A Utility Paradigm and Roadmap of Internet-of-Things in Thailand for Digital Economy Development towards ASEAN Economic Community

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Abstract: While the ASEAN Economic Community (AEC) is on the rise in global economy, a digital economy is consequently an effective and efficient policy, which is necessary to stimulate a rapid growth in an average Gross Domestic Product (GDP). Internet of Things (IoT), in which physical perceptions, cyber interactions, social correlations, and cognitive process can be united through ubiquitous interconnections, potentially enables a success in digital economy policy. Thailand as a part of AEC has realized the importance of the design and implementation of IoT ranging from physical layer to application layer. This paper presents the roadmap of IoT in Thailand towards AEC. In accordance to Thai environments and possible application platforms, the current status of IoT is described in terms of Internet-of-Device (IoO), Internet-of-Service (IoS), Internet-of-People (IoP), and Internet-of-Intelligence (IoI). The roadmap of IoT for Thailand until the year 2020 and beyond is suggested as for a perspective on an opportunity in international trading and investments. Challenges in major IoT implementation issues in Thailand such as security, standardization, and interoperability are also discussed. This paper offers new perspectives, utility paradigm, social and economic impacts of IoT implementation in Thailand as a potential country in terms of markets and production hubs in South East Asia region.

1 INTRODUCTION

The Association of Southeast Asian Nations (ASEAN) Economic Community (AEC) shall be the goal of regional economic integration by 2015 with ten countries, including Brunei Darussalam, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Vietnam, and Thailand. The AEC envisages such significant characteristics, involving a unique market and production base, a highly competitive economic region, a region of equitable economic development, and a region that will be fully integrated into the global economy. Consequently, the AEC would entail free flows of goods, services, investments, capital, and skilled labors in order to synergize markets and production hubs. The average GDP growth prospects of the ASEAN countries are projected to grow at 5.1% in 2015 and to continue to expand by 5.4% in 2016. It is expected that the success of AEC integration would lead to the fourth largest economy in the next few years (M. Palatino). Therefore, the advanced technology is ultimately essential to advocate and accelerate such a rapid growth in GDP of AEC.

Of particular interest in accelerating economic growth through the utilization of technological approaches, the digital economy concept has become an important policy that mainly determines economical strategies in some countries of AEC members. The digital economy can be considered as an economic system in which a digital Information and Communication Technology (ICT) is extensively employed as an integral part of developments. Such a digital economy can lead to rapid economic and social developments in the present interconnected societies, resulting in increasing efficient and uniform income distribution patterns. The foundation of success in implementing the digital economy involves complete developments in infrastructures of, for example, open government, data center, cloud computing, e-government services, digital entrepreneurs, digital

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Table 1: Summary of examples of IoT applications and platforms.

	Smart home	Smart retail	Smart city	Smart agriculture	Smart water	Smart transportation
Network size	Small	Small	Medium	Medium or large	Large	Large
User	Very few, Family members	Few, Community level	Many, Policy makers, General public	Few, Landowners, Policy makers	Few, Government	Large, Goverment General Public
Energy	Rechargeable battery	Rechargeable battery	Rechargeable battery, Energy harvesting	Energy harvesting	Energy harvesting	Rechargeable battery, Energy harvesting
Internet connectivity	Wifi, 3G, 4G LTE backbone	Wifi, 3G, 4G LTE backbone	Wifi, 3G, 4G LTE backbone	Wifi, Satellite communication	Satellite communication, Microwave links	Wifi, Satellite communication
Data management	Local server	Local server	Shared server	Local server, shared server	Shared server	Shared server
IoT Devices	RFID, WSN	RFID, WSN	RFID, WSN	WSN	Single sensors	RFID, WSN, single sensors
Bandwidth requirement	Small	Small	Large	Medium	Medium	Medium to large
Examples	Smart home [7]	Smart Enterprise [8]	Smart City [9]	Smart Monitoring of Potato Crop [10]	Sustainable Water Supply [11]	IBM smart transportation [12]

