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Original Research/Review

Applications of the Internet of Things in Industrial Revolution 4.0

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Abstract

The Internet of Things (IoT) represents a network of diverse electronic devices that communicate and exchange data via the Internet, both through wired and wireless connections. The core objective of IoT is to enable data exchange between individual devices without human intervention, thereby enhancing, facilitating, and supporting various aspects of daily life. Currently, IoT is a rapidly evolving technology that integrates numerous devices and their components, particularly various sensors and switches. This dynamic development forms the foundation for advancements in other economic sectors and the construction of diverse network models within economic and organizational processes, aiming to improve operational efficiency.

The effectiveness of these endeavors is often directly tied to the collection and analysis of large data sets, utilizing mechanisms provided by major cloud solution providers to support big data analytics. Exploring the capabilities of the Internet of Things and identifying cloud services to process data derived from it have become crucial to fully leveraging its potential. Cloud platforms enable real-time data processing, predictive analytics, and decision-making, significantly enhancing IoT applications across industries.

These developments are instrumental in driving the ongoing industrial revolution, commonly referred to as Industry 4.0, which emphasizes automation, data-driven operations, and smart technologies. This article explores the conceptual scope of IoT within this context, its applications in business, and the most important opportunities and challenges associated with them. It further highlights the synergy between IoT and cloud computing, showcasing how their integration fosters innovation and operational excellence in modern technological landscapes, including whether there are opportunities for IoT devices to be controlled by modern cloud solutions.

Keywords: IoT, Internet of Things, Industrial Revolution 4.0, DDoS, SMART, Cloud Computing, Big Data Analytics

1. Introduction

1.1. Literature review

Literature review encompasses diverse publications on the Internet of Things (IoT). Books such as "Internet of Things and Its Industrial Applications" by Buchwald, Granosik, and Gwiazda (Polskie Wydawnictwo Ekonomiczne, 2022) and "Internet of Things: How Smart TVs, Cars, Homes, and Cities Are Changing the World" by Miller (Wydawnictwo Naukowe PWN, 2016) focus on various aspects of IoT technology, including industrial applications, development status, and potential cybersecurity threats. There are also articles like "State of the IoT 2020: 12 billion IoT connections, surpassing non-IoT for the first time" by Lueth analyzing the state of IoT development and its societal and economic impacts. Publications such as "Technologies that Changed Industry - History of Industrial Revolutions" available on the industry portal "Automatyka B2B" provide context for understanding industrial changes. Key topics like SMART goals, IoT network construction, and abuse-related threats are discussed in publications like "SMART Goals Definition and Examples" by Kidal, Robert and "Abusing the Internet of Things. Blackouts, Freakouts, and Stakeouts" by Nitesh D. (O'Reilly Media, USA, 2015). The literature review provides a comprehensive insight into various aspects of the Internet of Things and is a valuable source of knowledge for those interested in this topic.

1.2. Technological progress

Technological progress, a continuous and systematic process of development and transformation, profoundly influences various aspects of social, economic, and personal life. At its core, this progress entails the ongoing development of new technologies, the creation of innovations, and the expansion of human potential to tackle a wide array of challenges, ranging from the mundane to the intricate. Among the pivotal domains of technological advancement are communication and industry. The evolution of the telecommunications sector, for instance, has revolutionized global communication patterns. The widespread adoption of smartphones, social media platforms, and internet connectivity has democratized access to information, enabling individuals across the globe to connect and exchange ideas seamlessly. Similarly, within the industrial sphere, the introduction of groundbreaking innovations such as production automation and robotics has ushered in unprecedented levels of efficiency and productivity. These advancements have not only streamlined workflows but have also contributed to the enhancement of industrial performance indicators on a global scale. The ramifications of technological progress extend far beyond mere economic considerations. It holds profound significance for the advancement of society and the global economy as a whole. By unlocking new avenues for innovation and growth, it generates both financial prosperity and strategic opportunities for enterprises to navigate and thrive in a rapidly evolving landscape.

However, amidst the multitude of benefits, the ethical and sustainable utilization of technology emerges as a critical imperative. As we harness the potential of technological innovation, it becomes imperative to prioritize ethical considerations and environmental sustainability. By adopting a conscientious approach to technology, we can maximize its benefits for humanity while safeguarding the delicate balance of our natural environment.

1.3. Internet of Things

An element that triggers technological advances can be the Internet of things (IoT) technology [1, 2, 12], which is a type of electronic system that has the ability to automatically interconnect its components and provide a range of data over a network without human intervention. This definition was first used by British entrepreneur and startup pioneer Kevin Ashton in 1999, but the first works, discussions and research on IoT were initiated as early as in the 1980s. Nowadays, there is a continuous growth of the number of devices on the market. At the moment, more than 20 billion pieces of equipment are cooperating with each other (and maybe much more). The dynamic growth of this industry shows that it is a fundamental branch of technological development, year after year increasing its financial value (Figure 1).

