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Brokering Intelligence as a Service for the Internet of Things

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ABSTRACT

The Internet of Things (IoT) has been hailed as the next best industrial revolution and is expected to influence the global economy. The tide has begun to shift away from old ways and several companies are working towards providing novel IoT applications and development solutions, which will change the way we approach everyday tasks in the future. The IoT ecosystem is characterized by complex interactions between technology, data suppliers and users, raising the need for an intermediate entity, the IoT broker and the corresponding brokering intelligence as a service, for the IoT business model. The main objective of this article is to introduce the innovative concept of the IoT broker, which will play an important role in the IoT networks, describe its conceptual framework and analyze the intermediation services by presenting typical case studies.

KEYWORDS

Brokering, Brokering Intelligence as a Service, Business Model, Cloud, Consulting Services, Intermediate, Internet of Things, IoT Broker, IoT Ecosystem, Market, Network, Smart Home, Techno-Economics

INTRODUCTION

The Internet of things (IoT) is the internetworking of physical devices embedded with electronics, software, sensors, actuators, and network connectivity that enable these objects to collect and exchange data (Gubbi et al, 2013). The IoT allows objects to be sensed and/or controlled remotely across existing network infrastructure, creating opportunities for more direct integration of the physical world into computer-based systems, and resulting in improved control, efficiency and economic benefit in addition to reduced human intervention. It is based on mesh networking, where devices with different configurations and standards announce their connection to the network, seeking to interact with the other connected devices. There are a number of technologies that could contribute to the IoT vision, either in the access or in the domestic network, such as Wi-Fi, cellular, satellite etc. (Reina et al,

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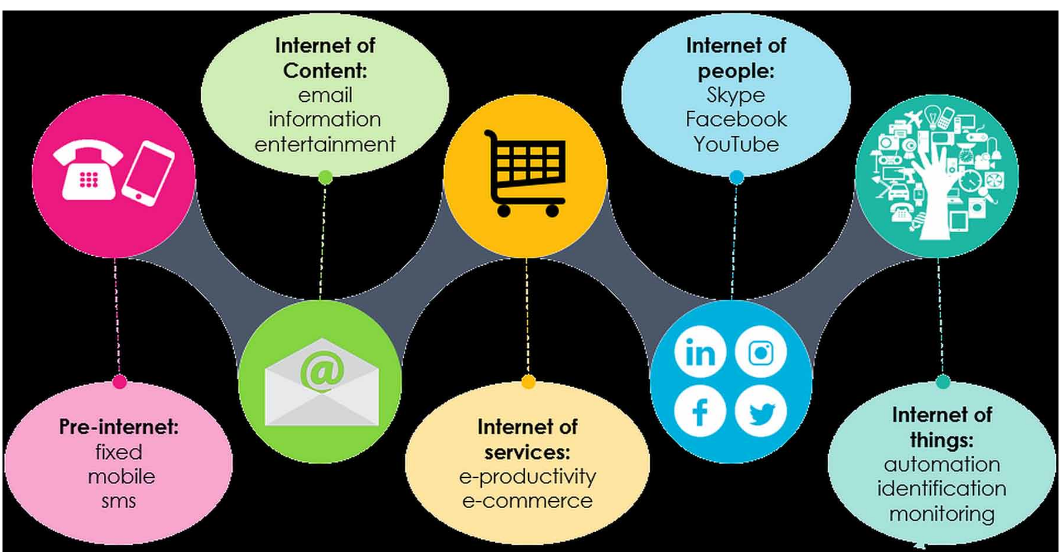
2013). When the IoT is augmented with sensors and actuators, the technology becomes an instance of the more general class of cyber-physical systems, which also encompasses technologies, such as smart grids, smart homes, intelligent transportation and smart cities. The IoT describes a web of machine-to-machine (M2M) networks that enable the free exchange of messages between so-called "smart objects" and associated applications within commercial, industrial, and civil organizations.

Although still at its infancy, the ability of IoT to provide real-time visibility and control of real-world objects, such as water and electricity meters, point-of-sale terminals and traffic lights has the potential to bring unprecedented efficiency and transparency to almost any aspect of our lives. According to Morgan Stanley's projections, 75 billion devices will be connected to the IoT by 2020 (Morgan Stanley Research, 2014). IoT is considered as the main driver for developing a System of Systems (SoS) approach. SoS is a collection of task-oriented or dedicated systems that pool their resources and capabilities together to create a new, more complex system which offers better functionality and performance. A typical example of a SoS application is smart cities, with separate subsystems for street lighting, traffic, energy, building management etc. (Cavalcante et al, 2016). IoT is considered by many to be the next best industrial revolution aiming at merging physical and virtual worlds and thus creating smart environments (DuBravac et al, 2015). The transition towards the IoT is expected to happen very quickly, driving the evolution from www to IoT, as illustrated in Figure 1.

