A Holistic Architecture of Internet of AI-Centric as a Conceptual Framework for Supporting Thailand Digital Economy

Varuth Tanomvorsin and Wimol San-Um

***Abstract*—Thailand has long been trapped by middle income, inequality, and imbalance, the "Digital Economy Policy" has therefore officially been announced as a national agenda by the Thai government in order to increase the GDP and shift the country towards the fourth industry evolution so-called "Thailand 4.0". Although digital technologies have been well-developed and highly diversified in various fields, there are few rigid frameworks on integrating and utilizing digital technologies to enable a success in digital economy policy under unique challenges in Thai contexts. Consequently, this paper focuses on an emerging paradigm on an Internet-of-X (IoX) concept where X separately represents three features, i.e. (i) physical things, (ii) services, and (iii) data. In addition, this paper also introduces a holistic architecture of an Internet of AI-Centric (IoAIC), which is particularly defined as "an approach that utilizes Artificial Intelligence (AI) as an essential computational core in major components of the Internet-of-X architecture in order to leverage the existing IoX ecosystem in terms of functionality and performance". Such IoAIC conceptual framework could be further recommended to cooperates, enterprises, and government agencies for supporting the concrete implementation of a roadmap and strategies of Thailand Digital Economy towards a hub country in South East Asia region.**

***Index Terms*—Thailand, Internet of AI-Centric, physical things, services, big data, Artificial Intelligence.**

I. Introduction

Thailand is a country in Southeast Asian where Bangkok is her capital city and has been involved into the Association of Southeast Asian Nations Economic Community (AEC) since the year 2015. Currently, the total population is approximately 68 million people, and the GDP expanded 3.7% from a year earlier in the June quarter of 2017, compared to a 3.3 % growth in the first quarter of 2017 [1]. Over the past decades, Thailand, however, has been trapped by middle income, inequality, and imbalance [2]. Consequently, an acceleration of economic growth through the utilization of digital technologies has been of much interest by both government and private sectors under unique challenges in Thai contexts. The utilization of digital technologies is expected (i) to raise capacity and competiveness in all economic sectors, (ii) to develop capacity and prepare both IT and non-IT workforce, (iii) to adapt and seize opportunities from AEC, (iv) to reduce inequality in all possible aspects, and (v) to eliminate corruption by increasing government transparency and civic engagement. In other words, Thai government has appointed an emphasis on the utilization of digital technologies to develop infrastructures, innovations, data capability, human capitals, and other resources, thus propelling economic and social developments towards stability, prosperity, and sustainability [3]. It is apparent that conception on digital transformations has been considered worldwide as a potential contrivance for accelerating economic growth.

European countries have long been fostered concrete policies on, for instance, industry 4.0, Factory of the Future (FoF), and smart manufacturing. As for example, United Kingdom [4] has publicized the campaign on "*Design in Innovation*". Centers for design excellence have been subsequently established to achieve greater commercial success through the effective use of early-stage design processes. The United States [5] has also announced a campaign on "*A Nation of Makers*", which focuses on a culture of abundance with inclusive community of practice through encouraging connections, broadly sharing resources, facilitating funding opportunities, engaging in policy development, and advocating for the maker movement.

Meanwhile, countries in ASIA have as well realized the importance of digital transformations. China [6] has clearly announced the theme of "*Made in China 2025*" as a world manufacturing power in order to promote the integration of informatization and industrialization, aiming to enforce a green manufacturing process and improve international competitiveness. Singapore [7] has already moved forward to "*Smart Nation*", stating an outstanding intelligent island for improving the quality of life, strengthening business, and building stronger communities. South Korea [8] has promoted a policy of "*Creative Economy*" based on a concept on realization of national welfare and new era of hope by establishing platforms to support commercialized creative ideas, stimulating ventures and startup ecosystem, creating new industries, new markets, and startups. In addition, Japan [9] has also raised a theme on "*Made by Japan*", indicating a vibrant, attractive nation in the 21th century by revitalizing society that draws on the talents of all its members and provides a rewarding environment.