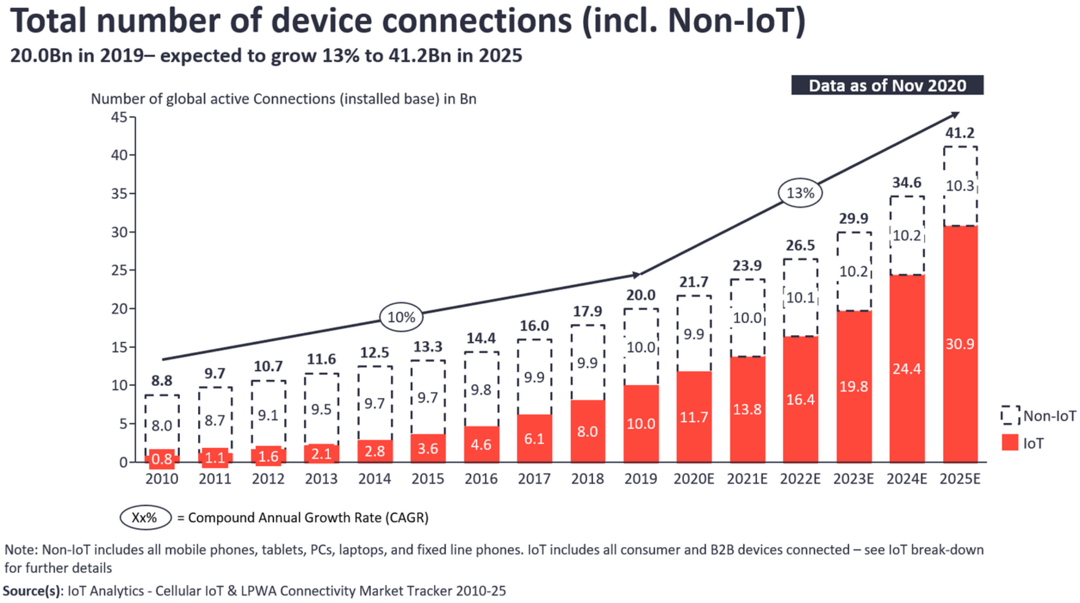

Fig. 1. Development perspective on the devices of the Internet of Things world [3].

The Internet of Things (IoT) refers to a network of interconnected physical devices that communicate and exchange data via the Internet. These devices can range from everyday objects such as televisions, refrigerators, ovens, lamps, to more advanced technologies such as industrial sensors, medical devices or smart monitoring systems, forming a sort of integrated technological ecosystem (Figure 2) of everything that can communicate and exchange data with each other.

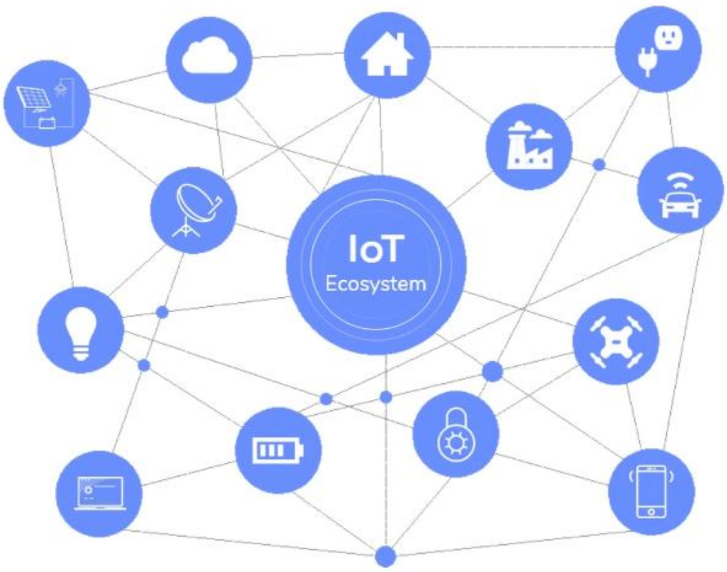

Fig. 2. The Internet of Things ecosystem [4].

The idea behind the Internet of Things is that devices can communicate with each other, exchange information and operate in an automated manner without direct human interaction. For example, a smart home can include sensors that monitor temperature, lighting and security, which are connected to a network and can respond to environmental conditions or commands given. With IoT, we can create smarter and more automated environments, with many benefits, such as energy savings, increased efficiency and improved quality of life. Another example is smart cities, which can use sensors to monitor traffic and optimize transportation systems, and smart energy systems can adjust energy consumption based on demand. However, there are also challenges associated with these benefits. As we bring more devices onto the network, we must ensure data security and user privacy, ensure network reliability, and address interoperability and scalability issues.