The development of the IoT ecosystem requires partnership and collaboration among industries, governments, technology companies and research institutes. As the number of sensors in the IoT network increases, the amount of data gathered, managed and even combined with other data and distributed is also augmented (OECD, 2014). To ensure the high quality of IoT performance, some important technical requirements should be satisfied, including power efficiency, computational power, storage availability and high-speed networking. The evolution of the IoT will undoubtedly follow an expansion of demand for bandwidth, data transfer rates, infrastructures and services. Towards this end, it seems that the deployment of the upcoming new 5G wireless technology will speed up the IoT evolution.

The IoT ecosystem is characterized by complex interactions between technology/data suppliers and users, with a dominant role of business-to-business interactions, where Information and communications technology (ICT) vendors provide IoT solutions to industries that leverage them to

Figure 1. Evolution towards the IoT



deliver services to their users. Service providers may play different roles in the IoT value chain and a key feature of the ecosystem is the dynamic interaction between providers of horizontal IoT platforms and those of vertical solutions or industry specific environments. Taking into account that the IoT generates massive amounts of data and that cloud computing provides a pathway for these data to reach their destination, there will be a major need for bridging or spanning IoT gateways in building solutions, combining infrastructure, services and communications among a number of providers and also between the demand and the supply side of the IoT market.

In current IoT solutions the individual end users mainly choose to implement IoT applications either by themselves (Do It Your own - DIY implementations, by using platforms such as arduino or raspberry etc) or by using the traditional channel of retail market. On the other hand, enterprises and governments are going directly to IoT providers in order to design and implement any IoT solution based on their needs (i.e. smart buildings, cities). Current solutions and implementations are usually based on strong vertical market models. However, in the near future, open horizontal platforms will dominate the IoT network, especially if open standards and interoperability can be ensured (Al-Fuqaha et al, 2015). The potential optimal balance between horizontal platforms and vertical environments is one of the critical issues of the IoT market evolution. Connecting and correlating data across devices and platforms will result in more efficient and resourceful networks, connecting a wide range of assets and infrastructure allowing each asset or device to interact in real-time with its surrounding environment. The resulting data need to be analyzed, transformed and re-communicated to other platforms or devices (Briodagh, 2018). The development of horizontal infrastructures for data collection processing and communication will be barely affordable, or not at all, and will undermine the effectiveness and efficiency of IoT performance. Moreover, it will raise great issues regarding compatibility and prototyping among the stakeholders and the various components.

It is rather obvious that the evolution of the IoT involves a significant increase of data, services, applications and interactions among different objects and hence the need for an intermediary acting as a middleware layer on a relational environment between all IoT entities. In this context, the present paper introduces the IoT broker a.k.a. the Broker of the Internet of Things (BIoT) as the intermediary entity in future IoT networks which implements the corresponding Brokering Intelligence as a Service (BIaS) IoT business model. The intermediary concept is frequently used in marketing literature to denote a particular category of market actors (Snehota et al, 2001). In (Bohli et al, 2009) the vision of intermediation in IoT networks has been introduced emphasizing the three main entities that will play key roles in the future IoT market: providers, consumers and intermediaries. In (Andersson et al, 2015) a conceptual framework reflecting network dynamics in IoT was proposed highlighting the need for intermediation. Moreover, the authors in (Al-Fuqaha et al, 2015) provide an overview on IoT emphasizing on enabling technologies, protocols and applications and presenting the crucial need for better horizontal integration among IoT services. Specific functionalities of an IoT intermediary are presented in (Sen et al., 2018), (D'Elia, 2015), (Karakostas et al. 2016) but refer only to certain area of IoT applications and not to a generalized business model that may lead to an interoperable, ubiquitous broker for all the cases of the IoT environments. The role of the intermediary or broker is also known in the area of cloud computing, where a cloud broker is a third-party that acts as an intermediary between the purchaser and the providers of a cloud services (Guzek et al, 2015). In financial terms, a broker makes a profit by matching buyer's demands with seller's supplies (Rogers et al, 2012). In general, a broker acts as an intermediary between two or more parties during negotiations. The BIoT, an evolution and a more complex realization of the cloud broker, will play an important role in future IoT networks. Brokering and intermediation services must be extended to include not only computing infrastructure and software but also telecommunication services, network access and consulting services to end users. The need for interoperation between IoT devices and services calls for an intermediate gateway, which allows for a better horizontal integration between the diverse IoT services, technologies, systems, data and user requirements. Integration of different protocols and standards in a heterogeneous environment is one of the main promising targets of the BIaS, together with the intention to bring a uniform access to the underlying devices and support different kinds of interactions between them.

Based on the above the objective of this paper is to define the role of BIoT describing its main functionalities under a structured conceptual framework. An inspection of previous literature, as analyzed above, reveals that the crucial need for an intermediary and horizontal integration among IoT services but no specific conceptual framework identifying the IoT broker entity in all cases of the IoT applications and environments. The proposed BIoT and the consequent BIaS business model is being promising concepts in the area of IoT both for industries and academia research in near future.

