МАТЕМАТИКА И МАТЕМАТИЧЕСКО ОБРАЗОВАНИЕ, 2023
MATHEMATICS AND EDUCATION IN MATHEMATICS, 2023
*Proceedings of the Fifty Second Spring Conference
of the Union of Bulgarian Mathematicians
Borovetz, April 10–14, 2023*

IN PURSUIT OF HORIZONTALITY IN THE DEVELOPMENT OF IoT PLATFORMS*

Ivan Ganchev

This paper presents an overview of the *horizontal* approach for the creation of Internet of Things (IoT) platforms, which allows to overcome many of the disadvantages of the *vertical* approach, by allowing a provider to supply only a horizontal slice in the delivery of IoT services, thus meeting better today's expectations for efficiency and effectiveness, flexibility and scalability, openness and easy adjustment to new use cases and application scenarios, and multi-purpose use of the IoT systems built on top of such platforms. The state of the art in the area of IoT platforms development is presented along with some examples of horizontal IoT platform solutions in use today. The EMULSION IoT platform, developed by following the horizontal approach, is briefly described at the end.

1. Introduction. The Internet of Things (IoT) has quickly turned into one of the main driving forces of the global economic development today. In 2022, the number of connected IoT devices reached 14.4 billion and some $202 billion were spent in the IoT area, [1]. The combination of artificial intelligence (AI) and IoT (the so-called AIoT) will add to the further growth of the IoT market, while the global industrial AIoT market alone may reach $102 billion by 2026, [2].

Generally speaking, IoT involves ubiquitous connected, uniquely identifiable things/objects/devices that possess the ability to autonomously collect data about their environment (physical world) and exchange these, either directly or indirectly via communication gateways, [3]. Typically, the IoT things/objects/devices consist of embedded computational hardware and software, with some form of network connectivity to a remote computing resource. By integration of IoT devices into automated systems, it is possible to capture valuable information about the physical world, and then to transmit, ingest, transform, filter, and enrich it by different system entities, forwarding it for further processing in the edge/fog/cloud, in order to make a decision, generate a prediction, trigger an action, create a value, help someone with a particular task, or learn from a process.

IoT includes the following main vertical domains:

*This invited talk has emanated from research conducted with the financial support of the Bulgarian National Science Fund (BNSF) under the Grant No. KP-06-IP-CHINA/1

2020 Mathematics Subject Classification: 68M10, 68M14, 68M18, 68T09.

Key words: IoT, platform, horizontal development, architecture, tiers.

- Industrial IoT (IIoT), involving the use of industrial end-devices such as pumps, conveyers, turbines, motors; industrial machinery; industrial assets in the field such as pipelines; robots; containers, trucks, and ships in logistics; warehouses; etc., [3]. For example, in January 2021, China announced its 3-year plan for creating 30 fully connected fifth-generation (5G) factories based on IIoT platforms, e.g., with an ability to perform quality control using high-definition cameras supported by AI, [2]. Recently, PTC and Microsoft have proposed the so-called "industrial metaverse" for describing mixed and augmented reality scenarios for IIoT-based product development and manufacturing, [2].
- Energy production and distribution, involving smart grids, advanced metering infrastructures, peak load management, distribution automation, smart meters, etc.
- Supply chain (the most accelerated IoT domain in 2022, [1]), utilizing IoT devices and visibility software for tracking and tracing of assets, along with intralogistics robots, autonomous and connected cars/fleets, etc.
- Smart healthcare, based on wearables (e.g., smart watches, health trackers, etc.) and implants.
- Smart environment monitoring and control (based on environmental sensors), including also structural health monitoring of bridges, buildings, etc.
- Smart agriculture, utilizing sensors, robots, unmanned aerial vehicles (UAVs), etc., in livestock, cropland, fisheries, and forests for increasing the production quality and quantity, and optimizing the human labor, while also tackling food security and climate change related problems.
- Smart cities – city traffic and transport control, smart parking, street lighting, infrastructure management, environmental sensing, etc. For example, the IoT strategy for the New York city builds on already existing IoT initiatives (e.g., 23,000 connected public-transport vehicles, myriad of connected smart speed cameras, 800,000 connected water meters, numerous air quality index (AQI) monitoring stations, and bike counters), and includes plans for further training, funding, consultancy, and coordination of deployment of the supporting communication networks, e.g., for connecting temperature and humidity sensors in an attempt to analyze the effect of various city-wide running initiatives on citizens, [2].
- Smart homes – smart air conditioning, heating facilities with smart thermostats, energy usage displays, well-being applications, etc.