It should be noted that the Internet of Things is a growing field that enables the physical world to connect with the digital world, creating the potential for innovation and improvements in fields ranging from smart homes to modern industry. Any device can be considered part of the Internet of Things, but must meet the condition of connectivity with other devices. IoT devices are usually equipped with sensors, microcontrollers and communication modules. They enable the collection of data, which is then processed and sent to other devices or services, these days especially to cloud services.

1.4. Industrial Revolution 4.0

The Industrial Revolution is defined [5] as a description of the profound changes that took place in industry and civilisation as a result of the introduction of new trends in technology and work organisation. The beginning of the Industrial Revolution dates back to the late 18th and early 19th centuries. The key innovations then were the mechanisation of production and the rise of the textile industry.

Today, we have Industrial Revolution 4.0, which began in the 2010s. This definition [6] comes from the German government's technology strategy, which promoted the idea of digitising manufacturing processes. It was first presented at the Hanover Industrial Fair in 2011. This is the era of smart manufacturing, where machines communicate with each other and people, and data is used to make fast and accurate business decisions.

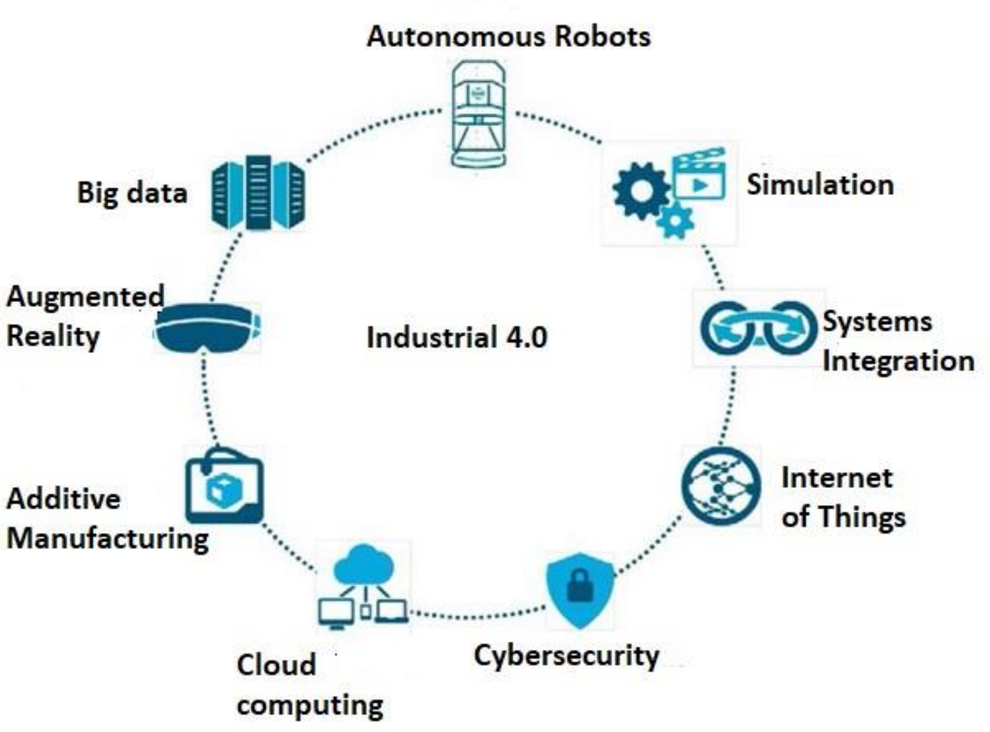

Fig. 3. The process of industrial revolution 4.0 [6].

Industry 4.0, characterised by the integration of digital technologies into industrial processes, offers numerous benefits that increase productivity and innovation. One significant benefit is the significant increase in productivity in various aspects of production and supply chain management.

2. Usage

The Internet of Things (IoT) encompasses a vast array of technologies and applications that have the potential to transform various aspects of our lives. This chapter delves into the description of two distinct approaches to utilizing IoT: one tailored for individuals and the other for the business world.

2.1. Internet of Things for individuals

The Internet of Things has benefits for individuals. It enables recipients to improve their life comfort, to be more efficient with household chores. It introduces new opportunities and possibilities from different perspectives for everyday functioning.

The most popular uses of IoT for individuals are presented below:

Smart Home – The Internet of Things (IoT) facilitates the process of automation and remote control of various aspects of the home environment, offering unparalleled convenience and flexibility. Through IoT-enabled devices, individuals can seamlessly manage and customize settings to suit their preferences, enhancing comfort and security within their homes.

