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Application of Complex Event Processing in the Express Business Automation

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Abstract

Complex Event Processing (CEP) is a promising technology that deals with event stream in a cenralized manner. But in some application scenario such as the express delivery business, business-related data is scattered in the network and must be obtained by request. For the purpose of resolving the difficulty to utilize and process such distributed infomation, the paper comprehensively utilizes various advanced technologies to design an automation Internet of Things (IoT) framework which can provide the rich-semantic complex events to the senior application. Firstly, this paper proposes the framework which can realize the automatic recognition of the parcel and positive request for the associated semantic data. Secondly, a hierarchical modularized ontology is established for the sake of sharing the background knowledge. Finally, we have implemented a prototype system with the proposed object and semantic event model and detection method. Test results from simulation data indicate that the system can operation stably and response quickly to express delivery business.

Keywords: *Internet of things technology, semantic complex event processing, express business automation, domain ontology*

1. Introduction

Intelligent logistics IoT has attracted the common attention of large-scale enterprises and research institutes at home and abroad in recent years. But its researche scope are mainly focused on solving the problem in supply chain domain, such as visual management, efficiency optimization and decision-making support, *etc*. However, as another important pillar one of the logistics industry, express delivery service has not attracted enough attention. The turnover of the Chinese express delivery market in 2011 reached RMB 85 billion yuan and the total business volume reached about 3.2 billion parcels. From January to September of 2012, large-scale express delivery enterprises of China delivered 3.83 billion parcels that averagely more than 20 million parcels were delivered in China every day. It can be seen that the express delivery industry facing so huge consumer groups in both the upstream and downstream demands for the safe and convenient transportation of various properties of parcels, and is in the urgent need of advanced technical support to realize the business automation.

A parcel in a flight of South Airways was burnt on October 22, 2012. It was investigated by the Civil Aviation Administration that the fire was caused by the self combustion of the slow-burning match in the parcel, whose shipper was an express delivery company. Besides,

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there was a lithium battery, also a kind of prohibited commodity, shipped by another express delivery company on the flight. It indicated that the property of the parcel was not effectively detected before the delivery. Currently the Chinese express delivery industry completely depends on the manual inspection of the parcel but it contains obvious weaknesses: on one hand, practitioners with different capabilities differ largely in the subjective determination of the dangerous commodity; on the other hand, speed is very important for the survival of the express delivery industry, so it is impractical to cost much time on opening, checking and packing the parcel. UPS, an international express delivery giant, possesses the biggest logistical port in the world and applies various advanced technologies to automatically sort the parcel, but it still faces the difficulty of detecting the property of the parcel. Obviously, following challenges block the computer in understanding all the information to complete the automatic detection without any manual operation: 1. Acquisition of the electronic information of the parcel: generally, the express delivery enterprise may only manually check the limited information (*e.g.*, shipping and receiving addresses) but may not obtain any other digital information about the content and composition of the parcel, so there is no foundation for the computer to analyze the property and type of the parcel; 2. Sharing of business environment and rule information: automatic processing of the air, railway and road transportation regulation to discover the prohibited and limited parcel requires the support of formalized business logical rule and environment information (*e.g.*, temperature and humidity of the warehouse), which may be established, collected, stored and maintained by the corresponding responsible party, but it is more difficult to share such heterogeneous information on the distributed network; 3. Feasibility architecture and scheme: relevant software and hardware architecture and critical technologies are integrated that only the perfect connection and cooperation of various aspects may realize the final target.

We utilizes IoT, semantic web and complex event processing (CEP) technologies to establish an automatic detection system of semantic complex event of the express delivery business. The system may automatically, rapidly and remotely identify the information of a large quantity of parcels on the conveyance belt by a non-contact way, share the background knowledge of many fields, and infer the events detected by CEP to produce the business semantic complex event that may be directly used in the senior application, such as the sorting line control system.

The paper is organized as follows. An overview of the state of the art of the different techniques used by the proposed system is explained in section 2. Then we put forward the system application framework model in Section 3. Section 4 describes the modeling of domain ontology using in semantic complex event processing (SCEP), while the detection of semantic complex event with data supporting from multidimensional space is described in Section 5, including event object and semantic presentation model, staged detection method, and event pattern definition. In Section 6, system performance evaluation are presented, followed by the conlusion in Section 7.