The provision of IoT services requires the use of suitable IoT platforms, supporting the interconnection and interoperability of heterogeneous IoT things, objects, electronic devices, communication modules and networks, and providing the required operation, administration, and management (OAM) functionalities with respect to provided data, services, and applications, [4], along with the required consumers' customization and personalization, [5]. The realization of different IoT use cases and application scenarios depends on the use of flexible IoT platforms, which can provide stable, efficient, effective, and secure solutions that meet the architectural and business requirements today, [6]. The main benefits of using IoT platforms include, [3]: (i) quicker and cheaper bringing of connected products to market and monitor operations; (ii) much simpler coding and deploying of applications for IoT solutions; and (iii) efficient edge-to-cloud communications, especially in the last few years.

The IoT platforms today are mostly of a *vertical* type, meaning they are focused on the service provision within a single IoT domain. By utilizing such platforms, IoT providers can operate in a vertical manner, involving separate applications and services, separate network connections, and separate things, objects, and devices for the provision of a particular service, as shown in Figure 1. The result of this approach was the formation of the 'Internet of Silos' instead of a real IoT, with all corresponding drawbacks, such as further fragmentation of the IoT domains, problematic interoperability and integration, difficult data exchange, increased OPerational EXpenditure (OPEX), obstacles to achieving sufficient scaling and openness to new IoT services, and to address cross-domain use cases and application scenarios. The result of following this vertical approach was the existence of 613 IoT platform vendors in 2021 (up from 450 in 2017). However, the platforms of the top 10 providers, namely the Microsoft's Azure IoT Hub, the Amazon Web Services (AWS) IoT Core, the Google Cloud IoT Core[1], and few others), had 65% market share in 2021 (up from 44% in 2016), [4].

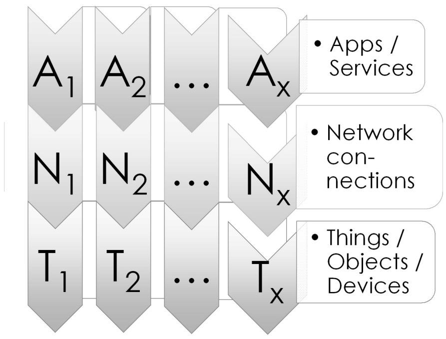

Fig. 1. The *vertical* approach for the creation of IoT platforms

The *horizontal* approach for the creation of IoT platforms, shown in Figure 2, overcomes many of the drawbacks of the vertical approach, by allowing a service/application/network provider to bring only a horizontal slice in the delivery of IoT services in multiple IoT domains. It allows seamless interaction between IoT applications and devices, even across industry verticals. The horizontal principle meets better today's expectations for efficiency and effectiveness, flexibility and scalability, easy and timely adjustment and openness to new use cases and application scenarios, and multi-purpose use of the IoT platforms. In addition, it ensures simplification of the IoT environment by removing the duplicate solutions, and allows inter-technology operation, easy integration and full interoperability possibilities, opening of new IoT business opportunities, and efficient OAM of the whole IoT ecosystem throughout its lifespan.

The aim of this paper is to point out to the need of applying the *horizontal* approach in the development of IoT platforms. The state of the art in this area is presented first, followed by some sample horizontal IoT platform solutions used today. Finally, the generic multi-service cloud-based IoT operational platform EMULSION [7], developed by following the *horizontal* approach, is briefly described.

