ENHANCING RELIABILITY IN RFID COMPLEX EVENT USING HASHED BASED APPROACH

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Ahmad Sayf Bin Ahmad Rifa'i

All praise to Allah. You were born on the night after mommy submitted this thesis for viva. Daddy is always by my side, making sure mommy is in the best condition while completing this thesis and delivering you safely.

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ABSTRACT

Complex Event Processing (CEP) is a technology used to describe a mechanism for processing information from the raw data processing layer to higher-level data processing. Complex situations such as intrusion or business activity can lead to uncertain and unknown tags makes data stream become unreliable. In this research, hashed based approach is used as it is known for its efficient searching and better synchronization data structure. This research proposed two approaches using the hash-based techniques to enhance the CEP engine in the Radio Frequency Identification (RFID) distributed system. The first approach detects unknown tags from the raw data processing level. Existing solutions irrelevantly interrogate all the tags in the system. Hence, a novel unknown tag detection algorithm (SWOR) is proposed. The key novelty of this technique is to build an algorithm that uses a modified sliding window and bitwise XOR filter to avoid the interference of known tags to unknown tags. Real dataset from supermarket warehouse is used to detect unknown tags. The second approach detects the uncertain condition in the RFID CEP level. Previous approach such as probabilistic approach leads to high memory consumption and low detection efficiency of RFID event detection. To solve this issue, uncertain detection algorithm (UDA) approach was proposed. The proposed approach is based on the hashing and threadpool technique to solve long processing times, high memory consumption and low event throughput in the current processing approaches. Real dataset from pharmaceutical company is used to detect uncertain event. In this research, the research design is based on quantitative and using quasi-experimental method. Experimental results showed SWOR algorithm achieved the lowest false positive rate of 9.99% and the highest accuracy of 99.18% compared to other approaches. UDA algorithm is 3.2 times faster than the baseline approach and achieved 100% accuracy with low memory consumption compared to previous approaches. Thus, this study successfully proposed approaches to enhance the RFID CEP in the distributed system.

ABSTRAK

Radio frekuensi identifikasi (RFID) ialah teknologi identifikasi automatik yang menggunakan gelombang radio untuk mengenal pasti dan menjejak objek fizikal tanpa penglihatan. Disamping memberi kebaikkan dalam pelbagai aspek, keperluan industri seperti kitaran hayat yang dipendekkan, produk yang sentiasa berubah-ubah adalah sebab kerumitan dalam sistem pengeluaran. Untuk memproses data penstriman ini, ia memerlukan teknik yang sesuai untuk mengesan keadaan dan perubahan yang tidak menentu. Pemprosesan data kompleks RFID (CEP), adalah teknik yang digunakan untuk memproses maklumat daripada satu atau berbilang peringkat data RFID dengan menganalisis, menapis dan proses pemadanan daripada peringkat pemprosesan data mentah kepada pemprosesan data peringkat tertinggi (CEP). Dalam penyelidikan ini, terdapat dua pendekatan yang digunakan untuk mempertingkatkan enjin CEP dalam sistem agihan RFID. Pendekatan pertama adalah untuk mengesan tag yang tidak diketahui daripada pemprosesan data peringkat mentah. Keadaan ini berlaku adalah kerana barang baharu dialihkan atau item tersalah letak. Apabila memproses sebilangan besar barang yang mempunyai tag di pusat pemgagihan, pengesanan tag yang tidak diketahui boleh membantu mengesahkan kumpulan tag dengan cekap. Penyelesaian sedia ada sama ada memeriksa semua tag secara remeh atau menggunakan pendekatan kebarangkalian yang tidak dapat menjamin pengecaman lengkap semua tag yang tidak diketahui. Untuk mengisi jurang ini, algoritma pengesanan tag yang tidak diketahui baru (SWOR) telah diperkenalkan. Kelebihan utama teknik ini adalah untuk membina algoritma yang menggunakan tetingkap gelongsor yang diubah suai dan penapis XOR bitwise untuk mengelakkan gangguan tag yang diketahui kepada tag yang tidak diketahui. Pendekatan kedua adalah untuk mengesan keadaan tidak menentu di peringkat pemprosesan tinggi (RFID CEP). Mengesan keadaan yang tidak menentu seperti barang tiruan dan barang hilang dalam persekitaran pembuatan memerlukan set teknologi khusus untuk menangani aliran data yang dicipta secara berterusan. Pendekatan algoritma pengesanan (UDA) telah diperkenalkan. Pendekatan ini adalah untuk mengesan kejadian yang tidak pasti seperti barang palsu dan hilang dalam sistem pengedaran RFID untuk persekitaran pembuatan. Kaedah yang dicadangkan adalah berdasarkan teknik pencincangan dan kumpulan benang untuk menyelesaikan masa pemprosesan yang lama, penggunaan memori yang tinggi dan daya pemprosesan peristiwa yang rendah dalam pendekatan pemprosesan semasa. Rekabentuk kajian adalah berasaskan kuantitatif, dan menggunakan kaedah kuasi eksperimen. Keputusan eksperimen menunjukkan bahawa pendekatan pertama yang dicadangkan, algoritma SWOR mencapai kadar *false positive* terendah iaitu 9.99 % dan ketepatan tertinggi 99.18 % berbanding dengan pendekatan garis dasar yang lain. Algoritma UDA adalah 3.2 kali ganda lebih pantas daripada pendekatan garis dasar dan mencapai ketepatan 100% dengan penggunaan memori yang rendah berbanding pendekatan terdahulu. Justeru kajian ini berjaya mencadangkan pendekatan yang boleh meningkatkan RFID CEP dalam sistem teragih.

