A new Middleware Architecture for RFID systems

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Abstract—1980 marked the start of a boom in radiofrequency identification (RFID) technology, initially associated with a growing need for traceability. In view of the technological progress and lower costs, RFID's area of application became much broader and, today, multiple business sectors take advantage of this technology. But in order to achieve the maximum benefits of RFID technology, the RFID information collected should be useful, for this it is necessary that we can collect it and deliver it in the best conditions for the whole applications that have need of its exploitation, for that a dedicated middleware solution is required to ensure the collection of RFID information and their integration in an information systems. The issues and key points of this integration as the description of the RFID technology will be summarized in the present paper, with a new middleware architecture.
We focuses mainly on components, and design of our middleware MedRFID, solution developed in our Lab, and which integrates mobility and provides extensibility, scalability, abstraction, ease of deployment and compatibility with IATA standards and EPCglobal standards.

Keywords-RFID; information system; middleware; technology; Protocols of communication;application.

I. INTRODUCTION

During the last decade, this wide spectrum of applications has been already observed, is nothing but the result of the emergence of research and development, which were conducted in different areas such as logistics, air, the army to field security and personal services. It falls into the so-called Internet objects or connected objects.

Connected objects and communicating could provide opportunities for the industry in the years to come, and a new middleware architecture become strategic regarding a massive rise of "unintelligent" internet of objects is expected by 2020. This work response to this need with a vision of connecting functions placed in objects.

An estimated 50 billion items could be tagged and 2020. This ability of communication will develop virtual reality devices.

Thus research and innovation in the field of data integration collected by technologies that deal with communication between objects is still needed to support this development and is a major factor for the success of these technologies and their relevance.

RADIO FREQUENCY IDENTIFICATION, or RFID, is a generic term for technologies that use radio waves to automatically identify people or objects. This technology has recently seen growing interest from a wide range of industries such as retail, pharmaceutical, and logistics. In these domains, RFID technology holds the promise to eliminate many existing business problems by bridging the economically costly gap between the virtual world of IT systems and the real world of products and logistical units. Common benefits include more efficient material handling processes, elimination of manual inventory counts, and the automatic detection of empty shelves and expired products in retail stores. RFID technology has a number of advantages over other identification technologies. It does not require line-of-sight alignment, multiple tags can be identified almost simultaneously, and the tags do not destroy the integrity or aesthetics of the original object. The location of tagged objects can thus be monitored automatically and continuously.

In traditional RFID applications, such as access control, there was little need for an RFID middleware because the RFID readers were not networked and the RFID data were only consumed by a single application. In novel application domains, such as supply chain management and logistics, there is no longer a 1-to- relationship between reader and application instance, however. In these domains, many readers distributed across factories, warehouses, and distribution centers capture RFID data that need to be disseminated to a variety of applications. This introduces the need for an RFID infrastructure that hides proprietary reader device interfaces, provides configuration and system management of reader devices, and filters and aggregates the captured RFID data.

II. RFID SYSTEMS

The RFID systems basically consist of two or three elements : a tag/transponder and a reader for a Simplified RFID system, or a tag/transponder a reader and a middleware deployed at a host computer. The RFID tag is a data carrier part of the RFID system which is placed on the objects to be uniquely identified. The RFID reader is a device that transmits and receives data through radio waves using the connected antennas. Its functions include powering the tag, and reading/writing data to the tag. As shown Fig. 1, the signals sent by the reader's antennas form an interrogation zone made up of an electromagnetic field. When a tag enters this zone, it gets activated to exchange data with the reader (Al-Mousawi, 2004). Later, the identification data read by the RFID reader is processed by the software system, known as the RFID middleware. The RFID middleware manages readers, as well as filters and formats the RFID raw tag data so that they can be accessed by the various interested enterprise applications (Floerkemeier & Lampe, 2005). Hence, the middleware is a key component for managing the flow of information between tag readers and enterprise applications (Burnell, 2008).

Major advantages of using RFID as an auto-ID system are the following:

- RFID readers do not require a line of sight to access data from the RFID tags.
- RFID systems can read data over varied range from few centimeters to few hundred meters.
- RFID readers can interrogate, and make RFID tags readings much faster.
- RFID systems can read and write different sizes of data from / to the tag, based on the type of tag.
- RFID systems can read tags in harsh environments, without any human interference.