The rest of the paper is organized as follows. The second section refers to the specifics of IoT market and policies and the third section introduces the BIoT conceptual description. The fourth section presents IoT applications and two representative case studies of BIoT. Finally, some concluding remarks are given in the last section of the paper.

IOT MARKET AND POLICIES

The European Union has early understood the benefits of IoT in the society and economy and has been actively cooperating with the private and public sector of both EU Member States and third countries to unleash the potential of the IoT technology. Towards this direction, a set of supporting policy actions have been adopted aiming at accelerating the take-off of IoT for the benefit of European citizens and industries. Among them the Alliance for Internet of Things Innovation (AIOTI) and the Digital Single Market (DSM) Strategy (European Union 2017) aim at working closely with all IoT stakeholders and actors and establish a competitive European market. In addition to the policy initiatives, the EU has set up concrete IoT research and innovation objectives in the ongoing Horizon 2020 (European Union 2015; 2013).

The IoT offers a great market opportunity for equipment manufacturers, internet service providers and application developers. All forecasts agree that the IoT market will substantially change people's lives (European Union 2013). The European IoT market is expected to expand at an annual growth rate of over 20% between 2013 and 2020 and the number of IoT connections within the EU28 will increase from approximately 1.8 billion in 2013 to almost 6 billion in 2020. The economic growth of IoT-based services is also considerable for other industries. Healthcare and manufacturing applications are expected to have a great economic impact. In terms of economic growth, IoT revenues in the EU28 will increase from more than €307 billion in 2013 to more than €1,181 billion in 2020, including hardware, software and services. The market value of the IoT in the EU is expected to exceed one trillion euros in 2020. It should be noticed that China has already earmarked €625m for IoT investments (DuBravac et al., 2015).

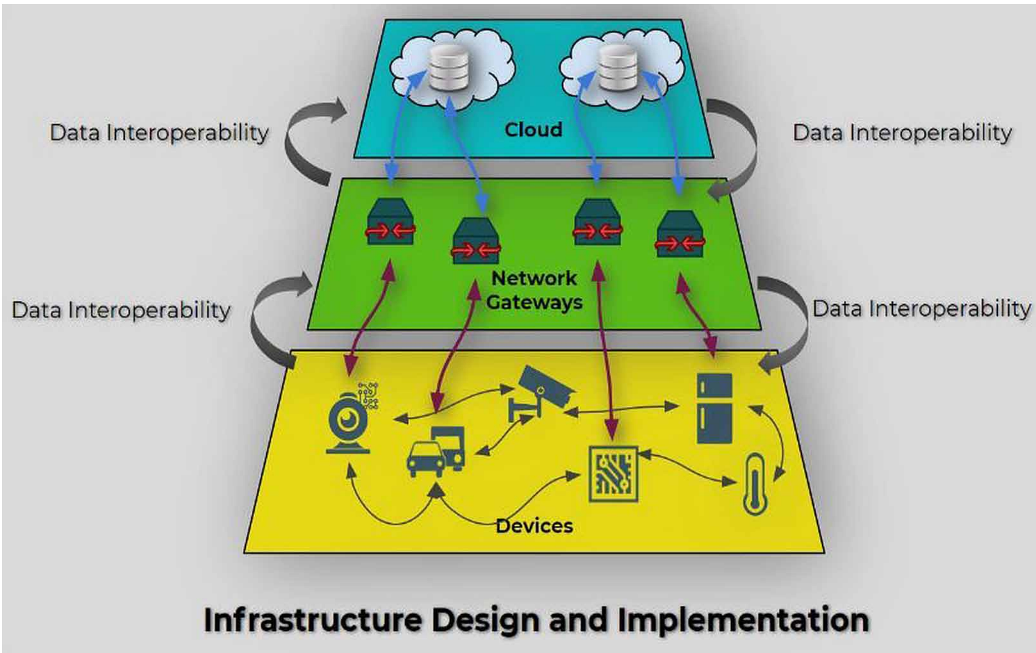
Based on the above, the IoT vision will come true in the near future, providing a great opportunity for traditional equipment and appliance manufacturers to transform their products into smart objects/things. The evolution of the IoT globally raises the need for horizontal integration among the IoT services and devices and hence the vision of the BIoT as an intermediary will become reality.

BIAS CONCEPTUAL DESCRIPTION

BIoT Functionalities

Since the IoT should be capable of interconnecting billions or trillions of heterogeneous objects through the Internet, there is a critical need for identifying distinct BIaS functionalities, in a flexible layered architecture, taking into account both research and industry driven requirements. The proposed BIaS architecture, illustrated in Figure 2, is mainly based on the IoT five-layer model presented in (Al-Fuqaha et al, 2015).

