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Dedication

To my farther may Allah have mercy on him. it is not such dedication instead it is another way to keep ongoing deeds as Abu Hurairah, may Allah be pleased with him, narrated that the Messenger of Allah (ﷺ) said: "When a person dies, his deeds are cut off except for three: Continuing charity, knowledge that others benefited from, and a righteous son who supplicates for him."

My charming, supporter family; my mother, sisters and brothers, my nephews and nieces. I wish to see them successful, good people and achieving their goals.

To my small family, my beloved husband, my coming kid (you are not with me in real life but you are growing up inner me), my powerful mother in law and my respectful father in law.

In law, he is not one of my relatives but in reality, I consider him as my father, my dear teacher Pr. Korichi Ahmed.

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Résume

L'Internet des objets (IoT) intègre un grand nombre de technologies et envisage une variété d'objets qui nous entourent, grâce à des schémas d'adressage uniques et des protocoles de communication standard. De plus en plus, d'objets intelligents seront connectés. Par conséquent, d'innombrables avantages seront disponibles pour les entreprises. Dans lequel, l'Internet des objets donne aux entreprises la possibilité de capture des données à partir d'une large source en temps réel, est devenu plus réactif aux tendances et menaces émergentes en plus des prévisions précises ainsi que de prédire de nouvelles formes d'outils d'analyse de données permettent à une organisation de prédire modèles et comportements futurs.

Ainsi, ces opportunités affectent les stratégies de l'entreprise, qu'elles soient internes ou externes. Alors que, de l'autre côté, les clients recherchent des services IoT à valeur ajoutée. À ce stade apparaît la nécessité d'outils d'aide à la décision qui sont plus communément appelés systèmes de recommandation. Par conséquent, développer des approches de recommandation efficientes et efficaces pour mieux répondre aux intérêts des utilisateurs et doit rencontrer des difficultés sans précédent pour trouver un service idéal parmi le grand nombre de services.

En effet, l'IoT a des caractéristiques particulières qui peuvent faire en sorte que certaines applications souffrent de certaines lacunes et peuvent devenir incapables d'accomplir des tâches efficaces dans l'IoT. Récemment, l'idée que la convergence des mondes « Internet des objets » et des « réseaux sociaux » est possible, voire souhaitable, ce qui est dû à la prise de conscience croissante qu'un paradigme « Internet des objets sociaux » (SIoT) aurait de nombreuses implications souhaitables, dans un monde futur peuplé d'objets intelligents tels que la gestion des relations et garantir la fiabilité entre les objets.

Mots clés : Web sémantique, système de recommandation, entreprise, IoT, SIoT.

ملخص

تدمج إنترنت الأشياء (IoT) عددًا كبيرًا من التقنيات وتتضمن مجموعة متنوعة من الأشياء والأجهزة من حولنا، وذلك من خلال أنظمة العنونة الفريدة وبروتوكولات الاتصال القياسية. مع مرور الوقت ، سيتم توصيل المزيد والمزيد من الأجهزة الذكية. لذلك ، ستكون فوائد لا حصر لها متاحة للمؤسسات. حيث يمنح إنترنت الأشياء الشركات الفرصة لجمع البيانات من مجموعة واسعة من المصادر في الوقت الحاضر، بالإضافة إلى أن المؤسسات تصبح أكثر استجابة للتوجهات الحديثة والتهديدات الناشئة إلى جانب التنبؤات الدقيقة باستعمال طرق جديدة من أدوات تحليل البيانات مما يسمح للمؤسسة بالتنبؤ أنماط وسلوكيات المستقبل.

وبالتالي ، فإن تلك الفوائد تؤثر على استراتيجيات المؤسسة سواء كانت استراتيجيات داخلية أو خارجية. في حين، على الجانب الآخر ، يبحث العملاء عن خدمات إنترنت الأشياء ذات القيمة المضافة. في هذه المرحلة ، تظهر ضرورة استخدام أدوات دعم القرار المعروفة باسم أنظمة التوصية. لذلك ، من الضروري تطوير نهج توصية يتسم بالكفاءة والفعالية لتلبية مصالح المستخدمين بشكل أفضل.

في الواقع ، تتمتع إنترنت الأشياء بخصائص خاصة قد تجعل بعض تطبيقات التوصية تعاني من بعض أوجه القصور وقد تصبح غير قادرة على تحقيق مهام ناجعة في إنترنت الأشياء. في الآونة الأخيرة ، فكرة التقارب بين عوالم "إنترنت الأشياء" و "الشبكات الاجتماعية" أمر ممكن ، أو حتى مستحسن بسبب الوعي المتزايد بأن نموذج "إنترنت الأشياء الاجتماعي" (SIoT) سيحمل العديد من النتائج المرغوبة في عالم مستقبلي تسكنه كائنات ذكية مثل إدارة العلاقات وضمان الجدارة بالثقة بين الأشياء.

في هذه المذكرة ، اقترحنا نهجًا للتوصية المختلطة باستخدام بيانات إنترنت الأشياء المتوفرة التي توفرها الأجهزة المختلفة لتزويد الخدمات بالبيانات المطلوبة باستخدام إمكانية العثور / اكتشاف الخدمة ، حيث يُسمح للاجهزة التي يمتلكها الأصدقاء بالتعاون لإنجاز خدمة إنترنت الأشياء نيابة عن المستخدم الحالي.

<u>الكلمات المفتاحية:</u> الويب الدلالي ، نظام التوصية ، المؤسسة ، إنترنت الأشياء ، SIoT.

Abstract

The Internet of Things (IoT) integrates several technologies and envisions a variety of things or objects around us that through unique addressing schemes and standard communication protocols. In addition, as time goes on, more and more smart objects will be connected. Therefore, countless advantage will be available for the enterprises. The Internet of Things allows companies to capture data from various sources in real-time and become more responsive to emerging trends and threats. Besides, accurate forecasts and new forms of data analysis tools allow the organization to predict future patterns and behaviors.

The IoT recommender system provides recommendations of IoT services appropriate to the users' preferences based on the historical utilization and evaluation. Therefore, when the preferences of some users change, the company can benefit from the updated recommendations to predict users 'needs and requirements. So, adopting IoT recommender systems enables enterprises to improve their strategies.

Indeed, IoT has specific characteristics which may make some applications suffer from some shortcomings and may become incapable of achieving efficient tasks in the IoT. However, recently the idea that the convergence between the "Internet of Things" and the "Social Networks" paradigms has become possible. The a "Social Internet of Things" (SIoT) is a promising paradigm that would carry many desirable implications, implications, such as relationships and trustworthiness management, into a future world populated by intelligent objects.

In this thesis, we proposed a hybrid recommendation approach using the available IoT data provided by different devices efficiently to feed the services by needed data using the findability/ service discovery as well as the service, in which, objects that belong to friends are allowed to collaborate to accomplish the IoT service on the behalf of the current user.

Keywords: Semantic Web, Recommender system, enterprise, IoT, SIoT.

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Journal Article

Halima Bouazza, Bachir Said, Fatima Zohra Laallam, A hybrid IoT services recommender system using social IoT, Journal of King Saud University - Computer and Information Sciences ,2022, ISSN 1319-1578. https://www.sciencedirect.com/science/article/pii/S1319157822000362.

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Bouazza, H., Zohra, L.F., Said, B. (2019). Integration of Internet of Things and Social Network. In: Alfaries, A., Mengash, H., Yasar, A., Shakshuki, E. (eds) Advances in Data Science, Cyber Security and IT Applications. ICC 2019. Communications in Computer and Information Science, vol 1098. Springer, Cham. https://doi.org/10.1007/978-3-030-36368-0_26.

Bouazza, H., Zohra, L.F., Said, B. (2019). Comparative Study of the Internet of Things Recommender System. In: Alfaries, A., Mengash, H., Yasar, A., Shakshuki, E. (eds) Advances in Data Science, Cyber Security and IT Applications. ICC 2019. Communications in Computer and Information Science, vol 1098. Springer, Cham. https://doi.org/10.1007/978-3-030-36368-0_23.

Acronyms

API :Application Programming Interface.

CF :Collaborative Filtering.

C-LOR :Co-location Object Relationship.

C-WOR :Co-work Object Relationship.

DPWS :Device Profile for Web Services.

EM :Embodied Micro-blogging.

FoaF :Friend of a Friend.

GBR :Graph Based Recommender.

GWA :Grey Wolf Algorithm.

IoT :Internet of Things.

IoTSRS :Internet of Things Service Recommender System.

KDI :Knowledge Desire Intention.

MEMS :Micro Electro-Mechanical systems.

MRN :Maximum Ranked Neighborhood.

MRS :Multilevel Recommendation System.

M2M :Machine to Machine.

M2P :Machine to Person.

OFRS :Object Recommendation Based Friendship Selection.

OFS :Object Friendship Selection.

OOR :Owner Object Relationship.

OWL :Ontology Web Language.

POR :Parental Object Relationship.

P2P :Person to Person.

RBAC :Role Based Access.

RDF :Resource Description Format.

RFID :Radio Frequency Identifier.

RS :Recommender System.

SIoT :Social Internet of Things.

SNS :Social Networks.

SSN :Semantic Sensor Network.

SOR :Social Object Relationship.

SWoT :Social Web of Things.

UOA :User Object Affiliation.

WOT :Web of Things.

Chapter01:

General Introduction

1. Introduction

Previously, when we used the term Internet, we didn't really refer to real-world physical connections. Instead, we prefer to see it as a formless set of connections. Thus, it is the space people go to look for information. The Internet has drastically changed the way we work, shop, play and learn within a very short time. Nevertheless, we have scratched the surface barely. We are linking the physical world to the Internet using current and potential technologies to move from the Internet to the Internet of Things is by connecting the unconnected(Cisco 2018).

Therefore, the notion of the Internet encompasses not only the computers and their peripherals but also every surroundings object, such as daily life objects (refrigerator, television, thermostat, air conditioner...etc) and wearable things (bracelet, clothes, glasses and so forth). These objects collaborate in order to achieve a common goal which is enhancing our lives in diverse aspects like domestic, healthcare, transportation, logistic ...etc. Furthermore, it offers a high quality of service.

Aside from the current hype, the Internet of Things will gradually become as important as the Internet itself, with plenty of possibilities and trials. This thesis introduces a dedicated methodology for companies preparing for the transition to IoT-based business models to investigate those choppy waters. In order to develop policies and methods to link the internal information and the media resources with reliable exterior knowledge bases and for open a part of information resources to the public, these policies can improve efficiency and enhance workflow and centralized management, providing enormous opportunities for rapid change in businesses and societies. These emerging developments and innovations will lead to considerable progress for certain enterprises. Failure to respond to the latest developments would undoubtedly result in losing their competitive advantage over other enterprises. Moreover, they will struggle to satisfy the needs and expectations of the clients they serve(Cisco 2018).

1.1. Background

Enterprises will be able to foresee and fix challenges proactively. They will be able to use this information to detect and address future issues before they become a significant issue. At the right time, they will be able to locate and communicate with the correct specialist. In addition, highly-trained and experienced workplace skills can be spread more efficiently across several locations.

IoT enables businesses to cultivate stronger relationships among workers who have innovative approaches to deals, solutions and processes. With the correct procedure, relations are meaningful and add value as the right information is provided in the required way to the right person at the right time(Cisco 2018).

However, connecting people, machines, and information requires handling massive amounts of data and high security. Processes facilitate people, things and data interactions. By integrating machine-to-machine (M2M), machine-to-people (M2P), and people-to-people (P2P) connections, the Internet of Things helps to bring them all together.

Figure 1.1: the four enterprise' component effected by IoT

Businesses may use the IoT to rationalize operating costs by combining teamwork and automation. In addition, companies deliver more specific deals using data obtained from consumers in real-time. However, the way businesses promote and sell goods to consumers still has to be updated.

Technology has transformed consumer habits, such as how to think about goods, compare brands, and even their buying patterns. For this purpose, companies must be able to tailor their ads and special offers for specific consumers and cut costs through targeted advertising. In addition, as a group, consumers can influence the company's bottom line by sharing their views online. Finally, enterprises need to be able to react quickly to any negative feedback from customers or employees.

Thus, the Internet of Things gives companies the opportunity to(Cisco 2018):

Hyper-awareness Data can be captured from a wide range of sources in real-time.

Ability to predict New forms of data analysis tools allow an organization to predict future patterns and behaviors.

Agility Increasingly accurate forecasts allow organizations to respond more to emerging trends and threats.

The combination of these three attributes enables businesses to develop better, communicate and execute their offers which impact the five basic strategic objectives:

Figure 1.2: The five basic strategic objectives

The Smart Connected things incorporate hardware, software, services, analytics and recommendations (Porter and Heppelmann 2015).

Component Hardware: Includes embedded sensors, actuators, processors, intelligent microcontrollers, Micro-Electro-Mechanical Systems (MEMS) and embedded systems.

Product Software: comprises edge-based systems that process sensor data. This field also includes filters, transformers, data aggregators, and machine learning modules.

Connectivity: Connectivity transmits data from the edge level to the Cloud.

Product Database: allows the consolidation, standardization, and real-time and historical data management.

Rules / Analytics Engines: empower future events prediction by applying machine learning and artificial intelligence algorithms.

Smart Product Recommendation Systems: Consumers are linked to actionable insights using the recommendation systems. Item-based recommendations and collaborative filtering are implemented as part of the system.

Security Systems: Access Control, Resource Authorization, and Role Based Access (RBAC) allow information protection.(Vuppalapati 2019)

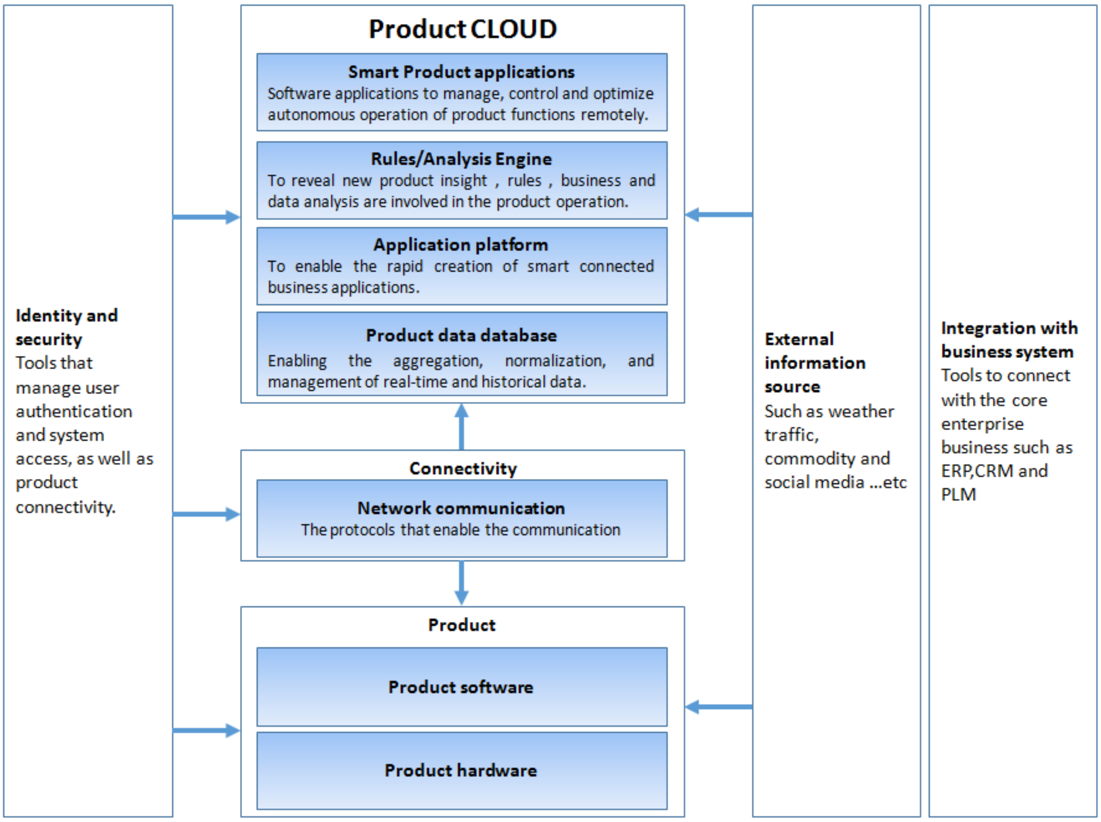

Figure 1.3: product stack

However, independently to the nature of the enterprise whether it is distributed or centralized, enterprises have many axes which have to be managed to get mature in their fields. Those axes encompass work relationships between the employees, Customer relationship, Data management and Security.

Work relationships (better together); Enterprises want to make their project more successful, gain an edge over their rivals and ensure continuous holistic business. Ensuring collaboration between workers or workgroups can be achieved by solid work relationship (collaborative communities). Due to a good driving of productivity, connected workspaces reduce latency by allowing separate teams to work together in real time and improve the interactivity of co-workers who have a common goal to achieve. Thus, the interactivity will be more efficient and more effective.

Data management is crucial for smart enterprises to create, integrate, and manage their applications, processes and entities, demanding timely and accurate data delivery.

It is decisive for enterprises to take all kinds of data (structured, unstructured, and semi-structured) and decide how to format the data to handle and analyze it(Cisco 2018).

Security, Trustworthiness and privacy; Obviously that the availability of data becomes definitive; therefore, a smart enterprise needs a fulfilling policy to manage and link its internal information and media resources with trustworthy external knowledge, furthermore, open a part of their information to the public. On the other hand, the enterprise has to manage access to its data and resources. Therefore, the access to enterprise data will be neither private nor public. Still, data will be smartly available anytime and anywhere, minimizing the risk of losing or leaking the enterprise's information by increasing security and defining the authority of every access.

Customer Relationship Management is a complicated process based on customers' collected data in order to know their habits and needs and understand their behavior. The required responsiveness level has changed; actually, customers demand an instant delivery and customization options. Smart enterprises should have an effective way to respond to their customer's needs, questions and concerns immediately. Efficient management of customer relationships can guarantee actual customer retention and attract new ones.

With the constant sharing of information using connected devices (e.g. consumer actions, behaviors, preferences), companies have a golden opportunity to capitalize on this vast amount of data and knowledge using intelligent systems(Mohammad Rizvi 2022). Hence, enterprises could harness this data to identify new opportunities using Big data analytics, as shown in the following figure.

