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RFID Middleware Benchmarking

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Abstract

This working paper presents our initial efforts to develop a benchmarking methodology for RFID middleware. In the paper, we conduct a context analysis to help focus the benchmarking on the right middleware features and metrics. Pairwise based workload generation is proposed to minimize the efforts and optimize the usefulness of the workload generated. A value driven benchmarking analysis framework with various patterns defined makes the benchmarking results comparable on either workload, RFID middleware capability, or the value the RFID Middleware has toward the value net.

Keywords:

RFID, middleware benchmarking, Quality, Value

1. Introduction

E-Logistics and Supply Chain Management (SCM) involves participants from a worldwide network of suppliers, factories, warehouses, distribution centers, retailers, and service and solution providers. This demands e-logistics infrastructure and networks that can support interconnections among these participants, and enable them to collaborate in an efficient and effective manner. It should support agile and responsive logistics planning and business decisions by enabling the use of timely information available from logistics participants' information systems. Radio frequency identification (RFID) technology is expected to become a critical and ubiquitous infrastructure technology for e-logistics and SCM related processes and services. It promises automatic data capturing and entering and makes it possible for real time information visibility for supply chain and logistics participants.

Further driven by the global market players like Wal-Mart, RFID poses a positive market future. We have seen development activities for RFID tags, readers, middleware systems, related standards and their deployment. Due to the complexity of RFID technology, and potential application domain including supply chain and logistics, a great concern over the RFID technology and standard development is interoperability. Such interoperability can also help to drive the RFID technology adoptions to a level such that RFID potential benefits can be materialized. Toward this direction, RFID benchmark development fits in and paves the road to analyze the RFID technology space and business market. In this working paper, we focus on benchmark development of the key components in RFID technology space, RFID middleware. The work of this RFID middleware benchmarking is targeted to yield a practical-to-use RFID middleware benchmarking methodology through a research oriented development roadmap.

In this paper, we will present several key benchmark criteria for RFID middleware with necessary evaluation over the RFID technology adoption and deployment. The outline of this paper is as follows. Section 2 motivates the need for RFID middleware benchmarking and reviews related work. In Section 3, we will identify the research problems in RFID middleware benchmarking. Section 4 will explain our methodology development. In Section 5, we will present the evaluation framework for the benchmarking. Section 6 will conclude this working paper.

2. RFID benchmarking

RFID technology space includes RFID hardware (tags, readers), middleware, and enterprise applications. There are a few RFID hardware test activities in the world. ODIN technologies is a company that has conducted independent, scientific benchmark analyses of EPC-compliant RFID tags, and readers [7]. RFID Alliance Lab, housed at University of Kansas, is a not-for-profit testing facility that provides objective test reports on RFID equipment, utilizing the combined expertise of its partners [8]. There are industry companies to incorporate RFID test into their product test domain, including Sun Microsystems. To the best of our knowledge, our work pioneers in the area of RFID middleware benchmarking. We have not come across any RFID middleware benchmarks.

In the market, there are existing middleware benchmarks and benchmarking frameworks (e.g. ECperf, JMeter, Load Runner, OpenCB, OpenSTA, RUBiS, etc.) [1]. Middleware benchmarking initiatives and standardization efforts (JCP, SPEC, TSS and others) also exist. Problems with these middleware benchmarking methods include:

- Fragmented. Due to the nature of middleware, many benchmarks center on specific middleware products. The benchmarking methodologies tend to be piece meal, lack holistic view on middleware benchmarking. This has made it difficult to reuse the existing methods and tools for new middleware.
- Hardly comparable. The benchmarking methods and their benchmarking results are hardly comparable, due to the different model to construct the test and benchmarking. It lacks interoperability to interpret the benchmarking results derived from different benchmarking methods.
- Proprietary testing suites. Companies tend to develop their own test tools, and rarely to release these tools to the public.
- Misinterpretation against scenarios. Scenarios are used to drive the benchmarking and test. Due to the difference among benchmarking model and methodologies, scenario construction lacks necessary annotation for better interpretation.

All of the issues and problems have made it difficult to apply the existing middleware benchmarking methodology to RFID middleware benchmarking. This has motivated us to develop a benchmarking methodology for RFID middleware, while avoiding falling into swarm of the issues/problems identified above. However, we have to admit that we have not yet solved all the problems.

