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Review of IoT Market and Open Source Technologies in IoT

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Abstract: **- Internet of Things (IoT) is an evolving technology in recent years. IoT serves the purpose of interlinking everyday objects, where objects are equipped with identifying, sensing and limited computing capabilities. Considering demand in fast-paced IoT environment, building a system from scratch is not always suggestible. Such needs have created many formal & informal open source technology forums where professionals can contribute in the improvement of technologies. Delivering a 'standard solution' in 'less time' are the two most attractive advantages which shall be achieved by utilizing open source technologies. In this paper we have highlighted the growth of IoT market while focusing on the value offered by open source technologies in IoT infrastructure. Along with the brief study of selective open source technologies in IoT.**

Keywords**- IoT devices, IoT Market, Open Source technologies, OSS.**

I. INTRODUCTION

With numerous technological advancements, from World Wide Web to social networking services, internet has evolved. Internet in recent years has taken steps towards always connected paradigm which is called as 'Future Internet'. Latest concept associated with 'Future Internet' is 'Internet of Things' (IoT). Internet of Things (IoT) is targeting to improve the reachability of any object, around the world. It is a pool of increasing information which supports to boost productivity and improving the end-customer experience. Therefore, users are motivated to join IoT ecosystem to get assistance in decision making by linking different sources of information. Technology focused companies have already started developing IoT technologies and end-to-end solutions, like: flexible battery technology laminated onto smart security cards, RFID tags for tracking lost bags on airports and similar more solutions are gaining popularity. Consequently, IoT is evolving each year and will impact various aspects, across the industries.

II. IOT GLOBAL MARKET SNAPSHOT

Business opportunities tied with IoT technologies are driving attention among users and companies. To generate revenues: predictive maintenance, automated inventory management, self-optimization production via IoT devices can be considered as the key market enablers. IoT is also considered as the door opener for many new global business avenues. The state-of-art business models and service portfolios are also setting path for organizations in defining new revenue stream. It is expected that organizations will increase their IoT spending, which will result in the exponential growth of market, i.e. double-digit numbers, in terms of percentage or USD 1.29 trillion by 2020. Manufacturing, utilities, and transportation and the major industries which will be fuelled by IoT-based technology.

2.1 Market Scenario, by installed devices

Investment in IoT devices, sensors, services and applications will act as major contributors in sources of revenue growth in the IoT market. Potential buyers and technology driven companies have also started realizing the value associated with solutions provided by IoT devices. In 2012, 6.1 billion IoT devices were installed all over the world and factors that affected installation are enhanced connectivity infrastructure for monitoring, assessing state of different equipment and ongoing development for smart cities among others. Requirement for enterprise systems to deploy, manage, and make use of IoT devices that generates data will be derived by addition of billions of devices to the network. Till 2020, 28.1 billion IoT devices with CAGR of 18.4% is expected to be installed. Growth of installed devices is leading IoT toward new business models such as banking industry is focused on mobile and micropayment technology using convenient point-of-sale (POS) terminals. Also, emerging connected sensor technology is making development in industries like utilities, transportation, agriculture and many more industries will be benefited from generic technologies used by installed devices.

2.2 IoT Spending- Top Industries, 2016

IoT is a leading factor of digital transformation for years to come. Industries that will see the fastest spending growth in IoT in coming years are insurance, consumer, healthcare, retail and manufacturing. Companies are investing more in the hardware, software, services, connectivity and by 2020 worldwide IoT spending will be USD 1.29 trillion. The industries that made the largest IoT investments in 2016 were manufacturing with 55%, transportation with 24%, utilities with 21% as shown in Table I.

Table I. IoT Investment in Industries (Year: 2016)

Industries	Spending (USD, Billion)
Manufacturing	178
Transportation	78
Utilities	69

The IoT use cases that attracted the largest investments in 2016 include manufacturing operations with 47%, freight monitoring with 26%, smart grid technologies for electricity, gas with 27% as shown in Table II. Cross industry such as connected vehicles, smart buildings has also seen significant investments in 2016.

Table II. IoT Investment in Use Cases (Year: 2016)

Industries	Spending (USD, Billion)
Manufacturing Operations	102.5
Smart Grid	57.8
Utilities	55.9

III. INTRODUCTION TO OPEN SOURCE TECHNOLOGIES IN IOT

These days open source software is playing a major role in ongoing development of IoT due to tough to tough competitive nature of IoT market. Crowded market of IoT with demand of better technology, makes organizations and users to be relied upon open source. With open source technologies, existing applications can be improved at low cost and much faster than ever before.