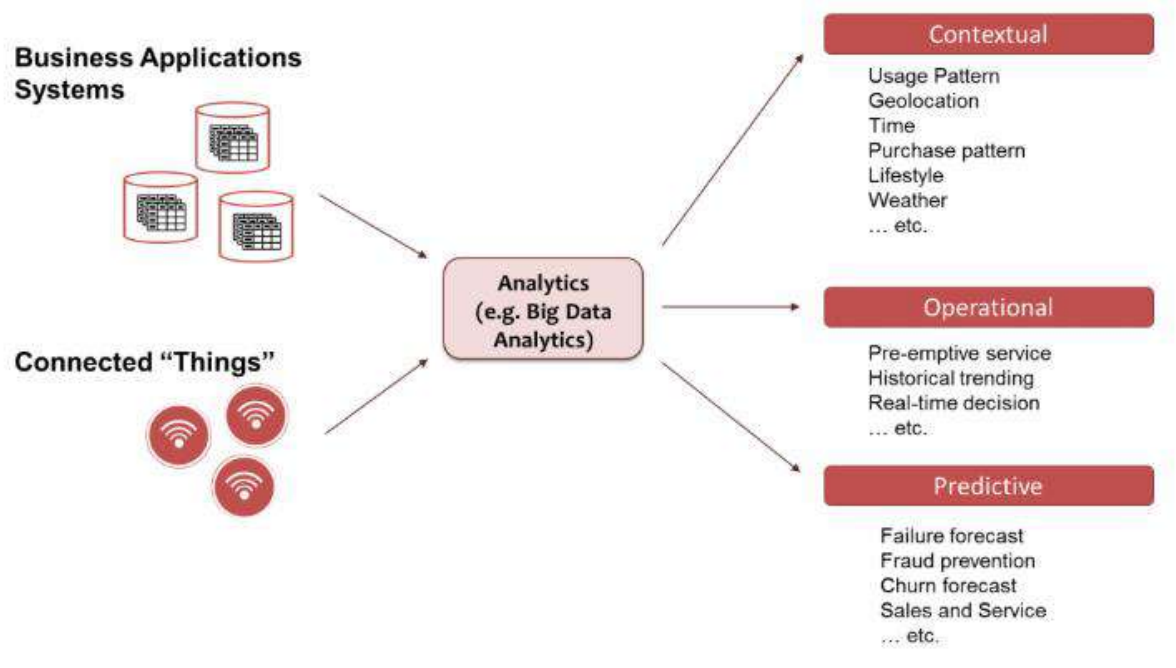

Figure 1.4:Enterprise IoT data analytics(Mohammad Rizvi 2022)

In addition, from the customer perspective, the key advantage presented by IoT will be new services provided by connected objects and (possibly) back-end services based on Big Data. Figure 1-2 provides an overview. Assets (or devices that are part of an asset) are connected to the cloud or business backend within different ecosystems.

New services take place with the software running both on the asset and on the backend. For example, the Connected Horizon (Slama et al. 2015) is a product produced by Bosch. This offers a backend that incorporates conventional map data with additional data such as road signs and road conditions and then uses this data in the car to provide critical advance information for the driver and the various vehicle control systems that make driving safer. This is a perfect example of a service that integrates a multitude of devices and external data sources. Integration between different objects may take place at multiple levels. Assets may communicate directly with each other (e.g. in Car2Car, Car2X, etc.) or the backend integration (e.g. Cloud2Cloud, Cloud2Enterprise, etc.) may take place.

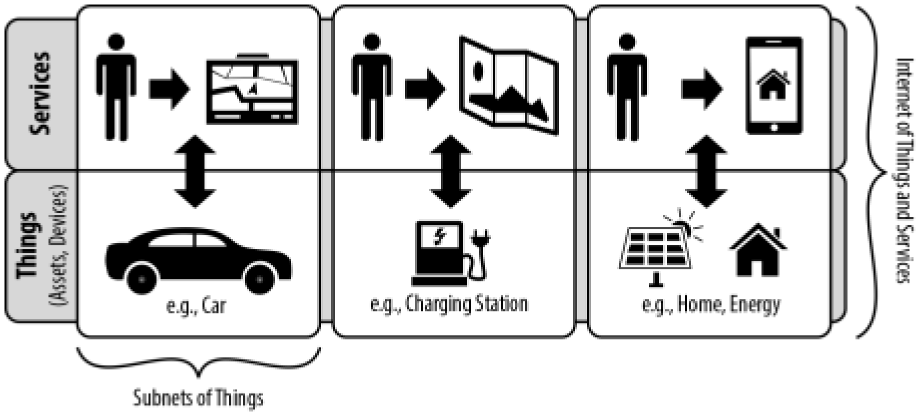

Figure 1.5: internet of things and services recommendation(Slama et al. 2015)

future Those advantages are value-added services based on connected assets and devices for the end-user. As seen in the Connected Horizon example, Big Data can provide contextual information. Furthermore, we can use Big Data analytics to initiate additional customer services, such as recommendations based on customer profile and current location(Slama et al. 2015). Recommender systems are defined as "software tools and techniques providing suggestions for items to be of use to a user"(Ricci et al. 2010). Recommender systems are usually classified into four categories depending on the recommendation approach: content-based, collaborative filtering, knowledge-based and hybrid techniques.

Content-based approaches

Recommender systems of this category use the user's historical ratings to suggest new items similar to those previously rated by the user. (Ricci et al. 2010). The recommendation combines the user’s attributes with those of the item. Thus, the results reflect essentially to the user's level of interest in this item crucially (Lops et al. 2011).

Collaborative filtering techniques

In this technique, the RSs rely on interactions between users and objects in the system.

Since collaborative filtering algorithms typically rely on the similarity between users who have interacted with the system similarly by implicitly or explicitly rate the same items. Therefore, items related to these users should also 1) be applicable to the active user and 2) be included in the list of recommendations(Sarwar et al. 2001).

Knowledge-based recommender system

This type of recommender system relies on knowledge engineering(Lu 2007). This latter is a controversial topic where specific techniques are used, i.e. knowledge representation is a crucial part of competency engineering. Therefore, knowledge engineering plays a vital role in knowledge-based methods, such as ontology, to represent all of the knowledge required in the system(Shishehchi et al. 2012).

Hybrid recommendation

Hybrid techniques are mainly used to achieve more accurate recommendations.(Burke 2002) The principle of combining simple recommendation methods is important so that one profits from offsetting the other's shortcomings.

Besides the advantages brought by the IoT to smart enterprises, no one can hide(deny) the limitation appeared in the environment that uses a large number of connected objects. The customer needs a scalable platform to get the required service easier. In addition, the modern business is fully conscious of targeted marketing, which creates derived customer-based offers. Of the whole reason, businesses require access to consumer data, where people are a central figure in each and every economic structure(Cisco 2018). People engage as data consumers and producers aiming to optimize well-being by meeting human needs. However, data alone does not serve any purpose. A considerable amount of knowledge created by various objects that no one can access serves nobody. Organizing that data to be intelligently accessible requires the definition of relationships to transform that data into useable information to make better-informed decisions and take appropriate actions to create economic value. Defining the relationships between objects is a hard step because of the large number of nodes. Still, we already have a shaped social network that describes relationships among people. Hence, investigate those predefined relations in the social network and the evolution of IoT to build a typical platform.

The is to integrate IoT and social network technologies to create platforms that can affect positively people's lives. Therefore, the goal is to use social networking aspects in the Internet of Things to enable objects to create social relationships autonomously(Atzori et al. 2014a). In addition, the concepts of social networking have proven to be of great importance in handling human relationships. In the same way they will profoundly impact IoT service management(Atzori et al. 2012).

Starting from the fact that things will be linked with the services / information they can provide. In the resulting social network object, the main goal would be to publish, search, and discover information and services and new resources to facilitate the implementation of complicated services and applications. This can be reached in a trustworthy and efficient manner by navigating the social network of "friend" things instead of relying on usual internet discovery tools, which cannot scale billions of future devices(Atzori et al. 2012). Further, a good presentation of services improves the service discovery. Those services will be performed successfully and efficiently using the clustered platform.

The primary motivation is that a social-oriented approach is supposed to improve the discovery, selection and composition of services and knowledge produced by distributed objects and networks that have access to the physical world. The proposed social-oriented approach is defined by the ability of the objects to build social relationships of different kinds independently(Atzori et al. 2014a).

To involve participants in the bottom-up development of a participatory sensing scenario, factors such as trust, reputation, the management of distributed objects and knowledge flows need to be appropriately adapted to monitor what happens to the information and objects submitted. Also, user identities should not be collected but instead kept anonymous. On the other hand, reputation management of the created data needs to be implemented to allow participatory sensing to be successful and to discard malicious or irrelevant data(Atzori et al. 2014a).

However, while SIoT inherits features from various computing and networking environments (i.e., IoT and SNS), an object social graph is constructed with objects connected by edges describing the relationships formed(Ali 2015). Therefore, this module is also crucial for calculating several spatial structures of the social resource graph, such as between-ness, proximity, degree / proprietary hubs and centrality measures of the authority that allow the identification of nodes / resources. In addition, monitoring data flows in the SIoT and influencing the rest of the nodes / resources will result in unintended aspects of data being distributed(Atzori et al. 2014a).

The latter point has been constructive, but what are the improvements brought to the enterprise strategy based on the semantic web using SIoT?

As we mentioned above, the customer requests to benefit from the offered IoT services as a value-added, whereas he could neither own all necessary objects nor trust any available data generated by anonymous owners. In this context, SIoT gives users the opportunity to be intelligently accessible; on the other hand, it gives them trustful and valuable data. Across the basis of accepted standards, people and objects will exchange and transmit information in a scalable, globally accessible manner. The data shared by these components and their social graph must be machine-readable and understandable(Dieter et al. 2019).

In this context, the semantic web proves its effectiveness in which Knowledge is given a well-defined which allows people and computers to work together effectively(Berners-Lee et al. 2001). Hence, ontologies often provide a clear description of the semantics. According to (Fensel and Badia 2002), “The explicit representation of the semantics underlying data, programs, pages, and other Web resources will enable a knowledge-based Web that provides a qualitatively new level of service." Furthermore, a significant feature of ontologies is combining human and machine understanding through comprehensive, real-world semantics and consensual terminology(Fensel and Badia 2002). This crucial ontology property facilitates the exchange and reuse of ontologies between humans and between machines(Dieter et al. 2019). Therefore, based on the IoT and SNS ontologies, we have built our SIoT ontology. Thus, the relationships built upon the SIoT are fairly easy to understand for the human reader because the meanings of the relationships are formally defined. The resulting ontology will be used for the experimental setup of the service IoT recommender system.

1.2. The problem and the objectives of the thesis

RSs have demonstrated their effectiveness in different domains, especially in the e-commerce domains. Since it is crucial problem in IoT recommender systems to find alternative resources of the missing data to fulfill the service requirements. On the other hand, a massive amount of data which is generated by different objects is inefficiently exploited.

This case raises the question about the way how could those available data be used efficiently and trustfully for the service recommendation.

In this thesis, we are interested in the recommendation of IoT services to the enterprise 'customers. We have decided to address the problem of the lacked data to fulfill the IoT service requirement to accomplish the IoT service recommendation in the case of the customer is interested in using the available data. While, Identifying the relationships between objects in order to use their generated data efficiently and trustfully is addressed as well.

Our objective is improving the enterprise strategic especially those related to the recommendation of IoT services using the SIoT. The SIoT is used to manage the relationships between objects based on those relationships between their owners as well as identify the object's profile which contains the IoT data that can be exchanged via SIoT. Therefore, it will be easy to deliver solutions with respect to user preferences and needs.

The main contributions in this thesis are:

- A comparative study of the internet of things recommender systems.
- A stat of the art on the Integration of Internet of Things and Social Network
- Building a dataset that contains information about users, objects and the IoT services.
- The creation of the SIoT ontology to define the relationships between the objects.
- The recommendation of the IoT services based on the interest of the user and the available data.

1.3. Thesis Organization

The rest of the thesis is organized as follows. The second chapter provides background about IoT, the move from IoT to SIoT and an overview of the existing works built upon the SIoT. Chapter 3 is devoted to building the SIoT ontology. The next chapter portrays the methodology and description of presented model in which we use the ontology for the experimental setup where we depict the implementation, evaluation and validation of the system recommender. Finally, the last chapter concludes the thesis with the conclusion and work.

Stat of Art

2. State of Art:

The Internet of Things (IoT) is a paradigm which integrates not only the traditional computer but also many kinds of things or objects around us, those objects are managed by a large number of technologies. Additionally, over unique addressing schemes and standard communication protocols, objects can communicate with each other and interact with their neighbors in order to reach common goals.

Currently, Social networks and IoT are the among most attractive technologies, Social networks are formed of nodes of people, and the edges between these nodes represent their relationships. Social Network (SN) services are essentially promoted as a huge network of people where the relationships between those are shaped and described.

Lately the idea of merging the "Internet of Things" and the "Social Networks" worlds is feasible, or even desirable. Things can not only be a component of traditional networks, they can also be a part of a SN of smart connected things that lead to an effective management of relationships by mimic human being behavior, a scalable and efficient service discovery and composition, as well as trustworthiness management (Atzori et al. 2012).

For this reason, the three worlds of Internet, IoT and SN are combined to bring the physical real world into the virtual world. The resulting paradigm, called Social Internet of Things (SIoT), has the potential to support new applications and networking services for IoT in more efficient and effective methods (Atzori et al. 2011b), this is due to the increasing of awareness, Hence, SIoT paradigm would carry various desirable implications into a future world populated by intelligent objects permeating the daily life of human beings.

This chapter is devoted to present a general review about how the social networks can be integrated with the IoT, the architecture and the key improvement of SIoT besides the application domain as well as the main challenges and open issues of the SIoT. Further, we have depicted the IoT recommender system as knowledge data analysis challenge while we have presented the IoT recommender system features as well as some attractive works.

2.1. Internet of Things:

The Internet of Things (IoT) is an innovative paradigm that is rapidly gaining momentum in the current wireless telecommunication scenario. The fundamental idea of this concept is the ubiquitous presence surrounding us with a set of things or different objects - such as Radio Frequency Identification (RFID) tags, sensors, actuators, smart phones, and so forth. - Which, through unique addressing schemes, are likely to interact and cooperate with each other to achieve common objectives(figure 2.1).

The Internet of Things (IoT) is someway a leading step to a smart world with ubiquitous computing and networking. It proposes to make different tasks manageable for users and give other tasks, such as easy monitoring of various events surrounding us. With ubiquitous computing, computing will be implanted wherever and programmed to act automatically with autonomous triggering; it will be omnipresent.

Indeed, the central power of the IoT idea is the high impact on various aspects of daily life and behavior of potential users. From a private user, the most apparent effects of the IoT will be evident in both working and domestic areas. In this context, assisted living, domestics, e-health, improved learning are simply some examples of possible application scenarios in which the IoT paradigm will play a leading role soon. Thus, from the aspect of business users, the most obvious consequences will be equally apparent in fields like automation and industrial manufacturing, logistics, business/process management and intelligent transport of people and goods (Atzori et al. 2012).

The principle objective of IoT is to allow us to uniquely identify, signify, access and manage things at anytime and anywhere using the internet. The network of interconnected devices can result a big number of intelligent and autonomous applications and services bringing significant personal, professional, and economic gains.

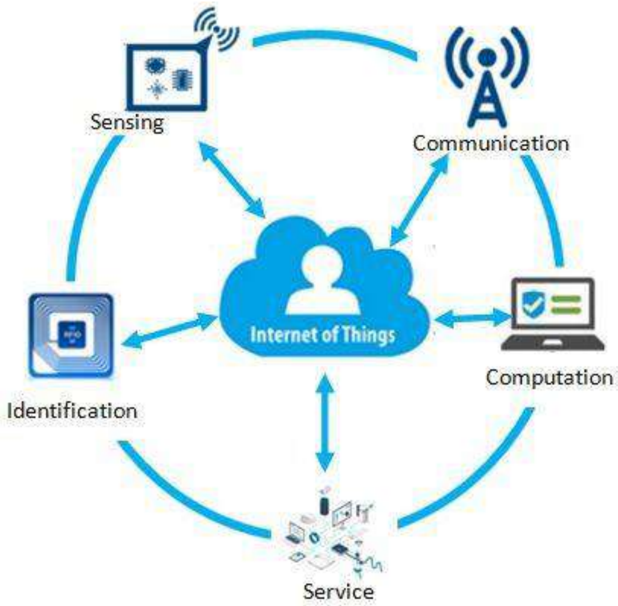

Figure 2. 1:The IoT elements

From the analysis of the potential communication model of IoT we can summarize the following IoT communication models as shown in the figure 2.2:

Thing-To-Thing Communication Model: this model represents that two devices or more can connect directly and communicate to each other without any intermediate application server, this model usually used in applications such as smart home, which use a small packet of data to communicate to each other.

Thing-To-Cloud: In this model, IoT devices connect directly to the cloud, Internet considered as the application service provider for data exchange and traffic control messages, nevertheless, the interoperability challenges emerge when we use things with different technologies.

Thing-To-Gateway: The IoT devices connect each other through an intermediate gateway application layer as a channel to access the cloud service.

Back-End Data Sharing Model: This model is an extension of the Single Thing-To-Cloud thus authorized third parties can accessed to objects and sensors to export and analyze data from the Cloud.

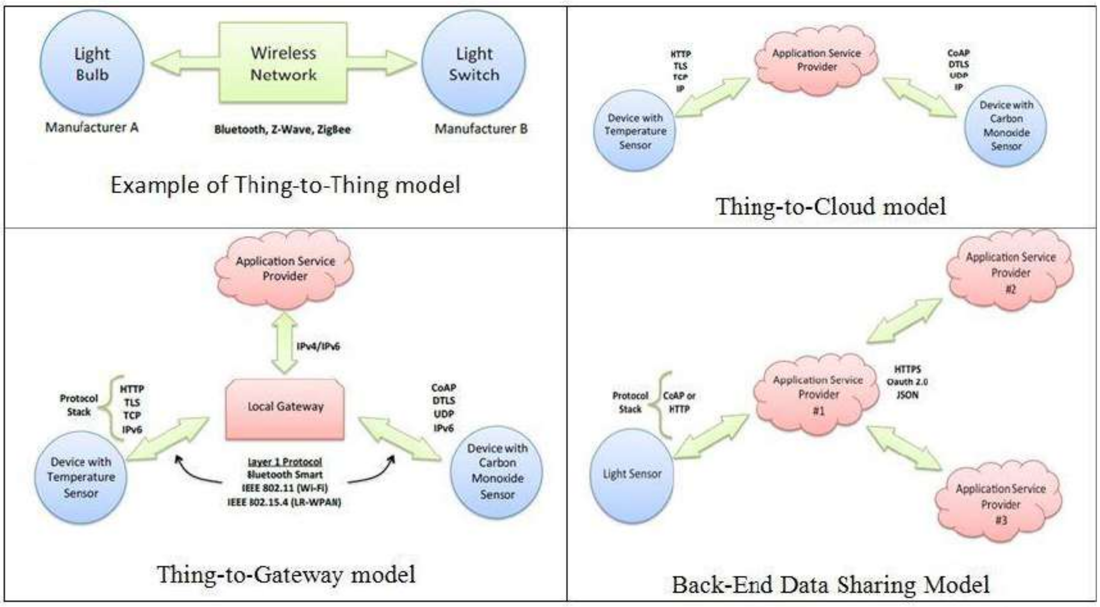

Figure 2. 2: the 4 models of communication of IoT

Scientist predicts that there will be around 50billions of connected objects in the near future. In addition, The IoT has broader overall scope than conventional host communications, Thus, whatever the application scale, small (smart home) or large (smart city, factory) scalability is an absolute need for the IoT, which can guarantee a seamless communication with objects and people. Each one of those objects might provide functionalities as a service; an efficient service discovery requests a good identification of suitable service. Furthermore, users want to know the available services and the information about events surrounding them.

