The Economics of Internet of Things: An Information Market System

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ABSTRACT

The Internet of Things (IoT) is one of the leading forces in modern-day technology. The concept has been proposed to be a new way of interconnecting a multiplicity of devices and rendering services to a variety of applications. According to the industry's insiders, IoT will make it possible to link transport, energy, smart cities, and healthcare together. The purpose of this paper is to understand the economics of the Internet of Things. It is meant to shed light on how world IoT applications can affect the information market. When every sector and industry of the world has been connected via this technology, what will become of the ICT niche? The information economic approach is currently being adopted and presented with its possible applications in IoT. Firstly, this paper reviews the kinds of economic models that have been designed for IoT services. Secondly, it focuses on the two major subject matters of information economics that are critical to IoT. While one considers the value of the information itself, the other addresses information with good pricing. Lastly, the paper proposes a game-theoretic model to examine the price competition of IoT-based services. We take a look at how these two sectors will fare against each, both at full capacity.

Key words: IoT, information economics, game-theoretic model, IoT-based services

INTRODUCTION

The Internet of Things is a new medium through which objects are link to the web. Per its theoretical propositions, the technology will enable people to easily transfer data over wired and wireless platforms without worry about third-party interference or intervention. Even devices will also be able to transfer data at will. The devices in question can be sensors or actuators. They need to generate data and receive human-born instructions before they can carry out off-functions (offline functions). From this perspective, IoT has the makings of innovation with the potential to foster services and consumption in specific domains.

It also can improve the performances of the systems in numerous applications, including manufacturing, tourism, and real estate (Atzori et al., 2010). Research shows that IoT can integrate a multiplicity of technologies—including hardware design, information storage, data storage, and the retrieval of intelligence. IoT also cuts across a good number of disciplines like engineering, social science, business administration, and computer science. The tech cuts across all these to achieve the goals of the target applications. Consequently, the design and development of the IoT systems and services need lots of wholesome approaches, some borrowed. As a result, the development of IoT-based platforms and services ensures that efficiency and every part of the concept is well managed. The current paper therefore asks the following questions: Do IoT possess some benefits to the market? What is the economic benefit of adopting IoT? An important contribution of this paper is to demonstrate the importance of the concept of the Internet of Things in relation to its promises to the ICT markets. Information marketing has been one of the cradles of modern-day business, but there is a reasonable amount of possibilities when IoT becomes a part of data.

LITERATURE REVIEW

Interoperability among IoT systems is expected to capture 40 percent (Vadlamudi, 2020), of the potential value that can be unlocked when it is put into use. According to

Vadlamudi, this is the overall potential value this type of technology can o0ffer, on average. But to achieve this, different IoT systems need to be working together. In a typical worksite setup, 60 percent of the expected value requires the capacity to integrate and analyze data from a variety of IoT-connected systems. Interoperability, on its own, is expected to unlock up to $4 trillion per year due to the use of IoT come 2025.

The majority of information collected today is not used for anything. Meanwhile, the data used are not completely exploited. For instance, just less than about one percent (Vadlamudi, 2016) of the data produced by the over 30,000 sensors on an offshore oil rig is adopted for making decisions. Out of the data put to use, most are leverages only for real-time control and the detection of anomalies or trends (Donepudi, 2021b). This is very common in manufacturing automation systems on factory floors. A great deal of leftover value is yet to be captured through the use of more data and the deployment of more sophisticated IoT applications (Ahmed et al., 2020).

Data can be harnessed for predictive maintenance and the analysis of workflows, to optimize operating efficiency. IoT can serve as a major source of Big Data that can be analyzed to realize more value. The technology can also be an avalanche of open data, available for use by more than one entity (Kumar et al., 2019). Khajenasiri et al. (2017) surveyed the IoT solutions used in smart energy control for the benefit of smart city applications, the research stated that the technology has been deployed in very few application areas to serve places and people. The information needed to make the system function more can be availed, but the extension of the technology is yet to be achieved. The scope of the Internet of Things is quite wide. Soon, then, it will be able to capture all application areas (Donepudi, 2021a). According to the survey, energy savings is one of the most important parts of society, wherein IoT can help in the development of smart energy control systems that will save the world a significant amount of money.

