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Ubiquitous Cloud Object for Fine-Grained Resource Management in E-Commerce Logistics

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Abstract. Logistics resources are of great importance in E-commerce as the essential factors of production, basically including man, machine and material. Optimization for E-commerce logistics always relys on the real-time information of logistics resources. Actually, these resources are exchanging information continuously when they interacting with each other. Since the management granularity for logistics resources still remains at a coarse level, most of the interaction information between resources cannot be well recorded and organized. To achieve fine-grained management of logistics resources that could provide real-time resources visibility, traceability interoperability and availability is urgently needed. The booming of IoT technologies makes it feasible to realize fine-grained management. However, how to make resources smart to interact with other resources and construct a resources-oriented information network to serve enquiries from EISs has not been well studied. This paper presents a ubiquitous cloud object (UCO) framework for logistics resources to achieve fine-grained management. A ubiquitous cloud object model is proposed to abstractly virtualize heterogeneous logistics resources into cloud mappings. The concept of object cluster achieves the flexible resource granularity with a designed object gateway service (OGS) to construct information network. Aiming at facilitating the integration of UCOs with Enterprise Information Systems (EISs), object chain is used to organize UCOs to fulfill the specific workflows.

Keywords. Ubiquitous Cloud Object, Object Cluster, Object Gateway Service, Object Chain

Introduction

Benefiting from the prosperity of E-commerce, E-commerce logistics has developed by leaps and bounds in recent ten years [1]. As a typical resource-oriented industry, the resources scale has extremely expanded accordingly [2]. Now the increasing competitions prompt these E-commerce logistics companies to change from extensive growth to intensive growth. Hence, the effective disposition of various logistics resources has been treated as a core competence and prompted E-commerce logistics companies to improve resource utilization. Resource management in E-commerce

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logistics focuses more on the resource visibility, traceability, interactivity and interoperability so that the three most important kinds of resources, including man, machine and material could be coordinated and synchronized intelligently to fulfill the goods transportation according to customers' orders [3, 4]. However, the management granularity for resources still remains at a coarse level in reality, which falls behind and is different from that in manufacturing [5]. For example, the number of operators for a specific work is usually regraded as the input for task allocation, but individual differences such as specific statuses, operation preference and applied knowledge are not well recorded to support refined decision-making to improve resource utilization. Thus, to achieve fine-grained resource management has become essential.

The booming of IIoT(industrial internet-of-things) makes it possible to realize fine-grained resource management. Several IIoT prototype systems have been designed and developed for similar purposes [6, 7]. For example, the concept of cloud asset is proposed to solve the asset management problem in flood control [8]. However, more practical problems have puzzled the E-commerce logistics companies to apply IIoT technology to achieve fine-grained resource management. The fast integration of logistics with IIoT technology is one of the most serious problems. Three research questions exist that impede the settlement of this problem as follows:

Firstly, how to use a ubiquitous resource model to describe the physical logistics resources and IIoT resources with fine granularity? The IIoT resource could be seamlessly integrated with the physical resource. The emerging industrial wearables which combines sensing technologies with industrial wearable technologies are the most suitable forms of IIoT resource. So the IIoT resource could be attached on the host physical resources to enhance the functionalities and intelligence. Resource description framework (RDF) is proposed by W3C as a resource model to describe collections of formalized statements about a Web resource [9]. While the media role of IIoT is without consideration in its model so that it lacks of connectivity between physical resources and software mappings. Some agent-based smart object models are successful to warp smart devices into software agents only [10, 11], but they neglect other resource types especially the human resources and these agent-based model are generally lack of resource structure, granularity and interactivity. For example, the smart asset agent provides real-time visibility and controllability for a ordinary pump through a smart device attached on the pump [12]. In terms of resource management, this agent is actually the result of two resources superposition and either resource should be organized in an individual resource object. Thus, a ubiquitous resource model is essential to fulfill the following three requirements for the description of physical resources with fine granularity. Firstly, the atomicity of physical resources should be well expressed by this model. Secondly, the model should have the reconfigurable feature so that the cloud mappings of resource objects could be able to be compitable for different software environments. Thirdly, the model should enable the UPnP management for physical resources.

Secondly, how to achieve flexible granularity for managing resource objects? The fine granularity realizes the expression of each resource object in atomic level. But several resource objects will have strong relationship in terms of their physical distribution or application preference. Logistics resource objects and IIoT resource objects typically have strong relation. For example, an operator may wear a smart glass and a RFID glove, then the three objects are treated as a whole for the management. But how to rapidly construct the information network for the three relation-based objects are a practical problem in reality.