3.1 Developers Inclination towards OSS

IoT developers, approximately 91%, all around the world uses open source technologies open hardware, or open data in at least one part of their development stack. Open source is also playing a head role in the security of IoT, providing greater transparency from a security stance and that is why more number of developers are attracting toward Open source technologies in IoT. Open source technologies is a way to gain efficiencies which allows to position technology oriented companies to on-board the modern kingmakers of IoT developers. Usage of open source technology by IoT developers at different layers and elements where open source can be implemented is depicted in Table III.

Table III. Developers Inclination towards Open Source Technology

Layers	Elements	Open Source developers Usage Year:2015	Example
IoT End-Points	Embedded operating system	64%	Raspbian, Ubuntu Core, RIOT
IoT Local Network & IoT Internet	Frameworks, software components and libraries	71%	Node-RED, IoTSys, OpenWRT, The Thingbox Project
Cloud & Data Centre	Cloud based IoT platforms	64%	SiteWhere, OpenRemote
Client Devices	Device-side IoT platforms	61%	OpenHab, Nimbits, IoT Toolkit

3.2 Components of OSS IoT implementation

For OSS implementation in IoT, many components with distinct nature are involved and major companies such as Linux Foundation have started focusing on different market trends associated with these components. Some examples are shown in Table IV. Components explained in Table IV are showing maximum support to open source in IoT ecosystem. Open source supports in stitching IoT solutions together so that there will be no expensive licence for development tools. Also, open source database such as MongoDB, MySQL/MariaDB, PostgreSQL and Cassandra helps IoT developers to manage data and accelerate project timelines.

Table IV. Components for OSS IoT Implementation

Component	Description	Focused Companies	Market Trend
Sensors	For Detecting and responding to electrical signals to convert physical parameters	Filament, Invensense, Libelium, Episesnor	Nowadays companies are focusing to develop low cost and low power consumption sensors
Networks	Collected signals get transmitted	Kontakt.io, Veniam, Econais,	Light as medium for communicat

	over network	WigWag	ion is now started to develop, giving network new direction
Standards	Standards maintains the handling, processing and storing of data from sensors	IPSO Alliance, IIC, AllSeen Alliance, OIC	To protect the users investment in IoT, standards such as IEEE 802.11ah, Z-Wave are taking place in IoT market
Intelligent Analysis	To extract the insights from data for further processing and analysis	Software AG, TempoIQ, Mnubo, exosite	New Analytics solutions such as centralised data repository are now being designed to handle different type of volume data on dashboards
Intelligent Actions	Interfaces like machine to machine and machine to human are used for actions	Gemalto, Sierra wireless, CalAmp, Axeda	For processing real time information and nodes to be self-powered, interfaces are now started to develop

IV. STUDY OF MAJOR OPEN SOURCE TECHNOLOGIES IN IOT

The approach to study the open source technologies in this section uses the functional parameters of IoT platforms. Parameters in below Table V are some of the major ones, there can be more also.

Table V. Functional Parameters of IoT

Functional Parameters	Definitions
Visualization	Device data in interactive dashboard
Service Orchestration	Combination of data streams, analytics and service components
Event and Action Management	Mapping of low level sensor events to high level events
Basic Analytics	Data normalization, cleansing, simple statistics
Storage	Cloud based storage and database capabilities
Device Management	Remote maintenance, interaction of devices
Modules and Drivers	Adaptable modules, drivers, source libraries
API	Point of interaction between IoT devices and network

Functional parameters supports the analysis of the features of different open source IoT platforms and helps in giving insights on these platform.

4.1 KAA

Introduction: For building end to end solutions Kaa can be used. IoT solutions providers can concentrate on maximizing product's unique value as Kaa aims to speed up IoT product development. Connectivity from devices to the backend and simple end-point management functionality for organising end-points into groups can be achieved by using Kaa. IoT Protocols: Kaa supports functions such as scalable data collection, event processing from different devices and also make them available to multiple applications. Server and endpoint SDK components in Java, C and C++ with the data management for connected object also provided by Kaa. Business Applications: Major applications where Kaa can be used as platform are agriculture for remote crop monitoring, healthcare for hospital asset management, retail for optimized inventory management.

Table VI. Analysis of Open Source IoT Platform

Functional Parameters	KAA
Visualization	No Support
Service Orchestration	No Support
Event and Action Management	Support
Basic Analytics	Support
Storage	Support
Device Management	Support
Modules and Drivers	Support
API	RESTful

4.2 Nimbits

Introduction: For providing connectivity between devices using data points, Nimbits is used that act as server which is built on cloud computing architecture. It first records and then processes geo informatics and time stamped data and then produces rule from that information IoT Protocols: Nimbits is PaaS that can be downloaded, Web Server, Amazon EC2, or Google App Engine. It is used for logging and retrieving large amounts of data from physical devices, triggering events and initiating complex analysis by recording and processing geo informatics and time stamped data Business Application: Using nimbits.io, Nimbits Android application has been developed and available on Google play which offer many features of nimbits client such as logging time and geo stamped sensor data to responding to events in real time.