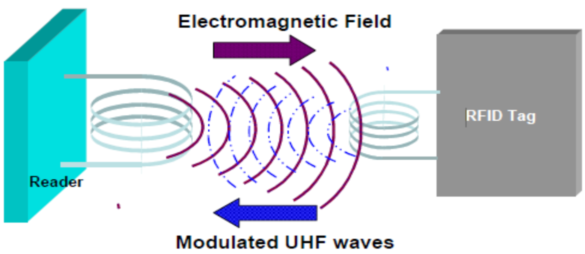

Fig. 1. Simplified RFID system components (IBM RFID Handbook 2006)

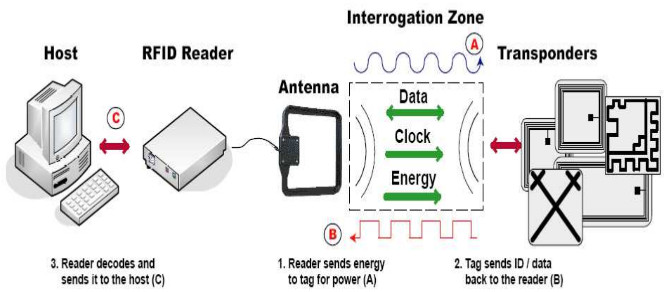

Fig. 2. RFID system components (Glasser et al., 2007)

A. RFID System Components

RFID systems are produced by many manufacturers and exist in countless variants. However, a RFID system consists mainly of three components; the transponder/tag, reader, and RFID middleware.

1) RFID Transponder/Tag

A RFID transponder, or tag, consists of a chip and an antenna. A chip can store a unique serial number or other information based on the tag's type of memory. The tag's type of memory can be read-only, read-write, or write-once and read-many (United States Government Accountability Office, 2005). *Read-only* tags are much cheaper to produce and are used in most current applications. *Read-write* tags are useful when information needs to be updated (Al-Mousawi, 2004). The antenna is used to transmit information from the chip to the reader, and the larger the antenna the longer the read range. The RFID tag can be either attached or embedded in an object to be identified, and can be scanned by mobile or stationary readers using radio waves (United States Government Accountability Office, 2005).

RFID tags exist in three different versions: passive tags, active tags, and semi-passive / semi-active tags.

a) Passive Tags

Present the simplest version of RFID tags which do not contain their own power source, such as a battery, and cannot initiate communication with the reader. The passive tag derives its power from the energy waves transmitted by the reader and responds to the reader's radio frequency emissions, therefore the passive tag relies entirely on the reader as its power source. A passive tag should store, at a minimum, a unique identifier for the item tagged, and can be read from a range of about 10 to 20 feet under perfect conditions (United States Government Accountability Office, 2005). Passive tags have lower production costs, meaning that they can be applied to less expensive disposable goods (e.g. a bottle of shampoo).

The cost of passive tags varies based on the radio frequency used, amount of memory, and design of the antenna, and other tag requirements. Passive tags can operate at low, high, ultrahigh, or microwave frequency. The development of passive RFID tags has made wide scale use of them in many organizations. Examples of passive tag applications include mass transit passes, building access badges, and consumer products in the supply chain (United States Government Accountability Office, 2005).

b) Active Tags

Unlike passive tags, active tags contain a power source and a transmitter, in addition to the antenna and chip, and send a continuous signal. These tags typically have read/write capabilities; tag data can be rewritten and/or modified. Active tags can initiate communication and communicate over longer distances up to 750 feet, depending on the battery power.

Because these tags contain more hardware than passive RFID tags, they are more expensive and are reserved for costly items that are read over greater distances (United States Government Accountability Office, 2005). RFID manufacturers typically do not quote prices for active tags without first determining their storage type and quantity, and range.

c) *Semi-Passive Tags*

This type of tags is called also semi-active tags. Semi-passive tags do not initiate communication with the reader but contain batteries that allow the tag to perform other functions, such as monitoring environmental conditions and powering the tag's internal electronics. In order to conserve battery life, some semi-passive tags do not actively transmit a signal to the reader. Instead, they remain dormant until they receive a signal from the reader. Semi-passive tags can be connected to sensors to store information for container security devices (United States Government Accountability Office, 2005). Semi-passive tags have the middle transmission range and cost (Vacca, 2009).