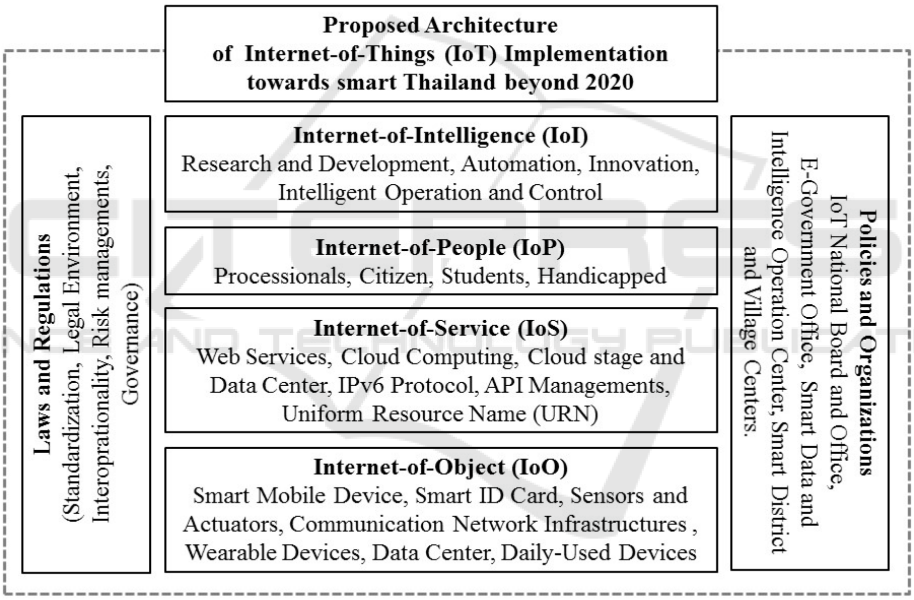

Figure 1: Proposed architecture of IoT implementation towards smart Thailand 2025.

business analytic center, and digital society promotion. As for instance, Singapore (Leong and Mun, 2013) and Malaysia (Ahmad et al., 2012) have officially announced the concrete plans of digital economy deployments since the years 2012 and 2014, respectively, in order to move the nations rapidly forward towards achieving national vision and aspirations by 2020. Thai government has also recently focused on digital economy as one of a major policy for economy alleviation in society, government, and business sector. One of advanced technologies that potentially enable a successful implementation of digital economy is an "Internet of Things (IoT)". The IoT has been becoming a significant system paradigm in which physical perceptions, cyber interactions, social correlations, and cognitive process, can be intertwined in the ubiquitous things interconnections (Huansheng et al., 2016). Based on the advancement of IoT implementation in AEC, Singapore is a leading country followed by Malaysia and Thailand whist other countries are still being studied for future economy improvements.

Table 2: Summary of characteristics of the Major devices used in IoT.

Devices	Example of device	Capabilities	Data rate	Maximum Distance	Reference Standard	Application
RFID	Book/CD/DVD tag, car-sharing cards, RFID passports, RFID badge	Identification storing, communication	Up to 640 kbps	3–10 m	ISO/IEC 1800	Transportation, logistics, tracking, animal ID, retail, access control, payment
Sensor (MEMS)	Environmental monitoring sensors, wearable sensors, digital camera	Sensing, storing, processing, communication	250 kbps	10–100 m	IEEE 802.15.4, ZigBee, Wireless HART, ISA 10(	Health/ environmental /industrial monitoring, intelligent agriculture, surveillance
NFC	NFC embedded in smartphone, ticket stamping machine, parking meter	Communication	106–424 kbps	610 cm	ISO/IEC18092/ ECMA-340, ISO/IEC21481/ ECMA-352, ISO/IEC14443	Sharing/access information, access control, contactless payment

Applications of IoT have extensively been implemented and suggested in recent years as smart platforms. Table 1 summarizes examples of IoT applications and platforms, involving smart systems in home, retail, city, agriculture, water management, and transportation (Du et al.,2013; In and Kyoochun ,2015 ; Aditya,2015; Ciprian-Radu,2015; Dan et al.,2015). It can also be seen from Table 1 that elements enabling successful IoT implementations are network size, user, energy, internet connectivity, data management, and devices. In accordance to such IoT implementations in Table 1, this paper has realized that IoT can be utilized to improve the digital economy in Thailand. Therefore, this paper presents the paradigm and roadmap of IoT in Thailand towards AEC. According to Thai environments and possible application platforms, the current status of IoT will be described in terms of four subcategories of IoT, including Internet-of-Object (IoO), Internet-of-Service (IoS), Internet-of-People (IoP), and Internet-of-Intelligence (IoI). The roadmap of IoT for Thailand is suggested as for a perspective on an opportunity in international trading and investments. Challenges in major IoT implementation issues in Thailand such as security, standardization, and interoperability are also involved.