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BUTI	Bloom filter based Unknown Tag Identification
CEP	Complex Event Processing
CEP2U	a name of CEP language
CSD-BGP	Collision Seeking Detection – Balance Group Partition
DAS	Data Analytic Server
DFA	Deterministic Finite Automata
ECA	Event Condition Action language
EM	Expectation Maximization
EPC	Electronic Product Code
EPL	Event Processing Language
ERP	Enterprise Resources Planning
Esper	name of industrial CEP tool
EUTI - SBF	Interactive Unknown Tag Identification – Sampling Bloom Filter
FPR	False Positive Rate
GHz	Gigahertz
HF	High Frequency
IFUTI	Interactive Filtering based Unknown Tag Identification
Instans	name of industrial CEP tool
IoT	Internet of Things
IPs	Intellectual Properties
ISM	Industrial, Scientific or Medical
KHz	Kilohertz
LAN	Local Area Network
LCA	an approach that use Lazy Evaluation Model
LF	Low Frequency
MHz	Mega Hertz

NFA	Non-Deterministic Finite Automata
NFA - HTBS	NFA – Hash Table B+ tree Structure
NFA- HTS	NFA – Hash Table
NUTIP	Unknown Tag Identification Protocol
PDA	Personal Digital Assistant
PUTI	Physical Layer Unknown Tag Identification
RAND	Reasonable and Non-discriminatory
RCEDA	a name of CEP engine
RFID	Radio Frequency Identification
SASE	SQL like syntax language
SBF-UDP	Sampling Bloom Filter -
SWOR	**S**liding **W**indow X**OR** (Unknown Tag Detection Algorithm)
UDA	**U**ncertain Event **D**etection **A**lgorithm
UHF	Ultra-High Frequency
UTI - SBF	Unknown Tag Identification – Sampling Bloom Filter
Wayeb	name of industrial CEP tool
Wi-Fi	Wireless Fidelity
WP	White Paper protocol
WSNs	Wireless Sensor Networks
WSO2	Web Service Oxygen

CHAPTER 1

INTRODUCTION

1.0 Introduction

Over the years, Radio Frequency Identification (RFID) technology has matured and is rapidly becoming the standard in such companies, especially in the manufacturing industry [1]–[3]. This technology has become the new norm where people even planted it inside them [4]. It is a technology that uses radio waves to automate the identification and tracking of anything from humans to animals by using a small electronic device, an RFID tag. RFID technology uses data-rich tags that contain unique numeric identifiers that can be read remotely over radio waves. The significant advantage lies in the information exchange between RFID -tags and RFID readers, which does not require direct contact or line of sight [5].

Complex Event Processing (CEP) is on the rise in the recent list of industry system trends with good reasons [6], [7]. CEP is a technique used to processes information from one or more event sources by analysing, filtering, and correlating low semantic events such as sensors, logs, and RFID data [8]. Complex events, also known as high-level semantic events, are usually associated with important business events to indicate that they will be processed in real-time. An example of business event or complex event is the delivery of a package or the completion of a product in factory. Previous research has shown that CEP has benefited any industry by providing forewarning [9], or a probabilistic forecast of market trends [10], demographic shifts [11], or any future threats [12] or opportunities that are undoubted of great value to any business leaders. They benefit by manipulating data streams to detect meaningful data.

A typical CEP system has two stages: raw data processing level and complex event processing level. Raw data processing level includes filtering redundancy, detecting anomalies and standardisation according to the domain. While complex event processing level recognises complex event based on set or sequence of occurrences of data from raw data processing level.