3. Context analysis

Problems in a single middleware benchmarking activity also exist, such as 1) incorrect selection of metrics, 2) artificial workload, 3) feature interference, 4) dependence ignorance. All of these problems are partly due to the lack of consideration for the benchmarking context. A benchmarking context includes 1) the metrics for describing the benchmarking target, 2) environment that the benchmarking target depends, and 3) input workload for the benchmarking. The challenges, i.e. the research issues, often exist in the benchmarking context. Thus, performing a RFID middleware benchmarking context analysis is necessary. A context based RFID benchmarking system is illustrated in Figure 1.

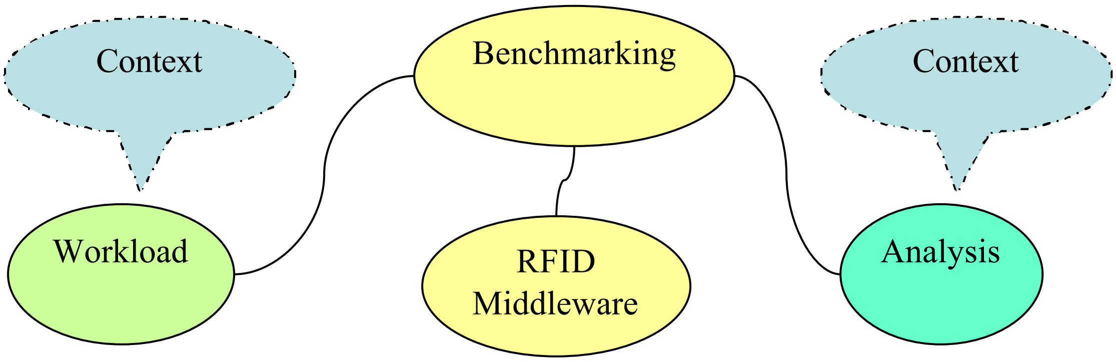

Figure 1. Context based RFID benchmarking system

In the context analysis, we have to identify the challenges to the RFID middleware capabilities. In the RFID technology and application domain, the challenges of data streaming, reactivity, proliferation and heterogeneity for RFID middleware systems we faced in e-logistics and SCM systems today have posed a new set of requirements for the development of the RFID middleware benchmarking.

3.1. Streaming

A wide variety of monitoring sensors like RFID devices are increasingly becoming cheaper while their deployment is increasingly wider. It is now increasingly important for many e-logistics and SCM systems to perform continual intelligence analysis much sooner than before. Given the streaming nature of data and the fact that the data might be redundant, even unreliable in certain cases, the RFID middleware systems must be capable of working in such environment to process such unreliable real time sensing data.

3.2. Reactivity

RFID and related technologies have promised real time global information visibility for e-logistics and SCM participants. To benefit from such visibility, the e-logistics and SCM participants have to be able to identify the interested situations and react to such situations when they happen. The events associated with the triggers have to be reported in a timely manner and notification has to be sent to interested e-logistics and SCM participants. This requires that we have to design the RFID middleware that manage the sensing devices and their data streams to scale up.

3.3 Integration

There are different types of RFID tags, and readers. Each RFID device will have an RFID middleware system in between to interface with business systems, requiring specific middleware functions, or data stream formats and semantics. This leads to the proliferation and heterogeneity of middleware systems for RFID devices. Furthermore, the change or removal of one sensing device usually requires removal of associated middleware systems and putting it into another middleware system. Thus, the system integration and maintenance burden increases with the number of choices of the middleware systems available to interface with the logistics and SCM systems.

4. Benchmarking methodology

Toward driving to the direction to facilitate new insights into the evaluation of RFID adoption, we develop the RFID middleware benchmarking methodology according to the unique characteristics and capabilities of the RFID middleware:

- Streaming
- Reactivity
- Integration

The level of capabilities can be defined and classified. To reach to each capability level, we have to set up different benchmarking contexts. In a benchmarking context, the capabilities usually involve many features of the RFID middleware. Thus, it is necessary to generate corresponding workloads with these features for the capability driven test and benchmarking. Dimensional size of these features such as data rate, data redundancy rate, data error rate, environment like operating system, application server, networks, is large enough to prevent complete workloads with all the combinations of the features to drive the benchmarking test. We have to resolve to use pairwise techniques [2, 3, 4, 6] to filter the feature combinations to generate workloads that are reasonable to derive trustworthy and meaningful RFID middleware benchmarks.