Digital-based industries have recently initiated to Thai society in terms of an exploratory to vast possibilities of implementation on sensitization and actuation of particular physical aspects. The study of Artificial Intelligence (AI) based action in all aspects of industry is subsequently a vital issue. This paper therefore realizes an emerging paradigm

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on an Internet-of-X (IoX) concept where X represents three features, involving (i) physical things, (ii) services, and (iii) data. Furthermore, this paper also introduces a holistic architecture of an Internet of AI-Centric (IoAIC), which could be recommended to cooperates, enterprises, and government agencies for supporting concrete implementation of a roadmap and strategies of Thailand Digital Economy.

II. Thailand 4.0: Digital-Driven National Agenda

In accordance to a paradigm shift to transform to Thailand 4.0, a value-based and innovation-driven economy so called "Digital Economy" has becoming a major issue through commodities to innovative products and emphasis on promoting innovation technology in focused industries [10]. Fig. 1 shows the first and second S-Curve paradigm as a mechanism to drive Thailand Digital Economy. On the one hand, the 1st S-Curve, which is expected to be achieved within the year 2020 that aims to enhance the current five key industries in order to continue the growth, involving Next-Generation Automotive, Smart Electronics, High-Income Tourism and Medical Tourism, Efficient Agriculture and Biotechnology, and Food Innovation. On the other hand, additional industries needed to be developed for future growth in the 2nd S-Curve are Automation and Robotics, Aerospace, Bio-Energy and Bio-chemicals, Digital, and Medical and Healthcare [11]. Although an apparent economics policy has been launched and activated with quick responses from both government and private sectors, digital technology is relatively new for Thai society, starting from digital literacy to high-ended technologies.

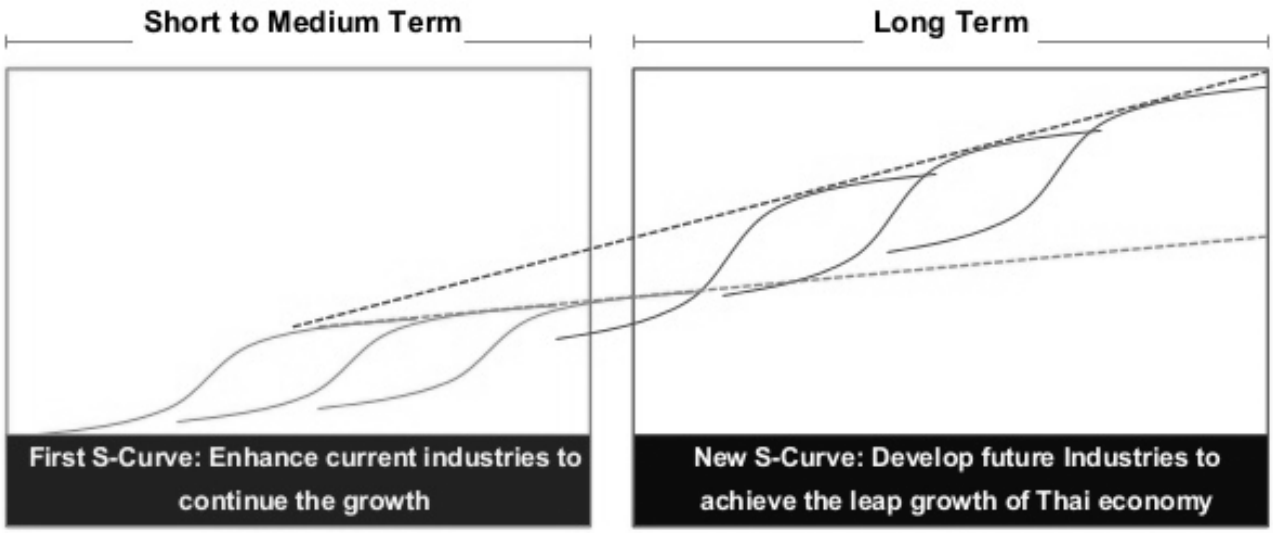

Fig. 1. First and second S-Curve paradigm as a mechanism to drive thailand digital economy strategy [10], [11].