2. Related Work

Intelligent logistical IoT technology make the visual management and real-time monitoring of the whole logistical process possible. Its foundation is the support of the EDA, which supplies the application service with data in asynchronous communication mode, but the processing of the high-speed, heterogeneous and large-volume event streams coming from EDA becomes the new problem to be solved. Traditional technology(*e.g.*, Business Process Management BPM, and Electronic Data Interchange EDI) have been unable to meet the demands for the real-time event stream processing[1], thus CEP is recognized as promising technology assets.

CEP may detect the causal and logical relationship contained in the event stream by matching the pattern. Former researches focus on excavating the predefined event sequential logic by the algebraic operator from the RFID(Radio Frequency Identification) event stream. For example, [2] recognizes successive 12 single commodity events detected by the time sequence operator on the assembly line as one complex event of package, and [3] applies the interval coding to store the package relation of the parcel offline to detect more abstract complex event of package. However, it is obvious that such CEP systems may only detect limited complex event but are incapable of semantic understanding and inference of the event concept; as a result, they may not integrate the background knowledge, business rule and environment information in the event processing. Recently, the research on the combination of semantic web and CEP technology effectively makes up the above-mentioned defect that the introduction of the ontology strengthens the deductive reasoning of the CEP technology.

Ontology, the normative explanation of the conceptual model, has been more and more applied in the computer knowledge engineering to deal with sharing and reusing of the knowledge. In terms of ontology constructing, Teymourian.k[4] points out that introduction of ontology and rule is a critical path to solve the non-event correlation and high-layer business abstraction in CEP, and releases the modularized model of the ontology that is widely quoted in subsequent researches. Detailed steps of establishing the logistical ontology have been instructed in [5]. Further works pay special attention to the establishment of the ontology of the logistical environment in order to extend the detection scope of CEP[6]. In terms of ontology utilizing, a event processing language (EPL) which uses ontology to annotate the event pattern semantics has been described in [7], so as to enables to dynamically change the event pattern according to the logistical environment. Following the basic concept of semantic extension of the critical part of the rule and event by the rewriting technology, [8] links the event processing with the semantic inference by the intermediate conversion method to keep the processing capability of CEP system. Additionally, some efforts hava been made to merge the static information extracting from database into dynamic event stream to conduct the event detection[9, 10].

Overall, introduction of ontology strengthens the detection capability and scope of CEP, and introduction of SCEP solves the problem of the business data stream processing in the logistical IoT. However, above researches also face following problems: 1. Application area concentrates in the supply chain management but there is no specific application related to the express delivery industry; 2. There is no effective method of integrating the ontology and presenting the event semantics during the CEP processing; 3. Compared with traditional detection methods such as automata[11] and Petri-Net, it is obviously less efficient to infer by the concept of ontology, but there is no method to balance the efficiency and capability of the detection at present. Different from previous researches, the present system comprehensively utilizes the advantages of IoT, semantic web and CEP technology, and overcomes the shortcomings discussed above. It is not only able to get supporting data from hyperspace, but also integrate domain ontology into CEP processing without prejudice to the detection efficiency of the automata.

3. Express Business Data Flow Processing Framework

The express delivery begins from the sorting and its main business is completed in this procedure. Therefore, we proposes the express delivery IoT automatic data acquisition (EIADA) framework basing on EDA as shown in Figure 1. This framework may detect the parcel property and apply the transportation rule to rapidly produce the relevant business complex event to effectively control the classified processing of the parcel.

The framework generally consists of three layers, namely, physical layer, business event processing layer and application layer. The physical layer includes RFID tag and reader. RFID tag in the inactive and plane design is attached to the back of the waybill, and it can be removed and used again by the deliverer when the parcel is successfully delivered. Contents stored in the RFID tag are generally in the electronic product code (EPC) mode, which shall be allocated by GS1 of International Organization for Standardization that for certain cost and is mainly applied in the commodity circulation, so this paper stores both the waybill number and the e-commerce order number in the tag for following advantages: 1. Chinese express delivery enterprises have been utilizing the independent waybill with 10-13 bits for a long period that the direct use is favorable for the business compatibility and system migration; 2. E-commerce order number is related to the property information of parcel in the database that necessary date for the express business processing may be directly obtained from different e-commerce database servers by collecting the order number; 3. Order number may group and link relevant events in the CEP system, and order number may become the sole identification of the parcel during the transportation and the sole tie between the digital system and the physical world.