4.1 Pairwise analysis

The application of pairwise techniques in our RFID middleware benchmarking is based on the following observations. Let's use scalability as one of the metrics for describing the RFID middleware functions and performance. In the test of scalability, we can control the data rate of the data stream, error rate in the data stream, data redundancy rate in the data stream, number of readers interfacing with the middleware, types of the readers, and the configurable parameters of the RFID middleware, etc. There are also things that we can not control, such as the interfaces provided by the RFID middleware. We generally filter out these features that we cannot control. And to simplify our description, we use data rate, data error rate, and data redundancy rate to illustrate our observation on pairwise analysis.

The data rate of the data stream fed into the RFID middleware varies. It actually associates with RFID applications. For example, real time RFID applications tend to require a middleware to process a higher data rate of the data streams. The data error rate affects the RFID middleware's scalability. Some data errors even will crash the RFID middleware. The data redundancy rate apparently will affect the RFID middleware scalability as well, challenging the data filtering capabilities of the RFID middleware. We have to examine the dependencies among these three features. If some features are dependent, then we could group them and count them as a single feature in the pairwise analysis. In this example, we can easily identify that these three features are actually independent of each other. Since data rate is unbounded, we have to give it a celling for the pairwise analysis. After celling, we can cut the data rate into several sections, in association with different application needs. Say we have 10 different data rate for the RFID middleware. For the error rate and redundancy rate, we have to perform similar celling mechanisms. If, through the celling mechanism, we have 10 different error rates, and 10 redundancy rates, all possible combinations of the data rate, error rate, and redundancy rate will be 10*10*10, i.e. 1000. In these 1000 combinations, we can identify pairwise pairs through pairwise identification process [2, 3, 4, 6]. These pairs will help use to test the RFID middleware by including often encountered data stream patterns.

4.2 Workload generation

Data stream patterns are just describing the technological aspect of RFID middleware. To describe the RFID middleware workload, we have to consider patterns in application, industry, standards, besides technology itself (see Figure 2).

Applications of RFID middleware are strongly associated with the workload. Industry sectors often have impacts on the workloads for their industry wide requirements. Standards often affect the functions as well as performance of RFID middleware. Technology implementation and execution environment directly determines the RFID middleware function and performance.

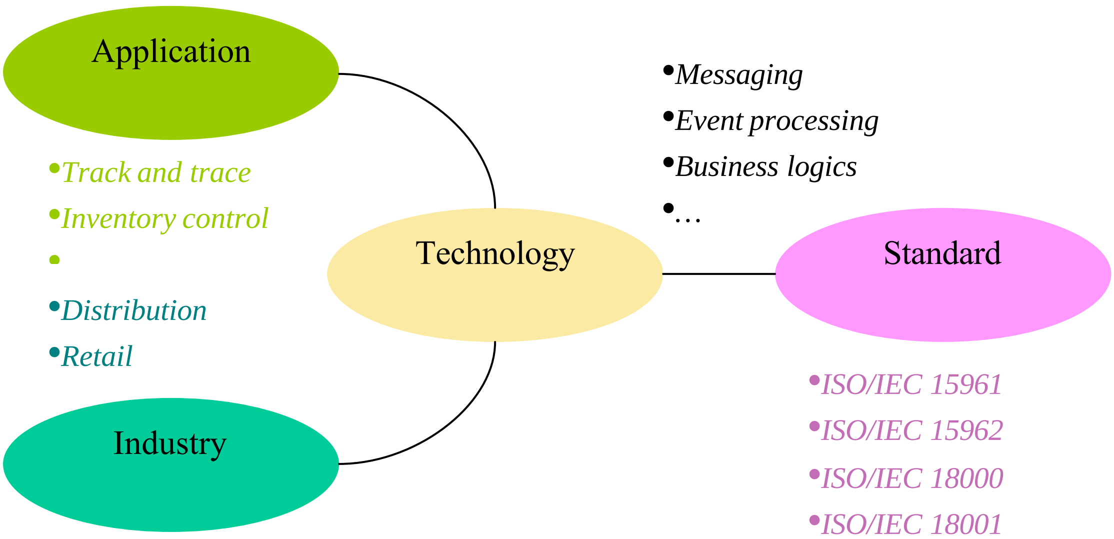

Figure 2 Workload pattern components

To facilitate the workload generation, we perform the following steps:

- Identify the patterns of application, technology, industry, and standards;
- Identify the controllable elements in them and apply celling process for their features;
- Analyze the dependencies among the features in each of them;
- Analyze the dependencies among the patterns of application, technology, industry and standards;

- Get pairwise combinations through pairwise processing;
- Generate pairwise matrix for workload generation.