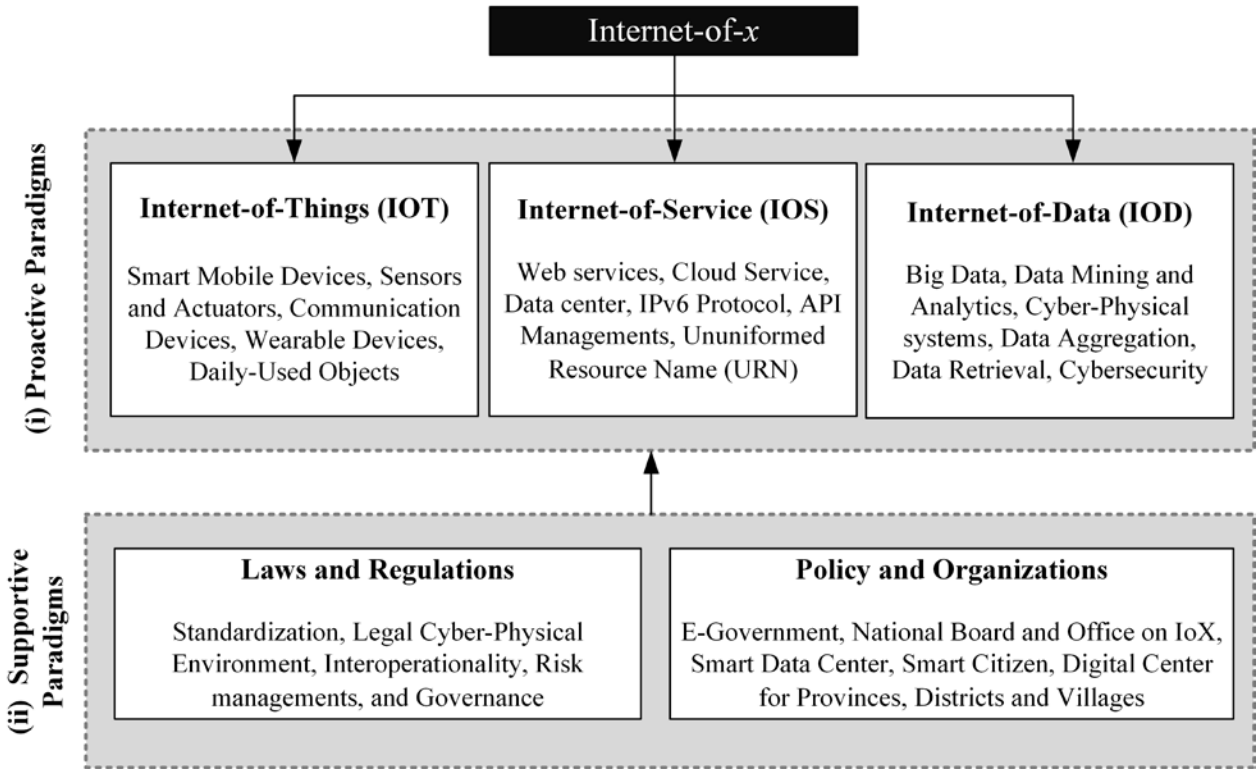

Fig. 2. Concepts and framework of Internet-of-*x*, involving both proactive and supportive paradigms.

For the sake of rapid innovation developments regarding the 1st S-Curve paradigm, a variety of emerging technologies have been suggested, including, for example, electric vehicles, smart factory, digital tourism, AriTech, and FoodTech. Such technologies are based on the realization of a physical-to-cybernetics platform. However, clear concepts and roadmap on digital technologies for concrete implementation with high efficiency are problematic and challenging issues. Based upon Thai contexts, Fig. 2 consequently visualizes a detailed summary of an early-mentioned IoX with proactive and supportive paradigms. Technically, the proactive paradigm in this paper focuses on Internet-of-Things (IoT), Internet-of-Services (IoS), and Internet-of-Data (IoD). On the other hand, it is also necessarily required to consider a supportive paradigm, which involves law, regulation, policy, and constitutional aspects. Details of proactive paradigm regarding IoX are particularly summarized as follows.

A. Internet-of-Things (IoT)

The IoT refers to as a physical-layer-based system in which physical attributes are perceived by sensors connected to embedded microcontroller, and controlled through actuators in order to establish an interaction via Internet protocol (IP) or Non-IP communication channels [12]-[15]. Key technologies that should be emphasized as a tool for the success of Thailand digital economy are Radio Frequency Identification (RFID), Near-Field Communication (NFC), Wireless Sensor Network (WSN), IEEE 802.15.4 Standard and Zigbee, and Bluetooth Low Energy (BLE). Recently, LoRaWAN [16] has been introduced as a new promising communication technology with high security and seamless interoperability among smart physical things.