Figure 2. BIaS basic architecture



The proposed BIoT model is designed on the premises of a five-fold role in the future IoT network. Its main functionalities include Data repository, Data interoperability, Hardware management and maintenance, Communication gateway, Infrastructure design and implementation. These functionalities are presented in more details in the following subsections.

Data Repository

BIoT may act as data repository for different applications and platforms using the same pool of data. The connected IoT devices need mechanisms to store, process and retrieve data. Nevertheless, big data exceeds the capability of commonly used hardware environments and software tools to capture, manage, and process them within an acceptable time slot. The IoT employs a large number of embedded devices, like sensors and actuators that generate big data, which in turn require complex computational efforts to extract knowledge, making the use of cloud as the best solution for the IoT to store and process data.

Towards a centralized cloud vision, BIoT cloud computing will offer a new management mechanism for big data, enabling the processing of data and the extraction of valuable knowledge from it. End users may not, and they don't need to be aware of the storage mechanisms and computer infrastructures their data will be stored in. Thus, the IoT broker will offer an intangible way of data repository, acting as an intermediate between the cloud providers and the end users' machines. This can be achieved by utilizing the available cloud platforms, having different capabilities and characteristics, such as ThingWorx, OpenIoT, Google Cloud, Amazon, GENI, etc. An important aspect of cloud platforms is their ability to interact with different application protocols. A cloud platform may have users performing with different application protocols and the limitation of the cloud, which offers just a specific application protocol, is a barrier to its expansion. The available cloud platforms hardly support all standard application protocols, while almost all of them support Representational State Transfer (Whitmore et al, 2015). Hybrid clouds can be a solution for the BIoT data repository. Into that context, the BIaS broker will offer either storage capability of virtual machines according to the end-user requirements.

Data Interoperability

BIoT will also play the role of the intermediary for data aggregation and processing, combining data from different sources-providers and making bundles according to application and user needs. End-to-end data interoperability is a significant challenge for the IoT, because of the crucial need to handle a huge amount of heterogeneous data sources, belonging to different platforms. Heterogeneous data coming from different devices such as cameras, environment sensors, tablets, household appliances, etc. need to be treated under a common data standard, in order to facilitate application interoperability. IoT needs a common data analytic platform which can be delivered as a service to IoT applications. Such an analytic service should not impose a considerable overhead on the overall IoT ecosystem.

Into that context, BIaS will also play the role of service manager pairing the services with its requesters based on addresses and names. This BIaS abstraction enables the support of heterogeneous objects and devices from different vendors without been locked into a specific hardware platform.

Hardware Management and Maintenance

IoT devices may include sensors and actuators to perform different functionalities such as querying location, temperature, weight, motion, vibration, acceleration, humidity, etc. BIoT should be capable of interconnecting huge amounts of heterogeneous such devices through the Internet. Standardized plug-and-play mechanisms need to be used by the BIoT to configure heterogeneous devices. The heterogeneity of the IoT devices needs a thorough solution to make ubiquitous IoT services a reality. Application protocols should stick to a common format, in order to support the administration and communication with heterogeneous devices. Device interoperability should be considered by both application developers and IoT device manufacturers, in order to ensure the delivery of services for all customers regardless of the specifications of the hardware platform that they use. Any complex IoT system must include hardware management capabilities in its architecture. Hardware management helps to protect devices and their data by making it easier to secure and monitor the devices. As the number and variety of IoT devices deployed increases, together with the complexity of the IoT system architecture, the capability of the BIoT to homogeneously managing the IoT devices becomes increasingly challenging. IoT device management includes authenticating, provisioning, configuring, monitoring and maintaining the device firmware and appropriate software that provides its functional capabilities. Effective device management is critical for the establishment and maintenance of health, connectivity and security of IoT devices. IoT application vendors typically provide comprehensive device management with their solutions, but all bets are off if that application vendor goes out of business and a user want to use the devices with a similar application from a different vendor. Consumers continuously face unexpected device obsolescence and landfills are starting to fill up with expensive IoT bricks. What the IoT consumer needs is a truly open IoT device management ecosystem that the BIaS broker may offer.

Communication Gateway

IoT broker will also act as a communication gateway, combining different networks and available connections to achieve high quality of network access. Communications gateway is responsible for providing the services requested by customers. For instance, BIaS gateway can provide temperature and air humidity measurements to the customer who asks for that data. It is very important the BIaS to provide high-quality smart services to meet customers' needs. BIoT should have the capability of connecting numerous vertical applications of different markets such as smart home, smart building, transportation, industrial automation and smart healthcare. The BIoT broker will be the interface by which end-users can interact with a device and query for data. The IoT communication technologies connect heterogeneous objects together to deliver specific smart services. Typically, the IoT nodes should operate using low power in the presence of lossy and noisy communication links. Examples of communication protocols used for the IoT are WiFi, Bluetooth, IEEE 802.15.4, Z-wave, LTE-Advanced, 5G, 4G, RFID, Bluetooth etc (Xu et al, 2014). Into this context, new protocols are required for communication compatibility between heterogeneous things (living things, vehicles, phones, appliances, goods, etc.). The different application protocols should fit together to deliver desired functionalities without having to go through RFCs and the standards specifications. The diverse devices in IoT environments rely on different network technologies. So, there is a need for interoperation of the underlying communication technologies and protocol adaptation services.