[1]Google announced the discontinuation of its IoT Core service, starting from 16 August 2023.

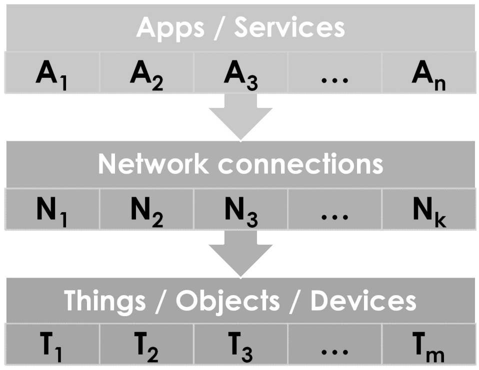

Fig. 2. The *horizontal* approach for the creation of IoT platforms

2. State of the Art in the Area of IoT Platforms Development. The commercial IoT platforms could be categorized into the following five general types, [4]:

- *Communications management/connectivity platforms* – 7% of IoT platforms in 2021, [4].
  These platforms are used for managing the connectivity and controlling the traffic to/from IoT devices, through different communication networks, such as:
  - ≫ 2G÷5G cellular networks
    As a general trend, users continue to move away from the legacy generations (2G/3G) toward the new generations of cellular communications (4G/5G). Due to this and because of the higher adoption of Long Term Evolution (LTE) Cat 1-, Cat 4-, and Cat 6-based chipsets, the 4G IoT connections grew by 24% in 2021, [8]. In addition, for many IoT implementations, LTE Cat 1 became an alternative to the Low-Power Wide Area Network (LPWAN) option (listed below), [8]. The competition between cellular operators is increasing as more and more IoT devices are equipped with an Embedded Subscriber Identity Module (eSIM), allowing their users to remotely change the current operator [9], if they are not satisfied anymore with the cost/quality aspect of the provided connectivity service.
  - ≫ LPWANs, e.g., LoRa, Sigfox[2], Narrow-Band IoT (NB-IoT), and LTE for Machines (LTE-M).
  - ≫ Wireless Local Area Networks (WLANs), a.k.a. Wi-Fi networks, based on the IEEE 802.11 family of standards, especially Wi-Fi 6 (IEEE 802.11ax) with its Target Wake Time (TWT) power-saving techniques.
  - ≫ Wireless Personal Area Networks (WPANs), e.g., Bluetooth Low Energy (BLE), Zigbee, Z-Wave.
  - ≫ Wireless Neighborhood Access Network (WNANs), including non-short-range mesh, e.g., Wi-Sun (IEEE 802.15.4g).
  - ≫ Fixed communication networks, e.g., LANs (IEEE 802.3/Ethernet) and Field-

[2]SigFox was acquired by UnaBiz in April 2022, but the question regarding the market acceptance of the SigFox technology remains, [1].

buses (connecting industrial Programmable Logic Controllers, PLCs, or I/O modules).

≫ Satellite IoT networks, which are coming up, aiming at providing ubiquitous (nano)satellite connectivity for IoT devices, [2].

Majority of cellular operators rely on this type of platforms to expand their IoT endeavors and extend their services to new IoT domains, [10]. Examples include Cisco's Jasper, Ericsson's DCP, Huawei Connection Management Platform, and Verizon's network + ThingSpace. Standard platform functionalities are charging and billing OAM, connectivity orchestration / OAM, and service provisioning [6]. Add-ons may also be included as part of the subscription to a communication service, e.g., in the form of bill analyzers, usage anomaly detectors, etc. For the 'smart homes' IoT domain, an important standard, released in 2022, is the IP-based home-automation Matter standard, which supports Ethernet, Wi-Fi, Thread, and BLE for configuring and over-the-air (OTA) updating of home devices, and in addition provides connection to devices supporting other protocols, like Zigbee, via communication bridges, [1].