Developments in smart grid systems, intelligent transportation, and low-power networks form the main drivers in the evolution of network industries, this directly impacts the value of information across different sectors and markets. Data is certain to become more valuable, as IoT creates an array of new requirements for data interpretation and transfer in information and communication technology (ICT). In addition to real-time and data repositioning, new service attributes emerge from the change of the conventional sender-receiver perspective of Transmission Control Protocol/Internet Protocol (TCP/IP) to content relevancy for many researchers (Donepudi et al., 2020). IoT will also contribute to the dynamic changes of the state of devices.

The Economic Models of the Internet of Things

This section addresses the nature of the Internet of Things, its relations with Big Data, and then the economic techniques and issues used in IoT.

Layers of IoT

The architectural build of the Internet of Things comprises five essential layers that define all the functionalities of the systems. The layers are the perception layer, network layer, middleware layers, application layer, and business layer. At the base of the architectural framework, the perception layer exists in the consistency of physical devices—including sensors, barcodes, and RFID chips among many others (Olivier et al., 2015). These devices collect data to deliver it to the network layer. So, the network layer works as a medium of transmission. It delivers the data from the perception layer to the information processing system of the IoT. This transfer of information may be carried out via a wired or wireless medium, including Wi-Fi, Bluetooth, 3G, and 4G (Temglit et al., 2018).

The next level of IoT is the middleware layer. Its major function is processing the information that it receives from the network layer and decide based on the results derived from computing by ubiquitous standards. After processing the informati0n, the middleware layer is collected by the application layer for global device management (Ahmed et al., 2021). Atop the architecture is a business layer that is the chief controller of the IoT system in general. This layer also controls the applications of IoT and the services it is based on. The business layer is the part that visualized the data and stats sent from the application layer. With the knowledge, the business layer plans future targets and strategies (Vadlamudi, 2019).

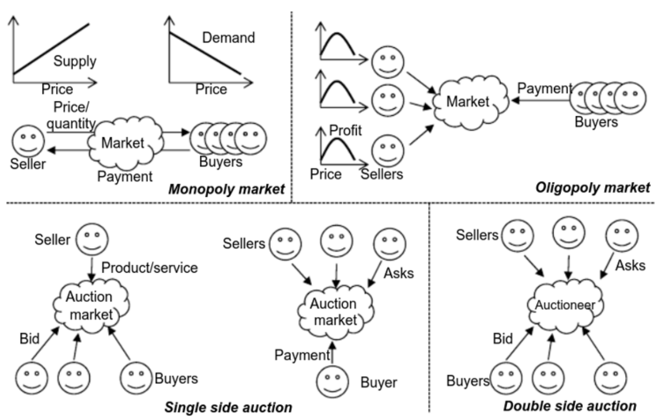

Figure 2: Layers of IoT

Additionally, the architectures of the IoT can be modified according to the need and the kind of application domain. Apart from a layered framework, the systems also comprise several functional blocks that bolster an array of IoT-based activities—e.g authentication, identification, mechanism, and control management.

The Importance of Big Data Analytics in IoT

The information technology markets form the canopy for both Big Data and the Internet of Things. Firstly, an IoT system comprises many devices that communicate with each other always—which means they are exchanging information. With the extensive growth and expansion of an IoT network, the number of these devices will rapidly increase. The more these devices communicate with one another, the more the amount of data that is transferred over the internet. The data itself may not be physical, but it is colossal (Erol-Kantarci and Mouftah, 2015). It will be streamed every second, which makes it qualified to be regarded as Big Data. The continuous expansion of networks based on the Internet of Things will result in the rise of complex issues like data management and control, data storage, processing, and analytics. For example, the IoT-Big Data framework for smart buildings is useful when it comes to often encountered issues like measuring to ensure hazardous gases, maintaining luminosity, and managing oxygens levels. This kind of framework is capable of collecting data from the sensors that have been installed in the building and carrying out the necessary analytics for decision making. Moreover, IoT-based cyber-physical systems can contribute to the improvement of industrial production. The system is, of course, equipped with information analysis and knowledge acquisition techniques. The real-time information for traffic, for example, can be ascertained via IoT devices and sensors that have been installed in traffic signals. This data can be analyzed in an IoT-based traffic management system and used to prevent hold-ups. In the healthcare analysis dimension, IoT sensors can be used to generate tons of information about the health status of the patient, every single second. This vastness of data needs to be integrated into one database so the system can make fast decisions accurately. This is where Big Data comes in (White et al., 2017). In the information market, Big Data and IoT are critical aspects of the dissemination of intelligence. The big question is: does the economics of IoT—whether in conjunction or separation from Big Data—based on the current realities of the ICT market. Is there real value in this network of countless signals and endless data transfer?