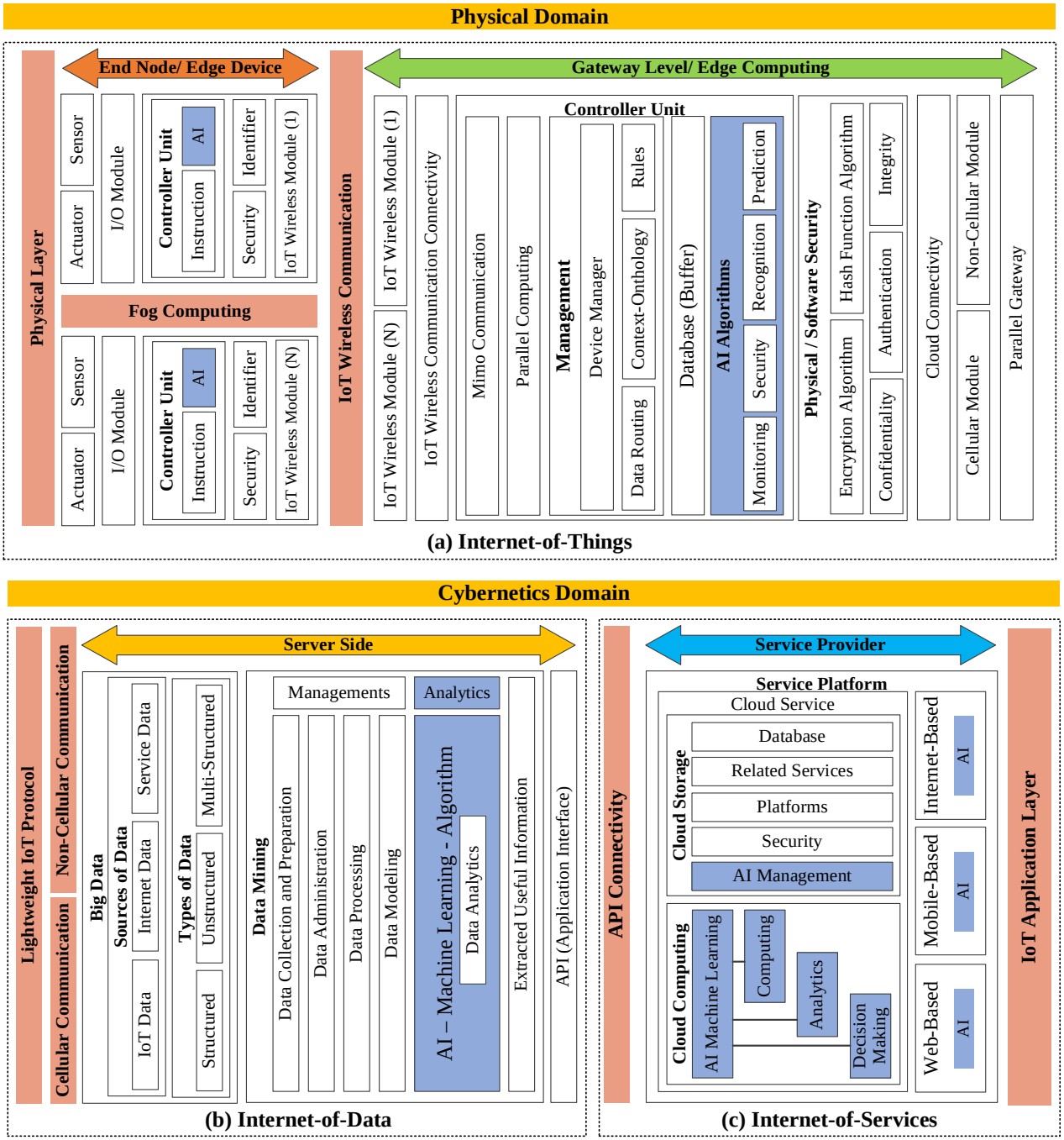

Fig. 3. Proposed holistic architecture of Internet-of-AI-Centric as a complete digital platform, ranging from physical layer to cybernetics layer.