At raw data processing level, raw data collected by the RFID readers may inherit unknown tags. According to the statistics [13], the consumers unable to find 16 percent of inventory items on average in the stores for the reason of item misplacement. Besides, noise readings naturally existed in the system[14]. These readings are important to determine the accuracy of the existing tagged items in the warehouse even though massive amounts of it can increase the cost of the infrastructure. Hence in the warehouse management, identifying misplace item is practically important to avoid financial loss. Industry such as manufacturing, cargo tracking and logistic rely on this technology to detect the unknown tags to minimise financial loss. For many applications, it is important to detect unknown tags accurately and quickly. When processing many tagged items in an industrial production area, finding unknown tags can help reliably validate batches of tags. For example, RFID-based inventory management needs to be aware of unknown tag events due to newly imported goods or improper placement of goods [15]. Unknown tag identification allows us to identify all unknown tags in the package, and it is not always necessary to collect information for all unknown tags. Instead, it is sufficient for many applications to know if the unknown tag is present with the required accuracy [16]. Due to the overwhelming number of objects, acceptable identification can hardly be achieved, e.g., RFID-compliant cross-border cargo management [17].

According to [18]–[20] the event source that passed to the CEP system may contain invalid data, resulting in ambiguous events generated by either event stream or event rules. Event stream uncertainty is associated with sensor inaccuracies and imperfections [21]. On the other hand, the uncertainty rule is an error judgment for an event or abnormalities in a situation or behaviour according to the business rule in a particular domain during the complex event detection process [22]. According to [23], a vital requirement for a CEP mechanism is to handle very large amounts of data with minimal latency, even with event rules and many incoming event streams. Due to low-latency requirements, high-speed CEP can consume CPU and memory capacity event detection process [24]. Intermediate results stored in the main memory may excessively grow since it is impossible to store all events in memory [8]. Not only that, the CEP engine may also result in an extended processing time due to high latency. Otherwise, user suffer from high configuration costs, hours of labour if the configuration settings are unknown [25]. Thus, lightweight processing and minimising memory consumption play an essential role in the robustness of event stream processing. Else, a system may result in false alarm without having CEP. This means a wrong signal in reportage or situations that do not present at a higher level.

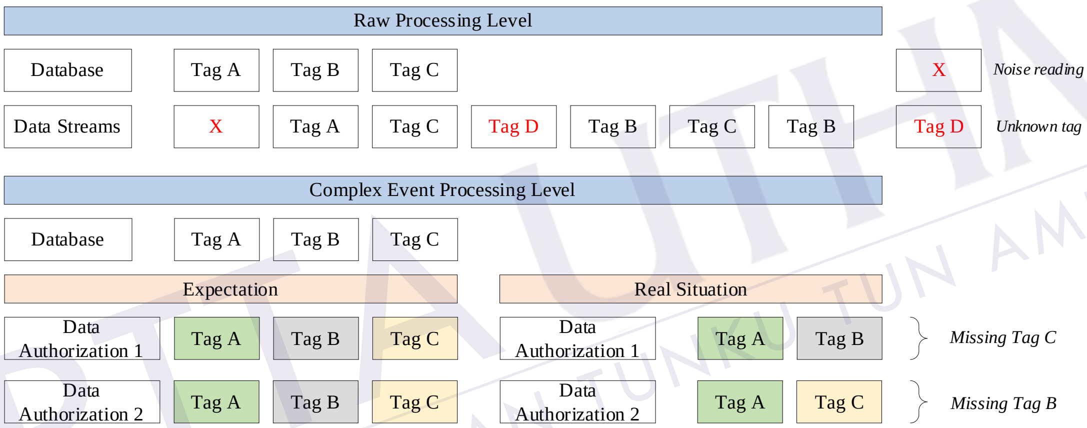

Figure 1.1: Differences of Unknown Tag and Uncertain Event

In this research, the definition of unknown tag and uncertain event is illustrated in Figure 1.1. At raw data processing level, RFID tags without pre-registration in advance are called unknown tags and typically occurs in a scenario where tagged objects move into the reader's interrogation area [26]. X is considered as noise and Tag D is considered as unknown tag as it does not appear or registered in the database. While complex event processing level, Tag A, Tag B and Tag C should be authorised two times according to business rules. On a real situation, the number of expectation tags is insufficient in each authorization. This shows that an uncertain events or abnormal situations happens in the system.

1.1 Problem Statement

In this research, we focused on the issues of RFID detections in the complex event processing systems. The first issue is the unknown tag at the raw data processing level. While the second issue is uncertain event in the complex event processing level.