As a summary, passive tags are consequently much lighter than active tags, less expensive, and offer a virtually unlimited operational lifetime. The trade off is that they have shorter read ranges than active tags and require a higher-powered reader (Association for Automatic Identification and Mobility, n.d.). Table 1 shows a comparison among passive, semi-passive, and active tags.

	Passive Tags	**Semi-Passive Tags**	**Active Tags**
On board power supply	No (From Reader)	Yes (Internal Battery)	Yes (Internal Battery)
Transmission range	Short (up to 6.096 meters)	Medium (up to 30.48 meters)	Long (up to 228.6 m)
Communication pattern	Passive	Passive	Proactive
Cost	Cheap	Medium	Expensive
Type of memory	Mostly Read-Only	Read-Write	Read-Write
Life of tag	Up to 20 years	2 to 7 years	5 to 10 years

Table 1. Characteristics of passive, semi passive and active RFID tags (United States Government Accountability Office, 2005; Vacca, 2009)

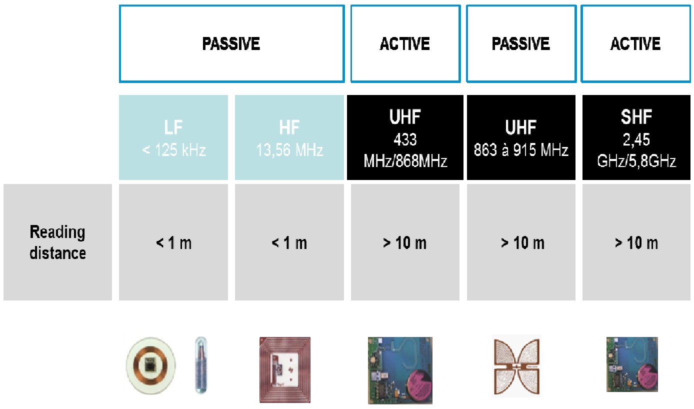

Fig. 6. Examples of Tags/types/The frequency bands

2) *RFID Reader*

A RFID Reader is a scanning device that reliably reads the tags and communicates the results to the middleware. A reader uses its own antennae to communicate with the tag by broadcasting radio waves to which all tags within range will respond. Readers can process multiple items at once, allowing for increased read processing times. They can be either mobile or stationary, and they are differentiated by their storage capacity, processing capability, and the frequency they can read (United States Government Accountability Office, 2005).

RFID reader consists of the following functional blocks:

a) *HF Interface*

The master part of the reader which has these functions (Al-Mousawi, 2004):

- Supplying RFID transponders with power by generating high frequency power;
- Modulation of the signal to the transponder;
- Reception and demodulation of signals from the transponders.

b) *Control Unit*

The slave part of the reader that performs the following functionalities (Al-Mousawi, 2004):

- Communication and execution of the application software's commands;
- Signal coding and decoding;
- Communication control with a transponder.

Some RFID readers have additional functionalities like *anti-collision algorithm*, *encryption* and *decryption* of transferred data, and *transponder-reader authentication* (Al-Mousawi, 2004).

Different designs of readers exist, because different applications have different requirements from each other. RFID readers are classified into three types (Al-Mousawi, 2004):

- *OEM readers*: Original Equipment Manufacturers readers are mostly used for data capture systems, access control systems, and robots.
- *Industrial use readers*: used in assembly and manufacturing plant.
- *Portable readers*: These readers are more mobile than the other readers, and supported with a LCD display and keypad. This kind of readers is used in animal identification, device control and asset management applications.

3) RFID Middleware

The middleware refers broadly to software or devices that connect RFID readers and the data they collect, to enterprise information systems. RFID middleware helps making sense of RFID tag reads, applies filtering, formatting and logic to tag data captured by a reader, and provides this processed data to back-end applications (Burnell, 2008). RFID middleware serves in managing the flow of data between tag readers and enterprise applications, and is responsible for the quality, and therefore usability of the information. It provides readers connectivity, context-based filtering and routing, and enterprise / B2B integration. RFID middleware design and components will be discussed further in the next sections.