B. Internet-of-Data (IoD)

The IoD is considered as an extension of IoT since the increase in advanced computational technologies has resulted in enormous data growth in size, complexity, and diversity. Massive data in an internet network has led to "Big Data", which typically has seven characteristics (7Vs), including Volume, Velocity, Variety, Veracity, Validity, Volatility, and Value [17]. Based upon Thai contexts, the IoD should be an emphasis on open data, linked data, and data management, which generally involves three consequent stages, i.e. (i) data collection, (ii) data administration, and (iii) data processing. First, the data collection is a retrieval of data from physical devices, polymorphism, and rich semantic presentation. Second, data administration deals with data cleaning, designs of flexible database, and effective indexing. Last, data processing regards to access managements, query optimization, aggregation, data mining, and analytics.

C. Internet-of-Services (IoS)

The IoS can be considered as a global communication network acting as a medium platform for retrieval, combination, and utilization of interoperable resources. Specifically, IoS involves website and application services, which are accessed through standardized protocols and expected to be an enabler for the integration of a unified application-to-application approach. Since a billion of physical devices are expected to be connected, the IPv6 internet protocol and cloud services are suggested as significant necessity in terms of internet-based services. Consequently, the role of Data center, API Managements, and Ununiformed Resource Name (URN) will receive more attention in regards to IoS platforms. In addition to technical perspectives, IoS is also a commercial transaction where one partaker grants semantic interoperability and temporary access to service repositories of other contributors in order to perform a prescribed function and a related benefit. Based upon service usage and peer technologies, the IoS eventually offers revenue sharing, premium service platform, new business models, licensed software operation, and effective maintenance.

III. Proposed Holistic Architecture of Internet of AI-Centric

Prior to a holistic architecture of Internet-of-AI-Centric, this paper defines Artificial intelligence (AI) as intelligence exhibited by machines, which is in contrast with the natural intelligence displayed by humans. In other words, AI can also be defined as the study of intelligent agents in which any devices can perceives its environment and takes actions that maximize its chance of success at certain achievements.

Colloquially, the term "artificial intelligence" is generally applied in the case where a machine mimics cognitive functions that humans associate with other human minds such as learning and problem solving activities. The golds of AI involve knowledge representation, planning, learning, natural language processing, perception, motion and manipulation, social intelligence, and creativity. Meanwhile, com tools in AI application include, for example, searching and optimization, fuzzy logic, probabilistic methods for uncertain reasoning, classifiers and statistical learning methods, neural networks, deep feedforward neural networks, deep recurrent neural networks, and evaluating progress.

Fig. 3 depicts the proposed holistic architecture of Internet-of-AI-Centric as a complete digital platform, ranging from physical to cybernetics layers. It can be seen from Fig. 3(a) that the physical domain, which is particularly a part of IoT, can be considered as two major consecutive parts, i.e. (i) the edge devices and fog computing in physical layer followed by (ii) a gateway layer and edge computing via wireless communication protocol. On particular consideration in Fig. 3(a) points that the edge nodes can be either sensors or actuators in order to respectively perceive and interact with the physical in a closed-loop configuration. In other words, the edge sensor perceives, by measuring physical attributes, and then subsequently transmits data to a controller unit via an I/O interface module. Such a controller unit is dedicated for processing the data from sensor and actuator through the use of predefined instructions. In this scenario, AI can be deployed to perform a dedicated task within a device level called "*Hardware-Based AI on Chip*" instead of the common implementation through external source such as in transport or cloud levels.

Besides, the identifier and security are primary concerns needed to be considered in terms of authentication and authority of devices permitted in a network. The rest of edge devices are proprietary IoT wireless communication modules with specific protocols. On the contrary to a single edge node, the fog computing in Fig. 3(a), which refers to as the processing unit of data from a number of end nodes (N^{th}) in a Wireless Sensor Network (WSN) system. Typically, the fog computing unit is placed prior to a hub or a router operating as a sub-gateway that does not allow data from endpoints to directly connect through the cloud via an internet. This approach of fog computing tends to tremendously reduce the excess load sending directly to the cloud, in order to conserve the network bandwidth, and also to improve a response time of the system in real-time operation.