The role of the broker is to interconnect all user devices and provide a reliable communication gateway to the cloud in a seamless manner. The end-user can be agnostic of the implementation and all low-level complexities should be undertaken by an intermediate networking layer flexible enough to interconnect many different physical layer interfaces.

The IoT broker intelligence should be also able to choose the best alternative network among the available (5G, Wi-Fi, etc.) or even combine them, taking into account not only technical but also socio-economical aspects.

Infrastructure Design and Implementation

Consultation services represent another crucial challenge for the BIoT, in order to suitably advise its customers to choose the best, among a great range of alternatives, according to their needs, in terms of IoT system installation and maintenance, cloud, devices, network, etc. BIoT will play the role of IoT system designer and may also utilize collaborators for the installation and maintenance services. BIoT should also act as a financial advisor of the end users (households, municipalities, etc.) based on decision making approaches (multi-criteria processes, multi-objective methods, etc.), techno-economic analysis and SoS perspective.

The broker needs to identify the best possible solution for the end-user, taking under consideration the technical requirements of the intended applications, as well as economic restrictions, security, safety and social factors. The BIoT will manage the overall IoT system activities and services offered to the end users. Its main responsibilities include business models, graphs, flow charts, etc. based on the received data. It should be able to design, analyze, implement, evaluate, monitor, and develop IoT system related elements according to customer needs. It is also necessary to support decision-making processes based on data analysis. In addition, monitoring and management of the underlying five BIoT roles must be achieved. BIoT should be capable of providing forecasts regarding the demand for IoT services and competition of the corresponding market based on data analytics. The broker will also support billing services with different pricing approaches.

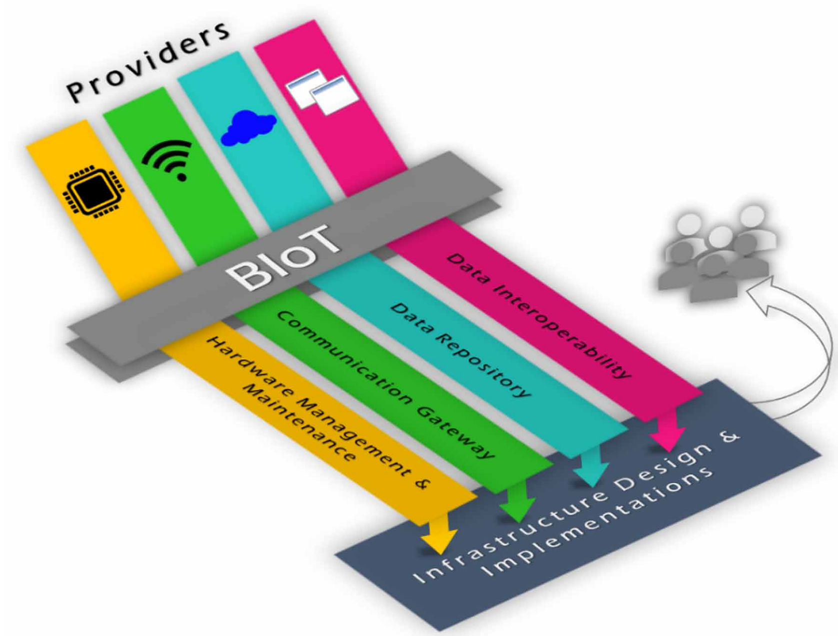
BIaS Conceptual Framework

This section focuses on the analysis of the conceptual framework of BIaS within the IoT ecosystem, based the functionalities of BIoT presented above. According to (Bohli et al, 2009) the main entities of BIaS ecosystem may be: i) providers, ii) intermediaries and iii) consumers, determining a three-layer environment of BIoT action. The front-end layer concerns the end-users' side of the IoT network, while providers are located in the back-end layer, as shown in Figure 3. In the middle layer, the BIoT acts as intermediary between consumers and providers.

