 2001). We have also only scratched the surface of the possibilities presented by personal agents. Agents that translate text on behalf of users or monitor the flow of triggers within the system are fertile areas for further research.

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