2 CURRENT STATUS AND PROPOSED ARCHITECTURE OF IoT IN THAILAND

Fig. 1 proposes architecture of IoT implementation towards smart Thailand in 2020 and beyond. This architecture presents a conceptual framework that IoT can be classified into four categories, i.e. Internet-of-Object (IoO), Internet-of-Service (IoS), Internet-of-People (IoP), and Internet-of-Intelligence (IoI). Besides, all categories is regulated by laws, and policies as well as IoT-oriented organizations should be established in order to drive the existence and successfulness of IoT. Consideration based on such a conceptual framework offers a systematic perspective on IoT with three basic implications, involving integration, interconnection, and interaction.

2.1 Internet-of-Object (IoO)

The IoO refers to as a physical system conceived in a linear dimension in which physical devices are respectively perceived and controlled by sensors and actuators in order to establish interactions via communication channels, remote collaboration, and real-time localizations. This section particularly considers five major key technologies that potentially enable the success of IoT in Thailand, including Radio Frequency Identification (RFID), Near-Field Communication (NFC), Micro-electro-mechanical systems (MEMS), Wireless Sensor Network (WSN), IEEE 802.15.4 Standard and Zigbee, and Bluetooth Low Energy (BLE). In particular, Table 2 summarizes characteristics of the main technologies used for collecting data in IoT.

2.1.1 Radio Frequency Identification

Radio Frequency Identification (RFID) employs an electromagnetic field to transfer data for automatic identification and tracking tags, which contain electronically stored information, attached to objects. RFID is a key technology that plays an important role in embedded system which enables design of microchips for wireless data communications. Two types of RFID tags based on battery used are active and passive tags. On the one hand, the passive RFID tag is not battery-powered and the tag uses the power of the reader's interrogation signal to communicate the ID to the RFID reader. On the other hand, the active RFID reader has its own battery supply and can instantiate the communication route.

The implementation of RFID stimulates innovation and the development of IoT. Industry and government mandates are regulating technologies leading to accepted standards across industries allowing for interoperability among devices. In addition, the cost and size of devices continues decreasing which allows companies to embed smaller, common items with RFID chips and sensors (Chunling, 2012). Thailand's National Telecommunications Commission has established regulations for RFID technology in Ultra-High Frequency (UHF) area. The typical frequencies are between 920 MHz and 925 MHz. The Frequency Hopping Spread Spectrum (FHSS) is utilized with a maximum power output, i.e. effective isotropic radiated power, of 4 Watts. Licensing is required for outputs above 0.5 Watts (Verdouw,2013). Current applications of RFID in Thailand are access control and security, logistics, transportation, membership, factory and process automation, warehouse and cargo managements, and retail store. This paper suggests that the RFID technology will be employed in service infrastructure in the near future, including agriculture and tourism as these two industries provide main incomes for Thailand.

2.1.2 Near-field Communication

Near field communication (NFC) is generally a set of interface and protocol which allows electronic devices to establish radio communication by touching the devices together or bringing into proximity to a distance of lower than 10 cm. In Thailand, the NFC is a SIM-based system and is relatively new technology introduced in the year 2013 (M. León-Coca,2013). The major applications are mobile payment in retails and touch-up fares on the BTS (Sky train transportation) and MRT (Underground Transportation). Other applications are still being considered to be implemented.

2.1.3 Micro-electro-mechanical Systems

A micro-electro-mechanical system (MEMS) is a technology which combines a computer in miniature mechanical devices embedded in integrated circuit silicon chips (Pinelis,2015). MEMS have been recognized as microsensor and microactuator, which can be categorized as a transducer, typically converting a measured mechanical signal into an electrical signal (P. Doe, 2015). Although MEMs are newly introduced in recent years, commercially available MEMs are, for instance, biometric sensors, health and environment sensors, imaging sensors, light sensors, microphones, and motion sensors (Vazquez-Mena,2014). Such MEMs-based sensor significantly allows the connection of end devices to IoT platform with real-time information gathering. Although MEMs has been commercialized in many countries, Thailand has not yet successful in using MEMS. Nonetheless, the National Electronics and Computer Technology Center (NECTEC) have induced dynamics in research and development on MEMs, including nanotechnology in order to support technology development and adoption in electronics such as nanosensor, Lab-on-a-chip, microfabrication, and MEMS devices (Yuksel et al.,2015).