One key area where IoT technology excels is in the automation of household tasks. By integrating smart devices such as smart thermostats, lighting systems, and appliances, homeowners can create tailored schedules and routines that align with their lifestyle. For example, lights can be programmed to adjust brightness levels throughout the day, heating systems can be set to maintain optimal temperatures based on occupancy patterns, and appliances can be remotely controlled to conserve energy and reduce utility costs.

Moreover, IoT enables remote monitoring and control of home security systems, providing peace of mind and enhanced protection against potential threats. Smart door locks, surveillance cameras, and alarm systems can be seamlessly integrated into a centralized platform, allowing homeowners to monitor and manage security measures from anywhere, at any time. This level of connectivity and control empowers individuals to respond promptly to security alerts, grant access to authorized individuals remotely, and deter potential intruders.

Crucially, the accessibility of IoT technology extends beyond traditional control interfaces to include smartphones, tablets, and voice-activated assistants. Through intuitive mobile apps and voice commands, users can effortlessly adjust settings, monitor activity, and receive real-time notifications, even when they are away from home. This level of remote access not only enhances convenience but also fosters greater connectivity and engagement with the home environment.

Fig. 4. Explanation of the SMART concept [7].

Energy management – The development of smart meters, supported by specialized systems, has revolutionized the way we monitor and manage electricity consumption in our homes. These advanced devices provide real-time insights into our energy usage, empowering us to make informed decisions that lead to cost savings and greater efficiency. By leveraging the insights provided by smart meters, individuals can implement strategies to reduce their electricity bills effectively. For example, they can identify and address energy wastage through behavioral changes, such as adjusting thermostat settings, optimizing lighting usage, or scheduling appliance usage during off-peak hours. Additionally, smart meters facilitate the implementation of demand response programs, where users can voluntarily reduce their electricity consumption during periods of high demand, thereby earning incentives or discounts from utility providers.

Overall, the integration of smart meters and specialized systems enables homeowners to take proactive steps towards reducing their electricity bills and promoting energy efficiency. By gaining visibility and control over their energy usage, individuals can make informed decisions that not only lead to cost savings but also contribute to sustainability efforts and environmental conservation.

Security – Monitoring cameras and alarm systems based on the Internet of Things (IoT) enable real-time monitoring of the home and its surroundings, significantly enhancing security measures. These integrated systems offer continuous surveillance capabilities and instant alerts in the event of any suspicious activity or security breaches. One of the key advantages of IoT-based monitoring cameras and alarm systems is their ability to provide live feeds and alerts directly to mobile devices. Homeowners can access these feeds and notifications through dedicated smartphone apps or web interfaces, allowing them to stay informed about their home's security status regardless of their location. This remote access feature not only increases convenience but also provides peace of mind, knowing that they can monitor their property at any time, from anywhere.

2.2. Internet of Things in business

IoT, or the Internet of Things, is becoming increasingly indispensable in the realm of business, offering a multitude of benefits that drive efficiency, competitiveness, and revenue growth. By harnessing IoT technologies, enterprises can revolutionize their operations across various domains. One significant advantage of IoT in business lies in its ability to facilitate the monitoring and management of assets. Whether it's machinery, equipment, vehicles, or other resources, IoT allows for real-time tracking and analysis of asset performance. This enables proactive maintenance strategies, helping to prevent costly breakdowns and optimize resource allocation. Moreover, IoT plays a crucial role in supply chain management, where it enhances visibility and transparency throughout the entire supply chain. By deploying IoT sensors and tracking devices, businesses can monitor the movement and condition of goods in transit, identify inefficiencies, and streamline logistics operations. This not only improves delivery times and reduces costs but also enhances customer satisfaction through timely and accurate order fulfillment.

In the industrial sector, IoT is a game-changer, empowering organizations to monitor machine health and production processes with unprecedented precision. By collecting data from sensors embedded in machinery and production lines, businesses can identify potential issues before they escalate into costly downtime events. This predictive maintenance approach maximizes equipment uptime, boosts production efficiency, and ensures consistent product quality.

Furthermore, IoT enables the creation of smart, connected products and services that offer enhanced functionality and value to customers. From smart home devices to industrial IoT solutions, interconnected ecosystems of devices and sensors enable innovative capabilities such as remote monitoring, predictive analytics, and autonomous operation. This opens up new revenue streams and business models, driving growth and differentiation in competitive markets. However, as businesses embrace IoT, they must also address challenges related to data security, privacy, and interoperability. Safeguarding sensitive information and ensuring compliance with regulatory requirements are paramount concerns. Additionally, integrating diverse IoT devices and platforms into existing IT infrastructures requires careful planning and implementation to ensure seamless operation and compatibility.

In summary, IoT holds immense potential to transform businesses across industries, offering unparalleled opportunities for optimization, innovation, and growth. By strategically leveraging IoT technologies, organizations can stay ahead of the curve and thrive in an increasingly interconnected and data-driven world.

