Integration challenges of Artificial Intelligence in Cloud Computing, Internet of Things and Software-defined networking

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***Abstract*—Artificial Intelligence is playing a pivot role in all the significant areas of technology. The nature-inspired capabilities of artificial intelligence are taking the enterprises into a new environment, which is more efficient, strategic, and insight-driven. Different technologies like cloud, Internet of Things (IoT) and Software-defined networking, have their benefits providing to the community. The integration of all these technologies with artificial intelligence are taking beneficiaries to the next level of performance. However, the fusion of these technologies is perturbed and has put forth many challenges for the researchers to address. This paper explains the challenges and opportunities faced in integrating these technologies for all the communities.**

Keywords—artificial intelligence; cloud computing; IoT; Software-defined networking

I. INTRODUCTION

Artificial intelligence is changing the trend of all significant areas of computing and technology but not limited to only these. The fact is that there is a lot of potentials to be utilized than what is being used at present using artificial intelligence. Artificial intelligence helps different technologies by collecting the historical data, perform a thorough analysis of them, identify the patterns and guide to make real-time decisions. Utilizing the advantages of artificial intelligence supports the users in automating the process and improves efficiency by removing the possibility of committing errors while passing through the manual process.

Several other technologies that are dominating the information technology field with their massive characteristics in an interrelated domain include cloud computing, Internet of Things (IoT), and Software-defined networking (SDN). As per fig.1, the hype cycle for artificial intelligence, according to Gartner shows that all the technologies mentioned above are in the innovative trigger stage showing to reach the plateau of productivity in the next 5 to 10 years. This hype cycle has always been a reference for the early researchers to consider and to decide on which technology has a scope to explore more. The artificial intelligence is leading towards cognitive intelligence by gaining knowledge and understanding from the past experience to make future decisions. The vision of industry 4.0 [1] encourages the development of a "smart factory" by automating the processes. And to make the industry smart, artificial intelligence is accelerating with its pace to reach the goal of creating technology that allows computers and machines to function in an intelligent manner. The services of the cloud while using IoT devices with a possibility to program according to each user's wish is now at the edge.

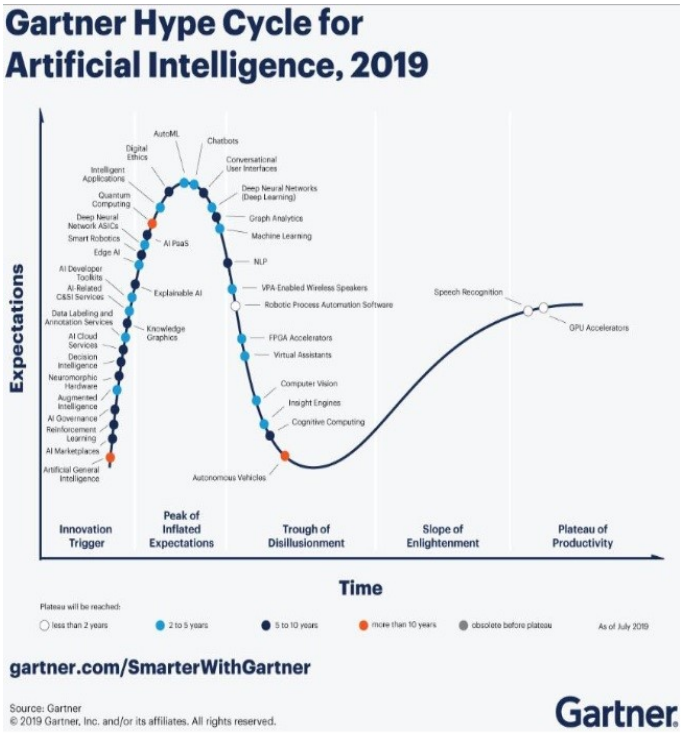

Fig.1. Gartner Hype Cycle for Artificial Intelligence, Sept 2019. [2]

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II. Related literature

The integration of these technologies has been studied and reviewed by various researchers, and in this section, we present some of the relevant research.