- *Device management/enablement platforms* – 35% of IoT platforms in 2021, [4].
These are utilized for remotely configuring, monitoring, controlling, and management of IoT devices. Typical platform functionalities include OTA firmware updates, deployment configuration, device monitoring, command and control, security, etc., [6].
- *Data management/enablement platforms* – 43% of IoT platforms in 2021, [4].
These are used for ingesting, storing, and analyzing of data collected from IoT devices. Standard platform functionalities are: data storage in databases, data lakes, data warehouses, etc.; data analysis by means of rules engines, event management, data preparation and extraction, transformation, and load (ETL); data analytics by utilizing AI / machine learning (ML) / deep learning (DL) techniques; and southbound data ingest/egress through data acquisition drivers and interfaces, IoT hubs, IoT device Software Development Kits (SDKs), and data brokers, [6].
- *Application management/enablement platforms* – 58% of IoT platforms in 2021, [4].
These are utilized for the rapid development, testing, verification, validation, and management of IoT applications. Standard platform functionalities include: IoT application management covering the application marketplace and lifecycle; IoT application development, e.g., based on digital twins, Integrated Development Environments (IDEs), etc.; northbound data ingest/egress via suitable Application Programming Interfaces (APIs), involving also corresponding alert/notification services, [6]. IoT platform vendors (and some third parties) make money out of applications created on top of such IoT platforms. Typical examples are the Siemens' Closed-Loop Foundation application and the Edge2Web's Director application (costing $288 per month!) sold for use with the Siemens' IoT platform MindSphere, [6].
- *IoT-based Infrastructure-as-a-Service (IaaS)* – only 3%[3] of IoT platforms in 2021, [4].

[3] The total number of percentages is greater than 100% because some of the platforms are identified in [4] as being of more than one type.

Despite the relatively small number of such platforms, cloud hyperscalers (with their platforms) make an increasing IaaS revenue by hosting also the IoT platforms of other companies on their infrastructures, [6]. For instance, the Microsoft's Azure is hosting Uptake and Walmart (aimed at connecting heating, ventilation, and air conditioning (HVAC) and refrigeration units for reducing the energy usage, and applying ML techniques for routing of thousands of trucks in the 'supply chain' IoT domain, [3]). Siemens' MindSphere uses Platform as a Service (PaaS[4]) and IaaS services from AWS, Alibaba, and Azure, [11]. This also facilitates the great involvement (and the huge increase of the use) of AI technologies capable of finding valuable insights and patterns in the data gathered from IoT devices, [9]. Hyperscalers are gaining more and more significance in the delivery of industrial AIoT, involving AI performed on IoT-type data sources in industrial enterprises, [11].

Most IoT platform companies today offer *vertical* solutions alongside their platforms [4], which contrasts with the *horizontal* approach for the development of IoT platforms. As cloud hyperscalers capture an ever-increasing amount of revenue with respect to platforms (via the PaaS model) and/or computing infrastructures (via the IaaS model), non-hyperscaler IoT platform providers progressively focus on more vertical purpose-built specific applications (e.g., GE Digital), services (e.g., Accenture), or solutions (e.g., Siemens), [6]. As the platform layer itself becomes less differentiated, many companies seem increasingly offering more vertical or use-case specific solutions by utilizing some underlying IoT platform. Large multinational companies and big enterprises had selected at early stage the IoT platform(s) for their own use, e.g., Walmart chose Microsoft's Azure, while Volkswagen selected also Siemens' MindSphere, and AWS IoT Core, for use in addition to choosing Microsoft's Azure, [6]. However, many small and medium enterprises (SMEs) cannot afford the use of these big-vendor platforms.

3. Horizontal IoT Platform Solutions. In the simplest understanding of the horizontal principle of building the IoT platforms, [12], a horizontal IoT platform solution should enable interoperability between several vertical solutions. In other words, a horizontal IoT platform should be able to contribute with a solution where the gathered IoT data from at least two different IoT domains can be shared within the platform with all interested players in an efficient, scalable, reliable, and secure way. Thus, horizontal IoT platforms can create possibilities for unproblematic logic and functionality exchanges between different public/business activities, [12]. For instance, the EMULSION IoT platform, presented in the next section, can provide solutions for 'smart environment monitoring and control', combined with those for 'smart healthcare'.