During raw data processing data level, raw data collected by the readers may inherit unknown tags (unidentified tags) [27], [28] and noise [14]. These unknown tags do not exist in the system but is available in the reader area. Noise readings existed generally caused by the factor of unknown aggregation or algorithm failure. Most of the existing approach assume perfect channel conditions and fail to exploit characteristic of backscatter channel [29]. If this problem persists in the system, the accuracy of unknown tag detection become unreliable. Identifying unknown tags is also time-consuming as it requires multiple scanning. Each tag cannot automatically identify itself as known or unknown. Existing solutions trivially query every tag in the system, either being very time-inefficient due to re-identification of all identified tags [16] or using a probabilistic approach that cannot guarantee complete identification of all the unknown tags [17], [28]–[30]. The efficiency of these methods [16], [27], [29], [31] has yet to be well optimized due to the transmission of redundant data for detection. These methods were intended to inspect all the tags in the system from scratch and can be very time consuming if applied directly to troubleshoot unknown tag identification. Recent method uses indicator vector [28], [31] and XOR filter [32] to collect only unknown tag in the system. This existing approach uses one and three hash functions. According to [33], a single hash function can generate about 37 % singleton slots when the number of tag is equal to the number of slots or size of the window. This shows that, collision slots that contribute nothing to detecting unknown tags are still included in the communication message, losing the great potential for transmission optimisation. Consideration of this method reveals that the accuracy of traditional approaches is not optimal for detection because of the transfer of meaningless data.

While at the complex event processing level, the incoming event that send into the CEP system might contain incorrect readings that cause uncertainty of events generated either from the source of event stream or event rules [18]–[21]. Uncertainty in the event stream is more associated to the imprecision and incompleteness caused by the sensor [21]. This research focused on detecting uncertainty in event rules especially abnormal behaviour such as counterfeit and missing items in complex event processing level. Complex events are raised based on incoming source production and according to a set of user-defined rules. However, as the complexity of CEP systems grow, the process for manually defining rules becomes time consuming and there is risk of dynamic changes occur in the domain environment. In such complex manufacturing processes, real-time decision-making and responses can be interrupted by multiple processes to detect uncertainty. Besides, high input rates of event streams may cause bottlenecks for the CEP system. Bottlenecks can slow down the complex event processing hence results in the poor quality of query results which has negative effects on decision making. NFA based approach has been widely studied and implemented in active database [34]–[38]. According to [39], the automata-based event detections are not scalable because the event expressions are merged into a single automaton. Besides bottlenecks, the NFA in CEP that using multi-probabilistic approach leads to high memory consumption and low detection efficiency of RFID event detection [40]–[44]. Although the techniques offer the greater whole and essential processing capabilities to the complex event, those processing strategies implement repetitive and unnecessary processing, insertion and lookup operations when detecting complex events. By implementing low-cost passive RFID tags, these multiple processes result in high memory consumption, which can interrupt the process of uncertain event detection. In CEP, computations often employ large datasets that exceed cache capacity, leading to excessive accesses to the memory subsystem. This also will invite unnecessary cost as it requires bigger capacity of memory. Therefore, lightweight processing and minimisation of memory consumption play an important role to produce accurate data in event stream processing [45]. Besides promoting green technology, the result of using lightweight processing is, it reduces the latency and energy overhead for these data-intensive applications.

To summarize the issues, unknown tag identification in large-scale RFID systems that need to be frequently checked up in real time. Nonetheless, we find that the efficiency of most previous works is not well optimized due to the transmission of unhelpful data. Besides, detecting uncertainty in complex event processing level requires high memory consumption and can caused bottlenecks. Lightweight processing is therefore required to reduce costs to detect uncertain event in complex event processing.

1.2 Research Questions

In general RFID CEP systems, commercial production desires to understand the object`s location. Below are two research questions addressed in this work.

i. How to detect unknown tags in raw-level data processing?

If a tagged object is lost or an unregistered tagged object is brought in, an unknown tag will appear in the RFID system at the raw data processing level. This scenario frequently leading to significant financial losses. This research question addresses the important and difficult problem of identifying unknown tags in large-scale RFID systems. To identify unfamiliar tags from known tags at the slot level, existing protocols use Aloha-like techniques [31]. These protocols are timing inefficient and rarely able to satisfy delay-sensitive applications. Borrowing directly from the tag-only identification strategy to identify all tags within the scan range is an easy way to identify unknown tags. By comparing the detected IDs with those in the database, it is then possible to determine the IDs of the unidentified tags. [32]. This technique, however, takes a lot of time because a lot of known tag IDs need to be remembered. Applications with strict latency requirements should not use this.

ii. How to detect uncertain event in complex event processing?