The authors in [3] have explained the distinction between the Internet of Things (IoT) and Internet of Everything (IoE), which are wrongly interpreted as the same by many researchers. Different countries have various concerns about transforming from traditional to smart industry and are paying importance accordingly. As in [4], the authors have conducted a survey and show that showing Mindscaping as the biggest challenge for Kuwait, Investment as the biggest challenge for India and Security & Privacy as the biggest challenge faced by the United States to have a smart-government implementation. The low power devices need to utilize the computing resources in a secure distributed architecture. Blockchain-based Distributed Cloud Architecture with a Software-Defined Networking (SDN) enables Controller Fog Nodes at the Edge of the Scalable IoT Network was proposed by the authors in [5] to address the challenges of availability, real-time data delivery, scalability, security, resilience, and low latency. The smart devices are connected in the IoT network on a large scale, and the main concern has been security. To address this issue, the authors have proposed blockchain technology enabled SDN known as DistBlockNet[6] to perform interaction of the devices without any trusted intermediary and detects the attacks in IoT with less overhead compared with other techniques to give better results by satisfying the needs of future IoT networks. The generated massive amount of data from the IoT network has been handled securely and more reliably with the proposed architecture called CENSOR by the authors in [7]. The authors in [8] proposed a deep learning-based prediction to assign a channel intelligently in Software-defined based IoT to forecast future traffic load and congestion in the network.

III. Integration of Artificial Intelligence with Cloud Computing, IoT, SDN

A. Artificial Intelligence and Cloud Computing

Cloud computing has already become an integrated part of various online activities[9]. The combined strategy of artificial intelligence and cloud computing has tremendously changed the way how information technology can be used in organizations and other industries. The integration of cloud technology with artificial intelligence is a witness for the source of innovation with the recent transformations. The various services [10] offered in cloud computing play a significant role in delivering cloud-based solutions. An example of this combination is seen with the digital assistants like Apple's Siri and Amazon's Alexa, which improved our daily lives. Also, the integration enables to gear up cloud resulting as self-managing with artificial intelligence. For instance, when AI is embedded into IT infrastructure, it predicts over time on how to behave when repetitive tasks occur after conducting a thorough analysis. The self-healing capability of AI allows the cloud to recover when issues arise. Artificial intelligence improves data management by storing and retrieving efficiently with vast amounts of data. It will enable streamlining the storage of data to provide accurate information to the clients. It also helps in triggering a signal whenever there is a malicious activity within the regular operation. AI, together with Software-as-a-Service (SaaS), delivers more value to the customers. Salesforce with Einstein AI tool [11] uses the customer's data to strategize their sales by advertising and advising them through different means of social communication.

Apart from the services cloud provides to the users, artificial intelligence is also available to the users as Artificial intelligence-as-a-Service (AIaaS)[12]. Machine learning and deep learning, which are part of artificial intelligence, collect massive datasets build, train, and deploy models to scale efficiently. This makes the analysis, computation, and statistics more accessible on the cloud with a distributed workload[13]. The cloud resources are intelligently used and can automatically scale up and down dynamically based on the utility. The fault tolerance mechanism is highly supported by artificial intelligence, and it monitors and manages the server failure by allowing seamless server migration.

B. Artificial Intelligence and Internet of Things

Internet of Things (IoT)[14] is a network of heterogeneous computing devices with the ability to communicate with each other device without human intervention. The application of the Internet over the personal, professional, and societal objects for identifying, sensing, connecting, and computing has made life better and challenging too. The combination of artificial intelligence with these devices has made them quasi-intelligent. Some of the protocols used to communicate with the devices are Bluetooth, ZigBee, RFID, DDS, Cellular, LoRaWAN, Z-Wave, Sigfox, Thread, etc.

The embedding of artificial intelligence in IoT devices has made a remarkable significance in terms of automating the process in the areas like Industrial Internet of Things (IIoT) and Consumer Internet of Things (CIoT) as shown in fig.2., where the IoT devices are used. For instance, in [15], the role of IoT in the healthcare sector plays a vital role in sustainable development in transmitting the patient's information to the doctor. The intelligent transport system emphasizes on vehicular technology and explores on vehicle-to-vehicle and vehicle-to- IoT devices through means of high communication medium to avoid traffic congestion and accidents in [16]. Cybersecurity is a significant concern in IoT, as most of the heterogeneous devices are connected and communicate with each other. And in this process, there is a scope for many threats and attacks to get into the network and perform vulnerable activities. Physical-cyber-social (PCS) big data consists of this IoT data, complemented by relevant Web-based and social data of various modalities., Artificial intelligence enables to tackle various types of attacks as mentioned in [17]. A plethora of IoT services and bigdata analytics have created opportunities for the cities to transform into smart cities. Financial technology is transforming into a new industry with IoT and artificial intelligence to come up with new business practices and challenge the banks[18].