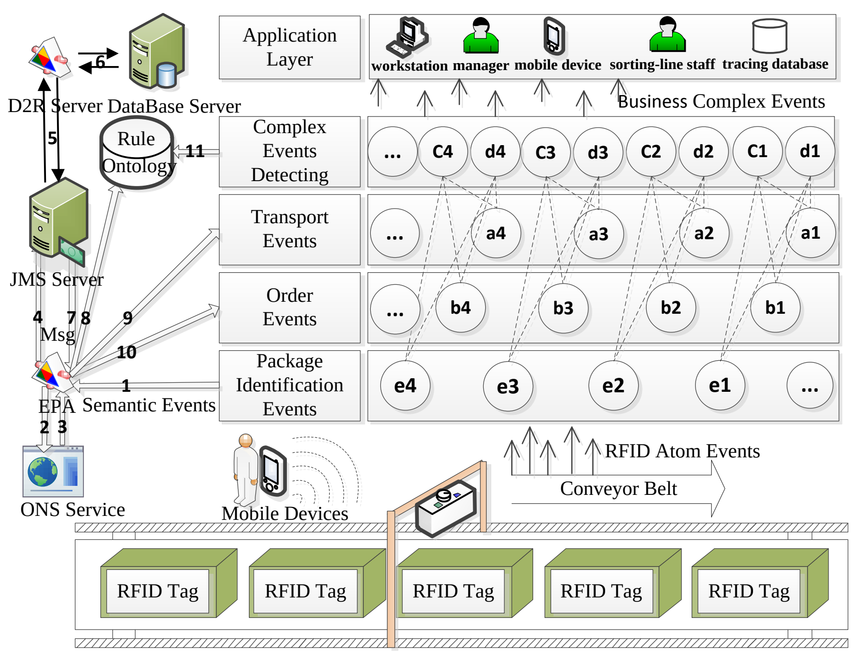

Figure 1. Express Business Data Flow Processing Framework

The intermediate layer includes two parts, namely, event processing agent (EPA) and semantic complex event processing engine(ESCEP-E). EPA is a significant auxiliary component of ESCEP-E that it plays an important role in the processing. Specific process of the intermediate layer is narrated as follows: firstly, ESCEP-E continuously receives the RFID parcel detection event from the conveyance belt (or wireless terminal) and sends the tag data to EPA. EPA inquires the server address of the waybill number contained in the tag from the object name service (ONS), and ONS judges the coding rule and returns the corresponding IS information. Upon receiving the asynchronous request about the commodity properties from EPA, the e-commerce server returns the results (including: all related semantic information about commodity, transaction, seller and purchaser) to EPA in the serialization format of Resource Description Framework (RDF). Whereafter receiving such data, EPA binds it with the corresponding domain ontology and processes it by the rule to seal the result to some object events, and send them to ESCEP-E later. ESCEP-E stores all the received event stream in the same buffer array and sets a sliding window in the detection process. Any parcel, which timestamp is beyond the time window, that cannot be detected with any normal sequence will be sent by the conveyance belt to the end-point for manual opration. As for the event detected with the sequence of e->b->a, ESCEP-E will utilize the ontology and rules to automatically infer that whether b is the dangerous commodity in the transportation mode provided by a. If so, it will send alarm complex event to the control terminal to control the conveyance belt to put the parcel in the stack to be rejected. If not, ESCEP-E will send the transportation complex event to the control terminal to enable the conveyance belt to produce the corresponding notice according to the characteristic of parcel (*e.g.*, fragile, or liquid) while automatically sorting the stack by province and city. For example: when the parcel with any fragile object is put into the stack, the red alarm light flashes, and when the parcel with any valuable object is put into the stack, the green alarm light flashes for the sorting worker to separately stack the special parcel for the convenience of inspection. Any package failing to meet the freight standard may be added with the plastic or foam package.