2.3. Internet of Things in Automation and Optimisation of Production Processes

Automating production processes using IoT is one of the cornerstones of Industry 4.0. Smart sensors and monitoring devices can collect data on machine performance, energy consumption and product quality in real time. For example, in automotive factories, IoT systems can monitor the health of production lines, detecting wear and tear on parts and predicting breakdowns. This approach allows the implementation of predictive maintenance systems that use advanced data analysis algorithms to predict machine failures. This makes it possible to plan maintenance and minimise production downtime, leading to increased efficiency and cost savings.

In integrated manufacturing systems, IoT enables automatic adjustment of production parameters in real time. For example, in the food industry, sensors can monitor temperature, humidity and other environmental conditions, automatically adjusting production processes to ensure the highest quality products. IoT also supports the automation of internal logistics, for example by controlling autonomous AGVs (Automated Guided Vehicles) that transport raw materials and products in the factory.

2.4. Supply Chain Management

Supply chain management in the era of Industry 4.0 is optimised through IoT, allowing products to be fully monitored and tracked from production to delivery to the customer. Real-time tracking systems allow shipments and inventory to be tracked in real time. For example, logistics companies can use IoT to monitor the location, temperature and status of shipments, allowing for better inventory management and optimised logistics.
The full transparency of the supply chain, enabled by IoT, makes it possible to react quickly to problems such as delays or damage to goods. For example, electronics manufacturers can monitor every stage of production and delivery, identifying and eliminating potential problems before they affect the final product. Additionally, data collected by IoT systems can be used to analyse supplier performance and optimise purchasing processes.

2.5. Systems Integration and Interoperability

Systems integration and interoperability are challenges that must be overcome to realise the full potential of IoT in Industry 4.0. Communication standards and protocols must be consistent so that different devices can work together effectively. Work on standards, such as OPC UA and MQTT, ensures interoperability between different IoT systems. For example, in the energy industry, where different energy management systems need to work together, these standards enable efficient data exchange between devices from different manufacturers. The development of integration platforms, such as IoT Hubs, makes it easy to connect different IoT systems and devices, ensuring seamless manufacturing operations. An example of this is the integration of building management systems (BMS) with manufacturing systems to optimise energy consumption and improve operational efficiency.

3. Development opportunities, threats and challenges from the Internet of Things

The Internet of Things has the potential to change our lives and impact business, but it involves both growth and threats to shared spaces. This chapter analyses the positives and negatives associated with the transformation of this industry, presenting its opportunities for development as well as its threats.

3.1. Development opportunities

- Efficiency and automation – make it possible to monitor and manage equipment from anywhere. This allows many processes to be automated, which can improve the efficiency of the work and save money.
- New services, business models – opens up new horizons for businesses, allowing them to create services under a given behaviour and meet the needs of their contractors. The consequence is the creation from scratch of business models and new UML (Unified Modeling Language) diagrams used in the creation of information systems.
- Tracking and security – can be used for monitoring, helping to make us feel safer in traffic, e.g. when stopping "traffic pirates" or finding missing persons via mobile applications.

3.2. Threats to development

- **Security –** Many IoT devices are poorly secured, making them vulnerable to hackers. The communication of devices is not fully encrypted and they use outdated network protocols such as: Telnet or FTP. Infected devices can be used for cyber-attacks or invasion of user privacy.

- **Costs and investments** – The implementation of IoT solutions generates expenses, both for businesses and consumers. They depend on the scale of project implementation and it requires investment in hardware, specialised software and staff training.
- **Network traffic exploration** – The increase in the use of IoT components exchanging data with each other via the Internet will not improve the efficiency of telecommunications networks, but on the contrary will contribute to network congestion and thus slow down the global exchange of data.

- **Dependence on technology** – Increasing reliance on technology can cause problems in the event of failures or cyber-attacks. A popular attack on servers and their machines is DDoS (distributed denial of service) [8]. This is a type of attack involving a so-called parallel attack from multiple locations (workstations) and the seizure of all free resources to prevent their standard operation (often completely saturating their computing power) carried out simultaneously from multiple locations [9]. Unlimited access to smart devices can affect users' digital hygiene or the development of civilisation diseases.

3.3. Challenges in data collection and processing and the achievements, solutions and concepts already developed in the Internet of Things

The collection and processing of data in the Internet of Things (IoT) field poses a number of significant challenges. Firstly, IoT devices generate huge amounts of data, which places high demands on the tools and infrastructure needed to manage it effectively. Secondly, data security is a key concern, as many IoT devices lack adequate security features, making them vulnerable to cyber-attacks. Another challenge is data storage, which requires large storage resources and effective management. Interoperability of IoT devices from different manufacturers is also a challenge, as they often use different communication standards. Finally, real-time data processing is necessary for many IoT applications, which further complicates the data management process [15].