In the context of the IoT network, we assume four different categories of the IoT providers and more specifically:

- **Telecommunications:** This category includes companies in general that provide voice or data transmission which is the main stream channel of transmitting data among the devices;
- **Hardware:** Manufacturer companies providing multiple components of an IoT application. For example, if we consider the case of smart home, a hardware provider may be the manufacturer of sensors, appliances or the end user devices on which client interacts within the system;

Figure 3. BIaS ecosystem and interactions



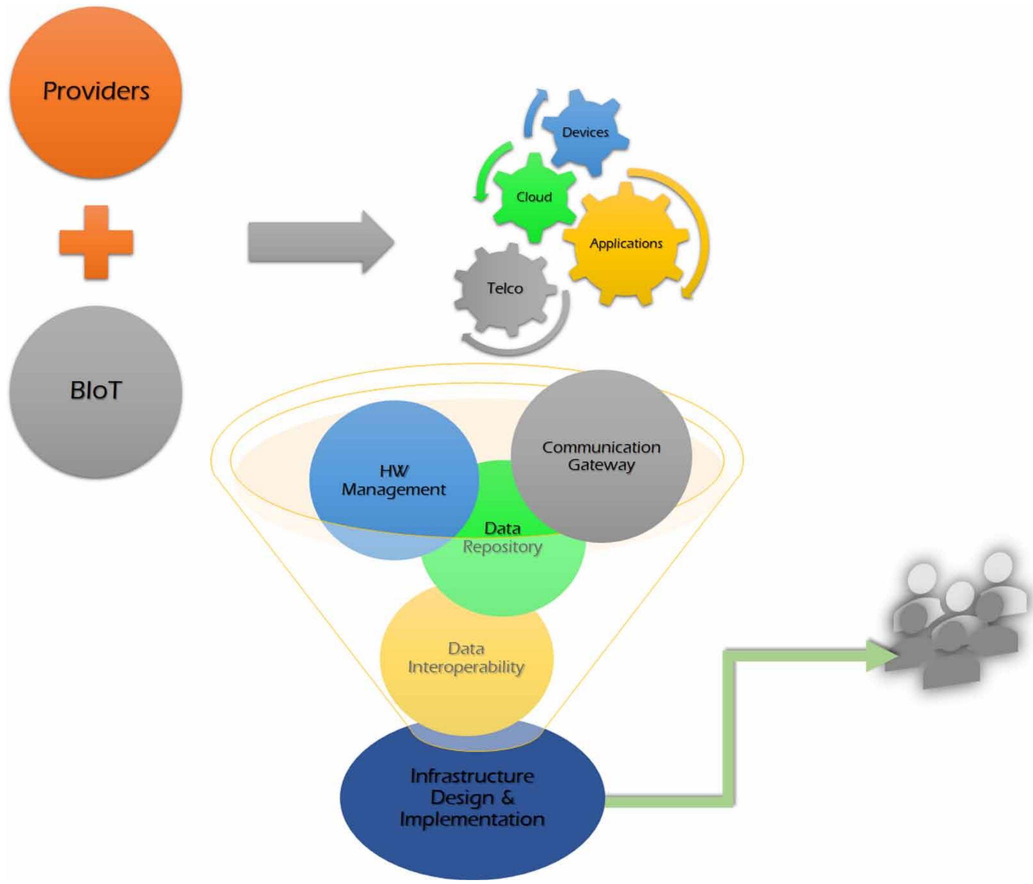
- **Data storage:** Data warehouse providers offered by companies such Amazon, Google Cloud etc. All the data related with an IoT application can be stored there;
- **Application providers:** Software companies developing the applications embedded in the IoT devices.

The initial requests for serving and implementing IoT solutions are driven by the end users' needs. Potential users may be industries, organizations, individuals, government, public services, etc. BIoT is responsible for defining the requirements, customized to end user needs and cooperating with providers in order to develop the appropriate architecture of each IoT application. That simple interaction of BIoT intermediary is based on a five-fold role of functionalities, analyzed in the previous section. The services offered to customers is a result of these functionalities. A basic concept of our proposal is the flexibility of the IoT broker supporting different application scenarios in the IoT environments such as smart home, smart factories etc. Some characteristic examples are described in the next section.

When BIoT is interacting with customers offering them the requested services, may be considered as distributor of the IoT technology, since these interactions leads to a successful sell of a product or a service. BIoT may also combine multiple IoT solutions in simplified bundles, in accordance with the potential providers/manufacturers. A characteristic example of such bundle may be a smart home ready solution with specialized components and functionalities where customers don't need to have any special knowledge of each technology.

IoT market ecosystem and its interactions within it can be alternatively shown in Figure 4 where it is rather clear that BIoT has a principal role in this lifecycle. BIoT may act as a consultant for end users and leads them to the most efficient solution for them. Interestingly enough, BIoT may act as a consultant among the providers and bring valuable information about the needs of the IoT market. This case allows providers and the IoT broker to develop innovative and useful solutions for IoT consumers. BIoT interacts as a link among the providers, in order to raise the interoperability between different technologies and products/services which interact in the context of the IoT network.