The application layer subscribes and receives the business complex event that can be directly used from ESCEP-E, makes swift decisions, sends the control commands to the sorting line according to the business reaction to complete the corresponding operation of the parcel, and provides dashboards to the user. Besides, it also stores the events for the later tracking sevice of the parcel.

4. Express Business Ontology Modeling

The business rules of express delivery are difficult to distinguish with that of other industries. For example: air and railway departments clearly define the type of prohibited commodity in the freight regulations, which is not determined by the express delivery industry but is closely related to its business. For purpose of making the domain knowledge to be shared and used among different platforms and application programs possible, EIADA extracts the knowledge model by the ontology.

Since OWL(Web Ontology Language) is quite expressive, supports the inference and is able to accurately define the complex event, so we regard OWL as the presentation language of the ontology, adopt Protégé in the modeling and conduct the deductive reasoning by Pellet. Besides, in order to effectively integrate the knowledge of things attribute, transportation vehicle, and freight regulation into the CEP and achieve the goal of flexible, scalability, maintainable and high-efficiency using such knowledge, we apply the layered modularized structure to establish the domain ontology. As shown in Figure 2, the ontology is divided by modules such as event, common, logistics and express delivery domain, and aligned by the statement about the concept and the instance. The domain ontology is established by the universal seven-step classification method and maintained by different groups. For example: the express delivery domain ontology is established by the express delivery company, the logistical domain ontology is established and improved by the air, railway or road transportation company, and the common domain ontology is established by the e-commerce.