Thirdly, how to make resource objects easy-to-adapt and resource information simple-to-acquire? Resources are required to be organized and arranged based on the definite working logics of a specific logistics operations. While the working logics for the same operations may vary in different E-commerce companies. So how to make the resource objects to easily suit different working logics is important. Furthermore, the working statuses such as the opeartion results and the resources information are critical for EISs to make decisions, so the sharing of resource information is also required.

In order to solve the three problem, this paper proposed a ubiquitous cloud object (UCO) to virtualize physical resources into cloud agents based on the UCO model. Object cluster is designed to achieve the flexible granularity with the construction of local information network. To make resources easily adapt to different working scenarios, the object chain is used to facilitate the integration of resources with EISs. The rest of this paper is arranged as follows: An overall framework is demonstrated in chapter 1 to illustrate the concept of cloud object in fine-grained resource management. Chapter 2 describes the concept of UCO in detail together with its model. UCO cluster and UCO chain is discussed in Chapter 3 and conclusion are given in chapter 4 finally.

1. Overall framework

The overall framework has abstracted fine-grained logistics resource management into three layers and two kind of spaces, as shown in Figure 1.

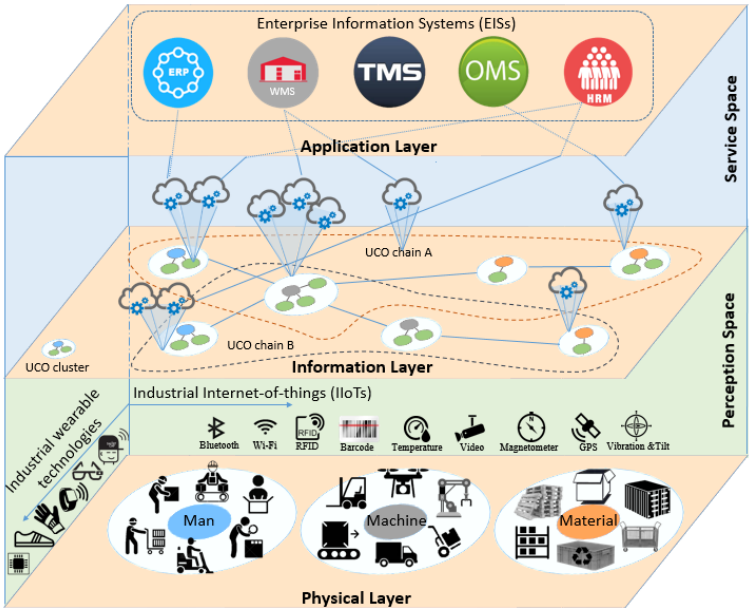

Figure 1. The conceptual framework for UCOs in fine-grained resource management.

- Physical layer

All the physical resources involved in E-commerce logistics operation belong to this layer. Fine-grained resource management aims at facilitating these resources

to seamlessly integrate with logistics operations. The fine-grained requirement is embodied in the granularity of resource objects. For human resource, each person is a resource object. While for machine, the granularity of resource object depends on the smallest controllable unit. For example, considering the automated conveyor with one controller, the controller can be treated as a resource object. The scope of machine is wide including infrastructure, facilities, equipment, tools, devices, vans and etc. Material is generally regarded as the passive resource that need to be tagged and recognized. Various kinds of carriers such as contains, boxes and pallets as well as goods are the typcial material resource objects.

- Perception space

The perception space is built upon the IIoT objects. Even though these objects are physically existed, their functions and applications are expressed in perception space. A variety of information technologies such as sensing technology, recognition technology and transmission technology are adopted to construct the preceprtion space. The rapid development of IC technology makes these information technologis easily to be integrated with traditional physical resources in the form of wearable or embedded system. So these resources could be able to be virtualized as cloud objects through the perception space.

- Information layer

The information layer focuses on the integration of fragmented data collected by resource objects into useful information. The types of information are converged in this layer. One is the expressed in the form of UCO cluster which represents the coupled relationship between UCOs. So the detailed information of a specfic logistics objects could be available for application. The other type is the working logics of UCOs or UCO clusters, which is described by UCO chain.

- Service space

Cloud service is the main form for resource sharing and applications. A UCO, UCO cluster or a UCO chain in information layer could be mapping into cloud services if they are shareable besides their fulfillments for operation. The service content is the embodiment of functionalities for its dependency. So a multi-functional resource object could be projected into several separate services. Then these services could be published, found and invoked by applications.