CEP is a vital tool for extracting conclusions from streams of information concerning dispersed occurrences from diverse sources of technology in real time. Inaccurate data sources and networks, measurement uncertainty, or the inability to establish if an event has occurred restrict these events from being completely certain [34]. Some rules have uncertainty if they are not 100% certain [38]. The representation, management, and propagation of uncertainty problems were also addressed in other continually enhancing a number of methodologies. [34-36]. However, their solutions have two major limitations. With that being said, they frequently only cover a small portion of the problem and concentrate on particular aspects of CEP system security. Second, the system simulation must do the laborious manual task of propagating attribute uncertainty through processes. This study addresses uncertainty in the occurrence of events, the values of their attributes, and the reliability of derived rules.

1.3 Research Objectives

The aim of this study was to detect unknown tags in raw data processing level and uncertain event in complex event processing level in RFID system. In order to achieve the research aim, three main objectives were identified as follows:

i. To propose an approach to detect unknown tags in RFID raw data processing level in RFID systems.
ii. To propose an approach to detect uncertain events in complex event processing levels in RFID systems.
iii. To evaluate and perform a comparative analysis of the performance of the developed unknown tag detection approach (i) and event detection approach (ii) with existing approaches.

1.4 Research Scopes

In this research, the scope of this study was on data quality and reliability of RFID readings obtained from passive tags commonly used in supply chain management specifically manufacturing and retailing [26]. This study focused on detecting unknown tags at the raw RFID processing level while eliminating noise in the data stream. Unknown tags appear in RFID systems when the tagged objects are misplaced, or unregistered tagged objects are moved in. Real dataset from supermarket warehouse is used to detect unknown tags in raw data processing level. Meanwhile, in the complex event processing level, this research focus on detecting uncertain events such as counterfeit and missing items in RFID distributed systems. Real dataset from pharmaceutical company is used to detect uncertain event in CEP level. This experiment is run on Apache Maven in Java.

1.5 Significance of Research

This section discusses the importance of the study of unknown tag detection in raw processing level and uncertain event detection in complex event processing in RFID distributed system.

Early detection of unknown tag can prevent an industry from generating incorrect inventory report thus avoiding the industry facing financial loss. By implementing unknown tag detection approach in RFID system, it can make manual labour a lot easier. Although many approaches on tag identification have been presented in previous studies, existing work on unknown tag detection mainly focuses on optimizing time and improving throughput by exploiting parallel working of multiple readers. However, these approaches target at interrogating all the tags in the system from scratch, which would highly time-inefficient if directly adopted to solve the unknown detection problem. The low efficiency of these solutions in identifying unknown tags stems from redundant re-identification of already identified tags which usually constitutes the majority of the population in large RFID system.

Uncertain event detection in complex event processing level has a great challenge and has a significant impact on the performance and the accuracy of results. Designing the algorithm for event detection in the existence of uncertainty is relatively complex and challenging. Most of the event detection models derive the patterns according to the event relationship. They do not consider the vagueness and uncertainty. Thus, it is necessary to examine the accuracy of incoming events prior to event matching during the detection processes. Uncertain events in the CEP affect the efficiency of query processing. The existing deterministic query languages are unable to process the uncertain event from unreliable sources. Therefore, it is an ongoing effort to develop a suitable uncertain event detection algorithm to detect the uncertainty associated with many continuous arriving events. The accuracy of event detection and effectiveness of uncertain event management are the key challenges to be resolved.

1.6 Research Organization

The thesis consists of a total of five (5) main chapters. The thesis is organised as follows:

i. Chapter 1: Introduction. This chapter tells the general prelim of overall research. It includes research problems, research objectives, research motivation, research scope, research significance and thesis organisation.

ii. Chapter 2: Literature Review. This chapter discussed an in-depth overview of RFID Complex Event Processing from raw data processing level to complex event processing level. This chapter also presents the relevant background and existing techniques and methods to solve unknown tags in raw data processing and uncertain events in complex event processing levels.

iii. Chapter 3: Research Methodology. Chapter 3 presents the research flow and research procedure of this study. The research procedure presented comprises two phases: Phase 1- Unknown Tag Detection, and Phase 2 –Uncertain Event Detection. A brief explanation of the two phases involved is presented.

iv. Chapter 4: Experimental Result and Analysis. This chapter presents results and comprehensive analysis of proposed approaches to detecting unknown tags in raw data streams and detecting uncertain events at the CEP level. The results and analysis of the simulation proposed algorithm were also included.

v. Chapter 5: Conclusion and Recommendations. This concluding chapter provides a summary of contributions and future research challenges.

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