Table VII. Analysis of Open Source IoT Platform

Functional Parameters	Eclipse Smart Home
Visualization	Support
Service Orchestration	No Support
Event and Action Management	Support
Basic Analytics	Support
Storage	Support
Device Management	Support
Modules and Drivers	Support
API	RESTful

4.3 Eclipse Smart Home

Introduction: Eclipse Smart Home consists major code and data structure that are required for home automation server. Solutions that deal with the integration of different protocols or standard can be implemented using it. Developers can easily build an individual smart home solution by adding their own extensions to eclipse smart home framework and the result can be deployed on embedded devices

IoT Protocols: To have uniform access between devices, information and facilitating different kinds of interactions with them, Eclipse Smart Home is used Different protocols such as enocean, KNX, MODbus are used in Eclipse Smart Home to provide a uniform access to devices and information

Business Application: Eclipse Smart Home provides an IoT gateway platform that is focused on home automation domain only.

Table VIII. Analysis of Eclipse Smart Home

Functional Parameters	Eclipse Smart Home
Visualization	Support
Service Orchestration	No Support
Event and Action Management	Support
Basic Analytics	Support
Storage	Support
Device Management	Support
Modules and Drivers	Support
API	RESTful

4.4 Fiware

Introduction: Enhanced Open Stack based Cloud capabilities and a set of tools and libraries are provided by Fiware through Generic Enablers (GEs) with public and open-source specifications and interfaces. Generic Enablers are classified into different technical chapters with different capacities such as Internet of Things chapter offers tools to connect sensors and other device and the applications chapter provides powerful business intelligence tools.

IoT Protocols: Fiware supports XML or JSON as representation format for request and response parameters. It has Generic Enabler (GE) that supports multiple authentication schemes. Resource representation is transmitted between client and server with help of HTTP 1.1 protocol Business Application: By using Fiware technologies and start up support, application is developed in Spain which provides contextual visitor information to travelers who are blind or visually impaired.

Table IX. Analysis of Fiware

Functional Parameters	Fiware
Visualization	Support
Service Orchestration	Support
Event and Action Management	Support
Basic Analytics	Support
Storage	Support
Device Management	Support
Modules and Drivers	No Support
API	HTTP/RESTful

4.5 OpenIoT

Introduction: OpenIoT allows to link together semantic Web services and internet connected devices through friendly user interface that works either in Cloud Computing environments or with local server. OpenIoT platform for the IoT supports unique functionalities such as the capability to compose non-trivial IoT services. Information from sensor clouds and connecting the information with Web services without worrying about exactly what different sensors are being used, all can be achieved by OpenIoT.

IoT Protocols: MQTT, CoAP, IPv6, HTTP, SPARQL Protocol, among others

Business Application: Application area where OpenIoT has been targeted is in agriculture where farmers can get crop performance analysis using a wide range of distributed remote sensors fetching various types of data in order to predict crop yields.

Table X. Analysis of OpenIoT

Functional Parameters	OpenIoT
Visualization	Support
Service Orchestration	Support
Event and Action Management	Support
Basic Analytics	Support
Storage	Support
Device Management	No Support
Modules and Drivers	Support
API	Open, standard

V. CONCLUSION AND RECOMMENDATIONS

Open Source IoT technologies that are mentioned previously defines a reference architecture model that offers wide range of technologies with different communication protocols. Market for Open Source is still evolving and IoT technology as a service is overcoming proprietary technology choices. IoT in conjunction with open source is setting ground for the development of novel applications in the areas of smart cities, healthcare, manufacturing among other. Also, to improve decision making, saving people and organizations time, open source technologies driving activities for future utilization of IoT concepts. As users already carried out wide range adoption of Open source IoT, still challenges in its development and confidentiality of the privacy and security is matter of concern. Issues such as unauthorized access to RFID, tampering with node data, requires attention of developers and users. Tools such as Data analytics can one of the option to identify above threats across the entire IoT ecosystem. Even analytics algorithms has tendency to help users in detecting various security issues by generating automatic alert and logging all priority issues. IoT technology as a whole including threats shows new age of technology. To participate in this new world, users will have to implement open source and data analytics in IoT framework. As the applications grows with IoT implementation, businesses grows with IoT and users will have to be prepared for more supporting technologies just like analytics and open source.

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