- Application layer

EISs and different domain systems locate in the application layer. These applications obtain resource services in the service space and bind or invoke them to fulfill application logics. So applications are the final users to use resources and the application scenarios make more requirements on service management such as the service pattern and service quality.

2. Ubiquitous cloud object

UCO is the software entity that represents physical resources in information systems. It maintains the direct or indirect connection with corresponding resource objects

including both physical resrouce objects and IIoT objects and is exposed as cloud service to be invoked by applications/EISs. So it works as the bond of physical resources and EISs. The ubiquity of the cloud object is also shown on two aspects. For the physical resource objects, the UCO should be able to virtualize, express and drive heterogeneous resources. For resource services, the UCO also should be ubiquitous for different service patterns and service modes.

The nature of UCO is agent. It encapsulates the resource objects as intelligent software agents. Zhang et al [11] has been adopted similar encapsulation using an agent-based model to wrap RFID readers into intelligent agents to be integrated with the execution systems. However, both ubiquity and sociability required in fine-grained management have not been considered in these agent-based models. So in this research we proposed the concept of UCO with its agent-based model.

The UCO model is an agent-based model that gives a conceptual framework for this kind of intelligent software agent. UCO will be created based on this model in the cloud and associated with physical resource object. A UCO consists of six core components, as shown in Figure 2. The functions of each component are briefly described as follows:

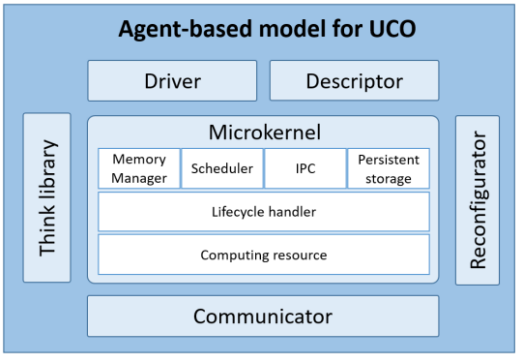

Figure 2. The agent-based model for UCO.

- Microkernel

The microkernel is near-minimum amount of software that realizes the most basic fuctions. It works as the brain of UCO to coordinate other components and enables five functions. The most important function is the lifecycle handler. It provides lifecycle management for UCOs considering the status of both physical resources and computing resources. The life status could directly influence the other four functions. The memory manager hosts the assigned memory resources and manages virtual memory according to the memory utilization and requirements. The scheduler is in charge of all the thread scheduling to perform specific tasks. IPC is required for the thread communication. Persistent storage is the file system that used to store necessary files such as configuration files.

- Descriptor

Descriptor is similar to the name card of UCO. Uniform resource identifier (URI) is used by descriptor to identify UCO and the descriptions are organized based on the resource description framework (RDF) data model. Descriptor is mainly in charge of updating the values for properties.

- Driver

Driver is an optional component which is used to drive the specific resource objects that owns the sensing ability actively. Through the driver, the microkernel establishes the physical link with corresponding resource object and realizes the remote control.

- Reconfigurator

The reconfigurator is designed to enhance the ubiquity of UCO for software running environment. So UCO could be capable to run on different systems. Reconfigurator will check the running environment for UCO and select the suitable cross-compiler to reconfigurate UCO.

- Think library

The think library realizes the intelligence of UCO. Based on the inputs given by microkernel, it could generate suggested decision parameters though rule-based intelligence. Two types of rule-based intelligence are provided. One is the rule-based expert system that rules are derived from the past experience or experts' suggestions. The other is autonomous learning-based rule which aims at learning, evolving rules practically.

- Communicator

The communicator is in charge of the external communication of UCO. Generally, agent communication language (ACL) is used for the communication between UCOs. While in most situations, the UCOs are required to communicate with external environments, for example, to exchange information with EISs. So the communicator also supports additional communication protocols via plug-in protocol modules. The specific formats of communication protocol could be configurated in the module templates.

3. Relationship network of UCO

3.1. UCO cluster

The UCO cluster refers to a set of UCOs that are physically connected together or in the closest relation. The flxible granularity of resource is enabled by UCO cluster through the flexible combination of UCOs. So the UCO cluster is similar to the UCO molecule that is comprised of multiple UCO atoms. The properties of a UCO cluster is the superposition of UCOs' properties. For example, a operator with his equipped wearable devices totally could be regarded as a UCO cluster. In additon, the UCO cluster facilitates the deployment of local network. Different from traditional computer networks, resource objects may have different communication or connection methods and their physical and logical relationships also have to be considerate in costructing this network.