The actually workload generation process is driven by a small set of real data. Then according to the pairwise matrix, we can randomly generate a large number of test workloads by setting different values for the features in the pairwise matrix. If we can foresee any additional benchmarking and test combinations to be done, we can include them into the generated workload.

5. Value driven benchmarking analysis

As found in [1], reported research and development activities in middleware benchmarking focus either on benchmarking to aid in the design of middleware, or on benchmarking to evaluate middleware. However, the evaluation of the benchmarking methodology is equally important, especially for this RFID middleware benchmarking. When RFID is gaining penetration into various application domains (e.g. e-logistics, SCM, etc.), the benchmarking evaluation has to be performed to a level to consider application impact. We take a value driven analysis approach to this benchmarking evaluation. A value net is shown in Figure 3.

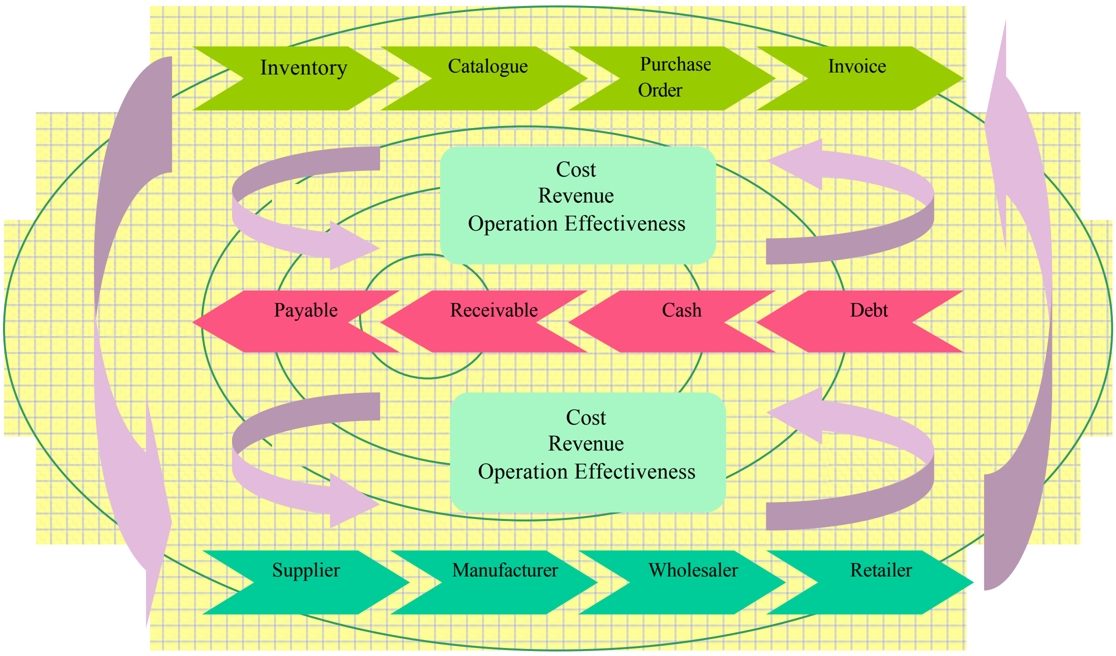

Figure 3. Value net for RFID middleware benchmarking

5.1 Quality of Workload

Quality of Workload (QoW) is the quality for workload patterns with the pattern combinations of technology, industry, application and standard. The quality is derived through benchmarking exercise, and result regression analysis. It is associated with the capability obtained for the RFID middleware.

5.2 Quality of Service

The metrics for the RFID middleware are under the umbrella of Quality of Service (QoS). This QoS includes functional metrics (e.g. hardware interface capability metrics, application enablement capability metrics etc.) and non-functional metrics (e.g. throughput, scalability, etc.). The QoS will be fine-tuned through pairwise analysis (to optimize the efforts in workload generation) and benchmarking result regression analysis (to understand the relationships among the metrics). The QoS is obtained through benchmarking driven by specific workload patterns, i.e. QoS is linked with QoW.

5.3 Quality of Value Contribution

Quality of Value contribution (QoV) is used to evaluate how big the contribution of a QoS or a single metrics has toward the element in the value net (see Figure 3). QoV usually includes measures for cost, revenue, operation efficiency, etc.