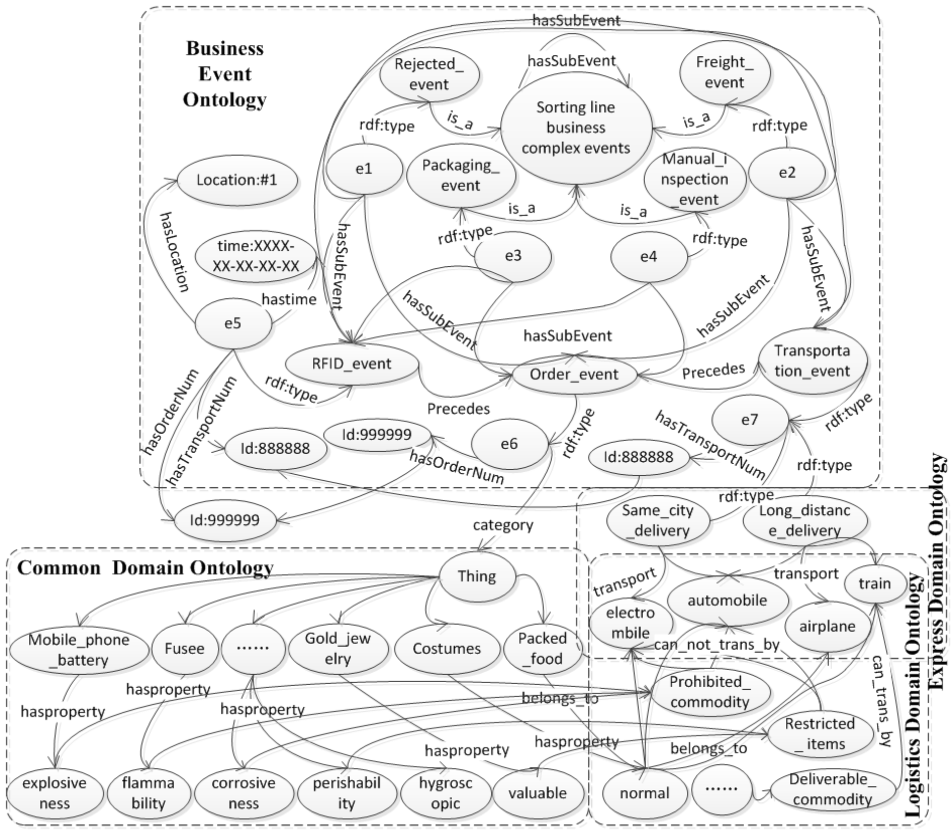

Figure 2. Express Business Ontology Model

Since the standard classification method of the Harmonized Commodity Description and Coding System(HS) is systematic, universal and accurate, the common domain ontology, which is established on the basis of the HS, is the most comprehensive one by now[5, 12]. However, the express delivery industry pays more attention to the composition and natural property of the commodity while the e-commerce trader only pays attention to the classification management; as a result, many classes in the above-mentioned ontology are not involved in the express delivery business. Therefore we follows the principle of classification by the natural attribute to divide the things in the common domain ontology into 18 major classes and 77 minor classes. Different types of class are annotated with different properties and a class instance may inherit all properties of the major and minor classes it belongs to by reasoning. For example: digital products include office device, laptop, mobile phone with battery and digital camera, which are fragile in the transportation, so the property of this class is annotated with 'hasProperty dropped_bust'. Besides, lithium battery of the mobile phone is explosive and the laptop is valuable, so any mobile phone with the battery may inherit fragile and explosive properties, while any laptop may inherit fragile and valuable properties.

The logistical domain ontology contains transportation regulations about types of vehicles and transportable goods. Figure 3 only shows certain part of the ontology used in the EIADA due to the limited space. It is shown that available transportation vehicles include airplane, train, automobile and electrombile, and each vehicle possesses its own type of deliverable and prohibited commodity. For example: inflammable, explosive, fragile and valuable commodities are prohibited to transport by the airplane.

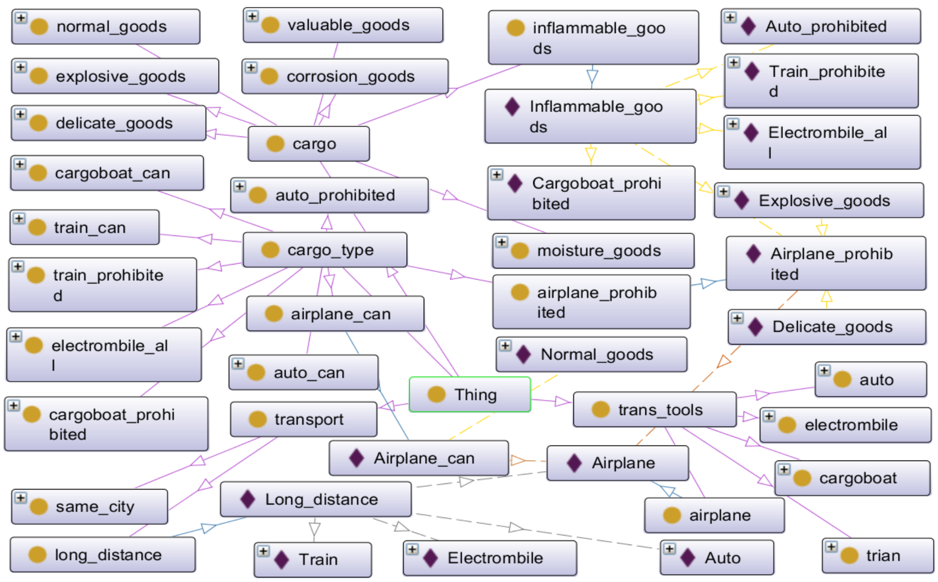

Figure 3. Exhibition of Part of the Logistical Domain Ontology

5. Semantic Complex Event Processing

5.1. Event Presentation Model

The event model of ESCEP consists of two part. One is object event model: e={(attributen, valuen)}, modeling the instance entering into the local express bussines system, which consists of N properties of the key and vaule pairs. Another one is semantics event model: e={(subject, predicaten, objectn)}, modeling the instance staying on the network server, which consists of N statements concerning one subject. The mutual conversion between the two kinds of event models may guarantee the independent work of the semantic web and CEP technology, and act as the communication bridge between these two technologies.

Advantages of this event presentation model: 1. It fuses multidimensional events: when ESCEP-E receives the input event stream, it insert it into the semantic request stage to acquire external relevant business data from the multidimensional space, so when such data is conversed to the object event and inserted into the event stream buffer array, ESCEP-E can handle them in a one-dinensional menory space. 2. It guarantees high processing efficiency: when ESCEP-E detects the event sequence, it inserts it into the business logic detection stage to strengthen the event semantic inference without influence on the processing efficiency of the traditional CEP; 3. It maintains the function modularization: relevant events may be rapidly filtered by the pattern matching that the group of events are integrally conversed to an independent semantic space to be bound with the corresponding domain ontology, and then they are wholly closed after the interference, thus constantly ensuring the modular processing.