- **oneM2M** (`https://onem2m.org`) – this is a general-purpose IoT standard for interoperable and scalable systems, ensuring a high degree of re-use and interoperation of vertical applications. A horizontal architecture is specified in the form of a three-layer model consisting of an application layer, a connectivity layer, and a common services layer. The latter defines a common middleware technology for use between IoT devices, communications networks, and IoT applications, over

[4]The focus of the PaaS model is not on selling a product/service, but on the provision of a shared platform by a vendor to all interested IoT players (hardware manufacturers, software developers, IoT service providers, and users), in which case, the IoT platform provider makes revenue from both the platform users, who use the platform to sell their product/service, and end users, who avail of IoT services provided through the platform, [9].

standardized links going through communication gateways to cloud infrastructures, which allows to mix and match components from different vendors. The standard allows any IoT application to discover and interact with any IoT device, so IoT solutions can interoperate across different industry verticals, thus reducing fragmentation, increasing reusability, and improving the cost base through economies of scale.

- **Chimera IoT** (`https://www.chimera-inc.io`) – this uses anonymized data, crowd-sourced remediation, and sophisticated rules-based analytics integrated with AI and validated through a human feedback loop. It allows to build a scalable and flexible IoT platform, which allows an enterprise IT personnel to quickly develop challenge-specific applications on top of it, by utilizing thousands of IoT devices, drawing a variety of use cases and application scenarios across an enterprise.
- **DeviceHive** (`https://devicehive.com`) – this is an open-source IoT data platform, distributed under Apache 2.0 license for free usage and change, which helps in the communication and management of smart devices, connected via REST API, WebSockets, or MQTT. It supports Android and iOS libraries written in various programming languages, which makes it a device-agnostic platform. Easy integration with any other device, cloud or platform is possible by using supported protocols and employing plug-in service features. The DeviceHive behavior can be customized by running custom JavaScript code. Batch analytics and ML can be run on top of device data by leveraging different 'big data' solutions, such as ElasticSearch, Apache Spark (with Spark Streaming support), Cassandra, and Apache Kafka for real-time and batch processing.
- **Distributed Services Architecture, DSA** (`http://iot-dsa.org`) – by allowing purpose-built products and services to interact with one another in a decentralized manner, this platform enables the distribution of functionalities among discrete computing resources, based on a network topology consisting of multiple DSLinks running on edge devices connected to a tiered hierarchy of DSbrokers, by taking advantage of all computing resources available on the edge, datacenter, and cloud.
- **Pico Labs** (`http://picolabs.io/`) – this is an event-based architecture, based on the so-called "picos" programming model using the specifically designed Kinetic Rule Language (KRL), optimized for building reactive, event-based decentralized applications that respond to events on behalf of users. KRL is similar to JavaScript (with some syntax differences), but with a very different execution model and memory model. Applications are formed from cooperating networks of "picos", employing the actor model abstraction for distributed computation and allowing the development of systems with a better match to the programmers' models. Using "picos", an IoT architecture can be created that allows interoperable interactions between devices produced by different vendors.
- **M2MLabs Mainspring** (`http://www.m2mlabs.com/`) – this is an open-source application framework, written in Java, for building machine-to-machine (M2M) applications, which after prototyping can be transferred to a high-performance execution environment, built on top of a standard J2EE server and a scalable Apache Cassandra database. It covers common functionalities required by M2M applications, such as flexible modeling and configuration of IoT devices, communication

between devices and IoT applications, and data validation, normalization, long-term storage, and retrieval for external applications.