5.4 Benchmarking development

Now we are ready for benchmarking development. When we conduct workload generation analysis, we have to identify the patterns for the workload. Similarly, we can derive benchmarks for the patterns of e-logistics and SCM, in short, SCM patterns. Each SCM pattern will be associated with QoV and QoS. A QoV for a SCM pattern means the value demand for the RFID middleware. Corresponding QoS that meet that QoV can be found by tuning the metrics in the QoS. Thus, we can use QoV to uniquely define a RFID middleware benchmark. And of course, among QoV, QoS, and QoW, if we know the value of any one, we can find out corresponding values of the other two. The relationships among QoW, QoS, and QoV are illustrated in Figure 4.

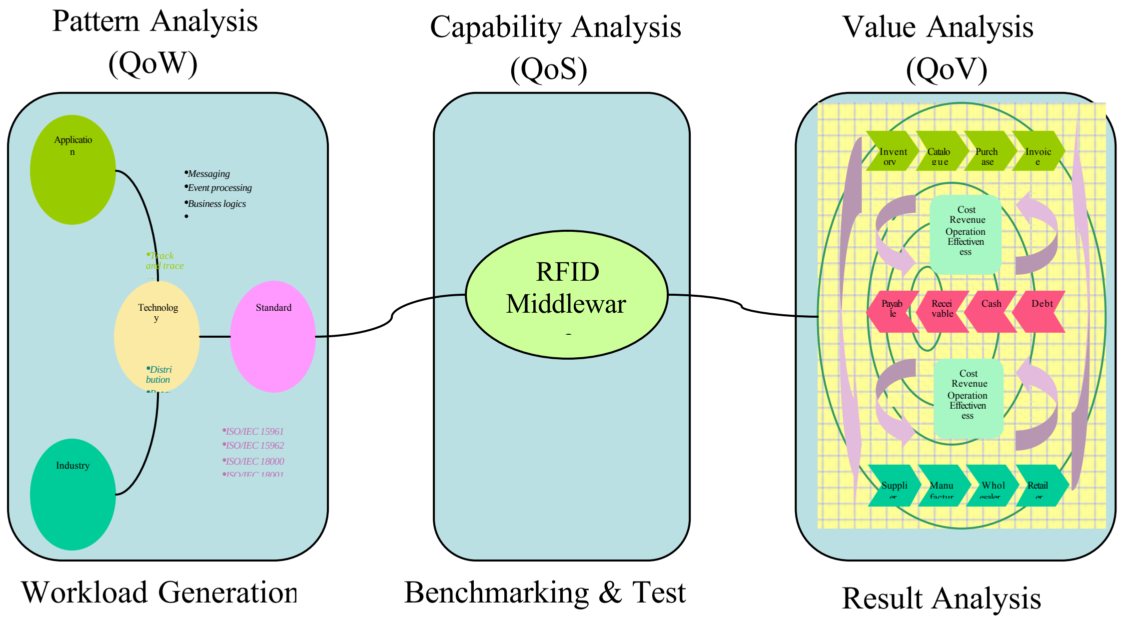

Figure 4 QoW, QoS and QoV relationship

6. Summary

In this paper, we have developed a methodology for RFID middleware benchmarking. Contribution of our work includes our proposed context analysis, pairwise based workload generation, and value driven benchmarking analysis. The context analysis helps steer the benchmarking to focus on the right features and metrics. Pairwise analysis optimizes the workload generation efforts. The value driven benchmarking links the QoV with QoS, i.e. links the value with capability.

When we use QoV to denote the value demand for RFID middleware, through benchmarking exercise, we can find RFID middleware systems with QoS matched. When a RFID middleware has a QoS label, we can always calculate its corresponding QoV. Likewise, we can have similar operations among QoS and QoW. This way, we have made our benchmarking comparable on any of the three, workload, middleware capability, or value, with others.

This is a piece of work in progress. Although we have gone through storyboard analysis of our benchmarking methodology, we find it necessary to go though quantitative analysis to evaluate our benchmarking methodology in case studies. We are making progress in this direction. Furthermore, it is also beneficial to have a knowledge repository to store the benchmarking context, workload information, value net, QoV, QoW, and QoS, etc. Then we can use the benchmarks obtained to construct analytic models (e.g. [5]) to analyze and predict RFID middleware's QoS and QoV.

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