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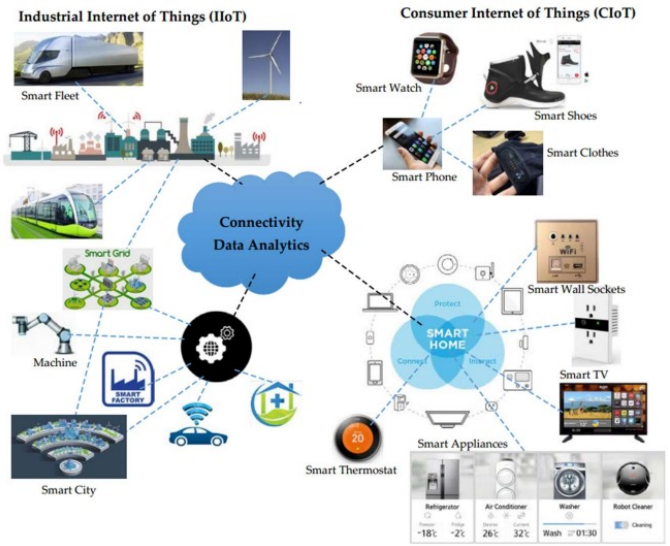

Fig. 2. Industry and Consumer IoT [19]

C. *Artificial Intelligence and Software-defined networking*

The field of networking, which was dominated by major vendors of networking like Cisco, Juniper, Huawei, Veriflow, Apstra, etc., is now open to be customized. Software-defined networking provides an abstraction of complete network topology and allows the administrators to customize the functionality according to the requirements. The strength of this technology is to program the network functionality and making it vendor-free. The various API's are used in three layers of SDN for communication. The standard OpenFlow protocol used to communicate between the infrastructure layer and the control layer programs the networking elements.

The challenges of SDN like scalability, reliability, consistency, interoperability, monitoring, and security, together with artificial intelligence, solves them and makes the networking smart. The ternary content addressable memory (TCAM) in the switch has minimal memory, and the rules updation in the switch are done by the controller[20]. A smart controller can do the updation based on past experiences for future inputs. The Gated Recurrent Unit Recurrent Neural Network (GRU-RNN)[21], which is a supervised learning technique in artificial intelligence is used to solve the problems of security by detecting the intrusion activity making the system more reliable. The gradient of the error function is calculated and is minimized by monitoring the behavior of the elements in the network. The networking elements which are manufactured by different vendors are interoperable as SDN has decoupled the control plane from the data plane of the switch. The centralized behavior[22] of the control plane has full control over the network making it more intelligent and smart, and the placement of controller in the network is a concern to ensure QoS.

D. *Orchestration of Artificial Intelligence with Cloud Computing, IoT and Software-defined networking*

The orchestration of these three technologies has changed the information technology world and has taken it to the next level. To support the scalability and flexibility of IoT devices, SDN has emerged as a promising technology to smartly route the IoT traffic via the cloud. With the invent of 5G, interdependence has increased a lot in cloud computing, IoT, and SDN. The data collected is obtained from different types of devices and is in different formats and structures, resulting in Bigdata, which has to be stored on the cloud to be accessed from any location and using a vendor-free device. The quality of service improves and which in turn increases the quality of experience. The data exchange in the IoT devices using SDN and cloud resources, as discussed in [23] is performed even when there is congestion in the network or network failure occurs. But artificial intelligence could better improve performance. The following fig.3, shows that artificial intelligence, though it has better results independently in combination with cloud computing, IoT and SDN, and integration of these three with artificial intelligence in various applications, can serve better.

It is observed from the above sections that artificial intelligence, in combination with each of the technology individually, is providing better benefits. The motivation to integrate artificial intelligence in conjunction with all three technologies is assured of serving the community better as well as will address the needs of industry 4.0 by automating the processes in all the areas of computing and technology. Artificial Intelligence Software-Defined Cloud of Things (AISDCoT), will enable the end-users to use smart short-range communication devices by storing or accessing the data stored in the cloud and transmit the information securely by following the principles of SDN.