- **Nimbits** (`http://www.nimbits.com/`) – targeting the provision of IoT-related services by constrained embedded systems, this solution provides an open-source data logging cloud server for recording and sharing of sensor data freely between users who can create data points on the cloud and can feed changing numeric, text-based, or XML-based values. Data points can be configured to perform calculations on the obtained sensor data, generate and manage alerts, relay data to social networks or can be connected to spreadsheets, websites, etc., [13].
- **Open Source Internet of Things, OS-IoT** (`https://www.os-iot.org/`) – this is a free open-source software library (developed in C++ and running under a variety of Linux operating systems), which allows simplification of the process of connecting IoT devices hooked into an open, interoperable oneM2M ecosystem. With the provided support for oneM2M network and protocol functions, the library allows application developers to interact with a system over a resource-oriented API, thus reducing the time spent and effort made to achieve that. Hence, application developers are freed to focus on the unique, value-added aspects of their applications, instead of having to deal with different communication networks and protocols. A further extension of the Linux OS-IoT library is the development of a bridge between the Open Connectivity Foundation (OCF[5]) standard and the oneM2M IoT standard.
- **prpl Foundation** (`https://prplfoundation.org/`) – focused on enabling next-generation datacenter-to-device portable software and virtualized architectures, this solution targets the development of a global IoT platform with certifiable containers and secure services affecting only their particular container but not the entire system.
- **SiteWhere** (`https://sitewhere.io/en/`) – this is an open-source application enablement IoT platform for the creation of IoT infrastructures and applications. Designed for reliable, high-throughput, low-latency processing, and dynamic scalability, the platform is built by means of a framework approach, which facilitates the easy addition of new concepts. The platform has a powerful multi-tenant distributed architecture, built with Java microservices, running on a Docker infrastructure with an Apache Kafka processing pipeline for resilient high-performance stream processing, providing the required key features for building and deploying IoT applications. The main functionalities include device state management, 'big data' event ingestion and persistence, large-scale command delivery, integration of device data with external systems, REST APIs, etc. Specializing on a specific task, each microservice is a Spring Boot application wrapped as a Docker container. The microservices self-assemble themselves into a platform instance, orchestrated as a highly available distributed system using Kubernetes, which allows SiteWhere to run on almost any existing cloud platform as well as on-premises installations. In addition, the platform provides Helm charts, allowing an instance to be bootstrapped with a single command, thus hiding the complexities of the system configuration. An Electron-based application allows easy administration

[5] The OCF standard defines interoperable IoT solutions, focussed on 'smart home' applications.

of the platform instances. Infrastructure technologies include Apache Zookeeper and Apache Kafka, a variety of databases (MongoDB, InfluxDB, Cassandra), and MQTT brokers.

- **Yaler** (`https://yaler.net/`) – this is a relay infrastructure for secure access from any browser or mobile phone to embedded systems, located behind a firewall, a network address translation (NAT) device, or mobile network router, with premium pay-per-use support. The web-based accessible and addressable devices (via a TCP socket) can be integrated with existing web applications or third-party services. In addition, YalerContrib contains various programming languages examples, libraries, contributions, and binary downloads for selected platforms released as open source.
- **IoTConnect** (`https://www.iotconnect.io/`) – this is a full-fledged PaaS horizontal IoT platform that allows IoT device communication and management, data storage, and applications enablement, supported by relevant security protocols. The platform consists of various components in the form of tools, smart SDKs (e.g., IoT portal, dashboard, rule engine, gateway edge analytics, command execution), APIs, and protocols (e.g., CoAP, MQTTS, HTTPS, AMQP), which allow the creation of a variety of IoT solutions for the specific business goals of each supported industry vertical.
- **EMULSION** – this is a horizontal IoT platform, developed jointly by the University of Plovdiv "Paisii Hilendarski" (Bulgaria) and the North China University of Science and Technology (China), which is presented separately in the following section.