Figure 4. BIoT's position on lifecycle flow of IoT implementations



APPLICATION SCENARIOS

IoT Applications and Services

A smart environment makes use of ICT to develop the critical infrastructure components and services containing sensors, actuators, displays, and computational elements, embedded seamlessly in the everyday objects of our lives, and connected through a continuous network (Xu et al., 2014).

In the context of the IoT there are four general categories of applications: personal and home, enterprise, utilities and mobile (Gubbi et al., 2013). More specific IoT applications are defined under these categories such as smart home, smart factories, smart transportation, smart city etc. Smart home is one of the most popular IoT environments and involves a variety of technologies and devices performing several functionalities, such as energy efficiency, security, entertainment, environmental efficiency etc. In the context of utilities category, we may consider smart industries and factories machinery and equipment which are able to improve processes through automation and self-optimization using efficient ways to reduce energy consumption. The benefits also extend beyond just the physical production of goods and into functions like planning, supply chain logistics, and even product development. The structure of a smart factory can include a combination of production, information, and communication technologies, with the potential for integration across the entire manufacturing supply chain (Mabkhot et al., 2018). Considering the case of a smart city, in the context of public utilities, all the infrastructures and services such as administration, education, healthcare, public safety, real estate, transportation and utilities are supported in a more aware, interactive and efficient way (Bélissent, 2010). In the context of mobile category smart transportation is representative application. Private and public transport continuously exchange data within city base stations and offers traffic, parking management and many other services.

In the following subsection two IoT application scenarios are presented, aiming to analyze the way that BIoT interacts within a smart home environment. The first example is characterized as a vertical integration scenario because all functionalities are supported. The case of horizontal integration scenario is also analyzed, where BIoT supports only one of the aforementioned functionalities.

BIoT in Smart Home - Vertical Integration Scenario

A smart home architecture consists of three basic elements, a set of elaborate control mechanisms to manage the devices, the already installed devices (either legacy or not) and home devices with embedded control mechanisms such as baby monitoring and other supported smart services (Harper, 2003). The role and the interaction of BIoT in each of these three elements is described as follows:

- The first IoT element consists of a set of elaborate control mechanisms of control devices such as mounted control panels, smartphones, tablets, which constitute the main interface of interactions between smart home users and IoT devices. BIoT is responsible to ensure high availability of these mechanisms. Security issues constitute another concern of a BIaS platform and despite the sensitivity of the exchanged data, spoofing and third-party control could cause serious problems. The relevant functionalities in this case is the hardware management and maintenance and data repository, as described in the previous section;
- The already installed devices in a smart home refer to any pre-existing appliance which interacts within the IoT network and exchanges data, depending on the provided service (i.e. kitchen equipment, heating, home security system, lighting, etc.). In this context, the BIoT should support the interoperation of any different protocols used by these devices, acting as a communication gateway. BIoT may also convert the legacy devices to smart devices by installing relevant receivers and transmitters. Such an example would be the water heater converted to be manageable remotely by the end user;
- Home devices with embedded control mechanisms is another crucial element of smart house. Practical issues of a family's everyday life drive the need for the provisioning of various services/facilities. Apart from baby monitoring, other IoT-ready mechanisms with an embedded control are security mechanisms which can inform automatically from distance the user for a breach. User may control the recording and send directly to authorities. Aspects such as bandwidth, storage and applications increase the complexity of choosing the most suitable bundle of that aspects. Towards this end, the BIoT should define the appropriate requirements customized according to end users' needs, leading to an efficient smart home design.

BIoT in Smart Home - Horizontal Integration Scenario

One of the biggest challenges in IoT implementations is the management of a large amount of big data collected by any kind of device in the IoT network. BIoT could bridge all the connected gateways in any smart building/home of a wide geographical area. Each deployed IoT network has a different purpose of use but all network elements are connected to a standardized gateway offering added value services to the end user. Such case is illustrated in Figure 5 where only the functionality of data repository is supported. Representative scenarios of this case may include the services of gathering environmental conditions and camera surveillance.

Figure 5. Data Repository functionality used for a specific use case

Smart Home - Environment Conditions

Imagine many smart homes involving sensors which collect measurements regarding humidity, temperature, speed wind and sending these data in a standardized data platform. Execution of a simple query through an API, managed by a BIoT platform, could give an overview of which actions must be taken in order to maintain the desired temperature inside the house, or protect the residents by strong winds by raising an alarm on their control devices (phones, tablets, etc.).

Camera Surveillance

A centralized platform of data collection from camera surveillance network in a wide area could be a characteristic example, where BIoT adds special value with his services. A new smart building, in this area, could focus on installing such cameras only on places not covered by any other building in the neighbor. Moreover, these data could be useful to any security service (police, security companies etc.) in order to have a direct information of attacks in smart homes or buildings.