2.1.4 Wireless Sensor Network

The advancement in Integrated Circuits (IC) for wireless communications have led to low-cost, low-power and robust small devices, which improve the capability of utilizing a Wireless Sensor Network (WSN) in which sensors are equipped with wireless interfaces that communicate with one another to form a network. The WSN comprises sensors that enable the collection, processing, analysis and dissemination of information. The WSN typically consists of four major components as follows. First, the WSN hardware mainly means node sensor interfaces, processing units, transceiver units, and power supply. Second, WSN communication in which the nodes are expected to be deployed in an Ad-Hoc configuration. Considerations on designing suitable network topology, routing and MAC layer are significant for the scalability and longevity of a network. Note that modern communication at any nodes should be able to interact with internet as a gateway to WSN subnet. Third, the WSN middleware is a mechanism to combine cyber infrastructure with a Service Oriented Architecture (SOA) and sensor networks to provide access to heterogeneous sensor resources. Last, the secure data aggregation which is an efficient and secure method required for expanding network lifetime and ensuring data collection reliability (Angela et al.,2015; De-gan et al.,2015; Flauzac et al., 2012).

The advantages of WSN are not only a connection between real physical and virtual worlds, but also allow the capability to observing previously unobservable data at a fine resolution over large spatiotemporal scales. The WSN has therefore become one of the most significant elements in IoT paradigm. The integration of WSN to other IoT elements affords heterogeneous information systems that can be able to collaborate and provide common services. This integration has lately been supported by several international companies. In Thailand, the WSN has been employed for mainly tracking and monitoring applications. The tracking applications, including military and object tracking, are still being in a research and development process. However, the monitoring has extensively been used in agriculture as an intelligent farming that monitors temperature and relative humidity. The use of WSN in Industrial and home monitoring has been increasing lately as the cost of equipment in WSN has been decreasing significantly.

2.1.5 IEEE 802.15.4 Standard and Zigbee

IEEE 802.15.4 is the standard for short-range low-rate wireless personal area networks, focusing on low deployment cost, low complexity, and low-power consumption. The communication topology among network devices can be either the star topology that communicates with a central controller or the peer-to-peer topology in which Ad Hoc or self-configuring networks can be formed. The physical layer supports 868 MHz or 915 MHz low bands and 2.4 GHz high bands and the MAC layer controls access to the radio channel using the CSMA-CA mechanism. There has been many WSN application using IEEE 802.15.4 standard, including residential, industrial, and environment monitoring, control, and automation.

ZigBee (Kunho et al., 2015) is a higher layer communication protocol based on IEEE 802.15.4 standard. ZigBee has been designed with easy-to-use configuration and low-power communication technology for embedded system applications. ZigBee-based devices can be able to form mesh networks where hundreds of devices can be connected. Three types of Zigbee are (1) ZigBee coordinator that initiates network formation, stores information, and connects networks together, (2) ZigBee router that links devices altogether and provides multi-hop communications, and (3) ZigBee end-device that comprises sensors, actuators, and controllers for collecting data and communicating solely with Zigbee router and coordinator.

Although the Zigbee has been suggested for a decade, it is now still being exploited in a variety of applications in Thailand such as home automation (Korkua, 2013), building automation, disaster warning system (Cholatip,2011), and security application. Integration of Zigbee into IoT platform for specific applications is now being researched and studied. It is expected in prototype currently studied will be in the market in the next few years.

2.1.6 Bluetooth Low Energy

Bluetooth Low Energy (BLE) is a wireless personal area network technology which considerably reduces power consumption and cost while similar communication range in common Bluetooth is maintained (Holler,2015). Typically, the BLE features provide ultra-low power consumption, an ability to operate for years on standard coin-cell batteries, lower implementation costs, and multi-vendor interoperability (Jensen,2015). Major applications of BLE are sports and fitness, health care, wearable and entertainment devices. Apparently, the BLE has been considered as another key technology in IoT implementations that help communicate between machine-to-machine (M2M), and machine-to-people (M2P). The BLE has recently been utilized in Thailand in the year 2014 with Ad Hoc mesh network mobile application such as AirTalk and some of social networking service (SNS) such as Photozuo. In the year 2015, iBeacon technology has been implemented in a shopping mall where iBeacon relies on data transmission and location in the building developed in conjunction with the core location APIs to locate the position of users and guidelines to send promotional information. The BLE in Thailand is still in an early stage. Many companies and universities are conducting research and development on iBeacon-based IoT platform and it is expected that the BLE will be used widely in the next few years.