IoT Economic Approaches and Limitations

The traditional system optimization may not suit IoT in many circumstances of the application. There are bound to be issues with the transmission of data in such a manner, and these are the reasons:

Heterogeneous Large Scale Systems

The internet of Things usually comprises a huge count of diverse components. That is the several thousands of sensors, the millions of devices, scores of access points, and tens of cloud data centers that are integrated with complexity. The way these components are arranged, they form layers and layers of computed work that interrelate every single second. The intricate formation and cohabitation of these variables make the management approaches in the central aspects of the IoT system depend on optimization. The optimization solution itself is derived with complete global data. By this very nature, it may not be a practically feasible and efficient way of transferring, processing, and interpreting information.

Multiple Entities

The components of the Internet of Things may be a part of different entities, note worthily, they are also operated by those different entities to which they belong. Data is sent from sensor owners, data center operators, and wireless services providers at the same time. Bear in mind that sending information has its constraints, depending on the type of data and where it is being transferred from. Sending information from these points at the same time forms plenty and different constraints and objectives. When the system optimizations support only a single objective and are set to address only one type of constraint, getting millions of queries at the same time will see to it that the prior model fails. It will also be unsuccessful at determining the optimal interaction that should exist between these rational and self-interested entities (Noura et al., 2019)

Incentive Mechanism

Besides system performance and QoS requirements, a business perspective is bound to consider cost, revenue, and profit as the main pillars on which the operation and the development of the IoT unit can be sustained. As a result, the creation and the application of services based on the Internet of Things need fully consider the existing incentive factors. This issue has the potential to grow into a more complex challenge when a multiplicity of entities is communicating with one another but achieve independent objectives (Noura et al., 2019)

Because of this roadblock, incentive mechanisms must be meticulously tailored to have the ability to accomplish maximum efficiency. They also need to be designed to be able to produce balanced and unbiased solutions among these rational entities exchanging information. Correspondingly, economic factors, as well as approaches, are considered as a Plan B when it comes to the design and execution of services based on the IoT system. These approaches entail the consideration, analysis, and optimization of the creation, marketing, distribution, and consumption of the said services. The economic approach looks to determine the way the Internet of Things economies work and understand how these inherent entities economically coexist (Erol-Kantarci and Mouftah, 2015).

METHODOLOGY

This paper examines, in detail, how the Internet of Things can create value for the ICT market. In the process, it was discovered how value can be captured by companies, governments, people, and economies of the world. The paper analyzes more than 10 use cases of IoT across the global economy. Also, it looks at the impact of these use cases on the information market. Using the information economic approach alongside its possible applications in IoT, the research looks inside the current economic models that were created for IoT-based services in a multiplicity of markets. The paper looks at the inherent value of data and the value it can be produced when it has been designated throughout many channels.

We estimated the economic impact of IoT on real-world applications as per the potential value they can formulate. We consider the productivity improvements, the amount of time that can be saved, the scores of people that can be reached more easily, and the betterment in asset utilization. The paper tries to ascertain the real impact of IoT on data itself, and how the information market can leverage the new platform to reduce humankind's problems. We do not consider the estimated potential value of IoT—and its applications—on data as equivalents to revenues. Neither do we use the data we gathered to calculate the possible values of the markets IoT-supported data will impact nor the general gross domestic product (GDP) of the economies considered. We have collected data from industry researchers, governmental organizations, and leading think tanks.