4. EMULSION. Following the horizontal trend, EMULSION is developed as a horizontal IoT platform of a combined (hardware and software) type, mainly for the needs of SMEs focused on the development of specific or regional solutions for niche use cases and application scenarios. Low-cost electronics and open-source software are integrated into a multi-tier IoT architecture (Figures 3 and 4). In the sensor & actuator tier, different types of sensors (S), location trackers (T) [14], and monitoring stations (MS) operate for capturing the changes occurring in the physical world and sending the corrsponding information towards information centers in the cloud tier, by means of data/remote transfer units (D/RTUs) [15] and smart communication gateways, through different wireless communication networks, e.g., 2G÷5G cellular networks, LOng-RAnge Wide Area Networks (LoRaWANs), WLANs (especially utilizing the Wi-Fi 6 standard), WPANs (e.g., utilizing the BLE standard), etc. For extending the communication range when trying to reach the corresponding gateway(s), additional wireless sensor networks (WSNs) are set up, where needed. The information centers, operating in the cloud tier, analyze the data sent by the sensor & actuator tier and make appropriate decisions and recommendations, which are sent back as a configuration information and/or commands to different actuators (A), controllers (C), and guards (G) in the sensor & actuator tier, thus enforcing the necessary OAM actions and realizing the imposed changes in the physical world.

The EMULSION IoT platform is successfully used as a basis for the development of various IoT prototype systems for different purposes, such as smart environment monitoring and control [16, 17], rented bicycles OAM, operation and control of smart electric boilers, and pure water monitoring and control [15, 18].