To sum up, the limitation of IoT became obvious as soon as one wants to integrate or deal with devices from various manufacturers, which leads to the introduction of web of things(Guinard 2016).

2.2. Web of Things Paradigm and Technologies

The evolution of the Internet of Things to the Web of Things (WoT), where web-enabled smart objects communicate and interact with each other, has raised many research issues, ranging from the implementation of the correct protocol and connectivity paradigms to the choice of the most fitting architecture types.(Pintus et al. 2011)

In (Guinard 2011), the architecture is described for the implementation of composite applications, interconnecting physical devices, on top of the open and basic standards that produced the success of the web. (REST, XML, HTTP, or Atom). The layered architecture is made up as follows:

- *Device accessibility layer*: A layer that provides clear access to all sorts of linked objects from the application perspective.

- *Find-ability layer*: this layer allows objects to fend their services to other connected objects.

- *Sharing layer*: despite the fact that both accessibility and find-ability layers are allowing the sharing of data. This layer is primarily designed to handle the authentication of the social circle, based on accounting and authorization procedures.

- *Composition layer*: a layer that allows objects to create composite services on the behalf of user.

The main objective of this layered architecture is to encourage the incorporation of smart things with current web services and to improve the implementation of web apps through the use of smart things.

2.2.1. Device accessibility

HTTP-enabled Smart Appliances, Like Wi-Fi printers, networked screens, smart phones. They have already been configured with a network connection and a full HTTP stack, but generally do not provide a WS (Web Service) stack.

In certain cases, they are configured under firewall constraints and can only participate as clients. One potential is to deploy a relay like YALER(Frei and Amberg 2010) in the center which empowers secure Web access to embedded systems behind a firewall/NAT/network gateway.

Internet-enabled Objects that are not fitted with a full HTTP stack but can still connect at the TCP/IP or UDP/IP level. It's simple to create an HTTP wrapper and a WS stack as a proxy for those objects.

Network-enabled Things that cannot communicate over IP networks, but still can communicate with different protocols like ZigBee, Bluetooth or X10. For those objects a proxy can, be deployed to present them in the HTTP addressing space, by also using WS technology standards. A viable solution to extend IP also to small devices that usually are not equipped with IP-stack is 6LoWPAN(Mulligan 2007).

Objects that are not digitally activated, bare physical objects. A digital equivalent must be created and released digitally for these objects. RFID or barcode sticks can be used to interface these objects with smart devices and networks. (Atzori et al. 2014a).

Moreover, objects in IoT establish relationships with "other objects" that can provide needed services when they come in contact, the malfunction of devices can carry out discriminatory attacks, so it is crucial to assess the trustworthiness of service providers and the performance of the application to satisfy the service requester and maximize application performance.

Besides, IoT encompass a huge number of objects, hence each object has to deal with an enormous number of accesses and receive a huge number of queries, furthermore the relationships established among those objects have to be effectively identified and efficiently managed by the IoT platform. That can be achieved by integrating social network with the IoT.

2.3. The Social Network (SN) and Its Features

A social networking sites are an online platform that allow users to create a public profile and interact with other users i.e., SN allow people (1) to build a public or semi-public profile, (2) describe the relationships between people (3) view and browse their list of connections. The nodes in SN refer to individuals and the edges between the nodes describe the relationships between the people. The SNs are characterized by the following characteristics:

- Community driven: In fact, social network users want to discover new friends as well as reconnect their old friends whom lost any contact with.

- Interactive: The SN gives the users a big space to interact with events, news and so forth so we can get and react with the latest news.

- User based: users update the information on social network in real-time and control their profile with contents.

2.3.1. The component of the Social Networks that can be used for the SIoT

During virtual/digital life, the profiling of the user, who is asked at the creation to identify the user and their personal details, is a key part of the SNS. The submitted profiles must therefore be accessible within the framework (and externally) by a social graph module that shows the links between the user and his "friends" publicly or semi-publicly.

The social presence, which allows users to interact with the functionality to cross connections (e.g., to view profiles associated with the 'friends' list), is strongly linked to the social graph.

In order to encourage users to stay in contact with the other participants, participation mechanisms are also used, such as: e-mail, instant messaging, chat rooms, blogs, message boards, telephony, video conferencing and others. Typically, each member is provided with resources to monitor their own presence (search, profile viewing) and how other individuals choose to communicate or be approached. This is the tool of relationship control.

In the current SNSs, another significant module is used and it is obtaining more and more popularity. The Service API feature is an interface that enables either third-party applications to be used in the SNS (the user get benefit from additional services) or external websites to integrate content into their services (e.g., Facebook and OpenSocial).

Therefore, the three fundamental features that can be adopted to give a social structure to the IoT are the following ones:

ID management: which refers to the assignment of an ID that universally identifies all types of objects in the real world. Thus, in order to maintain the new object detection, we are seeking for a framework in which emerging methods can be interoperable.

Object profile: It contains both static and dynamic object details. Objects can be grouped into classes in which each class is described based on the key characteristics of the object. Effective classification methods should be defined in this case. Wherein, the identification of the objects could be based either on the kind of services they deliver or on the kind of interfaces they introduce.

The Owner Control: the owner must be able to determine the functions that the object can perform, the data that can be shared (and the other object that is involved in the sharing), as well as the type of relationships to be formed. Relevant policies must also be defined for each future operation that can be carried out by/on each participant. Various security and access control management description languages can also be used for this purpose (Kamilaris and Pitsillides 2014). Therefore, Owner Control provides the SNS a control component functionality(Atzori et al. 2011a).

2.4. From IoT to social IoT historical

Most IoT systems were originally developed and built-in insulation, due to the limited and isolated small islands of heterogeneous smart things. This is the natural result of isolated experiments and inventions performed without generally recognized and interoperable reference architecture. This has inhibited and still inhibits the introduction of an entire IoT environment on top of which composite applications can easily be created. A simple but successful counter-measure to IoT fragmentation is to allow objects to communicate directly with the external frameworks by relying on web protocols and networking paradigms universally accepted by the modern Internet of Services.

The first innovation was the implementation of what is now widely known as the Web of Things (WoT)(Duquennoy et al. 2009), which depends on the application of web protocols in either the objects themselves or the proxies/gateways. Almost all current implementations use either the Device Profile for Web Services (DPWS) or the Representational State Transfer (RESTful) Application Programming Interfaces (APIs) (also in thing-specific versions, such as Thing-REST(He et al. 2012)). Consequently, the services and information provided may be incorporated into the open ecosystem of the Internet of Services. At the same time, applications can be introduced using standard web languages and tools.

Nevertheless, the WoT model itself has certain lacks, caused by challenges in advertisement, finding, accessing and exploiting objects and their services(He et al. 2012).

A further advantageous aspect is the ability of Internet users and providers to sense and operate on the physical world. One approach in this context is to build a platform where objects can be easily discovered, checked, exploited, and composed. This is the case for several solutions that have recently emerged on the web, such as SenseWeb (http:/www.sensormap.org) and Xively (formerly Pachube— http:/xively.com), that provide users with a central forum to exchange their sensor data and implement related applications.

The natural progression of this concept is to enhance users' attitudes towards sharing their smart devices with people they meet and trust (e.g., family members, colleagues, friends, and fellow researchers) without the need to build any additional social network or user database on a new web service from scratch.

Indeed, Holmquist et al. (Holmquist et al. 2001) have introduced one of the first ideas of pseudo-socialization between objects. Using the so-called Smart-Its Friends technique, users had a very convenient interface to enforce temporary friendship relationships on Smart-Its (smart wireless systems that typically combine sensing, computing, and communication functions) depending on the system context.

The so-called Blog-jects, corresponding to the "objects that blogs" presented in(Black 2011), are descriptions of this new approach towards strong interaction with the world, which is considered necessary to be embodied in traditional devices. The leap away from the past is illustrated here by a strong distinction between a "thing" that is merely linked to the Internet and a "thing" that plays an active role in the social network.

The conceptual idea of embodied microblogging (EM) proposed in (Nazzi and Sokoler 2011) is a fascinating example of an effort to reach further beyond the present vision of IoT as a mere opportunity to make objects linked and conveniently accessible over the web. It does not rely on thing-to-thing or human-to-thing interactions, but it proposes a novel feature for enhanced daily objects that are enabled the:

• Mediation of human-to-human communication.

• Boost additional approaches to render visible and noticeable events in daily life.

Reference(Kranz Matthias et al. 2010) gives an insightful description of the expected architecture of the IoT network, but does not specify which features the IoT social network structure may include.

A significant contribution to the description of a social IoT is presented in (Kranz Matthias et al. 2010). This article discusses the possibilities of combining IoT and social networks and presents useful examples of applications; however, it does not discuss potential protocols for forming social connections between objects and indicators or possible architectural solutions for social IoT.

Correspondingly, the idea of social IoT exists within the aims of many strategic study agendas, but only in the context of a mere declaration of interest (e.g., the Finnish Strategic Agenda for Science).

Significant emphasis is provided to the discovery of the social potential of the building blocks of IoT (Kosmatos et al. 2011). This study outlines the architecture in which objects are explicitly identified as potentially able of engaging in the group of objects, forming interest groups and taking collective action. However, this article also lacks a definition of how to create the intended social network of objects and how to incorporate the architecture and protocols required. In various ways,(An et al. 2011) the social features reflecting on the social relations of the nodes are evaluated and the results of the initial investigation of the system features are described in terms of certain main parameters. The action of mobile nodes is also analyzed by applying the typical principle of social networks(Atzori et al. 2014b). The following figure 2.3 shows in summary the historical movement from IoT to social IoT.

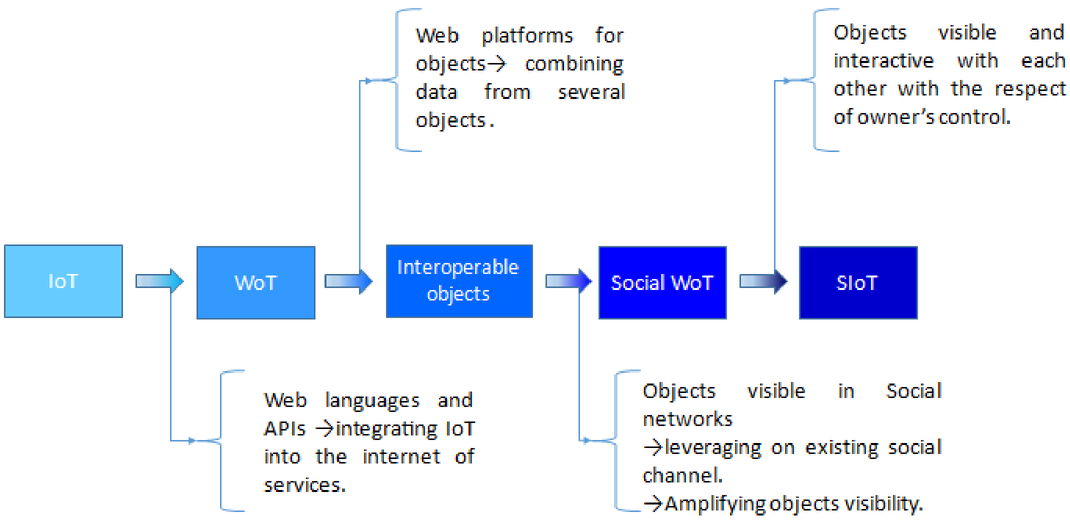

Figure 2. 3: the historical development from IoT to SIoT (Atzori et al. 2014b)

Consequently, we can get a new generation of social objects that: i) are able to communicate with other objects independently of the owners; (ii) can conveniently crawl the IoT made up of billions of objects to acquire services and information in a trust-oriented manner; and (iii) are able to advertise their existence in order to offer services to the rest of the network.

This results in a new vision of an improved IoT where principles and technology characteristic of social networks are extended to the world of things to facilitate resource visibility, service finding, object reputation estimation, source crowding, and service composition, equivalent to what has been partially achieved to solve the problem of routing in a delay-tolerant networks.

We are actually looking forward to an evolutionary leap from objects with a certain level of smartness to objects with a specific social consciousness.

2.5. SOCIAL IOT

Nowadays, SN and IoT are both among the most promising paradigms, merging these technologies (figure 2.4) leads to a wide range of intelligent services and applications to deal with many challenges that individuals and organizations face in their daily lives by allowing people to be related to anyone, anywhere, at any time. While IoT studies (ITU 2005),(Atzori et al. 2011b) have typically mentioned communication to the physical world by detecting or acting through many different devices to be the biggest novelty.

A new paradigm called Social IoT (SIoT) refers to a set of embedded objects connected via internet through unique addressing schemes, considering humans related data such as profiles, preferences, habits and social relationships i.e.: Social IoT is used for context awareness through engaging users and users' profile in order to provide user-oriented services and recommendations. For this purpose, there are two considerations: 1) increasing sociality (or connectivity) and 2) enhancing pervasiveness (or availability)(Ortiz et al. 2014).

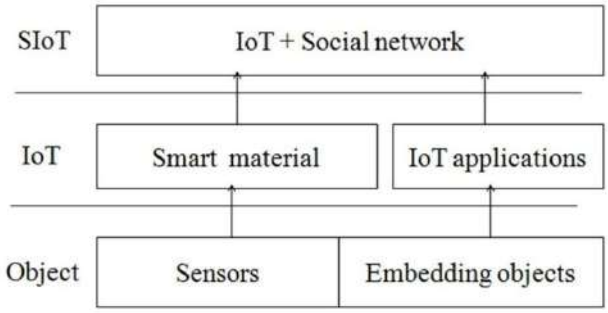

Figure 2. 4: Combination of social network and IoT

2.5.1. Key Improvement of SIoT

The actual implementation of the seamless integration between social and IoT worlds brings the main characteristics of social network to the IoT; here we summarized the main improvement expectant of SIoT:

Interactivity: The pairing between humans and things in IoT can take place in two forms: 1) human- to-human, or 2) machine-to-machine interaction, and it can be achieved using the normal physical interaction in case of humans or various computer networks in case of things. Authors in (Ortiz et al. 2014) claim that implementing human-to-machine cooperation is essential to achieve the completed vision of SIoT. The SIoT extend the notion of SN from people to the objects so the interactivity is one of the advantages of SIoT that has a positive influence overall system.

Collaboration and Sharing Information: This perspective appears to be the most critical one in order to realize a full convergence of both the social and IoT worlds because the collaboration and sharing information occur between human, between things and between human and things. Considering social values, SIoT ultimately enables humans and things to act as producers or consumers (Guinard 2011).

Handled-Data: It is also very important to consider the kind of data acquisition and handling techniques required to be considered in pervasive environments. Authors in (Ortiz et al. 2014) categorize data acquisition techniques into two categories: 1) proactive data recovery that is usually uses crawling techniques, learning algorithms, or various data analysis algorithms and 2) reactive data acquisition which habitually operates in a real-time way using various data mining and query techniques.

2.5.2. SIoT Architecture

The SIoT system contain server, gateway and object, these components are distributed to three main layers (Hussein et al. 2017), Sensing layer, Network layer and Application layer (Atzori et al. 2012). The architecture of each object may vary depending on the model of communication discussed in section 2.1.

- **SIoT server:** the server is situated in the application layer also it encompasses three sub-layers, The Base layer is *The Handling data layer* which consists of database for storing and managing data with their descriptors, ontology databases, semantic engines and communications. *The Resource management Sub-layer* comprises tools which implement the key functionality of the SIoT system such as ID management, profiling and relationships management. *The Interfaces sub-layer* is devoted to ensure the best way of communication between objects, humans, and services.

- **The object:** the sub-layers, which the objects consist of, may mainly vary rely on their nature, we have 2 kind of objects; dummy objects (sensors) and smart objects (smart phone)

In simple scenario, the dummy object' role is just sending the sensing data to another equipment (gateway) in this case the object encompasses just the lowest layer which is the sensing layer. Otherwise, the smart object may contain the three sub-layers, Sensing, Network and Application. This latter encompasses the SIoT application as well as the social agent and the service management agent, which are presented in Figure 2.5.

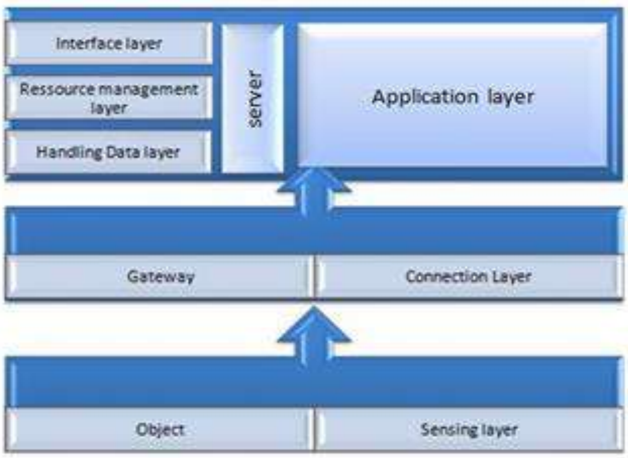

Figure 2. 5: Architecture for the SIoT ecosystem (Atzori et al. 2012)

The social agent is dedicated to communicate with SIoT servers to update profiles and friendships, discover and request social network services, it also implemented to allow objects to communicate to each other when they are close geographically.

The Service management agent is responsible for interfacing with humans that can control the object behavior of the object when communicating within their social network.

- **The Gateway** made up only of the Network layer to ensure the connection between the SIoT server and objects.

2.5.3. The contribution of SIoT comparing to the IoT

Relationships management: From the analysis of possible service and application typologies, Things on the Social IoT can mimic the human being behavior on Social Networks, by creating social relationships among each other on the envisaged Social Internet of Things. Authors in (Ortiz et al. 2014) propose the followed classifications of the defined relationships(figure 2.6):

Parental object relationship (POR): established among objects produced by the same production batch, that is to say, generally homogeneous objects from the same manufacturer and in the same period. Furthermore, objects can establish a *Co-location object relationship*(C-LOR), this type of relationships defined among objects (either homogeneous or heterogeneous) worked always in the same place (as in the case of sensors, actuators, and augmented things used in the same environment such as a smart home or a smart city) this relationships can also be established sporadically between vehicle and smart objects when they meet in the same space , also the objects can mimic the relationships between workmates in *Co-work object relationship* (C-WOR) this latter established whenever the objects cooperate to produce a common IoT application as in the case of objects coming into contact to be used together and cooperate for applications such as emergency response, telemedicine, and so forth.

Heterogeneous objects, which belong to the same owner (mobile phones, music players, game consoles, etc.), can establish relationships named *Ownership object relationship* (OOR). The last relationships defined in(Ortiz et al. 2014) is the *Social object relationship* (SOR) which established when objects come into contact, sporadically or continuously, because their owners come in touch with each other during their lives (e.g., devices and sensors belonging to friends, classmates, travel companions, colleagues).