2.2 Internet-of-Service (IoS)

The Internet-of-Service (IoS) aims to implement an internet as a medium for services, invocation and execution, and can be considered as a platform for retrieval, combination and utilization of interoperable resources. Web and application services have been emerged as a collection of networked services accessed through standardized protocols that can be integrated to form complex services in online applications. It is expected that web and application services is an enabler for a seamless application-to-application integration. Based on the current status of web services in Thailand, this section focuses on IPv6 internet protocol and other possible IoT-oriented protocols. For instance, a smart meter system

(Weerachai,2014), a smart disaster warning system (Jirapon,2011), and a smart health monitoring system (Suranan,2013) have been implemented as a prototype in Thailand.

2.2.1 IPv6 Internet Protocol

As critical features of creating a unique address in IoT include uniqueness, reliability, persistence and scalability, all connected devices must therefore be identified by their unique identification, location and functionalities. Currently, the fourth version of internet protocol (IPv4) is still being utilized. However, more spaces of IP address in IPv4 are necessary to connect new devices. Consequently, the internet mobility attributes in the sixth version of internet protocol (IPv6) has been suggested through the use of a 128-bit address, allowing 2128, or approximately 3.4×1038 addresses(Montavont,2014). Apparently, IPv6 would definitely alleviate the device identification problems. It should also be considered that the persistent network function that provides a channel for data traffic ubiquitously and persistently is one of the important features of IoT. Even though the conventional Transmission Control Protocol (TCP/IP) deals with this problem by routing through a reliable and efficient way, the IoT, however, still has a problem in the interface between the gateway and wireless sensor devices. Two possible solutions are as follows. First, the Uniform Resource Name (URN) system (Gubbi, 2013) can be used as a fundamental for the development of IoT. Such a URN creates replicas of the resources that can be accessed through the URL. Second, the IPv6 also provides a very good option to access the resources uniquely and remotely. In Thailand, IPv6 is not extensively used, excluding some national research centers or some research universities. The government is now accelerating all governmental organization to use IPv6 as well as fostering the implementation of IoT. As will be seen later in the roadmap, it is expected that IPv6 shall be used in the next three to five years.

2.2.2 Cloud Computing

Cloud computing plays a major role for the IoS, enabling the on-demand provisioning of applications, platforms, and computing infrastructures. Current cloud service frameworks realize individual data remotely stored in an online cloud server, and provide great conveniences for users to use the on-demand cloud services. Thai government has established Government-Cloud called G-Cloud operated by Electronic Government Agency (Public Organization) of Thailand since the year 2012. The G-cloud aims to improve public service data center consolidation delivery and access to G-Cloud public services. In addition, the G-cloud was expected to help increase the efficiently for public service delivery. Three classes of G-cloud were established, including Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS). It can be concluded that Thailand has high potential for data storages in all levels provided by Thai government.

2.2.3 Visualization and Application

Visualization is perhaps a crucial issue in IoT applications since visualization controls the interaction of users with environments. Smart tablets and phones have allowed an intuitive visualization due to the emergence of touch screen technologies. It should be noted that attractive and easy-to-understand visualization has to be utilized. It has been reported that the present numbers of smart devices in Thailand in the year 2015 is 98.93 million devices. As the screens are moving from 2-dimensional towards 3-dimensional display, information may be provided in meaningful ways for consumers. This advancement will allow policy makers to shift data into knowledge, resulting in fast decision making. Nonetheless, the visualization considered as own innovation of Thailand is in an early stage, most advanced devices are provided by international companies. However, some providers have started researching and developing mobile and web applications as our own innovation.

2.3 Internet-of-People (IoP)

Internet-of-People (IoP) focuses on human-oriented applications in which a person is a peer with other persons in a network for unrestricted interaction and resource sharing. The IoP deals with significant challenges as a mean of social and economic contracts for individuals and organizations, which are undergoing a change in digital societies (Jayavardhana,2013). According to real-time data driven interconnections, people in the network are assigned with the capabilities of accessing transparency, dynamic participation, and accountability. It can be considered that a web-based social network connects people who share the interests and activities without political, economic, and geographic boundaries.