RESULT AND DISCUSSION

Economic Approaches and IoT-related Works

Cost-Benefit Analysis

The CBA is a method of estimating an equivalent money value in relation to its benefits and costs from the IoT-based services and systems. The Cost-Benefit Analysis computes the benefits against what it cost the entities to make technician and economical choices. Case in point, the calculations determine whether the system or services need to be implemented or otherwise. The CBA is also the basis on which technology and design are decided to be adopted. It considers the risk factors and decides as to whether the action would provide value. Also duly considered are the cost (Uckelmann, 2012) and benefit of implementing the projects and justifying the IoT investment. Without the CBA, possible designs, projects and stakeholders cannot be determined. This method, thus, defines and calculates the metrics and cost/benefit elements of the system. Some of the most important metrics taken into consideration are the Economic Value Added (EVA), Activity-Based Costing (ABC), Total Cost of Ownership (TCO), and Net Present Value (NPV).

The Cost-Benefit Analysis leads to the classification of different categories. For instance, what then process costs in the physical world—including RFID tags, the cost of applying tags to the services or products, and the monetary consequences of purchasing—and deploying tag readers. Succinctly, every process has a cost and it is the purpose of this analysis to determine each. We also have the syntactic costs, which include what it took to integrate the IoT-based system. With the Cost-Benefit Analysis, it is discovered that the benefit can be spread across parties, such as bottling companies, wholesalers, and breweries. Based on this finding, the authors ushered in a simple Cost-Benefit Sharing (CBS) initiative to allow stakeholders to get different levels of rewards or benefits.

User Utility

A method from the stables of economies, the user utility represents the satisfaction and choices of the consumers regarding the services or the products that were produced by the entities. The utility concept has since been used in traditional computer networks. It has distributed computing to produce an abstraction of system performance senses by the users. An example is; the satisfaction of network bandwidth will be determined by a concave utility function. That is; the logarithmic function—one which plays by the law of diminishing returns. Particularly, the rate of satisfaction in the network increases or decreases in tandem with the size of the available bandwidth. When the bandwidth is larger, the satisfaction is more, and vice versa. In the Internet of Things, utility is adopted as an objective function for system optimizations. This is executed meaningfully to maximize the satisfaction of every user on the platform. In IoT, utility is employed to quantify the QoS performance of the sensor data collection systems for smart city projects (Munjin and Morin, 2012).

The system is made up of an access point that receives information from the mobile or fixed data collectors. These collectors gather sensing data from many sensors and put them together in arranged layers. With different Qos requirements, the access point received the data types—like delay tolerance and delay sensitivity. The utility for the delay, sensing quality, and trust is regarded upon exponential, sigmoid, and power functions, respectively. Case in point, when the delay increases, the utility of the system will exponentially decrease. At this point, the access point will use the information about the utility to optimize the revenue of sensing data collected services.

The utility method can be further applied in the determination of goods or service demand for the user base. The said demand can be identified as a function or price to indicate the amount of the offerings consumed by the users who maximize their utility. Let $U(q, p)$ denote the utility given that the users consume the good or service with amount q and price p. The demand is obtained as $D(p) = arg\ max(q, p)$. Based on this fact, service providers can set the price accordingly.

Market Pricing & Equilibrium

Markets exist as a result of economic systems, processes, available infrastructure. Social interactions and policies. All of these are there to support the exchange of goods and services. In the efficiency of trading, pricing is key. IoT applications markets can imitate that of the marketplace of mobile applications, like Google Play and App Store (Munjin and Morin, 2012).