When designing a RFID middleware solution, the following issues need to be considered:

- **Multiple hardware support**: The middleware must provide a common interface to access different kinds of hardware offering different features.
- **Synchronization and scheduling**: There should be intelligent scheduling and synchronization among all the processes of the middleware. This minimizes the latency and improves the efficiency of the middleware.
- **Real-time handling of incoming data from the RFID readers**: The middleware should handle the huge amount of data captured by the connected readers in real time without read misses.
- **Interfacing with multiple applications**: The middleware should be capable of interacting with multiple applications simultaneously, by catering to all the requirements of the applications with minimal latency.
- **Device neutral interface to the applications**: The application developer should only use the generic set of interfaces provided by the middleware independently of the type of hardware connected to the system.
- **Scalability**: The middleware design must allow easy integration of new hardware and data processing features.

B. RFID Middleware Components

A RFID middleware is the interface that sits between the RFID hardware and RFID applications. It provides the following advantages:

- It hides the RFID hardware details from the applications;
- It handles and processes the raw RFID data before passing it as aggregated events to the applications;
- It provides an application level interface for managing RFID readers and querying the RFID data.

A layer of the RFID middleware incorporates all the device drivers of different hardware and exposes to the application standard interfaces to access this hardware. If the application was provided with all the device drivers of all connected readers, it will be a hard job to manage and interface each of the devices. The application developer will then need to understand all the hardware specific internals and operations. Also, the application, if provided with the huge amount of raw tag data reported by the readers, will find it very difficult to process the data in real time. A RFID middleware provides a standardized way of dealing with this flood of information, which processes the raw data and provides the application with clean and filtered data.

As shown in Fig. 2 a RFID middleware is generally composed of four major layers:

- Reader Interface
- Data Processor and Storage
- Application Interface
- Middleware Management

1) Reader Interface

The reader interface is the lowest layer of the RFID middleware which handles the interaction with the RFID hardware. It maintains the device drivers of all the devices supported by the system, and manages all the hardware related parameters like reader protocol, air interface, and host-side communication.

2) Data Processor and Storage

The data processor and storage layer is responsible for processing and storing the raw data coming from the readers. Examples of processing logic carried by this layer are data filtering, aggregation, and transformation. This layer also processes the data level events associated with a specific application.

3) Application Interface

The application interface provides the application with an API to access, communicate, and configure the RFID middleware. It integrates the enterprise applications with the RFID middleware by translating the applications' requests to low level middleware commands.

4) Middleware Management

The middleware management layer helps managing the configuration of the RFID middleware, and provides the following capabilities:

- Add, configure, and modify connected RFID readers;
- Modify application level parameters such as filters, and duplicate removal timing window;
- Add and remove services supported by the RFID middleware.

RFID readers are typically abstracted as a logical reader which is either a collection of several readers or a part of the reader. This grouping mechanism is used where there is a need to have a set of readers capturing data from a particular area such as a warehouse with many loading docks. The advantage of this is that the application can query a small number of logical readers rather than having to aggregate events from each of the individual readers.

There are two standardized interaction models used to define the communication between the middleware and the applications. An application can operate at *synchronous mode* when requesting services on demand or *asynchronous mode* when it registers for information to be sent to it when certain conditions are met. RFID middleware usually provide some kind of data filtering, because sometimes it might be required to report only certain type and value of the tag data to the application. The application needs to provide a set of defined patterns to the middleware. The middleware then allows only data that matches the pattern to be reported to the application. E.g. if an application needs to see only tag data that starts with a specific pattern such as "XYZ20", the filter can be set to this value by the application and communicated to the middleware (Al-Mousawi, 2004).

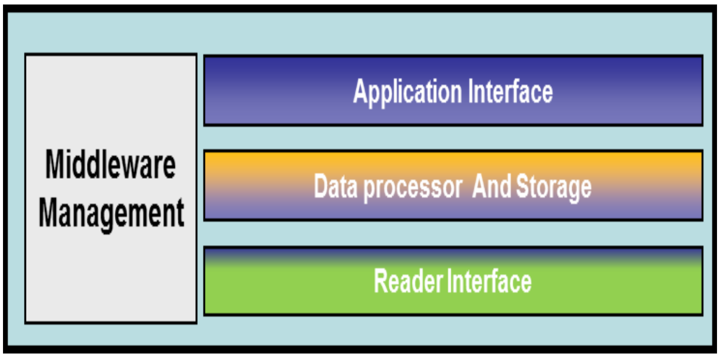

Fig. 8. RFID middleware components

V. Mains RFID problems and research domains

The appearance of the first RFID middleware on the market enables the integration of RFID technology in various fields (Air, Logistics, ...). Nevertheless, the fact remains that they allow the identification of several technical issues about this integration.