Based on a perspective of social networking services, the overall structure of social entities can be identified into local or global social patterns, determining the influential entities, and monitoring

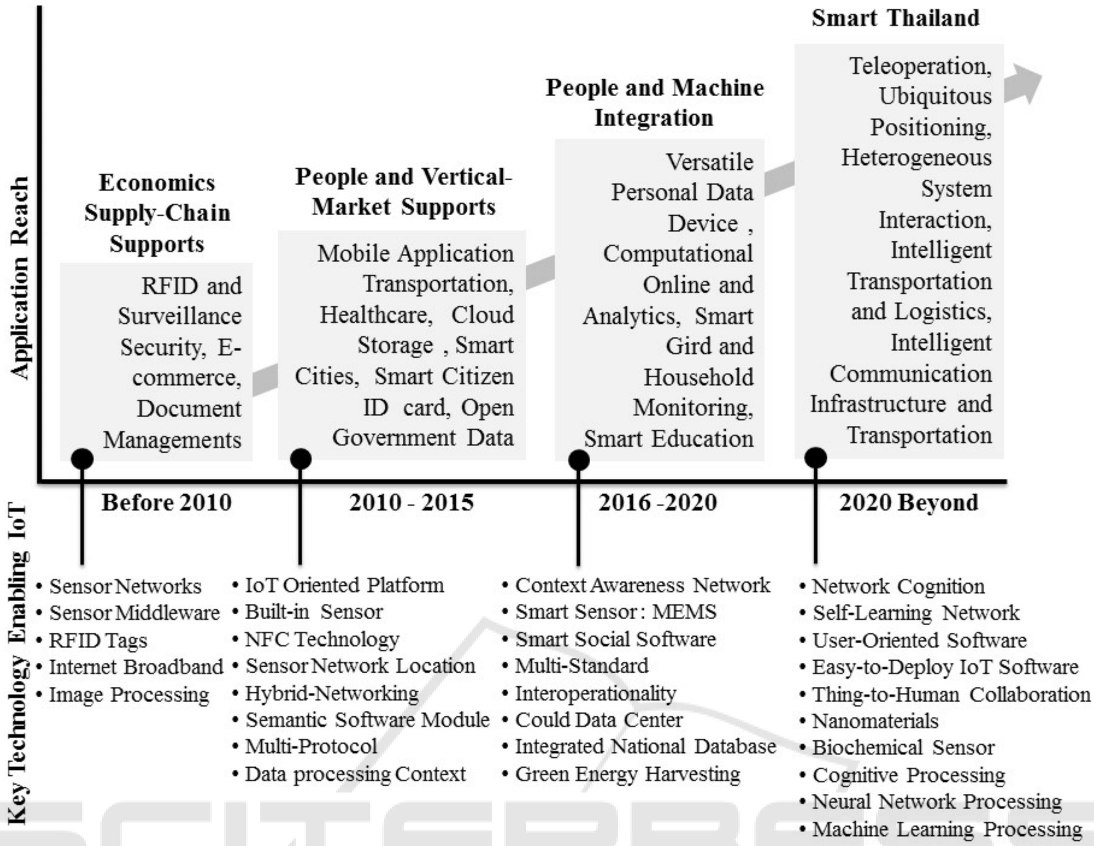

Figure 2: The proposed roadmap of IoT towards smart Thailand in 2020.

social relationship dynamics. Consequently, IoP interconnects growing population of users while promoting their continuous empowerment, preserving their control over their online activities and sustaining free exchanges of ideas. The IoP also provides means to facilitate everyday life of people, communities, organizations, allowing at the same time the creation of any type of business and breaking the barriers between information producer and information consumer. Based on the concept of IoP, Thailand should consider a human-centric approach for IoT implementation. The statistical data has revealed that Thai population is now approximately 68.23 millions . The percentage of people using internet via smart devices is 92%. It is also found that students keep online more than others and they use internet for online social network such as Facebook, Line and Tweeter. Therefore, the implementation of IoT in Thailand should categorize in appropriate target group, including professionals, citizen, students, and also handicapped. A clear target for IoT implementation through the framework of IoP would lead to efficient use of resources for end users.