3.4. Achievements, solutions and concepts already developed

Despite these challenges, significant progress has been made in IoT data collection and processing. One of the most important advances is the development of edge computing technology, which allows data to be processed closer to the source of generation, speeding up the analysis process and reducing the load on the network. Advanced data analytics algorithms, including artificial intelligence (AI) and machine learning (ML), enable efficient analysis of large data sets in real time, predicting failures and optimising processes. Cloud-based analytics platforms offered by leading providers such as AWS, Microsoft Azure and Google Cloud enable scalable storage and analysis of IoT data [16]. In response to data security challenges, advanced encryption protocols, multi-component authentication and real-time monitoring and threat detection systems have been developed. Organisations such as the Industrial Internet Consortium (IIC) and the Institute of Electrical and Electronics Engineers (IEEE) are working on standards to ensure the interoperability of IoT devices.

4. Privacy and [non]security Internet of Things

Having rich, interconnected devices and exchanging data with each other to facilitate coordination and greater productivity and goal orientation definitely helps to improve our lives. This already ubiquitous convenience has serious drawbacks and generates potential risks. In the case of many data-sharing services, particularly in the exchange of free services, our personal data as it appears in this technology becomes a very valuable product. Our data is aggregated, packaged and can be a valuable commercial product. It is well known that conventional computers can leave a trail of personal data. With this in mind, many users have taken precautions, protecting and using strong passwords, using data at rest and transmission encryption methods, ad blockers, anti-tracking software, etc. [13]. However, IoT devices have opened up a rich ecosystem of data that was not previously available. Even more dangerous is the possibility of multi-criteria analysis of the collected data, which, when subjected to specialised models of Data Mining technology, can uncover a lot of sensitive information about, for example, our health, our life status or our standard behaviour. At the very least, this can expose people to a variety of attacks or unpleasant events [11] (hacking, theft, blackmail) which, in the worst-case scenario, a sophisticated malicious actor can learn about our vulnerabilities and gain a few attack points.

5. Exploring the capabilities of the Internet of Things and identifying cloud services to process data derived from it.

Types of clouds supporting IoT

In the era of rapid growth of the Internet of Things (IoT), clouds play a key role in integrating, storing and processing data from IoT devices. Choosing the right cloud model is an important part of designing IoT systems, as different types of clouds have different characteristics in terms of scalability, security and maintenance costs. The main types of clouds supporting IoT are public, private and hybrid clouds.

Public cloud

The public cloud is widely used for IoT systems due to its characteristics, such as high scalability, availability and relatively low operational costs. In this model, the infrastructure is made available to multiple users over the internet and the management of the infrastructure rests with the cloud service provider. Examples of platforms supporting IoT in the public cloud include AWS IoT Core, Azure IoT Hub and Google Cloud IoT Core.

AWS IoT Core [17] enables IoT devices to be securely connected to the cloud, managed and analysed in real-time for transmitted data. The platform supports a wide range of communication protocols, such as MQTT, HTTPS and WebSocket, making it easy to integrate with a variety of devices. AWS offers IoT services and solutions to connect and manage billions of devices. Collect, store, and analyze IoT data for industrial, consumer, commercial, and automotive workloads.

The Azure IoT Hub, offered by Microsoft, on the other hand, provides two-way communication between devices and the cloud, as well as monitoring, diagnostics and automated fault management functions.

Google Cloud IoT Core is distinguished by its advanced integration with other cloud services, such as BigQuery and Google AI, which enables advanced IoT data analytics and the implementation of machine learning models. GCP IoT Core is a powerful and comprehensive platform that enables the management and deployment of IoT (Internet of Things) devices at scale. It provides a robust set of features designed to simplify the development and deployment of IoT solutions, making it an ideal choice for organizations looking to leverage the potential of IoT technologies.

Private and hybrid cloud

Private cloud is a computing infrastructure model where resources are dedicated exclusively to one organisation. This means that the data and infrastructure are fully controlled by the user or by the chosen service provider. This solution is particularly popular in sectors such as Industry 4.0 or healthcare, where strict security and data protection regulations apply. An example is the storage of medical records in a private cloud, which allows compliance with regulations such as RODO in Europe or HIPAA in the US. Private clouds provide a high level of security, as data is stored in a closed environment that can only be accessed by a designated user [18]. This allows companies to tailor the infrastructure to their needs, using specialised security protocols or integrating it with existing IT systems. In the industrial sector, private clouds are being used to monitor IoT machines, enabling predictive fault detection and optimising production processes. An example is the Siemens MindSphere platform, which allows production data to be managed securely in a private cloud.