5.2. Event Pattern Definition

It can be inferred from the characteristic of ESCEP-E that the definition of the event pattern consists of two parts. A part of this paper defines the pattern of the object event by the SQL-like declaration language, and the other part of this paper defines the semantic event pattern by the SWRL (Semantic Web Service Language). Structure of the object event pattern definition language is shown in Table 1.

Table 1. Object Event Pattern Definition Language and its Example

	Example:
Event [object event pattern]	Event SEQ(RFID_Event e, Order_Event b, Transportation_Event a)
Where [restriction on object event]	Where e.OrderNum=b.OrderNum ∧b.OrderNum=a.OrderNum
Within [time value]	Within 4000
Return [SPARQL inquiry]	Return [select ?subject (?subject enwrap:hastrigged true)]

The semantics of the language are briefly described as follows: The Event clause specifies an event pattern to be matched against the input stream. The Where clause imposes value-based constraints on the events addressed by the pattern. The Within clause declares a sliding window over the event pattern. The Event, Where and Within clauses form the event matching block. The Return clause detects what semantic complex events have taken place and transforms the result to the object event for final output. Meaning of the example is: ESCEP-E checks whether there is the sequence of e->b->a in the specified 4 seconds, among which the event of e, b and a contain the same value of OrderNum. In the sequence, e refers to the RFID detection event type, a refers to the order event type and b refers to the transportation event type, and if the sequence exists, it shall check what semantic complex events have been triggered, and the instance whose property value is true shall be conversed to the object event to be stored in the output stream.

Since SWRL strengthens the presentation capability of OWL, it is easy to conduct the comparison, conversion and computation, and define the complex business logic. Therefore, this paper specifies the rules by SWRL, which present not only the business regulations in each field but also the semantic relationships among event concepts. The rule example using to check express type is given blow.

TransTypeChecking:
enwrap:buyer_city(?b,?bc)^enwrap:seller_city(?s,?sc)^enwrap:order_buyer(?order,?b)^enwrap:order_seller(?order,?s)^swrlb:equal(?bc,?sc)->enwrap:hasTransType(?order,'same_city')

6. Implementation and Experimental Results

The EIADA framework indicates that the system's implementation should be composed of multiple parts. System software operates on the hardware of e-commerce database server, massage server, EPA and event processing middleware, and the total work time consists of the accumulated time of asynchronous network transmission, semantic data inquiry and ESCEP-E execution. We take win7, Mysql5.5, Intel i5-2500K 3.3GHz and 4G memory as the experimental environment to simulate the actual operation of the sorting line (parcels are arranged on the conveyance belt with intervals) to constantly produce the RFID detection event stream with no more than 1s of interval, and test every part of the system.

6.1. Conversion Between Object Event and Semantic Event

This experiment conducts the mutual conversion between object event model(Java object) and semantics event model(RDF instance) by JenaBean[13], declares the mapping relation between JavaBean property and RDF property by Java annotation, completes the transformation from POJO(Plain Old Java Object) to RDF by Bean2RDF and completes the inverse transformation from RDF node to POJO instance by RDF2Bean. An example of transformation from a RFID tag event to the RDF semantic event is shown in Table 2.

Table 2. Result of Conversion from a RFID Event to the RDF Semantic Event (N3 Format)

```
@prefix enwrap: <http://net.express.enwrap.org/0.1/> .
<http://net.express.enwrap.org/0.1/RFIDTag/10000000008> a enwrap:RFIDTag ;
enwrap:hasEventType "RFID_Event"^^xsd:string ;
enwrap:hasOrderNum "20000000008"^^xsd:string ;
enwrap:hasTimeStamp "1358481793189"^^xsd:string ;
enwrap:hasId "10000000008"^^xsd:string .
```

We assume that the RFID reader sends the latest data of parcel entering the scope of writer to the intermediate layer once a second, and in view of the regularity that the simulated input stream is composed of the data randomly selected in the interval of [100,1000]ms, the intermediate layer receives [1,10] RFID object events every time (it varies along with the actual operation speed of the sorting line). The experimental results can be seen from Fig. 4 that the conversion speed of a single event grows slowly mainly due to the influence of the number of property but seldom due to the content of property, and the overall conversion speed of multiple events is largely less than 1 seconds, so the system may complete the conversion before receiving the data from reader next time.