2.4 Internet-of-Intelligence (IoI)

This paper introduces the term "Internet-of-Intelligence" as the highest level under a framework of Internet-of-things as described in Fig. 1. Fundamentally, an Artificial intelligence (AI) can be considered as a general term representing the theory and technology related to simulating intellectual abilities of human being, including the ability to understand and solve problems. Typical processes of AI involve perception, cognition, decision-making, strategy execution, and strategy optimization. A particular case of IoI means the use of AI as a smart machine or algorithm in IoT. AI can provide the framework and tools to move beyond trivial real-time decision and automation use cases for IoT. The intelligence can be embedded either in a central level that help manage big data called data mining technique or in any end-device such as the controls of microcontrollers or actuators. Much attention paid on AI techniques in Thailand is natural language processing, expert systems, planning and scheduling, knowledge engineering, and human interface. In addition, particular techniques under research and development are artificial neural network, machine learning, and fuzzy logic control (Boonserm, 1999).

For the central data level, the data mining seems to be the most potential intelligent approach in Thailand. The extraction of useful information from sensing environments at different conditions and resolutions has been a challenging problem in IoI. The data mining can be considered as a computational process of discovering patterns in large data sets also called as big data, involving methods at the intersection of artificial intelligence, machine learning, statistics, and database systems (Chun-Wei,2014). Currently, the Electronic Government Agency (Public Organization) of Thailand has already initiated an open data center for use in governmental organizations and some enterprises. However, data mining is still required to analyze a large data set. For end-user application, IoI can be embedded in sensors and actuators through a microcontroller.

3 PROPOSED ROADMAP OF IoT TOWARDS SMART THAILAND IN 2020 AND BEYOND

Fig. 2 shows the proposed roadmap of IoT towards smart Thailand in 2020. It can be seen from Fig.2 that the real situation of IoT in Thailand before the year 2010 realized the existing technologies, including sensor networks, sensor middleware, RFID, internet broadband and image processing, for accelerating economics supply-chain supports. Example of apparent applications existed are RFID for surveillance security, e-commerce, and document managements. Lately from the year 2010-2015, many advanced technologies have been introduced commercially, IoT-oriented platform, built-in sensor, NFC technology, sensor network location, hybrid-networking, semantic software module, multi-protocol, and data processing context. These technologies consequently lead to people and vertical-market supports whose major applications are mobile application transportation, healthcare, cloud storage, smart cities, smart citizen ID card, and open government data.

Recently new technologies have been introduced to Thai society, involving context awareness network, smart sensor using MEMS, smart social software, multi-standard, interoperationality, could data center, integrated national database, and green energy harvesting. This paper therefore suggest the roadmap for the next five years from 2015-2020 that the IoT will initiate people and machine integration. Expected applications include versatile personal data device, computational online and analytics, smart gird and household monitoring, and smart education system. Additionally, the IPv6 will be implemented is this time frame. This convergence requires much effort from the government in terms of communication and data storage infrastructure developments.

Furthermore, this paper predicts that technology will be very advanced in the year 2020 and beyond. The advanced technologies based on IoI that are expected to be emerged include network cognition, self-learning network, user-oriented software, easy-to-deploy IoT software, thing-to-human collaboration, nanomaterials, biochemical Sensor, cognitive processing, neural network processing, and machine learning processing. Consequently, smart Thailand can be achieved with many applications, i.e. teleoperation, ubiquitous positioning, heterogeneous system interaction, intelligent transportation and logistics, intelligent communication infrastructure and transportation. According to Fig.1 the possibility of implementing smart Thailand require two matters in parallel to the development on IoT, i.e. (1) Laws and regulations (Standardization, Legal Environment, Interoprationality, Risk managements, Governance) and (2) Policies and Organizations (IoT National Board and Office, E-Government Office, Smart Data and Intelligence Operation Center, Smart District and Village Centers). It should be noted that Thai government should carefully implement IoT platform based on a perspective on Thai cultures, especially a self-sufficient economy paradigm.

Thailand is now on the process of establishment of “Artificial Intelligence Association of Thailand (AIAT)”, which involves twenty-four major universities, two national research centers, i.e. National Science and Technology Development Agency (NSTDA) and Defense Technology Institute (DTI), and fifty of laboratories. In addition, the AIAT involves two hundred of faculty members and six hundred junior researchers. The mission of AIAT focuses on pure AI, HLC, Knowledge Engineering, Image Processing, Robotics, and Biomedical Engineering. Therefore, there are currently six academic association/societies related AI and ICT as follows; Artificial Intelligence Association of Thailand (AIAT), IEEE Thailand Section, Association of Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI), Thai Embedded Systems Association (TESA), Thai Engineering in Medicine and Biology Society (Thai EMBS), and Thai Robotics Society (TRS).