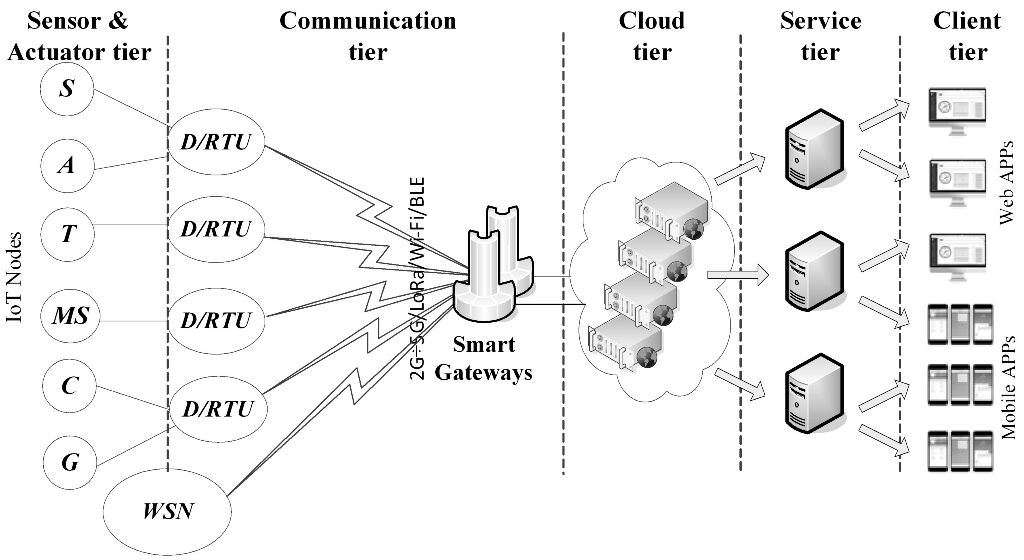

Fig. 3. Part of the IoT multi-tier architecture of EMULSION

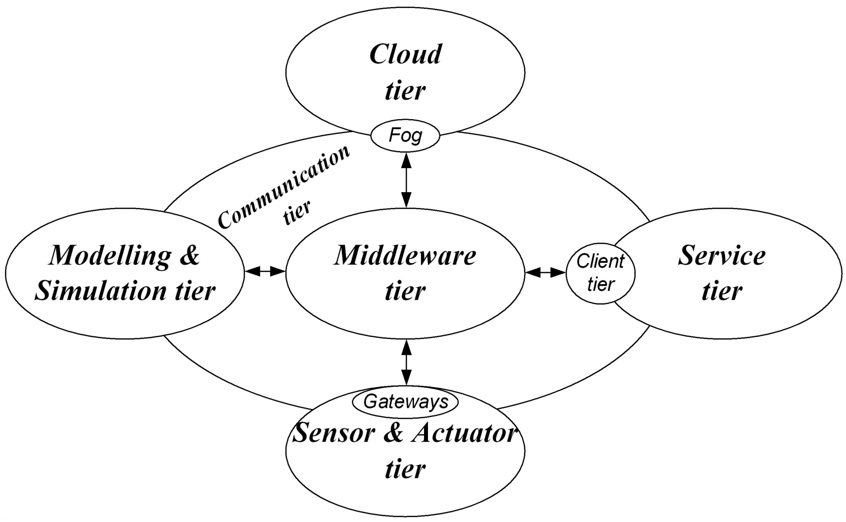

Fig. 4. The 7-tier structure of EMULSION

Future research work will be focused on further elaboration of novel techniques, algorithms, and models for the effective and efficient recommendation of IoT services, provided by the prototype systems, built on top of EMULSION, and accessible *anytime-anywhere-anyhow* through any kind of mobile device via the 'best' available wireless access network, in accordance with the ABC&S communication paradigm [19]. This will be followed by the development of corresponding software applications (running on multiple mobile platforms) ensuring the best quality of experience (QoE) for consumers when using different IoT services, supplied by EMULSION.

5. Conclusion. This paper has presented an overview of the *horizontal* approach for the creation of Internet of Things (IoT) platforms, allowing to overcome many of the disadvantages of the *vertical* approach, by allowing a provider to bring only a horizontal slice in the delivery of IoT services. The state of the art in the area of IoT platforms development has been described along with some examples of horizontal IoT platform solutions in use today. The EMULSION IoT platform, developed by following the horizontal approach, has been briefly presented at the end. As a typical horizontal IoT platform example, EMULSION can meet the requirements for achieving multi-dimensional flexibility, scalability, interoperability, and easy adjustment to new-emerging IoT use cases and application scenarios. By taking into account the current consumer-, service-, and (access) network context, it is able to provide highly personalized, customized, and contextualized IoT services to consumers by utilizing distributed real-time 'big data' processing and analytical techniques in the edge and cloud. Thus, EMULSION can convert the collected sensor data and gathered information about the IoT service activities of consumers into rich analytic datasets. While focusing primary on the 'smart environment monitoring and control' and 'smart healthcare' IoT domains, EMULSION has the capacity to provide services in other IoT domains as well.

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Ivan Ganchev
e-mail: igantchev@hotmail.com
Department of Computer Systems
University of Plovdiv "Paisii Hilendarski"
24 Tsar Assen Str.
4000 Plovdiv, Bulgaria

Institute of Mathematics and Informatics
Bulgarian Academy of Sciences
Acad. G. Bonchev St., Bl. 8
1113 Sofia, Bulgaria

Telecommunications Research Centre (TRC)
University of Limerick
Plassey, National Technological Park
Co. Limerick, Ireland

В ПРЕСЛЕДВАНЕ НА ХОРИЗОНТАЛНОСТ ПРИ РАЗРАБОТВАНЕТО НА ПЛАТФОРМИ ЗА ИНТЕРНЕТ НА НЕЩАТА

Иван Ганчев

В статията е представен обзор на *хоризонталния* подход при разработване на платформи за Интернет на нещата (IoT). Този подход води до преодоляване на много от недостатъците на *вертикалния* подход, като позволява на всеки доставчик да внесе своя хоризонтален принос при предоставянето на IoT услуги. По този начин се отговаря по-добре на съвременните очаквания за ефикасност и ефективност, гъвкавост и мащабируемост, отвореност и лесно приспособяване към нови случаи на използване и сценарии за прилагане, както и за многофункционално използване на IoT системите, изградени на базата на такива платформи. Представено е съвременното състояние в развитието на IoT платформите заедно с някои примери на хоризонтални IoT платформени решения, използвани днес. Накрая накратко е описана IoT платформата EMULSION, разработена чрез следване на хоризонталния подход.

Ключови думи: Интернет на нещата, платформа, хоризонтален подход, архитектура, слоеве.