Object gateway service (OGS) is then designed for the UCO cluster to build the information network autonomously. It works as the mobile device middleware that could be deployed on some UCOs which have advanced operting systems such as Android. Then these UCOs are served as the object gateways (OGs) which are capable

of managing other UCOs and sharing network services such as the 3G/4G/LTE/Wi-Fi network for them. The overall working process for OGS is shown in Figure 3.

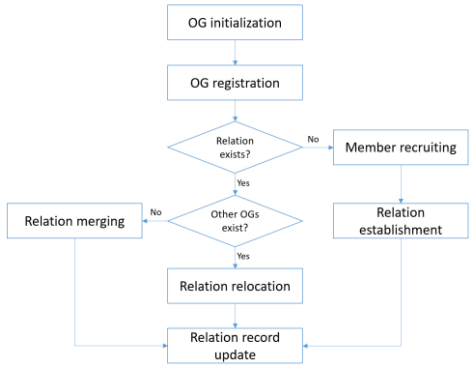

Figure 3. The OGS's working process.

3.2. UCO chain

The object chain emphasizes on integrating UCOs with operational working logics. Three steps are required for the generation of an object chain. Firstly, the definition of object chain should be made according to the specific workflow. Secondly, the UCOs or UCO clusters are required to be assigned to the nodes of the whole chain, as shown in Figure 4a. Finally, configurations should be made to ensure the data compatibility.

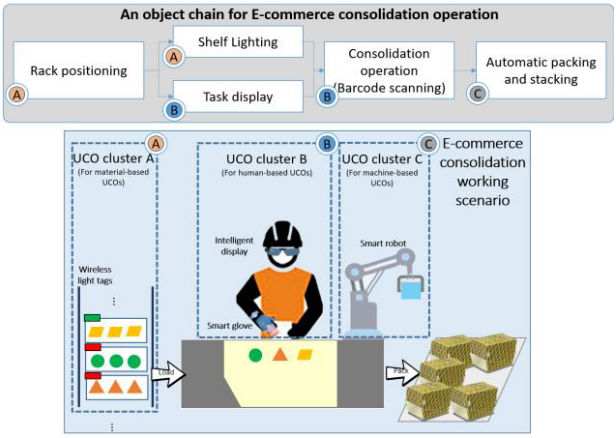

Figure 4. An object chain example for E-commerce consolidation operation.

```
func (*ResourceA) WorkNodeA(ResourceB, chFinishSignA, chFinishSignB) {
    A.RackPositioning()
    go b.WorkNodeB(chFinishSignA, chFinishSignB)
    A.ShelfLighting()
    chFinishSignA <- true
}
func (*ResourceB) WorkNodeB(chFinishSignA, chFinishSignB) {
    b.TaskDisplay()
    for {
        ch <- chFinishSignA
        if ch == true {
            break
        }
    }
    b.ConsolidationOperation()
    chFinishSignB <- true
}
```

Figure5a. The pseudocode for workflow script.

```
while(Interrupted()) {
    chFinishSignA := make(chan bool)
    chFinishSignB := make(chan bool)
    ResourceInit()
    a.WorkNodeA(b, chFinishSignA, chFinishSignB)
    for {
        ch <- chFinishSignB
        if ch == true {
            break
        }
    }
    c.AutomaticPacking()
}
```

Figure5b. The pseudocode for running script.

A workflow script will be generated according to the defined workflow as shown in Figure5a. The running script will be also generated and continued to execute if there is no interrupts as shown in Figure 5b.

4. Conclusion

The paper proposed the concept of UCO and its agent-based model to realize fine-grained resource management in E-commerce logistics. Three contributions have been made in this research. The first one is the proposion of agent-based UCO model, which virtualizes physical resource objects into UCOs. The UCOs bridge the gap between physical resource and EISs so that the physical resource objects could be easily and flexibly integrated, shared and controlled in EISs. The second contribution is introducing the UCO cluster, which achieves the flexible granularity of resources. An OGS is designed and adopted for the autonomous construction of information network. The third contribution is the concept of object chain that focuses on the integration of UCOs and UCO chains with EISs to make the easy accesses to real-time resource information.

This research could be extended in three aspects. Firstly, the optimization on OGS should be conducted considering quality and load of link in different scenarios. Secondly, a hybrid cloud platform is required to centrally manage and share UCOs in enterprise environment. Thirdly, the measurements for service quality should be proposed to evaluate the availability, reliability and sustainability for UCOs' services.

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