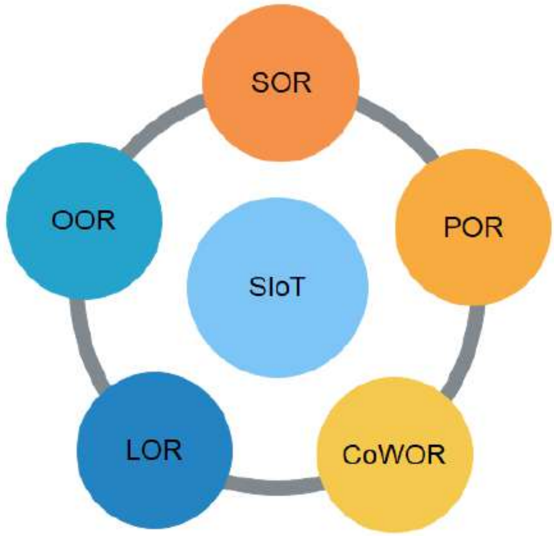

Figure 2. 6: Type of relationships between object on SIoT

Scalability: SIoT structure can be shaped as necessary to ensure the seamless of the network. Hence, the scalability is guaranteed as on human social network. Further, every node capable to create social relationships with other things.

Service discovery: based on the scalable system each object can look for the requisite service by exploiting its relationships to guarantee an efficient search for the desired services and objects in the same way as humans look for knowledge in SN.

Trustworthiness: fulfilling the trust management consist of: collect the required information in order to make a trust relationship decision, evaluate the criteria of choosing the trust relationship, verify and readdress the existed relationships, Moreover, ensure the dynamic change of trust relationships (Grandison and Sloman 2000). A level of reliability can be established to take advantages of the degree of interaction between things that are friends.

2.5.4. Application Domain

The Technological Assistant using the parental relationships to seek for relevant information (through such key features as class of object, brand, and typology), to find the suitable configuration by autonomously find a mate which has already addressed the same configuration issues, as well as fixing problems in order to maintain the current object.

Healthcare

As healthcare is one of the most attractive application in IoT because their vital role in saving human life. Thus, the SIoT can also affect positively the healthcare application by creating a social relationship among objects belonging to family members.

Therefore, objects will be automatically notified when detect current abnormal behavior and status of the current user so that this information can reach the members of his family as well as the doctor.

Logistics Management

Chests of perishable products know the condition and quantity of their contents (as set by the producer), thus, they will be able to constantly track the state of the environment and know their current location. They make this information accessible to the rest of the object community in compliance with particular rules specified by the owner(Atzori et al. 2014b).

Urban Traffic

Convenient "traffic efficiency" applications are widely requested as people hate to waste time trapped in traffic due to unforeseen congestion accident, strikes, or natural disasters. Recently, the car, as a member of SIoT, has been exchanging information on the state of traffic with the cars it regularly meets(Atzori et al. 2014b). This detail contains the route taken over the last ten minutes and the time spent. Collecting this information from a variety of reputable sources makes it easy to determine the fastest route to the next meeting and eliminate unforeseen bottleneck points.

2.5.5. Challenges and Open Research issues

Integrating IoT and SN is not a spur of the moment but this technology still an immature. With the aim of making a mature SIoT paradigm, there are still many challenges that must be faced prior to the worldwide deployment of this technology:

Interoperability and standardization: Due of the heterogeneous nature of IoT things, which include the different information processing and communication skills, as well as the characteristics and data, relationships and capabilities of the SN user, the system must be able to manage this variety of data types, to ensure the interoperability between all components, the most widespread method to achieve the interoperability is the use of the ontology. This latter is a well formulated technique of specification and conceptualization of a set of objects and the relationships among them.

Power and Energy Management: Objects that participate in the SIoT generally move around and they are not tied to unlimited power. Users use portable devices that usually work with batteries. Therefore, energy saving is a conditioning factor in the plan and operation of SIoT. Thus, the effective energy management should be implemented at all levels, M2M device communications to interface design.

Interactions and Interfaces: The SIoT base will focus on providing users with a high-level experience to be able to consume and produce data and services from objects and other users. Therefore, the human- centered interface should present a user-friendly way to interact with objects and users. The way users and devices interact with each other is always an open challenge. Some approaches such as (Saleem et al. 2017) and (Beltran et al. 2014) propose a set of possible interactions between the different elements, but most are focused on specific applications. A global set of interactions must be defined, as well as methods for managing these interactions, for example, users can obtain data from their own devices, Authors in (Saleem et al. 2017) propose that SIoT constructs an object profile based on IoT application data that can be exchanged with the SIoT network to be accessible to other IoT applications, in this way, SIoT recommends applications and information to users.

Semantics and Context Management: The SIoT aims to provide functionality in several situations as well as a set of devices can be used for several purposes simultaneously. Thus, the ability to properly manage the current context not only improves the performance of the system, but also makes it more usable by providing unequivocal access and interpretation of data. A semantic management context can be made as 1) first analyze existing definitions for each terms 2) conclude a definition of the whole term(Jacoby et al. 2017). Semantic approaches based on RDF (Resource Description Format) and OWL (Ontology Web Language) can be extended to include descriptors for SIoT users and device characteristics, which facilitates interoperability across all components (Ortiz et al. 2014).

Data mining and Emotional Artificial Intelligence: Humans contact their personal device more than their family members; more and more smart devices will be able to aware the emotions and moods of their owner rely on certain data and facts. Further, Emotional AI allows daily life objects to detect, analyze, process and react based on the emotional states and moods of humans. In addition, Emotional AI can lead to high quality of experience i.e. stockholders may base their decision on the emotional reactions rather than the rational ones.

2.6. Recommender system in IoT and SIoT

One of the intelligent uses of the data mining besides the context management is the recommender systems (RSs). Those latter have demonstrated their effectiveness in different domains, especially in the e-commerce domains. Since it is crucial problem in IoT recommender systems to find alternative resources of the lack data to fulfill the service requirements.

In which, SIoT speeds up the growth of data accessible on the Internet, inhibiting the ability of conventional research paradigms to get knowledge from steady and deep examination to meet end-user needs. Based on these available data, intelligence mechanisms are required to suggest or recommend suitable products to IoT users in order to get benefit from the communication and the useful data produced by objects from smart spaces and create automatic solutions and services.

2.6.1. IoT recommender system challenges

In this context, the IoT consists of special features that bring more complexities and more challenges to the IoT recommendation systems(Mashal et al. 2016a). The IoT features such as heterogeneity, real-time communication, scalability (Yao et al. 2019), and mobility provoke certain applications to encounter certain limitations and can hence become unable to perform successful IoT tasks(Bouazza et al. 2019). Likewise, the recommender systems face new challenges, and for many reasons, they are much more complex than conventional recommender systems:

• Highly dynamic(Mashal et al. 2016a): The changing nature of things needs models that can adjust rapidly to their ever-changing states and still reflect the most up-to-date recommendations.

• Findability refers to the process of finding alternative resources of information in case of a lack.

• Service composition(Bouazza et al. 2019) refers to the integration of the functionalities of multiple devices in a single process in order to accomplish complex services which could not be done by a single device. Thus, the service composition offers the ability to perform complex service using available data generated by various objects.

•Contextual information or spatiotemporal correlation(Yao et al. 2019), such as time and place. The heterogeneous complexity of spatiotemporal data is still a big challenge for the recommendation.

•Social Trust: one of the most important challenges in IoT recommender systems is related to reliable data fusion to benefit services. Thus, the social trust allows people to overcome not only data lack, but also perceptions of risks and uncertainties(Bouazza et al. 2019). Therefore, the use of IoT services and applications using trustful data generated by objects owned by different owners.

•Relationship between users(Yao 2016)to foster and generate a personalized recommendation.

•Relationship between objects(Mashal et al. 2016a): RS needs to be able to analyze heterogeneous relationships between various objects and facilities, which adds more complexity to RS. These relationships may be required thorough review and identification to generate precise results for recommendations.

2.6.2. Related works

Besides the fact that the RS proves its effectiveness in many fields, IoT recommender system is still in its emergence. There are many outstanding works in this field in which IoT is used as a source of information, propagation medium, or both. Besides, IoT recommender system proposes items such as food, objects, or IoT services in different daily life fields.

2.6.2.1. Information and tasks recommendation

A user recommendation scheme is proposed in(Bok et al. 2021), this study aims to facilitate data sharing through a user-device and user-user interaction analysis in SIoT environment. In the proposed scheme, the similarity between users is calculated from user preference defined by IoT device usage frequency and interest keywords, which are identified through an analysis of user-device and user-user interactions. Finally, the proposed scheme recommends new top-N users who have a high similarity as the users for data sharing.

To deliver the right information to the right person with spatiotemporal criteria according to his background, interests, priorities, profile, and the used devices. The authors of (Valtolina et al. 2014) have sought a multilevel recommendation system (MRS) in which a set of services are enabled to advise relevant information and create an interactive mechanism for integrating users in decision-making activities based on user profiles and use contexts. Otherwise, they have included the user not only as an IoT system participant, but also as a member of the social group of interest (Fischer 2001). Therefore, they make decisions based on the manipulation of social network content to incorporate the proposed service with social analysis and crowdsourcing, as well as interpretations which lead to new significant usage and data presentation.

In the same context, the integration of cognitive reasoning into Social IoT to suggest everyday activities in smart homes was addressed in (Hussein et al. 2015)where authors have used cognitive reasoning to incorporate objective and subjective elements of the environment to define user circumstances. This reasoning process has been implemented into a task-based smart recommender system to respond to user situational objectives that are sensed by schedules, interests, everyday activities, and smart home features and conditions.

Furthermore, the authors of (Frey et al. 2015)have introduced the concept of creating a digital inventory based on the data obtained from the installed application on the smart devices. Thus, the installed apps are also entities available to gather information on customer’s needs and preferences in order to automatically conduct a digital inventory for each user. Recommender systems can use these inventories for collaborative filtering and/or non-intrusive offering of consumer-related products and services.

2.6.2.2. Healthcare and tourism recommender systems

Healthcare data is very rich and often contains information relating to human safety. Considering the great potential of saving human life and enhancing the quality of life, analyzing healthcare data is of crucial importance. Therefore, IoT-based healthcare recommendation systems provide the greatest promise to track the human body efficiently, while recommending diets with specific foods and drugs. Authors of (Ali et al. 2018)suggested type-2 fuzzy logic and fuzzy ontology-based decision-making knowledge to streamline the overall food and drug recommendation procedures for IoT healthcare systems. This proposed framework contains two layers of information: a security layer, and a type-2 fuzzy ontology-based knowledge layer for decision making. The security layer prevents unauthorized access to a smart refrigerator and medical equipment and investigates the patient true condition before food and medication recommendations. The semantic knowledge layer based on type-2 fuzzy ontology extracts the patient hazard attribute values through wearable sensors. Through which it monitors the patient health status using type-2 fuzzy logic, retrieves medication and food information from the fuzzy ontology, and then recommends medicine for a smart medicine box and food for a smart refrigerator, depending on the patient's condition.

Furthermore, ProTrip is a health-centric tourism recommendation framework focusing on hybrid filtering mechanisms and intelligent recommendation models, which has been introduced in (Vijayakumar and Chilamkurti 2018). ProTrip is an ontology-based approach that exploits health and nutrition knowledge on a semantic basis and manipulates a hybrid filtering mechanism proposed by Blanco-Fernández et al (Blanco-Fernández et al. 2011). In which, authors have incorporated the three main forms of filtering, i.e., collaborative filtering, content-based filtering, and knowledge-based filtering. In Addition, considering the fact that certain climatic conditions and other foods are reserved for users due to their health problems(Al-Nazer et al. 2014). Nutrition and health-oriented profile are used to maximize fulfillment and to represent the recovered data to meet the needs of the user.

In the same context, Authors of (Lye et al. 2020) have recommended locations/places based on the user location histories using the trajectory analysis. In which, the use of a trajectory analysis framework applies user location histories, precisely the trajectories of users with similar behavior and movement patterns. Besides, profile users' data is collected explicitly (e.g., item ratings) and implicitly (e.g., location history and the number of orders) using the knowledge–desire–intention (KDI) model(Xing et al. 2018). As a result, they developed a hybrid recommendation approach to perform personalized recommendations using the available trajectory-based and contextualized data. Where the developed framework is appropriate for service discovery and composition in SIoT networks. While, in (Khelloufi et al. 2021), authors present a service recommendation system based on social relationships between IoT devices’ owners. Where, they use the social relationships defined in the SIoT to establish service recommendations between devices. As a result, the devices inherit their owners' social relationships in order to have a socially aware service recommendation. They also introduced a boundary-based group detection algorithm for forming socially connected device groups based on their shared preferences, interests, and social relationships. The proposed system's performance was demonstrated by comparing it to previous related works using detailed experiments on real-world data obtained from the Santander smart city.

2.6.2.3. Objects and services recommendation

Recommendation of appropriate objects to perform the necessary task was explored in(Yao 2016). Wherein the authors have built a RS by exploring the relationships between objects which have a major impact on user preferences and human decision-making. In addition, the association between objects can be identified and manipulated to support the prediction of user behavior. In particular, authors have established a hyper-graph to devise things with implicit correlations, in which composite relationships in user interactions can be revealed to the highest possible level. Finally, they have proposed a successive technique based on the Monte Carlo method to track continuously the availability status of physical objects and integrate this dynamic feature of physical objects in the proposed system to enhance the results of recommendations.

In addition, in(Rajendran and Jebakumar 2021), the authors proposed an Object Recommendation based Friendship Selection (ORFS) model to manage social relationships and enhance network navigability in the SIoT environment. The major contributions of the proposed model are: (i) The development of a User Object Affiliation (GWA-UOA) mechanism based on a Grey Wolf Algorithm for the Smarter Object Recommendation (SOR).(ii) The proposition of an Object Friendship Selection (OFS) through network navigability using Maximum Ranked Neighborhood (MRN) approach for navigating the desired service by establishing a friendship link. In which the MRN is calculated using collaborative filtering (Pearson correlation), while the OFS is used to select the suitable object to be the service provider. Besides, the GWA-UOA algorithm to detect the location of objects. Experimental results proved the performance of the proposed model for navigating smarter social objects in SIoT.

The authors of (Mashal et al. 2016b)have presented an IoT recommendation of IoT services and objects. In which, the authors have proposed a graph-based model for IoT systems to model the correlation between objects, users, and services where the system is presented by an intercorrelated tripartite graph with hyper-edges between users, objects, and services. In addition, authors have tested and evaluated recommendation algorithms in the IoT by censoriously compare the performance of different algorithms. Thus, they have conducted experiments in which they have examined and discovered correlations between outputs of different algorithms. Accordingly, they have shown that the graph-based recommendation algorithm can be used for maturing the performance of IoT recommender systems. In the same context, (Forouzandeh et al. 2017) have recommended IoT services and objects using collaborative filtering.
The following table (Table 2.1) summarizes a comparison between the related works based on the IoT recommender systems challenges above mentioned.

Works	Contextual data	Relation between objects	Relation between users	Findability	Service composition	Social Trust	Recommender type	Dataset
(Bok et al. 2021)	No	No	Similarity-based on object preference calculated from object usage and user interest	No	No	No	Collaborative filtering	IoT Network Dataset http://www.social-iot.org
(Valtolina et al. 2014)	Yes	No	Yes	No	No	No	Collaborative filtering	/
(Hussein et al. 2015)	Yes	Yes	No	No	Yes	Yes	Knowledge-Based Recommender	context synthetic dataset
(Frey et al. 2015)	No	No	No	No	No	No	Content based	/
(Ali et al. 2018)	Yes	No	No	No	No	Yes	Knowledge-Based Recommender	Dataset1(medicines with effects) + Dataset2(diseases with drug)
(Vijayakumar and	Yes	No	No	No	No	No	Hybrid	Collected dataset (food + climate datasets)

Chilamkurti 2018)								
(Lye et al. 2020)	Yes	No	Yes	No	No	Yes	Hybrid	GeoLife (GPS trajectory) + Wee places Brightkite and Gowalla (Check-in point)
(Khelloufi et al. 2021)	No	Yes	Based on interests	No	No	No	hybrid filtering	Devices' information and relationships
(Yao 2016)	Yes	Yes	Yes	Yes	No	Yes	Collaborative filtering	Cook and Schmitter-Edgecombe 2009+ Singla et al. 2010 http://casas.wsu.edu/datasets/
(Rajendran and Jebakumar 2021)	user's predilection	Social similarity via object's sociality analogous	No	Maximum Ranked Neighborhood (MRN) approach	No	Object's friendship link	Collaborative filtering	MIT and CASAS datasets (event data acquired from many smart residential apartments)
(Mashal et al. 2016b)	No	Yes	No	No	Yes	No	Knowledge-Based Recommender	collected dataset using a survey
(Forouzandeh et al. 2017)	No	Yes	No	No	Yes	No	Collaborative filtering	collected dataset using a survey

Table 2 1: Comparison Between Works

The above-mentioned related works are covering many domains whether are domain-specific (Information and tasks recommendation, Healthcare and tourism recommender systems) or generic domain (Objects and services recommendation). Despite the fact that many works are using the SIoT as an ecosystem but it has been used, only to foster similarities between users. On the other hand, the IoT service recommender systems are based on objects owned by users without taking, the social relationships of users or the social relationships between objects, into consideration. This has inhibited and still inhibits the implementation of an actual IoT ecosystem where composite services can easily be created(Atzori et al. 2014b) since it is serious problem in IoT service recommender systems to find alternative resources of the lack data to fulfill the service requirement to accomplish the service recommendation. An evident but efficient counter-measure to IoT fragmentation is to allow objects to interact directly with the external world by relying on SIoT using social relationships between users and their objects. Accordingly, this results an efficient use of available IoT data provided by different devices in which findability and service composition are essential parts of our proposed recommender system where objects that belong to friends are allowed to collaborate together to accomplish a service on the behalf of the current user using the SIoT. Consequently, we can visualize a new generation of social objects that (Asl et al. 2013):(i) are able to communicate and interact with other objects autonomously with the respect of the owner's control; (ii) can efficiently crawl the IoT network which made up of billions of objects to discover services and information in a trust-oriented manner; and (iii) are able to advertise their existence in order to offer services to the rest of the network.

Methodology and description of presented model

3. Methodology and description of presented model:

This chapter shows the methodology and description of presented model of the research. We introduce our proposition model for **IoT service recommendation using Social IoT** where we incorporate social relationships between objects into the recommendation process. In which, the increasing number of smart objects and devices which are connected to the Internet leads to the introduction of numerous IoT services. However, due to the overloading of information, many users suffer from several difficulties in obtaining useful and relevant services that meet their needs and interests. Recommender Systems (RSs) provide an efficient solution to this complex problem. Yet, the existing IoT recommender systems are based on objects owned by the users themselves because it is a serious problem, in IoT recommender systems, to find alternative resources of the lack data to fulfill the service requirements. Whereas, the IoT data that are generated by various objects are inefficiently used. An efficient IoT service recommendation can be reached using Social IoT (SIoT) using the generated data by various IoT devices owned by friends and friends of friends. In which, we want to recommend IoT services to users not only those that are interested in but those that are able to use. In this chapter, we propose a hybrid technique that combines implicit collaborative filtering and ontology to recommend personalized IoT services to users. Ontology is used for modeling the SIoT where we incorporate the social relationships among objects into the recommendation process alongside the ratings while collaborative filtering predicts ratings and generates recommendations.