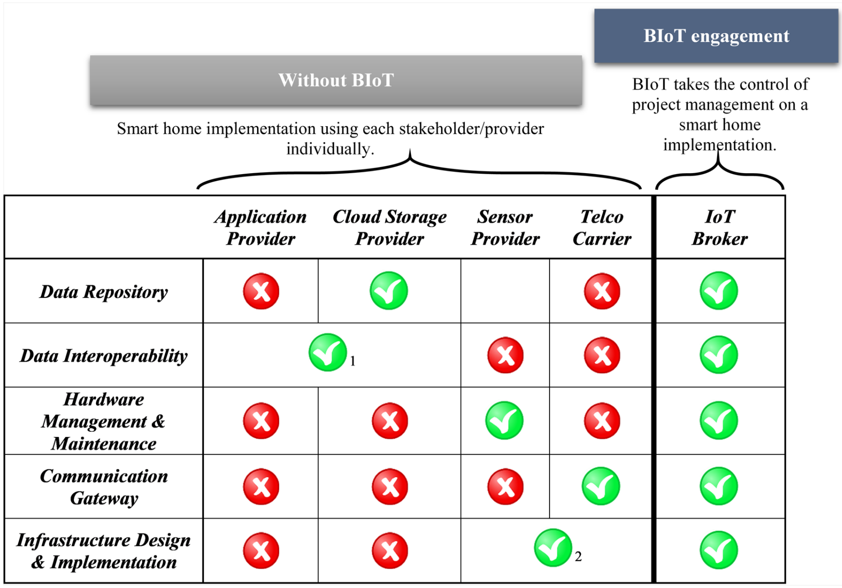
Both scenarios raise the need of an intermediary in the IoT network and the BIoT vision seem to be inevitable as the demand for IoT services is increased.

Smart Home With or Without BIoT

To further understand the importance of BIoT in IoT applications, the following figure presents the roles of stakeholders without BIoT aiming at achieving the functionalities depicted in the first column, as well as the advantage of using BIoT in future smart homes.

Considering an IoT smart home network without BIoT, all stakeholders act individually but cooperation is also expected in case at least two stakeholders have a duplicate role (as in cases 1 and 2 of Figure 6).

Figure 6. Smart home with or without BIaS enabled



In case of using the BIaS, BIoT is responsible for project management and acts as an intermediary between providers and customers supporting all the functionalities.

CONCLUSION

In this paper, the innovative concept of the IoT broker was introduced, under a structured conceptual framework emphasizing on BIoT main functionalities for intermediation services. The IoT market raises the need for intermediation among the various devices, services, technologies and horizontal solutions, making BIoT an important part of the value chain. BIoT is expected to play an important role in future IoT networks, including not only infrastructure and software intermediation but also telecommunication and consulting services.

The BIaS vision is expected to have a many-fold impact on society and economy by its nature, since it acts as an intermediary between the demand and the supply side of the IoT market. This will benefit the price levels as much as the quality of the offered services, in accordance with suitable Service Level Agreement (SLA) specifications, thus increasing the economic and the social surplus of the participating parties. In addition, the BIoT will substantially contribute to standardization processes and interoperability among the entities of the IoT ecosystem.

The proposed paper is an early stage research in IoT brokerage and there is a lot of work ahead, in order BIaS to become a successful and widely accepted business model, providing a wide range of research directions. Towards this end, the development of a detailed BIaS conceptual framework analyzing thoroughly all the relevant functionalities of BIoT is rather crucial for future research. In this context, data repository and interoperability mechanisms should be exhaustively defined, and hardware management and maintenance processes should be determined. Moreover, the role of BIoT as communication gateway as well as the supported technologies should be further analyzed. In the context of consulting services, techno-economic aspects, business processes, decision making methods, pricing and forecasting mechanisms are also characteristic features of BIaS that need an extensive research. A thorough BIaS framework that could speed up the deployment of IoT, should also be validated by extensive case studies in IoT applications, such as smart home, smart city, validated by qualitative/quantitative data.

There are also several challenges and considerations that need to be taken into account towards the BIaS vision. A major challenge is that BIoT should be continuously up-to-date on the new technologies, services and innovations. In addition, BIaS imposes a complexity to maintain end user security requirements, through the access network, since the broker is an additional layer between the end user and service providers. The auditing functionality plays an important role on this and on how the entities of this ecosystem handle users' sensitive data. More particular, the enforcement of state policies regarding the produced data of such applications is a crucial point. In addition, there is a major point of consideration, regarding the context for the management of the data by cloud or application providers, as it could turn out to be a drawback for BIoT, since the dependency of all entities in manipulating such data is nodal point in creating and offering valued services to end users.

The proposed paper provided an early stage framework in an attempt to shed light on IoT brokerage, a promising and challenging entity of future IoT. It is the hope of the authors that it will constitute a first step in developing an extensive conceptual framework that could speed-up the deployment of future IoT networks. An effective collaboration between academia and industry may guarantee the business prospects of BIaS wide scale deployment.

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