As a subsequent process of edge device and fog computing, it could be as well seen in Fig. 3(a) that the edge computing layer receives data using various wireless communication protocols to universal gateway. In other words, the edge computing layer is the sole linkage between physical and cybernetics domains. The gateway is a major component, mitigating drawbacks that exist in IoT ecosystem such as interoperability and scalability, which are conventionally caused by the complexity due to the utilization of various types of IoT protocol to communicate and interconnect in the same IoT system. As depicted in the gateway level boundary, especially in the controller unit, the gateway is also mainly responsibility for managing the data flow generating from each identified IoT devices connected wirelessly with the gateway. Subsequently, those data is temporarily kept in a prepared database as a buffer, and yet providing physical or software security to ensure confidentiality, authentication, and integrity of data before

sending directly to the cloud, assigning in the cybernetics domain, through the cellular or non-cellular communication. Additionally, the AI algorithm can be practically embedded within the controller unit to prominently enhance the capabilities of the physical device, i.e. gateway, such as overall system monitoring, improving security with the situation classification, normality or abnormality recognition, or prediction the upcoming scenario judged from the incoming data accordingly.

On the contrary to physical domain as depicted in Fig. 3(b) and (c), the cybernetics domain is considered as a public domain representing the internet, which comprises of other two major components within the IoAIC architecture i.e. IoD and IoS. Firstly, the IoD represents the existing data based on the server side. The data can be shortly subcategorized as IoT data generated from IoT devices connecting to the internet, internet data referring to general data formerly existing in the internet, and service data involving particularly with services. With several types of data source and existing data structure, i.e. structured, unstructured, or even multi-structured data, the utilization of data mining is essential to be deployed for managing the data and perform data analytics in order to extract or reveal both useful and hidden information for further uses afterwards. The suggestion is that the intended data should be properly managed and processed in order to form a well-structured model before performing any further data analytics. Since the analytics may highly result in vain as expectancy if the input data is the waste itself from the very beginning.

Referring to an analytics part, machine learning, i.e. a computational technique of computer learning without being entirely supervised, is deployed to analyze and categorize the pattern and yet behavior of the data sets, which results in gaining expected useful information. Secondly, the Internet-of-Service which is mainly focused on myriad service platforms comprising of typical cloud services and other-based services to ease the rapid implementation of the IoT system, especially in terms of storage and computing. Eventually, the data gathering in the internet is later utilized and exploited by the services interacting with each other through APIs that provide connectivity for communication between each software. Even within the service provider's boundary, AI can be entirely applied into every platform of the services to enhance the performance of the services or even formulate new abilities for some specific tasks. For example, the AI could be embedded in cloud computing to perform an intense analytics involving decision making, in cloud storage to manage the database, and other platforms such as website as a semantic web understandable and able to properly learn by machines or AI applications, e.g. AI-based mobile services that automatically assist users, or other related AI-based internet services.

IV. Contributions and Applications of IoAIC on the 1st S-Curve Growth Engine of Thailand

Table I summarizes contributions and applications of IoAIC to the key industries in 1st S-Curve growth engine. First, the next-generation automotive in Thailand has focused on Electric Vehicles (EVs). Regardless the mechanics of vehicle body, Intelligent Battery Management System (BMS) , which can be implemented through intelligent firmware embedded in industrial-grade microcontroller, has become challenging issues since those of conventional power balancing circuits is no longer effective for a large stack composition of Li-Ion batteries in EVs. In addition to Intelligent BMS, intelligent route management and vehicle monitoring are required through a tethered connection that exploits in-vehicle hardware, i.e. GPS, speed sensor, or tire measurement, in order to allow the telematics via smartphones remotely. Lately, Logistics Intelligence (LI) in supply chain and transportation planning has also attracted great attention. Such LI involves intelligent algorithms in dynamic routing, last-mile delivery planning, driver and customer behaviors analytics.

Second, the smart electronics industry has been a main focused industry that moves towards AI-based production. Such smart electronics can be categorized into three areas, i.e. (i) intelligent daily use products, e.g. smart appliances and wearable devices, (ii) intelligent product design process and manufacturing, and (iii) advanced electronics designs, e.g. microelectronics, embedded systems, and IC designs. Such harmonized combination of AI algorithm embedded in electronics leads to significant enhancement of whole-new higher-level electronic devices, resulting in a capability of responding or adapting itself to properly suit for condition changes. Besides, it is suggested that boosting the consumer needs on intelligent devices would support acceleration in the growth in both new and current potential product manufacturing processes.