Why we use the hybrid approach to recommend IoT services to enterprise' customer?

We decided to build a hybrid approach. We took this decision because of the following reason:

The IoT brings extraordinary flows of data, presenting performance, operational and management challenges to enterprises. By combining the major technical and business trends of mobility, automation, and data analytics, the Internet of Things (IoT) has the potential to provide enormous opportunities for rapid change in businesses by profoundly transform how enterprises gather data and information. On the other hand, from the customer perspective, the key advantage presented by IoT will be the IoT services provided by enterprises using the available data generated by connected objects.

In which, the more time elapses, the smart devices will be connected and endless data will be available. Thus, within the near future, many users will subscribe and request more of those value-added services.

The increasing proliferation of services has led to the information overload issue, which raises difficulties for enterprises to suggest the suitable service to their customer. on the other hand, users suffer to discover and access services of potential interests thus recommendation of IoT services will be a necessity in the coming years. Despite the fact that there are many attractive works on IoT recommender system, most of the those previous IoT recommender did not take social relationships among objects whereas even those works that takes social relationships among objects they used it only to foster the similarity.

Hence, in order to implement the IoT service recommender system taking social relationships into consideration not only to foster similarities but also to use those relationships for service composition we have done the following steps:

We model the SIoT using ontology in order to show how are the relationships built upon besides the main features like service composition and so on.

On the other hand, we collect data using a questionnaire about the services that users are interested in. The data were collected from 465 users. Each respondent was asked to choose the objects he/she owns or would like to own. Further, users were asked to pick IoT services they are interested in. the collected data will be latter prepared and preprocessed into a format that is required by the CF recommendation engine. In which, we use collaborative filtering as recommendation approach to calculate the similarities between users.
The service composition requests the availability of the data to be accomplished, in this context we use the tuning parameter (alpha) to guarantee this availability.

3.1. The Proposed Approach

In the following part, we will discuss our proposed recommendation system which is depicted in the following figure3.1 wherein the recommendation is made using a dataset that is used to calculate the similarities between users whereas IoT service recommender system (IoTSRS) is based on a hybrid approach, where we combine the implicit collaborative filtering with the ontology. This latter is devoted to depict the relationships built between objects into the SIoT besides the main features of the SIoT which are relationship management, service discovery, service composition, and trust management.

Thus, in our IoT recommender system, each service is defined by a profile containing the service role and the required data to be accomplished. The users own devices/objects where each object/device has a profile containing its performed process. Furthermore, the object does not only act as an information provider but also as a requester by crawling the social graph of objects/devices to feed the service with the data needed. In other words, when a node requests the lacked data to accomplish the service, it broadcasts the required information in the network and selects the most appropriate object from the responders that could provide this information. Selections

are made on the basis of the social graph of each object built by the ontology.
Indeed, the relationships examined in the proposed system are covering but not limited to ownership relationship, social relationship, and co-work relationships. Therefore, the service discovery and composition would be better applied because the trustworthiness is increased in those relationships.

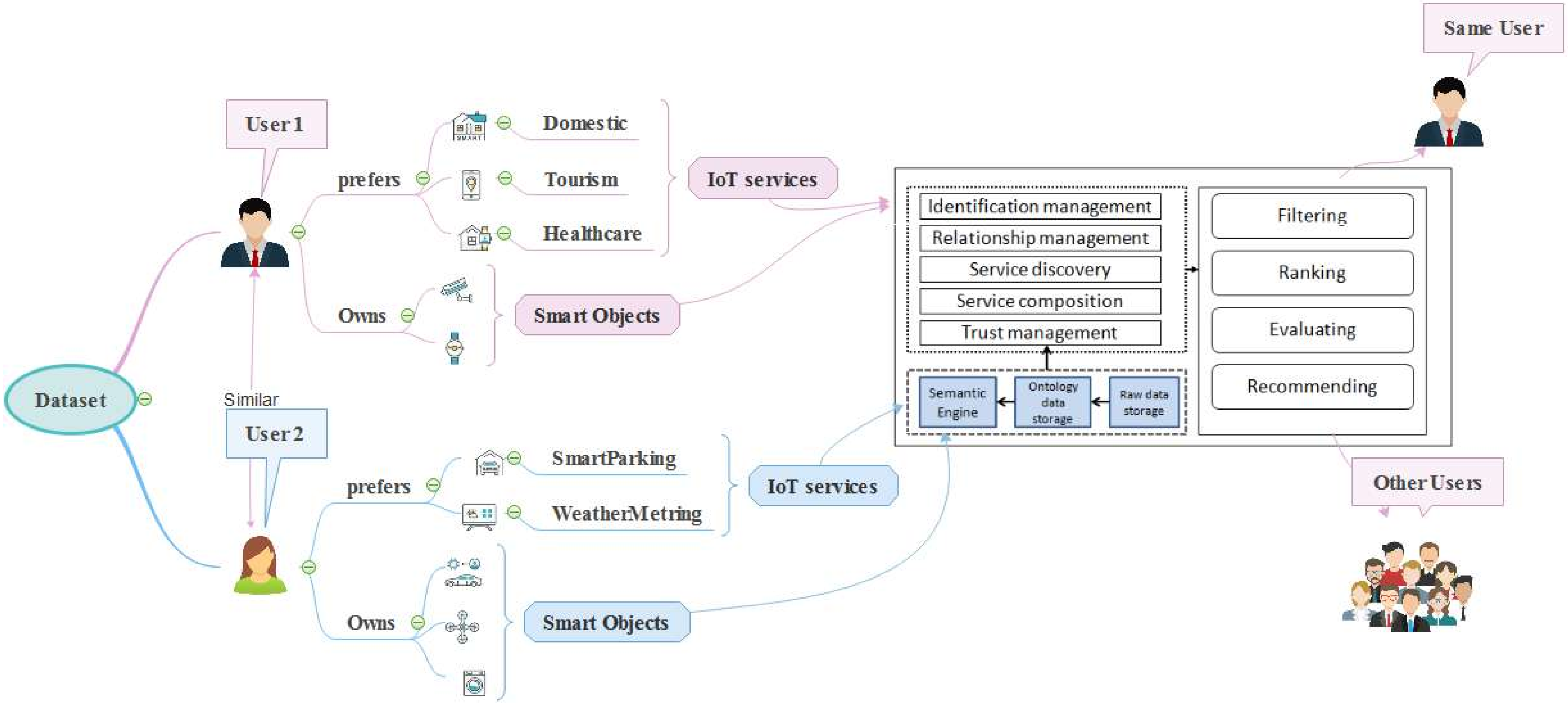

Figure 3. 1: The proposed IoT service recommender system (IoTSRS) architecture.

Accordingly, the system architecture comprises 4 key components including the user profile, the ontology of the social IoT network, the hybrid recommendation module, and the final part of recommendations. The recommendation process goes through three key steps, as seen in Fig. 3.2: (1) Build ontology to describe knowledge of the social IoT domain; (2) Compute the services preferences and predictions of user ratings based on knowledge of the ontology domain and collaborative filtering; (3) Generate top N services via the CF recommendation engine.

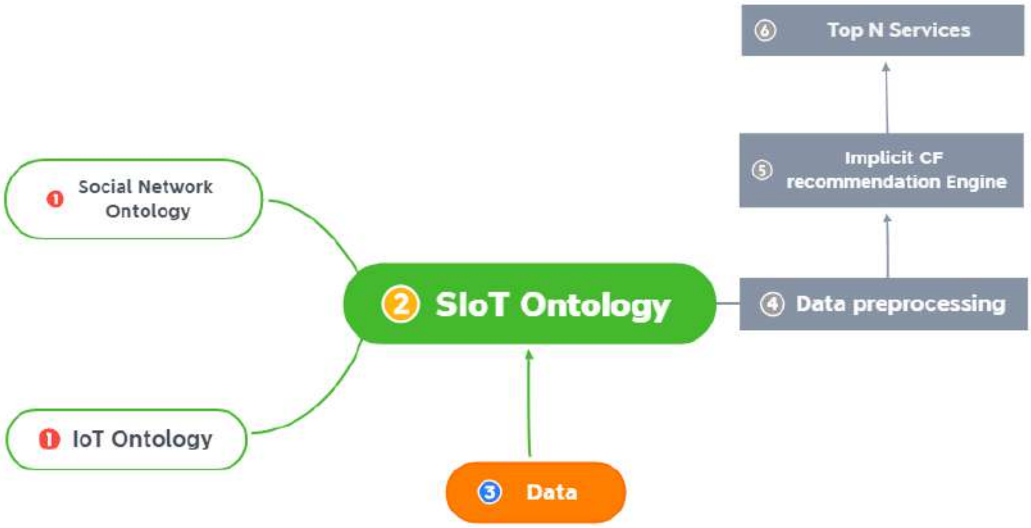

Figure 3. 2: Hybrid IoT services recommendation module.

Thus, to generate recommendations, our approach contains three main phases:
1st phase creation of the SIoT ontology in order to define the social graph wherein relationships between the three major factors (user, service, device) is described.
2nd phase calculation of the preference between users and services.
And 3rd phase generation of top N IoT services using the CF recommendation engine.

3.2. Creation of the SIoT ontology

In order to reveal how SIoT guarantees the navigability of the network, the discovery of objects and services as well as relationship management, we have created the ontology of the SIoT based on the existing ontologies of the IoT and the Social Network represented in SSN and FoaF respectively. In which, the Semantic Sensor Network (SSN) (Haller et al. 2017) ontology describes sensors and their observations, as well as the processes involved in, besides the actuators and their actuation. Whereas, FoaF(Brickley and Miller 2007) is used to describe the social relationships among objects. While, the generated data from the ontology will be saved in the suitable format to be used in the computing model. Figure 3.3 depicts the upper level of SIoT ontology which has three main classes (User, Object, and Service) that are managed by the SIoT ecosystem. Moreover, it depicts the relationships among the main concepts in a way that the user can own an object which performs a process that belongs to a given service. The process is either observation or actuation whereas the user consumes a service; this consumption is interpreted to {0,1} respectively for a computational purpose.

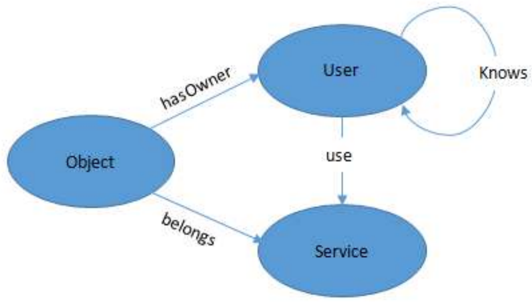

Figure 3. 3: the upper ontology of SIoT

The lower level of the SIoT ontology contains more specific information about the SIoT for example, the details about users and their social relationships which reflect on the relationships between objects. In other words, one or many objects are owned by a user; those objects have an ownership connection as well as the objects which are owned by friends have a social relationship. Besides, the ones which cooperate with other objects, to accomplish a common task, have a co-work relationship.

User profile: The user profile component contains the information and preferences of the user. Information in the user profile is acquired both explicitly and implicitly. The information defined in the user profile is: personal demographic data (name, gender, age, etc.) user preferences, the objects that he/she owns, and his/her social relationships. The CF recommendation engine will make use of this information in computing predictions of ratings as well as generating recommendations for the active user.

Object: The object component is classified into, although not restricted to, two classes: sensing devices and actuating devices. Further, IoT object contains more information about the object, such as the brand to which it belongs, location, and the process performed by. This latter is either actuation or observation, which is considered as the input or the output of a service. The object has also an Access-Modifier which can take the value of “Public”, “Private” or” Friend” to determine the users who are able to benefit from the process performed by the actual object.

Service: Users and software agents should be able to discover, invoke, construct and control objects providing different services and having particular characteristics, and should be able to do so with a high degree of automation, if necessary(David Martin et al 2004). It has, therefore, become almost obligatory to define these services and processes in order to increase interoperability, enabling them to be instantly discovered and called upon by several, heterogeneous systems(Charpenay et al. 2018). We define the general structure of the service and its two key parts: the advertisement and exploration service profile and the process model, which provides a comprehensive overview of the service to the user. Thus, the service profile contains general information about the service’s name and proper role. Whereas, the process model contains the sequence of processes that should be applied to perform the service.

As described above, SIoT offers us the ability to enhance the availability, exploration, and composition of services using the information available from the networks in a trustful manner (Atzori et al. 2012),(Saleem et al. 2017). Thus, the process performed by an object (o) will be available in three main cases based on the value of the access-Modifier:

- Private: the access modifier of the object is 'Private' thus the only one who can benefit from that process is the owner of the object.
- Friend: In this case, a social relationship is established among devices and sensors belonging to friends, classmates, travel companions, colleagues that know the owners of the object. Thus, they will be able to use this object to perform the desired service.
- Public: refers to objects that have a public access-Modifier. Consequently, the process performed by those objects is publicly available. For example, roadside vehicle speed sensors have a public access to their generated data. Furthermore, simple user can share some generic data like temperature thus make those sensors publicly available.

To ensure the effective and flexible exploration of objects and services based on the principle that each object should seek the desired service, using its relationships; objects request friends and friends of friends in a distributed way taking into consideration the access-Modifier of objects.

We follow Ontology Development 101 method in the creation of our ontology presented in(Noy and Mcguinness 2000), thus the next step is the definition of the classes and the class hierarchy, object properties as well as the data properties. The following tables; table 3.1, table 3.2 and table 3.3 show the classes and the class hierarchy, object properties and the data properties respectively:

3.2.1. The classes and the class hierarchy

Class	**Designation**	**Super class**
Object	Refers to the device	
Actuator	Refers to the object that has a role as an actuation	Object
Sensor	Refers to the object that has a role as an observation	Object
Human	Refers to the user	
Service	Refers to the IoT service	
Service-profile	Contains the information about the service	

Process	Refers to the atomic action which could be performed by the object	
Actuation	Refers to the action taken by the object	Process
Observation	Refers to the process of sensing data from the real world	Process
Agent	Imported from FOAF ontology	
Online account	Imported from FOAF ontology	
Location	Refers to the location of the object	

Table 3 1: the classes and the class hierarchy of the SIoT ontology

3.2.2. Object properties

Property	Domain	Range	Cardinality
holdsAccount	Human	Account	(1,1)
Knows	Human	Human	(1,n)
hasInput	Service	Observation	(1,n)
hasOutput	Service	Actuation	(1,n)
hasBrand	Object	Brand	(1,1)
hasLocation	Object	Location	(1,1)
hasOwner	Object	Human	(1,1)
hasProcess	Service	Process	(1,n)

isA	Object	Actuator/Sensor	(1,1)
isOwnerOf	Human	Object	(1,n)
Perform	Object	Process	(1,1)

Table 3 2: Object properties of the SIoT ontology

3.2.3. Data properties

Property	Description	Domain	Type
firstName	The first name of the user	Human	String
familyName	The family name of the user	Human	String
Age	The age of the user	Human	Integer
Gender	The gender of the user	Human	Male/female
accountName	The name of the account	Account	String
hasIdentifier	The identifier of the object	Object	String
isMobile	Indicate if the object is mobile	Object	yes/no
hasManufacturingYear	Indicate the year of the object manufacturing	Object	Year
hasManufacturerName	Indicate the name of the object manufacturer	Object	String
hasName	Indicate the name of the brand	Brand	String
hasRole	Indicate the role of the process	Process	String
hasAccessModifier	Indicate the access modifier of the object	Object	Private/ friend/public
has Altitude	Indicate the Altitude of the location	Location	Integer

hasLatitude	Indicate the Latitude of the location	Location	Integer
hasLongitude	Indicate the Longitude of the location	Location	Integer
hasPrecondition	Indicate the precondition of the service	Service	Test
hasResult	Indicate the result of the service	Service	Action

Table 3 3: data properties of the SIoT ontology

3.3. Class diagram

The following figure 3.4 shows the class diagram of the created ontology

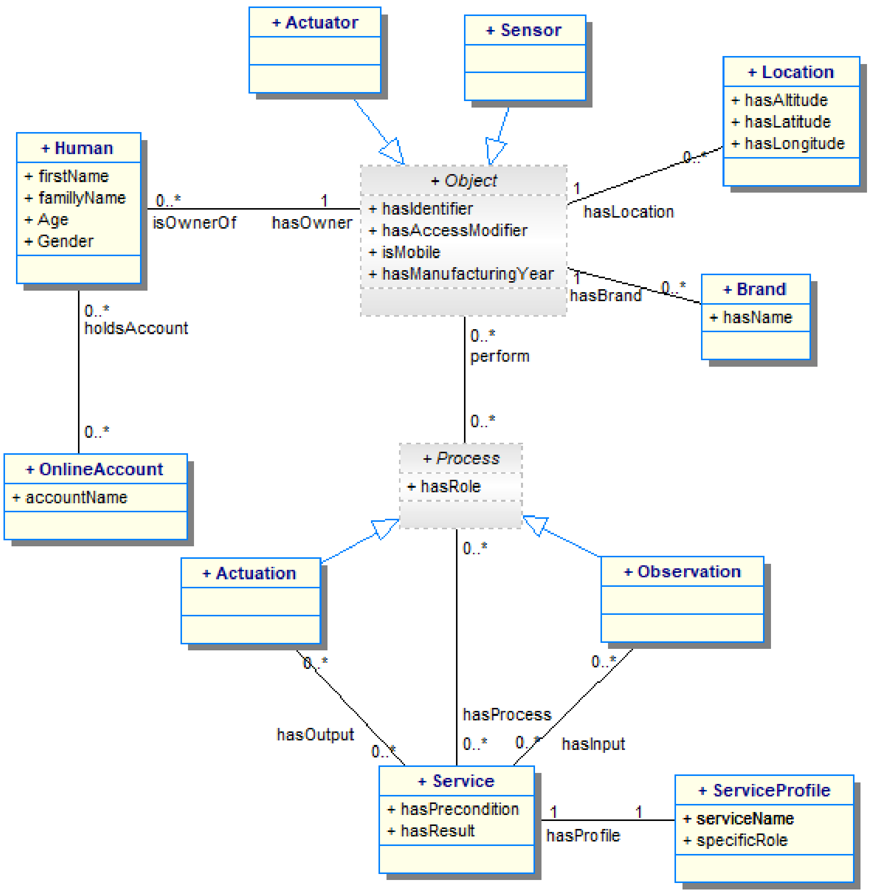

Figure 3. 4: class Diagram of the SIoT ontology

The following figure 3.5 shows the lower level of the created ontology, where both classes and relationships are depicted:

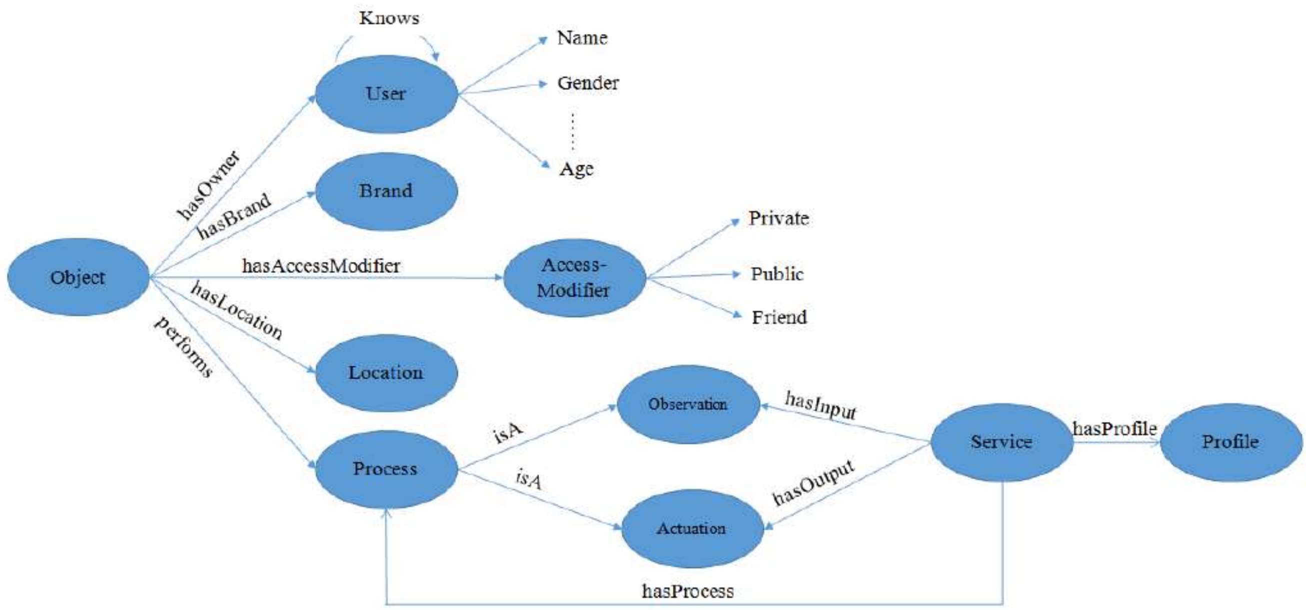

Figure 3. 5: the SIoT ontology

3.4. SIoT architecture

In this section we are going to present the proposed architecture depicted in the following figure 3.6 in which social interaction no longer exists only between human, but it is allowed between devices and the human-to-device. This architecture is divided into two main layers, sensing and application layers

1) Sensing layer consists of sensors, actuators or smart things belonging to the IoT as well as the social networking account of their owners which provides smart thing's metadata and context information as well as the personal profiles and social relationships respectively. Furthermore, it presents the level of interaction with the ecosystem.

2) *Application layer* presents the core of the SIoT ecosystem which is divided into two main sub-layers *the first sub-layer* is devoted to extracting and structuring data. On the other hand, to interact with the IoT and the Social networking.

The second sub-layer is devoted to manage the extracted data in order to identify the entities, manage the relationships, service discovery, service composition and trust management

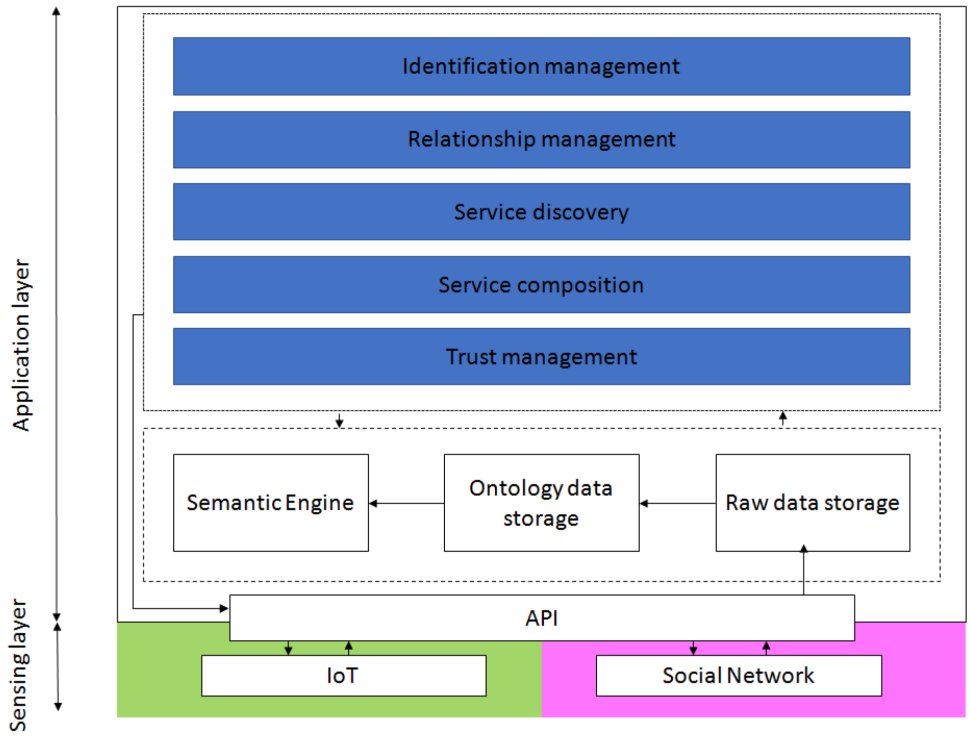

Figure 3. 6: SIoT architecture

3.5. Sequence Diagrams of the main features of the SIoT:

In this section we will provide the sequence diagram of the main features of the SIoT (relationship management, service composition, service discovery and trustworthiness) which appears in dealing with the new object entrance, colocation relationship (as example of creation of relationships) and service composition:

3.5.1. New object entrance

As depicted in the following diagram (Figure 3.7), once the object enters to the detection zone of the current object. It will get an identifier by the id management module, further the parental control is applied based on the profile of the current object. In that step the owner configures the owner control. Whereas the object crawls the friends of the owner in order to get acquire objects as friends.

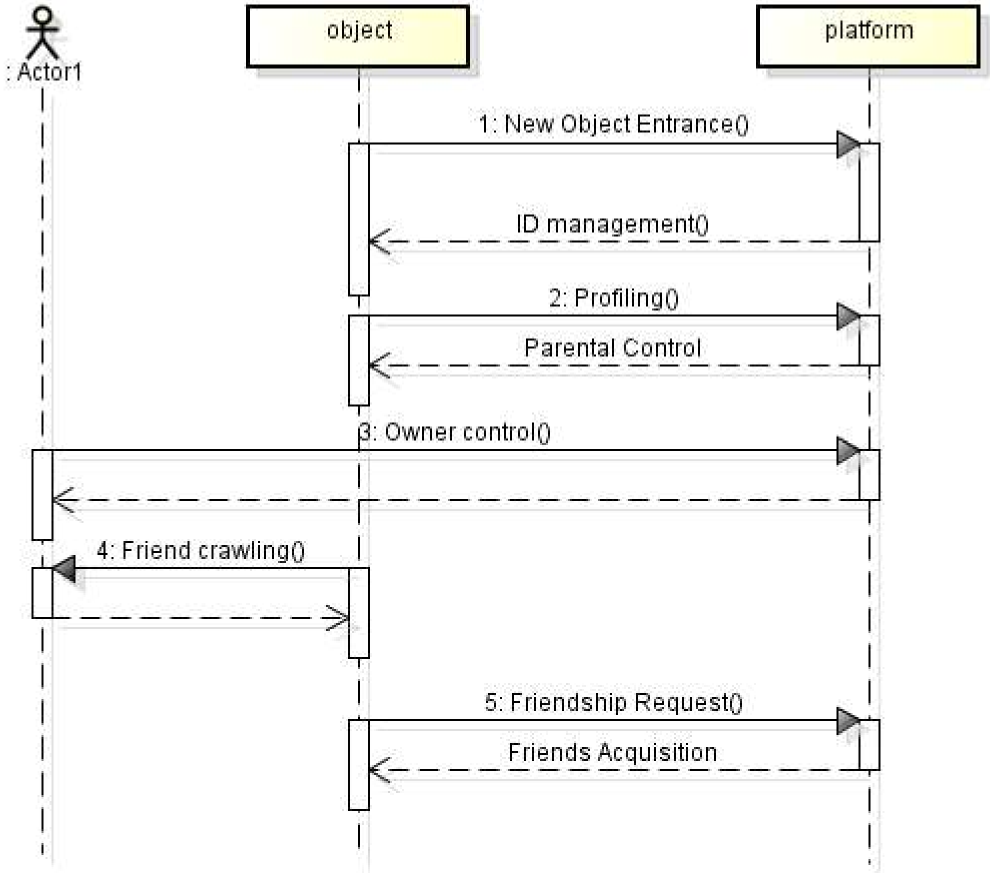

Figure 3. 7: sequence diagram of new object entrance

3.5.2. Colocation relationship

As shown in the figure 3.8 the object 1 as well as the object 2 detect the each other at the same location. Thus, they request for the co-location relationship which is deployed by the relationship management component taking the owner control into consideration.

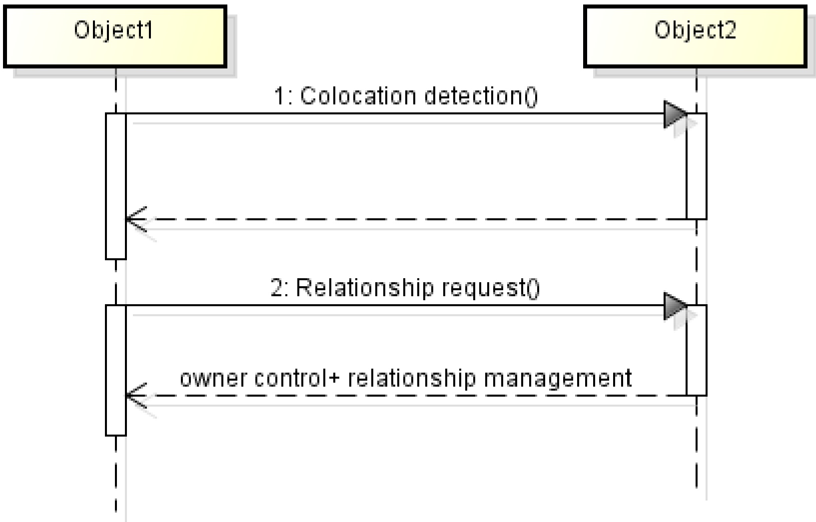

Figure 3. 8: sequence diagram of Co-location relationship

3.5.3. Service composition diagram

The figure 3.9 depicts the sequence diagram of the service composition, in the first step the current object request for the needed service/ information. Thus, the platform reacts by searching for that service/information using the service discovery component, while the object ranks the available services/data based on specific criteria taking the trust management into consideration.

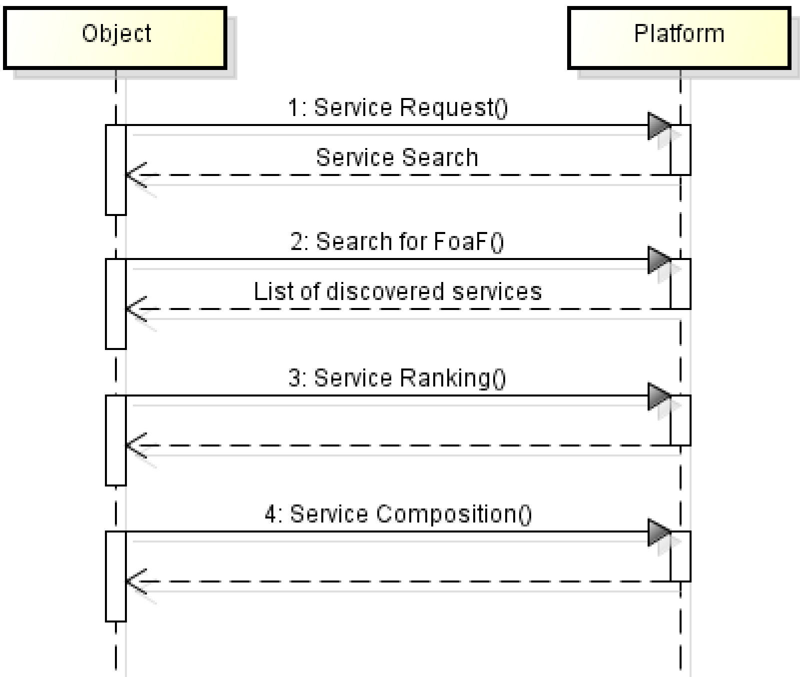

Figure 3. 9: sequence diagram of service composition

3.6. Create instances

The last step is creating individual instances of classes in the hierarchy. But before doing so we should make decision about the source of the individual should be created. Therefore, we have collected data to be insert into the ontology than be saved in the appropriate format to be used in the computing model.

3.6.1. Data collection method and tools

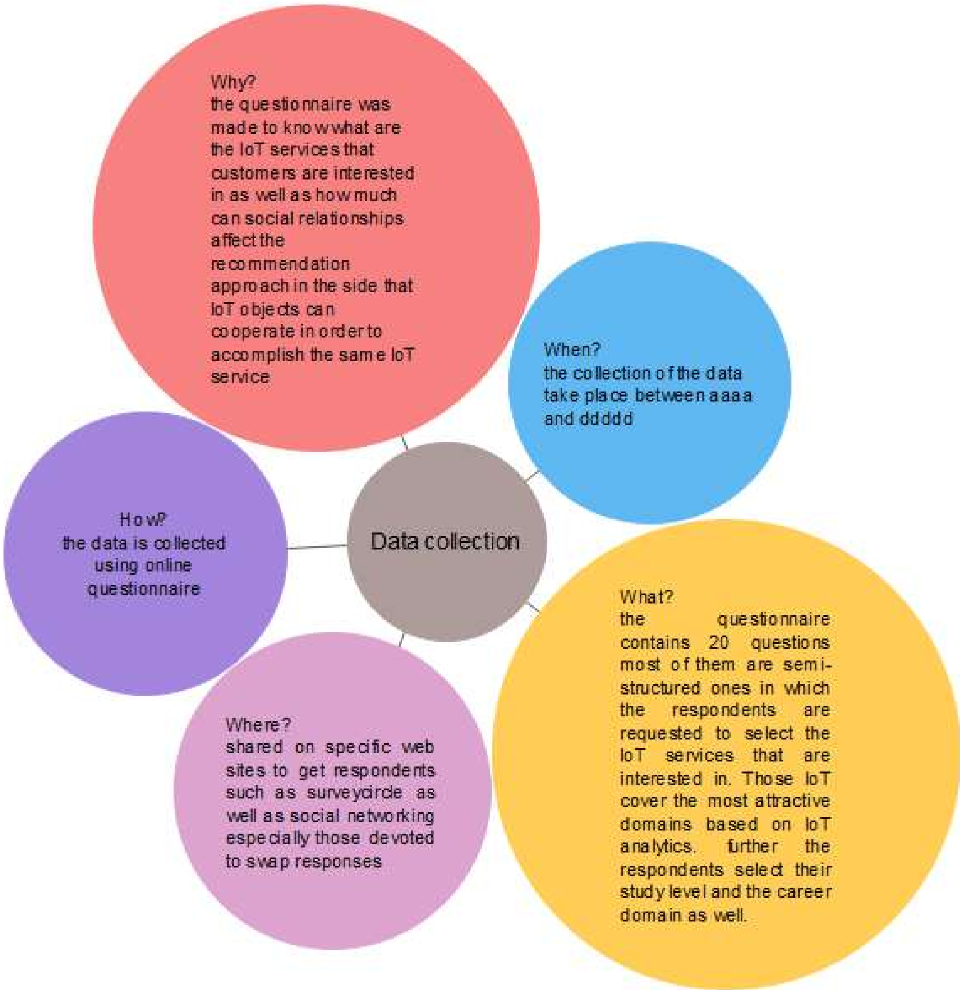

Figure 3. 10: Data collection method and tools

Data is any kind of information that, once analyzed, can help us to answer our research questions and either prove or disprove our hypotheses. whose aim is to identify participant's emotions, feelings, and opinions regarding our research subject which is measuring how much are customers are interested in the IoT services. The survey was conducted using a semi-structured questionnaire as far as data collection tools were required. Firstly, we prepare a questionnaire containing information about 60 IoT services covering many domains such as domestic, healthcare, industry and so on. The questionnaire was totally anonymous nevertheless some additional questions were made encountered during the questionnaire such as age, qualification, domain of study and work. Getting respondents was not an easy step, therefore, we share the link on many surveys' websites such as surveycircle[1]besides social networking on specific groups to get more respondents. After this not easy collecting journey we get 465 respondents. The following are some of the sample questions that were included in the questionnaire:

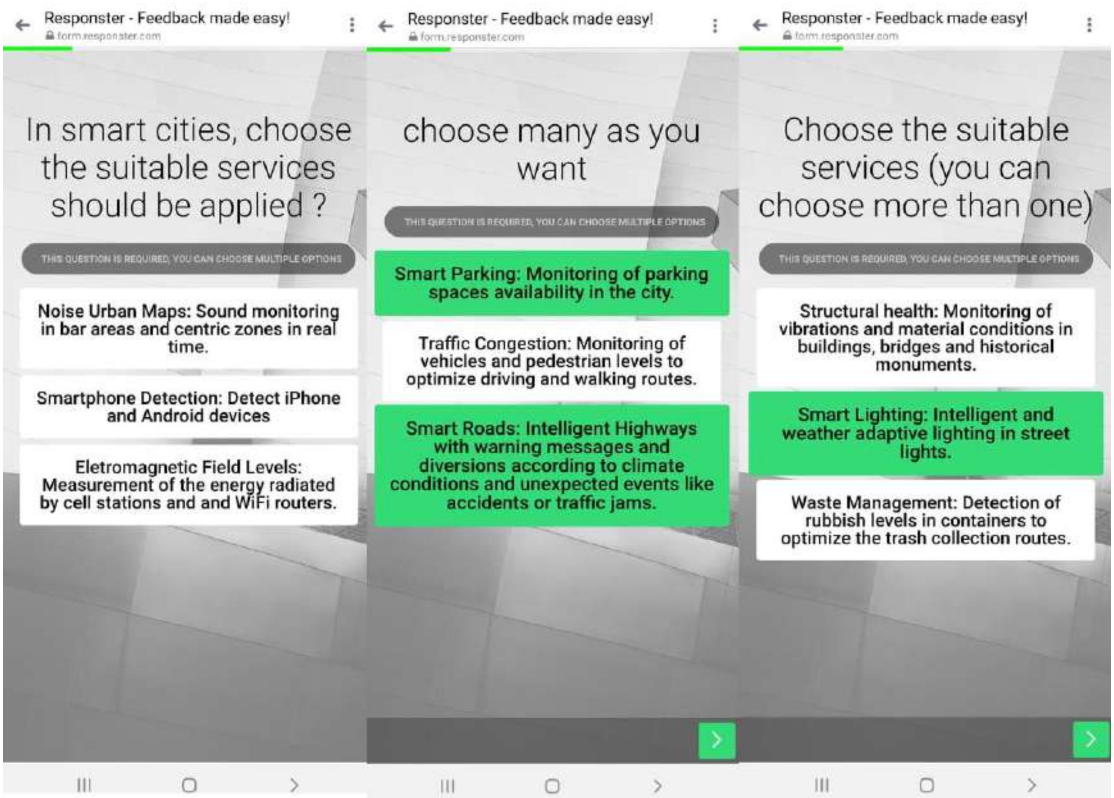

Figure 3. 11: Sample of the questionnaire questions

As shown the previous figure 3.11, the selected services are saved as semi-structured and implicit data whereas we need it as quantitative one which requires a preprocessing of that data. For this purpose, we use excel to do so. In which, if a respondent u chooses a service i; that interaction is interpreted as 1 while negative interaction is interpreted as 0.