The hybrid cloud, on the other hand, combines the advantages of public and private clouds. In this model, sensitive data is stored locally in the private cloud, while less critical operations such as analytics or storage of large data sets are handled by the public cloud. This approach allows organisations to benefit from the flexibility and scalability of the public cloud, while retaining full control over key resources. An example of a hybrid cloud application is retail. Customer data, such as payment data, is stored in the private cloud for security, while sales trend analysis or marketing campaign management

takes place in the public cloud, for example using the Microsoft Azure Arc platform. In public administration, the hybrid cloud can be used to store citizens confidential data in the private cloud, while publicly accessible applications such as tax portals can run in the public cloud.
In scientific research, hybrid clouds allow sensitive data, such as the results of experiments, to be stored in a private environment while using the computing power of the public cloud to analyse this data. An example is the use of Google Cloud in conjunction with local servers at research institutions to run advanced climate simulations.

Key IoT cloud computing services

IoT systems generate huge amounts of data, which require specialised tools to store and process it. Today's cloud solutions provide advanced services in this area, which can be divided into three main groups: data storage, data processing and IoT device management.

Data storage

Data lakes are flexible data stores that allow you to store information in any format - both structured (e.g. tabular data) and unstructured (e.g. logs, audio or video files).
AWS S3 is one of the most popular solutions in the data lakes category. It enables scalable storage of raw data from IoT devices, such as system logs or data sent by sensors in real time. Thanks to the flexibility of this solution, the data can then be processed by other analytics tools such as AWS Glue or Amazon Athena. Ideal for the collection of large amounts of data that are used in a later stage of analysis, such as in environmental monitoring systems.

Data warehouses

Data warehouses are optimised for storing structured data that is regularly processed for analytical purposes. These types of solutions require a predefined data structure (e.g. table schema), which allows for efficient queries and analysis.
Azure Synapse Analytics – This is a data warehouse platform that combines advanced analytics with the ability to integrate with IoT services in the Azure cloud. It enables reporting, historical analysis and trend prediction based on previously collected IoT data. Used for reporting and historical data analysis in fleet management systems or sales analysis.

Data processing

The data generated by IoT systems is often in streaming form, which means a continuous influx of data in real time. In order to efficiently process this data and respond to changing conditions, streaming analytics tools are used to process data 'on the fly'.
One such tool is AWS Kinesis, which offers scalable processing of streaming data from millions of IoT devices. This enables real-time data analysis, which is crucial for systems that require immediate responses. Examples of AWS Kinesis applications include analysing weather data collected by IoT sensors and monitoring equipment performance in industrial plants. The tool enables rapid decision-making based on up-to-date data, which is important in traffic management or production safety systems.
Another tool is Azure Stream Analytics, which enables real-time processing of stream data using SQL queries. By integrating with IoT services in the Azure cloud, users can easily analyse data generated by IoT devices and make quick decisions. Examples of Azure Stream Analytics applications include condition monitoring of industrial equipment and data analysis in energy management systems to optimise energy consumption in real time.

Retrospective analysis and Big Data

In addition to real-time analysis, IoT data also requires retrospective processing, which allows the analysis of large data sets collected over a longer period of time. Big data tools are crucial for IoT systems generating huge amounts of information, enabling historical analysis and pattern discovery.

Google BigQuery is a serverless tool that enables the rapid processing and analysis of large data sets. Thanks to its integration with Google Cloud IoT Core, BigQuery allows the analysis of historical data generated by IoT devices. This is particularly useful for applications such as fleet management, where analysing past data can help optimise routes or predict fuel consumption. The tool is also used to study trends in IoT device usage, which can support strategic business decision-making.

Azure Databricks, on the other hand, based on Apache Spark technology, offers advanced analytics capabilities, including training machine learning models on IoT data. With its high performance and tight integration with the Azure cloud, Azure Databricks is ideal for projects requiring advanced data processing. Example applications include failure prediction of IoT devices and analysis of sensor data in manufacturing systems. This type of analysis enables machine failures to be predicted, allowing maintenance activities to be planned in advance, minimising production downtime.

Example of using IoT in industry with cloud services

Below we present an example solution architecture that illustrates how a commercial IoT solution in the form of the HomeBridge gateway and AWS IoT services accelerate the implementation time of any IoT solution.