Indeed, since the introduction of RFID technology in global solutions, a main issue appeared : How RFID technology can be integrated in a transparent and efficient manner in an information system?

There is then a strong mobilization on the issue of research and development in mainly three areas:

1) Objects identification

For a better identification of object we need to focus the development on a standardization of RFID tags and a good transcription codes on RIFD tags (Algorithm).

2) Communication between objects and middleware

The start point for this part is a good choice of useful RFID technologies, after a development of communication protocols between readers is necessary, following the middleware standardization can help us to done a good follow up with the objects, then the normalization of protocols shall needed for the better lopping of the communication steps.

3) The information processing

Decoding the RFID information collected (standard, algorithm) is important for structuring collected RFID information to make it usable directly by any application of the information system, which need a real Time treatment volume (architecture allows scaling mass treatment of RFID data collected).

V. MedRFID

1) Introduction : Why MedRFID ?

Some existing RFID middleware use a standard functionalities, Our concern is to design and implement a specific middleware platform called "MedRFID, which is distinguished by its innovative aspects in terms of architecture including mobility to be able to collect information from mobile RFID readers, operating aspects of the data in real time with the ability to generate a business rules engine and especially by integrating communication protocol RFID readers disregarding the dependency to the initial manufacturer protocol.
The implementation of this innovative architecture will give real flexibility for users of the middleware and above all a means of real-time processing a large volume of data that emanate from heterogeneous environments while ensuring ease of integration of these data and information and their best use by business applications systems.

2) MedRFID : Design and Architecture

RFID middleware is the core in the implementation of RFID technology in companies that have large amount of data to be processed and, above all, to share with the various components of the value chain and with its partners. Thus, the successful integration of RFID within companies is conditioned by the successful design and implementation of RFID middleware.

That is why our research team chose to design and implement a RFID middleware which integrates the latest innovations in the field.

MedRFID is a middleware that has been designed to meet the overall functionality that must contain a conventional RFID middleware, but it also contains areas of innovation mainly around the mobility and independence of manufacturers. It is an innovative device management and event processing platform at the edge of the enterprise. It is designed to provide a scalable, extensible platform for deployment, and management of rich RFID and sensor solutions.

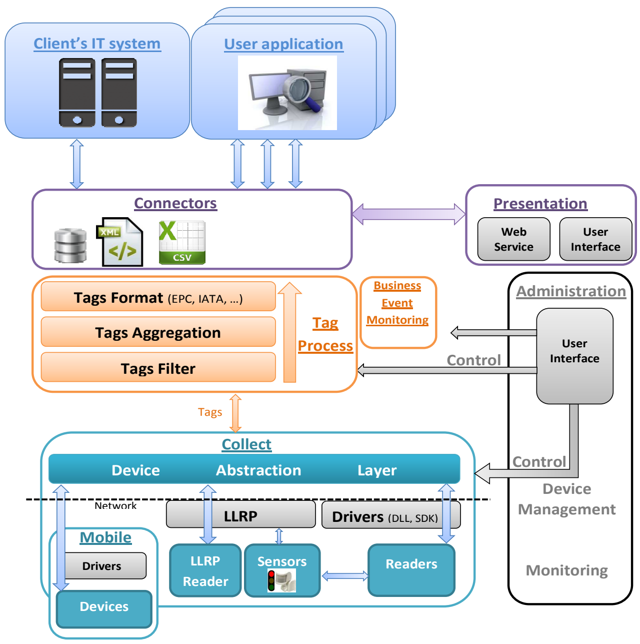

Fig. 9. MedRFID Architecture

3) MedRFID Application : ***FindLuggage***

a) Introduction

With tens million passengers traveling through the major European cities each year, through hundreds check-in desks, luggage is extremely important for these airports. Traditional moving-belt bar code scanners require 'line of sight' in order to correctly read labels, but these could be hidden as the luggage moves on conveyor belts, rendering the baggage unidentifiable. This could slow the process down, as manual intervention is required to obtain the information and locate the luggage, and could directly contribute to misplaced or lost bags.