Therefore, we have the original matrix $\boldsymbol{R}$ of size $x * y$ with x respondents, y services and some type of feedback data (0,1). Using Alternating Least Squares (ALS) for implicit feedback we will turn that matrix $\boldsymbol{R}$ into two matrices the first one $\boldsymbol{U}$ with users and hidden features of size $x * f$ and the second one $\boldsymbol{V}$ with services and hidden features of size $f * y$ as shown in the following figure 3.12:

[1]https://www.surveycircle.com/en/

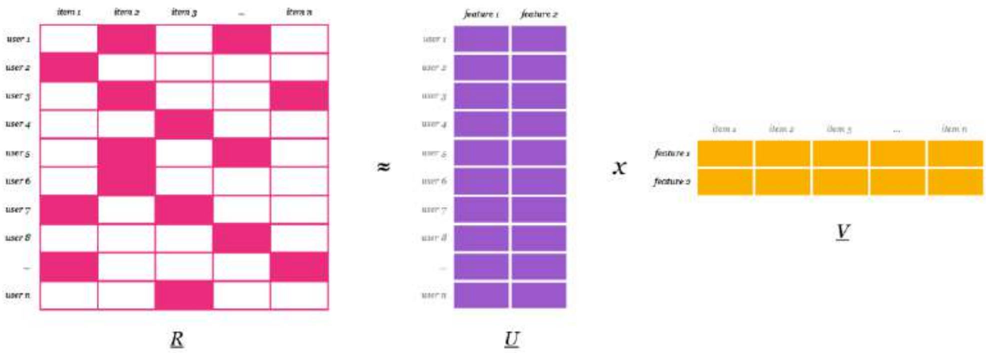

Figure 3. 12: use the ***ALS*** to turn the matrix ***R*** into two matrices

In *least squares* ***U*** and ***V*** are calculated by randomly designate the values in ***U*** and ***V*** iteratively till achieve the best approximation of ***R***. The *least squares* technique works; in its basic forms; on fitting some line to the data, besides measuring the sum of squared distances from all points to the line and thus trying to get an ideal fit by minimizing this value.
Despite the fact that the *alternating least squares* technique uses the same principle but iteratively alternate between optimizing **U** and fixing **V** and vice versa. We repeat this process for each iteration to get closer to ***R = U * V.***
The used approach for implicit dataset is outlined in Collaborative Filtering for Implicit Feedback Datasets(Hu et al. 2008)

The principle of that approach is merging the *preference (**p**)* for a service with the *confidence (**c**)* we have for that preference. In which the preference refers to the interaction between user and service. Missing values are first treated as a negative preference, while existing values are treated as a positive preference whereas the confidence value depends on the availability of the necessary data to accomplish the IoT service. Where, the availability is derived from the ontology in which to figure the findability of the lacked data to accomplish the service composition, we have used the built ontology to depict the social relationships among objects where each service of the 60 mentioned in the survey is deployed using 3 objects/devices whereas each user of the respondents has 20 friends and owns 10 objects.

3.7. The computing model

Firstly, we will calculate the confidence parameter which indicates whether the data is available or not. Therefore, the confidence parameter is used to calculate the user and item factors which are used in their turn to generate the top N recommendation list by calculating the user preference $p_{ui}$of service i.
As we mention in the data collection, the values of the interaction matrix (R), are occurrences that have clear values r_{ui}. In which, the r_{ui} are the ratings of service i by the user u. First, let's create a series of binary variables p_{ui}, indicating the preference of user *u* to a service *i*. If there is an interaction(check/view) between the user and service pair, it is considered as a positive preference else negative.

$$p_{ui} = \begin{cases} 1 & R > 0 \\ 0 & R = 0 \end{cases} whereR = r_{ui} \qquad (1)$$

In other words, if a user u interacts with a service i (r_{ui}> 0), then we have an indication that u likes i (p_{ui}= 1). But, if u does not interact with the service i, we believe no preference (p_{ui}= 0). However, our view, in this regard, is not fully proved confident. In which, due to the existence of the data zero values of p_{ui}; low confidence means the user did not take any meaningful action on a service that might be resulting from many other factors other than disliking it. For example, the user might be unaware of the real role of the service, or unable to consume it due to the unavailability of the data necessary to deploy it. Thus, we will have different confidence levels reliance - in the first step- on the availability of the data also among services that are indicated to be preferred by the user. The confidence is calculated using the following formula:

$$C_{ui} = 1 + \alpha r_{ui} \qquad (2)$$

The value r is referred to the interaction between user u and service i whereas α is a tuning parameter.

Indeed, to recommend any service to users, we should make sure about the availability of the data. Therefore, if we have data available, we are more confident in recommending the service. In other words, the data available means crawling the SIoT network to get the necessary data to accomplish the service where, in the first step, we check whether the user owns the objects to fulfill the service requirements, and in the same manner, we crawl the objects of friends and friends of friends as well as the objects publicly available. So, the confidence is scaled on the tuning parameter α. The authors of(Hu et al. 2008)typically, have recommended the α value between 15 to 40 in the high level of confidence status. Consequently, we use the following expression in our model:

$$\alpha = \begin{cases} 15 \; if data is available \\ 0 \qquad otherwise \end{cases}$$

Algorithm 1 displays the calculation of the confidence parameter.

Algorithm 1: Compute the confidence parameter C_{us}

Input:
Service s, User u: integer
list of necessary objects to deploy each service D(s)
list of objects owned by each user and the access-Modifier of each object W(u)
list of friends of each user Fr(u)
Function: Confidence(s, u): integer
Begin
i=1
Foreach object(o) *in* D(s) *do*
    if o∈ W(u) *then*
        *i=i*1*
    else foreach *f* in Fr(u)*do*
        if o∈ W(f) and the o. Access-Modifier=friend *then*
            *i=i*1*
        else if o.Access-Modifier= public *then*
            *i=i*1*
        Else *i=0*
data_available$(s, u) = i.tobooleen$

If (data_available(s,u))
α=15
else α=0
compute C_{us}using eq. (2)
return (C_{us})
End

Thus,the goal is to find p_{ui} based on vector $x_u \in R^f$ for each user u and vector $y_i \in R^f$ for each service i that will factor user preferences. That is, in other words, preferences are supposed to be the inner products:

$$p_{ui} = x_u^T y_i \qquad (3)$$

Where x_u, y_i are vectors that are known as the user-factors and the item-factors, respectively.

$$X_u = (Y^T C^u Y + \lambda\, \mathrm{I})^{-1} Y^T C^u p(u). \qquad (4)$$

$$Y_i = \left(X^T C^i X + \lambda\, \mathrm{I}\right)^{-1} X^T C^i p(i). \qquad (5)$$

Where:

X and Y: The user and item matrices. They will get updated alternately.
Cu and Ci: The confidence values.
λ: is the user-defined parameter that inhibits over-fitting. (we're using 0.1).
p(u) and p(i): The binary preference for an item. It takes the value either 1 or zero depending on the user interaction.
I (eye): The identity matrix. Thus, it is a square matrix that has ones on the diagonal and zeros elsewhere.

3.8. Generation of top N list of recommended IoT services

The top N recommendation list of services is generated by the CF recommendation engine based on the predicted ratings for the target user and ontology domain knowledge.

Let U denote the set of all users $U = \{u1, u2, \ldots, um\}$, let S be the set of all possible IoT services $S = \{s1, s2, \ldots, sn\}$ that can be recommended; and let O be ontological domain knowledge about the user, objects and IoT services. Let R be the rating function that measures the usefulness of IoT service S to user U. The possible rating values are defined on a numerical scale.

R: $SxUxORatings$ and R $(u, s \in \{0,1\})$

Algorithm 2 shows how the top N recommendation list is generated.

Let r_{ui} be the ratings of service i by the user u and P_{ui} be the predicted preferences for service i for the target user. e.g., the user owns set of objects {o_1, o_2, o_3…, o_n} and knows many users that own set of objects in their turn. Those objects perform a specific task that belongs to an IoT service. To recommend a service s to user u we have first calculated the confidence C_{us} which indicates how much we are confident about the availability of the necessary data to deploy that service. Then the preferences will be calculated based on the user and item factors calculated previously based on the confidence value. The steps for generating the list of recommended services (top N) are shown in Algorithm 2

Algorithm 2: Generate Top N Recommendation List

Input:
The ontological data which contains:
Set of IoT services
$S = \{s1, s2, s3, \dots\dots, sn\}$
Set of users
$U = \{u1, u2, u3, \dots\dots, un\}$
Set of objects
$O = \{o1, o2, o3, \dots\dots, on\}$
list of necessary objects to deploy each service
list of objects owned by each user and the access-Modifier of each object
list of friends of each user
Ratings of users $R = \{r1, r2, \dots, rn\}$ where $R\epsilon$ {0,1}
Output:/*Predicted ratings & top N recommendation list Method*/
1: foreach sϵS, uϵU
2: compute C_{us} using the Algorithm 1
3: Compute user-factors using eq. (4)
4: Compute item-factors using eq. (5)
end foreach
5: Compute predicted ratings P_{ui} using eq. (3)
6: Generate top N recommendation list for target user u

Experimentation and validation

4. Experimentation and evaluation:

In this section, we explain, in detail, the implementation step which contains the ontology creation, the dataset collection besides the computing model implementation, and the evaluation method as well as the metrics used to validate the IoT service recommendation system.

In order to implement our algorithms, we use Python 3.7 as a programming language with the Anaconda and Implicit libraries installed on windows 10 because certain packages work only on windows 8 and higher versions. Further, in developing the SIoT ontology, the concepts, and relationships among them, we use Protégé 5.5.0 ontology editor environment. The recommendation engine will make use of the SIoT ontology domain knowledge alongside the users' preferences in computing similarity and predictions for the target user. Subsequently, after ontology has been created, the dataset is prepared and preprocessed into a format that is required by the CF recommendation engine,

4.1. Creation of the ontology

The ontology is created in order to module the SIoT ecosystem where the social relationships among owners are extended to encompass their objects. The followed figures 4.1, depicts the ontology classes object properties and data properties respectively:

Figure 4. 1: ontology classes and properties

As we mention in the section 2.5.3 where we explain the contribution of the SIoT comparing the IoT in which the creation of social objects is considered among the main features of the SIoT, in this context, the relationships among objects can be derived from the interference rules:

Relationship	Inference rule
Co-location relationship	Object(?o1) ^ hasLocation(?o1, ?L1) ^ Object(?o2) ^ hasLocation(?o2, ?L2) ^ sameAs(?L1, ?L2) →coLocationRelationship(?o1, ?o2)
Ownership relationship	Object(?o1) ^ hasOwner(?o1, ?a1) ^ hasAccessModifier(?o1, "Private") ^ Object(?o2) ^ hasOwner(?a2, ?o2) ^ sameAs(?a1, ?a2) →ownershipAvailability(?o1, ?o2)
Social relationship	Object(?o1) ^ hasOwner(?o1, ?a1) ^ perform(?o1, ?p) ^ hasAccessModifier(?p, "Friend") ^ knows(?a1, ?a2) ^ isOwnerOf(?a2, ?o2) →friendshipAvailability(?p, ?o2)
Parental relationship	Object(?o1) ^ hasBrand(?o1, ?b1) ^ hasManufacturingYear(?o1, ?year1) ^ Object(?o2) ^ hasBrand(?o2, ?b2) ^ hasManufacturingYear(?o2, ?year2) ^ sameAs(?b1, ?b2) ^ sameAs(?year1, ?year2) →parentalRelationship(?o1, ?o2)
Co-work relationship	Service(?s) ^ hasProcess(?s, ?p1) ^ Process(?p1) ^ Object(?o1) ^ perform(?o1, ?p1) ^ isA(?p1, ?observation) ^ hasInput(?s, ?observation) ^ hasProcess(?s, ?p2) ^ Process(?p2) ^ Object(?o2) ^ perform(?o2, ?p2) ^ isA(?p2, ?actuation) ^ hasOutput(?s, ?actuation) → workRelationship(?o1, ?o2)
Publicly available	Object(?o1) ^ perform(?o1, ?p) ^ hasAccessModifier(?p, "Public") ^ Object(?o) →publiclyAvailable(?p, ?o)

Table 4 1: inference rules of the created relationships among objects

4.2. Creation of individuals

The individuals of the ontology encompass IoT services, users, objects as well as the interest of each user in IoT services. Thus, before the creation ontology individuals we have collected a dataset to be used in IoT Service Recommendation. Firstly, we build service profiles that cover 60 services. Those services belong to the most popular IoT application areas in the world[2]. The information about the services is obtained from their websites from the catalogs of Libelium[3], TELUS[4], and blueRover[5].

One of those service is Smart road which recommend the best road to be used to achieve the destination is safe and quickly way. Therefore, we have used the smart roads as an example to display it as instantiation example. The instantiation of that IoT service is displayed in figure 4.2.

[2]https://iot-analytics.com/
[3]https://www.libelium.com/
[4]https://iot.telus.com/en/business/on/
[5]https://bluerover.ca/

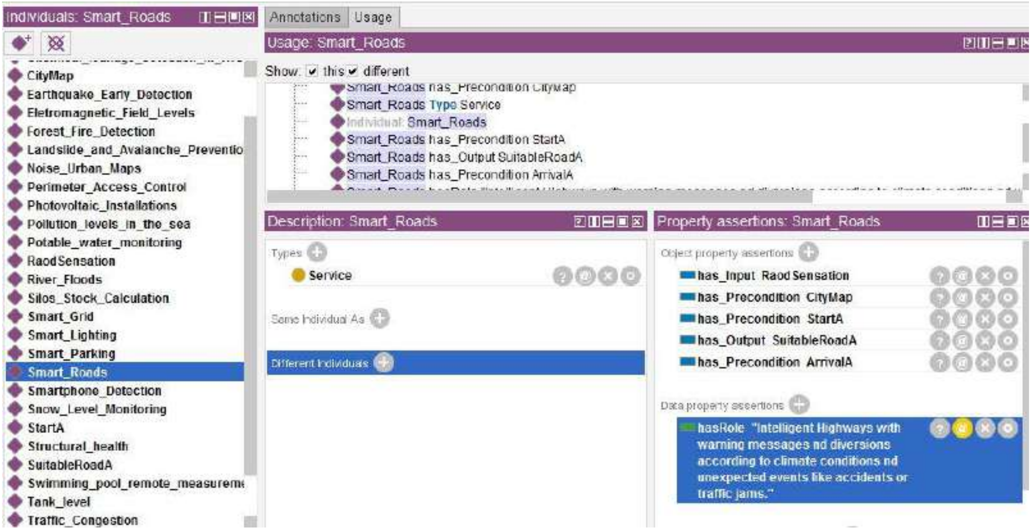

Figure 4. 2: the instantiation of the created ontology.

On the other hand, for the users, we tried to use real-world datasets using a questionnaire about the services that users are interested in. The data were collected from 465 users. Each respondent was asked to choose the objects he/she owns or would like to own. Further, users were asked to pick IoT services they are interested in.