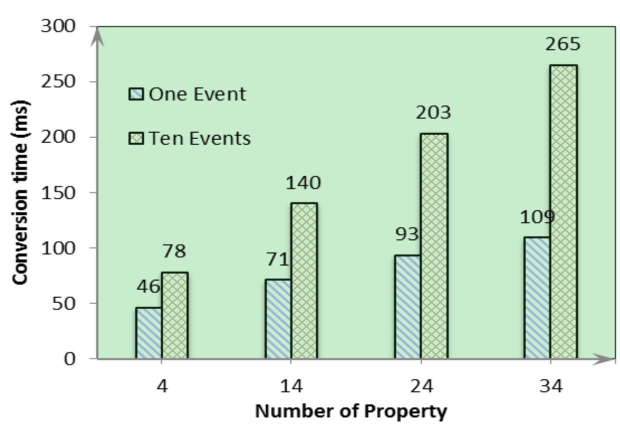

Figure 4. Conversion Time between Object and Semantice Event

6.2. Request and Inquiry of the Parcel Semantics

In the actual operation process, an e-commerce database server responds to many requests from various sorting lines simultaneously, and parcels on the same sorting line come from different e-commerce traders. It is obvious that under such multiple-to-multiple communication mode, it is critical for the system to guarantee the parallel, efficient and unblocked data transmission. Our experiment adopts the ActiveMQ massage bus, an open source implementation of JMS (java message service) asynchronous massage communication mechanism, to carry out request handling on the JMS server. The data from the EPA stores to the request queue firstly. JMS server inquires the parcel semantics according to the order number of the request in the queue by the FIFO (first input first output) principle, and then it serializes and stores the results in the response massage queue for the EPA to pick and conduct the subsequent processing.

Our experiment realizes conversion from relational data to the semantic model on D2R server by the D2RQ[14] tool, which enables the e-commerce trader to release rich information in the form of RDF while maintaining the invariability of the back-end relational data. Figure 5 shows the specific mapping relationship of such conversion, in which tables of order, buyer, seller and commodity respectively represent the four core business of the e-commerce. Through the declaration of mapping definition like :ClassMap, :PropertyBridge, and :refersToClassMap, the e-commerce database will be mapped as a virtual RDF graph model, and the application program may be later inquired in the DESCRIBE mode of SPARQL(Simple Protocol and RDF Query Language) to obtain the complete linked data of an order.

Figure 5. Mapping Relationship from E-R Data Model to RDF

6.3. Detection of Business Semantic Complex Event

ESCEP-E prototype system is realized by extending function modules like the event model conversion and deductive reasoning on the basis of SASE [11], so it completely inherits the temporal and logical detection capability of the traditional CEP. Since there are many stages of conversion, request, inquiry, extracting and production of the object event after ESCEP-E receives the RFID detection event, we set the sliding window of ESCEP-E as 4s after testing the processing time of a single event in every stage(conversion costs 45-50ms, request costs 60-70ms, inquiry costs 810-840ms and event production costs 1,590-1,640ms) and the overall processing time of this section(2,850-2,880ms). Furthermore, we simulate 1,00 items, and respectively produce 1,00 parcel records for each item. System output 1,0000 semantic complex events, and the average detection time is 4470(ms). It can be proved that ESCEP-E can process express business events quickly and accurately.

7. Conclusions

EIASS Framwork, which is proposed in the paper, can effectively integrate related information distributed in the network, providing support for the express delivery business automation. ESCEP-E, which combins the ablility of complex event processing and ontology knowledge sharing, can detect business logic events with high-level semantics, providing decision making support for application such as logistics sorting line. Our next step will focus on the efficiency of the system (e.g., reduction of the event model conversion time) and the data semantic conversion of more data format (e.g., XML) on the network.

Acknowledgements

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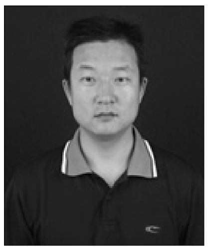

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