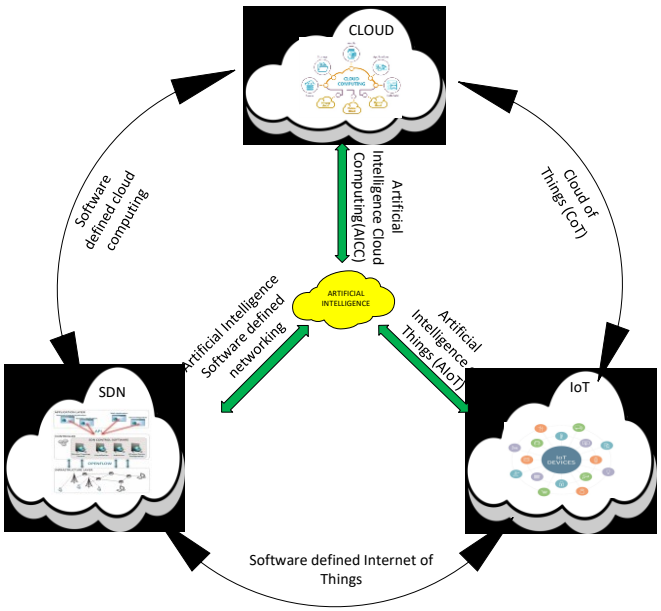

Fig. 3. Artificial Intelligence Software-Defined Cloud of Things (AISDCoT)

IV. Research Challenges And Opportunities

The following are the challenges to be addressed during the integration of artificial intelligence with cloud computing, Internet of Things, and Software-defined networking.

- Security: The flow tables in SDN have minimal memory and can hold a few flow entries. And if these

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entries are changing dynamically and frequently, as the smart devices are scalable, it is very much prone to attacks. So, an artificial intelligence technique is necessary to detect and prevent all types of attacks at all the stages to make this integration more effective.

- Routing: The communication in IoT network using SDN can happen between machine-to-machine or machine-to-application, which requires the information to be stored on the cloud. A suitable artificial intelligence enabled routing algorithm has to be developed to fulfil the requirements of transmitting the information to the destination in a reliable shortest way.
- Load balancing: The requests initiated from various IoT devices pass through the controller in SDN. The controller dynamically changes the flow tables to balance the load on the connected switches using the OpenFlow protocol. An effective artificial intelligence algorithm must balance the load considering the related inputs like bandwidth, response time, execution time to reduce the transmission delay, overhead, and improve the throughput, CPU utilization. The QoS can be enhanced when such an optimized algorithm is developed.
- Resource management: The resources are valuable elements in the process. And these resources should be utilized effectively to improve the quality of service parameters. Statistical information of each resource should be maintained to keep track of resource availability, resource allocation, resource scheduling, and resource utilization. By developing an artificial intelligence algorithm, resource management can be done and can automate the process.
- Green Computing: The emission of heat from several devices has to be controlled to enable green computing. So the energy consumption of these devices should be minimized and efficiently done only when needed. Energy consumption is a significant concern of many researchers to reduce the hazardous heat generated by the devices while performing any operation.
- Interoperability: Interoperability plays a vital role in the success of communication as different devices are communicating using various technologies and also there are no universal standards to guide. So, an intelligent and holistic artificial intelligence technology is needed to solve the interoperability issue at all the levels of communication.
- Data: Deep learning to be effective needs on a vast amount of data. It is useful only when there are several layers in the architecture and needs more storage space to accommodate this enormous amount of data.

V. Conclusion

This paper presents some of the challenges concerning the fusion of artificial intelligence with Cloud computing, IoT, and SDN, as these are the dominating trends these days. Artificial intelligence techniques are widely used in research, and when these concepts are fused with these trends, it makes them function with little or no human efforts and making it act smart. The challenges concerning this fusion have invited the attention of researchers to address them. However, by addressing the joint issues of all these trends will also solve the independent technology issue. This paper would help users and researchers who wish to carry out further research in any of the combination of above-considered technologies in future.

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