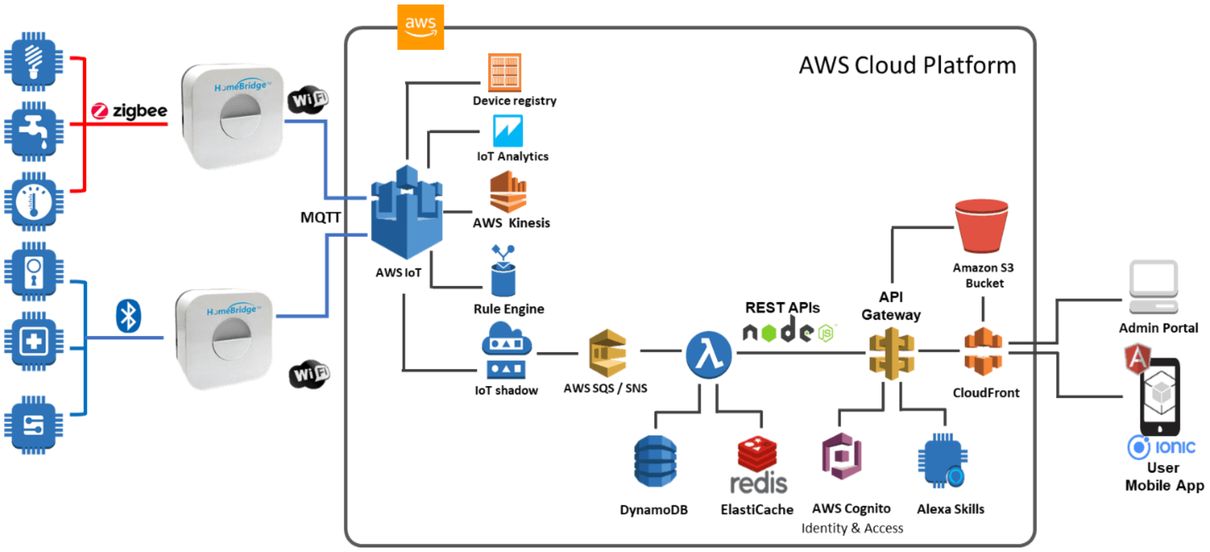

Fig. 5. Example of commercial configurable IoT Gateway Platform cooperated with AWS IoT [19].

All the components shown in the diagram can operate within a unified IoT cloud platform. The main commercial integration layer HomeBridge enables data collection and communication with cloud services, creating a kind of bridge between the world of IoT devices and cloud services. AWS IoT collects data from the HomeBridge device and further manages it depending on the defined user requirements.

6. Conclusion

The Internet of Things (IoT) plays a key role in the Industrial Revolution transformation, enabling a variety of devices and systems to be connected, leading to smart ecosystems. It allows everyday objects, industrial machines, vehicles, or even buildings to communicate with each other, collect data, and respond to changes in the environment in real time. This opens up a wide range of possibilities, from automating processes in homes and businesses to monitoring health and the environment, and improving logistics and managing urban infrastructure.

However, the increasing number of connected devices raises significant challenges, especially in terms of data security and privacy. Every connection becomes a potential point of attack for cybercriminals, so it is essential to implement effective protective measures, including data encryption and network monitoring. In addition, there is a need to develop security standards and regulations that protect users from abuse and unauthorized access to their information. As IoT technology develops, it becomes increasingly important to guarantee privacy and data security. The introduction of appropriate legislation and security standards can provide users with a sense of security and trust in the use of IoT devices.

One of the key steps in fully harnessing the potential of IoT is exploring its capabilities and identifying cloud services that can efficiently process the data it generates. IoT devices produce vast amounts of data, requiring scalable, reliable, and secure infrastructure for storage and analysis. Cloud platforms, such as Amazon Web Services (AWS), Microsoft Azure, and Google Cloud, provide robust solutions for real-time data processing, advanced analytics, and integration with machine learning and artificial intelligence tools. These cloud services enable businesses to derive actionable insights from IoT data, optimize operations, and develop innovative solutions for diverse applications, including smart cities, healthcare, and industrial automation.

Furthermore, IoT solutions combined with other technologies, such as SDN (Software Defined Network) technology [14], can allow for earlier detection of a potential attack, its visualization, understanding the attack's input vectors and its scope, and taking effective defensive actions. Integrating these advanced technologies ensures not only enhanced operational efficiency but also strengthens the security of IoT systems against potential cyber threats.

Respect for ethical standards and privacy is also key. As more and more data are collected by IoT devices, it is important to follow ethical principles and respect users' privacy. Companies developing IoT technologies should consider these issues in the design and implementation of their solutions. Awareness of the implications of data collection and processing must be an integral part of the design process of IoT systems. Consumers should be informed about what data is collected, how it is stored, and how it is used. Transparency in the use of data can increase user trust and reduce privacy concerns.

Ultimately, IoT development must consider the balance between innovation and accountability. While IoT has enormous transformative potential, it is important that its development is done in a manner that is consistent with ethical and legal principles to ensure user privacy and security. By leveraging the power of cloud computing and adhering to ethical standards, IoT can achieve its full potential, creating a safer, smarter, and more connected world while maintaining the trust and confidence of its users.

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