Third, it is true that alleviating medical and wellness tourism in Thailand has encountered some difficulties due to the lack of adequate supports for quality reputation, efficacy to produce more values from tourism resources, and capabilities against global competitiveness. Consequently, the IoAIC can be exploited based on a perspective on Hospitality Bridging Healthcare (H2H), which transforms an ordinary healthcare center into a comfort place that considers human-centric approach with intelligent devices, systems, and real-time data center. On the other hand, Thailand should focus on digital tourism which involves (i) the aid of data analytics for discovering valuable relational knowledge related to particular expectation on destination, period of stay, and feedbacks, and (ii) an intelligent recommendation system for tourists through web-based or mobile applications.

Fourth, the current agriculture should shift to precision agriculture in order to create value-added for products and natural materials. The smart farming can be achieved through the utilization of sensors and actuators, multipurpose drones, or automatic farming machines. Such smart farming should collect and process data via cloud server with embedded AI technique for predictive growing period, decision making, and planning. Besides, biotechnology is also required to be rapidly fostered in terms of understanding, characterizing and managing genetics. The IoAIC can be further applied to as a potential tool in data intelligent data analytics of agriculture and biotechnology, particularly sale and marketing as well as product quality assessments.

Last, the food innovation in Thailand can be focused on

processing foods such as functional, medical, and supplementary foods. The IoAIC can be employed for intelligent synthesis of functional and medical foods as well as nutrition analytics processes. In addition, the IoAIC can predict the expected profiles of foods based upon the predefined characteristic such as taste and texture, and identify changes in sensory profiles of the products caused by the variation of additive inputs. Customer preferences can also be predicted in advance by means of data analytics in order to assist in new food production with certain nutrition and benefit appropriate for matching the expected groups of consumer. Recently, food traceability is a crucial issue for customers and therefore the IoAIC can be applied in data managements and visualizations.

TABLE I: SUMMARY ON APPLICATIONS OF IOAIC TO THE KEY INDUSTRIES IN 1ST S-CURVE GROWTH ENGINE

Industries in 1st S-Curve	Applications and Contributions of IoAIC
(1) Next generation Automotive	• Intelligent Battery Management System (BMS) • Intelligent Route Monitoring and Management • Intelligent Driving Behaviors Analytics • Logistics Intelligence (LI)
(2) Smart Electronics	• Smart and automatic Home via Smart Phone • Intelligent Production Line Operation, Monitoring, and Control • Intelligent Human Interactive Wearable Devices • Intelligent Embedded Devices
(3) Affluent, Medical and Wellness Tourism	• Digital Tourism • Hospitality Bridging Healthcare (H2H) • Smart International Convention and Intelligent Data Centers • Tourist Behavior Analytics
(4) Agriculture and Biotechnology	• Advanced and Automated Agriculture Machines • Understanding, Characterizing and Managing Genetics • Agricultural Product Sale and Marketing Analytics • Intelligent Agricultural Product Quality Assessments
(5) Food Innovation	• Food Traceability • Intelligent Synthesis of Functional and Medical Foods • Food Innovation • Intelligent Nutrition Analytics Processes

V. CONCLUSIONS

This paper has introduced the Internet of AI-Centric (IoAIC), which has been defined as "an approach that utilizes AI as an essential computational core in major components of the Internet-of-X architecture in order to leverage the existing IoX ecosystem in terms of functionality and performance". The holistic architecture of IoAIC as a conceptual framework has been proposed where AI techniques are embedded throughout the overall architecture, involving the integrated layers of IoT, IoD, and IoS. A comprehensible contributions and applications of the IoAIC to the key industries in the 1st S-Curve growth engine of Thailand within the year 2020, involving (i) Next generation Automotive, (ii) Smart Electronics, (iii) Affluent, Medical and Wellness Tourism, (iv) Agriculture and Biotechnology, and (v) Food Innovation, has also discussed. The IoAIC provides a straightforward ecosystem to be utilized for implementation of roadmap and strategies of Thailand 4.0 through the enhancement of competitiveness and heterogeneity of internet-connected devices, computational techniques, and communication capabilities. This paper has therefore offered an emerging paradigm on social and economic impacts through the use of IoAIC for supporting the concrete implementation of a roadmap and strategies of Thailand Digital Economy towards a future business and investment hub country in South East Asia region.

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