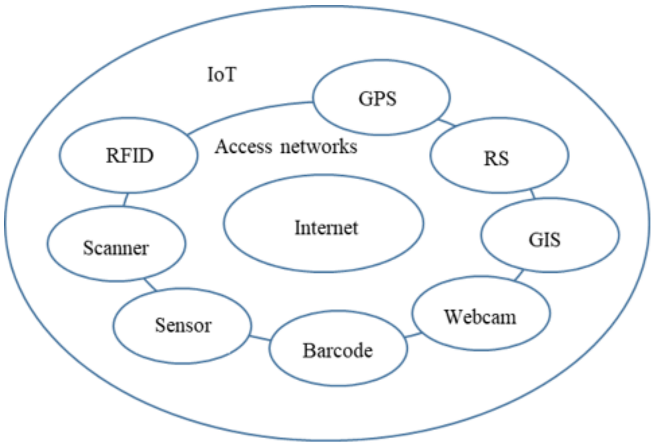

Figure 4: Market equilibrium

The authors posit that the IoT application marketplace needs to focus on the data market and introduce a fundamental marketplace structure. In the to-be marketplace, IoT devices and sensors are linked with a middleware and data broker. The data broker sells what he has in the application markets. People buy the data on the other side of the marketplace and use it for their software applications. Though pricing was not considered, the market equilibrium was given enough light in this study (Munjin and Morin, 2012). This approach considers the demand levels from the buyers and supply levels from sellers. The demand becomes low when the supply is high and the price is going down. In semblance to the Walrasian equilibrium, the market equilibrium is the point where supply and demand are equally ranged.

Market Duopolies & Oligopolies

In this context, duopoly markets are the ones with only two data sellers. Oligopoly market structures, on the other hand, are the ones with more than two sellers. In both markets, sellers' computer with each other in terms of price and supply quality to maximize their profits. These are called the Bertrand and Cournot competition models, respectively.

To analyze the Nash equilibrium solution, game theory comes to use. This study looked at the monopoly and oligopoly markets of cloud resource pricing to bolster services based on the Internet of Things. The users will choose a seller if their utility from using cloud resources, when subtracted from the price, is of positive value. Should there be multiple sellers, it is the one who can yield the maximum utility minus the price that the users will patronize. The researchers looked at the essential attributes of the Nash equilibrium, including the existence of the Nash equilibrium itself.

Auction, Energy & Spectrum

An auction can be used as the pricing mechanism of IoT-based services. There is the single auction and the double-side auction. In the former, one seller typically auctions goods or services by chasing bids from different buyers. Or, one buyer will ask from multiple sellers and patronize the one with the maximum utility minus the price. In the double-side auction, though, the many sellers and buyers tender their tasks and bid. The auctioneer will then determine the sets who win buying and selling. This clears the price and service allocations (Munjin and Morin, 2012).

Energy is the fuel that powers a variety of IoT components. Everything from sensors to gateway, base stations to backbone networks, and Wi-Fi connection to data centers consume energy to work and produce results. In a smart grid, for example, Chavali and Nehorai (2012) energy can be traded in the utility market, in monopolistic or oligopoly markets, utility companies can optimize the process of the energy they sell to data centers and wired/wireless networks. That is also to maximize their profits and beat the competition. The spectrum, as well as the network bandwidth, are among the scarce resources, particularly when it comes to wireless systems. In cognitive radio networks, for instance, the spectrum can be traded in the markets in a very dynamic manner. The licensed users, specifically, can sell their free spectrum to unlicensed users to make more money and improve on the utilization of the spectrum. Trading models like auctions are also introduced Palattella et al. (2016).

Data & Information Services

These services can be offered and integrated to bolster various IoT applications. For instance, information searching data, data storage, and mining of information security protection can be offered in the marketplace. The idea of "anything as a service (XaaS) is introduced to allow any resources to be considered and used as services. The typical offerings are the Software as a Service (SaaS) and Monitoring Service (MaaS). In this research, the authors of this paper Xu et al., (2015), introduced a contract theory to study the data mining services that enable the owners of the data to sell what they have to the collectors in the marketplace. To secure the privacy of the owners of the data, the collectors carry out data anonymization, reselling the information to the miners. The collectors will optimize the copies of the contracts based on the quality of the data in hand. Privacy requirements and payment proposed to the data owners are also huge factors that determine whether or not the profit is going to be maximized. In the economics of the Internet of Things, data and information can be treated as services that are waiting to be optimized (or put to use). They need to be offered in the proposed marketplace so the owners can realize revenues and make profits.

Conclusion

The Internet of Things (IoT) came into the industry as a technology that promises to connect devices and provide data-based services to millions of people around the world. In this paper, the economics of IoT has been considered and the essential aspects of issues in space. The study specifically looks into the value of information and good pricing directions for data. To throw light on the applications of information economics, the paper presents the game-theoretic model for sensing the price competition of data. Our model pays keen attention to the substitute services and their complementary offerings. All the solutions proposed are based on the Nash equilibrium. Conclusively, the important directions for intensive research are highlighted.

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