The distribution of respondents based on their gender, age, study degree and specialization are depicted in the following tables 4.1, 4.2, 4.3 and 4.4 respectively in which those tables are made by SPSS:

Gender					
		Frequency	Percentage	Valid Percentage	Cumulative Percentage
Valid	Male	223	48,0	48,0	48,0
	Female	242	52,0	52,0	100,0
	Total	465	100,0	100,0	

Table 4 2: The distribution of respondents based on their gender

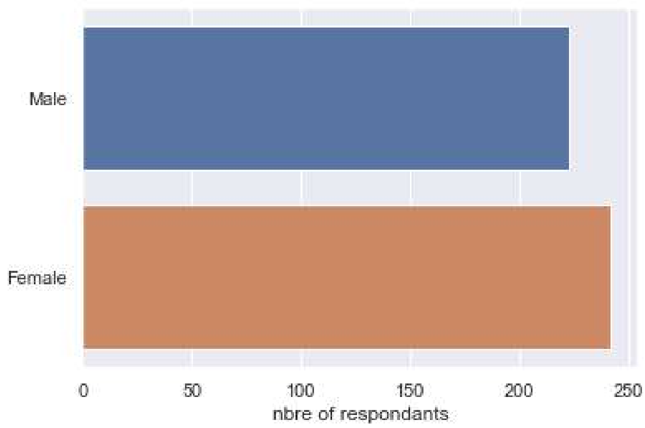

Figure 4. 3: The distribution of respondents based on their gender

Age					
		Frequency	Percentage	Valid Percentage	Cumulative Percentage
Valid	less than 25	177	38,1	38,1	38,1
	Between 25 and 30	139	29,9	29,9	68,0
	Between 30 and 35	69	14,8	14,8	82,8
	Between 35 and 40	36	7,7	7,7	90,5
	More than 40	44	9,5	9,5	100,0
	Total	465	100,0	100,0	

Table 4 3:The distribution of respondents based on their age

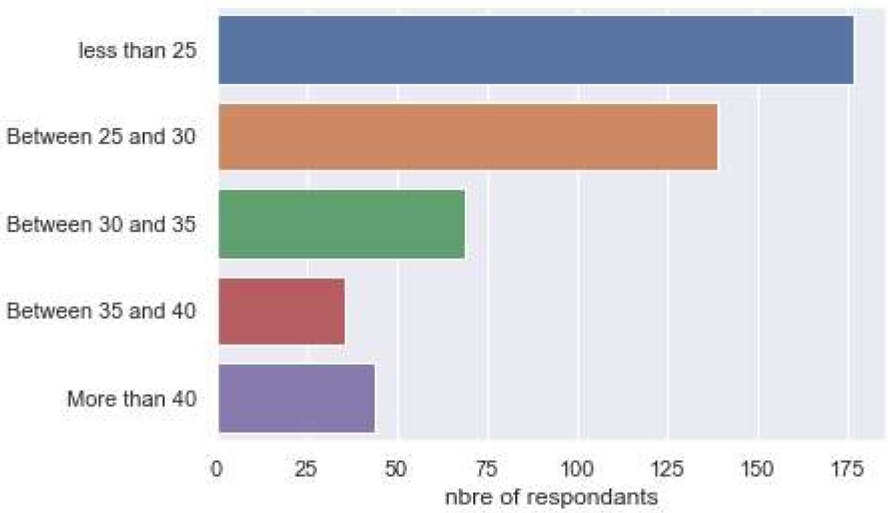

Figure 4. 4: The distribution of respondents based on their age

Study degree					
		Frequency	Percentage	Valid Percentage	Cumulative Percentage
Valid	None	3	,6	,6	,6
	Elementary school	5	1,1	1,1	1,7
	Middle school	10	2,2	2,2	3,9
	High school	44	9,5	9,5	13,3
	Diploma Bachelor's level	166	35,7	35,7	49,0
	Master level	184	39,6	39,6	88,6
	Doctoral level	53	11,4	11,4	100,0
	Total	465	100,0	100,0	

Table 4 4: The distribution of respondents based on their study degree

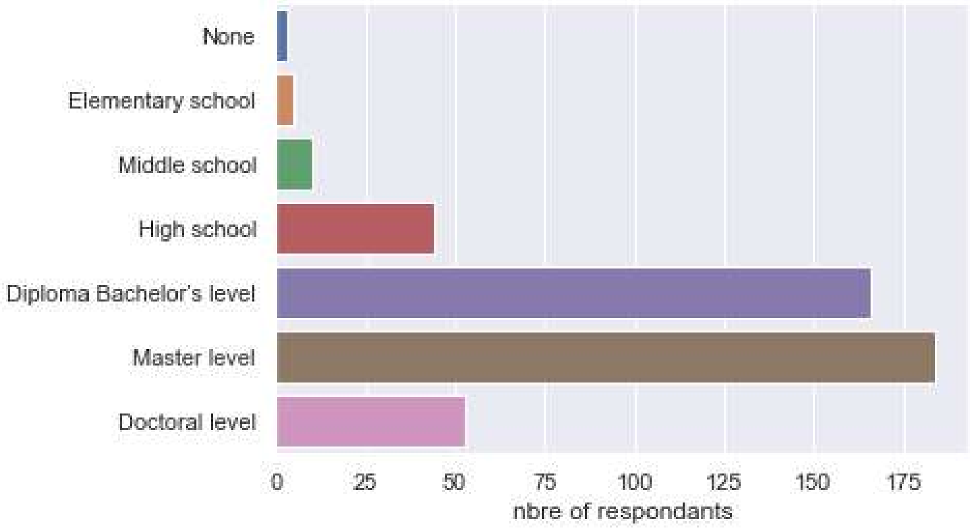

Figure 4. 5:The distribution of respondents based on their study degree

Specialization					
		Frequency	Percentage	Valid Percentage	Cumulative Percentage
Valid	Engineering	99	21,3	21,3	21,3
	Medical	36	7,7	7,7	29,0
	Sciences	82	17,6	17,6	46,7
	Business Management	92	19,8	19,8	66,5
	Fine Arts and design	14	3,0	3,0	69,5
	Law	5	1,1	1,1	70,5
	Other	137	29,5	29,5	100,0
	Total	465	100,0	100,0	

Table 4 5: The distribution of respondents based on their specialization

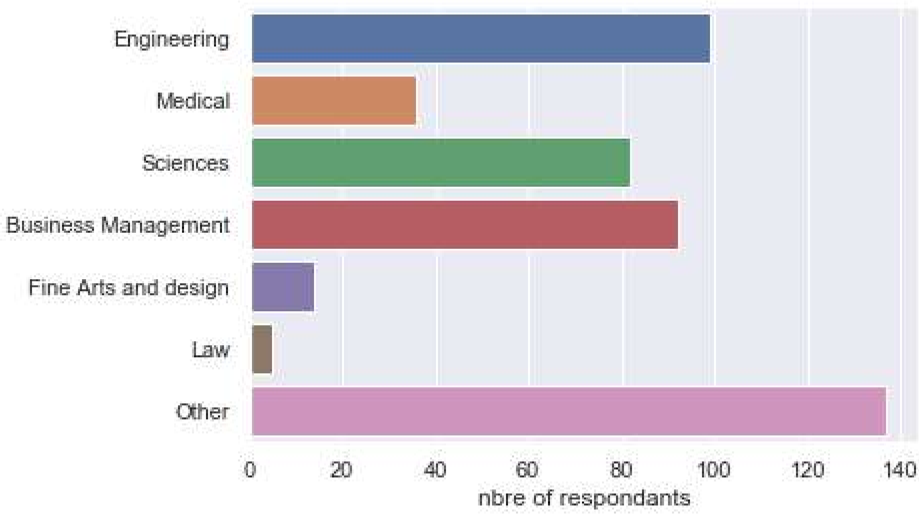

Figure 4. 6:The distribution of respondents based on their specialization

Though, IoT is still in the cuddle where IoT devices and services are not widely used by people, which results a serious impact on data collection and the discussion on the results accuracy. Results revealed that those respondents believe that eHealth, Smart Home, and Smart Cities services are the most essential services of all IoT systems as shown in the following figure (figure 4.7).

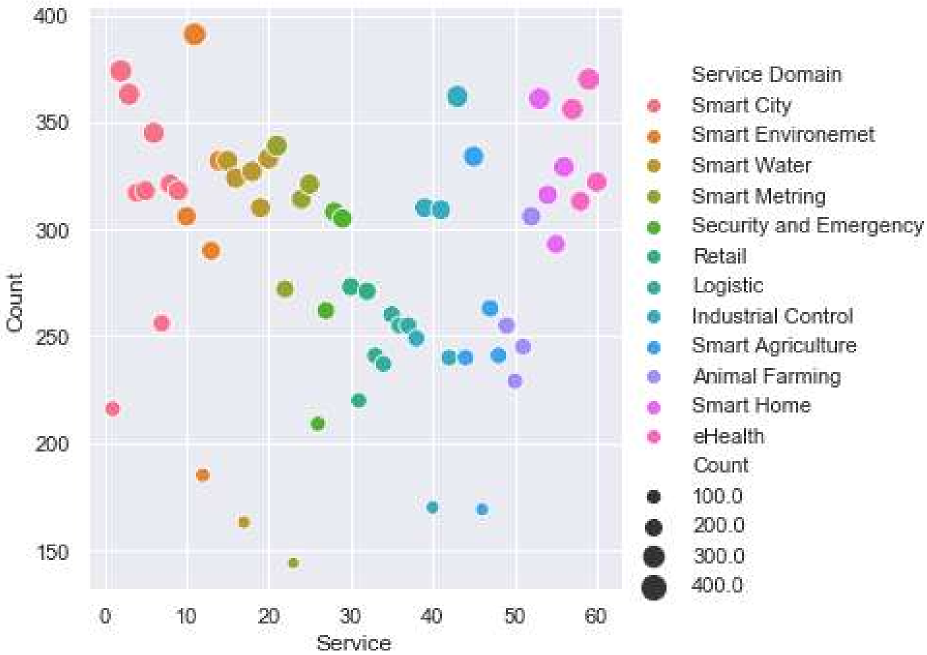

Figure 4. 7: Sparsity of the services based on the respondents' choices

Furthermore, to figure the findability of the lacked data to accomplish the service composition, we have used the built ontology to depict the social relationships among objects where each service of the 60 mentioned in the survey is deployed using 3 objects/devices whereas each user of the respondents has 20 friends and owns 10 objects.

4.3. Evaluation method

To evaluate the prediction quality and performance of our RS, we partitioned our dataset into training and test sets via 5 folds cross-validation. Thus, experimentations were carried out and the proposed algorithm is evaluated. The experimental results were compared with the other recommendation algorithms. The proposed hybrid algorithm combines CF and the SIoT ontology whereas the other algorithms are evaluated for comparison without taking into account the social relationships between the objects. Therefore, The first algorithm is a graph-based recommender (GBR) system presented in (Mashal et al. 2016a) besides the recommender system based on collaborative filtering (CF) presented in (Forouzandeh et al. 2017).

Firstly, let us define our variables:

TP: denotes the recommended IoT services to user correctly.
TN: denotes the non-recommended IoT services which are non-relevant to the user.
FP: denotes the recommended IoT services which are non-relevant to the user.
FN: denotes the non-recommended services which are relevant to the user.

Recall(R) is a metric, which is computed as the ratio of the correctly recommended services comparing to the number of relevant services.

The following equation defines the formula of Recall:

$$R@K = \frac{correctlyrecommendedservices}{total\ relevant} = \frac{1}{n}\sum_{i=1}^{n}\frac{TP}{TP+TN}$$

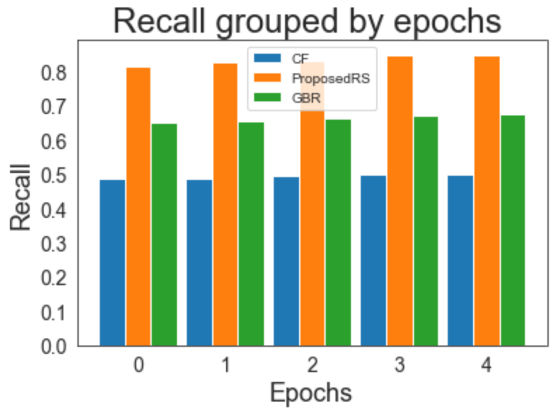

Figure 4. 8: the recall measure

Precision (P) refers to the ratio of relevant services selected by the recommender system to the number of services selected. Precision is used to measure the positive patterns that are correctly predicted from the total predicted patterns in the positive class.

$$P@K = \frac{correctlyrecommendedservices}{totalrecommended} = \frac{1}{n}\sum_{i=1}^{n}\frac{TP}{TP+FP}$$

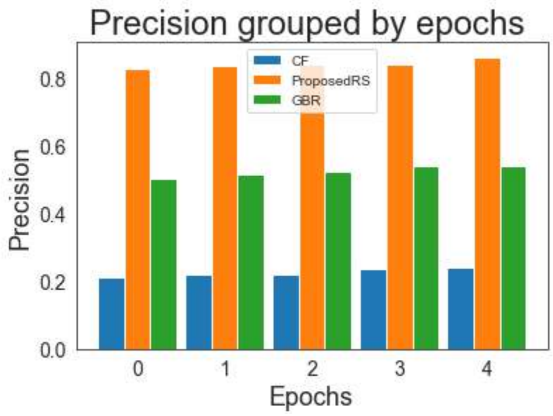

Figure 4. 9: the precision measure

F-Measure (FM)this metric represents the harmonic mean between recall and precision

$$FM = \frac{1}{n}\sum_{i=1}^{n} 2 * \frac{P@K * R@K}{P@K + R@K}$$

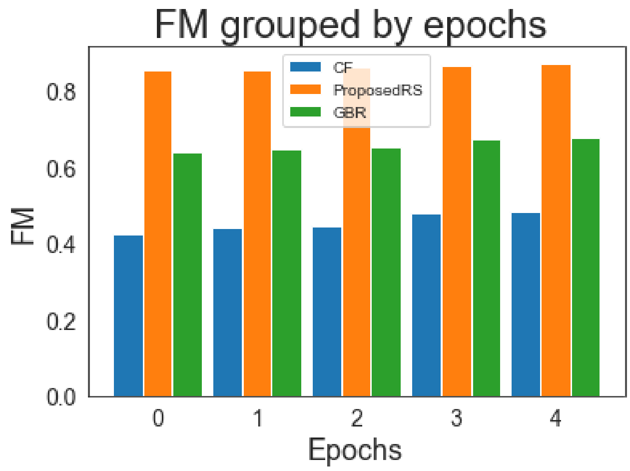

Figure 4. 10: The F- measure

Accuracy The accuracy metric measures the ratio of correct predictions over the total number of instances evaluated.

$$ACC@K = \frac{1}{n}\sum_{i=1}^{n}\frac{TP + TN}{m}$$

where m is the total number of services.

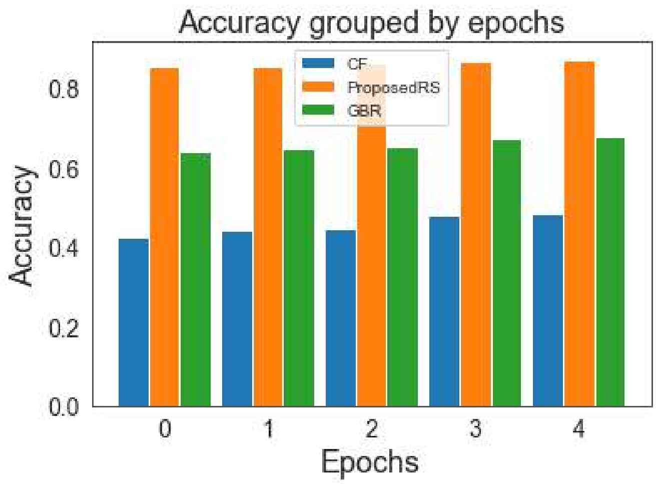

Figure 4. 11 : The Accuracy measure

Mean Absolute Error (MAE) measures the average deviation between the predicted and the true ratings. The lower the MAE, the more accurate prediction is. To compute MAE, the following formula was used.

$$MAE = \frac{1}{n}\sum_{i=1}^{n}|p_i - r_i|$$

Where $p_i$is the predicted rating for service i, r_i is the actual rating given to service i by the user, and n is the number of users.

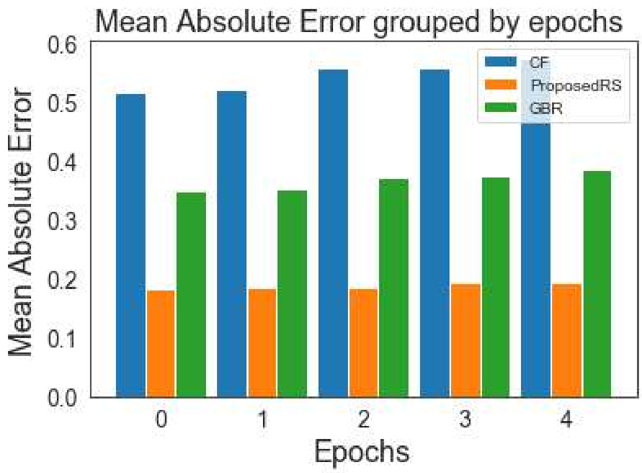

Figure 4. 12: The Mean Absolute Error measure

Root Mean Square Error measures the distance between predicted preferences and true preferences over items where RMSE tends to penalize larger errors.

$$RMSE = \sqrt[2]{\frac{\sum_{i=1}^{n}(p_i - r_i)^2}{n}}$$

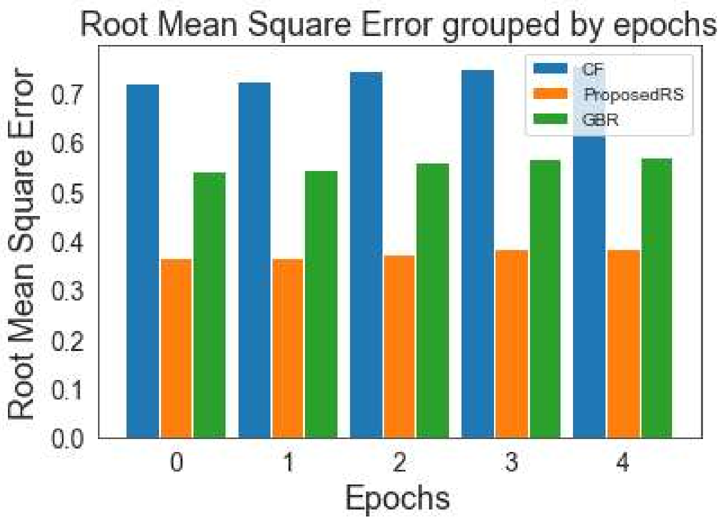

Figure 4. 13: The Root Mean Square Error measure

The experiments conducted in this research have shown that the new SIoT-based hybrid recommender system has improved efficient and deemed predictive than the other algorithms without the SIoT. The benefit of the proposed hybrid approach is that the knowledge presented by the ontology domain initializes the user and the service profiles before recommendation by first entering into the cascade (Fig. 3), then this solution will solve the problem of finding lacked data not counted in by the previous recommendation method which relies on the objects owned by the users themselves.

Conclusion

5. Conclusion

As time goes on, we are intended to live into fully connected objects. This leads to tremendous changing in our daily life as well as business opportunities. For enterprises, IoT will empower management in making intelligent decisions about the enterprise's future development. IoT-enabled programs will be able to collect data such as a history of enterprise productivity, demand for manufactured items, material pricing, and industry trends in the markets.

In addition, from the customer perspective, the key advantage presented by IoT will be new services provided by connected objects and (possibly) back-end services based on Big Data Thus, users face tremendous challenges in identifying not only the perfect service from the extremely vast number of providers, but also the correct object to satisfy the precondition for taking advantage of the service. This object may not be owned by the user whereas it could be owned by their friends or friends of friends. The overwhelming of the data shared by objects as well as IoT services provided by enterprise impose data analytics to provide the suitable service to users based on the available data that they are able to use. Thus, the recommendation of the IoT services is critical to the success of the IoT. In which, the selection of the data provider to accomplish the service requirement is considered as among most critical challenges in the IoT services recommendation.

The massive numbers of IoT services that will be available leads to tremendous challenges in identifying not only the perfect service from the extremely vast number of providers, but also the correct object to satisfy the precondition for taking advantage of the service. This object may not be owned by the user whereas it could be owned by their friends or friends of friends. The main benefit of SIoT over traditional IoT is that smart objects can establish social relationships among themselves in an autonomous manner to feed the lacked data.

Thus, to solve the complex problem of recommending the suitable service and finding the necessary data to accomplish the service, we proposed a hybrid recommender system (RS) to discover and recommend services based on users' interests and the IoT social graph of objects created by the SIoT while the social graph of objects refers to the network relationships between objects.

In this thesis, we looked for the potential of a hybrid knowledge-based recommender system based on ontology and collaborative filtering to recommend services to users in an IoT environment. The proposed approach incorporates additional knowledge of the ontology domain and CF techniques into the recommendation process.

We built the ontology where we show knowledge about the users, objects, and services in order to depict the relationships amid the objects and users to facilitate the discovering of services and the data available to accomplish the service. Further, we have used CF techniques to predict the preferences of the user. From the experimental results, it can be seen that the proposed hybrid algorithm can obtain better performance and accuracy than the other related algorithms. In which, those related work are used to recommend IoT services without taking the social relationships among objects.

In the future, we plan to develop a more powerful model and improve IoT Service

Recommendation System to make more accurate recommendations taking into consideration the spatiotemporal criteria. In addition, we plan to consider the trust as well as the privacy preservation of the users by applying well-known privacy preservation techniques, such as differential privacy and k-anonymity besides the trustworthiness techniques.

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