4 CRITICAL AND CHALLENGING ISSUES IN IoT IMPLEMENTATION IN THAILAND

This section analyses the critical and challenging issues in IoT in Thailand as well as suggests the emerging research directions. The three critical issues are security, and standardization and interoperability whilst the challenging research direction should focus on context-aware computing, and intelligent system.

4.1 Primary Concerns Issues for IoT Implementations

It is apparent in most IoT implementation platform that the main limitations of implementing IoT are security, and standardization and interoperability. The security remains a significant concern in IoT since a low level of security causes system vulnerability. This is due to the communication channels are only from human-to-machine (H2M) but also from machine-to-machine (M2M) in which the guarantee on access control, authorization, privacy, and protection from malice is a major obligation. Regarding the nature of wireless and ubiquitous infrastructure, the IoT is vulnerable to attacks that aim to control the physical environments or obtain private data. Therefore, the implementation of IoT should consider all different levels of security and privacy, ranging from physical to application layers. Note that integrating security in IoT should not affect the quality of service. This paper suggests that the implementation of IoT in Thailand must carefully consider hardware-coded security at the device level, and security and privacy in storage at the data level.

The standardization and interoperability are also critical issues for IoT implementation as the interaction among heterogeneous sources of data and devices is achieved through the use of standard interfaces in order to ensure interoperability in diverse systems. Consequently, issues relating standardization and interoperability to be suggested to Thai government are ontology based semantic standards, spectrum energy communication protocols standards, and international quality and integrity standards for data creation, and data traceability.

4.2 Challenging Research Direction on IoT in Thailand

Based on Thai culture and environments, this paper suggests that challenging research direction should focus on context-aware computing, and intelligent system. The context awareness might be a promising topic to be studied. Context awareness refers to as any kind of information that can be used to describe situations of entities [43]. Context awareness may provide a great support to process and store the big data, providing easy-to-understand interpretation, as well as an efficient service. In fact, the IoT services are operated in extremely dynamic environment composed of huge amount of nodes. Therefore, services can be suddenly appear or disappear at any time. Consequently, the study on information of object features, status, geographical location, and security data may attract research interests in order to enrich the knowledge on services.

In addition to context-aware computing, this paper also suggests based on the roadmap to smart Thailand in 2020 and beyond that another challenging issue for research is the intelligence-driven IoT in order to enable things, devices, and systems to become smarter. In the near future, more autonomous things are required to share and exchange experiences with other things or even human. In particular, the strong research areas that yield potential market applications in Thailand are agriculture, healthcare, tourism, logistics and supply chain, and creative and design.

5 CONCLUSIONS

This paper has presented the utility paradigm and road map for the implementation of Internet-of-Things in Thailand for digital economy development towards ASEAN Economic Community (AEC). The current status and potentiality of IoT implementations in Thailand have been described based on a newly introduced IoT architecture framework, including four categories, i.e. Internet-of-Object (IoO), Internet-of-Service (IoS), Internet-of-People (IoP), and Internet-of-Intelligence (IoI). Perspectives on laws, regulations, policy and organizations have been involved in the proposed architecture. The results reveal that Thailand should accelerate the use of electronic components, involving RFID, NFC, and MEMs while IPv6 protocol should be implemented throughout the country in order to maximize the number of IP address for an upcoming IoT enabled technology. In addition, the real need in IoT implementation from Thai people such as professionals, citizen, students, and handicapped should be an important factor that sets the strategy of implementing IoT.

The roadmap of IoT in Thailand has also been proposed. The development based on such a road map would lead to people and machine integration in the period of the next five years and ultimately smart Thailand in 2020 and beyond. Critical issues were found to be security, and standardization and interoperability. Finally, challenging research direction for IoT in Thailand was concluded to context-aware computing since most Thai people use social network in their daily life. Research on intelligence-driven IoT is also another research topic that helps foster Thai advanced innovations. As a result, this paper has revealed perspectives, utility paradigm, social and economic impacts of IoT implementation in Thailand as a potential country in terms of markets and production hubs in South East Asia region.

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