We thus decided to address these challenges and decided to design and implement an application based on RFID technology and using the middleware MedRFID for collecting traceability information to develop a value-added service to search for baggage loss in the airport: **FindLuggage.**

FindLuggage is a web application that allows you to locate luggage in an airport

*b) Description of the global solution : **MedRFID** + **FindLuggage** ?*

To use this service, simply implement RFID readers in different points of traceability, and put each piece on an RFID tag; we can then use to collect information MedRFID baggage tracking on these different points of traceability at the airport and save them in a database. Comes after the role of the application to integrate these data and allow them to operate to provide us with information about the baggage.
RFID readers can be deployed at both the check-in and the baggage collection stages, which enable to read tags attached to luggage as it left the airport or, prior to collection by passengers.

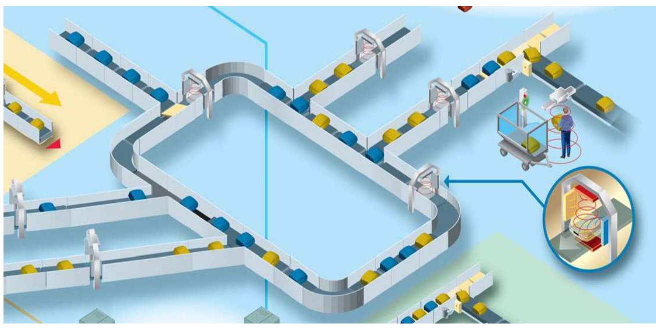

Fig. 10. Example of platform tracking baggage within an airport

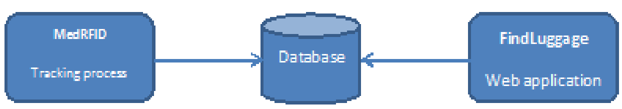

Fig. 11. Communication between **MedRFID** and **FindLuggage**

*c) Description of the application **FindLuggage** ?*

RFID readers are now implemented, the middleware **MedRFID** collecting traceability information on baggage on all tracking points within the airport and make them available to the application via a database. The application **FindLuggage** operates and integrates these data and then uses them to be able to display different way of each luggage in the airport. It allows to find a luggage misplace or give more details on the passage of a bag on a given collection point.

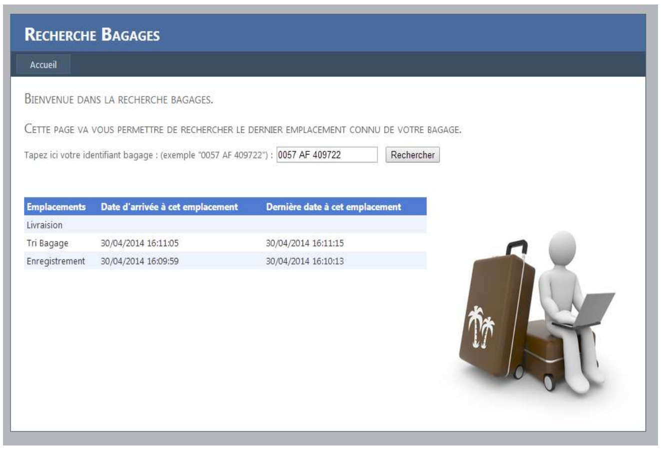

Fig. 10. ***MedRFID*** Application: ***FindLuggage***

V. Conclusion

This paper introduces RFID technology and the role of RFID middleware in the enterprise information systems. It also describes the design of our middleware ***MedRFID*** and its architecture in five important layers:

- **Control devise manager :**
  Administration of RFID readers, Sensors and Mobile devises
- **Devise abstraction layer :**
  Collection layer events
- **Tag Process :**
  Multiple operations such as filtering, eliminating duplicates, time stamping, contextualization and/or formatting
- **Business Rule Engine :**
  For Business Events
- **Connectors :**
  For communication with applications via connectors such as Database or Files.

With such an innovative architecture, ***MedRFID*** provides extensibility, scalability, abstraction and ease of deployment.
To be compatible with different areas including logistics and airports, it integrates respectively EPCglobal standards and IATA standards making it easily deployed in heterogeneous sites.

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